



Environment
Canada

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A New Global Ice Analysis System

Seminar

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Outline

- Current global ice analysis
- A new global ice analysis:
 - Data assimilation approach
 - Observations
- Global configuration
- Experiments and verification
- Summary

Current global ice analysis

- No significant improvements done to the operational ice analysis since its installation ~ 1997
- It uses only 2 types of observations... SSM/I (DMSP-15) and ice bulletins from CIS
- It is produced once a day, valid at 00 UTC
- It is done for NWP at ~35km
- It is done by averaging available observations...more weight giving to CIS data when available
- When observations are not available, it uses climatology

Sea ice data assimilation project

- Goal is to produce automated analyses of sea-ice conditions for operational needs of MSC:
 - enhanced ability of CIS to deliver operational sea-ice products over larger area than currently possible
 - improved NWP by supplying better sea-ice analyses for initializing coupled ice-ocean-atmosphere forecasts in the polar regions
- Assimilate numerous observation types using variational data assimilation
- Same system is used for all applications: only version and configuration differ between applications (including regional and global)

Variational data assimilation approach

- Based on variational data assimilation approach
- Assumes Normally distributed errors, but ice concentration in range [0,1] (reset unphysical values after analysis)
- Like NWP system, uses the preconditioned form of cost function:

$$J(\xi) = \frac{1}{2} \xi^T \xi + \frac{1}{2} (H[\mathbf{x}_b] + \mathbf{H}\mathbf{B}^{1/2}\xi - \mathbf{y})^T \mathbf{R}^{-1} (H[\mathbf{x}_b] + \mathbf{H}\mathbf{B}^{1/2}\xi - \mathbf{y})$$

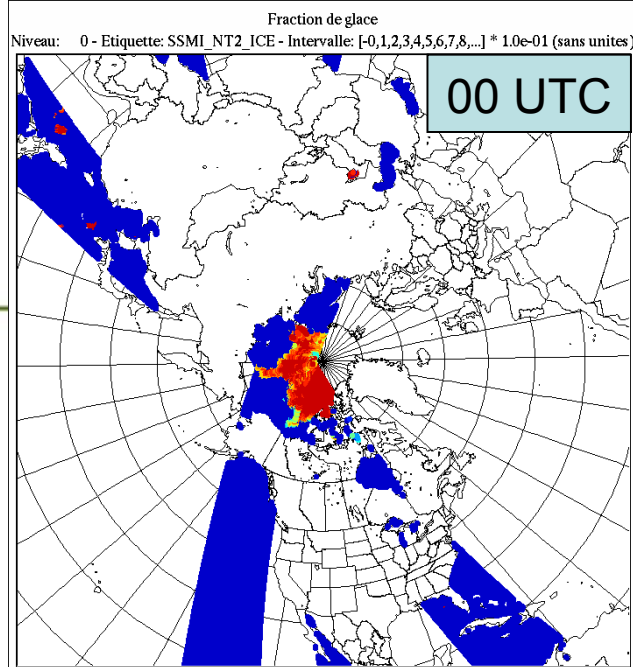
- where:
 - \mathbf{x}_b is the short-term forecast used as the background state
 - \mathbf{B} is the background-error covariance matrix
 - \mathbf{y} is the vector of observations
 - \mathbf{R} is the observation-error covariance matrix
 - H observation operator: maps model variables into observation space

Assimilated observations

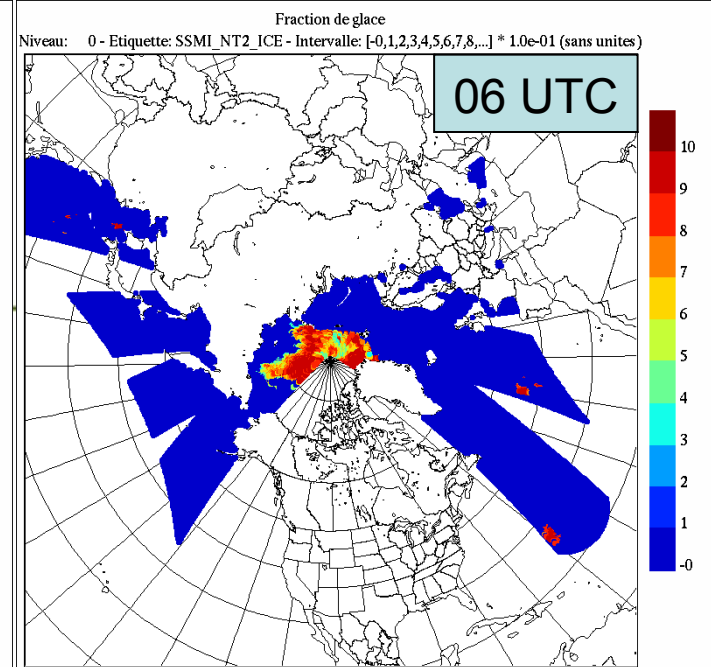
- CIS products (total ice concentration only):
 - Daily ice charts
 - Image analysis charts
 - Lake ice bulletins
- Passive microwave (ice concentration retrievals from the Enhanced NASA Team (NT2) algorithm):
 - SSM/I – DMSP15
 - SSM/IS – DSMP16-17-18 (3 satellites)
 - Data rejected where:
 - (Sea Surface Temperature > 4°C AND IC ≠ 0.0) OR
 - (Surface Air Temperature > 0°C) OR
 - (Climatological frequency of occurrence = 0 AND IC ≠ 0.0)

SSM/I

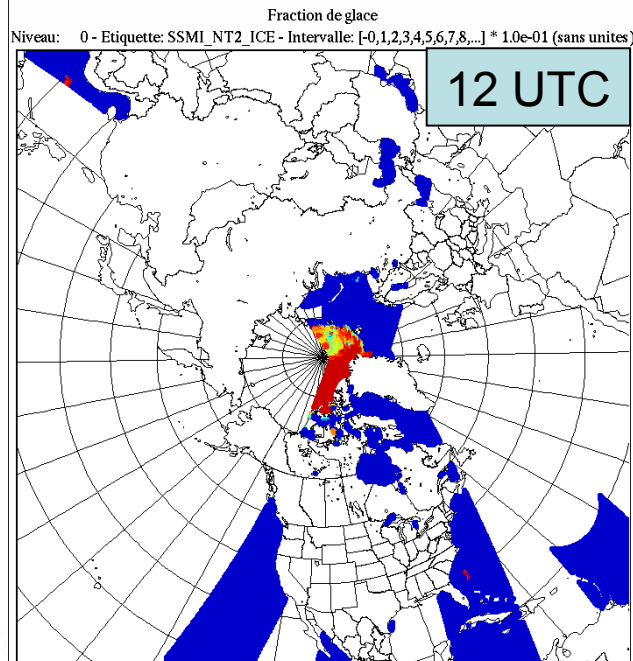
Ice
Concentration
NT2
Retrievals



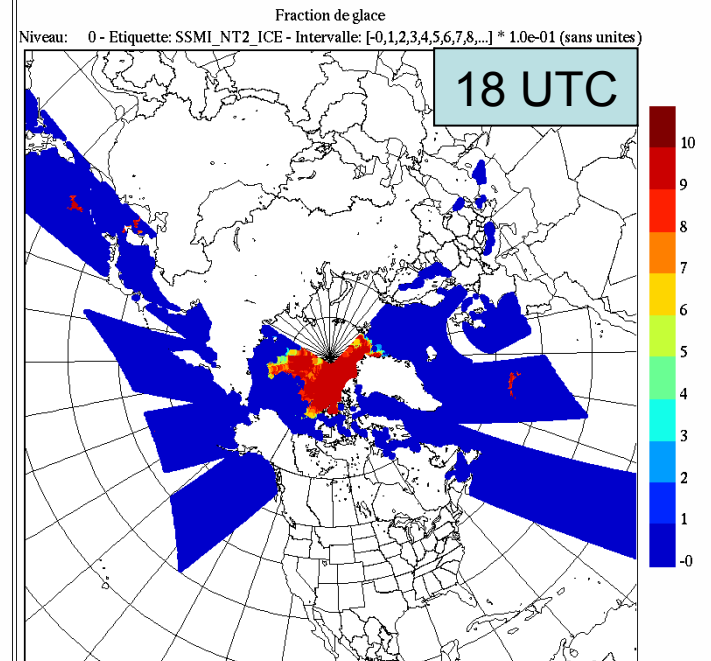
Champ valide 03:00Z le 27 aout 2010



Champ valide 09:00Z le 27 aout 2010



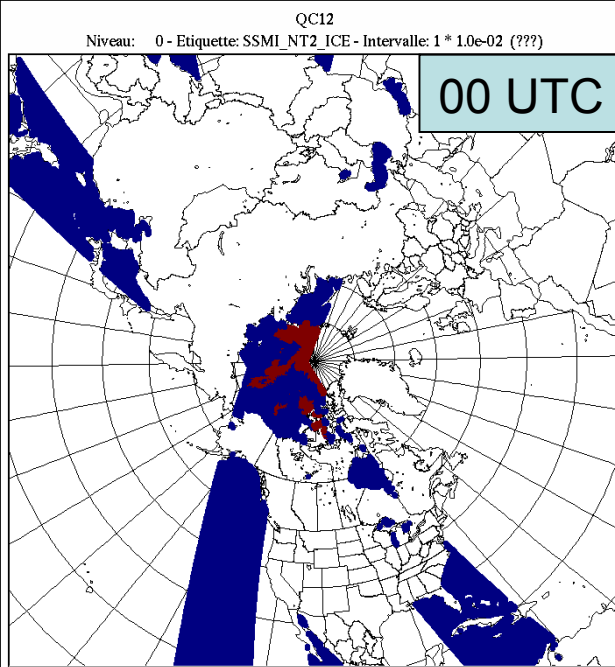
Champ valide 15:00Z le 27 aout 2010



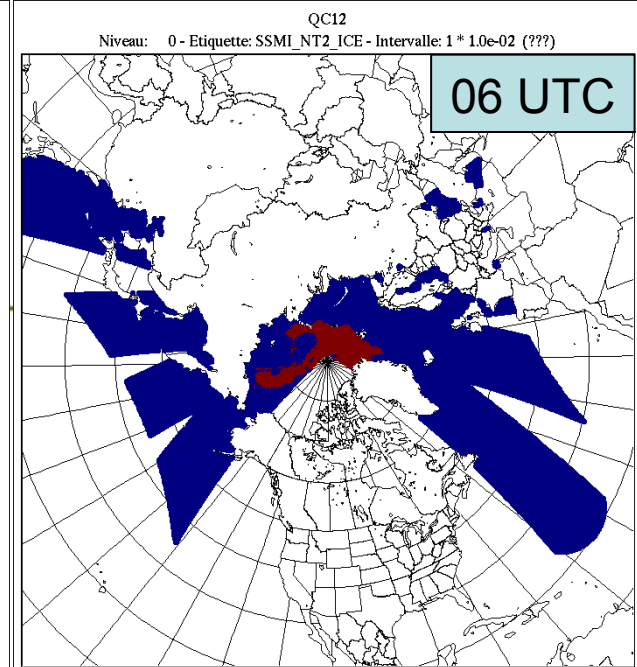
Champ valide 21:00Z le 27 aout 2010

SSM/I

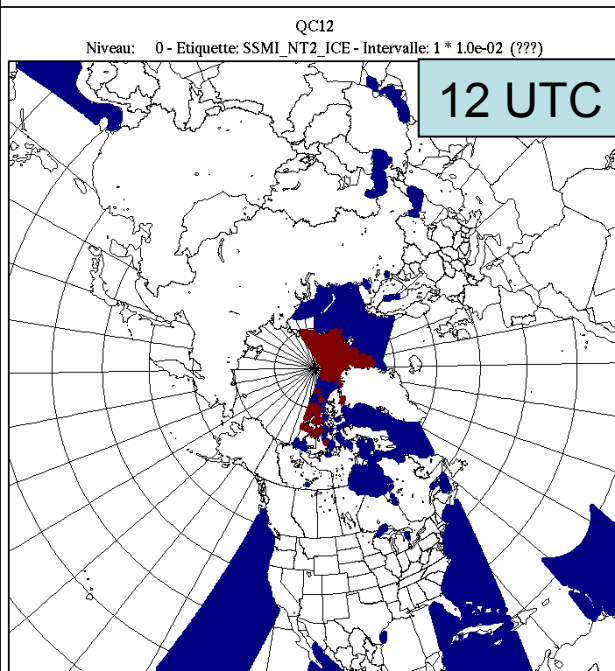
Assimilated
no = 0
yes = 1



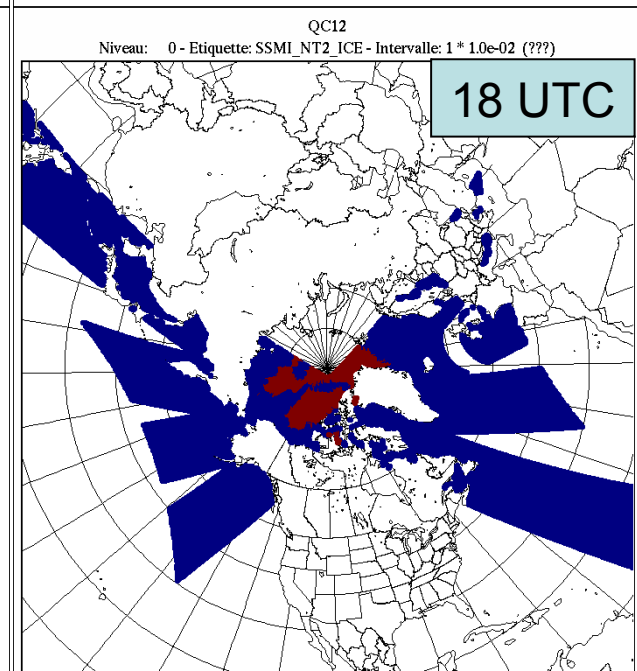
Analyse valide 03:00Z le 27 aout 2010



Analyse valide 09:00Z le 27 aout 2010



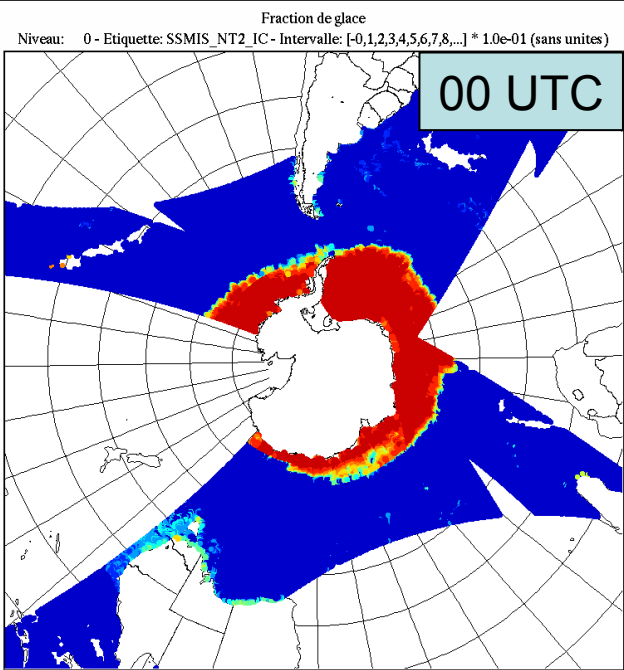
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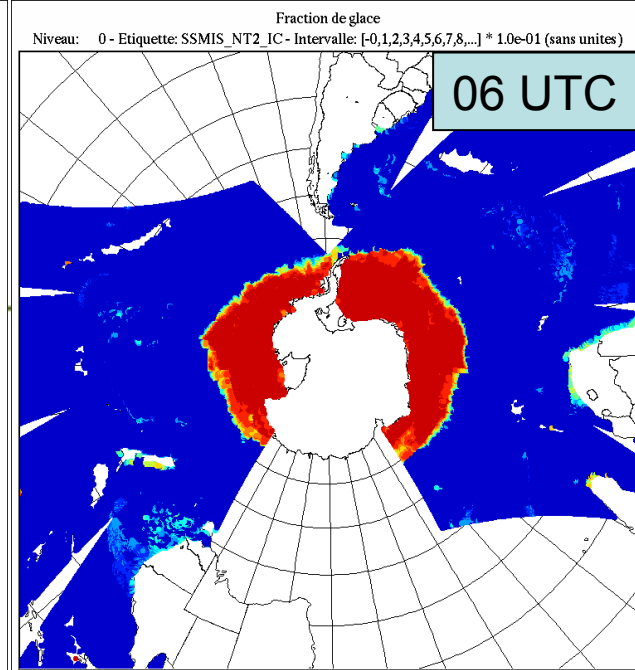
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SSM/IS

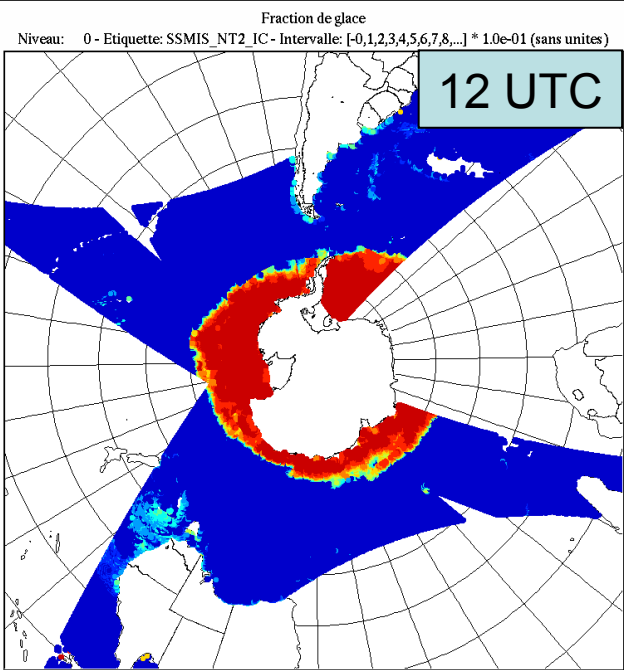
Ice
Concentration
NT2
Retrievals



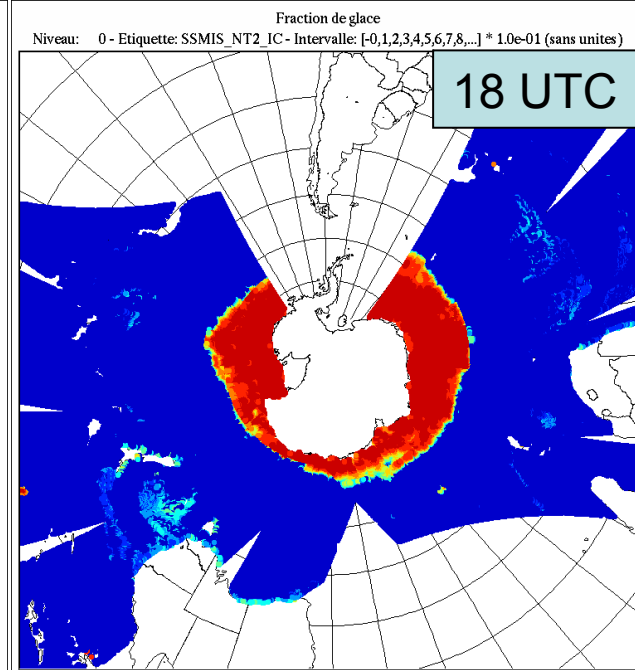
Champ valide 03:00Z le 27 aout 2010



Champ valide 09:00Z le 27 aout 2010



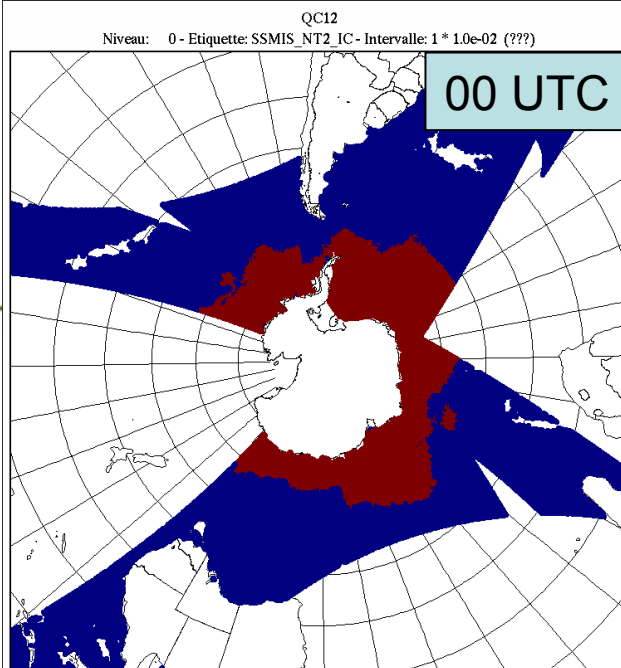
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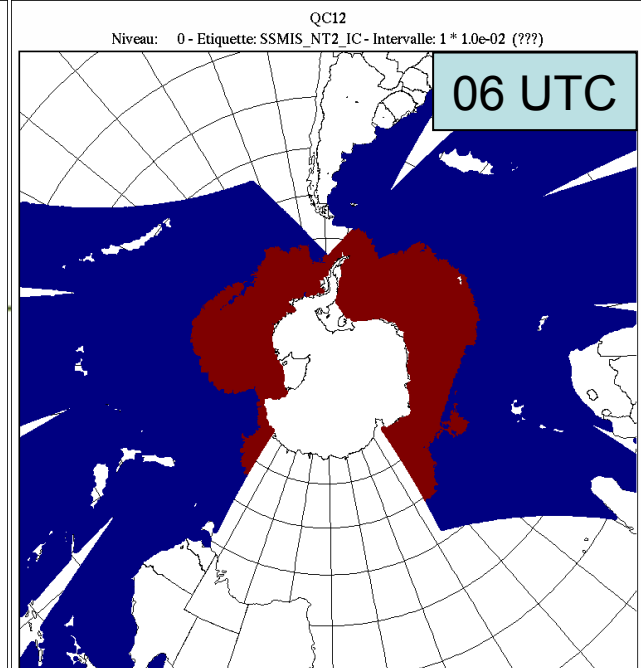
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SSM/IS

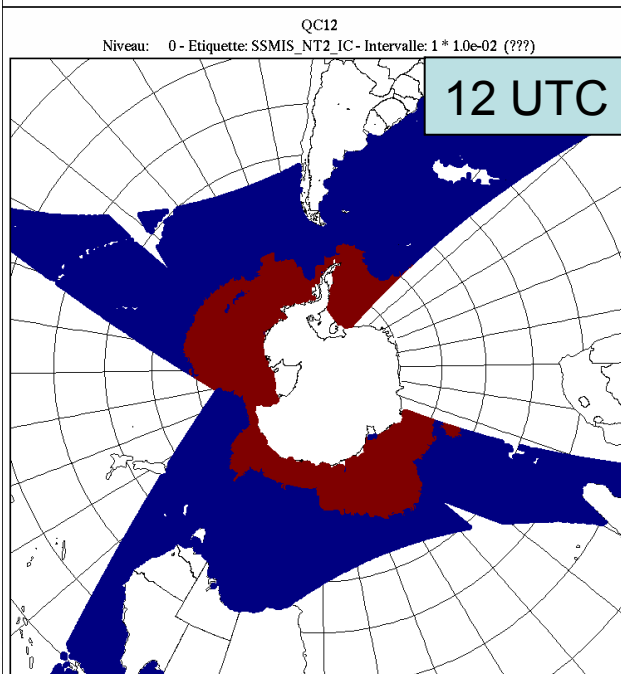
Assimilated
no = 0
yes = 1



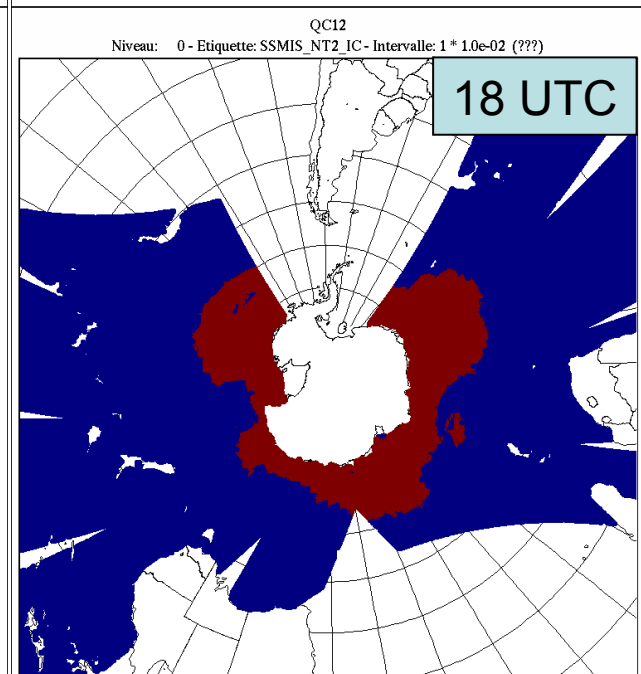
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Analyse valide 09:00Z le 27 aout 2010



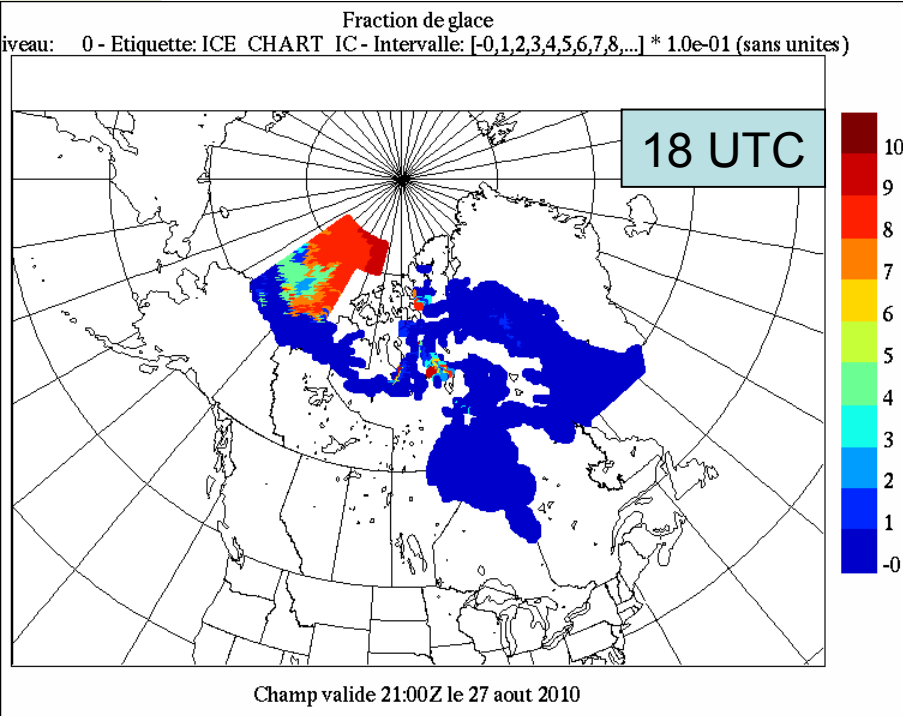
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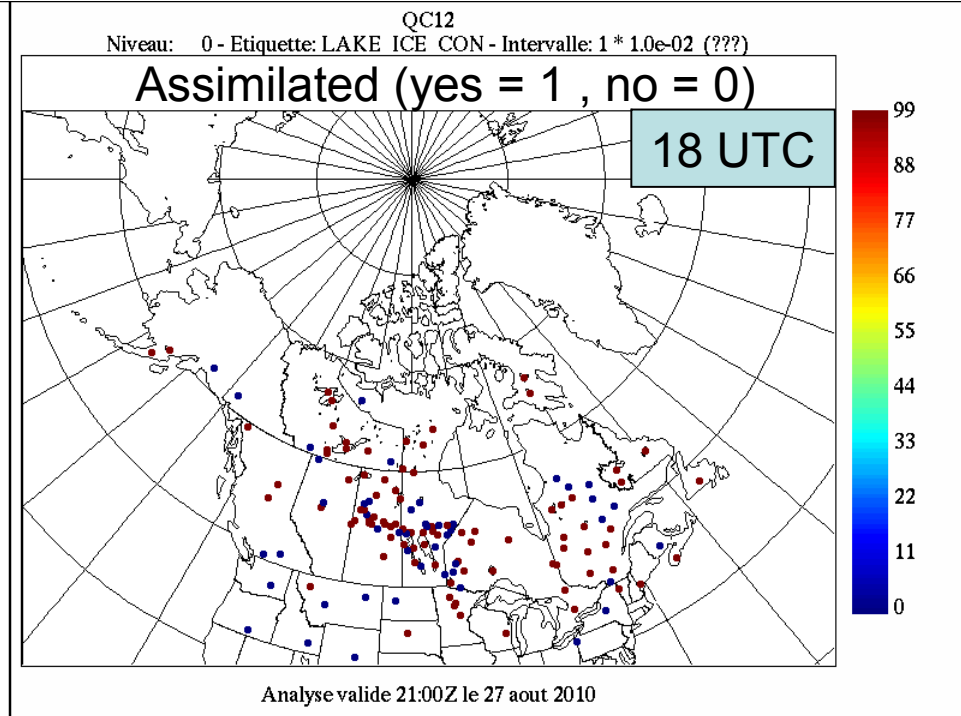
Analyse valide 21:00Z le 27 aout 2010

Assimilated data: Typical data coverage

CIS daily ice charts



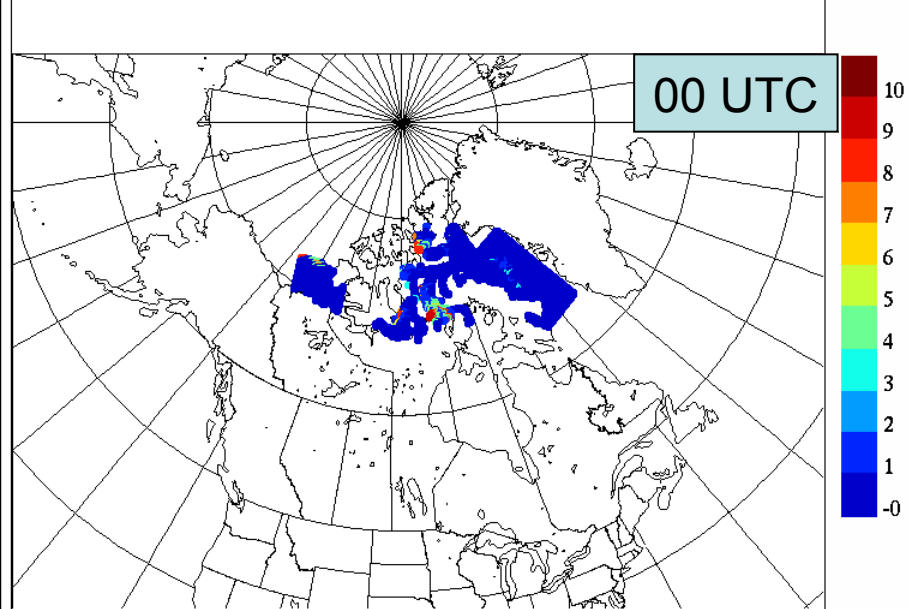
CIS lakes (once a week)



91 assimilated (out of 139)



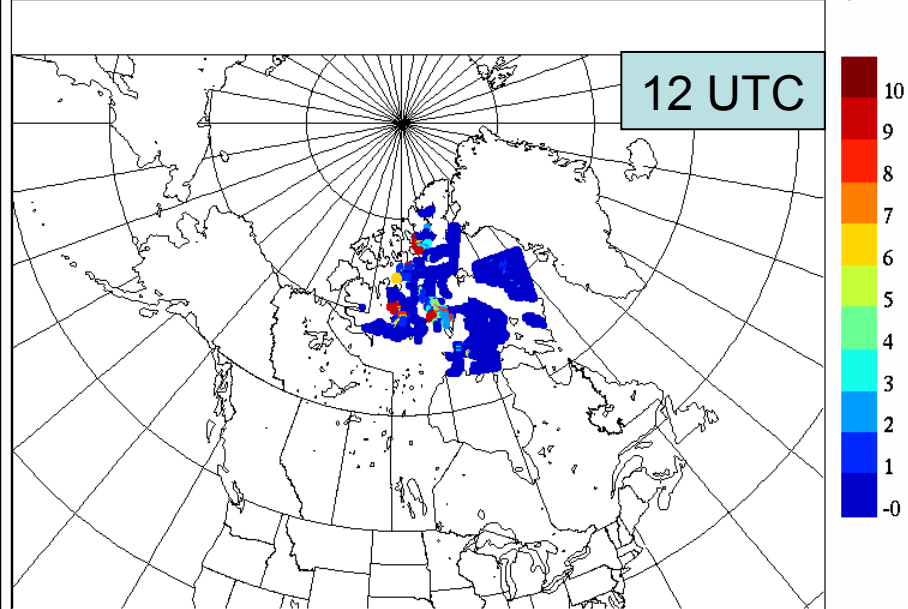
Fraction de glace
niveau: 0 - Etiquette: IMAGE ANAL I - Intervalle: [-0,1,2,3,4,5,6,7,8,...] * 1.0e-01 (sans unites)



Champ valide 03:00Z le 27 aout 2010

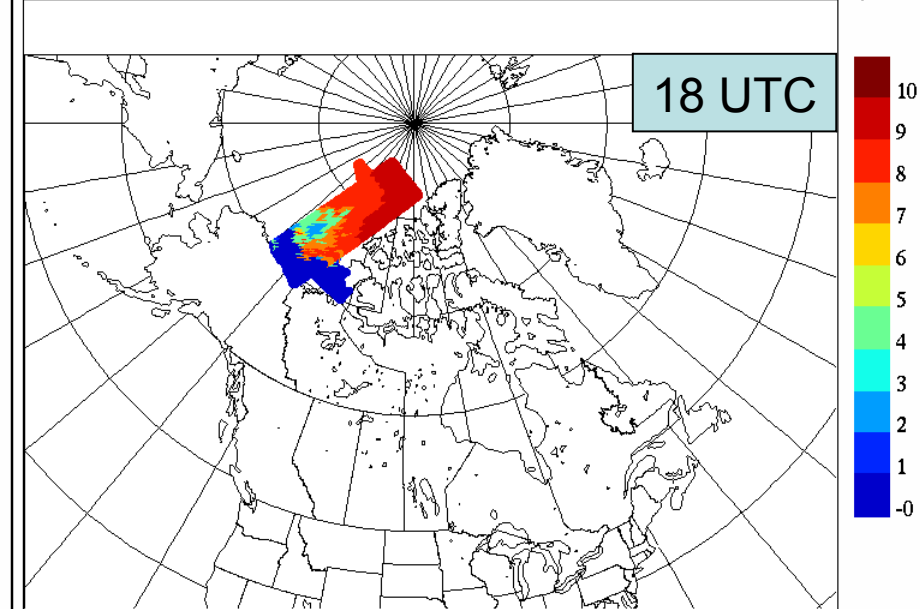
CIS image analyses

Fraction de glace
niveau: 0 - Etiquette: IMAGE ANAL I - Intervalle: [-0,1,2,3,4,5,6,7,8,...] * 1.0e-01 (sans unites)



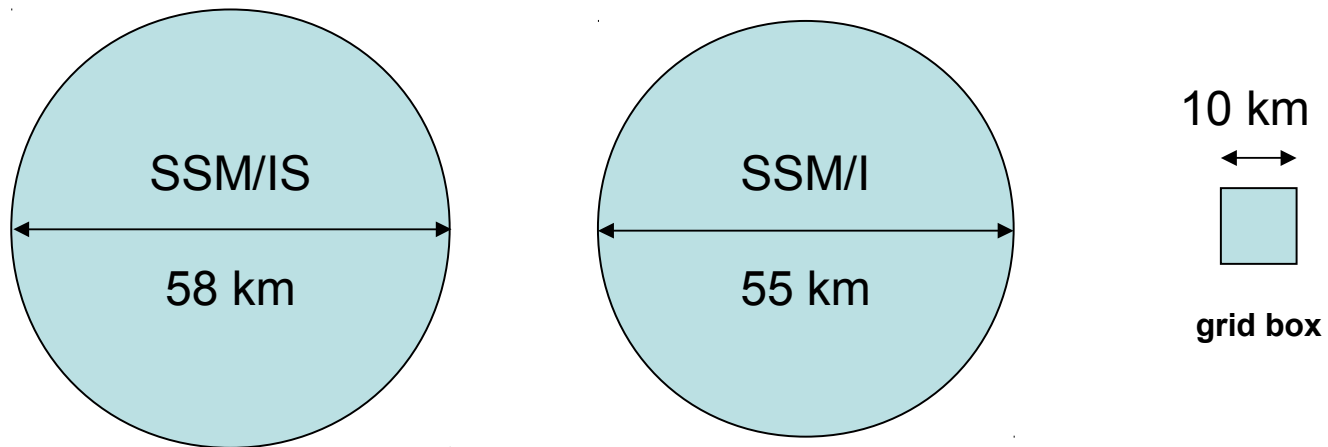
Champ valide 15:00Z le 27 aout 2010

Fraction de glace
niveau: 0 - Etiquette: IMAGE ANAL I - Intervalle: [-0,1,2,3,4,5,6,7,8,...] * 1.0e-01 (sans unites)



Champ valide 21:00Z le 27 aout 2010

Observation footprints



Generation of background state

- Set ice concentration to 0% where sea surface temperature $> 4^{\circ}\text{C}$
- Persist previous analysis to produce background state for 3D-Var analysis
- Track number of days since an observation has influenced the analysis at each grid point: provides level of confidence in analysis

The Global Ice Analysis System



Systems comparison

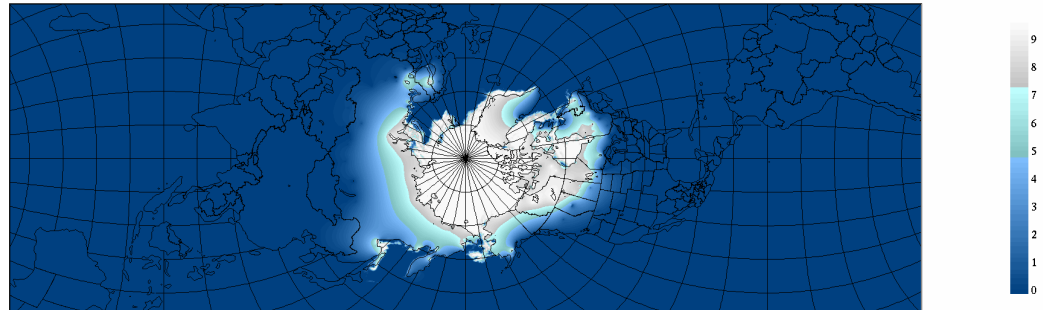
	Operational global ice analysis	New global ice analysis
Resolution	LG ~ 35km	GL and LG ~ 10km
Assimilation method	Averaging with more weight to CIS data	3D-var
Return to climatology	Over oceans and lakes	Over lakes
Frequency	Once a day at 00 UTC	00, 06, 12, 18 UTC
Retrieval algorithm	AES-York	NASA Team 2 (NT2)
Observations	CIS – daily ice charts CIS – lakes ice bulletins SSMI – DMSP15	CIS – daily ice chart CIS – lakes ice bulletins CIS - RADARSAT image analysis SSMI – DMSP15 SSMIS – DMSP16-17-18



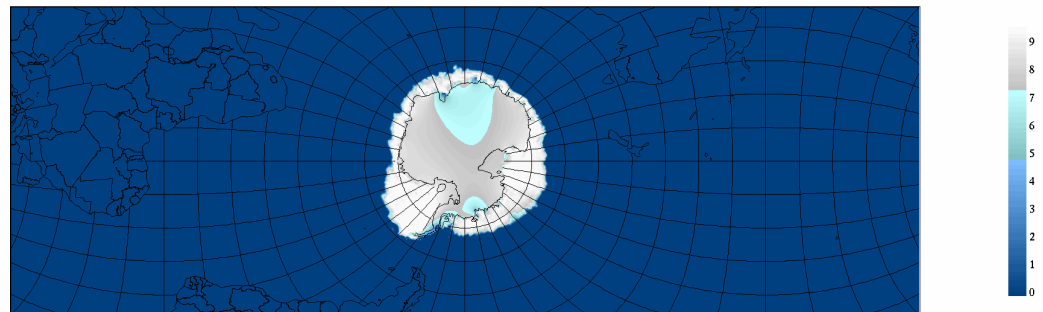
Domain of the new Global Ice Analysis

- Ice concentration analysis produced on 2 separate overlapping grids (Yin-Yang approach)

“Yin” grid = Arctic +
North America + Asia

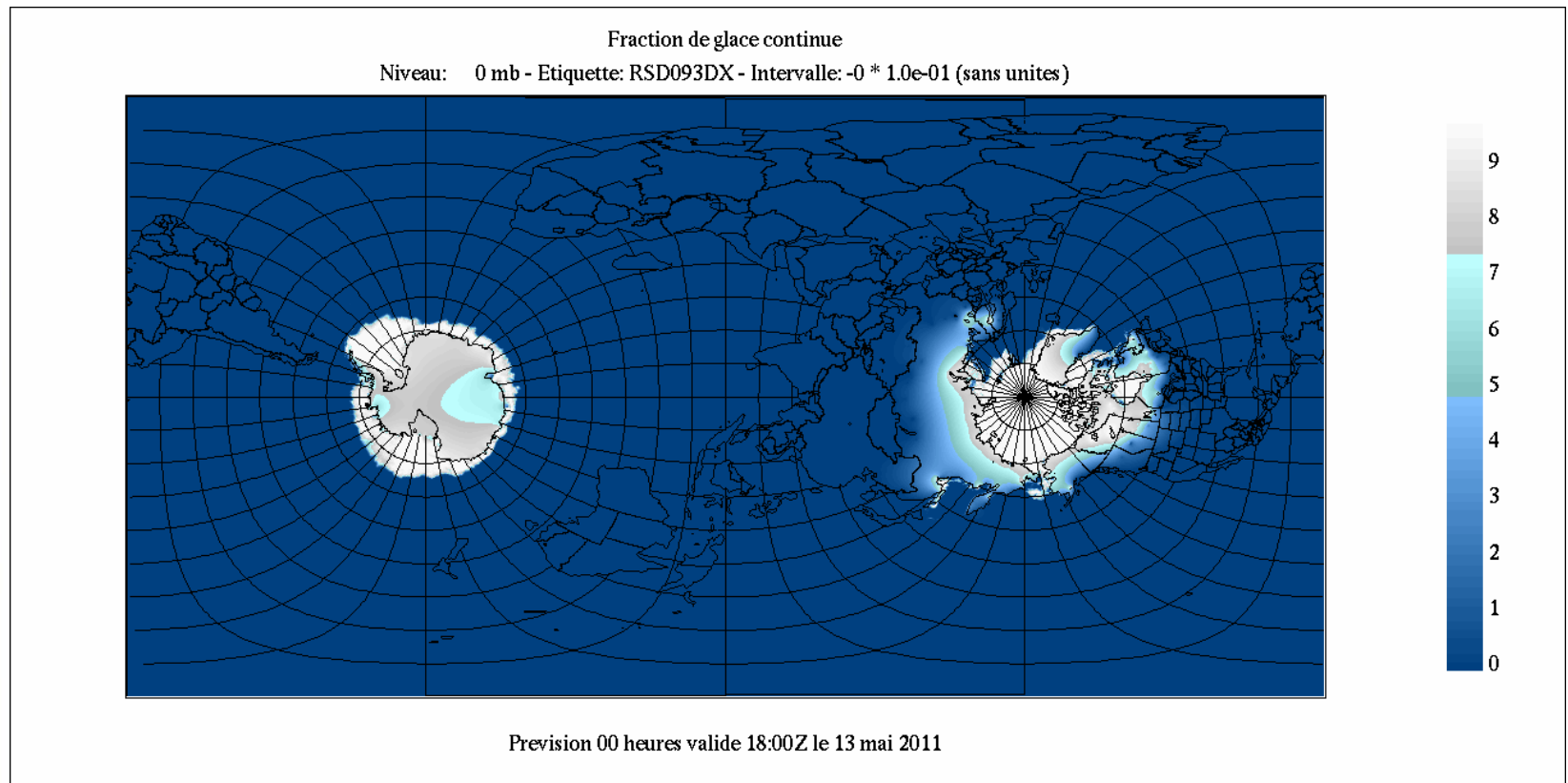


“Yang” grid = Antarctic
+ Africa

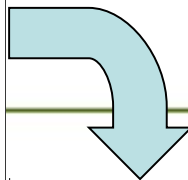
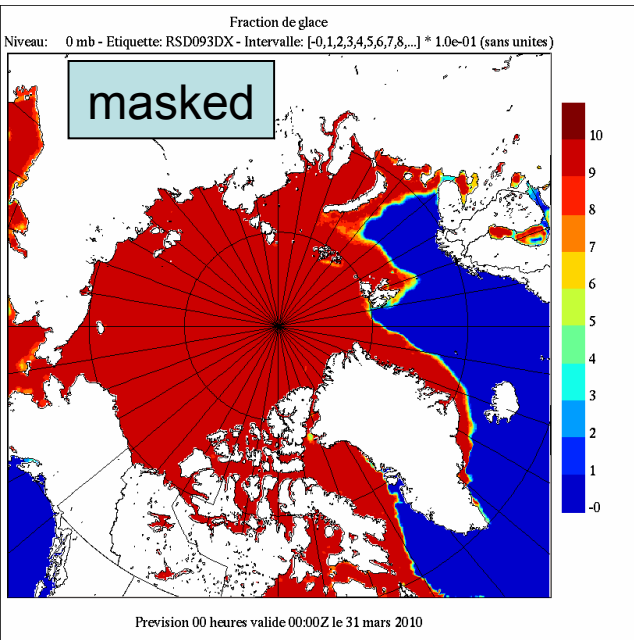


The new Global Ice Analysis

Global grid at 10km resolution produced by interpolating Yang grid (Antarctic) onto global version of Yin grid (Arctic) and combining both

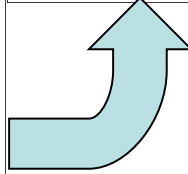
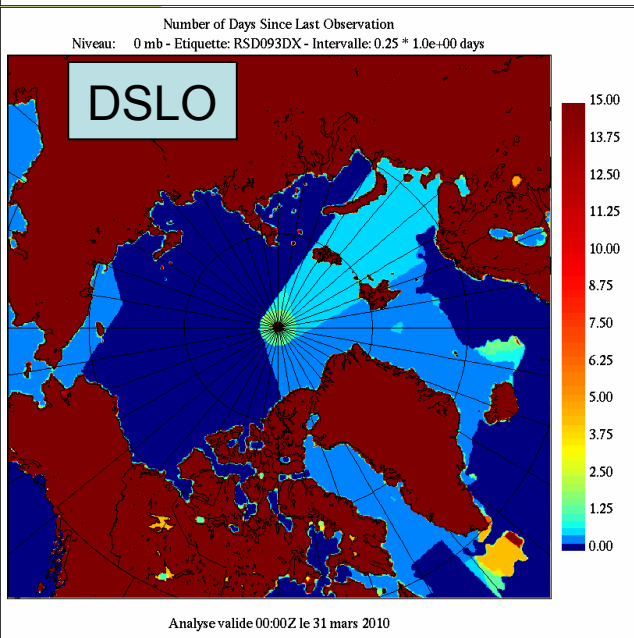
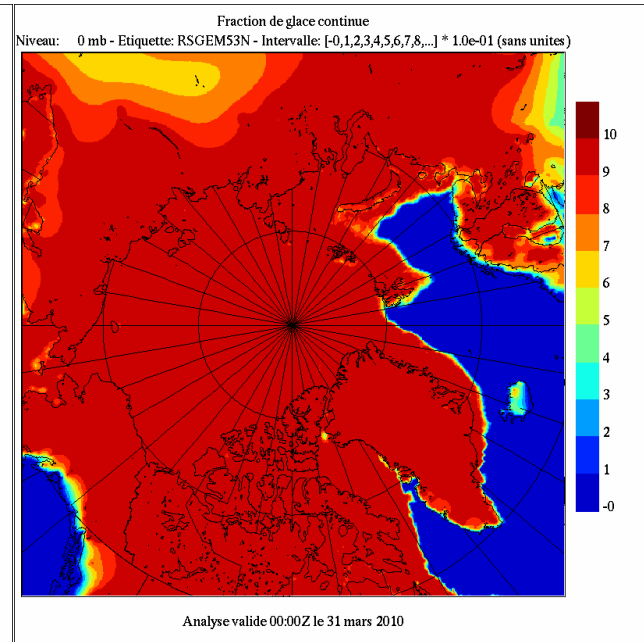
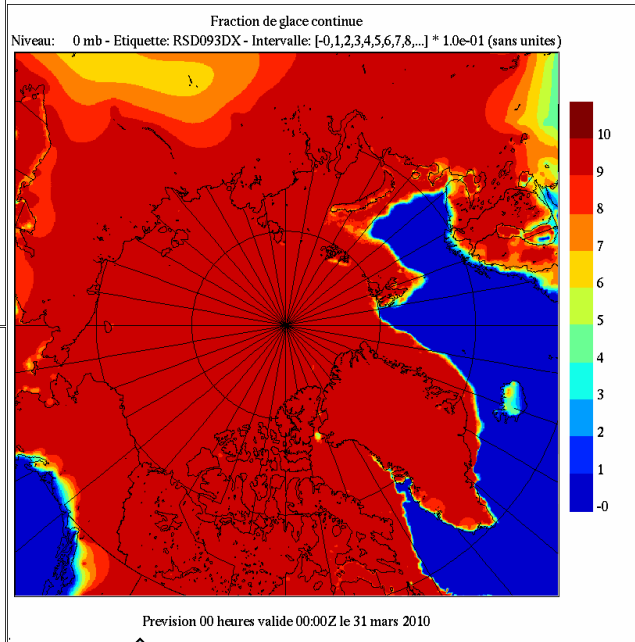


Making of the continuous field



10-km continuous

35-km continuous



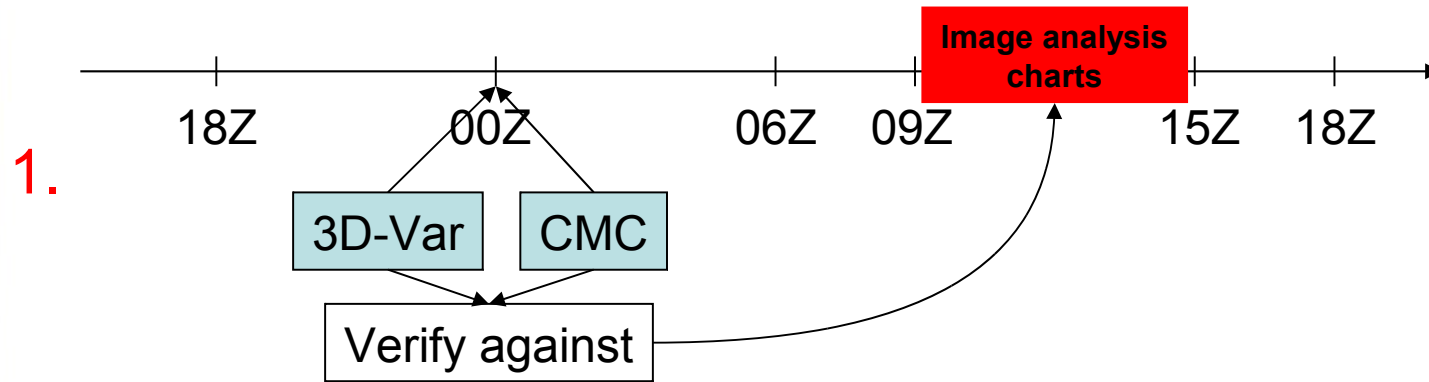
Only points where Days Since Last Obs (DSLO) is larger than 8 days are modified when generating the continuous field.

ment

Experiments: over all of 2010

verification strategy

For verification purposes, the 3D-Var analysis is interpolated onto same grid as the operational CMC ice analysis.

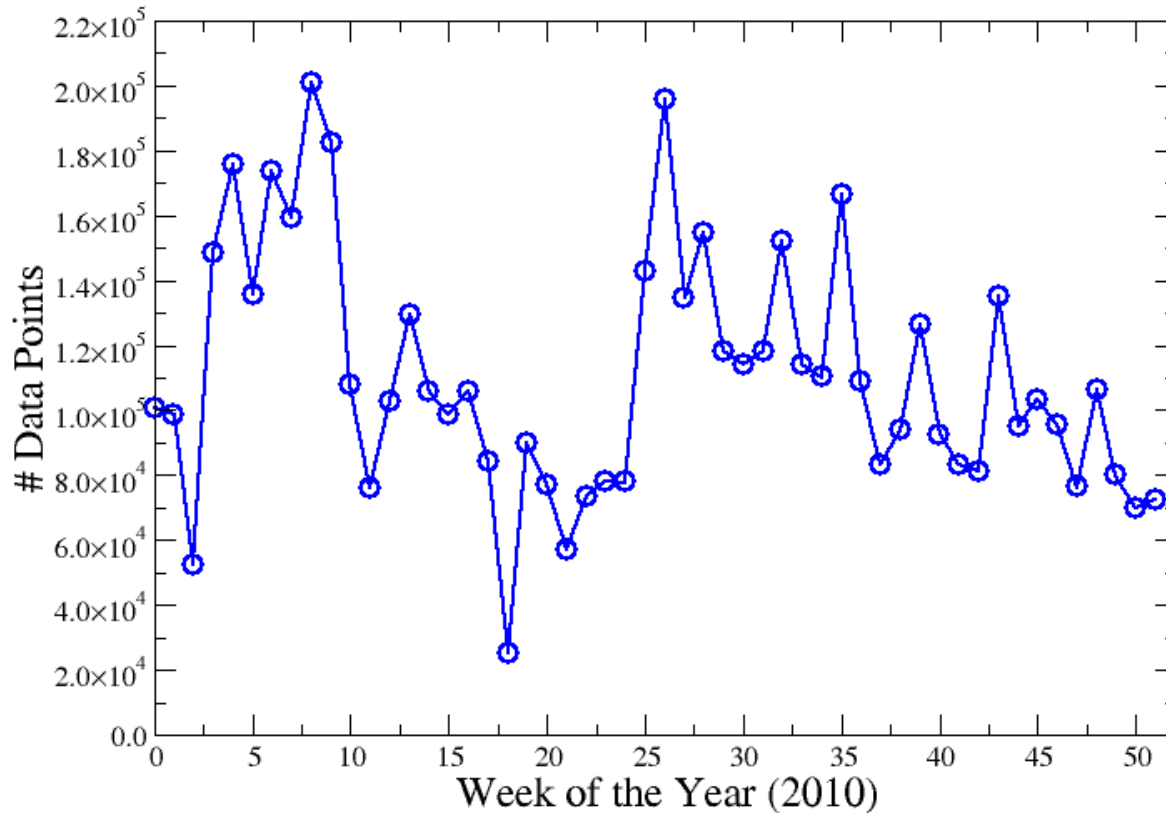


2. Compare 00Z 3D-Var analysis with that of CMC and verify against
- IMS ice extent
 - NIC bi-weekly ice charts

CIS Image Analysis Charts

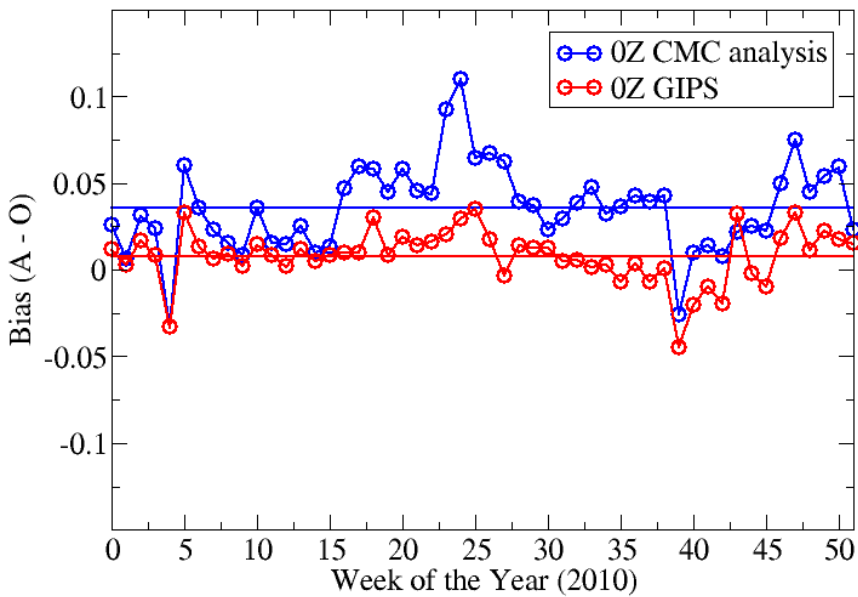
- Valid at time of satellite RADARSAT (ENVISAT) pass
- Prepared by CIS SAR image analysts (experts)
- Includes: knowledge of environmental conditions; in situ observations from ships; climatology;
- Regional dependence according to the operational season
- Data is independent because we use analyses valid from 09 to 15Z, available after the assimilation window (6 to 18 hours later)

Availability of Image Analysis Charts

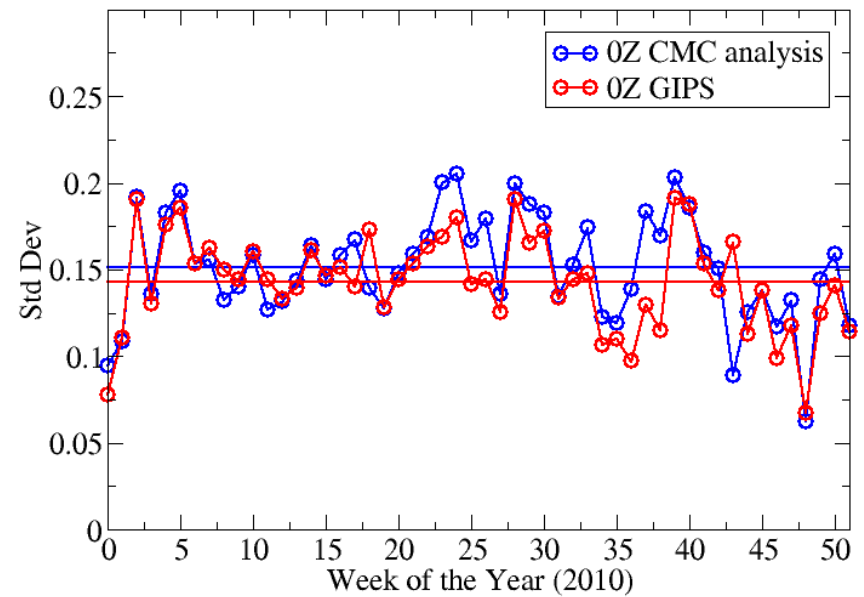


00Z 3DVar vs CMC Ice Analyses Compared to 9-15Z Image Analysis Charts

Total Ice Concentration



Total Ice Concentration



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
- High resolution ~4 km
- Available daily over entire northern hemisphere analysis domain, including lakes (scores computed over sub-regions)
- 3D-Var analysis is interpolated on the IMS analysis grid and then converted to ice/no-ice using a 40 % threshold on ice concentration

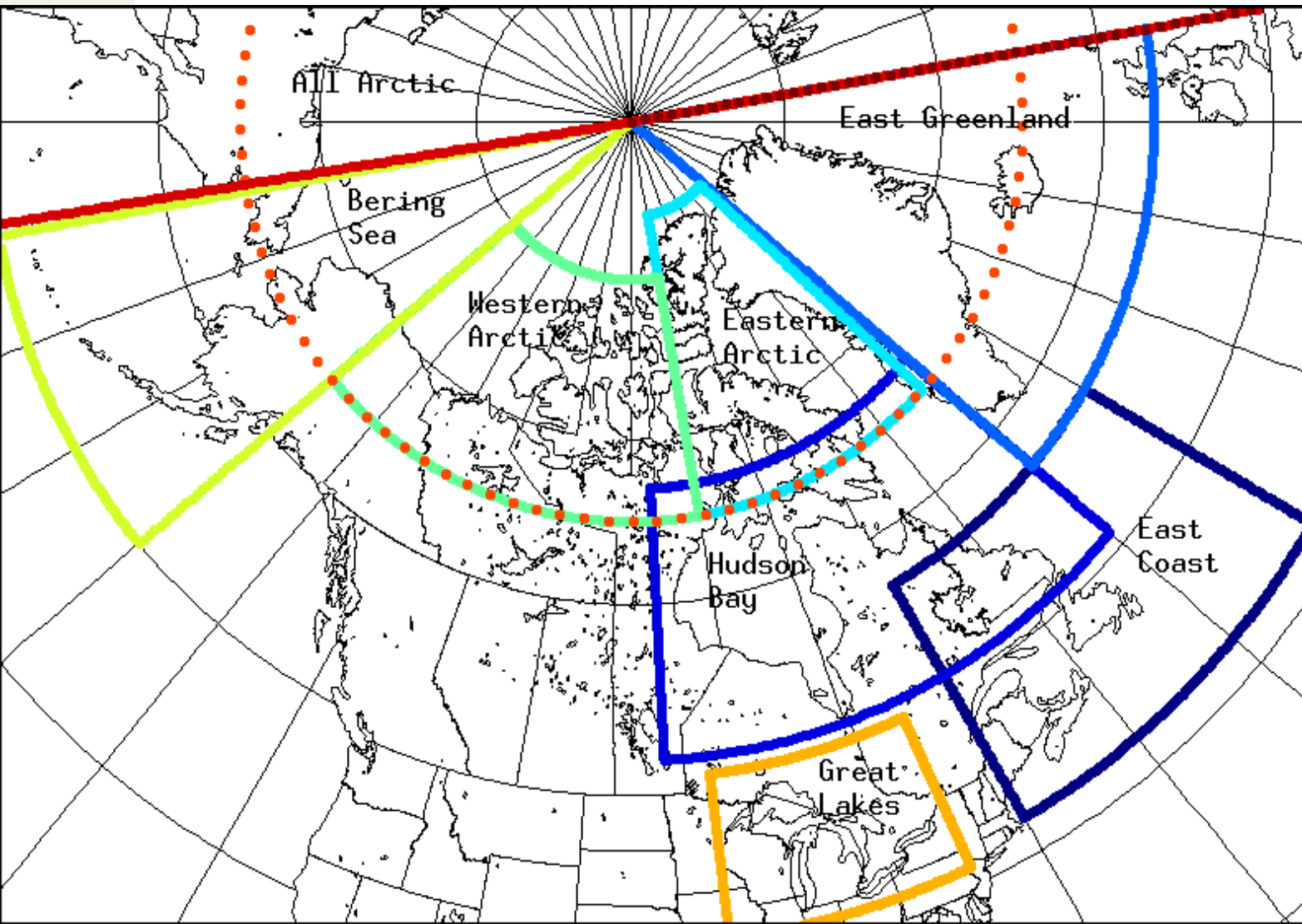
Scores are based on a contingency table

- 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 - ∞ ; ∞

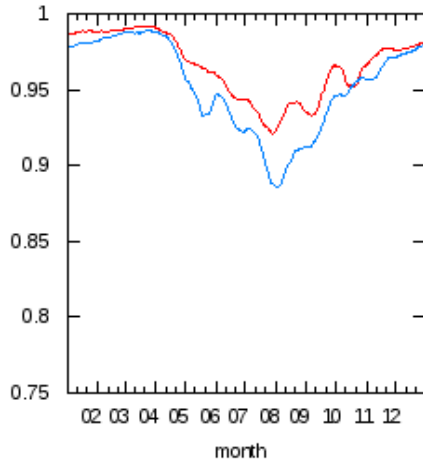
IMS verification regions



Verification against IMS ice extent

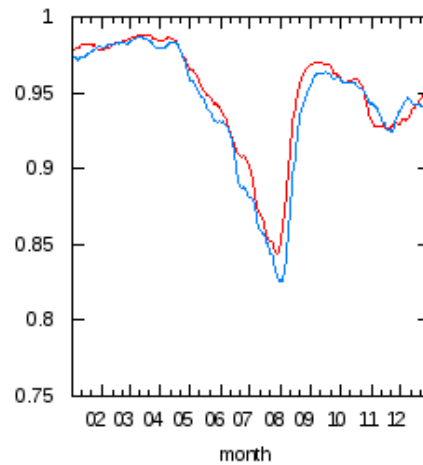
ALL ARCTIC

Proportion Correct Total



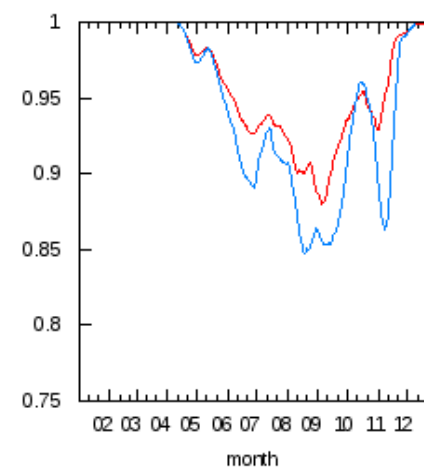
EASTERN ARCTIC

Proportion Correct Total



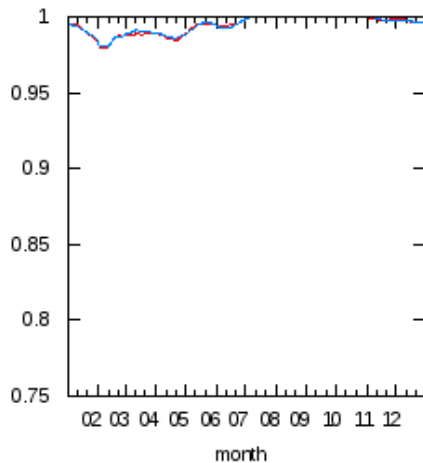
WESTERN ARCTIC

Proportion Correct Total



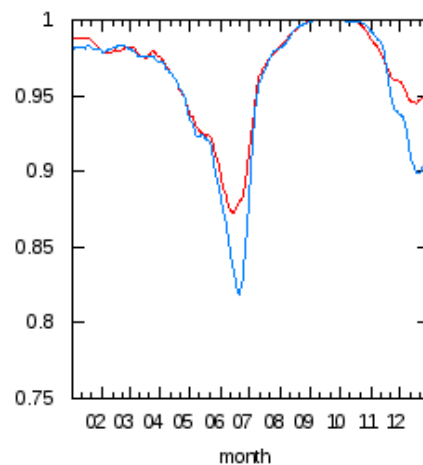
EAST COAST

Proportion Correct Total



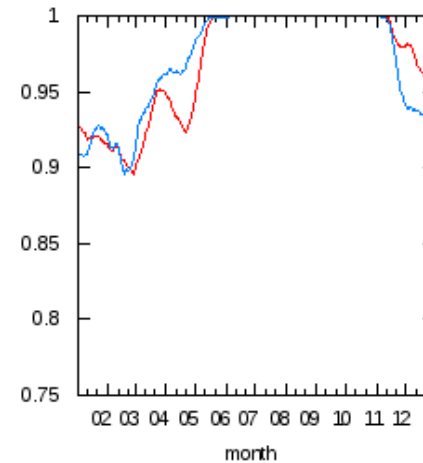
HUDSON BAY

Proportion Correct Total



GREAT LAKES

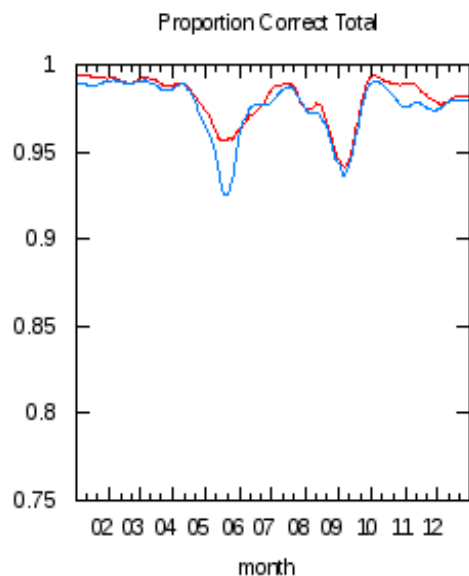
Proportion Correct Total



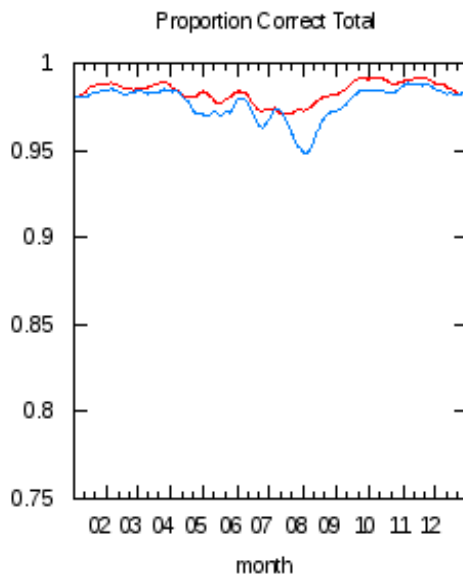
CMC ops
3D-Var

Verification against IMS ice extent

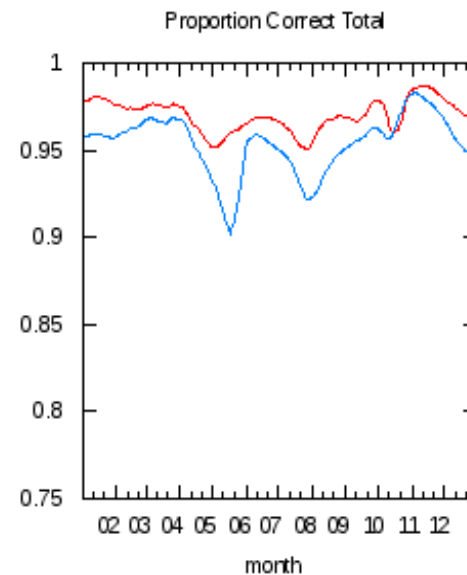
BERING SEA



EAST GREENLAND



EUROPE-ASIA



CMC ops
3D-Var



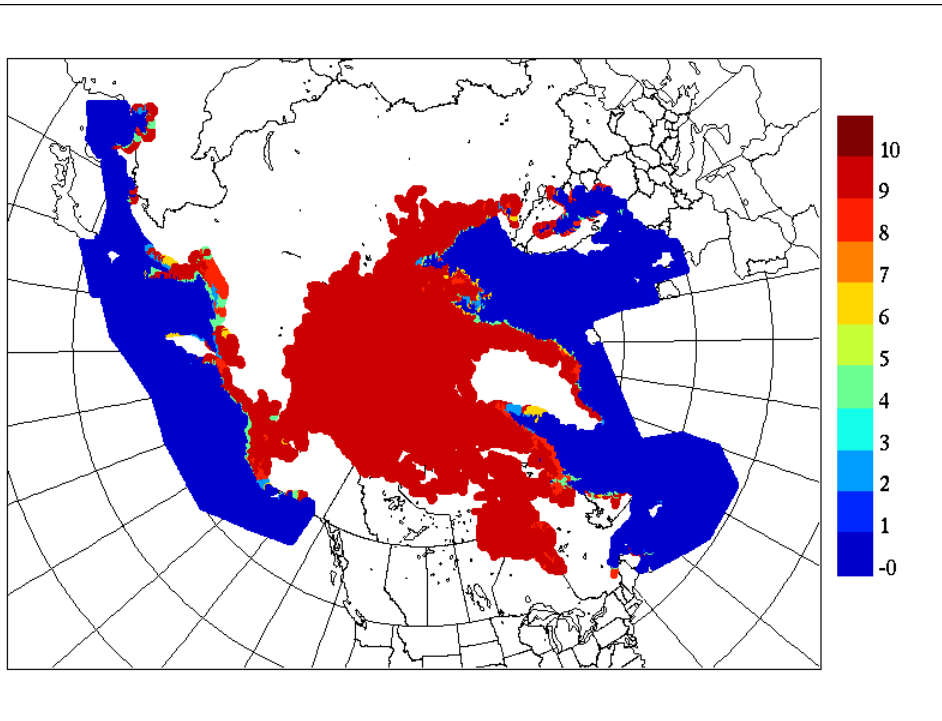
U.S. NIC ice charts in SIGRID-3 vector format

- 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

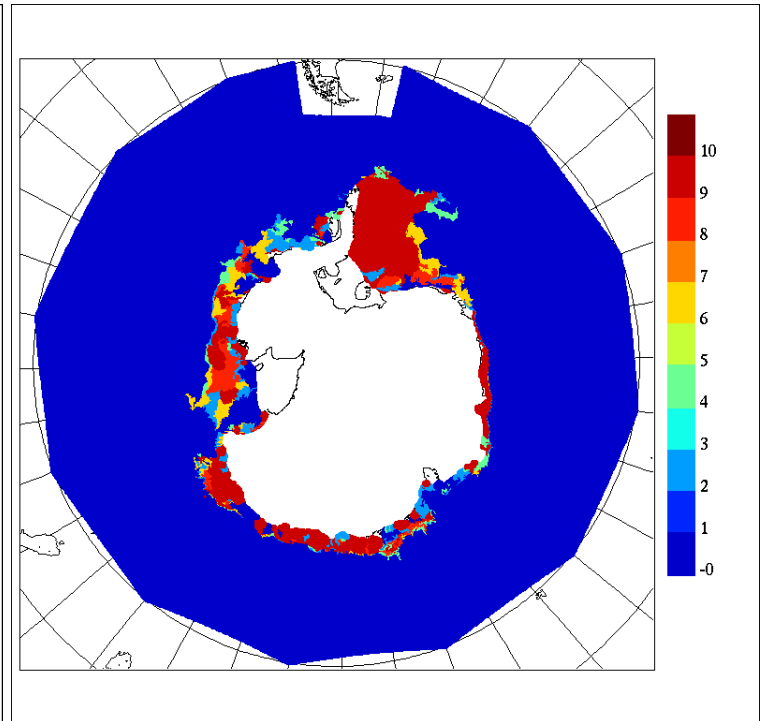
NIC ice charts

- Example from January 4th, 2010.

Arctic

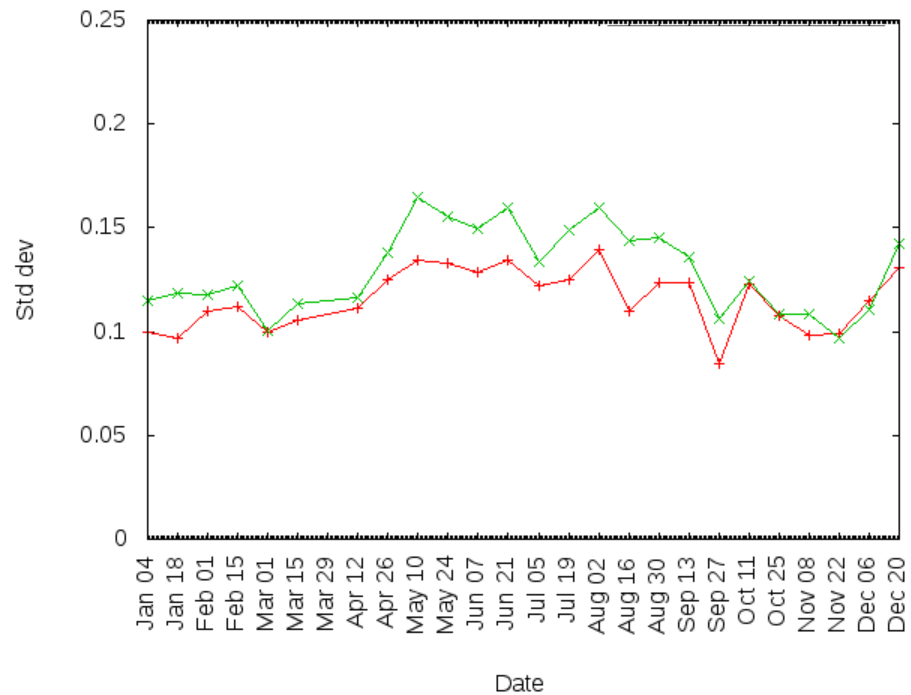
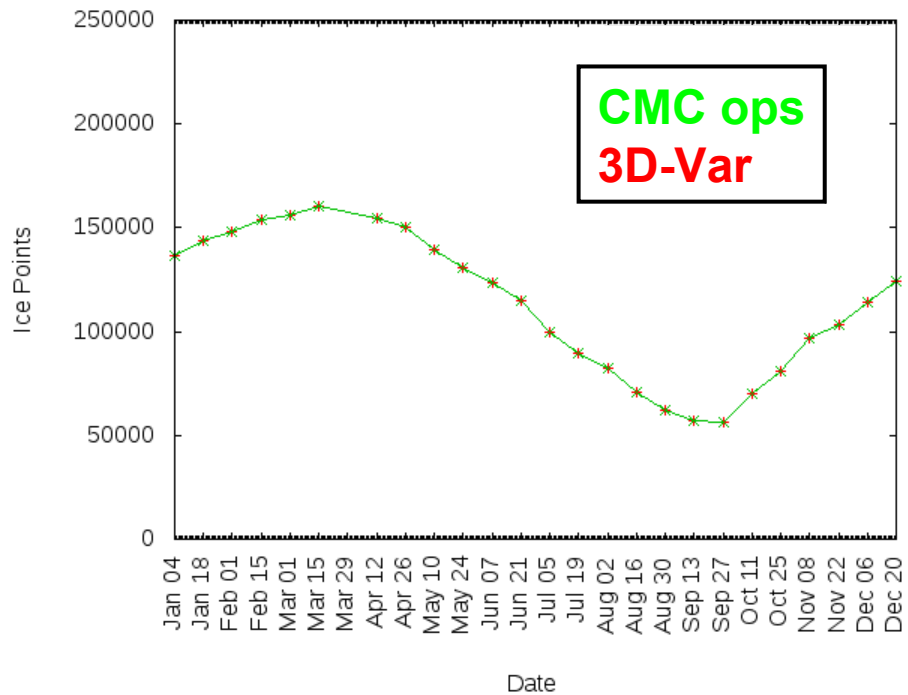
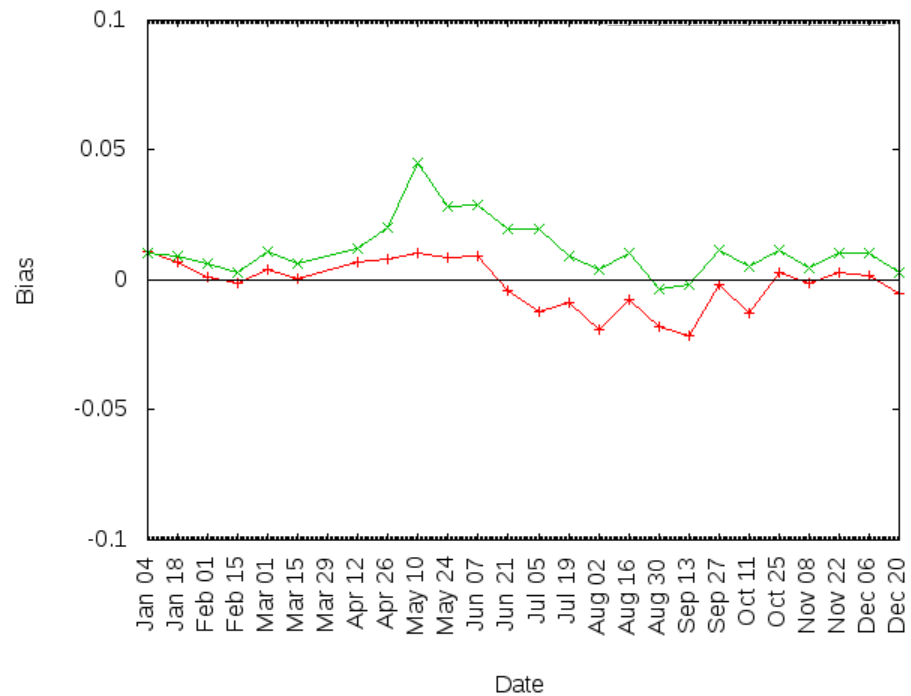


Antarctic



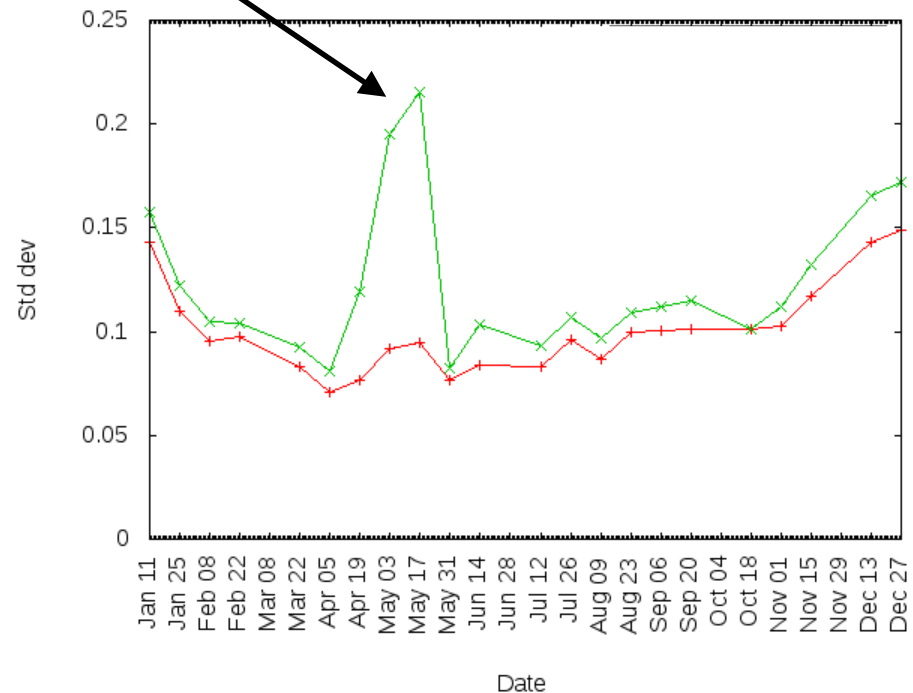
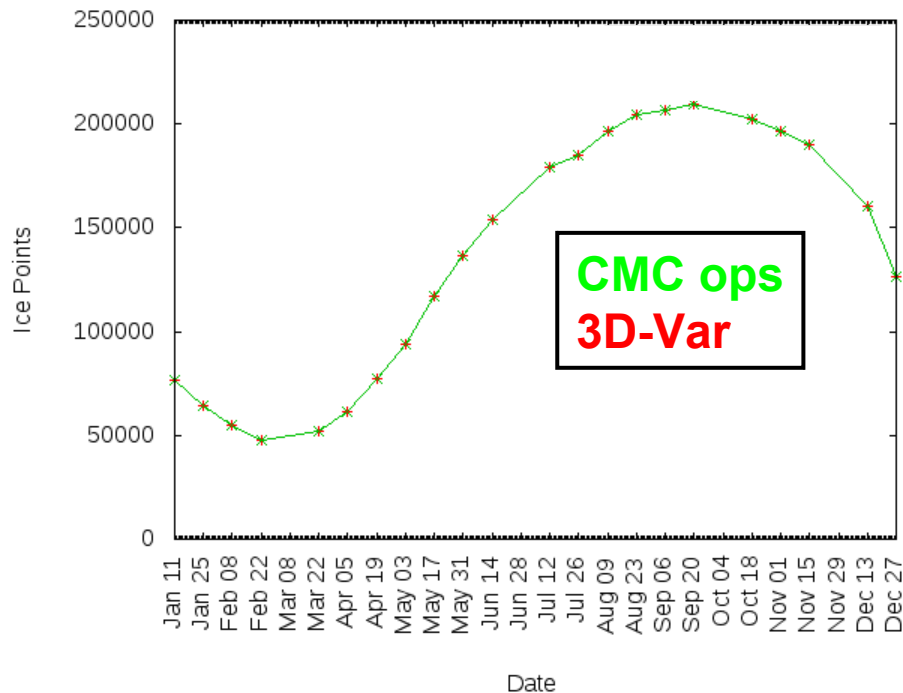
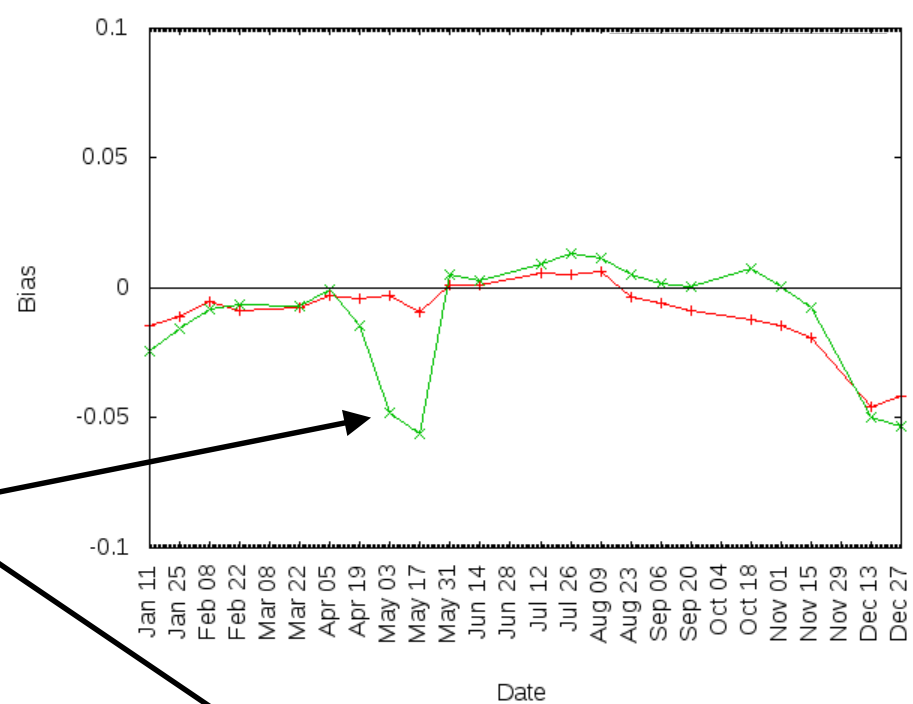
Arctic ice concentration

- Bias and std dev against NIC charts

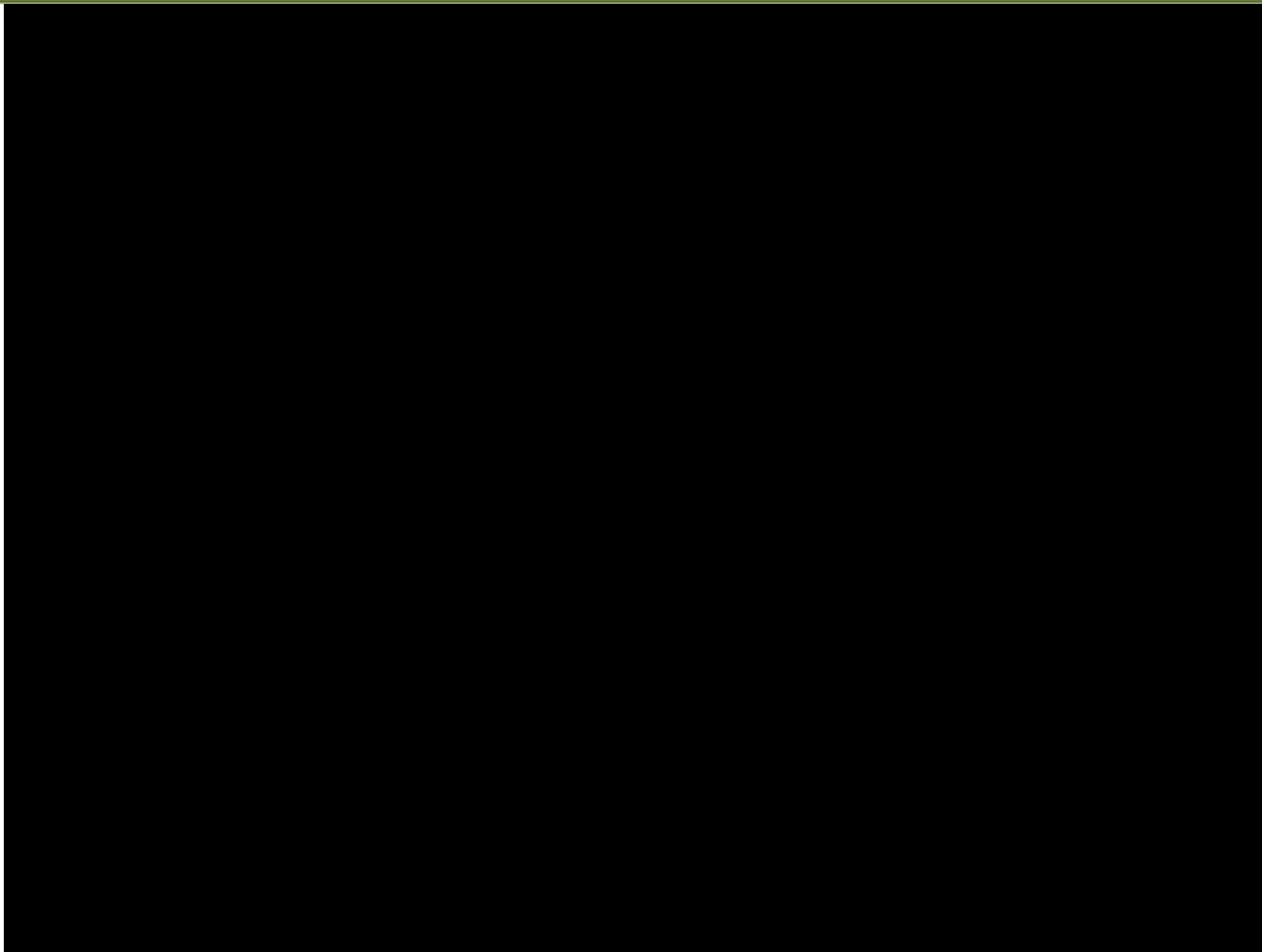


Antarctic ice concentration

No SSM/I data between April 17 and May 26 2010 in the CMC sea ice analysis ! (LINUX migration => new TM not seen by g6icelg)
More apparent than in Arctic scores.

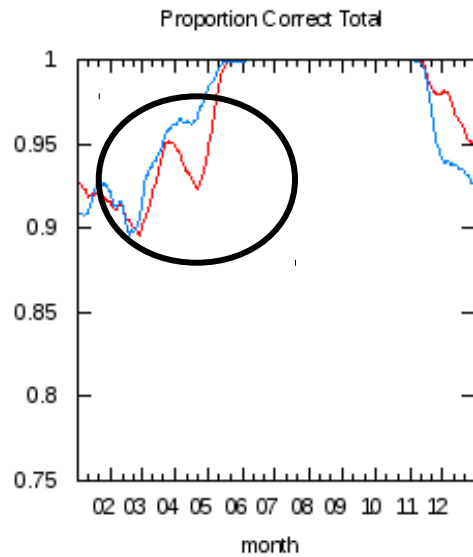


CMC ice analysis



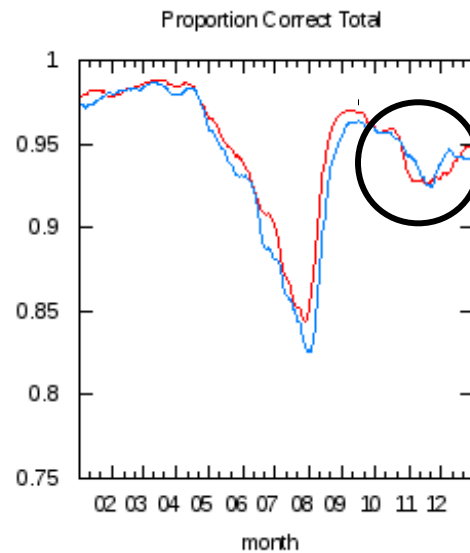
What happened?

Great Lakes



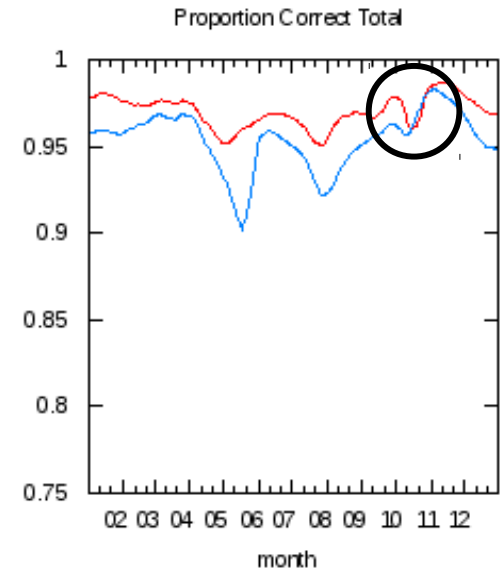
Mar-Apr-May

Eastern Arctic



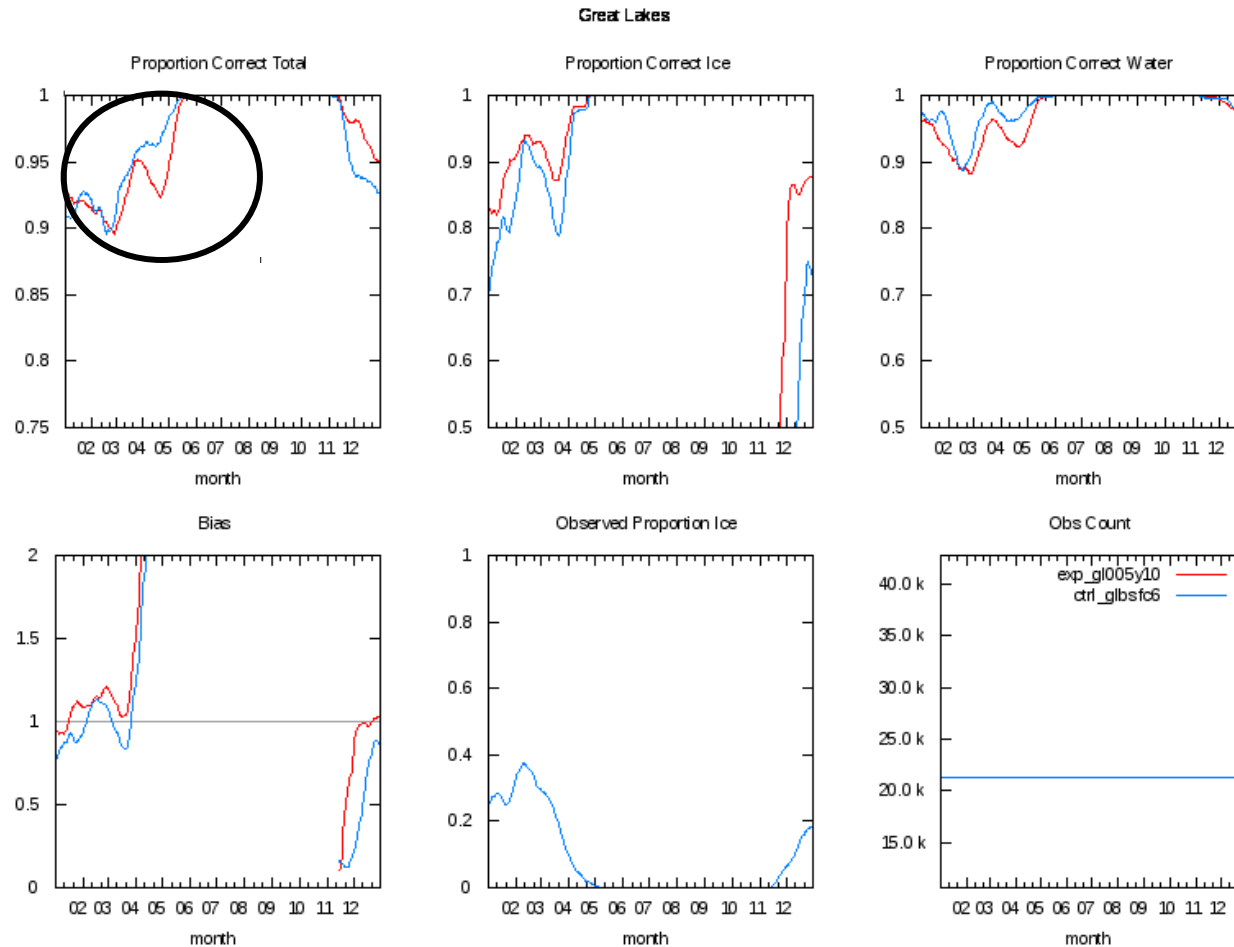
end Oct to mid Nov

Europe-Asia



mid-Oct

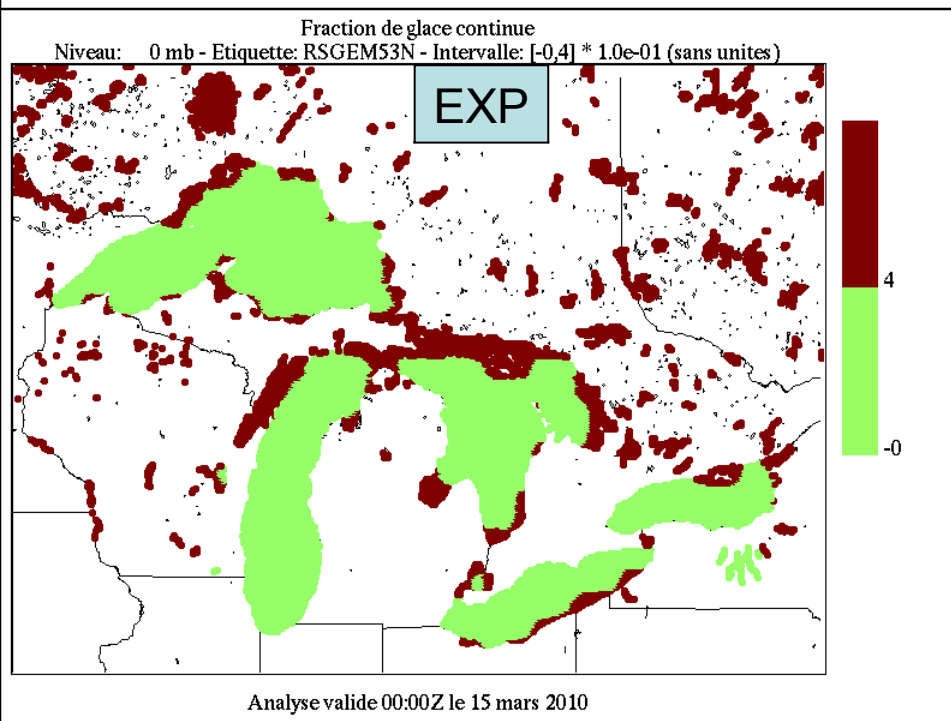
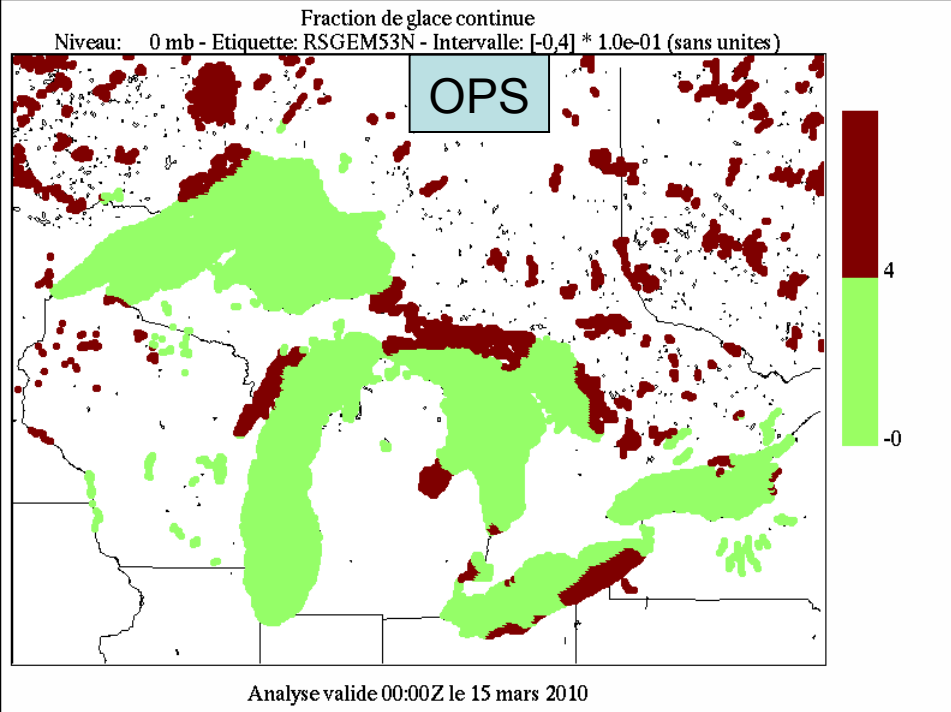
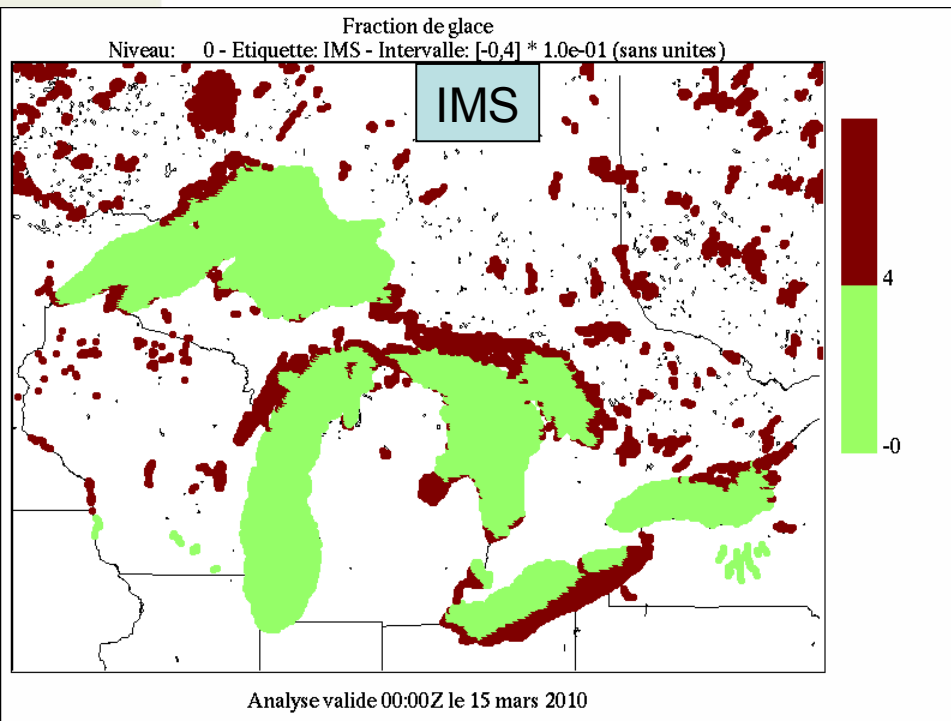
Great Lakes ~March/April/May



EXP
OPS

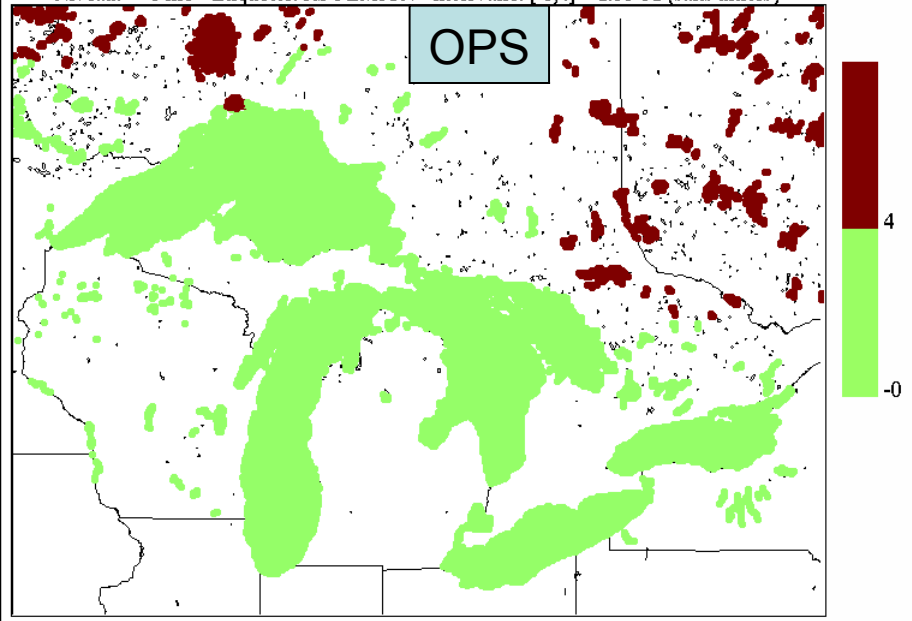


Great Lakes, March 15, 00 UTC 40% threshold



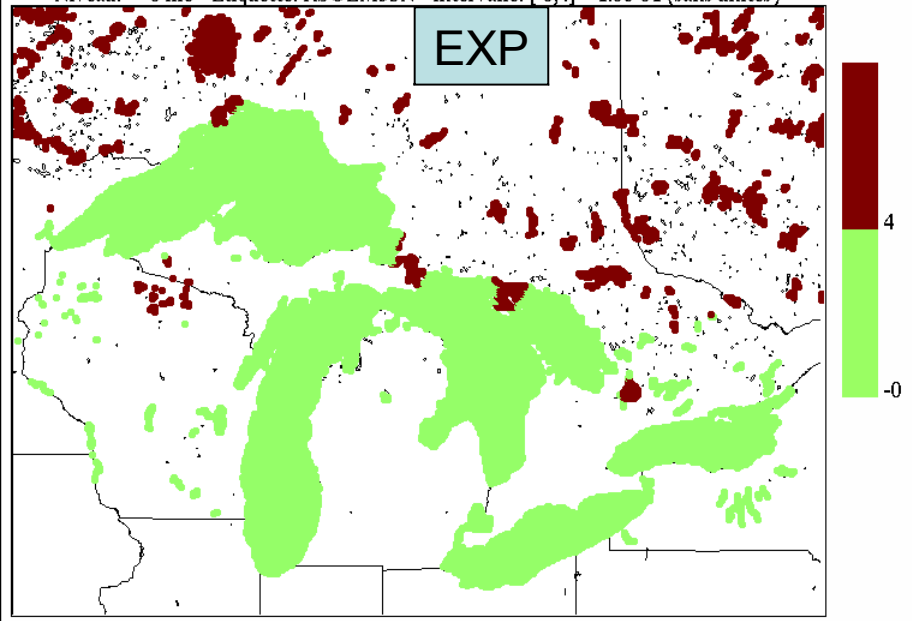
Great Lakes, April 15, 00 UTC 40% threshold

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



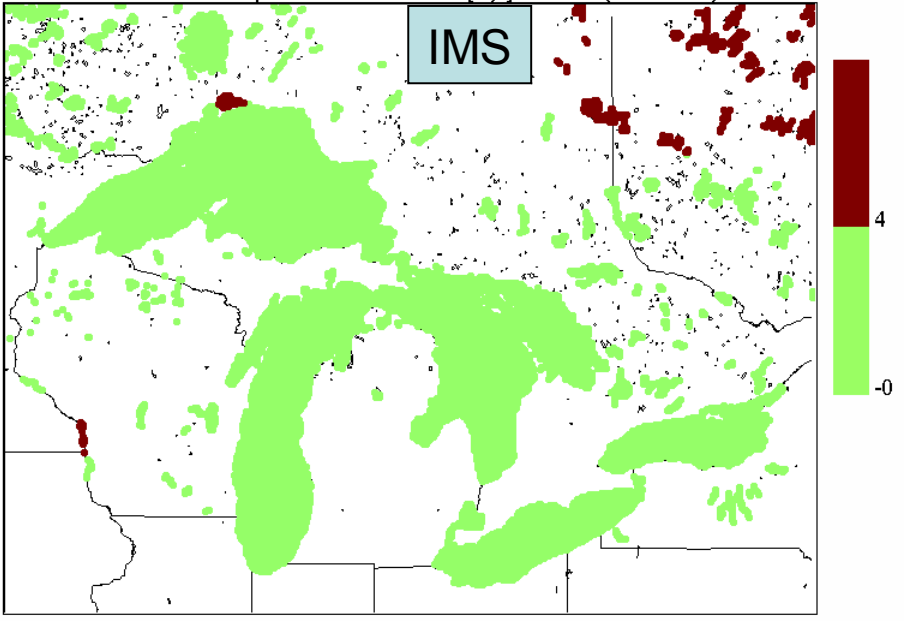
Analyse valide 00:00Z le 15 avril 2010

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



Analyse valide 00:00Z le 15 avril 2010

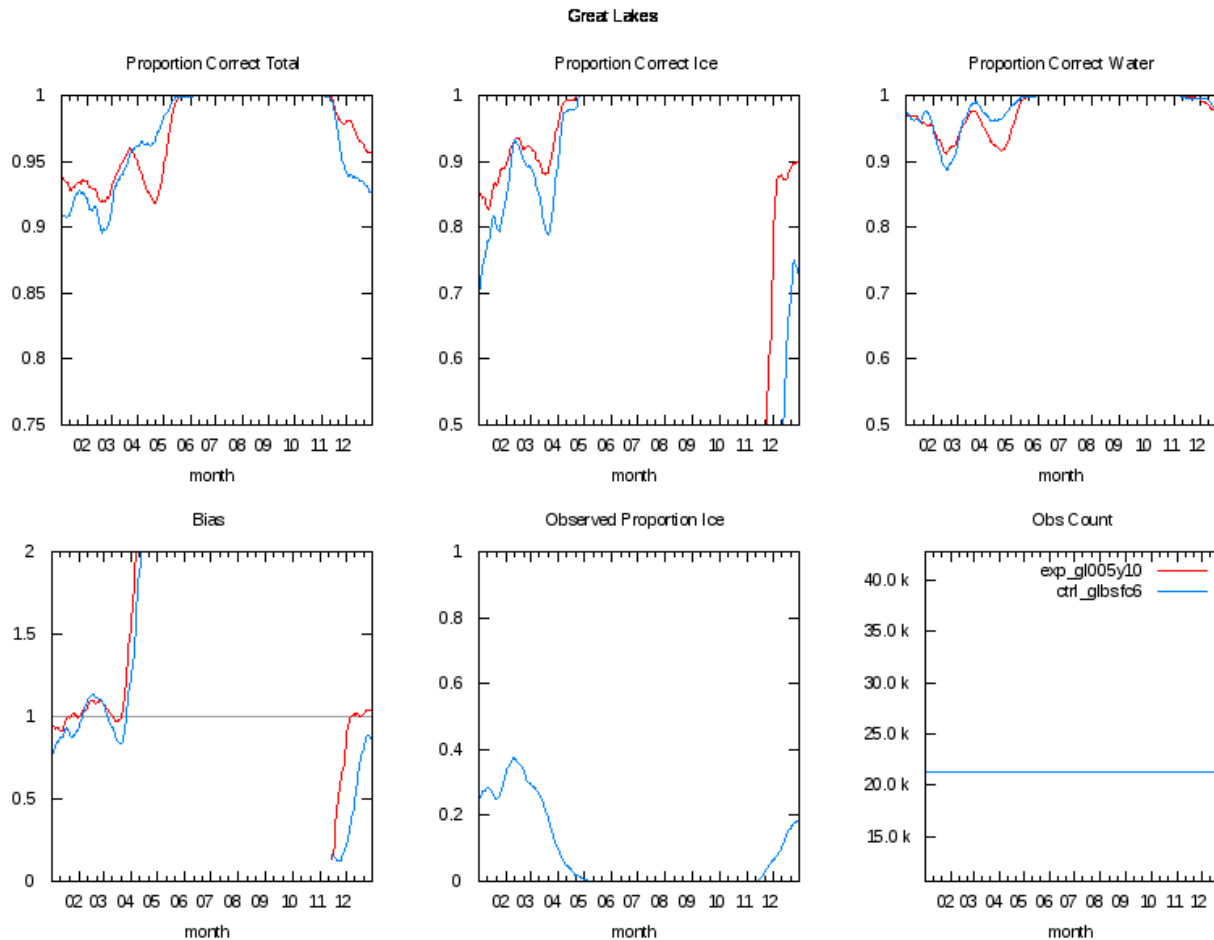
Fraction de glace
Niveau: 0 - Etiquette: IMS - Intervalle: [-0,4] * 1.0e-01 (sans unites)



Analyse valide 00:00Z le 15 avril 2010

Great-Lakes...resolution 10km vs 35km

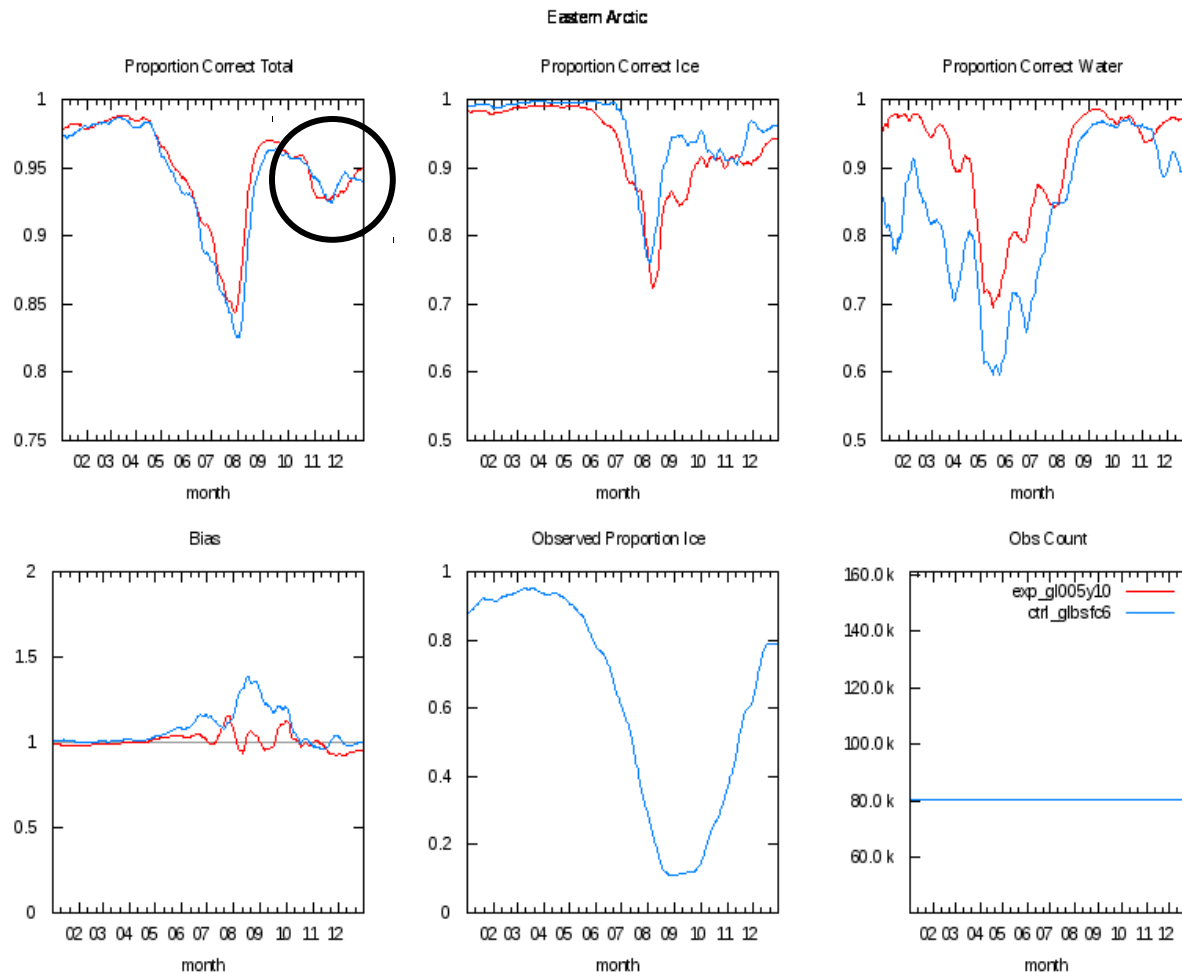
April/May



EXP 10km
OPS 35km

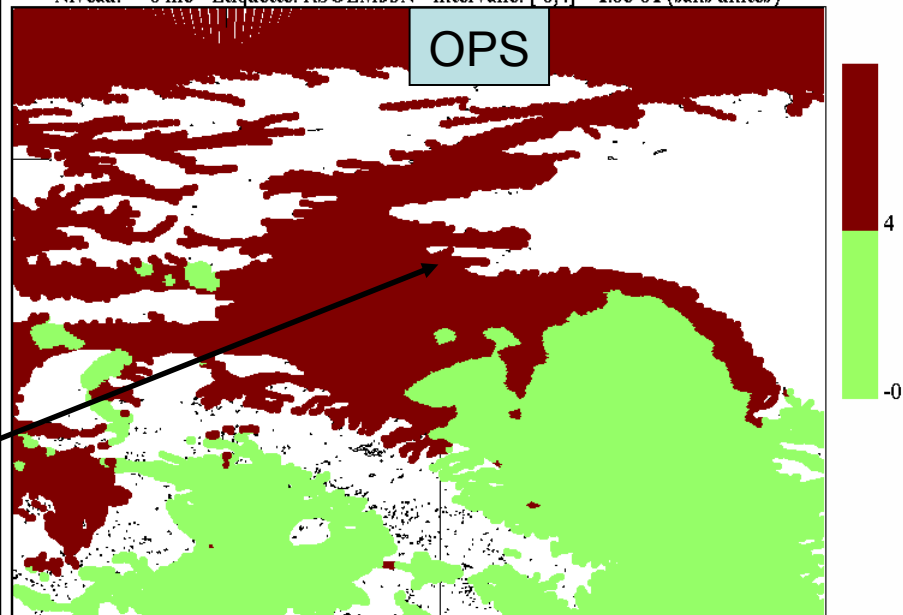


Eastern Arctic ~Oct 27th to Nov 19th



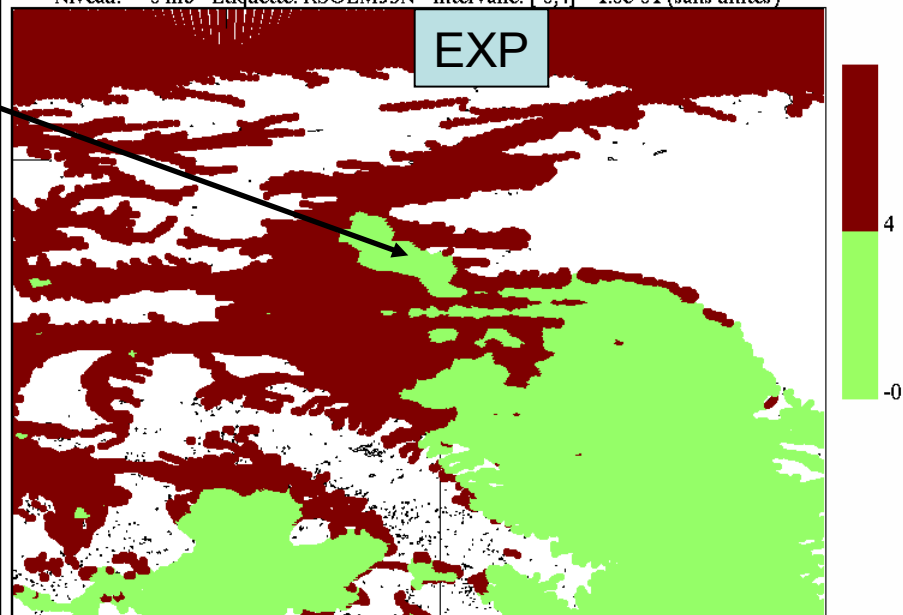
Eastern Arctic – Nov 2 – 00 UTC 40% threshold

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



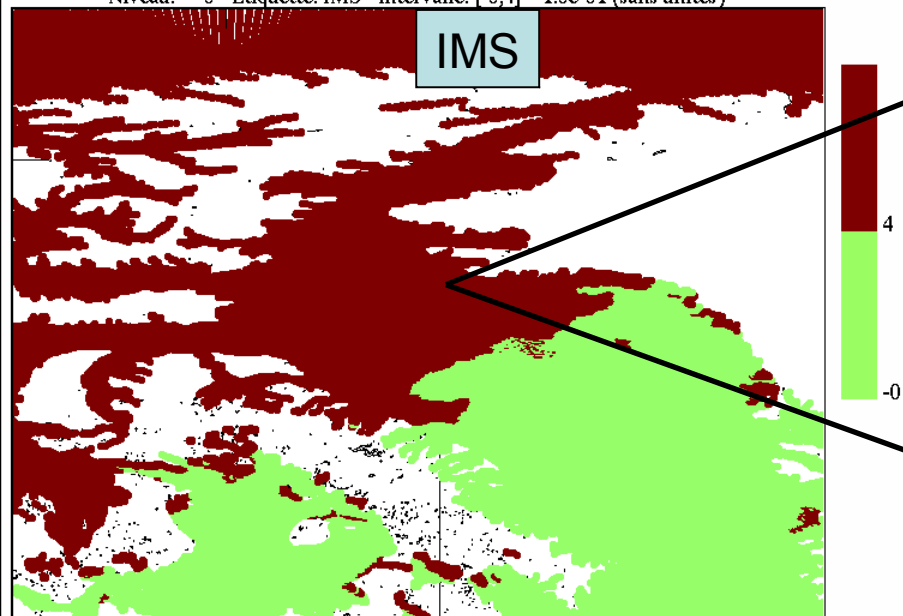
Analyse valide 00:00Z le 02 novembre 2010

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



Analyse valide 00:00Z le 02 novembre 2010

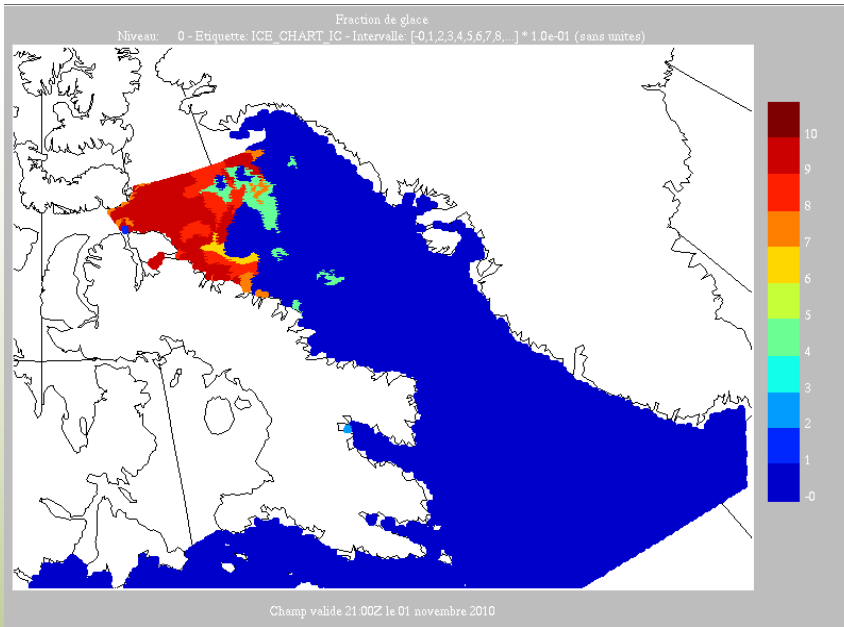
Fraction de glace
Niveau: 0 - Etiquette: IMS - Intervalle: [-0,4] * 1.0e-01 (sans unites)



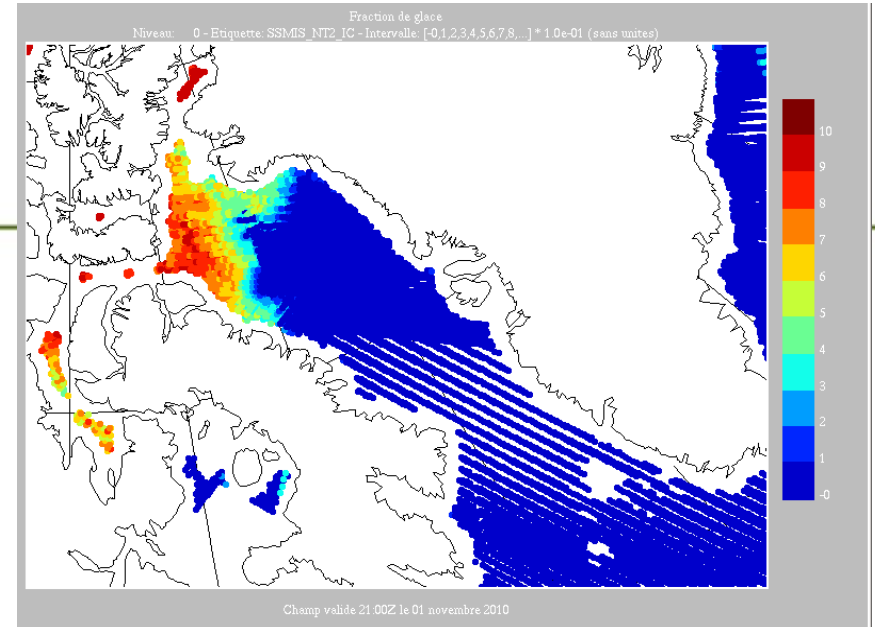
Analyse valide 00:00Z le 02 novembre 2010



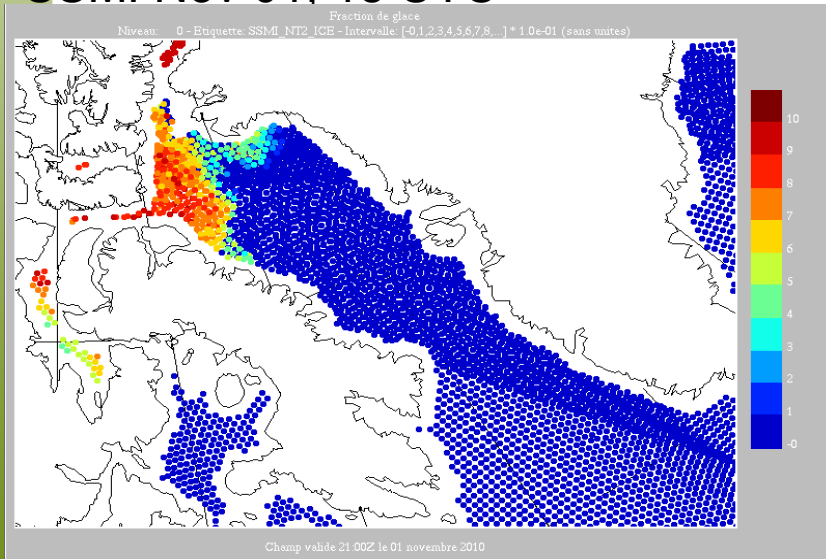
Ice chart Nov 01, 18 UTC



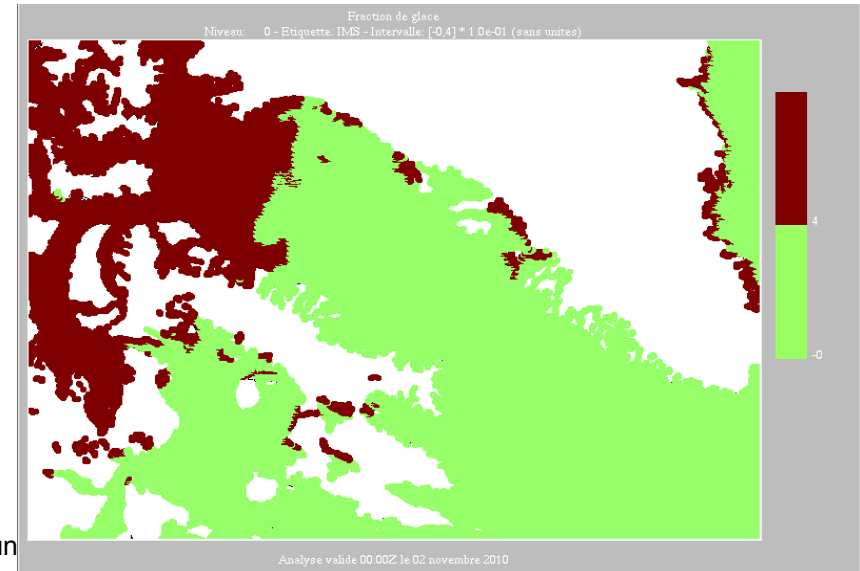
SSMIS Nov 01, 18 UTC



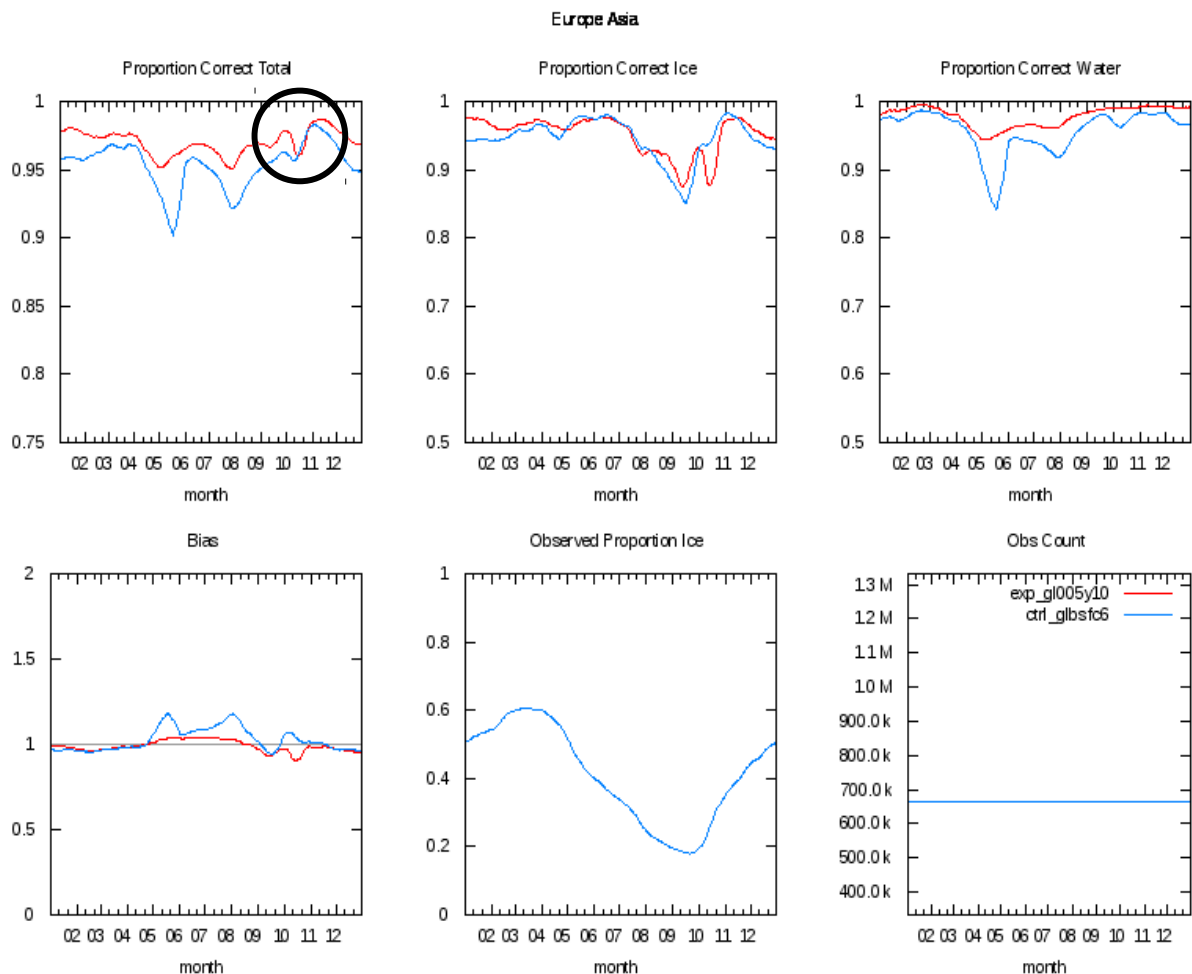
SSMI Nov 01, 18 UTC



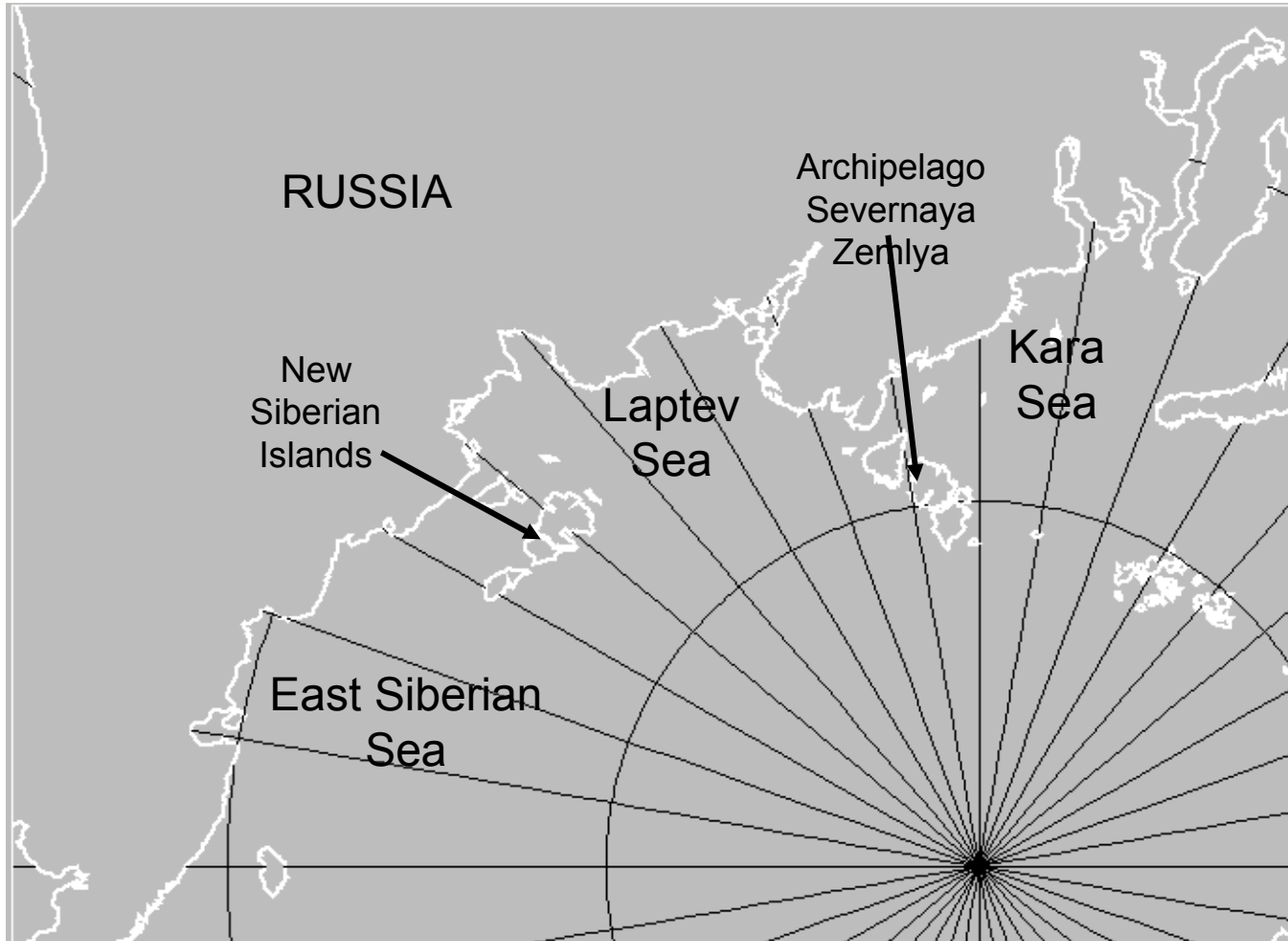
IMS Nov 02, 00 UTC



Europe/Asia ~Oct 16 to Oct 20

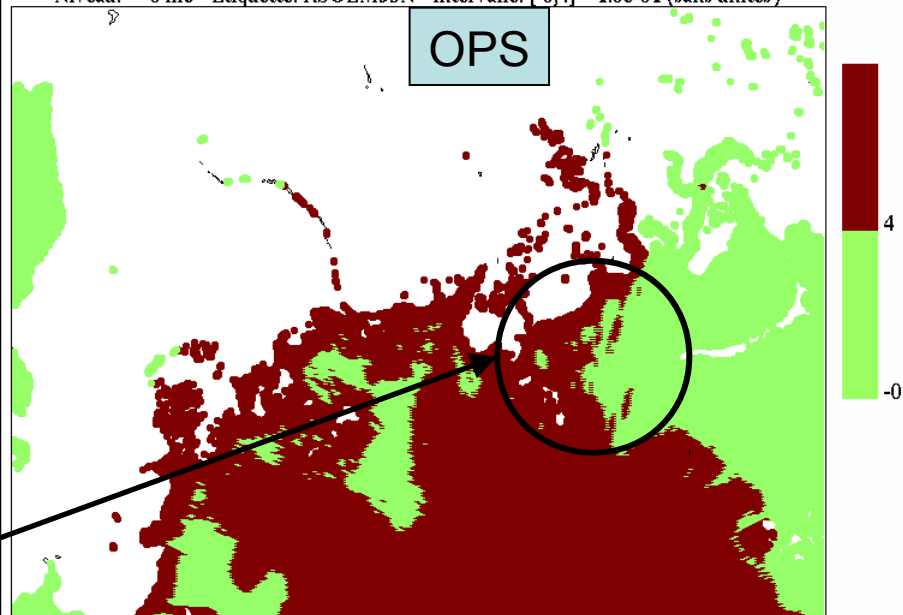


What to look for



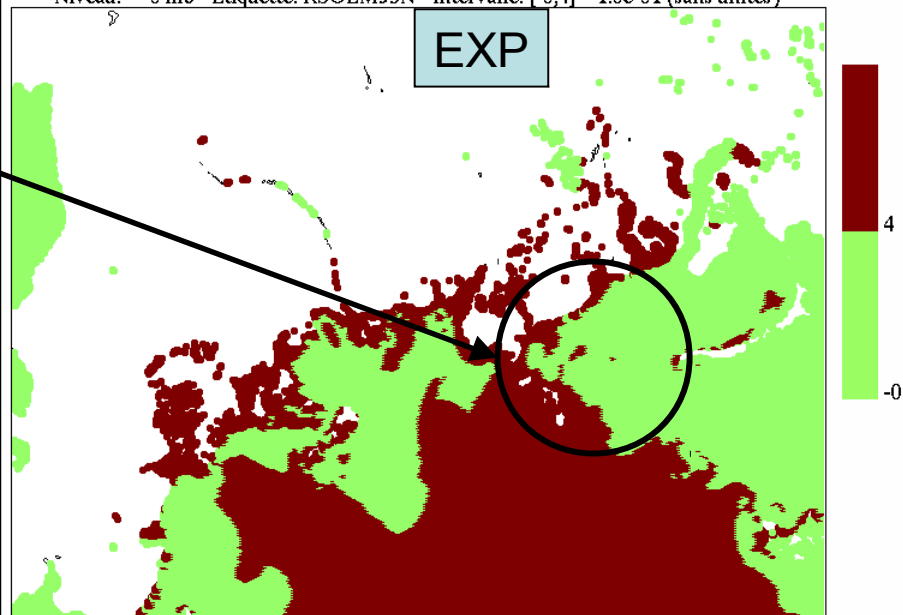
Europe/Asia – Oct 18 – 00 UTC 40% threshold

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



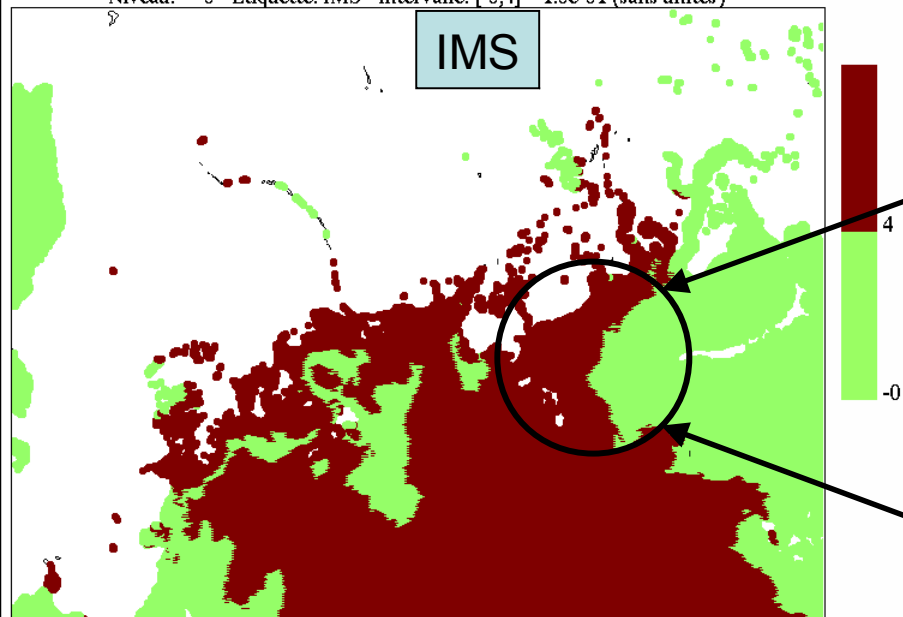
Analyse valide 00:00Z le 18 octobre 2010

Fraction de glace continue
Niveau: 0 mb - Etiquette: RSGEM53N - Intervalle: [-0,4] * 1.0e-01 (sans unites)



Analyse valide 00:00Z le 18 octobre 2010

Fraction de glace
Niveau: 0 - Etiquette: IMS - Intervalle: [-0,4] * 1.0e-01 (sans unites)

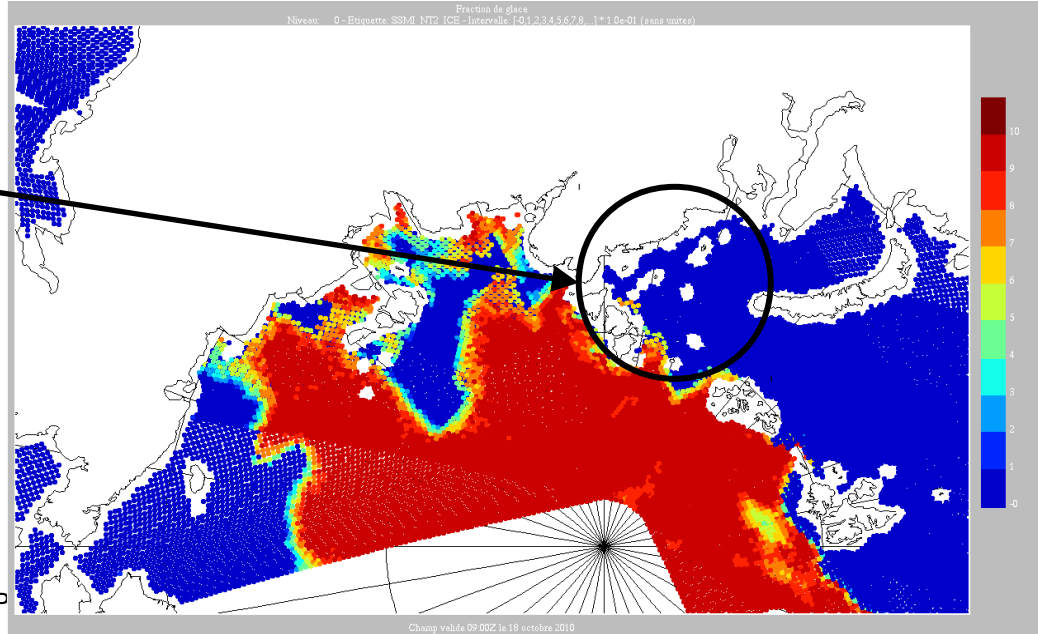
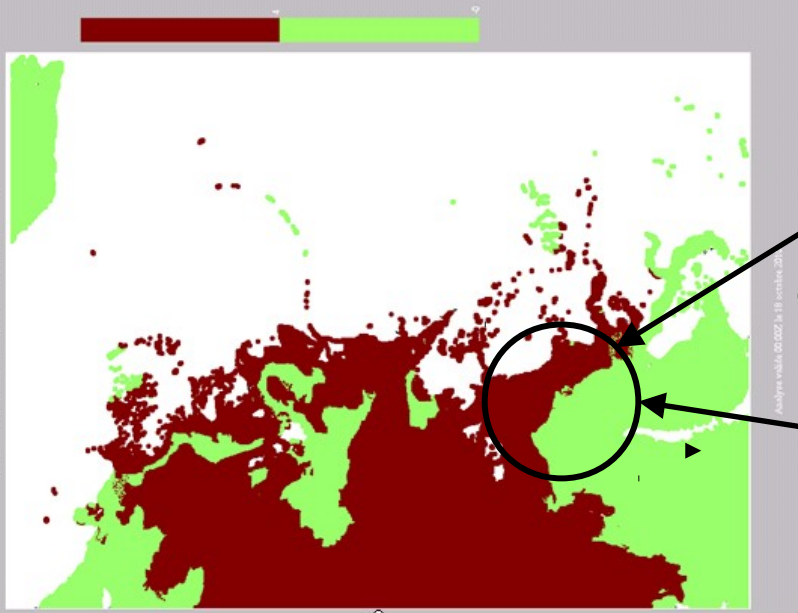
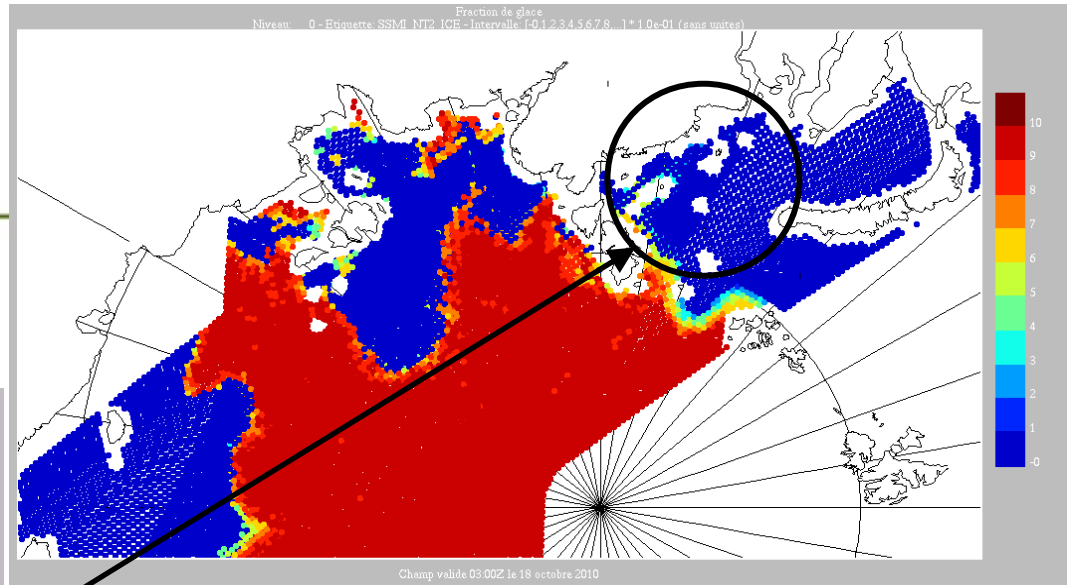


Analyse valide 00:00Z le 18 octobre 2010



SSM/I – NT2 Oct. 18, 00 UTC

IMS Oct. 18, 00 UTC



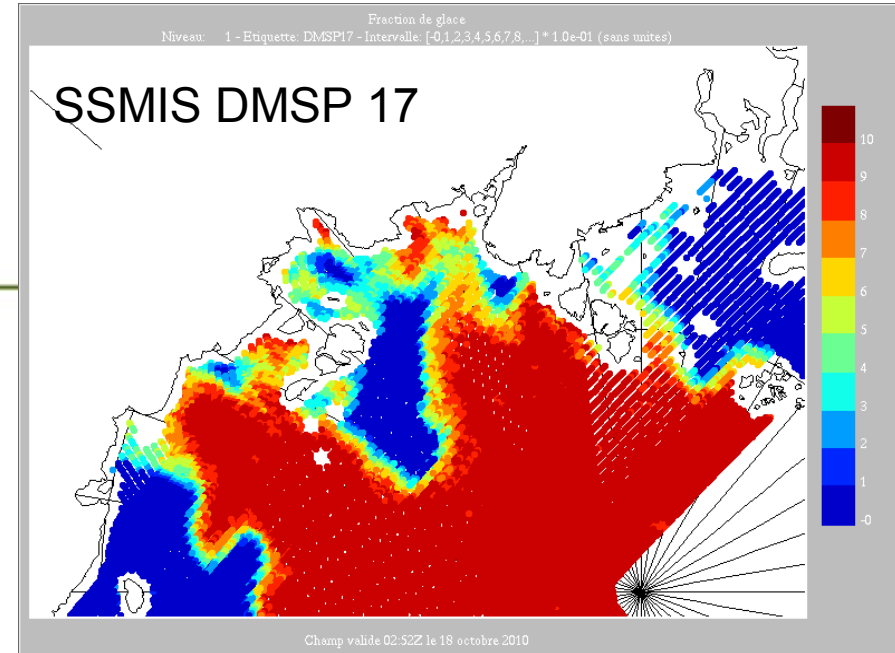
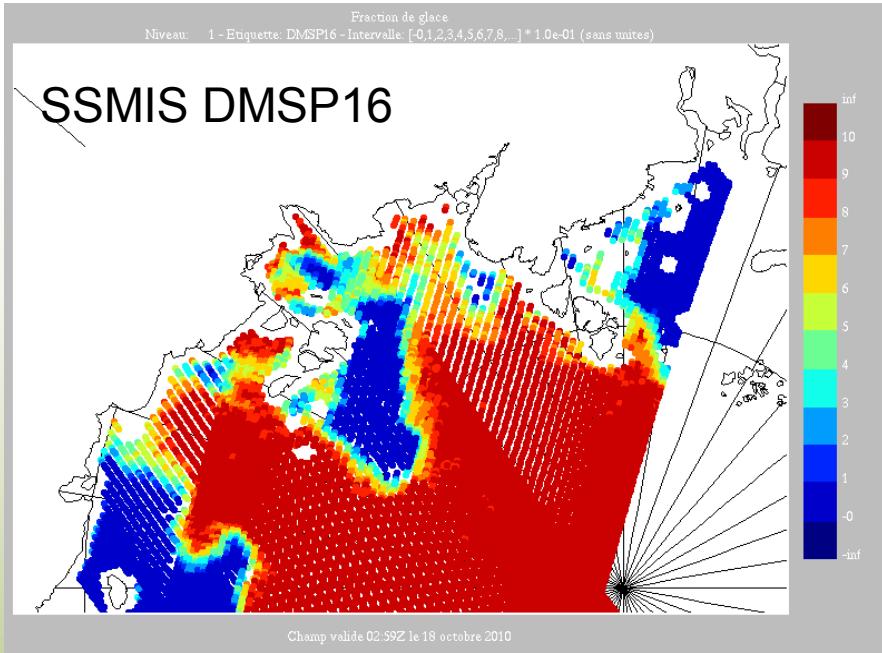
SSM/I – NT2 Oct. 18, 06 UTC P



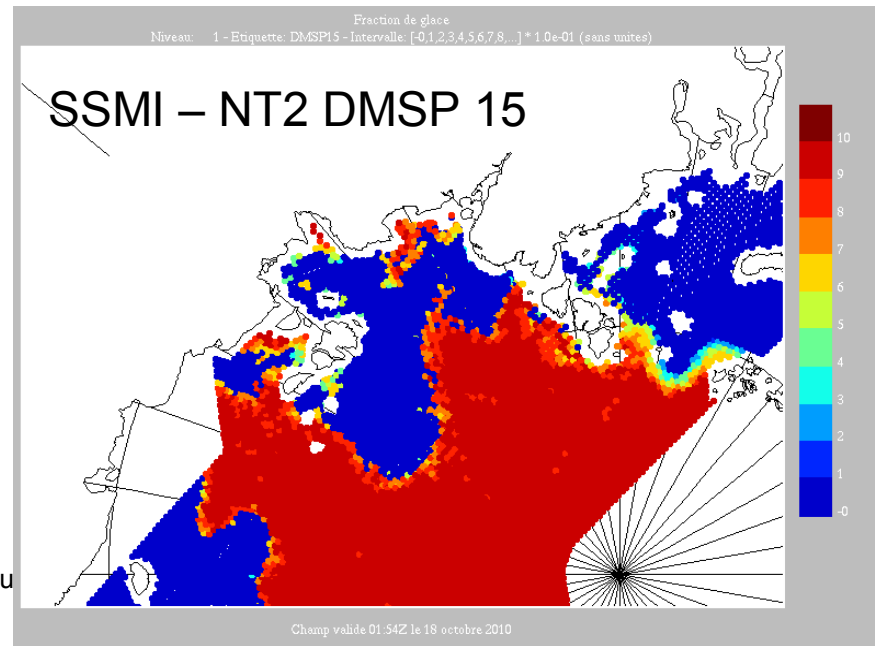
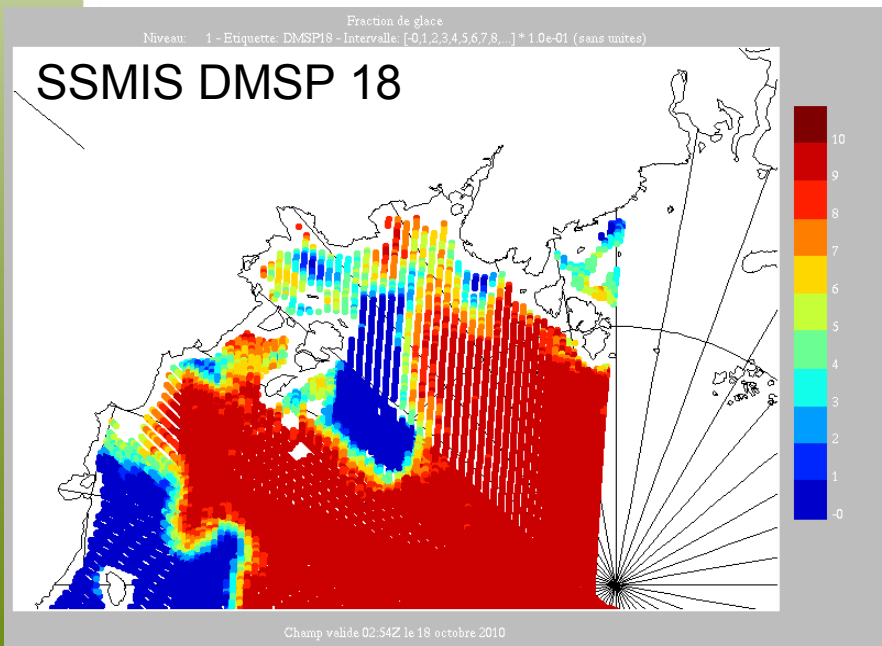
Environment
Canada

Environnement
Canada

Canada



Valid Oct. 18 - 00 UTC



- Ju

Verification summary

- Based on 3 different types of objective verifications, this new ice analysis is significantly better than the operational ice analysis, especially during summer
- Through case studies we also found that the new ice analysis is better than the operational ice analysis...but we also found some minor weaknesses...
- For both systems, scores are generally worse during summer than winter:
 - Water over ice results in underestimated ice concentration retrievals from passive microwave data
 - Quality control rules were added to the 3D-Var system to reject such satellite observations
 - Consequently, the ice analysis may keep ice cover longer than reality during period of melting – other types of satellite observations should help

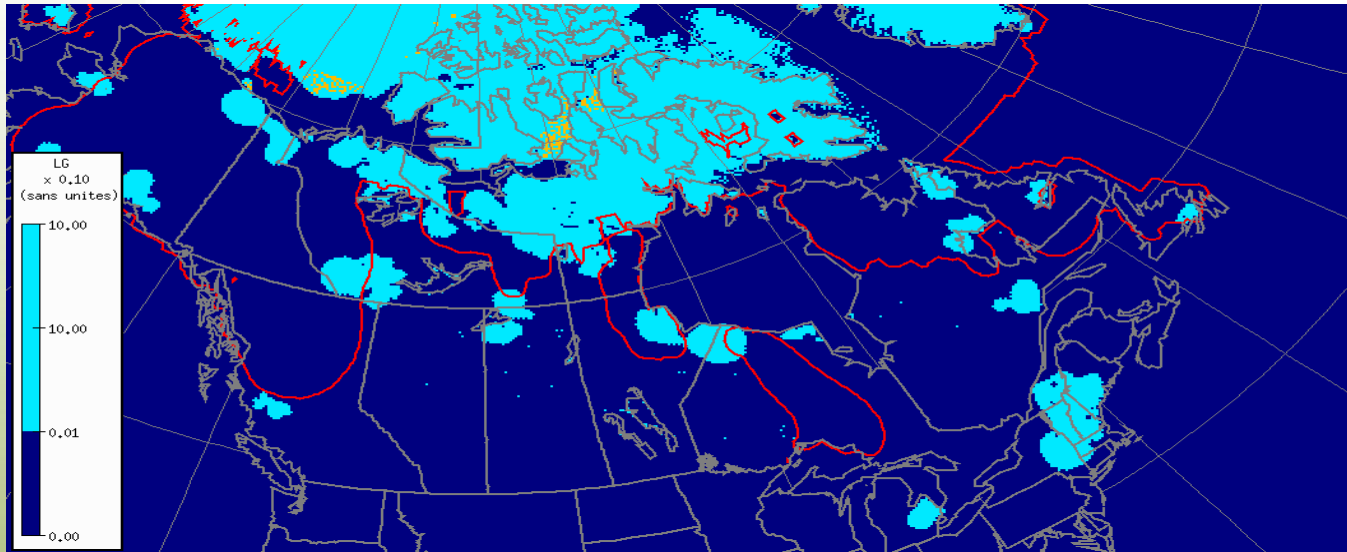
Return to climatology for lakes

- Relying on climatology for the unobserved lakes is helpful, but results highly dependent on quality and relevance of climatology
- The introduction of high-resolution observations (SAR, AVHRR, etc) will eventually allow us to get rid of this climatology



Ice in August?

Ice extent 1%

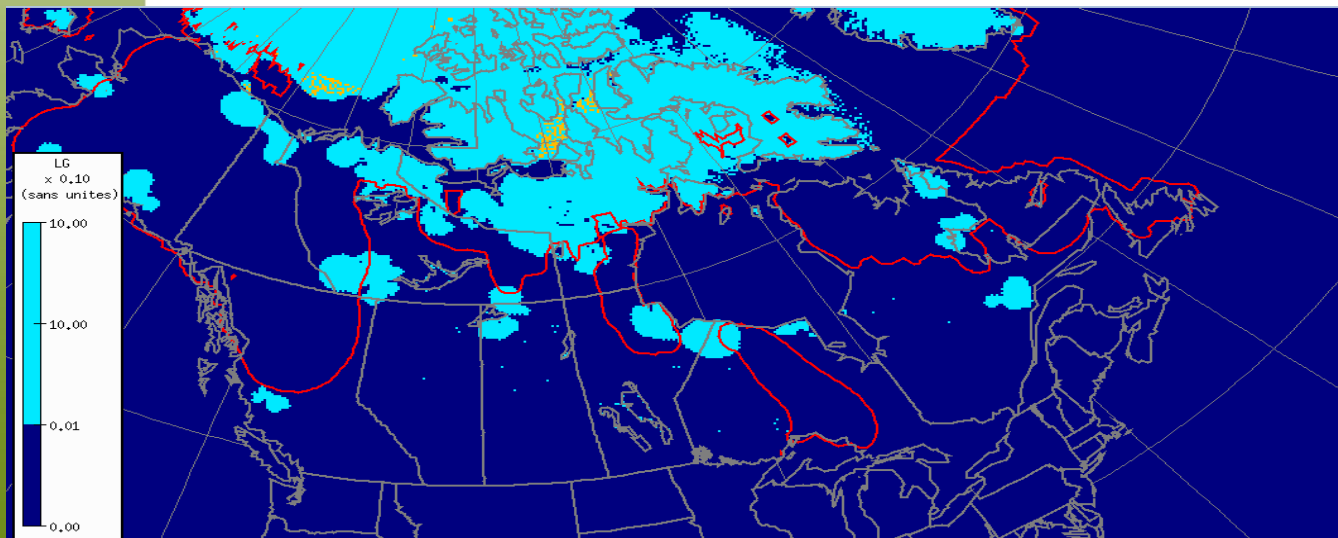


OPS 35km red

EXP 10km color

With original climatology

Aug 1st, 2010

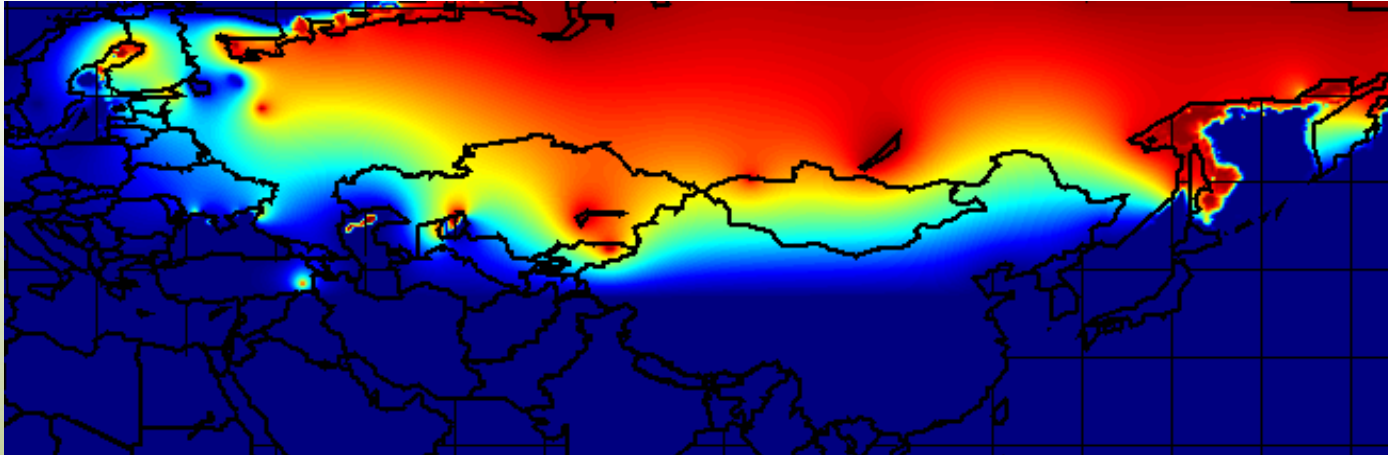


With an improved climatology
(applying freezing-degree-day model)

The beauty of this new ice analysis

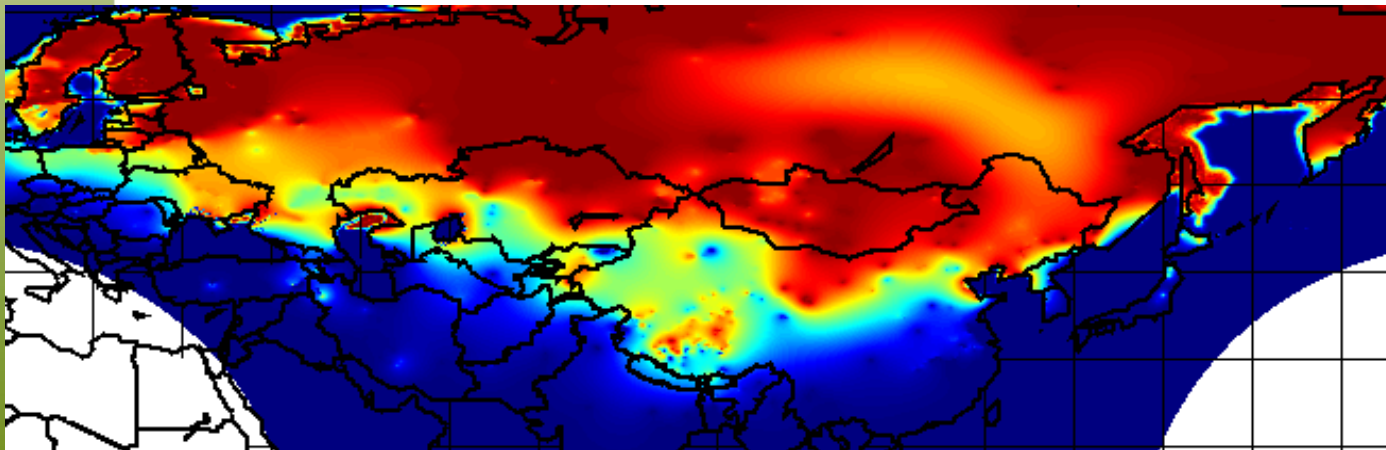


Lakes over Tibet



Operational

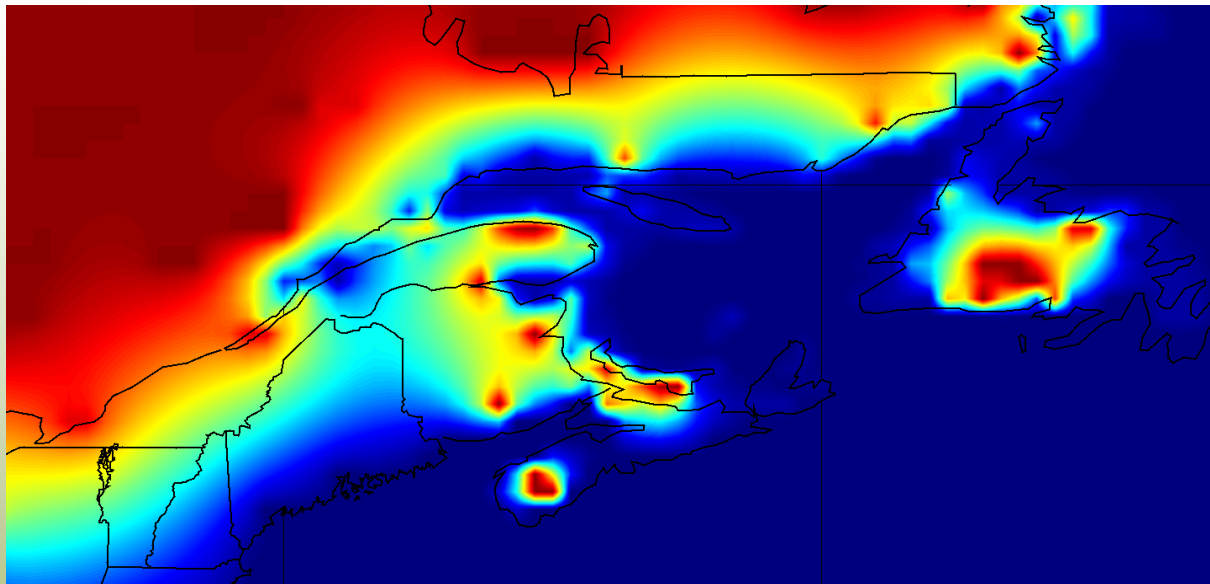
Jan 31st, 2010



New ice analysis

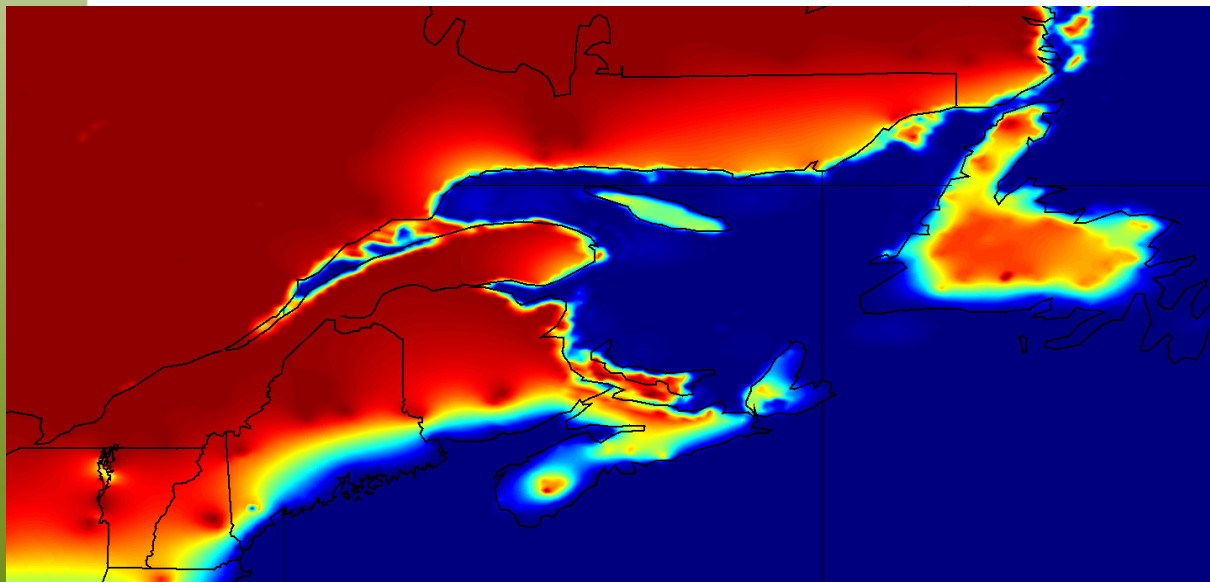


East coast



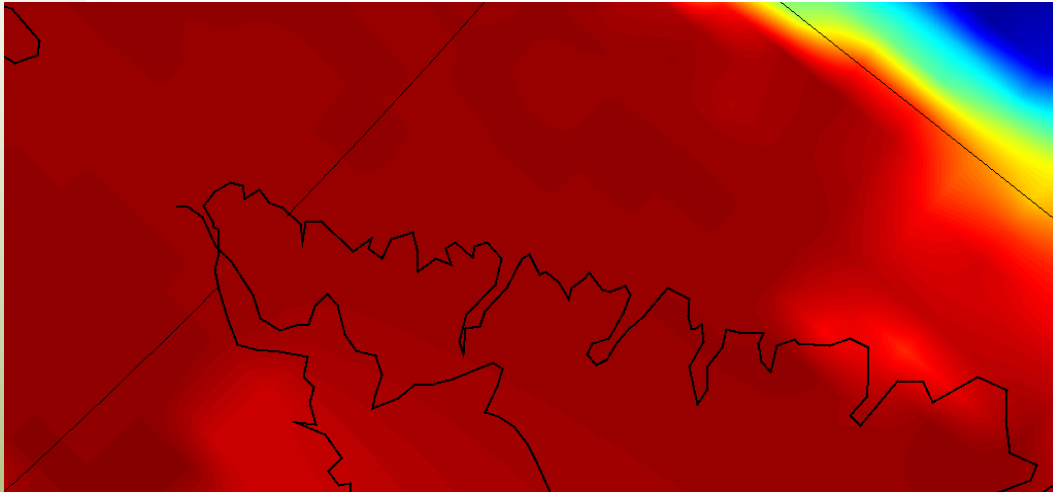
Operational

Jan 31st, 2010



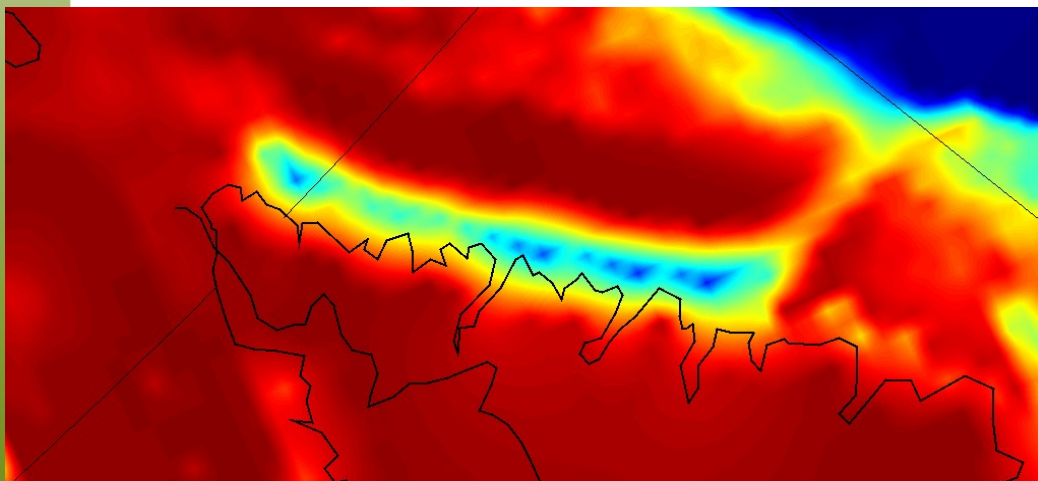
New ice analysis

Off northern Labrador coast



Operational

Jan 31st, 2010



New ice analysis

12



Environment
Canada

Environnement
Canada

Canada

What is next?

- Proposal to CPOP for implementation in « experimental mode »
- Encourage users of ice analysis to test their systems with this new ice analysis: GDPS, RDPS, GEPS, etc.
- Develop « operational » monitoring tool and verification process
- Documentation
- Continue to improve the analysis for future upgrades:
 - better climatology for lakes
 - assimilation of new data: ASCAT, AMSR-2, etc
 - more case studies

Thanks/Merci



Extra slides



Known factors to affect verification differences between the two systems

- Migration LINUX in 2010:
 - + April 17 to May 26...operational ice analysis did not see SSMI...problem with etiket for TM...this had an impact especially over the Antarctic
 - + up to July 08...few occasions in the past 2 months that bulletins from CIS were not used in the operational ice analysis...change in the manipulation of CIS bulleting done at CMC...could not see any significant impact

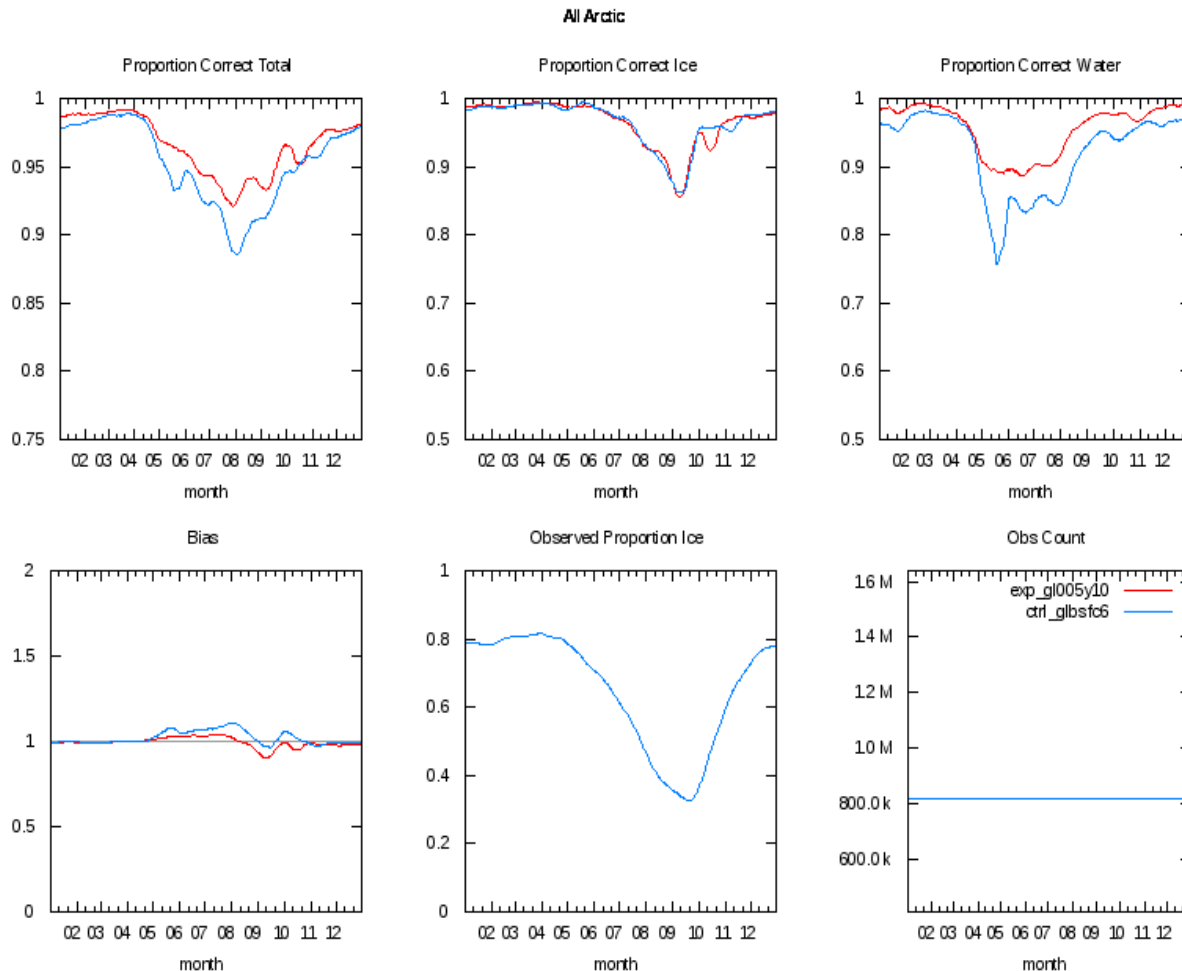
Known factors to affect verification differences between the two systems

- Missing SSMIS:
 - + started to process operationally SSMIS at CMC on Nov 2nd 2010...so database for 2010 needed to be built by research team
 - + few periods where SSMIS were missing for several days...
 - * March 30-31
 - * April 18-19
 - * Mai 18-19-20
 - * Aug 23
 - * Oct 12/18z til Oct 18/18z
 - * Nov 02

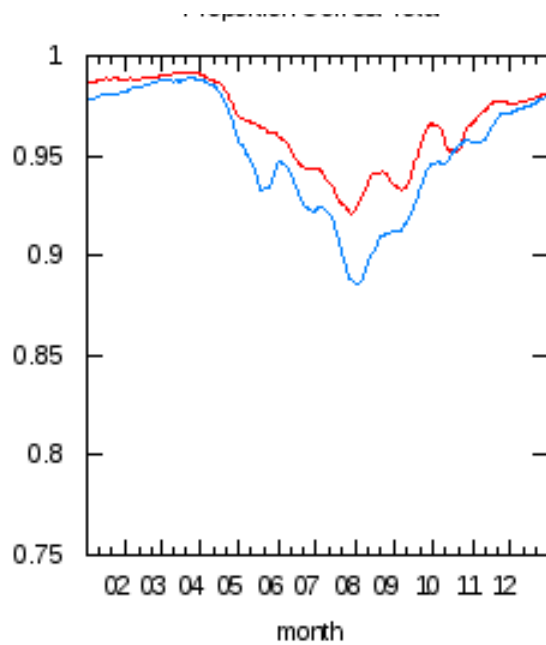
Known factors to affect verification differences between the two systems

- Satellite retrieval different between the 2 systems:
 - + AES York for the operational ice analysis
 - + NT2 for the new ice analysis
- Climatology and how it is apply is different:
 - + OPS...apply a climatology when no observations is available...over lakes and sea
 - + EXP... apply a climatology only over lakes when no observations are available
- Resolution:
 - + OPS...2 analysis done...GL at 100km....LG at 35km
 - + EXP...1 analysis done at GL 10km...than produce LG at 10km and at 35km(to compare with OPS)
- Verification IMS...looking at ice extent of 40%...so even if 35% is analysed, it will be considered as a « missed »

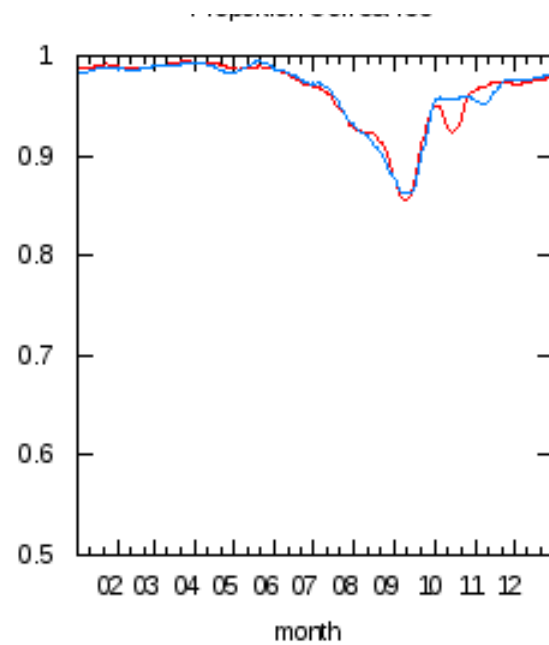
All Arctic



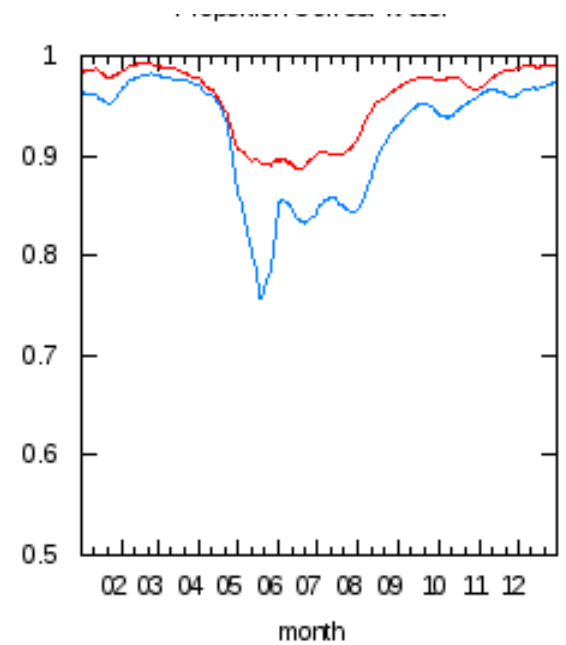
All Arctic



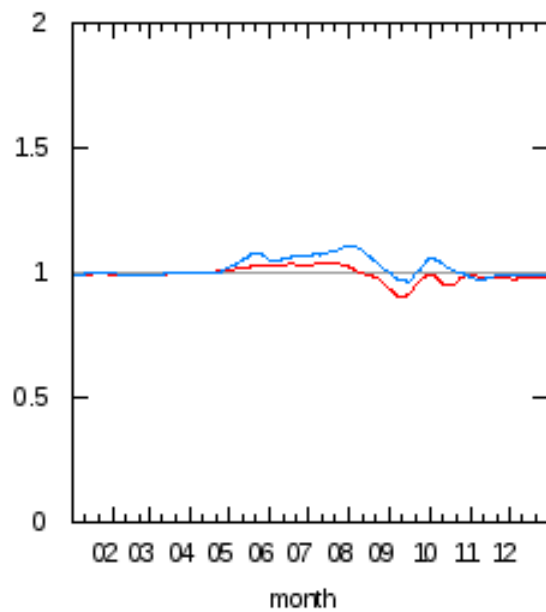
Bias



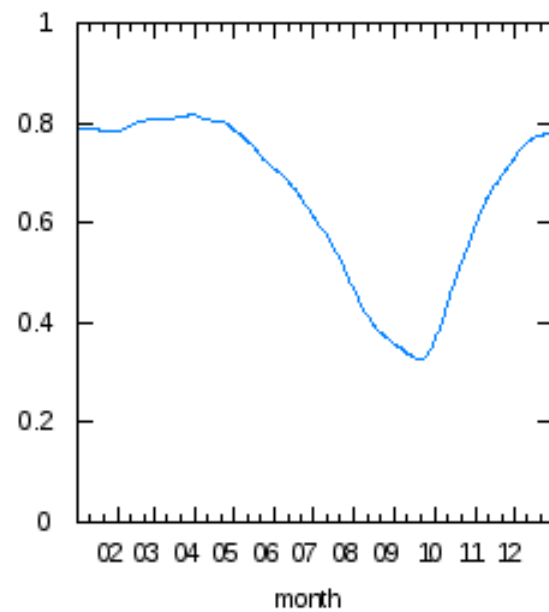
Observed Proportion Ice



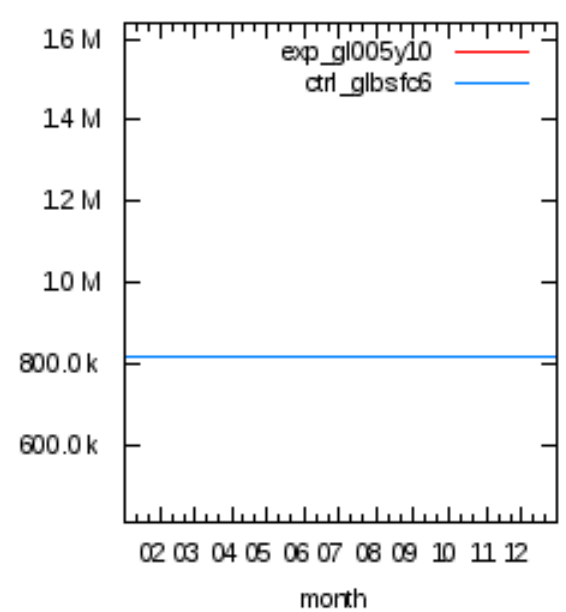
Obs Count



Bias

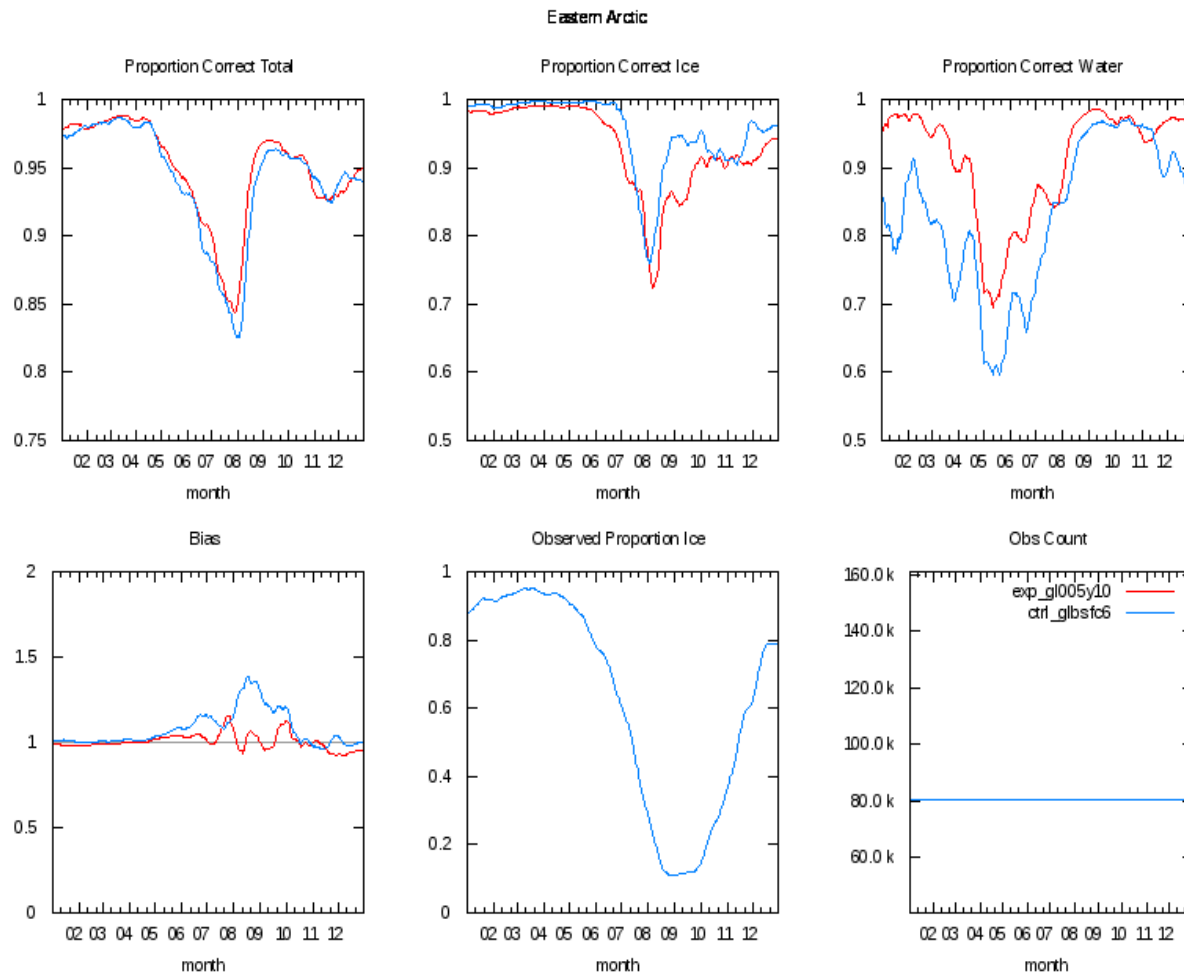


Observed Proportion Ice

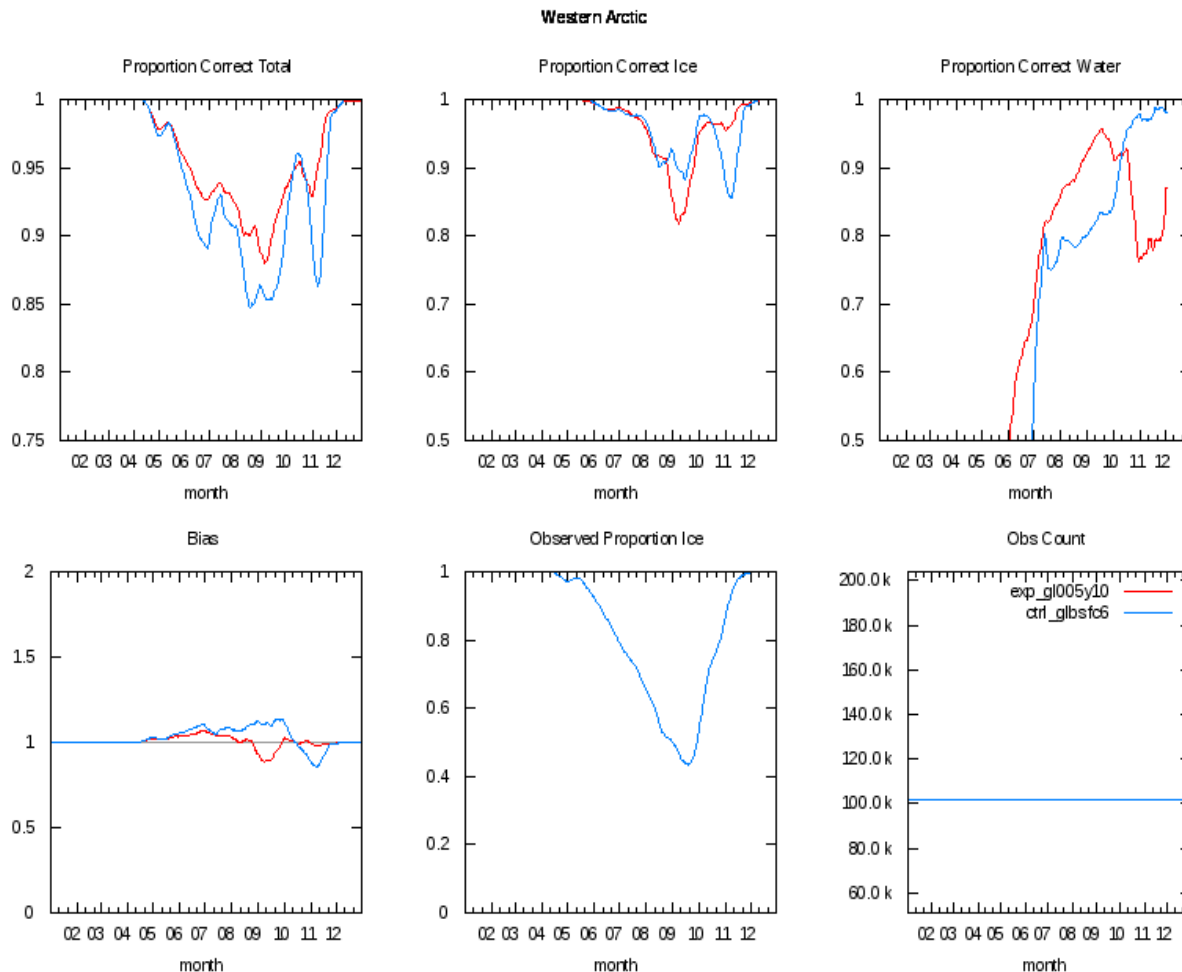


Obs Count

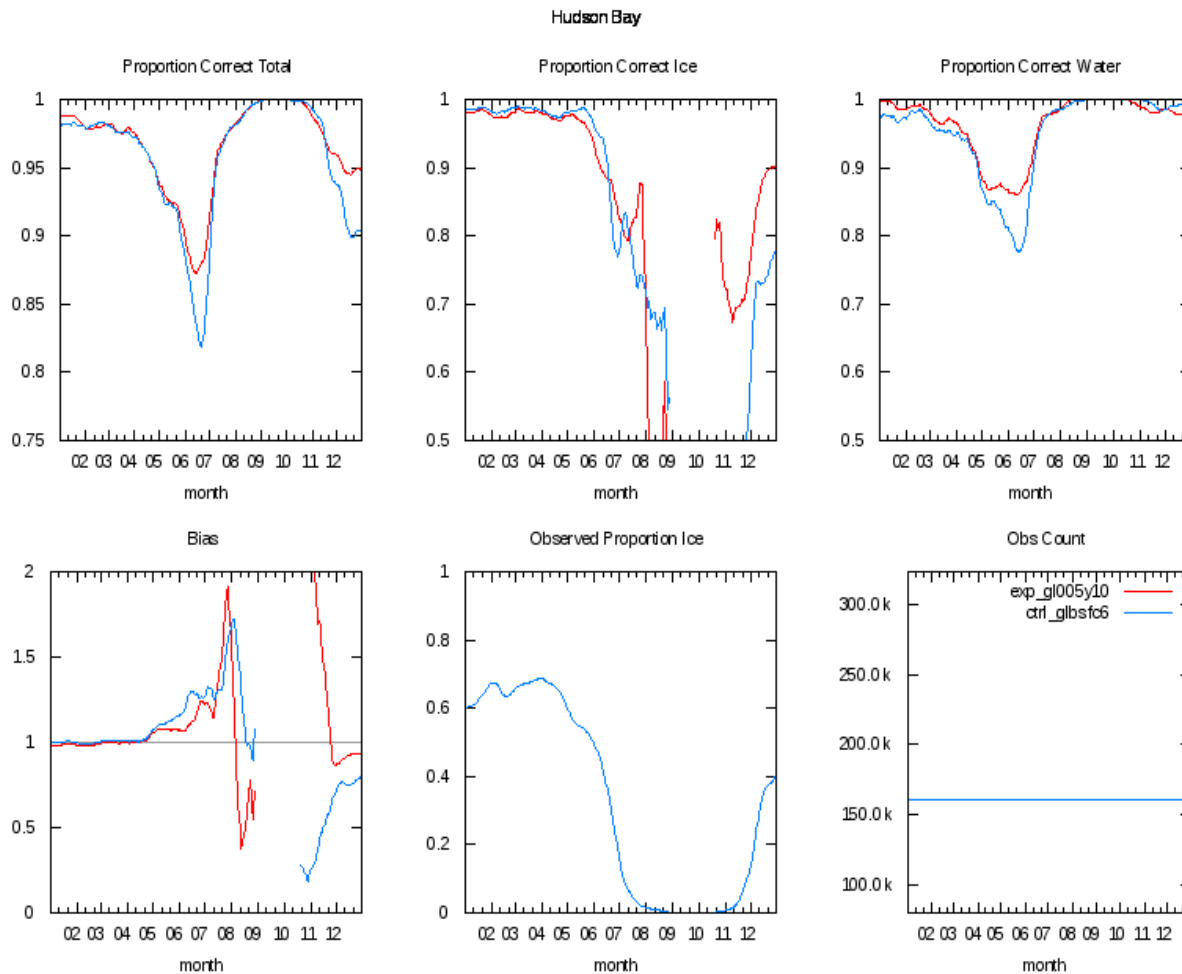
Eastern Arctic



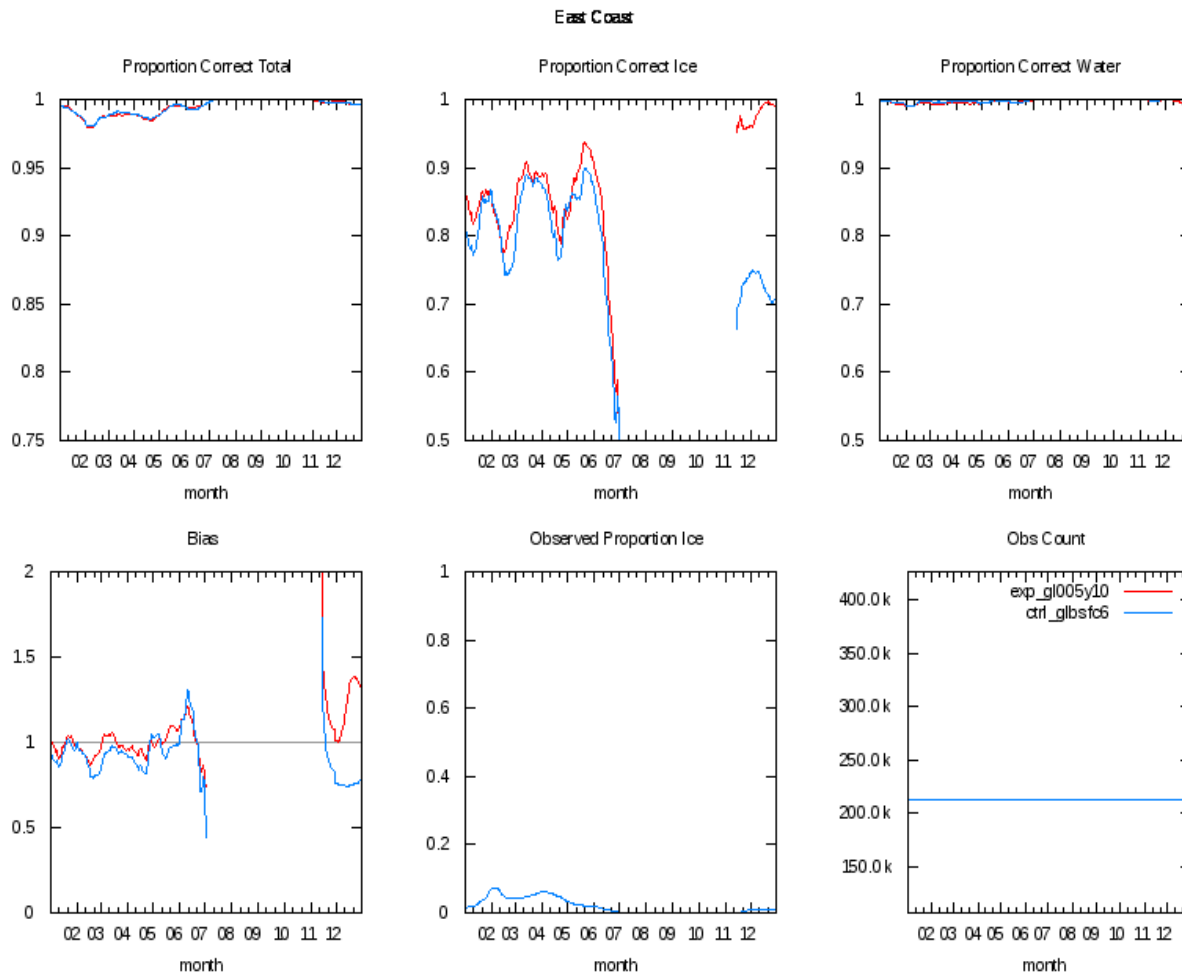
Western Arctic



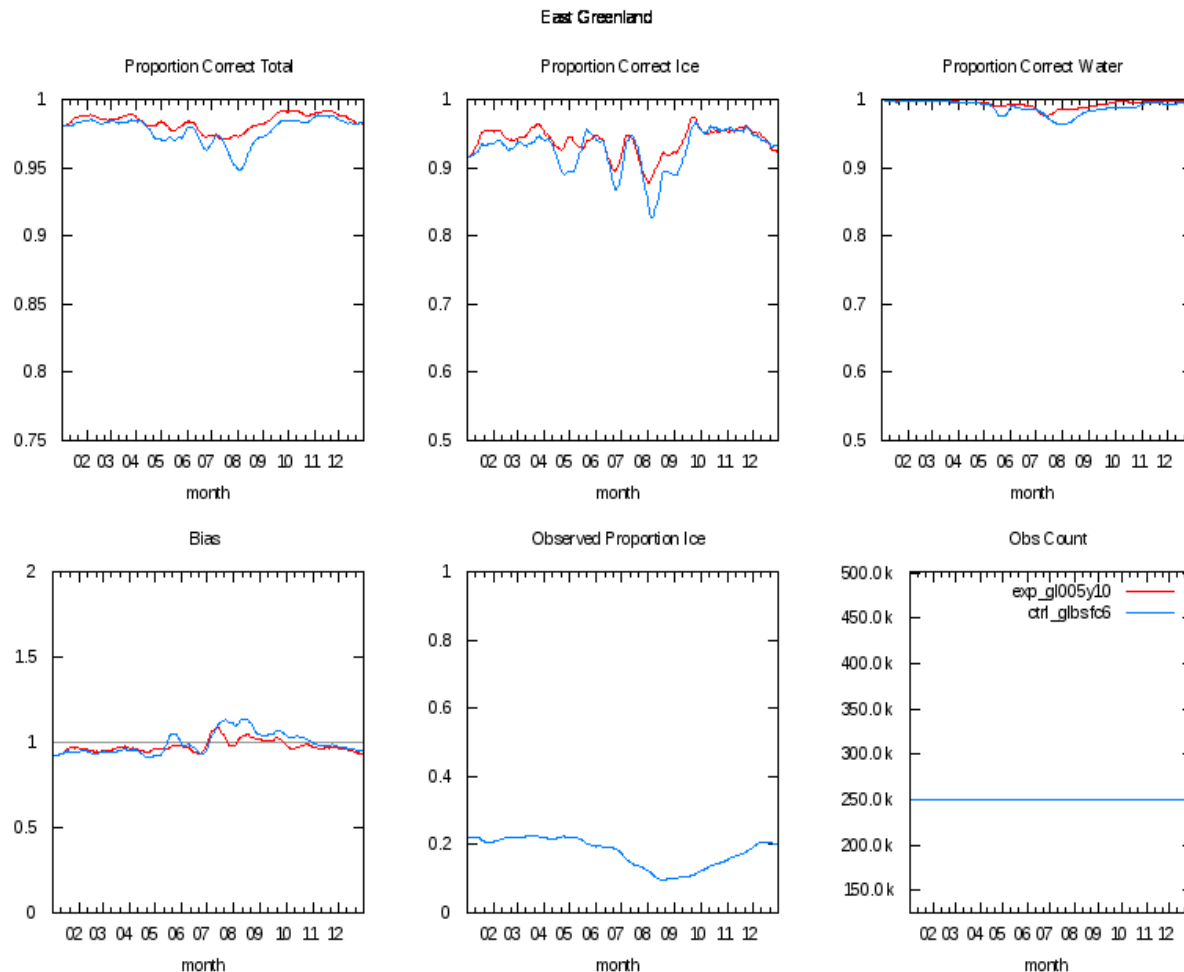
Hudson Bay



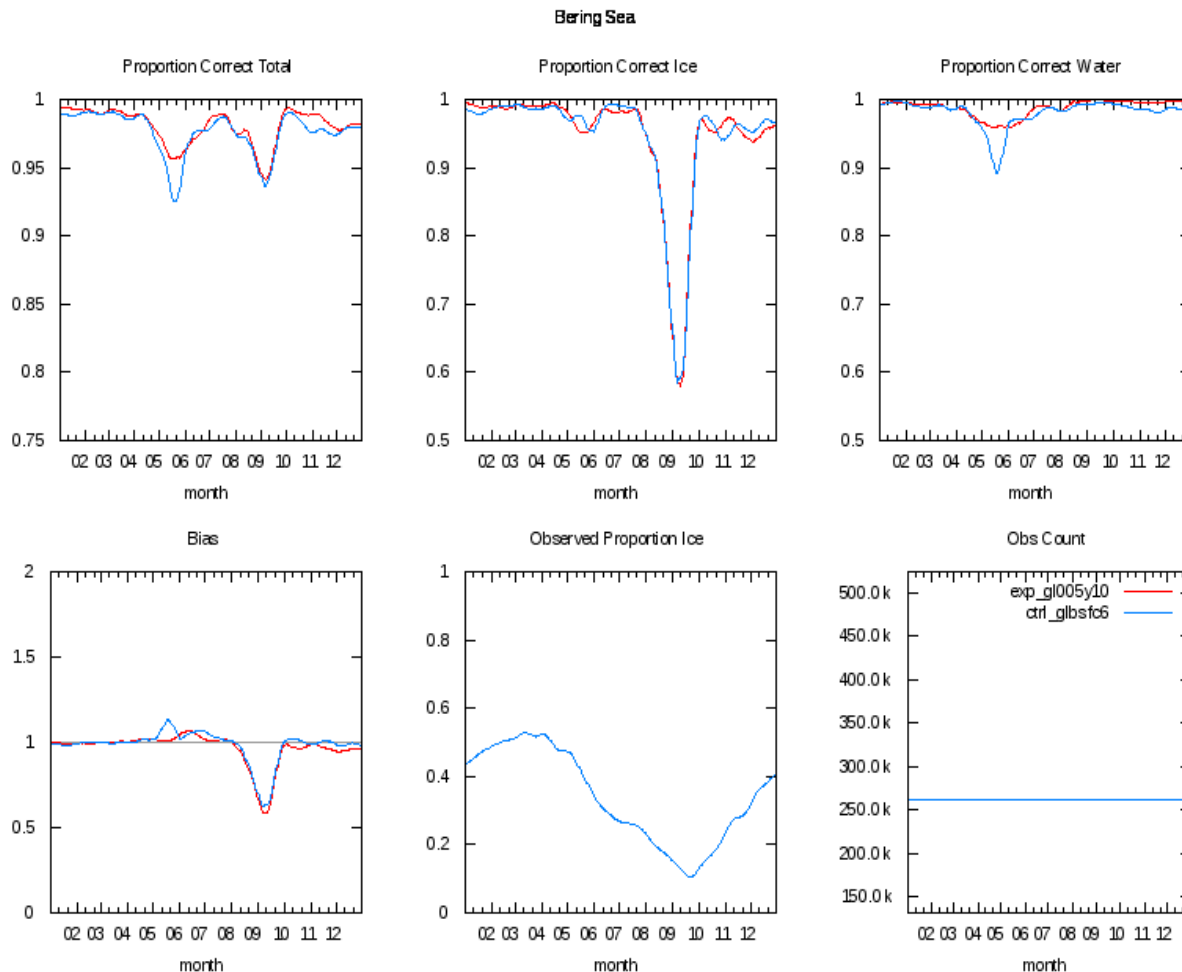
East Coast



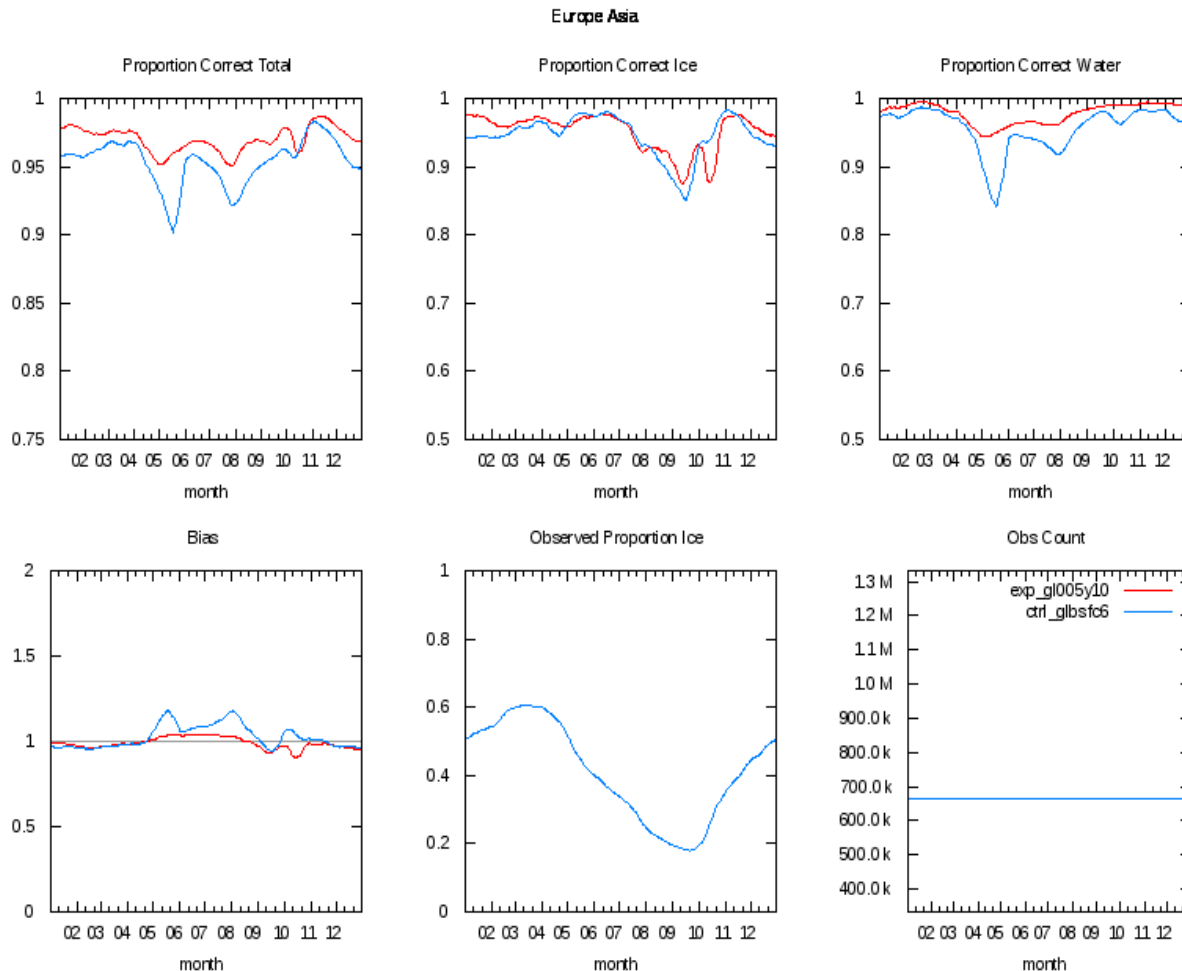
East Greenland



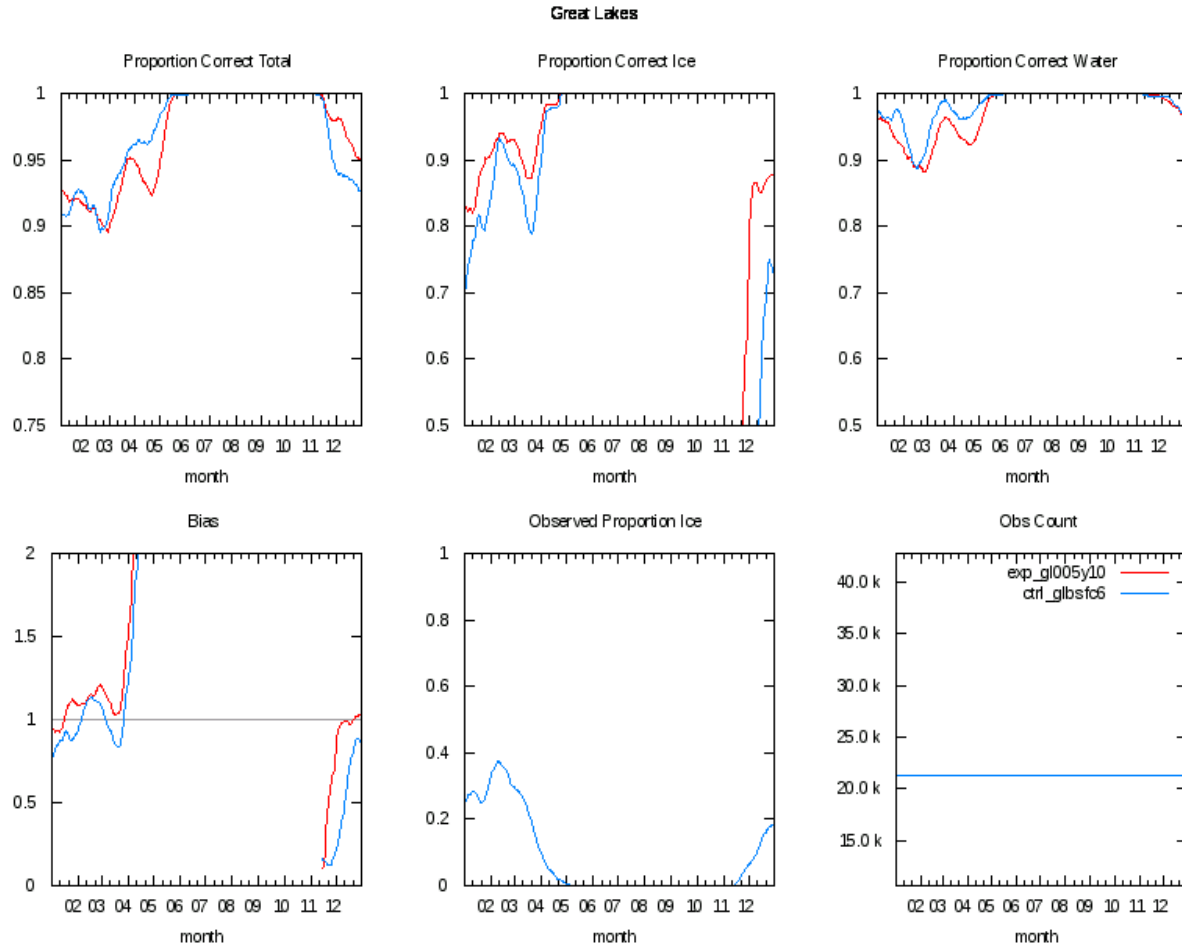
Bering Sea



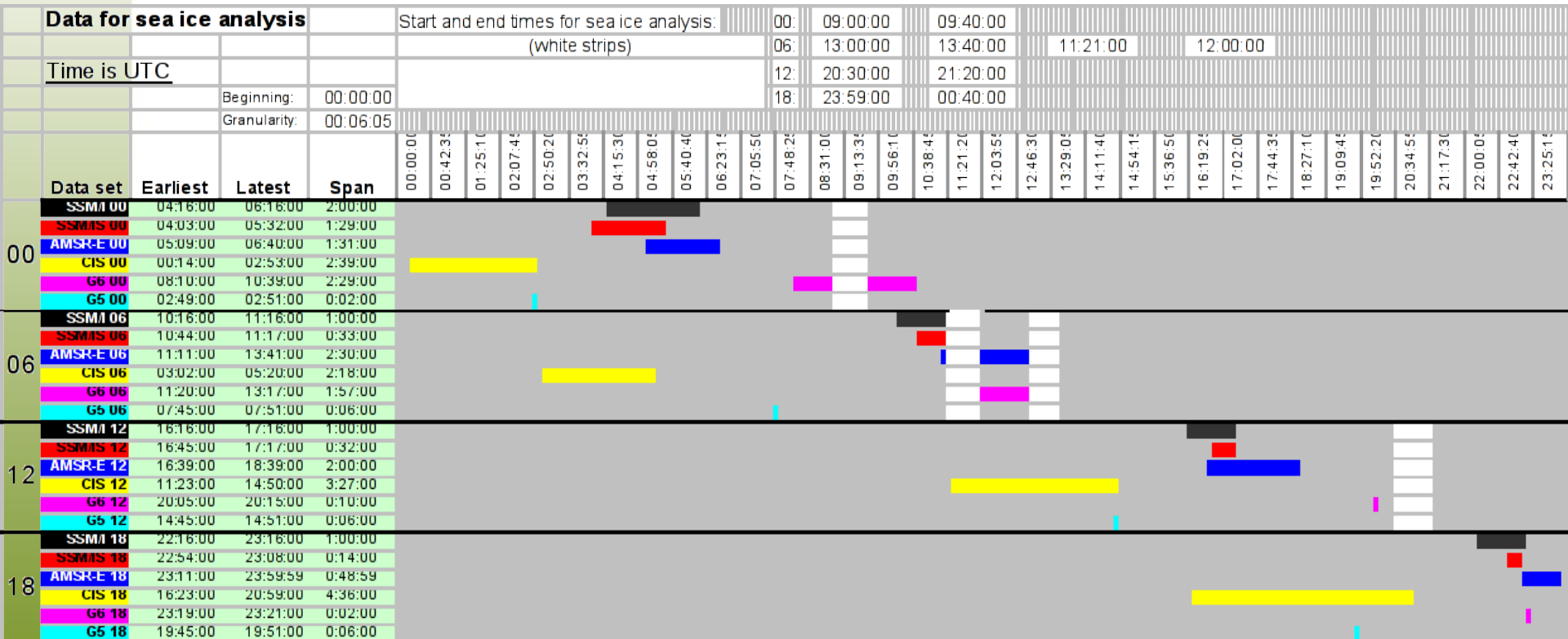
Europe - Asia



Great Lakes



Data for sea ice analysis



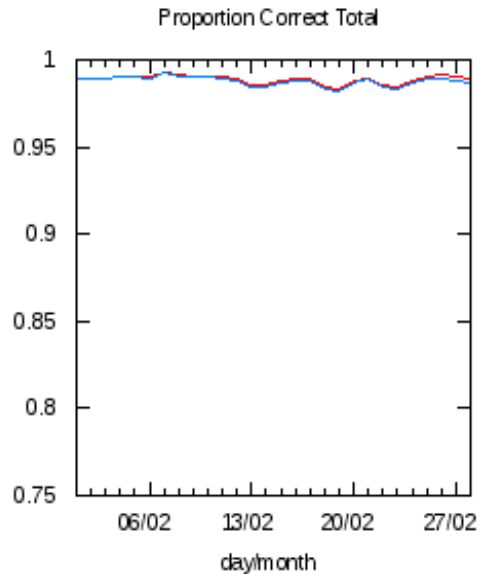
Testing TM 0.2deg

- Tested for 2 months: FEB and AUG
- QC for satellite data used TM 0.2deg

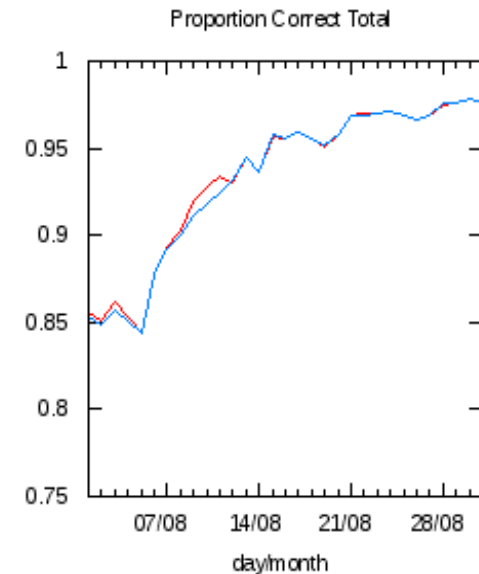


TM 0.2deg

East Greenland
Feb



Eastern arctic
Aug



Blue = EXP with TM 0.3deg
Red = EXP with TM 0.2deg

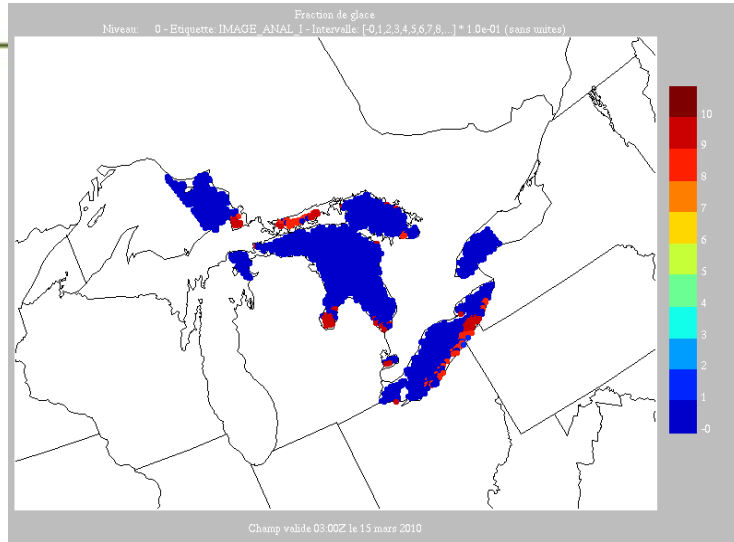
Page 72 – June 14, 2012



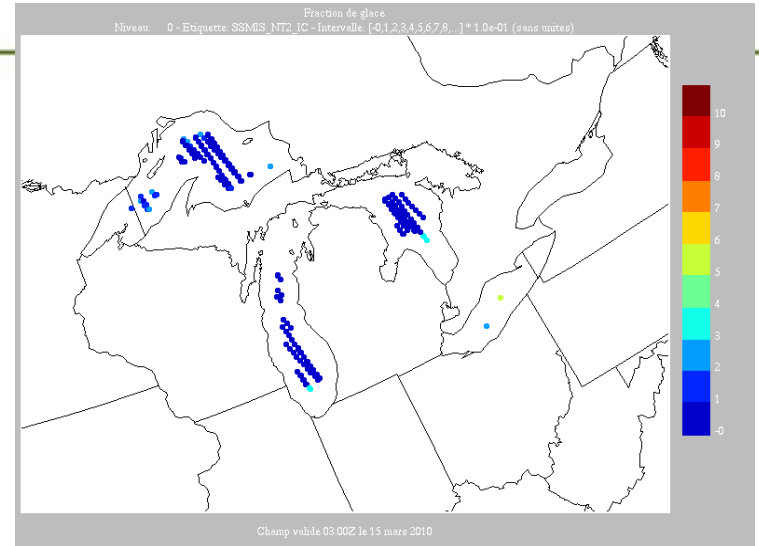
Great Lakes March 15 00 UTC

40% threshold

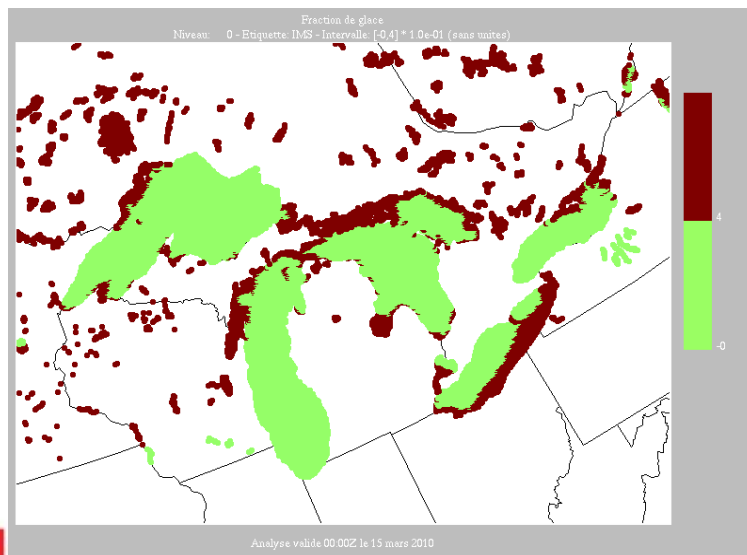
CIS



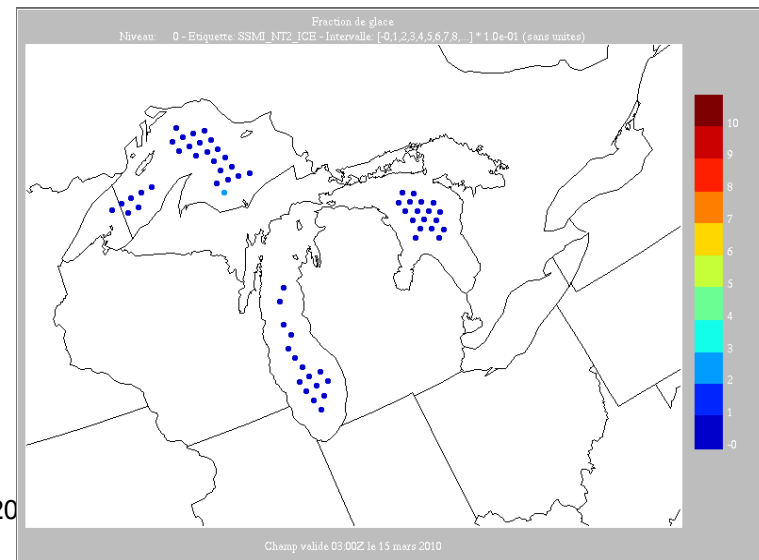
SSMIS



IMS



SSMI



3 - June 14, 20

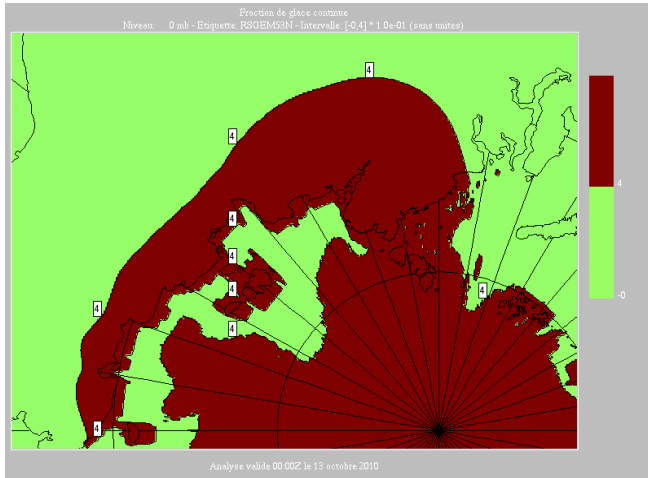
Europe - Asia



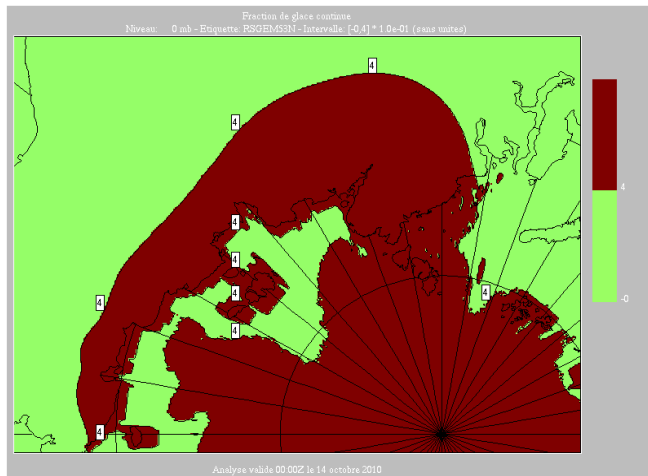
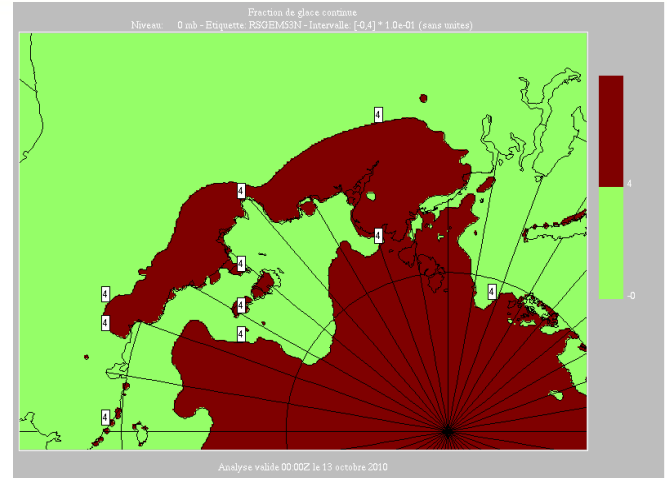
OPS

VS

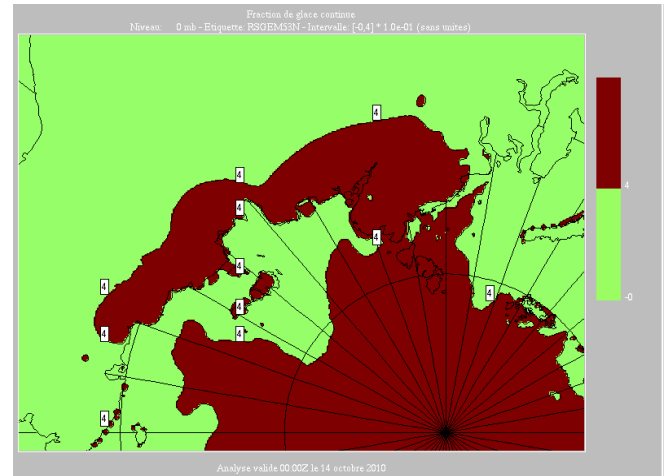
EXP



13 oct.
00 UTC



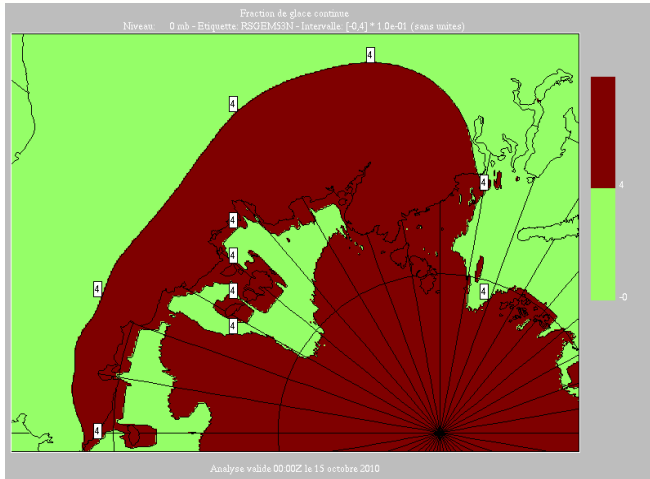
14 oct.
00 UTC



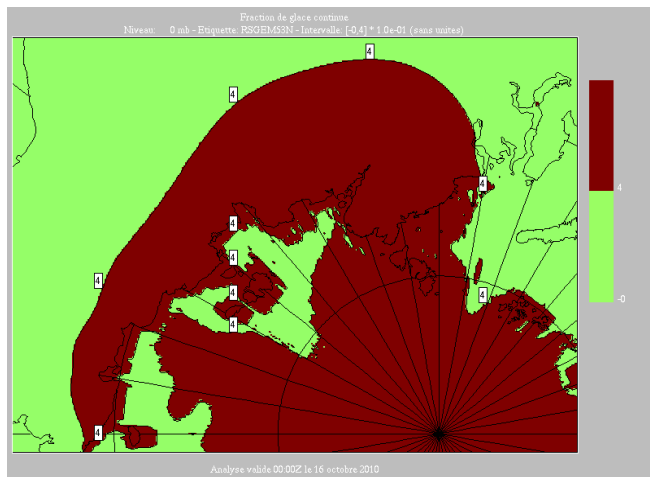
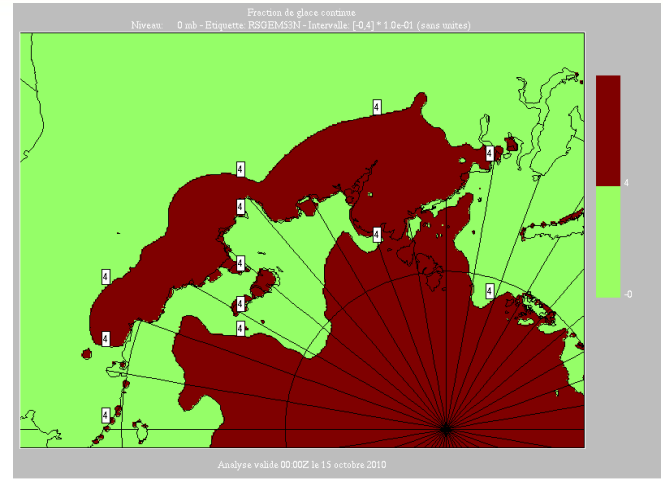
OPS

VS

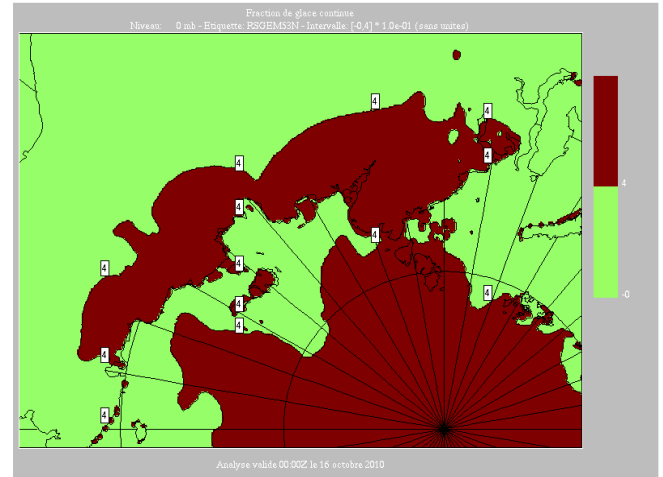
EXP



15 oct.
00 UTC



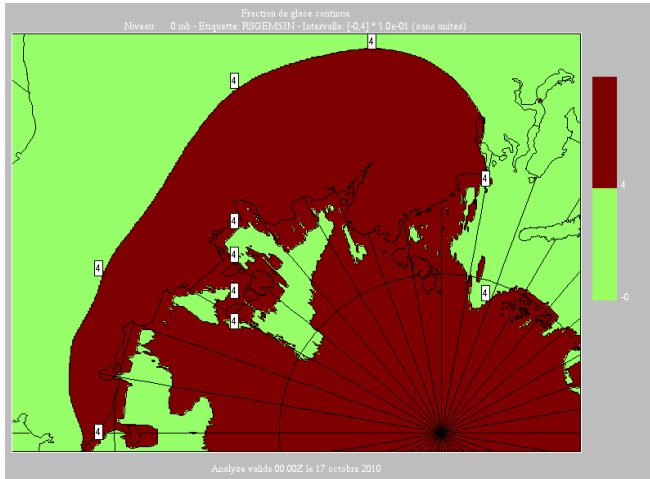
16 oct.
00 UTC



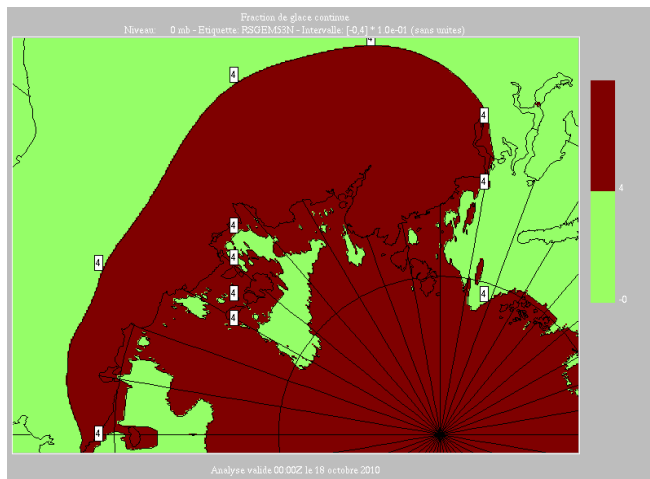
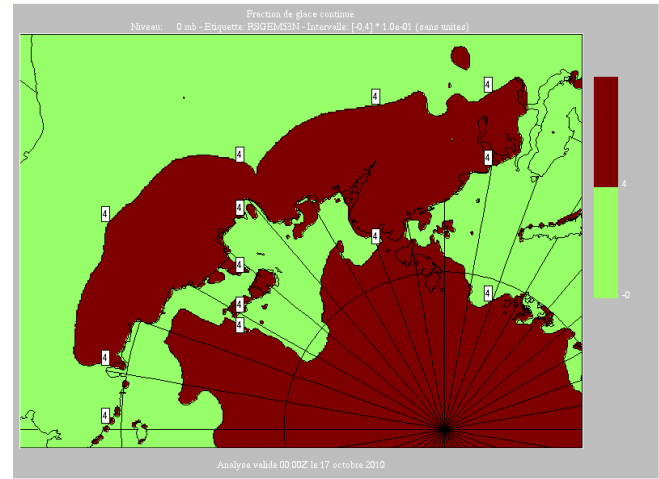
OPS

VS

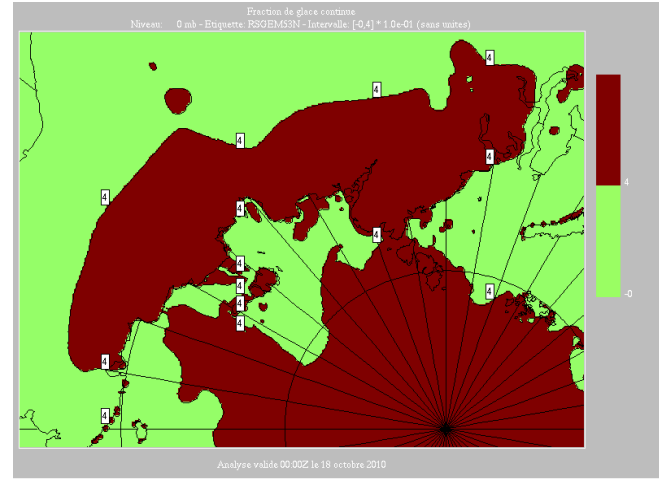
EXP



17 oct.
00 UTC



18 oct.
00 UTC

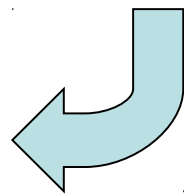
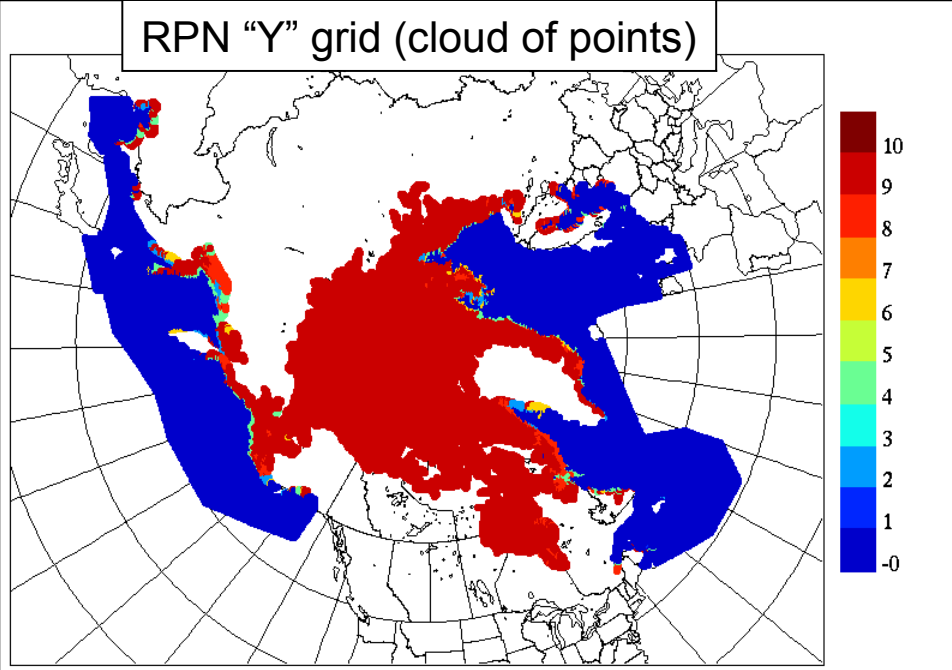
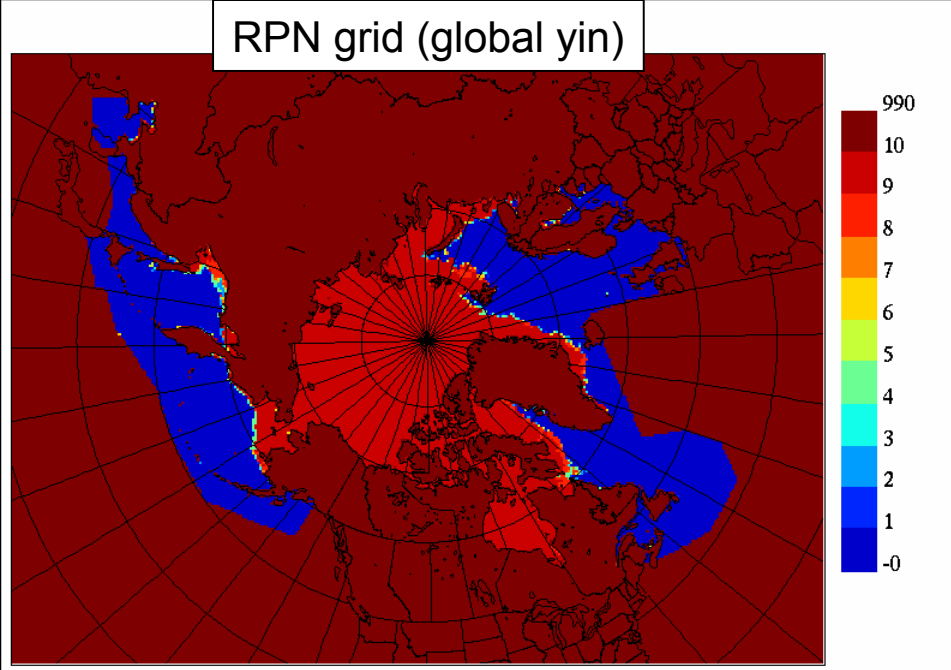
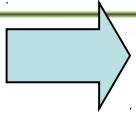
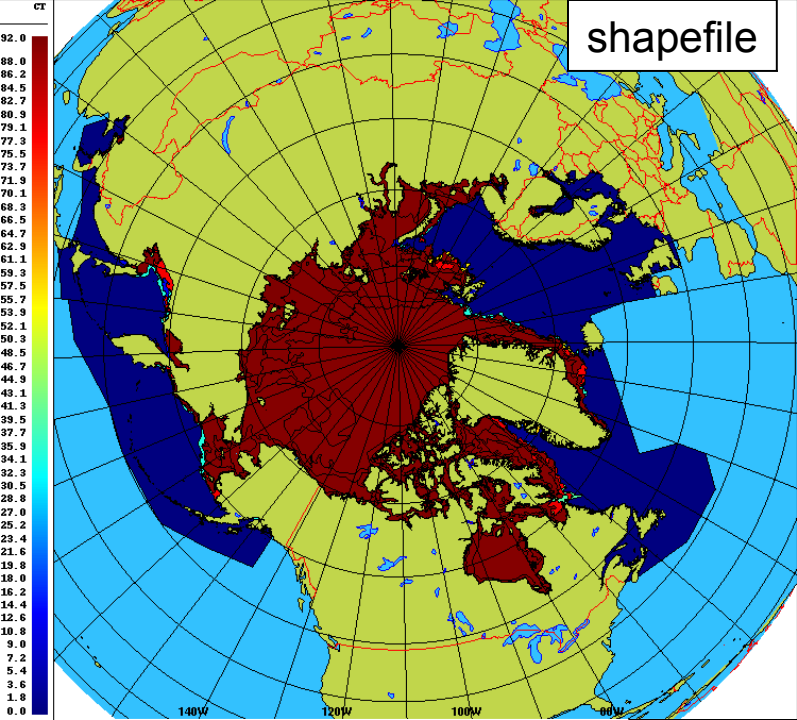


The new Global Ice Analysis

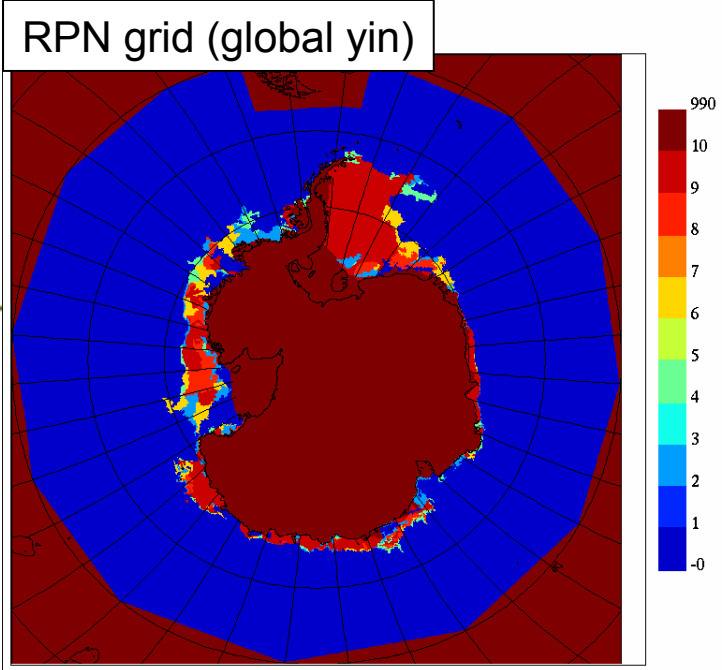
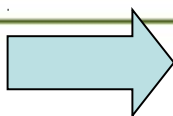
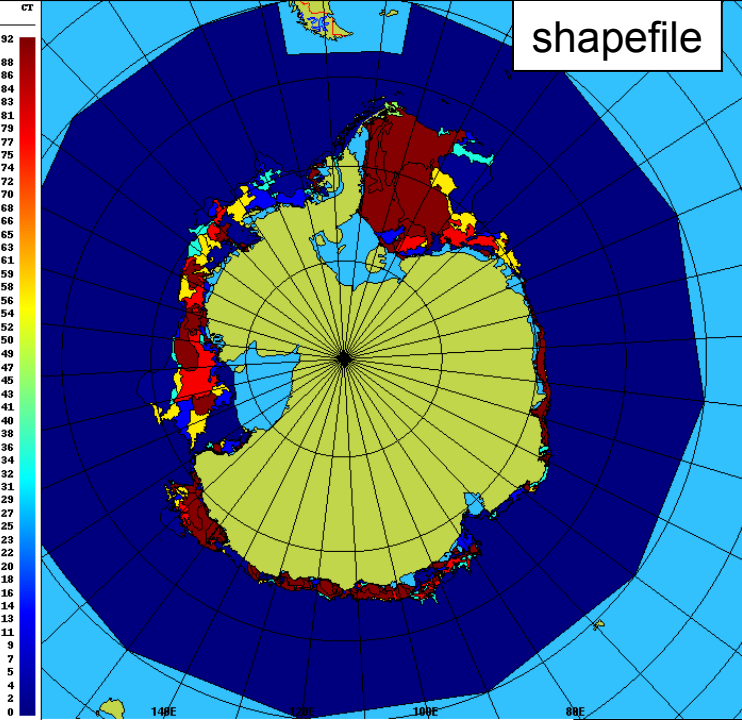
- The Global Ice Analysis System is based on the RIPS, with the following differences:
 - Yin-Yang domains (with some overlapping) at 10km resolution
 - Assimilation of passive microwave data over lakes:
 - **Need tie points for NT2 over lakes**
 - QC based on SST over lakes is deactivated (because SST over lakes is not very accurate)
 - Return to climatology over lakes (and land) where Days Since Last Obs > 8 days (= climatology after 14 days):
 - Climatology is the weekly average of IMS analyses between 2007-02-24 and 2011-02-23 inclusively
 - Sea ice is not removed over lakes when SST > 4°C
 - When making the field continuous, freshwater points are fixed

Ice climatology for lakes

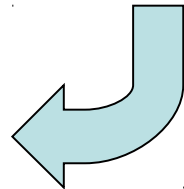
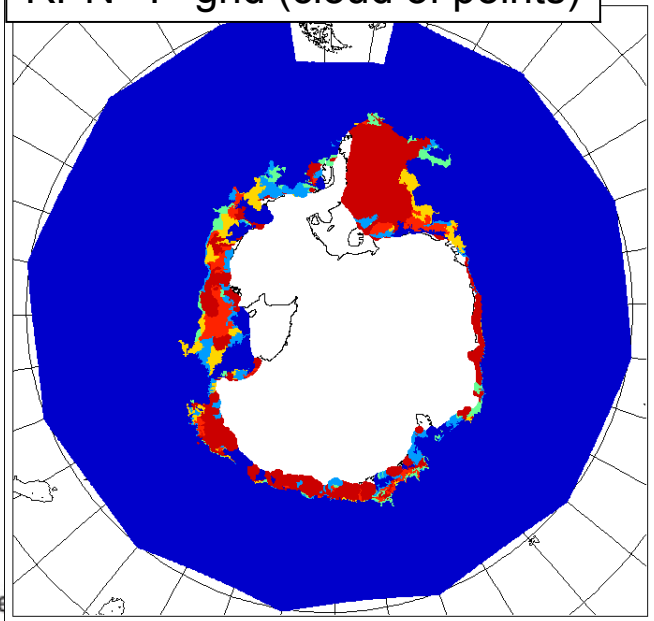
- This new climatology considers the Accumulated Freezing Degree-Day" calculated from the field TS to remove unwanted ice from the climatology build from NIC data.
- When we started the experiment, we needed to start with a « trial field » which was generated from the operational global ice analysis...so we inherited some of that unwanted ice and it is melting very slowly.
- For now this is not a major problem as NWP apply an « ice line » to the global ice analysis (http://iweb.cmc.ec.gc.ca/~afsgapm/Doc/Ligne_de_glace_aplante-2005.htm)



Arctic



RPN "Y" grid (cloud of points)



Antarctic