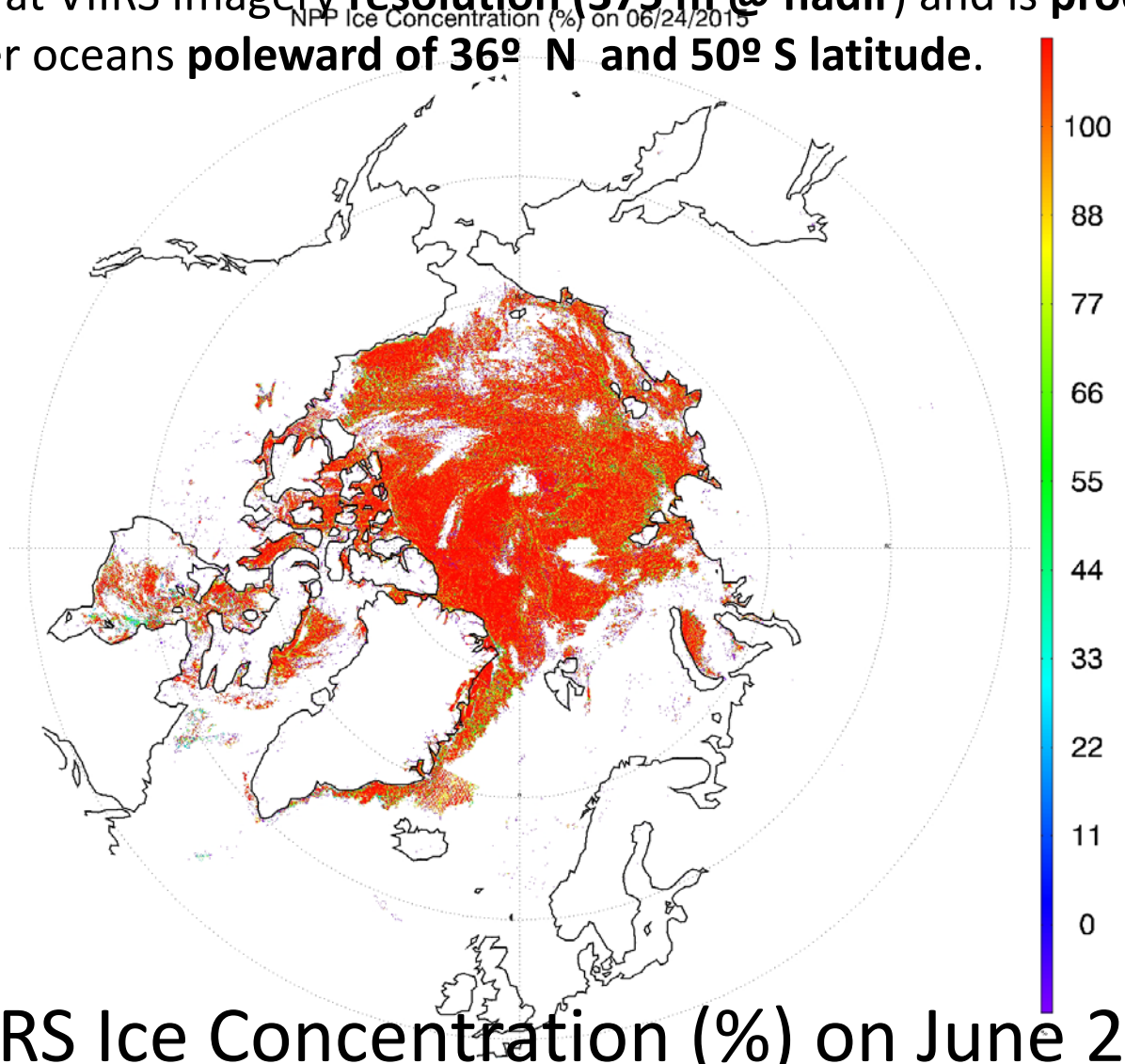
VIIRS Sea Ice Concentration IP Status

Yinghui Liu (CIMSS,UW-Madison)
Dan Baldwin (CU), Jeff Key (NOAA/NESDIS), Mark Tschudi (CU)

August 27, 2015

Sea Ice Concentration Product Description

•**Product Description:** The VIIRS Sea Ice Concentration IP consists of retrieved ice concentration at VIIRS Imagery **resolution (375 m @ nadir**) and is **produced both day and night**, over oceans **poleward of 36º N and 50º S latitude**.



NPP VIIRS Ice Concentration (%) on June 24 2015

Sea Ice Concentration IP Algorithm Description

•**Heritage:** No Vis/IR operational heritage. AVHRR research heritage (Comiso & Massom, 1994). Microwave heritage NASA Bootstrap and Team tie point based ice concentration retrieval algorithms.

• **Inputs:** TOA reflectances (VIIRS I1 and I2 bands) and Surface Temperature IP at imagery resolution, Ice Quality Flags IP, Ice Weights IP

• **Outputs:** Ice Reflectance/Temperature IP, Ice Concentration IP

•**Algorithm Description**

Tie point based retrieval of ice concentration at VIIRS imagery resolution (375 m @nadir). Ice and water tie points are determined for the visible TOA reflectance (VIIRS I1 band), near infrared TOA reflectance (VIIRS I2 band), and Surface Temperature.

–Tie points are established from the local distribution of reflectance and temperature within a sliding search window centered on each VIIRS Imagery resolution pixel.

– Ice/water thresholds are derived from the local minimum of the distribution of reflectance and temperature. Derived tie points are specific to the local region contained within the search window.

–Transition to Surface Temperature IP thermal tie points only for night is controlled by quality weights. De-weighted reflective quality weights for VCM cloud shadow flagged pixels favor thermal tie point based ice fraction retrievals

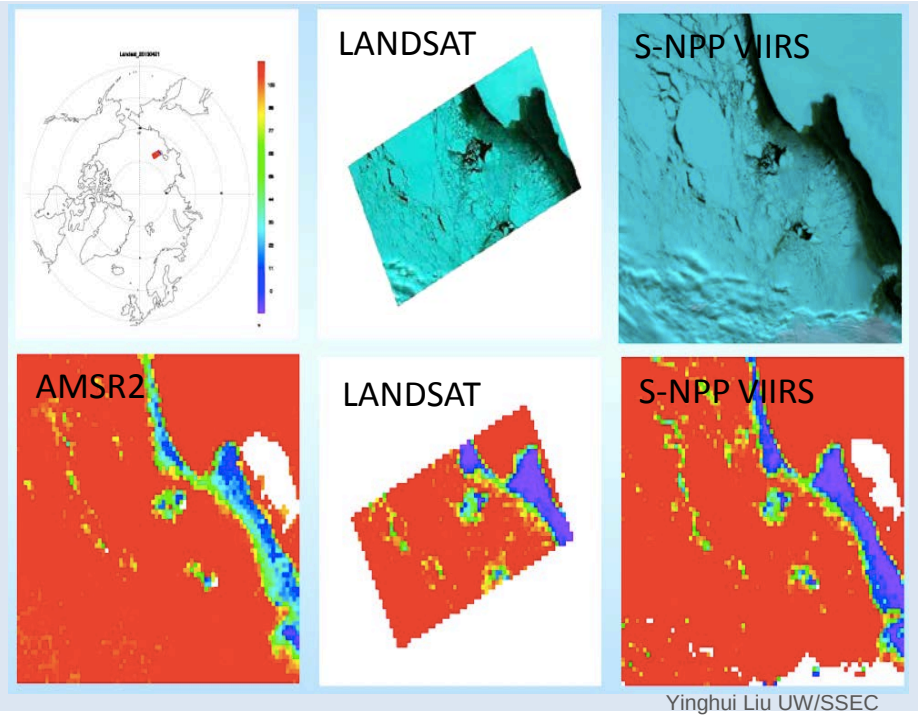
– VIIRS Surface Temperature IP is determined using the VIIRS I5 (11.5 µm), M15 (10.8 µm) and M16 (12.0 µm) bands

Performance Evaluation

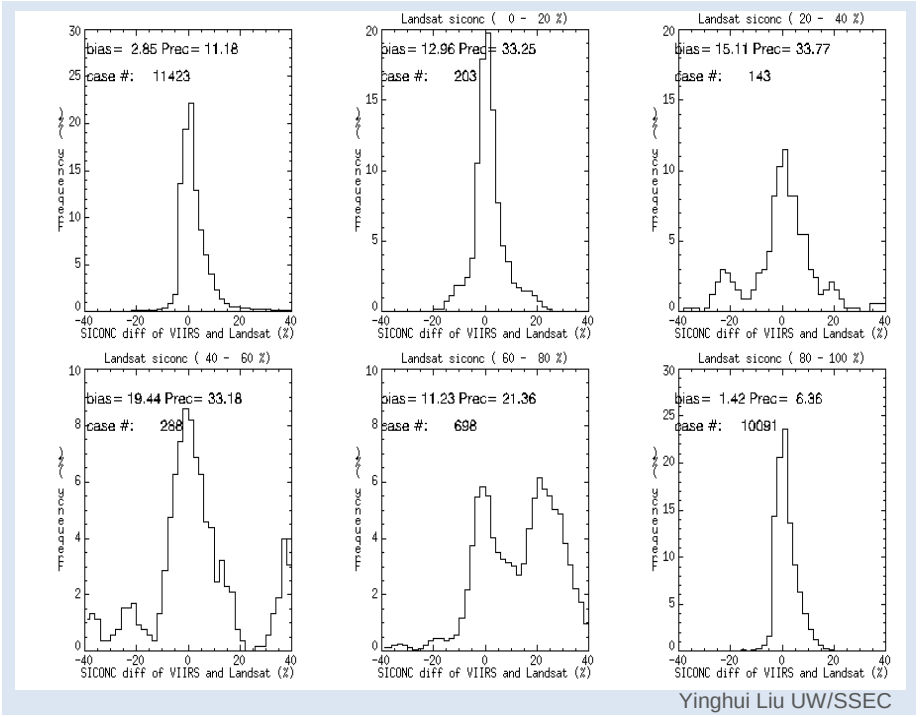
- Evaluation Approaches
  1. LANDSAT 8 derived ice concentration, quantitative comparisons to VIIRS SIC for 25 clear LANDSAT scenes(2014), for all available cases in 2013 and 2014
  2. Daily, global hemispheric VIIRS Sea Ice Concentration (SIC) and SSMIS passive microwave ice concentration visual and quantitative comparisons from 2012 to the present.
  3. Visual and quantitative comparisons with DigitalGlobe (DG) World View2 Multispectral reflectance images and derived SIC
  4. Visual comparison of NIC Weekly Ice Charts, VIIRS SDR false color reflectance imagery, MODIS Aqua MYD29 product for 30+ S-NPP/Aqua Simultaneous Nadir Overpass (SNO) scenes that span1 year and both hemispheres

(1) Comparison of VIIRS SIC to LANDSAT 8 (example)

Panel A



Panel B VIIRS vs. LANDSAT Ice Concentration

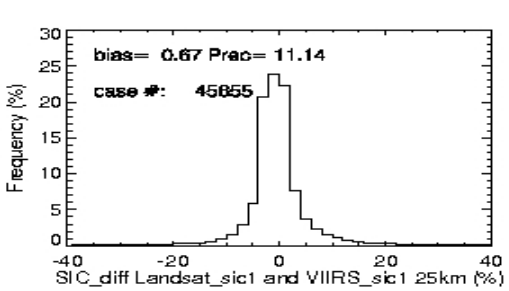


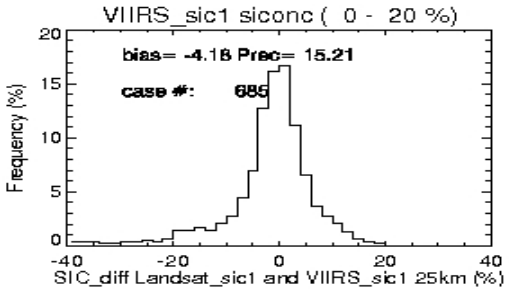
Panel A: upper image left to right: location of the scene, LANDSAT and VIIRS SDR false color image; Panel A, lower image left to right: Sea Ice Conc. from AMSR2, LANDSAT, and the Suomi NPP VIIRS on 4/21/2013 .

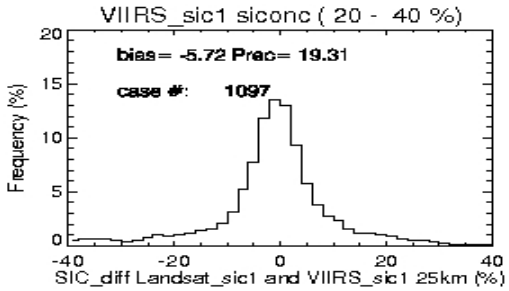
Ice Fraction Range	Total	0-20%	20-40%	40-60%	60-80%	80-100%
Bias	2.85	12.96	15.11	19.44	11.23	1.42
Precision	11.18	33.25	33.77	33.18	21.36	6.36

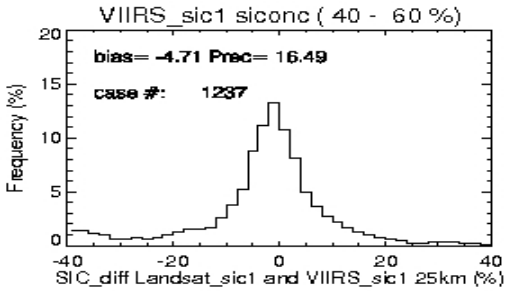
Panel B: Ice concentration differences between VIIRS and LANDSAT for all cases (top left) and cases with LANDSAT sea ice concentration in the ranges 0–20%, 20–40%, 40–60%, 60–80%, and 80–100%. Measurement accuracy (bias) and measurement precision (Prec) are indicated for each bin.

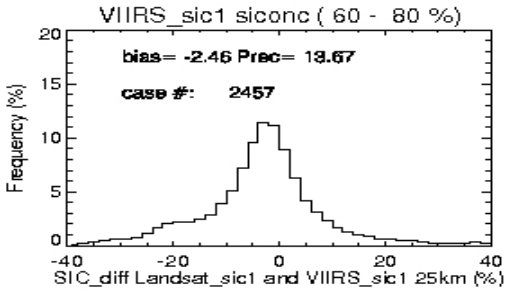
(1) Comparison of VIIRS SIC to LANDSAT (all cases from 2013 and 2014)

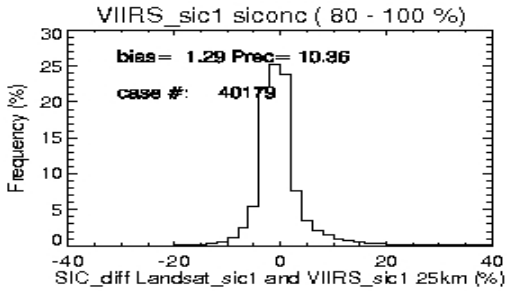


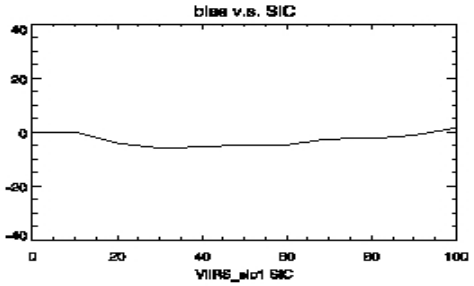


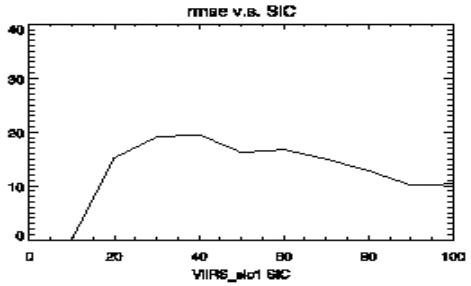








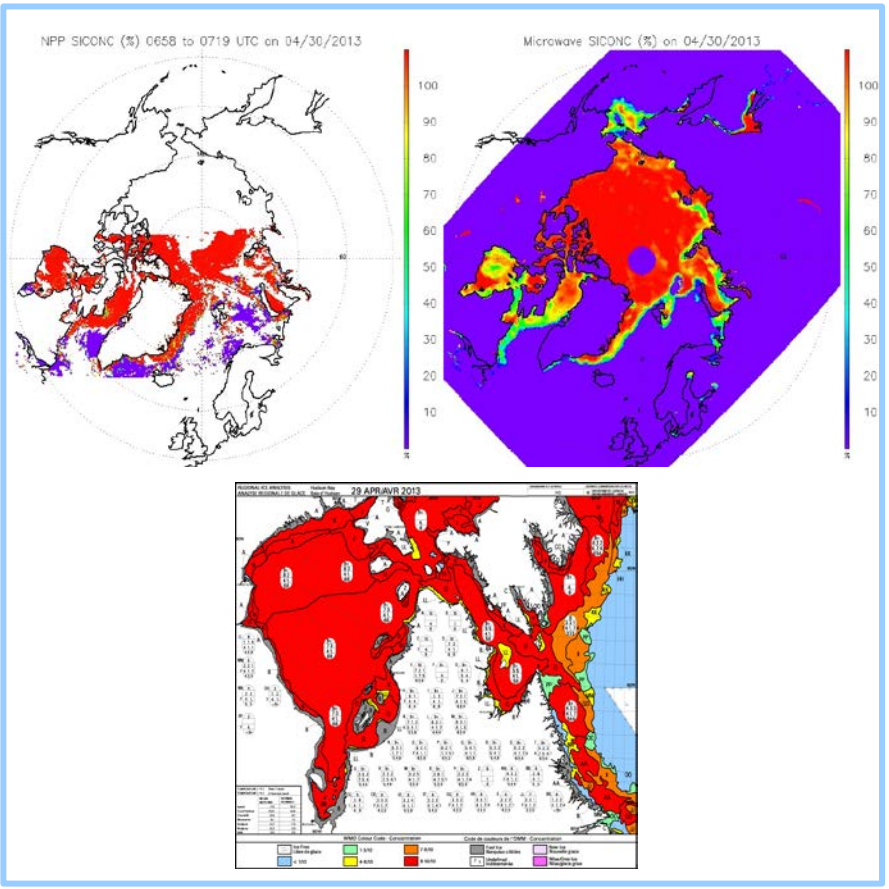




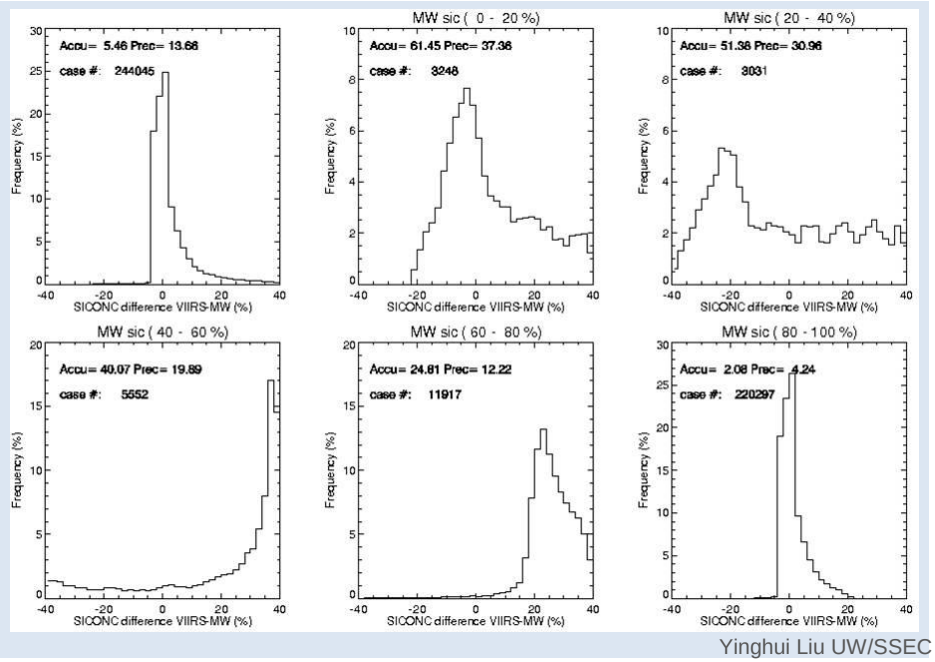
Ice Fraction Range	Total	0-20%	20-40%	40-60%	60-80%	80-100%
Bias	0.67	-4.18	-5.72	-4.71	-2.46	1.29
Precision	11.14	15.21	19.31	16.49	13.67	10.36

(2) Comparison of VIIRS SIC to Passive Microwave and Ice Chart (example)

Panel A



Panel B



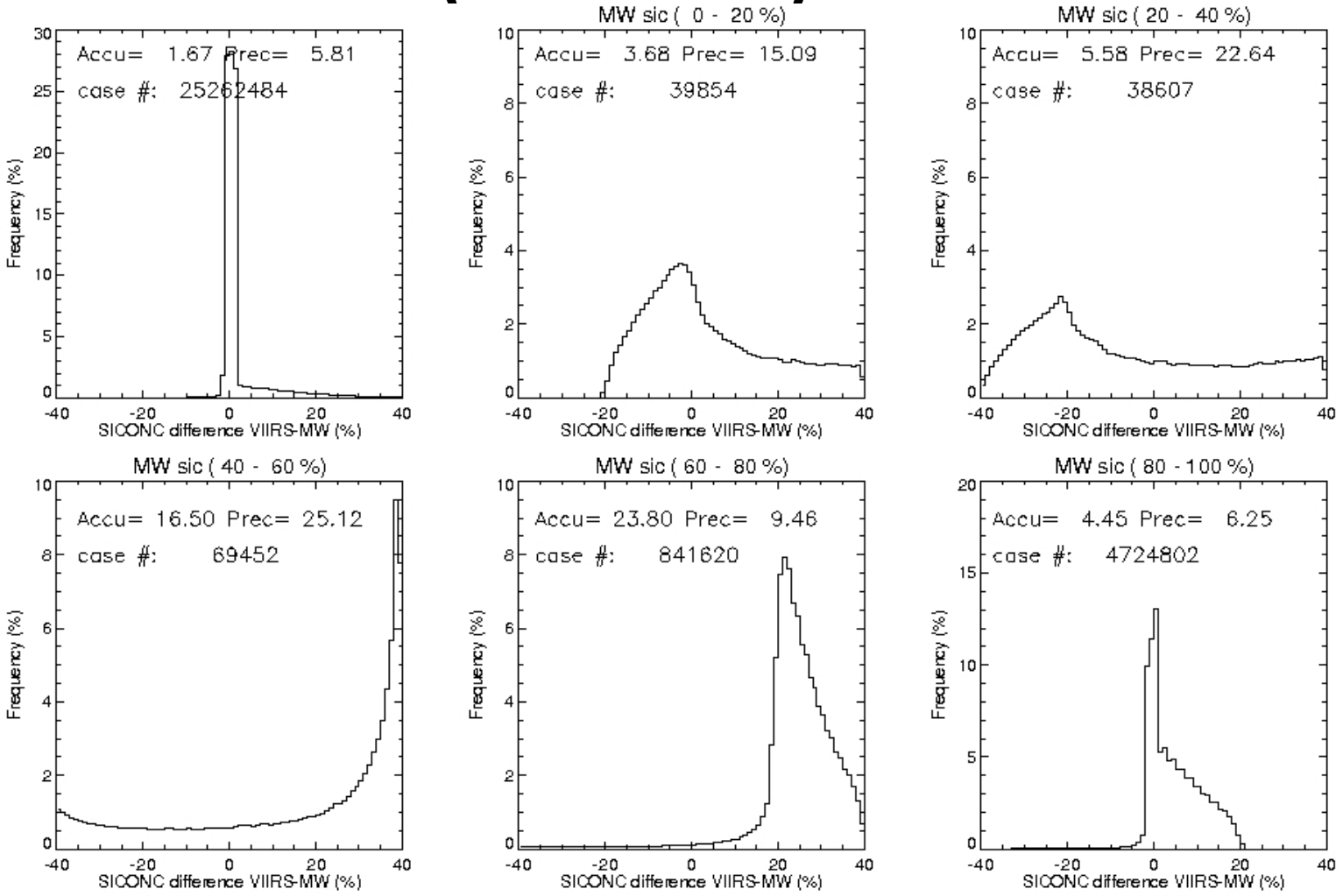
Yinghui Liu UW/SSEC

Ice Fraction Range	Total	0-20%	20-40%	40-60%	60-80%	80-100%
Accuracy	5.46	61.45	51.38	40.07	24.81	2.08
Precision	13.66	37.36	30.96	19.89	12.22	4.24

Panel A: Ice Concentration from S-NPP VIIRS Sea Ice Concentration IP (top left), SSMIS using NASA team algorithm (top right) on April 30, 2013, and from the weekly ice chart on April 29th 2013 from the Canadian Ice Service (bottom right).

Panel B: Accuracy and precision and ice concentration difference histograms for total, 0-20%, 20-40%, 40-50%, 0-80% and 80-100% ice fraction range.

(2) Comparison of VIIRS SIC to Passive Microwave (2012-2015)



Ice Fraction Range	Total	0-20%	20-40%	40-60%	60-80%	80-100%
Accuracy	1.67	3.68	5.58	16.50	23.80	4.45
Precision	5.81	15.09	22.64	25.12	9.46	6.25

(3) Comparison of VIIRS SIC to DigitalGlobe (DG) derived SIC in melting season

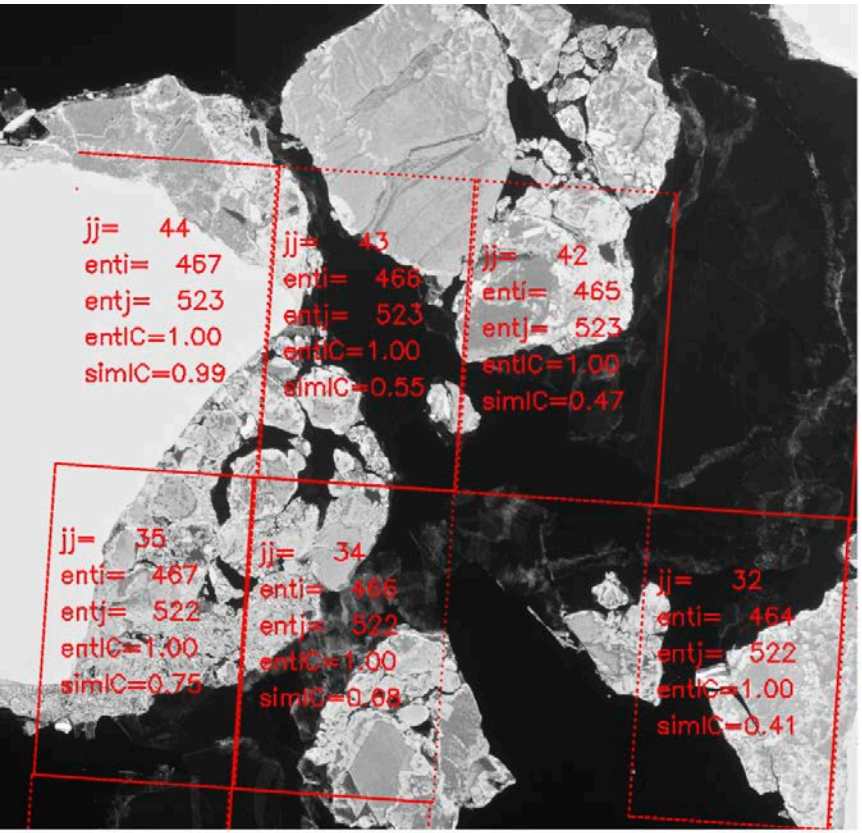


Figure 1 Example pixels of Enterprise IC vs Dig Glb Simulated IC
May 10, 2014 VIIRS Time: 18:29 UT Dig Glb Time: 18:15 UT
21 Enterprise FOVs with valid Ice Concs
Bias= -0.29 Stddev= 0.20 RMS= 0.35
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Moderate band FOVs Spatial resolution ~800m
Values in boxes are: Box number, FOV column, FOV row,
Enterprise Ice Conc, Simulated Ice Conc

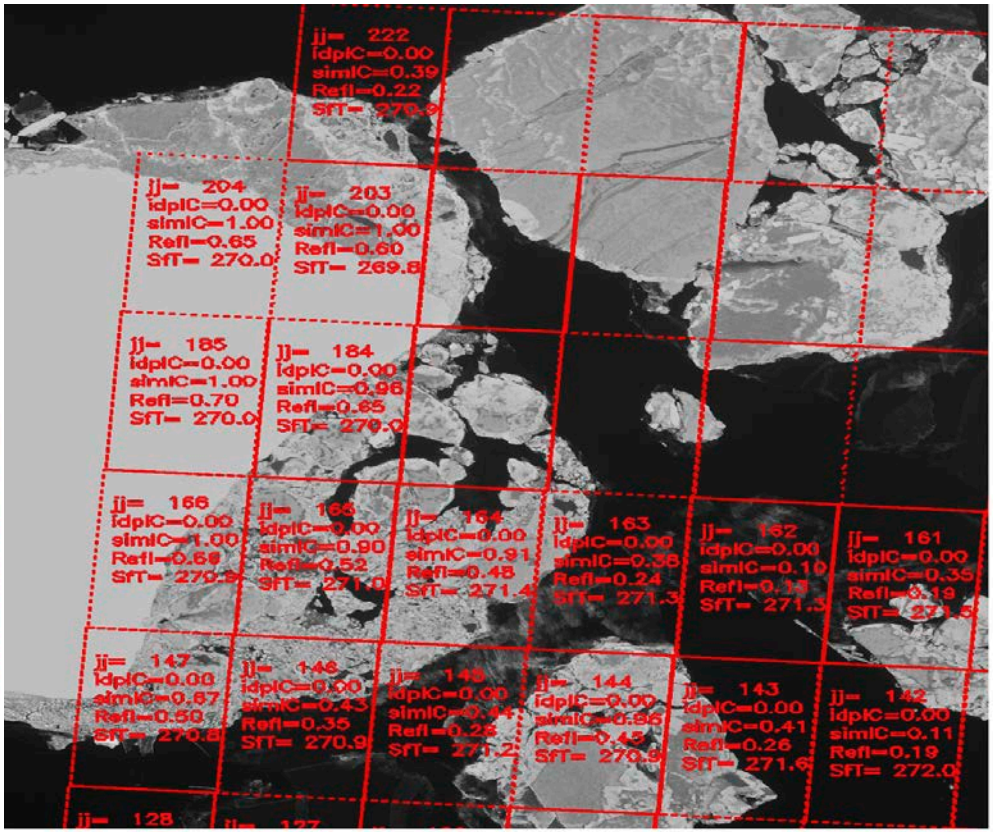
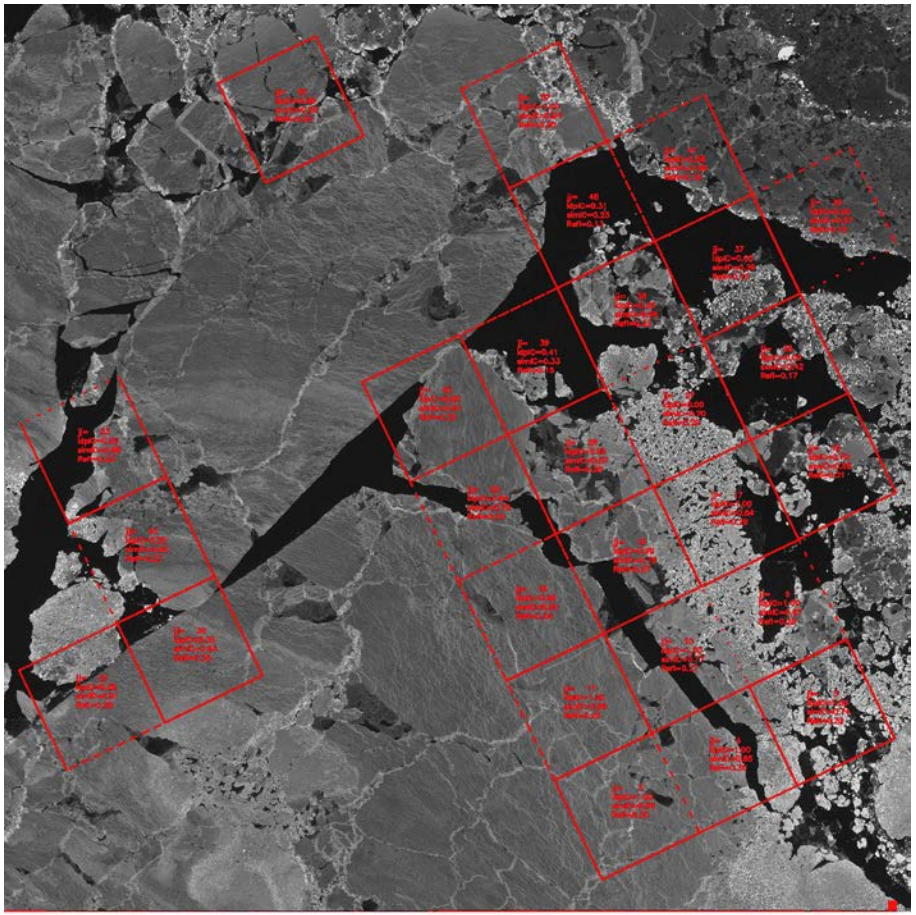


Figure 2 Example pixels of IDPS IC vs Dig Glb Simulated IC
May 10, 2014 VIIRS Time: 18:29 UT Dig Glb Time: 18:15 UT
71 IDPS FOVs with valid Ice Concs
Bias= 0.362 Stddev= 0.317 RMS= 0.48
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Image band FOVs Spatial resolution ~400m
Values in boxes are: Box number, IDPS Ice Conc, Simulated Ice Conc,
VIIRS I1 Band Reflectance and VIIRS Surface Temperature

Enterprise

IDPS

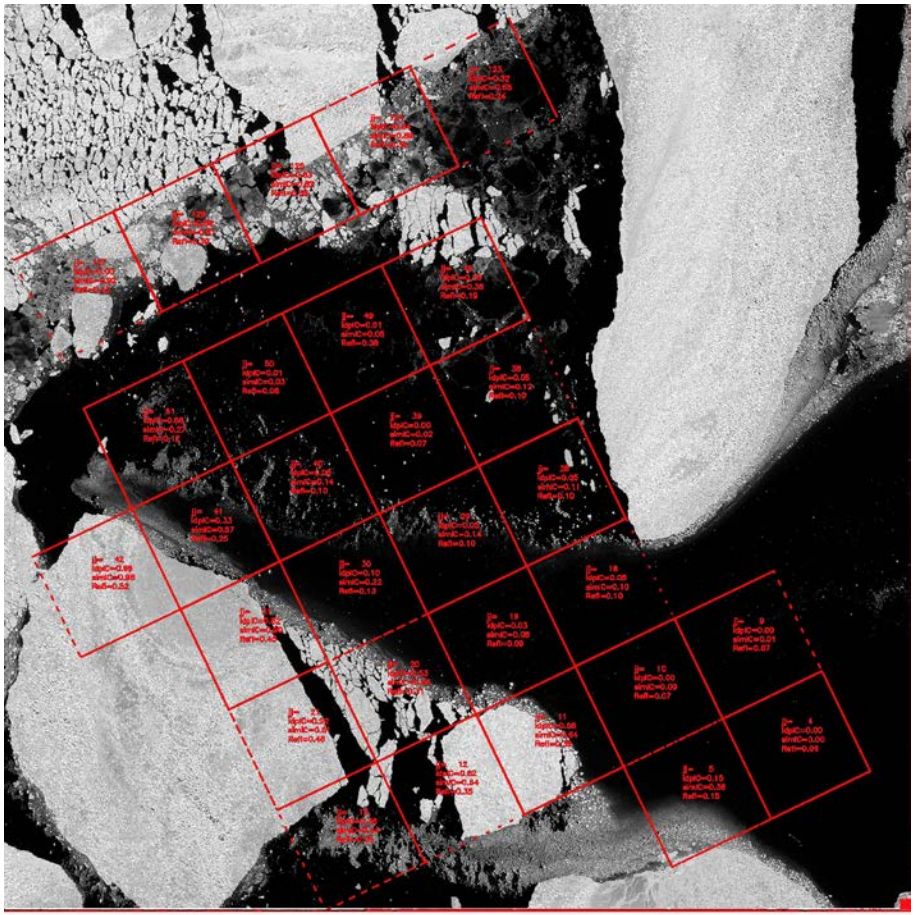
(3) Comparison of VIIRS SIC to DigitalGlobe (DG) derived SIC in non-melting season



March 21, 2014
VIIRS Time: 22:24 UT
Dig Glb Time: 22:25 UT
Row 2 Column 2

Statistics From this example:
27 VIIRS FOVs with valid Ice Concs
Bias= 0.151 Stddev= 0.393 RMS= 0.41

Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Image band FOVs Spatial resolution ~400m
Values in boxes are: Box number
VIIRS Ice Conc, Simulated Ice Conc,VIIRS I1 Band Reflectance



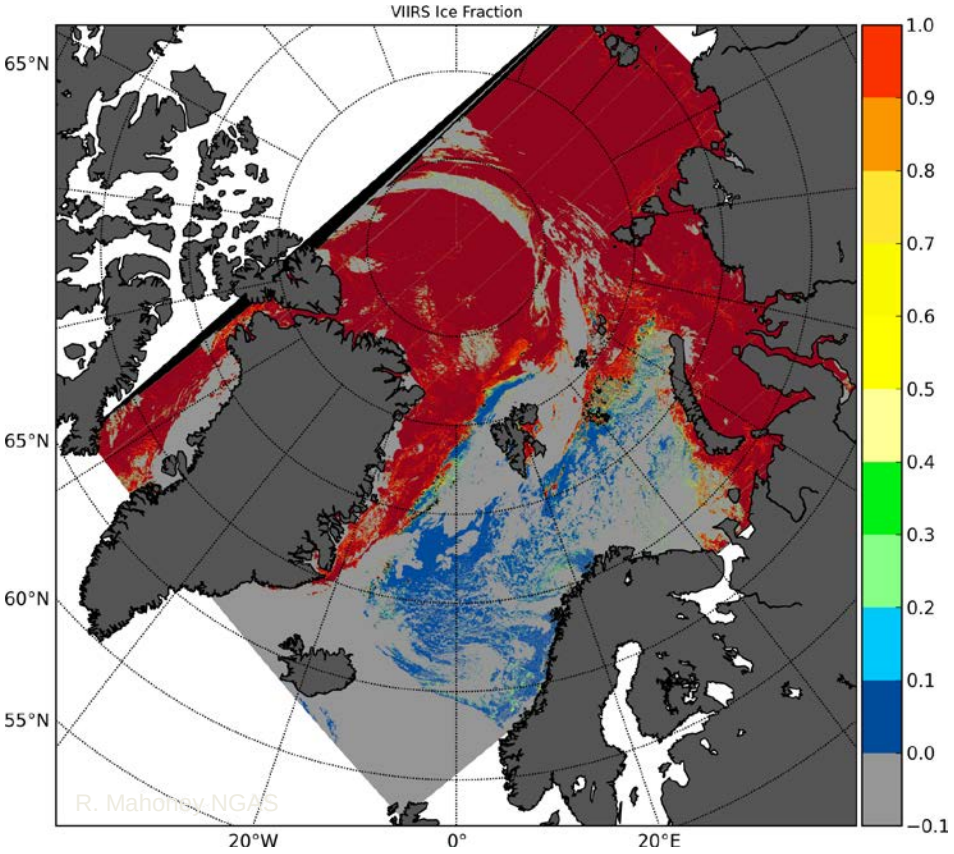
March 21, 2014
VIIRS Time: 22:24 UT
Dig Glb Time: 22:25 UT
Row 8 Column 2

Statistics From this example:
29 VIIRS FOVs with valid Ice Concs
Bias= 0.117 Stddev= 0.181 RMS= 0.21

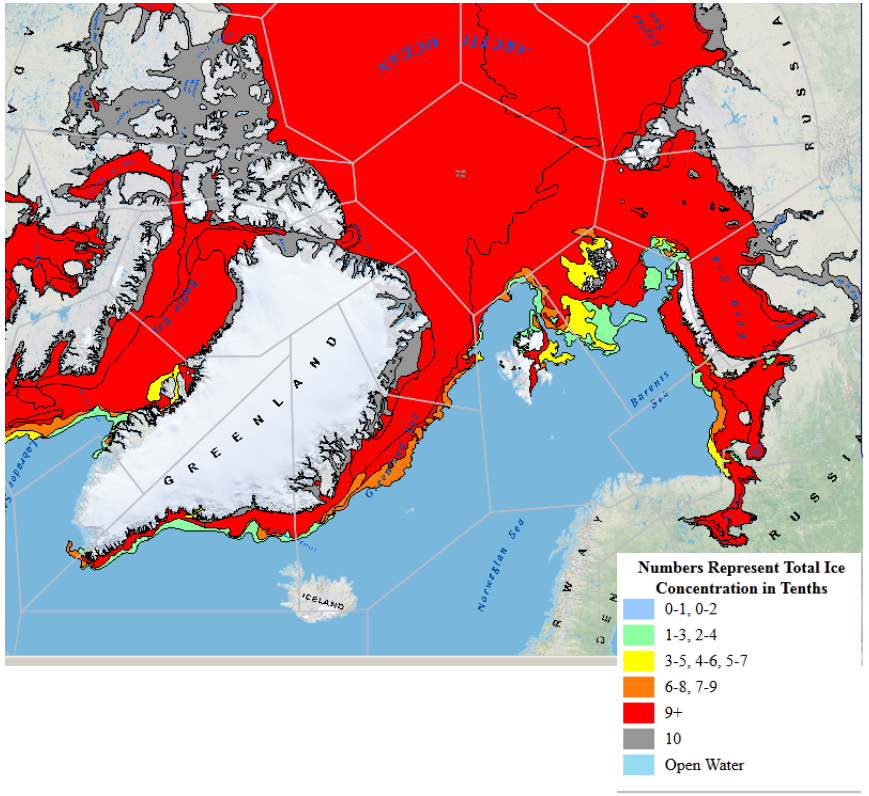
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Image band FOVs Spatial resolution ~400m
Values in boxes are: Box number
VIIRS Ice Conc, Simulated Ice Conc,VIIRS I1 Band Reflectance

(4) Comparison of VIIRS SIC to National Ice Center Ice Charts (night scene example)

VIIRS Ice Concentration IP Feb. 20, 2014 (04:39-04:46 UTC)

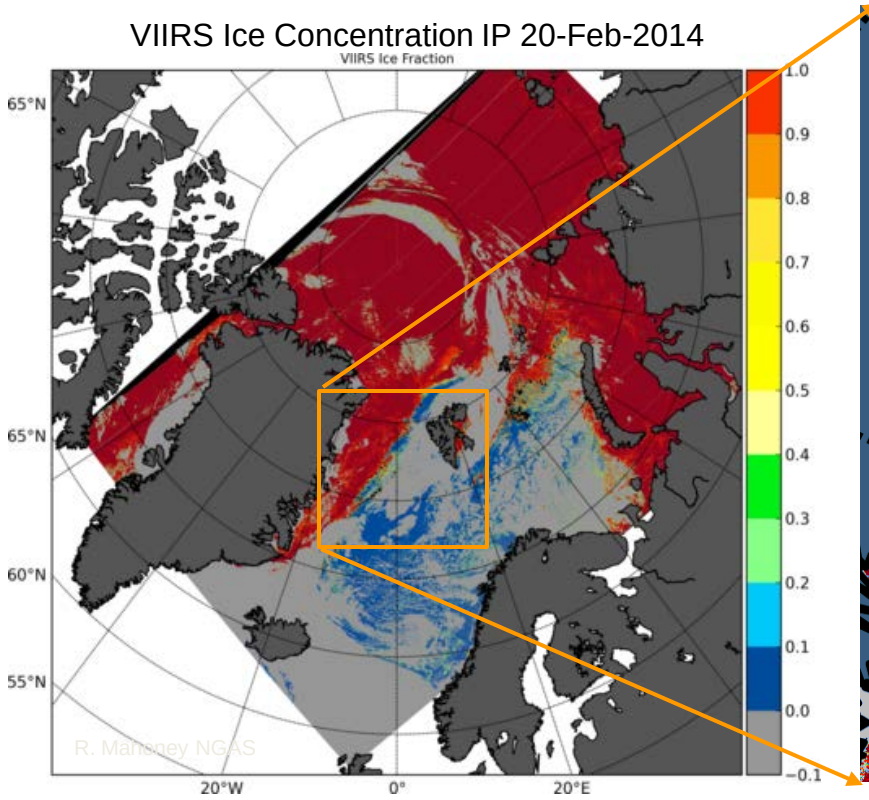


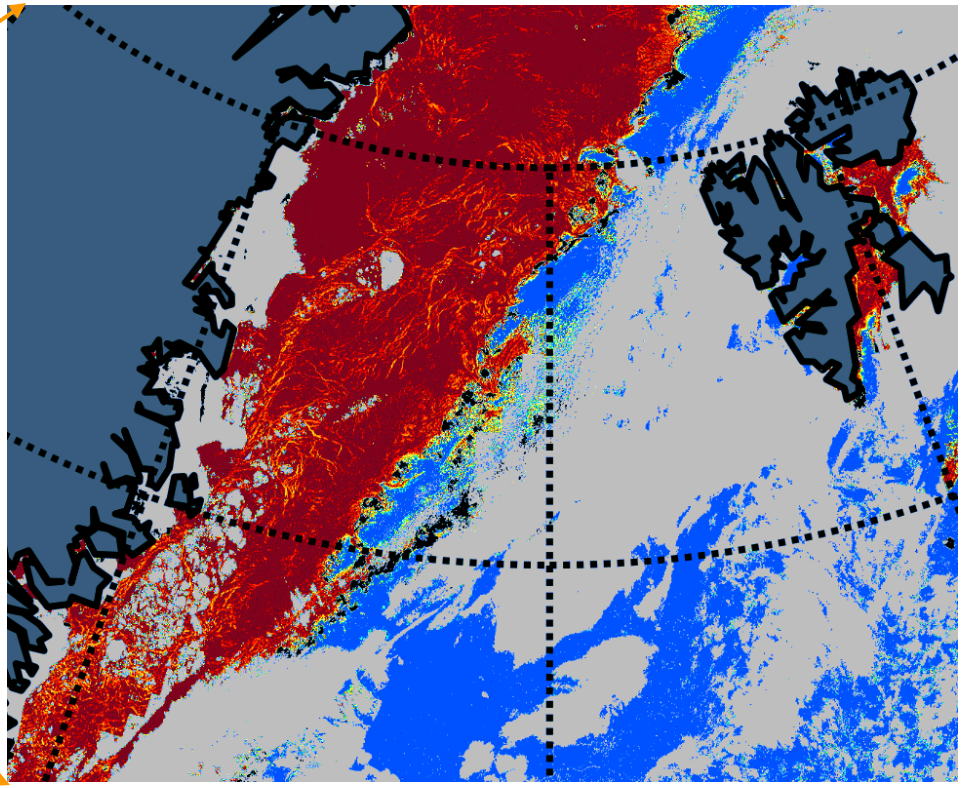
Reference: http://www.natice.noaa.gov/ps/javascriptproductviewer/index.html



VIIRS Ice Concentration IP for Feb. 20, 2014 night scene is consistent with that of the corresponding National Ice Center weekly ice chart for Feb. 20, 2014 and the ice extent matches extremely well

VIIRS SIC Shows Detailed Structure of Ice Edges and Leads

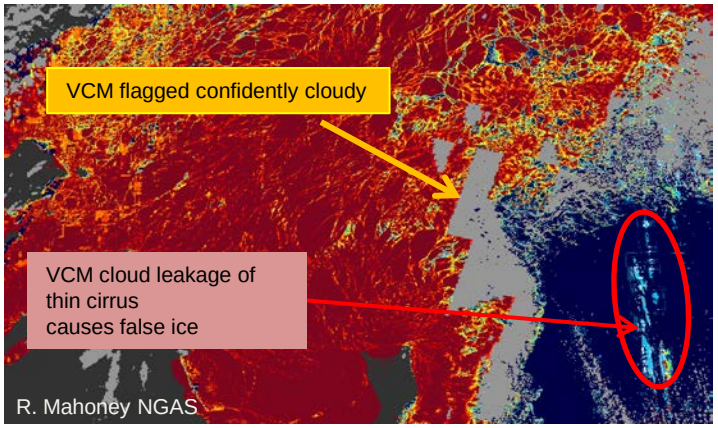


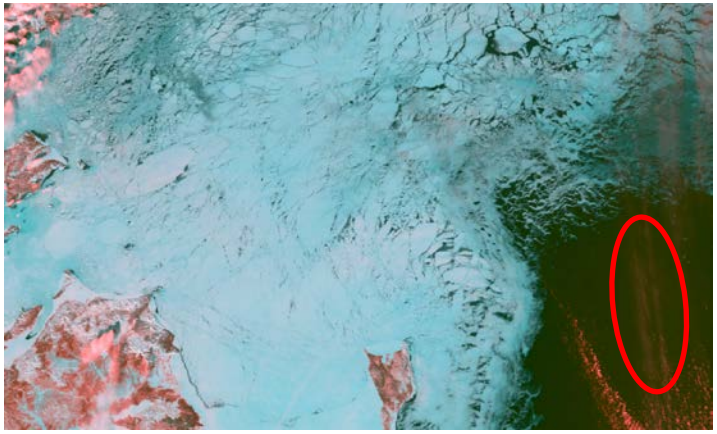


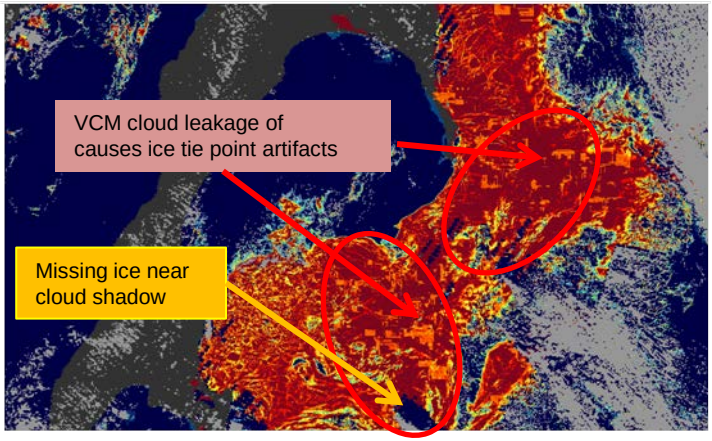
Zoom of boxed region. Note that the zoom is not at full resolution (zoom of sub-sampled, mapped image)

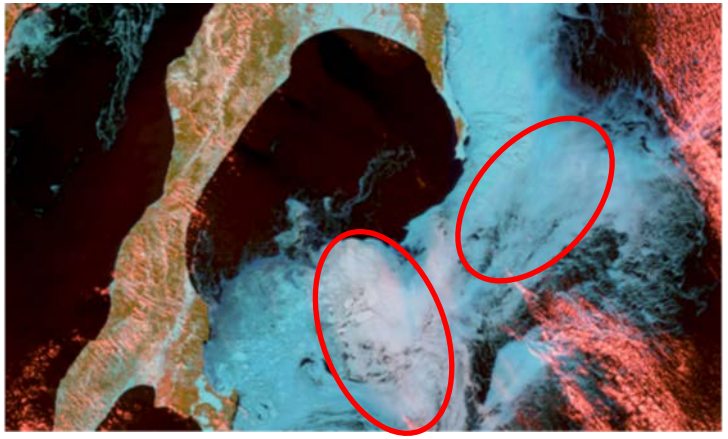
Detailed structure of the ice edge and leads can be seen in the Ice Concentration IP as shown in the zoomed subset region in the right figure. The current Ice Concentration IP if produced as a product should allow users to identify ice edges more accurately.

Comparison of VIIRS SIC to Zoomed VIIRS False Color SDR for Day Scenes – Issues



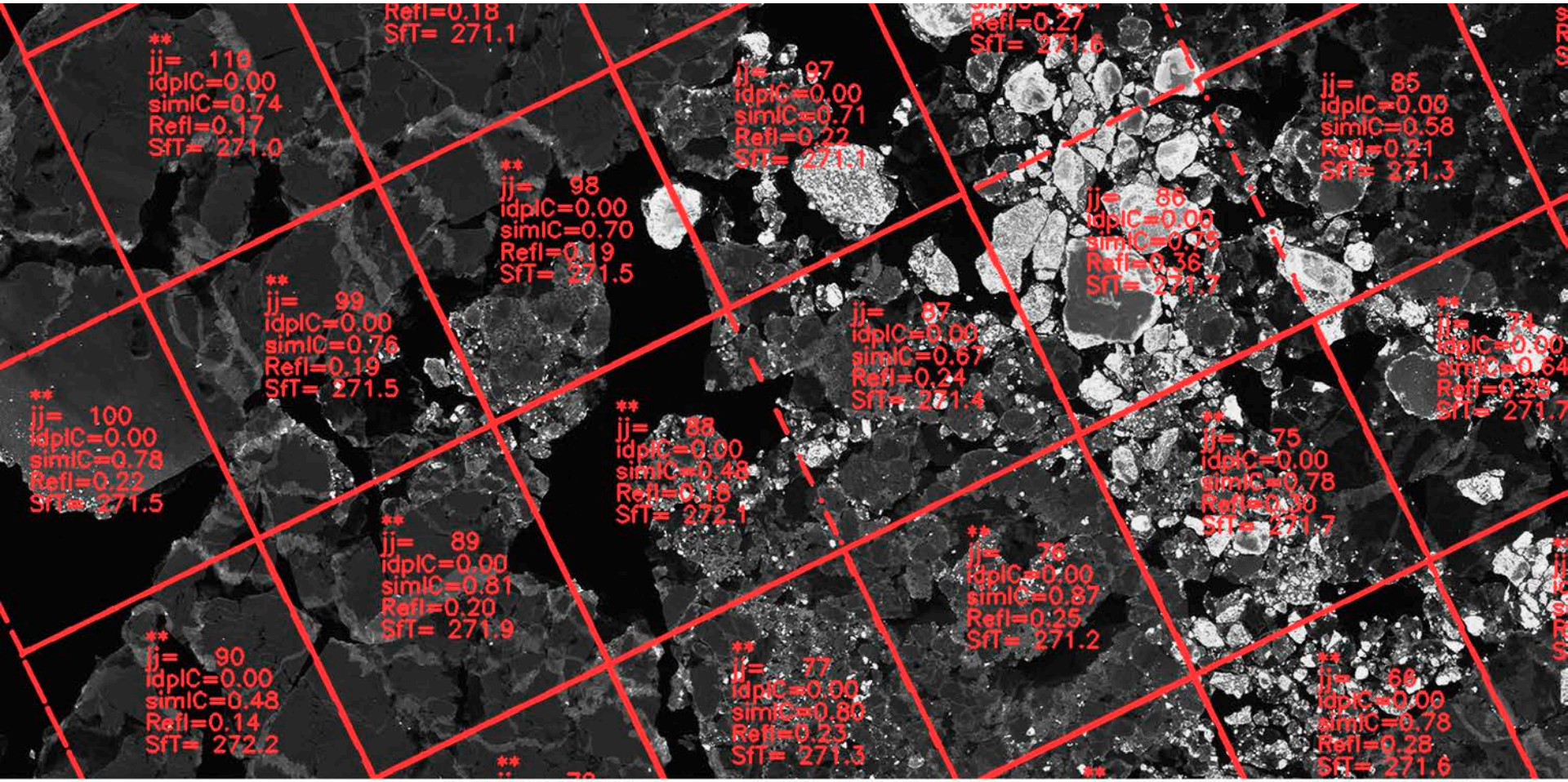






(1) Rectangular fill values are associated with VCM positive M7 and M1 threshold test triggered by out of date manually updated GMASI snow/ice (top left). (2) False ice is seen in the product (top left) corresponding undetected thin cirrus (red circle, top right). (3) Rectangular and linear artifacts seen within the circled regions in the VIIRS Ice Concentration IP (bottom left) are thought to be associated with ice tie point window fall back to default values. This often occurs over regions with ill defined ice tie point histogram peaks such as regions with undetected clouds as shown within the red circled regions in the false color SDR reflectance image (lower right). A possible fix is to fall back to a running mean ice tie point in instead of a global default.

Comparison of VIIRS SIC to DigitalGlobe (DG) derived SIC in non-melting season – Issues



Section of Dig Glb tile R1C2
IDPS IC vs Dig Glb Simulated IC
March 21, 2014 VIIRS Time: 22:24 UT Dig Glb Time: 22:25UT
Bering Sea off of SE coast of Alaska (lat= 58.7 N, lon= -161.9)

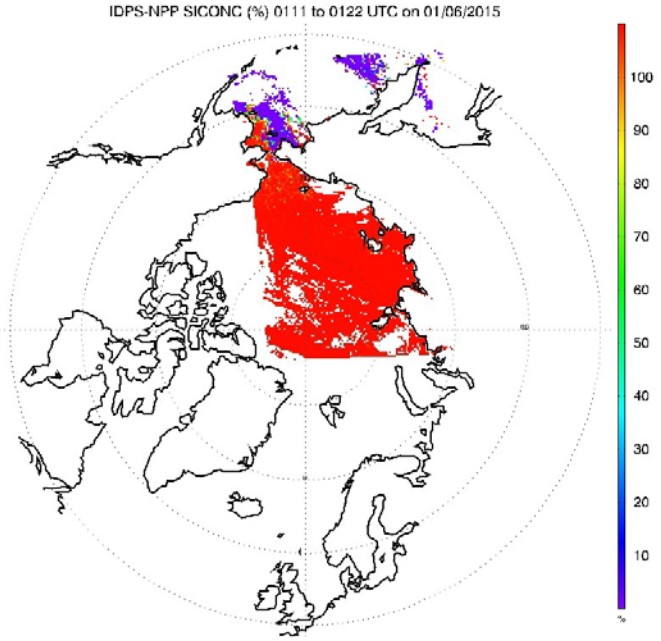
31 IDPS FOVs with valid Ice Concs
Bias= 0.69 Stddev= 0.18 RMS= 0.72
FOVs with ** were used in comparison
FOVs with no ** are cloud shadowed and not used in comparison statistics

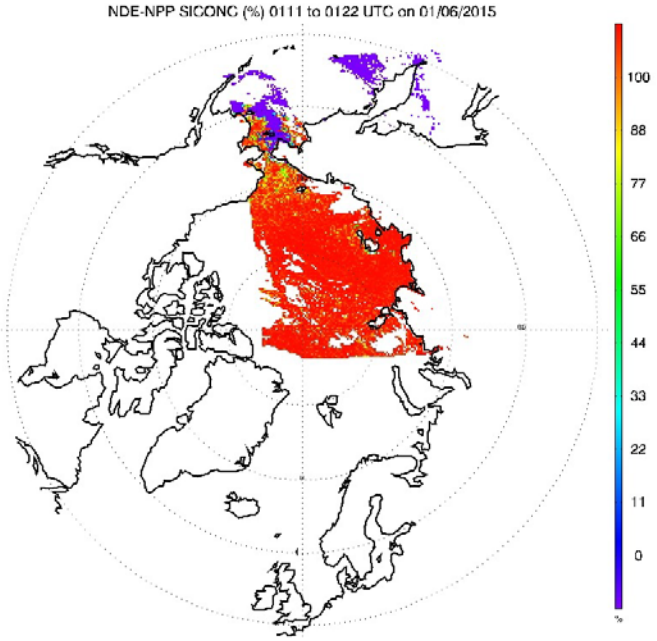
For this tile, 26 of the 31 non shadowed VIRRS FOVs had an IDPS IC=0.0 with the simulated IC > 0.4
All 26 of these FOVs had indeterminate reflective Ice Tie Points

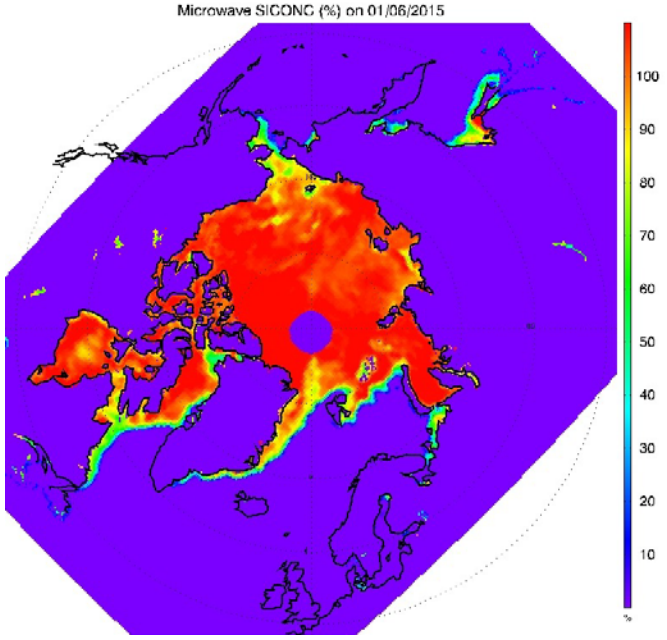
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Image band FOVs Spatial resolution ~400m
Values in boxes are: Box number, IDPS Ice Conc, Simulated Ice Conc, VIIRS I1 Band Reflectance and VIIRS Surface Temperature

Enterprise SIC

IDPS, Enterprise SIC with MW SIC on January 6, 2015







VIIRS SICs to DG derived SIC in melting season

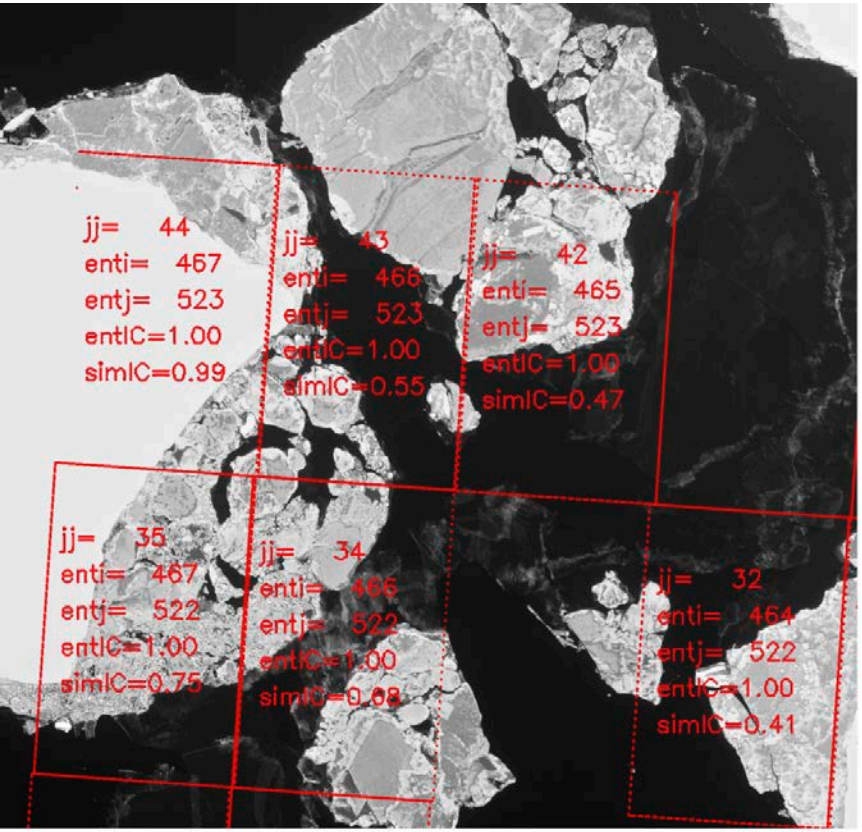


Figure 1 Example pixels of Enterprise IC vs Dig Glb Simulated IC
May 10, 2014 VIIRS Time: 18:29 UT Dig Glb Time: 18:15 UT
21 Enterprise FOVs with valid Ice Concs
Bias= -0.29 Stddev= 0.20 RMS= 0.35
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Moderate band FOVs Spatial resolution ~800m
Values in boxes are: Box number, FOV column, FOV row,
Enterprise Ice Conc, Simulated Ice Conc

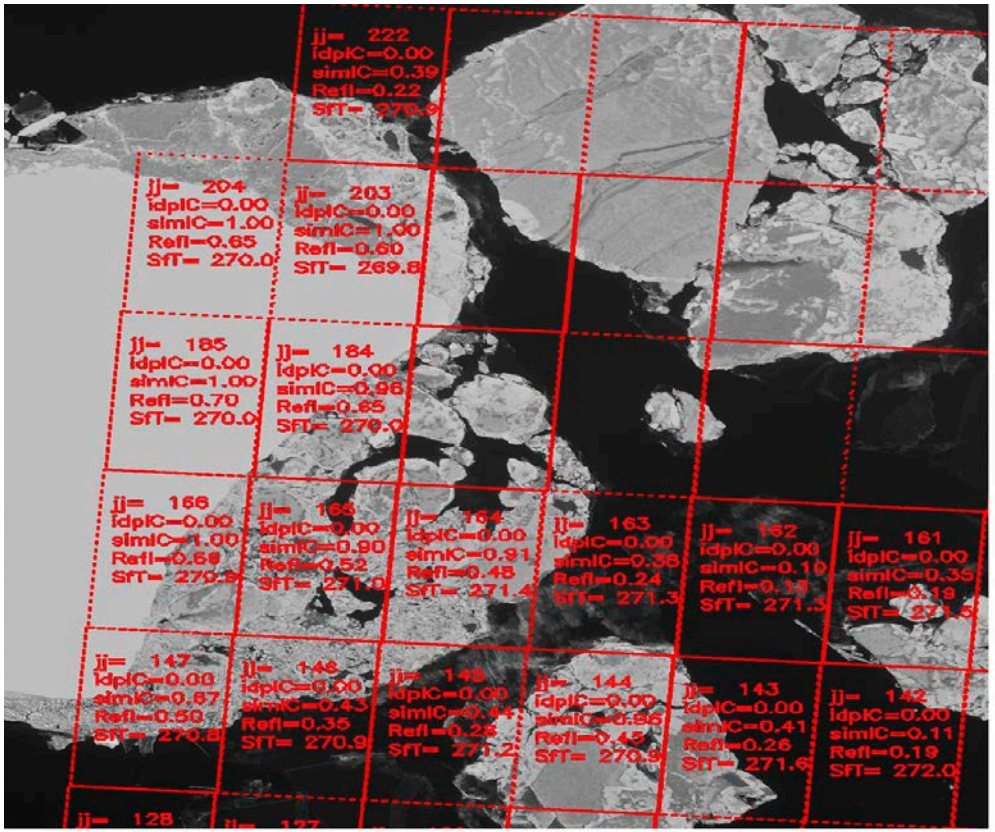


Figure 2 Example pixels of IDPS IC vs Dig Glb Simulated IC
May 10, 2014 VIIRS Time: 18:29 UT Dig Glb Time: 18:15 UT
71 IDPS FOVs with valid Ice Concs
Bias= 0.362 Stddev= 0.317 RMS= 0.48
Digital Globe WV2 Multispectral Band 1 Spatial Resolution ~ 2m
Red boxes are VIIRS Image band FOVs Spatial resolution ~400m
Values in boxes are: Box number, IDPS Ice Conc, Simulated Ice Conc,
VIIRS I1 Band Reflectance and VIIRS Surface Temperature

Enterprise

IDPS

SIC EDR requirement

1. Clear	1.0 km	0.5 km
2. All Weather	No capability	1 km
c. Mapping Uncertainty, 3 Sigma		
1. Clear	1 km at Nadir	0.5 km
2. Cloudy	No capability	1 km
d. Measurement Range	0 - 100%	0 - 100%
e. Measurement Accuracy	10% (Notes 1, 2, 3)	5%
f. Measurement Uncertainty	25% (Notes 1, 2, 3)	10%
g. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	6 hrs.
h. Geographic coverage	All ice-covered regions of the global ocean	All ice-covered regions of the global ocean
		v3.0, 8/27/14

Notes:

1. VIIRS produces sea ice concentration in clear sky conditions only.
2. Performance Exclusion Conditions:
   a. VCM IP cloud confidence: confidently cloudy and probably cloudy.
   b. Sun glint regions

Summary

• **Detailed structure of Ice edges and ice leads are observable in the VIIRS Sea Ice Concentration IP** at VIIRS Imagery resolution for both day and night, out to edge of scan based on visual comparisons

  – Ice extent compares well with VIIRS SDR False color imagery, National Ice Center Ice Charts, MODIS Aqua/MYD29 (see backup slide) reference data and full resolution zoomed VIIRS SDR reflectance imagery

• Quantitative performance based on comparison with LANDSAT ice fractions show relatively small bias and good precision for the total (0.67% and 11%) and high ice fraction range (1.29% and 10.36%), with relatively reduced performance for mid range ice fractions (5% and 20% in bias and precision) based cases from 2013 and 2014

•Quantitative performance based on comparison with ice fractions from microwave products show small bias and good precision for the total (1.67% and 5.81%) and very high high ice fraction (4.45% and 6.25), but very high positive bias and relatively low precision for mid range ice fractions (23.8% and 9.46%) using collocated cases from 2012 to 2015.

•Quantitative performance based on comparison with ice fractions from DigitalGlobe show large bias and precision in the melting season, and relatively smaller bias and good precision in the non-melting season.

• Improvement in VCM will improve the VIIRS Ice Concentration IP performance. The VIIRS Ice Concentration IP performance in the melting season needs further improvement.

Conclusions

• Observed performance of the VIIRS Ice Concentration IP is such that this product has high potential to become an extremely useful JPSS product due to its high spatial resolution in both day and night.

• Performance evaluation indicates that the VIIRS Ice Concentration IP in its current state may already be an extremely useful product for identifying ice extent for both day and night for clear sky conditions

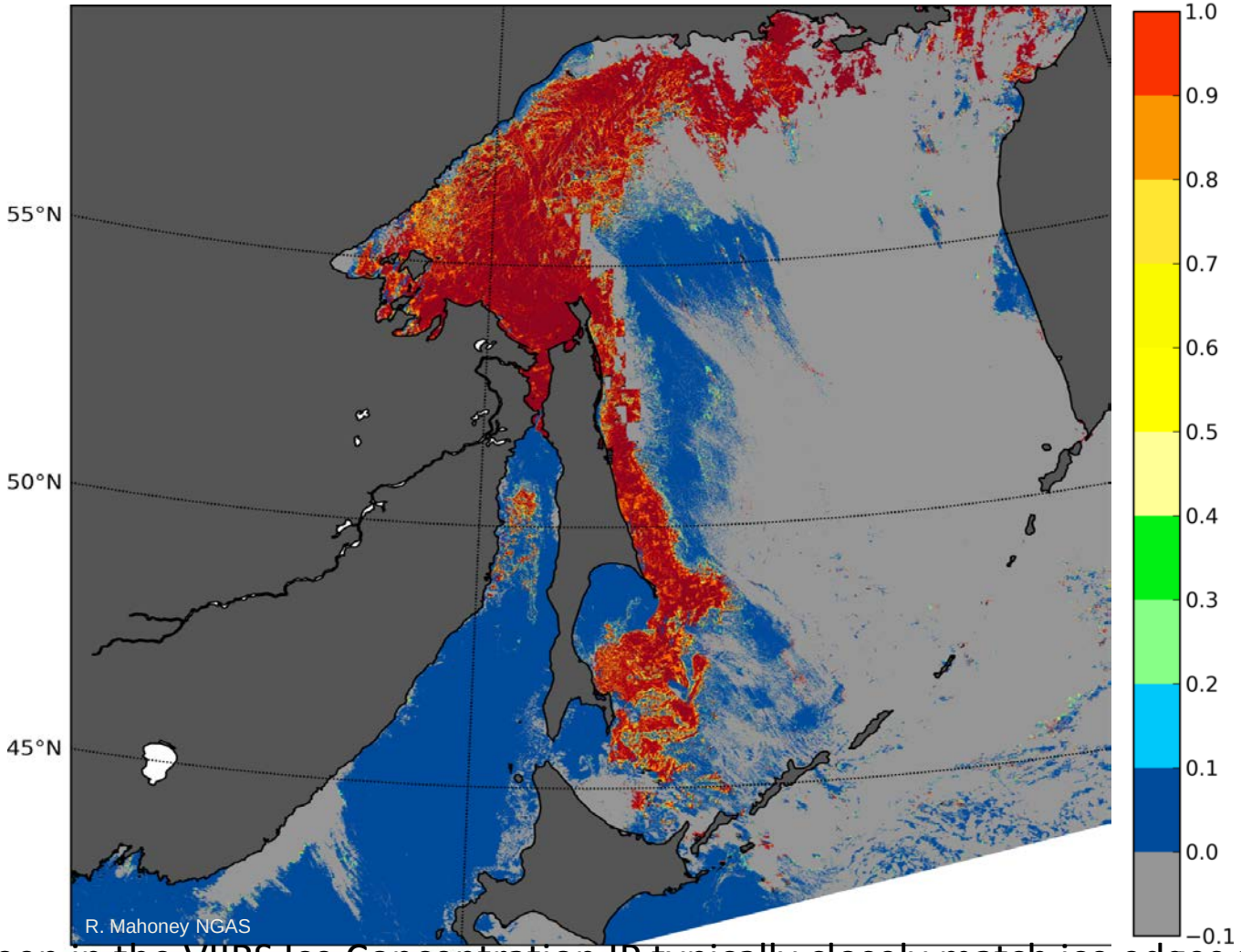
• The VIIRS Ice Concentration IP for NPP is a currently non-deliverable Retained Cal/Val IP. Promotion to a deliverable product will require minor level of effort for addition of product quality flags, implementation of extended cloud adjacency quality flagging and correction of minor defects

•The VIIRS Ice Concentration using Enterprise algorithm is expected to perform better than the IDPS product.

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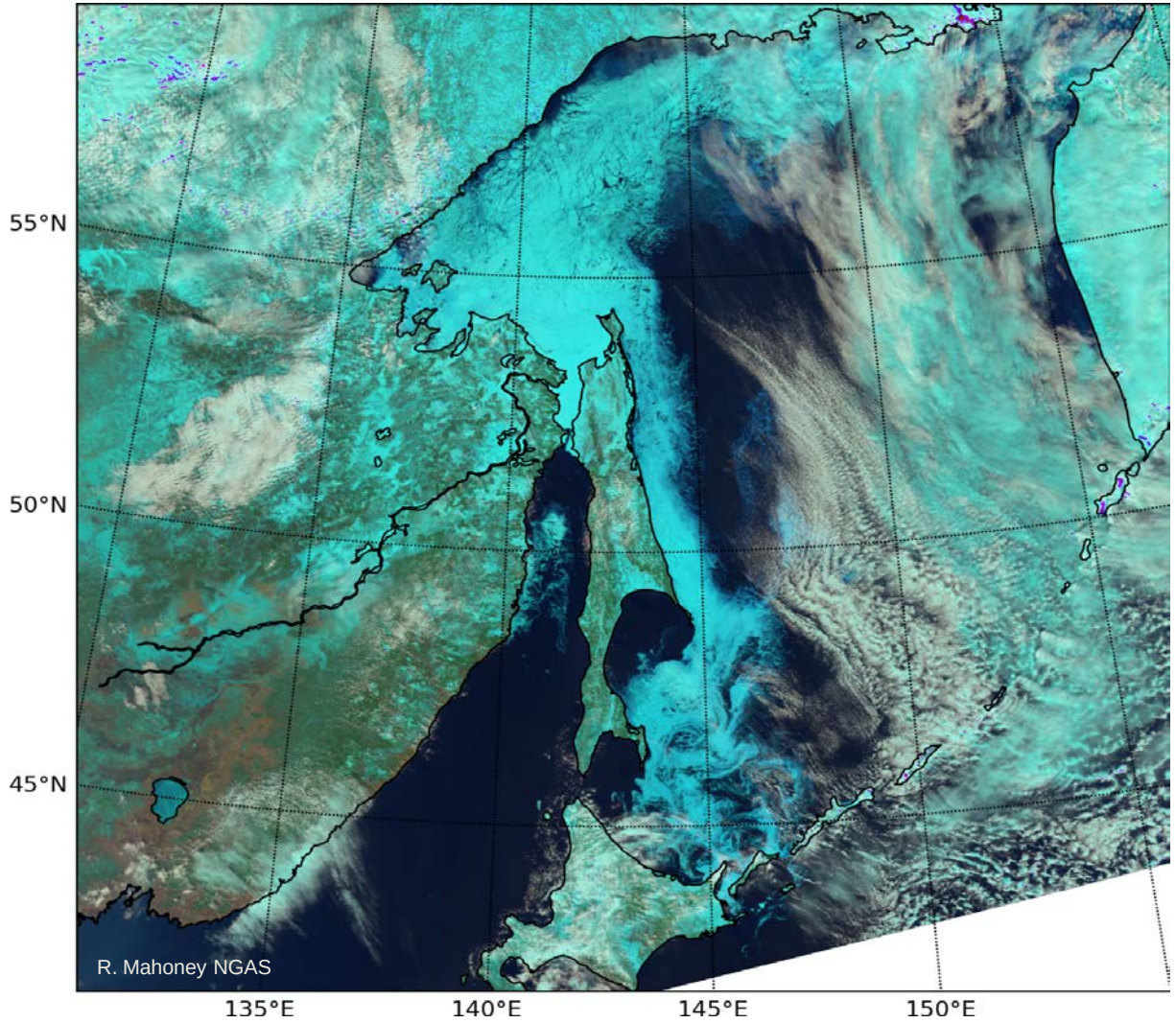
Backup slide

Comparison of VIIRS Ice Conc. to VIIRS False Color SDR for Day Scene



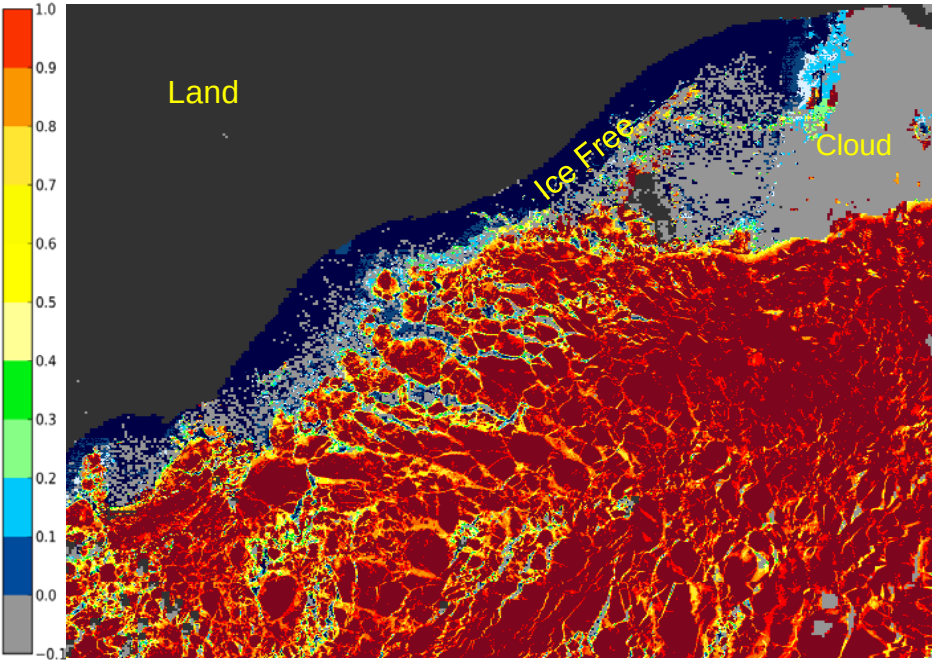
The ice edges seen in the VIIRS Ice Concentration IP typically closely match ice edges seen in false color SDR reflectance band imagery as in this day case of melting sea ice in the Sea of Okhotsk (March 23, 2014, 03:05-03:11 UTC)

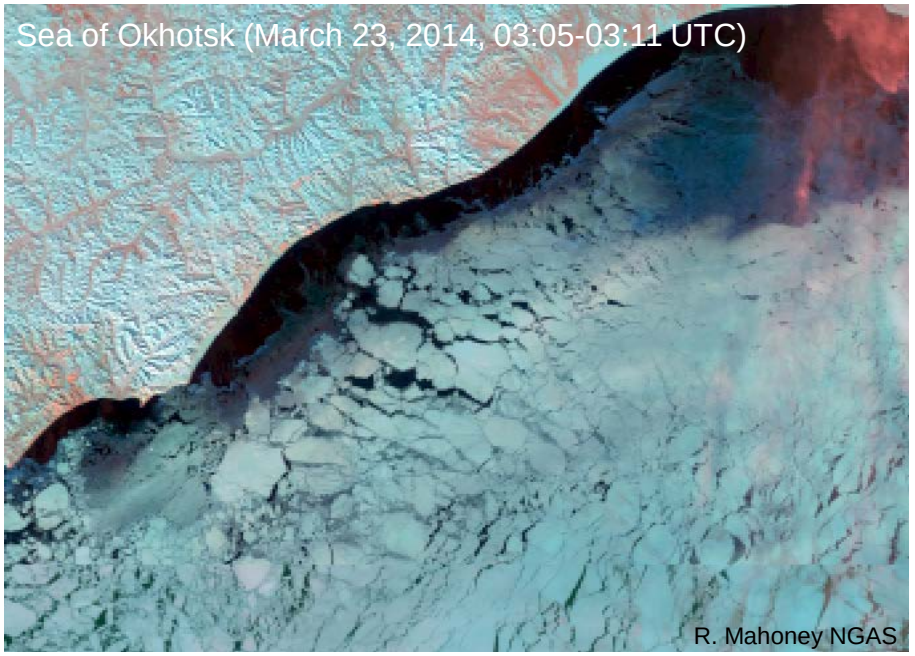
Comparison of VIIRS Ice Conc. to VIIRS False Color SDR for Day Scenes



Reference false color VIIRS SDR reflectance band imagery showing melting sea ice over the Sea of Okhostk for March 23, 2014.

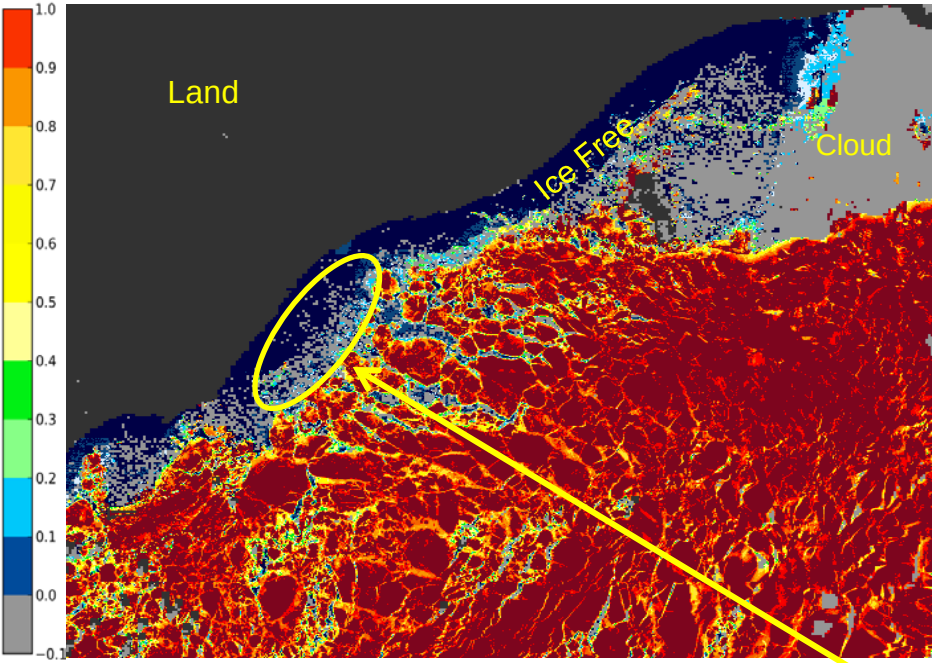
Comparison of VIIRS Ice Conc. to VIIRS False Color SDR for Day Scenes – Full Resolution Zoom

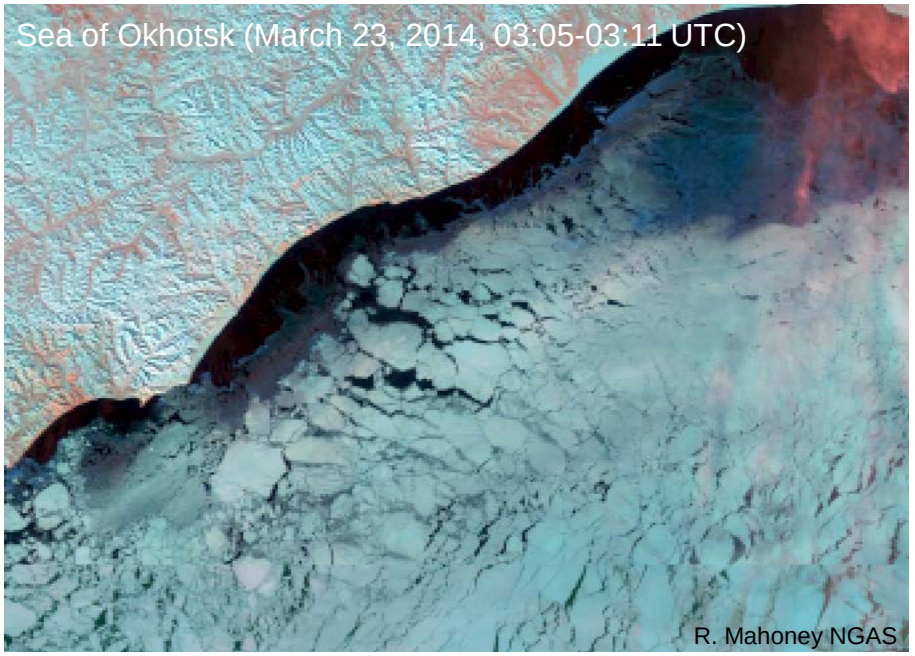




VIIRS Ice Concentration IP (left) shows fine detail of ice edge and lead features. An ice fraction threshold of 0.1 yields an ice extent that very closely matches the ice edges seen in the corresponding VIIRS SDR reflectance band imagery zoomed at full VIIRS imagery resolution (right).

Comparison of VIIRS SIC to VIIRS False Color SDR for Day Scenes – Issues





Many pixels near ice edges are flagged by VCM as confidently cloudy are clear in the corresponding false color SDR image

Many ice edge pixels however, are flagged as confidently cloudy by the VCM and are not retrieved by the ice concentration algorithm.