VIIRS Vegetation Health Products (VIIRS/VHP-4)

Critical Design Review

June 26, 2014

Prepared By: Felix Kogan (STAR)
Wei Guo (IMSG)

Vegetation Index from VIIRS

VIIRS-VH CDR Agenda

Introduction	9:30 – 9:40	Felix Kogan
PDR Report	9:40 – 9:50	Felix Kogan
Operations Concept	9:50 – 10:00	Hanjun Ding
Requirements	10:00 – 10:10	Felix Kogan
Algorithm Theoretical Basis	10:10 – 10:40	Felix Kogan
Software Architecture & Interfaces	10:40 – 10:50	Wei Guo
Detailed Design	10:50 – 11:20	Wei Guo
Quality Assurance	11:20 – 11:30	Felix Kogan
Project Status	11:30 – 11:40	Felix Kogan
Risks and Actions	11:40 -- 11:50	Felix Kogan
Summary and Conclusions	11:50 -- 12:00	Felix Kogan

1) **INTRODUCTION**
2) PDR RISKS AND ACTIONS
3) OPERATIONS CONCEPT
4) REQUIREMENTS
5) ALGORITHM THEORETICAL BASIS
6) SOFTWARE ARCHITECTURE
7) DETAILED DESIGN
8) QUALITY ASSURANCE
9) PROJECT STATUS
10) RISKS AND ACTIONS
11) SUMMARY AND CONCLUSIONS

Section 1 – Introduction

Presented by

Felix Kogan
STAR Process Lead / VIIRS-VH QA

Project Objectives

- **Meet user request** # : 1105-0004 (NWS/NCEP/CPC) and 1105-0009 (USDA/FAS & WAOB)
  - » Develop S-NPP/VIIRS 4 km resolution Vegetation health (VH) products.
    - – Will be used globally by the NOAA/NWS/NCEP's Climate Prediction Center, USDA's World Agricultural Outlook Board, NWS/OAR's NIDIS, USDM, International Organizations (WMO, FAO) & others.
  - » **The current operational POES/AVHRR** 4 km VH product will be replaced by the VIIRS/VHP-4.
- Meet the specified product requirements by (a) developing & implementing a multi-channel **VH retrieval algorithm** (Kogan 2001)[1] , (b) developing **products** & (c) **providing** this product operationally to users.

[1]**Kogan. F.N., 2001**: Operational Space Technology for Global Vegetation Assessment. *Bull. Amer. Meteor. Soc*. **82**, 9, 1949-1964.

Integrated Product Team

- IPT Lead: Felix Kogan(STAR)
- IPT Backup Lead: Hanjun Ding(OSPO)
- NESDIS team:
  - STAR: Felix Kogan, Wei Guo (IMSG), Min Li (IMSG)
  - NDE: Geof Goodrum, Dylan Powell
  - OSPO: Hanjun Ding, Jing Han
  - OSD: Tom Schott
  - Data Center: NCDC
- User team
  - NWS/NCEP CPC: Contact (Matthew Rosencrans)
  - USDA WAOB: Contact (Eric Luebehusen)
- Product Oversight Panel: Land Surface POP (LSPOP)

Project Stakeholders

- NESDIS/STAR, OSPO, OSD, NCDC, NDE

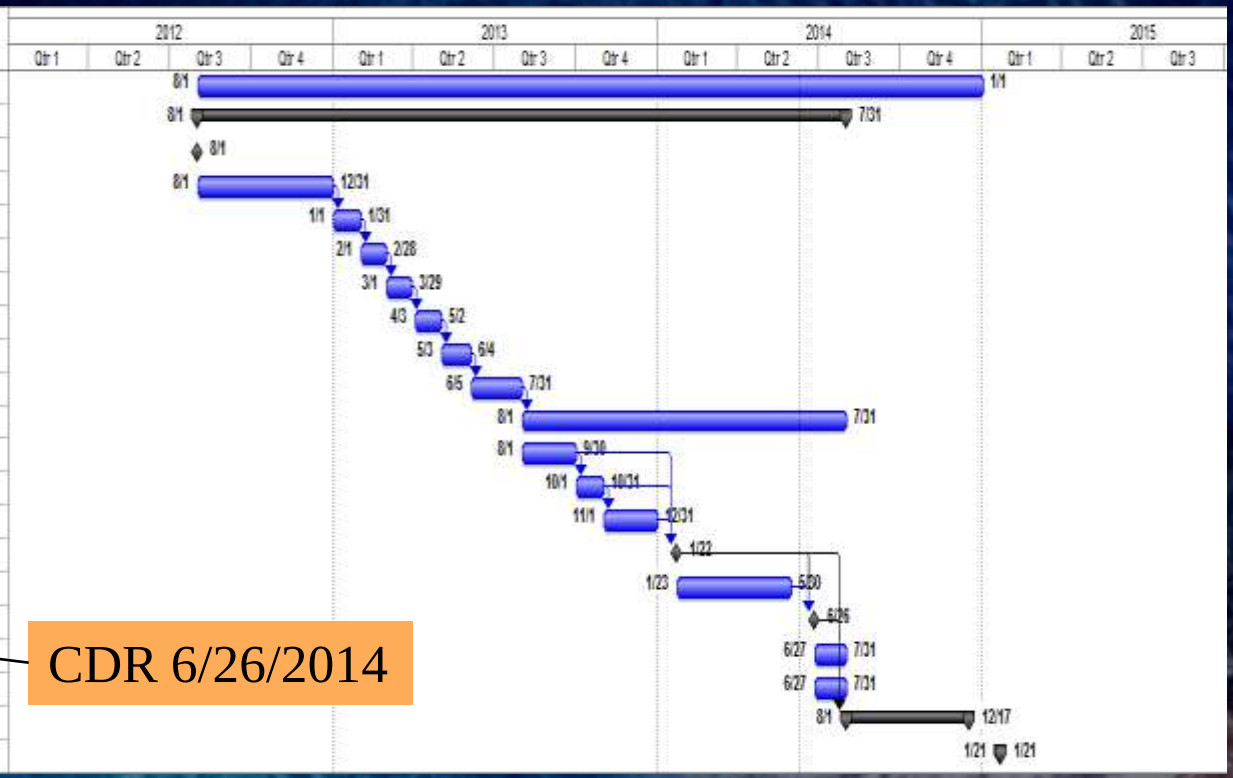
- NWS/NCEP CPC
- NWS/OAR NIDIS
- USDA WAOB
- USDM

Project Plan (1)

- Year 1 – Design and Development (2013 – 2014)
  - Verify Requirements
  - Design the **VIIRS VH system**
  - VIIRS SDR **data retrieval**
  - Calculate **NDVI & BT**
  - Develop **daily composite map**
  - Develop **weekly composite map**
  - Conduct **PDR**
  - Produce NDVI & BT time series and **noise removal**
  - Develop **adjustment** for VIIRS NDVI and BT
  - Develop **climatology** records
  - Develop **VH products**
  - Conduct **CDR**

Project Timeline

ID	Task Name
1	VIIRS-Veg. Health Project
2	**Development Phase**
3	VIIRS becomes operational providing data; Start of VIIRS & MODIS data collection
4	Development of VIIRS daily composite maps and files; Calculation of NDVI & BT
5	Development of procedur for spatial data sampling, data geolocation & filing gaps
6	Adjusting VIIRS NDVI and BT to the AVHRR parameters
7	High frequency noise removal from the adjusted NDVI & BT
8	Testing the adjusted NDVI and BT with standard VH climatology
9	Calculation of VIIRS-VH indices (VCI, TCI, VHI) & time series
10	Testing the VH indices against in situ data
11	Beginning of operational product development
12	Initial Archive Requirement identified
13	Quality Monitoring Concept Defined
14	Long term maintenance concept defined
15	Preliminary Design Review
16	Development processing system defined
17	Critical Design Review
18	Code is prepared
19	Final Archive requirements identified
20	**Pre-Operational Phase**
30	**Operational Phase Begins**



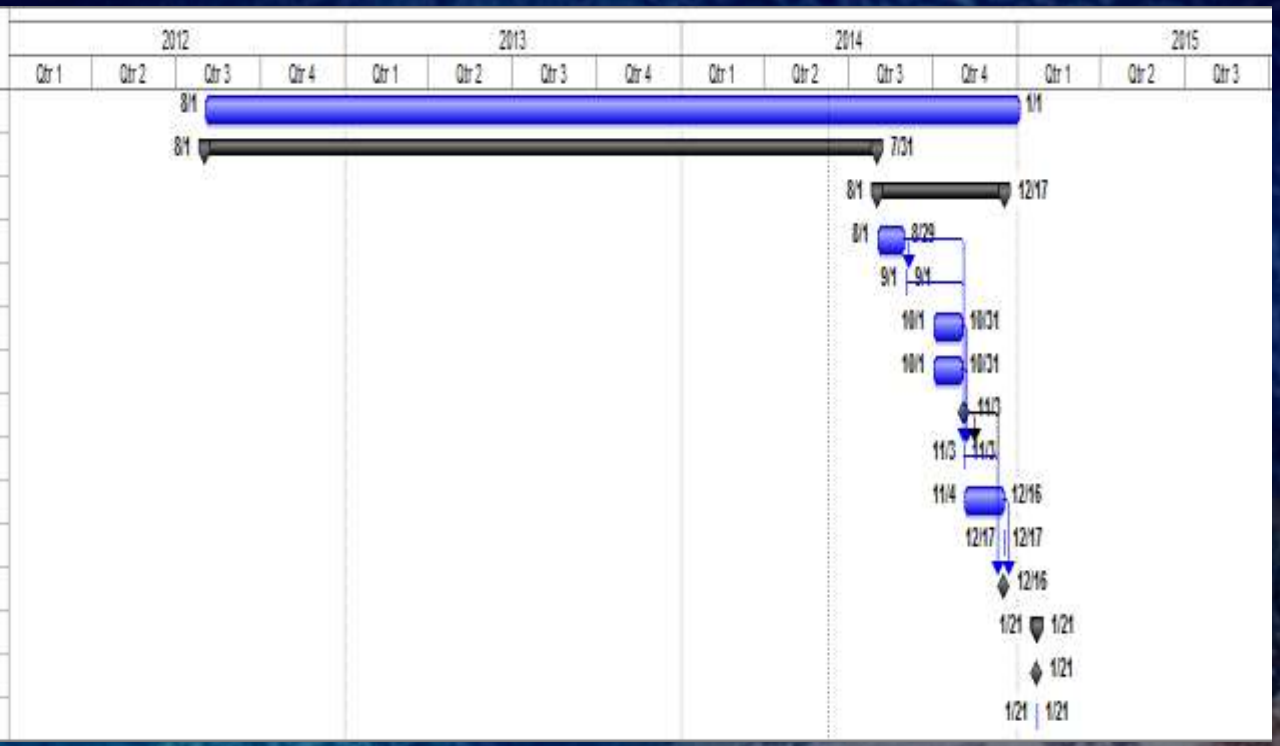
CDR 6/26/2014

Project Plan (2)

- Year 2 –Transition to Pre-Operations (2014 – 2015)
  - » **Validation**
  - » Algorithm **adjustment**
  - » **Implement** VIIRS VH system
  - » Conduct Algorithm Readiness Review for products
  - » Transition and test system within the **NDE** environment
  - » Conduct **Code Review** for products

Project Timeline contd.

ID	Task Name
1	VIIRS-Veg. Health Project
2	Development Phase
20	Pre-Operational Phase
21	Software Code Review
22	Initial DAP to NDE
23	Provide test data to users
24	Pre-operational product output evaluated and tested
25	Algorithm Readiness Review
26	Final DAP to NDE
27	Code transitions to operations; all documentation is complete
28	Brief SPSRB Oversight Panel on product status
29	Brief SPSRB capability is ready to go operational
30	Operational Phase Begins
31	SPSRB declares product operational
32	End users start using VH system operationally



Project Milestones

- Preliminary Design Review -- 01/22/2014 (Jan14)
- Critical Design Review -- 06/26/2014 (Jun 14)
- Software Code Review – 08/29/2014
- Algorithm Readiness Review -- 11/03/2014
- Decision Briefing to SPSRB – 12/17/2014

CDR Entry Criteria

- Requirements Document
- Veg. Health PDR Report
- Review of Project:
  - Requirements **(R)**
  - Operations Concept **(OC)**
  - Algorithm Theoretical Basis **(ATBD)**
  - Software Architecture **(SA)**
  - Detailed Design
  - Quality Assurance **(QA)**
  - Risks and Actions

CDR Exit Criteria

- Veg. Health **CDR Report**
  - The report will contain:
    - Actions
    - Comments
    - CDR presentation
- Updated Veg. Health RID
- Updated Veg. Health RAD

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Section 2 –
PDR Risks and Actions

Presented by

Felix Kogan

PDR Report

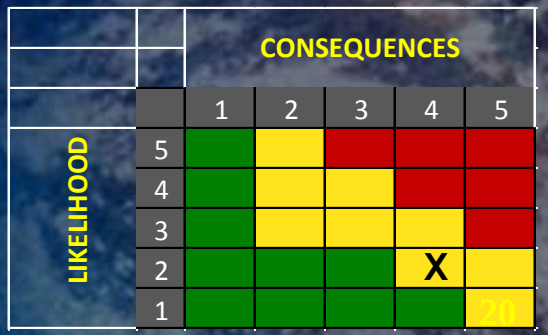
- The PDRR includes the status of the PDR entry criteria and exit criteria
- The PDRR includes assessment of risk items, with recommendations for risk mitigation
  - » Status of the risk items will be addressed later in this CDR
- The PDRR has established the entry criteria and exit criteria for the VIIRS-VH CDR
- The **PDRR can be accessed at** http://star.nesdis.noaa.gov/smcd/emb/vci/VHsecure/ViirsVHdoc.php

*PDR Report

- The VIIRS Veg Health Review Item Disposition (RID) spreadsheet contains the projects Review Items
- The RID covers the following:
  - » PDR Risks, Actions, and Comments
  - » CDR Risks, Actions, and Comments
- Risks closed in previous reviews are not shown here, but are located in the RID and are identified by a green color
- Risks shown here that are marked as “closed” will be closed with the approval of this review and are identified in the RID with a light blue color.
- Change in Impact and Likelihood in the RID are identified by a blue color

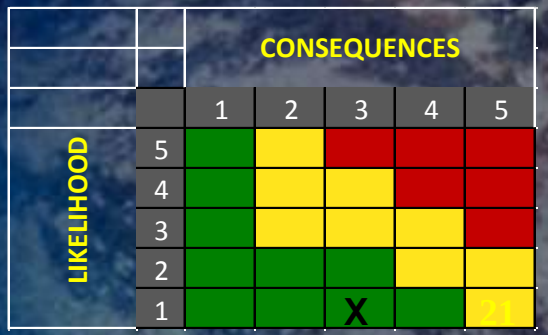
PDR Risks and Actions

- **Risk 1:** Align file nomenclature with **NDE standards**
  - » NDE standard requires creating time in file name
- **Risk Assessment:** Low
- **Impact:** If NDE standards are not followed, then will impact production of intermediate and final product
- **Likelihood:** Low
- **Mitigation:** Adjusted file names to NDE standards
- **Status:** Closed



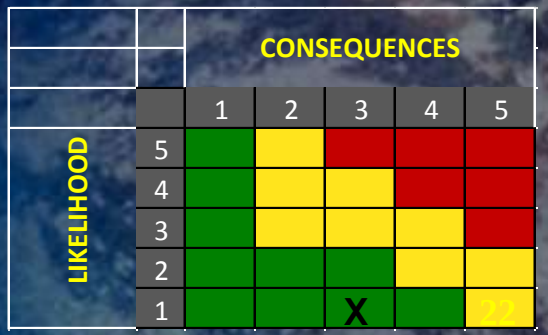
PDR Risks and Actions

- **Risk 2: Update climatology as needed** (using most recent dataset).
- **Risk Assessment:** Low
- **Impact:** If climatology data is not updated then will impact quality of the VIIRS VH product
- **Likelihood:** Low
- **Mitigation:**
  - » Update climatology by using from longer series of data set
- Status: Open



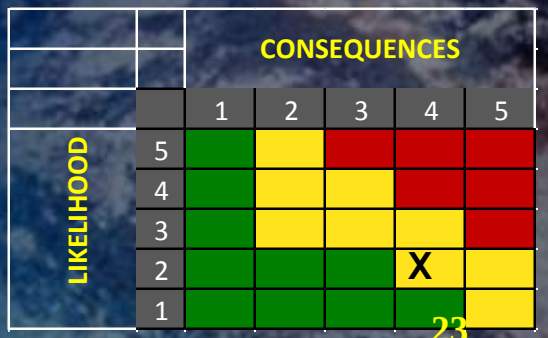
PDR Risks and Actions

- **Risk 3: Adjust VIIRS NDVI/BT** to AVHRR equivalent
- **Risk Assessment:** Low
- **Impact:** If proper adjustments are not made then the product will not meet requirements.
- **Likelihood:** Low
- **Mitigation:**
  - » Continue investigation of stability VIIRS NDVI/BT – AVHRR NDVI/BT relationship;
  - » Update the adjustment parameters
- **Status:** Open



PDR Risks and Actions

- **Risk 4: Run program in NDE environment** with limited resource (disk space and CPU) and controlled by process control file (PCF).
- **Risk Assessment:** Medium
- **Impact:** If the VHP system is not able to run using planned NDE resources, then product will not meet latency.
- **Likelihood:** Low
- **Mitigation:**
  - » Meet with NDE personnel to understand the limitations
  - » Change program interface and make the program more efficient.
- **Status:** Closed



PDR Review Item

- **Review item 5:** Update PDR slides with the following:
  - 83 & 84 – Replace ESPC DDS with NDE Distribution Servers moving to PDA
  - 85 – For Test say “NDE PE-2” for Operations say “NDE PE-1”
  - 86 – Ingest will be via IDPS; Ancillary will be from ESPC (DDS now, but PDA close the date this project is operational.
  - 88 – Needs to be revised to show NDE PE-1 and PE-2 systems
  - 92 – Wei and Kathy won’t be involved in distribution services. I’d remove those bullets. Keep bullet 1 and change my role to “Distribution Lead”
  - 93 – Not sure what you mean by the 2nd bullet about real-time product monitoring. NDE will provide monitoring on product production (as well as system monitoring mentioned in your 1st bullet). There will be no other monitoring by help desk. Product personnel will monitor product quality 8x5 via Zhaohui’s system
  - 98 – same note as slide 86

Mitigation: Made updates.

PDR Review Item

- **Review item 6:** Update NDE system specifications with the following:
  - Product Generation Servers:
  - 2 Dell Linux Servers (adding 4 more late Spring 2014) each w/:
  - 1.5 TB local storage, this is for everything – OS, algorithm binaries/scripts, static ancillary data – and multiple algorithms running multiple simultaneous jobs on the same server
  - 24 Intel CPUs @ 2.67 GHz (64 bit)
  - 35 GB (total memory)
  - OS: Linux RHEL 5 x86_64
  - SAN: 60 TB (product retention period is configurable)
  - Distribution: FTPS push or pull (8 Dell Linux Servers – 4 for push and 4 for pull)

Mitigation: Made slide update

PDR Review Item

- **Review item 7: Verification slide will** be in ATBD
- **Mitigation:**
  - » Update the slides.

PDR Review Item

- **Review item 8:** Identify and recognize that the performance of the VIIRS VHP will adhere to **JPSS L1RD** supplement requirements. The CDR slides should include the table from the JPSS L1RD and show how VHP meets requirements.
- **Mitigation:**
  - » Updated slide prior to CDR

Risk and Actions Summary

- There are currently 8 PDR Risks and Review Items identified for the Veg. Health Product project.
  - » Of the 4 Risks 2 have been closed
  - » All the 4 Review Items have been closed
  - » The severity of the 2 remaining Risks are Low

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Section 3 –
Operations Concept

Presented by

Hanjun Ding(OSPO)
VIIRS-VH Development PAL

Operations Concept - Overview

- Identify intentions of the customers/users of the products
- 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 Vegetation Health System Integrated 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?

- The VIIRS VHP system will produce a weekly product that consists of three vegetation health indices,
  - » Vegetation Condition Index (VCI)
  - » Temperature Condition Index (TCI)
  - » Vegetation Health Index (VHI)
- Each index will be a global gridded composite map in Lat/Lon projection with 4km resolution at the equator.
- Specific product requirements, based on SPSRB User Request, will be discussed later in this CDR

What is the Product - Cont.
Product Deliverable Details

					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	VIIRS-VegHealth-4	Vegetation Condition Index	S-NPP	VIIRS	1			1		Formats: NetCDF, GeoTiff, PNG; Resolution: 4km, Weekly
FY15	VIIRS-VegHealth-4	Vegetation Health Index	S-NPP	VIIRS	1			1		
FY15	VIIRS-VegHealth-4	Temperature Condition Index	S-NPP	VIIRS	1			1		

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

Why Are The Products Being Produced?

- The VIIRS-VH will provide continuity to existing AVHRR derived VH products
  - » Longest records (34-year)
  - » Highest spatial resolution (4 km)
  - » Weekly composite
  - » Including indices from infrared channels
  - » Suppressed noise
  - » Biophysical climatology
  - » Useful for monitoring the environmental and socioeconomic activities

How Will The Products Be Used? – NCEP CPC

- Weekly gridded (4 km) vegetation health products in latitude/longitude geographic projection will be used to improve drought monitoring and early detection
- NWS/NCEP/CPC will acquire VHP directly via ftp pull from the NDE Distribution Servers moving to PDA
  - » Weekly composite netCDF4 file at 4-km resolution
  - » Weekly composite PNG file at 4-km resolution
  - » PNG file is also desired for monitoring and displaying

How Will The Products Be Used? USDA WAOB

- Weekly gridded (4 km) vegetation health products in latitude/longitude geographic projection will be used to improve crop/pasture production predictions
- The USDA WAOB expects to acquire VHP directly via ftp pull from the NDE Distribution Servers moving to PDA
  - » Weekly composite GeoTIFF file at 4-km resolution

How Should The Products Be Produced?

- There will be three distinct environments
  - » Development Environment (STAR)
    - – Development and unit testing of pre-operational codes will be conducted on Redhat Linux OS in STAR
  - » Test Environment (OSPO)
    - – Pre-operational codes and documents (DAP) received from STAR will be implemented and tested on NDE PE-2 and modified as needed before it is promoted to operations
  - » Operations Environment (OSPO)
    - – Operational DAP will be run on NDE-PE-1 Linux machine and the products monitoring images will be posted on the intranet web server and accessed under ESPC VPN by operators, PALs and maintenance programmers

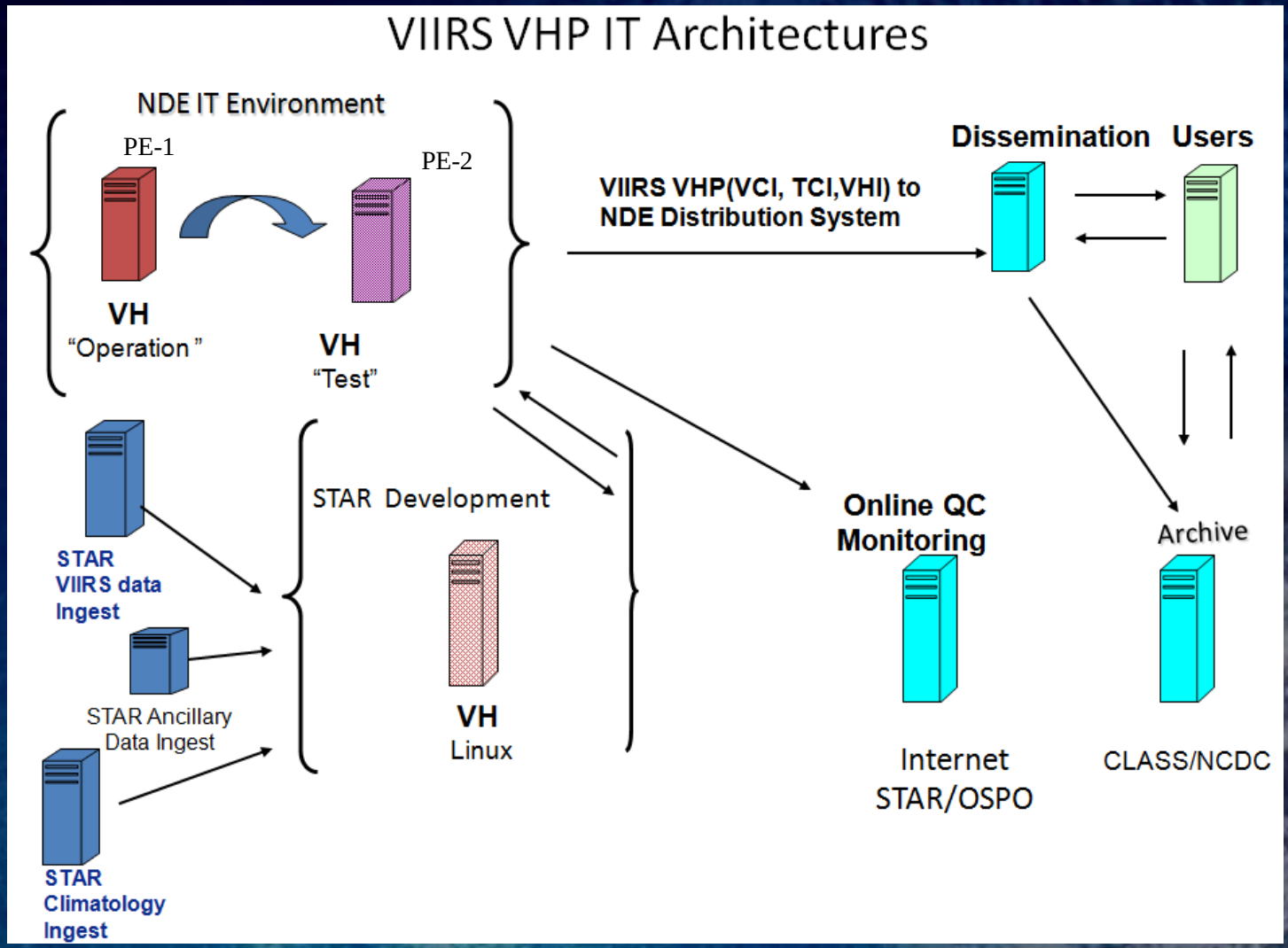
How Should The Products Be Produced? (Cont.)

- Production and Delivery Scenarios
  - The ESPC Ingest systems will handle all input satellite data via IDPS and ancillary data from ESPC (DDS now, but PDA close the date this project is operational).
  - The VHP product system will collect the satellite inputs and required ancillary data to run the VHP algorithms
  - The generated weekly VH indices are written to output files in the required formats (netCDF4, Geo-Tiff, PNG).
  - The products in NetCDF4 will be distributed to CLASS for archive purpose
  - The VHP metadata will be provided to the product monitoring tool system
  - The product users will be granted access to the ESPC distribution system through the data access request submission process
  - ESPC will handle the distribution of VHP products

Development Environment – Function

- A development system will be established on a Linux server in the STAR Collaborative Environment (CE)
- Science code will be adapted into pre-operational software units that implement the VHP algorithm in accordance with the system design.
- Unit tests will be conducted to ensure that the software units function as designed, producing expected outputs from defined inputs.
- Code will be modified as needed to achieve successful completion of the unit tests.
- Following successful unit testing, software units will be integrated into an integrated pre-operational system
- A system test will be conducted to ensure that the integrated pre-operational system meets all requirements

VIIRS VHP IT Architectures



Development and Operational System Environments

Project Name:	VIIRS VHP	
IT Item	**Research**	**Operations**
Agency	STAR	OSPO
Platform(s) and need dates	1 Dell Linux Server with 2 Gigs of RAM 2012	Linux Servers with 2 Gigs of RAM 2013/2014
Operating Systems	Red Hat Linux	Linux
Programming languages/compilers *	C++, IDL, C-shell	C++, IDL, C-shell
Scripting languages	Perl	Perl, C shell
Graphical/Imaging programs, COTS S/W, other tools, libraries, etc	IDL	IDL on Linux
Helpdesk Monitoring Tool (standardized tool or customized tool?)	Standard Tool	Customized Website
Other platforms needed for monitoring/imaging/graphics (specify platform & operating system)	None	Linux Servers
Other (tools, shareware, libraries, critical non-static ancillary data, etc)	NetCDF, HDF, GeoTIFF	NetCDF, HDF, GeoTIFF

Red font indicates new IT resource requirements for this project
Blue font indicates existing IT resources will be used for this project

Operational Agency System Requirements

Project Name:	VIIRS VHP			
			Back-up Operations	
IT Item	Development	Operations	On-Site	Off-Site
Agency	STAR	OSPO(ESPC)		CIP
Platform(s) and need dates (include secondary platforms for monitoring, imagery or graphics, if necessary)	1 Dell Linux Servers w/ 2 Gigs of RAM2/2012/13	Linux server with 2 Gigs of RAM 2014/15	Linux server with 2 Gigs of RAM 2014/15	Linux server with 2 Gigs of RAM 2014/15
Storage required on systems	2 TB per server	SAN 20 GB per server	SAN 20 GB per server	SAN is mirrored
How often does system run	daily	daily	daily	Quarterly
Memory used at run time	2 GB	2 GB	2 GB	2 GB
Input data volume and input data sources	1 TB per day VIIRS SDR data on STAR disk library	1 TB per day VIIRS SDR data on disk	1 TB per day VIIRS SDR data on disk	1TB per day VIIRS SDR data on disk
Data volume for distribution; planned distribution server; specific push users & volumes	1 GB per week	1 GB per week	1 GB per week	N/A
Communication Requirements/Protocol	Internet	ESPC Data Distribution Server, FTP Internet	ESPC Data Distribution Server, FTP	N/A
Days to retain input and output data	3 days for input orbits 7 days for daily composite 15 weeks for weekly output	3 days for input orbits 7 days for daily composite 15 weeks for weekly output	3 days for input orbits 7 days for daily composite 15 weeks for weekly output	3 days for input orbits 7 days for daily composite 15 weeks for weekly output

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Development and Operational System Maintenance Resources

- Felix Kogan (STAR) – Development Readiness and Quality Control support
- Wei Guo (STAR) – Development support
- Kathy Moore(OSPO) – Operational Maintenance support
- Hanjun Ding (OSPO) – Operational Readiness and Quality control support

Distribution Environment – Capabilities and Resources

- NDE Data Distribution System

- Personnel
  - » NDE Personnel
  - » Donna McNamara (OSPO) – Distribution Lead
  - » Jing Han (OSPO) NDE Lead

Production Scenarios – Monitoring and Maintenance

- NDE will provide the system monitoring capability
- OSPO PAL will perform product quality monitoring as part of the Product Monitoring project.
- OSPO PAL and STAR Scientists will perform routine validation of the VHP products

Production Scenarios – Monitoring and Maintenance – (cont.)

- Production Monitoring and Maintenance Scenarios
  - The product monitoring images will be monitored by ESPC operators and email alerts will be generated when an anomaly occurs
  - The PAL and maintenance personnel at OSPO will monitor the product monitoring system's function and resolve any issues.
  - The maintenance personnel at OSPO will maintain and back up the database

Vegetation Health System Requirements

- The Vegetation Health 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

- An Archive Product will be produced for the CLASS archive.
- The Archive Product will be the output netCDF4 files that are produced by the Weekly Production run.
- Delivery may also include metadata files and supporting documentation

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 VHP data products to the user community
  - » Resolves user issues through coordination with the Vegetation PAL (Products Area Lead).
- The Vegetation PAL will coordinate further with the STAR Vegetation health scientists for any product quality issues when identified and communicate with users.

Summary

- The Ingest Systems will handle all input satellite data via IDPS and ancillary data will be from ESPC (DDS now, but PDA close the date this project is operational).
- OSPO will run the VH system to produce VCI, TCI, and VHI
- VH products will be sent to CLASS for archive and web server for product monitoring and displaying
- OPSO PAL and STAR scientists will perform product validation
- NCEP and USDA will use the VH products within their models and applications

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Section 4 – Requirements

Presented by

Felix Kogan

Requirements Overview

- SPSRB Requirements were presented to the developers in a document entitled: "Joint Polar Satellite System (JPSS) Program Level 1 Requirements SUPPLEMENT – Final"
- All VHP requirements are presented here as. Additional requirements were obtained in a series of discussions between the developers, EMC (the customer) and the heritage product teams.
- Text in yellow are those requirements derived from the original SPSRB requirements.
- Requirements which have been updated/added since the last review are in green.
- A Single Requirements Allocation Document (RAD) has been generated for the VIIRS-VH project.

Veg. Health Requirements shown with the JPSS L1RD Supplement Requirements

Veg. Health Index Suit

EDR Attributes	JPSS L1RD	Veg. Health Product System
Horizontal Cell Size	Threshold – 0.036º (4km) Objective – 0.018º, 0.009º (2,1 km)	Threshold – 0.036º (4km) Objective – 0.018º, 0.009º (2,1 km)
Vertical Reporting Interval	NS	NS
Mapping Uncertainty, 3 sigma	Threshold – <0.036º (4km) Objective – <0.018º, <0.009º , <0.0045º	Threshold – <0.036º (4km) Objective – <0.018º, <0.009º , <0.0045º
Measurement Precision	Threshold – 4.0% (For the range 0-100%) Objective – NS	Threshold – 4.0% (For the range 0-100%) Objective – NS
Measurement Accuracy	Threshold – 1.0% Objective – NS	Threshold – 1.0% Objective – NS
Refresh	Threshold – Every 7 day period Objective – Every 5 day period	Threshold – Every 7 day period Objective – Every 5 day period

Requirements #0

- VIIRS-VH-R 0.0: *The Vegetation Health Products (VHP) development project shall* ***adopt the standard practices of the Satellite Product and Services Review Board (SPSRB)****, except for specific tailored practices to be itemized in derived requirements (0.x).*

- VIIRS-VH-R 0.1: *The VHP development project practices shall be tailored from the SPSRB process.*

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Requirements #1 (1)

- VIIRS-VH-R 1.0: *The VHP system shall generate a gridded weekly Vegetation Health Product.*

- Derived Requirement 1.1 to 1.4:
  - *Horizontal resolution:* ***0.036 degree (4 km)***
  - *Projection:* ***Lat/Lon***
  - *Temporal resolution:* ***Week***
  - *Latency :* ***4 hours after*** *the 7-day period*

Requirements #1 (2)

- Derived Requirement 1.5 to 1.10
  - *VHP Products include:*
    *Vegetation Condition Index (**VCI**)*
    *Temperature Condition Index (**TCI**)*
    *Vegetation Health Index (**VHI**)*
  - *VHP Products measurement range: **0-100%***
  - *VHP Products accuracy: **<4%***
  - *Quality information: Added*
  - *Validation & verification: Added*
  - *Generate **NetCDF4** files*
  - *Flag anomalous values*
  - *Generate imagery*

Requirements # 2

- VIIRS-VH-R 2.0: *The VHP system shall have a data ingest capability*

- VIIRS-VH-R 2.1: *The VHP system shall read daily orbit **VIIRS L1b** radiances in the visible (band I1), near infrared (band I2) and thermal (band I5) channels.*
  - VIIRS-VH-R 2.1.1: *The VIIRS SDR data shall be ingested from **SCDR** server or NDE server.*
  - VIIRS-VH-R 2.1.2: *The VIIRS data shall be SDR swath data **in HDF5** format.*

- VIIRS-VH-R 2.2: *The VHP system shall read ancillary data.*
  - VIIRS-VH-R 2.2.1: *Ancillary data shall include 30 arc second resolution **Land Sea Mask converted to HDF format**.*
  - VIIRS-VH-R 2.2.2: *Ancillary data shall include **Land Cover Type from IGBP converted to HDF format.***

Requirements #3 (1)

- VIIRS-VH-R 3.0: *The VHP system shall implement the VHP algorithm to generate VCI, TCI, and VHI*

- VIIRS-VH-R 3.1: *The VHP algorithm shall perform the processing functions described in the VHP ATBD*
  - VIIRS-VH-R 3.1.1: *The VHP algorithm shall create **daily maps** for each band by projecting VIIRS observations from each channel into geographic grid.*
  - VIIRS-VH-R 3.1.2: *The VHP algorithm shall create **a weekly composite** of VIIRS channels 1, 2, and 5 by selecting the pixels with maximum NDVI value from 7 VIIRS daily maps.*
  - VIIRS-VH-R 3.1.3: *The VHP Algorithm shall calculate a raw **NDVI** for the calibrated weekly composite.*
  - VIIRS-VH-R 3.1.4: *The VHP Algorithm shall **adjust the raw NDVI** using statistical technique.*
  - VIIRS-VH-R 3.1.5: *The VHP Algorithm shall apply a digital smoothing filter on NDVI and BT.*
  - VIIRS-VH-R 3.1.6: *The VHP Algorithm shall calculate/update **NDVI and BT climatology** from the multi-year smoothed NDVI and BT time series.*

Requirements #3 (2)

- VIIRS-VH-R 3.1.7: *The VHP Algorithm shall **calculate Vegetation Condition Index (VCI).***
- VIIRS-VH-R 3.1.8: *The VHP Algorithm shall calculate Temperature Condition Index **(TCI).***
- VIIRS-VH-R 3.1.9: *The VHP Algorithm shall calculate Vegetation Health **Index (VHI).***

- VIIRS-VH-R 3.2: *The VHP algorithm shall be implemented by processing code written **in C++.***
- VIIRS-VH-R 3.3: *The VHP processing code shall be able to run in the Development Environment (**Linux, Red Hat**).*
- VIIRS-VH-R 3.4: *The VHP processing code shall be able to run in the **NDE Operational Environment (Linux).***

Requirements # 4

- VIIRS-VH-R 4.0: *The VHP system shall generate a **metadata product** for the NCDC CLASS archive facilities.*

Requirement # 5

- VIIRS-VH-R 5.0: *The VHP system shall have QC monitoring capability.*
- VIIRS-VH-R 5.1: *The VHP system output shall include overall **quality control flags** and quality summary level metadata.*
- VIIRS-VH-R 5.2: *The VHP system shall be **capable of monitoring product distribution status** to ensure that the data/products are successfully available for transfer to the user community.*

Requirement # 6 (1)

- VIIRS-VH-R 6.0: *The VHP developers shall produce a fully functional pre-operational system in the STAR Development Environment.*
- *The Development Environment shall :*

  VIIRS-VH-R 6.1: *be capable of hosting the* ***conversion of VHP science code to VHP pre-operational code.***

  - VIIRS-VH-R 6.1.1: *include* ***a C++ compiler.***

  VIIRS-VH-R 6.2: *be capable of hosting unit tests and a system test.*

  - VIIRS-VH-R 6.2.1: *have* ***2 GB of memory.***
  - VIIRS-VH-R 6.2.2***: 2 TB of data storage****.*
  - VIIRS-VH-R 6.2.3: *have* ***access to VIIRS data****.*
  - VIIRS-VH-R 6.2.4: *have* ***access to ancillary data****.*

Requirements for #6 (2)

- VIIRS-VH-R 6.3: *The Development Environment shall* ***host the VHP pre-operational system.***
  - » VIIRS-VH-R 6.3.1: *The pre-operational system shall include all processing code and ancillary files needed to conduct unit tests.*
  - » VIIRS-VH-R 6.3.2: *The pre-operational system shall include all input test data needed to conduct unit tests.*

- VIIRS-VH-R 6.4: *The Development Environment* ***shall host the VHP integrated pre-operational system.***
  - » VIIRS-VH-R 6.4.1: *The integrated pre-operational system shall include all processing code and ancillary files needed to conduct a system test.*
  - » VIIRS-VH-R 6.4.2: *The integrated pre-operational system shall include all input test data needed to conduct a system test.*

Requirement # 7

- VIIRS-VH-R 7.0: *The VHP integrated pre-operational system shall be transitioned in the form of a **Delivered Algorithm Package (DAP)** generated following the standards set in the Standards for Algorithm Delivery and Integration using Delivered Algorithm Package (DAP) v1.4 , from the STAR Development Environment to **NDE**'s Operational Environment*

Requirements #7 cont.

- VIIRS-VH-R 7.1: *The integrated pre-operational system shall include all processing code and ancillary files needed to reproduce the system test.*
- VIIRS-VH-R 7.2: *The integrated pre-operational system shall include all input test data needed to reproduce the system test.*
- VIIRS-VH-R 7.3: *The integrated pre-operational system shall include all output data produced by the system test.*
- VIIRS-VH-R 7.4: *The VHP development team shall deliver the integrated pre-operational system to NDE as a Delivered Algorithm Package (DAP) following standards set in the Standards for Algorithm Delivery and Integration using Delivered Algorithm Package (DAP) v1.4 document to NDE's Science Algorithm Development and Integration Environment (SADIE)*
  - » VIIRS-VH-R 7.4.1: *VHP shall be transitioned from SADIE to NDE TEST Environment by NDE personnel*
-

Requirement # 8

- VIIRS-VH-R 8.0: *The VHP shall **deliver a document package to NDE.***
- *The VHP document package shall include:*
  - VIIRS-VH-R 8.1: *a **README** text file.*
    - VIIRS-VH-R 8.1.1: *The README file shall list each item in the final pre-operational system baseline, including code, test data, and documentation.*
  - VIIRS-VH-R 8.2: *a Review Item Disposition (**RID**) document.*
    - VIIRS-VH-R 8.2.1: *The RID shall describe the final status of all development project tasks, work products, and risks.*
  - VIIRS-VH-R 8.3: *an Algorithm Theoretical Basis Document **(ATBD**).*
  - VIIRS-VH-R 8.4: *a Requirements Allocation Document **(RAD**).*
  - VIIRS-VH-R 8.5: *a System Maintenance Manual (**SMM)**.*
  - VIIRS-VH-R 8.6: *an External Users Manual (**EUM**).*
  - VIIRS-VH-R 8.7: *an Internal Users Manual **(IUM**).*
  - VIIRS-VH-R 8.8: *The SRRR shall document the approved readiness of the integrated pre-operational VHP system for transition to operations.*

Requirement #9

- VIIRS-VH-R 9.0: *The VHP system shall* ***comply with OSPO Code Review Security check lists.***

- *The VHP system shall comply with OSPO*
  - VIIRS-VH-R 9.1: *data integrity check list.*
  - VIIRS-VH-R 9.2: *security check list.*
  - VIIRS-VH-R 9.3: *code check list.*

Requirement # 10

- VIIRS-VH-R 10.0: *The VHP developers shall* ***specify IT resource needs for operations.***

- *The VHP system shall be able to :*
  - VIIRS-VH-R 10.1: *process data using 2 TB of data storage.*
  - VIIRS-VH-R 10.2: *operate on a Linux operational server.*

VHP System Requirements – Summary

- The VHP 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.
- As development continues the detailed product requirements shall continue to be refined.

1) INTRODUCTION
2) PDR RISKS AND ACTIONS
3) OPERATIONS CONCEPT
4) REQUIREMENTS
5) **ALGORITHM THEORETICAL BASIS**
6) SOFTWARE ARCHITECTURE
7) DETAILED DESIGN
8) QUALITY ASSURANCE
9) PROJECT STATUS
10) RISKS AND ACTIONS
11) SUMMARY AND CONCLUSIONS

Section 5 –
Algorithm Theoretical Basis

Presented by

Felix Kogan

Algorithm Theoretical Basis

- **Purpose: Provide** product developers, reviewers and users with a theoretical description (scientific and mathematical) of the algorithm that is used to create a product that meets user requirements.
- Documented in the Algorithm Theoretical Basis Document (ATBD)
  - » SPSRB Guidelines for the ATBD are at http://projects.osd.noaa.gov/spsrb/doc_standards_guildlines.htm
  - » ATBD v1r1, a PDR artifact, is available at http://www.star.nesdis.noaa.gov/smcd/emb/vci/VHsecure/ViirsVHdoc.php

Algorithm Objectives (1)

- **34-year data records** characterizing climate, land cover, atmosphere near the ground was created from the Advanced Very High Resolution Radiometer (AVHRR) flown on the NOAA polar-orbiting satellites (POES).
- **Several global data sets** have been developed from the AVHRR records since the early 1980s (Tarpley et al 1984, James and Kalluri 1994, Kidwell 1997, Tucker et al 2004), including:
  - NOAA's Global Vegetation Index (GVI and GVI-2, AVHRR-VHP),
  - NASA's Pathfinder
  - NASA's Global Inventory Modeling and Mapping Studies (GIMMS)

Algorithm Objectives (2)

- Background1: The NOAA/GVI, NASA/Pathfinder & GIMSS datasets from AVHRR **focused only on the Normalized Difference Vegetation Index (NDVI**), ignoring infrared measurements, which are very useful for monitoring land, climate and socioeconomics
- Background2: In 2012, NOAA developed a new AVHRR-based dataset entitled the Vegetation Health Product- VHP (Kogan 1995, 1997). The VHP has **advantages** over other long-term global data sets:
  - » Higher spatial resolution (4 km)
  - » Data, indices and products from infrared channels
  - » Originally observed reflectance and emission
  - » Basic indices with suppressed long- and short-term noise
  - » Biophysical climatology
  - » Products for monitoring environmental and socioeconomic activities
  - » Biophysical theory and interpretation

  - The new Polar-orbiting Operational satellite system (SNPP and JPSS) requires development of the new VHP

Algorithm Objectives (3)

- VIIRS has the VIS,NIR and IR bands similar to AVHRR. They can be used to develop Vegetation Health product similar to AVHRR-VHP for monitoring the environment & continuity of data records.

Table 3.2.1-1 Summary of AVHRR/3 Spectral Channel Characteristics

Parameter	Ch. 1	Ch. 2	Ch. 3A	Ch. 3B	Ch. 4	Ch. 5
Spectral Range (μm)	0.58-0.68	.725-1.1	1.58-1.64	3.55-3.93	10.3-11.3	11.5-12.5
Resolution (km) *	1.09	1.09	1.09	1.09	1.09	1.09

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

Retrieval Strategy

- **Read VIIRS SDR** granule data from image bands (VIS-I1, NIR-I2, & IR-I5 bands), geo-location and geometry angles for each VIIRS granules.
- **Project** VIIRS/SDR's I1, I2 & I5 granule data to a basic GVI grid map
- Develop I1, I2 & I5 **VIIRS daily map**.
- Calculate **NDVI** from I1 and I2 & brightness temperature (**BT**) from I5
- Generate NDVI and BT **weekly maps** performing 7 day compositing procedure
- Generate NDVI and BT **weekly time series**
- Remove **high frequency noise** from NDVI and BT time series
- **Adjust VIIRS's** NDVI and BT to the standard climatology
- **Read** adjusted NDVI and BT climatology
- **Generate weekly maps** of Vegetation Condition Index (**VCI**) & Temperature Condition Index (**TCI**) from no noise NDVI & BT plus their climatology
- Generate weekly maps Vegetation Health Index (**VHI**) from VCI and TCI

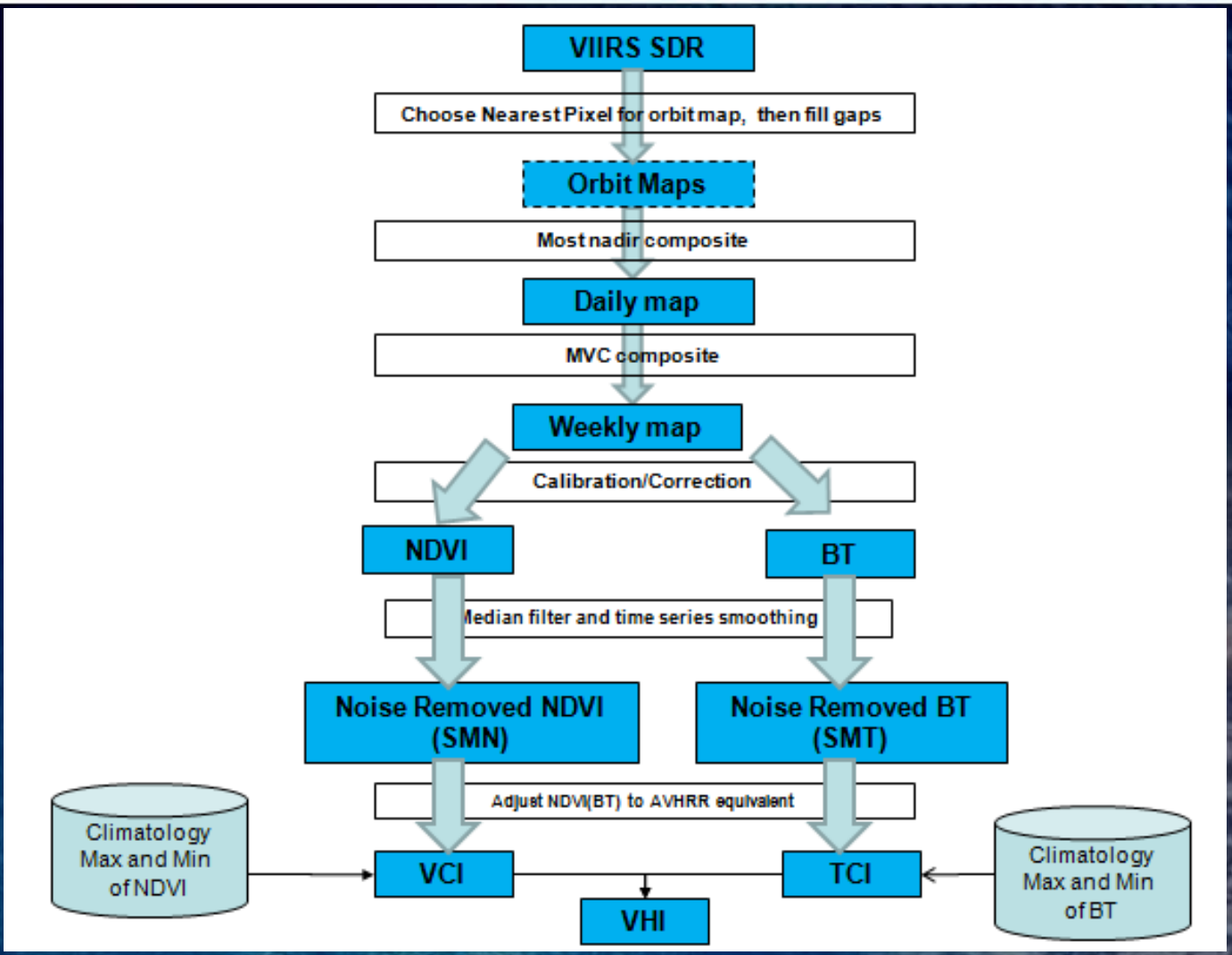
Processing Overview – Major Processing Steps (1)

- Step 1: **Retrieval** of VIIRS I1, I2, I5 radiances, solar & satellite geometry angles from the Scientific Data Records (SDR) granules and **mapping** into geographic grid (GG) or Plate Carree projection.
- Step 2: **Filling gaps**
- Step 3: Development of **daily map**
- Step 4: Development of **weekly composite map** by selecting the pixels with maximum NDVI value from 7-day maps.

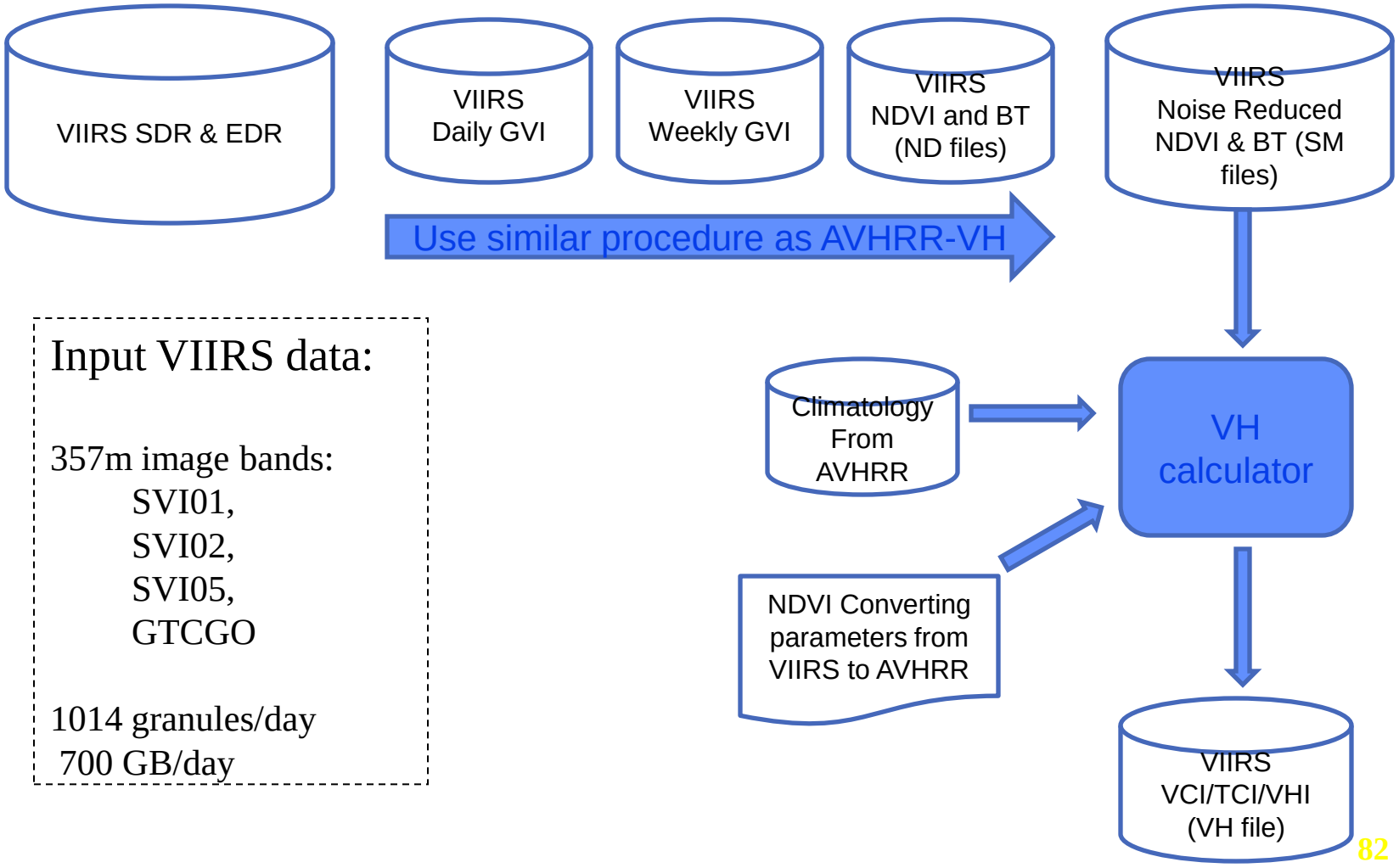
Processing Overview – Major Processing Steps (2)

- Step 5: **Calculation** of NDVI (from I1 and I2) and BT (from I5)
- Step 6: **Noise removal** from NDVI and BT
- Step 7: Calculate/**update climatology** of NDVI and BT based on three biophysical laws (Law-of-Minimum, Law –of –Tolerance and Carrying Capacity).
- Step 8: **Adjustment** of no noise NDVI and BT to the standard climatology
- Step 9: **Calculation** of VCI, TCI and VHI.

VHP Algorithm Process Flow



VIIRS-VH system System Level Data Flow



Input VIIRS data:

357m image bands:
- SVI01,
- SVI02,
- SVI05,
- GTCGO

1014 granules/day
700 GB/day

Algorithm Inputs – VIIRS Data

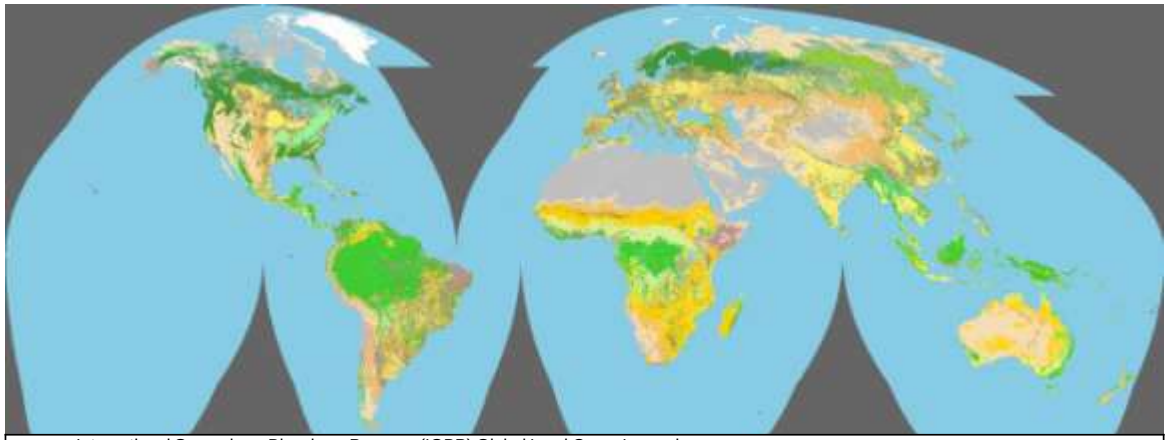
- VIIRS Visible and near infrared channels (I1 – 0.64µm, I2 - 0.86µm) are used to produce the NDVI. VIIRS SDR files are organized by data type and granule. There are about 1014 granules per day. The following VIIRS SDR files are required for each granule.
- SVI01: reflectance's image **band I1**
- SVI02: reflectance's image **band I2**
- SVM03: reflectance of moderate band 3 (optional)
- SVI05: emission's image **band I5**.
- IICMO: cloud information
- GITCO: geo-location file, including the data fields: latitude, longitude, solar and sensor zenith angles.
-
- Other optional data generated by JPSS as intermediate products are also useful for **analysis** of VH products:
- VLSTO: land surface type
- VIVIO: EVI at the top of canopy
- VSCMO: snow cover bitmap
- VSTYO: vegetation fraction and surface type

Algorithm Inputs – Land / Sea Map

- USGS land sea mask in lat-lon grid with columns = 43200 and rows=21600, resolution 30 seconds.
- Covers full surface of the earth, latitude:[-90S to 90N], longitude: [-180,180].
- The first pixel is at [-180,90N].
- landseamaskll.img
  - » Original raster image 43200x21600, 1 byte per pixel.
  - » This file was obtained from Dr. Aleksandar Jelenak.
- landseamaskll.img.bit
  - » The binary data of bit map converted for above raster image, 1 bit per pixel.
- landseamaskll.bit.hdf
  - » The HDF file contains the above bit map. 1 bit per pixel.
  - » This file will be used as input when making daily and weekly composite maps.

Algorithm Inputs – Land Cover Map

- The International Geosphere-Biosphere Programme (IGBP) Land Cover map is used to correctly set the Quality Assessment (QA) for areas where the Vegetation Health retrieval capability of the VHP algorithm is weak, such as desert area.
- Global coverage at a 30 arc second resolution using 17 categories.
- Details are available at http://edc2.usgs.gov/glcc/



International Geo-sphere Biosphere Program (IGBP) Global Land Cover Legend

Code	Class Name
0	INTERRUPTED AREAS (GLOBAL GOODES HOMOLOSINE PROJECTION)
1	EVERGREEN NEEDLELEAF FOREST
2	EVERGREEN BROADLEAF FOREST
3	DECIDUOUS NEEDLELEAF FOREST
4	DECIDUOUS BROADLEAF FOREST
5	MIXED FORESTS
6	CLOSED SHRUBLANDS
7	OPEN SHRUBLANDS
8	WOODY SAVANNAS
9	SAVANNAS
10	GRASSLANDS
11	PERMANENT WETLANDS
12	CROPLANDS
13	URBAN AND BUILT-UP
14	CROPLAND/NATURAL VEGETATION MOSAIC
15	SNOW AND ICE
16	BARREN OR SPARSELY VEGETATED
17	WATER BODIES
100	NO DATA

(ftp://edcftp.cr.usgs.gov/pub/data/glcc/globe/latlon/igbp2_0.leg)

Algorithm Inputs – NDVI and BT Climatology

- AVHRR NDVI and BT climatology maps were generated from nearly 30 year smoothed weekly NDVI and BT.
- There are 8 data fields: maximum, minimum, mean and standard deviation for NDVI and BT respectively. They are statistics based on smoothed NDVI and BT on a **pixel by pixel basis**.

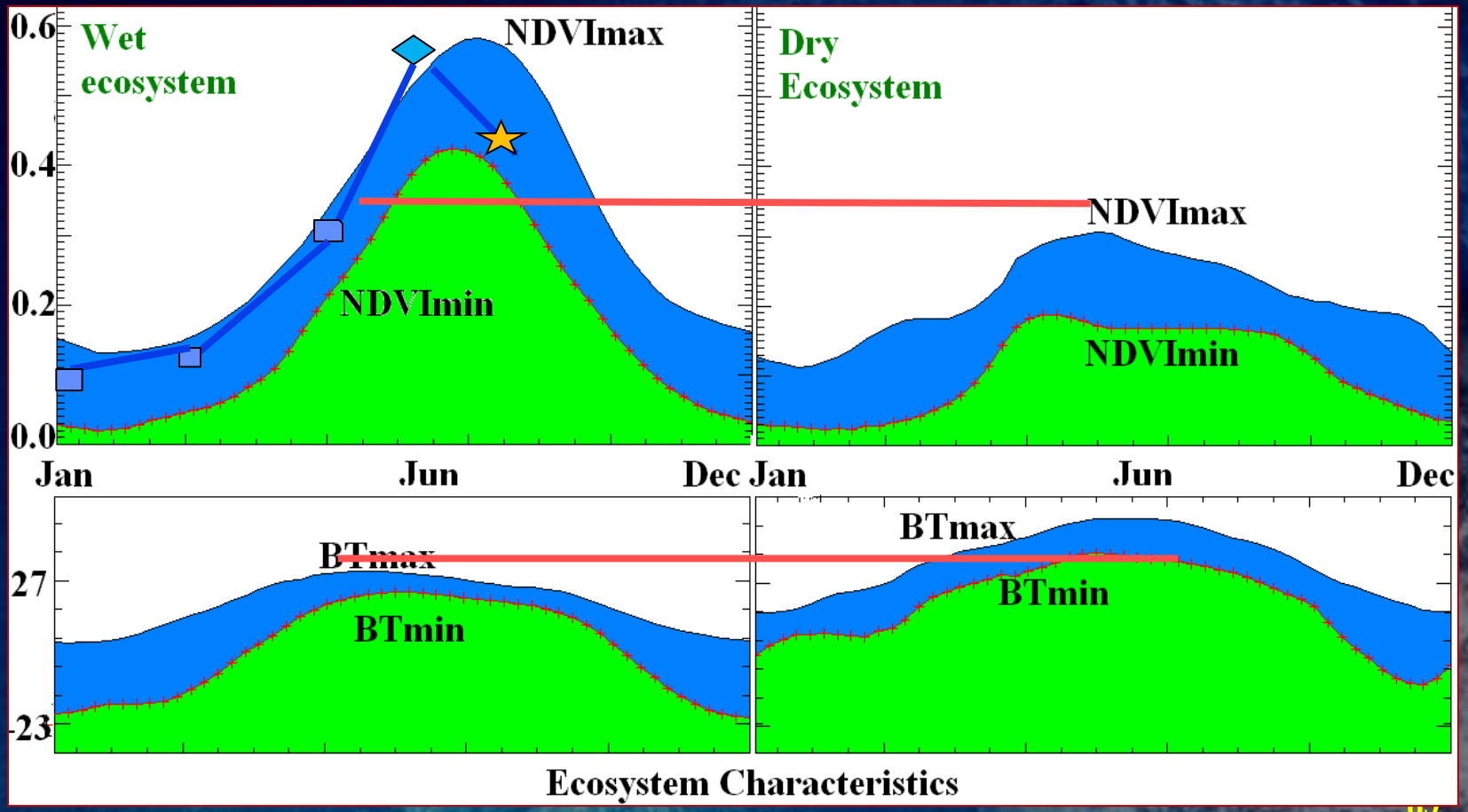
Theoretical Description

- After noise removal, weather-driven differences in NDVI and BT between the years become apparent: lower NDVI and higher BT in dry years and opposite in normal and wet years.
- This principle of comparing NDVI and BT for a particular year with their dry-wet range calculated from 30-year observations was laid down in the VHP algorithm development.
- The absolute maximum and minimum of NDVI and BT during 1981-2005 were calculated for each of the 52 weeks and for each pixel.
- They were then used as the criteria to estimate the upper (favorable weather) and the lower (unfavorable weather) limits of the ecosystem resources.
- For estimation of weather impacts on vegetation condition, NDVI and BT values for a particular time (one week or several weeks) were normalized relative to the absolute max/min interval.
- Following this procedure, NDVI and BT were rescaled to better characterize vegetation response to weather impacts:
  - » Vegetation Condition Index (VCI) - characterizes moisture conditions
  - » Temperature Condition Index (TCI) - characterizes thermal conditions
  - » Vegetation Health Index (VHI) - characterizes vegetation health

NDVI & BT Carrying Capacity Central USA

Wet Ecosystem

Dry Ecosystem



Mathematical Description

- VCI=100*(NDVI-NDVImin)/(NDVImax-NDVImin) (3.1)
- TCI=100*(BTmax - BT)/(BTmax - BTmin) (3.2)
- VHI = *a**VCI + (1- *a*)*TCI (3.3)

- NDVI, NDVImax, and NDVImin (BT, BTmax, and BTmin) are the smoothed weekly NDVI (BT), their multi-year absolute maximum, and minimum, respectively.
- The VCI, TCI and VHI approximate the weather component in NDVI, BT and their combination values. They fluctuate from 0 to 100, reflecting changes in vegetation conditions from extremely bad to optimal.
- The weighting factor (a) in equation 3.3 was determined by experience, currently, a=0.5).

Out of Range Indices

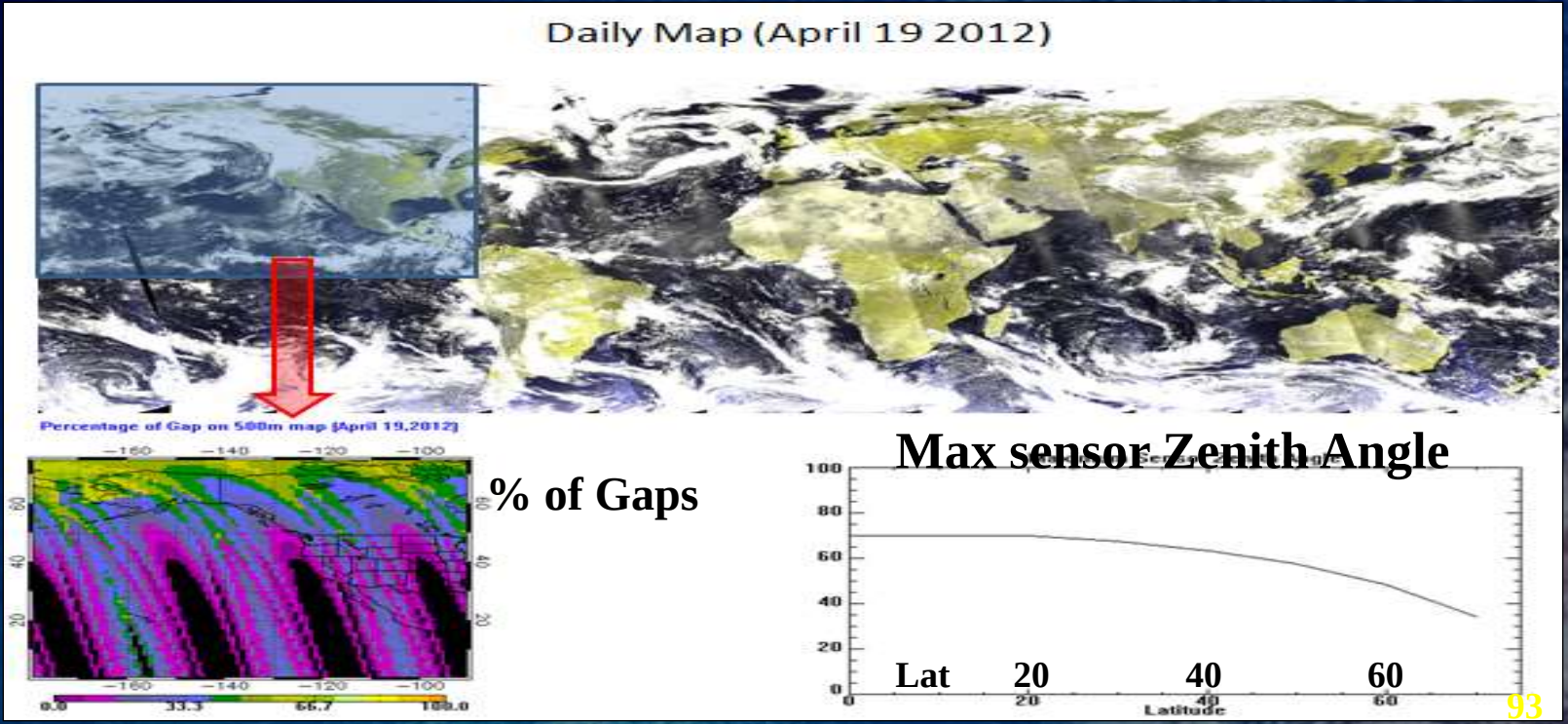
- Due to some limitation of climatology, it is possible for equation 3.1 & 3.2 to produce VCI and TCI out of climatology range (< 0 or > 100).
- In such rare cases VCI and TCI are reset to 0 or to100, respectively.
- These rare cases do not indicate poor quality of the products.

VIIRS daily map

- Challenge in creating VIIRS daily map
  1. Huge data volume (1TB)
  2. Huge number of data files (1014x 6)
  3. Duplicate /missing files -- SDR file contains file creation time
  4. Gaps in original resolution data
  5. Granule overlapping

VIIRS daily map

- Two steps procedure for creating VIIRS daily map
  - Orbit Maps →Daily map
  - Orbit map: pick pixels close to grid center
  - Daily map: pick pixels close to nadir



Weekly Composite

- Daily data are aggregated to a weekly composite using a Maximum Value Compositing (MVC) method (saving the day with the highest NDVI during a 7-day period).
- The compositing starts on the first day of a year and the first compositing period must have at least four days in the same year.

Weekly Composite (NDVI)

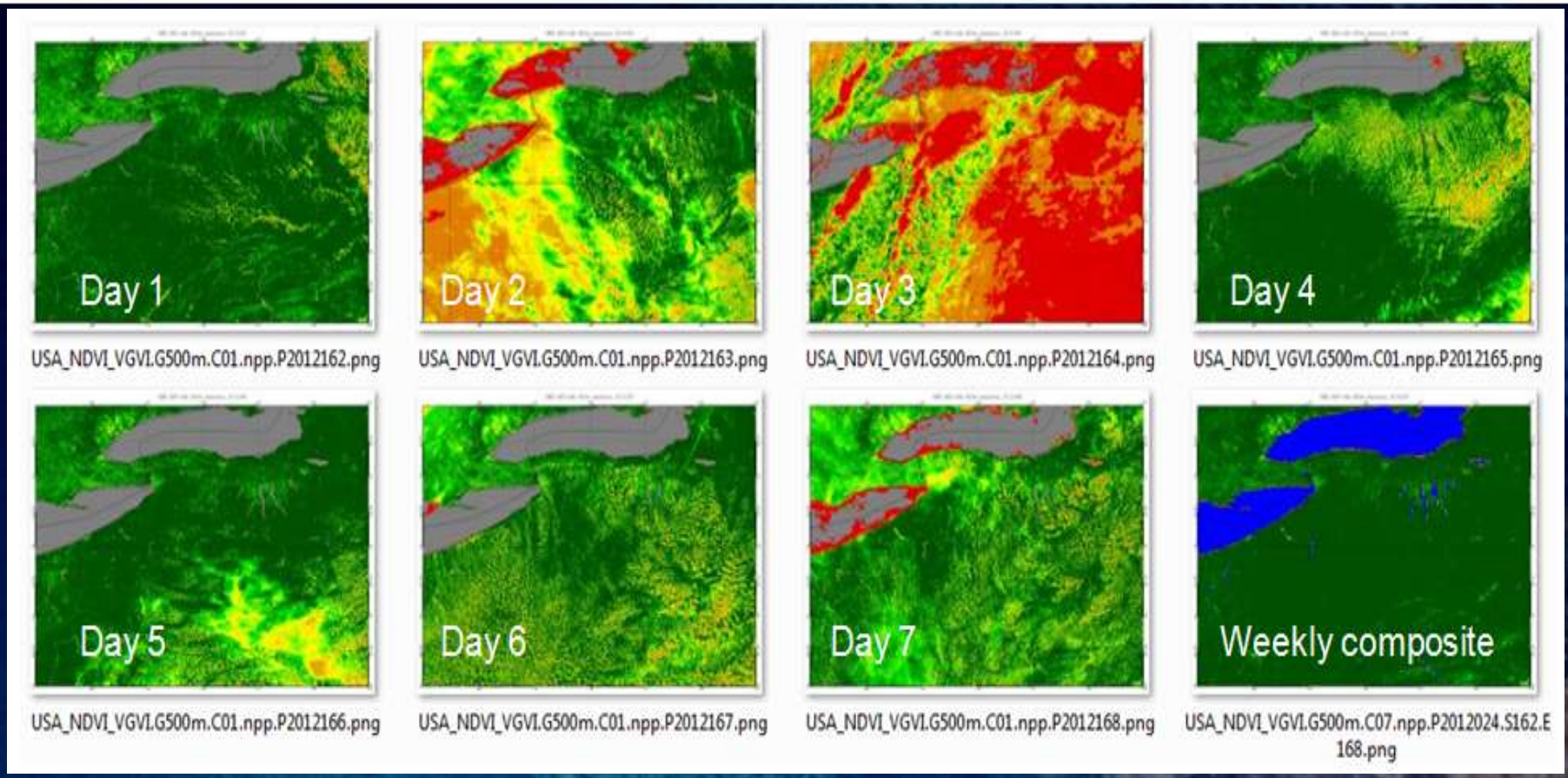
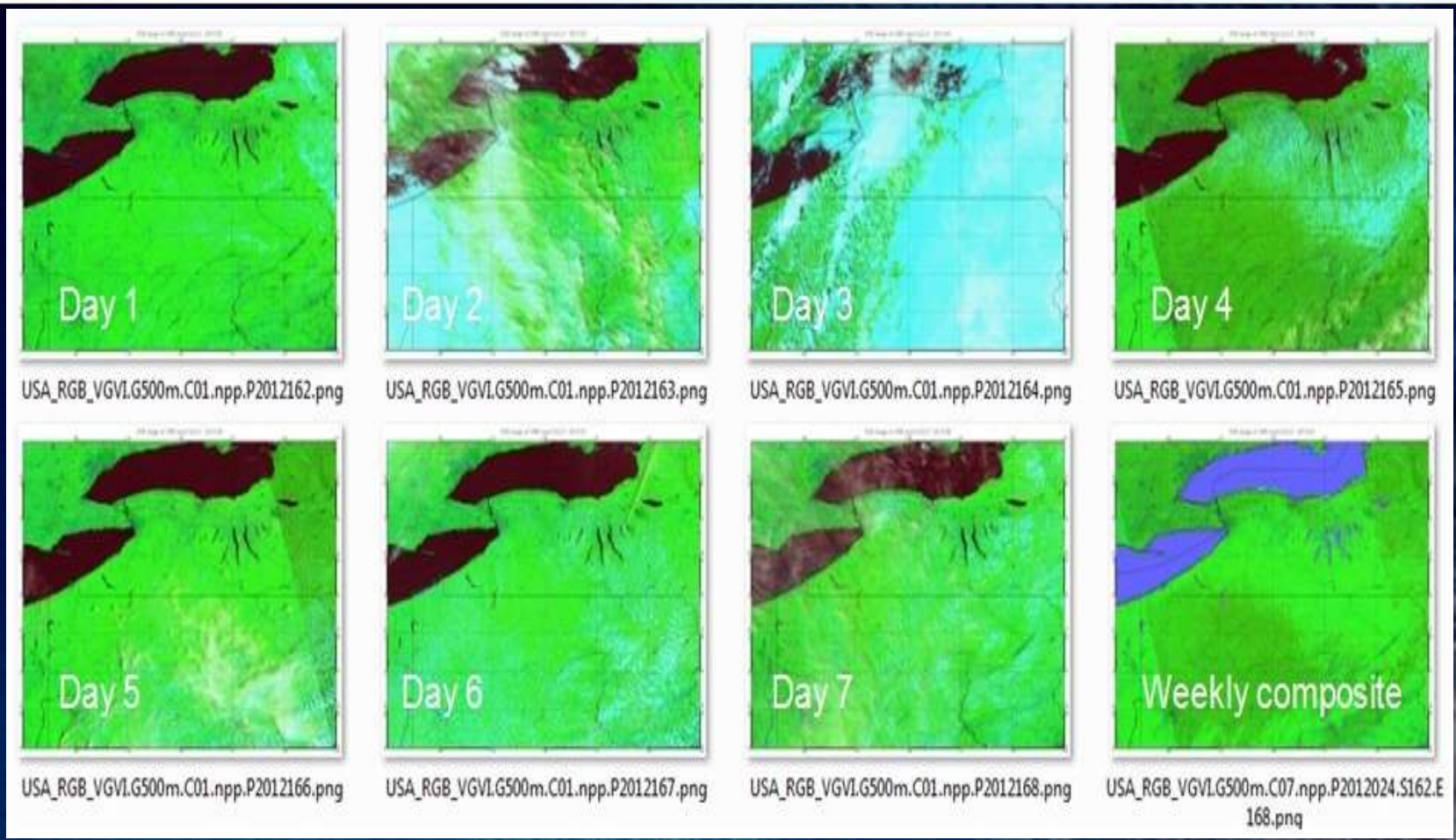


Image of daily and weekly composed NDVI, NDVI on some daily maps was very low because they were contaminated by cloud, while, the weekly composite successfully reduced the cloud contamination.

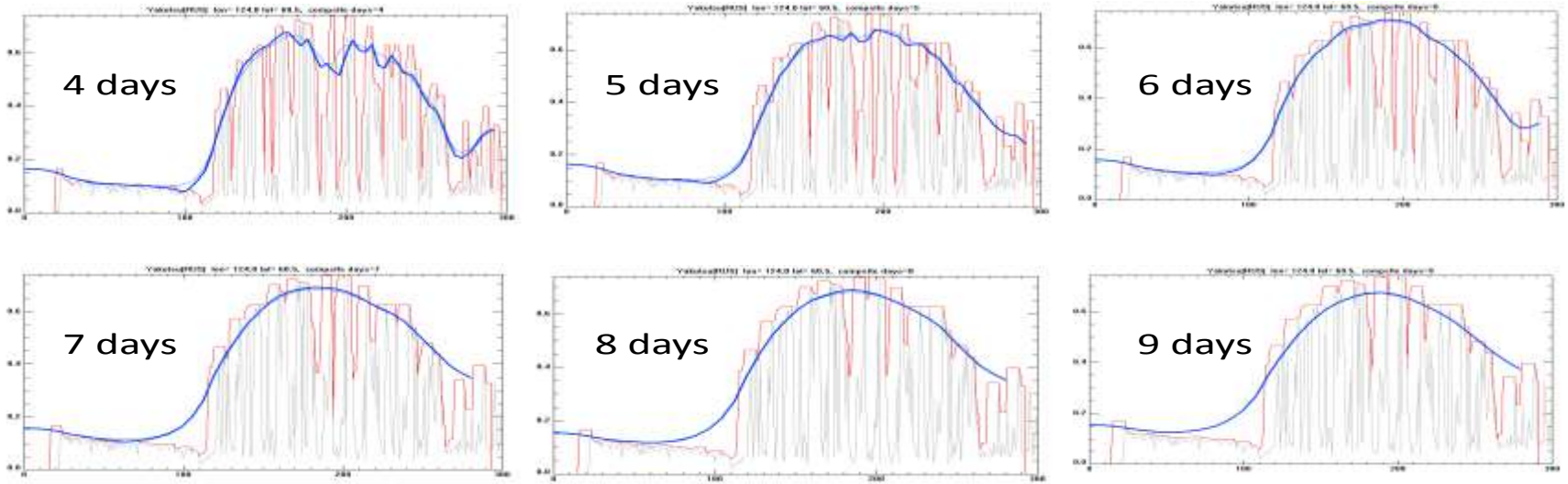
Weekly Composite (RGB-clouds)



RGB Image of daily and weekly composed map, Cloud can be seen on some daily maps.

Selecting weekly composite procedure

Smoothed Time Series by various Number of composite days



Grey: raw NDVI
Red: N-days Max NDVI composite
Blue thick: smoothing NDVI by sliding smoothing window = (composite days*2+1)
Blue thin: smoothing NDVI by sliding smoothing window =whole time series

NDVI time series smoothed by various number of composite days. Six and seven days composite is the best choice for this case.

Noise

- Noise in VIIRS data creates fundamental constraints to the remote sensing of the Earth.
- The noise sources are physical, geometrical, mechanical, mapping, environmental, random etc; some of them long-term, some short-term and some both (Kogan *et al* 1996, Rao and Chen 1993, 1999, Cracknell 1997, Kidwell 1997).
- Clouds and other atmosphere constituents (aerosol, water vapor etc) obscure the land surface reducing NDVI considerably. In case of unusual events, such as sharp volcanic aerosol increase, NDVI can be depressed for a long time (Kogan et al., 1994).
- Changes in viewing and illumination geometry can lead to both an increase and decrease in NDVI depending on location, type of vegetation, position of sun and sensor.
- Satellite orbital drift, sensor degradation, and satellite change create long-term noise in NDVI data, especially after a satellite has been in service for more than three years.

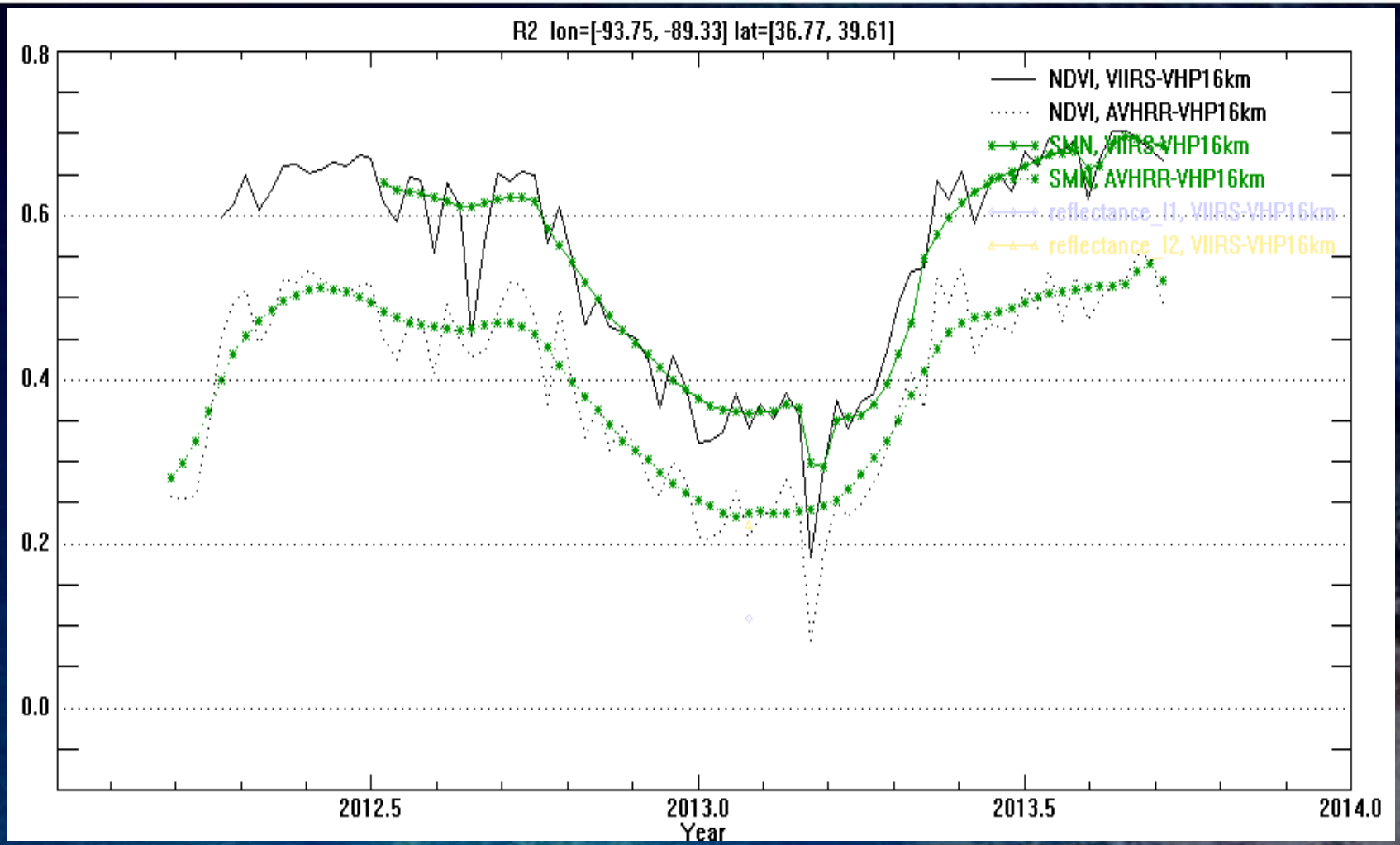
Noise Reduction Principles

- Different sources of noise affect NDVI & BT either reducing their values (sensor degradation, orbital drift, equator crossing time, atmospheric attenuation, volcanic eruptions, etc) or increasing (spectral response function, off-nadir view, etc) or both depending on parameters (sensor type, surface anisotropy, forward/backscattering, sampling, random errors, etc).
- Several sources of noise affect the measured parameters at the same time and with different intensity. It is hard to develop individual procedure for each source of noise because it is unknown how to separate them (for example elevated stratospheric aerosol and sensor/orbit degradation).
- Therefore, the noise in VHP data is removed empirically by median filter and least square technique applied to NDVI & BT time series. These results were validated comparing satellite and in situ data.

High Frequency Noise Removal (1)

- The vegetation-oriented method for a comprehensive noise reduction stems from a statistical approximation of the vegetation and temperature annual time series.
- The principles: (a) single out the seasonal cycle; (b) suppress high frequency noise, and (c) enhance medium and low frequency variations related to large-scale & persistent weather fluctuations.
- This technique considers smoothing the weekly time series with a combination of a compound median filter and the least squares technique (Kogan et al. 1993).
- Numerous tests showed that this smoothing eliminated completely the high frequency outliers, including random, approximated accurately the annual NDVI & BT cycles, and, more importantly, singled out medium-to-low frequency weather-related fluctuations (valleys and hills in the NDVI and BT time series) during the annual cycle (Kogan, 1995).

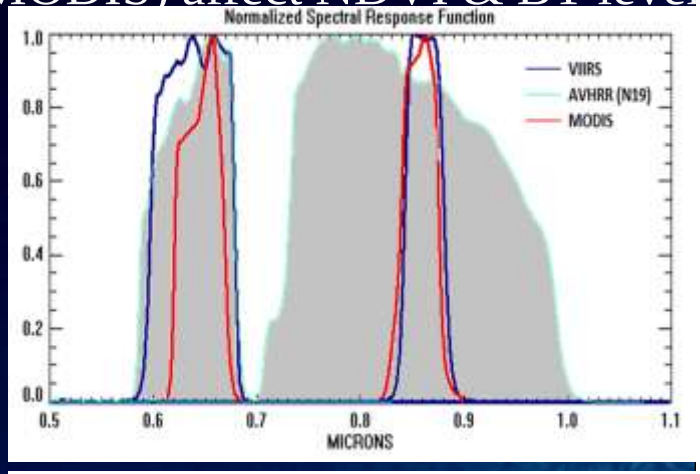
High Frequency Noise Removal (2)

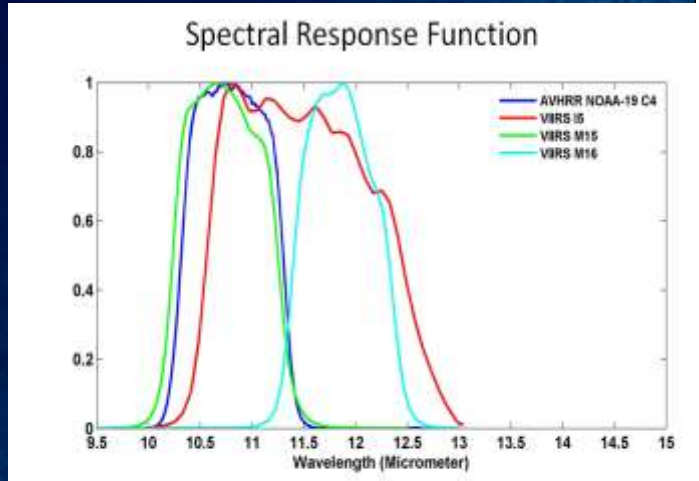


Example result of smoothing on time series of NDVI

Convert VIIRS NDVI to AVHRR equivalent NDVI

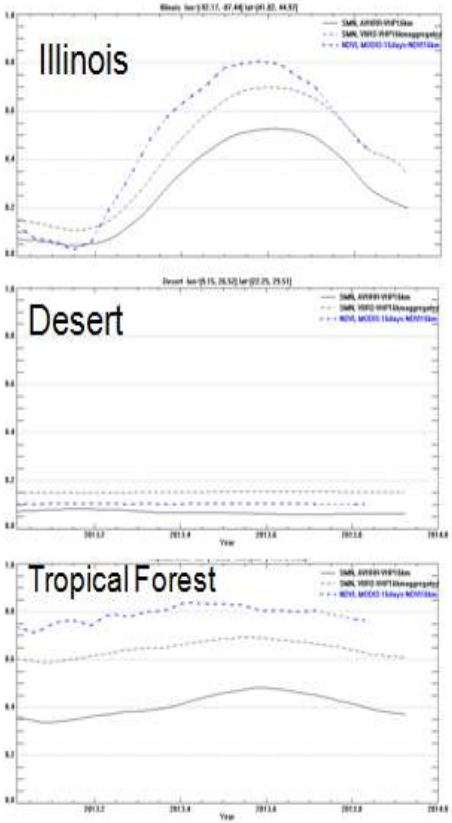
Differences in spectral response functions between VIIRS and AVHRR (& also MODIS) affect NDVI & BT level



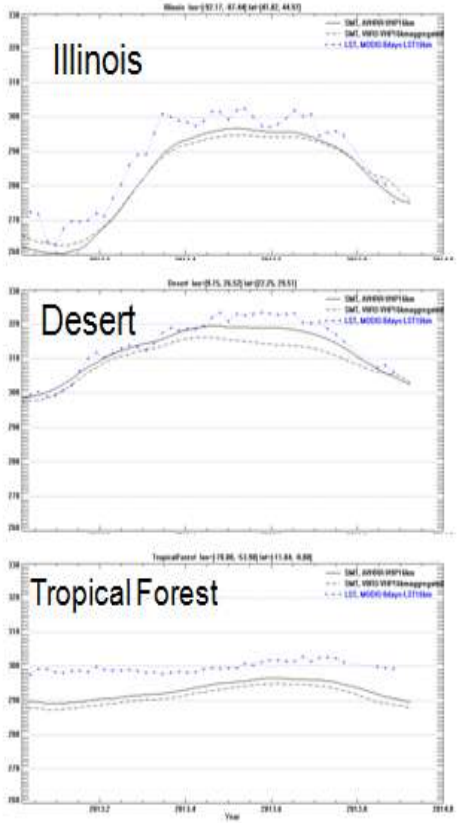


•VIIRS M15 is very close to AVHRR channel 4.
•VIIRS I5 is very broad, needs correction with band around 12 micrometers (M16) if use VIIRS I5 to correlate with AVHRR Channel 4 .

NDVI



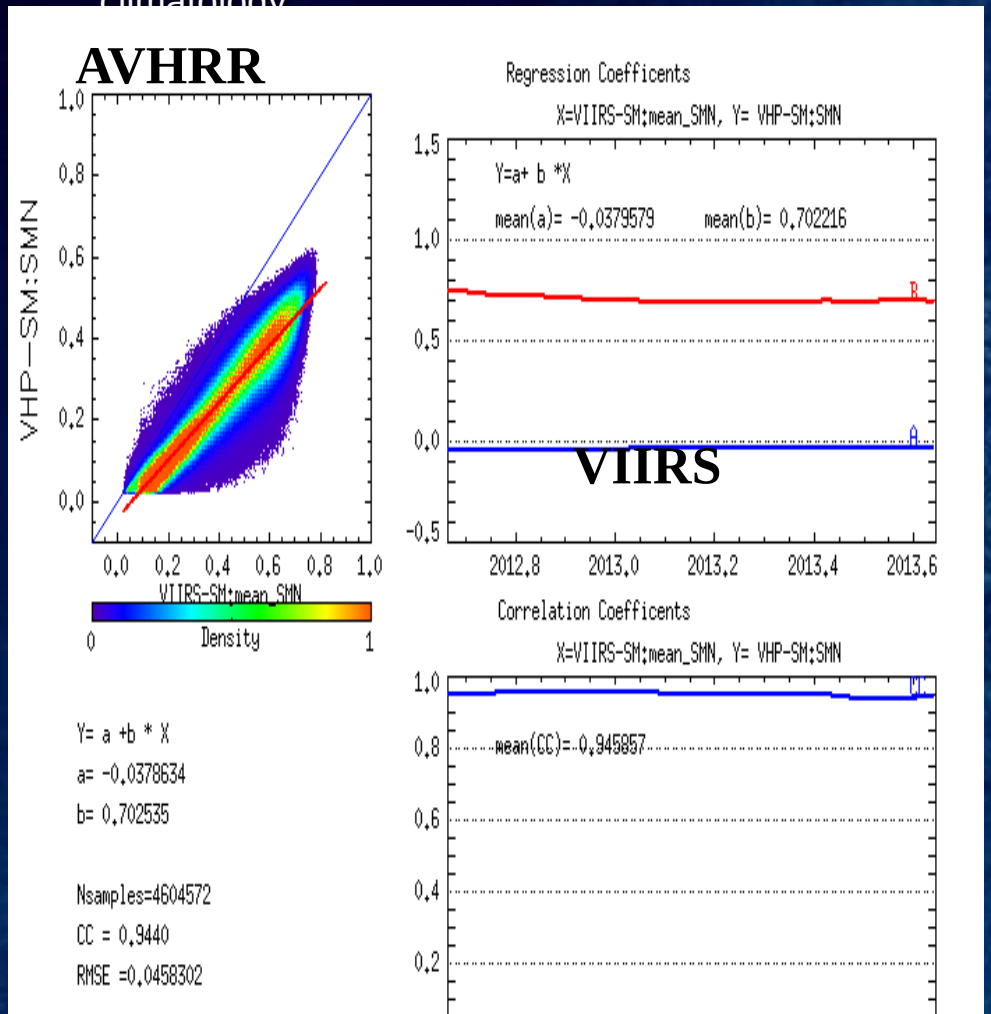
BT



AVHRR
VIIRS
MODIS

Convert VIIRS NDVI to AVHRR equivalent NDVI

- The relationship between VIIRS/NDVI (BT) and AVHRR/NDVI (BT) is strong (R=0.94) and stable over time; VIIRS/NDVI (BT) can be adjusted to AVHRR/NDVI (BT) in order to use climatology

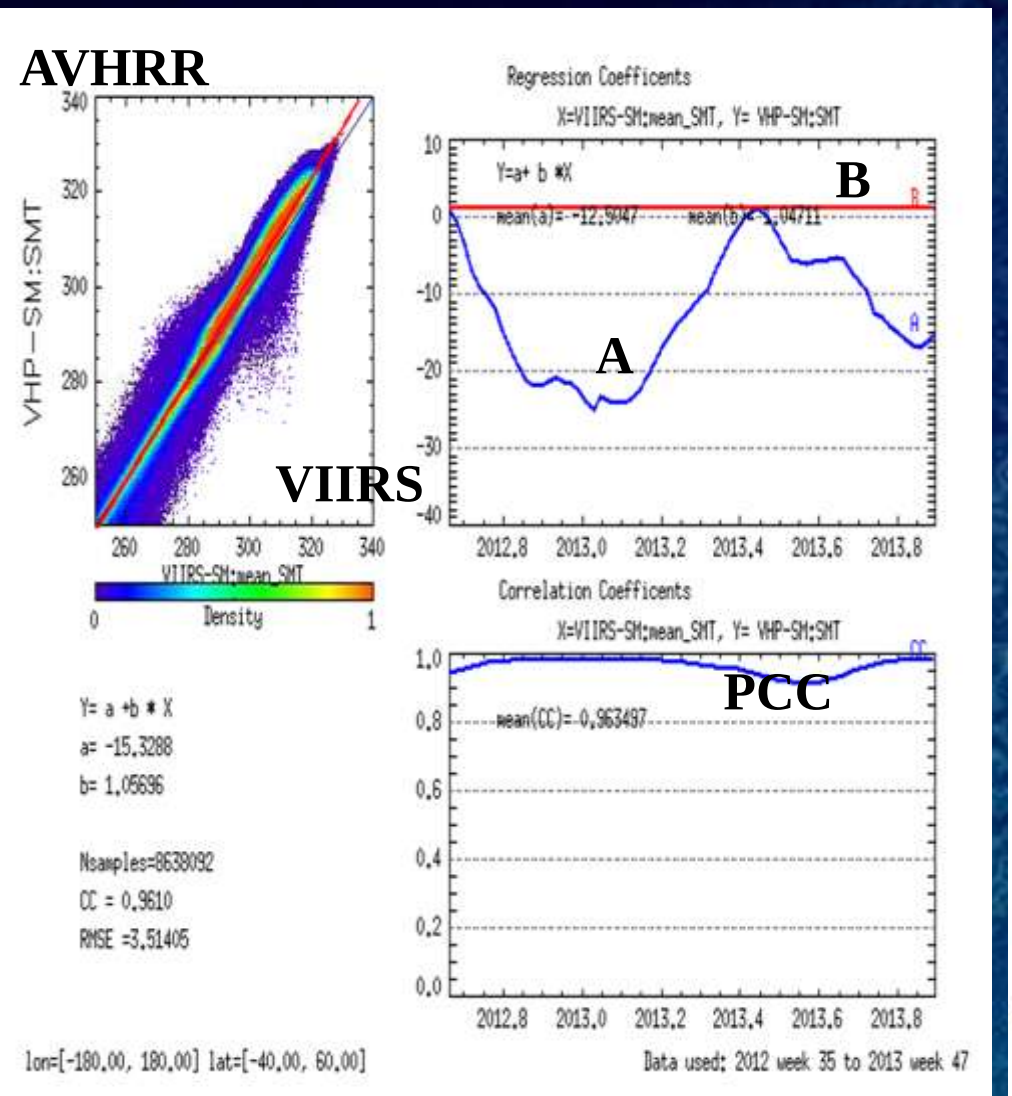


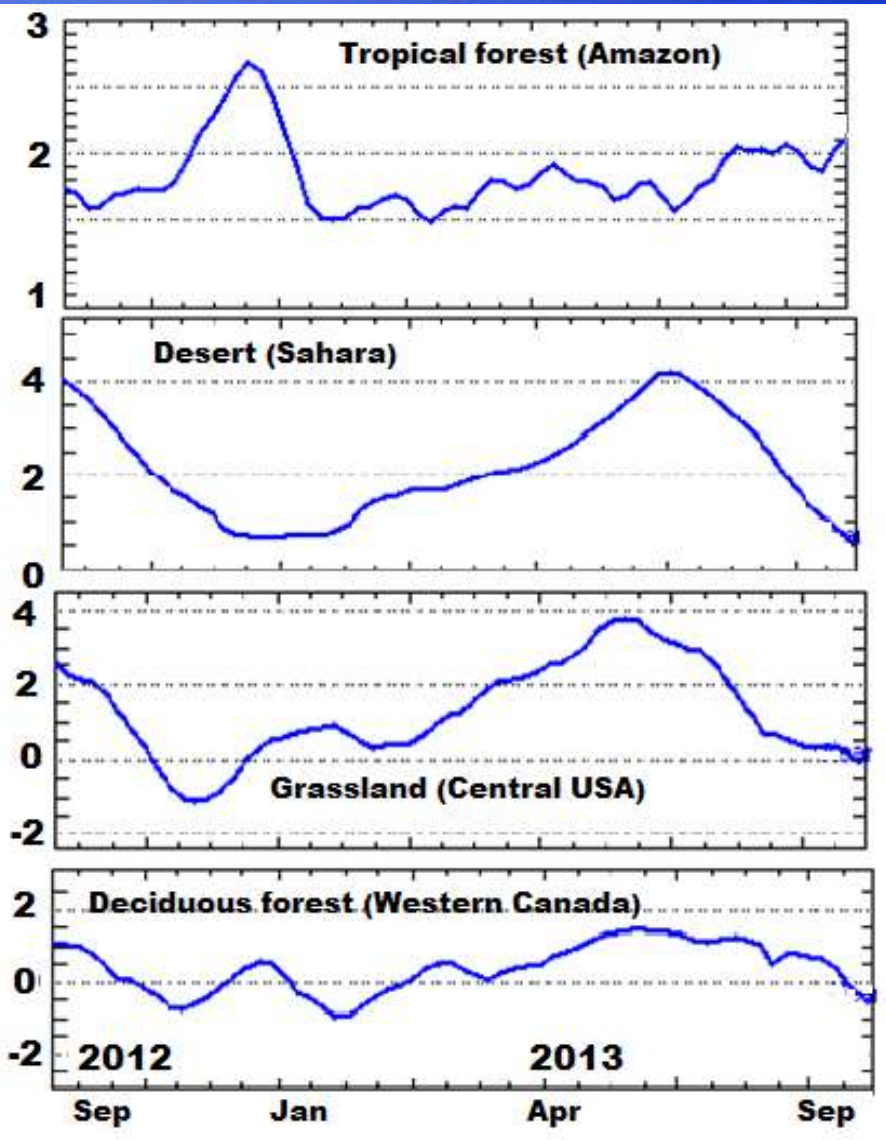
B

A

PCC

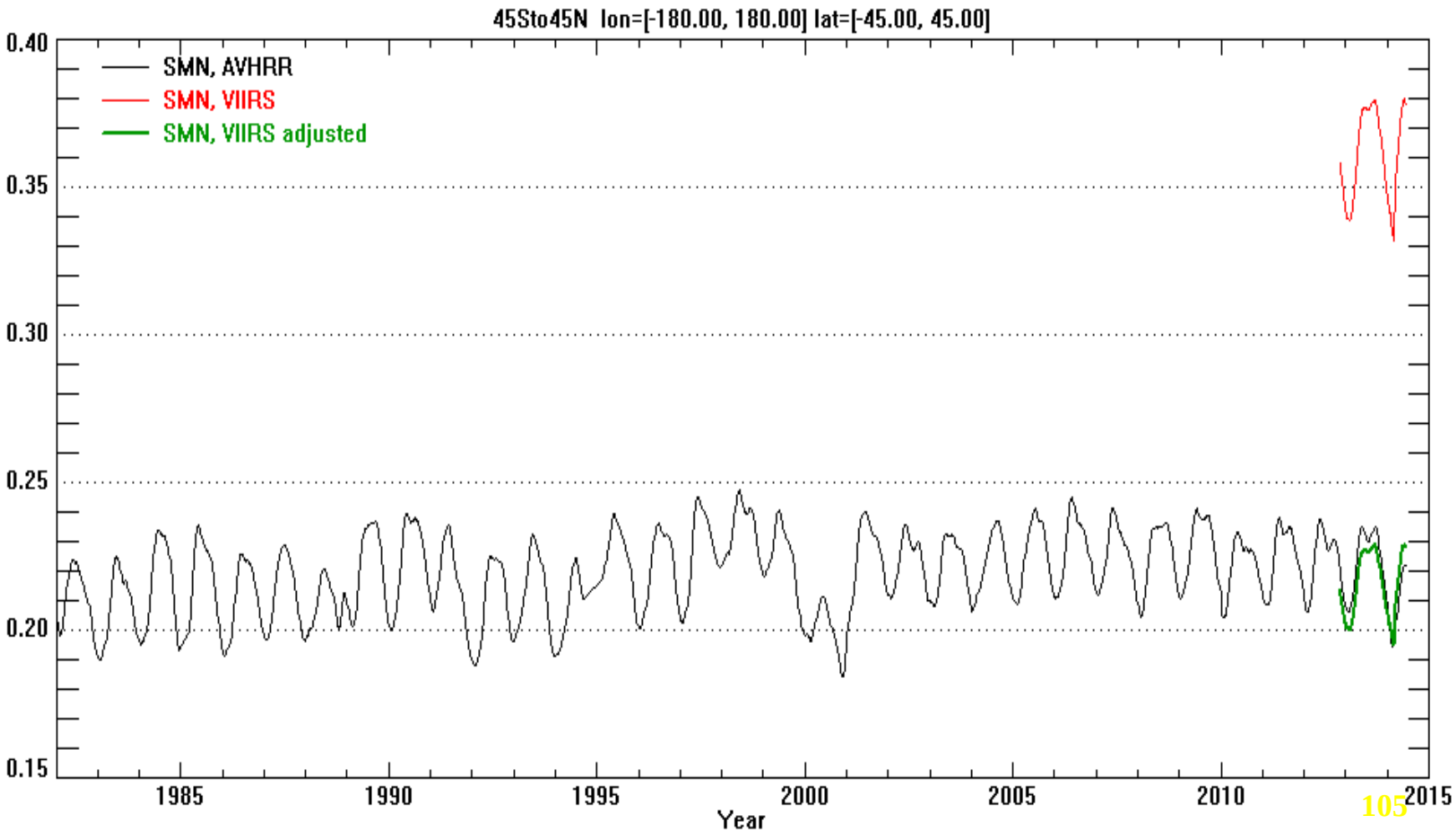
Convert VIIRS BT to AVHRR equivalent BT





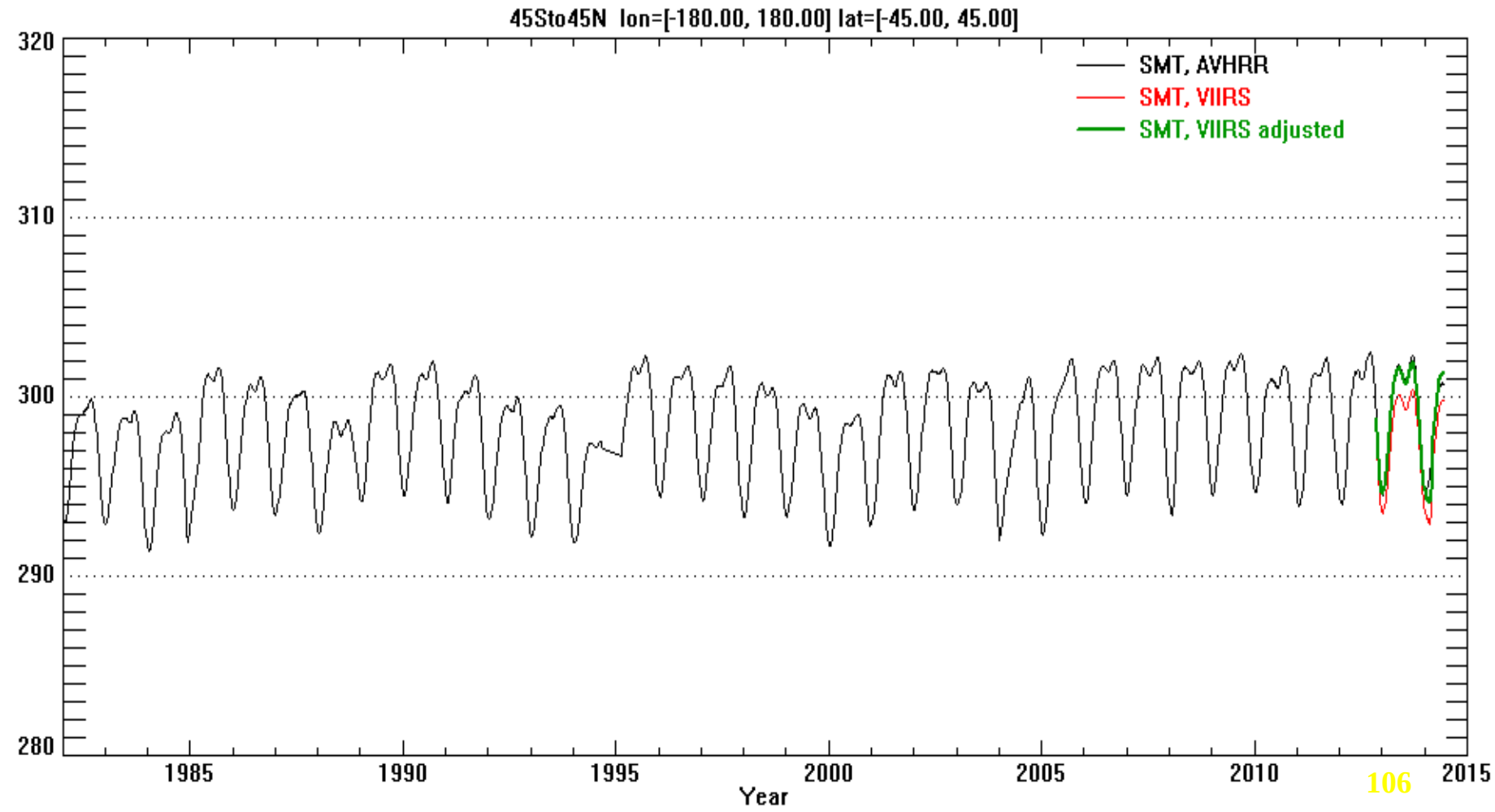
NDVI Time Series

AVHRR (1981-2014) & VIIRS (2012-2014) original and adjusted



BT Time Series

AVHRR (1981-2014) & VIIRS (2012-2014) original and adjusted



Algorithm Output (1)

- Three VIIRS/VH indices (**VCI, TCI, VHI**) on 4 km Lat/Lon geographic projection grid in NetCDF format
  - » There is one accompanying data set for quality assurance (QA) stored in the same file. QA flags indicate if there are potential issues (Ex: desert or snow ice) on quality of VH products.

Algorithm Output (2)

- Vegetation indices data in Geo-TIFF
- Intermediate files (NetCDF):
  - VIIRS daily map
  - VIIRS weekly composite
  - Calibrated raw NDVI and BT (ND files)
  - No noise (smoothed) NDVI and BT (SM files)
  - These files are not required to deliver to end user, nor required to archive at OSPO.
- Metadata (NetCDF):
  - Major metadata will be saved as file attributes
  - They are also saved in META data file in XML format together with additional statistic information which are useful to monitor the VHP product data quality and processing status.
  - It will be used by OSPO only and do not need to be archived.

Sensitivity Studies – GVI-X Cross-Validation Data

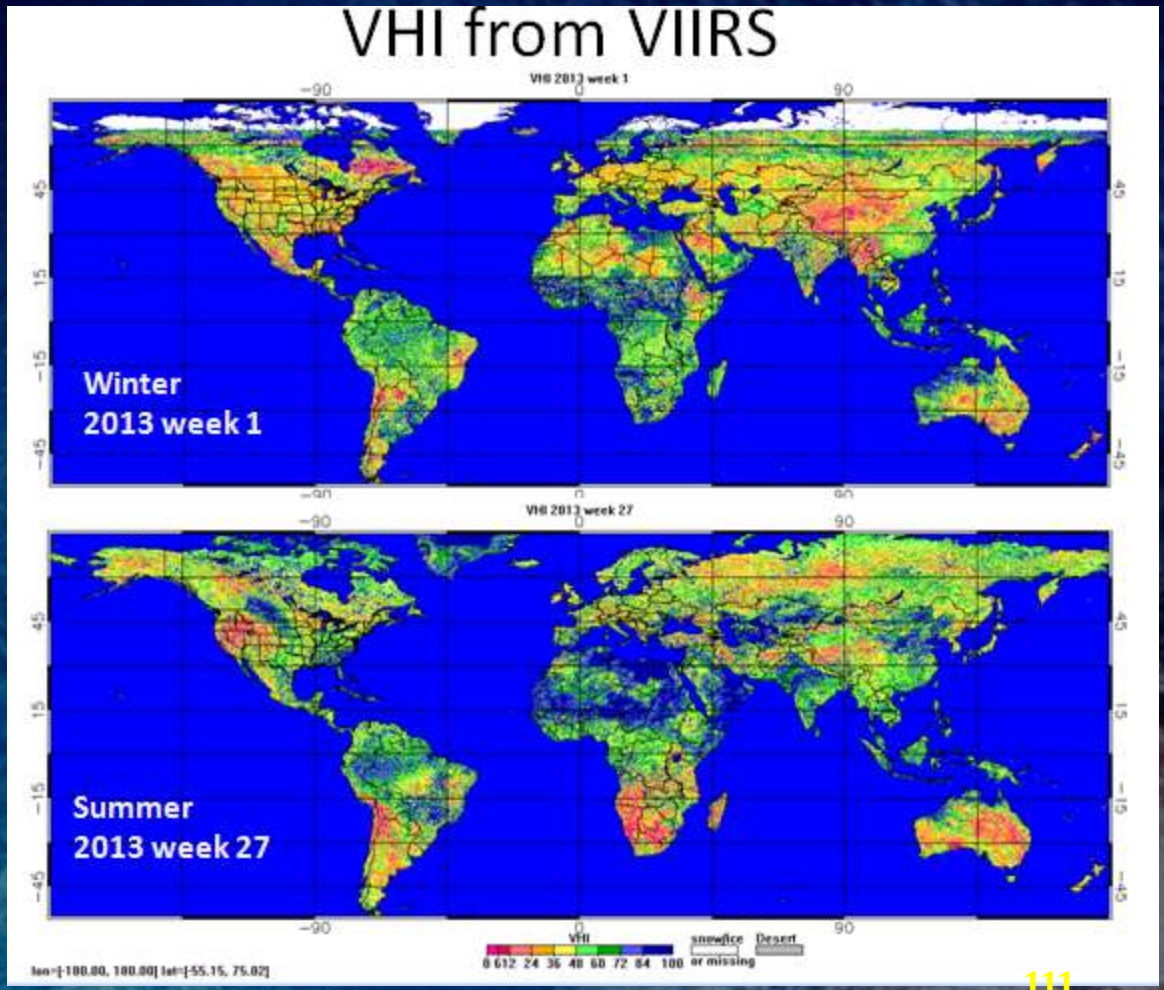
- The NOAA-19/AVHRR-VHP dataset will be used for testing and validation
- The samples of AQUA/MODIS dataset will be used for testing and validation
- VIIRS-VH indices data and daily/weekly maps has been produced from May 2012.
- VIIRS-VH products were compared with AVHRR-VHP dataset which is research prototype of VIIRS-VH system.

Practical Considerations

- The VIIRS-VH algorithm is designed to optimize calculations & minimize processing time.
- Since input data is huge, a list of granule files was create for better management and reducing processing time.
- VIIRS-VH code will be run: (a) daily to created daily composites data and maps & once per week to create weekly MVC composites VH indices.
- Unit testing and system testing will include quality assessment with historical in situ observations.

Sample Results

- The Figure shows examples of composite maps presenting typical summer and winter Vegetation Health maps produced by this algorithm for week 27 and week ,2013).
- The retrieved Vegetation Health values generally exhibit a good dynamic range from 0-100 indicating that this algorithm is capable of retrieving the required range of Vegetation Health values given different vegetation type and brightness temperature inputs from satellite sensors.
- The spatial patterns shown in the maps are also consistent with global dry/wet patterns of climate regimes.



1) Introduction
2) PDR Risks and Actions.
3) OPERATIONS CONCEPT
4) REQUIREMENTS
5) **ALGORITHM THEORETICAL BASIS**
6) SOFTWARE ARCHITECTURE
7) DETAILED DESIGN
8) QUALITY ASSURANCE
9) PROJECT STATUS
10) RISKS AND ACTIONS
11) SUMMARY AND CONCLUSIONS

Section 6 – Software Architecture and Interfaces

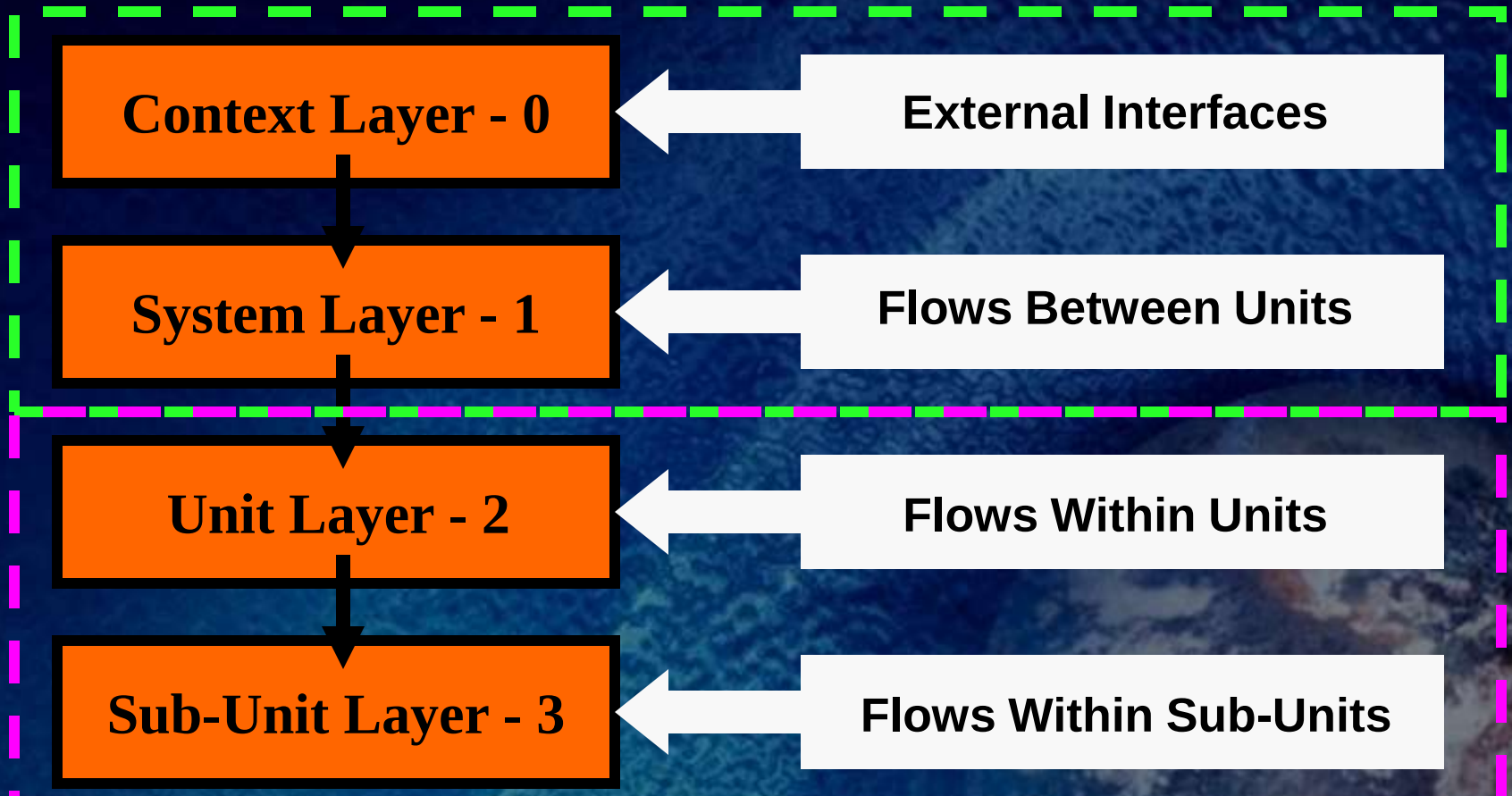
Presented by

Wei Guo (IMSG)
VIIRS-VH Development Programmer

Software Architecture

- Software Description
  - External Interfaces
  - System Level
  - Unit Level
- Data Files
  - Input Files
  - Static/Ancillary Files
  - Output Files
  - Run Files
- Hardware and Software
  - Development and Unit testing
  - Test Product Distribution
  - Production

CDR Software Architecture



Detailed Design Adds 2 Layers

The Context-Layer

- The Context-Layer describes the flows between the system and its external interfaces
- 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 data sink that is produced by the system for an external user

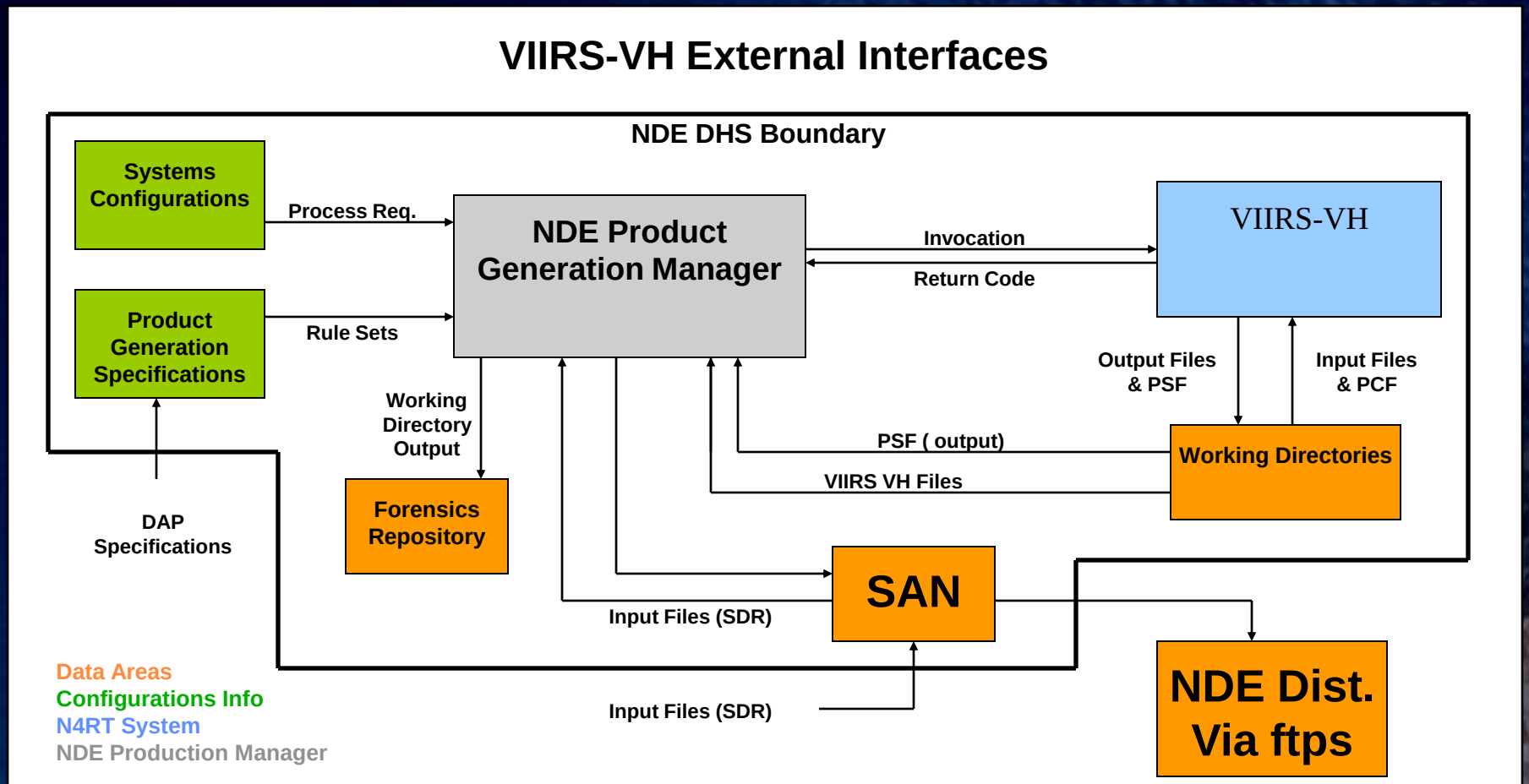
VIIRS-VH External Inputs

Item	Type	Source	Description
VIIRS SDR	Input	DDS	VIIRS SDR granule data, including reflectance of image band 1 and 2, brightness temperature of image band 5.
USGS land/sea mask	Input	USGS	Static file contains 30 arc second resolution land sea mask from USGS, It was converted to HDF format.
IGBP land types	Input	STAR	Land cover types from IGBP program, It was sampled to the grid of VH product to HDF format.
Calibration data	Input	STAR	Calibration parameters for VIS and NIR bands from NOAA/NESDIS/STAR,
NDVI and BT Climatology from AVHRR and MODIS	Input	STAR	Multiple year climatology of NDVI and BT, created from AVHRR and MODIS
Process Control File	Input	NDE	Provide input file names

VIIRS-VH External Output

Item	Type	Source	Description
VH Product	Output	VIIRS-VH	Global Gridded Vegetation Health data in NetCDf format, using Lat/Lon projection with 0.036 degree (about 4km at equator) resolution. Files are in NetCDF format.
VH metadata	Output	VIIRS-VH	Metadata in XML format,
VH in Geo-TIFF	Output	VIIRS-VH	VH data in Geo-TIFF format, it is in Lat/Lon projection, with resolution of 0.144 degree. It is possible to provide it in higher resolution (example: 0.036 degree)
VH images	Output	VIIRS-VH	VH data presented in PNG format, with resolution of 0.036 degree.
Process Status file	Output	VIIRS-VH	Output file names need to archive or distribute

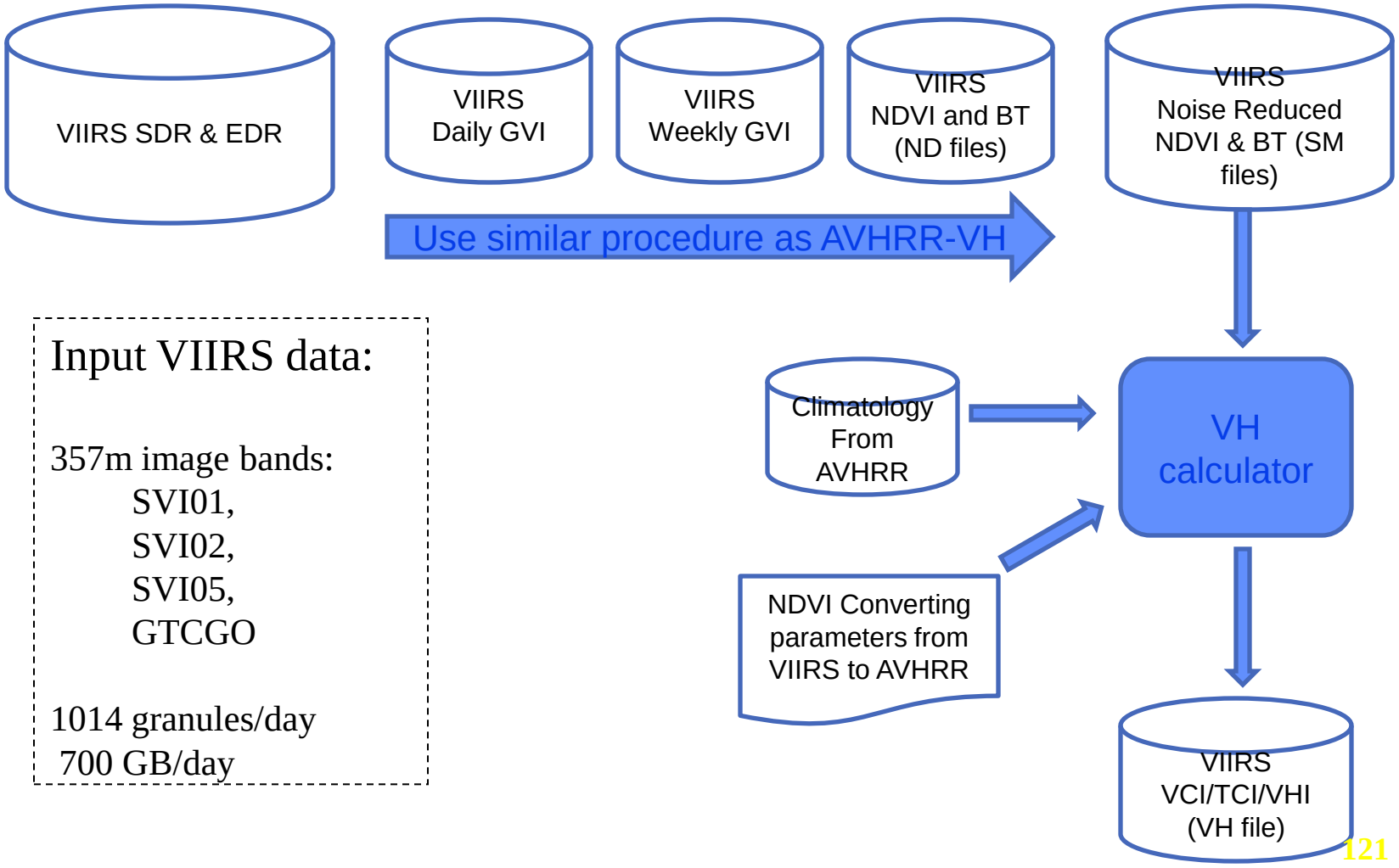
VIIRS-VH External Interfaces to NDE



The System-Layer

- The System-Layer data flow expands upon the Context-Layer data flow, showing the first layer of decomposition.
  - » In addition to the System-Layer inputs and outputs, the major processing units are shown along with their inputs and outputs.
  - » Each unit is designed as a stand-alone program for ease of testing and integration into a System-Layer scheduler.

VIIRS-VH system System Level Data Flow



Input VIIRS data:

357m image bands:
- SVI01,
- SVI02,
- SVI05,
- GTCGO

1014 granules/day
700 GB/day

System-Layer Components – Processing Units (1)

- GVI Daily Map Creator (DMC)
  - » Creates daily maps of from VIIRS SDR and EDR files.
  - » If only a portion of input granules were provided, it creates a “partial daily map”
- GVI Daily Map Merger (DMM)
  - » Merger partial daily maps together. (it is an optional unit)
- GVI Weekly Map composer (WMC)
  - » Makes weekly maximum value composite (MVC) from Daily Maps.
- Calibration unit (CAL)
  - » Reads GVI weekly composite map and calibration parameters
  - » Generates calibrated (raw) NDVI and BT (ND) files by applying optimized (or most recent updated) post-launch calibration parameters to reflectances

System-Layer Components – Processing Units (2)

- Corrections unit (COR)
  - » Reads weekly NDVI and BT4 (ND files) of 15 weeks
  - » Performs time series smoothing to remove high frequency noise and generate smoothed NDVI and BT (SM) files. The last 7 weeks' SM files are updated.
- Vegetation Health Calculator (VHC)
  - » Reads latest SM file of smoothed NDVI and smoothed BT
  - » Reads climatology data (CLIMAT file)
  - » Generates vegetation health (VH) files.
- Metadata Write unit (MTW)
  - » Reads VH product and intermediate products in NetCDF format
  - » Generates metadata files in XML format.

System-Layer Commands

- 1 executable for all units (except the unit using IDL)

```
» VHsuite.exe  -S configure_file  DailyMap          npp year1 jday1 year2 jday2
» VHsuite.exe  -S configure_file  MergeDailyMaps    npp year1 jday1 year2 jday2

» VHsuite.exe  -S configure_file  CompositeMap      npp  year1 week1 year2 week2
» VHsuite.exe  -S configure_file  ND                 npp  year1 week1 year2 week2
» VHsuite.exe  -S configure_file  SM                 npp  year1 week1 year2 week2
» VHsuite.exe  -S configure_file  VH                 npp  year1 week1 year2 week2
```

System Level Scripts

- The VIIRS-VH driver scripts will have Perl scripts that act as a wrappers for the compiled VIIRS-VH code.
  - There will be no hard coded paths in the script. All needed information regarding locations of files will come through the PCF.
  - All system calls have their return values checked so the exits are graceful and informative.
  - All standard out and standard error will be directed to a single log file.
  - The driver script will translate the low-level program errors into the high-level numerical error codes expected by the PGM.
  - The Perl script will generate an internal control file for the main VIIRS-VH program.

VIIRS-VH Software: Script

- It will be run via the execution of a single driver script that will be invoked, monitored, and managed by the NDE DHS Product Generation Manager.
- Execution of the script will be driven by data (process product when data is available)
- NDE will run the script in a working directory. All input/output paths are defined in Product control file (PCF). A static working space will be used to update intermediate product SMN and VH files)
- The driver script will run VIIRS-VH, handle program output and errors, direct required NDE error codes to the DHS, generate an output log, and generate a PSF.
- If there are errors, NDE will save the contents of the run in a forensics repository.
- NDE will manage and direct error status to the operators from the DHS system.

System Level Perl Scripts

- 3 Perl scripts will be created for

1. Create partial daily map, input will be granule data files listed in PCF, may run multiple times per day.

2. Merge daily map, input will be partial daily maps listed in PCF, may run once per day.

3. Run weekly procedure, input will be 7 daily maps files listed in PCF, run once per week. Will run the following units in sequence:
    1. Weekly composite
    2. Calibration unit (create ND file)
    3. Correction unit (create SM file)
    4. VH calculation unit (create VH)

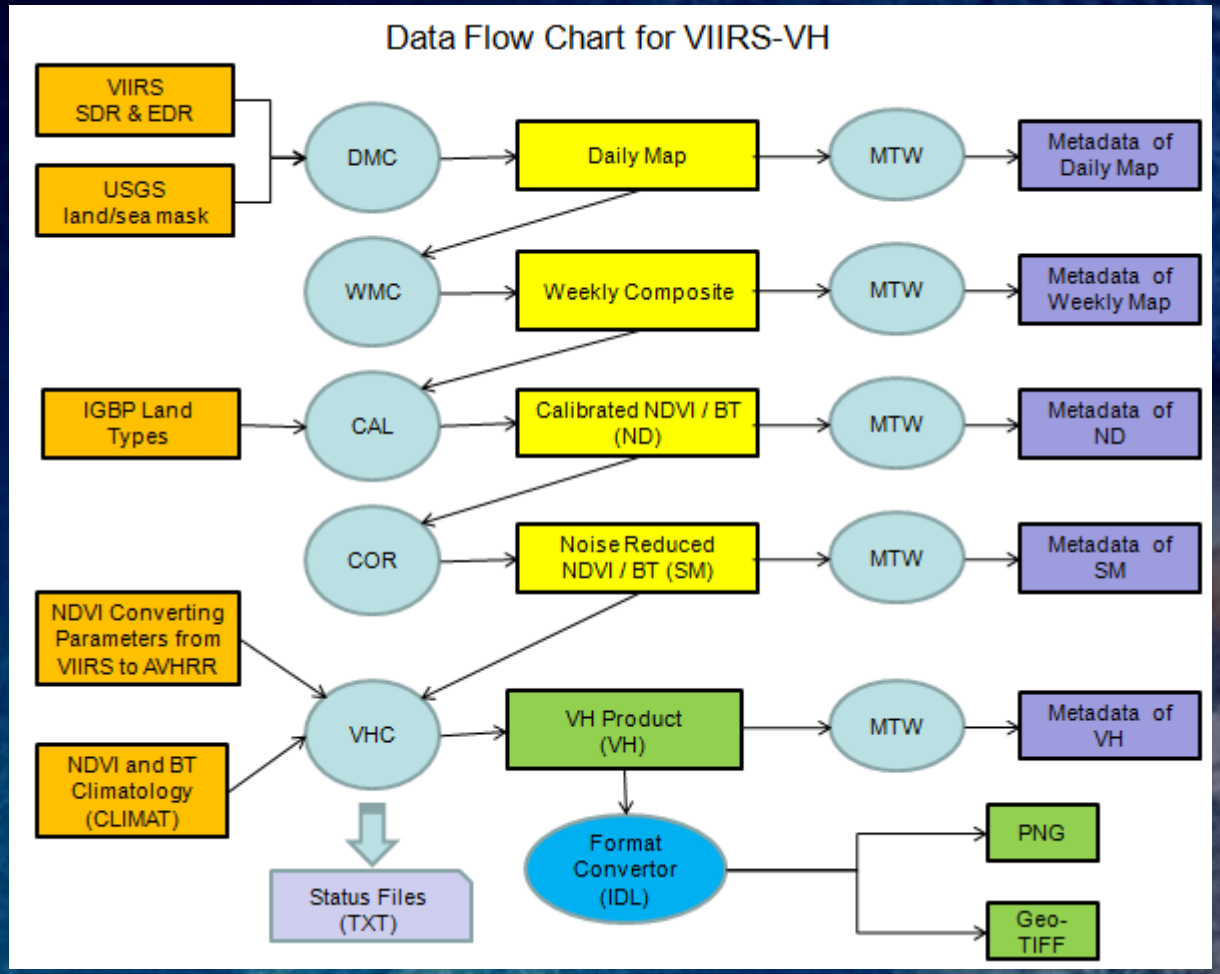
VIIRS-VH Software: Unit Level

- In term of functionality, VIIRS-VH can be described in 8 units.
  - DMC: daily map composer
  - DMM: daily map merger
  - WMC: weekly map composer
  - CAL: calibration unit
  - COR: correction unit
  - VHC: VH calculator
  - MTW: metadata writer
  - FCV: Format convertor unit (IDL)
- The lowest-level VIIRS-VH functions (in C++):
  - Perform the actual reading and writing of the specific file types (HDF, HDF5,and netCDF4)
- General VIIRS-VH compiled with code characteristics:
  - The status of all functions are checked to allow for graceful and informative exits.
  - No paths are hard coded in the compiled code.
  - All code will be compiled as 64 bit to utilize the IBM architecture.

VIIRS-VH Software: Libraries

- HDF4 version 4.2 (or latest)
  - » available at http://www.hdfgroup.org
- HDF5 version 1.8.7 (or latest)
  - » available at http://www.hdfgroup.org
- netCDF4 version 4.2 (or latest)
  - » Available at https://www.unidata.ucar.edu/downloads/netcdf/index.jsp

VIIRS-VH Unit Level Data Flow



Hardware Development / Operation

- Development Hardware - Unit tests will be conducted on the Linux development machine at STAR .
  - Linux
  - 2 TB disk space
  - dual CPU
  - 2 GB memory/CPU
  - C/C++ compiler

VIIRS-VH Test Product Distribution

- STAR Data Server - test products will be available on a distribution server at STAR (ftp.star.nesdis.noaa.gov).
  - Linux
  - 3.2 TB disk space
  - Access via anonymous ftp

System-Layer Components – Unit Data Flows (1)

- Daily Map
  - » Data Flow
    - – From DMC Unit to WMC Unit
    - – From DMC Unit to MTW Unit
  - » Description:
    - – Daily maps of reflectance, BT or other variables in EDR, geometry angles, observation time and “packed_cloud_mask”.
    - – For each VIIRS-VH grid cell, the AVHRR data for the observation closest to the center of the cell is selected to produce a gridded daily map of digital counts
- Weekly Composite
  - » Data Flow:
    - – From WMC Unit to CAL Unit
    - – From WMC Unit to MTW Unit
  - » Description:
    - – For each VIIRS-VH grid cell, the daily map with the maximum NDVI is selected to produce a gridded weekly map.
    - – Weekly composite includes all variables in daily maps. It also includes the maps of “days with valid data” and the selected date.

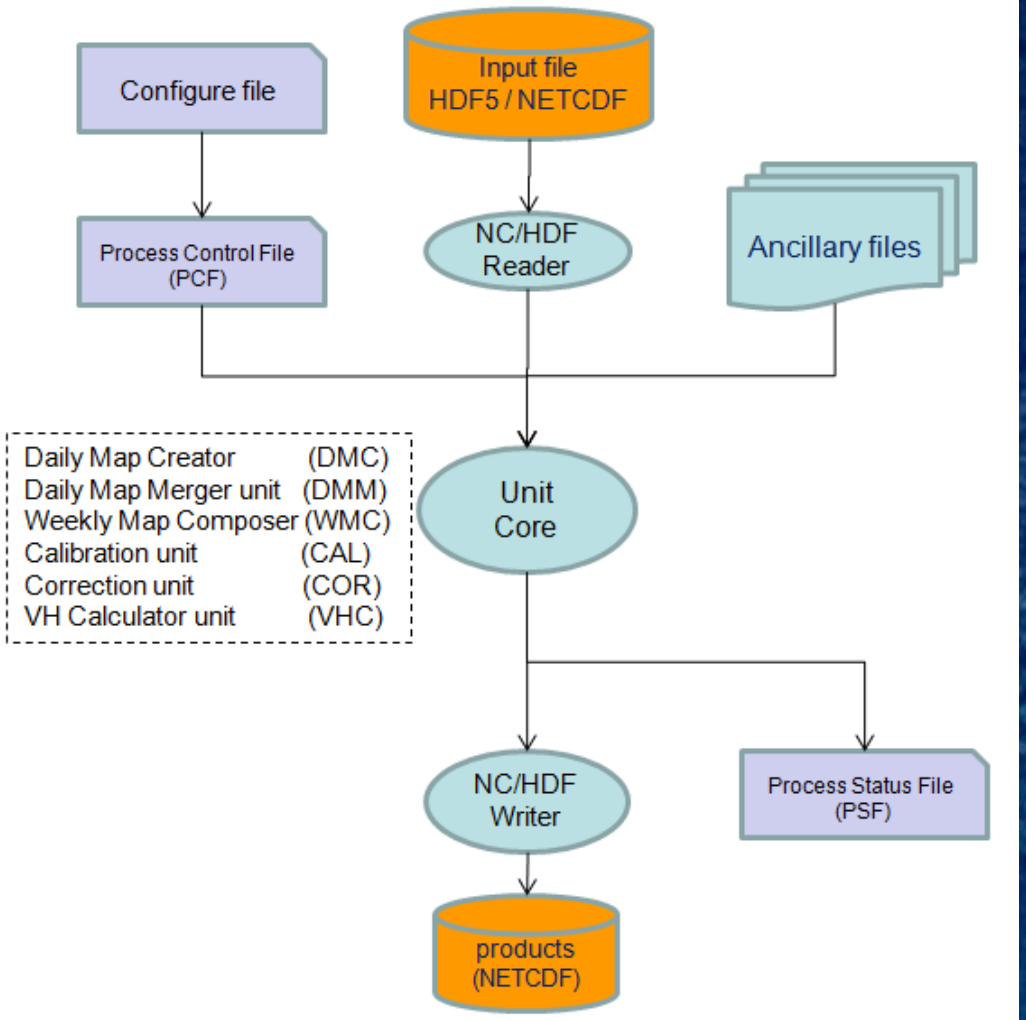
System-Layer Components – Unit Data Flows (2)

- Calibrated NDVI / BT (ND)
  - » Data Flow:
    - – From CAL Unit to COR Unit
    - – From CAL Unit to MTW Unit
  - » Description: NDVI and BT with post-launch calibration applied
- Smoothed NDVI / BT
  - » Data Flow:
    - – From COR Unit to VHC Unit
    - – From COR Unit to MTW Unit
  - » Description: NDVI and BT with high frequency noise removed
- VH Product
  - » Data Flow:
    - – From VHC Unit to FMC Unit
    - – From VHC Unit to MTW Unit
  - » Description: VH product file in netCDF format

The Unit Layer

- The Unit Layer Data Flow decomposes the system level software architecture to the next (unit) level.
- In this layer, the data flows within units are described.

Unit Layer – Shared code structure



- Configure file: parameters / paths for VH
- PCF: input file names (NDE required)
- PSF: output file names (NDE required)

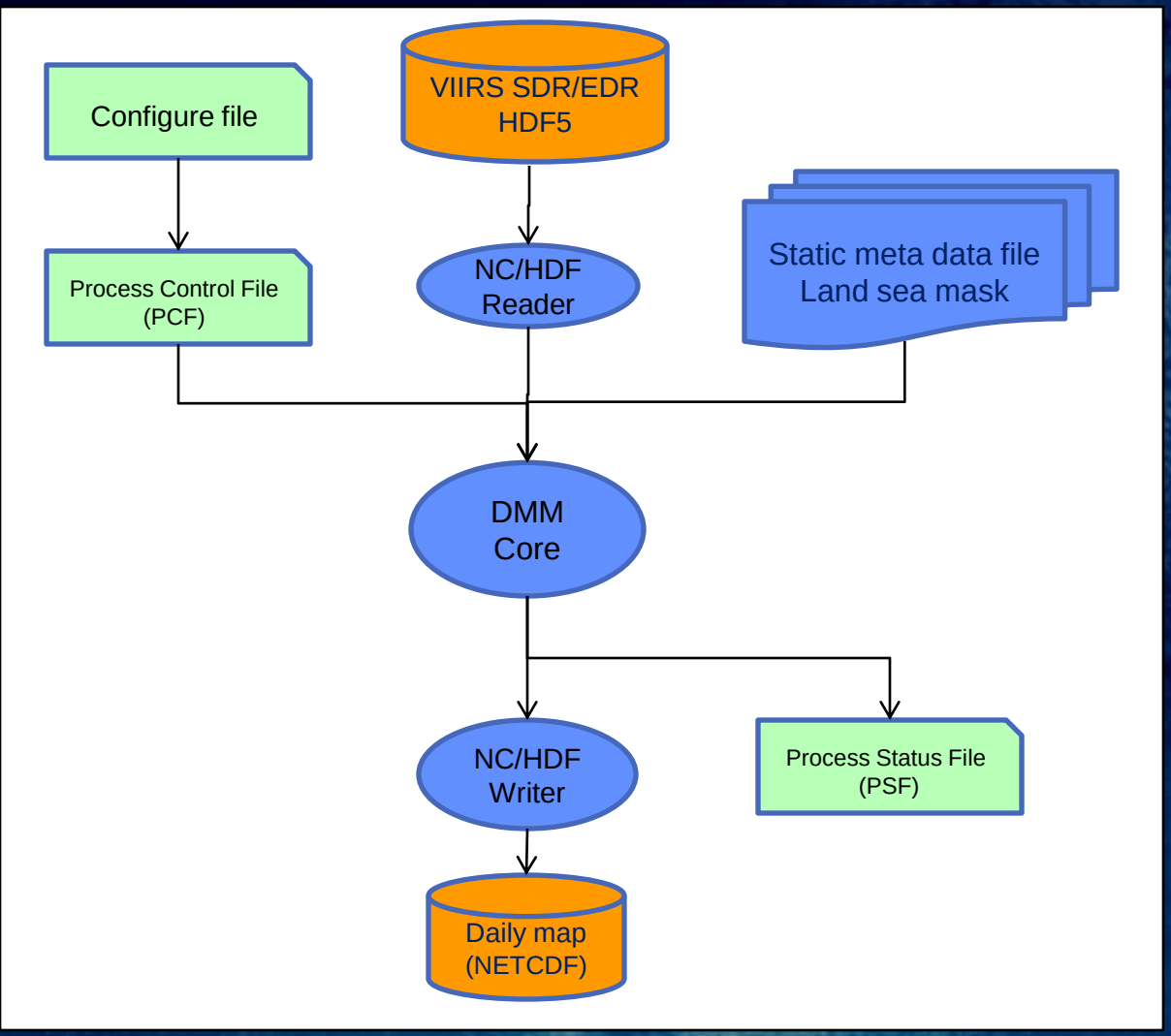
- Input files:
  HDF5 (VIIRS SDR, EDR)
  NETCDF (VH products)

- Ancillary files:
  HDF, NETCDF or ASCII format

Carry out in order:

- Parse the command line and get task name and optional parameters.
- Read VH configure file to get directory names and other parameters
- Read Process Control File (PCF) to obtain the input file names
- Switch to corresponding unit, and process this unit
- Output the product NETCDF file
- Write the output file to process status file

Unit Layer- DMC Unit

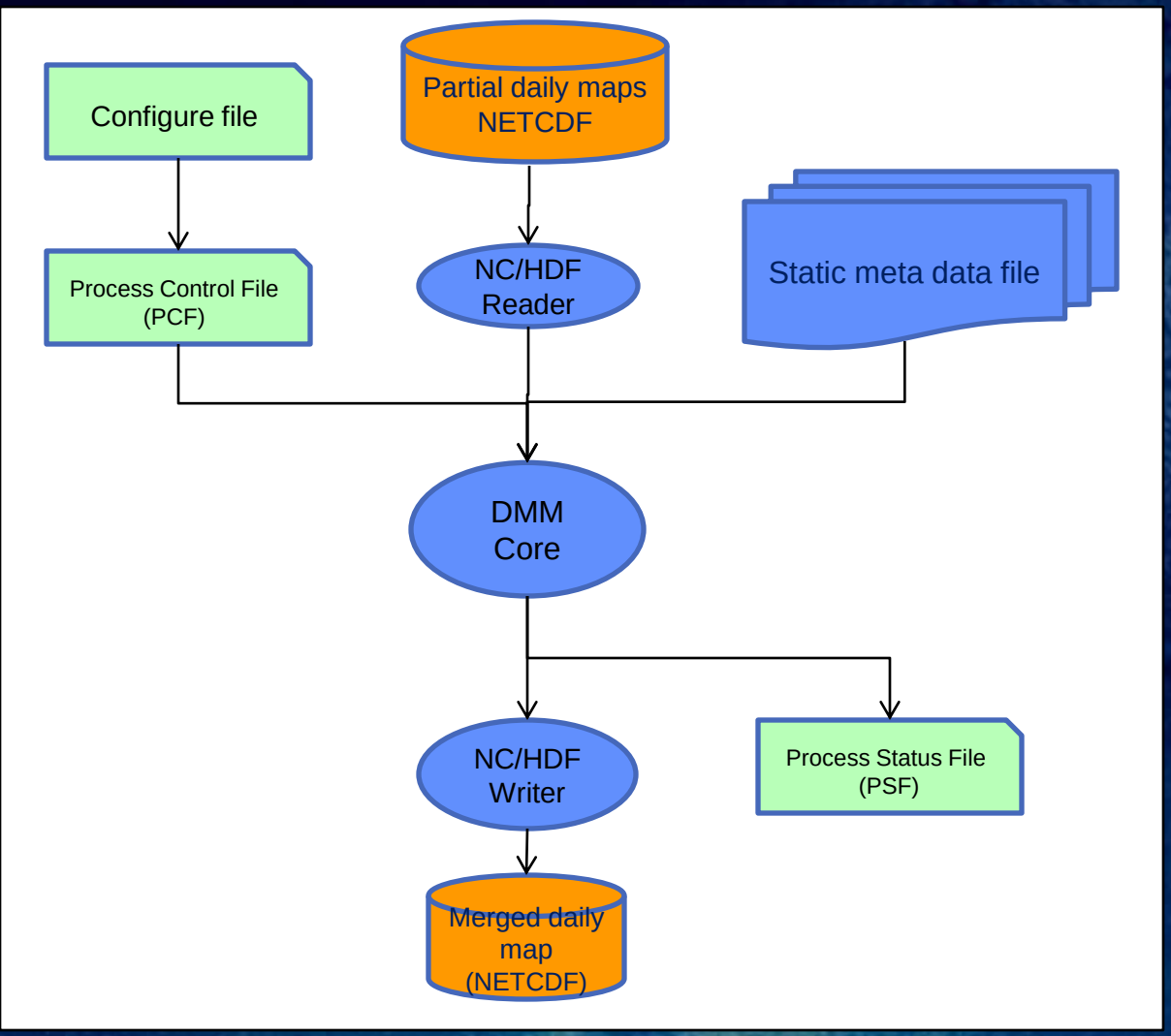


Create (partial) daily maps

Packed_cloud_mask is set and Serve as QA flags:

General Quality bit
Land /coastal bit from landse a mask file
Cloud bits (6-7) from IICMO
Sun glint was calculated from the geometry angles

Unit Layer- DMM Unit

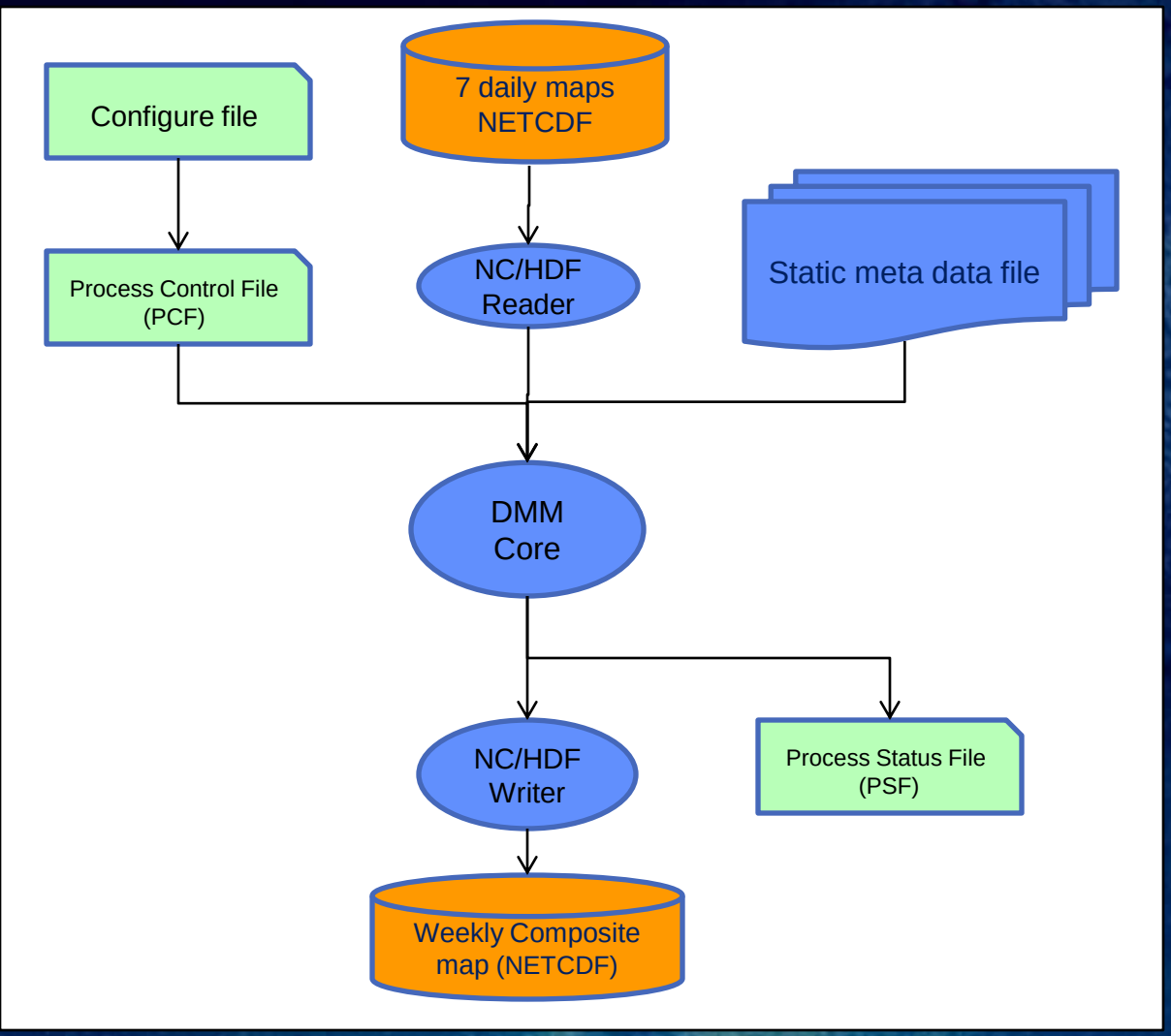


Merge partial daily maps

It is optional unit, only used when daily maps are processed in multiple runs.

Packed_cloud_mask was transfer from Daily Map

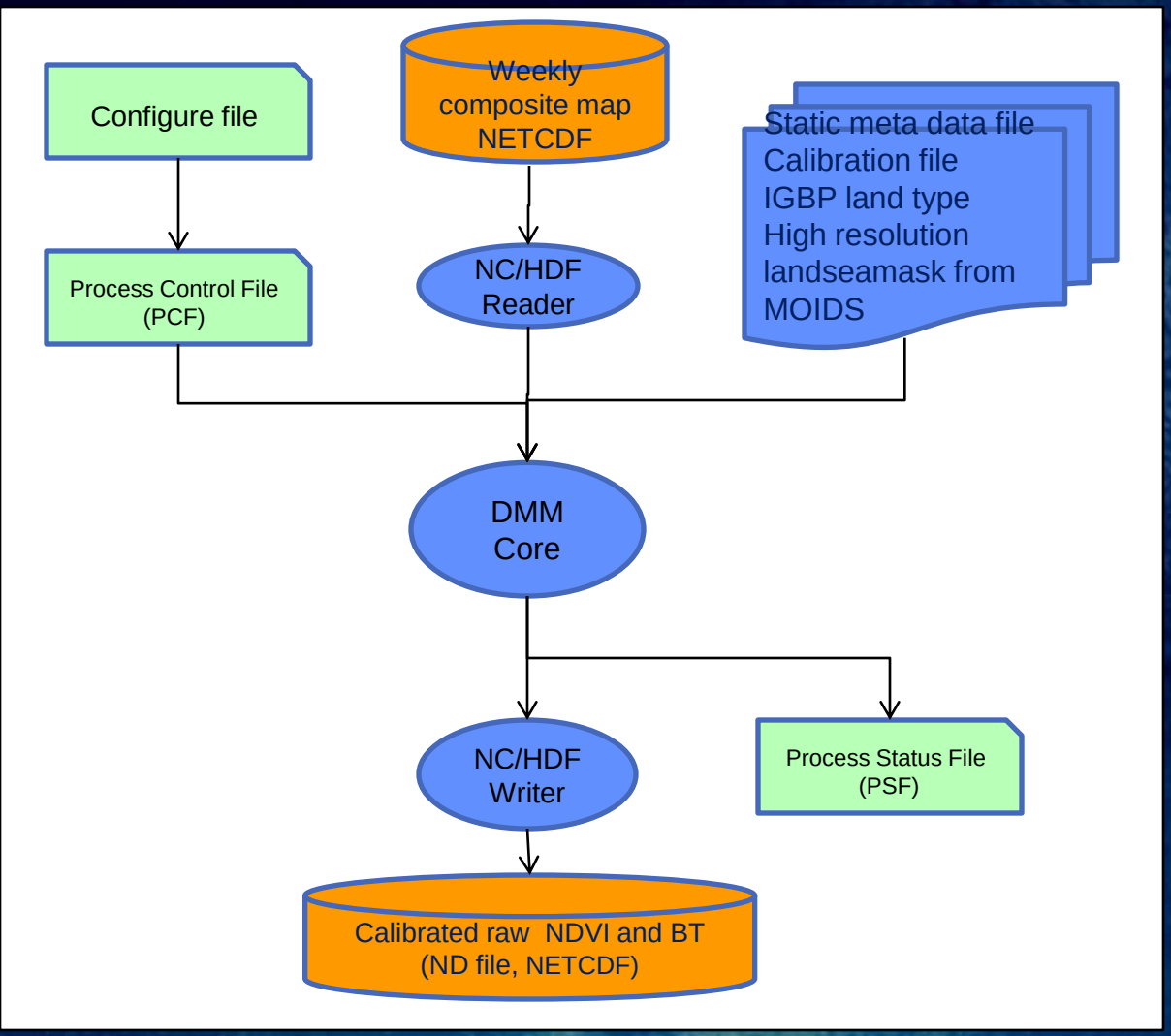
Unit Layer- WMC Unit



Make weekly composite by max NDVI composite

Packed_cloud_mask was transfer from Daily Map

Unit Layer- CAL Unit



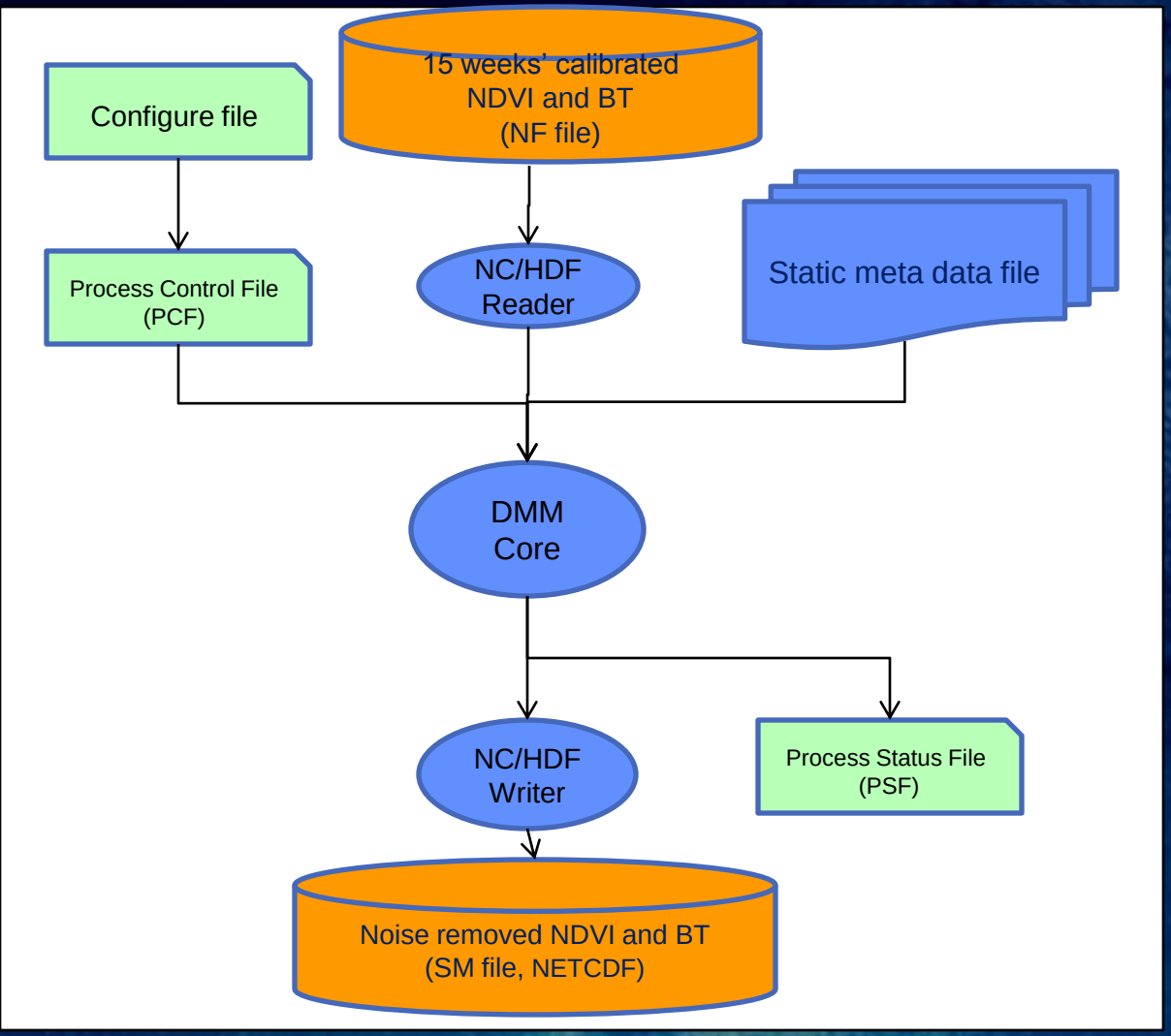
Calculate NDVI and BT by applying latest launch calibration.

IGBP land type was used to set desert bit in QA

High resolution land sea mask from MOIDS was used to set land and coastal bit in QA

BT <0° C , set too-cold bit in QA

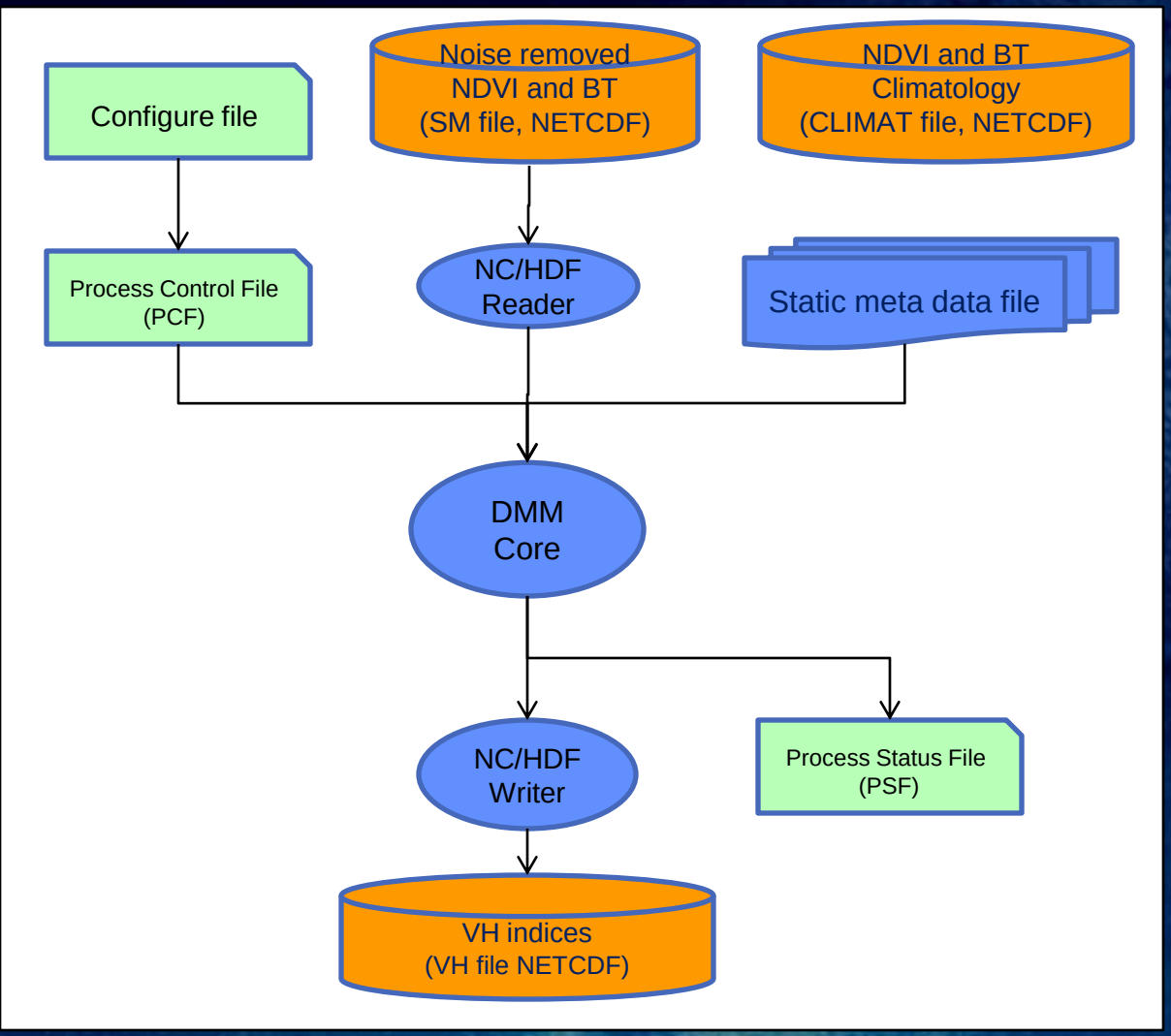
Unit Layer-COR Unit



Remove noise by time series smoothing

QA was transferred from ND file

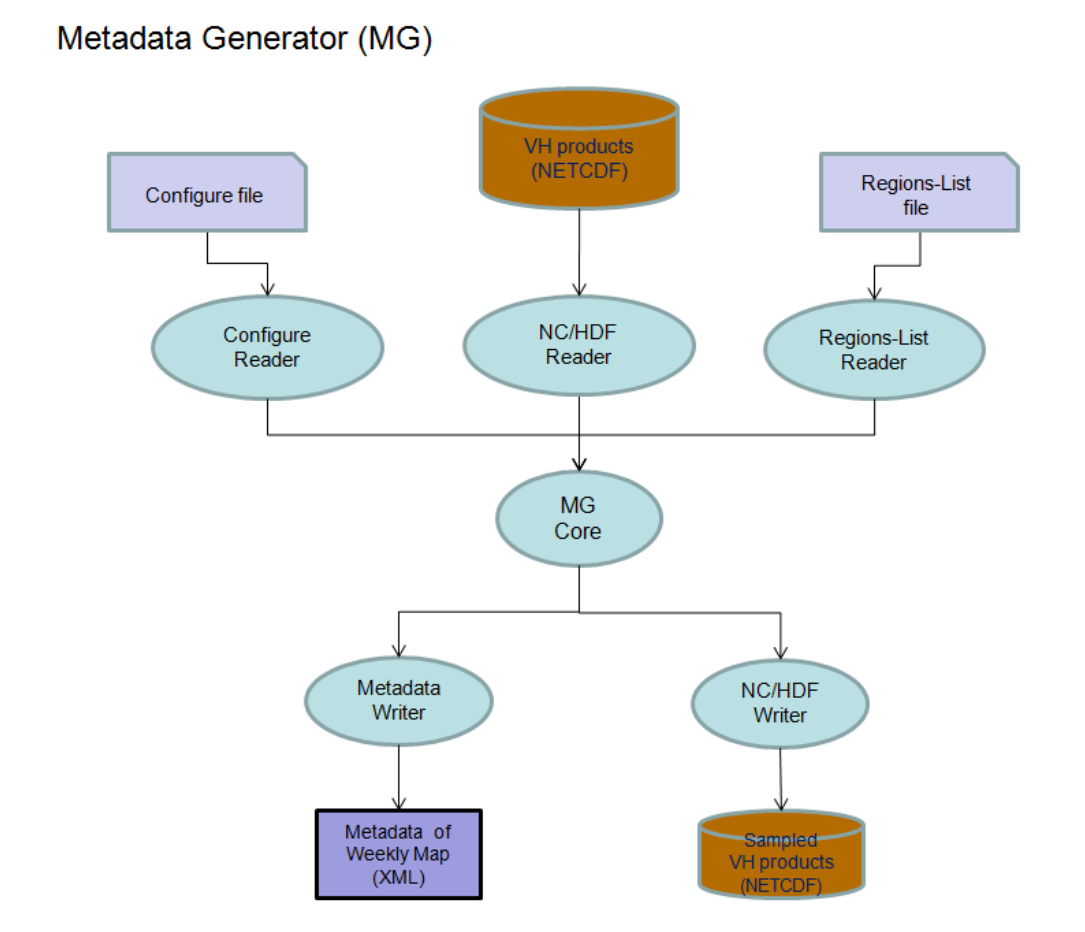
Unit Layer- VHC Unit



Calculate VHI from noise removed NDVI and BT and climatology.

QA was transferred from SM file

Unit Layer- Metadata Generator (MG) Unit



- Read a VH product file
- Create sampled dataset
- Calculate statistic information for each selected region and Save statistic information in XML file

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Section 7 –
Detailed Design Description

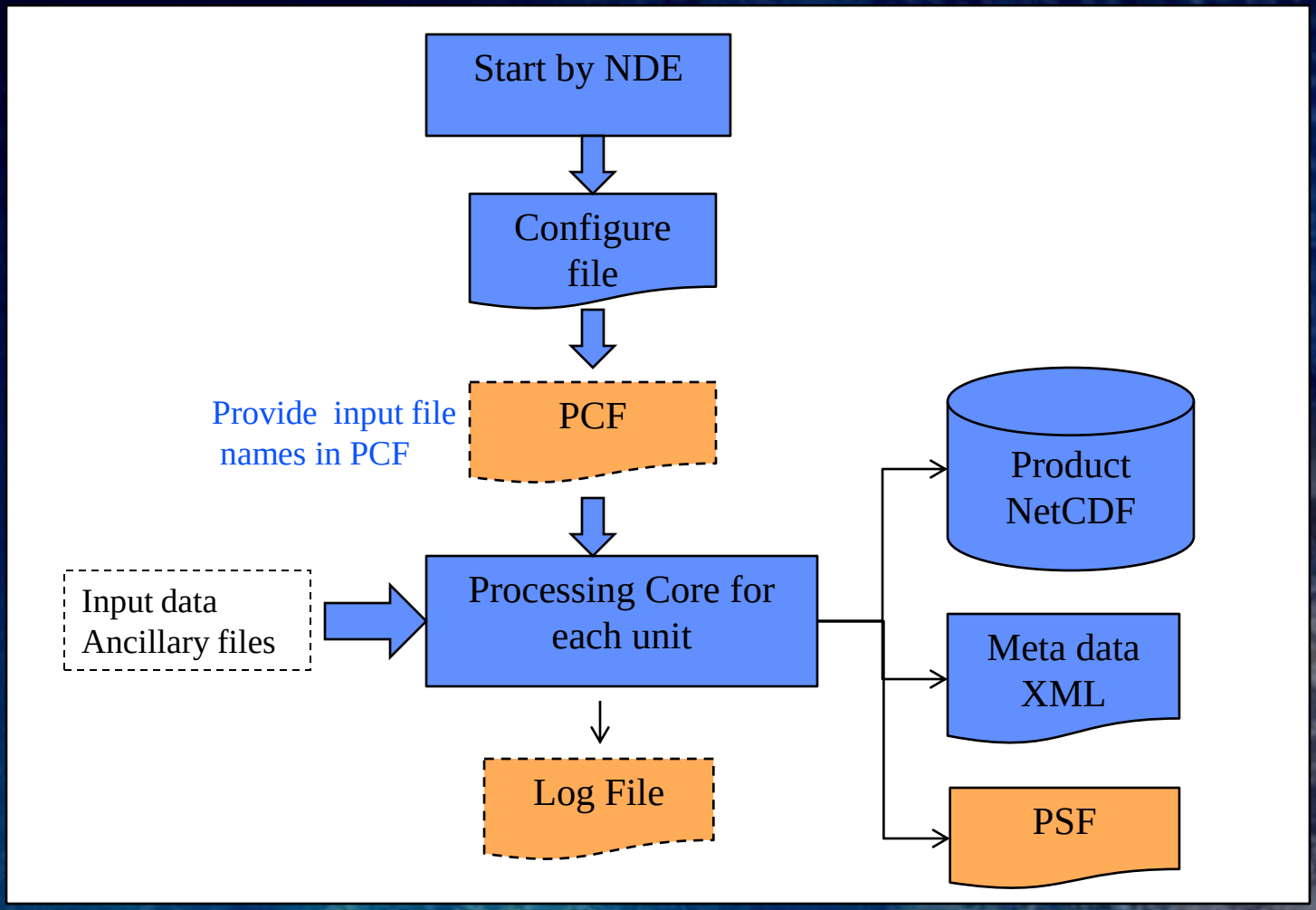
Presented by

Wei Guo

Detailed Design

- The detailed design builds on the software architecture by providing a detailed description of each system element that is defined in the software architecture
  - » Its purpose is to describe the product design at a level of detail that is sufficient for development programmers to write fully functional pre-operational code

General Structure of C++ code



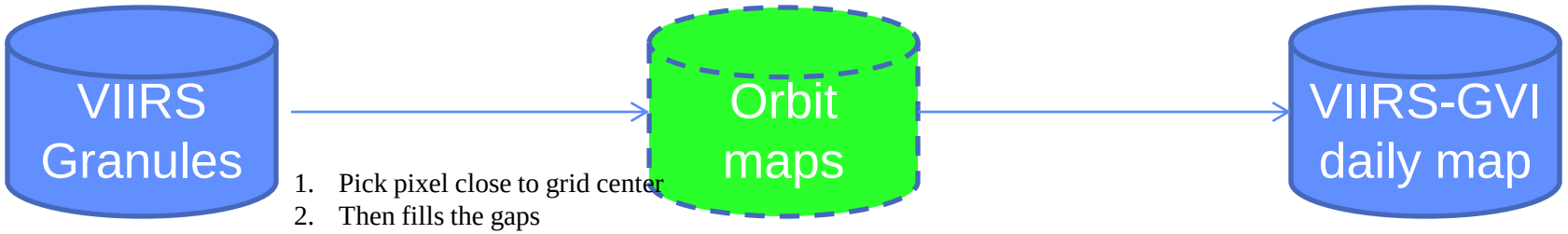
Unit layer – Modules

Module name	Function
DMC core	The major control procedure to process daily map.
VIIRS SDR reader	Read file lists of granules for required data types; Read the geo-location and geometry angles, find the spatial range for each granule. Read reflectance and BT data for required granules Project valid data to geographic grid calculate / Interpolate geometry angles
Land sea mask reader	Read USGS high resolution (30 arc second) land sea mask Calculate the percentage of land for a given box area Check if it is over land for a given location
DMC Configure Reader	Read configure file decode values for parameters and save to a configure structure.
DMM core	Merge partial daily maps to 1 daily map
WMC core	The major control procedure to process weekly composite map.
CAL core	The major control procedure to process calibrated (raw) NDVI and BT.
Land types reader	Read IGBP land type data
COR core	The major control procedure to process smoothed NDVI / BT
VHC core	The major control procedure to process VH product (VCI/TCI/VHI)
Metadata Generator	Read VH product, perform statistics and generate metadata in XML format
Region list reader	Read region list file
Static metadata reader	Read static metadata file and insert the meta data to product
shared configure file reader	Read shared configure file, decode values for parameters and save to a configure structure.
Process Control File Reader	Read PCF and get input file names
NC/HDF Writer	Write data and attributes to NetCDF or HDF file.
PSF Writer	Write output file names to process status file

VIIRS-VH Data

- The input data files are VIIRS SDR granules (I1, I2, I5) in HDF5 format.
- Ancillary/Static files are in HDF4, NETCDF or ASCII format
- All output will be in NETCDF format.

DMC unit: Algorithm for VIIRS Daily Map



1. Pick pixel close to grid center
2. Then fills the gaps

At least 6000 files
(6 types x 1014 granules),
About 700GB / day.

Orbit map is virtual
(do not save to file)

VIIRS-GVI in 500m data are saved by 8x8 tiles, with array size,10000 x 3616.

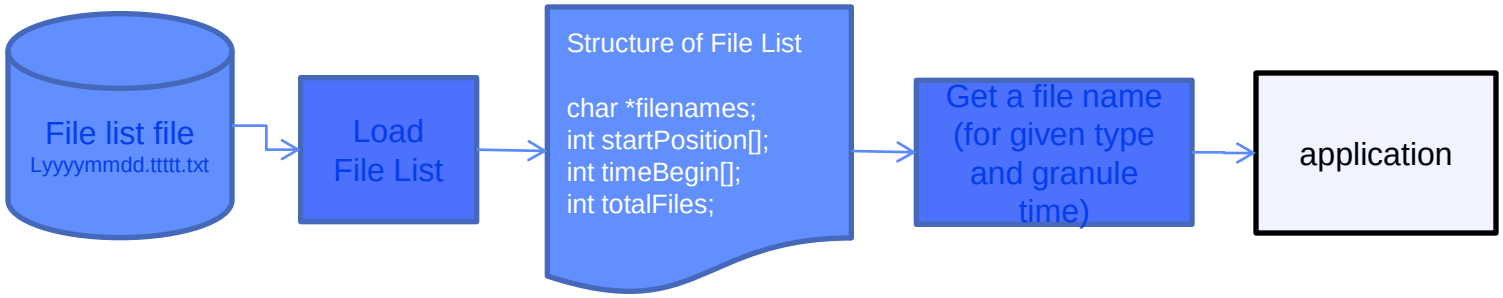
220MB /file
14GB /day

VIIRS SDR/EDR file list

- A list file is a text file contains file names for a given data type.
- Granule list is the unique list of geo-location files. It can be extracted from the file list for geo-location (GITGO) .
- Granule is identified by “begin time” of geo-location file
- File for data types of a granule match with geo-location file by “begin time” in the file name.

```
L2014141.GITCO.txt
L2014141.IICMO.txt
L2014141.IVISR.txt
L2014141.SVI01.txt
L2014141.SVI02.txt
L2014141.SVI03.txt
L2014141.SVI04.txt
L2014141.SVI05.txt
L2014141.SVM01.txt
L2014141.SVM02.txt
L2014141.SVM03.txt
L2014141.SVM04.txt
L2014141.SVM05.txt
L2014141.SVM06.txt
L2014141.SVM07.txt
L2014141.SVM08.txt
L2014141.SVM09.txt
L2014141.SVM10.txt
L2014141.SVM11.txt
L2014141.SVM12.txt
L2014141.SVM13.txt
L2014141.SVM14.txt
L2014141.SVM15.txt
L2014141.SVM16.txt
L2014141.VIVIO.txt
L2014141.VLSTO.txt
L2014141.VSCMO.txt
L2014141.VSTYO.txt
```

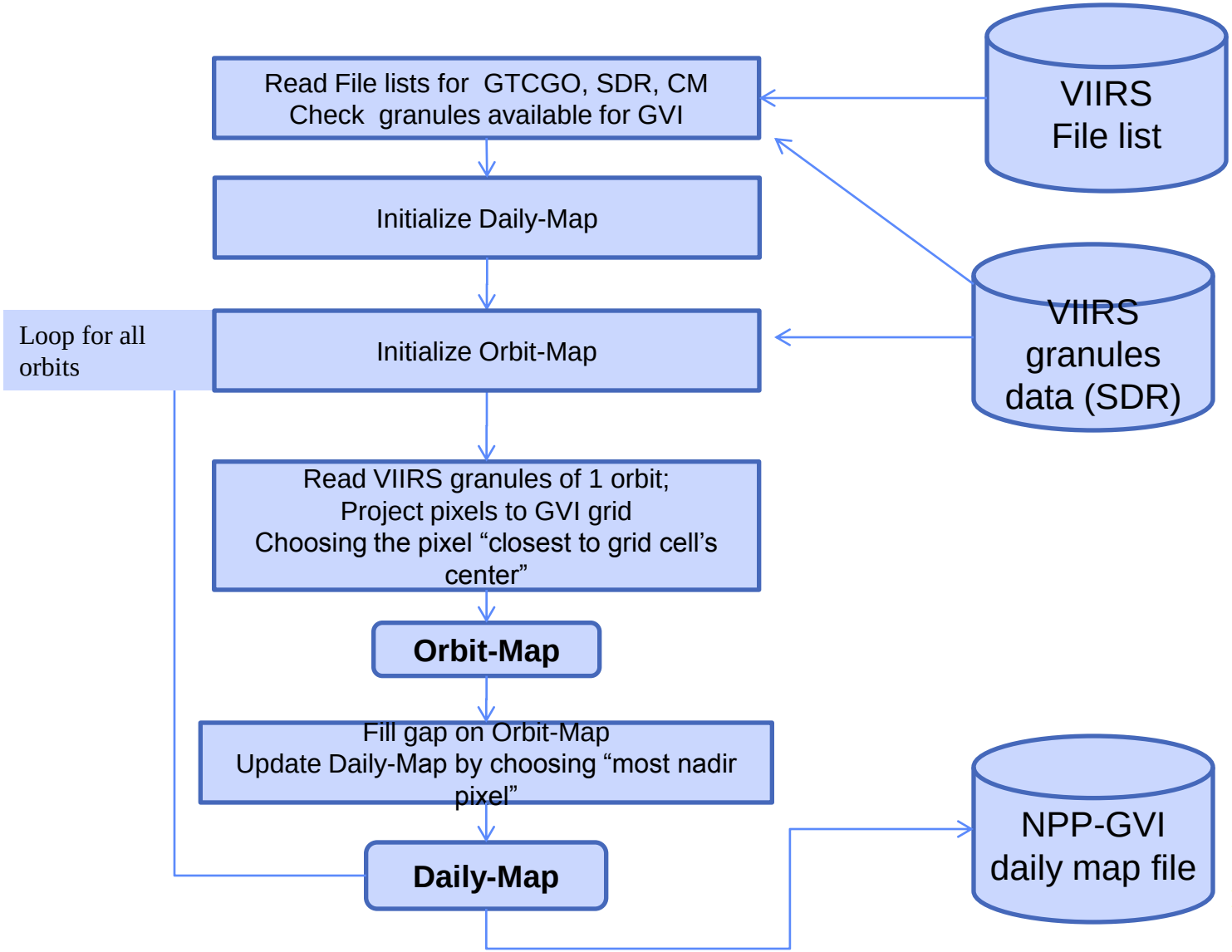
VIIRS granule list



The file list contains all file names for a given data type and given day;
When loading file list, duplicated files are skipped;
Always seraching file by given type and granule begin time

GITCO_npp_d20130318_t2359539_e0001181_b07202_c20130319062132436830_noaa_ops.h5

DMC unit Detail Data Flow chart

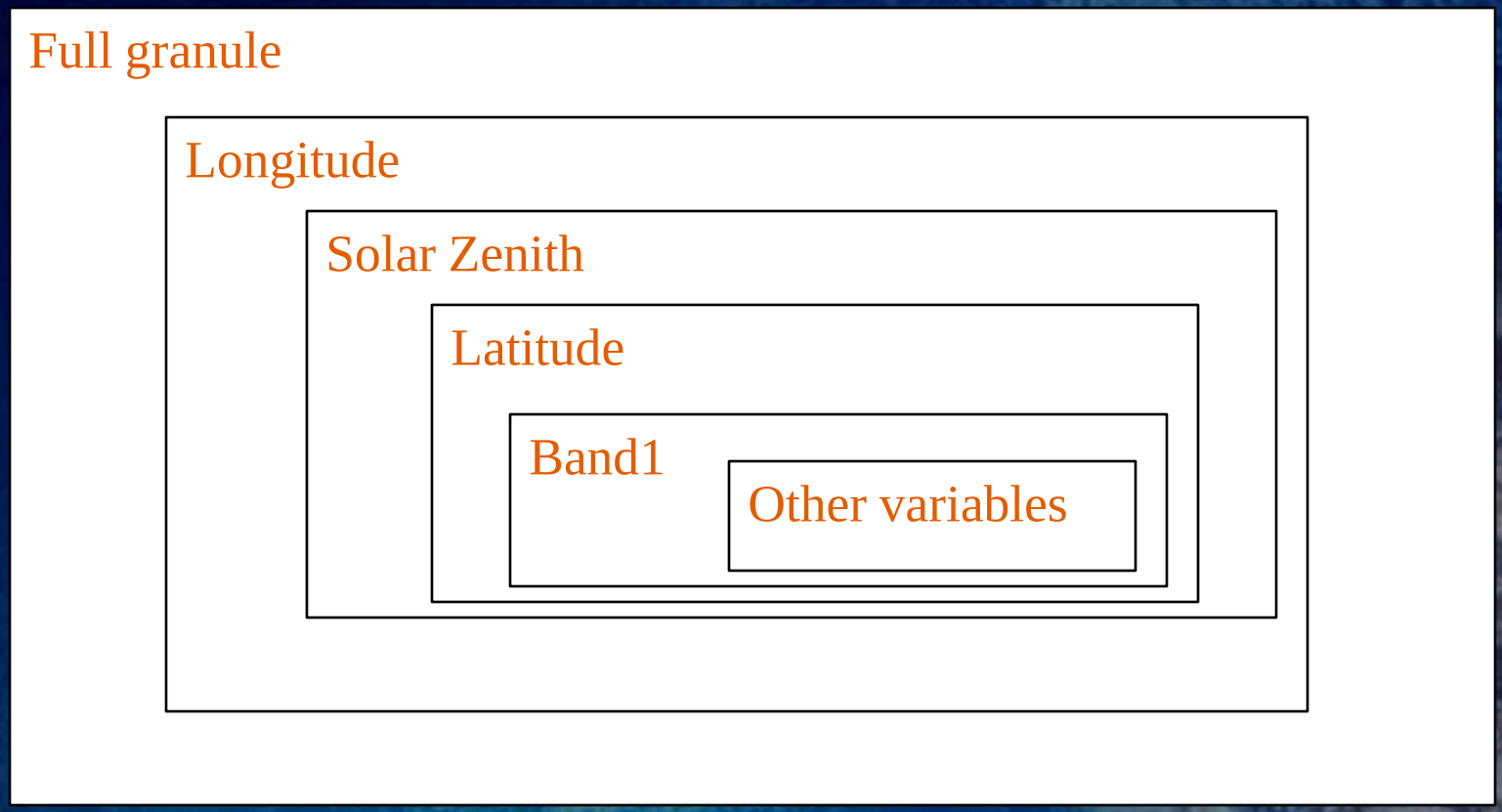


Quick processing for VIIRS VH daily map

- For each granule, read the bounding geo-location and status of Day/Night from geo-location file and save them in a structure for file-list .Use these information to check if a granule is required to process for a specific tile.
- When reading lati/lon and Solor Zenith, search the valid data section so that always narrow down the searching and reduce the reading volume;
- map Band 1, and solar zenith, calculate the position in GVI grid for granule pixels
- Then, map Sensor Zenith and cloud mask using position in GVI grid for granule pixels, merge orbit map to daily map by most nadir criteria, record the granule number and position in granule for GVI pixel,
- Calculate the data section required to read for each granule
- For all other variable, read the granules for required section only, and put the selected pixels directly to daily map.

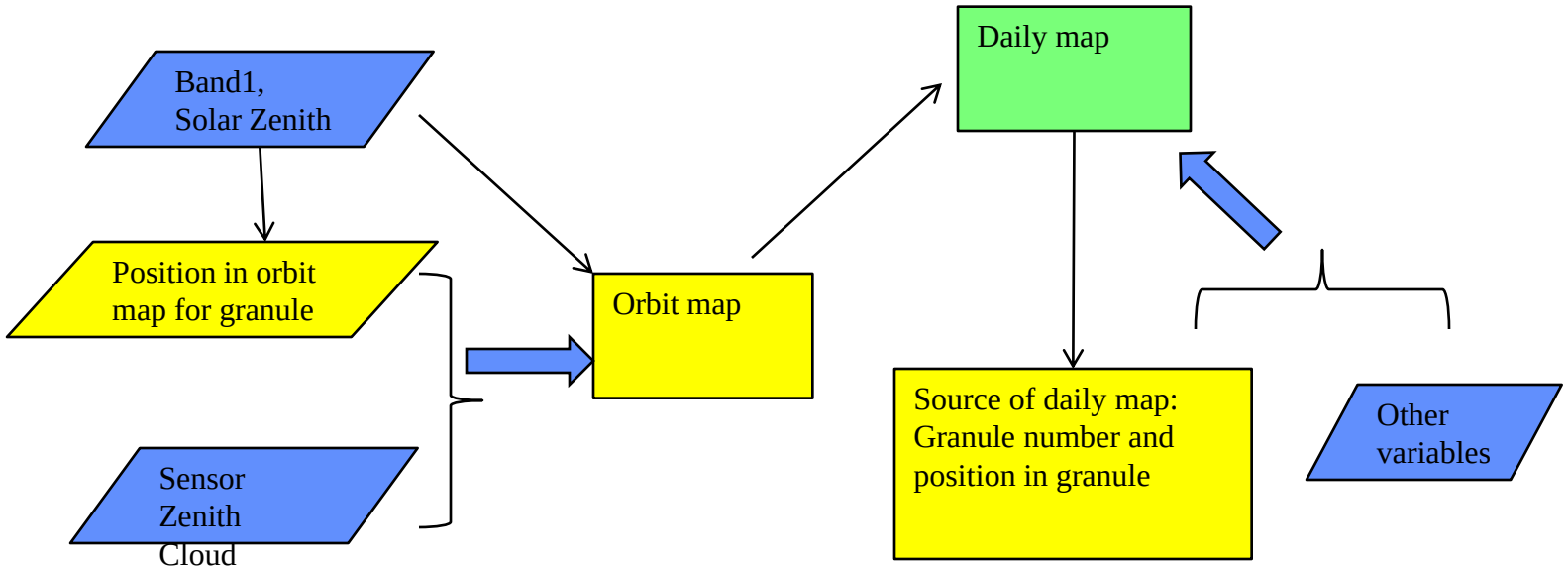
Quick processing for VIIRS VH daily map

Reduce the read reading by searching valid data section for key variable



Quick processing for VIIRS VH daily map

Mapping Key variables to orbit maps, then merge to daily map
Mapping other variables directly to daily map



Unit Layer- DMC Unit Modules

Module name	Function
DMC core	The major control procedure to process daily map.
VIIRS SDR reader	Read file lists of granules for required data types; Read the geo-location and geometry angles, find the spatial range for each granule. Read reflectance and BT data for required granules Project valid data to geographic grid calculate / Interpolate geometry angles
Land sea mask reader	Read USGS high resolution (30 arc second) land sea mask Calculate the percentage of land for a given box area Check if it is over land for a given location
DMC Configure Reader	Read configure file for viirs_gvi.exe, decode values for parameters and save to a configure structure.
Static metadata reader	Read static metadata file and insert the meta data to product
Process Control File Reader	Read PCF and get input file names
NC/HDF Writer	Write data and attributes to NetCDF or HDF file.
PSF Writer	Write output file names to process status file

Dedicated Disk Space

- VH algorithm requires to update product files of previous weeks: therefore, NDE will allocate a dedicated disk space (<20GB) to keep intermediate products and climatology data.

- A clean-up procedure will be implemented to prevent the dedicated space to grow.

Configure Files

- Although the VH suite builds only one executable file, different tasks have different configure files. They provides paths for I/O files and other parameters to control programs.

- The configure files are ASCII files specifying the parameters to run the VIIRS-VH programs
  - » The parameters are entered in format of “name=value”, one entry per line.
  - » The order of parameters is not significant, thus it is a free style file.
  - » Can be shared by multiple VHP tasks.

Process Control File (PCF)

- PCF content:
  - » Paths of input and output files
  - » Optional parameters
- PCF may override the setting in configure file
- If PCF is not available, input files will be searched in specific folders. This helps re-processing products.

Process Status File (PSF)

- PSF will contain files required to save or distribute:
- Example:

VH_FILE=data/VH/GVH4kmFinalVH-P2014001_npp_s201401010000000_e2014010723599_c201401080101000.nc

Ancillary files

- Static meta data file:
  - » contains parameters which will be inserted to product file as file attributes. It allows to change the file attributes without modifying the source code.
- 1.1km Land sea mask
- IGBP land type
- Calibration files
- List of Regions for statistics:
  - » Contains spatial range of selected regions.
  - » Used to extract regional averaged data for metadata

Log File

- Each time a VIIRS-VH program is started to run, standard (screen) output can be dumped to a log file. It is suggested to save log file for problem resolving.

Metadata Files

- VIIRS-VH product (NetCDF) may have an accompanying metadata file with the same file name except the extension (*.xml) replaces the extension (*.nc).
- These metadata files are in standard XML format, containing general information that is saved in VIIRS-VH product file as file attributes.
- They also contain statistic information for global and selected small regions.
- They are created for monitoring the status of product processing and data quality.

Metadata File Content

- Statistic information includes:
  - » Histogram data for the dataset (e.g., NDVI,BT, VCI, TCI and VHI).
  - » Mean value and percentage of missing data over 8 selected regions and latitude zones (each zone covers latitude of 10-degree).

#	Ecosystem	Name	lon W	lon E	lat S	lat N
1	Global	Global	-180	180	-40	40
2	Desert	E. Sahara (LIB)	23	24	28	29
3	Semi-Desert	Great-Sandy (AUS)	125	126	-21	-20
4	Steppe	Colorado (USA)	-103	-102	36	37
5	Crops	Illinois (USA)	-89	-88	39	40
6	Broad Leaf Forest	Kentucky (USA)	-85	-84	36	37
7	Coniferous Forest	Oregon (USA)	-122	-123	43	44
8	Tropical Forest	Amazon (BRA)	-63	-62	-3	-2

Product Files

- VIIRS-VH products are written in NetCDF format
- A common I/O utility is called to manipulate NetCDF/HDF files
- NetCDF/HDF reader/writer modules were built upon this common I/O utility
- VIIRS-VH products are also written in Geo-TIFF format and as PNG image files by IDL code

Product Files
Internal file names

File Type	File name	Description
Daily Map	VHP.G04.C01.NN.Pyyyyddd.nc	VHP daily map
Weekly Composite	VHP.G04.C07.NN.Pyyyywww.Ssss.Eeee.nc	WHP weekly composite
ND	VHP.G04.C07.NN.Pyyyywww.ND.nc	VHP weekly raw NDVI and BT
SM	VHP.G04.C07.NN.Pyyyywww.SM.nc	VHP weekly smoothed NDVI and BT
VH	VHP.G04.C07.NN.Pyyyywww.VH.nc	VHP weekly VCI/TCI/VHI
CLIMAT[1]	VHP.G04.C07.CLIMAT.Pwww.nc	VHP multi-years climatology

[1] CLIMAT files are external input files that are generated by an off-line process

www = Week number (range = [001,052])

sss = Start day of weekly composite = www*7 – 6

eee = End day of weekly composite = www*7

Product Files
file names for archiving

The VH files for archiving/distribution will have NDE style file names:

prefix-Pyyyywww_npp_syyyymmdd_eyyyymmdd_cyyyymmddhhmmsss.nc

Prefix: GVH4kmInitalVH: initial Global VH 4km VH
GVH4kmFinalVH: final Global VH 4km VH
Pyyyywww: year and week number

Others are required by NDE, they are start, end time of data used, and file creation time.

VIIRS-VH File Attributes (1)

File attributes includes general metadata such as:

- product name,
- version,
- satellite,
- Time begin and end
- spatial range,
- citation to documents.
- ancillary files
- input orbit files.
- the content of configure file.
- Other parameters listed in static metadata file.

VIIRS-VH File Attributes (2)

Daily Map	Weekly composite	ND/SM/CLIMAT/VH
FILENAME	FILENAME	YEAR
YEAR	YEAR	PERIOD_OF_YEAR
PERIOD_OF_YEAR	PERIOD_OF_YEAR	DAYS_PER_PERIOD
DAYS_PER_PERIOD	DAYS_PER_PERIOD	Product_Name
Max_Solar_Zenith	Max_Solar_Zenith	Version
Max_Sensor_Zenith	Max_Sensor_Zenith	Satellite
Product_Name	Product_Name	Instrument
Version	Version	Date_Begin
Satellite	Satellite	Date_End
Instrument	Instrument	Time_Begin
Date_Begin	Date_Begin	Time_End
Date_End	Date_End	Ancillary_Files
Time_Begin	Time_Begin	Citation_To_Documents
Time_End	Time_End	Contact
Ancillary_Files	Ancillary_Files	Configure_File_Content
Citation_To_Documents	Citation_To_Documents	PROJECTION
Contact	Contact	END_LATITUDE_RANGE
Configure_File_Content	Configure_File_Content	START_LONGITUDE_RANGE
PROJECTION	PROJECTION	START_LATITUDE_RANGE
END_LATITUDE_RANGE	END_LATITUDE_RANGE	END_LONGITUDE_RANGE
START_LONGITUDE_RANGE	START_LONGITUDE_RANGE	
START_LATITUDE_RANGE	START_LATITUDE_RANGE	
END_LONGITUDE_RANGE	END_LONGITUDE_RANGE	
Calibration_CH1	Calibration_CH1	
Calibration_CH2	Calibration_CH2	
L1B_FILES_USED_TOTAL	L1B_FILES_USED_TOTAL	
L1B_FILES_USED		

VIIRS VH File Scientific Data Sets (SDS)

- Each VIIRS-VH product file in NetCDF format contains a few Scientific Data Set (SDS).
- These SDS are on the 2-dimensional VIIRS-VH grid in geographic projection.

Scientific Data Set of Daily Map Files

Reflectance_I1	Reflectance of image band 1
Reflectance_I2	Reflectance of image band 1
Temperature _I5	Temperature of image band 5
solar_zenith	Solar zenith angle
sensor_zenith	Sensor zenith angle
solar_azimuth	Solar azimuth angle
sensor_azimuth	Sensor azimuth angle
packed_cloud_mask*	Packed cloud mask (served as part of QA)

[*] The variables marked by * are stored in byte array, all others are scaled and stored in 2-byte integers.

Scientific Data Set of Weekly Composite Files

Weekly composite contains the same SDS as daily map. It also contains additional two SDS:

cell_jday	**day of year of selected pixel**
ValidDaysForVH1	the number of days with valid CH1 data

Scientific Data Sets of VIIRS-VH Indices Files

File Type	SDS name	Description
ND	NDVI	Calibrated (raw) NDVI
	BT4	BT4 with non-linear correction applied
	QA *	Quality Assurance Flags
SM	SMN	Smoothed NDVI
	SMT	Smoothed BT4
	QA *	Quality Assurance Flags
VH	VCI	Vegetation Condition Index
	TCI	Thermal Condition index
	VHI	Vegetation Health Index
	QA *	Quality Assurance Flags
CLIMAT	NDVI_MAX	Maximum, minimum, mean and standard deviation of NDVI and BT4 derived from Multiple years SMN and SMT
	NDVI_MIN	
	NDVI_MEAN	
	NDVI_STDDEV	
	BT_MAX	Maximum, minimum, mean and standard deviation of BT4 derived from Multiple years SMN and SMT
	BT_MIN	
	BT_MEAN	
	BT_STDDEV	
	QA *	Quality Assurance Flags

[*] QA are stored in byte array, all others are scaled and stored in 2-byte integers.

Scientific Data Set Attributes

SDS Attribute	Description	Note
long_name	The name of the variable	For all SDS
coordsys	Projection type “cartesian” means Plate Carree Projection (Lat/Lon grid)	
units	Unit of the variable	
range	Range of the variable	
_FillValue	Fill value in SDS	
scale_factor	Scaling factor	If values are scaled.
Add_offset	Scaling add offset	
Remark	Remark on how to convert a scaled value back to physical value.	

- For each SDS, there are a set of attributes to describe the data property and scaling parameters
- Unless a variable is in type “byte”, VIIRS-VH products data are scaled and saved in 2-bytes integer array. A simple scaling scheme was implemented, following the style of MODIS Level 1B products.
  - » Value= scale_factor * (ScaledInteger - add_offset)

QA Flags – Daily Map and Weekly Composite

- For Daily Map and Weekly Composite NetCDF files, the “packed_cloud_mask SDS serves as the QA data set.
- The Snow flag is not set yet due to lack of operational global snow product.
- Cloud mask may be set if the input cloud mask data are available .

From the least significant bit (LSB)	Description
0	Invalid pixel
1	Is day time
2	Land
3	Coast
4	Sun glint
5	Snow -- not set ,
6-7	Cloud mask: (0~3), clear(0),partial-clear(1), partial-cloudy(2), cloudy(3)

QA Flags – ND, SM, CLIMAT and VH Files

- For VIIRS-VH ND, SM, CLIMAT and VH files, a pixel is invalid when all variables are missing (= fill value).
- If a variable has valid value, it still may not be meaningful if it is over an area without nature vegetation, for example, VCI over desert, water or very cold area.

From the least significant bit (LSB)	Description
0	Invalid pixel
1	Desert
2	Land
3	Coast
4	Too cold surface
5-7	Reserved

Source code *.cpp

Major units of the VIIRS-VH Product processing system are written in C++. Type are the bricks to build the VIIRS-VH system

File name	Class	function
AvhrrGvi.cpp	CAvhrrGvi	Make GVI daily map from AVHRR data
ViirsGvi.cpp	CViirsGvi	Make GVI daily map from VIIRS data
VHsuite.cpp	CVHsuite	Process weekly composite, calibration,correction and VH calculation
AvhrrCalibration.cpp	CAvhrrCalibration	Calibration file reader Calculate calibrated reflectance and NDVI
GridFile.cpp	CGridFile	I/O Operation on NECDF/HDF files with 2-D arrays
GviInterpolation.cpp	CGviInterpolation	Interpolation on geolocation and geometry angles for AVHRR GAC/LAC data
L1BS.cpp	CL1BS	Read and decode AVHRR GAC/LAC L1B files
Landseamask11.cpp	CLandseamask11	Read and 1.1km landsea mask file Get land sea mask for a given point
NetFile.cpp	CNetFile	I/O Operation on NECDF/HDF file
VhFile.cpp	CVhFile	Operation on VH files, including daily map, weekly composite, ND, SM and VH files
lib_basic.cpp	C code	Functions for common use

C++ Classes
CViirsGvi

- Class: CViirsGvi
  - » Major Functions: Contain major components for making GVI daily maps from VIIRS and EDR input files.
  - » Associated Data Files:
    - – Configure file
    - – VIIRS and EDR
    - – Landseamask11.bit.hdf
    - – Daily map files
    - – Static metadata
    - – List of regions for statistics
    - – Process Status File
    - – Process Control File
  - » Units that use this class: DMC

C++ Classes
CAvhrrGvi

- Class: CAvhrrGvi
  - » Major Functions: Contain major components for making GVI daily maps from AVHRR L1B or L1BS input files.
  - » Associated Data Files:
    - – Configure file
    - – GAC orbit files
    - – Landseamask11.bit.hdf
    - – Daily map files
    - – Static metadata
    - – List of regions for statistics
    - – Process Status File
    - – Process Control File
  - » Units that use this class: DMC

C++ Classes CVHsuite (1)

- Class: CVHsuite
  - » Major Functions: Contain major components for producing Weekly composite, ND, SM, VH files, and corresponding sampled product and metadata
  - » Associated Data Files:
    - – Configure file
    - – Daily maps
    - – Weekly composite file
    - – VH files in NetCDF format
    - – Metadata XML files
    - – Static metadata
    - – List of regions for statistics
    - – Process Status File
    - – Process Control File
  - » Units that use this class: DMM, WMC, CAL, COR, VHC

C++ Class CVHsuite (2)

- Run control
  - Read configure file
  - Show configure options
  - Show description of GVH variables
  - Check if a message need to show
- Set Input / Output GVH file
  - Get file name based on setting
  - Set grid buffers size
  - Set scaling parameters for variables
  - Allocate memory for buffers;
  - Create NETCDF file, if it is for output
- Perform statistics and generate meta data file
- Process products:
  - Merge daily maps
  - Make weekly composite
  - Calibrate VIS and NIR bands and calculate NDVI
  - Smooth the time series of 15 weeks
  - Calculate multi-year climatology
  - Calculate VH indices: VCI/TCI/VHI

C++ helper Classes (1)

- Class: CGviInterpolation
  - » Major Functions: Perform interpolation for AVHRR GAC
  - » Associated Data Files: None
  - » Units that use this class: DMC
- Class: CL1B
  - » Major Functions: Operate on input GAC data stored in L1B or L1BS format.
  - » Associated Data Files:
    - – GAC orbit data
    - – SETUP
    - – Structure
  - » Units that use this class: DMC
- Class: CAvhrrCalibration
  - » Major Functions: Manage calibration data of AVHRR VIS and NIR bands
  - » Associated Data Files:
    - – Pre-launch calibration
    - – Post-launch calibration
  - » Units that use this class: DMC, WMC, CAL

This class are for AVHRR-VHP, they are here to make sure this application works

C++ helper Classes (2)

- Class: CLandseamask11
  - » Major Functions: Manage land sea mask data from USGS
  - » Associated Data Files: landseamask11.bit.hdf
  - » Units that use this class: DMC

C++ helper Classes (3)

- Class: CNetFile
  - » Major Functions: The basic interface directly dealing with input/output file in NetCDF or HDF4.
  - » Associated Data Files: All NetCDF and HDF4 files
  - » Units that use this class: DMC, DMM,WMC, CAL, COR, VHC
- Class: CGridFile
  - » Major Functions: The I/O interface extended from CNetFile for 2D grid data.
  - » Associated Data Files: All NetCDF and HDF4 files
  - » Units that use this class: DMC, DMM,WMC, CAL, COR, VHC
- Class: CVhFile
  - » Major Functions: The I/O interface extended from CGridFile for VIIRS-VH products.
  - » Associated Data Files:
    - – NetCDF and HDF4 files specific to ND, SM, and VH products
    - – Metadata XML files
  - » Units that use this class: DMC, DMM, WMC, CAL, COR, VHC

lib_basic.cpp C Functions (1)

- Check I/O exception
- File/directory operation
  - » Make a directory
  - » Get directory name of a file
  - » Check if a file exists
  - » Get file base name
  - » Replace extension of a file
- Configure file operation
  - » Read configure file as a string
  - » Remove comments/spaces/empty lines from configure string
  - » Get configure string of a section
  - » Get integer/float/string value for a variable from configure string
- Allocate/Free memory

lib_basic.cpp C Functions (2)

- Date/Time operation
  - » Check if a year is leap year
  - » Get month, date from jday (day of the year)
  - » Get jday (day of the year) from year, month and date
  - » Get jday (the day of the year) of yesterday
  - » Get week number of the previous week
  - » Calculate and print CPU time used for a processing step
- Array operation
  - » Find max, min values of an array
  - » Calculate mean and standard deviation of an array
  - » Re-size an array
  - » Print values of a array
  - » Initialize an array

lib_basic.cpp C Functions (3)

- Set scaling parameters for variables
- Linear interpolation
- Linear regression
- Geometry calculation
  - » Calculate distance of 2 points on earth surface
  - » Calculate sun-earth distance
  - » Calculate earth angle for given locations of target and pixel
  - » Calculate solar angles for given time and location
  - » Calculate sun position for given time
  - » Calculate azimuth for given location of target and pixel
  - » Calculate sensor angles for given locations of satellite and pixel
- Get IGBP Land Type legend string

lib_basic.cpp C Functions (4)

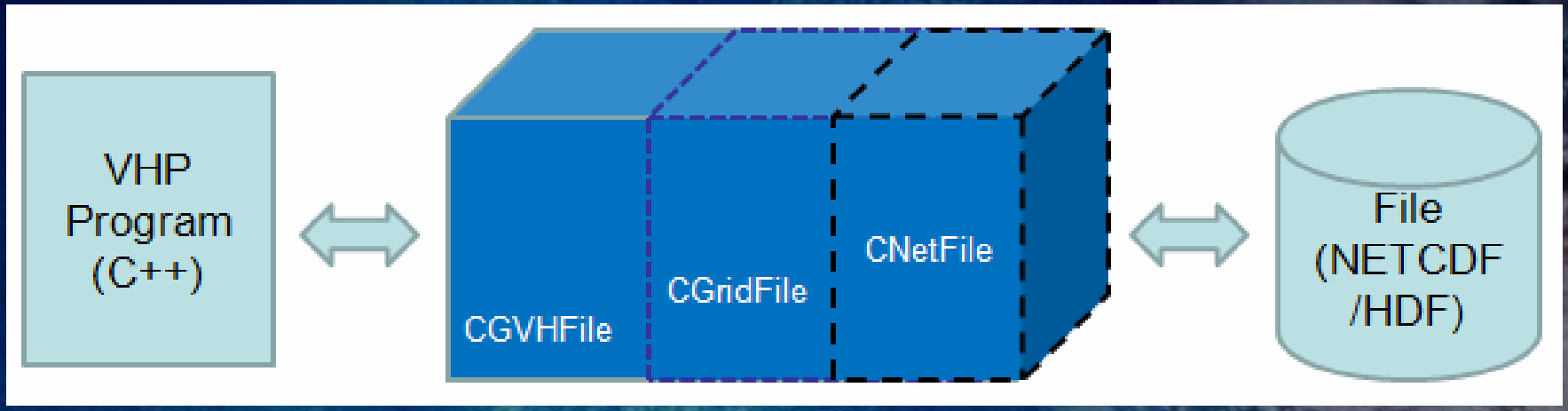
- Find the category of a VH variable
  - » find category of a data type (Climatology, NDVI, BT or VHI)
- Calculation equations for VCI, TCI, VHI
- Functions for time series smoothing
  - » Sort an array
  - » Fill gaps in time series
  - » Median filter
  - » Digital smoothing filter for removing high frequency noise

Land Sea Mask Reader

- The land sea mask dataset used by VIIRS-VH system (landseamaskll.bit.hdf) was re-formatted from USGS 1.1 km land sea mask, which is on a lat/lon grid with size 43200 * 21600, covering the whole globe.
- Because there are only 2 values in the mask file (0 or 1), land sea mask data were re-formatted, compressed and saved as HDF4 file, 1 bit per pixel. The compression feature of HDF4 reduced the file size from 900MB to 3MB.
- The land sea mask reader is implemented by C++ class “CLandseamask11”.
  - » It loads land sea mask data for a particular latitude zone, manages memory required and checks if a pixel is over land (direct check the nearest pixel or calculate percentage of land portion within a radius for a given location).

NetCDF/HDF Files

- In the VIIRS-VH system, there are 3 interface classes which handle VIIRS-VH product files in NetCDF or HDF4 format.
  - » Class CNetFile directly deals with files. It has a switch so that it can support either NetCDF or HDF4 file.
  - » Class CGridFile is extended from CNetFile, which managing operation on Grid buffers by calling class CNetFile.
  - » Class CGVHFile is further extended from CGridFile, which contains functions specific to VIIRS-VH files.



Class
CNetFile, CGridFile and CVhFile

Class name	CNetFile / CGridFile / CGVHFile
Associated Files	NetCDF/HDF4
Function of CNetFile	**This class is the basic I/O interface directly dealing with an input or output file in NetCDF or HDF4 format.** •Set file type, name, and message-output-level •Open/close the file •Define/read/write attributes •Define/read/write SDS
Function of CGridFile	**This class is the I/O interface extended from CNetFile for 2D grid data.** •Set file type, name, and message-output-level, size of grid buffer and geolocation range of SDS •Print message based on message level •Write grid attributes to SDS •Read/write a pixel from/to buffer •Operation on buffers ○ Allocate/free/Initialize buffer ○ Read/write buffers from/to file
Function of CVhFile	**This class is extended from CGridFile for VHP products. It is specific for VHP products.** •Read Spatial Range of VHP dataset •Read Scaling Parameters •Perform statistics (calculate mean value and percentage of missing cells for global and selected areas) •Save metadata to NetCDF/HDF •Copy file attributes from NetCDF/HDF to XML • Save metadata and statistics data to XML •Check outlier in shot integer array • Load IGBP land type for output buffer, data re-format/projecting may be required.

Software Architecture Summary

- VIIRS-VH software development, testing, and operation will be conducted on comparable Linux machines at NDE and STAR.
- The VIIRS-VH code will run as stand-alone application within the NDE DHS.
- The code will be modular to allow for easy reuse of code and expansion to accommodate new products.
- The code will use only the official releases and NDE compatible versions of the netCDF4, HDF4 and HDF5 libraries.

1) INTRODUCTION
2) PDR RISKS AND ACTIONS
3) OPERATIONS CONCEPT
4) REQUIREMENTS
5) ALGORITHM THEORETICAL BASIS
6) SOFTWARE ARCHITECTURE
7) DETAILED DESIGN
8) **QUALITY ASSURANCE**
9) PROJECT STATUS
10) RISKS AND ACTIONS
11) SUMMARY AND CONCLUSIONS

Section 8 – Quality Assurance

Presented by

Felix Kogan

Quality Assurance Background

- STAR AVHRR-VHP system **is the prototype** of VIIRS-VH system. AVHRR-VHP systems has been transitioned to operations successfully.

- SPSRB Review Process is used and modified from the STAR EPL process.

Quality Assurance – Project

- Preliminary Design Review (January 2014)
  - Will present the initial draft of the requirements and discuss a proposed design.
  - An Requirements Allocation Document (RAD) has been made available to VIIRS-VH stakeholders. It will be updated throughout the lifecycle of the project.
- Critical Design Review (June 2014)
  - To finalize requirements and to verify that the chosen design is meet them.
- Software code unit test review (September 2014)
  - Will be conducted to ensure that the software is able to fulfill the functional software requirements.
- Algorithm Readiness Review (December 2014)
  - Will be conducted to ensure that the software is able to fulfill the functional hardware requirements.

Configuration Management (CM)

- CM Tool (subversion)
  - » Has been purchased and implemented in the Collaborative Environment.
- CM personnel have been identified.
- CM training:
  - » Administrator training completed.
  - » Developers will be trained by the CM administrator.
- **Detailed CM Plan is under development**.

STAR 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.

Quality Assurance – Software (1)

- VIIRS-VH **software will be delivered incrementally** as part of the series of algorithm package deliveries:
  - » Initial DAP Delivery– August 2014
  - » Final DAP Delivery – November 2014

Quality Assurance – Software (2)

- All **code development is being conducted on a platform that is nearly identica**l 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 VIIRS-VH code meets STAR coding standards.
- The status of all system calls and intrinsic functions are checked.
- Unit tests will have the VIIRS-VH system generated VH product and compared with AVHRR-VHP products.

Quality Assurance – Software (3)

- An official **DAP will be delivered:**
  - All VIIRS-VH code and system files
  - Test plans
  - Test data sets
  - Error messaging/handling
  - PCF format
  - Production rules
  - Product file specifications
  - Data flow diagrams
  - Estimates of resource usage
  - ATBD
  - SWA
  - Delivery memo

Quality Assurance – Products

- VIIRS-VH **system developers will work with NWS/EMC**, heritage product developers, and NPP **operational** algorithm teams to ensure consistency with heritage products with respect to format and content.

- VIIRS-VH system developers will make test products available to users before the operational products are made available. This will allow for preliminary product content validation.

Quality Assurance – Archive and Maintenance

- Archive Plan
  - » VIIRS-VH system will **be integrated into NDE** system and made available to CLASS by NDE
  - » Product archive requirements are addressed within product development projects
    - – NPP program office works with CLASS to archive xDRs
    - – NOAA Unique Product (NUP) projects work with CLASS as required
- Long Term Maintenance Plan
  - » The VIIRS-VH will be maintained by the OSPO staff
  - » STAR system developers will be available for support

Quality Assurance – Documentation and Metadata

- Documentation/Metadata Plan
  - The Documentation will include the SPRSB documents with the **RAD and RID**
  - Metadata is generated for these products in the form of xml files.

Verification and validation approach

- VIIRS-VH product **will be verified** by
  - Images pattern
  - time series plots.

- VIIRS-VH product will be validated by
  - comparing images and time series with VH product derived from AVHRR.
  - Comparing noise removed NDVI and BT with climatology.
  - Correlation analysis between VH and crop yield.

Quality Assurance Summary

- Quality assurance plan will consist of:
  - Project reviews at which stakeholders are encouraged to participate.
  - Ongoing interaction with customers, heritage product developers, operations, NDE, and the SPSRB.
  - Adhering to STAR/NDE software standards and use of standard libraries only.
  - Software unit tests shall be presented in the TRR.
  - Documentation of the VIIRS-VH code operation, production rules, and software tests will be in the DAP.
  - Documentation of requirements will be in the VIIRS-VH RAD.

1) INTRODUCTION
2) PDR RISKS AND ACTIONS
3) OPERATIONS CONCEPT
4) REQUIREMENTS
5) ALGORITHM THEORETICAL BASIS
6) SOFTWARE ARCHITECTURE
7) DETAILED DESIGN
8) QUALITY ASSURANCE
9) **PROJECT STATUS**
10) RISKS AND ACTIONS
11) SUMMARY AND CONCLUSIONS

Section 10 – Development Project Status

Presented by

Felix Kogan

Stakeholder Involvement

- **Development Team** has been working successfully
- **Customers/Users:**
  - » Communication with the requestors has been maintained from time to time;
  - » Communication has been maintained with NDE

Status of Resources

- **Hardware/Computer Resource Allocation**
  - Dell Power Edge 1950 III Linux server with 2 GB memory, 1 TB hard drive, 2 TB data storage, Red Hat Linux OS, C++ compiler, NESDIS network connection, Dell license. These have been supplied by OSD PSDI.
- **Personnel Resource Allocation**
  - IMSG: 1.0 FTE with capability for C++ programming, code testing, documentation, and CM. Mr. Wei Guo is on board for the project.
  - STAR base: 0.37 FTE. Felix Kogan (0.25 FTE) will serve as the VIIRS-VH Development Lead.
  - OSPO base: 0.05 FTE. Hanjun Ding will provide VIIRS-VH Development Scientist support.
  - NDE review and adjustments

Status of Milestones

- PDR have been achieved
- CDR is in progress
- Remaining milestones have been scheduled

1) Introduction
2) PDR Risks and Actions.
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11) SUMMARY AND CONCLUSIONS

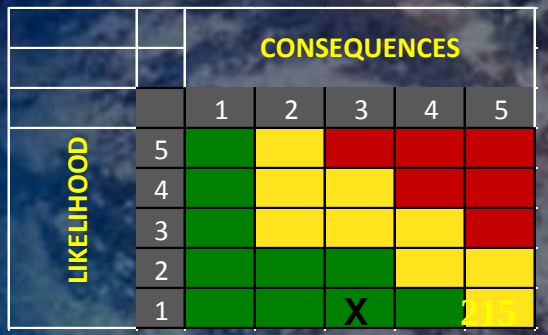
Section 11 – Risks and Actions

Presented by

Felix Kogan

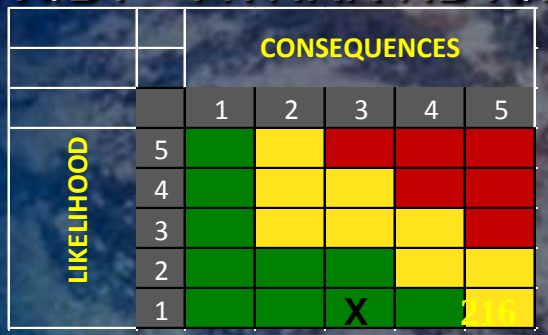
PDR Risks and Actions

- **Risk 2: The climatology data set need to be updated** by using most recent dataset.
- **Risk Assessment:** Low
- **Impact:** If climatology data is not updated then will impact quality of the VIIRS VH product
- **Likelihood:** Low
- **Mitigation:**
  - » Update climatology by using from longer series of data set
- Status: Open



PDR Risks and Actions

- **Risk 3: Adjustment of VIIRS NDVI/BT to AVHRR** equivalent: May require update.
- **Risk Assessment:** Low
- **Impact:** If proper adjustments are not made then the product will not meet requirements
- **Likelihood:** Low
- **Mitigation:**
  - » Continue investigation of stability VIIRS NDVI/BT – AVHRR NDVI/BT relationship;
  - » Update the adjustment parameters
- **Status:** Open



Summary

- Summary of Risks and Actions after CDR
  - 2 existing PDR open risks
  - No new CDR risk.

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Section 12 – Summary and Conclusions

Presented by

Felix Kogan

Review Objectives Have Been Addressed

- The Project Mission and Schedule has been reviewed.
- PDR Report & actions has been developed & reviewed
- Operations concept has been reviewed
- Requirements changes have been reviewed
- Algorithm theoretical basis has been reviewed
- Software architecture, hardware, data, and interfaces have been reviewed.
- Detailed Design has been reviewed
- Quality assurance have been reviewed.
- Risks and Actions have been reviewed.

Current Status

- VIIRS 4km sub-system (GVI-type) was implemented
- VIIRS raw data collections was implemented from May 2012
- VIIRS daily mapping system was implemented
- VIIRS weekly composite system was implemented
- VIIRS initial parameters system was implemented
- VIIRS weekly data adjustment system was implemented
- Blended 4 km climatology dataset was developed from AVHRR data.
- VH indices calculation system was implemented

Issues, Actions And Risks

- All **risks from the PDR have been closed** or have been reduced to LOW risks
- **No code risk has been identified**, because the existing science code is fully functional and should be readily converted to pre-operational code

Next Step – Code and Test Data Development

- Further **evaluation & tuning VIIRS** weekly composite and climatology is required
- Continue to **monitor VIIRS reflectance and VH indices**
- **Code Development** Phase
- Prepare for Algorithm Readiness Review **(ARR)**
- **Conduct ARR**

Open Discussion

- The review is now open for free discussion

Comments of Tom Schott

- Priyanka, Felix and Hanjun,
  Good review.

  Here's some areas that need work.
  - Action Item: NWS doesn't need Geo-TIFF and USDA uses the same tool. Matt will contact USDA to determine whether Geo-TIFF is required.
  - Has a request for archive been submitted to NCDC? Hanjun answered yes.
  - S48: CLASS archive funding is not fully determined. CLASS requires funding. Schott has some FY15 funding. I think this is a risk to be worked between CLASS and OSD.
  - Action item: Schott will attempt to get VH in his FY15 archive task agreement w/CLASS.

  Here's some suggestions for updating the CDR package:
  - Add slide numbers on all slides
  - S35: show PNG as an output but this output is not shown on S33
  - S40: need to add SAIDE in this IT picture. In fact, need to do a scrub to show DAPs are delivered into SAIDE by STAR. NDE (Dylan) ensures they run on SAIDE and then OSPO promotes them to PE2 (test system).
  - S59: change L1b to SDR. JPSS doesn't use the L1b terminology.
  - S88 is blank.
  S183 is for AVHRR. Delete?

  Tom

Comments of Donna McNamar

- Hi Felix and Hanjun,

  Just a few comments about the PPT:

  Slide 7 - Please add Jing Han to the IPT. She's the OSPO NDE lead.

  Slide 27 - Last bullet - product monitoring GUI will not be viewed by ESPC operators.

  Slide 44 - Add Jing Han as OSPO NDE Lead. (Yes -- I am the distribution lead -- that's fine)

  Slide 46 - Product monitoring GUI will not be viewed by ESPC operators.

  General question (I may have missed it in the briefing) - when will the code undergo a code review by OSPO? I am specifically asking this because I believe the legacy code has some unusual directory structure.

  Thanks,

  Donna