Requirements to Snow Fraction Retrieval (uncertainty)

- Initially , the U.S. Government (USG) threshold requirements formulated by DoD and DOC in the Integrated Operational Requirements Document (IORD) included 10% measurement uncertainty under clear conditions for 1.3 km horizontal cell size

- The threshold requirements needed for Improved Freshwater Resource Management consider snow information for North America as Mission Critical data with measurement accuracy 10% and horizontal resolution 0.5 km

- It is logical that the requirement to measurement uncertainty for Fractional Snow Cover remained unchanged in the latest version of the Level 1 Requirements, Supplement

Significance of Snow Fraction

- Binary snow and snow fraction have quite different meaning. Under certain conditions, the binary data even in the case of perfect retrieval will systematically miss huge areas covered by snow (is illustrated in the presentation later)
- Snow fraction is an important component of land surface models and hydrological models using different spatial scales (down to 90 m cells)
- Not only does snow fraction describe snow cover properties, but it also modifies surface energy balance influencing processes in the atmosphere and on land
- Snow cover determines boundary conditions for numerous atmospheric processes
- Information on snow fraction improves downstream VIIRS products: vertical atmosphere profiles, soil moisture, etc.

Status of Snow Fraction Retrieval

- GOES-R program considers snow fraction as an option-one product. The requirements for Fractional Snow Cover (FSC), are well documented in the GOES-R Mission Requirements Document (MRD). The remotely senses fractional snow cover will be assimilated into the NOHRSC's snow model and used by more than a dozen of River Forecast Centers
- NASA provides users by fractional snow cover information and stopped retrieval of binary snow cover. Their estimates show that VIIRS could provide better snow fraction at finer resolution
- Snow fraction is a standard GOES product undergoing further improvements
- In Europe 'Snow Cover' data by default include information on snow fraction

Requirements to Snow Fraction Retrieval (Horizontal Cell Size)

- The NOAA Line Offices requirements to Horizontal Resolution (0.5 km) are more strict than initial USG requirements (1.3 km) or the latest Level 1 Requirements (1.6 km at the end of scan)

- However the difference between the resolutions is not very significant. The finer resolution is considered reasonable when applied to North America

- More important that for all variants of the Horizontal Cell Sizes the only possible approach to meet Snow Fraction uncertainty requirements is to retrieve sub-pixel information on snow cover

NPOESS Snow Fraction Retrieval

- Originally, an application of the Multiple Endmember Spectral Mixture Analysis (MESMA) was developed for VIIRS to retrieve the Snow Fraction product

- The spectral mixture analysis defines subpixel proportions of spectral endmembers related to mappable surface constituents

- It “unmixes” the mixed pixel, determining the fractions of each spectral endmember combined to produce the mixed pixel’s spectral signature

- The performance analysis indicated that the measurement uncertainty requirement can be achieved, except for scenes with forest canopy

MESMA Performance Analysis (1999)

Snow Fraction Measurement Uncertainty: Stratified Performance for Typical Case

Scan Angle	Snow Fraction (Truth)			
	0.0– 0.25	0.25 – 0.5	0.5 – 0.75	0.75 – 1.0
Nadir	.070	.072	.076	.081
Edge-of-Scan	.077	.079	.089	.102

Benefit and Opportunity of Using MESMA (*exceptional circumstances*)

Taken from Cryosphere Products Validation Team meeting, May 2, 2013

- MESMA was a part of all NPOESS algorithm and code developments for more than 10 years and delivered to IDPS
- The approach was considered, approved, and recommended to retrieve snow fraction at many meetings at all levels
- The code is still a part of a relatively recent version of software
- MESMA is currently a standard approach to such kind of tasks
- Existing experience of applying MESMA to retrieve snow fraction clearly demonstrates the advantages of the approach considered as one of the best for snow remote sensing
- There is no need for a lengthy process of approving a new approach since it has been already approved

Transformation of NPOESS Algorithm

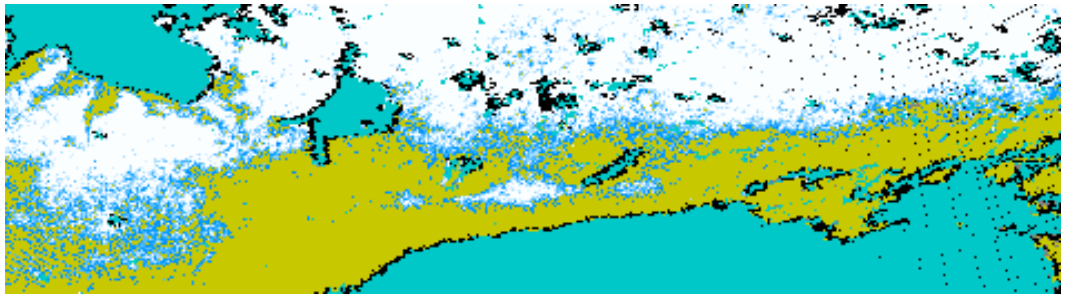
- In the current version of the VIIRS processing system, the MESMA was (temporarily?) replaced by the aggregation of the Binary Snow within 2x2 pixel blocks

- According to one of versions, Snow Fraction computed based on a 2x2 aggregation of the binary map replaced the originally proposed Multiple End Member Spectral Mixture Analysis (MESMA) approach due to uncertainty in the effort required to understand complex behavior in the initial results

- Snow fraction computed based on a 2x2 aggregation of the binary map is not a valid approach and provides no additional information beyond that already provided by the Snow Binary Map

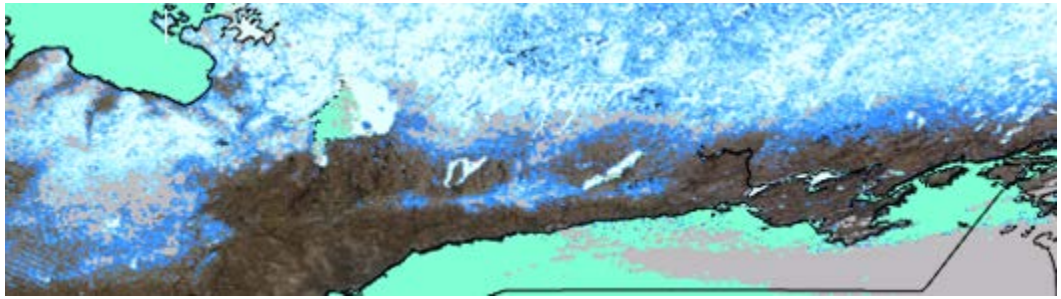
Transition Zones from Snow Covered Regions to Snow Free Areas are Very Narrow

VIIRS fraction



Image

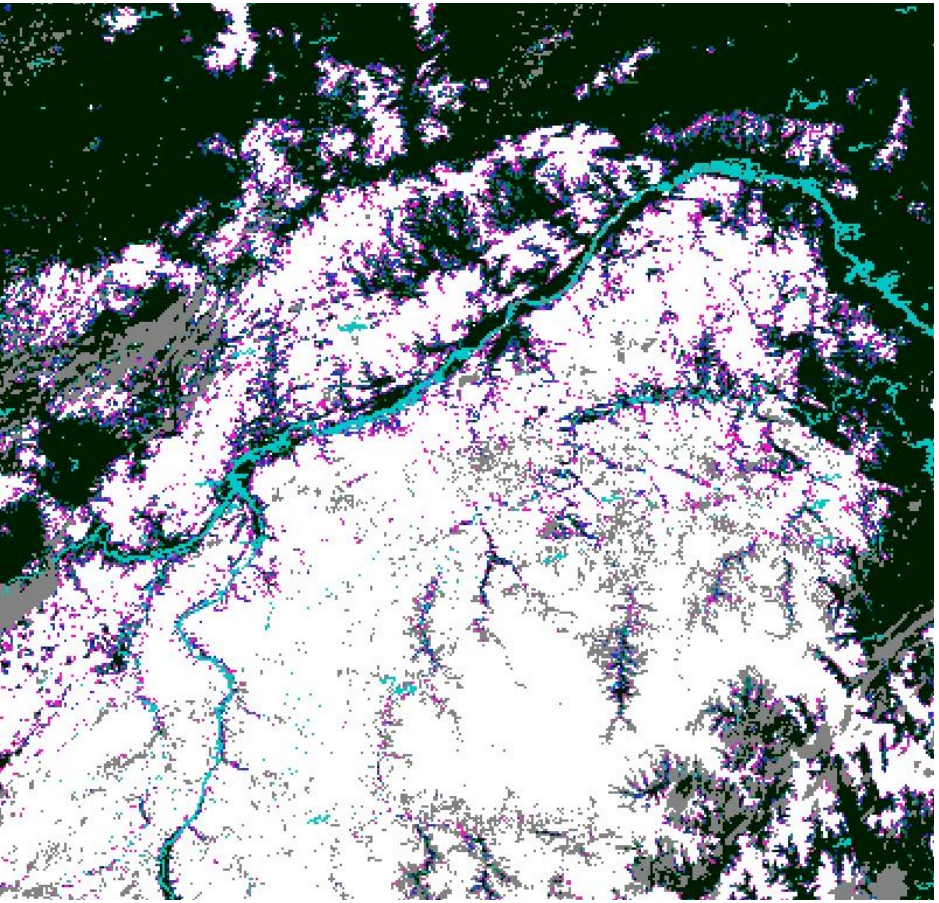
MODIS fraction

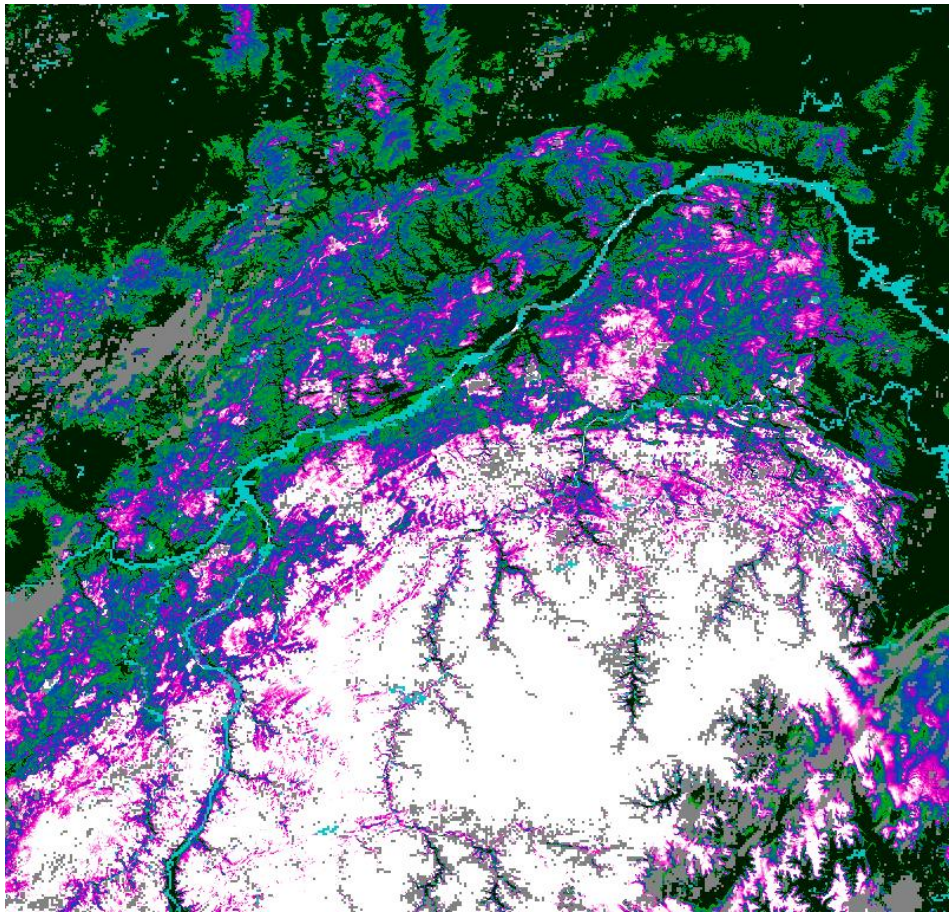


In 2x2 snow fraction (top) snow to no snow transition regions are unrealistically narrow compared to the MODIS based snow fractions

Comparison of Snow Fractions

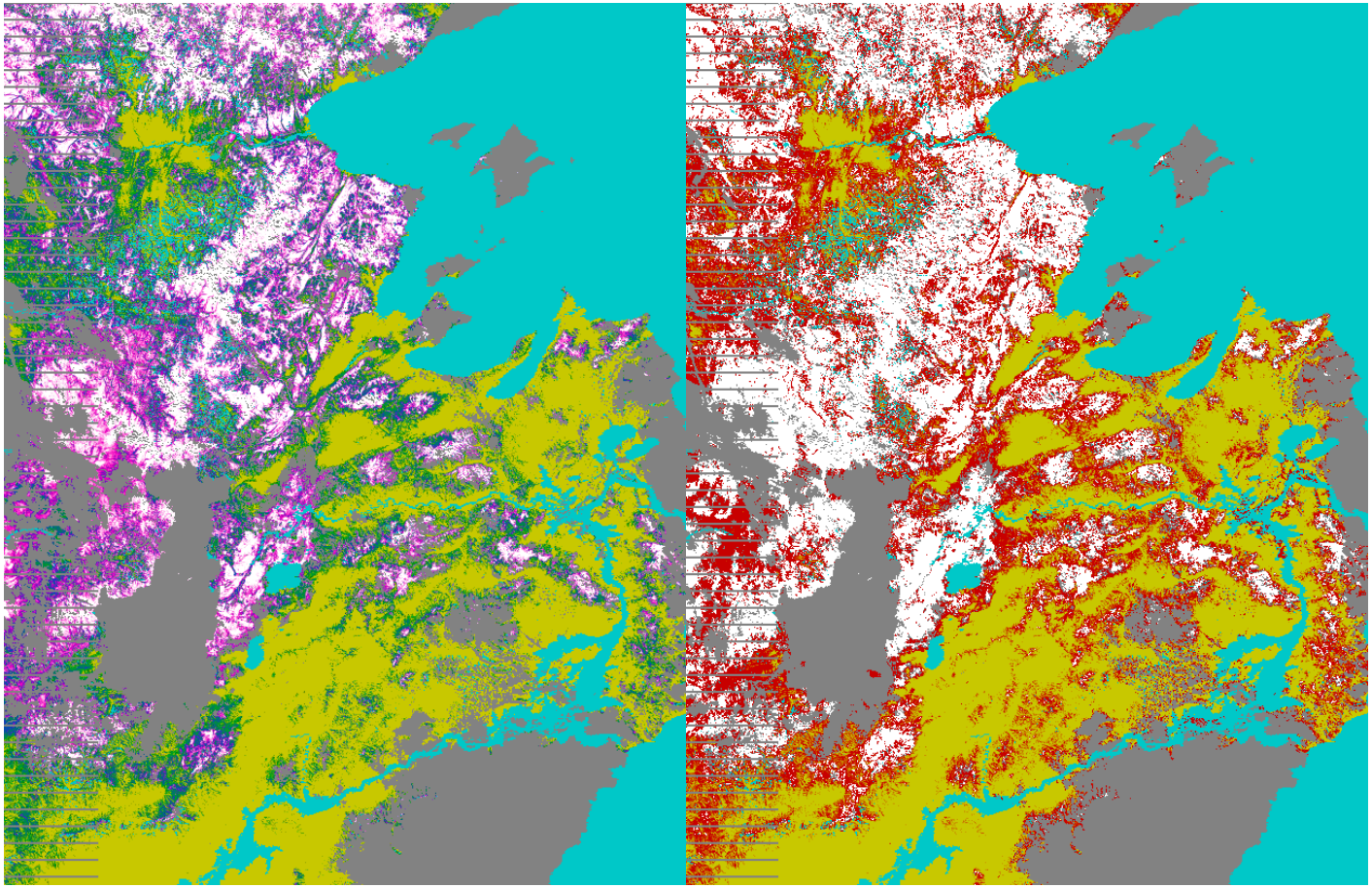
VIIRS Product 0%  100% Simulated Fraction





Current VIIRS 2x2 snow fraction will miss substantial amounts of snow with fraction greater than 0 and less than 100%

Snow Fraction and Binary Snow (10/24/2013 at 03:15)



snow

confidently cloudy

fractional snow cover in areas of non-snow binary retrieval

non-snow in binary and fractional retrievals

water

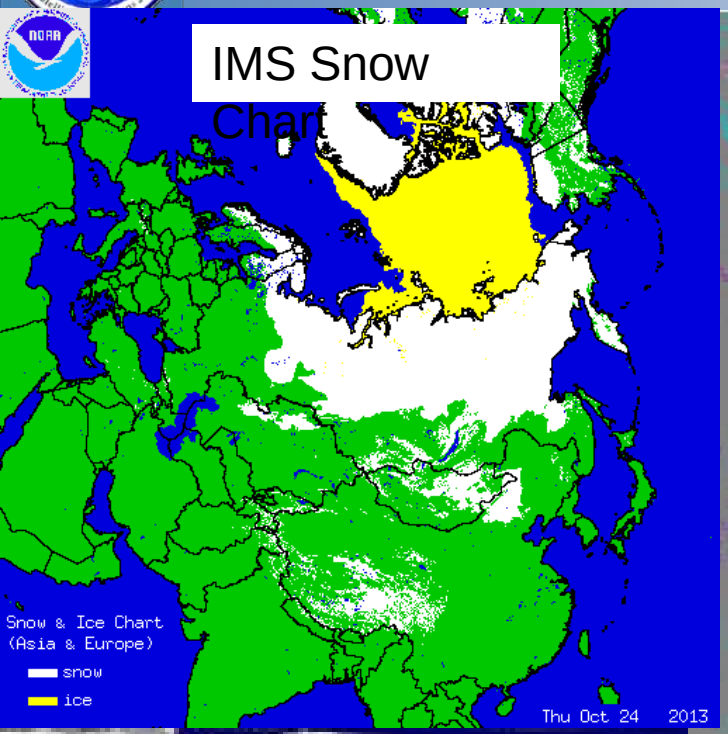
100 %

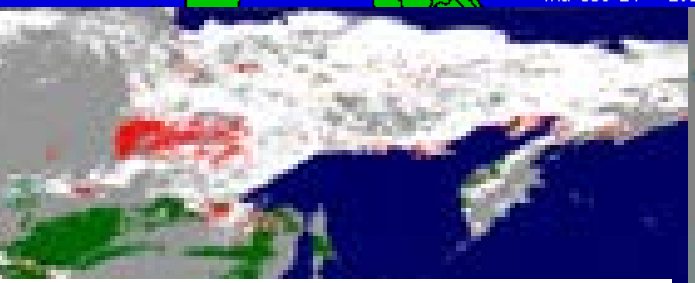
0%

Snow Fraction

Snow Fraction on 10/24/13 (03:20)

IMS Snow Chart





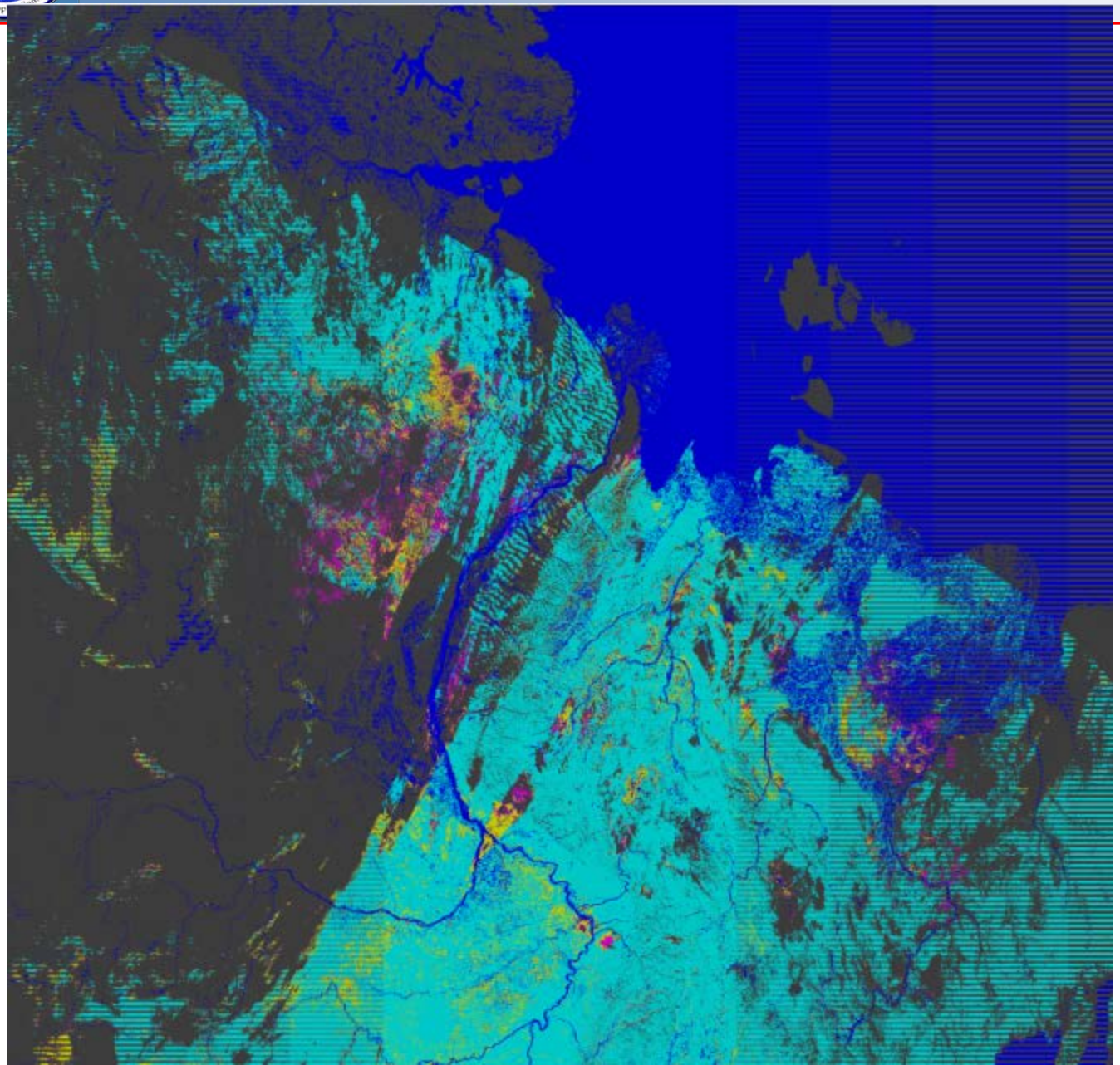
Missing Snow in Binary retrieval

VIIRS snow map disagreement to IMS:

Omission (snow miss)

Commission (false snow)

Cloud Mask on 10/24/13 (03:20)



Confidently clear

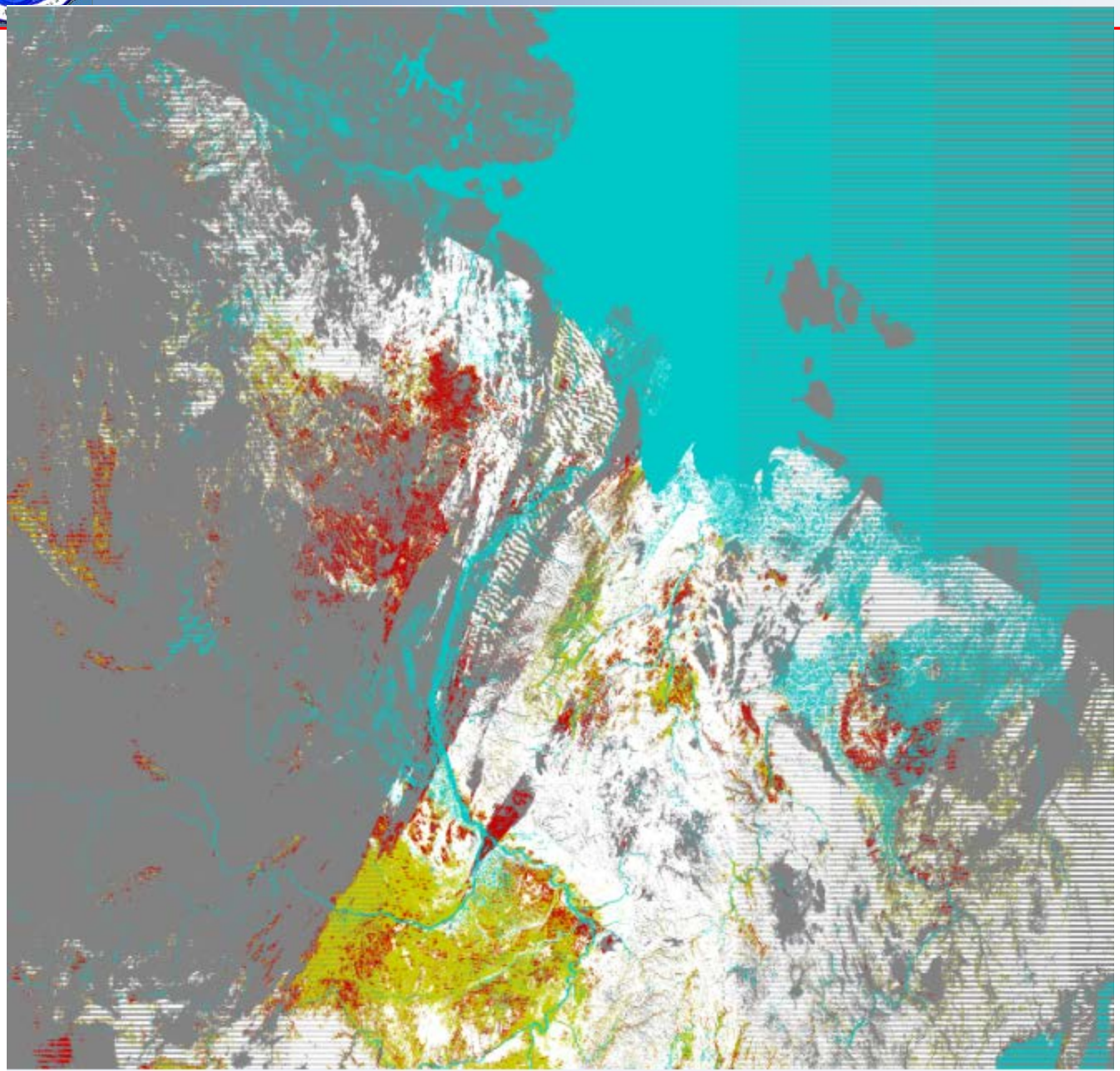
Probably clear

Probably cloudy

Confidently cloudy

Water

Binary Snow on 10/24/13 (03:20)



snow

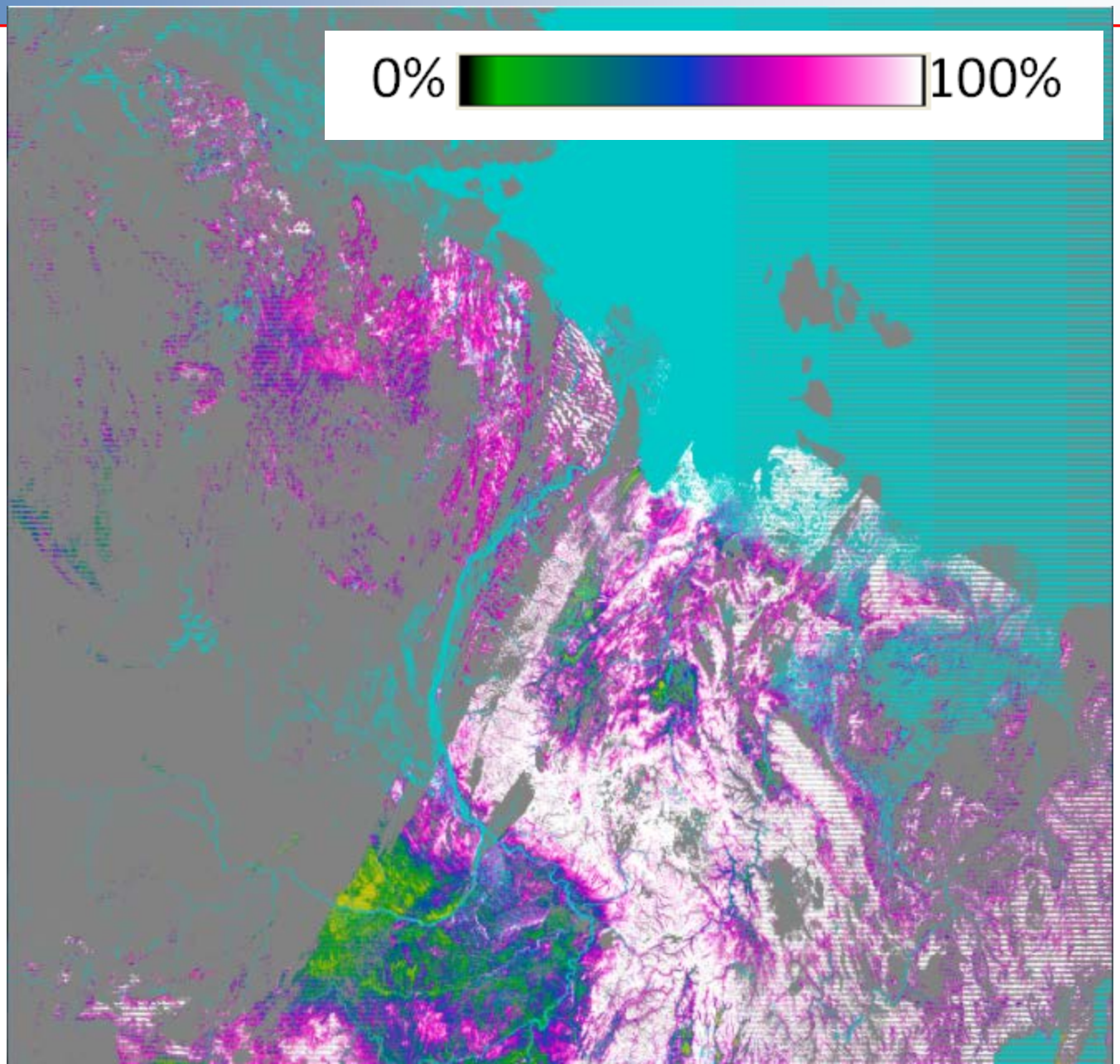
confidently cloudy

no snow retrieval in probably cloudy and probably clear areas

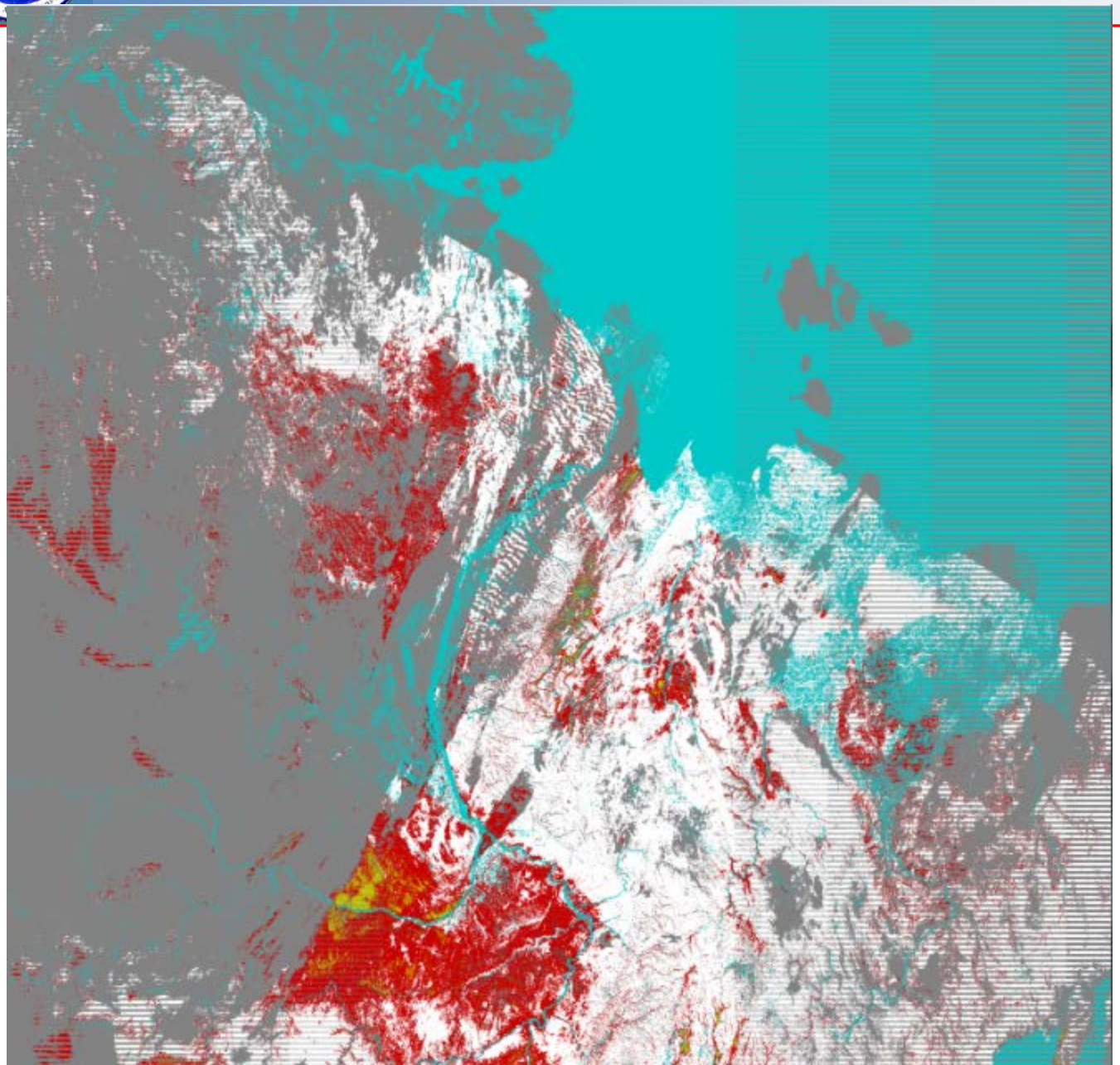
no snow retrieval in confidently clear areas

water

Snow Fraction on 10/24/13 (03:20)



Snow Extent on 10/24/13 (03:20)



snow

confidently cloudy

fractional snow cover in areas of non-snow binary retrieval

non-snow in binary and fractional retrievals

water

Alternative Algorithms

- There are three Approaches Alternative to 2x2 Aggregation under consideration:

  - Single visible band interpolation
  (used in NOAA for GOES)

  - Regression of snow fraction on NDSI
  (traditionally used in NASA)

  - Multiple Endmember Spectral Mixture Analysis
  (initially developed, approved, and coded for NPOESS; proposed later to GOES-R)

Similarity between Alternative Algorithms

- In a very general sense, one-band (a), NDSI (b), and MESMA (c) algorithms could be considered as different realizations of the interpolation between reflective characteristics corresponding to pure snow and non-snow

- It is possible to apply “endmember” term for all those algorithms meaning a reflectance (a), NDSI (b), and spectral signature (c)

- All the methods could provide comparable results if snow and non-snow properties are known to each pixel

- Endmembers depend on local conditions. Snow local endmembers could not be predetermined

Role of Changes in Endmembers

- The quality of snow cover information provided by remote sensing varies from region to region as well as from day to day depending on

  - snow and background surface types

  - the geometry of satellite observations

  - the state of the atmosphere

- Observed changes in pixel reflectances should not be ascribed exclusively to variable fraction, because they depends also on local variability in spectral signatures of the endmembers

- Allowing for local variability in spectral signatures of endmembers within a scene is a key requirement to snow algorithms

Scene-specific Approach to Snow Retrieval

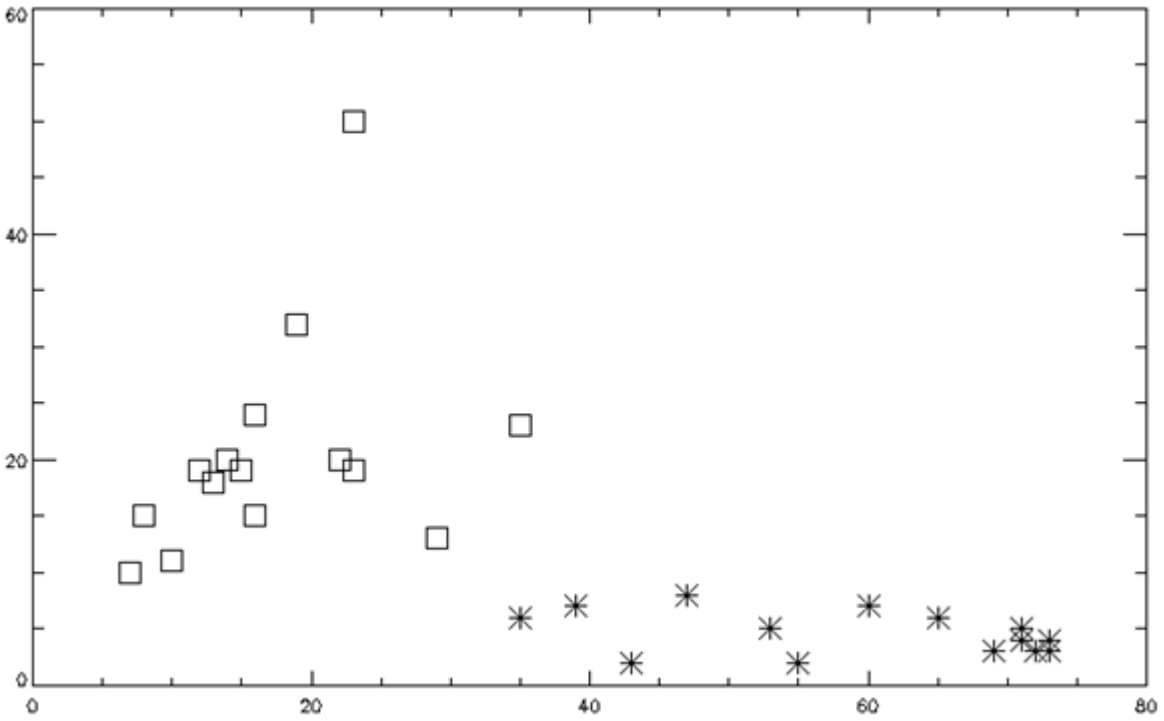
- The quality of snow retrieval could be improved if the variability of reflective properties characterizing different snow and underlying non-snow states is taken into account

- The one of possible approaches to better estimate the VIIRS snow fraction for varying local conditions is to use the scene-specific approach

- The adjustment of the parameters in snow algorithms to specific local conditions is a promising improvement leading to better quality of the VIIRS snow products

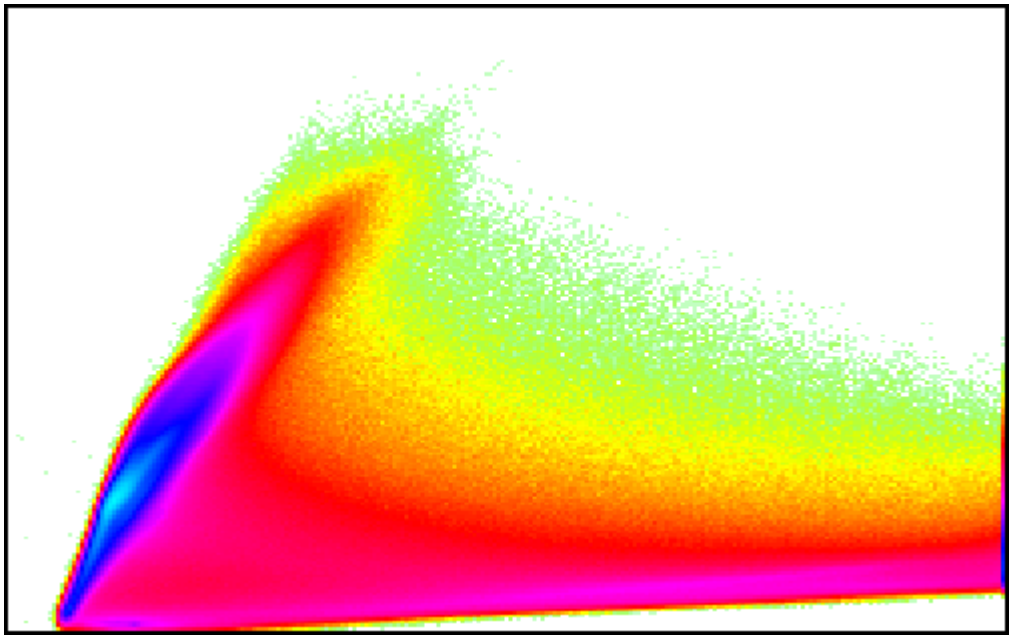
- The motivation for tuning snow retrieval in NDSI algorithm came from research of the optimized versions of algorithm for different conditions

Variability of snow & non-snow reflectances (from scene to scene)



The most probable snow (asterisks) and non-snow (squares) VIIRS reflectances (x axis – M5, y axis – M10) for 16 scenes with good illumination conditions within a narrow range of latitude and sun elevation (24˚ - 36˚)

Variability of snow & non-snow reflectances (within a scene)



The simplest case of a two-dimensional histogram presenting the joint probability densities for Landsat band 2 (X axis) corresponding to VIIRS band M5 (0.64 µm) and Landsat 5 (Y axis) corresponding to VIIRS band M10 (1.61µm) illustrates significant variability in reflections characterizing snow and non-snow endmembers

Choice between Alternatives

- Different points of view were formulated during discussions regarding possible alternatives

  - the linear regression approach with NDSI would be the easiest and have the least impact on the system;

  - regarding a more simple, single (visible) band unmixing algorithm, the problems are much the same as in the multi- end member multispectral algorithm;
- There is no comprehensive quantitative comparison of alternatives results with ground truth
- Individual preference to one or other algorithm is not important
- Selection will be based on the quality of results that need to meet existing requirements (10% uncertainty)

Possible Approach to Replace Algorithm

To begin works doing the following

- Implement a simple algorithm making some enhancements to improve the retrieval quality
- Consider potential use of other alternative algorithms
- Make the emphasis on the comparative quantitative estimate of fractional snow product quality for global coverage

In the case if further improvements are needed

- It is very reasonable to assume that the uncertainty requirements could be met only if specific local conditions are taken into consideration
- Estimate applicability of scene specific approaches to modify the algorithms

Programmatic Recommendations

- Remove obsolete Algorithm Maturity schedule created for the snow fraction EDR that should be replaced

- Take into consideration that
  - snow fraction is just a half of Snow Cover EDR
  - less than 1 FTE is allocated per cryosphere EDR

- Available FTE per EDR is at at least twice less than for any other team even with a low people allocation

Discrepancy Report 4246

- Title: Snow algorithm inconsistent with … requirements
- Submitter: Neal Baker
- Program Officer Monitor: Paul Meade
- Description: … a 10% (uncertainty) value cannot be achieved. We will have to investigate sub pixel snow algorithms.
- Secondary comment of 20130416: … this algorithm … is of little value to a user and it really deserves to be delete and replaced by an alternate algorithm
- Secondary comment of 20131029: … Program Office Monitor set to … Cryospheres EDRs JAM to begin work looking at substitute fractional snow cover algorithms, per recommendation of Mitch Goldberg and Jim Gleason during data product Beta Maturity AERB and direction of Cryo Cal/Val Lead Jeff Key

Discrepancy Report 7270

- Title: JPSS-1 Algorithm improvements: mandated: Snow Cover Fraction EDR
- Submitter: Lance Williams
- Program Officer Monitor: Paul Meade
- Description: The cryosphere cal/val team has identified JPSS-1 algorithm improvements mandated in the Level 1 RD.

  - algorithm changes are required in the snow cover fraction EDR to meet the L1RD measurement uncertainty requirement of 10%

  - the aggregation approach must be revised for a new, pixel-by-pixel algorithm
- This DR serves as a tracking and development tool for those improvements

Conclusions

- VIIRS observations give the opportunity of daily snow fraction mapping at 375 m (or at least 800 m) at nadir, that is adequate for most applications

- A number of needed enhancements to algorithms are foreseen to improve the accuracy of snow retrievals to meet requirement to the uncertainty of the VIIRS snow fraction

- The optimal approach to improve moderate resolution remote sensing information on snow fraction will allow for the variability of snow and non-snow properties within a scene-specific snow algorithm