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# The Regional Ice Prediction System (RIPS) 2.0: an update to the analysis component

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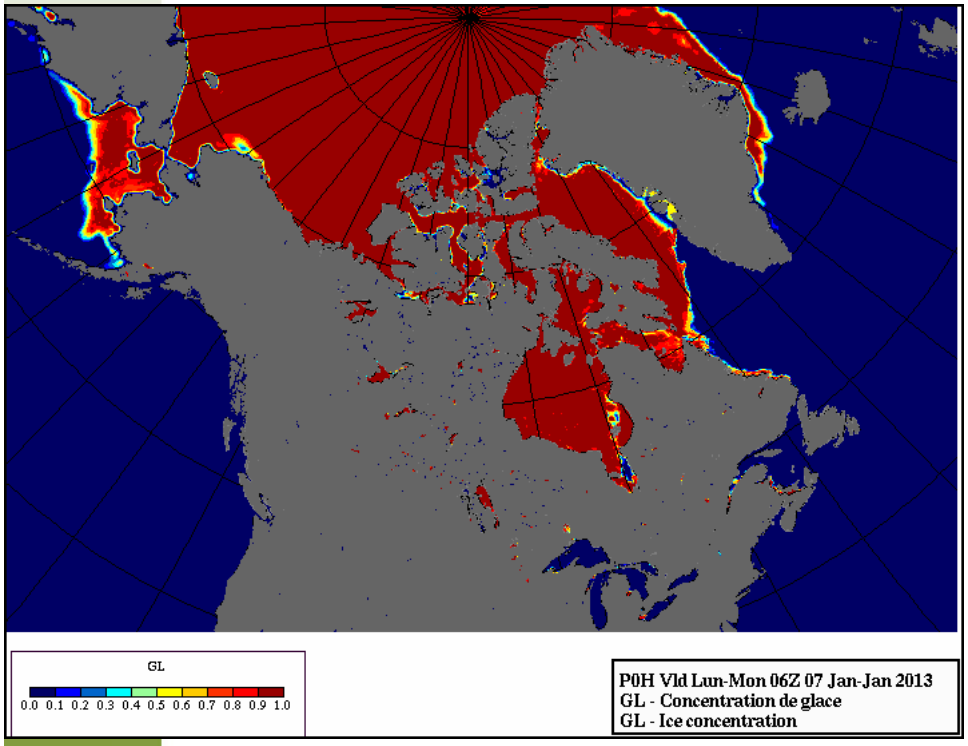
# The Regional Ice Prediction System (RIPS) analysis: introduction

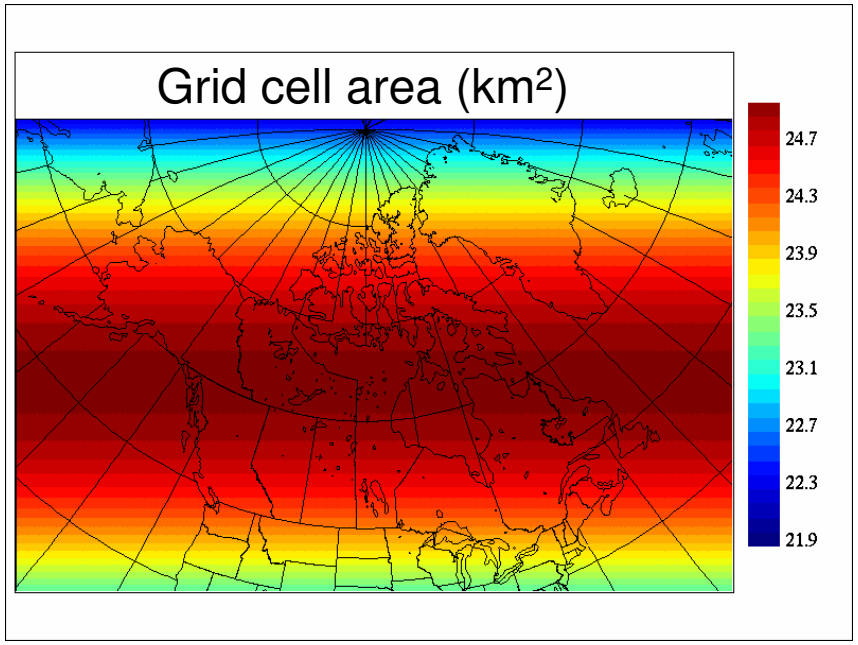



- Main use: provides input for generation of CIS operational products (both manual and automated)
- The system is based on a variational approach to data assimilation
- Four analyses per day of ice concentration at 5 km resolution on rotated lat-lon grid
- Domain chosen to include new METAREAs and meet the needs of North American Ice Service (USA/Canada)
- Includes the Great Lakes and many other lakes (those for which CIS already produces analyses)
- Also serves as the test-bed for evaluating upgrades for all implementations (global and regional)

# Versions of the Regional Ice Prediction System

# Regional Ice Prediction System

- RIPS 1.0 (in experimental mode since March 16th, 2011):
  - analysis of total sea ice concentration
  - 0.045° (between 4.7 and 5.0 km) resolution
  - 4 analyses (at 00, 06, 12, and 18 UTC) each day
  - 6-hour assimilation windows
  - background = persistence (analysis 6 hours earlier)
  - observation types assimilated (ice concentration):
    - CIS daily ice charts
    - CIS image analyses charts
    - CIS lake bulletins
    - AMSR-E (no longer available since October 4th, 2011)
    - SSM/I (DMSP-15)
  - ice in the analysis is removed where CMC SST > 4°C
- Buehner *et al*. 2012, Atmosphere-Ocean



# Regional Ice Prediction System

- RIPS 2.0 (~Jan 2013):
  - Additional observations:
    - SSM/IS (DMSP16-17-18)
    - ASCAT (1 satellite)
  - Assimilation of all satellite data over lakes
  - An estimation of the analysis-error standard deviation for ice concentration
  - Sea ice model CICE4 is used to produce short-term forecasts (lead time up to 48 hours):
    - This will be the subject of a separate presentation in the near future (J.-F. Lemieux, C. Beaudoin, F. Roy, F. Dupont, G. Smith)

- The new 10-km global ice analysis is similar to RIPS 2.0, except for ASCAT assimilation.

# Regional Ice Prediction System

- RIPS 2.1 (~Jan 2014):
  - Additional observations:
    - AVHRR (with automated CV calculation)
    - VIIRS (on Suomi National Polar-orbiting Partnership (NPP))
    - AMSR-2
  - Sea ice model CICE4 is also used to produce background fields (instead of using persistence)
  - Possibly use automated CV calculation and different retrieval algorithm for passive microwave data

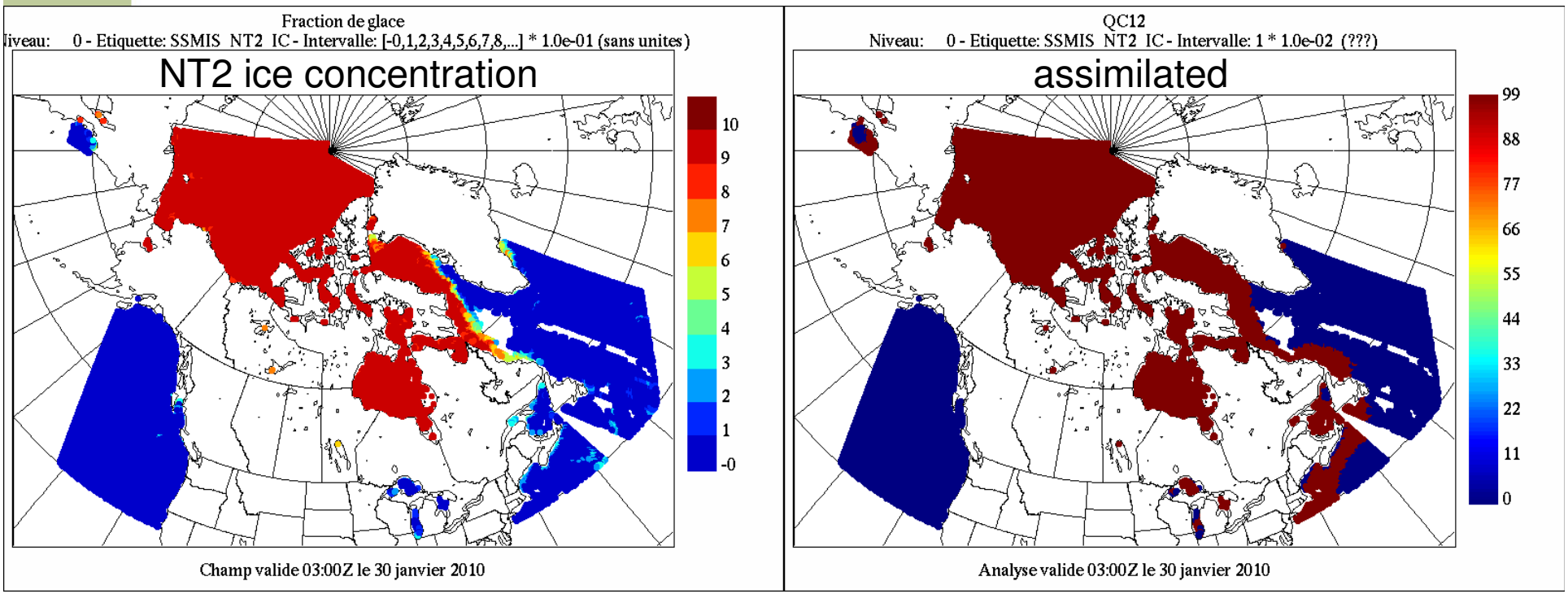
# Regional Ice Prediction System

- RIPS ?.? (TBD):
  - Ice thickness and drift as new analysis fields
  - Ensemble-based data assimilation procedure and ensemble forecasts
  - Additional observations:
    - SAR
    - Ice thickness from AVHRR/VIIRS/AMSR/SMOS
    - Ice drift
    - Higher resolution (frequency) passive microwave channels
  - Increase resolution to 1-2 km

# Impact of SSM/IS and ASCAT data

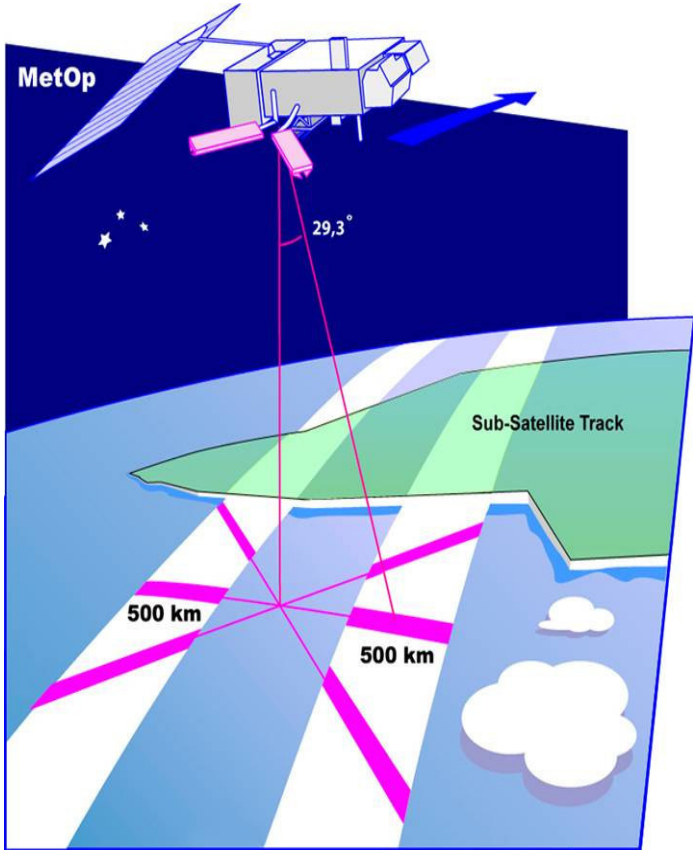
# Assimilation of SSM/IS data

- NT2 ice concentration retrievals from brightness temperature data, same tie-points as for SSM/I:
  - Tests with NT2 were better than with NT
- Data from 3 satellites (DMSP16-17-18), but data from DMSP18 only available from May 2010 onward
- Data not assimilated where SST > 4°C or Surface Air Temperature > 0°C

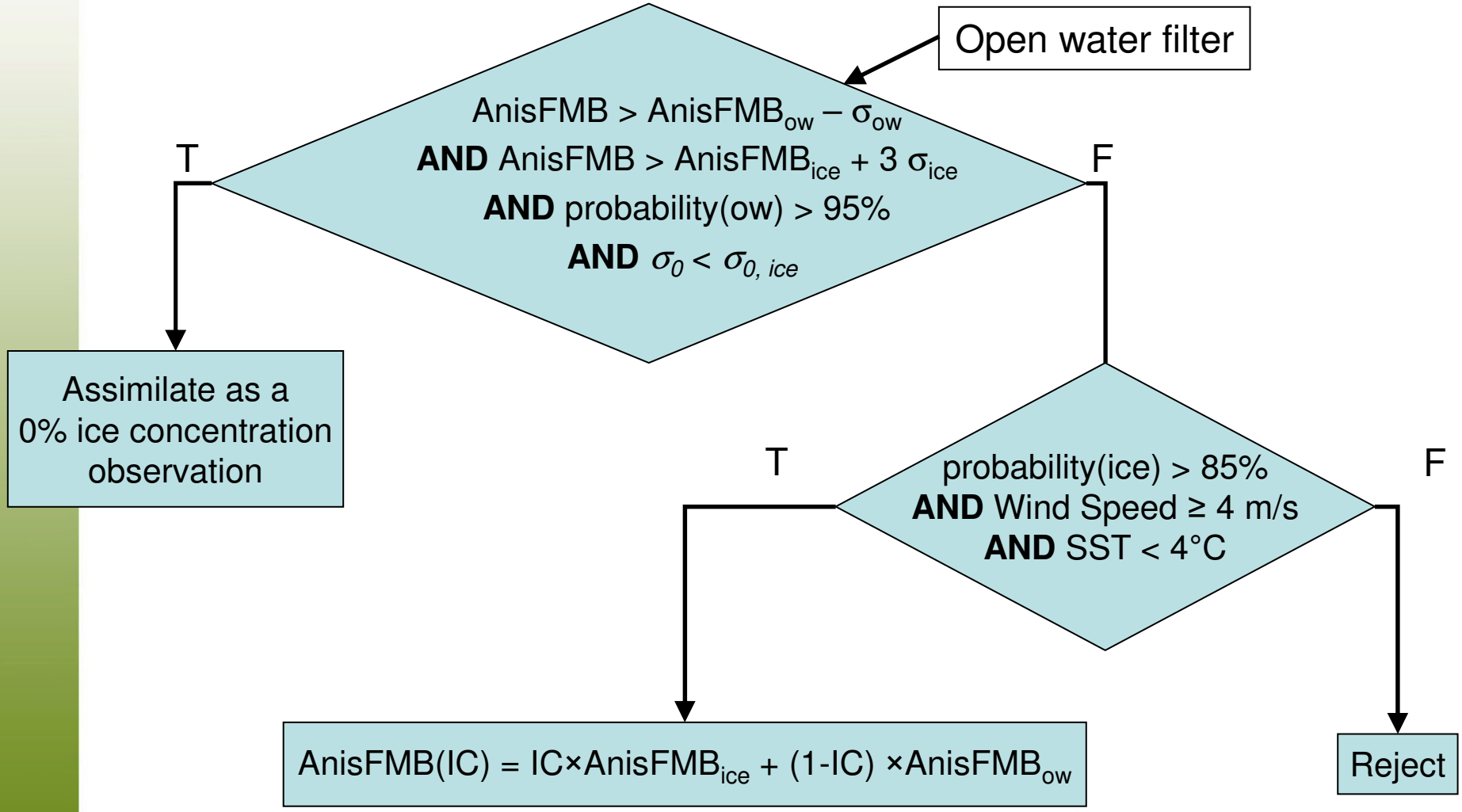


# Assimilation of ASCAT data

- Following approach developed by OSI-SAF:
  - ASCAT instrument has 3 antennae (fore, mid and back) giving radar backscatter measurements from 3 different look angles
  - backscatter from sea-ice tends to be more isotropic with respect to look angle than from open water

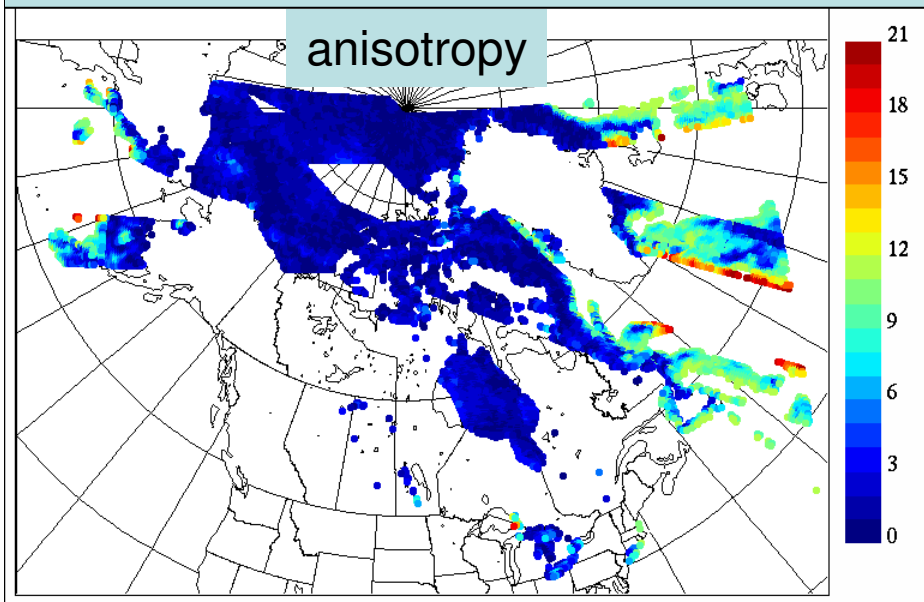


# Assimilation of ASCAT data



# ASCAT- derived observations in a 6-hour assimilation window

## anisotropy

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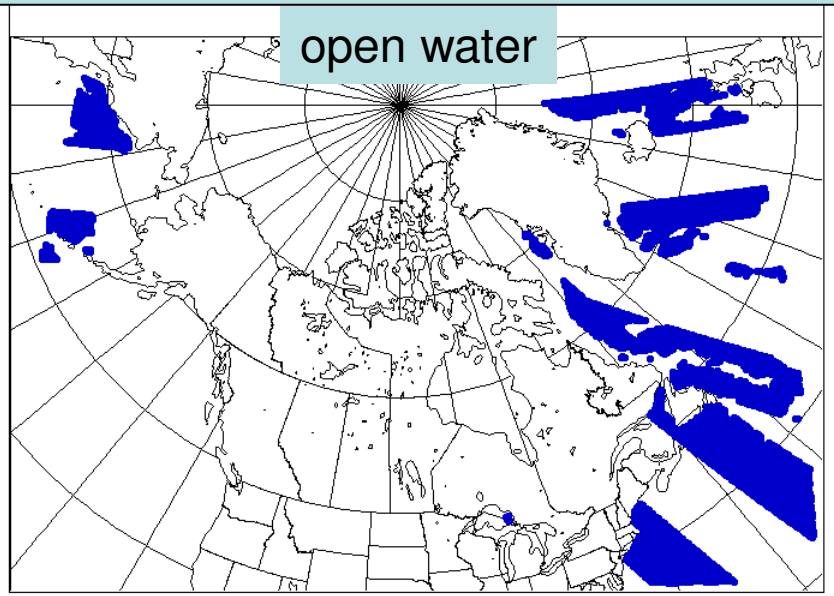
## open water



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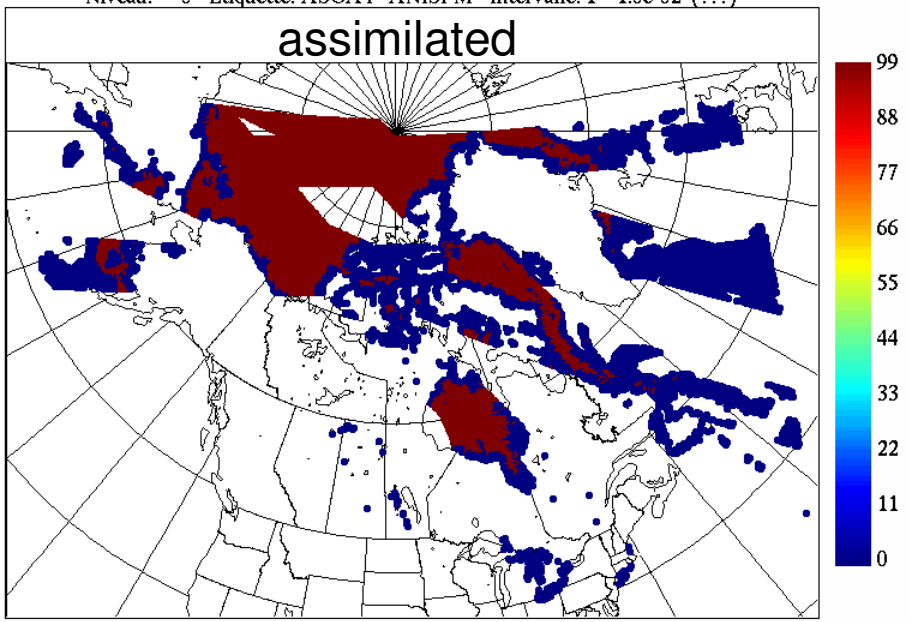
QC12
Niveau: 0 - Etiquette: ASCAT ANISFM - Intervalle: 1 * 1.0e-02 (???)

## assimilated

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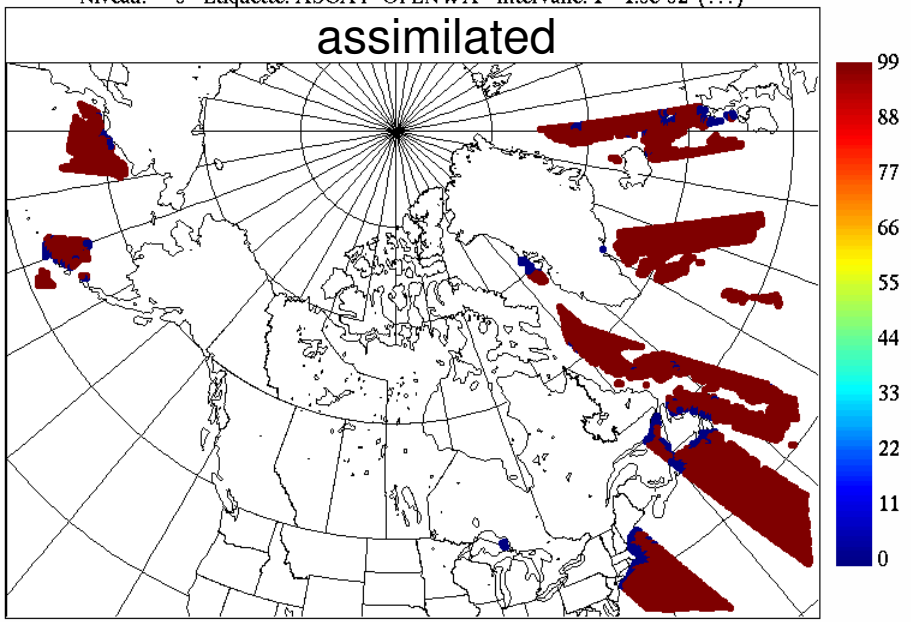
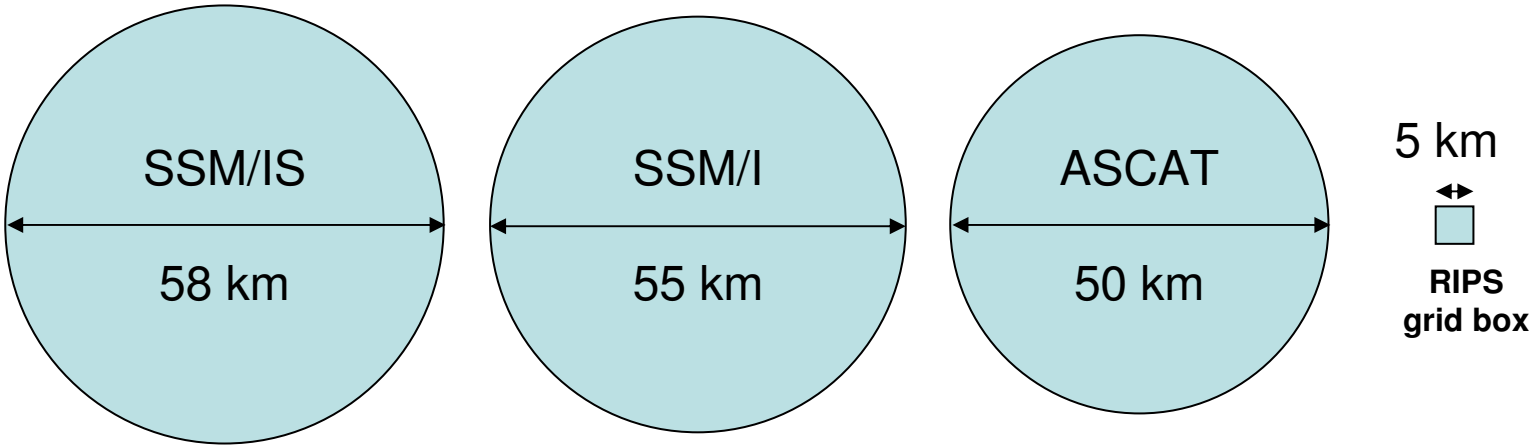
QC12
Niveau: 0 - Etiquette: ASCAT OPENWA - Intervalle: 1 * 1.0e-02 (???)

## assimilated




Analyse valide 03:00Z le 30 janvier 2010

# Observation footprints



# Verification against IMS ice extent analysis from NOAA

- IMS is the Interactive Multisensor Snow and Ice Mapping System (http://www.natice.noaa.gov/ims/)
- Only ice/no-ice
- Manual production using a wide variety of satellite data
- Resolution ~4 km
- Available daily over entire northern hemisphere analysis domain, including lakes (scores computed over sub-regions)
- RIPS ice concentration analysis is interpolated on the IMS analysis grid and then converted to ice/no-ice using a 40 % threshold

# Scores are based on a contingency table

- Scores are ratios and are calculated only when the denominator is greater than 500.

| | **Observed ice** | **Observed no ice** |
|---|---|---|
| **Analysed ice** | Hits (a) | False alarms (b) |
| **Analysed no ice** | Misses (c) | Correct no (d) |

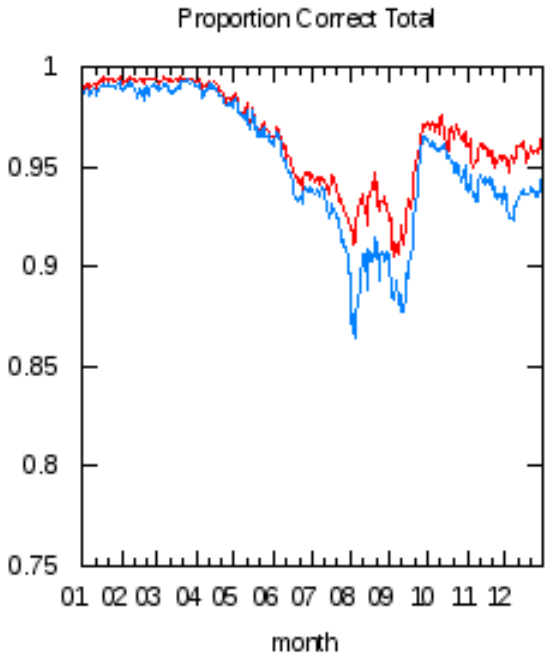
| Name | Definition | Range ; best score |
|---|---|---|
| Proportion Correct Total | PCT = (a+d)/n | 0 - 1 ; 1 |
| Proportion Correct Ice | PCI = a/(a+c) | 0 - 1 ; 1 |
| Proportion Correct Water | PCW = d/(b+d) | 0 - 1 ; 1 |
| Bias | BIAS = (a+b)/(a+c) | 0 - ∞ ; 1 |
| Observed Proportion Ice | OPI = (a+c)/n | 0 - 1 |
| Obs Count (sample size) | n = a + b + c + d | 0 - ∞ ; ∞ |

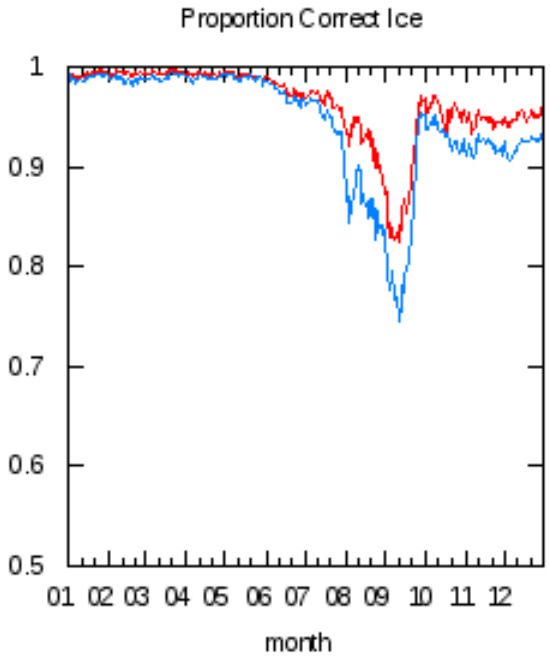
# Experiments (2010)

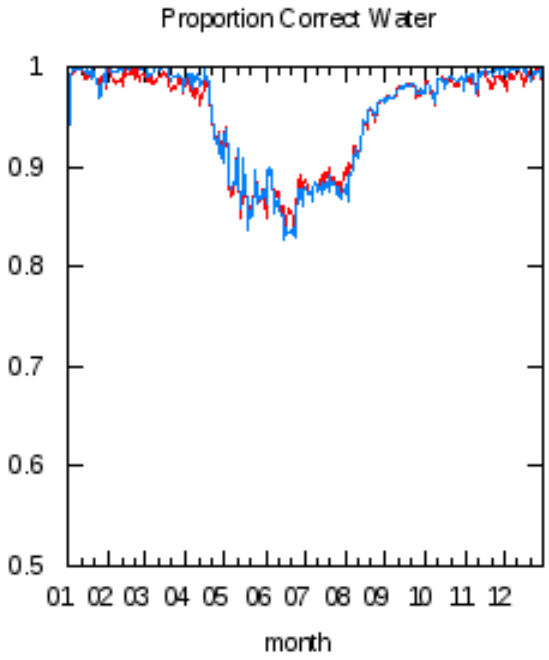
- Experiment 1 (control_no_AMSR):
  - Observations:
    - SSM/I
    - CIS daily ice charts
    - CIS image analyses
    - CIS lake ice bulletins
- Experiment 2 (RIPS1_SSMIS):
  - experiment 1
  - SSM/IS

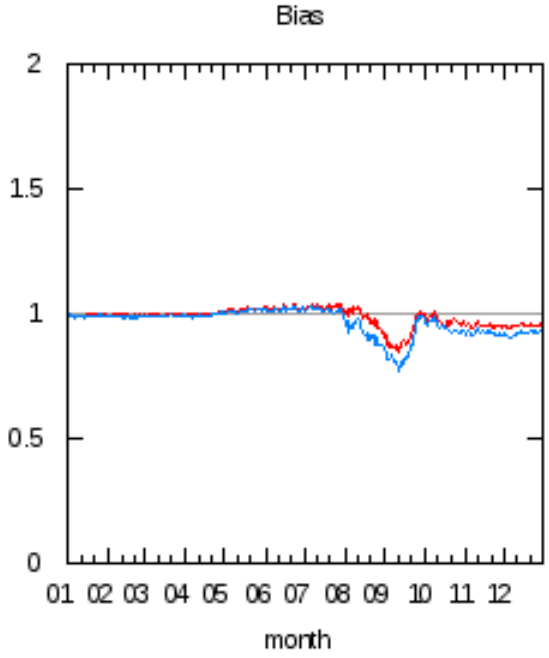
All Arctic

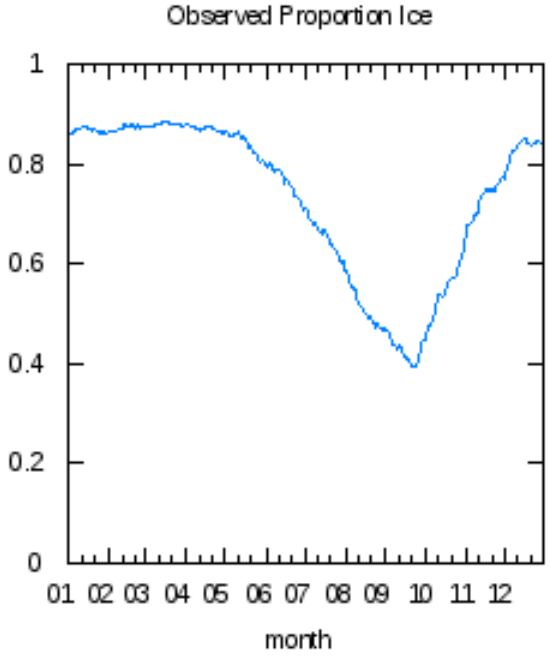
# North of 65°N

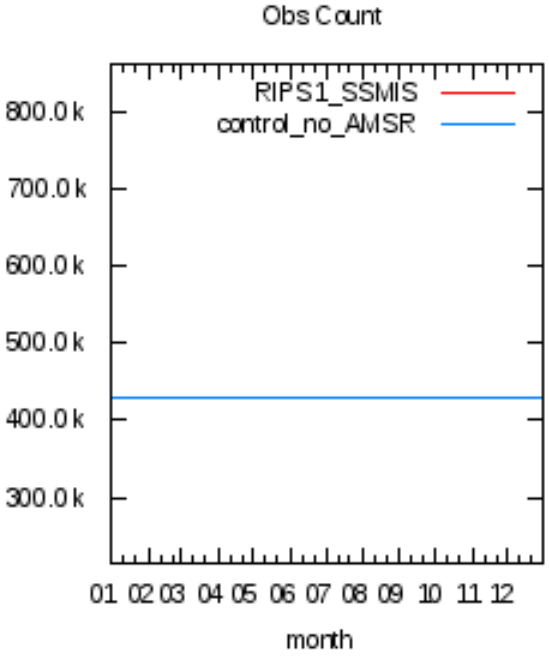


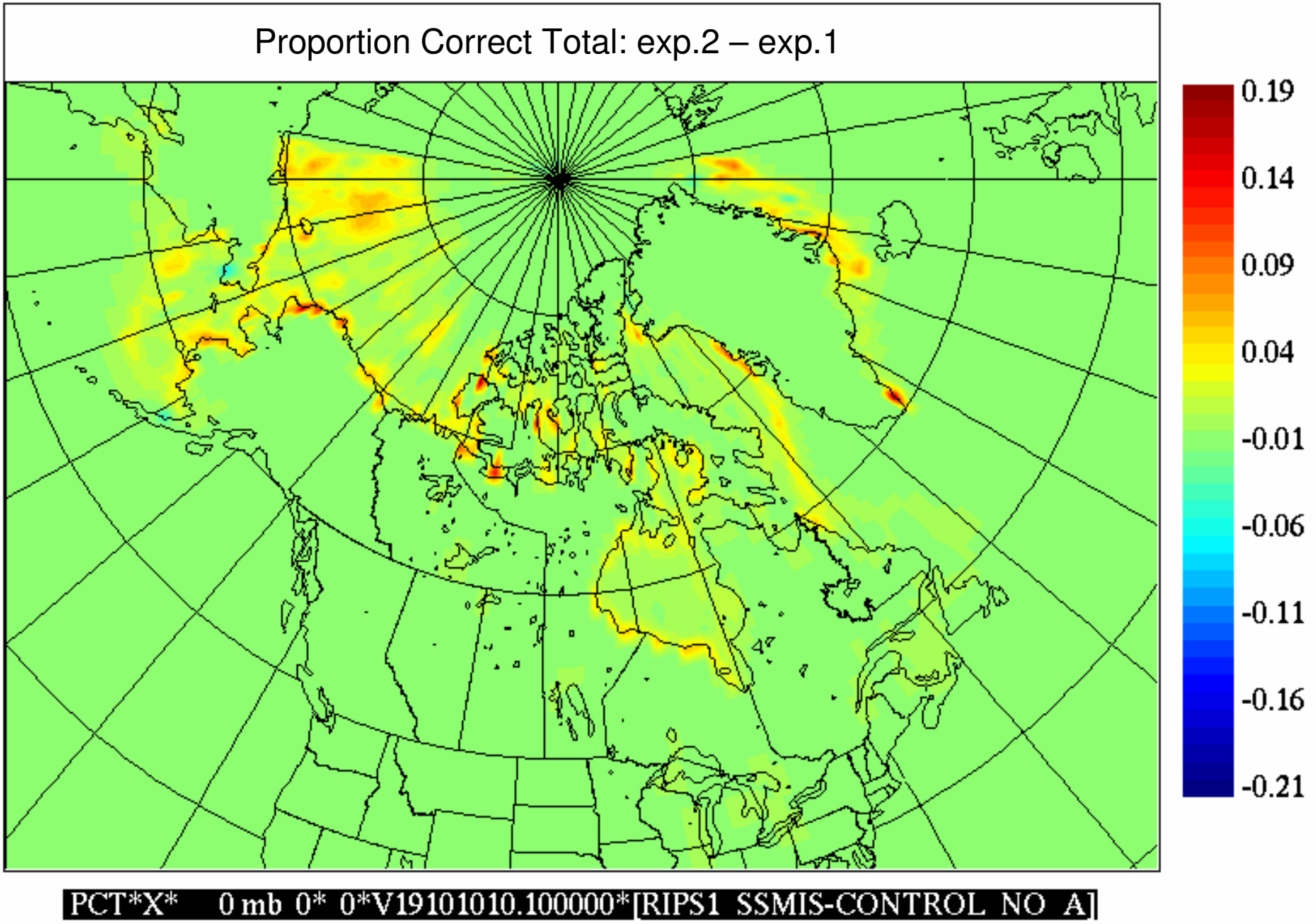



# Impact of SSM/IS data (2010)

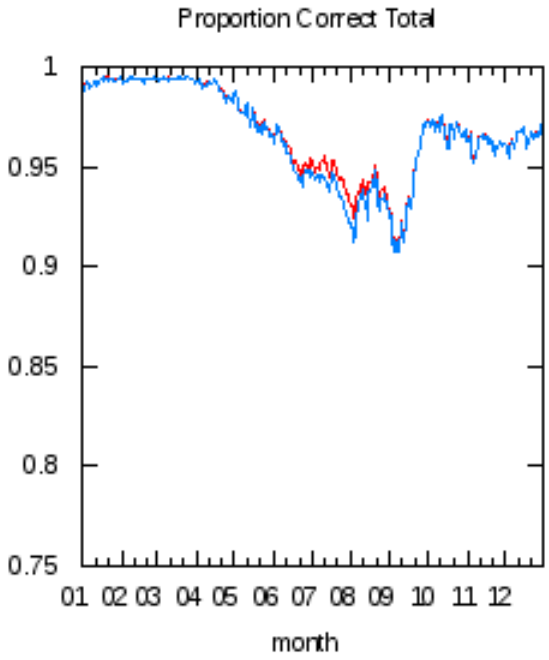


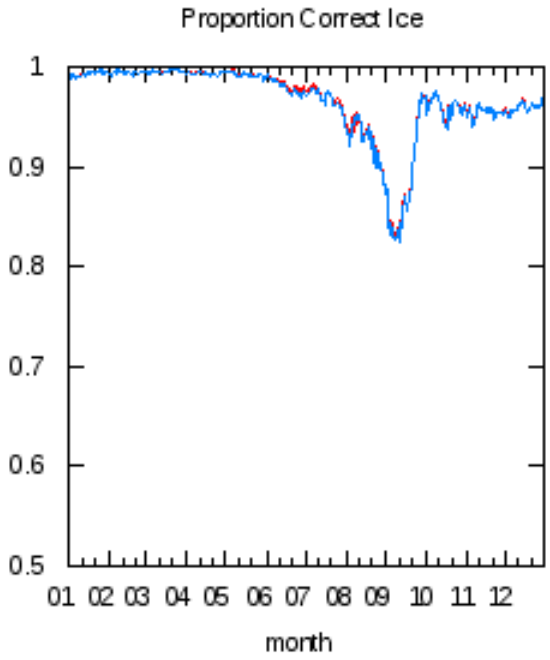
# Experiments (2010)

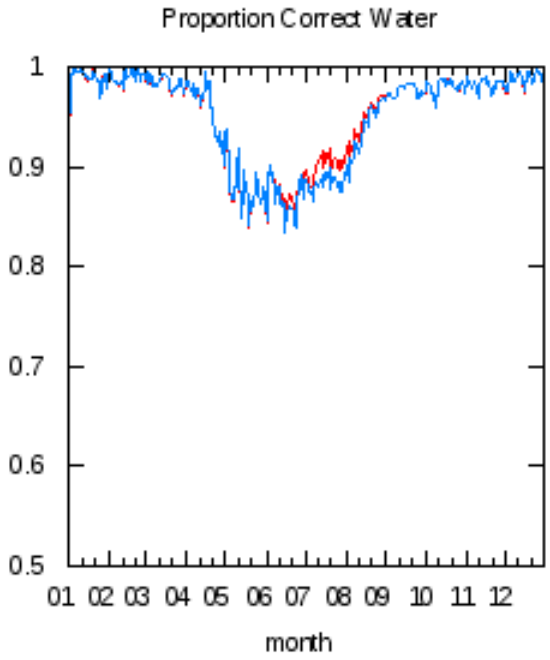
- Experiment 2 (in blue):
  - Observations:
    - SSM/I
    - CIS daily ice charts
    - CIS image analyses
    - CIS lake ice bulletins
    - SSM/IS
- Experiment 3: (in red)
  - experiment 2
  - ASCAT

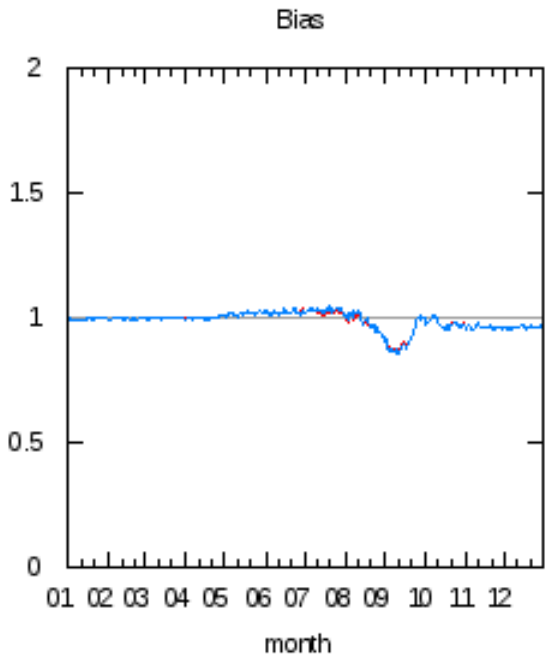
All Arctic

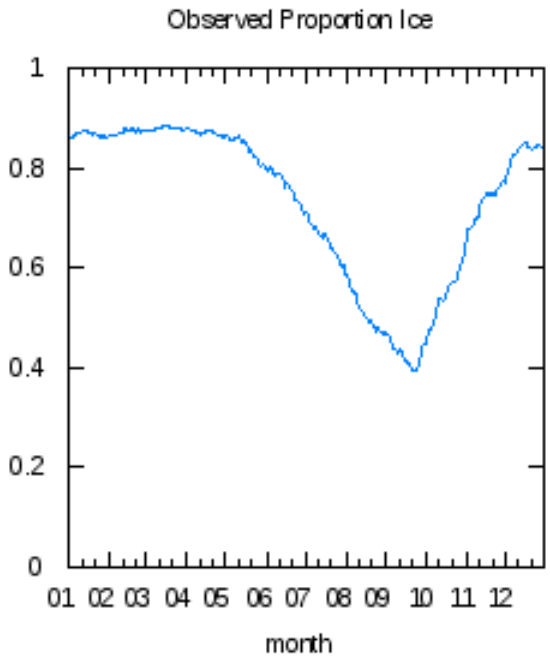
# North of 65°N

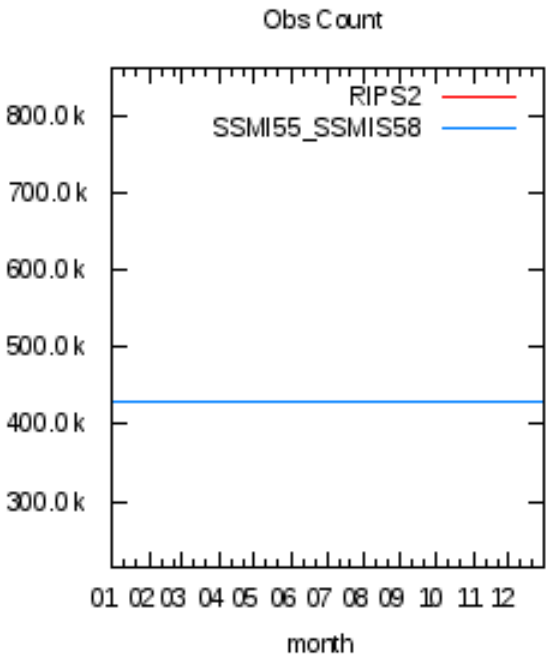


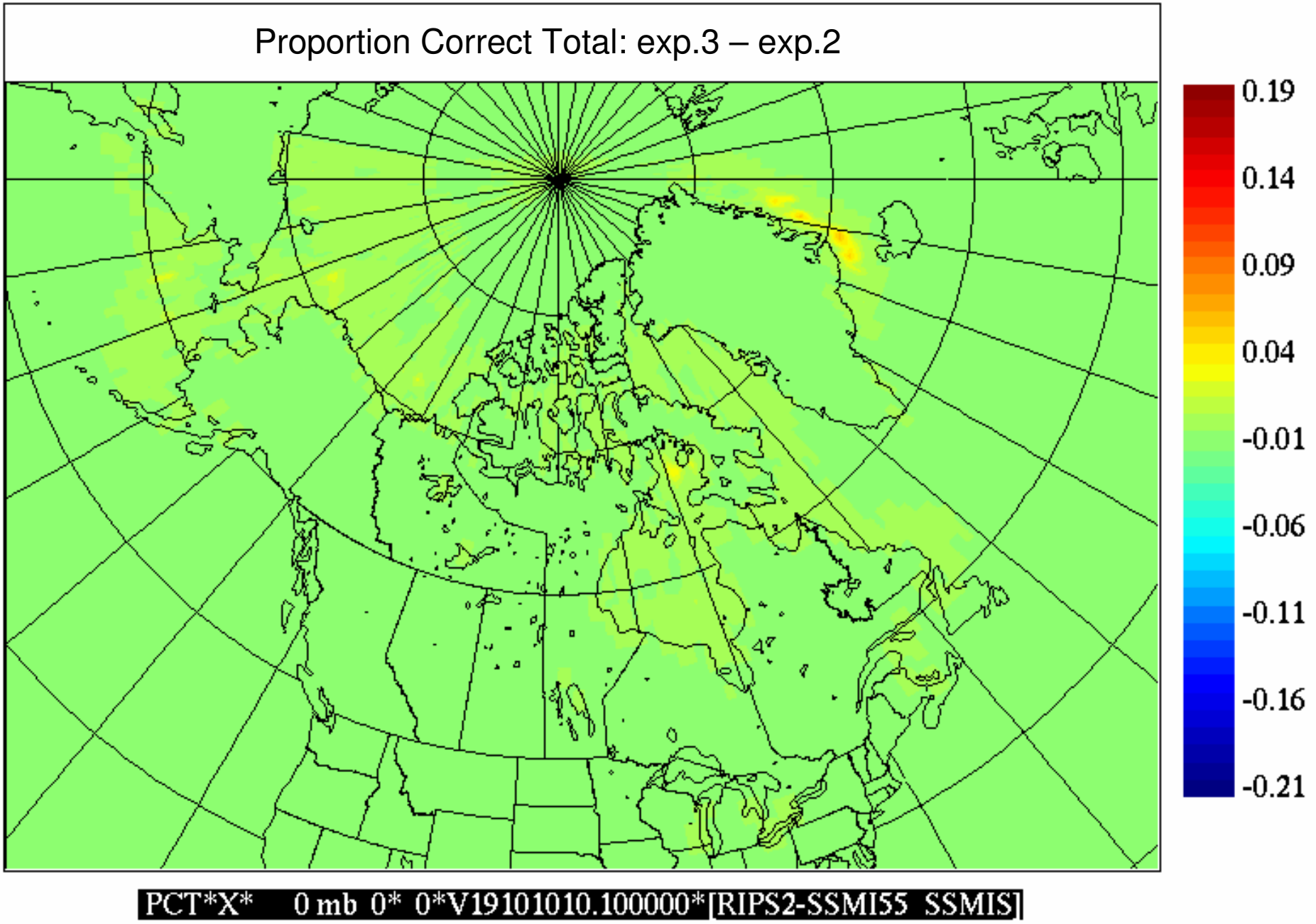



# Impact of ASCAT data (2010)



# An estimation of analysis error

Helps correcting errors along coast lines

# Introduction

- During the ice growth season, ice concentration does not increase fast enough along the coast line in the analysis.
- The problem is more apparent where only low-resolution (large footprint) observations are available.
- In this situation, the Days Since Last Observation (DSLO) index is not useful to indicate that the analysis is very uncertain.
- A new indicator is required to track these points and to correct the ice concentration at these locations.

# Simplified Kalman filter

- This is an approximation to the assimilation problem, where it is assumed that only a subset of the observations influence the analysis at a grid point.
- It is only used to estimate the analysis error, not for the analysis itself.
- Analysis-error equation:

$$\mathbf{P}^{\mathbf{a}} = \left(\mathbf{I} - \mathbf{KH}\right)\mathbf{P}^{\mathbf{b}}$$

- Kalman gain:

$$\mathbf{K} = \mathbf{P}^{\mathbf{b}}\mathbf{H}^{\mathbf{T}}\left(\mathbf{H}\mathbf{P}^{\mathbf{b}}\mathbf{H}^{\mathbf{T}} + \mathbf{R}\right)^{-1}$$

- Only the calculation for the analysis-error variance are done here.
- The analysis-error variance is set to zero where SST > 4°C

# Simplified Kalman filter

- Theoretical error propagation:

$$\mathbf{P}_{\mathbf{k+1}}^{\mathbf{b}} = \mathbf{M}\mathbf{P}_{\mathbf{k}}^{\mathbf{a}}\mathbf{M}^{\mathbf{T}} + \mathbf{Q}$$

- Instead, use simple modeling for the error variance $(\sigma^2)$:

$$\sigma_{b,k+1}(A) = \sqrt{\max\left(\sigma_{a,k}^2(A), \Delta^2(A)\right)} + const$$

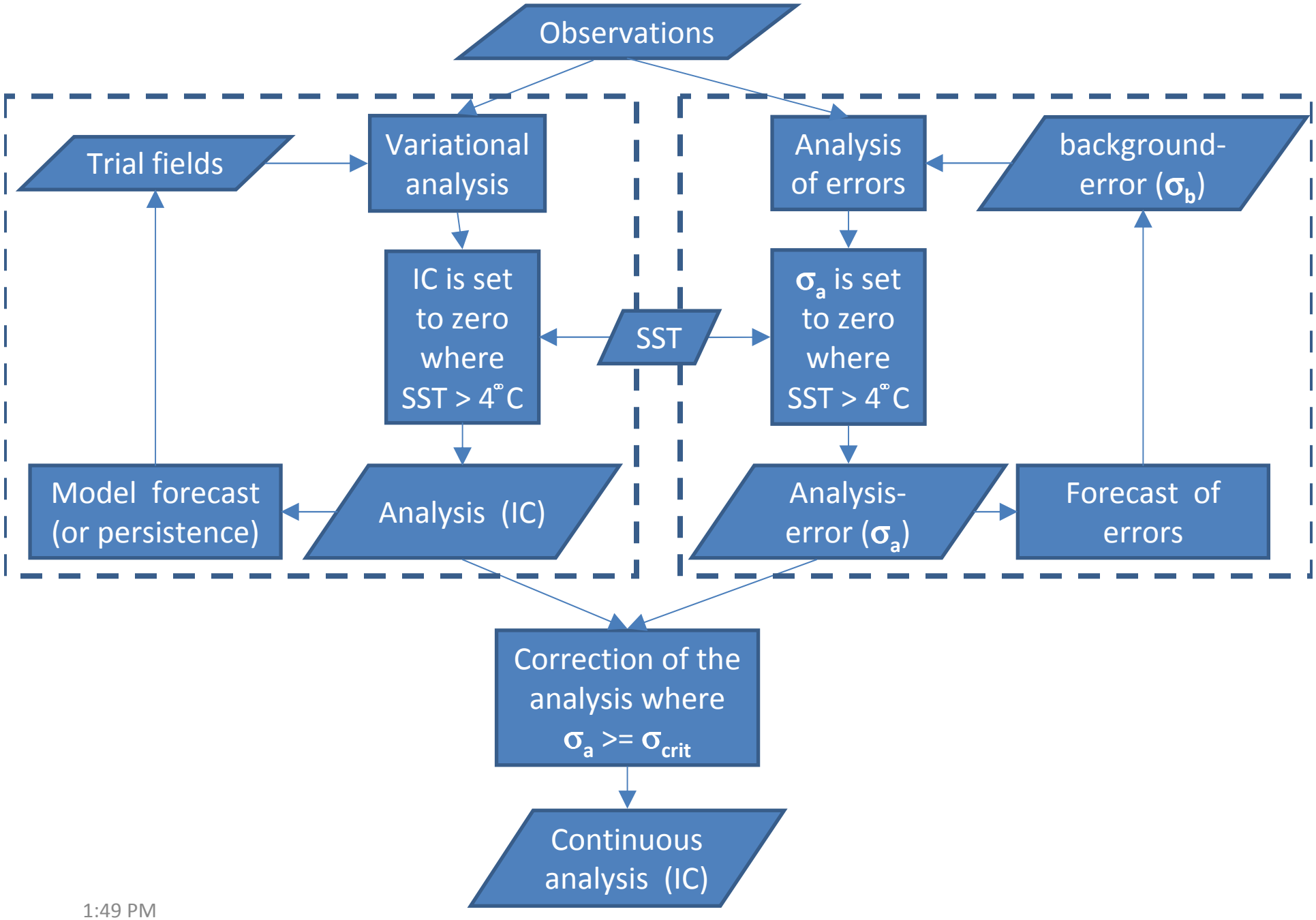
$$const = 6 \text{ h} / (24 \text{ h/day} \times 16 \text{ days}) \approx 0.0156$$

$$\Delta_{i,j}^2(A) = \frac{1}{9}\sum_{l=j-1}^{j+1}\sum_{k=i-1}^{i+1}\left(A_{k,l} - A_{i,j}\right)^2$$

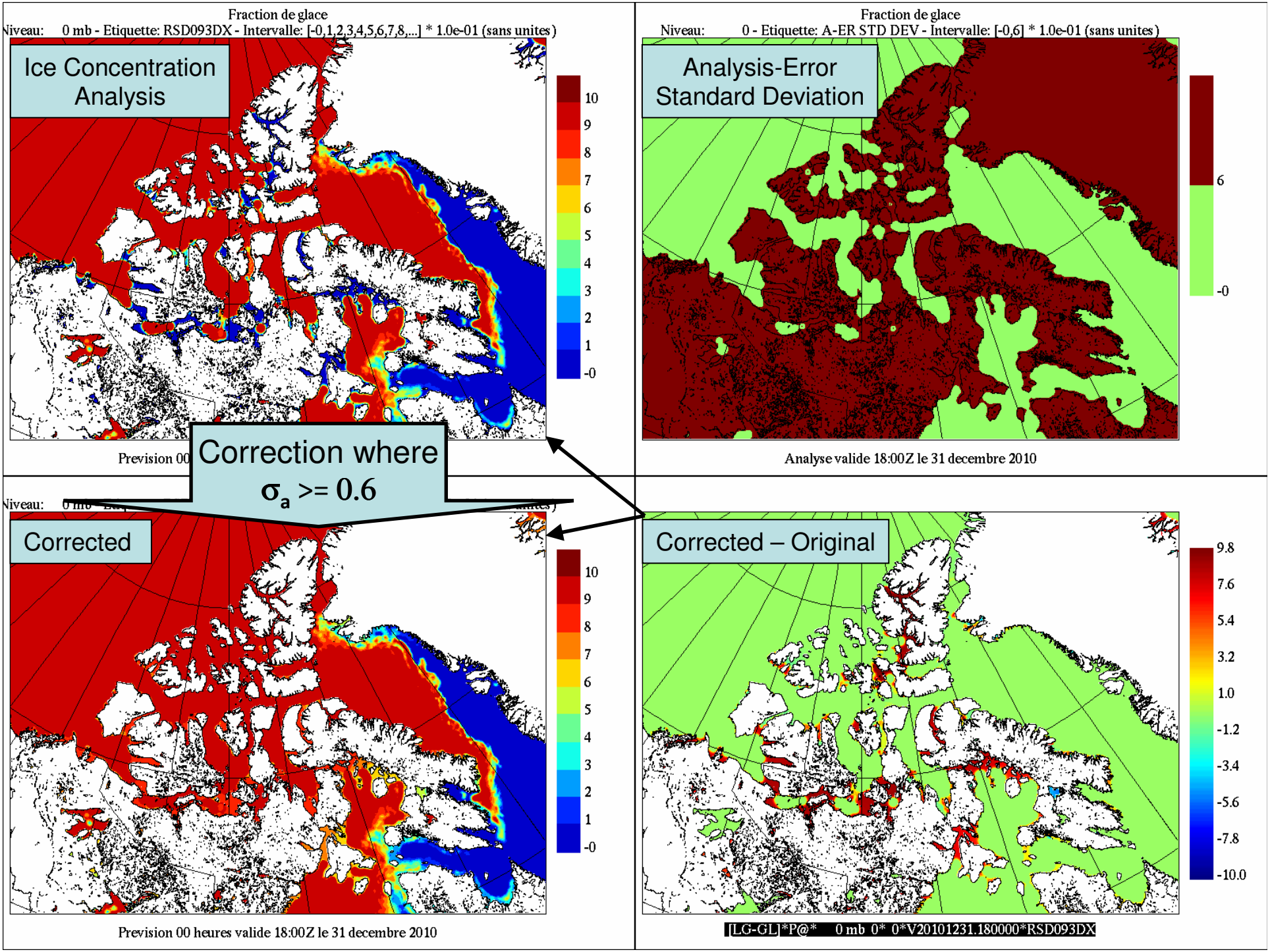
| | | |
|---|---|---|
| i-1, j+1 | i, j+1 | i+1, j+1 |
| i-1, j | i, j | i+1, j |
| i-1, j-1 | i, j-1 | i+1, j-1 |

# Correction of the analysis

- This is done by solving Laplace's equation using the method of sequential (or Liebman) relaxation.
- For the ocean, the correction procedure is applied where $\sigma_a >= \sigma_{crit}$.
- For fresh water (lakes), the correction procedure is applied where DSLO > 8 days.
- At these locations, the ice concentration is defined by extending the field where $\sigma_a < \sigma_{crit}$ for ocean and where DSLO <= 8 days for lakes.


Observations
Trial fields
Variational analysis
Analysis of errors
background-error ($\sigma_b$)
IC is set to zero where SST > 4°C
SST
$\sigma_a$ is set to zero where SST > 4°C
Model forecast (or persistence)
Analysis (IC)
Analysis-error ($\sigma_a$)
Forecast of errors
Correction of the analysis where $\sigma_a >= \sigma_{crit}$
Continuous analysis (IC)

1:49 PM

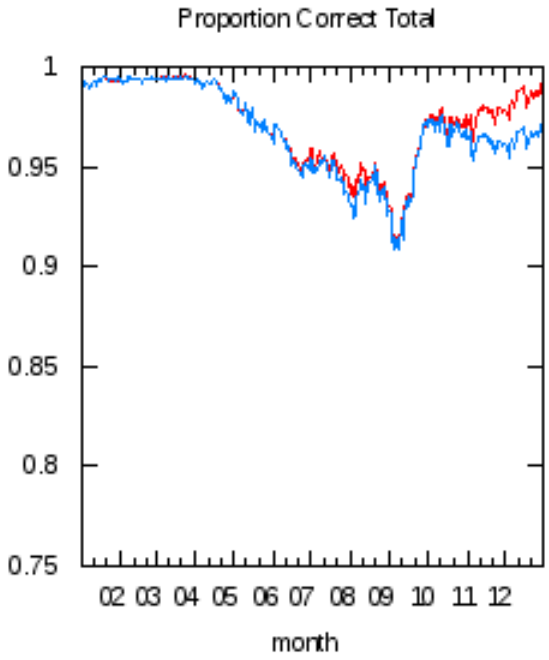

Fraction de glace
Niveau: 0 mb - Etiquette: RSD093DX - Intervalle: [-0,1,2,3,4,5,6,7,8,...] * 1.0e-01 (sans unites)
Ice Concentration Analysis
10
9
8
7
6
5
4
3
2
1
-0
Prevision 00
Fraction de glace
Niveau: 0 - Etiquette: A-ER STD DEV - Intervalle: [-0,6] * 1.0e-01 (sans unites)
Analysis-Error Standard Deviation
6
-0
Analyse valide 18:00Z le 31 decembre 2010
Correction where
$\sigma_a$ >= 0.6
Niveau:
Corrected
10
9
8
7
6
5
4
3
2
1
-0
Prevision 00 heures valide 18:00Z le 31 decembre 2010
Corrected – Original
9.8
7.6
5.4
3.2
1.0
-1.2
-3.4
-5.6
-7.8
-10.0
[LG-GL]*P@* 0 mb 0* 0*V20101231.180000*RSD093DX

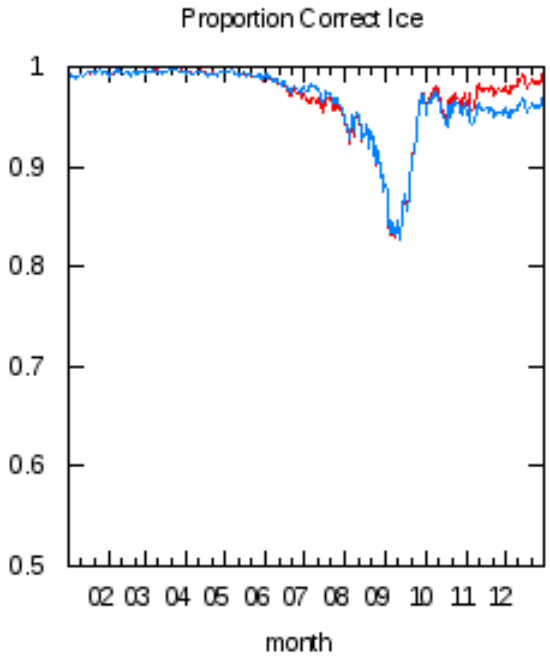
# Experiments (2010)

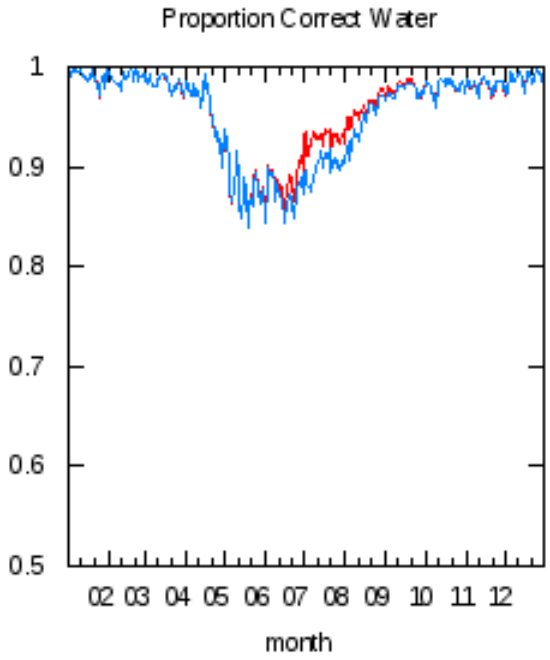
- Experiment 3 (in blue):
  - Observations:
    - SSM/I
    - CIS daily ice charts
    - CIS image analyses
    - CIS lake ice bulletins
    - SSM/IS
    - ASCAT
- Experiment 4: (in red)
  - experiment 3
  - Use analysis-error (threshold = 0.6) to correct ice concentration

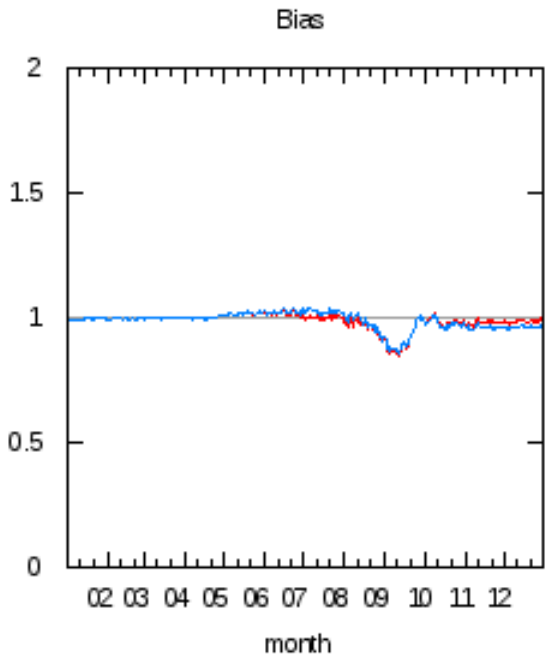
All Arctic

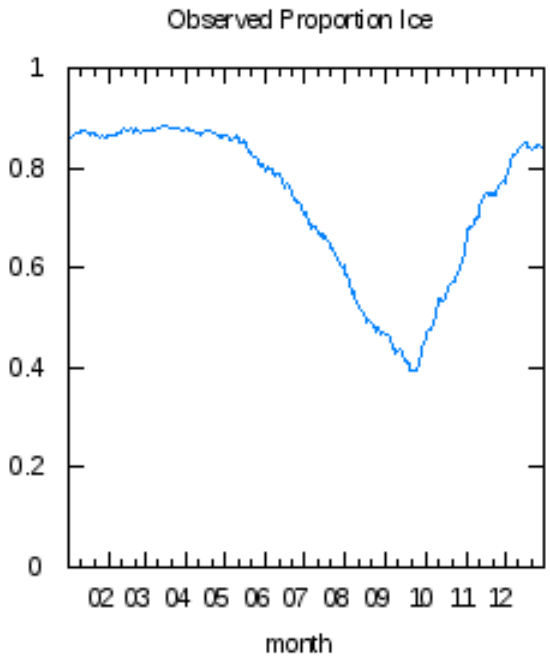
# North of 65°N

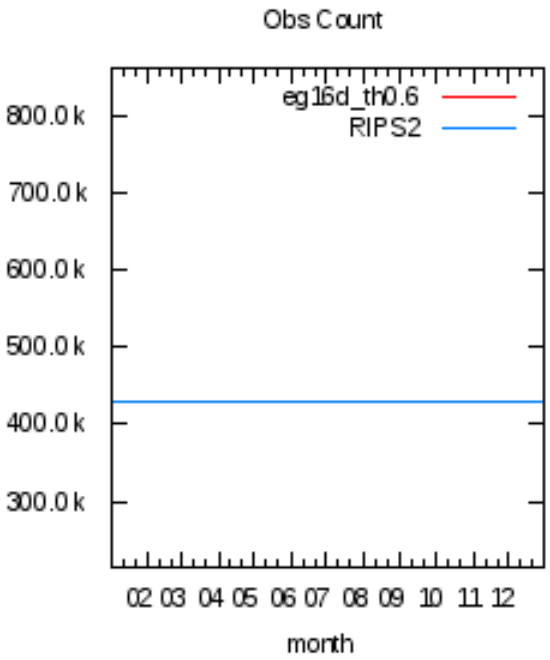


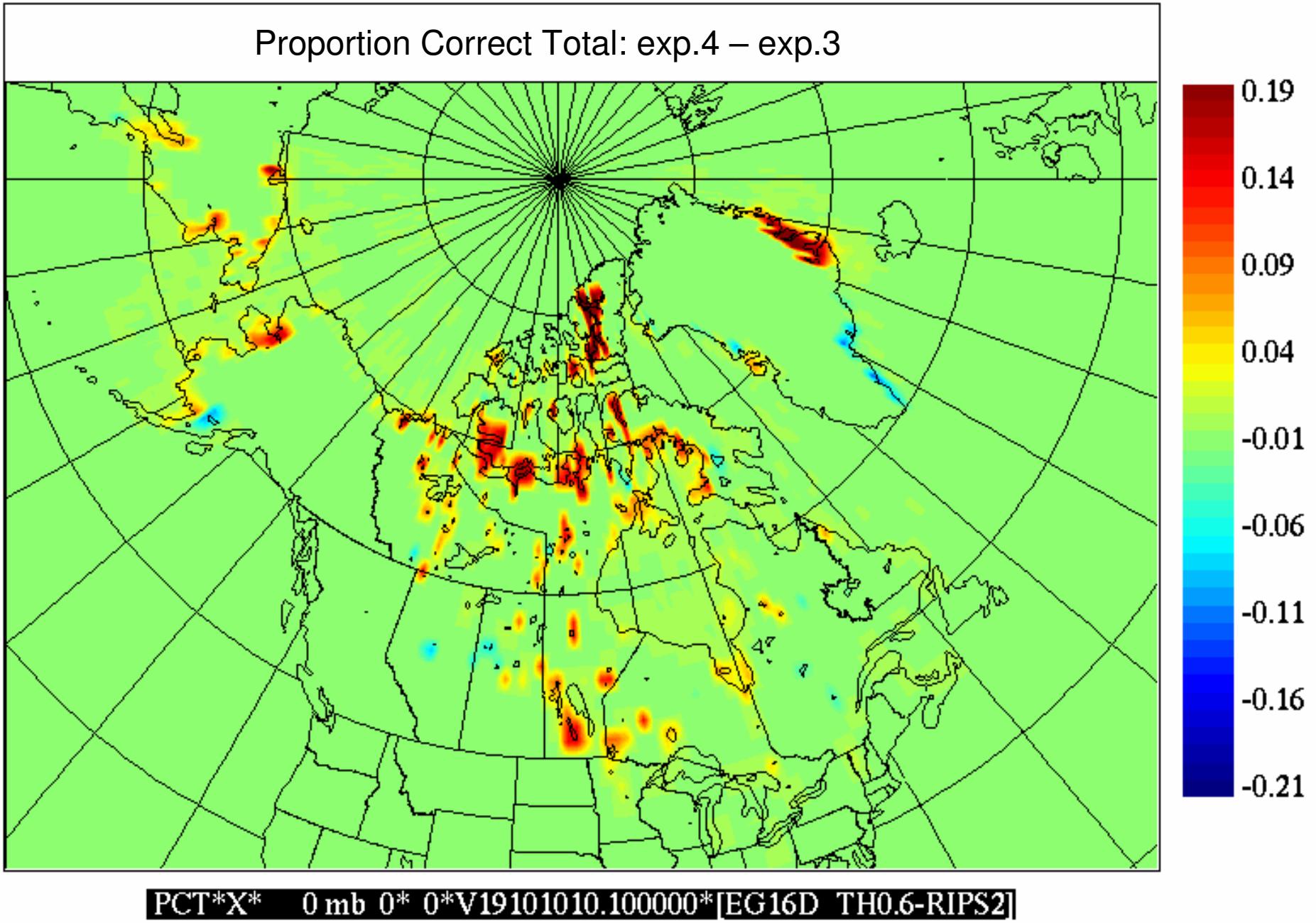



# Impact of correction based on analysis-error (2010)



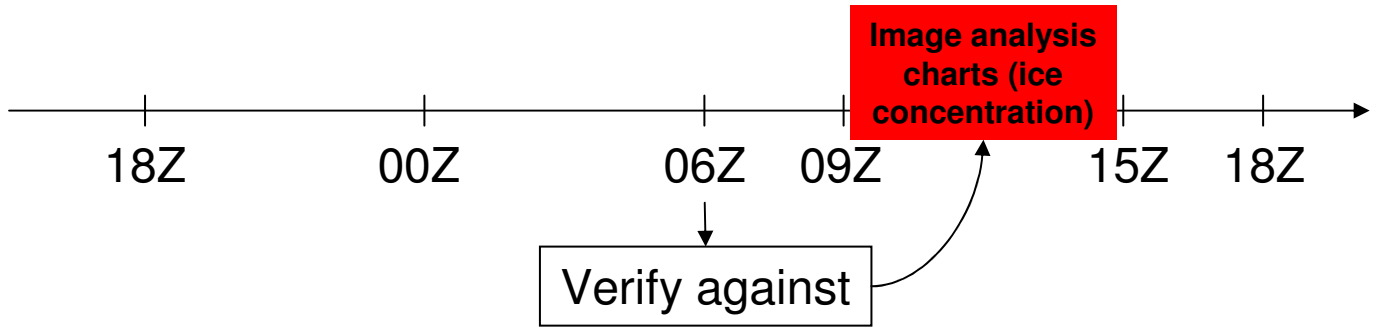
# RIPS 2.0 vs RIPS 1.0 analyses

# Experiments: 12-month 2010 cycles

## Verification strategy

1. Verification of 00Z ice analysis against:
   - NOAA IMS daily ice extent (ice / no ice)
   - NIC bi-weekly ice charts (ice concentration)

2.

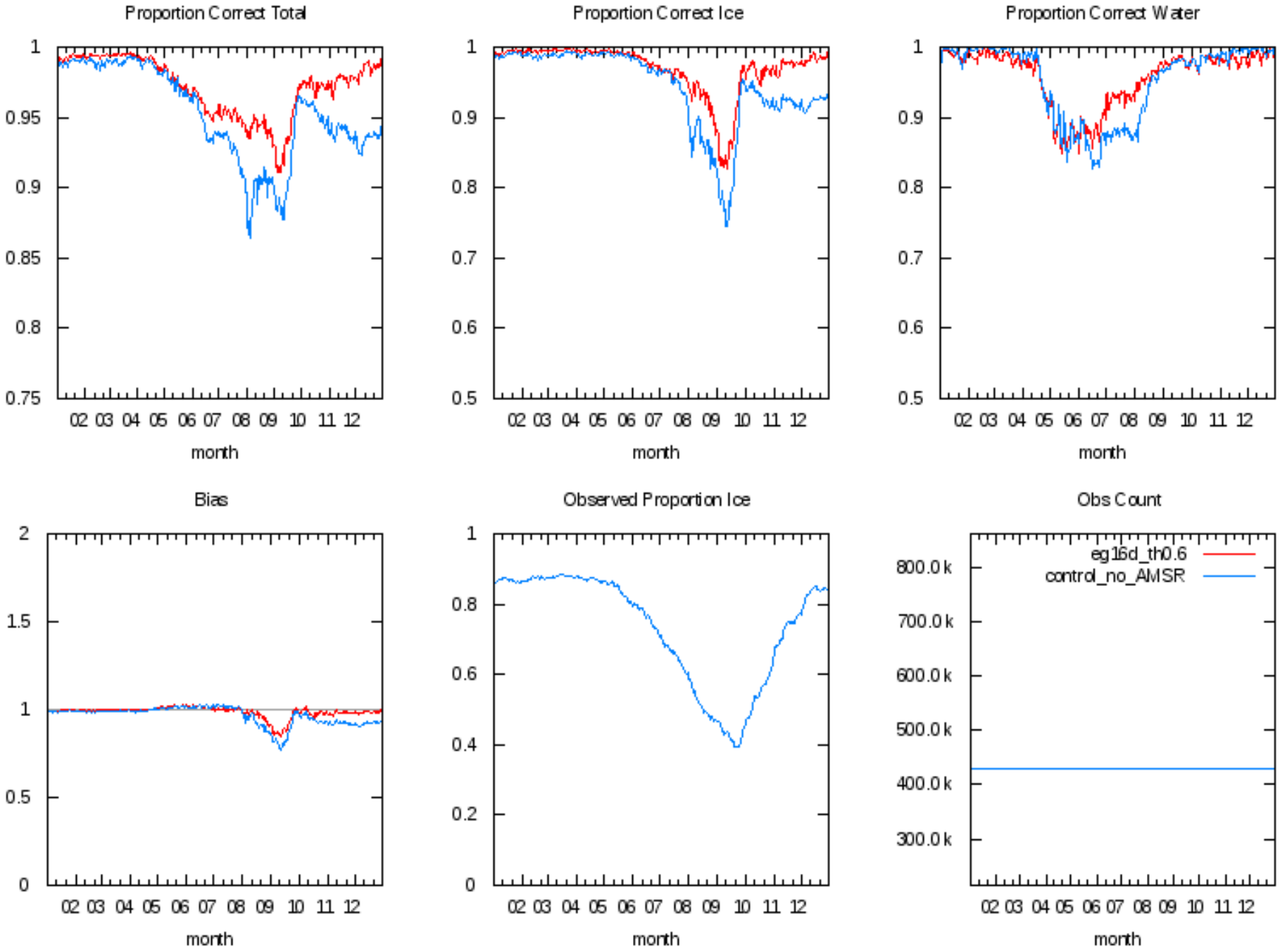



3. Verification of 18Z ice analysis against CIS regional weekly ice charts (ice concentration)

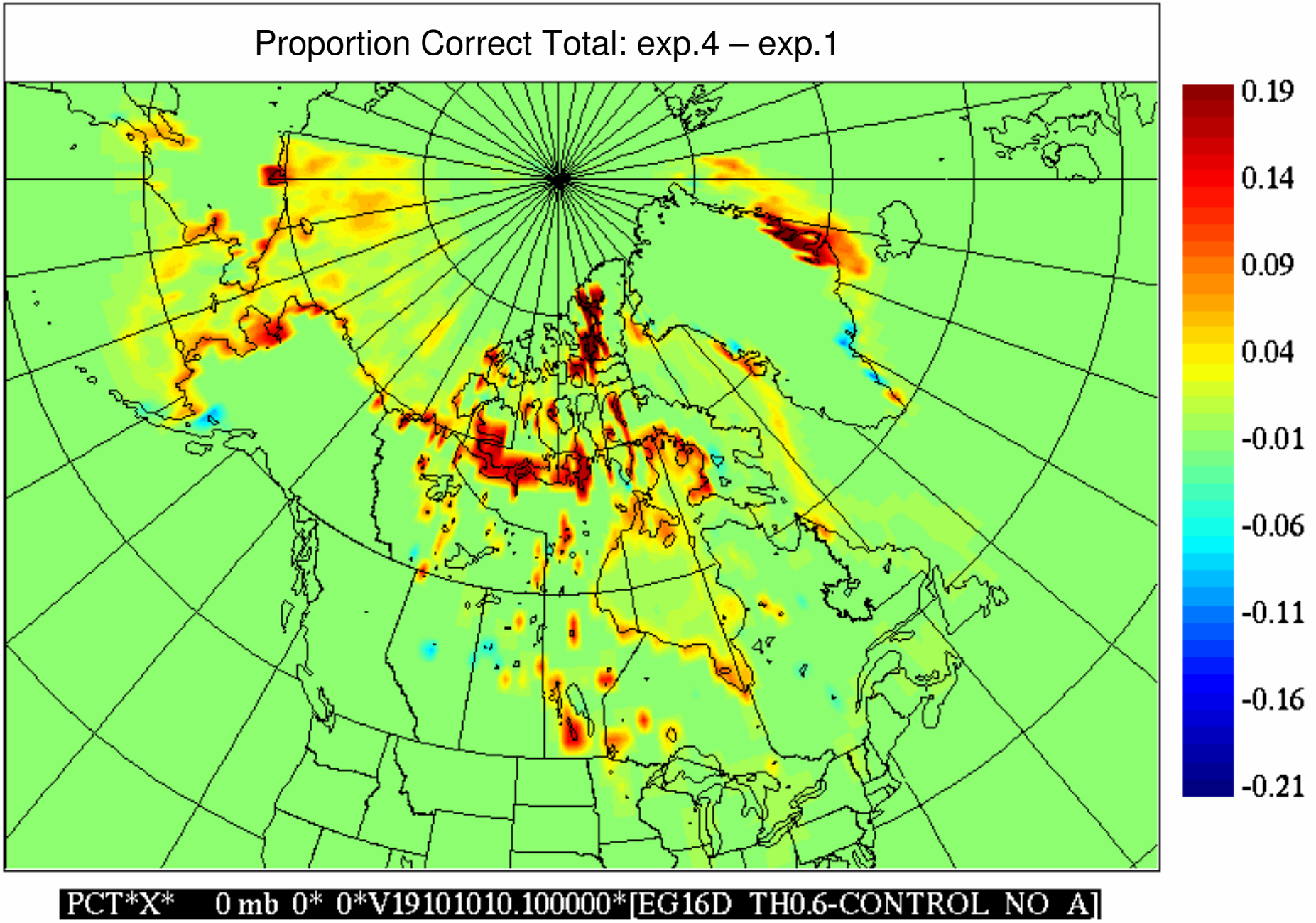
Verification against IMS @ 00Z

All Arctic

North of 65°N



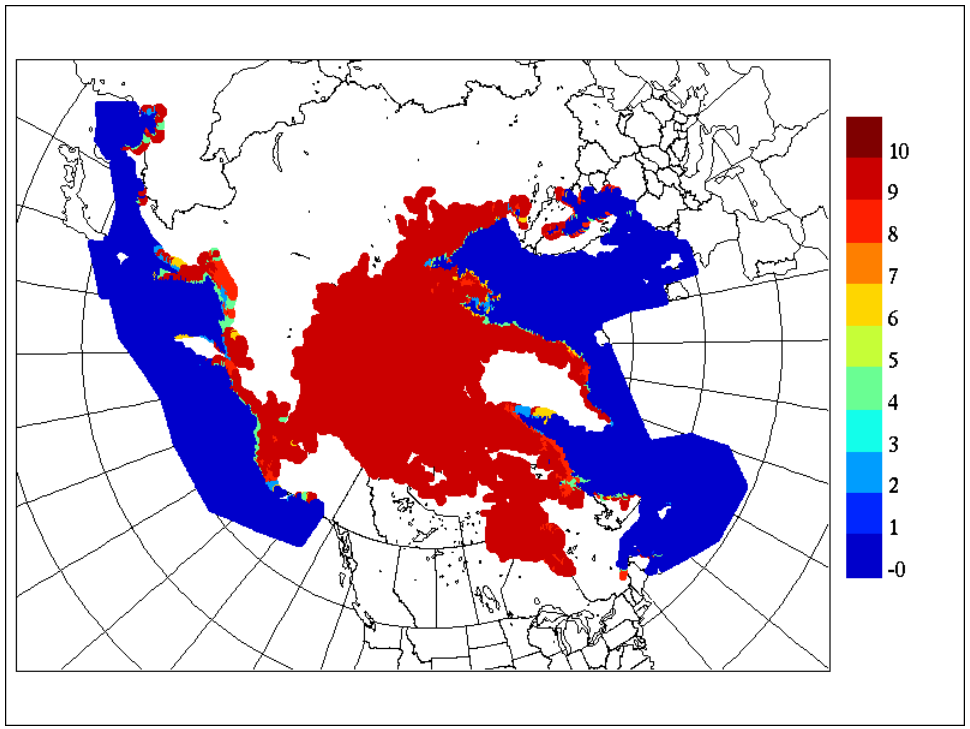
# Impact of all changes (2010)



# U.S. NIC ice charts in SIGRID-3 vector format

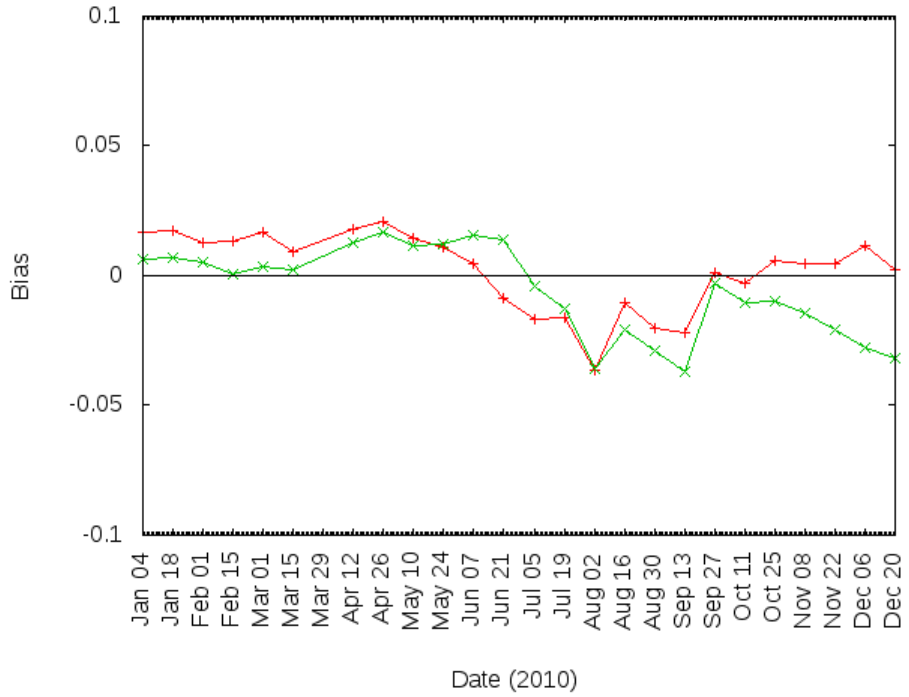
- Manually produced weekly/bi-weekly ice analysis products (similar to CIS daily ice charts)
- Represent the ice conditions for the week in which they are published
- Regional ice analyses for all of the northern and southern hemisphere seas are produced every other week
- These charts provide detailed information about ice concentration

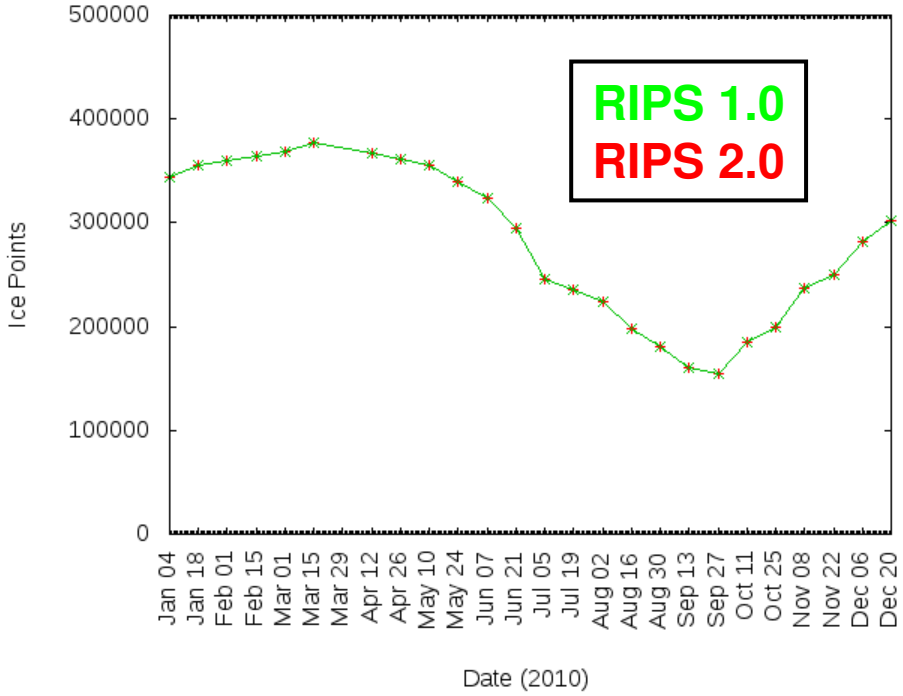
Example from January 4th, 2010:

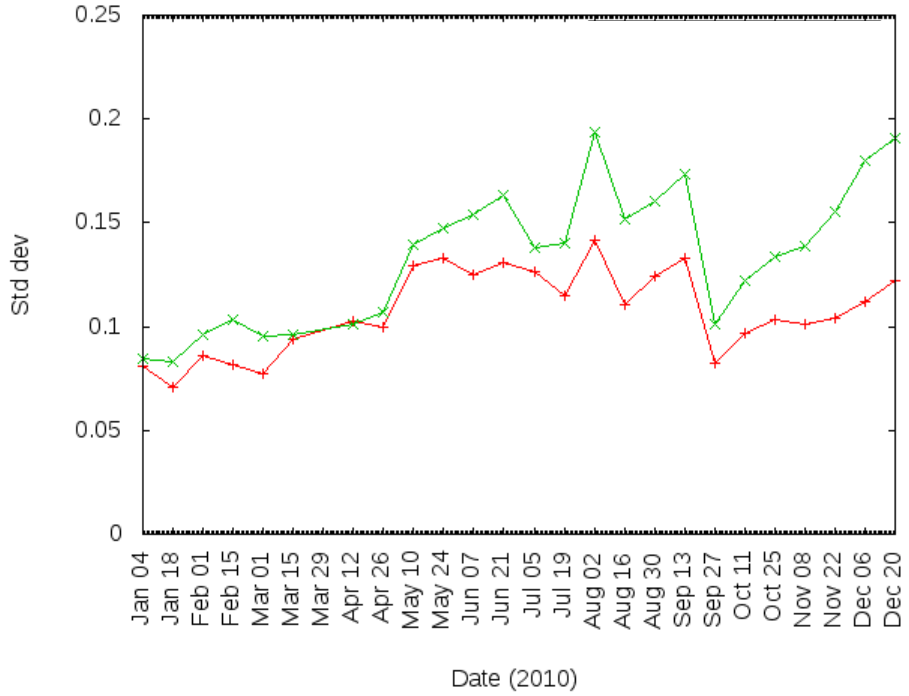


# Ice concentration

- Bias and std dev against NIC charts



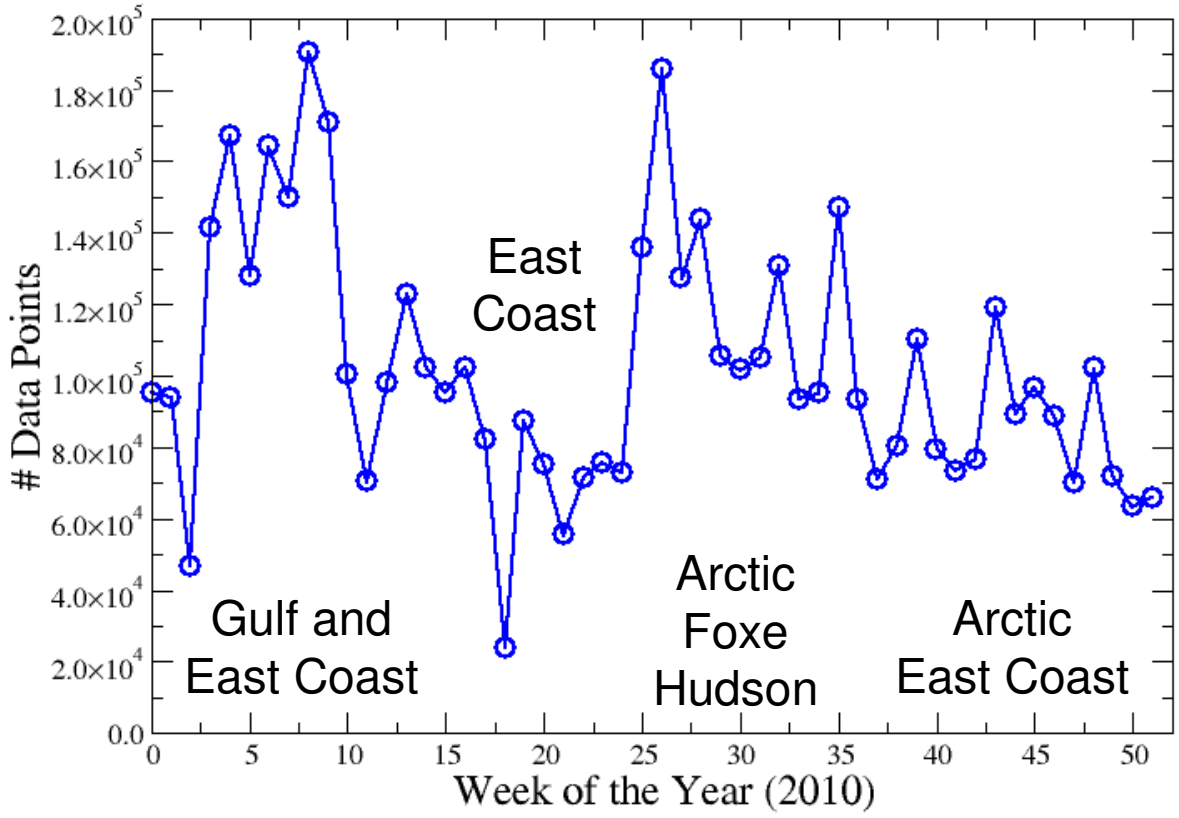



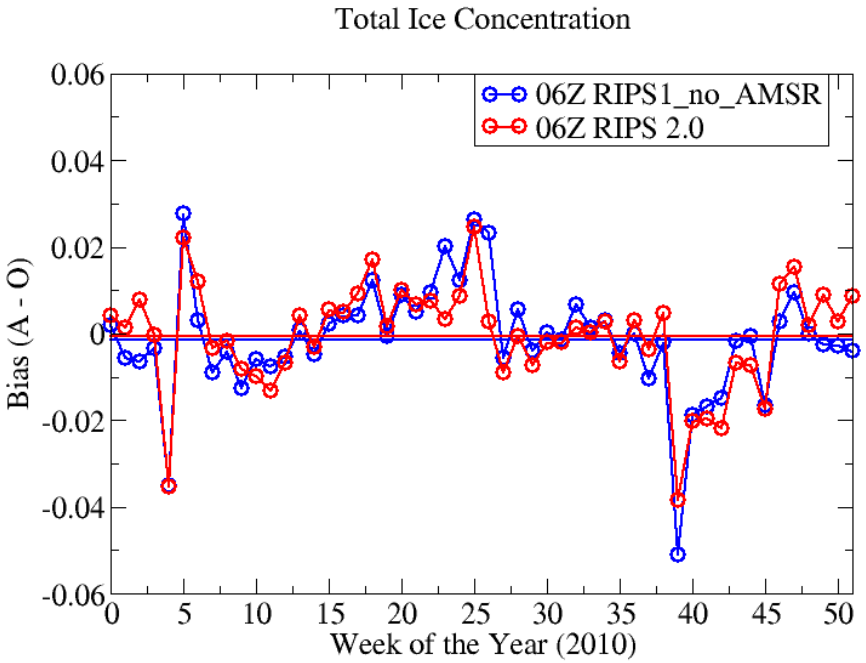
# CIS Image Analysis Charts

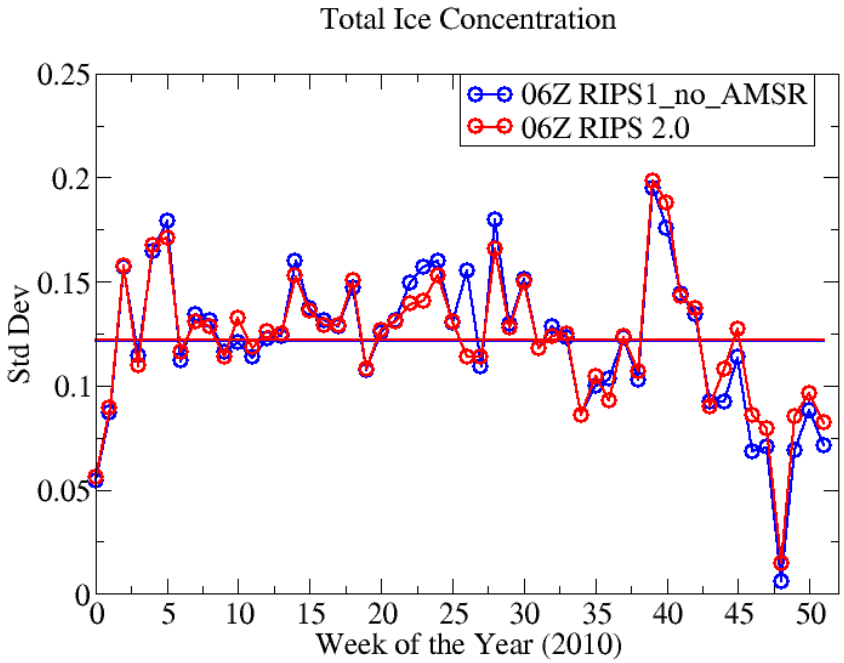
- Valid at time of satellite RADARSAT (ENVISAT) pass
- Prepared by CIS SAR image analysts (experts)
- Includes: knowledge of environmental conditions; in situ observations from ships; climatology;
- Regional dependence according to the operational season
- Verification data is independent of the analysis because we use images valid from 09 to15Z (12Z assimilation window), not assimilated in the 06Z assimilation window

# Availability of Image Analysis Charts

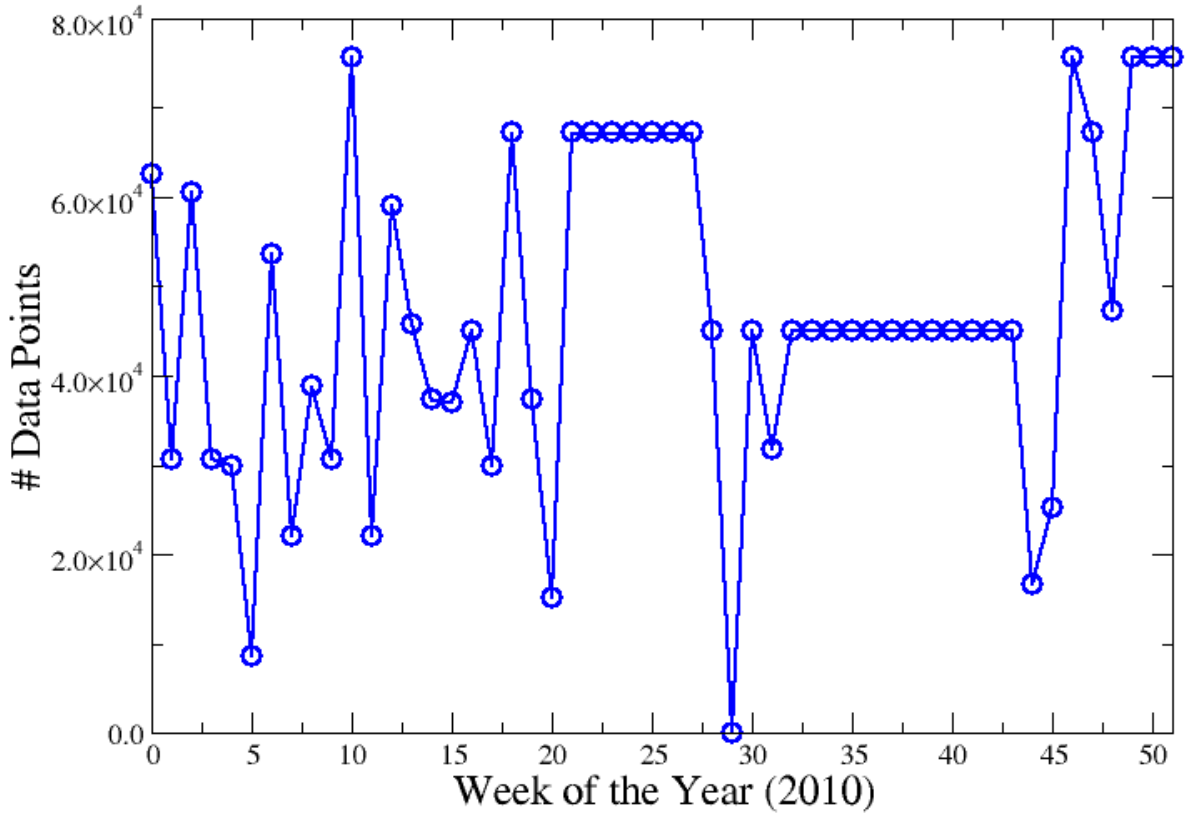


# 06Z RIPS 2.0 vs RIPS 1.0 Ice Analyses Compared to 9-15Z Image Analysis Charts

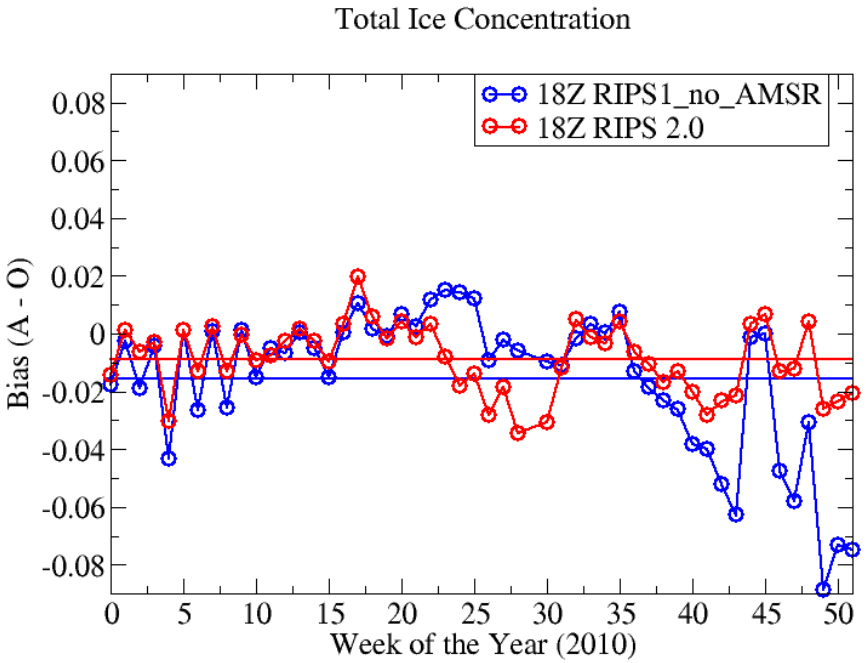


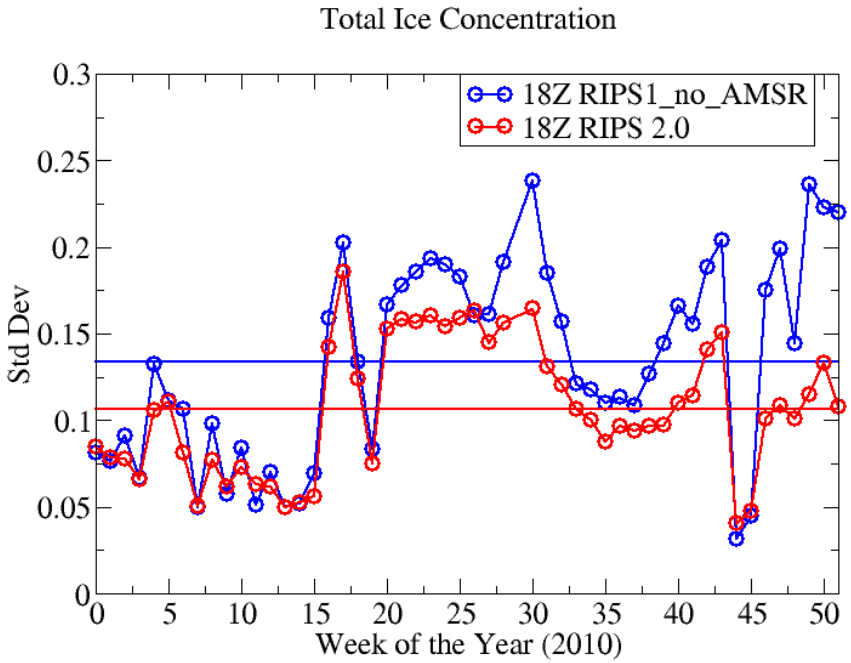



# Availability of Regional Analysis Charts

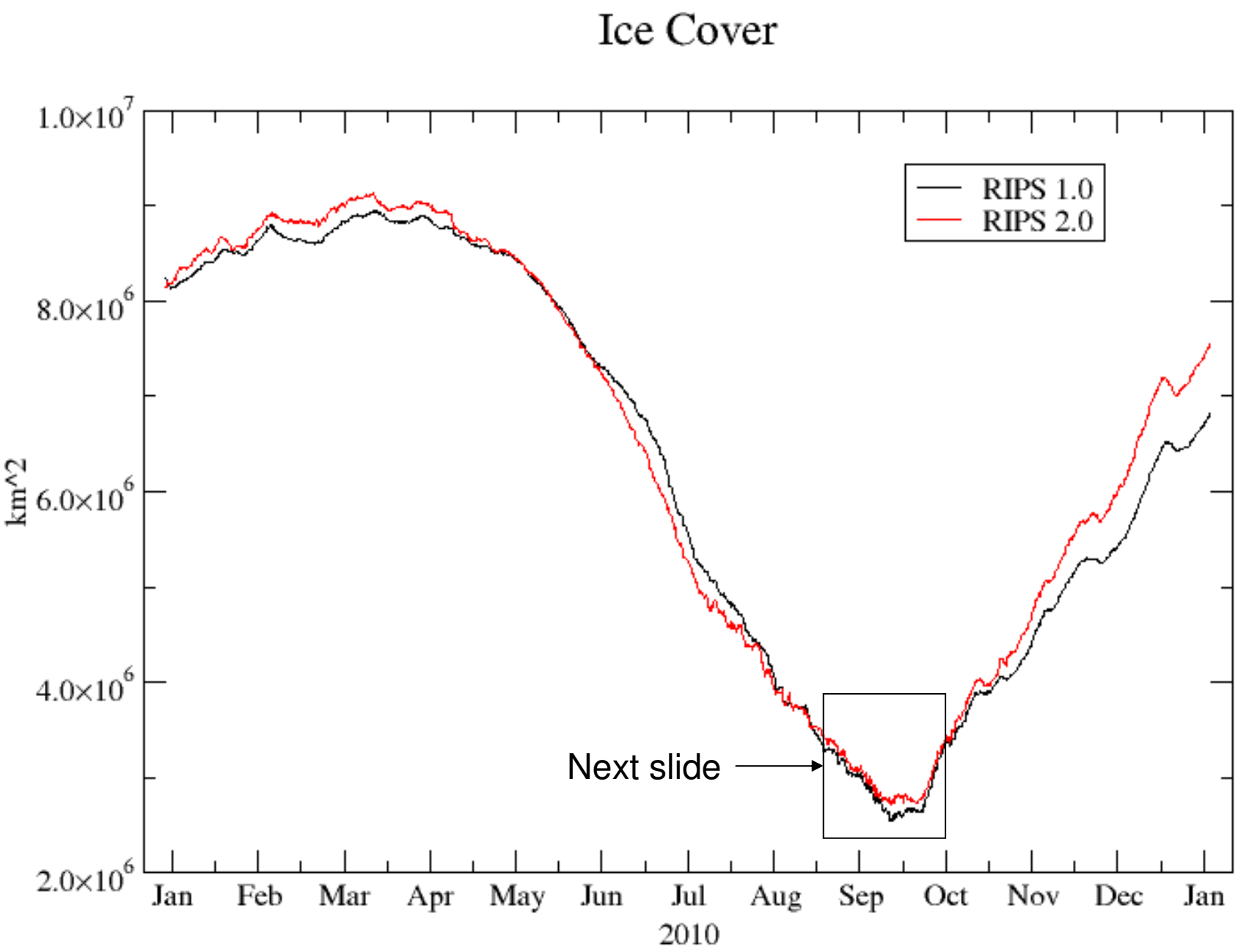


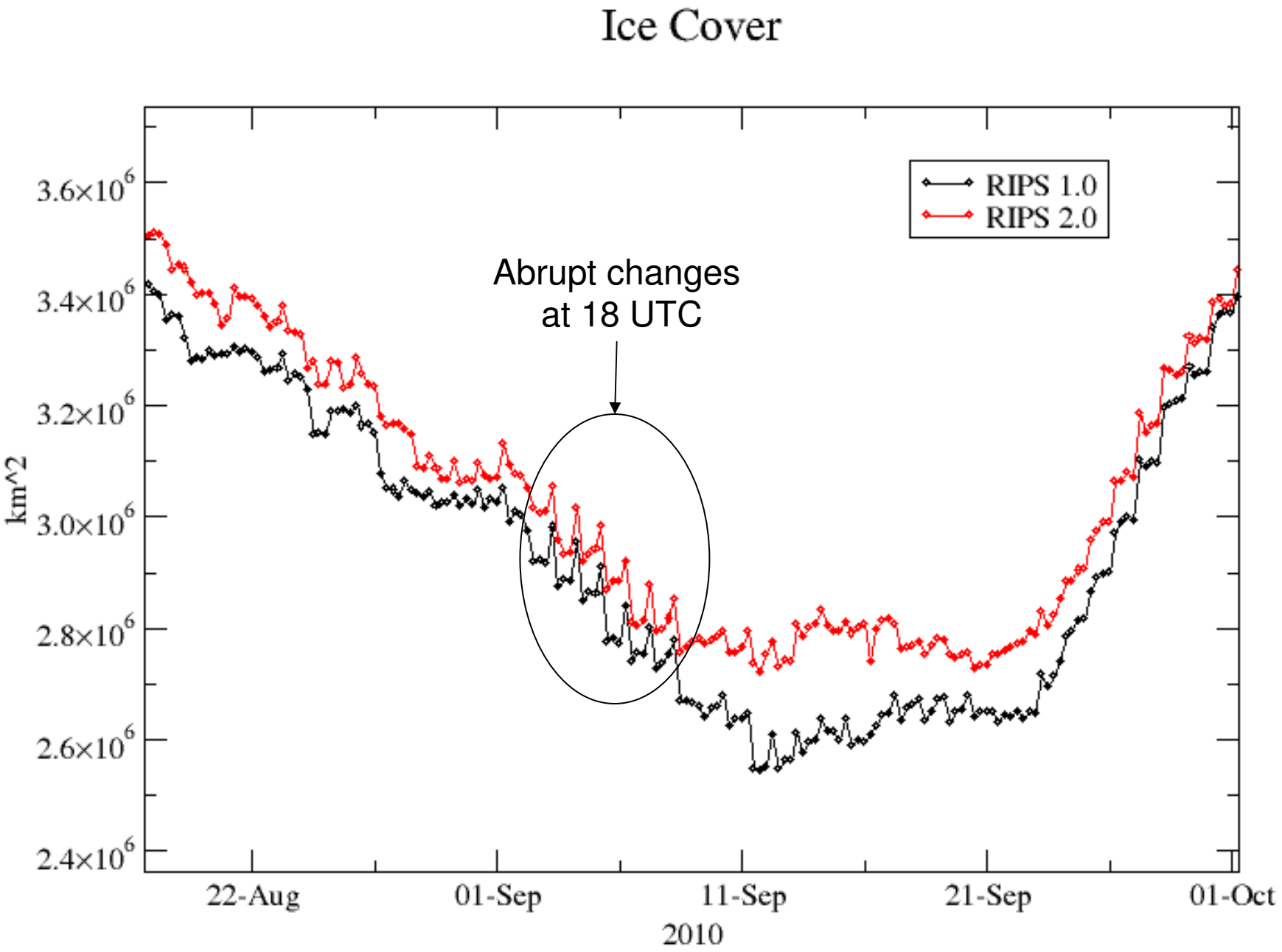
# 18Z RIPS 2.0 vs RIPS 1.0 Ice Analyses Compared to 18Z Regional Analysis Charts



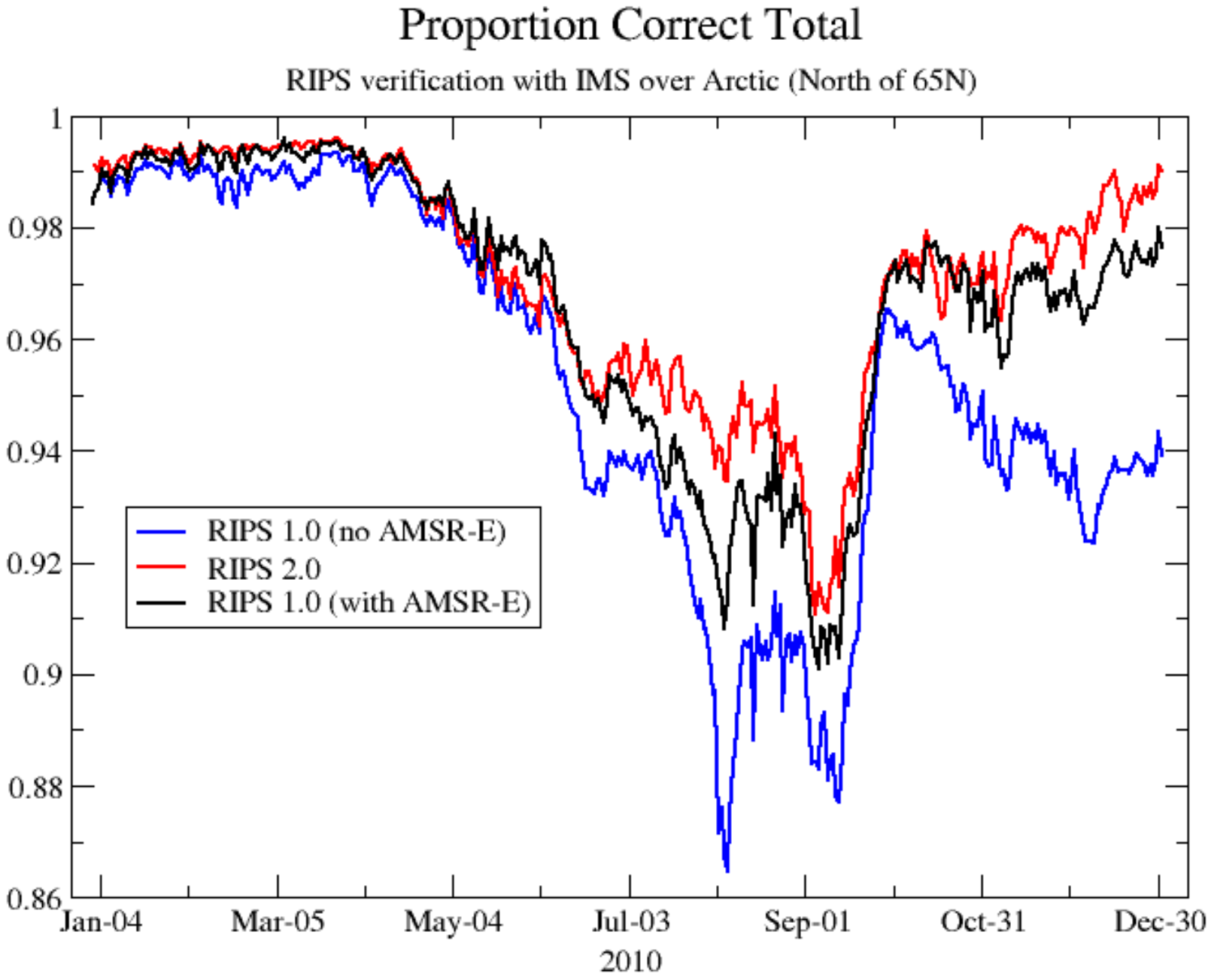



# Temporal consistency


Ice Cover
RIPS 1.0
RIPS 2.0
Next slide
km^2
1.0×10^7
8.0×10^6
6.0×10^6
4.0×10^6
2.0×10^6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2010


Ice Cover
RIPS 1.0
RIPS 2.0
Abrupt changes
at 18 UTC
km^2
3.6×10^6
3.4×10^6
3.2×10^6
3.0×10^6
2.8×10^6
2.6×10^6
2.4×10^6
22-Aug
01-Sep
11-Sep
21-Sep
01-Oct
2010

# Impact of the loss of AMSR-E


Proportion Correct Total
RIPS verification with IMS over Arctic (North of 65N)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
RIPS 1.0 (no AMSR-E)
RIPS 2.0
RIPS 1.0 (with AMSR-E)
Jan-04
Mar-05
May-04
Jul-03
Sep-01
Oct-31
Dec-30
2010

# Summary

- Assimilation of SSM/IS and ASCAT data has the biggest (positive) impact in regions where no CIS charts are available
- ASCAT data has largest (positive) impact in the verification during summer
- Correction where the analysis-error estimation is large (i.e. > 0.6) improves the results mostly during the ice growth season in narrow channels and along coast lines. Some improvement is also seen during the summer. However, results are deteriorated in some of the lakes and along the east coast of Greenland.
- Some temporal inconsistency remains in the summer where CIS charts are available. This is caused by a lack of reliable, unbiased, satellite observations in the summer.
- The loss of AMSR-E significantly degraded the quality of the analysis but new improvements to the system overcome much of it.

# Thank you ! / Merci !