Request for
VIIRS Sea Ice Characterization EDR
(Ice Age) Beta Maturity

DR # 7132

CCR # 474-CCR-13-0945

DRAT discussion: April 19, 2013

AERB presentation: April 24, 2013

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Outline

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- Beta EDR Maturity Definition
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VIIRS Sea Characterization EDR (Ice Age) Product Users

- ## U.S. Users
  - NSIDC, National Snow Ice Data Center
  - NIC, National/Naval Ice Center
  - OSPO, Office of Satellite and Product Operations
  - STAR, Center for Satellite Applications and Research
  - GSFC, NASA/Goddard Space Flight Center Hydrological Sciences Branch
  - NWS, National Weather Service, including the Alaska Ice Desk
  - CLASS, Comprehensive Large Array-data Stewardship System

- ## User Community
  - Navigation
  - Emergency Management
  - Operational Weather Prediction
  - Climate Research
  - DOD

Beta EDR Maturity Definition

- Early release product.

- Minimally validated.

- May still contain significant errors.

- Versioning not established until a baseline is determined.

- Available to allow users to gain familiarity with data formats and parameters.

- Product is not appropriate as the basis for quantitative scientific publication studies and applications.
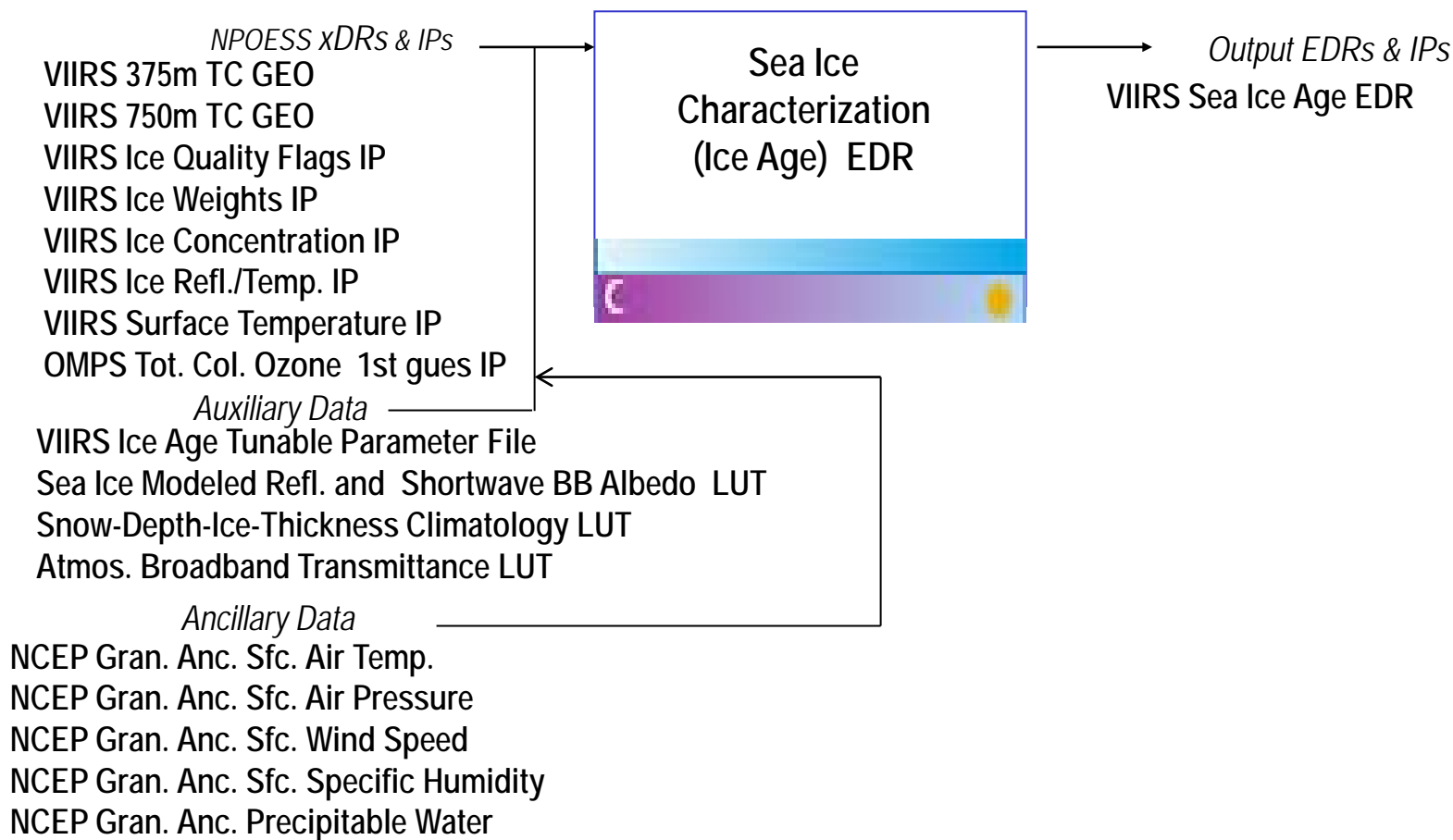
Summary of the VIIRS Sea Ice Characterization EDR

- The VIIRS Sea Characterization EDR (Ice Age) consists of ice classifications for *Ice Free*, *New/Young* and *Other Ice* at VIIRS moderate spatial resolution (750 m @ nadir), for both day and night, over oceans poleward of 36ºN and 50ºS latitude.

- New or Young ice is discriminated from thicker ice (Other Ice) by a threshold ice thickness of 30 cm. Discrimination of New/Young ice from thicker ice is achieved by two algorithms:
    1. Energy (heat) balance based retrieval for night and high solar zenith angles
    2. Reflectance/ice thickness retrieval using modeled Sea Ice Reflectance LUT for daytime

- Inputs: Ice Reflectance/Temperature IP, Ice Quality Flags IP, AOT IP, granulated ancillary surface wind speed, surface air pressure, surface air temperature and surface air specific humidity. Modeled Snow Depth/Sea Ice Climatology LUT, modeled sea ice reflectance LUT, sea ice spectral albedo and broadband albedo LUTs, atmospheric transmittance LUT

- Heritage: No operational Visible/IR heritage. AVHRR research heritage (Comiso and Massom 1994, Yu and Rothrock 1996 and Wang et al. 2010)
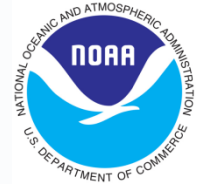
Summary of the VIIRS Characterization EDR (Ice Age) Algorithm Inputs

NPOESS xDRs & IPs

VIIRS 375m TC GEO
VIIRS 750m TC GEO
VIIRS Ice Quality Flags IP
VIIRS Ice Weights IP
VIIRS Ice Concentration IP
VIIRS Ice Refl./Temp. IP
VIIRS Surface Temperature IP
OMPS Tot. Col. Ozone 1st gues IP

Sea Ice Characterization (Ice Age) EDR

Output EDRs & IPs

VIIRS Sea Ice Age EDR

Auxiliary Data

VIIRS Ice Age Tunable Parameter File
Sea Ice Modeled Refl. and Shortwave BB Albedo LUT
Snow-Depth-Ice-Thickness Climatology LUT
Atmos. Broadband Transmittance LUT

Ancillary Data

NCEP Gran. Anc. Sfc. Air Temp.
NCEP Gran. Anc. Sfc. Air Pressure
NCEP Gran. Anc. Sfc. Wind Speed
NCEP Gran. Anc. Sfc. Specific Humidity
NCEP Gran. Anc. Precipitable Water

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Summary of VIIRS Sea Characterization EDR (Ice Age) Algorithm Overview

Reflectance Threshold Branch (Day Region Algorithm)

- Input ice tie point reflectance (I1, I2), VCM IP, AOT IP

- Input granulated NCEP gridded precipitable water, total ozone fields

- Obtain snow depth for each ice thickness bin obtained from climatology modeled snow depth/ice thickness LUT

- Retrieve ice thickness from sea ice reflectance LUT using ice tie point reflectances, modeled snow depth, AOT, precip. water and solar and satellite view geometry

- Classify by comparing retrieved ice thickness to 30 cm ice thickness threshold

Energy Balance Branch (Terminator and Night Region Algorithm)

- Input Ice Temperature Tie Point IP

- Input granulated NCEP gridded surface fields (sfc.P, sfc air temp, specific hum. etc...)

- Compute snow depth for 30cm ice thickness threshold from heat/energy balance

- Classify by comparing computed and climatology LUT snow depth for a 30 cm ice thickness threshold

The Snow-Depth-Ice Thickness Climatology LUT contains:

- predicted snow accumulation depths for modeled ice thickness threshold growth times based on monthly climatology surface air temperatures and precipitation rates

Sea Ice Characterization (SIC)

• "Sea ice age is defined as the time that has passed since the formation of the surface layer of an ice-covered region of the ocean. The sea ice characterization EDR provides an ice age class. Sea ice concentration, which is the fraction of a horizontal cell covered by ice, is an intermediate product (IP)"

Sea Ice Characterization Requirements from L1RD version 2.4

EDR Attribute	Threshold	Objective
a. Vertical Coverage	Ice Surface	Ice Surface
b. Horizontal Cell Size 1. Clear 2. All weather	1.0 km No capability	0.5 km 1 km
c. Mapping Uncertainty, 3 sigma 1. Clear 2. Cloudy	5 km No capability	0.5 km 1 km
d. Measure Range 1. Ice Age 2. Ice Concentration	Ice Free, New Young, all other ice 0/10 to 10/10	Ice free, Nilas, Gray White Grey, White, First Year Medium, First Year Thick, Second Year, Multiyear, Smooth and Deformed Ice 0/10 to 10/10
e. Measurement Uncertainty 1. Probability of Correct Typing (Ice Age) 2. Ice Concentration	70% Note 1	90% 5%
f. Refresh	At least 90% coverage of the global every 24 hours (monthly average)	6 hrs
g. Geographic coverage	All Ice-covered regions of the global ocean	All Ice-covered regions of the global ocean
Notes: 1. VIIRS produces a sea ice concentration IP in clear sky conditions, which is provided as an input to the ice surface temperature calculation		

History of Algorithm changes/updates

Date	Update/DR#	Reason	Status
2/27/2013	DR 7068	RTN Sev2 PCR (VIIRS-SIC-EDR fill conditions not applied to both fields in the EDR)	open
02-03-2011	DR 4197	Sea Ice Model based problems	Future Re-Evaluation
07-17-2009	DR 2844	Sea ice age ATBD does not meet scientific standards	open
07-17-2009	DR 2723	Snow-depth-on-sea-ice-LUT	To be re-evaluated

- **Beta Maturity Evaluation Approaches**

  - Our analysis has focused on the Beaufort Sea, but other regions in the Arctic and Antarctic, as well as global coverage, have been analyzed for one or more days

  - Comparison of Summer Sea Ice Characterization (SIC) EDR to ice coverage shown by 4-km IMS data
    - At this time of year, all ice should be "other ice" (not new/young) so comparison is possible

  - Manual inspection of SIC EDR images in specific regions and globally

  - Comparison of SIC EDR ice classification to National Ice Center charts

VIIRS SIC EDR for Dec 17, 2012, with ice quality = good. Ice coverage here looks reasonable, but note large areas of New/Young ice, which are incorrectly classified.
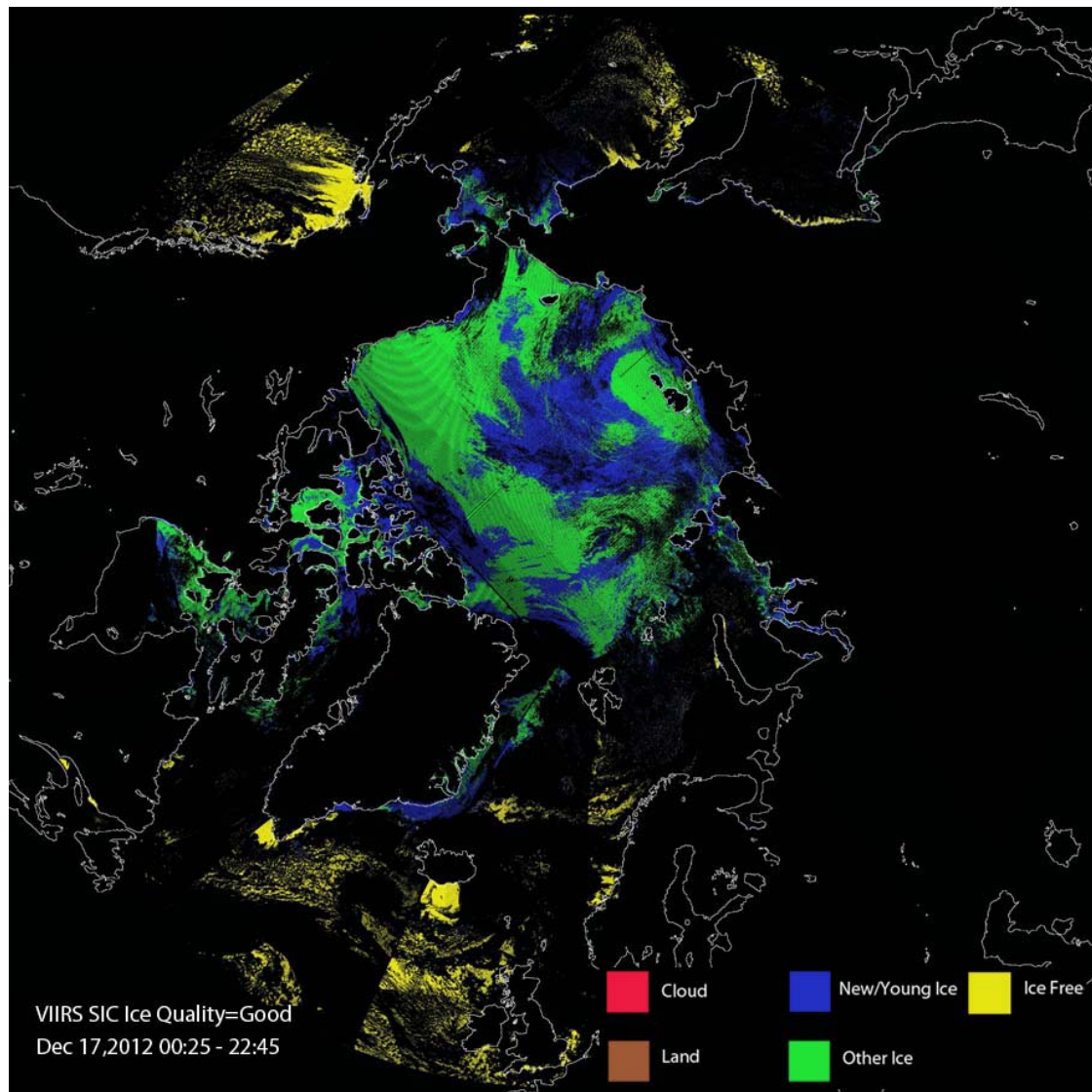
VIIRS SIC Ice Quality=Good
Dec 17,2012 00:25 - 22:45

| Cloud	New/Young Ice	Ice Free
Land	Other Ice	

Sea ice extent is realistic, but with some false ice over open water, misclassification of new/young vs. other ice, and some misplacement of land values.

SSM/I Sea Ice Concentration (1 Feb. 12)   VIIRS Sea Ice Characterization (1 Feb. 12)   SSM/I vs. VIIRS ice extent

Open water
New/young ice
Other ice
Land
Cloud
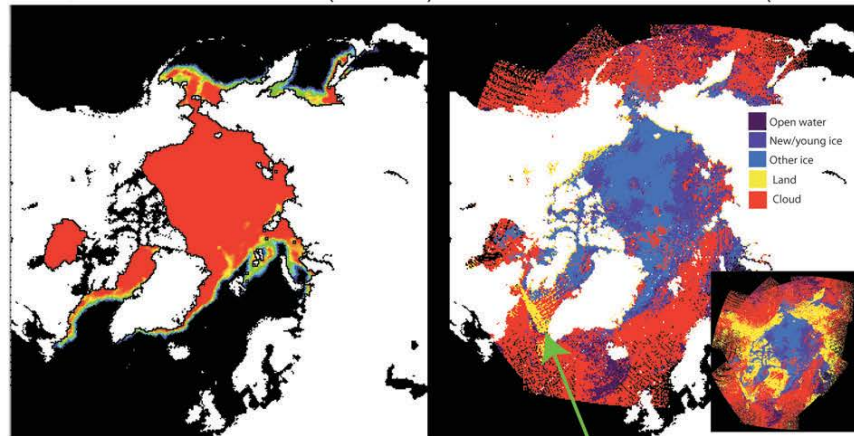
Land mask pixels in incorrect locations
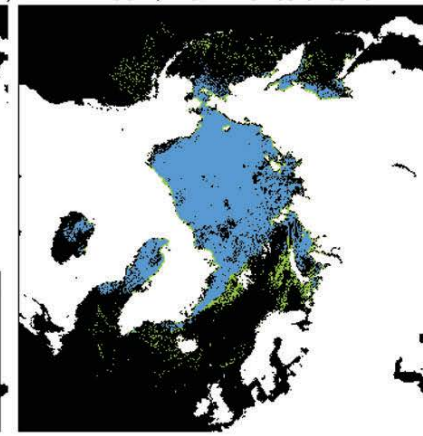
Green = pixels indicated as ice by VIIRS but not by SSMI
Likely due to cloud mask classifying cloud as clear sky

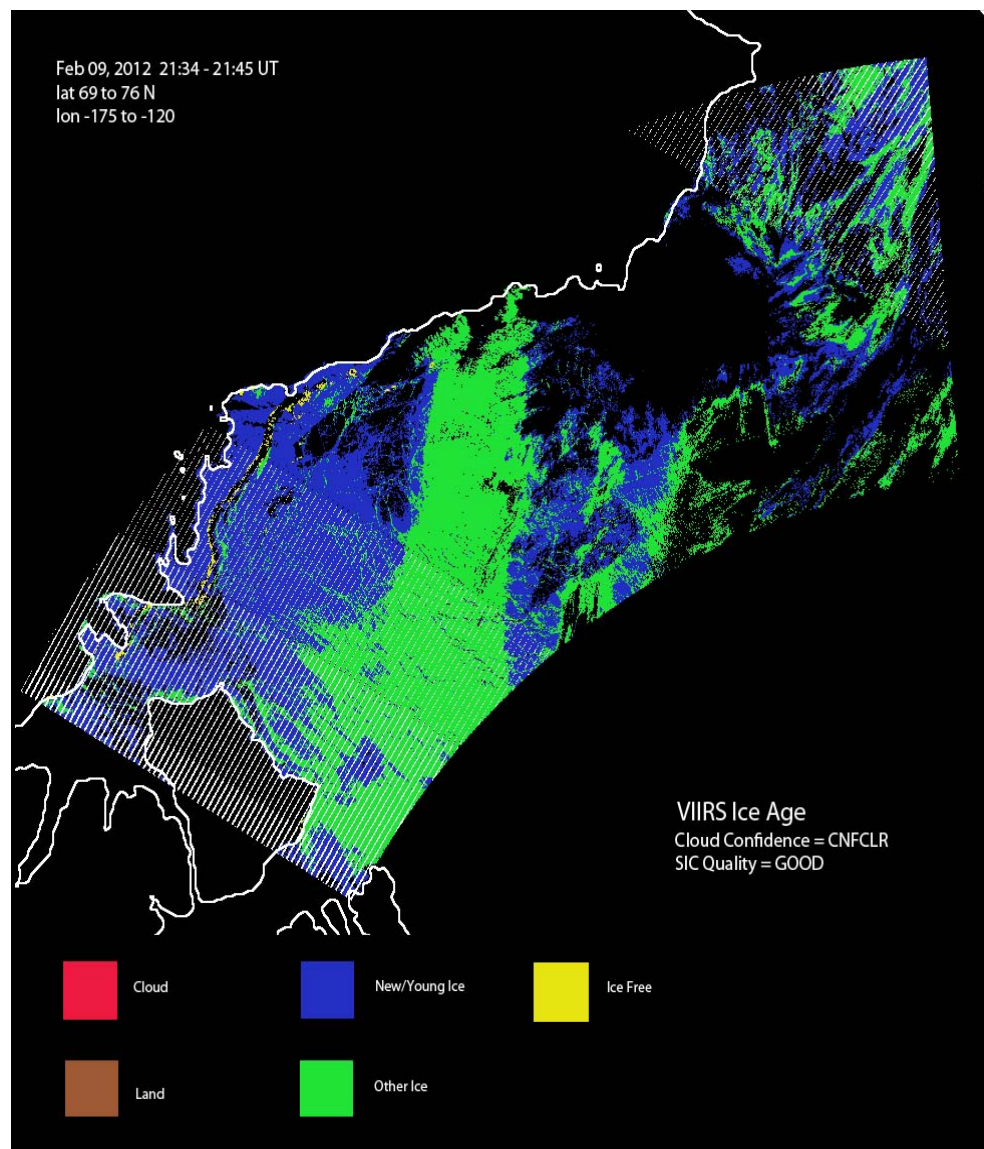SSM/I Sea Ice Concentration (29 Jan. 12) VIIRS Sea Ice Characterization (29 Jan. 12) SSM/I vs. VIIRS ice extent
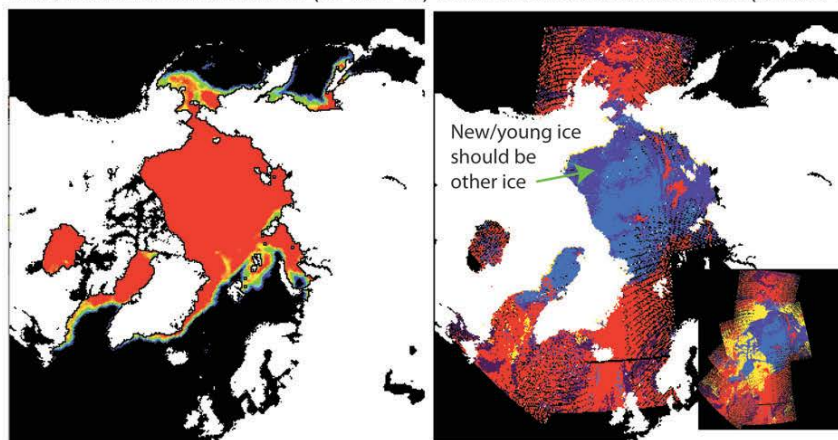
New/young ice
should be
other ice
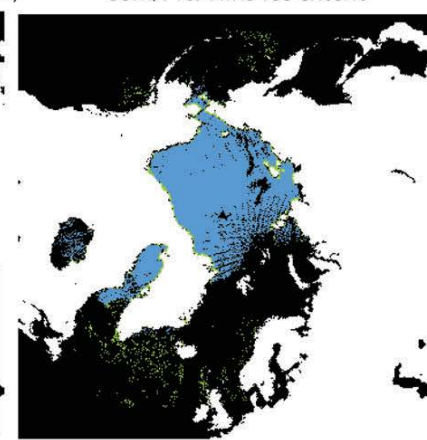
VIIRS SIC on Feb 9, 2012 in the Beaufort Sea for VIIRS cloud mask confidently clear and good SIC quality flag data. New/Young ice (in blue) on left is misclassified, likely due to the presence of cloud.
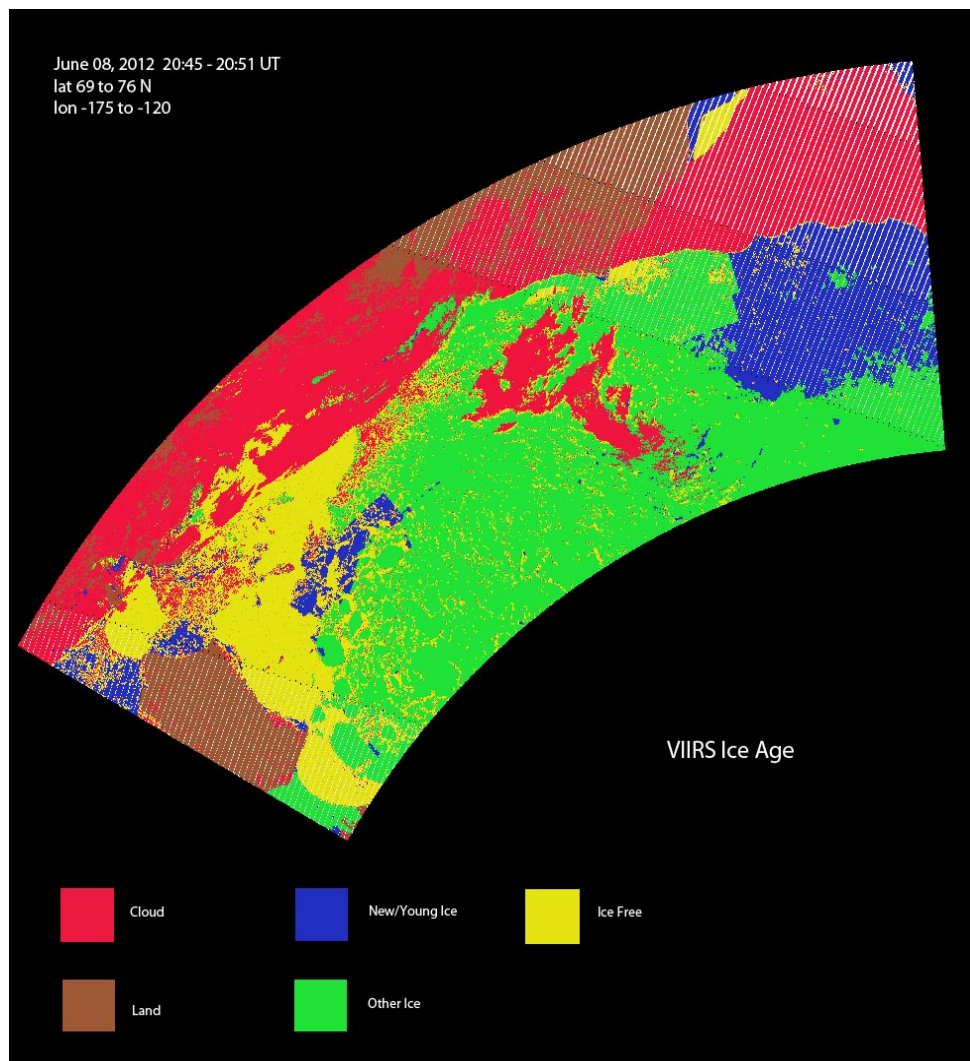

Feb 09, 2012 21:34 - 21:45 UT
lat 69 to 76 N
lon -175 to -120

VIIRS Ice Age
Cloud Confidence = CNFCLR
SIC Quality = GOOD

Color	Label
Red	Cloud
Blue	New/Young Ice
Yellow	Ice Free
Brown	Land
Green	Other Ice

SIC EDR for June 8, 2012, Beaufort Sea. New/Young ice (blue) is misclassified. It should not exist in June.

June 08, 2012 20:45 - 20:51 UT
lat 69 to 76 N
lon -175 to -120

VIIRS Ice Age

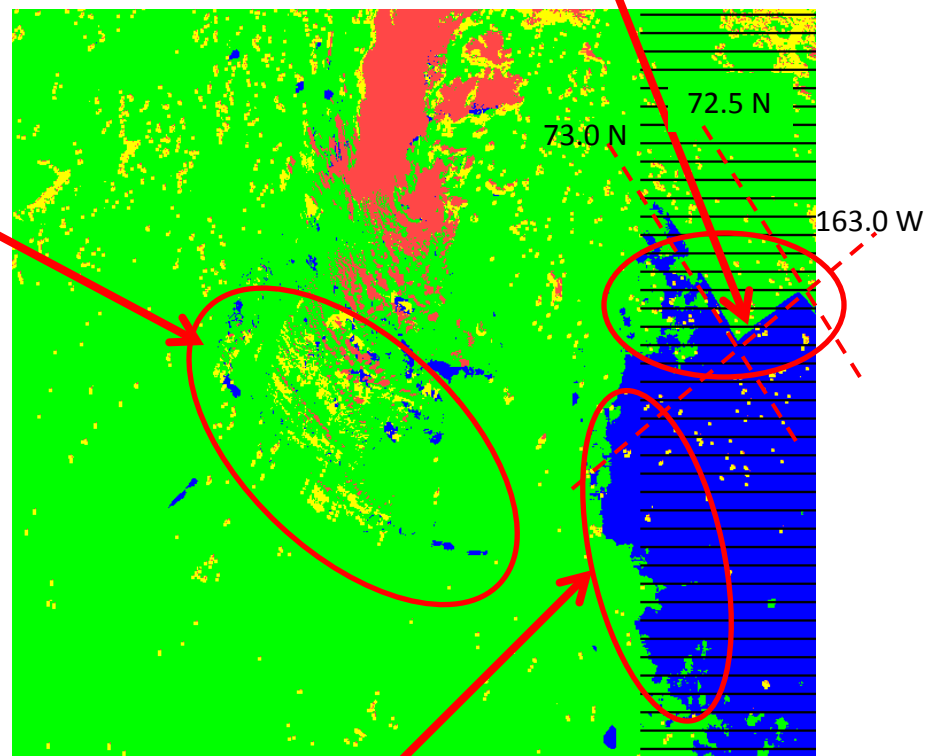Cloud — New/Young Ice — Ice Free — Land — Other Ice

VIIRS Sea Ice Characterization EDR Anomalies over Beaufort Sea (June 8, 2012)

Some misclassification evident due to VCM IP cloud leakage and cloud shadows
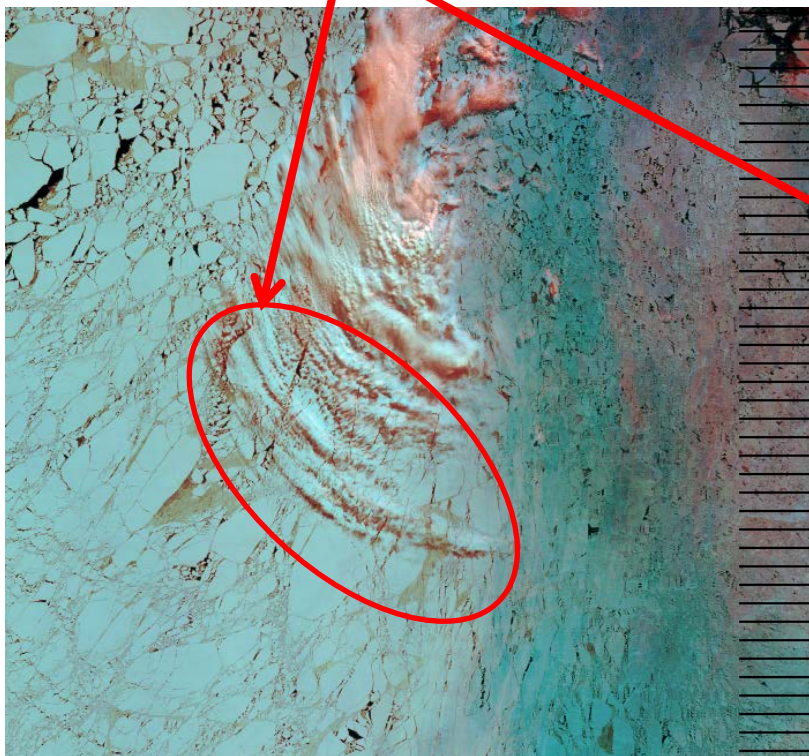
Discontinuities detected along lat/lon boundaries spaced 0.5 deg.

72.5 N

73.0 N

163.0 W

Large region misclassified where ice tie point reflectance values drop below ~ 0.53

Several discontinuities that align along 0.5 steps of latitude and longitude are evident as shown along the black dashed lines. The reflectance based day algorithm has dependencies on the coarse resolution NCEP ancillary fields for precipitable water and total column ozone. In addition the algorithm also has a dependency on the climatological snow depth/ice thickness LUT (modeled using 2.5 deg. surface air and precipitation rate climatology data) . The 0.5 deg. are strongly suggestive of sensitivity to the NCEP precipitable water field.

Ice Age Day (reflectance based) Algorithm Dependencies on Ancillary Data and LUTs
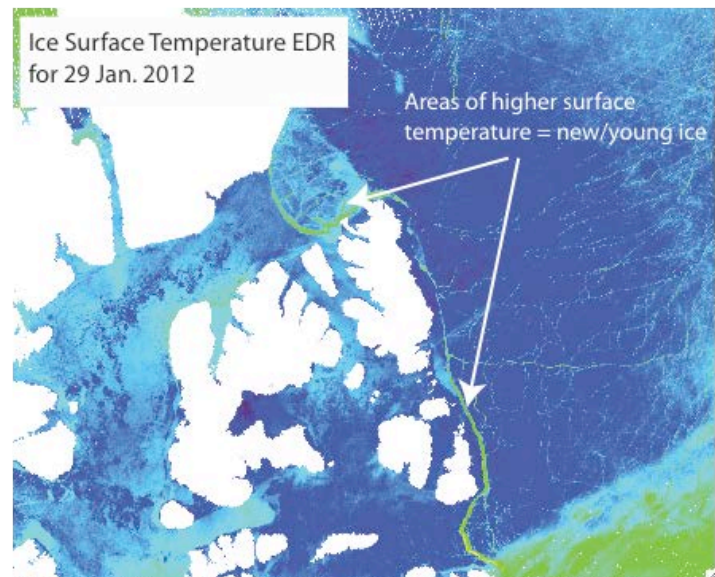
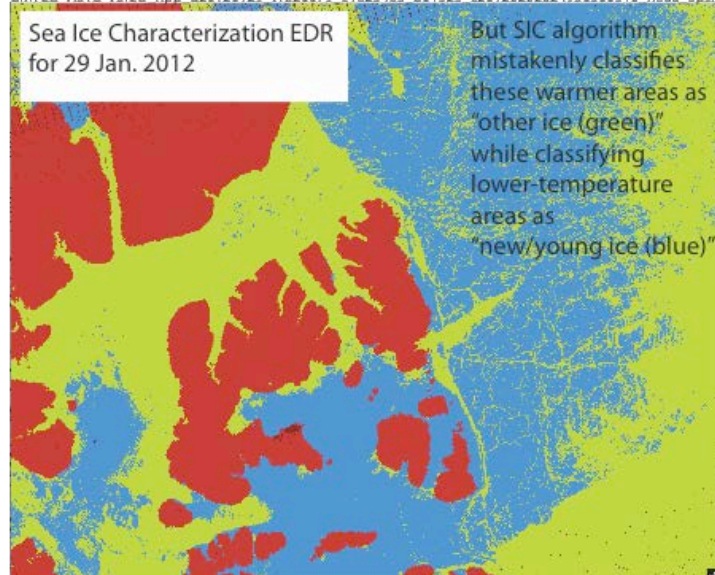| Data Type	Description
O3	NCEP granulated Total Col. Ozone
PW	NCEP granulated Precip.Water
Snow Depth/Ice Thickness Climatology LUT	Modeled snow depth accumulation as a function of ice thickness (based on computed ice thickness growth time from long term monthly NCEP climatology precip. rate and surface. air temp)
Sea Ice Reflectance LUT	Sea Ice reflectance (RTM modeled) for I1, I2 as a function of : ice thickness, snow depth, precip. water , total ozone, aot , aerosol model(2), solar zenith, relative azimuth, sat. view zenith

The 0.5 deg. are strongly suggestive of sensitivity to the NCEP granulated ancillary fields.

Winter scenes show misclassification of new/young ice and other ice. Sea ice "leads" consisting of relatively warm and thin ice should be classified as new/young ice. SIC winter scenes examined instead show some of this ice as "other ice" while thick, cold ice is mapped to "new/young ice" in some locations.
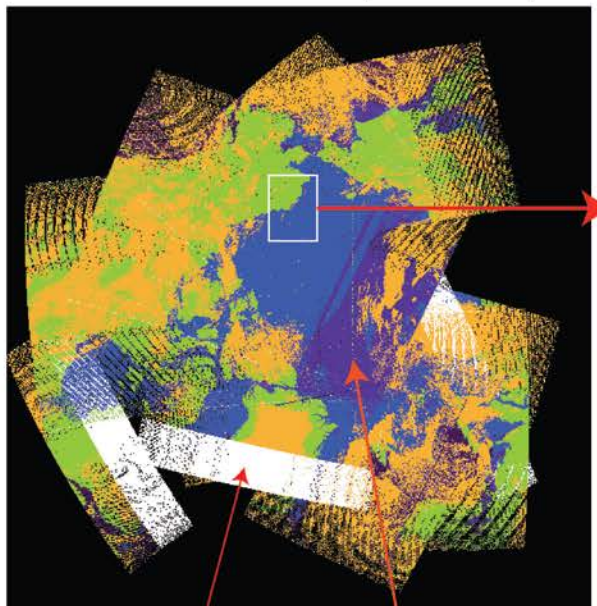

Ice Surface Temperature EDR for 29 Jan. 2012

Areas of higher surface temperature = new/young ice

GMTCO-VISTO-VSICO_npp_d20120129_t1820079_e1825483_b01325_c20120202024950500510_noaa_ops.h5

Sea Ice Characterization EDR for 29 Jan. 2012

But SIC algorithm mistakenly classifies these warmer areas as "other ice (green)" while classifying lower-temperature areas as "new/young ice (blue)"
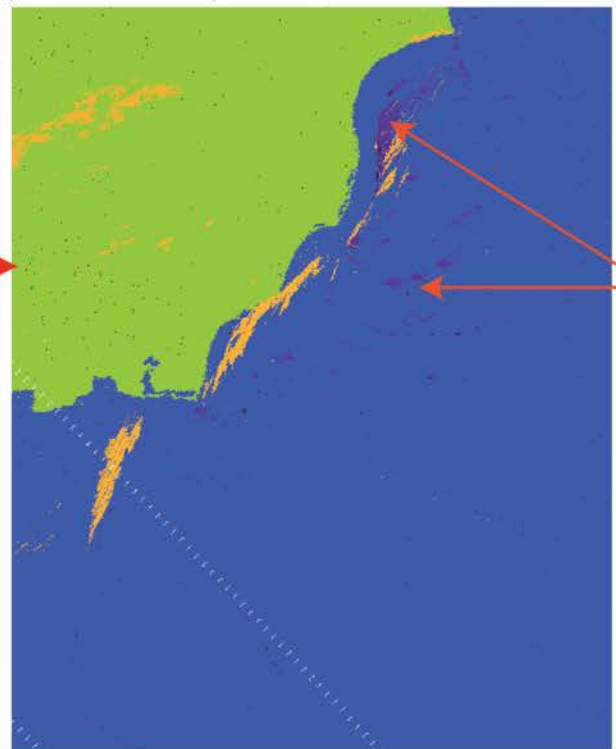
Ice type misclassification: Suggests that new/young ice vs. other ice classification may be working relatively well for daytime passes, but not for nighttime.


Sea Ice Characterization (30 March 12)

VIIRS Ice Surface Temperature (30 March 12)

Warmer locations are areas of true new and young ice
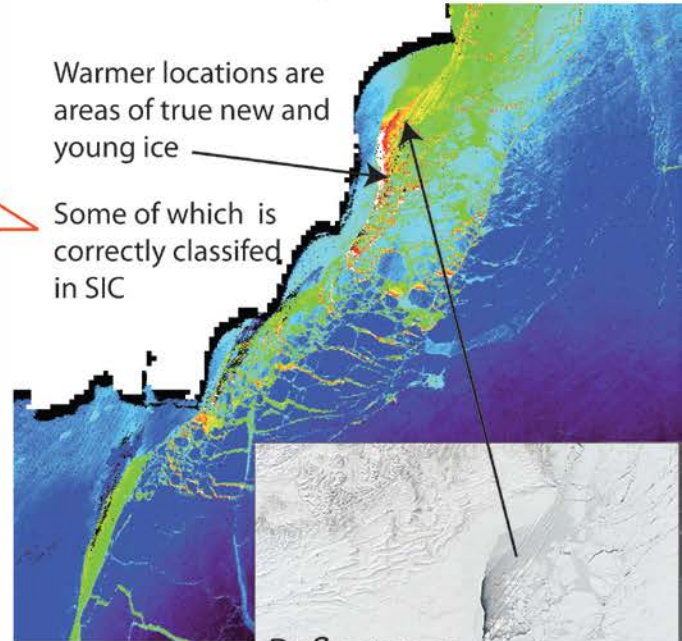
Some of which is correctly classifed in SIC

data value = 254 (ice free). Should be data value =1 (ice free) to be cons, sent with other values.

Large area incorrectly classified as new/young ice

New/young ice

All other ice

Cloud

Land

Reflectance: Darker = thinner ice
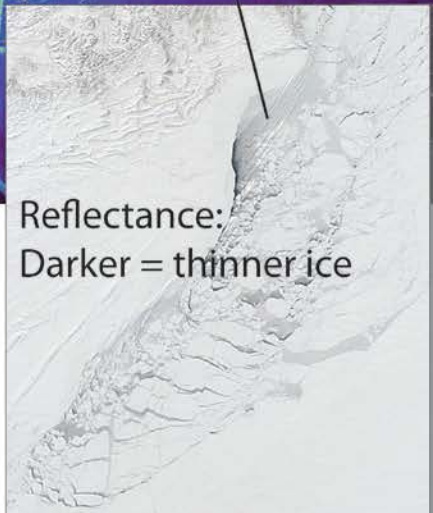
SIC EDR is compared to MODIS over sea ice during the melt period, when only "other ice" is expected.

Beaufort Sea, July 23, 2012

NOTE BOTTOM ROW

ALLCLD=No Cloud Cover Quality Flag Filter
ALLQUAL=No Ice Quality Flag Filter
CNFCLR=Only Pixels with Confidently Clear Cloud Cover Flag
GOOD=Only pixels with Good Ice Quality Flag

	ALLCLD ALLQUAL #1	ALLCLD GOOD #2	CNFCLR ALLQUAL #3	CNFCLR GOOD #4
MODIS Ice Pix	63252	27889	40190	27889
VIIRS Ice Pix	45136	32458	33368	32458
VIIRS New/Young Ice Pix	42708 (94.6%)	31867 (98.2%)	32485 (97.4%)	31867 (98.2%)
VIIRS Other Ice Pix	2428 (5.4%)	591 (1.8%)	883 (2.6%)	591 (1.8%)
Ice Agree	30695 (48.5%)	27608 (99.0%)	27902 (69.4%)	27608 (99.0%)
MODIS Ice Free Pix	83064	59067	62080	59067
VIIRS Ice Free Pix	109187	61632	80778	61632
Ice Free Agree	74192 (89.3%)	58511 (99.1%)	61479 (99.0%)	58511 (99.1%)
MODIS ICE VIIRS Cloud	15599	N/A	N/A	N/A
MODIS Ice VIIRS Free	16958	281	12288	281
Ice Type Classification Accuracy*	5.4%	1.8%	2.6%	1.8%

- Criteria: Early release product
  - Sea Characterization EDR performance is dependent on VIIRS Imagery resolution SDRs and the VIIRS Surface Temperature IP tie points. It is also dependent on the VIIRS Cloud Mask IP, and AOT IP through the Ice Quality Flags IP and Ice Weights IP, and NCEP ancillary surface data. Dependencies on LUTs include LUTs for model TOA snow/ice reflectance, broadband albedo, atmospheric transmittance and a modeled climatology based snow depth/ice thickness LUT.

    - VIIRS SDR Cal and Geo products reached provisional maturity in Mar. 2013

    - VIIRS Cloud Mask IP reached provisional maturity in Feb. 2013

    - VIIRS Aerosol Optical Thickness reached beta maturity in Sep. 2013

    - VIIRS Surface Temperature IP beta maturity pending approval

- Criteria: Minimally validated
  - Evaluation is based on a limited number of focus days (hemispheric comparisons for retrieval products)
    - NH data: 1/29/2012, 2/1/2012, 2/27/2012
    - Antarctica: 10/12/2012
  - Some detailed analysis has been done on other days with a limited set of granules focused on a region
    - Beaufort Sea: 1/29/2012, 2/9/2012, 3/30/2012, 4/5/2012, 6/8/2012, 7/23/2012

Beta Justification Summary

- Criteria: Available to allow users to gain familiarity with data formats and parameters
  - Cryosphere team has evaluated IDPS EDR products available from CLASS
    - Users can access and read the products and the product compares reasonably with the heritage satellite snow map products
  - Beta release will allow other users within the community to gain experience with the data formats and parameters.
    - This is important to allow users to complement the validation activity.

Beta Justification Summary

- Criteria: Product is not appropriate as the basis for quantitative scientific publication studies and applications

  - The product has known flaws (see caveats slides later in this presentation). It is clearly not suitable for use in publications.

- Known problems and proposed technical solutions
    - In general, significant discontinuities in ice classification between New Young and Other Ice have been observed in the granule level mapped composite data.
    - Ice classification discontinuities are most evident near the terminator region where the algorithm transitions from the day reflectance based algorithm to the night energy balance based algorithm
        - Proposed solution: Nighttime algorithm could be revised to utilize a local sliding IST window. For example, if the IST for the pixel is greater than the mean plus a threshold of the IST in the moving window, then it would be re-classified as new/young ice.
    - The snow depth thresholds based on the snow/depth ice thickness climatology LUT are problematic
        - Proposed solution: Investigate use of ancillary precipitation to derive snow depth and compute an ice thickness based on that snow depth. Dependence on the problematic SnowDepth/IceThickness Climatology LUT can then be eliminated.

- False ice is frequently observed near cloud edges
  - Proposed solution: Implement additional quality checks for extended cloud adjacency and partly cloudy conditions within the ice tie point search window in the Sea Ice Concentration IP
- Ice misclassifications occur due to low opacity clouds or ice fog, particularly during nighttime
  - Proposed solution: Assistance from VCM to improve cloud vs. ice detection
- Lower reflectance of melting sea ice appears to cause the SIC EDR to indicate New/Young Ice, although this type of ice cannot be present this time of year.
  - Proposed solutions: Define and utilize melt season period where New/Young ice cannot exist. Could do this by date/latitude or possibly with IST or NCEP air temp input. During this time, ALL ice would be classified as "other ice."
  - Investigate reflectance and temperature thresholds used in the algorithm
  - Investigate and mitigate sensitivity of retrievals to NCEP ancillary data inputs
- Replace the algorithm
  - It is not known if the proposed solutions above will be sufficient. It may therefore be necessary to test a completely different algorithm. One possibility is the one-dimensional thermodynamic ice model (OTIM) of Wang et al. (2010). A simpler approach based only on temperature may also be possible.

Additional Supporting Documentation

- TIM Meetings and Presentations
  - Cal/Val Team Meeting, April 2012
- Monthly/weekly reports
 https://groups.ssec.wisc.edu/groups/jpss/cryosphere/reports

Future Plans and Issues

- We are working to get these changes into the IDPS
  - Implement additional quality checks for extended cloud adjacency and partly cloudy conditions within the ice tie point search window in the Sea Ice Concentration IP

- Detailed performance characterization requires:
  - Analysis of sensitivity of retrievals to NCEP ancillary data inputs and snow depth on sea ice

- Major actions for the provisional maturity justification and schedule
  - Revision, testing and implementation of SIC EDR Nighttime Algorithm, possibly utilizing a local sliding IST window.
  - Revision, testing and implementation of SIC EDR Daytime Algorithm to possibly include:
    » Definition and utilization of melt season period where New/Young ice cannot exist, or utilize IST checks to assist with ice type definition (Oct. 2013)
    » Use of ancillary precip. field to improve snow depth estimates and to derive ice age based on ice thickness computed from snow depth   (Oct. 2013)
  - *Mapping of fresh-water ice*

Conclusion
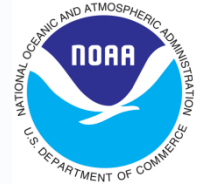
- VIIRS Sea Ice Characterization EDR has met the beta maturity stage based on the definitions and the evidence shown
  - It exceeds the definition of beta in most cases
  - Off-line product performance appears to be of sufficient quality for Beta maturity
- Some issues have been uncovered during validation and solutions are being evaluated.