JPSS Risk Reduction: Uniform Multi-Sensor Cryosphere Algorithms for Consistent Products Critical Design Review

April 5, 2013

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Products Covered in this CDR

- Snow Cover
- Ice Concentration and Cover
- Ice Surface Temperature
- Ice Thickness/Age

Review Agenda
Part I – April 18th

• Introduction	8:30 am – 8:45 am	Wolf
• Requirements	8:45 am – 9:30 am	Wolf
• Operations Concept	9:30 am – 9:50 am	Wolf
• ATB – Snow Cover	9:50 am – 10:50 am	Romanov
• Break	10:50 am – 11:00 am	
• Ice Concentration and Cover	11:00 am – 11:40 pm	Liu
• Ice Surface Temperature	11:40 am – 12:00 pm	Liu

Review Agenda
Part II – April 19th

• Ice Thickness/Age	8:30 am – 9:30 am	Wang
• Software Architecture & Interface	9:30 am – 10:10 am	Wolf
• Detailed Design	10:10 am – 10:30 am	Wolf
• Quality Assurance	10:30 am – 10:45 am	Wolf
• Algorithm Package	10:45 am – 10:55 am	Wolf
• Risks & Actions	10:55 am – 11:05 am	Wolf
• Summary and Conclusions	11:05 am – 11:30 am	Wolf

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Design Overview and System Description
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Introduction

Presented by

Walter Wolf

Contents

- Project Objectives
- Stakeholders
- Teams
- Project Plan
- Entry and Exit Criteria

Project Background

- NWS requests continuity of NOAA products between current and future NOAA operational satellites
- Demonstration of cost effective processing for NOAA JPSS products
- Demonstration of NOAA’s goal of enterprise solutions by employing same algorithms for “POES” and “GOES”
- Supports NWS OS&T implementation strategy of multi-sensor algorithms and products

Project Background – NDE

- Disseminate JPSS/S-NPP Data Records to customers.
- Generate and disseminate tailored JPSS/S-NPP Data Records (versions of JPSS/S-NPP Data Records in previously agreed alternative formats and views).
- Generate and disseminate NOAA-unique products (augmented environmental products constructed from JPSS/S-NPP Data Records).
- Deliver NOAA-unique products, product processing elements, and associated metadata to CLASS for long-term archiving.
- Provide services to customers, including NDE product training, product enhancement, and *implementation support across NOAA.*

- Provide software for JPSS/S-NPP Data Record format translation and other

Project Objectives

- Modification of the NOAA Heritage Cloud, Cryosphere, Volcanic Ash, and Aerosol algorithms to work on VIIRS data
- This will bring scientific consistency between the current operational products, GOES-R products and VIIRS products
- Run the product system within NDE

Products Objectives
Cloud Products

- Cloud Mask
- Cloud Top Phase
- Cloud Type
- Cloud Top Height
- Cloud Cover Layers
- Cloud Top Temperature
- Cloud Top Pressure
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Liquid Water
- Cloud Ice Water Path

Products Objectives
Aerosol Products

- Aerosol Detection
- Aerosol Optical Depth
- Aerosol Particle Size
- Volcanic Ash Mass Loading
- Volcanic Ash Height

Products Objectives
Cryosphere Products

- Snow Cover
- Ice Concentration and Cover
- Ice Surface Temperature
- Ice Thickness/Age

JPSS Risk Reduction Integrated Product Team

- IPT Lead: Walter Wolf (STAR)
- IPT Backup Lead: AK Sharma (OSPO)
- NESDIS team:
  - » STAR: Andy Heidinger, Jeff Key, Shobha Kondragunta, Istvan Laszlo, Mike Pavolonis
  - » OSPO: Gilberto Vicente, Hanjun Ding, Zhaohui Cheng
  - » OSD: Tom Schott, Jim Silva, Geof Goodrum
  - » NOAA JPSS: Mitch Goldberg
  - » NIC: Sean Helfrich
  - » Data Center: Lei Shi (NCDC)
  - » Others: Shanna Sampson, Peter Romanov, Xingpin Liu, William Straka III, Ray Garcia
- User team
  - » Lead: Kevin Schrab (NWS) Mike Johnson(NWS), John Derber (NWS/NCEP/EMC), Jeff Ator (NWS/NCEP/NCO), Lars Peter-Riishojgaard (JCSDA), Gary Hufford (NWS), VAACs
  - » Others: International NWP users, NWP FOs, Climate Users
- Sounding Product Oversight Panel
- Other POPs involved: EPOP, ICAPOP, CAL/NAVPOP, ACPOP, SURPOP

Project Stakeholders

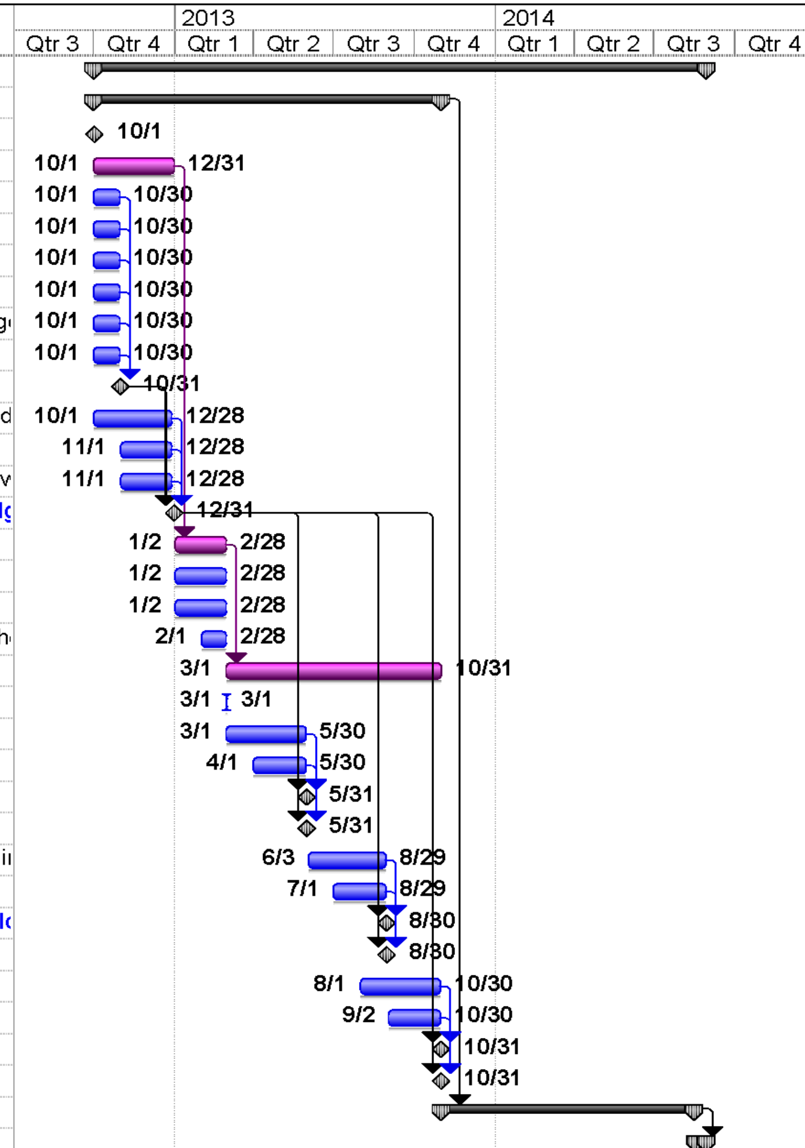
- OSPO
- STAR
- OSD
- NOAA National Weather Service
- Department of Defense
- Global NWP

Project Plan

- Year 1 – Design and Development (2012 – 2013)
  - » Develop Requirements Document
  - » Product leads to identify updates to the algorithms to work with VIIRS data
  - » Identify ancillary data for the algorithms
  - » Conduct CDR
  - » Algorithm development
  - » Implement algorithms within the Framework
  - » Conduct TRR

Project Timeline
Year 1

ID	Task Name
1	**JPSS Risk Reduction**
2	**Development Phase**
3	**IPT Lead informed to begin product development**
4	**Algorithm Evaluation/Preliminary Development**
5	Initial Archive Requirements identified
6	Quality Monitoring Concept Defined
7	Long-term Maintenance Concept Defined
8	Development processing system defined
9	Evaluate the modifications required to create VIIRS products from the GOES-R alg
10	Initial Information Technology (IT) Security concept defined
11	**Requirements Review**
12	Preliminary development Aerosol, Cloud, Cryosphere and Volcanic Ash algorithm d
13	Identify ancillary data inputs for all the algorithms
14	Preliminary development of infrastructure to implement the NetCDF4 readers and w
15	**Critical Design Reviews for Aerosol, Cloud, Cryosphere, and Volcanic Ash alg**
16	**Algorithm Developmen**
17	Development of Aerosol, Cloud, Cryosphere and Volcanic Ash algorithms
18	Define Aerosol, Cloud, Cryosphere and Volcanic Ash output files
19	Development of infrastructure to implement the NetCDF4 readers and writers for th
20	**Algorithm Implement/Testing/Demonstratio**
21	Begin documentation of the framework
22	Implement Cloud Mask, Height, and Phase algorithms into the framework
23	Cloud Mask, Height, and Phase test cases processed
24	**Test Readiness Review for Cloud Mask, Height, and Phase**
25	**Deliver preliminary Cloud DAP to NDE**
26	Implement Aerosol Detection, Aerosol Optical Depth and Volcanic Ash algorithms i
27	Aerosol Detection, Aerosol Optical Depth and Volcanic Ash test case processed
28	**Test Readiness Review for Aerosol Detection, Aerosol Optical Depth and Vol**
29	**Deliver preliminary Aerosol and Volcanic Ash DAP to NDE**
30	Implement Cryosphere algorithms into the framework
31	Cryosphere algorithm test case processed
32	**Test Readiness Review for Cryosphere algorithms**
33	**Deliver preliminary Cryosphere DAP to NDE**
34	**Pre-operational Phase**
56	**Operational Phase**

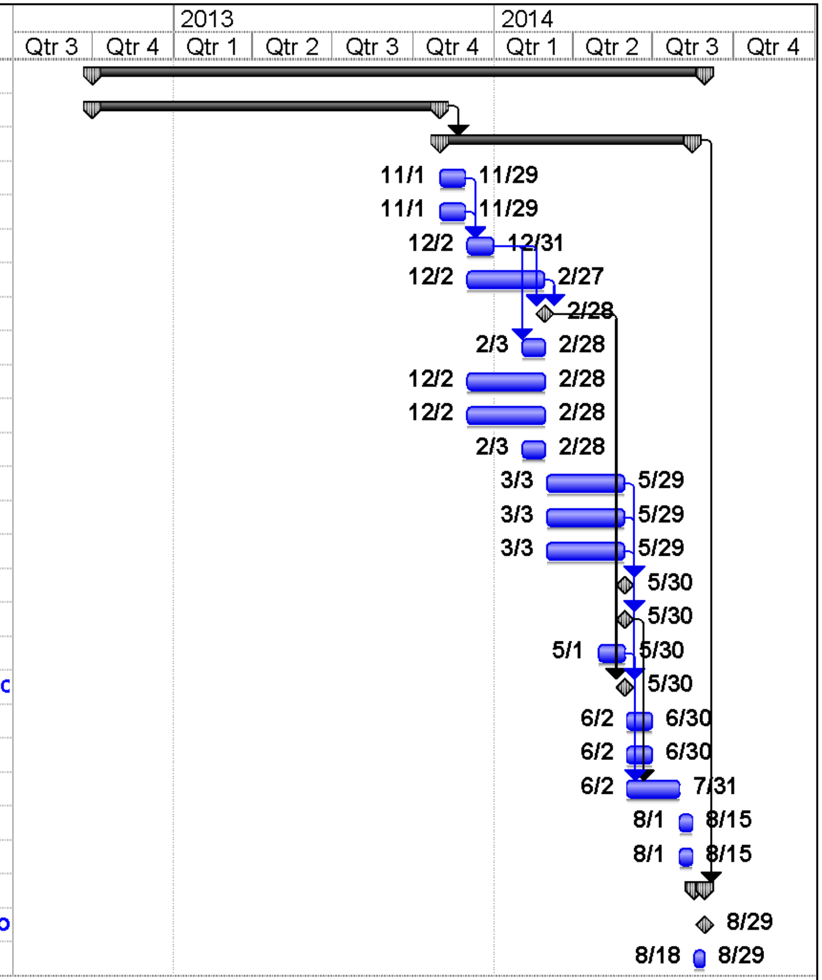


Project Plan

- Transition to Pre-Operations (2014 – 2016)
  - » Deliver initial DAP (Framework with pre-operational algorithms) to NDE
  - » Conduct Software Review
  - » Update algorithms
  - » Transition and test system within the NDE environment
  - » Perform test data flows
  - » Conduct Algorithm Readiness Review
  - » Deliver final DAP to NDE

Project Timeline
Year 2

ID	Task Name
1	**JPSS Risk Reduction**
2	**Development Phase**
34	**Pre-operational Phase**
35	Transition Framework to the pre-operational system on the NDE hardware
36	NDE/OSPO Contractor Staff Training for the Framework
37	Pre-operational product output evaluated & tested within the NDE environment
38	Aerosol, Cloud, Cryosphere, and Volcanic Ash algorithms are upgraded
39	**Software Review for Aerosol, Cloud, Cryosphere, and Volcanic Ash algorithms**
40	Provide test products to the end users
41	Prepare Documentation
42	Developed Operational Products Implementation Plan
43	Baseline products system
44	Evaluated and Modify Operational Documentation
45	Validation and Verification of Operational Quality Assurance for Products
46	Validation and Verification of Monitoring capability for Products
47	**All documentation is complete**
48	**Final DAP delivered to NDE**
49	Prepare for Transition to Operations
50	**Conduct System Readiness Review for Aerosol, Cloud, Cryosphere, and Volcanic**
51	Operational and backup processing capabilities in place
52	Final IT Security Concept Defined
53	Transition DAP to operations
54	Brief SPSRB Oversight Panel(s) on product status
55	Brief SPSRB capability is ready to operational
56	**Operational Phase**
57	**SPSRB manager and secretaries notified JPSS Risk Reduction NOAA Unique Pro**
58	SPSRB Secretaries/manager update the SPSRB product metrics web page



Project Plan
Cryosphere Schedule

- **Schedule (Milestones)**
  - » Project begins – 10/05/12
  - » Requirements Review – 12/27/12 (10/31/12)
  - » Critical Design Review – 04/05/13 (12/31/12)
  - » Test Readiness Review – 10/31/13 (05/31/13, 08/30/13, 10/31/13)
  - » Software Review – 02/28/14 (02/28/14)
  - » System Readiness Review – 05/30/14 (05/30/14)

CDR Entry Criteria

- Reviewed Requirements Document
- Review of JPSS RRPS Project:
  - » Requirements
  - » Operations Concept
  - » Algorithm Theoretical Basis
  - » Software Architecture & Interfaces
  - » Detailed Design
  - » Algorithm Package
  - » Quality Assurance
  - » Risks and Actions

CDR Exit Criteria

- Critical Design Review Report
  - » The CDR Report (CDRR), a standard artifact of the SPSRB Process Lifecycle, will be compiled before the TRR
  - » The report will contain:
    - – Actions
    - – Comments
    - – CDR presentation

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Requirements for JPSS Risk Reduction: Uniform Multi-Sensor Algorithms for Consistent Products

Presented by
Walter Wolf

JPSS Risk Reduction System Requirements

- All JPSS Risk Reduction System Project requirements are present in this section.

- All JPSS Risk Reduction System Project requirements are documented in a single RAD located in the project repository at:

- Basic requirements are shown in all yellow text on a single slide.

Basic Requirement 0.0

- **JPSS-PS-R 0.0:** *The JPSS Risk Reduction Product System (JPSS RRPS) development project shall adopt the standard practices of the Satellite Product and Services Review Board (SPRB).*

  » **Driver:** *STAR Enterprise Product Lifecycle (EPL)*. The SPSRB process has been updated by incorporating aspects of the STAR EPL Process.

Basic Requirement 0.0

- **GOES-PS-R 0.1:** *The JPSS RRPS development project practices shall be tailored from the SPSRB process.*

  » This requirement should be met by following the SPSRB process, as long as the tailoring does not introduce an incompatibility.

Basic Requirement 1.0

- **JPSS-PS-R 1.0:** *The JPSS RRPS shall generate Global Cloud products.*

- **Driver:** **SPSRB requirements:**
  - » 1107-0011: Gridded Cloud Products for NWP Verification
  - » 0909-0018: CLAVR-x and GSIP cloud product composites over Alaska

Basic Requirement 1.0

- **JPSS-PS-R 1.1:** *The Cloud products shall include Cloud Mask, Cloud Phase, Cloud Type, Cloud Top Height, Cloud Cover Layers, Cloud Top Temperature, Cloud Top Pressure, Cloud Optical Depth, Cloud Particle Size Distribution, Cloud Ice Water Path, Cloud Liquid Water.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.1:** *The Cloud Mask Product shall have accuracy of 90% correct detection.*

- **JPSS-PS-R 1.1.2:** *The Cloud Phase Product shall have accuracy of 80% Correct Classification (5 phases).*

- **JPSS-PS-R 1.1.3:** *The Cloud Type Product shall have accuracy of 60% correct classification (7 categories).*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.4:** *The Cloud Top Height Product shall have accuracy of 500 m for clouds with emissivity > 0.8.*

- **JPSS-PS-R 1.1.5:** *The Cloud Cover Layers Product shall have accuracy of 80% Correct Classification (Low, Mid, High).*

- **JPSS-PS-R 1.1.6:** *The Cloud Top Temperature Product shall have accuracy of 3 K for clouds with emissivity > 0.8.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.7:** *The Cloud Top Pressure Product shall have accuracy of 50 mb for clouds with emissivity > 0.8.*

- **JPSS-PS-R 1.1.8:** *The Cloud Optical Depth Product shall have accuracy of better than:*
  - *Liquid phase:*
  - *20% error (Day), 20% (Night);*
  - *Ice phase:*
  - *20% (Day), 30% (Night)*

  - Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.9:** *The Cloud Particle Size Distribution Product shall have accuracy of:*
  - » *4 µm for liquid phase*
  - » *10 µm for ice phase*

- **JPSS-PS-R 1.1.10:** *The Cloud Ice Water Path Product shall have accuracy of greater of 25g/m2 or 30% error.*

- **JPSS-PS-R 1.1.11:** *The Cloud Liquid Water Product shall have accuracy of greater of 25g/m2 or 15% error.*

  - » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.12:** *The Cloud Mask Product shall have horizontal resolution of 0.75 km.*

- **JPSS-PS-R 1.1.13:** *The Cloud Phase Product shall have horizontal resolution of 0.75 km.*

- **JPSS-PS-R 1.1.14:** *The Cloud Type Product shall have horizontal resolution of 0.75 km.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.15:** *The Cloud Top Height Product shall have horizontal resolution of 0.75 km.*
- **JPSS-PS-R 1.1.16:** *The Cloud Cover Layers Product shall have horizontal resolution of 0.75 km.*
- **JPSS-PS-R 1.1.17:** *The Cloud Top Temperature Product shall have horizontal resolution of 0.75 km.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.18:** *The Cloud Top Pressure Product shall have horizontal resolution of 0.75 km.*
- **JPSS-PS-R 1.1.19:** *The Cloud Optical Depth Product shall have horizontal resolution of 0.75 km.*
- **JPSS-PS-R 1.1.20:** *The Cloud Particle Size Distribution Product shall have horizontal resolution of 0.75 km.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.1.21:** *The Cloud Ice Water Pass Product shall have horizontal resolution of 0.75 km.*

- **JPSS-PS-R 1.1.22:** *The Cloud Liquid Water Product shall have horizontal resolution of 0.75 km.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.2:** *The Cloud Products shall have global coverage.*
  - Current operational products, with upgraded capabilities.
- **JPSS-PS-R 1.2.1:** *The Cloud Products shall have latency of 30 minutes after granule data is available.*
  - Latency is defined as the interval from the last observation to when the product is available to users. Current capability is 60 minutes.

Basic Requirement 1.0

- **JPSS-PS-R 1.2.2:** *The Cloud Products shall at least 90% coverage of the globe every 12 hours (monthly average).*

- **JPSS-PS-R 1.2.3:** *The Cloud Products shall have timeliness of ≤ 3 hours.*

  » Current operational products, with upgraded capabilities.

Basic Requirement 1.0

- **JPSS-PS-R 1.3:** *The Cloud Products shall include quality information.*
  - » QC flags will be specified in the External Users Manual.

- **JPSS-PS-R 1.4:** *The JPSS RRPS shall write Cloud Products files in NetCDF4 formats.*
  - » SPSRB requirement

Basic Requirement 1.0

- **JPSS-PS-R 1.5:** *The JPSS RRPS developers shall perform validation and verification of the Cloud Products.*
  - » Validation tools will be based upon the GOES-R validation tools and/or the heritage validation tools
- **JPSS-PS-R 1.5.1:** *The JPSS RRPS developers shall plot datasets for verification of the Cloud Products.*

Basic Requirement 1.0

- **JPSS-PS-R 1.5.2:** *The JPSS RRPS developers shall verify that Cloud Products files are generated correctly.*
  - » Will be included in the unit tests described in the UTR and the system test described in the SRR.
- **JPSS-PS-R 1.5.3:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the input data.*
  - » Anomalous values will be flagged. These checks will be included in the code and described in the SRR.

Basic Requirement 1.0

- **JPSS-PS-R 1.5.4:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the Cloud Products.*
  - » Out-of-range values will be flagged. These checks will be included in the code. UTR will address.
- **JPSS-PS-R 1.5.5:** *The JPSS RRPS developers shall generate matchup datasets between Cloud Products retrievals and in situ measurements.*
  - » In situ data obtained from NCEP & ECMWF analysis, SURFRAD measurements, and CALIPSO data.

Basic Requirement 2.0

- **JPSS-PS-R 2.0:** *The JPSS RRPS shall generate Aerosol Products.*

Driver: **SPSRB requirements:**

» *1009-0016: Dust Aerosol Concentration Product*

» *0707-0014: Support satellite-based verification of the National Air Quality Forecast Capability*

Basic Requirement 2.0

- **JPSS-PS-R 2.1:** *The Aerosol Products shall include Aerosol Optical Depth and Aerosol Detection.*

- **JPSS-PS-R 2.1.1:** *The Aerosol Optical Depth Product shall have accuracy based on Aerosol Optical Depth ranges:*
  - » *Over land:*
  - » *< 0.04: 0.06*
  - » *0.04 – 0.80: 0.04*
  - » *> 0.80: 0.12*
  - » *Over water:*
  - » *< 0.40: 0.02*
  - » *> 0.40: 0.10*

» Current operational product, with upgraded capabilities.

Basic Requirement 2.0

- **JPSS-PS-R 2.1.2:** *The Aerosol Detection Product shall have accuracy:*
  - » *Dust: 80% correct detection over land and ocean*
  - » *Smoke: 80% Correct detection over land; 70% correct detection over ocean*
- **JPSS-PS-R 2.1.3:** *The Aerosol Optical Depth Product shall have horizontal resolution of 0.75 km (nadir).*
- **JPSS-PS-R 2.1.4:** *The Aerosol Detection Product shall have horizontal resolution of 0.75 km.*

  - » Current operational products, with upgraded capabilities.

Basic Requirement 2.0

- **JPSS-PS-R 2.2:** *The Aerosol Products shall have global coverage.*
  - » Current operational products, with upgraded capabilities.
- **JPSS-PS-R 2.2.1:** *The Aerosol Products shall have latency of 30 minutes after granule data is available.*
  - » Latency is defined as the interval from the last observation to when the product is available to users. Current capability is 60 minutes.

Basic Requirement 2.0

- **JPSS-PS-R 2.2.2:** *The Aerosol Products shall have at least 90% coverage of the globe every 12 hours (monthly average).*

- **JPSS-PS-R 2.2.3:** *The Aerosol Products shall have timeliness of ≤ 3 hours.*

    » Current operational products, with upgraded capabilities.

Basic Requirement 2.0

- **JPSS-PS-R 2.3:** *The Aerosol Products shall include quality information.*
  - » QC flags will be specified in the External Users Manual.

- **JPSS-PS-R 2.4:** *The JPSS RRPS shall write Aerosol Products files in NetCDF4 formats.*
  - » SPSRB requirement

Basic Requirement 2.0

- **JPSS-PS-R 2.5:** *The JPSS RRPS developers shall perform validation and verification of the Aerosol Products.*

  » Validation tools will be based upon the GOES-R validation tools

- **JPSS-PS-R 2.5.1:** *The JPSS RRPS developers shall plot datasets for verification of the Aerosol Products.*

Basic Requirement 2.0

- **JPSS-PS-R 2.5.2:** *The JPSS RRPS developers shall verify that Aerosol Products files are generated correctly.*
  - » Will be included in the unit tests described in the UTR and the system test described in the SRR.
- **JPSS-PS-R 2.5.3:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the input data.*
  - » Anomalous values will be flagged. These checks will be included in the codeand described in the SRR.

Basic Requirement 2.0

- **JPSS-PS-R 2.5.4:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the Aerosol Products.*

  » Out-of-range values will be flagged. These checks will be included in the code. UTR will address.

- **JPSS-PS-R 2.5.5:** *The JPSS RRPS developers shall generate matchup datasets between Aerosol Products retrievals and in situ measurements.*

  » In situ data obtained from AERONET Measurements

Basic Requirement 3.0

- **JPSS-PS-R 3.0:** *The JPSS RRPS shall generate Volcanic Ash Products.*

- **Driver:** **SPSRB requirements:**
  0507-05: Polar/Geostationary Volcanic Ash Detection and Height on CLAVR-X

Basic Requirement 3.0

- **JPSS-PS-R 3.1:** *The Volcanic Ash Products shall include Volcanic Ash Detection (Mass Loading) and Height.*

- **JPSS-PS-R 3.1.1:** *The Volcanic Ash Detection (Mass Loading) and Height Product shall have accuracy:*
  - » *2 tons/km2, 3 km height.*

JPSS-PS-R 3.1.2: *The Volcanic Ash Detection (Mass Loading) and*

Height Product shall have horizontal resolution of 0.75 km (nadir).

- » Current operational product, with upgraded capabilities.

Basic Requirement 3.0

- **JPSS-PS-R 3.2:** *The Volcanic Ash Detection (Mass Loading) and Height Products shall have global coverage.*
    - » Current operational products, with upgraded capabilities.
- **JPSS-PS-R 3.2.1:** *The Volcanic Ash Detection (Mass Loading) and Height Product shall have latency of 30 minutes after granule data is available.*
    - » Latency is defined as the interval from the last observation to when the product is available to users. Current capability is 60 minutes.

Basic Requirement 3.0

- **JPSS-PS-R 3.2.2:** *The Volcanic Ash Detection (Mass Loading) and Height Product shall have at least 90% coverage of the globe every 12 hours (monthly average).*
  - » Current operational product, with upgraded capabilities.
- **JPSS-PS-R 3.2.3:** *The Volcanic Ash Detection (Mass Loading) and Height Product shall have timeliness of ≤ 3 hours.*
  - » Current operational product, with upgraded capabilities.

Basic Requirement 3.0

- **JPSS-PS-R 3.3:** *The Volcanic Ash Detection (Mass Loading) and Height Product shall include quality information.*
  - » QC flags will be specified in the External Users Manual.
- **JPSS-PS-R 3.4:** *The JPSS RRPS shall write Volcanic Ash Detection (Mass Loading) and Height Product files in NetCDF4 formats.*
  - » SPSRB requirement.

Basic Requirement 3.0

- **JPSS-PS-R 3.5:** *The JPSS RRPS developers shall perform validation and verification of the Volcanic Ash Detection (Mass Loading) and Height Product.*
  - » Validation tools will be based upon the GOES-R validation tools
- **JPSS-PS-R 3.5.1:** *The JPSS RRPS developers shall plot datasets for verification of the Volcanic Ash Detection (Mass Loading) and Height Products.*

Basic Requirement 3.0

- **JPSS-PS-R 3.5.2:** *The JPSS RRPS developers shall verify that Volcanic Ash Detection (Mass Loading) and Height Products files are generated correctly.*
  - » Will be included in the unit tests described in the UTR and the system test described in the SRR.
- **JPSS-PS-R 3.5.3:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the input data.*
  - » Anomalous values will be flagged. These checks will be included in the code And described in the SRR.

Basic Requirement 3.0

- **JPSS-PS-R 3.5.4:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the Volcanic Ash Detection (Mass Loading) and Height Products.*
  - » Out-of-range values will be flagged. These checks will be included in the code. UTR will address.

- **JPSS-PS-R 3.5.5:** *The JPSS RRPS developers shall generate matchup datasets between Volcanic Ash Detection (Mass Loading) and Height Products retrievals and in situ measurements.*
  - » In situ data obtained from CALIPSO data.

Basic Requirement 4.0

- **JPSS-PS-R 4.0:** *The JPSS RRPS shall generate Cryosphere Products.*

  » **<u>Driver:</u> SPSRB requirements:**

Basic Requirement 4.0

- **JPSS-RRPS-R 4.1:** *The Cryosphere Products shall include Ice Concentration, Ice Age, Ice Surface Temperature, and Snow Cover.*
  - » Continuity with GOES-R product, upgraded VIIRS capability

- **JPSS-RRPS-R 4.1.1:** *The Ice Concentration Product shall have accuracy of 10% Uncertainty.*
  - » Continuity with GOES-R product, upgraded VIIRS capability

Basic Requirement 4.0

- **JPSS-RRPS-R 4.1.2:** *The Ice Age Product shall have accuracy:*
  - » *80% correct classification (Ice free areas, First year ice, Older ice)*
  - » Continuity with GOES-R product, upgraded VIIRS capability
- **JPSS-RRPS-R 4.1.3:** *The Ice Surface Temperature Product shall have accuracy of 1K.*
  - » Continuity with GOES-R product, upgraded VIIRS capability

Basic Requirement 4.0

- **JPSS-RRPS-R 4.1.4:** *The Ice Snow Cover Product shall have accuracy of 90% correct classification.*

.

  » Continuity with GOES-R product, upgraded VIIRS capability

- **JPSS-RRPS-R 4.1.5:** *The Ice Concentration Product shall have horizontal resolution of 0.75 km.*

  » Continuity with GOES-R product, upgraded VIIRS capability

Basic Requirement 4.0

- **JPSS-RRPS-R 4.1.6:** *The Ice Age Product shall have horizontal resolution of 0.75 km.*
  - » Continuity with GOES-R product, upgraded VIIRS capability
- **JPSS-RRPS-R 4.1.7:** *The Ice Surface Temperature Product shall have horizontal resolution of 0.75 km.*
  - » Continuity with GOES-R product, upgraded VIIRS capability
- **JPSS-RRPS-R 4.1.8:** *The Snow Cover Product shall have horizontal resolution of 0.375 km.*
  - » Current operational product, with upgraded capabilities.

Basic Requirement 4.0

- **JPSS-RRPS-R 4.2:** *The Cryosphere Products shall have global coverage.*
  - » Current operational products, with upgraded capabilities.

- **JPSS-RRPS-R 4.2.1:** *The Cryosphere Products shall have latency of 30 minutes after granule data is available.*
  - » Latency is defined as the interval from the last observation to when the product is available to users. Current capability is 60 minutes.

Basic Requirement 4.0

- **JPSS-RRPS-R 4.2.2:** *The Cryosphere Products shall have at least 90% coverage of the globe every 12 hours (monthly average).*

  » Current operational products, with upgraded capabilities.

- **JPSS-RRPS-R 4.2.3:** *The Cryosphere Product shall have timeliness of ≤ 3 hours.*

  » Current operational product, with upgraded capabilities.

Basic Requirement 4.0

- **JPSS-RRPS-R 4.3:** *The Cryosphere Products shall include quality information.*
  - » QC flags will be specified in the External Users Manual.
- **JPSS-RRPS-R 4.4:** *The JPSS RRPS shall write Cryosphere Products files in NetCDF4 formats.*
  - » SPSRB requirement.

Basic Requirement 4.0

- **JPSS-RRPS-R 4.5:** *The JPSS RRPS developers shall perform validation and verification of the Cryosphere Products.*

  - Validation tools will be based upon the GOES-R validation tools

- **JPSS-RRPS-R 4.5.1:** *The JPSS RRPS developers shall plot datasets for verification of the Cryosphere Products.*

Basic Requirement 4.0

- **JPSS-RRPS-R 4.5.2:** *The JPSS RRPS developers shall verify that Cryosphere Products files are generated correctly.*
  - » Will be included in the unit tests described in the UTR and the system test described in the SRR

- **JPSS-RRPS-R 4.5.3:** *The JPSS RRPS system shall perform routine data range checks to flag anomalous values in the input data.*
  - » Anomalous values will be flagged. These checks will be included in the codeand described in the SRR.

Basic Requirement 4.0

- **JPSS-RRPS-R 4.5.5:** *The JPSS PS developers shall generate matchup datasets between Cryosphere Products retrievals and in situ measurements.*

  » In situ data obtained from NCEP & ECMWF analysis, AMSR-E products, Upward Looking Sonar data, Canadian Ice Service measurements and Buoy data.

Basic Requirement 5.0

- **JPSS-RRPS-R 5.0:** *The JPSS PS system shall have a data ingest capability.*

  » **Driver:** This basic requirement is traced to algorithm input needs, as documented in the Algorithm Theoretical Basis Documents (ATBDs).

Basic Requirement 5.0

- **JPSS-RRPS-R 5.1:** *The JPSS PS system shall ingest NPP VIIRS L1 data.*
  - » Required algorithm input. Ingest from the IDPS. Data link for development is established by NDE.

Basic Requirement 6.0

- **JPSS-RRPS-R 6.0:** *The JPSS RRPS developers shall modify the GOES-R algorithms to generate a retrieval of Cloud Products, Aerosol Products, Volcanic Ash Products, and Cryosphere Products.*

    - » **Driver:** This basic requirement is traced to user needs for Cloud Mask products.

Basic Requirement 6.0

- **JPSS-RRPS-R 6.1:** *The JPSS RRPS Algorithms shall be implemented by processing codes written in C, C++ and Fortran 90.*
  - » Adaptation of current algorithm/framework code.

- **JPSS-RRPS-R 6.1.1:** *The JPSS RRPS processing code shall be able to run in the Development Environment (Linux with 12 dual core 2.33 GHz CPUs.*
  - » *S/W: Intel Compiler (C/C++/Fortran) and IDL for Validation*
  - » *Storage: 100 TB)*

  - » C code, C++ code, and Fortran code can run in this environment

Basic Requirement 6.0

- **JPSS-RRPS-R 6.1.2:** *The JPSS RRPS processing code shall be able to run in the NDE Test Environment (Linux machine with 6 quad core 3.2 GHz CPUs*
  - » *S/W: Intel Compiler (C/C++/Fortran) and IDL for Validation*
  - » *Storage: 30 TB)*
  - » C code, C++ code, and Fortran code can run in this environment
- **JPSS-RRPS-R 6.1.3:** *The JPSS RRPS processing code shall be able to run in the OSPO Operations Environment: (Linux machine with 6 quad core 3.2 GHz CPUs*
  - » *S/W: Intel Compiler (C/C++/Fortran) and IDL for Validation*
  - » *Storage: 30 TB)*
  - » C code, C++ code, and Fortran code can run in this environment

Basic Requirement 7.0

- **JPSS-RRPS-R 7.0:** *The JPSS RRPS system shall generate metadata for each retrieved product.*

  » ***Driver:*** *Metadata will be used by the Product Monitoring Project*

Basic Requirement 7.0

- **JPSS-RRPS-R 7.1:** *The JPSS RRPS system shall write a metadata text files associated with the retrieved products.*
  - » Coordinate with the Product Monitoring Project.
- **JPSS-RRPS-R 7.1.1:** *The metadata shall include overall quality and summary level metadata.*
  - » Coordinate with the Product Monitoring Project.

Basic Requirement 7.0

- **JPSS-RRPS-R 7.1.2:** *The metadata shall include Granule metadata.*

    » Coordinate with the Product Monitoring Project.

- **JPSS-RRPS-R 7.1.3:** *The metadata shall include product specific metadata.*

    » Coordinate with the Product Monitoring Project.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.0:** *The JPSS RRPS system shall have QC monitoring capability.*

- **Driver:** This basic requirement is traced to an OSPO need for QC monitoring.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.1:** *The JPSS RRPS Product files shall include overall quality control flags and quality summary level metadata.*
  - » Needed for distribution, quality control and post-processing. JPSS PS code will generate metadata for this purpose.
- **JPSS-RRPS-R 8.2:** *The JPSS RRPS system shall be capable of monitoring input data latency and overall quality.*
  - » Need to import metadata from input file and create code for generating metadata.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.3:** *The JPSS RRPS system shall be capable of monitoring product latency.*

  » Run status file will include processing time.

- **JPSS-RRPS-R 8.4:** *The JPSS RRPS system shall produce real-time imagery for visual inspection of output files.*

  » Will be done with IDL.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.5:** *The JPSS RRPS system shall be capable of monitoring product distribution status to ensure that the data/products are successfully available for transfer to the user community.*
  - » A run status file will be produced. Work with OSPO to determine needs.
- **JPSS-RRPS-R 8.5.1:** *Each run status file shall include all runtime error messages.*
  - » Error messages will include system messages and error conditions written by the code.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.5.2:** *Each run status file shall indicate whether or not the run was completed without error.*
  - » Code will write this message. This indication will be the last message in the file, so that operators can find it easily.
- **JPSS-RRPS-R 8.6:** *The JPSS PS system shall write a log file for each production run.*
  - » Used by OSPO for QC monitoring and troubleshooting.

Basic Requirement 8.0

- **JPSS-RRPS-R 8.6.x:** *Placeholder for TBD requirements for the log file.*

  » Log file requirements will be specified at the UTR.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.0:** *The JPSS PS developers shall produce a fully functional pre-operational system in the STAR Development Environment.*

    » **Driver:** This basic requirement is traced to an NDE need for a unit-tested, fully functional system delivered to its Test Environment.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.1:** *The Development Environment shall be capable of hosting the conversion of JPSS RRPS science code to JPSS RRPS pre-operational code.*
  - » See derived requirements 9.1.x.

- **JPSS-RRPS-R 9.1.1:** *The Development Environment shall include the INTEL FORTRAN 90/95 compiler.*
  - » Needed for the Framework FORTRAN code. Development Environment servers have this.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.1:** *The Development Environment shall be capable of hosting the conversion of JPSS RRPS science code to JPSS RRPS pre-operational code.*
  - » See derived requirements 9.1.x.
- **JPSS-RRPS-R 9.1.1:** *The Development Environment shall include the INTEL FORTRAN 90/95 compiler.*
  - » Needed for the Framework FORTRAN code. Development Environment servers have this.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.1.2:** *The Development Environment shall include the INTEL C compiler.*
  - » Needed for the Framework C code. Development Environment servers have this.
- **JPSS-RRPS-R 9.1.3:** *The Development Environment shall include the INTEL C++ compiler.*
  - » Needed for the Framework C++ code. Development Environment servers have this.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.1.4:** *The Development Environment shall include Linux machine with 100TB of disk storage.*
  - » Development Environment servers have this.
- **JPSS-RRPS-R 9.2:** *The Development Environment shall be capable of hosting unit tests and a system test.*
  - » Unit tests and system test required prior to delivery of pre-operational system to OSPO.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.2.1:** *The Development Environment shall have access to the OSPO DDS/PDA.*
  - » For ingest of VIIRS data and GFS data.
- **JPSS-RRPS-R 9.2.2:** *The Development Environment shall have access to the OSPO DDS/PDA server.*
  - » For ingest of IMS daily snow cover data.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.3:** *The Development Environment shall host the pre-operational system.*
  - » For development and unit testing. Complete unit test of the pre-operational system is expected before delivery to NDE.
- **JPSS-RRPS-R 9.3.1:** *The pre-operational system shall include all processing code and ancillary files needed to conduct unit tests.*
  - » Complete unit test of the pre-operational system is expected before delivery to NDE. The UTR will provide a detailed description of the source code units and ancillary files.

Basic Requirement 9.0

- **JPSS-RRPS-R 9.3.2:** *The pre-operational system shall include all input test data needed to conduct unit tests.*

  » Complete unit test of the pre-operational system is expected before delivery to NDE. The UTR will provide a detailed description of the unit test data.

- **JPSS-RRPS-R 9.3.3:** *The JPSS RRPS pre-operational system baseline shall be established and maintained with the Clear Case CM tool.*

  » CM of the pre-operational system is expected throughout its development.

Basic Requirement 10.0

- **JPSS-RRPS-R 10.0:** *The JPSS RRPS integrated pre-operational system shall be transitioned from the STAR Development Environment to the NDE Test Environment.*

  » **Driver:** This basic requirement is traced to an NDE need for a system-tested, integrated pre-operational system delivered to its Test Environment.

Basic Requirement 10.0

- **JPSS-RRPS-R 10.1:** *The Development Environment shall host the JPSS RRPS integrated pre-operational system.*

  » For system testing. A complete system test of the integrated pre-operational system is expected before delivery to NDE.

- **JPSS-RRPS-R 10.1.1:** *The integrated pre-operational system shall include all processing code and ancillary files needed to conduct the system test.*

  Complete system test of the integrated pre-operational system is expected. The SRR will provide a description of the processing software system and ancillary files.

Basic Requirement 10.0

- **JPSS-RRPS-R 10.1.2:** *The integrated pre-operational system shall include all input data needed to conduct a system test.*
  - » Complete system test of the integrated pre-operational system is expected. The SRR will provide a description of the system test data.
- **JPSS-RRPS-R 10.1.3:** *The integrated pre-operational system shall include all output data produced by the system test.*
  - » Needed by NDE to verify the system test in its Test Environment. Comparison of outputs from system test in STAR and NDE environments will be part of the NDE system test. Specific items will be listed in the SRR.

Basic Requirement 10.0

- **JPSS-RRPS-R 10.1.4:** *The JPSS RRPS integrated pre-operational system baseline shall be established and maintained with the Clear Case CM tool.*
  - CM of the integrated pre-operational system is expected throughout its development.

Basic Requirement 10.0

- **JPSS-RRPS-R 10.2:** *The JPSS RRPS development team shall set up an internal FTP site for transferring the integrated pre-operational system to NDE as a Delivered Algorithm Package (DAP).*

  » NDE needs to reproduce the system test in its Test Environment. ftp.star.nesdis.noaa.gov is a currently functioning site that will be used.

- **JPSS-RRPS-R 10.2.1:** *The JPSS RRPS development team shall ensure that the NDE PAL has the information needed to acquire the JPSS RRPS DAP from the internal FTP site.*

  » Use of ftp.star.nesdis.noaa.gov ensures this.

Basic Requirement 11.0

- **JPSS-RRPS-R 11.0:** *STAR shall deliver a JPSS RRPS document package to OSPO.*

  » **Driver:** This basic requirement is traced to an OSPO need for documentation to support operations, maintenance, and distribution.

Basic Requirement 11.0

- **JPSS-RRPS-R 11.1:** *The JPSS RRPS document package shall include a README text file.*

- **JPSS-RRPS-R 11.1.1:** *The README file shall list each item in the final pre-operational system baseline, including code, test data, and documentation.*

  » All required deliverable items must be correctly identified

Basic Requirement 11.0

- **JPSS-RRPS-R 11.2:** *The JPSS RRPS document package shall include a Review Item Disposition (RID) document.*

- **JPSS-RRPS-R 11.2.1:** *The RID shall describe the final status of all development project tasks, work products, and risks.*

  » Supports the final System Readiness Review Report (SRRR)

Basic Requirement 11.0

- **JPSS-RRPS-R 11.3:** *The JPSS RRPS document package shall include an Algorithm Theoretical Basis Document (ATBD).*
  - » The ATBD will follow SPSRB Version 2 document standards
- **JPSS-RRPS-R 11.4:** *The JPSS RRPS document package include a Requirements Allocation Document (RAD).*
  - » The RAD will follow document standards stated in EPL v3 process asset DG-6.2

Basic Requirement 11.0

- **JPSS-RRPS-R 11.5:** *The JPSS RRPS document package shall include a System Maintenance Manual (SMM).*
  - » The SMM will follow SPSRB Version 2 document standards.
- **JPSS-RRPS-R 11.6:** *The JPSS RRPS document package shall include an External Users Manual (EUM).*
  - » The EUM will follow SPSRB Version 2 document standards.

Basic Requirement 11.0

- **JPSS-RRPS-R 11.7:** *The JPSS RRPS document package shall include an Internal Users Manual (IUM).*
  - » The IUM will follow SPSRB Version 2 document standards.
- **JPSS-RRPS-R 11.8:** *The JPSS RRPS document package shall include a Critical Design Document (CDD).*
  - » The CDD will follow STAR EPL document standards in DG-8.2 and DG-8.2.A.

Basic Requirement 11.0

- **JPSS-RRPS-R 11.9:** *The JPSS RRPS document package shall include a Code Test Document (CTD).*
  - » The CTD will follow STAR EPL document standards in DG-10.3 and DG-10.3.A.
- **JPSS-RRPS-R 11.10:** *The JPSS RRPS document package shall include a System Readiness Document (SRD).*
  - » The SRD will follow STAR EPL document standards in DG-11.5 and DG-11.5.A.

Basic Requirement 11.0

- **JPSS-RRPS-R 11.11:** *The JPSS RRPS document package shall include a System Readiness Review Report (SRRR).*
  - » The SRRR will follow document standards stated in EPL v3 process asset DG-11.6

- **JPSS-RRPS-R 11.11.1:** *The SRRR shall document the approved readiness of the JPSS RRPS system for transition to operations.*
  - » This is an SRR exit criteria item

Basic Requirement 12.0

- **JPSS-RRPS-R 12.0:** *The JPSS RRPS system shall undergo an OSPO Code Review Security for security compliance*

  » **Driver:** OSPO Security

Basic Requirement 12.0

- **JPSS-RRPS-R 12.1:** *The JPSS RRPS system shall comply with OSPO data integrity check list.*
  - OSPO data integrity check list is part of the OSPO Code Review Security check lists.
- **JPSS-RRPS-R 12.2:** *The JPSS RRPS system shall comply with OSPO development security check list.*
  - OSPO development security check list is part of the OSPO Code Review Security check lists.

Basic Requirement 12.0

- **JPSS-RRPS-R 12.3:** *The JPSS RRPS system shall comply with OSPO code check list.*

  » OSPO code check list is part of the OSPO Code Review Security check lists.

Basic Requirement 13.0

- **JPSS-RRPS-R 13.0:** *The JPSS RRPS developers shall specify IT resource needs for operations.*

  » **Driver:** OSPO IT Capacity Planning

Basic Requirement 13.0

- **JPSS-RRPS-R 13.1:** *The JPSS RRPS system shall run on Redhat Linux.*
  - » Servers are available.
- **JPSS-RRPS-R 10.2:** *Operational server shall have 30 TB of disk space.*
  - » Available servers have this capability.
- **JPSS-RRPS-R 13.3:** *Each operational server shall have 8 GB of RAM for each core.*
  - » Available servers have this capability.

JPSS RR Requirements shown with the JPSS L1RD Supplement Requirements

Cloud Mask

	JPSS L1RD	JPSS RRPS
Name	Cloud Mask	Cloud Mask
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Reporting Interval	N/A	N/A
Horizontal Cell Size	0.8 km at Nadir	0.75 km.
Mapping Uncertainty, 3 Sigma	4 km threshold; 1 km objective	4 km threshold; 1 km objective
Measurement Range	Cloudy/Not Cloudy	Cloudy/Not Cloudy
Measurement Accuracy	1. Ocean, Day, COT>1.0 – 94%; 2. Day, Land, COT>1.0 – 90%; 3. Ocean, Night, COT>1.0 – 85%; 4. Land, Night, COT>1.0- 88%;	90%
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Cloud Leakage Rate	1. Ocean, Day, COT>1.0, outside Sun Glint region – 1%; 2. Day, Land, COT>1.0 – 3%; 3. Land, Ocean, Night, COT>1.0 – 5%	1. Ocean, Day, COT>1.0, outside Sun Glint region – 1%; 2. Day, Land, COT>1.0 – 3%; 3. Land, Ocean, Night, COT>1.0 – 5%
False Alarm Rate	1. Ocean, Day, COT>1.0- 5%; 2. Land, Day, ToC NDVI < 0.2 or ToC NDVI > 0.4, or Desert, COT > 1.0 – 7%; 3. Land, Ocean, Night, COT>1.0 – 8%;	1. Ocean, Day, COT>1.0- 5%; 2. Land, Day, ToC NDVI < 0.2 or ToC NDVI > 0.4, or Desert, COT > 1.0 – 7%; 3. Land, Ocean, Night, COT>1.0 – 8%;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Cloud Mask

Cloud Mask Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.
- 2. Cloud Mask shall be computed and reported for the total cloud cover.

Cloud Top Phase

	JPSS L1RD	JPSS RRPS
Name	Cloud Phase	
User & Priority		
Geographic Coverage		Global coverage
Vertical Reporting Interval		
Horizontal Cell Size		0.75 km.
Mapping Uncertainty, 3 Sigma		
Measurement Range		
Measurement Accuracy		80% Correct Classification (7 phases)
Product Refresh Rate		Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency		30 minutes after granule data is available
Timeliness		≤ 3hours

Cloud Type

	JPSS L1RD	JPSS RRPS
Name	Cloud Type	
User & Priority		
Geographic Coverage		Global coverage
Vertical Reporting Interval		
Horizontal Cell Size		0.75 km.
Mapping Uncertainty, 3 Sigma		
Measurement Range		
Measurement Accuracy		60%
Product Refresh Rate		Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency		30 minutes after granule data is available
Timeliness		≤ 3hours

Cloud Top Height

	JPSS L1RD	JPSS RRPS
Name	Cloud Top Height	Cloud Top Height
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold - Tops of up to four cloud layers (1); Objective - Tops of all distinct cloud layers	Threshold - Tops of up to four cloud layers (1); Objective - Tops of all distinct cloud layers
Horizontal Cell Size	Threshold – 7 km; Objective – 1 km;	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold 4 km; Objective 1 km;	Threshold 4 km; Objective 1 km;
Measurement Range		
Measurement Accuracy	Threshold – 1. COT ≥1 – 1.0 km; 2. COT < 1 – 2.0 km; Objective – 1. COT ≥ 1 – 0.3 km; 2. COT < 1 – 035 km;	500 m for Clouds with emissivity > 0.8
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold – 1. COT ≥1 – 1.0 km; 2. COT < 1 – 2.0 km; Objective – 1. COT ≥ 1 – 0.15 km; 2. COT < 1 – 0.15 km;	Threshold – 1. COT ≥1 – 1.0 km; 2. COT < 1 – 2.0 km; Objective – 1. COT ≥ 1 – 0.15 km; 2. COT < 1 – 0.15 km;

Cloud Top Height (CTH)

CTH Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.

Cloud Cover/Layers

	JPSS L1RD	JPSS RRPS
Name	Cloud Cover/Layers	Cloud Cover Layers
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global
Vertical Reporting Interval	Threshold -Up to four cloud layers; Objective – 0.1 km;	Threshold -Up to four cloud layers; Objective – 0.1 km;
Horizontal Cell Size	Threshold – 7 km; Objective – 1 km;	0.75 km
Mapping Uncertainty, 3 Sigma	Threshold - 4 km; Objective - 1 km	Threshold - 4 km; Objective - 1 km
Measurement Range(Applies only to total cloud cover; Not applicable to layers)	Threshold - 0 to 1.0 HCS Area; Objective – 0 to 1.0;	Threshold - 0 to 1.0 HCS Area; Objective – 0 to 1.0;
Measurement Accuracy	0.1 + 0.3(TBR-7) sin (SZA) of HCS Area	80% Correct Classification (Low, Mid, High)
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule is available
Timeliness		≤ 3hours

Cloud Cover/Layers

CC/L Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.
- 2. Cloud Cover shall be computed and reported at each separate, distinct layer,
- as well as for the total cloud cover.

Cloud Top Temperature

	JPSS L1RD	JPSS RRPS
Name	Cloud Top Temperature	Cloud Top Temperature
User & Priority	JPSS 4	JPSS 4
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold – Tops of up to four cloud layers; Objective – Tops of all distinct cloud layers	Threshold – Tops of up to four cloud layers; Objective – Tops of all distinct cloud layers
Horizontal Cell Size	Threshold – 7 km; Objective – 1 km;	0.75 km.
Mapping Uncertainty, 3 Sigma	4 km threshold; 1 km objective	4 km threshold; 1 km objective
Measurement Range		
Measurement Accuracy	Threshold – 1. Optical thickness ≥ 1 – 3K; 2. Optical Thickness < 1 – 6K; Objective - 1. Optical thickness ≥ 1 – 1.5K; 2. Optical Thickness < 1 – 2K;	3 K for clouds with emissivity > 0.8
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold – 1. Optical thickness ≥ 1 – 3K; 2. Optical Thickness < 1 – 6K; Objective – N/A	Threshold – 1. Optical thickness ≥ 1 – 3K; 2. Optical Thickness < 1 – 6K; Objective – N/A

Cloud Top Temperature (CTT)

CTT Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.

Cloud Top Pressure

	JPSS L1RD	JPSS RRPS
Name	Cloud Top Pressure	Cloud Top Pressure
User & Priority	JPSS 4	JPSS 4
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold – Tops of up to four cloud layers	Threshold – Tops of up to four cloud layers
Horizontal Cell Size	Threshold – 7 km; Objective – 1 km;	0.75 km.
Mapping Uncertainty, 3 Sigma	4 km threshold; 1 km objective	4 km threshold; 1 km objective
Measurement Range	Cloudy/Not Cloudy	Cloudy/Not Cloudy
Measurement Accuracy	Threshold – COT ≥ 1 1. Surface to 3 km – 100 mb; 2. 3 to 7 – 75 mb; 3. > 7 km – 50 mb; Objective – 1. Surface to 3 km – 30 mb; 2. 3 to 7 – 22 mb; 3. > 7 km – 15 mb;	50 mb for clouds with emissivity > 0.8
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold – COT ≥ 1 1. Surface to 3 km – 100 mb; 2. 3 to 7 – 75 mb; 3. > 7 km – 50 mb; Objective – 1. Surface to 3 km – 10 mb; 2. 3 to 7 – 7 mb; 3. > 7 km – 5mb;	Threshold – COT ≥ 1 1. Surface to 3 km – 100 mb; 2. 3 to 7 – 75 mb; 3. > 7 km – 50 mb; Objective – 1. Surface to 3 km – 10 mb; 2. 3 to 7 – 7 mb; 3. > 7 km – 5mb;

Cloud Top Pressure (CTP)

CTP Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.

Cloud Optical Thickness

	JPSS L1RD	JPSS RRPS
Name	Cloud Optical Thickness	Cloud Optical Thickness
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold – up to four cloud layers; Objective – 4 layers;	Threshold – up to four cloud layers; Objective – 4 layers;
Horizontal Cell Size	Threshold – 7 km; Objective – N/S;	1 km.
Mapping Uncertainty, 3 Sigma	Threshold - 4 km; Objective - 1 km;	Threshold - 4 km; Objective - 1 km;
Measurement Range	Cloudy/Not Cloudy	Cloudy/Not Cloudy
Measurement Accuracy	Threshold – Greater of 24 % or 1 Tau Objective – 5%;	Liquid phase: 20% error (Day), 20% (Night); Ice phase: 20% Day), 30% (Night)
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold – Greater of 33 % or 1 Tau Objective – 2%;	Threshold – Greater of 33 % or 1 Tau Objective – 2%;

Cloud Optical Thickness (COT)

COT Applicable Conditions:

- 1. Requirements apply whenever detectable clouds are present.

Cloud Effective Particle Size

	JPSS L1RD	JPSS RRPS
Name	Cloud Effective Particle Size	Cloud Effective Particle Size
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold – up to four cloud layers; Objective – 0.3 km;	Threshold – up to four cloud layers; Objective – 0.3 km;
Horizontal Cell Size	Threshold – 7 km; Objective – 1 km;	1 km.
Mapping Uncertainty, 3 Sigma	4 km threshold; 1 km objective	4 km threshold; 1 km objective
Measurement Range	Threshold - 0 to 50 μm; Objective – N/S	Threshold - 0 to 50 μm; Objective – N/S
Measurement Accuracy	Threshold – Greater of 22% or 1 μm for water; Greater of 28% or 1 μm for ice; Objective – 5%;	4 μm for liquid phase 10 μm for ice phase
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold – Greater of 22% or 1 μm for water; Greater of 28% or 1 μm for ice; Objective – 2%;	Threshold – Greater of 22% or 1 μm for water; Greater of 28% or 1 μm for ice; Objective – 2%;

Cloud Effective Particle Size (CEPS)

CEPS Applicable Conditions:

- 1. Requirements apply both day and night and whenever detectable clouds are present.

Cloud Liquid Water

	JPSS L1RD	JPSS RRPS
Name	Cloud Liquid Water	Cloud Liquid Water
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Reporting Interval	N/S	N/S
Horizontal Cell Size	Threshold m- 15 km @ nadir;	1 km.
Mapping Uncertainty, 3 Sigma	N/S	N/S
Measurement Range		
Measurement Accuracy	Threshold – Sea: 0.03 mm; Objective – Sea: 0.02 mm;	Greater of 25 g/m2 or 15% error
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – N/S;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – N/S hrs;
Latency	96/130 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Threshold –Sea: 0.08 mm; Objective – Sea: 0.06 mm;	Threshold –Sea: 0.08 mm; Objective – Sea: 0.06 mm;

Cloud Ice Water Path

	JPSS L1RD	JPSS RRPS
Name		Cloud Ice Water Path
User & Priority		
Geographic Coverage		Global coverage
Vertical Reporting Interval		
Horizontal Cell Size		1.0 km.
Mapping Uncertainty, 3 Sigma		
Measurement Range		
Measurement Accuracy		Greater of 25g/m2 or 30% error
Product Refresh Rate		Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency		30 minutes after granule data is available
Timeliness		≤ 3hours

Aerosol Detection

	JPSS L1RD	JPSS RRPS
Name	Suspended Matter	Aerosol Detection
User & Priority	JPSS 2	JPSS 2
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold: Total Column Objective: 0.2 km	Threshold: Total Column Objective: 0.2 km
Horizontal Cell Size	Theshold: 3 km Objective: 1 km	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold: 3 km Objective: 0.1 km	Threshold: 3 km Objective: 0.1 km
Measurement Range	Radioactive Smoke Plumes: 0 to 150 microg/m3	Smoke: 0 to 200 microg/m3
Measurement Accuracy	Threshold: Suspended Matter: 80% Dust: 80% Smoke: 70% Volcanic Ash: 60% Objective: Suspended Matter, Dust, Smoke, Volcanic Ash: 100% Mixed Aerosol: 80%	Dust: 80% correct detection over land and ocean Smoke: 80% Correct detection over land 70% correct detection over ocean
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	Threshold: 96 min Objective: 30 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Aerosol Optical Thickness

	JPSS L1RD	JPSS RRPS
Name	Aerosol Optical Thickness	Aerosol Optical Depth
User & Priority	JPSS 4	JPSS 4
Geographic Coverage		Global coverage
Vertical Reporting Interval	Threshold - Total column; Objective - Total column	Threshold - Total column; Objective - Total column
Horizontal Cell Size	Threshold - 6 km (nadir); 12.8 km (Edge Of Scan); Objective – 1 km;	0.75 km (nadir)
Mapping Uncertainty, 3 Sigma	Threshold – 4 km; Objective – 1 km;	Threshold – 4 km; Objective – 1 km;
Measurement Range	Threshold – 0 to 2; Objective – 0 to 10;	Threshold – 0 to 2; Objective – 0 to 10;
Measurement Accuracy	Threshold – 1. Over Ocean - 0.08 (Tau < 0.3) 0.15 (Tau ≥ 0.3) (1,2,4); 2. Over Land – 0.06 (Tau < 0.1); 0.05 (0.1 ≤ Tau ≤ 0.8); 0.2 (Tau > 0.8) (1,2,4); Objective – 1. Over Ocean – 1%; 2. Over Land – 1%;	Based on Aerosol Optical Depth ranges: Over land: < 0.04: 0.06 0.04 – 0.80: 0.04 > 0.80: 0.12 Over water: < 0.40: 0.02 > 0.40: 0.10
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Aerosol Optical Thickness (AOT)

AOT Applicable Conditions:

- 1. Clear, daytime only
- 2. Zenith angles less than or equal to 80 degrees. (3)

Aerosol Particle Size Parameter

	JPSS L1RD	JPSS RRPS
Name	Aerosol Particle Size Parameter	Aerosol Particle Size
User & Priority	JPSS 4	JPSS 4
Geographic Coverage		Global coverage
Vertical Coverage	Threshold - Surface to 30 km; Objective - Surface to 50 km;	Threshold - Surface to 30 km; Objective - Surface to 50 km;
Vertical Cell Size	Threshold – Total Column; Objective – 0.25 km;	Threshold – Total Column; Objective – 0.25 km;
Horizontal Cell Size	Threshold - 6 km (nadir); 12.8 km (Edge Of Scan); Objective – 1 km;	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold – 4 km; Objective – 1 km;	Threshold – 4 km; Objective – 1 km;
Measurement Range	Threshold Operational -1 to +3 alpha units; Objective -2 to +4 alpha units;	Threshold Operational -1 to +3 alpha units; Objective -2 to +4 alpha units;
Measurement Accuracy	Operational over Ocean Threshold – 0.3 alpha units; Objective – 0.1 alpha units;	Fine/Coarse Angstrom exponent: 0.3 over ocean and land
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average); Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours
Product Measurement Precision	Operational over Ocean Threshold – 0.3 alpha units; Objective – 0.1 alpha units;	Operational over Ocean Threshold – 0.3 alpha units; Objective – 0.1 alpha units;

Aerosol Particle Size Parameter (APSP)

APSP Applicable Conditions:

- 1. Clear, daytime only

Volcanic Ash and Height

	JPSS L1RD	JPSS RRPS
Name	Volcanic Ash	Volcanic Ash Detection (Mass Loading) and Height
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Vertical Cell Size	Threshold – Total Column; Objective – 0.2 km;	Threshold – Total Column; Objective – 0.2 km;
Horizontal Cell Size	Threshold - 3 km Objective – 1 km;	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold – 3 km; Objective – 0.1 km;	Threshold – 3 km; Objective – 0.1 km;
Measurement Range	N/S	N/S
Measurement Accuracy	Threshold –50%; Objective – 100%	2 tons/km2, 3 km height
Product Refresh Rate	Threshold - At least 90% coverage (product retrieval is attempted regardless of sky condition) of the globe ovr 24 hours (monthly average).Objective – 3 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 3 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Volcanic Ash

Applicable Conditions:

- 1. Clear, for AOT greater than 0.15, daytime only.

Snow Cover

	JPSS L1RD	JPSS RRPS
Name	Snow Cover	Snow Cover
User & Priority	JPSS 3	JPSS 3
Geographic Coverage		Global coverage
Sensing Depth	Threshold – N/S; Objective – 1.0 m;	Threshold – N/S; Objective – 1.0 m;
Horizontal Cell Size	Threshold 1. Clear - 1.6 km EOS; 2. Cloudy and/or nighttime – H/S Objective – 1. Clear - 1.0 km; 2. Cloudy and/or nighttime – 1.0 km	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold 1. clear – 3km; 2. Cloudy – N/S Objective 1. Clear – 1 km; 2. Cloudy – 1km;	Threshold 1. clear – 3km; 2. Cloudy – N/S Objective 1. clear – 1 km; 2. Cloudy – 1km;
Measurement Range	0 - 100% HSC area fraction; 0 or 1 BSC mask	0 - 100% HSC area fraction; 0 or 1 BSC mask
Measurement Accuracy	Threshold 1. Clear: 10% of FSC area; 90% probability of correct snow/no-snow classification (2,3); 2. Cloudy – N/S Objective 1. Clear: 10% for snow depth (microwave instrument); 90% probability of correct BSC snow/no snow classification (VIIRS); 2. Cloudy: 10% for snow depth	90% correct classification
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average).Objective – 4 hrs;	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 4 hrs;
Latency	96/130 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Snow Cover

Snow Cover Applicable Conditions:

- 1. Clear Daytime, only

Sea Ice Concentration

	JPSS L1RD	JPSS RRPS
Name	Sea Ice Concentration	Ice Concentration
User & Priority	JPSS 3	JPSS 3
Geographic Coverage	All ice-covered regions of the global ocean	Global coverage
Vertical Coverage	Ice surface	Ice Surface
Horizontal Cell Size	Threshold 1. Clear - 1km 2. All weather – No capability Objective 1. Clear – 0.5 km 2. All weather - 1 km	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold 1. Clear - 1km @ nadir 2. Cloudy -No capability Objective 1. Clear – 0.5 km 2. Cloudy - 1 km	Threshold 1. Clear - 1km @ nadir 2. Cloudy -No capability Objective 1. Clear – 0.5 km 2. Cloudy - 1 km
Measurement Range	0/10 to 10/10	0/10 to 10/10
Measurement Uncertainty	Threshold Note 1 Objective 5%	10%
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average). Objective 6 hrs	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 6 hrs;
Cloud Leakage Rate	1. Ocean, Day, COT>1.0, outside Sun Glint region – 1%; 2. Day, Land, COT>1.0 – 3%; 3. Land, Ocean, Night, COT>1.0 – 5%	1. Ocean, Day, COT>1.0, outside Sun Glint region – 1%; 2. Day, Land, COT>1.0 – 3%; 3. Land, Ocean, Night, COT>1.0 – 5%
Latency	96 / 130 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Ice Age

	JPSS L1RD	JPSS RRPS
Name	Ice Age	Ice Age
User & Priority	JPSS 3	JPSS 3
Geographic Coverage	All ice-covered regions of the global ocean	Global coverage
Vertical Coverage	Ice surface	Ice Surface
Horizontal Cell Size	Threshold 1. Clear - 1km 2. All weather – No capability Objective 1. Clear – 0.5 km 2. All weather -1 km	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold 1. Clear - 1km @ nadir 2. Cloudy -No capability Objective 1. Clear – 0.5 km 2. Cloudy - 1 km	Threshold 1. Clear - 1km @ nadir 2. Cloudy -No capability Objective 1. Clear – 0.5 km 2. Cloudy - 1 km
Measurement Range	Threshold- Ice free, New/Young Ice, all other ice; Objective- Ice Free, Nilas, Grey White, Grey, White, First Year Medium, First Year Thick, Second Year, and Multiyear; Smooth and Deformed Ice	Threshold- Ice free, New/Young Ice, all other ice; Objective- Ice Free, Nilas, Grey White, Grey, White, First Year Medium, First Year Thick, Second Year, and Multiyear; Smooth and Deformed Ice
Measurement Uncertainty	Threshold -70% Objective - 90%	80% correct classification (Ice free areas, First year ice, Older ice)
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average). Objective - 6 hrs	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 6 hrs;
Latency	96/130 min	30 minutes after granule data is available
Timeliness		≤ 3hours

Ice Surface Temperature

	JPSS L1RD	JPSS RRPS
Name	Ice Surface Temperature	Ice Surface Temperature
User & Priority	JPSS 4	JPSS 4
Geographic Coverage	Threshold - Ice-covered oceans (1) Objective - All ice-covered waters.	Global coverage
Sensing Depth	Ice Surface	Ice Surface
Horizontal Cell Size	Threshold 1. Nadir - 1km 2. Worst Case –1.6 km Objective 1. Nadir - 0.1km 2. Worst Case – 0.1 km	0.75 km.
Mapping Uncertainty, 3 Sigma	Threshold 1. Nadir - 1km 2. Worst Case – 1.6 km Objective 1. Nadir - 0.1km 2. Worst Case – 0.1 km	Threshold 1. Nadir - 1km 2. Worst Case – 1.6 km Objective 1. Nadir - 0.1km 2. Worst Case – 0.1 km
Measurement Range	Threshold- 213 - 275 K Objective- 213 - 293 K (2 m above ice)	Threshold- 213 - 275 K Objective- 213 - 293 K (2 m above ice)
Measurement Uncertainty	Threshold - 1K Objective - N/S	1K
Product Refresh Rate	Threshold - At least 90% coverage of the globe every 24 hours (monthly average). Objective 12 hrs	Threshold - At least 90% coverage of the globe every 12 hours (monthly average); Objective – 12 hrs;
Latency	96 min	30 minutes after granule data is available
Timeliness		≤ 3hours

JPSS RRPS System Requirements – Summary

- The JPSS Risk Reduction System Requirements have been established.
- The Requirements have been documented in the Requirements Allocation Document (RAD).
- The Requirements are traceable to drivers (customer needs or expectations) and other requirements.

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Operations Concept

Presented by

A. K. Sharma

Operations Concept - Overview

- Identify intentions of the customers/users of the products
  - » Identify the SPSRB user requests
    - – 1107-0011: Gridded Cloud Products for NWP Verification
    - – 0909-0018: CLAVR-x and GSIP cloud product composites over Alaska
    - – 0507-05: Polar/Geostationary Volcanic Ash Detection and Height on CLAVR-X
    - – 1009-0016: Dust Aerosol Concentration Product
    - – 0707-0014: Support satellite-based verification of the National Air Quality Forecast Capability
    - – 0403-1: CrIS/ATMS Products for NWS
  - » Interact with the customers/users to produce an initial algorithm/system design that is consistent with their concept of operations

Operations Concept - Overview

- Review the answers to the following questions based on customer/user needs and expectations and production constraints
  - » What is the product?
  - » Why is this product being produced?
  - » How will this product be used?
  - » How should this product be produced (operational scenario)?

- The operations concept will be refined by the JPSS Risk Reduction Product Team (IPT), in consultation with customers/users, as the product solution and design are matured through the design development phase.

What is the Product?

- Cloud Mask
- Cloud Top Phase
- Cloud Type
- Cloud Top Height
- Cloud Cover Layers
- Cloud Top Temperature
- Cloud Top Pressure
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Liquid Water
- Cloud Ice Water Path

What is the Product?

- Aerosol Detection
- Aerosol Optical Depth
- Aerosol Particle Size
- Volcanic Ash Mass Loading
- Volcanic Ash Height

What is the Product?

- Snow Cover
- Ice Concentration
- Ice Age
- Ice Surface Temperature

What is the Product - Cont.

					Product Type and Number					
Fiscal Year (FY)	Product Delivery/Tracking Name	Environmental Observational Parameters	Satellites	Sensors	N #	E #	R #	T #	O #	Tailoring Options or Comments
FY15	JPSS Risk Reduction	Cloud Mask	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Phase	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Cover Layers	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Height	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Top Pressure	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Top Temperature	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Type	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds

What is the Product - Cont.

					Product Type and Number					
Fiscal Year (FY)	Product Delivery/Tracking Name	Environmental Observational Parameters	Satellites	Sensors	N #	E #	R #	T #	O #	Tailoring Options or Comments
FY15	JPSS Risk Reduction	Cloud Optical Depth	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Particle Size Distribution	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Ice Water Path	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Cloud Liquid Water Path	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Aerosol Detection	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Aerosol Optical Depth	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Aerosol Particle Size	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Volcanic Ash Detection & Height	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds

What is the Product - Cont.

					Product Type and Number					
Fiscal Year (FY)	Product Delivery/Tracking Name	Environmental Observational Parameters	Satellites	Sensors	N #	E #	R #	T #	O #	Tailoring Options or Comments
FY15	JPSS Risk Reduction	Snow Mask	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Ice Concentration	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Ice Age/Thickness	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds
FY15	JPSS Risk Reduction	Ice Surface Temperature	NPP	VIIRS	1					Formats: NetCDF4, Coverage: Granule Update Cycle: 87 seconds

N=New E=Enhanced R=Replacement T=Tailored O=Other

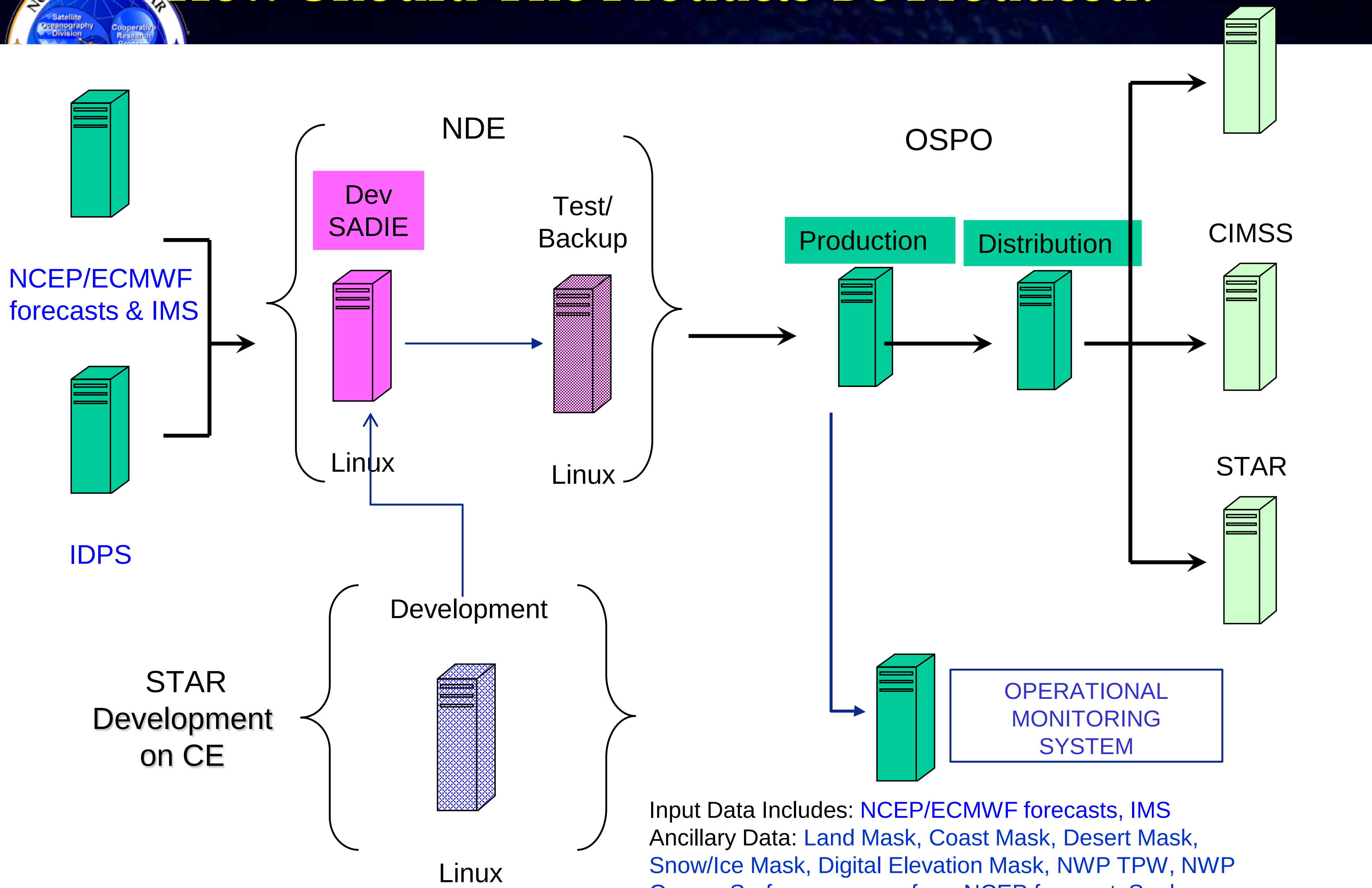
Why Are The Products Being Produced?

- NWS requests continuity of NOAA products between current and future NOAA operational satellites
- Demonstration of cost effective processing for NOAA JPSS products
- Demonstration of NOAA's goal of enterprise solutions by employing same algorithms for "POES" and "GOES"
- Supports NWS OS&T implementation strategy of multi-sensor algorithms and products

How Will The Products Be Used?

- Gridded Cloud Products for NWP Verification
- CLAVR-x and GSIP cloud product composites over Alaska
- Polar/Geostationary Volcanic Ash Detection and Height on CLAVR-X
- Dust Aerosol Concentration Product
- Support satellite-based verification of the National Air Quality Forecast Capability
- CrIS/ATMS Products for NWS

How Should The Products Be Produced?



Input Data Includes: NCEP/ECMWF forecasts, IMS
Ancillary Data: Land Mask, Coast Mask, Desert Mask, Snow/Ice Mask, Digital Elevation Mask, NWP TPW, NWP Ozone, Surface pressure from NCEP forecast, Seebor Surface Emissivity, Surface Type, Surface Reflectance

How Should The Products Be Produced? Cont.

- There will be four distinct environments
  - » Development Environment (STAR)
    - – Development and testing of pre-operational codes on Redhat Linux OS
  - » SADIE Development Environment (NDE)
    - – Transition point for the Algorithm Package. Testing of Algorithm Package on Redhat Linux OS
  - » Test environment (OSPO)
    - – Pre-operational codes and documents (DAP) received from STAR will be implemented and tested on the designated Red Hat Linux machine by NDE and modified as needed before it is promoted to operation
  - » Operation Environment (OSPO)
    - – Operational DAP will be run on the designated Redhat Linux machine at ESPC and the products monitoring GUI will be posted on the intranet web server and accessed under ESPC VPN by the operators, PALS and maintenance programmers. Products will be distributed via NDE first, and then the PDA and OSPO ftp/http servers when PDA is available.

How Should The Products Be Produced? Cont.

- Production and Delivery Scenarios
  - » The ESPC Ingest Systems will handle all input satellite data and ancillary data
  - » The JPSS RR product system will collect the satellite inputs and required ancillary data to run the OMPS LP algorithms
  - » The product will be generated in NetCDF4
  - » The JPSS RR metadata will be available for the Product Monitoring Tool system to use
  - » The product users will be granted access to the ESPC distribution system (PDA, when available) through the data access request submission process.
  - » Prior to PDA availability, NDE will distribute the JPSS RR products.
  - » When PDA is available, ESPC will handle the distribution of JPSS RR products

Development and Operational System Environments

Project Name:	JPSS Risk Reduction	
IT Item	Research	Production
Agency	STAR	OSPO (ESPC)
Platform(s) and need dates	Linux (RHEL OS on x86-64 platform) with 12 CPUs (dual core) and 48 GB of memory. Dates: August 2013.	Linux (RHEL OS on x86-64 platform) with 6 CPUs (quad core) and 48 GB of memory. Dates: August 2013. (Purchased by NDE)
Operating Systems	Linux (RHEL OS on x86-64 platform)	Linux (RHEL OS on x86-64 platform)
Programming languages/compilers ***	Intel Compiler (C/C++/Fortran)	Intel Compiler (C/C++/Fortran) libraries
Scripting languages	Perl (version 5.8 or higher)	Perl (version 5.8 or higher)
Graphical/Imaging programs, COTS S/W, other tools, libraries, etc	IDL (version 7.0 or higher)	IDL (version 7.0 or higher)
Helpdesk Monitoring Tool (standardized tool or customized tool?)	None	NPP Product Monitorinig Tool (PSDI project)
Other platforms needed for monitoring/imaging/graphics (specify platform & operating system)	None	None
Other (tools, shareware, libraries, critical non-static ancillary data, etc)	Libraries: netCDF 4.0, HDF5, and BUFR Utilities: wgrib2	Libraries: netCDF 4.0, HDF5, and BUFR Utilities: wgrib2

Development and Operational System Environments – cont.

Project Name:	JPSS Risk Reduction			
			Back-up Operations	
IT Item	Development	Production	On-Site	Off-Site
Agency	OSPO (ESPC)	OSPO (ESPC)	OSD (ESPC)	CIP
Platform(s) and need dates (include secondary platforms for monitoring, imagery or graphics, if necessary)	Linux with 6 CPUs (quad core, 3.2 GHz), 8 GB/CPU Dates: June 2012 – June 2017.	Linux with 6 CPUs (quad core, 3.2 GHz), 8 GB/CPU memory. Dates: August 2013. This is to be purchased by NDE.	Linux with 6 CPUs (quad core, 3.2 GHz), 8 GB/CPU memory. Dates: August 2013. This is to be purchased by NDE.	Linux with 6 CPUs (quad core, 3.2 GHz), 8 GB/CPU memory. Dates: August 2013. This is to be purchased by NDE.
Storage required on systems	30 TB	30 TB	30 TB	30 TB
How often does system run (granule time, orbital, daily); event or schedule driven?	87 seconds (Event)	87 seconds (Event)	87 seconds (Event)	87 seconds (Event)
Memory used at run time	4 GB for nominal processing	4 GB for nominal processing	4 GB for nominal processing	4 GB for nominal processing
Input data volume and input data sources	CLASS: 2 TB/day NCEP ftp server: 0.6 GB/day	IDPS: 2 TB/day TBD: 0.6 GB/day	IDPS: 2 TB/day TBD: 0.6 GB/day	IDPS: 2 TB/day TBD: 0.6 GB/day
Data volume for distribution; planned distribution server; specific push users & volumes	N/A	NDE DS: 100 GB/day	NDE DS: 100 GB/day	NDE DS: 100 GB/day
Communication Requirements/Protocol	DDS: ftp NCEP ftp server: ftp	ftp-s (managed by NDE)	ftp-s (managed by NDE)	ftp-s (managed by NDE)
Days to retain input and output data	96 hours	96 hours	96 hours	96 hours

Development and Operational System Maintenance Resources

- Walter Wolf, Andy Heidinger, Jeff Key, Shobha Kondragunta, Istvan Laszlo, Mike Pavolonis (STAR) and Peter Romanov (CREST) – Development Readiness and Quality Control support

- Shanna Sampson, Xingpin Liu (STAR), William Straka III, Ray Garcia (CIMSS) – Development support

- A. K. Sharma, Gilberto Vicente, Hanjun Ding, Zhaohui Cheng (OSPO), NIC – Operational Readiness and Quality control support

Distribution Environment – Capabilities and Resources

- NDE Data Distribution System
- Personnel
  - » NDE Personnel
  - » STAR Personnel
  - » OSPO Personnel

Production Scenarios – Monitoring and Maintenance

- NDE, working with OSPO, will provide the system monitoring capability
- OSPO will provide the routine validation capability
- OSPO PAL, STAR, and NIC will perform routine validation of the VIIRS Risk Reduction products

Production Scenarios – Monitoring and Maintenance – cont.

- Production Monitoring and Maintenance Scenarios
  - » The PAL and maintenance personnel at OSPO will monitor the system's function and resolve the issues.
  - » The maintenance personnel at OSPO will maintain and back up the database
  - » STAR personnel are available for operational science issues
  - » The JPSS Risk Reduction product files will have variables available for product monitoring

VIIRS Risk Reduction System Requirements

- The VIIRS Risk Reduction System Requirements have been established.
- The Requirements have been documented in the Requirements Allocation Document (RAD).
- The Requirements are traceable to drivers (customer needs or expectations) and other requirements.

Production Scenarios – Archive Product

- The VIIRS Risk Reduction products will not be archived to CLASS / NCDC archive

User Interaction

- The ESPC help desk will serve as the operational point of contact to provide 24/7 service support for users
  - » Provides information about the VIIRS RR data products to the user community
  - » Resolves user issues through coordination with the associated PALs
- The PALs will coordinate further with the STAR scientists for any product quality issue when identified and communicate with users.

Summary

- The OSPO Ingest Systems will handle all input satellite data and ancillary data
- OSPO will run the VIIRS RR system
- OPSO PAL, STAR team and NIC team will perform product validation
- NCEP will use the associated products within their models and will provide the support for products testing and validation
- VIIRS RR products will be available to be sent the to Reformatting Toolkit project, the Product Monitoring project and CLASS

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Algorithm Theoretical Basis Snow Cover

Presented by

Peter Romanov

Algorithm Theoretical Basis Document

- Purpose: Provide reviewers and users with a theoretical description (scientific and mathematical) of the NPP-Suomi VIIRS Snow Cover algorithm
- Will be documented in the ATBD of NPP-Suomi VIIRS Snow Cover Product

Requirements
Snow Cover

Name	Geographic Coverage	Horizontal Res.	Mapping Accuracy	Measurement Range	Measurement Accuracy (probability of correct typing)	Product Measurement Precision	Temporal Coverage Qualifiers	Cloud Cover Conditions Qualifier
Snow Cover	Global	375m	1 km	Binary yes/no detection	> 90%	5%	Sun at 85 degree solar zenith angle or less	Clear sky conditions

Snow Cover: Needs

- Accurate, spatially detailed and timely information on the snow cover is needed in NWP, hydrological and climate models. VIIRS snow cover retrievals also play a critical role in the NOAA Unique VIIRS data processing system since many algorithms require information on the snow cover to derive other land surface and atmospheric parameters (aerosol and clouds)

Algorithm Objectives

- Meet the requirements for the snow cover EDR
- Provide quality indicators to snow cover products.
- Provide needed performance information
- Be computationally efficient

VIIRS Snow Cover Algorithm Heritage

- NOAA Unique VIIRS Snow Cover Algorithm
  - » Description: Discriminates between snow-covered and snow-free land scenes. Uses decision-tree threshold-based approach to classify satellite images. Performs additional tests (spatial consistency, climatology) to identify spurious snow.
  - » Heritage:
    - – NASA MODIS and NPP VIIRS algorithm – D. Hall, 2003, RSE
    - – GOES Imager algorithm – Romanov et al, 1999, 2003
    - – NOAA AVHRR algorithm – Romanov, 2012
      - GOES Imager and NOAA AVHRR algorithms are currently implemented operationally at NESDIS OSDPD as part of the Global Multisensor Snow and Ice Mapping System (Autosnow)

Snow Cover
Sensor Input Data

VIIRS Band	Spectral Range (µm)	Nominal Central Wavelength (µm)	Nadir HSR (m)	Similar medium resolution (750m) VIIRS bands
I1	0.600-0.680	0.640	375	M5
I2	0.846-0.885	0.865	375	M7
I3	1.580-1.640	1.61	375	M10
I4	3.550-3.930	3.740	375	M12
I5	10.500-12.400	11.45	375	M15 & M16

Current Input

Expected Added Input

Snow Cover
Sensor Input Details

NPP-Suomi VIIRS Snow Cover product requires for each pixel:

- » **VIIRS-observed calibrated surface reflectance and brightness temperature data**
- » **Observation geometry (satellite zenith, solar zenith and relative azimuth angles)**
- » **Geolocation (latitude, longitude)**
- » **VIIRS SDR and cloud mask processing information (quality flags)**

Current Input (yellow)

Expected Added Input (orange)

Name	Type	Description	Dimension
Band I1 reflectance	Input	Calibrated VIIRS-observed scene reflectance at 0.64 um	Granule (xsize, ysize)
Band I2 reflectance	Input	Calibrated VIIRS-observed scene reflectance at 0.865 um	Granule (xsize, ysize)
Band I3 reflectance	Input	Calibrated VIIRS-observed scene reflectance at 1.61 um	Granule (xsize, ysize)
Band I5 brightness temperature	Input	Calibrated VIIRS-observed scene brightness temperature at 11.45 um	Granule (xsize, ysize)
Band I4 brightness temperature	Input	Calibrated VIIRS-observed scene brightness temperature at 3.74 um	Granule (xsize, ysize)

Snow Cover
Sensor Input Details, Cont'd

Name	Type	Description	Dimension
Latitude	Input	VIIRS Latitude	Granule (xsize, ysize)
Longitude	Input	VIIRS Longitude	Granule (xsize, ysize)
Solar zenith angle	Input	Solar zenith angle	Granule (xsize, ysize)
Satellite view angle	Input	VIIRS view zenith angle	Granule (xsize, ysize)
Relative azimuth	Input	VIIRS relative azimuth angle	Granule (xsize, ysize)
QC flags	Input	VIIRS SDR and cloud mask quality control flags	Granule (xsize, ysize)

Snow Cover Ancillary Input Data

- Two types of ancillary data needed:
  - » VIIRS Data:
    - – Cloud mask (including cloud shadow flag if available)
    - – SDR quality flags
  - » Non-VIIRS Static Data:
    - – Land/water mask
    - – Surface elevation
    - – Snow cover climatology
    - – Land surface temperature climatology (ISCCP)
    - – Algorithm control parameters (threshold values)

Snow Cover
Ancillary Input Data Details (1/2)

VIIRS Data

Name	Type	Description	Dimension
Cloud Mask	Input	Derived VIIRS Cloud Mask & Cloud Shadow Mask	Granule(xsize, ysize)
SDR Quality Flags	Input	Flags characterizing the quality of input Sensor Data Records	Granule(xsize, ysize)

Snow Cover Ancillary Input Data Details (2/2)

Non-VIIRS Static Data

Name	Type	Description	Dimension
Land/Water Mask	Input	Binary file discriminating land and water-covered pixels	Granule(xsize, ysize)
Surface elevation	Input	Binary file specifying surface elevation for every pixel of the granule	Granule(xsize, ysize)
Snow Cover Climatology	Input	Weekly maps of snow cover frequency of occurrence on 1/3 degree global lat/lon grid.	1080x540 (0.33^0 x 0.33^0)
Land Surface Temperature Climatology	Input	Monthly mean land surface temperature	144x72 (2.5^0 x 2.5^0)
Algorithm Control Parameters	Input	Threshold values and other parameters controlling the VIIRS image classification (snow detection) algorithm.	

Snow Cover Algorithm Output

Name	Type	Description	Dimension
Binary Snow Cover Map	Output	Pixel level output: binary snow map with cloud mask and land/water mask overlaid	granule (xsize, ysize)
Quality flags	Output	Pixel level output: quality flag for binary snow cover retrieval	granule (xsize, ysize)
Quality Control Information	Output	granule level output: snow retrievals statistics	Text

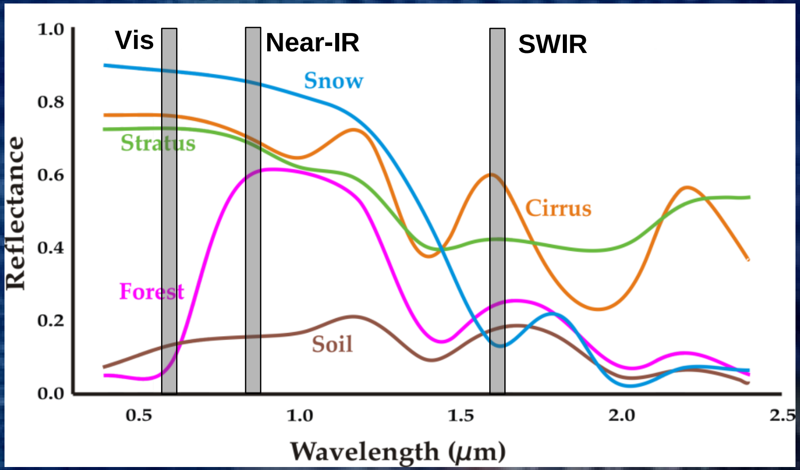
Physical Description; Channels Selection (1/2)

- **Visible /Near-Infrared/SWIR/IR, Justifications for Use:**

  » **Vis (I1, 0.64um) and SWIR (I3, 1.61um)**
  – Large difference between the scene reflectance in the visible and shortwave infrared spectral bands is the primary indicator of the presence of snow

  » **Near-IR (I2, 0.86um)**
  – Helps to identify snow partially masked by vegetation (forest), used to calculate NDVI

  » **IR (I5, 11.4um)**
  – Helps to discriminate snow cover from other land surface s that “look” similar to snow in reflective bands but are typically warmer than snow (e.g., sand, salt)

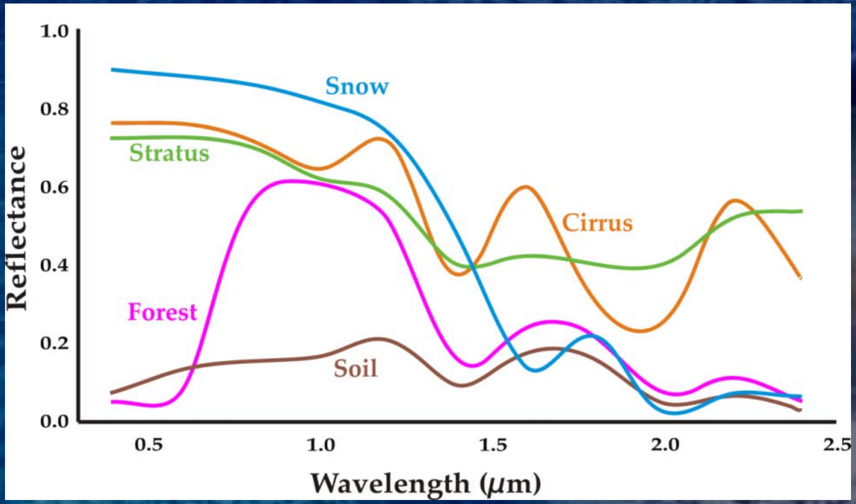


Physical Description; Channel Choice (2/2)

- Mid-IR *(I4, 3.7um)*
  - **Justifications for Use:**
    - May improve discrimination of snow from land surface types that exhibit a spectral response similar to snow in VIRS other reflective bands (e.g., sand, dry salt lakes)
    - This is an additional band inclusion

Physical Description
Snow Reflectance (1/4)

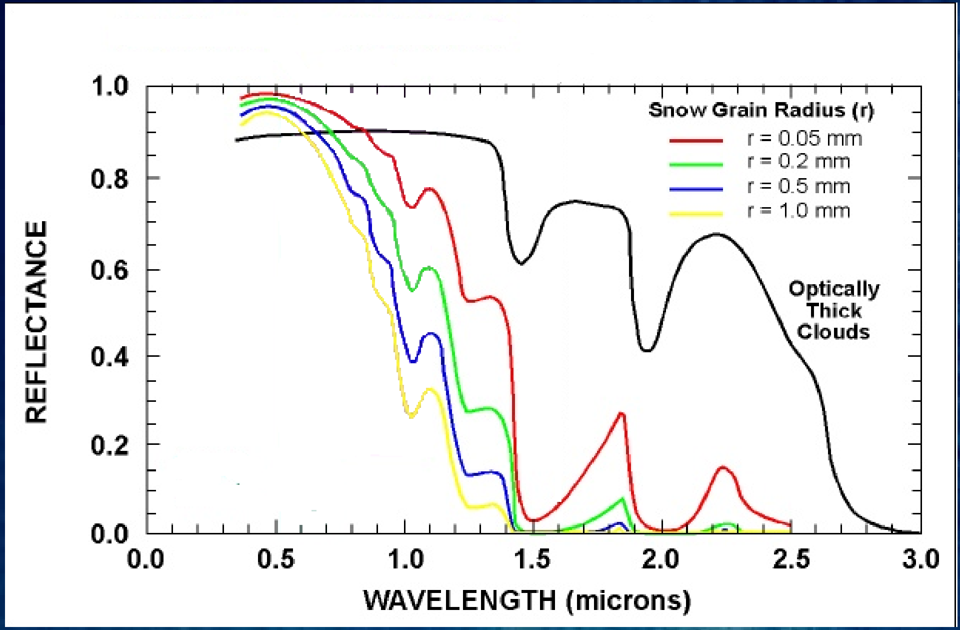
Snow has a specific spectral reflectance pattern: Snow reflectance drops from very high values in the visible and near-infrared to very low values in the shortwave and mid-infrared spectral range. This spectral pattern is different from spectral reflectance of most other natural land surface cover types.

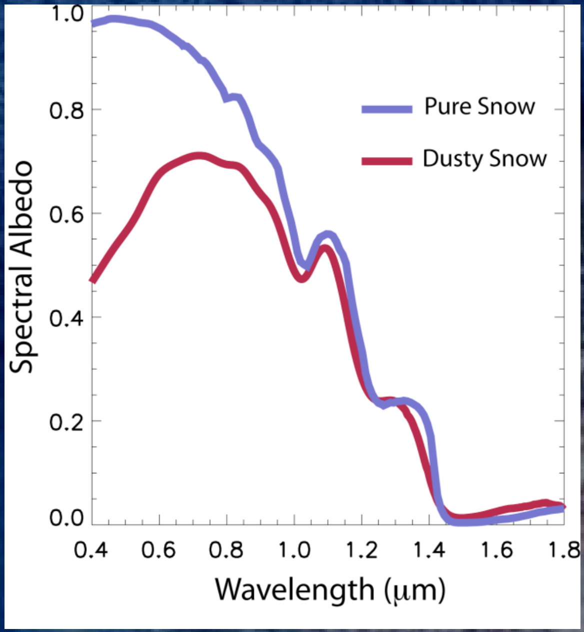


However there is number of factors that complicate identification of snow in satellite imagery ….

Physical Description
Snow Reflectance (2/4)

Snow reflectance depends on physical properties of snow (e.g., grain size, impurities, forest litter)

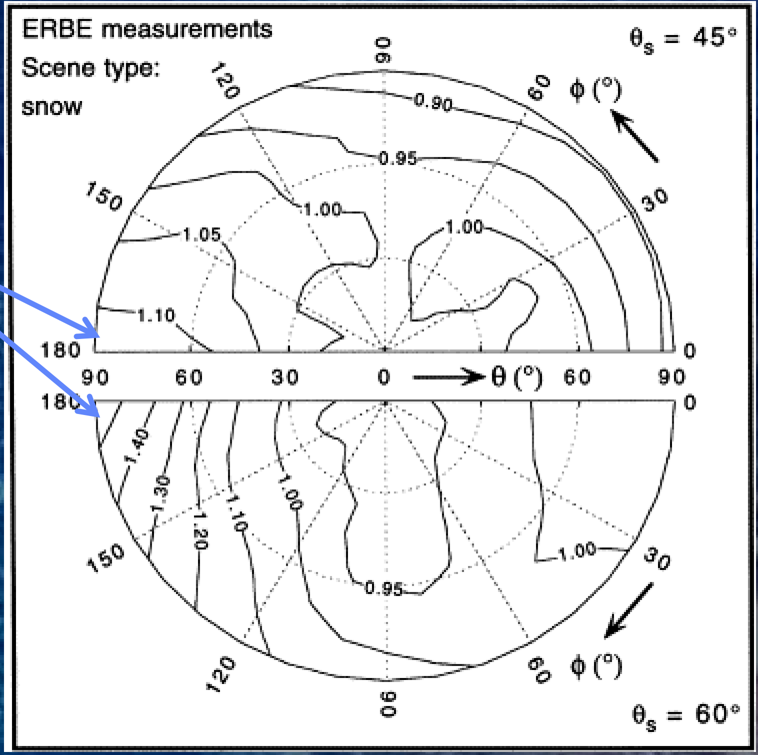




Physical Description
Snow Reflectance (3/4)

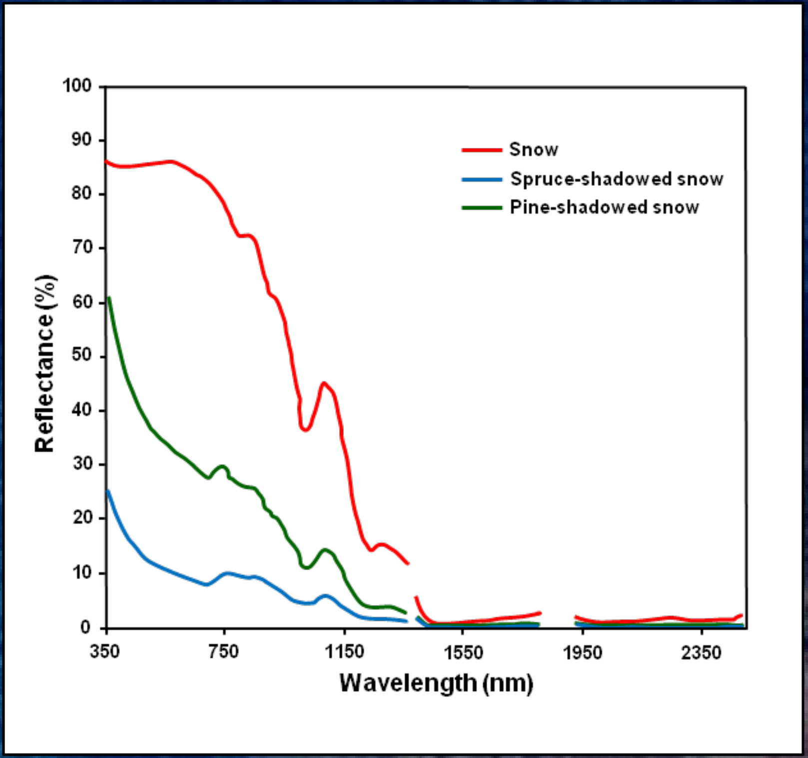
Snow reflectance varies with the viewing and illumination geometry of observations

Snow reflectance is larger in the forward scatter direction



Physical Description
Snow Reflectance (4/4)

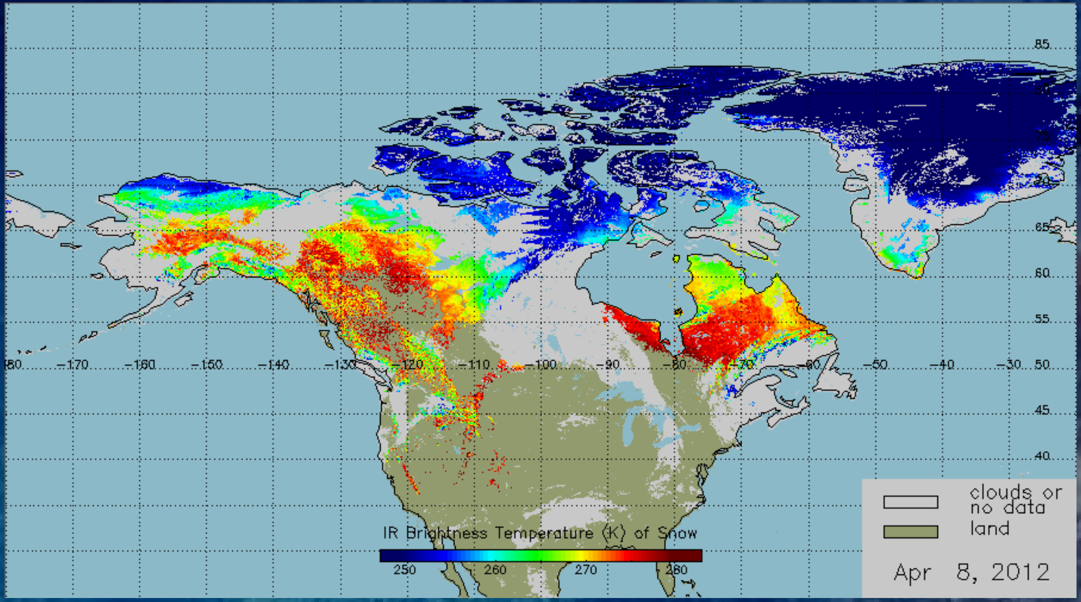
Reflectance of snow-covered land surface changes when snow is shadowed or masked by tree canopy



From Vikhamar & Solberg (2003)

Physical Description
Snow IR Brightness Temperature

IR brightness temperature of snow covered land scenes is typically low (below 273 K). However it may reach 285K and even higher values when the snow cover is not continuous or is masked by vegetation.



METOP AVHRR IR brightness temperature
of snow covered land

Physical Description
Snow vs Clouds

Clouds are the major factor hampering snow cover identification in satellite imagery

No cloud detection algorithm is perfect. Some clouds are always missed and some clear sky scenes are classified as “cloudy”

Missed clouds are often interpreted as “snow” by the snow algorithm causing spurious snow cover in the snow product.

Portion of VIIRS global gridded snow map over South America on Jan 13, 2013

Approach to Snow Mapping with VIIRS Data

- Use daytime imagery. Accurate snow identification is not possible without the use of reflective bands data.

- Assume that the cloud detection algorithm is run prior to the snow algorithm. Therefore no general cloud identification procedure is needed.

- Perform preliminary identification of snow cover using spectral-based tests using VIIRS bands

- Apply additional filters to identify spurious snow that may have occurred to the cloud mask leak. Use both VIIRS data and auxiliary information.

Current VIIRS Snow Cover Algorithm

- Decision-tree ,threshold-based algorithm

- Almost identical to MODIS

- Applied to cloud clear land pixels (uses external cloud mask)

- Requires daytime observation conditions

- Uses

  Reflectance in VIIRS bands I1 (R_1) , I2 (R_2), I3 (R_3)

  Brightness temperature in VIIRS band I5 (T_5)

- Calculates

  NDSI= $(R_1-R_3)/(R_1+R_3)$: Norm. Dif. Snow Index

  NDVI= $(R_2-R_1)/(R_2+R_1)$: Norm. Dif. Vegetation Index

Current VIIRS Snow Cover Algorithm

Pixel is identified as snow-covered if

(1) $T_5 < 283K$

and

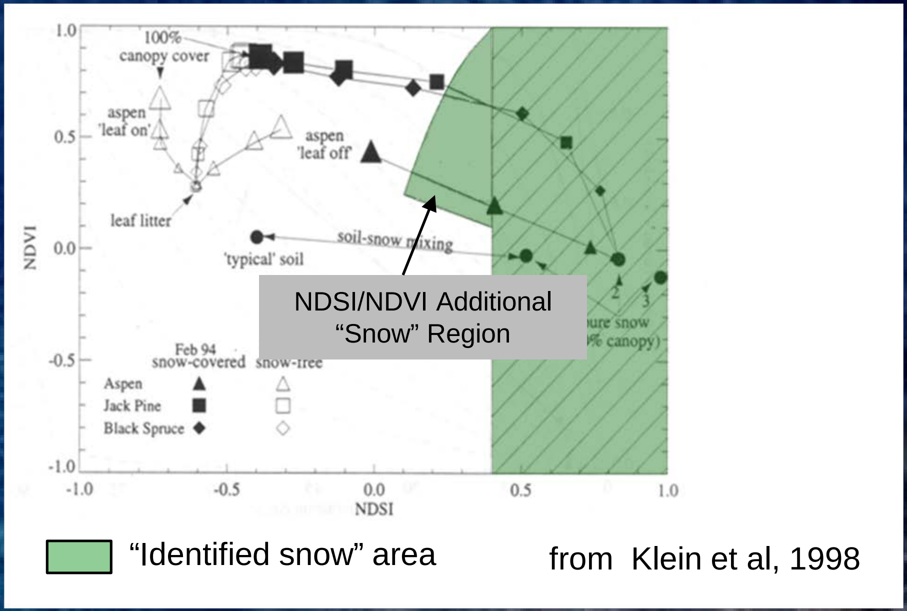
(2) NDSI > 0.4

or

0.1 < NDSI < 0.4

and

NDSI/NDVI values fit into the additional "snow" region



Additional "snow" region is defined as

$NDVI=a_1 + a_2 *NDSI$: lower NDVI threshold

$NDVI= b + b_2* NDSI + b_3* NDSI^2 + b_4 * NDSI^3$: upper NDVI threshold

Current VIIRS Snow Cover Product

snow　land　cloud　No data / not processed

Current VIIRS Snow Cover Product Accuracy

Snow cover mapped in the current VIIRS snow product qualitatively agrees well to the snow cover mapped by human analysts within NOAA IMS system.

VIIRS/IMS snow cover overlay, January 22, 2013

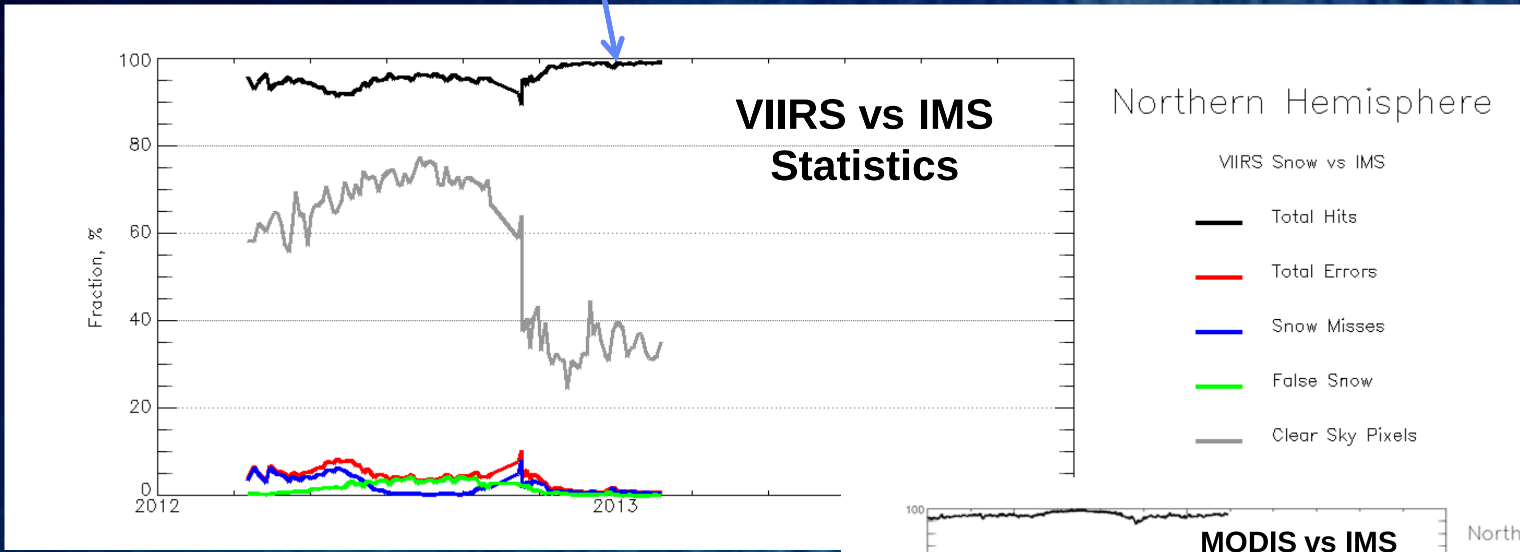
VIIRS snow map errors:

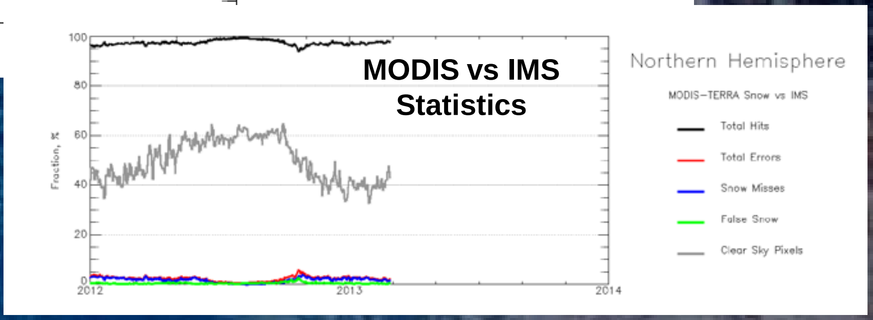
Omission

Commission

Current VIIRS Snow Cover Product Accuracy

The current accuracy of VIIRS snow cover product is over 95% as compared to IMS snow maps.

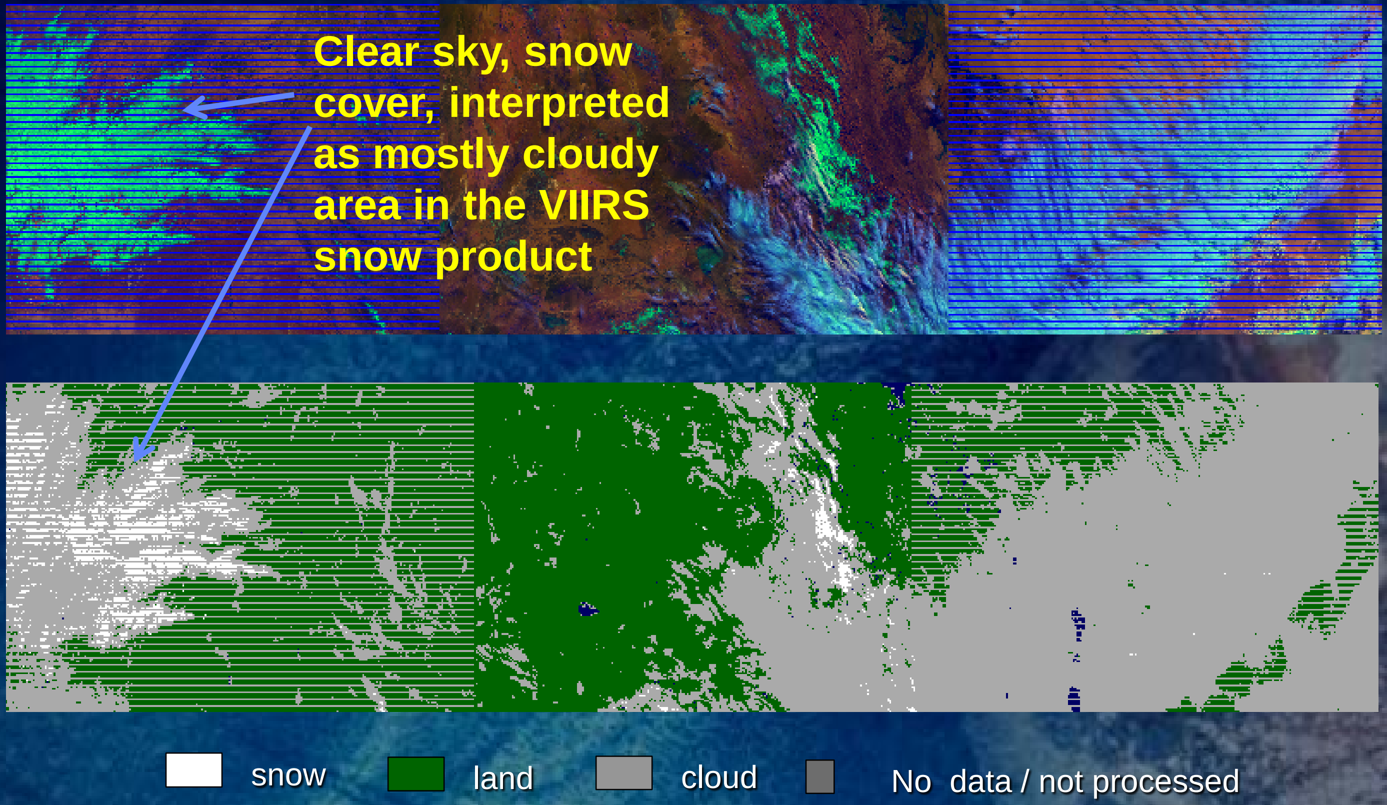




This high accuracy of the VIIRS snow product is partially due to a very conservative VIIRS cloud mask: The fraction of confidently cloud clear pixels in the VIIRS snow product is about 30% compared to 40% fraction of clear pixels in the MODIS snow product.

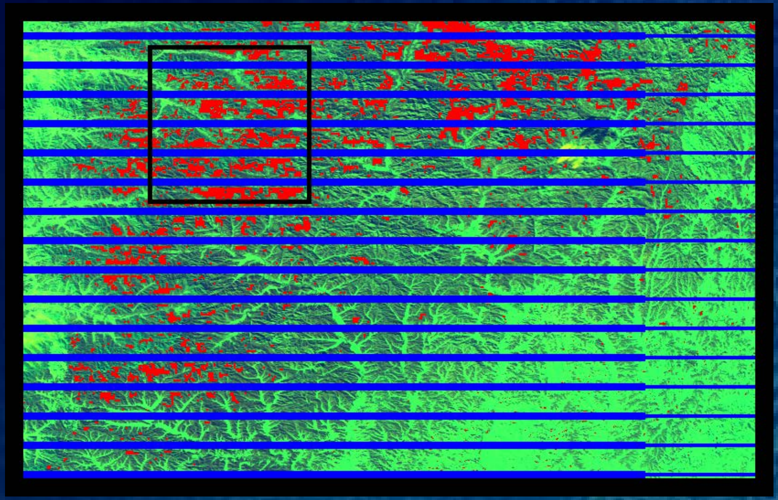
Current VIIRS Snow Cover Product Accuracy

Conservatism of the cloud mask results in the cloud clear snow cover scenes frequently labeled as cloudy.

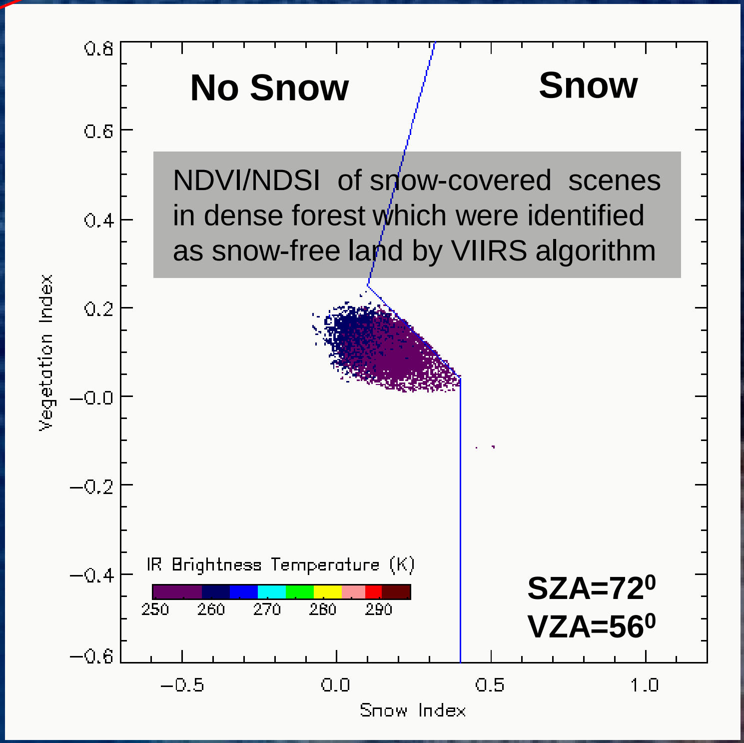


Current VIIRS Snow Cover Other issues (1/4)

NDVI/NDSI in dense snow covered forests may fall beyond the VIIRS NDVI/NDSI snow test threshold values. As a result snow cover is missed.



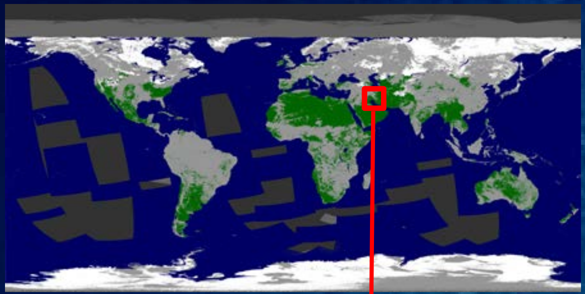
Red: Dense forest with snow on the forest floor identified as snow-free land with the current VIIRS snow algorithm

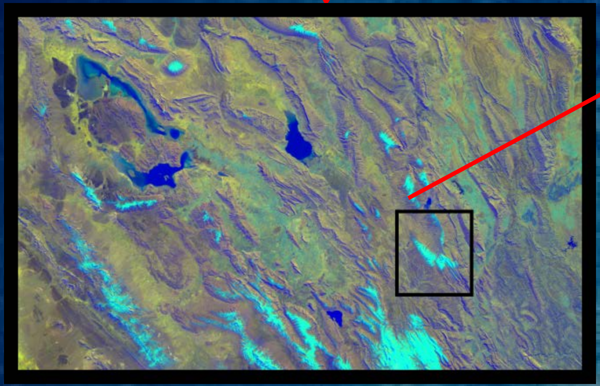


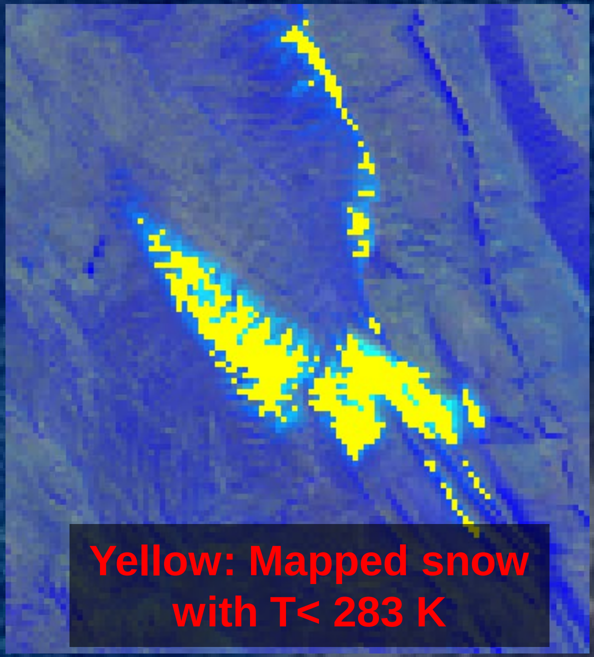
Current VIIRS Snow Cover Other Issues (2/4)

The algorithm frequently misses snow in the mountains.

Reason: too low temperature threshold (T_5<283K)





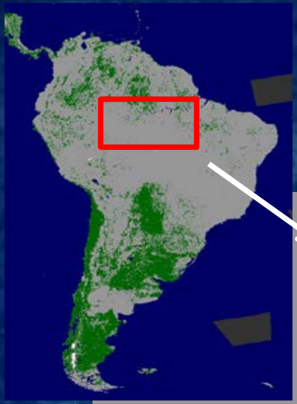


A higher temperature threshold value for snow-covered scenes should be used

Current VIIRS Snow Cover Other Issues (3/4)

Missed clouds are most often are interpreted as snow and appear in the snow product as spurious snow.

The extent of spurious snow cover is small compared to the true snow. However these errors tend to accumulate in the VIIRS clear sky snow/ice composited images and affect other VIIRS products that rely on them (e.g., LST, NDVI, Albedo, etc)



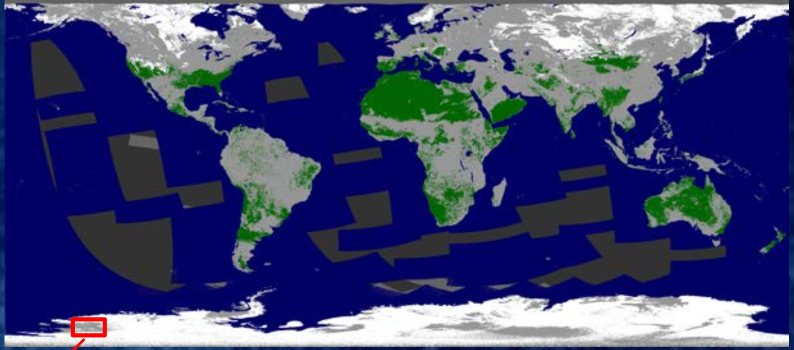
Portion of VIIRS global gridded snow map over South America on Jan 13, 2013

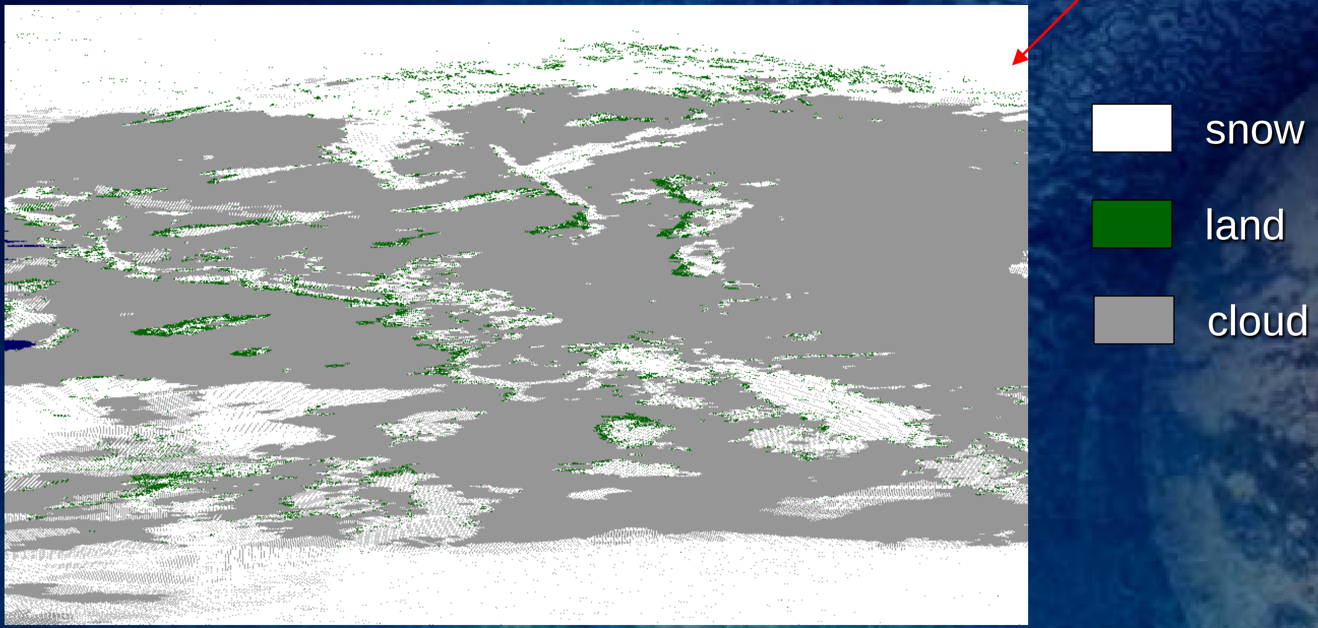
Current VIIRS Snow Cover Other Issues (4/4)

Occasional failures to detect snow shadowed by clouds.

Cloud shadow mask may help

VIIRS snow cover, January 31, 2013 (day 2013031)





New VIIRS Snow Cover Algorithm: Basics

The current algorithm generally performs well but may be improved

Modifications to the algorithm are focused primarily at
- Snow misses in dense forests
- Misses of patchy snow cover (particularly in the mountains)
- False snow due to cloud misses

Modifications include
- Improved spectral-based snow identification tests
- Added consistency tests
  - Consistency with climatic information
  - Analysis of the spatial pattern of derived snow cover

Retrieval Strategy

VIIRS Snow Cover algorithm includes the following steps:

1. Read input data
2. Identify snow covered pixels based on the analysis of the scene's spectral response
3. Identify "spurious snow" : examine pixels labeled as "snow" at the first step for possible misclassifications of clouds as snow.
4. Save output data

Retrieval algorithm

Read input data

⇩

Pixel-by-pxel snow detection

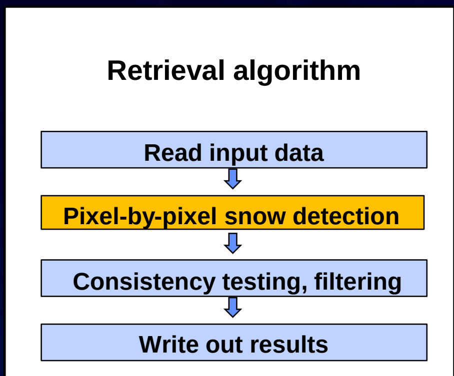
⇩

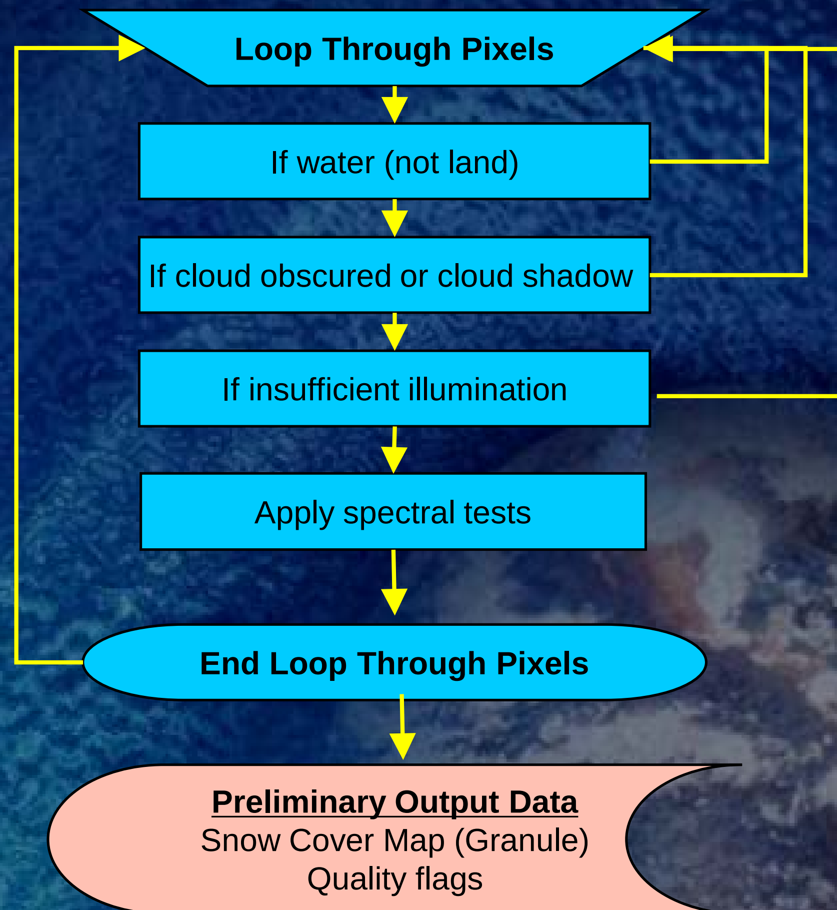
Consistency testing, filtering

⇩

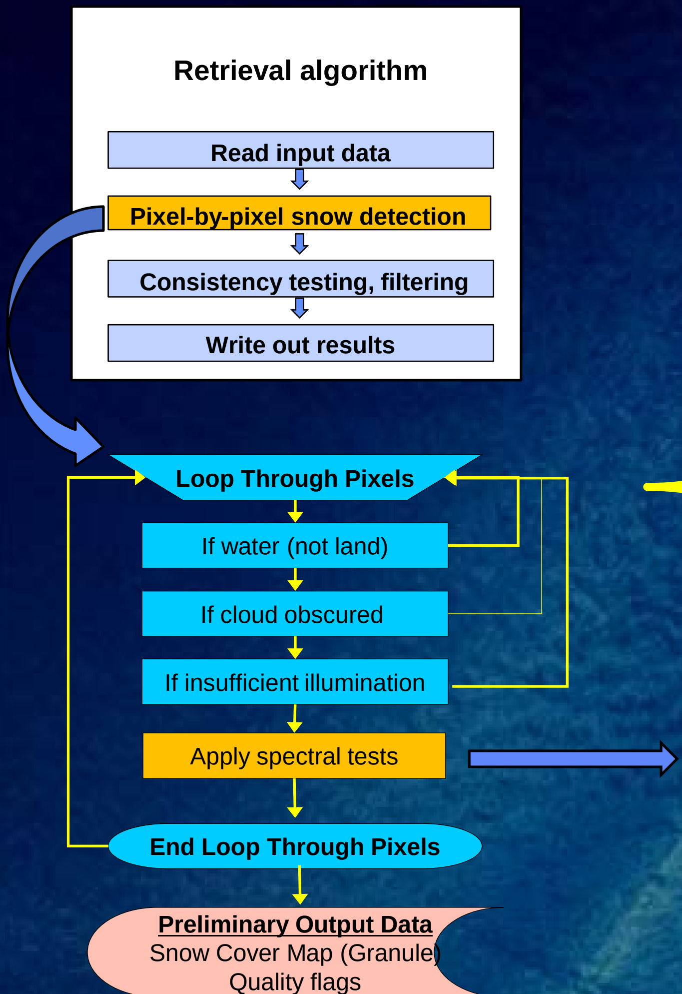
Write out results

Mathematical Basis
Pixel-based processing





Mathematical Basis
Spectral Tests



Pixel is identified as "potential snow" if

(1) $T_5 < T_{5T}$ ("cold scene" test)

and

(2) $R_1 > R_{1T}$ ("bright scene" test)

and

(3) $R_3 > R_{3T}$ ("dark SWIR scene" test)

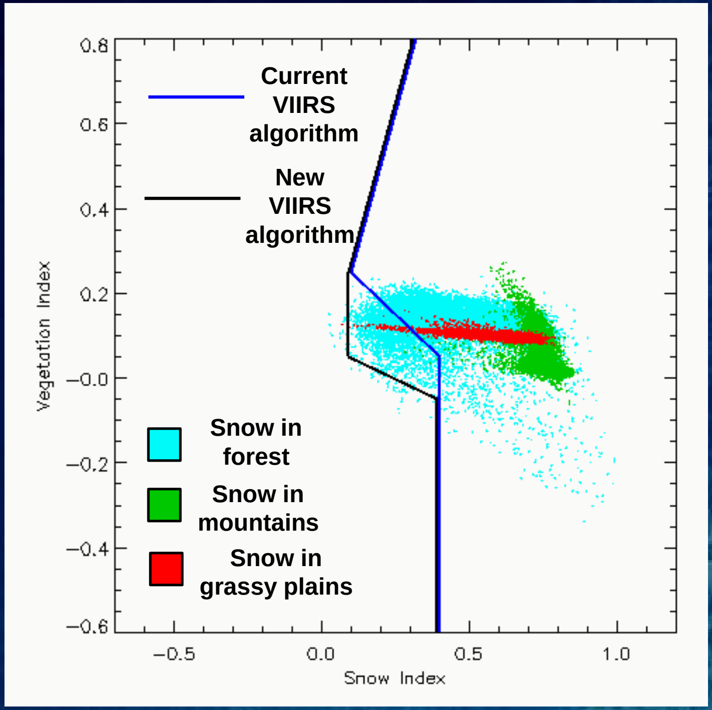
and

(4) NDSI > $NDSI_T$ (NDVI) ("snow" test)

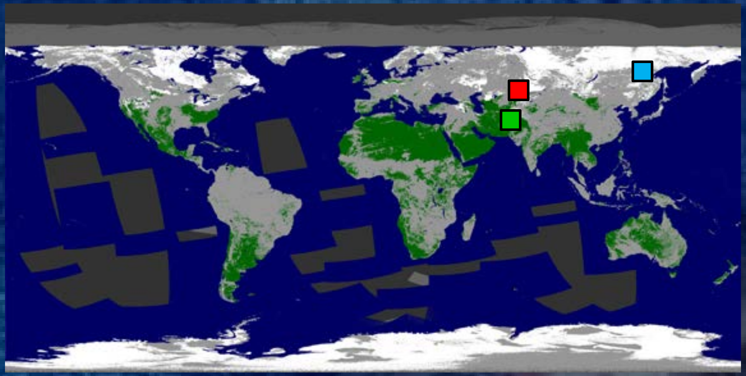
$NDSI_T$ (NDVI) is defined as a 5 point broken line separating "snow" and "no snow" regions in the NDSI - NDVI feature space

T_{5T}, R_{1T} , R_{3T} and $NDSI_T$ (NDVI) point coordinates are tunable parameters

Mathematical Basis
NDSI – NDVI Test

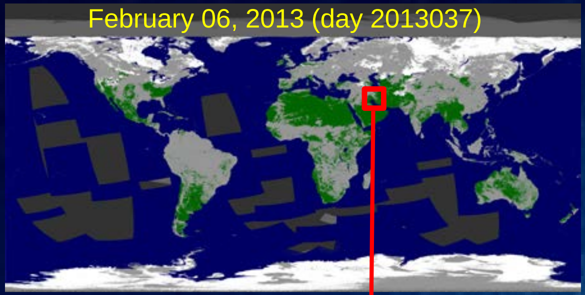


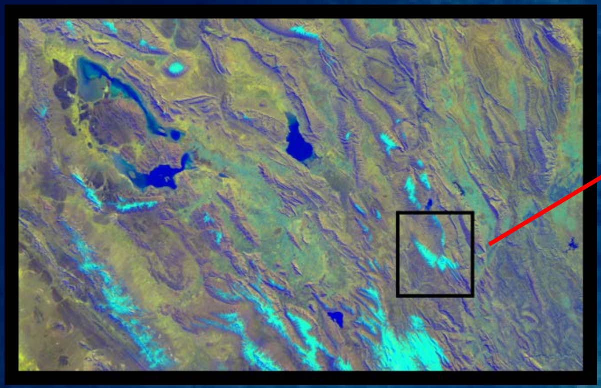
VIIRS data: Dec 18, 2012 and Feb 06, 2013

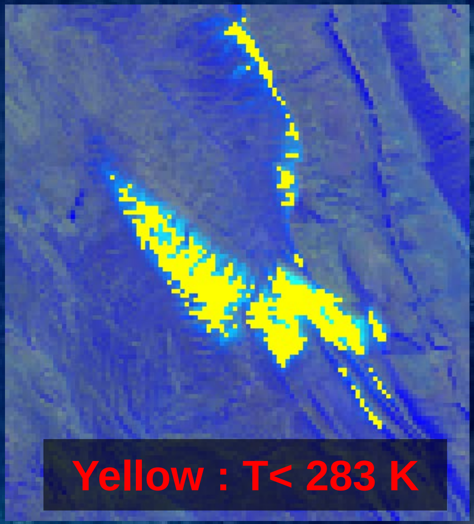


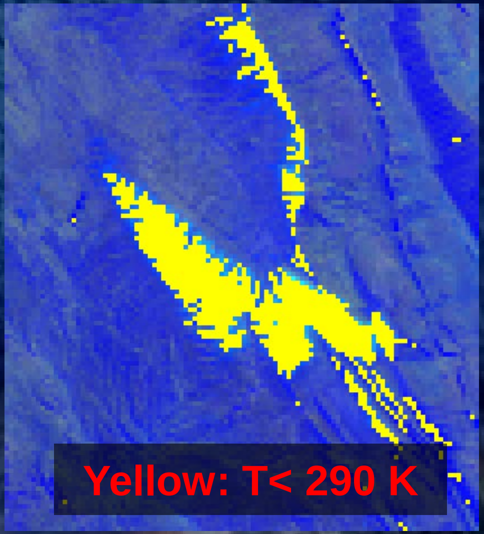
Change of the NDVI/NDSI test configuration should improve snow detection in forested regions and delineation of patchy snow cover in the plains.

Mathematical Basis
Upper Temperature Threshold









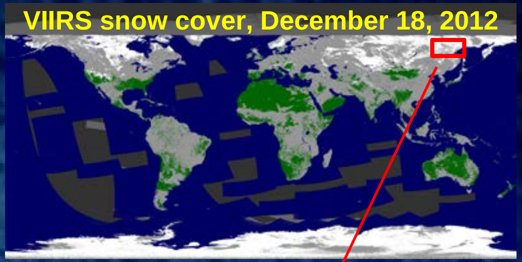
The T_5 threshold is set to 290K to better reproduce snow cover in the mountains. The same value is used in the METOP AVHRR operational snow mapping system

Mathematical Basis
"Bright Vis" and "Dark SWIR" Test

snow

land

cloud

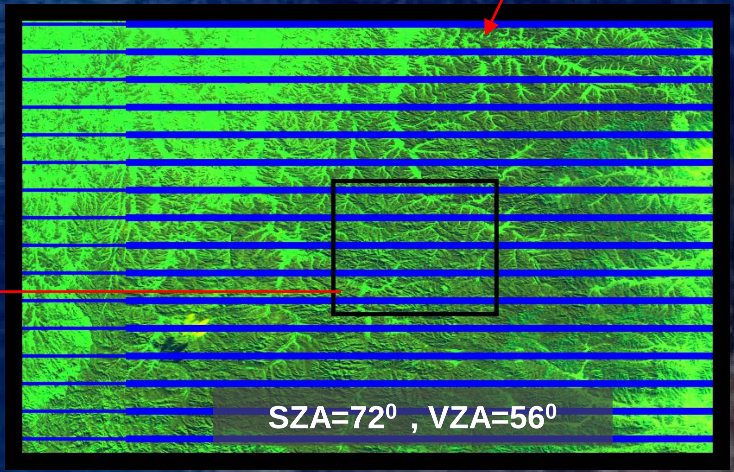


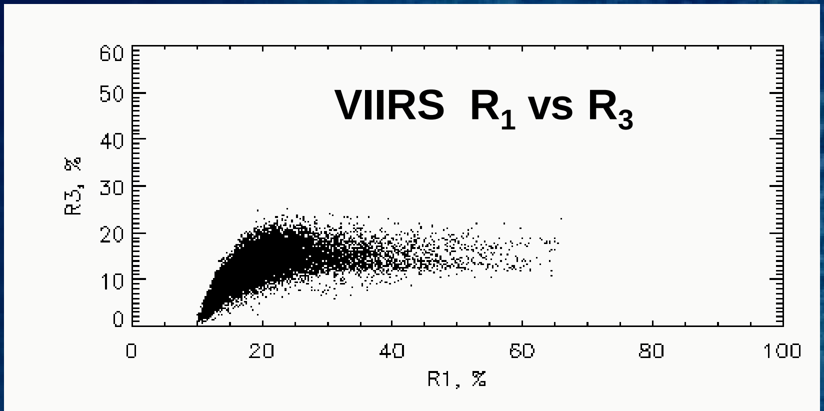
Snow-covered forest:

$R_1 > 0.1$ & $R_3 < 0.25$

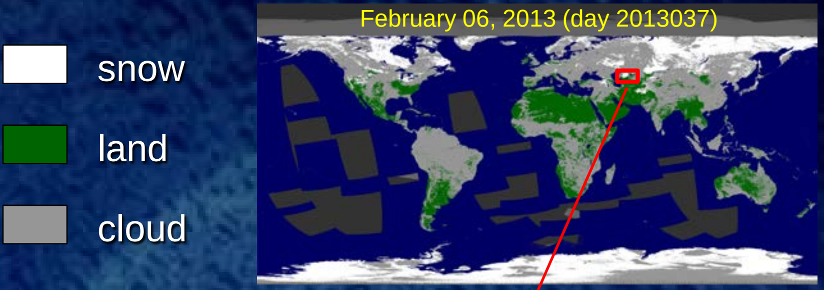
Other types of snow covered land surfaces exhibit larger R_1 and smaller R_3 reflectance

VIIRS RGB false color image



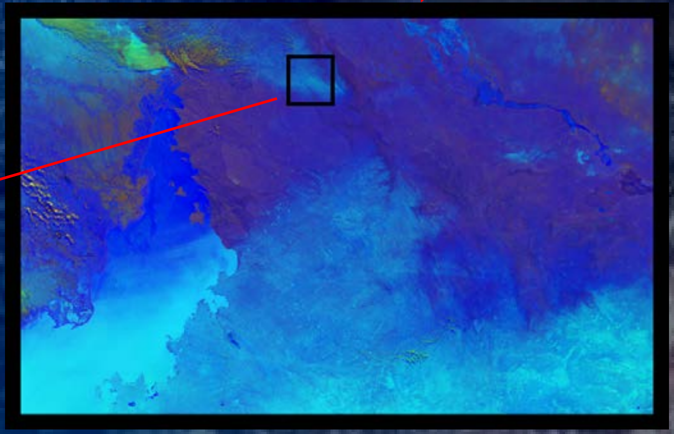


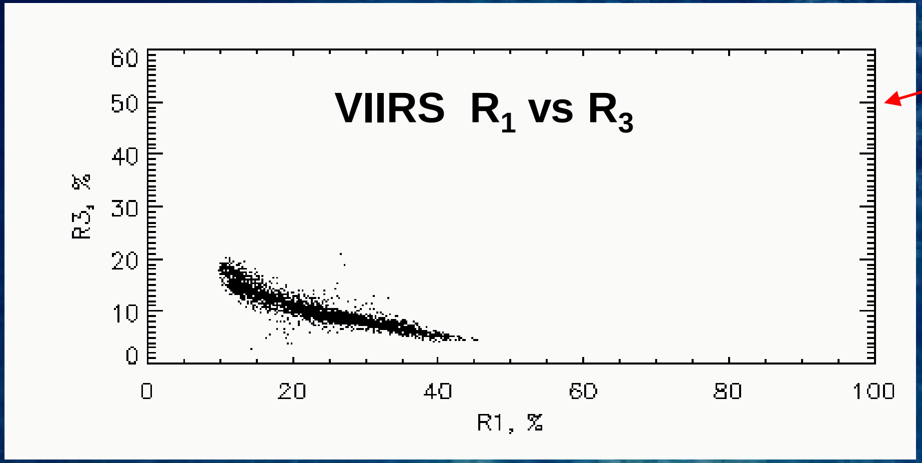
Mathematical Basis
"Bright Vis" and "Dark SWIR" Test



Snow covered grassy plain area: $R_1 > 0.1$ & $R_3 < 0.25$ also work well

VIIRS RGB false color image





Mathematical Basis
Observation Geometry Effects

Analysis of the current VIIRS snow product has not revealed any strong effects of varying viewing-illumination geometry on the accuracy of snow retrievals.

Therefore in the current version of the new VIIRS snow algorithm angular correction of reflectance-based threshold values has not been assumed.

Mathematical Basis
Detected Snow Consistency Tests

Retrieval algorithm

Read input data
↓
Pixel-by-pixel snow detection
↓
Consistency testing, filtering
↓
Write out results

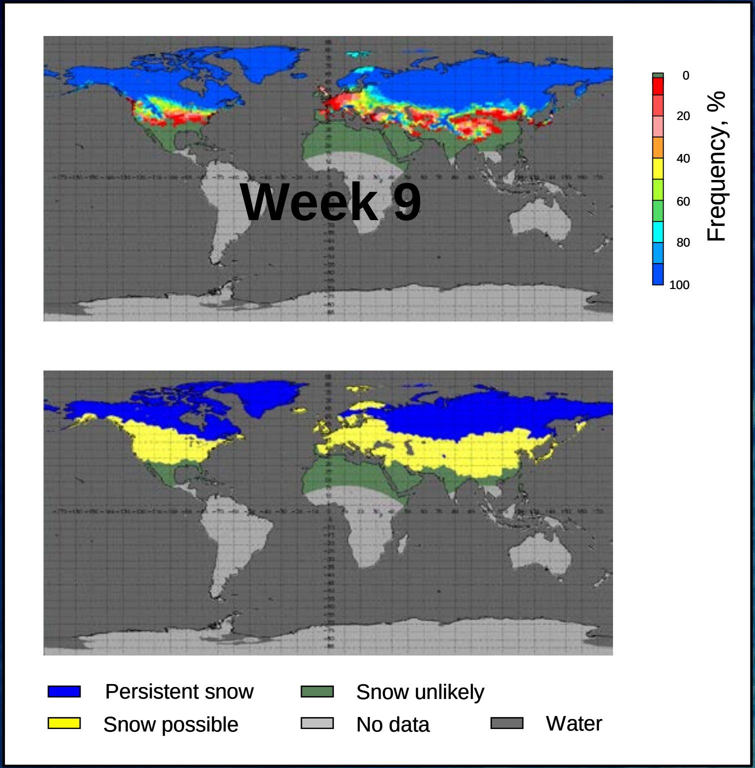
1. Snow Cover Climatology Test
   - Checks whether detected snow is climatically possible
2. Surface Temperature Climatology Test
   - Checks whether the brightness temperature of the “potential snow” pixel is consistent with the LST climatology
3. Spatial Consistency Test
   - Identifies individual “potential snow” pixels or small clusters of “potential snow” pixels inside extensive areas of continuous cloudiness
4. Surface Temperature Spatial Uniformity Test
   - Checks whether the spatial gradient of the temperature of pixels identified as “cloud clear” is realistic

Switches turning all tests on and off are tunable parameters

All tests have been implemented and are used with METOP AVHRR data within NESDIS Multisensor Snow and Ice Mapping System

Mathematical Basis
Snow Cover Climatology

- Derived from NOAA interactive snow charts for the period 1972-1998
- Defined on a weekly basis, covers Northern Hemisphere
- Resampled to lat-lon grid, 1/3 ^{0} grid cell size (~30 km)



Weekly snow frequency of occurrence

Converted to

Weekly snow occurrence categories of "persistent snow", "snow possible" and "snow unlikely"

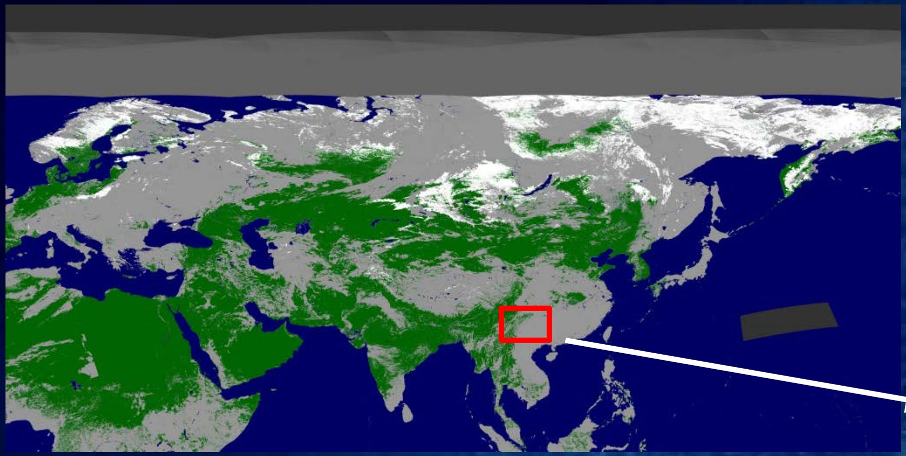
Mathematical Basis
Snow Cover Climatology Test (1/2)

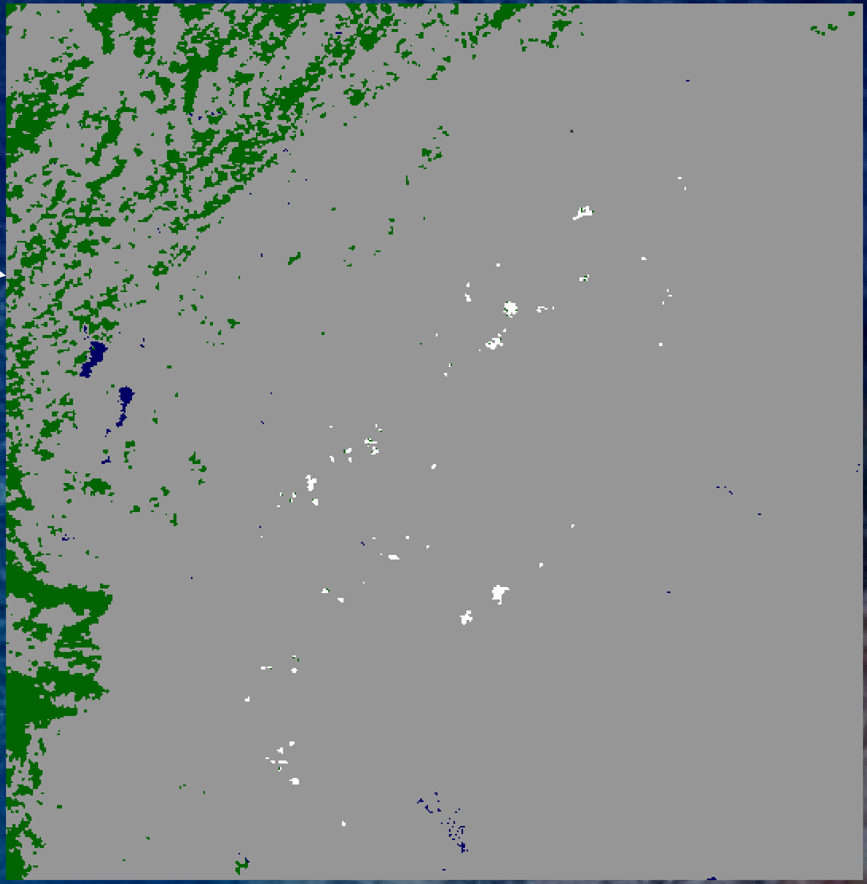
Test:

- Identify "potential snow" pixels within "snow unlikely" region
- Exclude elevated areas ($H > H_T$)
- Label all remaining "potential snow" pixels as "unconfirmed snow"
- Modify pixels' QC flags accordingly

H_T is a tunable threshold parameter (current value is 1000m)

Mathematical Basis
Snow Cover Climatology Test (2/2)

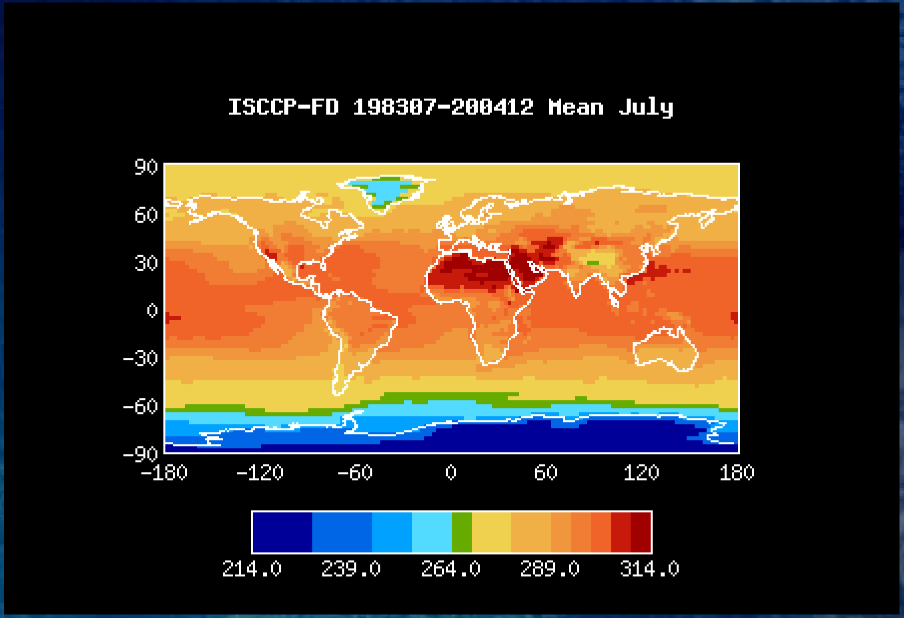




The test is intended to identify false snow which occurred due to the cloud mask leakage

Mathematical Basis
LST Climatology

- Provided by ISCCP (ftp://isccp.giss.nasa.gov/pub/data/surface/)
- Defined on a monthly basis, covers the globe
- Defined on a lat-lon grid, 5 ^{0} grid cell size



ISCCP mean land surface (skin) temperature for the month of July

Mathematical Basis
LST Climatology Test

Test:

- Test compares T_5 with the multiyear mean value of the daytime land surface temperature (T_{clim_LST}) for the pixel location.
- If $T_5 < T_{clim\_LST} - DT_T$, “snow” is rejected and the pixel is labeled “unconfirmed snow”.
- DT_T is a tunable parameter. The current value is 20K
- DT_T is corrected for the surface elevation assuming 8K/km vertical temperature gradient

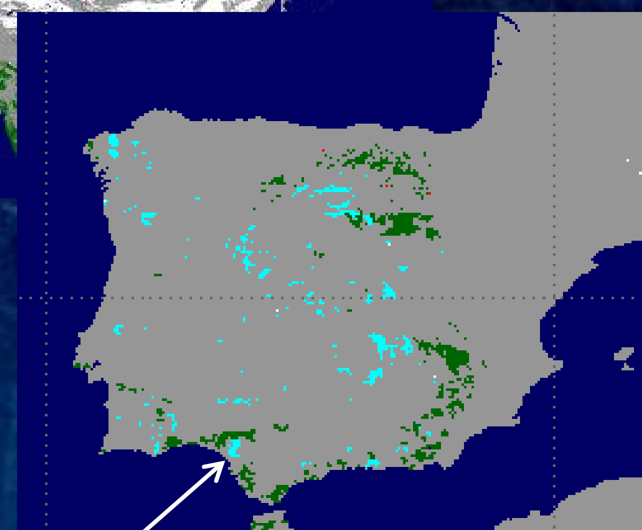
Mathematical Basis
Spatial Consistency Issue

- Small clusters of “potential snow” pixels inside extensive areas of continuous cloudiness are often “false” snow resulting from the cloud mask leak

VIIRS/IMS Overlay, January 19, 2013

VIIRS snow map errors:

Omission Commission



False snow in the VIIRS snow map (blue)

Mathematical Basis
Spatial Consistency Test

- Moving window of N x N pixels is used to identify isolated small clusters of “potential snow” pixels fully enclosed by cloudy pixels.

- If the fraction of clear pixels is less than FC(%), pixels identified as “potential snow” are labeled as “unconfirmed snow”

- N and FC are tunable parameters. At this time N=21 and FC=10%

Mathematical Basis
LST Spatial Uniformity Test

- Assumes LST max spatial gradient of ~10K/km.
- Checks each “potential snow” pixel and looks for much warmer pixels (dT) in the close proximity (within 51 x 51 grid cell area)
- If more than FW(%) of checked pixels are much warmer than the “potential snow” pixels, the latter is labeled as “unconfirmed snow”
- The test is not applied in high altitude areas (H < 500 m)
- dT and FW are tunable parameters. Current values are 20K and 5% respectively.
- This is a planned improvement

Algorithm Flow
Output Data

- Output data
  - » Snow cover map
  - » Quality flags

Proposed snow map coding: mostly follows MODIS snow product coding

255	Fill Data (no VIIRS coverage)
254	Bad or missing VIIRS sensor data
200	Snow
50	Cloud, no retrieval
39	Water
25	Snow-free land
11	Dark (insufficient daylight)
2	Unconfirmed snow (did not pass any of consistency tests)
1	Undetermined

Including water, cloud and other masks in the snow map makes it easier to apply and hence more attractive to potential user

Algorithm Summary

- Spectral threshold-based snow identification followed by consistency testing of identified snow
- Slightly modified spectral thresholds (as compared to current VIIRS and MODIS) to better identify and map patchy snow cover
- Consistency testing: attempt to identify “false snow” using auxiliary information
    - Verification against snow cover climatology (NH only)
    - Verification against land surface temperature climatology

Practical Considerations

- The VIIRS snow cover algorithm is affected by the following practical consideration:
  - Computational considerations
  - Cloud masking considerations
  - Constraints

Practical Considerations

- Computational Considerations

  » The threshold-based tests do not require substantial computational resources. Spatial consistency tests are more time consuming

  » Spatial consistency tests may be modified to incorporate smaller area in the sliding window. This will cut the CPU time but may reduce the efficiency of the tests.

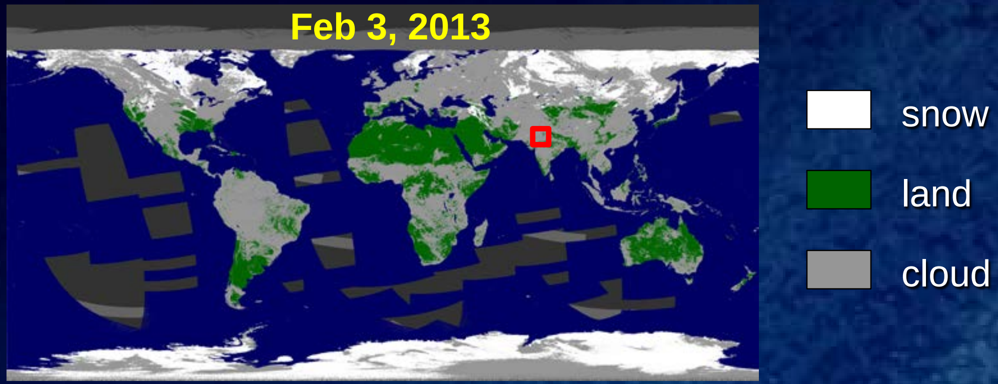
Practical Considerations

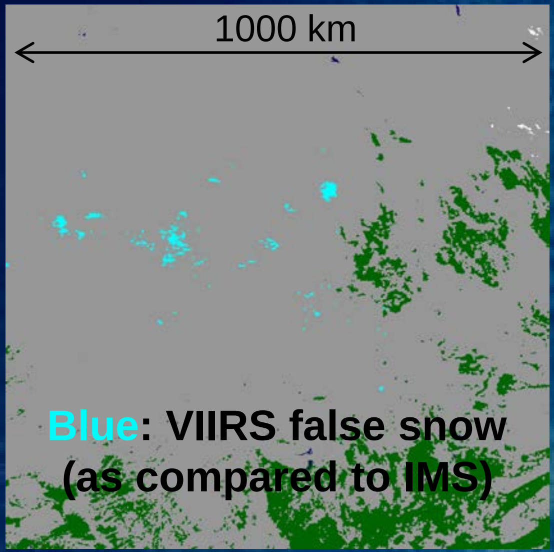
- Cloud Mask
  - » Accurate cloud masking is critical for snow retrievals. Missed clouds may show up in the product as spurious snow cover.
  - » Too conservative cloud masking improves the accuracy of snow/no snow discrimination, but increases cloud gaps in the product and hence reduces it value
  - » Particular algorithm threshold values should be tuned after the cloud mask is finalized.
- Land/water mask
  - » Current VIIRS land/water mask needs improvement. Better land/water mask will help to better characterize small-scale features in the snow cover distribution and snow cover in the coastal region

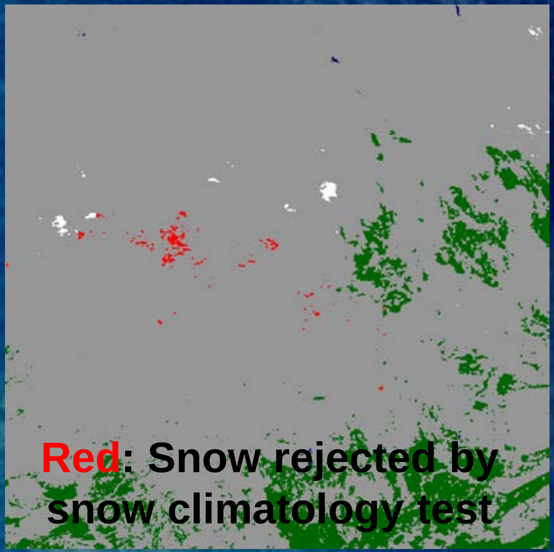
Practical Considerations

- Constraints
  - » Proper snow identification is impossible
    - – When clouds obscure the view
    - – At night and at low solar elevation angles

Testing and Validation: Snow Cover Climatology Test







Snow climatology test

- Applied outside of mountainous areas (h<1 km)

- Identifies at least part of "false snow" which occurs due to the cloud mask leak

Testing and Validation: Temperature Climatology Test

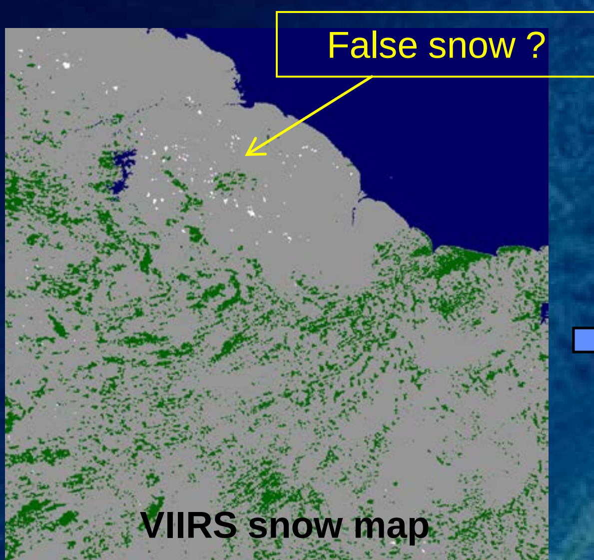
snow

land

cloud

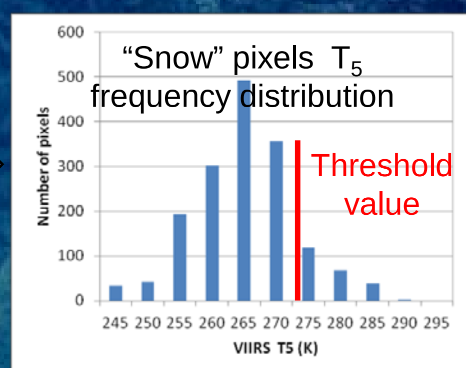
Surface temperature climatology test

- Identifies at least part of "false snow" which occurs due to the cloud mask leak



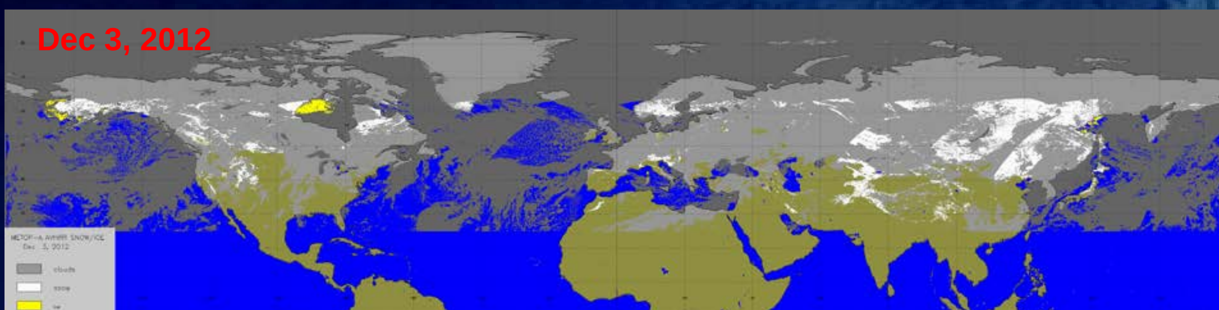
Climatic LST is ~294K

T_5 threshold value is set to 274K

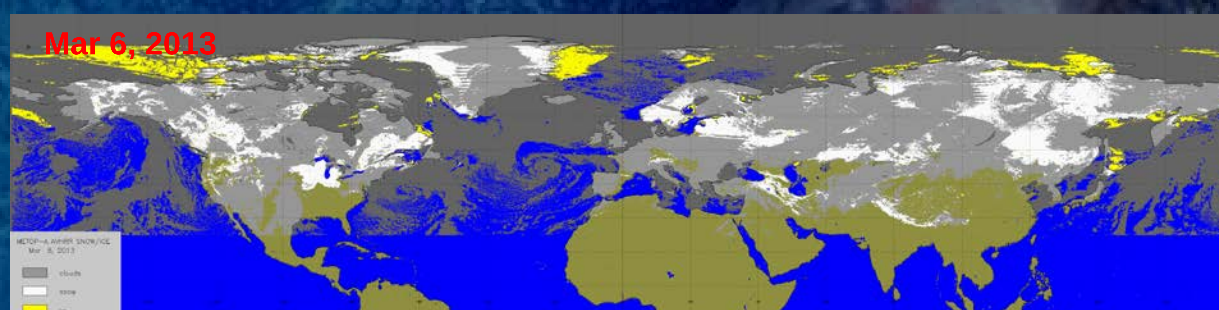


Testing and Validation

Detailed testing and validation of the snow algorithm has been performed with METOP AVHRR data in 2012-2013.



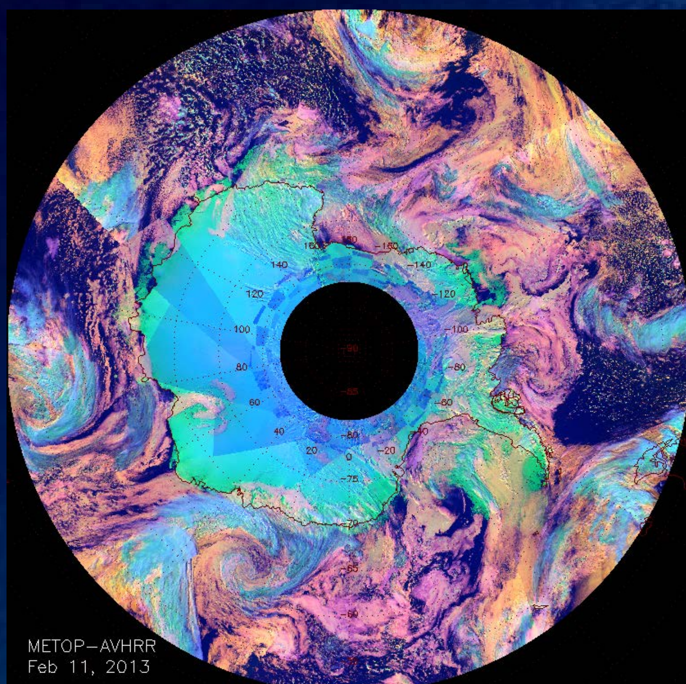
Snow
Ice
No snow
Cloud



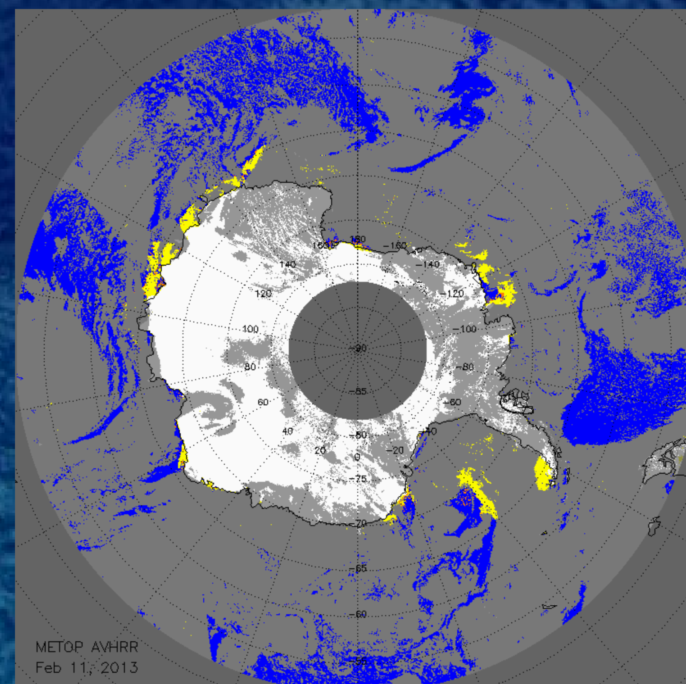
- In the Northern Hemisphere snow and ice is derived from METOP AVHRR data in the region above 25^0N
- Clouds and ice are mapped using a different (not VIIRS) algorithm

Testing and Validation

Snow and ice in Antarctic



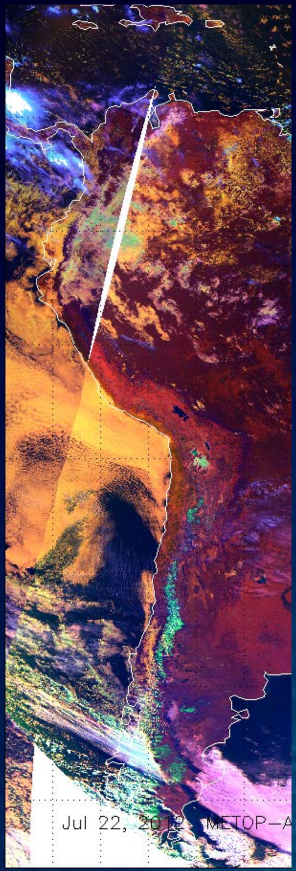
METOP AVHRR RGB false color image



Snow Ice

No snow Cloud

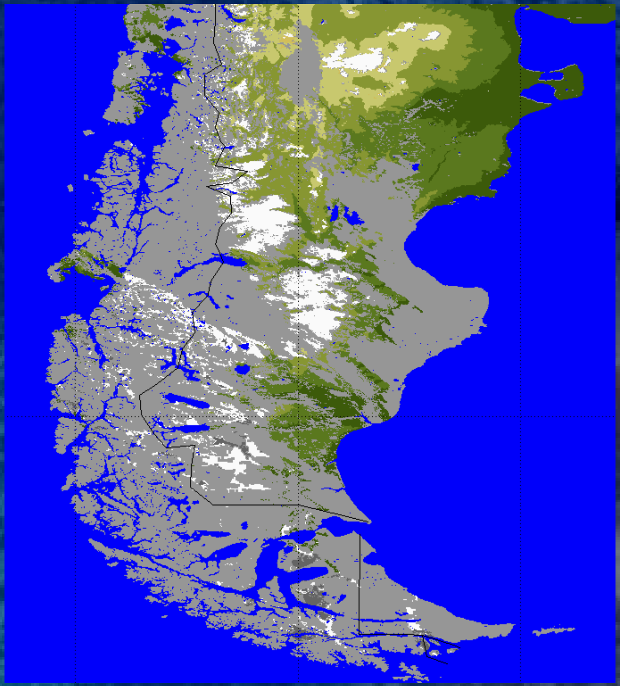
Testing and Validation



RGB false color image

Snow map

Snow in South America



Testing and Validation

METOP AVHRR snow map with IMS snow cover overlaid

Snow, both METOP and IMS

No snow, both METOP and IMS

Cloud METOP

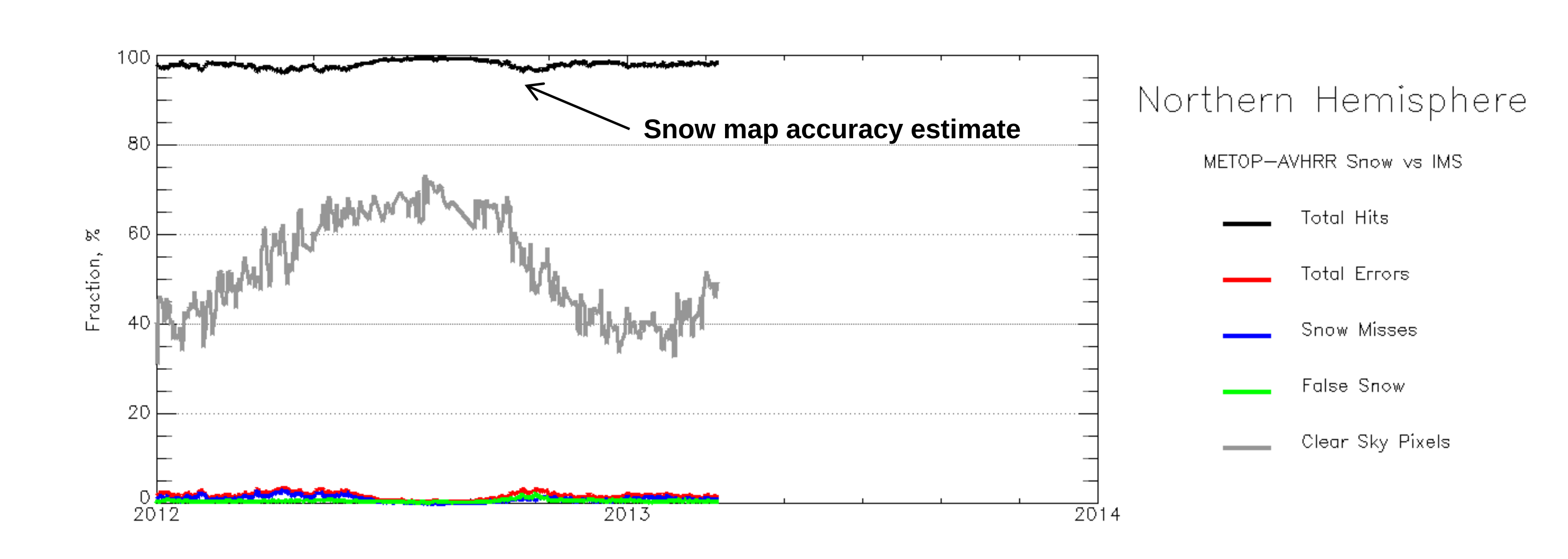
Snow miss METOP

False snow METOP

- Good qualitative agreement between the two products.

Testing and Validation

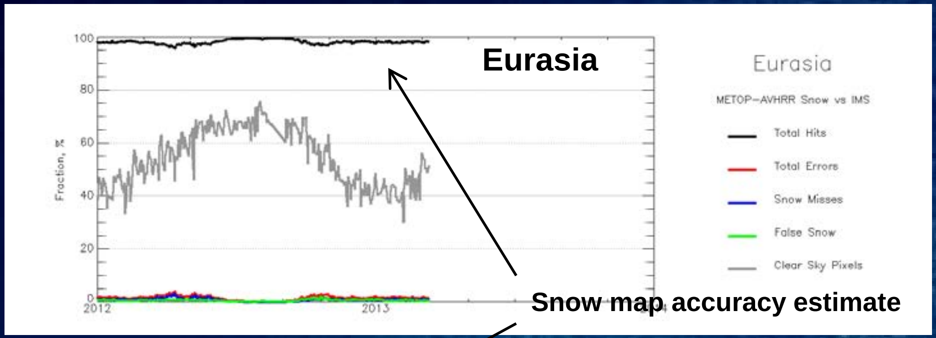
METOP snow agreement to IMS snow, Northern Hemisphere 2012-2013

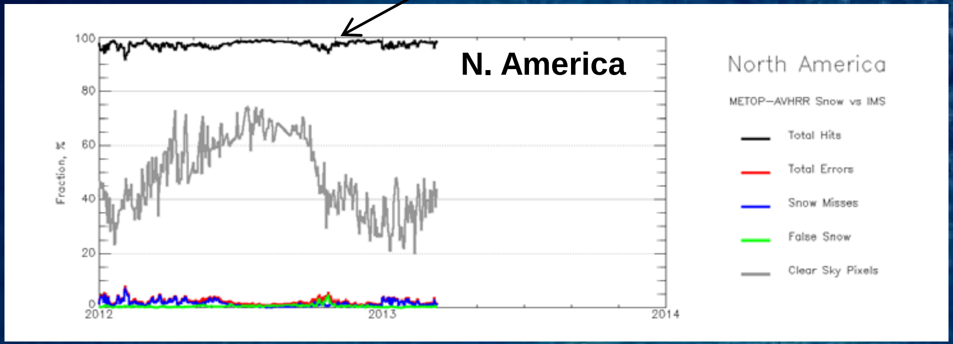


METOP-IMS agreement on the snow cover distribution ranges within 96-99%

Testing and Validation

METOP snow agreement to IMS snow, Eurasia and North America 2012-2013

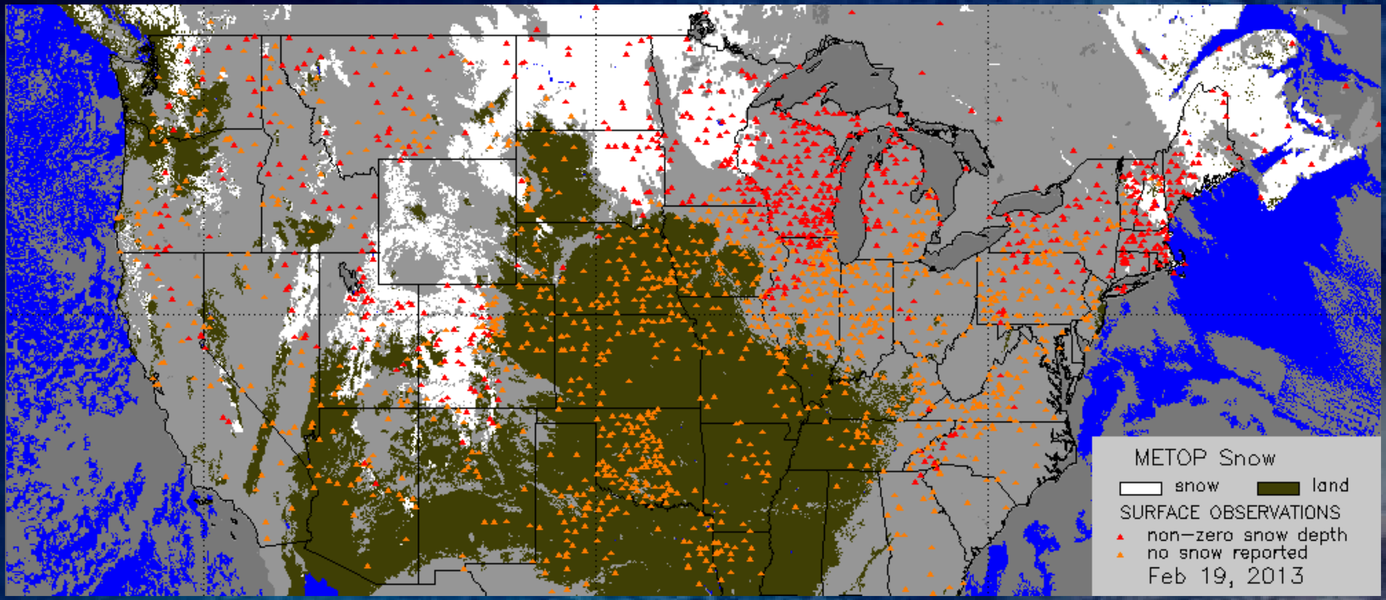




METOP-IMS agreement on the snow cover distribution ranges within 94-99%

Testing and Validation

METOP snow agreement to surface snow observations



Validation is limited to the CONUS region only since most WMO stations do not report “zero” snow depth

Agreement ranges within 90-95% during winter months

Summary

- Snow identification has been developed for VIIRS
- The algorithm includes a two-stage approach, the threshold-based spectral snow detection and consistency testing of snow retrievals
- Algorithm testing and validation has been performed mostly with METOP AVHRR data. METOP retrievals were compared with
  - » IMS charts
  - » Surface observation data
- Consistency checks have been tested with VIIRS data and demonstrated good performance
- Retrieval accuracy is within specifications
  - » Above 95% as compared to IMS
  - » Above 90% as compared to in situ measurements

Snow Cover Exception Handling

- Unavailable/bad input radiance data
  - » Pixel is labeled as "missing data"
  - » Processing of the granule continues
- Insufficient daylight conditions (SZA > 85^0)
  - » Pixel is labeled as "dark"
  - » Processing of the granule continues
- Any of the required ancillary data file is not available
  - » All pixels in current the granule are flagged as "undetermined"
  - » Switch to processing of the next product

Snow Cover: Assumptions

- Assumptions
  - VIIRS observation data are within specifications
  - All ancillary static datasets are accurate
  - Snow is not extremely littered
  - Cloud mask accuracy is the same as the accuracy of the current VIIRS operational cloud mask

Snow Cover: Limitations

- Limitations
  - No retrievals in cloudy conditions and at night
  - Reduced performance of the algorithm should be expected at large solar zenith angles, over dense forests and rugged terrain
  - Scenes with small fractional snow cover on the ground may be interpreted as “snow-free”
  - Dry salt lakes at cold temperatures may be interpreted as snow cover

Snow Cover: Other Considerations

- Overall accuracy of the snow product depends on the accuracy and conservatism of the cloud mask. More conservative cloud mask → More pixels with intermittent snow cover are attributed to clouds → Better accuracy, but decreased effective coverage → Delay in detection of changes in the snow cover.
- Accurate land/water mask is needed to properly reproduce the snow cover distribution and accurately assess the snow extent. Current VIIRS operational land/water mask has problems.
- Accurate navigation and geographical registration of satellite data along with high accuracy of the surface elevation dataset is critical for mapping snow in the mountains.

Snow Cover: Preplanned Product Improvements

- Improvement of the snow cover climatology: incorporate 1998-2012 data, increase spatial resolution
- Tuning threshold values and other parameters controlling snow detection
- Implementing additional consistency tests (surface temperature gradient test)
- Incorporation of observation geometry-dependent threshold values (e.g., NDVI/NDSI, R1)
- Use of VIIRS 3.7 µm band data
- Adding snow fraction retrievals
  - » Based on the VIIRS ch. 1 reflectance (Romanov et al, 2003)
  - » Linear mixture approach

Snow Cover Risk

- **Risk 1** Algorithm has been developed and tested with the current VIIRS operational cloud mask. Algorithm will need tuning when the NOAA unique cloud mask is used
- **Risk Assessment:** Medium
- **Impact:**
  - » Inaccurate cloud mask may lead to the snow cover not meeting requirements
- **Mitigation:**
  - » Start testing and evaluating the new cloud mask as soon as it is available
- **Status:** Open

Snow Cover References

- Romanov P., D. Tarpley, G. Gutman and T.Carroll (2003) Mapping and monitoring of the snow cover fraction over North America. Journal of Geophysical Research, D108, 8619, doi:10.1029/2002JD003142, 2003

- Romanov P. (2012) Algorithm Theoretical Basis Document (ATBD) for Southern Hemisphere Automated Snow Mapping System.

- Hall, D. K., Riggs, G. A., Salomonson, V. V., DiGiromamo, N., and Bayr, K. J. (2002), MODIS snow-cover products, *Remote Sensing of Environment*, 83(1-2): 181-194, doi:10.1016/S0034-4257(02)00095-0

- Vikhamar D., Solberg R., (2003) Subpixel mapping of snow cover in forests by optical remote sensing, Remote Sensing of Environment, 84, 69-82.

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Algorithm Theoretical Basis

Ice Concentration and Ice Cover

Presented by

Yinghui Liu

UW-Madison CIMSS

Ice Concentration and Ice Cover Algorithm Theoretical Basis

- The purpose of the JPSS VIIRS Ice Concentration and Ice Cover Algorithm Algorithm Theoretical Basis is to provide programmers, reviewers and users with a theoretical description (scientific and mathematical) of this algorithm.

- Heritage algorithm information has been documented in the GOES-R ABI ATBD.

CDR Requirements
Ice Concentration

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Res.	Horiz. Res.	Mapping Accuracy	Msmnt. Range	Msmnt. Accuracy	Product Refresh Rate/Coverage Time	Product Measurement Precision	Temporal Coverage Qualifiers	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Ice Concentration	JPSS VIIRS	All ice-covered regions of the global ocean	Ice Surface	0.75 km	1 km	Ice concentration – 0/10 to 10/10	Ice concentration – 10%	At least 90% coverage of the globe every 24 hours	30%	All conditions	Clear conditions associated with threshold accuracy	Over specified geographic area

CDR Requirements
Ice Cover

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Res.	Horiz. Res.	Mapping Accuracy	Msmnt. Range	Msmnt. Accuracy	Product Refresh Rate/Coverage Time	Product Measurement Precision	Temporal Coverage Qualifiers	Product Extent Qualifier	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Ice: Cover (mask)	JPSS VIIRS	FD	N/A	0.75 km	1 km	From the 100% ice concentration at the land edge to the less then 15% ice concentration that is the ice extent	1 km	90% coverage of the globe every 24 hours	80% probability of correct typing	All condition	All Conditions	Clear conditions associated with threshold accuracy	Over specified geographic area

Ice Concentration and Ice Cover CDR Algorithm

Preferred Solution

- **Daytime** (solar zenith angle less than 85 degree)
  - Combination of MODIS sea ice mapping algorithm and NPP/VIIRS ice algorithm
  - This algorithm updates the tests of the MODIS sea ice mapping algorithm, and uses the ice concentration retrieval results to further refine the ice mask.
- **Nighttime** (solar zenith angle larger than 85 degree)
  - Combination of ice surface temperature algorithm and NPP/VIIRS fresh water ice algorithm; further refines the ice extent from ice concentration.

- Designed for easy portability and adaptation
- Applicable to all water surface conditions
- Algorithm simple and fast
- For both day and night
- Consistent with the ABI algorithm

Ice Concentration and Ice Cover Algorithm Objectives

- The JPSS VIIRS Ice Concentration and Ice Mask Product will be produced for each VIIRS image and will provide ice mask, and ice concentration over all water surfaces of the globe.
- The primary output consists of a map of ice concentration, ice mask, and corresponding quality control flags.
- Applications of ice mask and ice concentration include numerical weather prediction and data assimilation, hydrological modeling, climate modeling, transportation, recreation.

Ice Concentration and Mask Algorithm Observing System Overview

- Instrument Characteristics

JPSS VIIRS band	Nominal Central Wavelength (µm)	Nominal sub-satellite IGFOV (km)	Sample Use
I1	0.64	0.375	Ice concentration and ice mask
I2	0.865	0.375	Ice concentration and ice mask
I3	1.61	0.375	Ice concentration and ice mask
I5	11.450	0.375	Ice concentration and ice mask
M5	0.672	0.75	Ice concentration and ice mask
M7	0.865	0.75	Ice concentration and ice mask
M10	1.61	0.75	Ice concentration and ice mask Ice surface Temperature
M15	10.763	0.75	Ice concentration and ice mask Ice surface Temperature
M16	12.013	0.75	Ice concentration and ice mask Ice surface Temperature

Ice Concentration and Cover Algorithm Input and Output

- **JPSS VIIRS Ice concentration and mask Algorithm requires for each pixel:**
  - » Calibrated/Navigated VIIRS reflectance and brightness temperatures
  - » Solar zenith angle and satellite viewing angle
  - » Cloud mask and land mask
  - » Longitude and Latitude
  - » Imagery can be in native satellite projection or remapped projection

Ice Concentration and Cover Algorithm Input and Output

Name	Type	Description	Dimension
M15 brightness temperature	Input	Navigated and Calibrated VIIRS level 1b brightness temperatures for band M15	Scan grid (xsize, ysize)
M16 brightness temperature	Input	Navigated and Calibrated VIIRS level 1b brightness temperatures for band M16	Scan grid (xsize, ysize)
M5 (I1) reflectance	Input	Navigated and Calibrated VIIRS level 1b reflectance for band M5 (I1)	Scan grid (xsize, ysize)
M7 (I2) reflectance	Input	Navigated and Calibrated VIIRS level 1b reflectance for band M7 (I2)	Scan grid (xsize, ysize)
M10 (I3) reflectance	Input	Navigated and Calibrated VIIRS level 1b reflectance for band M10 (I3)	Scan grid (xsize, ysize)
Latitude	Input	Pixel Latitude	Scan grid (xsize,ysize)
Longitude	Input	Pixel Longitude	Scan grid (xsize,ysize)
Solar zenith angle	Input	Solar zenith angle	Scan grid (xsize, ysize)
satellite viewing angle	Input	satellite viewing angle	Scan grid (xsize, ysize)
QC flags	input	VIIRS level 1b quality control flags	Scan grid (xsize, ysize)

Algorithm Input: Ancillary Data

- Two types of ancillary data needed:
  - » VIIRS Product: Cloud mask
  - » Non-VIIRS Dynamic Data: N/A
  - » Non-VIIRS Static Data: Land/Water Mask

Name	Type	Description	Dimension
Land/Water mask	Input	Map of land and water flags	Scan grid (xsize, ysize)

Name	Type	Description	Dimension
Cloud mask	Input	VIIRS Cloud Mask	Scan grid (xsize, ysize)

Algorithm Input and Output

- Output Data:
  - Ice concentration and cover can be presented in a variety of methods
  - Ice surface skin temperature derived within this algorithm and will be described within the next section

Name	Type	Description	Dimension
Ice cover	output	Output contains ice extent map for each pixel with water surface type	Scan grid (xsize, ysize)
Ice concentration	output	Output contains ice concentration for each pixel identified as ice	Scan grid (xsize, ysize)
QC flags for Ice Concentration/cover	output	Quality Control Flags for every pixel	Scan grid (xsize, ysize)
Ice surface skin temperature	output	Output contains ice surface skin temperature for each pixel identified as ice	Scan grid (xsize, ysize)
QC flags for ice surface skin temperature	output	Quality Control Flags for every pixel	Scan grid (xsize, ysize)

Ice Cover & Concentration Output Diagnostic Data

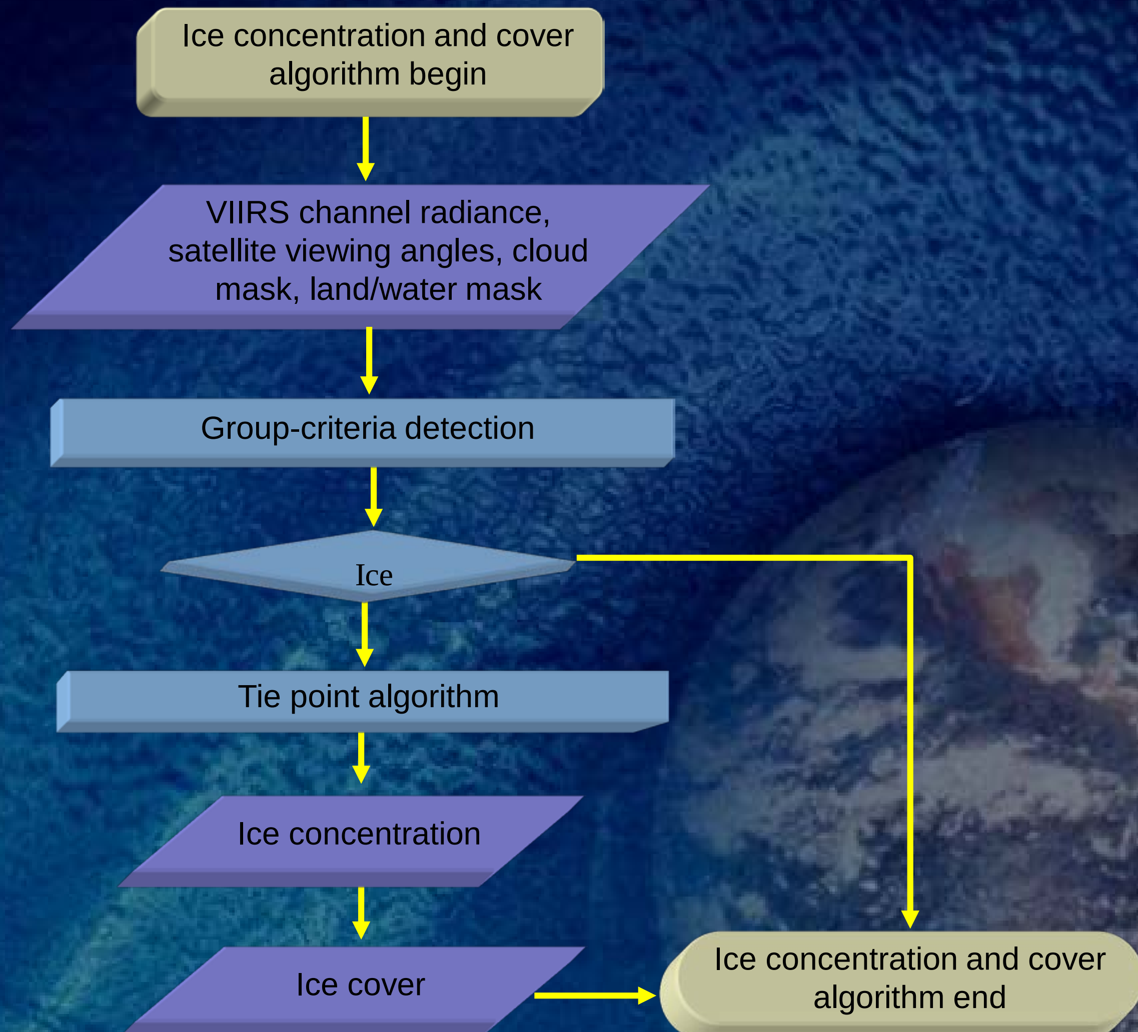
Name	Type	Description	Dimension
IceSrfTemp	Real(Single)	Ice surface tempreture	Grid (xsize, ysize)
IceTiePoint	Real(Single)	Ice tie point values	Grid (xsize, ysize)
NDSI	Real(Single)	Normalized difference snow index	Grid (xsize, ysize)
AncilPath	Character(LEN=128)	Directory of the ancillary data file	static
CoeffFileName	Character(LEN=256)	Coefficient file name	static

Ice Concentration and Cover Algorithm Description

- **Procedures of ice concentration and cover algorithm**
  1. Use threshold tests to detect possible ice cover: Daytime and Nighttime
  2. Use a tie-point algorithm to derive reflectance (temperature) for pure ice pixel, and then calculate ice concentration
     - Reflectance (temperature) of pure ice and pure water are tied to points in a frequency histogram, and the ice fraction in a pixel (ice concentration) is determined by linearly interpolating between these tie points
  3. Ice pixels with retrieved ice concentration larger than 15% are identified as ice. Ice pixels with retrieved ice concentration smaller than 15% are not identified as ice

Ice Concentration and Cover Algorithm Processing Outline

High Level Flowchart of the ice concentration and cover algorithm



step1

step2

step3

Ice Concentration and Cover Algorithm Description

Step 1: Use threshold tests to detect possible ice cover

- Daytime
  - Normalized Difference Snow Index (NDSI) is the key index used to detect ice cover in sunlit conditions ("daytime").
  - Reflectance at near infrared channel is another parameter considered.

Ice Concentration and Cover Algorithm Description

- Top of the atmosphere NDSI is defined as

$$NDSI=(R_{vis}-R_{swir})/(R_{vis}+R_{swir})$$

  - R_{vis} = visible (or near infrared) channel reflectance
  - R_{swir} = short-wave infrared channel reflectance

- Retrievals require
  » Clear-sky conditions
  » Enough daylight

Ice Concentration and Cover Algorithm Description

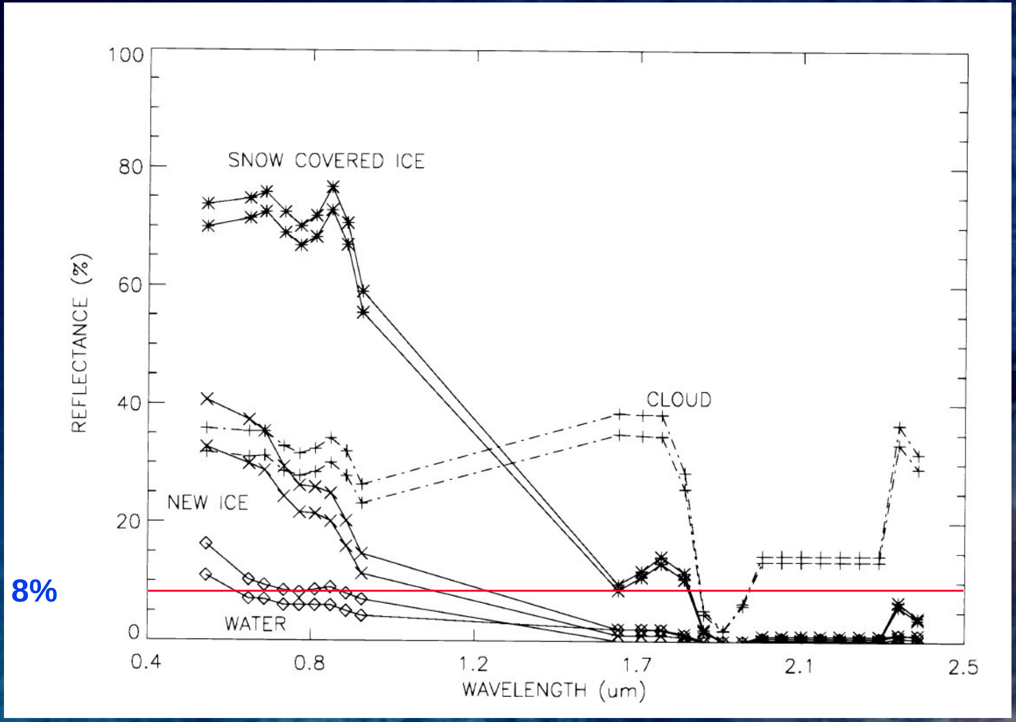
NDSI value:

Water: ~ 0.5

New ice: ~ 1.0

Snow ice: ~ 1.0

Cloud: ~ 0.0



Reflectance means for samples of ice, clouds, and water (Riggs et al. 1999).

Snow reflectance shows very high values at visible channels, but low values at short-wavelength channels longer than 1.4 microns. Clouds have high reflectance at both visible and near infrared channels. Water surface is dark at almost all wavelengths.

Ice Concentration and Cover Algorithm Description

- Pixels with both NDSI and reflectance larger than set thresholds is ice.
- Reflectance at near infrared channel, 0.865 μm
  - Threshold 0.08
- These thresholds are derived based on observed data, not directly derived from figure in the previous slide.

Ice Concentration and Cover Algorithm Description

Step 1: Use threshold tests to detect possible ice cover

- Nighttime
  - A pixel is identified as ice if the surface skin temperature is less than a threshold
  - Threshold 273.1 K

Ice Concentration and Cover Algorithm Description

Ice/snow surface temperature is retrieved by the following equation (Key et al. 1997).

$$Ts = a + b\,T11 + cT12 + d\,[(T11-T12)(\sec\theta-1)]$$

Ts = the estimated surface temperature (K)

T11 = the brightness temperatures (K) at 11 um

T12 = the brightness temperatures (K) at 12 um

θ = sensor scan angle

a, b, c, d = coefficients, derived for the following temperature ranges: T11 < 240K, 240K < T11 < 260K, T11 > 260K.

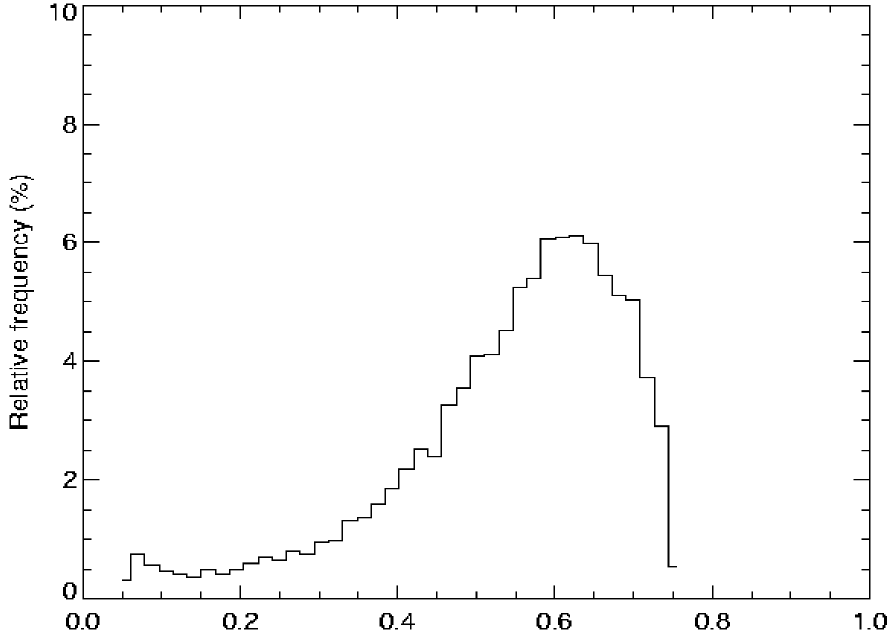
Ice Concentration and Cover Algorithm Description

Step 2a: Use tie point algorithm to calculate ice concentration

- The first step of tie point algorithm: determine reflectance (temperature) of pure ice in a search window.
  - In a 50 pixel by 50 pixel search window in JPSS VIIRS imager, there is only one predominant ice type.
  - The reflectance (temperature) of a pixel in this search window increases linearly with the increasing ice fraction.
  - In this search window covered by ice and water, pure ice pixels exist; the reflectance (temperature) of these pure ice pixels is determined.

Ice Concentration and Cover Algorithm Description

In a search window, the reflectance (temperature) of pure ice is determined as the reflectance (temperature) with the maximum relative frequency.



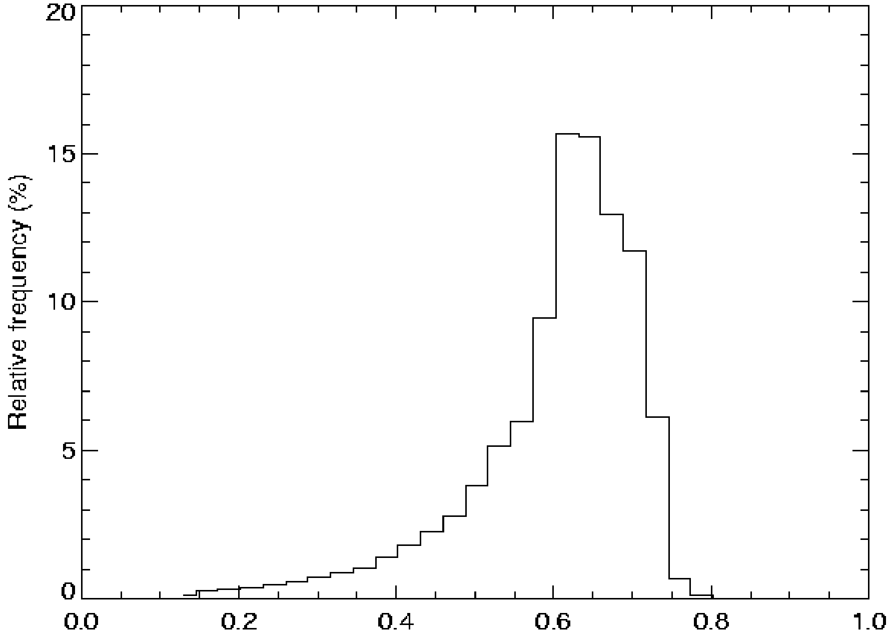


Figure: Reflectance probability density distribution at 0.64 μm for ice cover over Lake Erie on Feb 24th, 2008 (left), and over Barents and Kara Seas on Mar 31st, 2008 (right) . The ice tie points (0.6, 0.65) are indicated by the peaks in both plots.

Ice Concentration and Cover Algorithm Description

Step 2b: Use tie point algorithm to calculate ice concentration

- The second step of tie point algorithm: calculate ice concentration for each pixel in a search window
  - Use visible reflectance at JPSS VIIRS Band M5 (I2) (0.64 μm) at daytime and derived surface skin temperature at nighttime. Reflectance at 0.64 μmis less sensitive to aerosols compared to other shorter wavelengths.
  - Window size is 50 pixel by 50 pixel.
  - Reflectance at JPSS VIIRS Band M5 (I2) (temperature) of pure water pixels is set to 0.05 (273.1 K), where water has a reflectance below that value.

Ice Concentration and Cover Algorithm Description

Fractional ice concentration for each pixel (F_p) in a search window is then calculated as

$$F_p = (B_p - B_{water}) / (B_{ice} - B_{water})$$

B_{water} = the reflectance/temperature (K) of a pure water pixel

B_{ice} = the reflectance/temperature (K) of a pure ice pixel

B_p = the observed reflectance/temperature (K) of the pixel.

❖ In this algorithm, reflectance at JPSS VIIRS Band M5 (I2) (0.64 μm) is selected in daytime, and surface temperature is selected in nighttime.

❖ The spatial resolution is 0.75 (0.375) km at 0.64 μm channel, and 0.75 km for surface temperature at sub-satellite FOV

Ice Concentration and Cover Algorithm Description

Step 3:

For final ice cover product:

- Ice pixels with retrieved ice concentration larger than 15% are identified as ice.
- Ice pixels with retrieved ice concentration smaller than 15% are not identified as ice.

Ice Concentration and Cover Algorithm Description

Summary of Ice Concentration and Cover Algorithm

- Use threshold tests to detect possible ice cover in both daytime and nighttime
- Use tie-point algorithm to determine pure ice reflectance and temperature; and calculate the ice concentration.
- Use the retrieved the ice concentration to refine the final ice extent.
- This algorithm is easily implementable, and effective
- Suitable for routine processing of large image archives
- Works in both daytime and nighttime

Ice Concentration and Cover Practical Considerations

- **Numerical Computation Considerations**

This ice concentration and extent algorithm is implemented sequentially. The computation time is very economic.

- **Programming and Procedural Considerations**

This ice concentration and extent algorithm requires spatial information distributions in a search window. Temporal information is not necessary.

Ice Concentration and Cover Algorithm Practical Considerations

• Quality Assessment and Diagnostics

The following procedures are recommended for diagnosing the performance of this algorithm.

- Monitor the products with other products using different satellite input, and real time in-situ observations.
- Check input data, surface skin temperature, and reflectance for all pixels.
- Periodically image the individual test results to look for artifacts or non-physical behaviors.
- Maintain a close collaboration with the other teams using the output of this algorithm in their product generation.

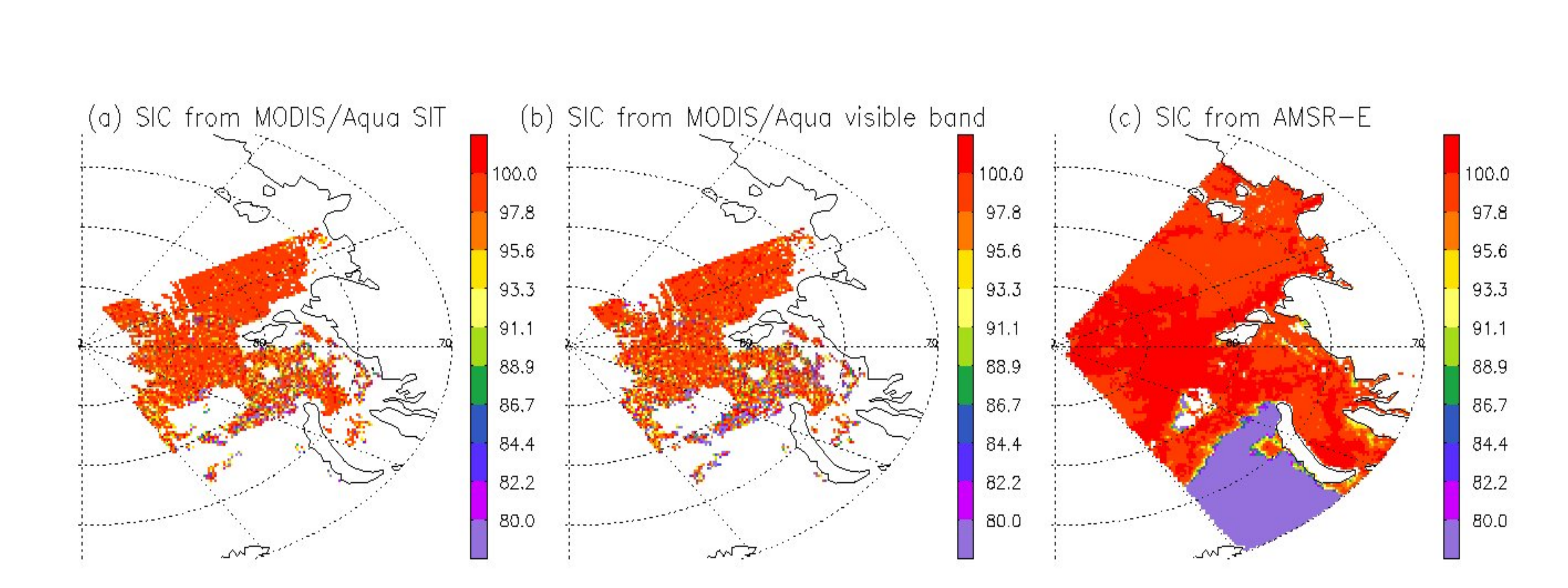
• Exception Handling

This algorithm includes checking the validity of input data before running. This algorithm also checks for missing input variables values.

Ice Concentration and Cover Algorithm Verification

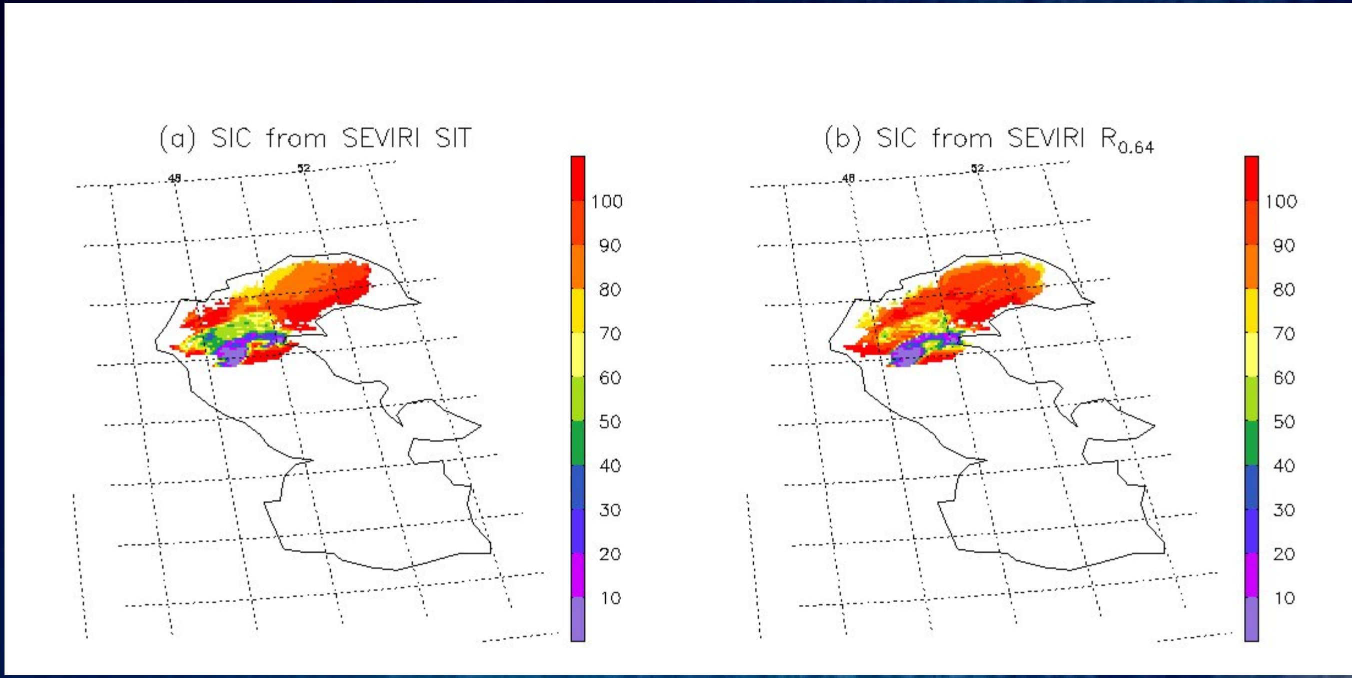
- **Truth Measurements and other products**
  - » **Truth**
    - – AMSR-E/Aqua Daily L3 12.5 km Sea Ice Concentration (pixel averaging of ABI ice fraction is needed because AMSR-E is lower resolution)
    - – Ice chart from National Ice Center and Canadian Ice Service with 0.25 degree resolution (pixel averaging of ABI ice fraction is needed because AMSR-E is lower resolution)
  - » Verification (qualitative)
    - – MODIS true color imagery

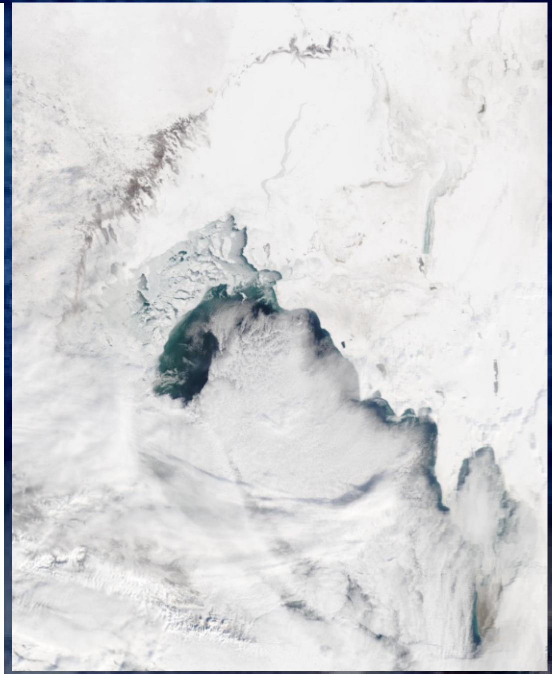
Ice Concentration and Cover Algorithm Verification , Cont' d



Sea ice concentration (SIC) (%) retrieved from (a) MODIS Sea Ice Temperature (SIT), (b) MODIS visible band reflectance, and (c) from Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) Level-3 gridded daily mean from NSIDC on March 31, 2006.

Ice Concentration and Cover Algorithm Verification, Cont'd



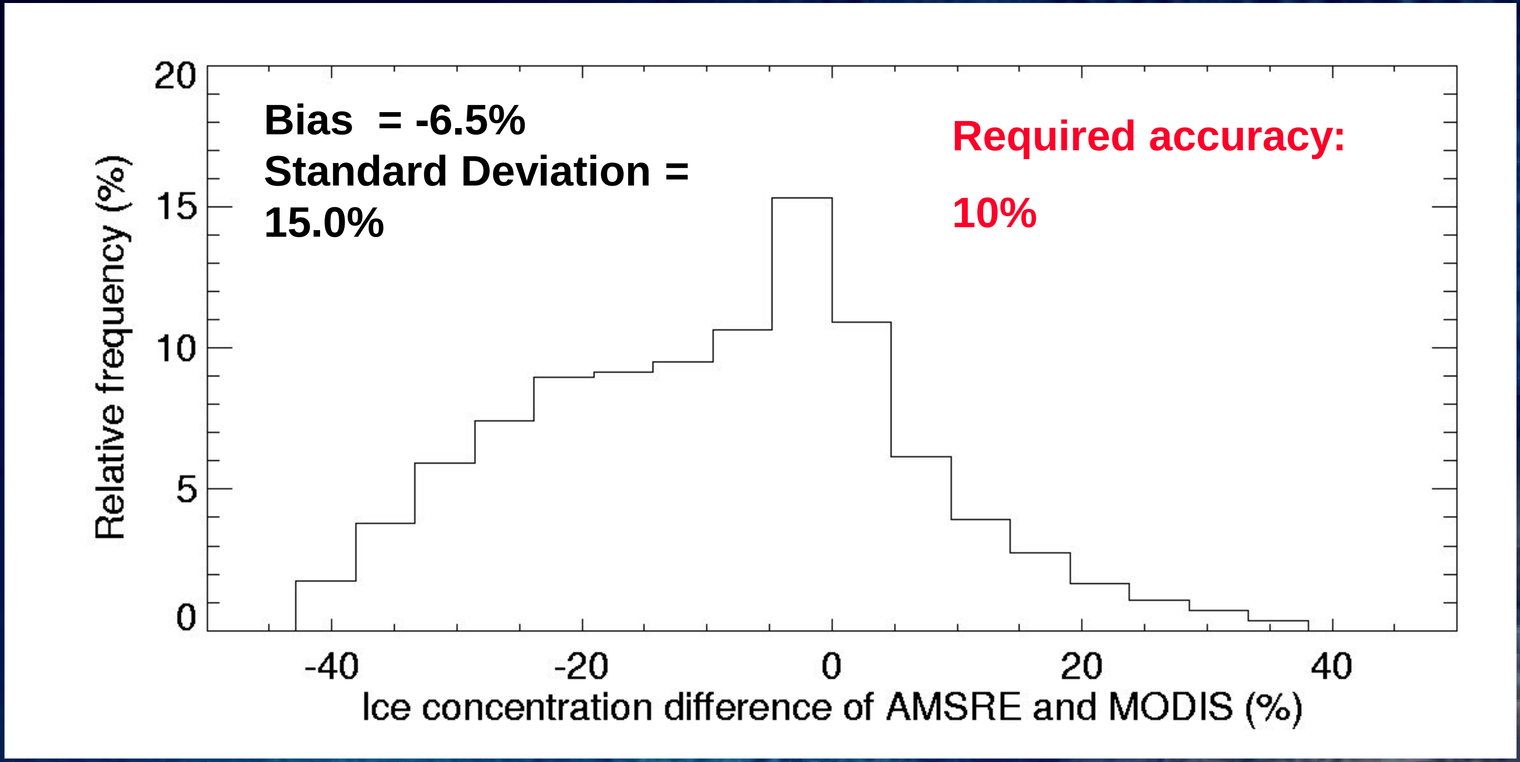


Lake ice concentration (%) retrieved from (a) SEVIRI Surface Ice Temperature (SIT), (b) SEVIRI visible band reflectance (0.64 μm, an (c) satellite true color image over Caspian Sea on January 27th, 2006

Ice Concentration and Cover Algorithm Verification, Cont' d

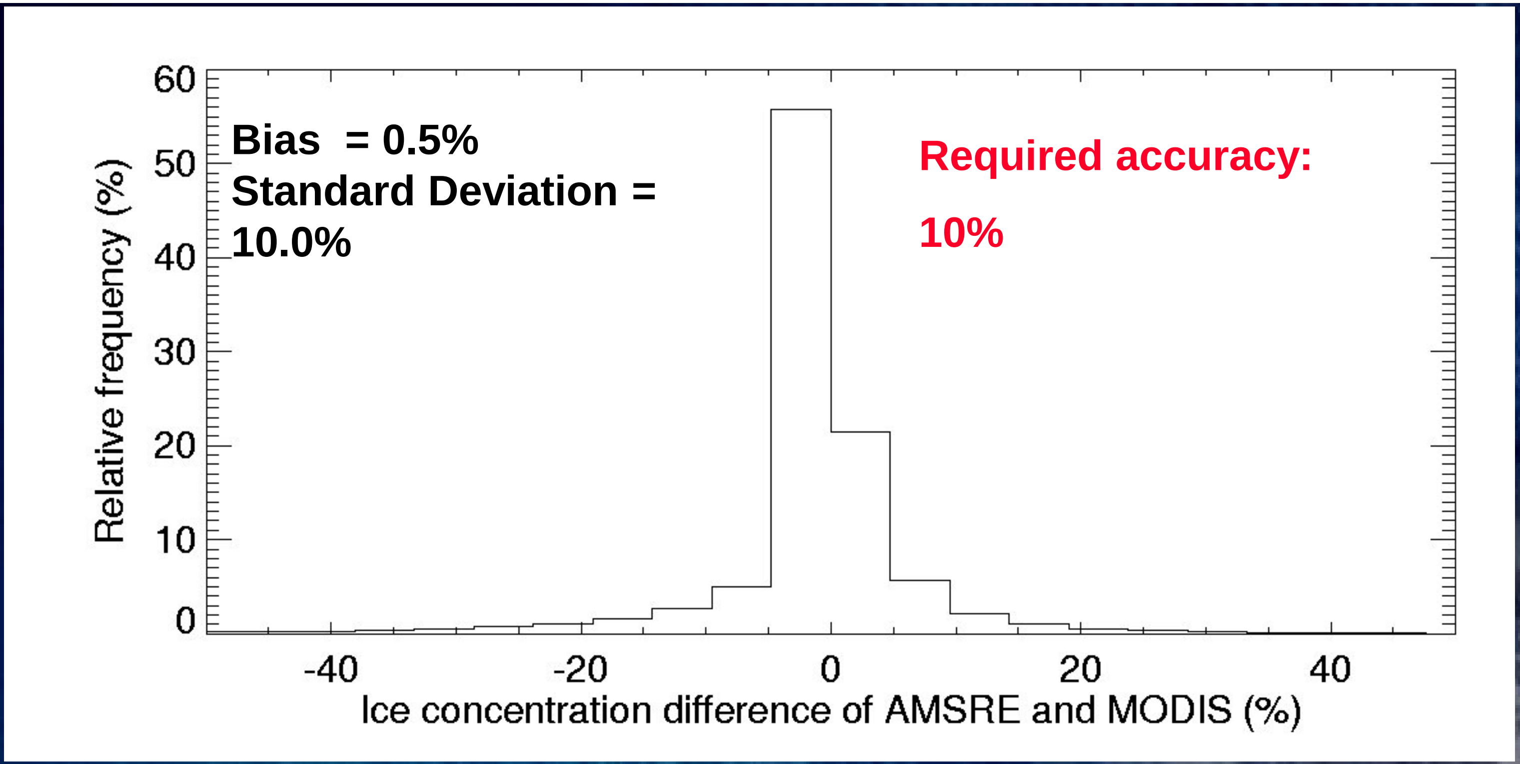
Lake ice concentration (%) with MODIS Aqua data (left), MODIS true color image (middle), and from AMSR-E (right) over Great Lakes on February 24, 2008.

Ice Concentration and Cover Algorithm Verification, Cont' d



Frequency distribution of ice concentration difference between AMSR-E sea ice concentration product and retrievals using this algorithm based on selected 20 clear day MODIS data from 2004 to 2008 in Great Lakes region.

Ice Concentration and Cover Algorithm Verification, Cont'd



Frequency distribution of ice concentration difference between AMSR-E ice concentration product and retrievals using this algorithm based on selected 20 clear day MODIS data in 2007 over the Arctic Ocean.

Ice Concentration and Cover Algorithm Performance Estimate

- Ice concentration retrievals meet the required accuracy 10%, in comparison with the AMSR-E product.
- Some tuning of the algorithm, including test threshold, and some constants, may be required
- This algorithm works for any water surface, including lake, river, and ocean. More verification will be done over rivers.
- Quantitative validation of the product will be conducted by comparing the derived ice concentration and extent with ice chart product.
- Major risks are associated with
  - » Inaccurate cloud identification
  - » Inaccurate identification of cloud shadows

Ice Concentration and Cover Algorithm Assumptions and Limitations

- **Sensor Performance**
  - » All satellite channel calibration and navigation will be correct and uniform from image to image
  - » Cloud mask eliminates all possible cloud contamination.
  - » Land/sea mask is accurate
  - » Changes of reflectance/temperature in each search window are mainly caused by difference in ice concentration.

Ice Concentration and Cover Algorithm Assumptions and Limitations

- **Product improvements may result from these studies:**
  - » Size of the search window will be tested to get the best results.
    - – Current size of the search window is 50 pixel by 50 pixel
  - » The tie point reflectance (temperature) is being evaluated to get the best result.
  - » The instrument noise on the final retrieval results is being investigated.

Ice Concentration and Cover Risk

- **Risk 2:** Persistent cloud cover and false cloud detection in the polar regions
- **Risk Assessment:** Medium
- **Impact:**
  - » Persistent cloud cover and false cloud detection may lead to the ice concentration and cover failing to meet the requirements
- **Mitigation:**
  - » Work closely with the cloud team to ensure accurate cloud classification
  - » Use alternate source of snow/ice information (GFS, IMS, Global Snow & Ice Mapping System) to flag persistent clouds
- **Status:** Open

Ice Concentration and Cover Risk

- **Risk 3:** Lack of truth data for ice concentration and cover validation
- **Risk Assessment:** Medium
- **Impact:**
  - » Without truth data, we may not know if the ice concentration and cover products meet the requirements
- **Mitigation:**
  - » Work with the community to develop more truth data sites
- **Status:** Open

Ice Concentration and Cover Algorithm References

Appel I., and J. A. Kenneth, 2002, Fresh water ice Visible/Infrared Imager/Radiometer Suite algorithm theoretical basis document, Version 5. SBRS document #: Y2404.

Bolsenga, S.J. 1983, Spectral reflectances of snow and fresh-water ice from 340 through 1100 nm. J. Glaciology, 29(102), 296-305.

Grenfell, T. C. and G. A. Maykut, 1977, The optical properties of ice and snow in the Arctic

Basin, J. Glaciol., 18, 445-63.

Hall D.K., G.A. Riggs, and V.V. Salomonson, 2001, Algorithm theoretical basis document for the MODIS snow and sea ice mapping algorithms.

Hall D.K., G.A. Riggs, and V.V. Salomonson, 2006, MODIS sea ice products user guide to collection 5.

Key, J., J. Collins, C. Fowler, and R. Stone, 1997, High-latitude surface temperature estimates from thermal satellite data. Remote Sensing Environ., 61, 302-309.

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Markus, T., and D. Cavalieri 2000, And enhancement of the NASA Team sea ice algorithm, IEE Transactions on Geoscience and Remote Sensing 38, 1387-1398.

Riggs G.A., D.K. Hall, and S.A. Ackerman, 1999, Sea ice extent and classification mapping with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator. Remote Sensing of Environ., 68, 152-163.

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Algorithm Theoretical Basis

Ice Surface Temperature

Presented by

Yinghui Liu

UW-Madison CIMSS

Ice Surface Temperature Algorithm Theoretical Basis

- The purpose of the JPSS VIIRS Ice Surface Temperature Algorithm ATBD is to provide programmers, reviewers and users with a theoretical description (scientific and mathematical) of this algorithm.

- Information has been documented in the JPSS VIIRS ATBD.

CDR Requirements
Ice Surface Temperature

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Res.	Horiz. Res.	Mapping Accuracy	Msmnt. Range	Msmnt. Accuracy	Product Refresh Rate/Coverage Time	Product Measurement Precision	Temporal Coverage Qualifiers	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Ice Surface Temperature	JPSS VIIRS	All ice-covered regions of the global ocean	Ice Surface	0.75 km	1.0 km	213 – 275 K	1 K	At least 90% coverage of the globe every 24 hours	1 K	All conditions	Clear conditions associated with threshold accuracy	Over specified geographic area

Ice Surface Temperature Algorithm Objectives

- The JPSS VIIRS Ice Surface Temperature Product will be produced for each VIIRS image and will provide values over all water surfaces of the globe.
- The primary output consists of a map of ice surface temperature, and corresponding quality control flags.
- Applications of ice surface temperature include numerical weather prediction and data assimilation, hydrological modeling, climate modeling, transportation, recreation.

Ice Surface Temperature Algorithm Observing System Overview

- Instrument Characteristics

JPSS VIIRS band	Nominal Central Wavelength (µm)	Nominal sub-satellite IGFOV (km)	Sample Use
M15	10.763	0.75	Ice surface Temperature
M16	12.013	0.75	Ice surface Temperature

Ice Surface Temperature Algorithm Input and Output

- **JPSS VIIRS Ice Surface Temperature Algorithm requires for each pixel:**

  » Calibrated/Navigated VIIRS brightness temperatures
  » Satellite viewing angle
  » Cloud mask and land mask
  » Ice concentration and ice cover
  » Longitude and Latitude
  » Imagery can be in native satellite projection or remapped projection

Ice Surface Temperature Algorithm Input and Output

Name	Type	Description	Dimension
M15 (I5) brightness temperature	Input	Navigated and Calibrated VIIRS level 1b brightness temperatures for band M15 (I5)	Scan grid (xsize, ysize)
M16 brightness temperature	Input	Navigated and Calibrated VIIRS level 1b brightness temperatures for band M16	Scan grid (xsize, ysize)
Latitude	Input	Pixel Latitude	Scan grid (xsize,ysize)
Longitude	Input	Pixel Longitude	Scan grid (xsize,ysize)
satellite viewing angle	Input	satellite viewing angle	Scan grid (xsize, ysize)
QC flags	input	VIIRS level 1b quality control flags	Scan grid (xsize, ysize)

Algorithm Input: Ancillary Data

- Three types of ancillary data needed:
  - » VIIRS Products:
    - – Cloud mask
    - – Ice concentration and ice cover
  - » Non-VIIRS Dynamic Data: N/A
  - » Non-VIIRS Static Data: Land/Water Mask

Name	Type	Description	Dimension
Land/Water mask	Input	Map of land and water flags	Scan grid (xsize, ysize)

Name	Type	Description	Dimension
Cloud mask	Input	VIIRS Cloud Mask	Scan grid (xsize, ysize)
Ice concentration and ice cover	Input	VIIRS ice concentration and ice cover	Scan grid (xsize, ysize)

Algorithm Input and Output

- Output Data:
  - Ice surface skin temperature derived by this algorithm

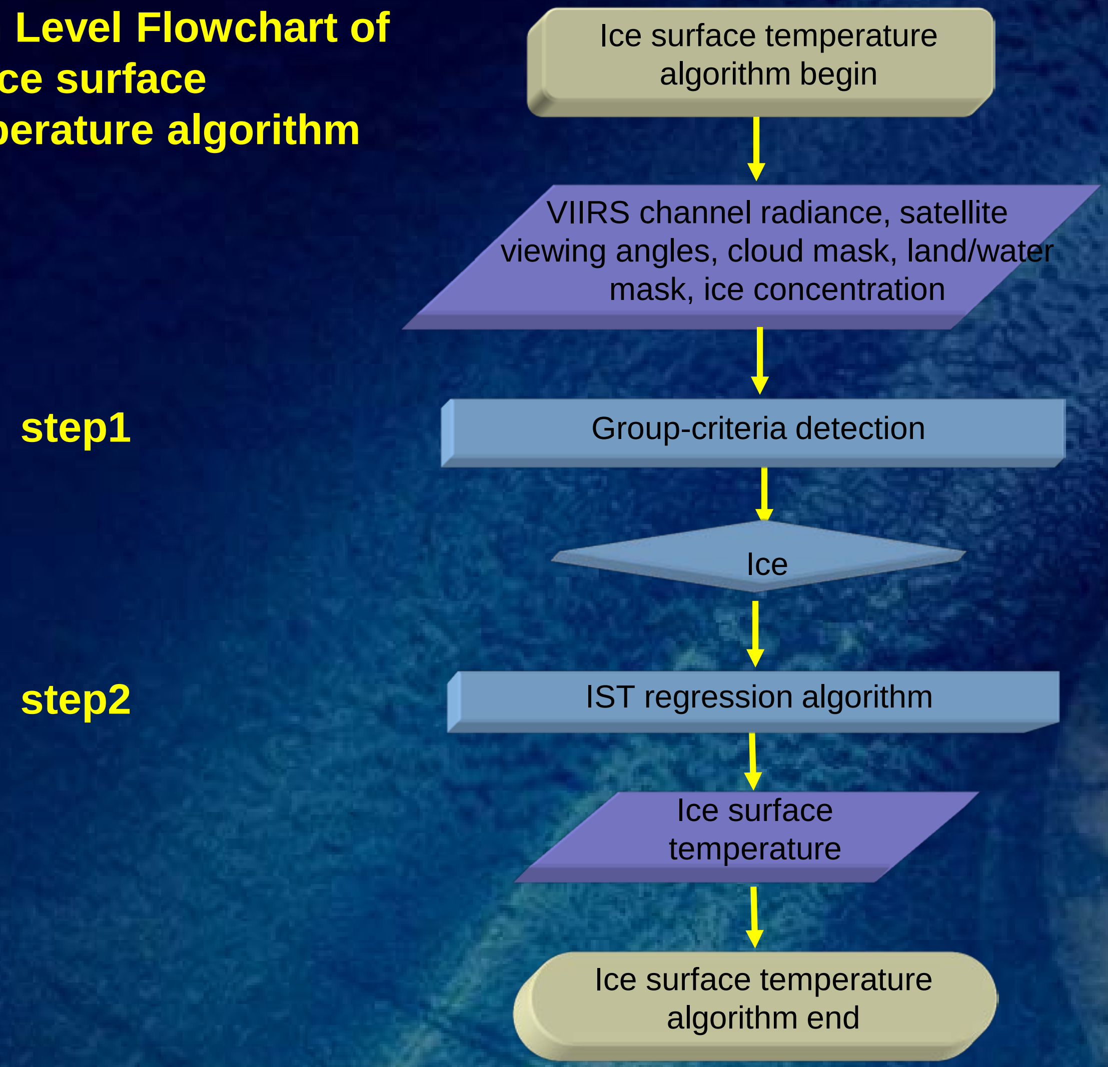
Name	Type	Description	Dimension
Ice surface skin temperature	output	Output contains ice surface skin temperature for each pixel identified as ice	Scan grid (xsize, ysize)
QC flags for ice surface skin temperature	output	Quality Control Flags for every pixel	Scan grid (xsize, ysize)

Ice Surface Temperature Algorithm Description

- **Procedures of ice surface temperature algorithm**
  1. Select pixels for IST retrieval: clear sky, ice pixels only. Daytime and nighttime.
  2. Use a regression algorithm similar to the conventional split-window (infrared) sea surface temperature algorithms. IST is a simple calculation based on two channels with regression coefficients that are a function of temperature.

Ice Surface Temperature Algorithm Processing Outline

High Level Flowchart of the ice surface temperature algorithm



Ice Surface Temperature Algorithm Description

Ice/snow surface temperature is retrieved by the following equation (Key et al. 1997).

$$Ts = a + b\,T11 + cT12 + d\,[(T11 - T12)(\sec\theta - 1)]$$

Ts = the estimated surface temperature (K)

T11 = the brightness temperatures (K) at 11 um

T12 = the brightness temperatures (K) at 12 um

θ = sensor scan angle

a, b, c, d = coefficients, derived for the following temperature ranges: T11 < 240K, 240K < T11 < 260K, T11 > 260K.

Ice Surface Temperature Practical Considerations

- **Numerical Computation Considerations**

This ice surface temperature algorithm is implemented sequentially. The computation time is very economic.

Ice Surface Temperature Algorithm Practical Considerations

• Quality Assessment and Diagnostics

The following procedures are recommended for diagnosing the performance of this algorithm.

- Monitor the products with other products using different satellite input, and real time in-situ observations.
- Check input data for all pixels.
- Periodically image the individual test results to look for artifacts or non-physical behaviors.
- Maintain a close collaboration with the other teams using the output of this algorithm in their product generation.

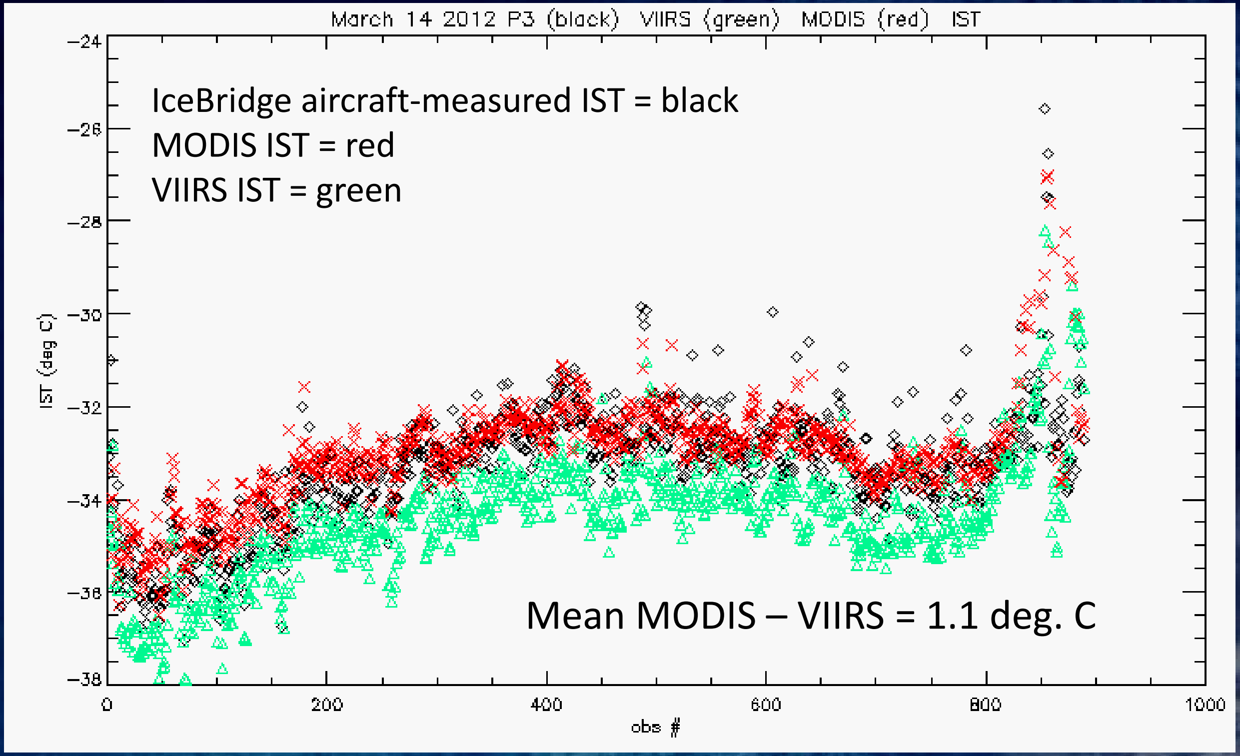
• Exception Handling

This algorithm includes checking the validity of input data before running. This algorithm also checks for missing input variables values.

Ice Surface Temperature Algorithm Verification

- **Truth Measurements and other products**
  - » **Truth**
    - – In situ observations of ice surface temperature from field campaigns
    - – Co-located ice surface temperature retrievals from MODIS

Ice Surface Temperature Algorithm Verification , Cont' d



IST comparison along NASA P-3 flight track (March 2012) for one Ice Bridge flight. The operational VIIRS IST and MODIS IST are shown for comparison. Note that the IST algorithm to be used for this project is the MODIS algorithm with coefficients adapted to VIIRS (in progress), not the operational VIIRS algorithm.

Ice Surface Temperature Algorithm Performance Estimate

- Some tuning of the algorithm may be required
- This algorithm works for any water surface, including lake, river, and ocean. More verification will be done over rivers.
- Quantitative validation of the product will be conducted.
- Major risks are associated with
  - » Inaccurate cloud identification
  - » Inaccurate identification of cloud shadows

Ice Surface Temperature Assumptions and Limitations

- **Sensor Performance**
  - » All satellite channel calibration navigation will be correct and uniform from image to image
  - » Cloud mask eliminates all possible cloud contamination
  - » Land/Water mask is accurate

Ice Surface Temperature Risk

- **Risk 2:** Persistent cloud cover and false cloud detection in the polar regions
- **Risk Assessment:** Medium
- **Impact:**
  - » Persistent cloud cover and false cloud detection may lead to the ice surface temperature failing to meet the requirements
- **Mitigation:**
  - » Work closely with the cloud team to ensure accurate cloud classification
  - » Use alternate source of snow/ice information (GFS, IMS, Global Snow & Ice Mapping System) to flag persistent clouds
- **Status:** Open

Ice Surface Temperature Algorithm References

Hall D.K., G.A. Riggs, and V.V. Salomonson, 2006, MODIS sea ice products user guide to collection 5.

Key, J., J. Collins, C. Fowler, and R. Stone, 1997, High-latitude surface temperature estimates from thermal satellite data. Remote Sensing Environ., 61, 302-309.

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- Summary and Conclusions

Algorithm Theoretical Basis

Ice Thickness and Age

Xuanji Wang

UW-Madison CIMSS

Ice Thickness and Age Algorithm Theoretical Basis

- The purpose of the VIIRS Ice Thickness and Age Estimation Algorithm ATBD is to provide programmers, reviewers and users with a theoretical description (scientific and mathematical) of the VIIRS ice thickness and age estimation algorithm.

- Information is documented in the GOES-R ABI ATBD.

Ice Thickness and Age
EDR Requirements

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Res.	Horiz. Res.	Mapping Accuracy	Msmnt. Range	Msmnt. Accuracy	Product Refresh Rate/Coverage Time	Product Measurement Precision	Temporal Coverage Qualifiers	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Sea & Lake Ice: Thickness /Age	JPSS	All ice-covered regions of the global ocean	Ice Surface	0.75 km	1 km	Ice thickness , ice free, New/Young ice, all other ice	80% probability of detection	At least 90% coverage of the globe every 24 hours (monthly average)	15%	Day and night	Clear conditions associated with threshold accuracy	Over specified geographic area

Ice Thickness and Age Algorithm Design

- One-dimensional Thermodynamic Ice Model (OTIM) algorithm design:
  - Solid physical foundation with all components of surface energy budget considered,
  - Capable of retrieving daytime and nighttime sea and lake ice thickness under both clear and cloudy sky conditions,
  - Very computationally efficient compared to more complex models such as NCAR's Community Sea Ice Model (CSIM), and its sole objective of retrieving ice thickness and age makes it easy to implement with the application of satellite products,
  - Flexible, fast and easy to maintain and improve later with more and accurate satellite retrieved products like radiative fluxes, snow cover and snow depth over ice,
  - Independent of historical records for ice thickness and age estimation.

Ice Thickness and Age Observing System Overview

- **Products Generated**
  - » Near real-time ice thickness and age estimates.
  - » Ice thickness and age will be produced for each pixel observed by the VIIRS that is covered with ice.

Ice Thickness and Age Processing Overview

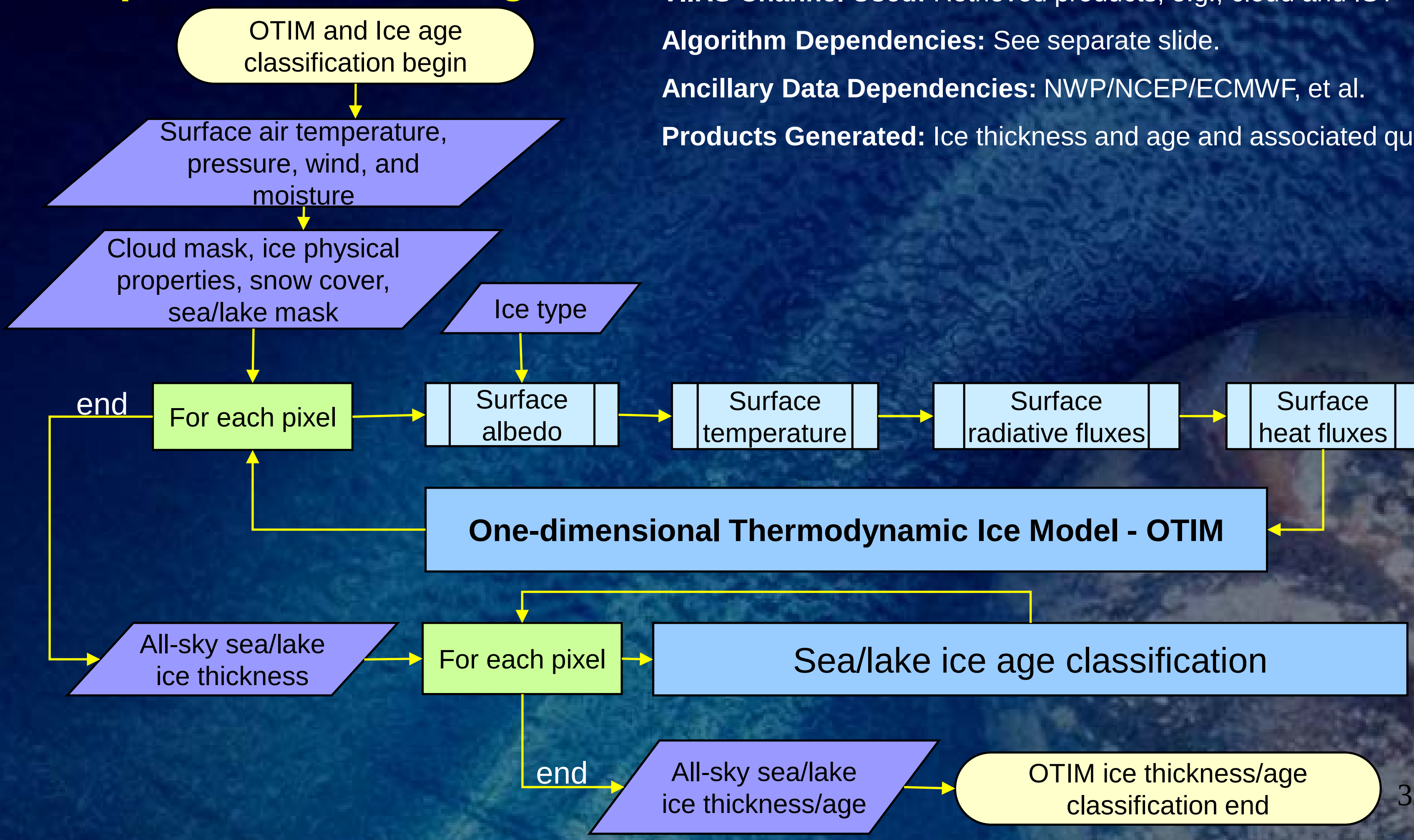
- **Top-Level Processing**

VIIRS Channel Used: Retrieved products, e.g., cloud and IST

Algorithm Dependencies: See separate slide.

Ancillary Data Dependencies: NWP/NCEP/ECMWF, et al.

Products Generated: Ice thickness and age and associated quality flags.



Ice Thickness and Age Algorithm Input

- No sensor input data, but retrieved products, are currently needed in the algorithm
- Three types of ancillary data needed:
  - » Static Non-VIIRS Data:
    - – Ice and snow microphysical properties
    - – Surface land mask
  - » Dynamic Non-VIIRS Data:
    - – Surface air temperature
    - – Surface wind speed
    - – Surface air pressure
    - – Surface air moisture
    - – Snow cover and depth

Ice Thickness and Age Algorithm Input

- Three types of ancillary data needed (cont.):
  - VIIRS Derived Data:
    - Cloud mask and fraction
    - Surface skin temperature
    - Surface broadband albedo (daytime only)
    - Ice mask and concentration
    - Surface solar radiation
    - Surface thermal radiation
    - Navigation information

Ice Thickness and Age Algorithm Input

- Three types of ancillary data needed

Name	Type	Description	Dimension
Static Non-VIIRS Data			
Ice and snow microphysical properties	input	Ice and snow microphysical properties, e.g. conductivity, reflectance, transmittance, emissivity, salinity, density. Some of those are parameterized inherent in the OTIM.	Variable
Surface Land mask	input	Surface land mask that would be able to identify sea, lake, river, et al.	2-D
Dynamic Non-VIIRS Data			
Surface air temperature	input	In-situ measurement, VIIRS retrievals or NCEP/ECMWF. Default values may be used for ice thickness retrieval.	2-D
Surface wind speed	input	In-situ measurement, VIIRS retrievals or NCEP/ECMWF. Default values may be used for ice thickness retrieval.	2-D
Surface air pressure	input	In-situ measurement, VIIRS retrievals or NCEP/ECMWF. Default values may be used for ice thickness retrieval.	2-D
Surface air moisture	input	In-situ measurement, VIIRS retrievals or NCEP/ECMWF. Default values may be used for ice thickness retrieval.	2-D
Snow cover and depth	input	In-situ measurement, VIIRS retrievals or NCEP/ECMWF. Some parameterization inherent in the OTIM may be used.	2-D

Ice Thickness and Age Algorithm Input

- Three types of ancillary data needed

Name	Type	Description	Dimension
VIIRS Derived Data			
Cloud mask and fraction	input	Cloud identification and fractional coverage for each pixel.	2-D
Surface skin temperature	input	VIIRS retrieved ice/snow surface skin temperature.	2-D
Surface broadband albedo (daytime only)	input	VIIRS retrieved ice/snow surface broadband albedo in solar band.	2-D
Ice mask and concentration	input	VIIRS retrieved ice mask and ice concentration from cryosphere team.	2-D
Surface solar radiation	input	VIIRS retrieved ice surface downward solar radiation flux or from the algorithms inherent parameterization schemes.	2-D
Surface thermal radiation	input	VIIRS retrieved ice surface downward and upward thermal radiation flux or from the algorithms inherent parameterization schemes.	2-D
Navigation information	input	VIIRS data acquisition date and time, VIIRS instrument viewing geometry (scan and azimuth angles), and the Sun illumination geometry (zenith and azimuth angles).	Variable

Ice Thickness and Age Algorithm Output

- OTIM output

  - Automated sea and lake ice thickness
  - Automated sea and lake ice age
  - Quality information variables being used in validation
    - Surface solar and thermal radiation fluxes
    - Surface turbulent latent/sensible heat fluxes
    - Surface air temperature, humidity, wind speed
    - Ice and snow conductivity
    - Sea water and ice salinity

Ice Thickness and Age Algorithm Output

OTIM output parameters and their definitions.

Name	Type	Description	Dimension
Ice Thickness	Output	Ice thickness is defined as the total vertical length of the ice under and above water surface. The reliable ice thickness retrieved from this algorithm ranges between *0 ~ 5.0 m*.	2-D
Ice age	Output		2-D
1: New	Output	New ice *0~10 cm* thick. Recently formed ice which includes frazil ice, grease ice, slush, shuga, and nilas. These types of ice include ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat, and a thin elastic crust of ice that is easily bending on waves and swell and under pressure growing in a pattern of interlocking "fingers" (finger rafting).	2-D
2: Grey	Output	Young ice *10-15 cm* thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.	2-D
3: Grey-white	Output	Young ice *15-30 cm* thick. Under pressure it is more likely to ridge than to raft.	2-D
4: First-year Thin	Output	First-year ice of not more than one winter's growth, *30-70 cm* thick.	2-D
5: First-year Medium	Output	First-year, ice *70-120 cm* thick.	2-D
6: First-year Thick	Output	First-year ice *120-170 cm* thick.	2-D
7: Old Ice	Output	Sea ice which has survived at least one summer's melt. Topographic features generally are smoother than first-year ice, and *more than 170 cm* thick. May be subdivided into second-year ice and multi-year ice. Second-year Ice: Old ice which has survived only one summer's melt. Multi-year Ice: Old ice which has survived at least two summer's melt.	2-D

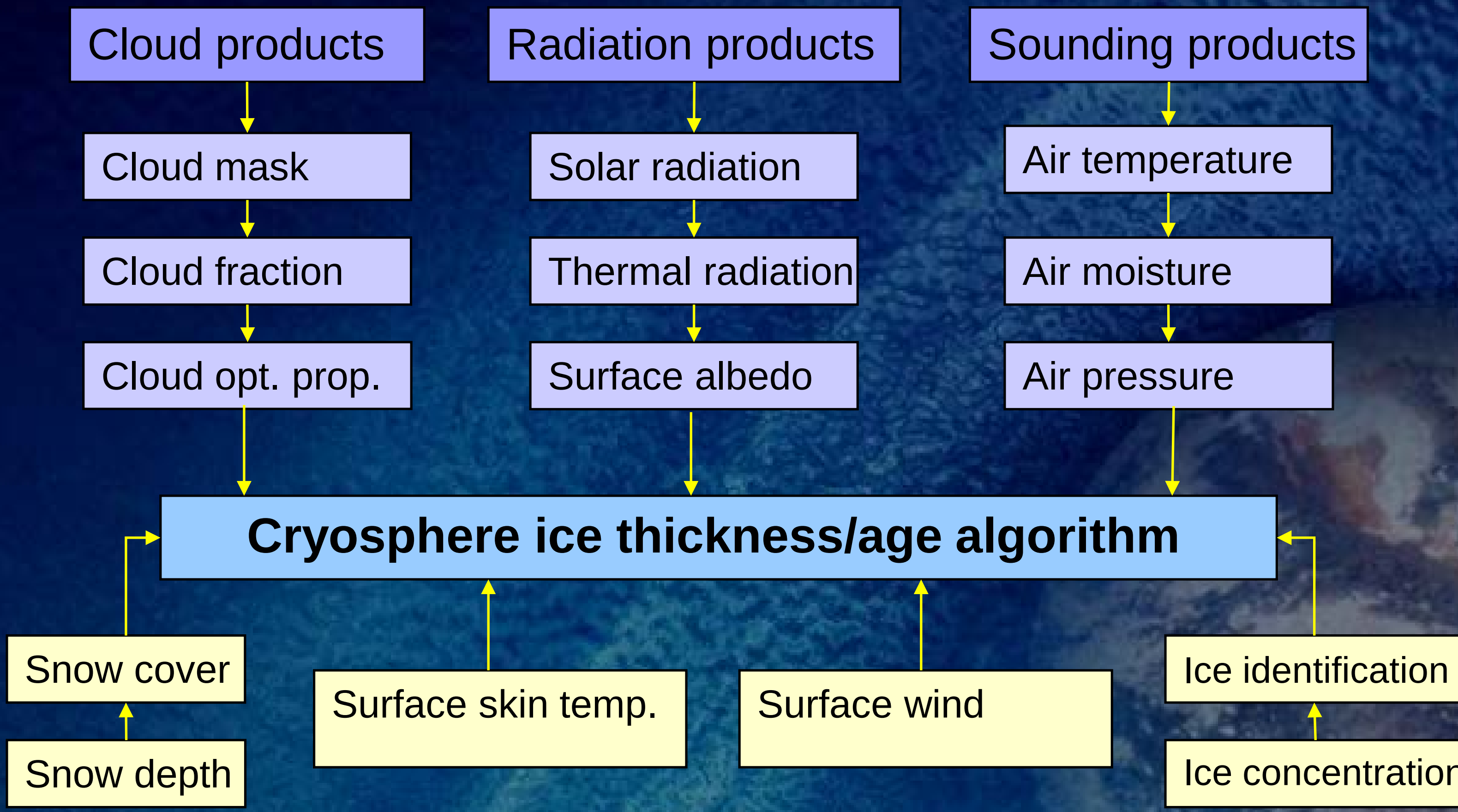
Ice Thickness and Age Algorithm Output

OTIM quality information variables being used in validation and their definitions

Name	Unit	Description
Cloud mask/fraction	0 ~ 1	Clear or Cloudy over the ice surface, observed.
Surface broadband albedo	0 ~ 1	Ice/snow surface broadband albedo, modeled or in-situ measured, daytime only.
Ice Transmittance	0 ~ 1	Ice slab transmittance for solar radiation, modeled or measured, daytime only.
Surface downward solar radiation flux	$W{\cdot}m^{-2}$	Downward solar radiation flux at the surface, modeled or observed, daytime only.
Surface upward thermal radiation flux	$W{\cdot}m^{-2}$	Upward thermal radiation flux at the surface, modeled or observed.
Surface downward thermal radiation flux	$W{\cdot}m^{-2}$	Downward thermal radiation flux at the surface, modeled or observed.
Surface turbulent sensible heat flux	$W{\cdot}m^{-2}$	The turbulent sensible heat flux at the interface of ice and the above atmosphere modeled or observed.
Surface turbulent latent heat flux	$W{\cdot}m^{-2}$	The turbulent latent heat flux at the interface of ice and the above atmosphere modeled or observed.
Conductive heat flux	$W{\cdot}m^{-2}$	Conductive heat flux within the ice slab.
Surface skin temperature	K	Ice/snow surface skin temperature, observed.
Surface air temperature	K	Surface air temperature at 2 m above the ground, modeled or observed.
Surface air humidity	0%~100%	Surface air humidity, relative or mixing ratio, modeled or observed.
Surface wind	$m{\cdot}s^{-1}$	Surface wind speed at 2 m above the ground, observed.
Sea water salinity	PPT	Sea water salinity, modeled or observed.
Sea ice salinity	PPT	Sea ice salinity, modeled or observed.
Snow depth	m	Snow accumulation over the ice in meter, modeled or observed.
Water freezing point	K	The temperature at which water freezes, modeled or observed.
Snow conductivity	$W{\cdot}m^{-1}{\cdot}K^{-1}$	Snow conductivity, modeled or observed.
Ice conductivity	$W{\cdot}m^{-1}{\cdot}K^{-1}$	Ice conductivity, modeled or observed.

Ice Thickness and Age Algorithm Processing Outline

OTIM Algorithm Dependencies



Ice Thickness and Age Algorithm Processing Overview

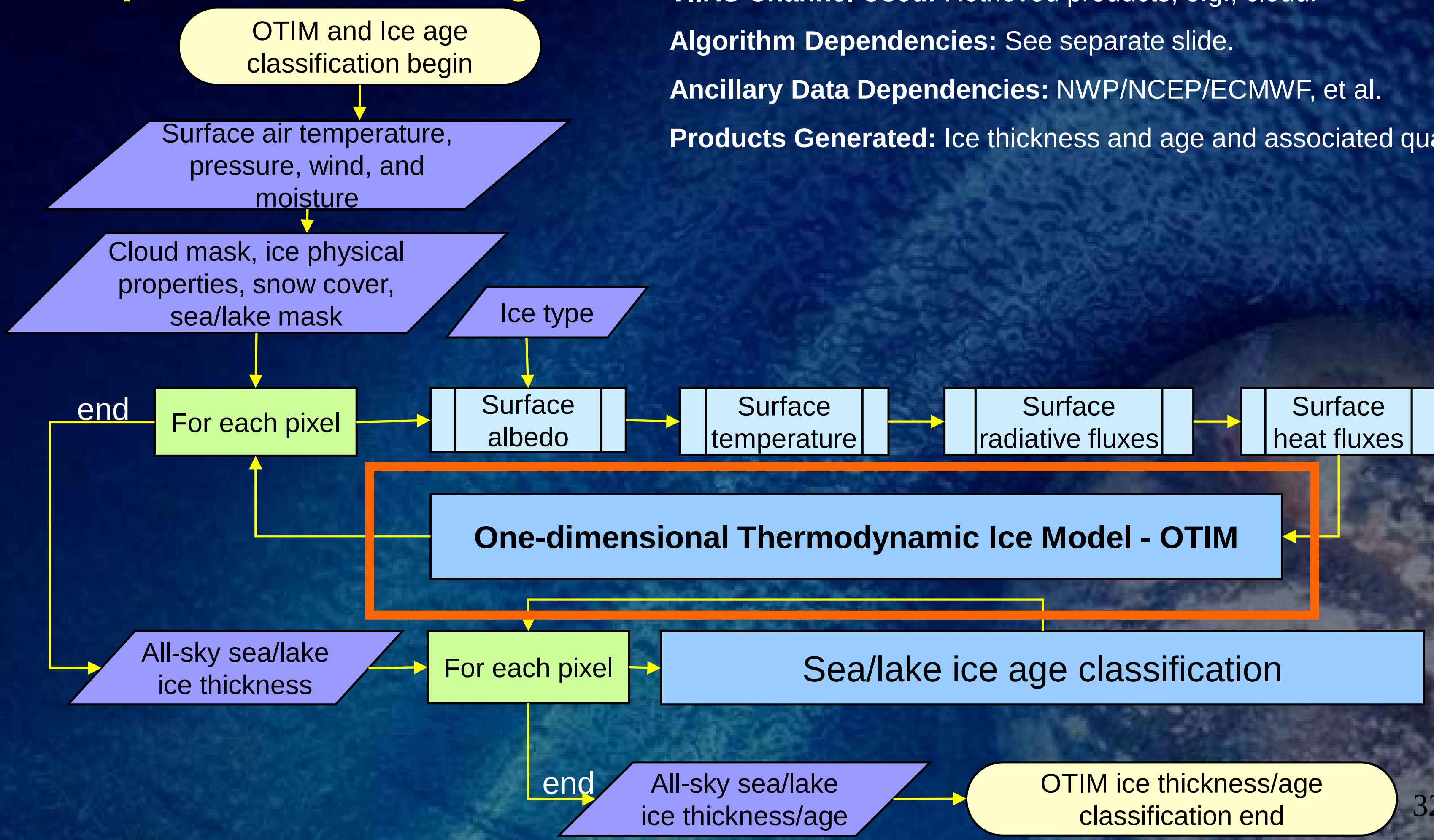
- **Top-Level Processing**

VIIRS Channel Used: Retrieved products, e.g., cloud.

Algorithm Dependencies: See separate slide.

Ancillary Data Dependencies: NWP/NCEP/ECMWF, et al.

Products Generated: Ice thickness and age and associated quality flags.



Ice Thickness and Age Algorithm Description

- Theoretical Basis
  - » Based on the surface energy balance at thermo-equilibrium, containing all components of the surface energy budget to estimate sea and lake ice thickness.
  - » Based on the estimated ice thickness and classification scheme, ice age will be determined.
  - » Analytical and numerical solution.

Ice Thickness and Age Algorithm Description

- ***One-dimensional Ice Model (OTIM)***

$$(1-\alpha_s)\, F_r - I_0 - F_l^{up} + F_l^{dn} + F_s + F_e + F_c = F_a \qquad (1)$$

- α_s is ice surface broadband albedo where ice may be covered with a layer of snow,
- F_r is downward solar radiation flux at the surface,
- I_0 is the solar radiation flux passing through the ice interior,
- F_l^{up} is upward longwave radiation flux from the surface,
- F_l^{dn} is downward longwave radiation flux from the atmosphere towards the surface,
- F_s is turbulent sensible heat flux at the surface,
- F_e is turbulent latent heat flux at the surface,
- F_c is conductive heat flux within the ice slab,
- F_a is residual absorbed energy that contributes to melting at or near the surface.

Ice Thickness and Age Algorithm Description

- ***One-dimensional Ice Model (OTIM)*** (Cont)

$$(1-\alpha_s) F_r - I_0 - F_l^{up} + F_l^{dn} + F_s + F_e + F_c = F_a \qquad (1)$$

By the definitions of the terms in the equation (1), α_s, F_r, I_0, F_l^{up}, F_l^{dn} should be always positive, and F_s, F_e, and F_c would be positive or negative in terms of the operational symbols used in the equation (1), and F_a is residual heat flux that would be zero in the absence of a phase change. The details of each term will be addressed in the following subsections.

Ice Thickness and Age Algorithm Description

Surface Net Solar Radiation = $(1-\alpha_s) F_r$:

$$\alpha_s = 1 - A \exp(-Bh) - C \exp(-Dh) \qquad (2)$$

where *A, B, C*, and *D* are the coefficients of which values can be determined from the Table on the next slide, and *h* is ice (h_i) or snow (h_s) thickness in meter.

Ice Thickness and Age Algorithm Description

Surface Net Solar Radiation = $(1-\alpha_s) F_r$ (Cont):

The coefficient values of A, B, C, and D in the Eq. (2) (from Thomas C. Grenfell, 1979)

Ice type	*Cloudiness*	*A*	*B*	*C*	*D*	*Error*
Blue ice **0.8m >= h_i>=0.02m**	**Clear**	**0.130**	**15.46**	**0.820**	**0.1216**	**< 1%**
	Cloudy	**0.150**	**12.02**	**0.800**	**0.2161**	**< 1%**
White ice **0.8m >= h_i>=0.02m**	**Clear**	**0.419**	**12.40**	**0.531**	**0.1958**	**< 2.5%**
	Cloudy	**0.540**	**10.11**	**0.410**	**0.2827**	**< 3%**
Dry packed snow over blue ice **0.4m >= h_s >= 0.01m**	**Clear**	**0.2213**	**77.48**	**0.1980**	**0**	**< 5%**
	Cloudy	**0.3181**	**77.81**	**0.100**	**0.050**	**< 7%**

Ice Thickness and Age Algorithm Description

Solar Radiation Passing through Ice Interior $I_0 = i_0 (1-\alpha_s)F_r$:

$$i_0 = A \exp(-Bh) + C \exp(-Dh) \qquad (3)$$

where i_0 is ice slab transmittance, *A, B, C*, and *D* are coefficients given in the table on the next slide.

Ice Thickness and Age Algorithm Description

Solar Radiation Passing through Ice Interior $I_0 = i_0 (1-\alpha_s)F_{r,}$ (Cont):

The coefficient values of A, B, C, and D in the Eq. (3) (from Thomas C. Grenfell,1979)

Ice Type	*Cloudiness*	*A*	*B*	*C*	*D*	*Error*
Blue ice **0.8m >= h_i >=0.02m**	**Clear** **Cloudy**	**0.1925** **0.1553**	**12.96** **12.84**	**0.515** **0.755**	**1.227** **1.081**	**< 4%** **< 2%**
White ice **0.8m >= h_i >= 0.02m**	**Clear** **Cloudy**	**0.3894** **0.3456**	**12.39** **10.30**	**0.350** **0.590**	**1.578** **1.315**	**< 4%** **< 2.5%**
Dry packed snow over blue ice **0.4m >= h_s >= 0.01m** **0.8m <= h_i >= 0.01m**	**Clear** **Cloudy**	$A = 0.2257 \exp(-16.73h_s) + 0.4174 \exp(-43.89h_s)$ $B = 0.7280 \exp(-0.1862\ h_s) + 0.3532 \exp(-13.04h_s)$ $C = 0.1561 \exp(-92.79h_s)$ $D = [0.06 + 0.0995 \exp(-94.20h_s)]^{-1}$ $A = 0.980 \exp(-17.81h_s)$ $B = 0.6945 \exp(-0.1048h_s) + 0.303 \exp(-54.92h_s^{1.42})$ $C = D = 0.0$				**< 6%** **< 6%**

Ice Thickness and Age Algorithm Description

Surface Downward Solar Radiation Parameterizations = F_r :

Bennett (1982) scheme for the Arctic under clear sky condition:

$$F_r^{clr} = 0.72\, S_0\, \mu \qquad (4)$$

where S_0 is solar constant, and μ is cosine of solar zenith angle. This one is recommended for its simplicity and acceptable accuracy.

Bennett (1982) scheme for Arctic sea ice under cloudy sky condition:

$$F_r^{all} = F_r^{clr}\,(1 - 0.52\, c) \qquad (5)$$

This one is recommended for its simplicity and acceptable accuracy for this study.

Ice Thickness and Age Algorithm Description

Surface Upward Longwave Radiation = F_l^{up} :

$$F_l^{up} = \varepsilon \sigma T_s^4 \qquad (6)$$

- ε is longwave emissivity of the ice or snow surface, default is 0.988,
- $\sigma = 5.6696 \times 10^{-8}\ W\ m^{-2}\ deg^{-4}$ is the Stefan-Boltzman constant,
- T_s is surface skin temperature in K.

Ice Thickness and Age Algorithm Description

Surface Downward Longwave Radiation Parameterizations = F_l^{dn} :

Ohmura (1981) scheme for the temperature range *243-289K under clear sky condition*:

$$F_{l,clr}^{dn} = \sigma T_a^4 (8.733 * 10^{-3} T_a^{0.788}) \qquad (7)$$

where *σ is Stefan-Boltzman constant,* T_a is surface air temperature. This one is recommended for the simplicity and acceptable accuracy in this work.

Jacobs (1978) scheme for Arctic summer and winter under cloudy sky condition:

$$F_l^{dn} = F_{l,clr}^{dn} (1 + 0.26 \cdot c) \qquad (8)$$

where *c* is fractional cloud cover. This one is recommended for the simplicity and acceptable accuracy in this work.

Ice Thickness and Age Algorithm Description

Surface Turbulent Sensible Heat Flux = F_s :

$$F_s = \rho_a c_p C_s u (T_a - T_s) \qquad (9)$$

- ρ_a is the air density (*1.275* kg·m^{-3}),
- c_p is the specific heat of air (*1004* J·Kg^{-1}·K^{-1}),
- C_s is the bulk transfer coefficients for heat and evaporation,
- u is surface wind speed,
- T_a is near surface air temperature at *2* m above the surface,
- T_s is surface skin temperature.

Ice Thickness and Age Algorithm Description

Surface Turbulent Latent Heat Flux = F_e :

$$F_e = \rho_a L C_e u (w_a - w_{sa}) \qquad (10)$$

- ρ_a is air density (*1.275* kg·m^{-3}),
- L is latent heat of vaporization (*2.5*·10^{6} J·Kg^{-1}),
- C_e is the bulk transfer coefficients for evaporation,
- u is surface wind speed,
- w_a is surface mixing ratio,
- w_{sa} is surface saturation mixing ratio.

Ice Thickness and Age Algorithm Description

Ice Slab Conductive Heat Flux = F_c :

$$F_c = \gamma\,(T_f - T_s) \qquad (11)$$

- $\gamma = (k_i\,k_s) / (k_s\,h_i + k_i\,h_s)$, h_s is snow depth, and h_i is ice thickness, k_s is the conductivity of snow, k_i is the conductivity of ice,
- T_f is water freezing temperature,
- T_s is ice/snow surface skin temperature in the unit of degree Celsius.

Ice Thickness and Age Algorithm Description

Relationship between Snow Depth and Ice Thickness

Doronin (1971) used the following relationship to estimate snow depth in terms of ice thickness, which was also used in Yu's paper (1996):

$$h_s = 0, \qquad \text{for } h_i < 5 \text{ cm};$$

$$h_s = 0.05 \cdot h_i, \qquad \text{for } 5 \text{ cm} \le h_i \le 20 \text{ cm};$$

$$h_s = 0.1 \cdot h_i, \qquad \text{for } h_i > 20 \text{ cm}.$$

In reality, snow accumulation over the ice may not obey the relationship above, and most likely not be that simple. So we set snow depth as one input variable in the OTIM once climate data or measurements are available.

Ice Thickness and Age Algorithm Description

Relationship between Surface Skin Temperature and Ice Temperature

In general, we can obtain surface skin temperature T_s through satellite retrieval techniques more or less directly, but not T_i if the surface is covered with certain thick snow. Yu and Rothrock (1996) suggested that assuming T_i equal to T_s can cause 5% and 1% errors when ice is 5 cm thick and 100 cm thick, respectively. That assumption may hold valid when it is dark.

Relationship between Sea Ice Thickness and Sea Ice Salinity

Kovacs (1996) scheme:

$$S_i = 4.606 + 0.91603/h_i, \qquad \text{for } 0.10 \text{ m} \le h_i \le 2.0 \text{ m.}$$

Where S_i is sea ice salinity (ppt), and h_i is sea ice thickness.

Ice Thickness and Age Algorithm Description

Ice age determination strategy

- Generally speaking, older ice is thicker than younger ice. In essence, this assumption is valid as tested and verified by many other researchers (e.g., Tucker et al., 2001; Yu et al., 2004; Maslanik et al., 2007).
- There is an internationally accepted terminology for ice form and conditions, coordinated by the WMO.
- This terminology is used by the Canadian Ice Service as the basis for reporting ice conditions (refer to http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=1&Lang=eng), and adopted here with minor modifications for classifying ice age in terms of ice thickness.

Ice Thickness and Age Algorithm Description

Ice age determination – Lake ice age

- New: Recently formed ice *less than 5 cm* thick
- Thin: Ice of varying colors, *5-15 cm* thick
- Medium: A further development of floes or fast ice, *15-30 cm* thick
- Thick: Ice *30-70 cm* thick
- Very Thick: Floes or fast ice developed to *more than 70 cm* thickness

Ice Thickness and Age Algorithm Description

Ice age determination – Sea ice Age

- New: New ice *0~10 cm* thick. A general term for recently formed ice which includes frazil ice, grease ice, slush, shuga. And nilas. These types of ice include ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat, and a thin elastic crust of ice, easily bending on waves and swell and under pressure growing in a pattern of interlocking “fingers” (finger rafting).
- Grey Ice: Young ice *10-15 cm* thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.
- Grey-white Ice: Young ice *15-30 cm* thick. Under pressure it is more likely to ridge than to raft.
- Thin First-year Ice: First-year ice of not more than one winter's growth, *30-70 cm* thick.
- Medium First-year Ice: First-year, ice *70-120 cm* thick.
- Thick First-year Ice: First-year ice *120-180 cm* thick.
- Old Ice: Sea ice which has survived at least one summer's melt. Generally *more than 180 cm* thick. May be subdivided into second-year ice and multi-year ice.
    - Second-year Ice: Old ice which has survived only one summer's melt.
    - Multi-year Ice: Old ice which has survived at least two summer's melt.

$F_c = \frac{k_0 k_s}{k_s h_i + k_0 h_s}(T_f - T_s)$

Ice Thickness and Age Algorithm Processing Details

- Direct Solution from Conductive Heat Flux
  - » Fresh Water Ice

    For fresh water or lake ice, S_w=0, S_i=0, T_f=273.16K, k_i=k_0, therefore it is easy to reorganize equation (1) into the following form and get analytical solution for ice thickness h_i :

$$F_c = \frac{k_0 k_s}{k_s h_i + k_0 h_s}(T_f - T_s) \longrightarrow h_i = \frac{k_0}{F_c} \cdot (T_f - T_s) - \frac{k_0}{k_s} \cdot h_s$$

Ice Thickness and Age Algorithm Processing Details

- Direct Solution from Conductive Heat Flux
  - » Sea Ice

$$k_i = \frac{(k_0 T_i - T_0 k_0 + \beta S_0)h_i + \beta S_1}{(T_i - T_0)h_i}$$

where S_0=4.606, S_1=0.91603, and T_0=273.15.

Let $T_i - T_0 = u$, $T_f - T_s = v$, $F_c = f$, then from the Eq. (27) and (30) we have

$$f = \frac{k_i k_s}{k_s h_i + k_i h_s} \cdot v$$

and let $a = f k_i u$, $b = (k_0 u + \beta S_0)(f h_s - k_s v)$, $c = \beta S_1$, $h = h_i$, we have ice thickness monadic quadratic equation as $ah^2 + bh + c = 0$, therefore when $b^2 - 4ac \geq 0$, two real solutions exist as

$$h_1 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}, \text{ and } h_2 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

When $b^2 - 4ac = 0$, $h_1 = h_2$; and when $b^2 - 4ac < 0$, no real solution for ice thickness.

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness

The OTIM can be solved for ice thickness analytically or numerically in terms of input options and variable status as described in the following subsections. First let's rewrite the Eq. (1) into the following form

$$(1-\alpha)(1-i)F_r + F_c + F = 0$$

where $F = -F_l^{up} + F_l^{dn} + F_s + F_e - F_a$, $\alpha = \alpha_s$.

$\alpha = 1 - A_s e^{-B_s h} - C_s e^{-D_s h}$, where h is ice/snow thickness, and A_s, B_s, C_s, D_s are *coefficients* to be determined from Table 2.

$i = A_i e^{-B_i h} + C_i e^{-D_i h}$, where i is ice *transmittance*, and A_i, B_i, C_i, D_i are *coefficients* to be determined from Table 3.

$F_c = r(T_f - T_s)$, let $T_f - T_s = T_r$, $T_i - T_0 = T_k$, $S_i = S_0 + S_1 h$, and $k_0 T_k + \beta S_0 = g$, we have

$$k_i = \frac{(k_0 T_k + \beta S_0)h + \beta S_1}{T_k h}, \quad r = \frac{k_s[(k_0 T_k + \beta S_0)h + \beta S_1]}{k_s(T_k h^2 + \beta S_1) + h_s(k_0 T_k + \beta S_0)h},$$

$$F_c = \frac{k_s T_r (gh + \beta S_1)}{k_s(T_k h^2 + \beta S_1) + h_s gh}.$$

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness
  - » Known Surface Albedo and Known Ice Transmittance

If the values of ice/snow surface albedo α and the ice slab transmittance i are both known, let

$(1-\alpha)(1-i)F_r + F = F_1$, then we have $F_1 + F_c = 0$, so $F_1 + \dfrac{k_s T_r (gh + \beta S_1)}{k_s (T_k h^2 + \beta S_1) + h_s gh} = 0$

$F_1 k_s T_k h^2 + (F_1 h_s g + k_s T_r g)h + F_1 \beta S_1 + k_s \beta S_1 T_r = 0$, let $a = F_1 k_s T_k$, $b = F_1 h_s g + k_s T_r g$, and

$c = F_1 \beta S_1 + k_s \beta S_1 T_r$, then $h = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, when $b^2 - 4ac \ge 0$, there are real solutions.

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness
  - » Known Surface Albedo and Unknown Ice Transmittance

If the value of ice surface albedo α is known or snow is present over the ice with known depth, but the ice slab transmittance i is unknown, let $(1-\alpha)F_r = F_{ra}$, then $(1-i)F_{ra} + F_c + F = 0$.
Let $F + F_{ra} = F_2$, then $F_c - iF_{ra} + F_2 = 0$, so we have

$$\frac{k_s T_r (gh + \beta S_1)}{k_s (T_k h^2 + \beta S_1) + h_s gh} - F_{ra}(A_i e^{-B_i h} + C_i e^{-D_i h}) + F_2 = 0,$$ after a series of derivation, we finaly have

$$F_{ra}(A_i e^{-B_i h} + C_i e^{-D_i h})(k_s T_k h^2 + h_s gh + k_2) - [F_2 k_s T_k h^2 + (gk_s T_r + F_2 g_2)h + T_r k_2 + F_2 k_2] = 0,$$

where $k_2 = k_s \beta S_1$, $g_2 = h_s g$. There is no analytical solution for this nonlinear equation, numerical approach must be applied to solve it for the ice thickness h.

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness
  - » Unknown Surface Albedo and Known Ice Transmittance

If the value of ice surface albedo α is unknown, but the ice slab transmittance i is known, let $(1-i)F_r = F_{ri}$, then $(1-\alpha)F_{ri} + F_c + F = 0$. We know $\alpha = 1-(A_s e^{-B_s h} + C_s e^{-D_s h})$, therefore $F_{ri}(A_s e^{-B_s h} + C_s e^{-D_s h}) + F_c + F = 0$, and $F_c = \dfrac{k_s T_r(gh + \beta S_1)}{k_s(T_k h^2 + \beta S_1) + h_s gh}$. Finally, we have

$$F_{ri}(A_s e^{-B_s h} + C_s e^{-D_s h})(k_s T_k h^2 + g_2 h + k_2) + F k_s T_k h^2 + (k_s T_r g + F g_2)h + (1+F)k_2 = 0,$$

where $k_2 = k_s \beta S_1$, $g_2 = h_s g$. There is no analytical solution for this nonlinear equation, numerical approach must be applied to solve it for the ice thickness h.

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness
  - » Unknown Surface Albedo and Unknown Ice Transmittance

If the values of both ice surface albedo α and ice slab transmittance i are known, we have $(1-\alpha)(1-i)F_r + F_c + F = 0$, $\alpha = 1-(A_s e^{-B_s h} + C_s e^{-D_s h})$, $i = 1-(A_i e^{-B_i h} + C_i e^{-D_i h})$,

$F_c = \dfrac{k_s T_r (gh + \beta S_1)}{k_s (T_k h^2 + \beta S_1) + h_s gh}$, and $F = -F_l^{up} + F_l^{dn} + F_s + F_e - F_a$. After a series of derivation,

$$F_r (A_s e^{-B_s h} + C_s e^{-D_s h})(1 - A_i e^{-B_i h} - C_i e^{-D_i h})(k_s T_k h^2 + g_2 h + k_2) + F k_s T_k h^2 + (k_s T_r g + F g_2) h + (1+F)k_2 = 0,$$

where $k_2 = k_s \beta S_1$, $g_2 = h_s g$. There is no analytical solution for this nonlinear equation, numerical approach must be applied to solve it for the ice thickness h.

Ice Thickness and Age Algorithm Processing Details

- Solving the OTIM for Ice Thickness
  - » Nighttime and Hybrid Solution

    For hybrid method, The term F_a=(1-α)(1-i)F_r + F_a is estimated by regression with surface and near surface atmospheric conditions.

At night, there is no need to consider solar radiation in the OTIM, so basically we can set $F_r = 0$, therefore from $(1-\alpha)(1-i)F_r + F_c + F = 0$, we have $F_c + F = 0$, and we know $F_c = \frac{k_s T_r (gh + \beta S_1)}{k_s(T_k h^2 + \beta S_1) + h_s gh}$, so $\frac{k_s T_r (gh + \beta S_1)}{k_s(T_k h^2 + \beta S_1) + h_s gh} + F = 0$. Finally we have

$$Fk_s T_k h^2 + (k_s T_r g + F g_2)h + (1+F)k_2 = 0$$

Let $a = Fk_s T_k$, $b = k_s T_r g + F g_2$, $c = (1+F)k_2$, then we have $ah^2 + bh + c = 0$, so the solution for the monadic quadratic equation is $h = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, and when $b^2 - 4ac \geq 0$, there are real solutions.

Ice Thickness and Age Physical Description Summary

- The OTIM is based on the surface energy balance at thermo-equilibrium state that contains all components of the surface energy budget to estimate sea and lake ice thickness, and then based on the ice thickness, ice age is classified into new/fresh, grey, grey-white, first year thin, first year medium, first year thick, and multi-year ice.

Ice Thickness and Age Algorithm Practical Considerations

- **Numerical Computation Considerations**
  - » The OTIM is implemented sequentially. Because ice thickness and age retrievals relies on the values of the ancillary data flags, the ancillary data flags need to be computed first.

- **Programming/Procedural Considerations**
  - » Needs spatial information for accurate pixel geographic location and land mask information for identifying sea, lake, river, and et al.
  - » Needs temporal information for each pixel regarding the solar radiation in case daytime algorithm is used.
  - » The algorithm operates pixel by pixel.

Ice Thickness and Age Algorithm Practical Considerations

- **Quality Assessment and Diagnostics**
  - » Monitor the percentage of pixels retrieved for ice thickness, and check the value uniformity over the small and smooth area without cracks and leads.
  - » Check input ancillary data such surface skin temperature, air temperature, humidity, wind speed, and snow depth for all pixels of the OTIM. See how those ancillary variables changes affect ice thickness estimation.
  - » Periodically image the individual test results to look for artifacts or non-physical behaviors.
  - » Maintain a close collaboration with the other teams using the OTIM in their product generation.

Ice Thickness and Age Algorithm Practical Considerations

- **Exception Handling**
  - » This includes checking the validity of input data before applying the OTIM and ice age algorithm.
  - » The OTIM does check for conditions where the OTIM can not be performed. These conditions include missing input variables values and unsolvable numerical solutions. In those cases, the appropriate flag is set to indicate that no ice thickness and age are produced for that pixel.
- **Algorithm Validation**
  - » Quasi-routine validation of the OTIM performance can be performed at several Canadian stations where the New Arctic Program of the Canadian Ice Service has been running since 2002.
  - » Other occasional field experiments and submarine cruise measurements can also been used for validation purpose.

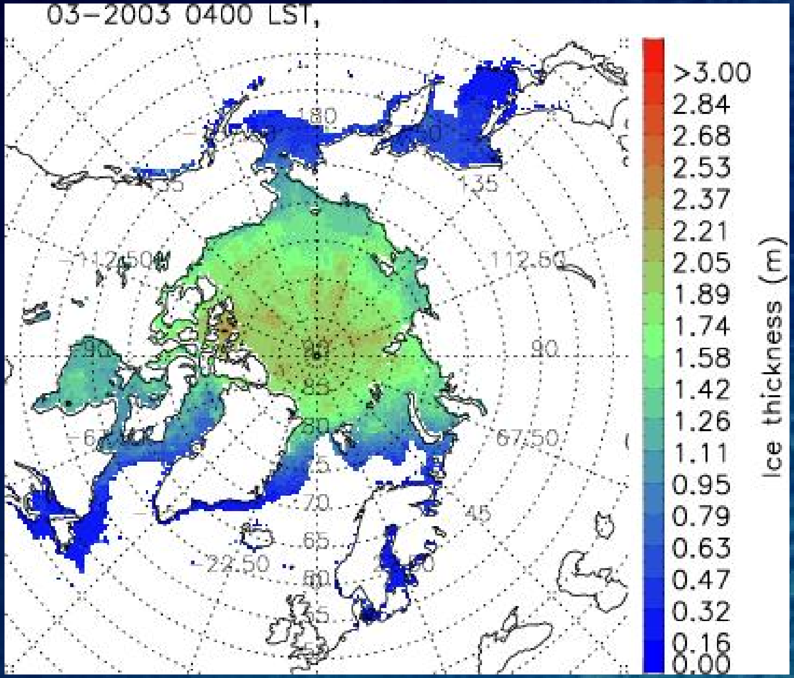
Ice Thickness and Age Algorithm Testing and Validation

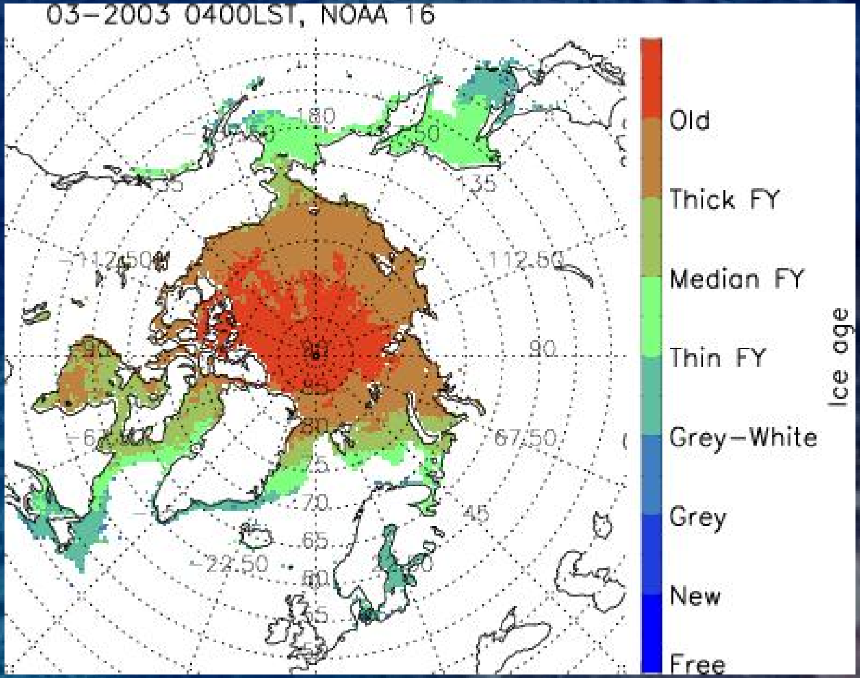
- **Advanced Very High Resolution Radiometer (AVHRR) Polar Pathfinder (APP) Extended (APP-x) Data Products**
  - » **APP-x**
    - – Cloud information, surface skin temperature, surface broadband albedo, and surface radiation fluxes.
  - » **NCAR/NCEP and NASA/MERRA**
    - – Atmospheric profile data including surface air temperature, surface air pressure, surface air humidity, and surface wind.
- **MODIS Data**
  - » Retrieved cloud mask, ice surface temperature, ice concentration as inputs.
- **VIIRS**
  - » Retrieved cloud mask, ice surface temperature, ice concentration as inputs.
- **SEVIRI Data**
  - » Retrieved cloud mask, ice surface temperature, ice concentration as inputs.
- **ICESat**
  - » Retrieved ice thickness
- **IceBridge**
  - » Retrieved ice thickness (will do)
- **Submarine Cruise Measurements**
  - » Submarine measured ice draft data.
- **Station Measurements**
  - » Station measured ice thickness.

Ice Thickness and Age Algorithm Testing and Validation

- APP-x Data

Ice Thickness **Ice Age**



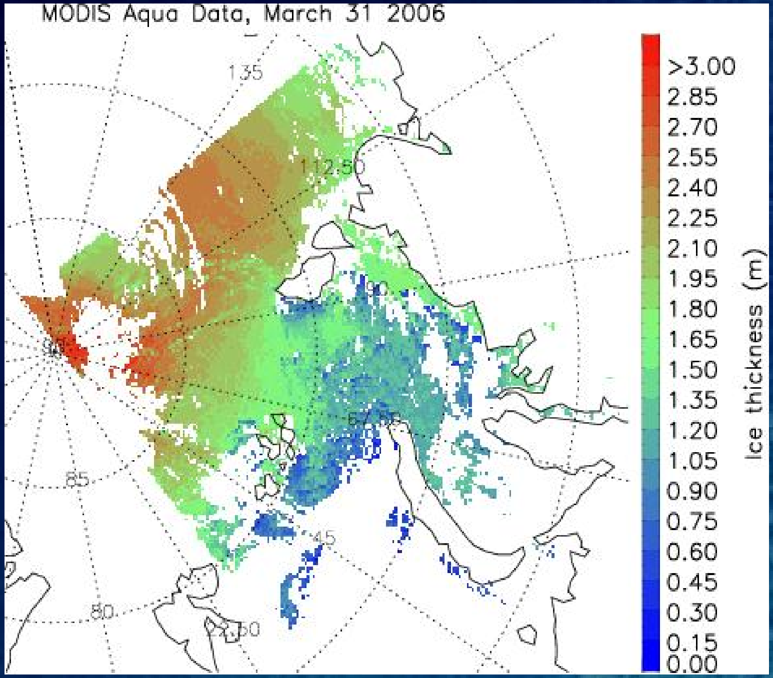


OTIM retrieved monthly mean ice thickness (left) and ice age (right) with APP-x data for March 2003 under all sky condition..

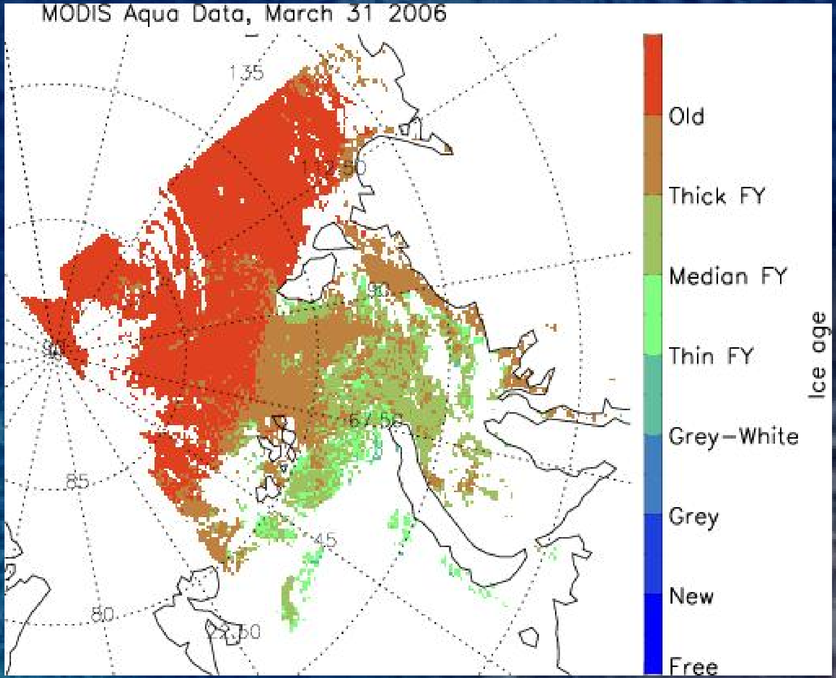
Ice Thickness and Age Algorithm Testing and Validation

- MODIS Aqua Data

Ice Thickness



Ice Age

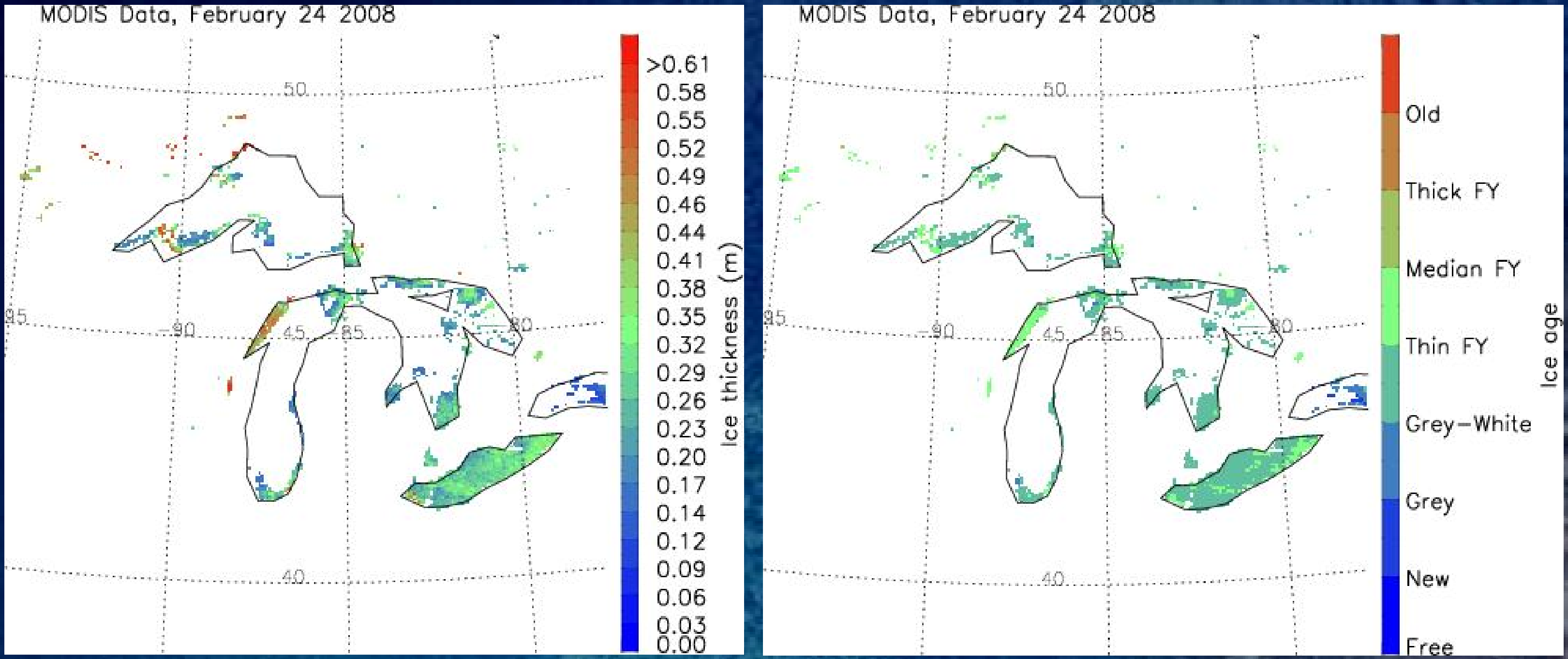


OTIM retrieved ice thickness (left) and ice age (right) with MODIS Aqua data on March 31, 2006 under clear sky condition.

Ice Thickness and Age Algorithm Testing and Validation

- MODIS Aqua Data

Ice Thickness **Ice Age**

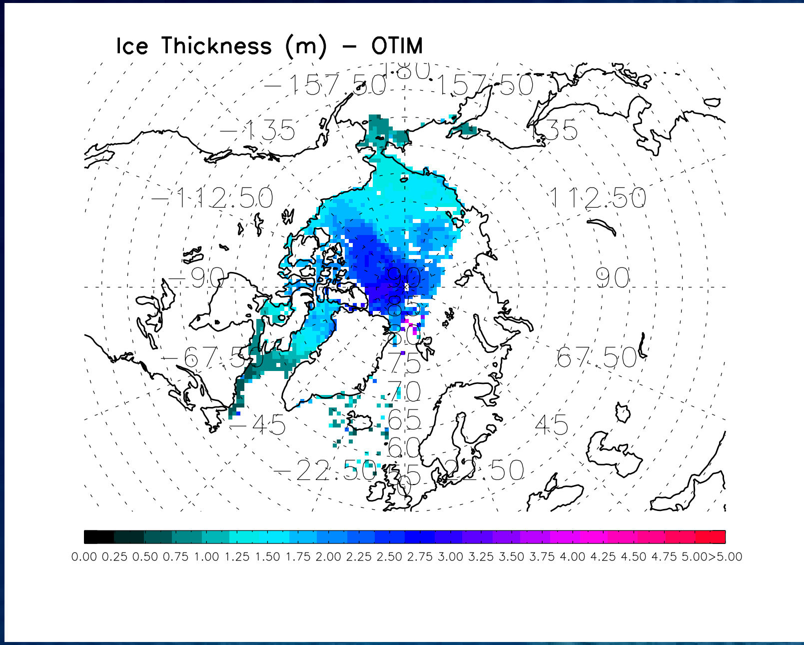


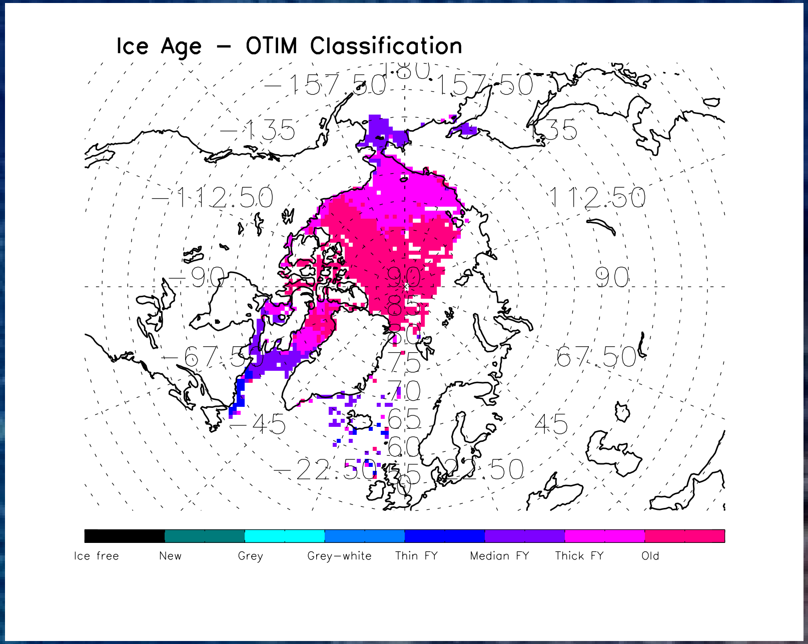
OTIM retrieved ice thickness (left) and ice age (right) with MODIS Aqua data on February 24, 2008 under clear sky condition.

Ice Thickness and Age Algorithm Testing and Validation

- VIIRS Data

Ice Thickness | **Ice Age**



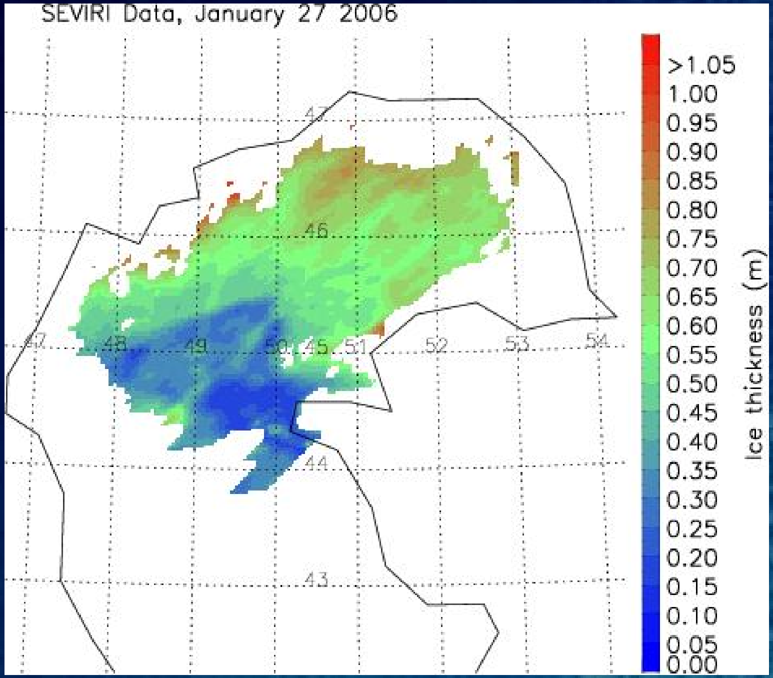


OTIM retrieved ice thickness (left) based on VIIRS ice surface temperature, and ice age (right) derived on March 4 ,2012 for the Arctic region.

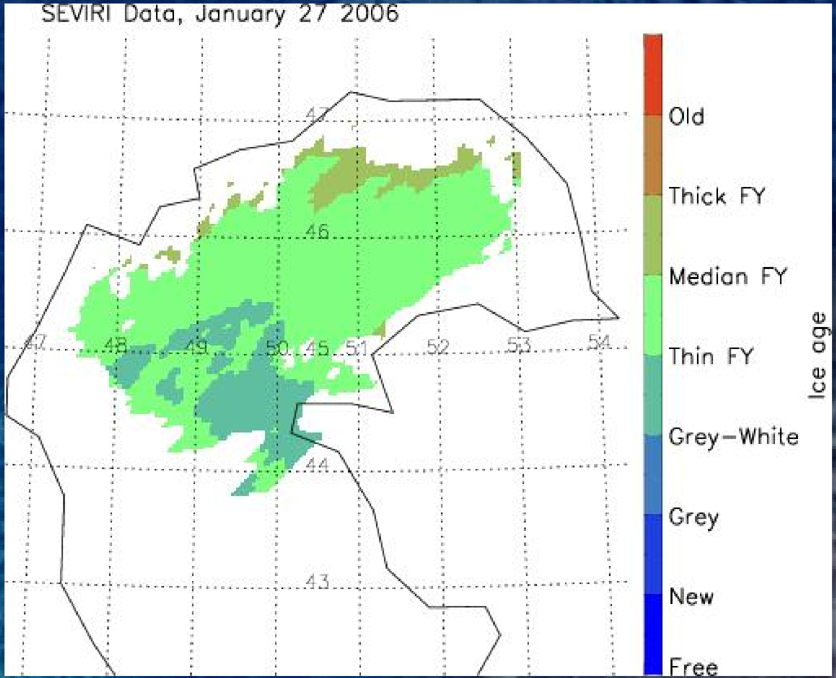
Ice Thickness and Age Algorithm Testing and Validation

- SEVIRI Data

Ice Thickness



Ice Age

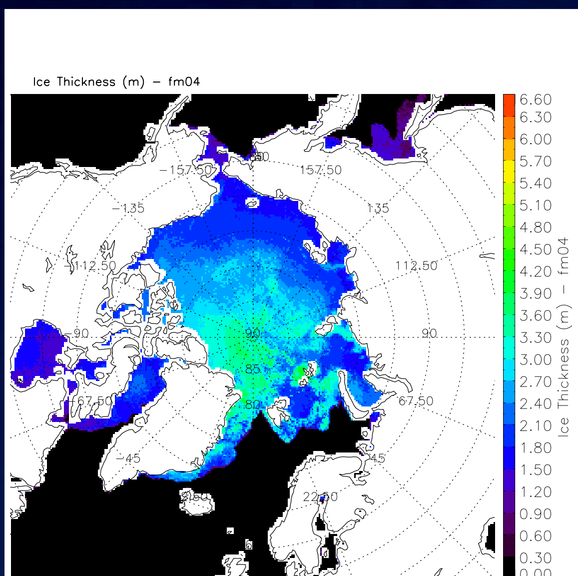


OTIM retrieved ice thickness (left) and ice age (right) with SEVIRI data on January 27, 2006 under clear sky condition.

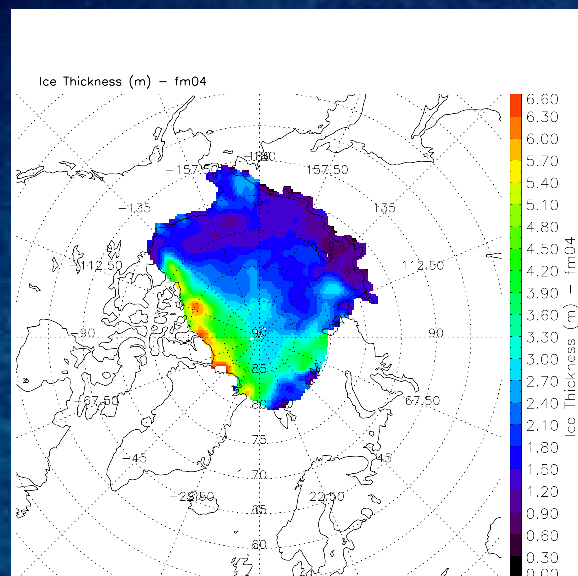
Ice Thickness and Age Algorithm Performance Estimate

- ICESat vs APPx in sea ice thickness

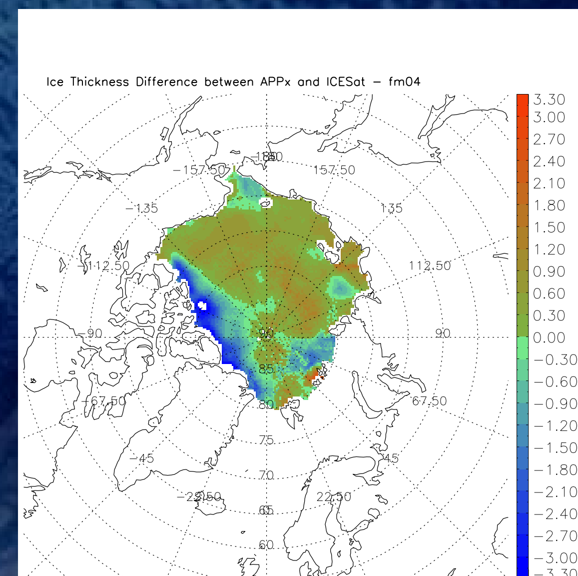
APPx



ICESat



APPx - ICESat



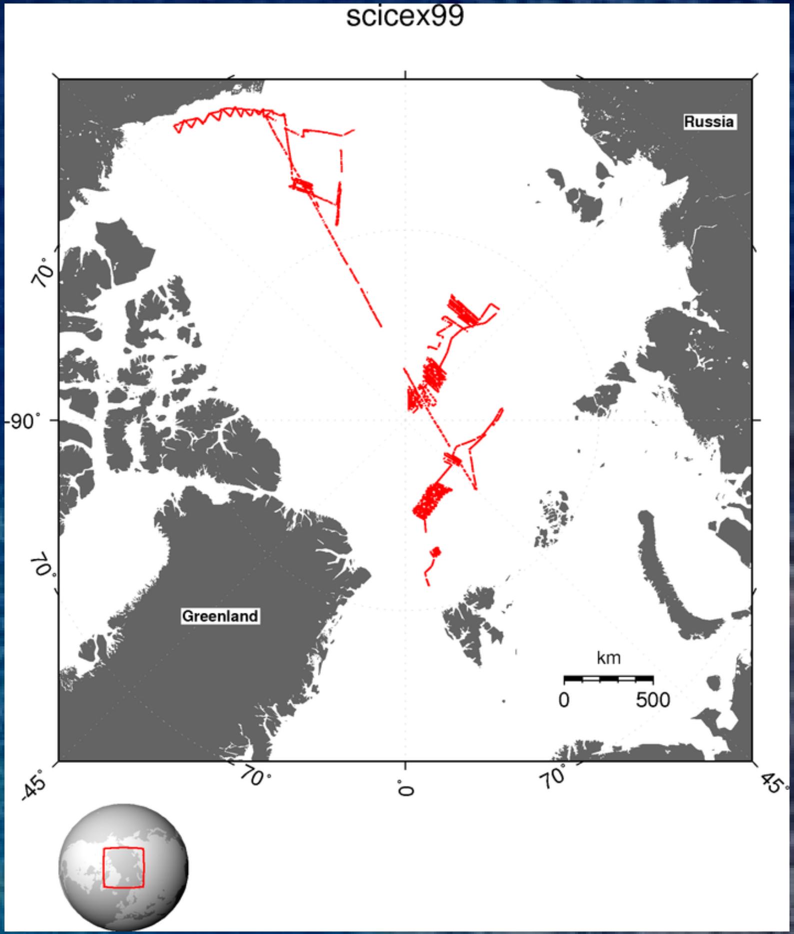
Comparisons between APP-x and ICESat in sea ice thickness for the periods of Feb 17-Mar 21, 2004 (FM04, above), Oct 13-Nov 08, 2004 (ON04, not shown), Sep 24-Nov 18, 2003 (ON03, not shown), and Feb 17-Mar 24, 2005 (FM05, not shown). Statistics of the comparisons are listed below, measurement unit in meter.

PERIOD	APPx Mean	ICESat Mean	Mean Bias	Mean Absolute Bias
ON03	*1.37256*	*2.14024*	*-0.767686*	*0.828870*
FM04	*2.49637*	*2.44960*	*0.0467678*	*0.689932*
ON04	*1.35478*	*2.18681*	*-0.832034*	*0.930355*
FM05	*2.53071*	*2.51933*	*0.0113749*	*0.634077*

Ice Thickness and Age Algorithm Performance Estimate

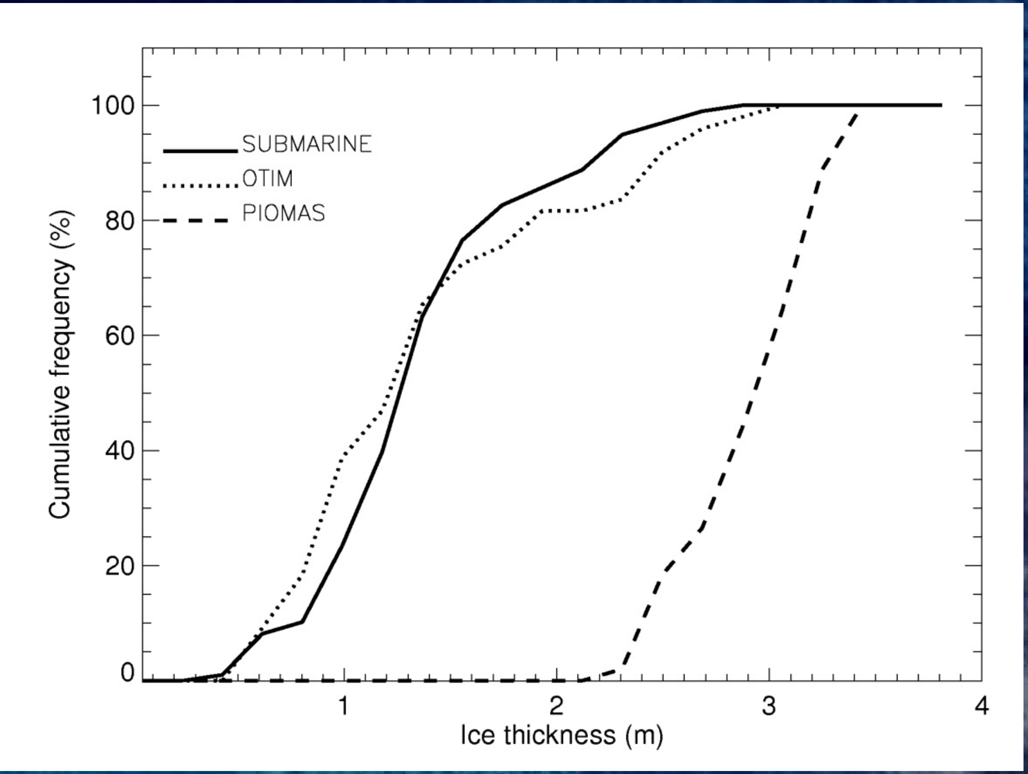
- Submarine Cruise Measurements

A program called Scientific Ice Expeditions (SCICEX) used U.S. Navy submarine for research. SCICEX data are not classified and do not have restrictions on reporting the precise location and date for the data; therefore the SCICEX ice draft data in this collection are reported with their date of acquisition, and position is reported to six decimal places, which make the SCICEX data suitable for scientific study. The U.S. Navy submarine track is shown on the right figure.



Ice Thickness and Age Algorithm Performance Estimate

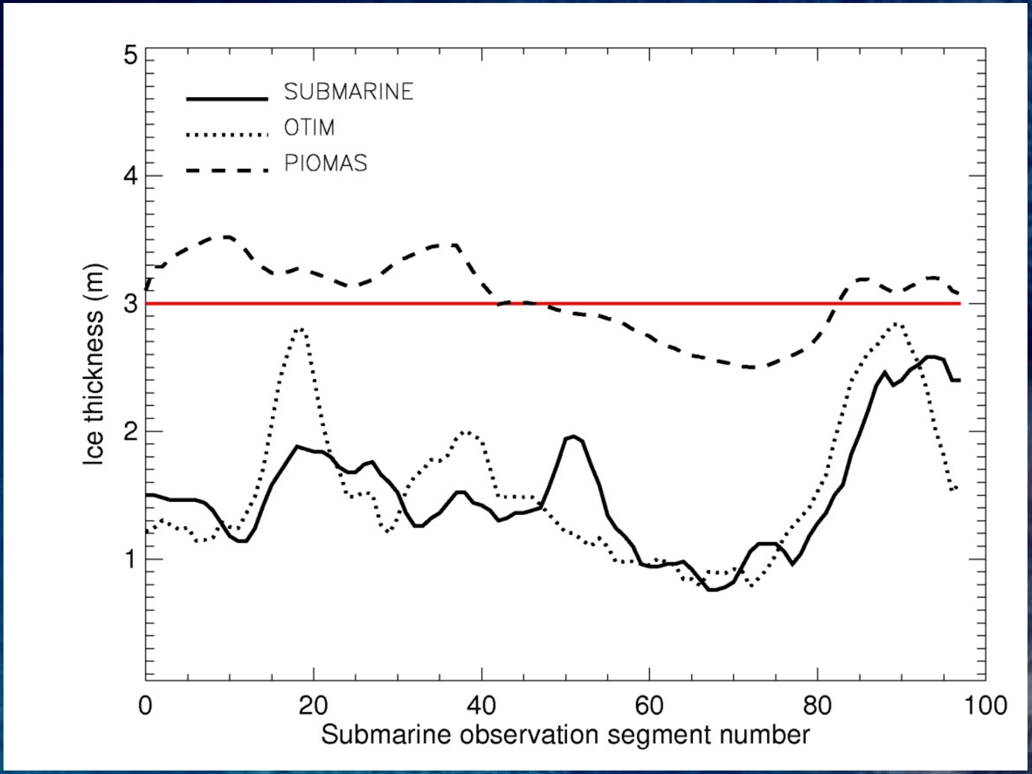
- Submarine Cruise Measurements



Comparisons of ice thickness cumulative distribution retrieved by OTIM with APP-x data, measured by submarine, and simulated by Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS) developed by Polar Science Center at University of Washington.

Ice Thickness and Age Algorithm Performance Estimate

- Submarine Cruise Measurements



Comparisons of ice thickness values retrieved by OTIM with APP-x data, measured by submarine, and simulated by PIOMAS alone the submarine track segments.

Ice Thickness and Age Algorithm Performance Estimate

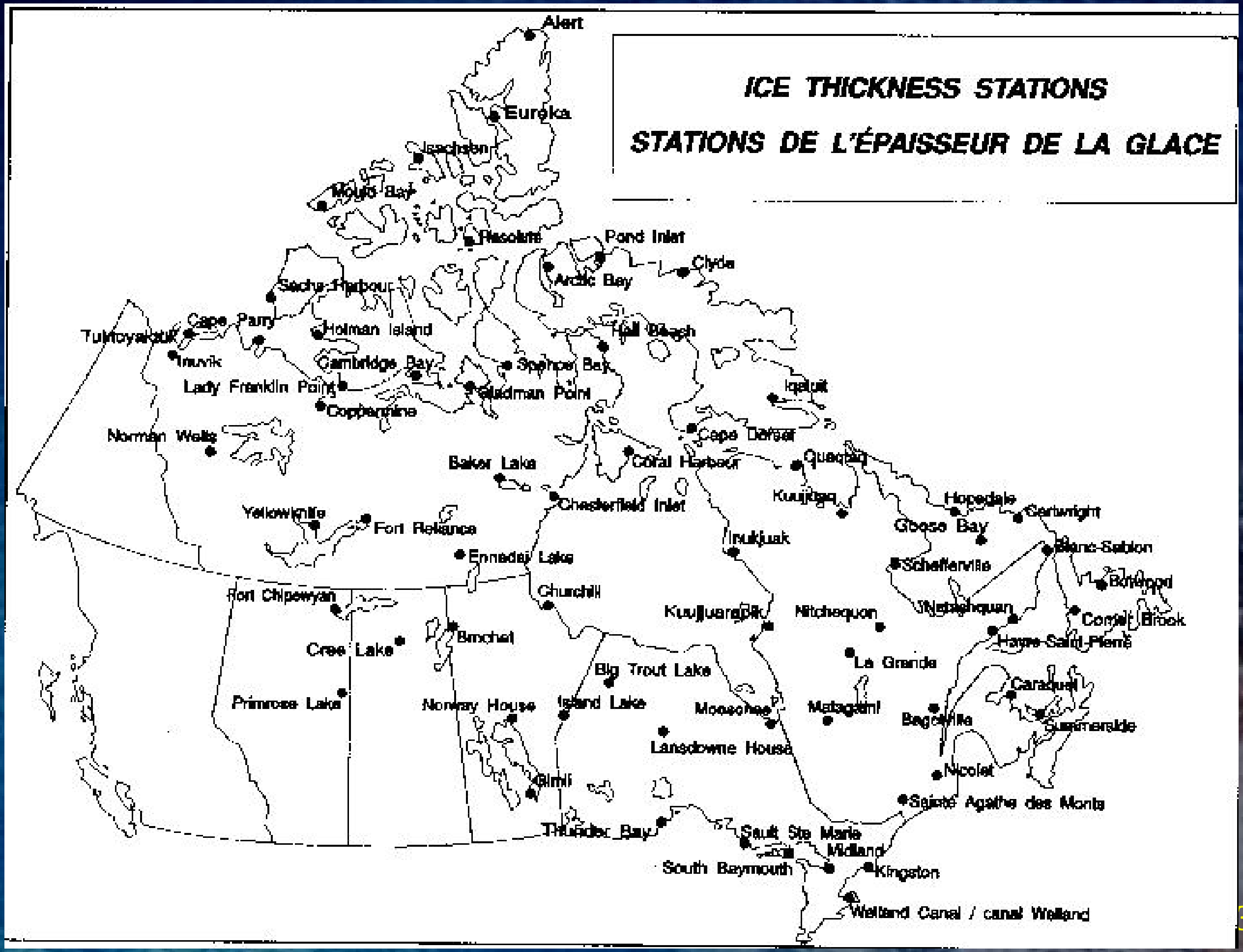
- OTIM vs Submarine

	OTIM	Submarine
Thickness Mean (m)	1.55	1.51
Bias Mean (m)	0.04	
Bias Standard Deviation	0.52	
OTIM Ice Age	Ice free water, new/fresh, nilas, grey, grey-white, first year thin, first year medium, first year thick, and multi-year ice.	
EDR Requirements	Distinguish between ice free, new/fresh ice, and all other ice.	

Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements

The Canadian Ice Service (CIS) maintains archived Ice Thickness and On-Ice Snow Depth Measurements for Canadian Stations back as far as 1947 for the first established stations in the Canadian Arctic (Eureka and Resolute). But, unfortunately, By the beginning of 2002 most stations from the original Ice Thickness program had stopped taking measurements.



Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements

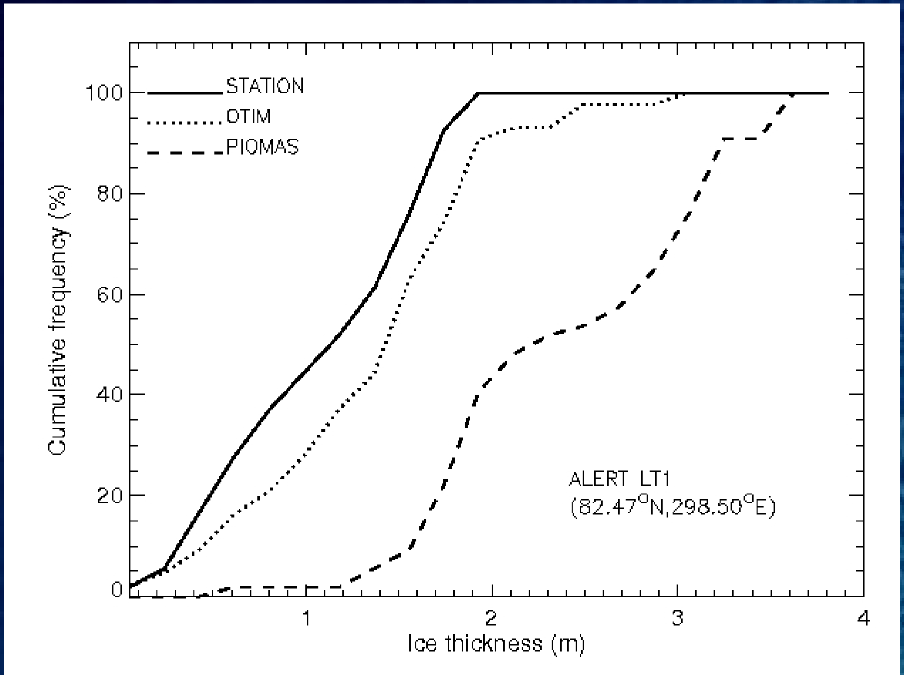
Fortunately, due to an increasing interest in updating this historical dataset to support climate change studies a new program was started in the fall of 2002, called New Arctic Program starting from 2002. Several stations in the Canadian Arctic were re-opened and started taking measurements. These New Arctic Program stations are listed in the Table on the right.

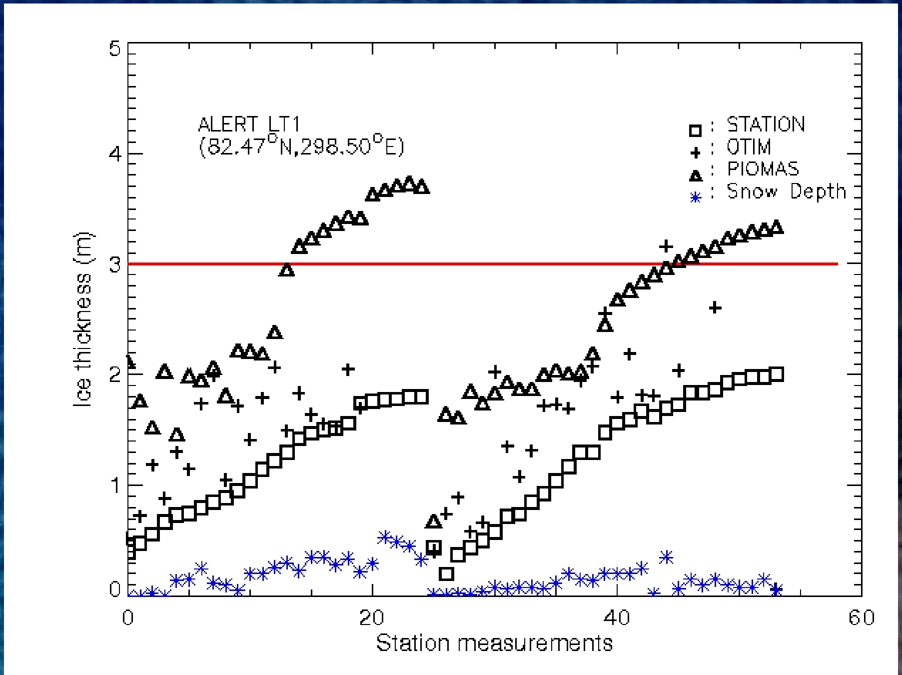
Station ID	Station Name	Start Date	LAT	LON
LT1	ALERT LT1	10/16/2002	82.466667	-61.5
YLT	ALERT YLT	10/16/2002	82.500275	-61.716667
YBK	BAKER LAKE YBK	11/27/2002	64.316666	-95.966667
YCB	CAMBRIDGE BAY YCB	12/07/2002	69.10833	-104.95
YZS	CORAL HARBOUR YZS	11/15/2002	64.119446	-82.741669
WEU	EUREKA WEU	10/11/2002	79.986115	-84.099998
YUX	HALL BEACH YUX	11/10/2002	68.765274	-80.791664
YEV	INUVIK YEV	11/29/2002	68.35833	-132.26138
YFB	IQALUIT YFB	01/04/2003	63.727779	-67.48333
YRB	RESOLUTE YRB	12/13/2002	74.676941	-93.131668
YZF	YELLOWKNIFE YZF	11/29/2002	62.465556	-114.36556

Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements

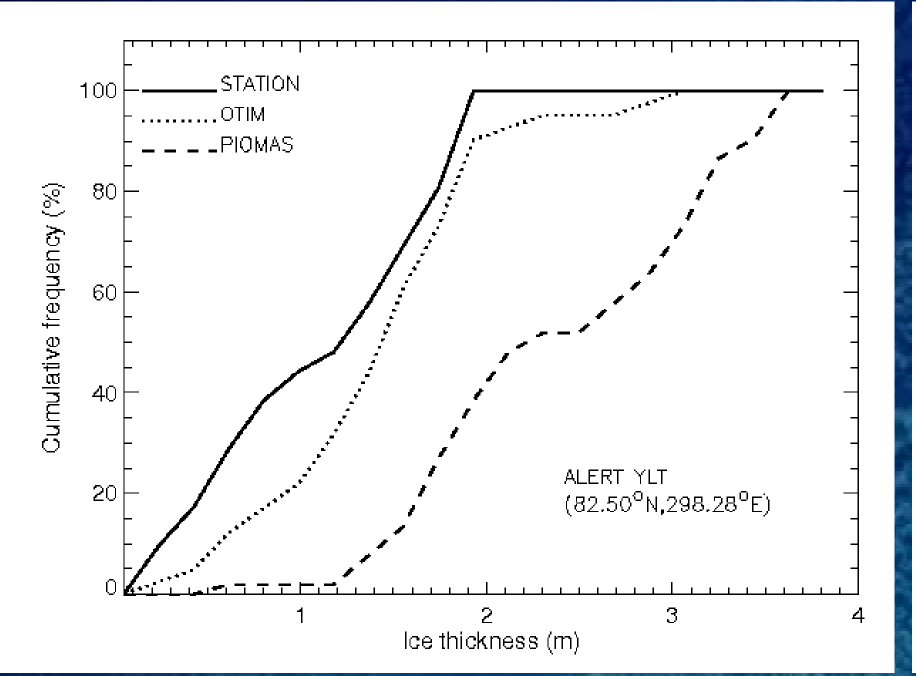
  »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Alert LT1

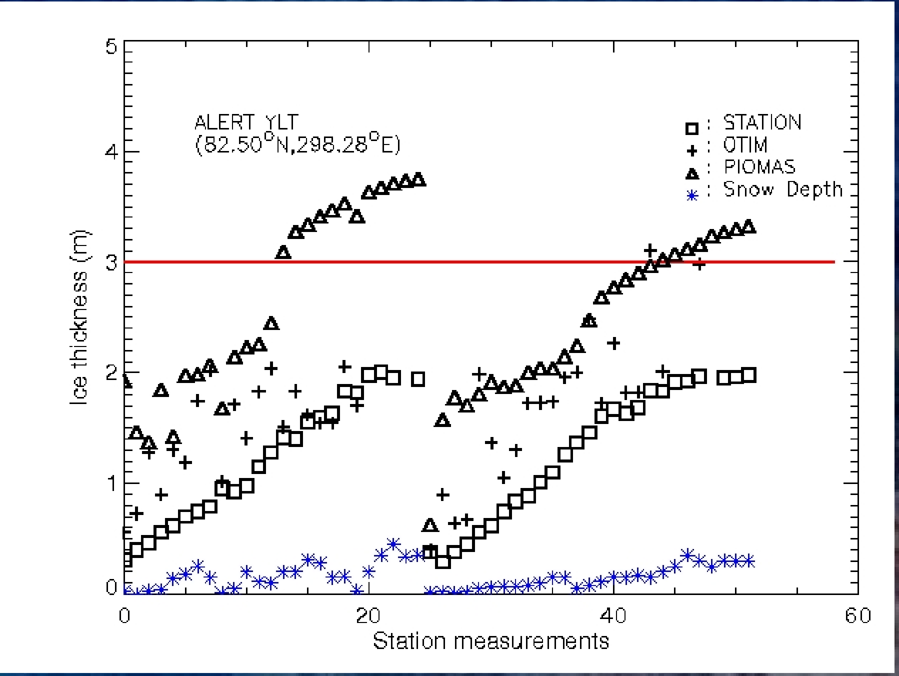




Ice Thickness and Age Algorithm Performance Estimate

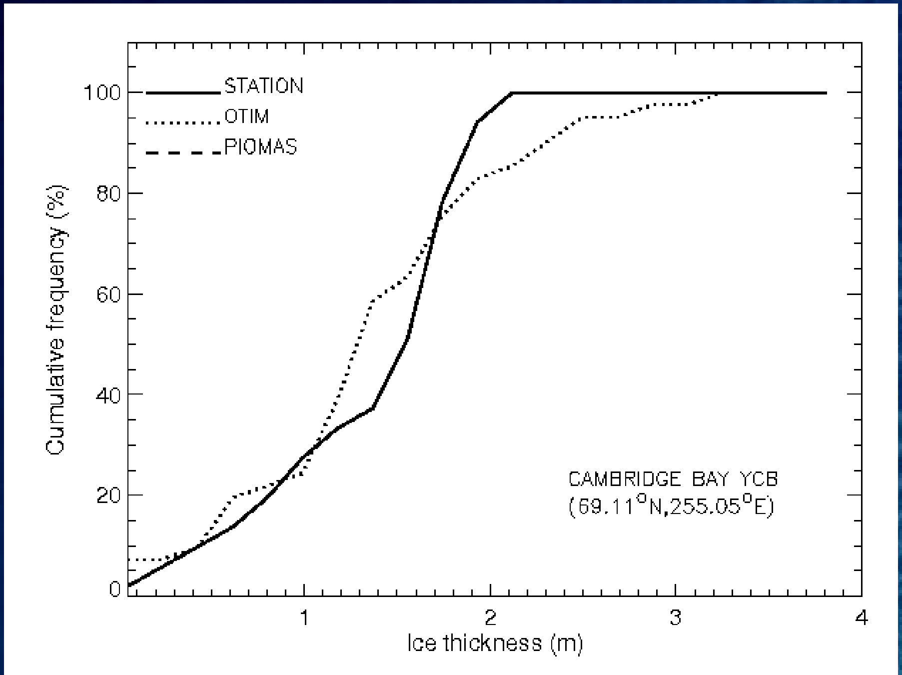
- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Alert YLT

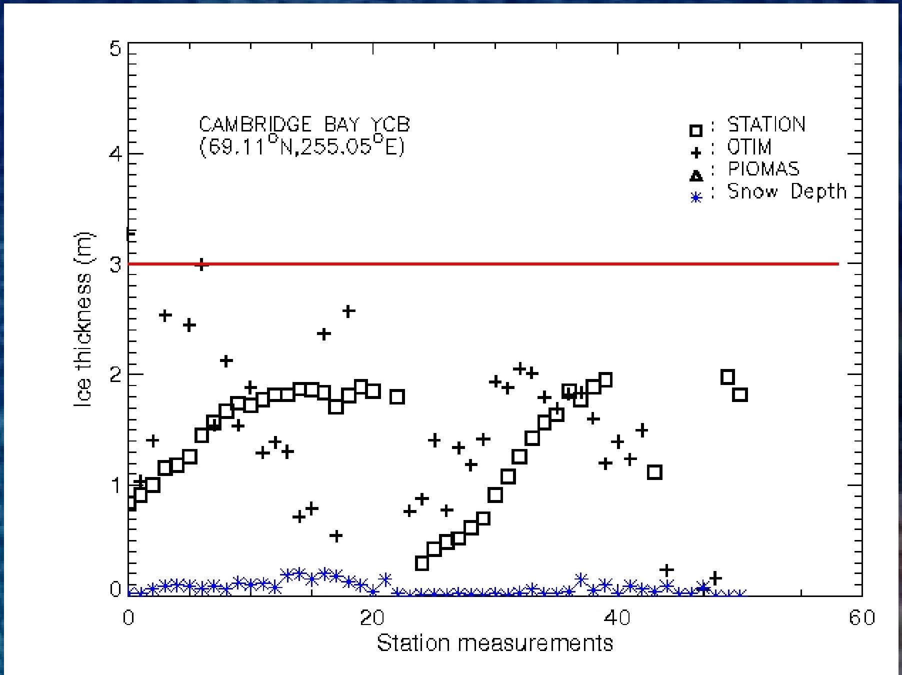




Ice Thickness and Age Algorithm Performance Estimate

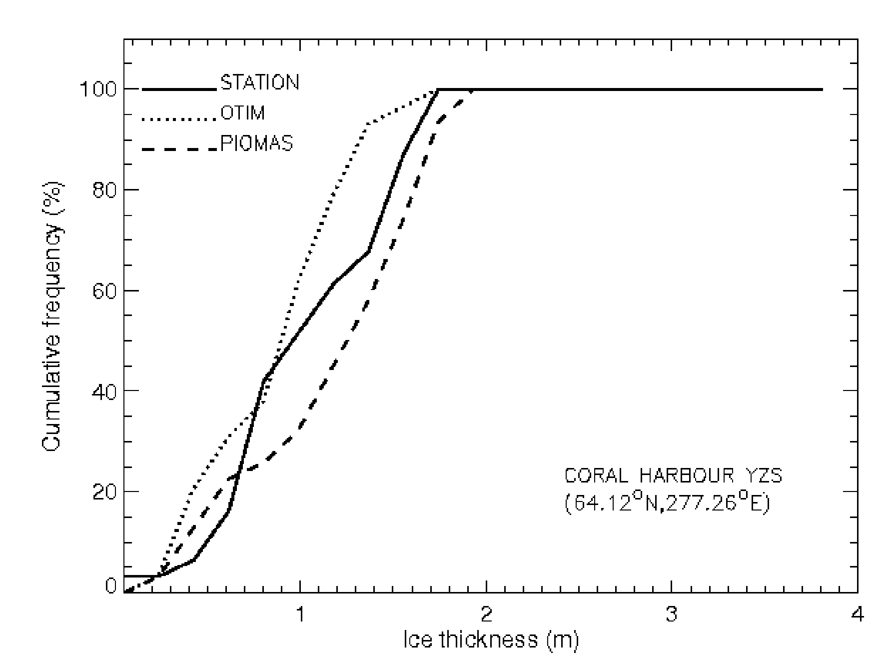
- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Cambridge Bay YCB

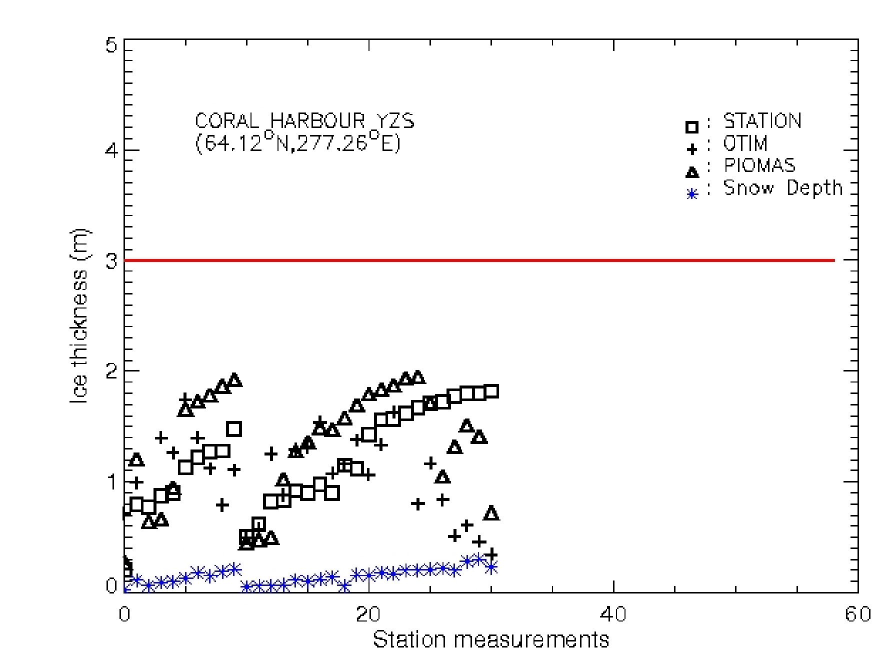




Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Coral Harbour YZS

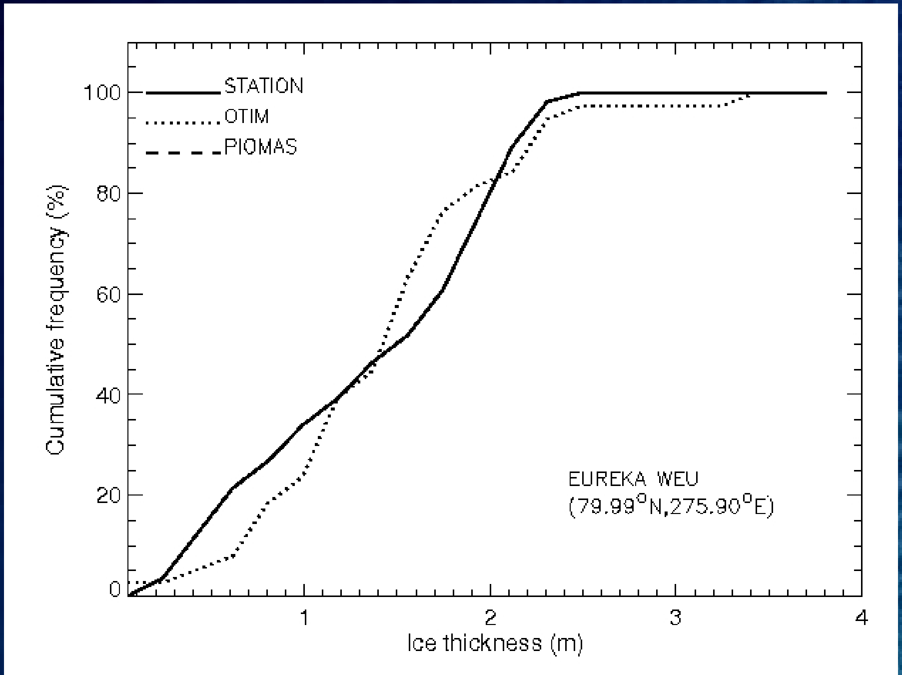


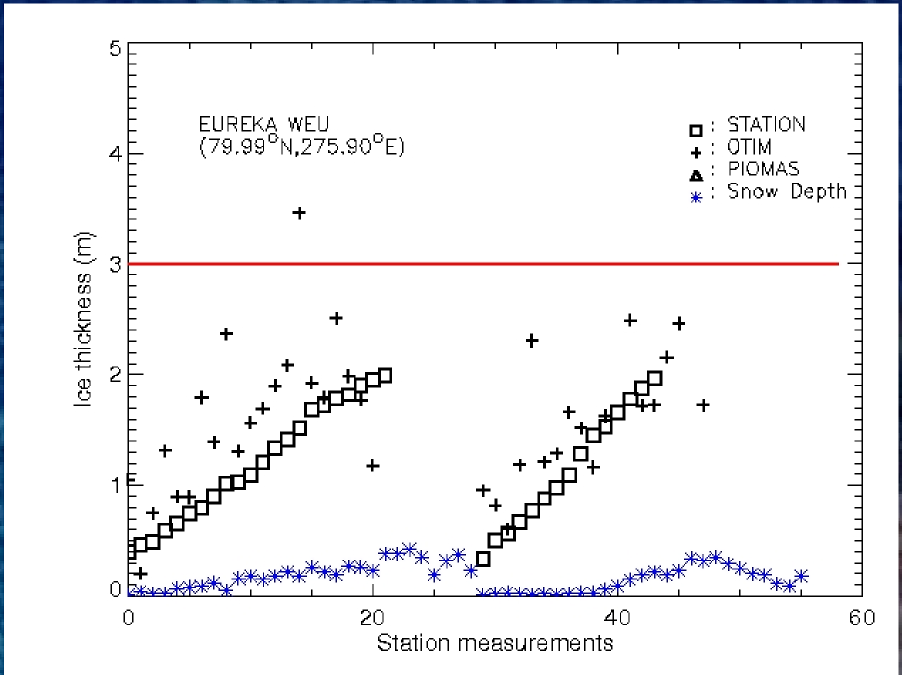


Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements

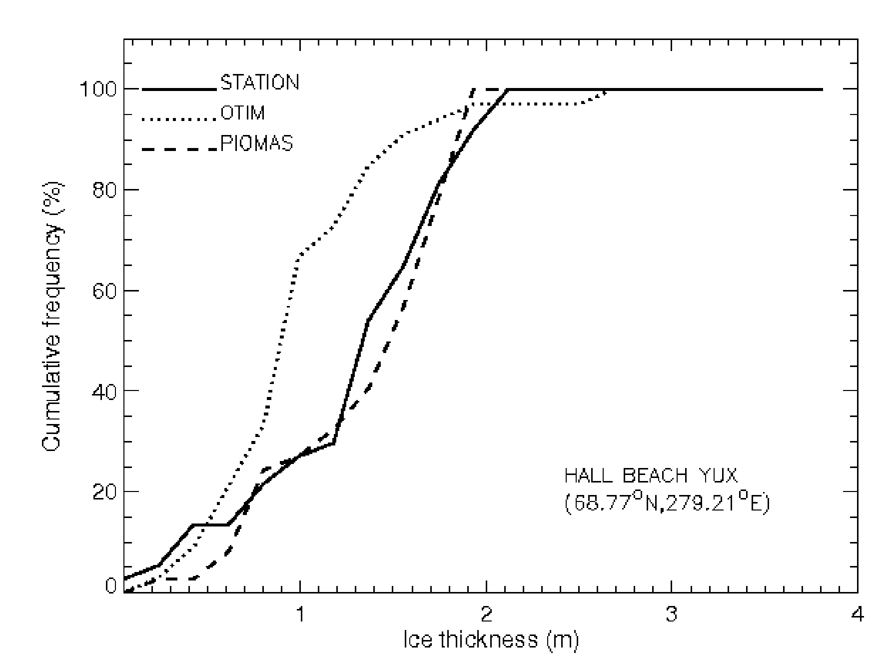
  »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Eureka WEU

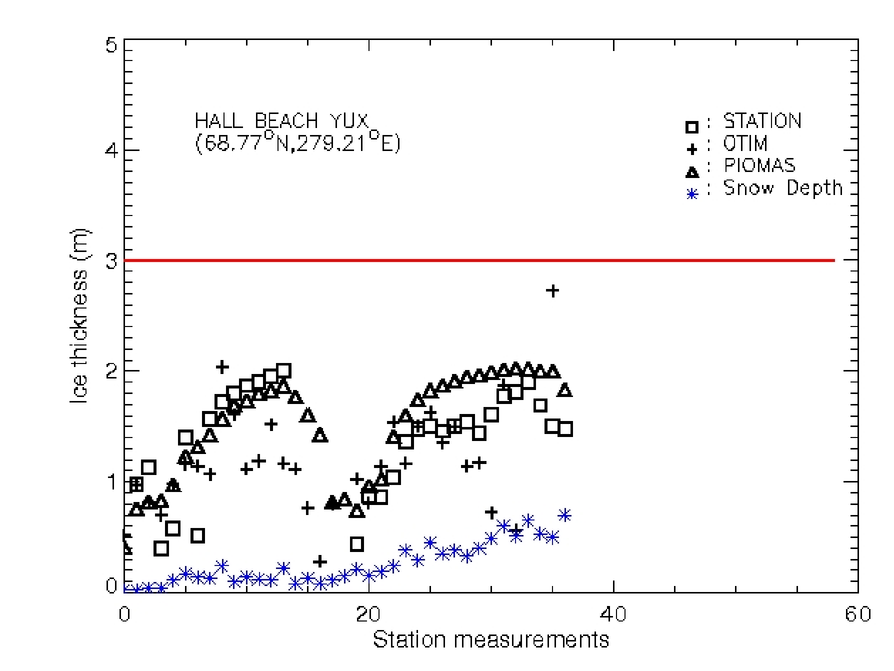




Ice Thickness and Age Algorithm Performance Estimate

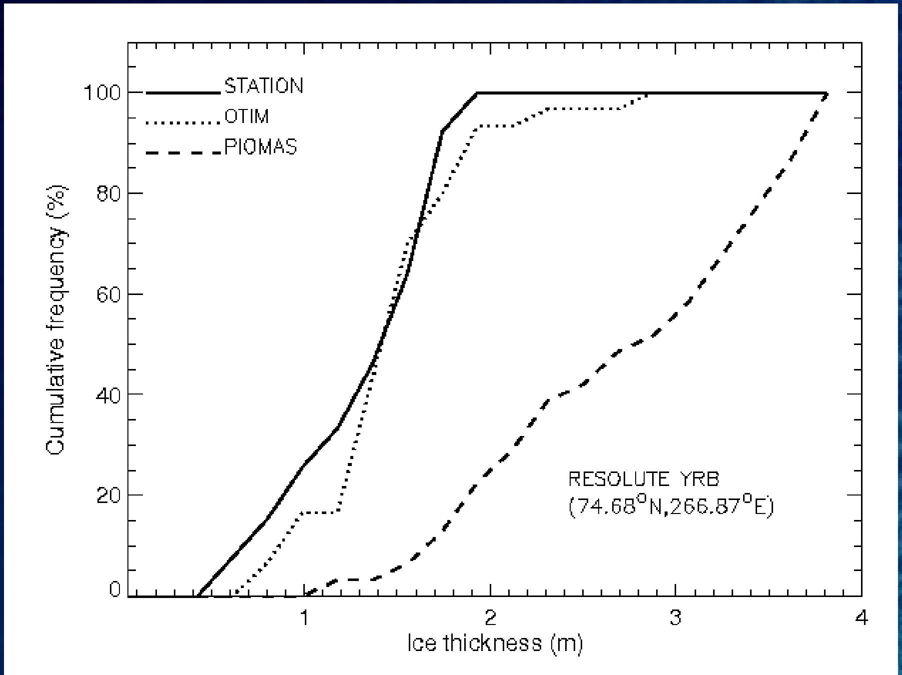
- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Hall Beach YUK

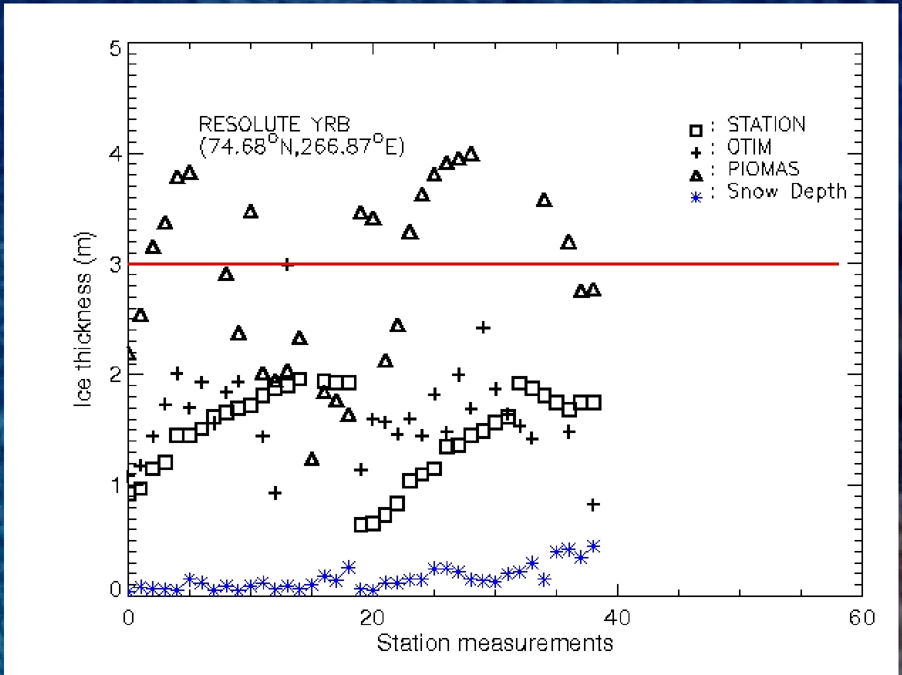




Ice Thickness and Age Algorithm Performance Estimate

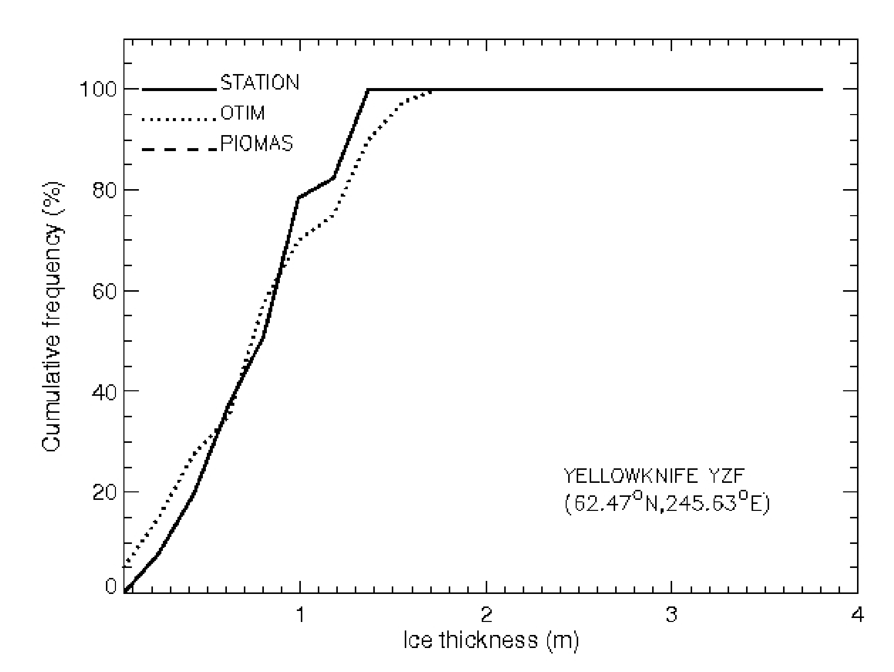
- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Resolute YRB

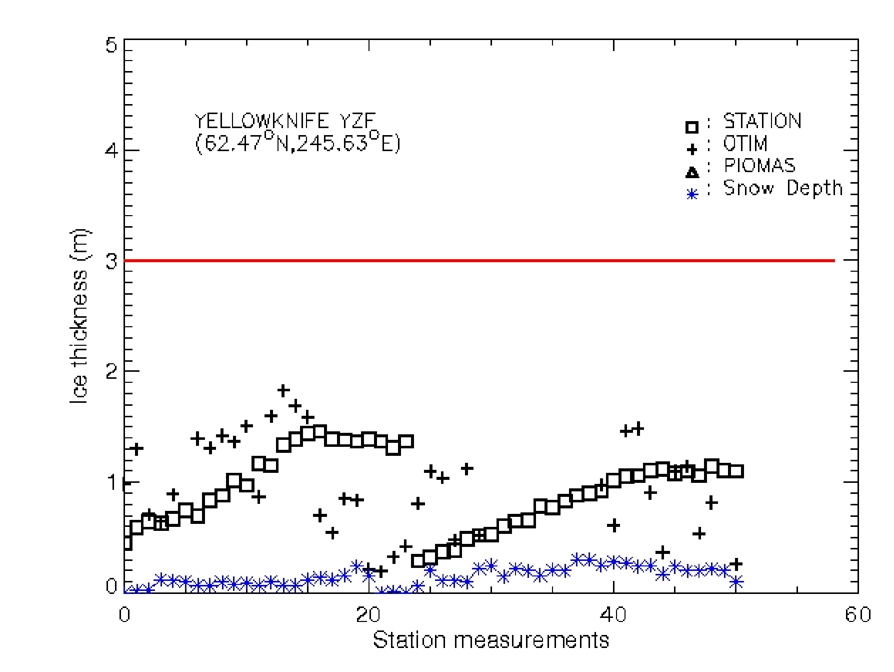




Ice Thickness and Age Algorithm Performance Estimate

- Station Measurements
  - »Comparisons of ice thickness cumulative distribution (left) and absolute values (right) retrieved by OTIM with APP-x data, measured by stations, and simulated by numerical model PIOMAS – Station Yellowknife YZE





Ice Thickness and Age Algorithm Performance Estimate

- OTIM vs Station

OTIM / Station	OTIM ALERT LT1	OTIM ALERT YLT	OTIM CAMBRIDGE BAY YCB	OTIM CORAL HARBOUR YZS	OTIM EUREKA WEU	OTIM HALL BEACH YUX	OTIM RESOLUTE YRB	OTIM YELLOWKNIFE YZF
Thickness Mean (m)	1.52 1.09	1.59 1.09	1.51 1.44	1.04 1.20	1.59 1.22	1.18 1.41	1.63 1.38	0.95 0.98
Bias Mean (m)	0.43	0.50	0.07	-0.16	0.37	-0.23	0.25	-0.03
Bias Standard Deviation (m)	0.52	0.39	0.97	0.62	0.52	0.68	0.50	0.58
OTIM Ice Age	Ice free water, new/fresh, grey, grey-white, first year thin, first year medium, first year thick, and multi-year ice.							
EDR Requirements	Distinguish between ice free, new/fresh ice, and all other ice.							

Ice Thickness and Age
Algorithm Assumptions and Limitations

- Algorithm Performance
  - » The algorithm is executed in a completely automated fashion.
  - » The algorithm is computationally efficient.
  - » The algorithm is only used when the ice is identified with /without snow cover on it.

Ice Thickness and Age
Algorithm Assumptions and Limitations

- Sensor Performance
  - » All satellite channel calibration will be correct and uniform from image to image for correct product retrievals to be called by this work, especially:
    - Surface skin and air temperature,
    - Surface radiation fluxes,
    - Surface air moisture, wind, and pressure.
  - » Satellite navigation errors are not present. Correct navigation is vital during automated processing for correct locations of ice and snow.

Ice Thickness and Age
Algorithm Assumptions and Limitations

- Assumptions and Proposed Mitigation Strategies
  - » Atmospheric profile and wind speed data are available from NWP or other teams' retrieved products. In case no profile data available, it is valid assumption as used by other researchers that surface air temperature generally is about 0.5 ~ 2 degree higher than surface skin temperature depending on the cloud condition, and relative humidity is about 90% over ice/snow, and wind speed of 10~20 m/s at night. But wind speed should be observed or simulated to guarantee to be realistic.
  - » Radiation fluxes are available from NWP or other teams' products, otherwise parameterizations will be used and assumed reliable, and accurate enough for each pixel. (*Use parameterization schemes over ice and/or snow surface from Bennett (1982), Ohmura (1981), Jacob (1978) as recommended*).

Ice Thickness and Age
Algorithm Assumptions and Limitations

- Assumptions and Proposed Mitigation Strategies
  - » Snow maps and climatological depths are available from NWP or other teams' products, or general assumption of 2~15 cm snow depth will be used over ice. (*Use snow information from NWP or elsewhere*).
  - » Land mask maps are also available to identify different surface types.
  - » All of the static ancillary data is available at the pixel level. (*Reduce the spatial resolution of the surface type, land mask and or coast mask*).

Ice Thickness and Age Pre-Planned Improvements

- Algorithm Improvement
  - » The OTIM serves other applications. Its development is closely tied to the development and feedback from the other team algorithms and ancillary data.
  - » Improve and/or develop reliable and efficient parameterization schemes for ice/snow reflectance, transmittance, emissivity, conductivity, salinity, and et al.
  - » Investigate modification to snow information on the ice, and radiation estimation over the ice.

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Ice Thickness and Age Algorithm References

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Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Software Architecture and Interfaces

Presented by

Walter Wolf

Software Architecture

- **Purpose: Demonstrate that the algorithm process flow provides for an implementation that is consistent with the theoretical basis and meets requirements.**

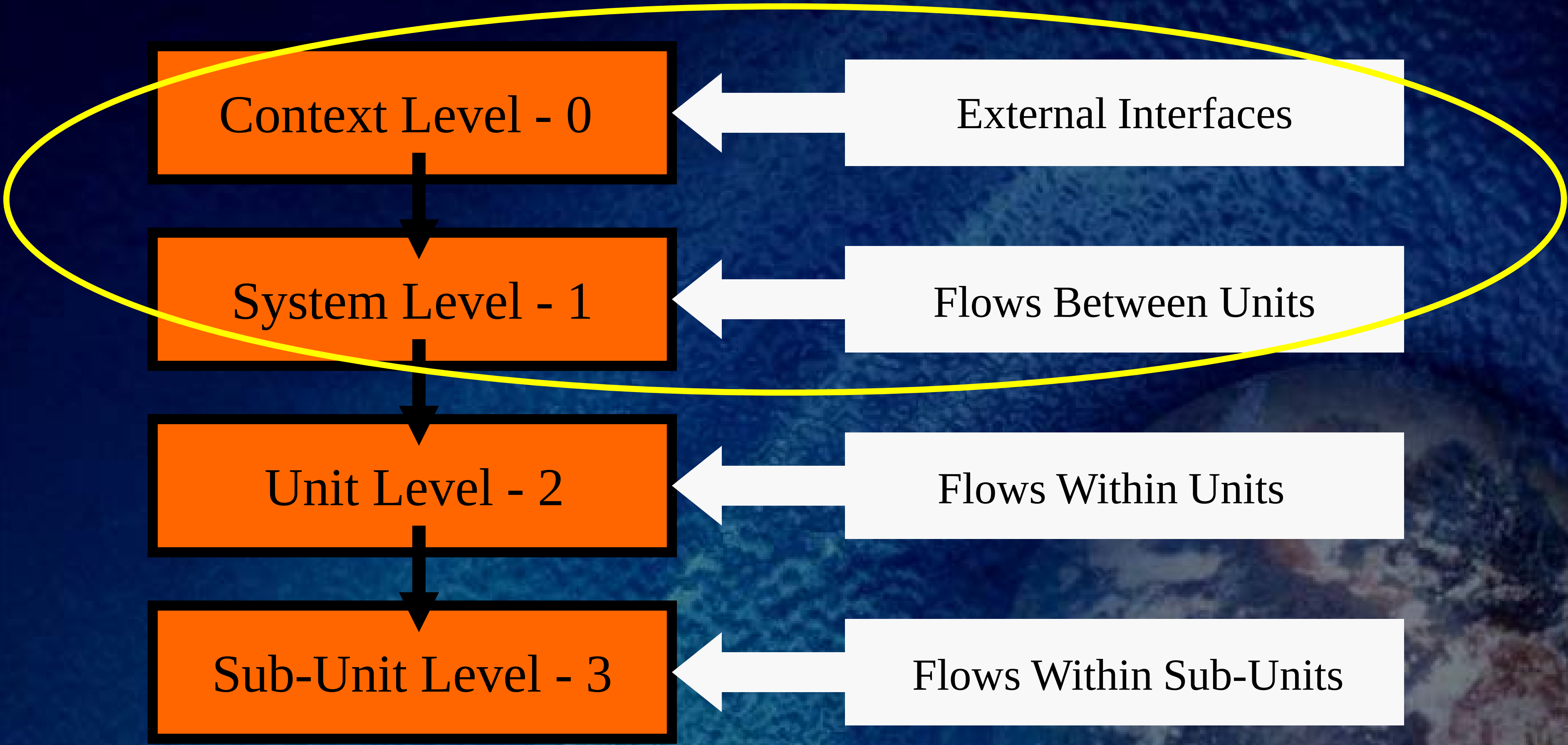
CDR Software Architecture

- A preferred solution has been selected for the Aerosol, Cloud and Cryosphere Products
- The software system is an integrated collection of software elements, or code, that implements the preferred solution, producing well-defined output products from a well-defined set of input data.
- The software architecture describes the structure of the system software elements and the external and internal data flows between software elements.

Software Architecture Levels

Context Level - 0	External Interfaces
System Level - 1	Flows Between Units
Unit Level - 2	Flows Within Units
Sub-Unit Level - 3	Flows Within Sub-Units

Software Architecture Levels



External Interfaces -- Definition

- An external input is defined as a data source needed by the system that is produced or made available by a process external to the system

- An external output is defined as a product that is created by the system for an external user

External Interfaces - Criteria

- Most input/output data files for the Aerosol, Cloud and Cryosphere algorithms will be in NetCDF4 format.
  - » Exceptions:
    - – NCEP model forecast data
    - – CRTM coefficients
    - – PCF file
    - – Log file

- The data passed to the units and sub-units will be stored in arrays.

External Interface Design at CDR

AIT Framework

Purpose

- **Purpose: Demonstrate that the AIT Framework provides an infrastructure that will enable the implementation of the Aerosol, Cloud and Cryosphere algorithms that meet the requirements.**

STAR AIT Framework Overview

- The STAR AIT Framework is a main program designed to run any scientific algorithm
- The Framwork is a C++ program that interfaces with C++/C/Fortran 90/95 algorithms
- The Framework is run by perl scripts
- Production Control Files (PCF) determine what algorithms are run when the framework is executed

STAR AIT Framework Details

- Common ancillary data is used across algorithms (where possible)
- Forward model is run once for all algorithms
- Satellite data and ancillary data is stored in memory for use by the algorithms
- Algorithms may be run in any order – determined by the PCF file

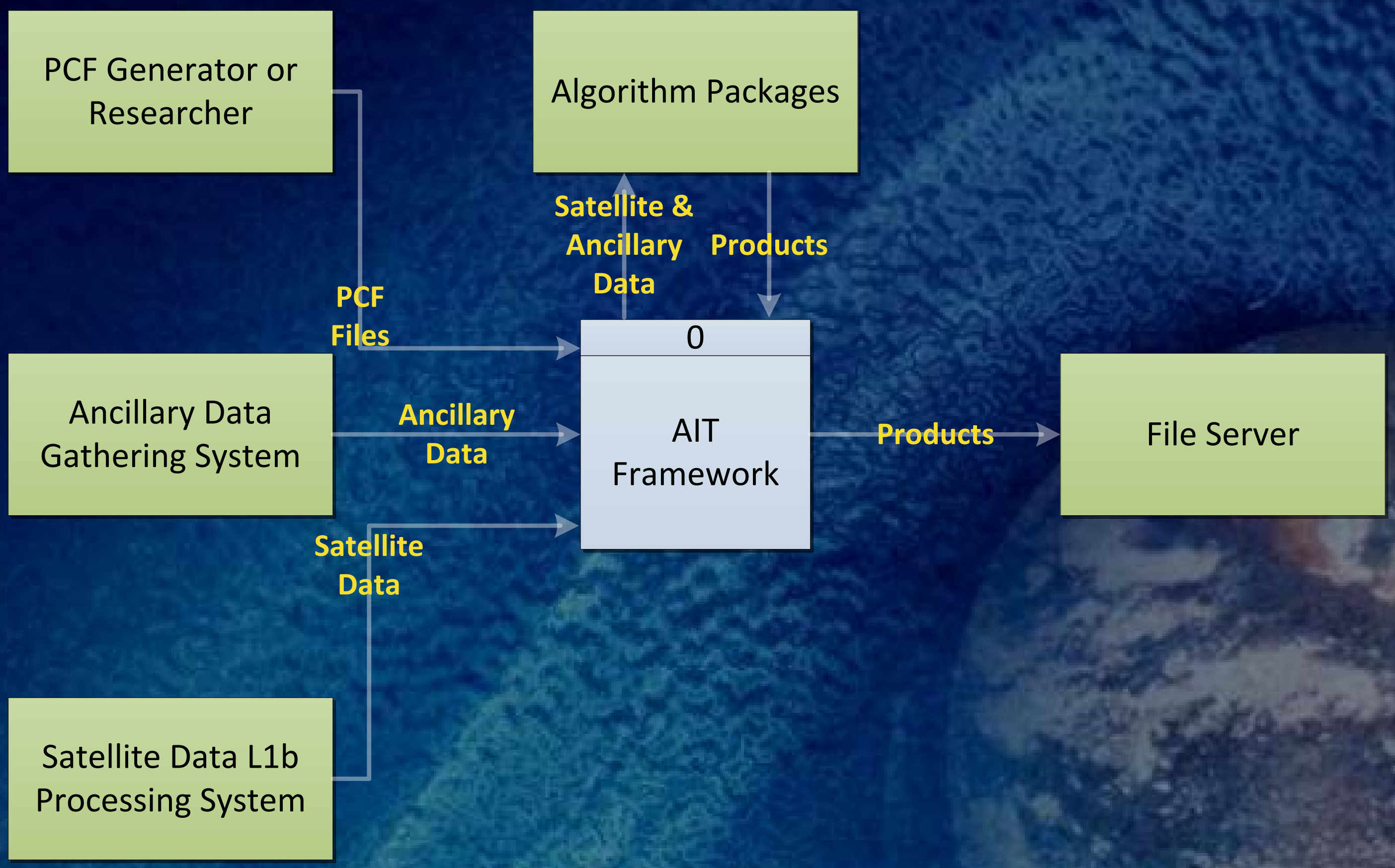
STAR AIT Framework Algorithms

- Algorithms plugged into the framework are subroutine calls
- Data is not read within the algorithm, all input data is either passed into the algorithm or is read via a function call
- Readers and writers of all types of input and output data are treated as algorithms

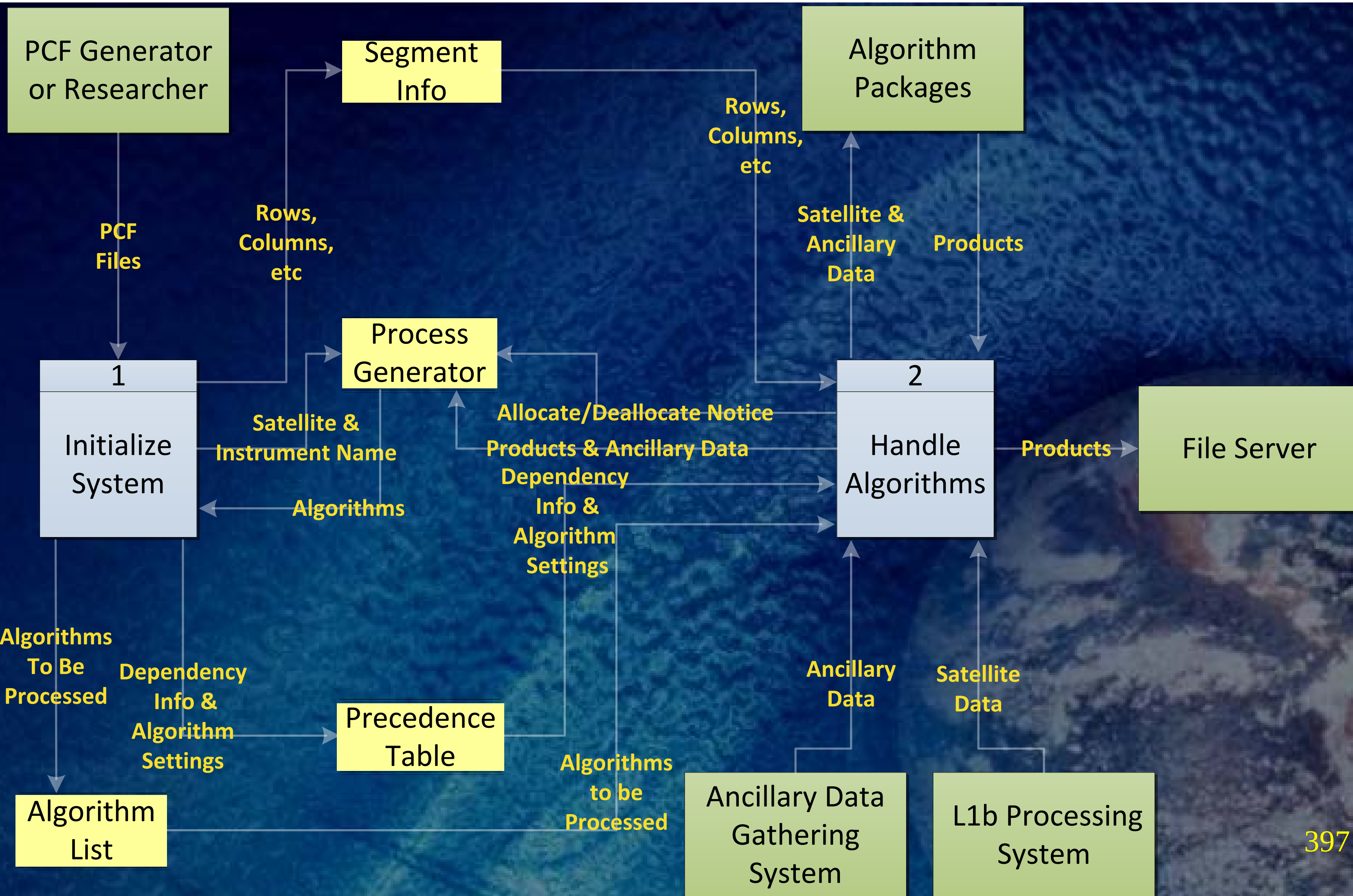
Framework Data Flow and Interfaces

- The following slides show the data flow and interfaces in the framework.

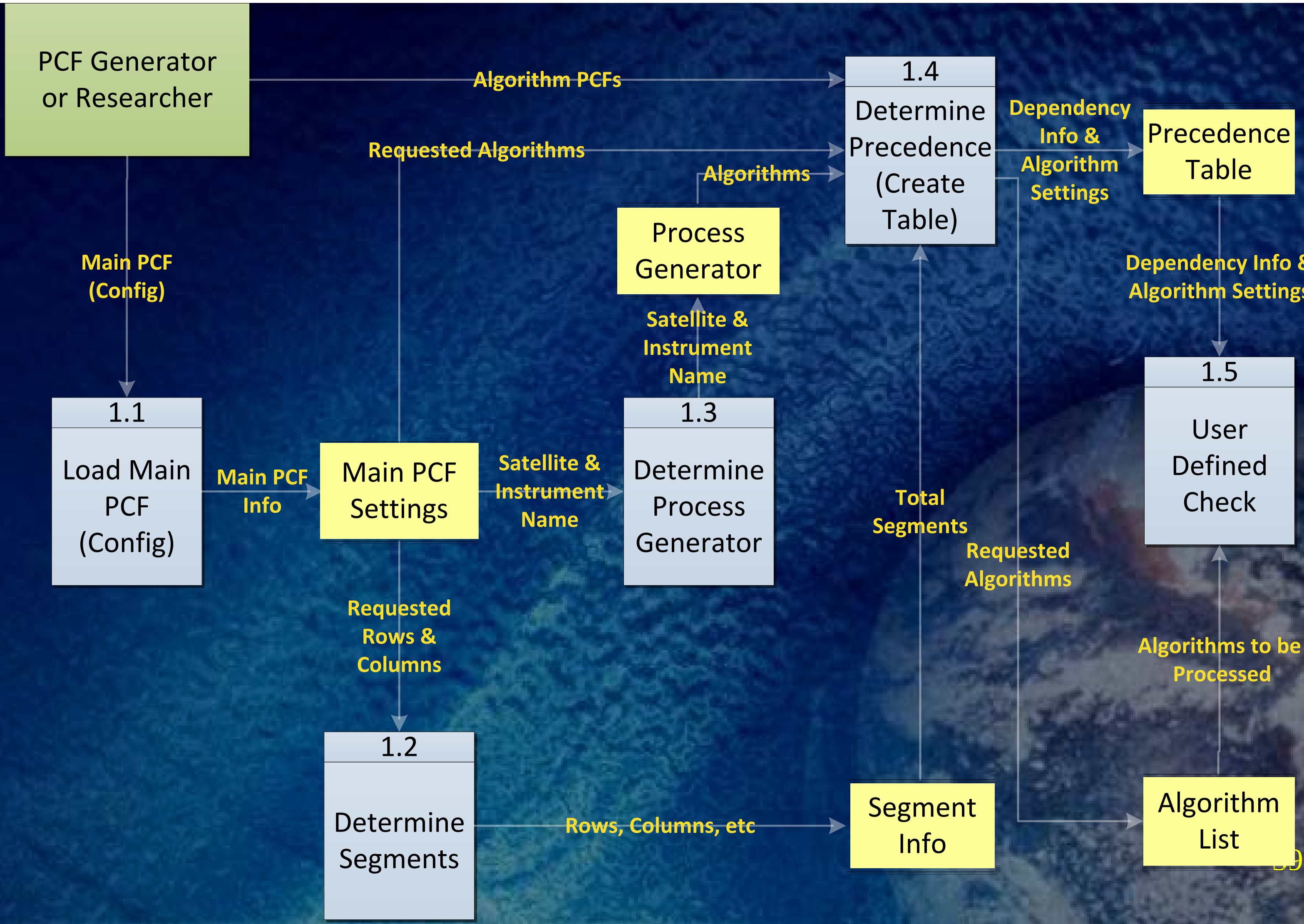
Framework Context Diagram



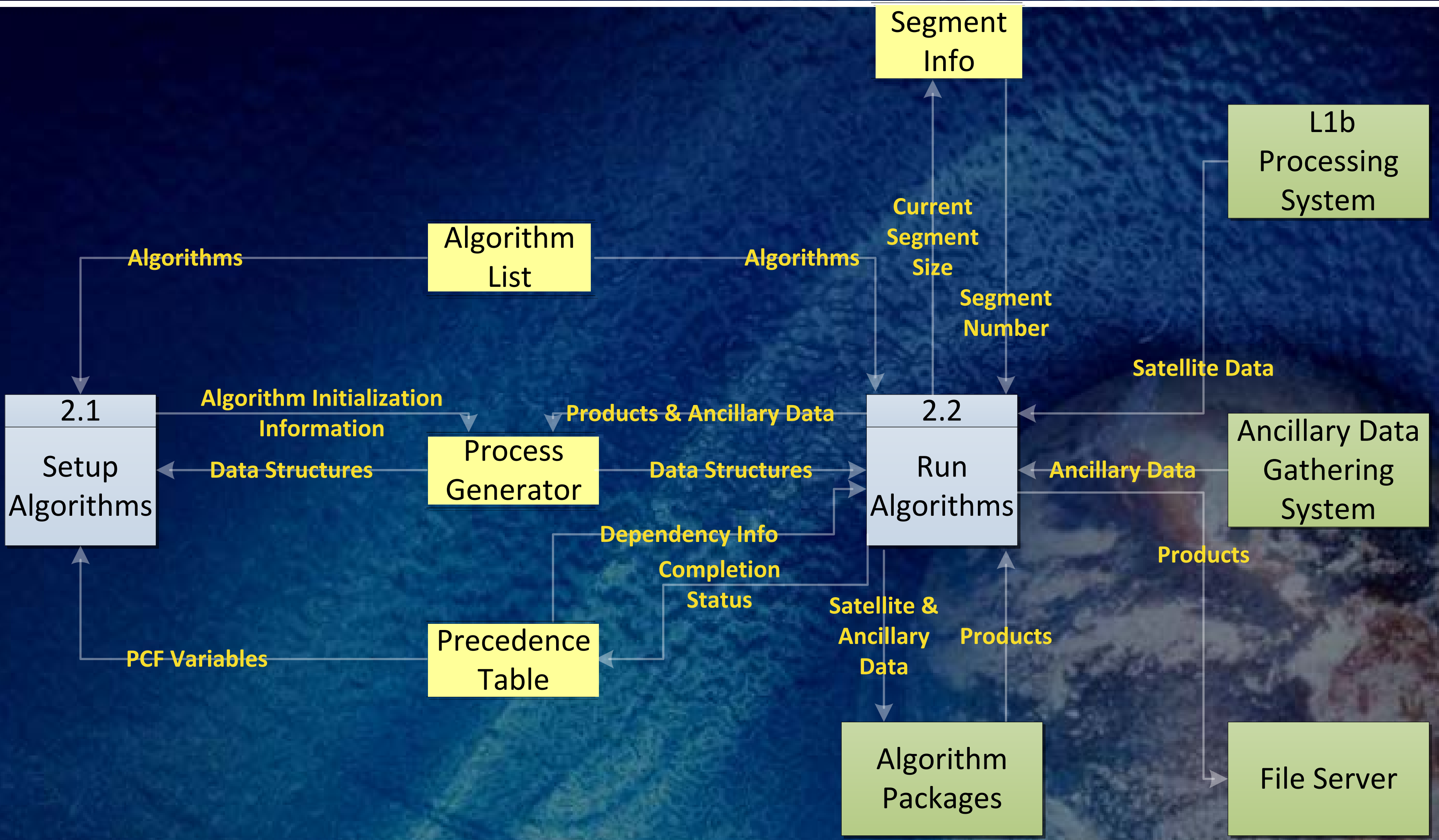
Framework System Level



Framework Unit Level 1 Initialize System



Framework Unit Level 2
Handle Algorithms



Inputs

- PCF files
- Data
  - » Common ancillary data
  - » Radiance data
  - » Specific algorithm data

PCF Files

- Production Control Files (PCF) contain the information required to run an algorithm
  - Algorithm dependencies to determine product precedence
  - Algorithm specific variables such as flags and thresholds
  - Framework loads the contents of the PCF file when the algorithm has been flagged to run in the configuration file or if it is needed by something that has been flagged to run in the configuration file.

PCF File:
3 Main Sections

- DEPENDENCIES
  - » List the Type and PCF ID for each dependency the algorithm requires
- OTHER
  - » This section contains algorithm specific variables such as thresholds, flags, etc that are flexible and can be changed at run time.
- TEMPORAL
  - » This section dictates temporal needs for the algorithm if requested.

PCF Layout Example

(Default_PCF/MSG8/SEVIRI/AWG_Cloud_Mask.pcf)

```
#
# AWG_CLOUD_MASK
#
AWG_CLOUD_MASK
```

PCF ID indicates beginning of entry.

```
PRODUCT
```

PRODUCT or ANCILLARY

```
#
# Set flag for output
#
OUTPUT_TO_FILE: Y
```

Output result to file (Y/N)

```
#
# Dependencies
#
DEPENDENCIES:
```

"DEPENDENCIES" keyword indicates dependency section of the PCF.

```
SATELLITE_DATA:
```

SATELLITE_DATA dependency type doesn't have a dependency below. The framework will look for what satellite data to use in the config file. This avoids tedious modification to each PCF.

```
LAND_MASK:
```

Dependency Type

```
LAND_MASK
```

Dependency PCF ID

PCF Layout (cont 1)

```
COAST_MASK:
COAST_MASK_NASA_1KM

DESERT_MASK:
DESERT_MASK

SNOW_MASK:

SNOW_MASK_IMS_SSMI

SNOW_MASK_NWP


PSEUDO_EMISSIVITY:
GOESR_ABI_CHN7_EMISS

SURFACE_ELEVATION:
SFC_ELEV_GLOBE_1KM

SURFACE_EMISSIVITY:
SFC_EMISS_SEEBOR
SFC_EMISS_CONSTANT

NWP_DATA:
NWP_GFS
```

1st Dependency

Backup Dependency

PCF Layout (cont 2)

```
RTM:
CRTM

TEMPORAL_DATA:
TEMPORAL_DATA_FIXED
```

Temporal data is special – has it's own section that needs to be filled out if it is specified to run.

```
#
# Create this section only if Temporal Data part of dependencies
#
TEMPORAL:
```

"TEMPORAL" keyword indicates temporal section. Only required for algorithms needing temporal data.

```
Timestep_Type: MSG_SEVIRI
```

Each satellite/instrument has a different time increment. Informs system what to expect.

```
Timestep: -1
```

-1 = most recent previous time step

```
Actual_Time: -900.0
```

Actual time difference in seconds. (-15 min)

```
Load:
```

Load keyword tells system the following list needs to be loaded into the system as temporal data.

```
AWG_CLOUD_MASK = /need/to/create/file
```

PCF ID & Filename

PCF Layout (cont 3)

```
#
# Settings
#
OTHER:
```

Keyword "OTHER" indicates algorithm variables/settings section.

```
CldMask_Packed_Constant: 4
Flag_Constant: 24
Ancillary_Path: cloud_team_delivery_0/data_algorithms/
Ancillary_SubDir: baseline_cloud_mask/
```

AWG_CLOUD_MASK specific variables.

```
END AWG_CLOUD_MASK
```

End of algorithm entry

Specific Algorithm Data

- Each algorithm currently reads its own specific ancillary data (such as coefficient files, look up tables, etc)

- See algorithm section for details

Product Precedence

- The following 6 slides show the ancillary data product precedence information:
  - » VIIRS SDR data
  - » Static Ancillary data
  - » Dynamic Ancillary data
  - » Radiative Transfer Model (RTM)
- The full product precedence chart for the Aerosol, Cloud and Cryosphere algorithms is shown later in this section.

Product Precedence
S-NPP VIIRS

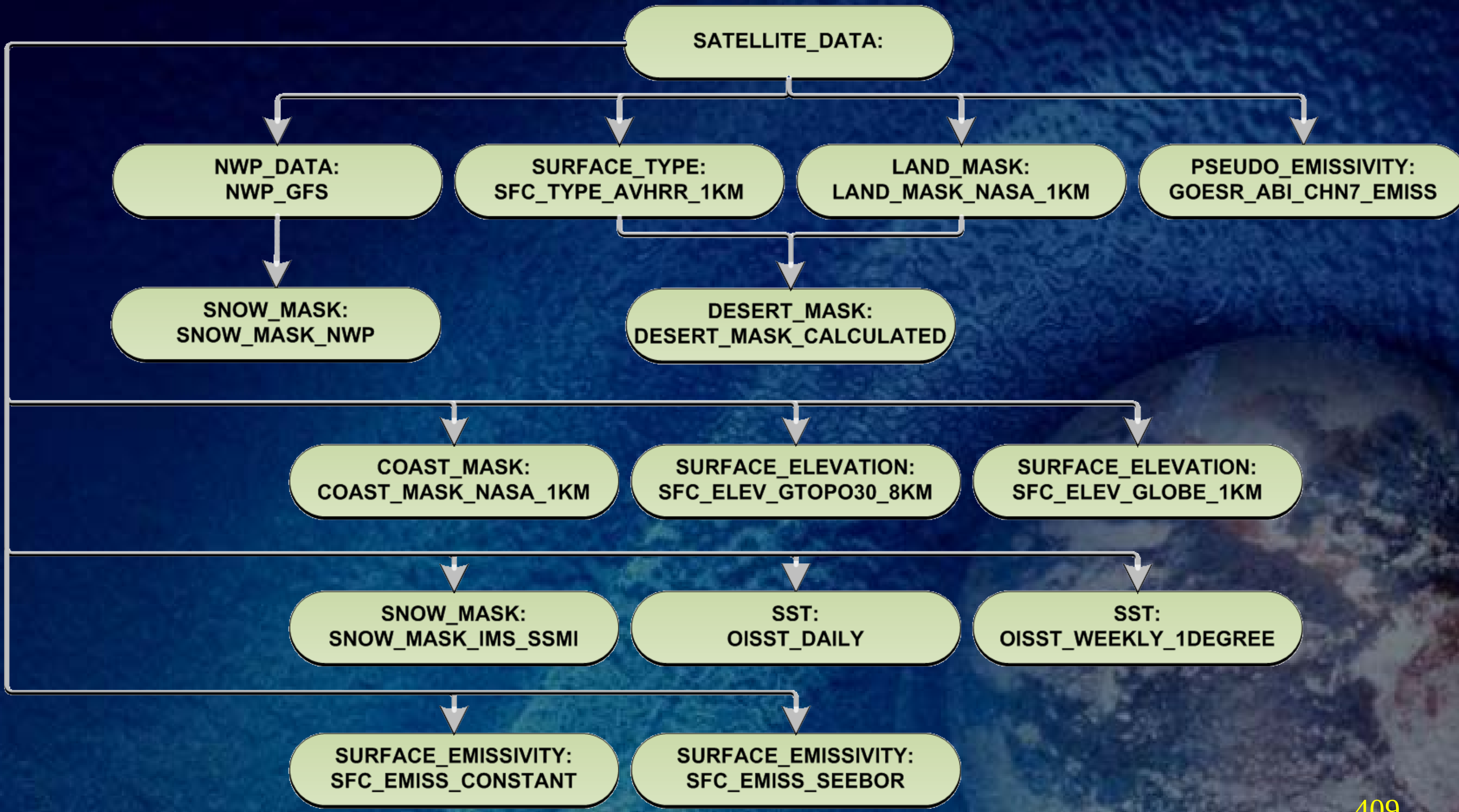


Table of DynamicAncillary Data

Ancillary Data	Description	Filename	Size
CRTM	Community Radiative Transfer Model	N/A	N/A
NWP_GFS	NCEP GFS model data in grib format – 1 x 1 degree (360x181), 26 levels	gfs.tHHz.pgrbfhh	26MB
OISST_WEEKLY_1DEGREE	NCEP EMC Reynolds OISST weekly analysis, 1 degree resolution	oisst.YYYYMMDD.nc	778704 bytes
SNOW_MASK_IMS_SSMI	Snow/Ice mask, IMS – Northern Hemisphere, SSM/I – Southern Hemisphere 4km resolution – the 25 km SSM/I has been oversampled to 4km	snow_map_4km_YYMMDD.nc	39mb
SNOW_MASK_NWP	Snow/Ice mask, calculated from snow surface variable in the GFS grib file	N/A	N/A

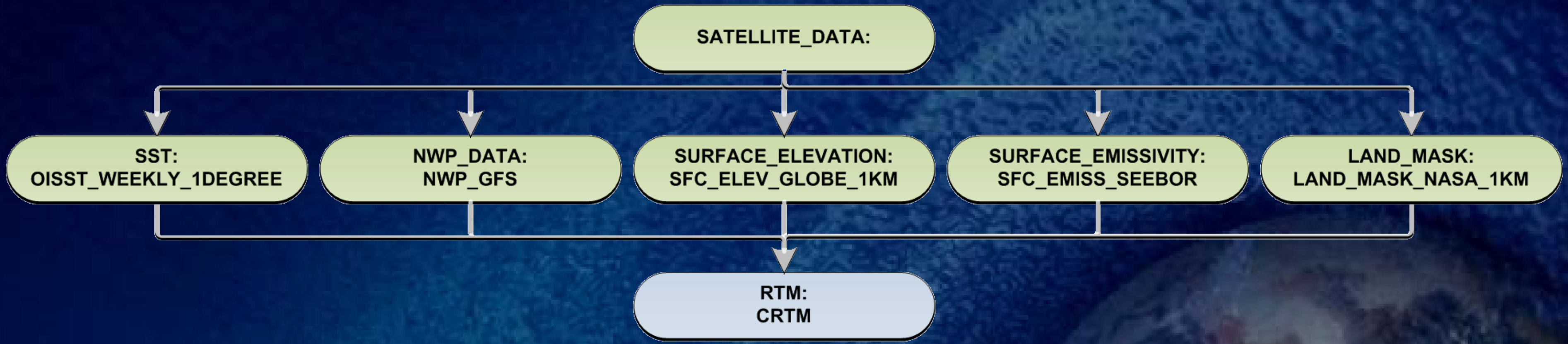
Table of Static Ancillary Data

Ancillary Data	Description	Filename	Size
COAST_MASK_NASA_1KM	Global 1km land/water used for MODIS collection 5	coast_mask_1km.nc	890 MB
DESERT_MASK_CALCLTED	Desert mask calculated using LAND_MASK_NASA_1KM and SFC_TYPE_AVHRR_1KM	N/A	N/A
LAND_MASK_NASA_1KM	Global 1km land/water used for MODIS collection 5	lw_geo_2001001_v03m.nc	890 MB
SFC_ALBEDO	MODIS White Sky Surface albedo	AlbMap.WS.c004.v2.0.YYYY.DDD.0.659_x4.nc AlbMap.WS.c004.v2.0.YYYY.DDD.1.64_x4.nc	28 MB x 2
SFC_ELEV_GLOBE_1KM	Digital surface elevation at 1km resolution	GLOBE_1km_digelev.nc	1843.2 MB
SFC_ELEV_GTOPO30_8KM	Digital surface elevation at 8km resolution	digelev_hires_le.map	32 MB

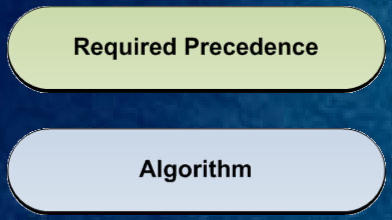
Table of Static Ancillary Data

Ancillary Data	Description	Filename	Size
SFC_EMISS_CONSTANT	Surface emissivity, constant value -- The emissivity is read in from the PCF file and is set to 0.98 (it's default value)	N/A	N/A
SFC_EMISS_SEEBOR	Surface emissivity at 5km resolution, climatology monthly	global_emiss_intABI_2005DDD.nc	693 MB x 12
SFC_TYPE_AVHRR_1KM	Surface type mask based on AVHRR at 1km resolution	gl-latlong-1km-landcover.nc	890 MB
VOLCANO_SMITH_1KM	Volcano mask	volcano_mask_1km.nc	890 MB
NEEDLELEAF MASK	Needle-leaf forest cover fraction data reader	gl-latlong-1km-needleleaf.nc	933120444 bytes
TREECOVER MASK	tree cover fraction data reader	gl-latlong-1km-treecover.nc	933120420 bytes
EEZ MASK	Exclusive Economic Zone mask	eez_global.nc	933120440 bytes

Product Precedence
RTM



Key:



CRTM Inputs and Outputs

Filename	Size
viirs-m_npp.SpcCoeff.bin	928 bytes
viirs-m_npp.TauCoeff.bin	6.3 kb

Output Files

- Output files are in NetCDF format
- See individual algorithms for details on the contents

STAR Hardware

- Rack of Linux Dell Processors (72 CPUS) for product development.
- 20 TB of disk space on the SAN for all simulated data, proxy data and products.

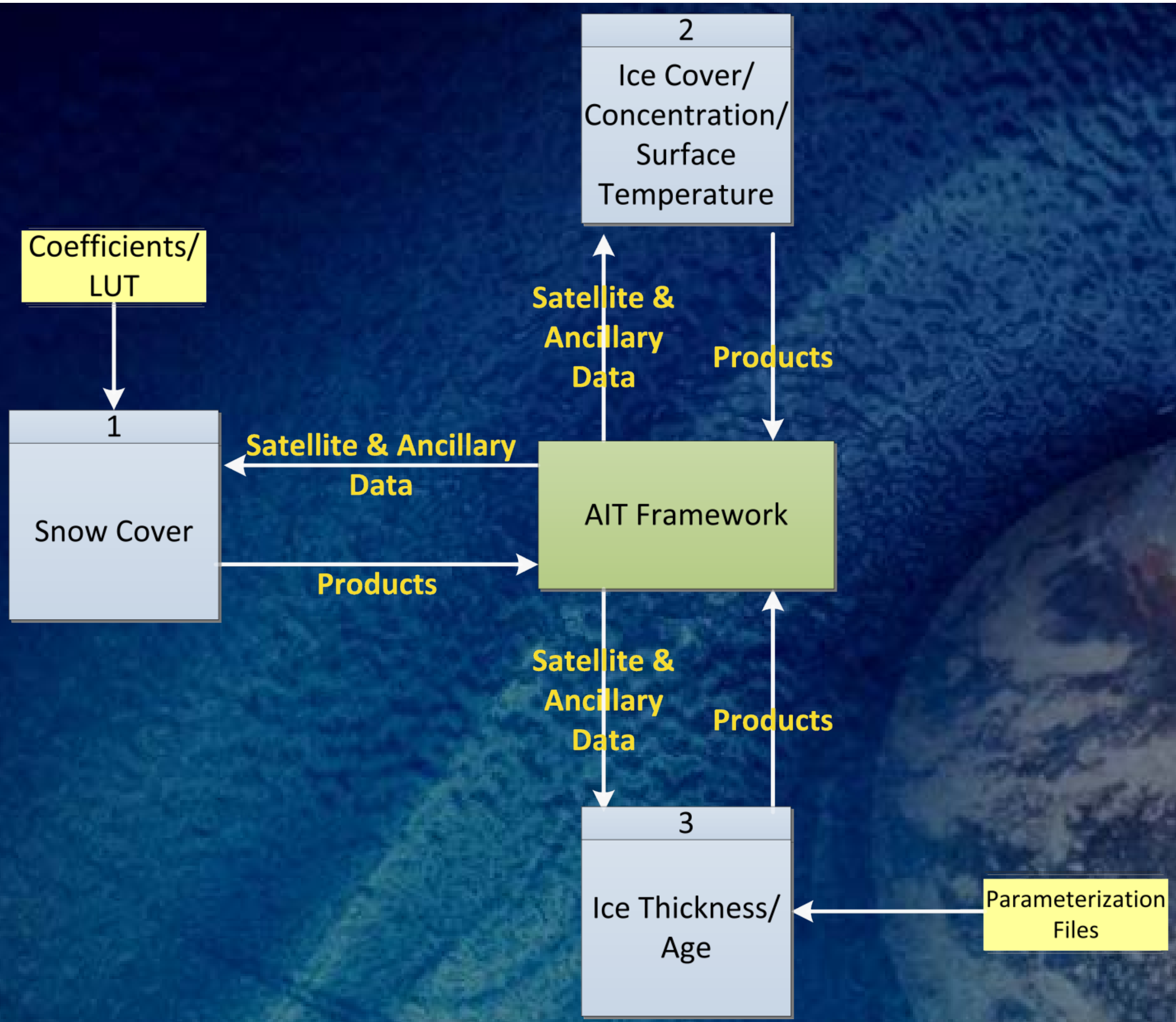
Software/Compilers

- Framework uses netCDF libraries
  - » NetCDF 4
  - » HDF 5 (required by NetCDF 4)
- Framework uses wgrib commands
- Perl scripts
  - » Code generation
  - » Standards checking
- Currently runs on Intel 12+ compilers
- ClearCase and ClearQuest used for version control
- Valgrind used to check for memory leaks

External Interface Design at CDR

System Level

Ice Thickness/Age System Level Data Flow-Diagram



System Level Data Flow – Table

Snow Cover
Input, Internal, and Output Data Flows at the System Level

Interface Item	Interface Type	Source	Description
Coefficients	Input	CREST	Threshold Values
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated reflectance in bands I1, I2, and I3 along with solar and satellite view angles.
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
Surface Elevation	Input	NGDC	Digital surface elevation at 1km resolution
Snow cover climatology	Input	CREST	Weekly maps of snow cover frequency of occurrence on 1/3 degree global lat/lon grid.
Land surface climatology	Input	CREST	Monthly mean land surface temperature
VIIRS Snow Co ver	Output	VIIRS Snow Cover	Snow Cover produced by VIIRS Snow Cover algorithm

Yellow = Static White = Dynamic

System Level Data Flow – Table

Ice Concentration & Ice Cover
Input, Internal, and Output Data Flows at the System Level

Interface Item	Interface Type	Source	Description
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated reflectance for channels I1, I2, and I3 with Brightness Temperature in Channel M5, M7, M10, M15 and M16 along with solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Ice Concentration and Ice Cover	Output	VIIRS Ice Concentration and Ice Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm

Yellow = Static

White = Dynamic

System Level Data Flow – Table

Ice Surface Temperature
Input, Internal, and Output Data Flows at the System Level

Interface Item	Interface Type	Source	Description
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated Brightness Temperature in Channels M15 and M16 with solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Ice Concentration and Ice Cover	Input	VIIRS Ice Concentration and Ice Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm
VIIRS Ice Surface Temperature	Output	VIIRS Ice Surface Temperature	Ice Surface Temperature produced by the VIIRS Ice Surface Temperature Algorithm

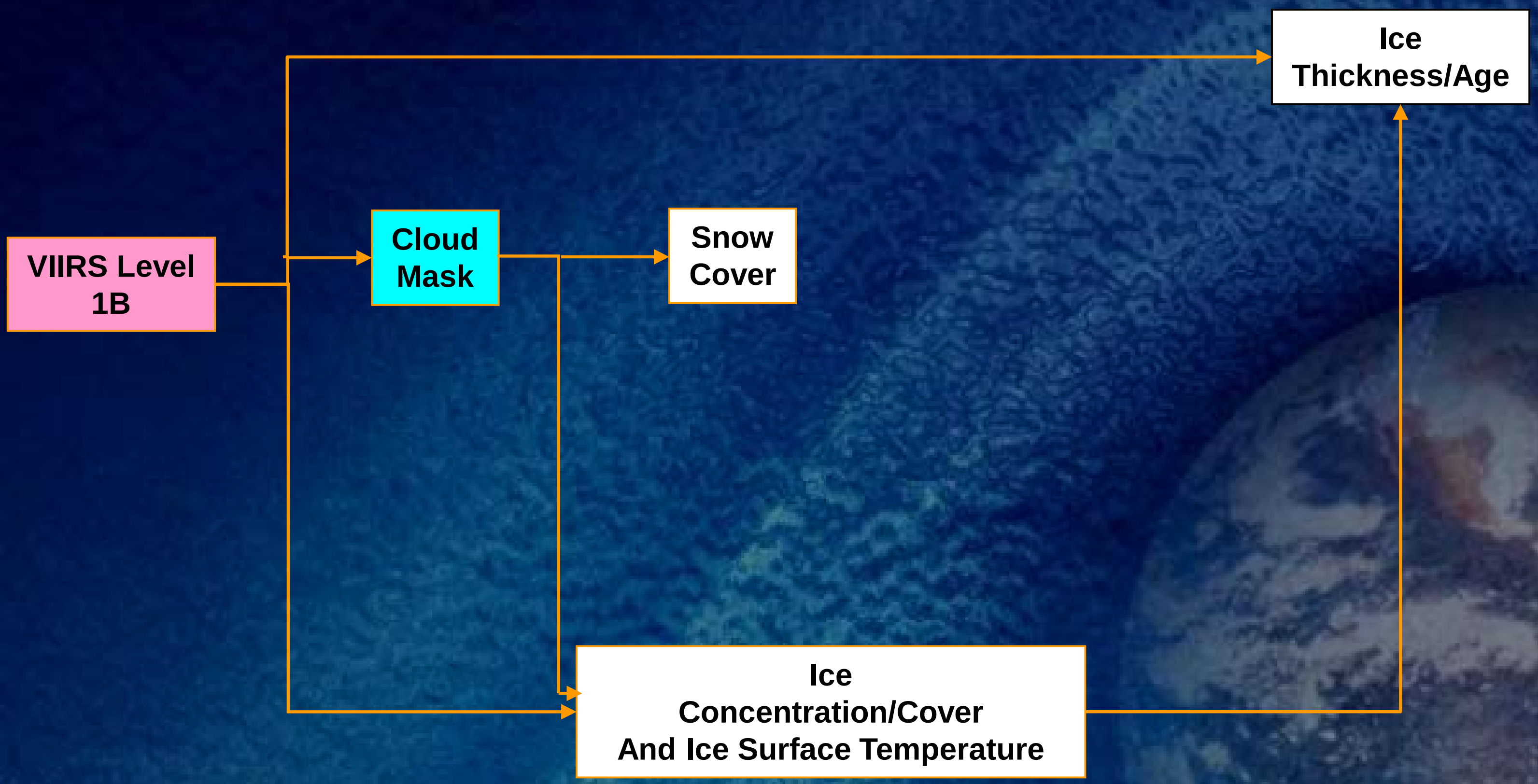
Yellow = Static White = Dynamic

System Level Data Flow – Table

Ice Thickness/Age
Input, Internal, and Output Data Flows at the System Level

Interface Item	Interface Type	Source	Description
Ice and Snow Microphysical Properties	Input	CIMSS	Coefficients for the Ice and Snow Microphysical Properties
VIIRS SDR	Input	VIIRS	VIIRS solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
NWP Derived	Input	GFS Soundings	Surface air temperature, surface air pressure, surface air moisture, surface wind speed, snow cover, snow depth
VIIRS Ice Concentration and Ice Cover	Input	VIIRS Ice Concentration/Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm
VIIRS Ice Surface Temperature	Input	VIIRS Ice Surface Temperature	Ice surface skin temp. produced by VIIRS ice surface temperature algorithm
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Surface Solar Radiation	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Solar Radiation
VIIRS Surface Thermal Radiation	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Thermal Radiation
VIIRS Surface Broadband Albedo	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Broadband Albedo
VIIRS Ice Thickness	Output	VIIRS Ice Thickness/Age	Ice thickness produced by VIIRS Ice Thickness/Age algorithm
VIIRS Ice Age	Output	VIIRS Ice Thickness/Age	Ice Age produced by VIIRS Ice Thickness/Age algorithm

System Level
Data Flow – Precedence



System Level Data Flow – Sequence(1)

- The framework reads in common datasets such as VIIRS SDR and ancillary data for all products. The following apply to Cryosphere products:
  - VIIRS SDR
  - Land/Coast Mask
  - Surface Elevation
  - NWP

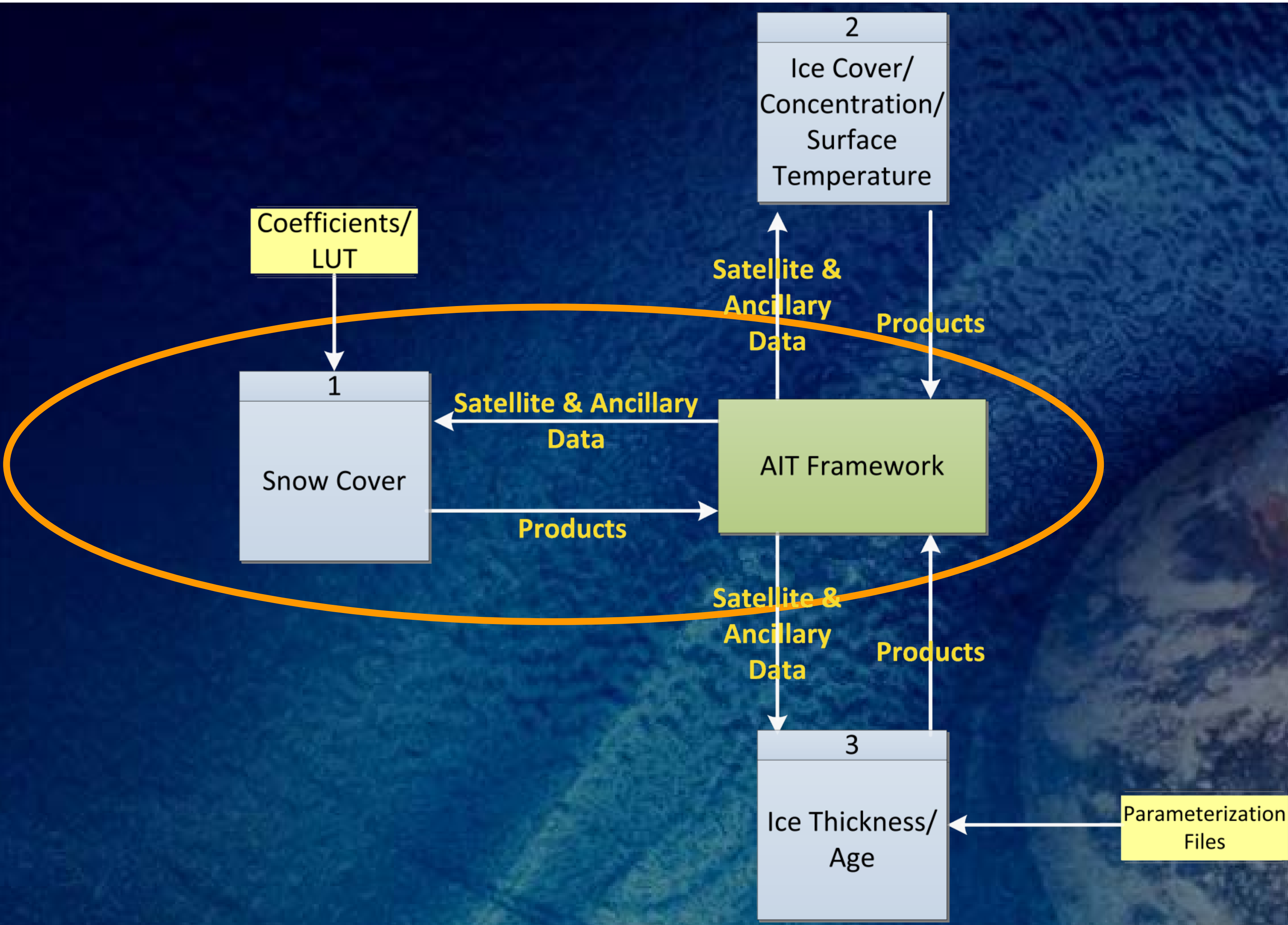
System Level Data Flow – Sequence(2)

- The framework checks the precedence to produce cryosphere products. It will run the following products upstream:
  - VIIRS Cloud mask
- All the ancillary data including VIIRS SDR will be passed to the cryosphere algorithms through data structures.
- Cryosphere algorithms read in their product specific inputs such as look up table and coefficient files.
- Cryosphere product outputs will be sent back to the framework through data structures.

External Interface Design at CDR

Unit Levels

Snow Cover
Unit Level Data Flow-Diagram

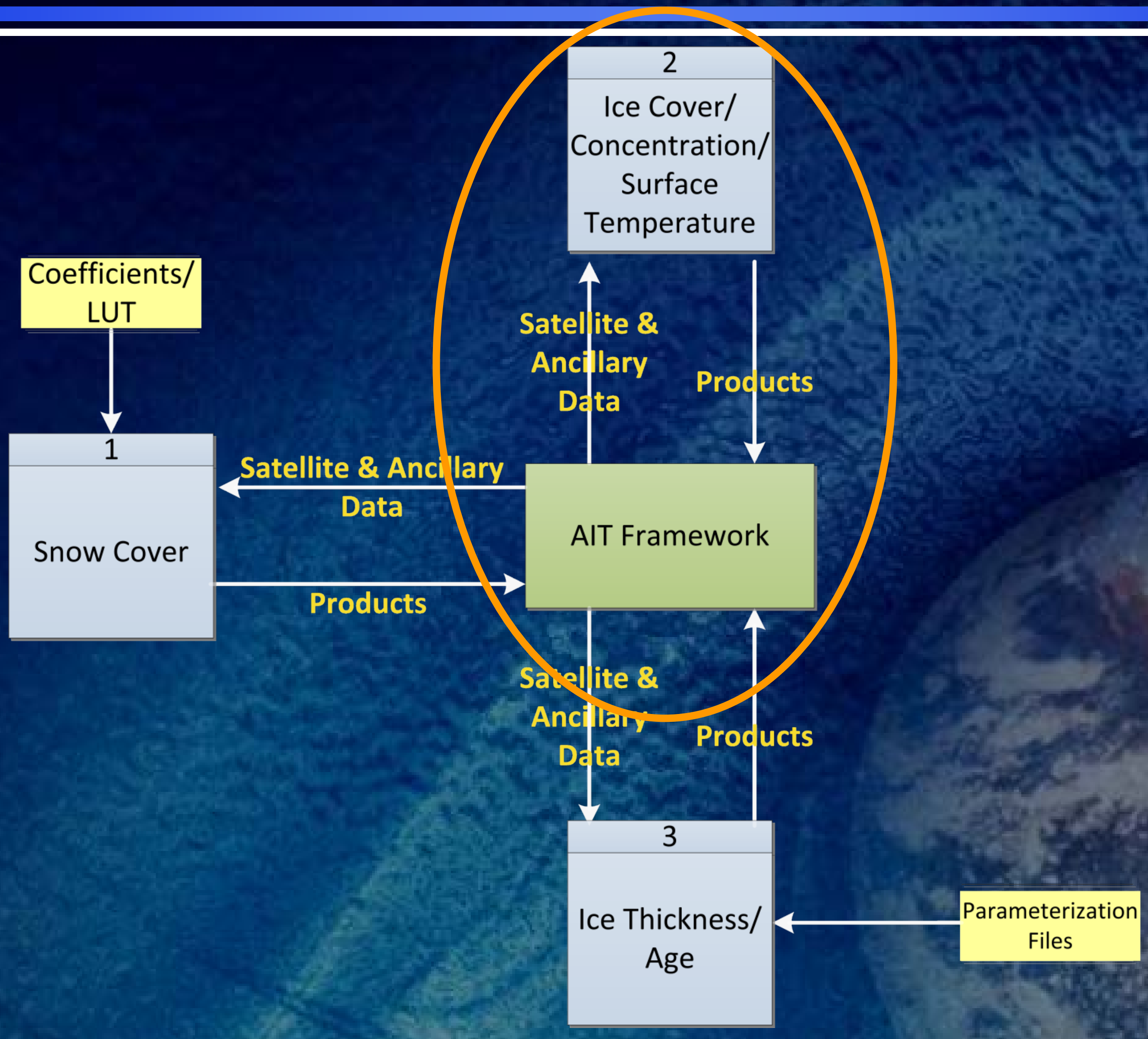


Snow Cover
Unit Level Data Flow-Table

Input, Internal, and Output Data Flows at the Unit Level

Interface Item	Interface Type	Source	Description
Coefficients	Input	CREST	Threshold Values
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated reflectance for channels I1, I2, and I3 along with solar and satellite view angles
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
Surface Elevation	Input	NGDC	Digital surface elevation at 1km resolution
Snow cover climatology	Input	CREST	Weekly maps of snow cover frequency of occurrence on 1/3 degree global lat/lon grid.
Land surface climatology	Input	CREST	Monthly mean land surface temperature
VIIRS Snow Co ver	Output	VIIRS Snow Cover	Snow Cover produced by VIIRS Snow Cover algorithm

Ice Cover/Concentation/Surface Temperature Unit Level Data Flow-Diagram



Ice Cover/Concentration Unit Level Data Flow-Table

Input, Internal, and Output Data Flows at the Unit Level

Interface Item	Interface Type	Source	Description
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated reflectance for channels I1, I2, and I3 with Brightness Temperature in Channel M5, M7, M10, M15 and M16 along with solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Ice Concentration and Ice Cover	Output	VIIRS Ice Concentration and Ice Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm

Ice Surface Temperature Unit Level Data Flow-Table

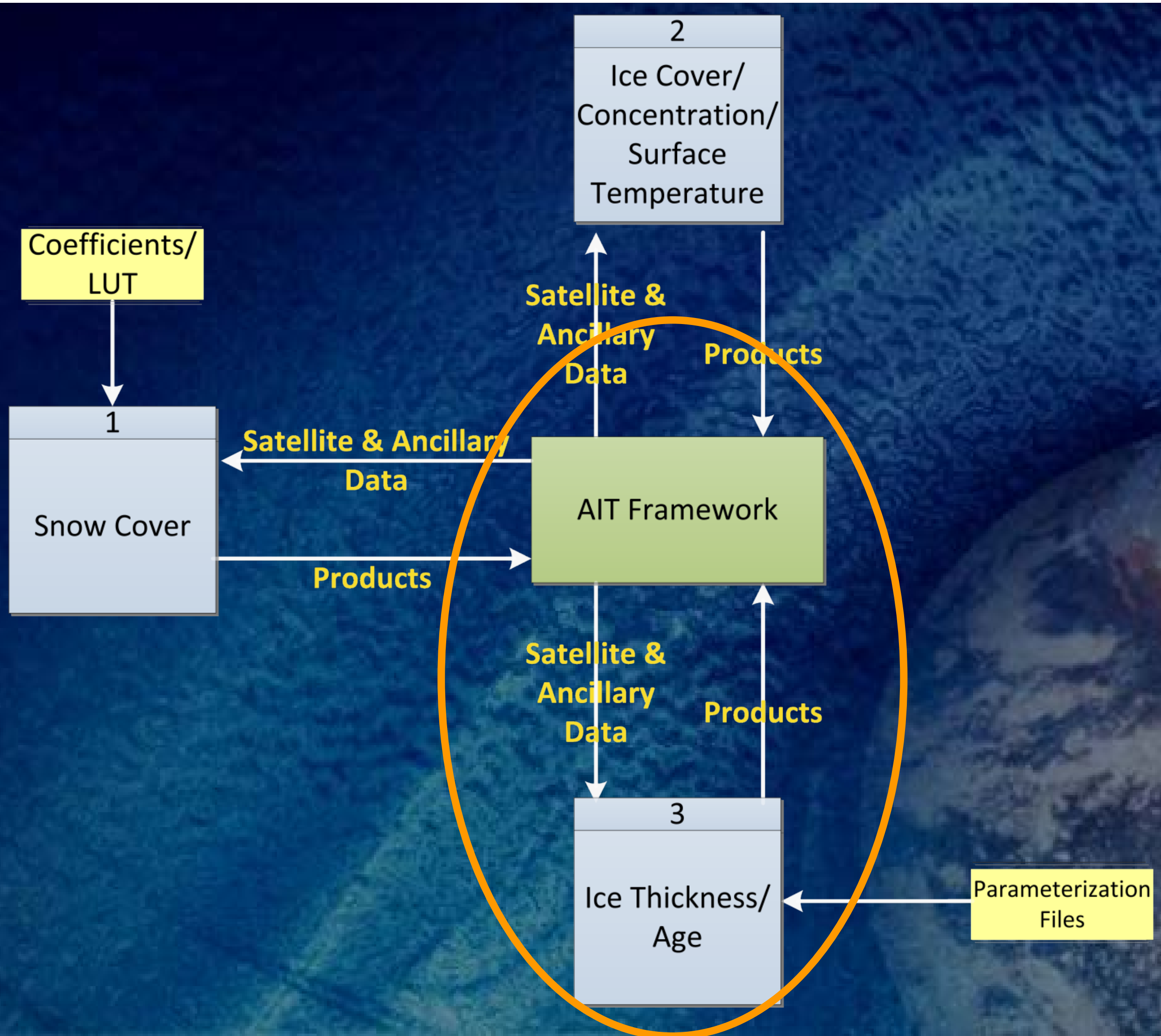
Input, Internal, and Output Data Flows at the Unit Level

Interface Item	Interface Type	Source	Description
VIIRS SDR	Input	VIIRS	VIIRS calibrated and navigated Brightness Temperature in Channels M15 and M16 with solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Ice Concentration and Ice Cover	Input	VIIRS Ice Concentration and Ice Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm
VIIRS Ice Surface Temperature	Output	VIIRS Ice Surface Temperature	Ice Surface Temperature produced by the VIIRS Ice Surface Temperature Algorithm

Ice Cover & Concentration & Surface Temperature Input Ancillary Data

Name	Type	Description	Dimension
IceSrfTempCoeff.nc	Input	Lookup table of coefficients used for calculating ice surface temperature based on three air temperature ranges	4 x 3 (4 sets of coefficients for 3 temperature ranges)

Ice Thickness/Age Unit Level Data Flow-Diagram



Ice Thickness/Age Unit Level Data Flow-Table

Input, Internal, and Output Data Flows at the Unit Level

Interface Item	Interface Type	Source	Description
Ice and Snow Microphysical Properties	Input	CIMSS	Coefficients for the Ice and Snow Microphysical Properties
VIIRS SDR	Input	VIIRS	VIIRS solar and satellite view angles
Land & Coast Mask	Input	NASA	Global 1 km land/water & coast mask used for MODIS collection 5
NWP Derived	Input	GFS Soundings	Surface air temperature, surface air pressure, surface air moisture, surface wind speed, snow cover, snow depth
VIIRS Ice Concentration and Ice Cover	Input	VIIRS Ice Concentration/Cover	Ice concentration and Ice cover produced by VIIRS ice concentration/cover algorithm
VIIRS Ice Surface Temperature	Input	VIIRS Ice Surface Temperature	Ice surface skin temp. produced by VIIRS ice surface temperature algorithm
VIIRS Cloud Mask	Input	VIIRS Cloud Mask	Cloud mask produced by VIIRS cloud mask algorithm
VIIRS Surface Solar Radiation	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Solar Radiation
VIIRS Surface Thermal Radiation	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Thermal Radiation
VIIRS Surface Broadband Albedo	Input	Parameterization File	Parameterization File to represent the VIIRS Surface Broadband Albedo
VIIRS Ice Thickness	Output	VIIRS Ice Thickness/Age	Ice thickness produced by VIIRS Ice Thickness/Age algorithm
VIIRS Ice Age	Output	VIIRS Ice Thickness/Age	Ice Age produced by VIIRS Ice Thickness/Age algorithm

Ice Age & Thickness Input Ancillary Data

Name	Type	Description	Dimension
AITA_INPUT_ Coefficients_ResiFlux .nc	Real	Lookup table of residual heat flux adjustment coefficients of intercepts and slopes to calculate ice growth rate for twelve months .	12 x 2 2 sets of coefficients for 12 months

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Detailed Design

Presented by

Walter Wolf

Design Overview Description

- The design overview builds on the software architecture by providing a high level description of each system element that is defined in the software architecture.
- The design overview describes the project system's functionality and design characteristics at a high level that covers, for each system elements:
  - » Its purpose
  - » External interfaces
  - » Decomposition into sub-elements
  - » Functional sequence
  - » Design Language
  - » Input and Output File Descriptions

Design Overview

- Fully defines the structure and capabilities of the software product components.
  - » Software architecture details are finalized
  - » Software components are completely defined
  - » Interfaces to software components are fully characterized
  - » Connects the design to the allocated product-component requirements, architecture, and higher level designs

Metadata Design

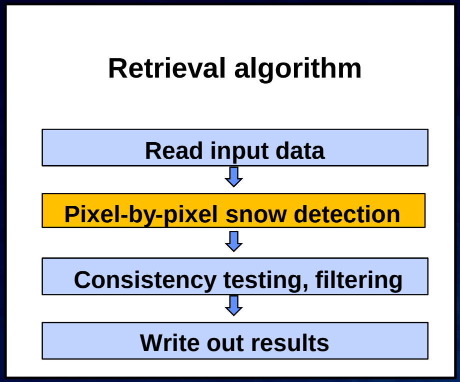
- Metadata design should respond to metadata requirements
- There is no archive requirement for this project, so the only metadata with be product level metadata for OSPO trending
- From our experience, the Cryosphere Team can populate the metadata from Snow Cover, Ice Cover & Concentration, Ice Age, and Ice Surface Temperature

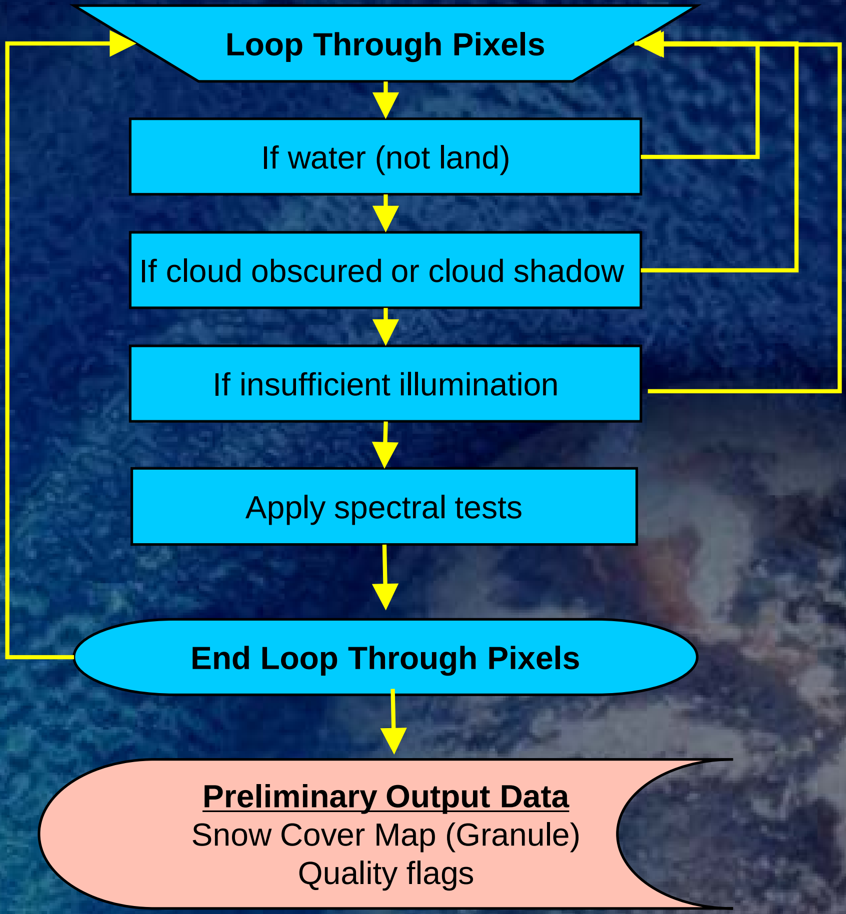
Snow Cover
Unit Description (1)

- Produce fractional snow cover, fractional grain size, fractional vegetation cover, fractional rock/soil cover, and fractional other (ice) with associated quality flags.

- Interfaces
  - VIIRS calibrated and navigated reflectance in bands I1, I2, and I3 along with solar and satellite view angles
  - VIIRS Cloud Mask
  - Land/water mask
  - Surface elevation
  - Snow cover climatology
  - Land surface climatology
  - Algorithm control parameters (threshold values)

Snow Cover
Unit Description (2)





Snow Cover
Unit Description (3)

- Design Language – F90/95

- Assumptions applied to the unit design:
  - » VIIRS observation data are within specifications
  - » Cloud mask accuracy is the same as the accuracy of the current VIIRS operational cloud mask

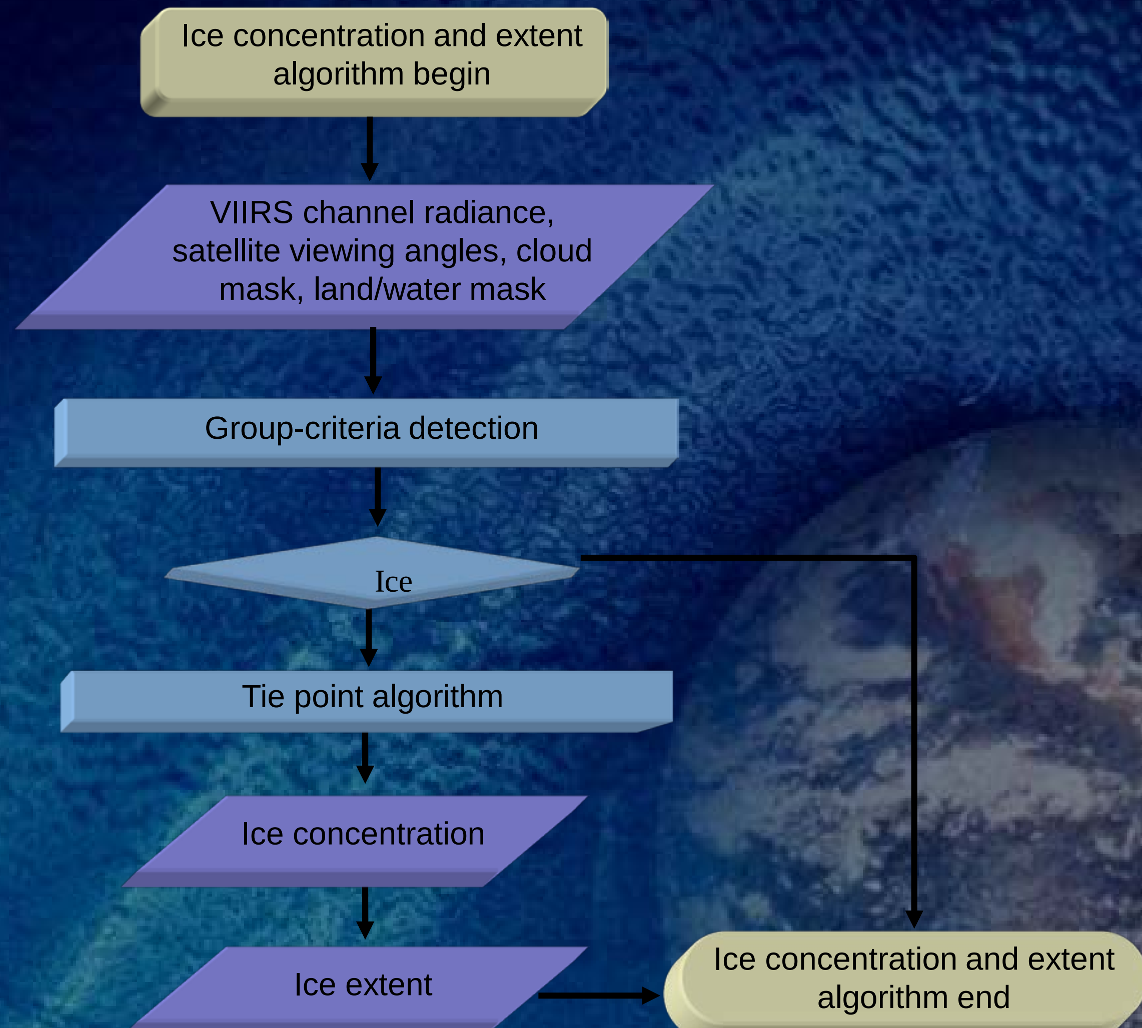
- Limitations applied to the unit design:
  - » No retrievals in cloudy conditions and at night

Ice Concentration and Cover Unit Description (1)

- Produces ice concentration and ice cover with associated quality flags.

- Interfaces
  - » VIIRS calibrated and navigated reflectance for channels I1, I2, and I3 with Brightness Temperature in Channel M5, M7, M10, M15 and M16 along with solar and satellite view angles
  - » VIIRS Cloud Mask
  - » Land/Water Mask

Ice Concentration and Cover Unit Description (2)



Ice Concentration and Cover Unit Description (3)

- Design Language – FORTRAN 90/95

- Assumptions apply to the unit design:
  - » VIIRS reflectance and brightness temperature data are within specs.
  - » Cloud mask eliminates all possible cloud contamination

- Limitations apply to the unit design:
  - » Changes of reflectance/temperature in each search window are mainly caused by difference in ice concentration

Ice Surface Temperature Unit Description (1)

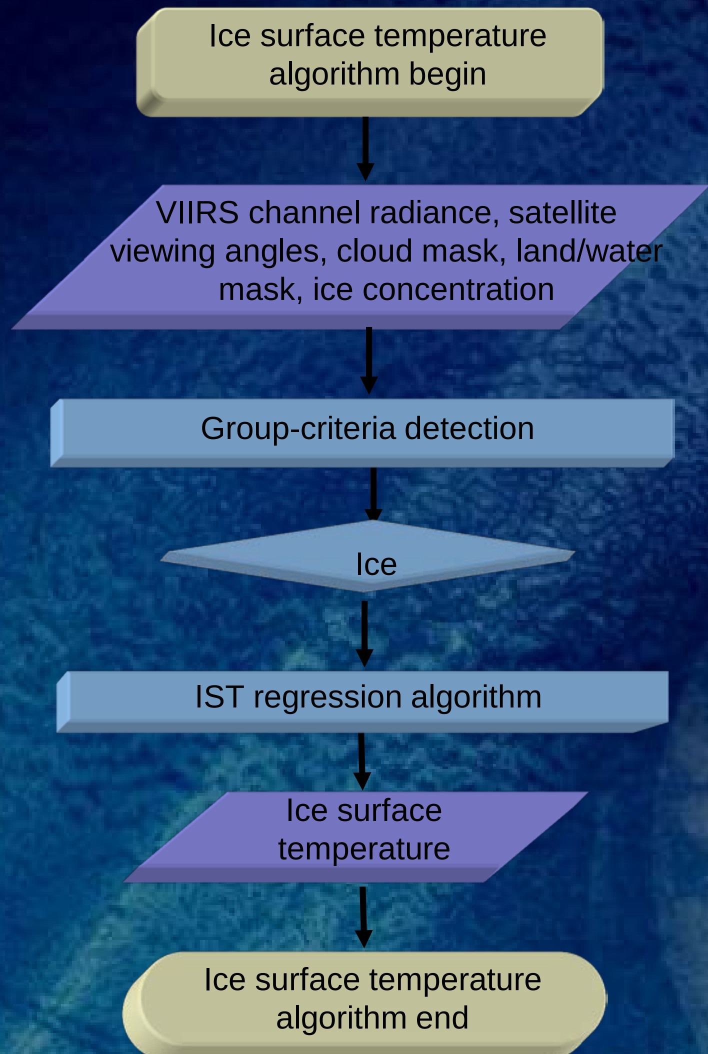
- Produce ice surface temperature with associated quality flags.
- Interfaces
  - » VIIRS calibrated and navigated Brightness Temperature in Channels M15 and M16 with solar and satellite view angles
  - » VIIRS Ice Concentration & Ice Cover
  - » VIIRS Cloud Mask
  - » Land/Coast Mask

Ice Surface Temperature Unit Description (2)

High Level Flowchart of the ice surface temperature algorithm

step1

step2



Ice Surface Temperature Unit Description (3)

- Design Language – FORTRAN 90/95

- Assumptions apply to the unit design:
  - VIIRS radiance data are within specs.
  - Cloud mask eliminates all possible cloud contamination.

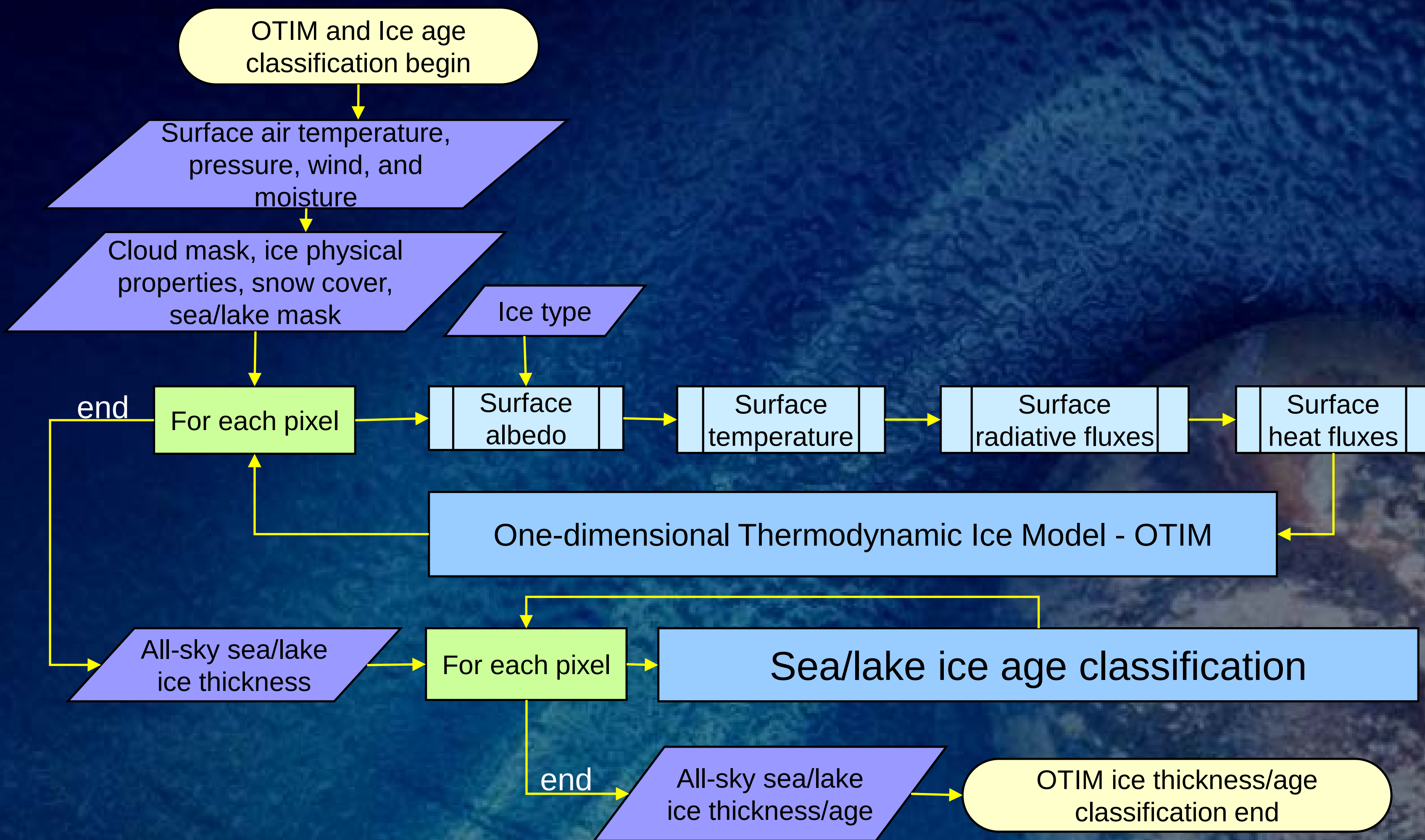
- Limitations apply to the unit design:
  - None

Ice Thickness/Age Unit Description (1)

- **Produce ice age and ice thickness with associated quality flags.**

- **Interfaces**
  - » **VIIRS Cloud mask and fraction**
  - » **VIIRS Surface skin temperature**
  - » **VIIRS Surface broadband albedo (daytime only)**
  - » **VIIRS Ice mask and concentration**
  - » **VIIRS Surface solar radiation**
  - » **VIIRS Surface thermal radiation**
  - » **VIIRS Navigation information**
  - » **Land Mask**
  - » **Ice and snow microphysical properties (coefficient file)**
  - » **Surface temp., press., moisture, wind speed, snow cover, snow depth from NWP**

Ice Thickness/Age Unit Description (2)



Ice Thickness/Age Unit Description (3)

- Design Language – FORTRAN 90/95

- Assumptions that apply to the unit design
  - » VIIRS radiance data are within specs.
  - » NWP data is available
  - » Land/Sea Mask is available
  - » All static ancillary data is available at the pixel level

- Limitations that apply to the unit design
  - » None

System Description

Output

Input

Unit/Sub-Unit	Snow Cover	Ice Concentration & Ice Cover	Ice Surface Temperature	Ice Thickness/Age
VIIRS SDR	√	√	√	√
Land & Coast Mask	√	√	√	√
Surface Elevation	√			
NWP - GFS				√
VIIRS Cloud Mask	√	√	√	√
VIIRS Snow Cover				
VIIRS Ice Concentration & Ice Cover			√	√
VIIRS Ice Surface Temperature				√
VIIRS Broadband Surface Albedo				√
VIIRS Surface Solar Radiation				√
VIIRS Surface Thermal Radiation				√
Snow Cover Climatology	√			
Land Surface Climatogy	√			
Coefficient File	√	√		√

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Algorithm Package

Presented by

Walter Wolf

VPW DAP

- The DAP shall contain:
  - » Science algorithm source code, including make files and scripts.
  - » Test plans, test description, test procedures, and detailed performance testing results.
  - » Test input data, temporary files, and expected output data.
  - » Coefficient files and/or look-up tables.
  - » Quality monitoring information (quality flags, quality flag values).
  - » Production rule-set definitions.
  - » Product file specifications – layout, content, and size.
  - » Data flow diagrams.
  - » List of exit codes and their associated messages.
  - » List of expected compiler warnings (see bullet 5 below).
  - » Estimates of resources required for execution.
  - » Algorithm Theoretical Basis Documents (ATBDs) or reference to where the ATBDs can be obtained.
  - » Delivery Memo.
  - » README text file.

VPW DAP

- Delivery memo will contain:
  - » Point(s) of contact for questions specific to the algorithm (include name, telephone, e-mail address).
  - » List of delivery contents.
  - » Purpose of the delivery, e.g. an initial release, modification, etc.
  - » Description of problem(s) resolved, if any, and method of resolution.
  - » Description of significant changes from previous version, if any.
  - » List of documents updated/added/superseded, if any.
  - » List of known remaining defects.

- The README text file in the DAP must contain:
  - » Location of all required DAP contents.
  - » DAP version number.
  - » Supporting COTS/Open Source software package requirements.
  - » Target configuration for setup (directories and files after setup scripts have been executed). This is understood to be a list of where everything is located once the DAP has been unpacked.
  - » Other pertinent information as judged by the algorithm developer(s) (e.g. compiler settings, etc.).

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- Algorithm Package
- Quality Assurance
- Risks and Actions Summary
- Summary and Conclusions

Quality Assurance

Presented by

Walter Wolf

Quality Assurance Background

- STAR has used the Capability Maturity Model Integrated (CMMI) to improve processes and practices for development and the transfer of research to operations.
- The Product Monitoring Project will follow the updated SPSRB process that has been influenced by the STAR EPL process.

Quality Assurance – Project

- The Requirements Review (December 2012)
  - » Will present the initial draft of the requirements and a Requirements Allocation Document (RAD) has been made available to the project stakeholders. It will be updated throughout the lifecycle of the project.
- The Critical Design Review (April 2013)
  - » To finalize requirements and to verify that the chosen design is able to meet those requirements.
- A Test Readiness Review (Oct 2013)
  - » Will present the unit tests to demonstrate that the system is ready to be run in the Test Environment.
- A Software Review (February 2014)
  - » Will be conducted to ensure that the Product Monitoring software is able to fulfill the functional software requirements.
- The System Readiness Review (May 2014)
  - » Will show that the Product Monitoring System is ready to be transitioned to operations.

Configuration Management (CM)

- STAR CM Tool (IBM Rational ClearCase, Version 7.0)
  - » Has been purchased and implemented in the Collaborative Environment.
- OSPO CM Tool – Subversion
  - » Open source
- CM personnel have been identified.
- CM training:
  - » Administrator training completed.
  - » If required, developers will be trained by the CM administrator.

SPSRB Coding Standards

- Coding standards guidelines and quick references are available.
- Provide a common list of abbreviations.
- Adhere to the standards throughout the development life cycle.
- Have checklists available for developers to keep track of the delivery status of the code.
- Code is checked for compiance during the software review.

Quality Assurance – Software

- The JPSS Risk Reduction software will be delivered incrementally as part of the series of algorithm package deliveries.
- This will allow system testing of the code within NDE.

Quality Assurance – Software

- All code development is being conducted on a platform that is nearly identical to the test and production target platforms using the same compilers and operating system.
- STAR code checking tools will be used to minimize coding bugs and to ensure that software meets the coding standards.
- The status of all system calls and intrinsic functions are checked.
- Unit tests will be conducted for each product individually.
  - » The PALs will have access to test data products to verify that values appear reasonable.

Quality Assurance – Software

- An official algorithm package will be delivered:
  - » All Product Monitoring code and system files
  - » Test plans
  - » Test data sets
  - » Error messaging/handling
  - » Configuration files
  - » Production rules
  - » Database specifications
  - » Data flow diagrams
  - » Estimates of resource usage
  - » Delivery memo

Quality Assurance – Products

- JPSS Risk Reduction developers will work with:
  - The algorithm developers to ensure that the implemented algorithms are producing the correct results
  - The PALs to ensure that the system has been implemented correctly
  - The users to ensure that the products are what the users require

Quality Assurance – Archive and Maintenance

- Archive Plan
  - » Currently no plan to archive any of the products
- Long Term Maintenance Plan
  - » The Product Monitoring System will be maintained by the OSPO staff
  - » STAR system developers will be available

Quality Assurance – Documentation and Metadata

- Documentation/Metadata Plan
  - » The Documentation will include the SPRSB documents with the RAD and RID
  - » Metadata associated with these products are the variables that may be used for product monitoring

Quality Assurance Summary

- Quality assurance plan will consist of:
  - » Project reviews at which stakeholders are encouraged to participate.
  - » Ongoing interaction with algorithm developers, NDE and OSPO PALs.
  - » Adhering to SPSRB software standards and use of standard libraries only.
  - » Software unit tests shall be presented in the TRR.
  - » Documentation of the code operation, production rules, and software tests will be in the algorithm package.
  - » Documentation of requirements will be in the Product Monitoring RAD.
  - » Early release of software will allow for early system implementation.

Outline

- Introduction
- Requirements
- Operations Concept
- Snow Cover
- Ice Cover and Concentation
- Ice Surface Temperature
- Ice Thickness/Age
- Software Architecture and Interfaces
- Detailed Design
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Risks and Actions

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Snow Cover Risk

- **Risk 1** Algorithm has been developed and tested with the current VIIRS operational cloud mask. Algorithm will need tuning when the NOAA unique cloud mask is used
  - » **Mitigation:**
    - – Start testing and evaluating the new cloud mask as soon as it is available

Ice Concentration, Cover and Surface Temperature Risk

- **Risk 2:** Persistent cloud cover and false cloud detection in the polar regions
  - **Mitigation:**
    - Work closely with the cloud team to ensure accurate cloud classification
    - Use alternate source of snow/ice information (GFS, IMS, Global Snow & Ice Mapping System) to flag persistent cloud

Ice Concentration and Cover Risk

- **Risk 3:** Lack of truth data for ice concentration and cover validation
  - » **Mitigation:**
    - – Work with the community to develop more truth data sites

Risk and Actions Summary

- There are currently 3 risks identified from the CDR
- All 3 risks remain open
  - » With a severity of Medium

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Summary and Conclusions

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Review Objectives Have Been Addressed

- The following have been reviewed
  - » Requirements
  - » Operations Concept
  - » Algorithm Theoretical Basis
    - – Snow Cover
    - – Ice Surface Temperature
    - – Ice Concentration and Cover
    - – Ice Thickness and Age
  - » The Software System Architecture
  - » The Detailed Design
  - » The Quality Assurance Plan

Next Steps

- Begin preparing the documentation
- Code Development phase
  - » Develop and implement algorithms
  - » Begin software deliveries to the AIT
- Test Readiness Review is the next major review for the Cryosphere products.

Open Discussion

- The review is now open for free discussion