ERA-CLIM2 Project
Mercator Ocean Contributions to WP2.2

Task 2.2 : Development of assimilation techniques

Mercator Ocean
Ocean Forecasters

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…

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WP2 task2.2 : Development of assimilation techniques for improved use of surface observations

MO Sub task : Assimilation of Sea Ice Concentration

Objective: to improve coupled ocean/sea-ice data assimilation.
Developing and testing a scheme that transforms sea-ice concentration to a Gaussian variable during the assimilation process.

Deliverable D2.2 (t0+27+12):
Results from a study
Documented code and library applicable in the context of NEMOVAR.

Mercator activities in the ERA-CLIM2 Project
General Work Plan for WP2 task2.2

Mercator Ocean
Ocean Forecasters

1 - Production of reference simulation without the use of Gaussian transformation in the sea ice analysis

→Development of a multivariate sea ice analysis vs univariate sea ice analysis (used in operational)

⇒Well posed to demonstrate the interest of the Gaussian transformation due to the presence of wrong extrapolation

→Use the Arctic-Northern Atlantic Configuration at 1/4°(75lev,CREG4/NEMO3.6/LIM3) coupled with the Mercator Assimilation System (SAM2) and the multivariate/univariate sea ice analysis.

⇒a low-cost and recent model configuration centred on the Arctic Sea will be more efficient for this study…

→Production of reference simulation using **multivariate sea ice analysis** with CREG4/NEMO3.6/LIM3

We have realized various multi-years reanalysis using different tuning for the state vector and we are working on the identification of an optimal set up for sea ice analysis.

2 - Development of libraries dedicated to the anamorphosis approach

→ First version of libraries and tools dedicated to transformation

→ First application through a very simple method considering a post analysis 1D extrapolation of the SIC update to the others variables

→Production of multi-year hindcast using this post analysis 1D extrapolation :… **Work in Progress…**

Experimental set up with the CREG Configuration

CREG = One of the tools identified in the Partnership with Canada (Env. Canada and DFO).

CREG configuration = tailored (20% of the global cost) for sea ice developments (Model, Assimilation, Observations)

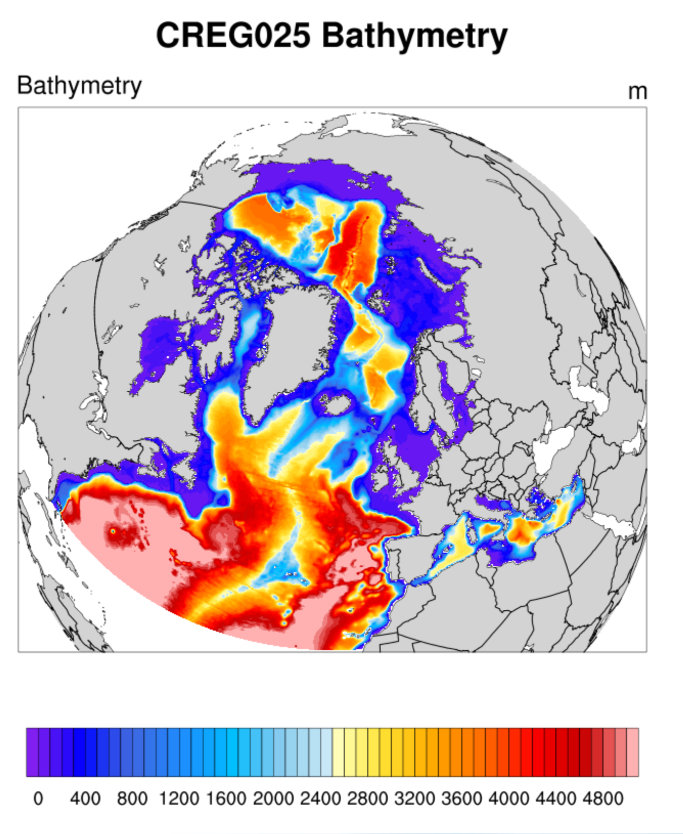
Configuration used in ICE ARC FP7 Project.

Experimental set up at ¼° with the NRT protocol …:

✓ ERA INTERIM Forcing (3H) (Oct 2006-2014)
✓ Boundaries conditions from global ¼° operational systems
✓Initial Conditions from WOA13 for (T,S) and GLORYS for sea ice thickness, OSI SAF for sea ice concentration
✓Bathymetry ETOPO/GEBCO
✓Runoff (Dai & Trenberth, 2009) + Greenland and nordic glaciers.
✓No restoring.

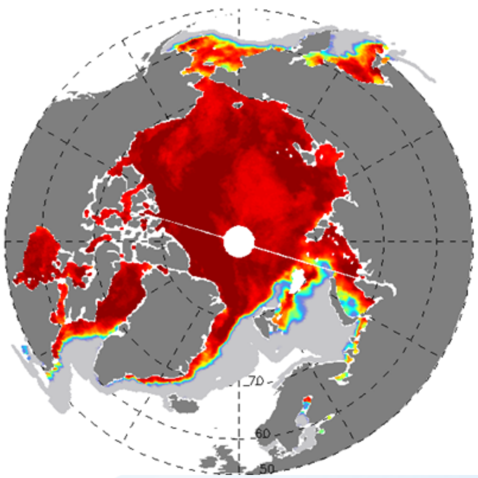
… But with different physics and parameterisation:

✓NEMO3.6
✓LIM3 (multi-category) (Drags = 1.4E-03 (ice/air), 5.10-03 (ice/ocean), P*=20000)
✓Time-splitting, VVL, 75 z-levels, GLS vertical mixing, …
✓Tests already made with LIM2, ocean/ice drag (Roy et al., 2015), with wave breaking cutoff, …



Assimilation of Sea Ice Concentration :

Sea Ice Concentration (OSI-SAF)



Model

- **Nemo 3.6, LIM3/Multi-categories(1:5)**
- **CREG ¼, 75 levels**

Assimilation

- **Analysis based on a 2D local multivariate SEEK/LETKF filter**
- **Weakly-coupled DA system using 2 separate analyses :**
- **Ocean Analysis (SLA, InSitu Data from CORA3.2, SST) , IAU on (h,T,S,U,V)**
- **Sea Ice Analysis**
  - SIC Error: 1% open ocean, linear from 25% to 5% for SIC values between 0.01 and 1
  - Forecast error covariances are built from a prior ensemble of Sea Ice Model anomalies
- **Unidata/Multivariate Sea Ice analysis with various multivariate state vector**
  - **REA111 experiment using multivariate state vector [SIC, SIVOLU]**
    - **+** fixed distribution giving **SICONCAT(1:5), SIVOLUCAT(1:5)**
  - **REA113 experiment using multivariate state vector [SIC, SICONCAT(1:5), SIVOLUCAT(1:5)]**

CREG4 Mercator ocean and sea-ice near real-time system
2006-2013 Free simulation using Nemo3.6/LIM3 with 5 categories

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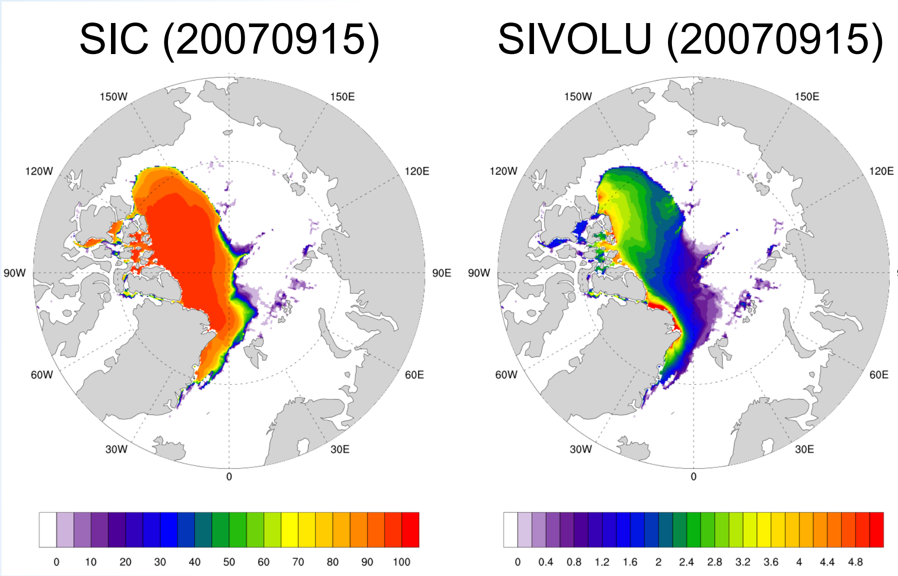
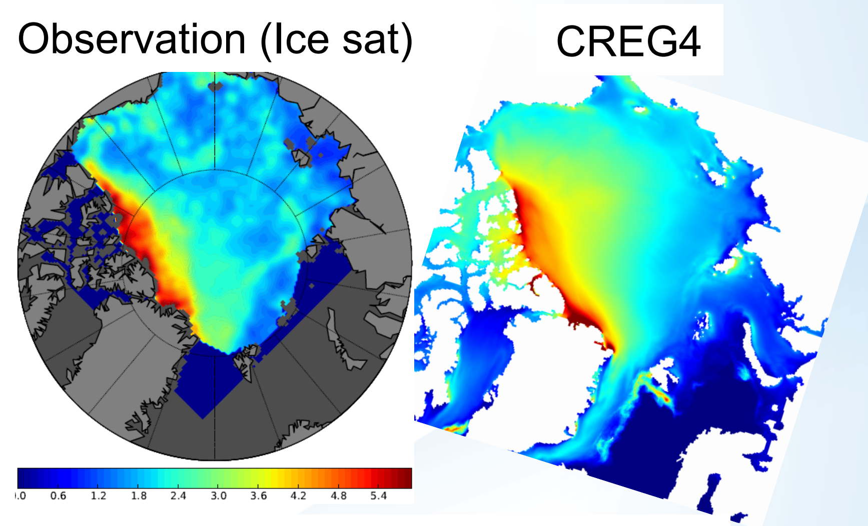
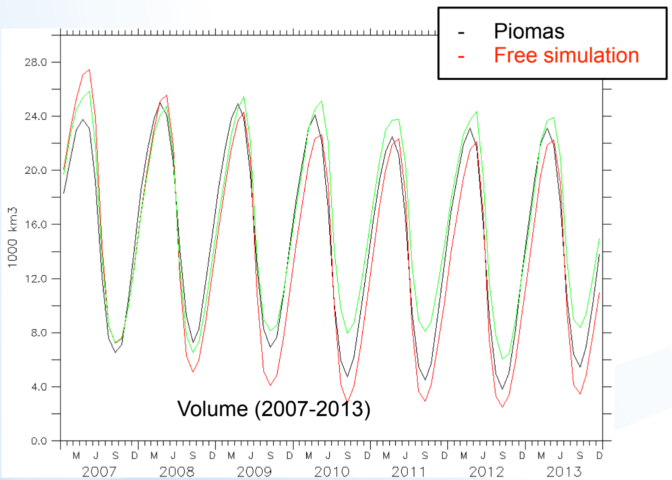




Mean thickness (March-April 2007)



This Free simulation is used to build background error as a prior ensemble of Sea Ice Model anomalies.

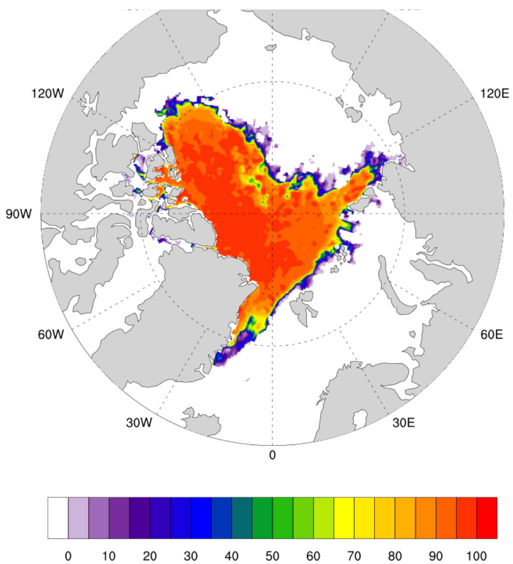
Sea ice state vector (general case) :
[SIC, SIVOLU, SICONCAT(1:5), SIVOLUCAT(1:5)]

CREG4 Mercator ocean and sea-ice near real-time system
(2007-2013 hindcast experiment assimilating OSI-SAF SIC Observations)
Starting from 20070102

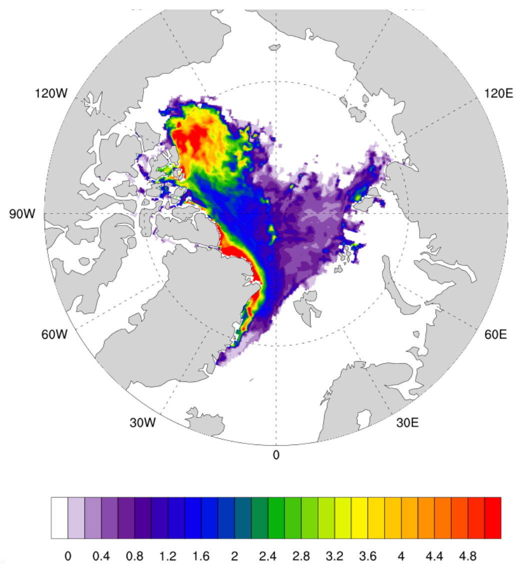
REA111
Model update from analysis : [siconc,sivolu]
prior distribution [0.77 0.15 0.05 0.02 0.01]
(Δsiconcat(1:5), Δsivolucat(1:5)) estimated from (Δsiconc,Δsivolu) update **using fixed distribution**

20070915

SIC (%)



Ice Volume (m)



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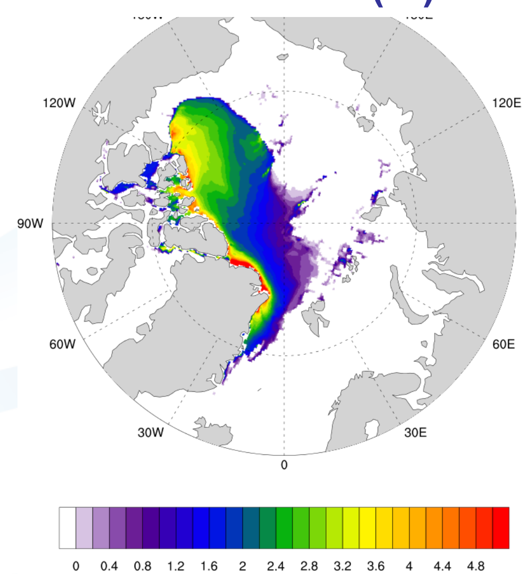

Hindcast experiment

Free Simulation

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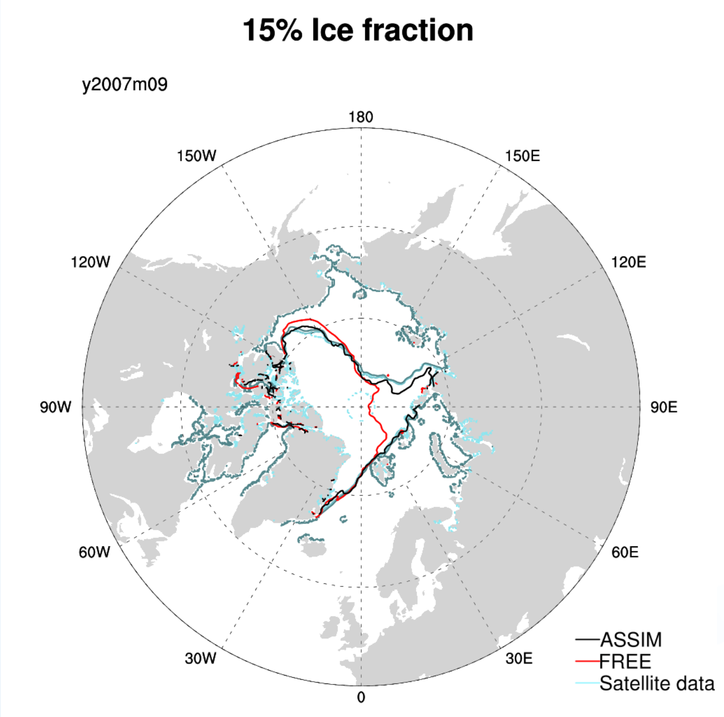

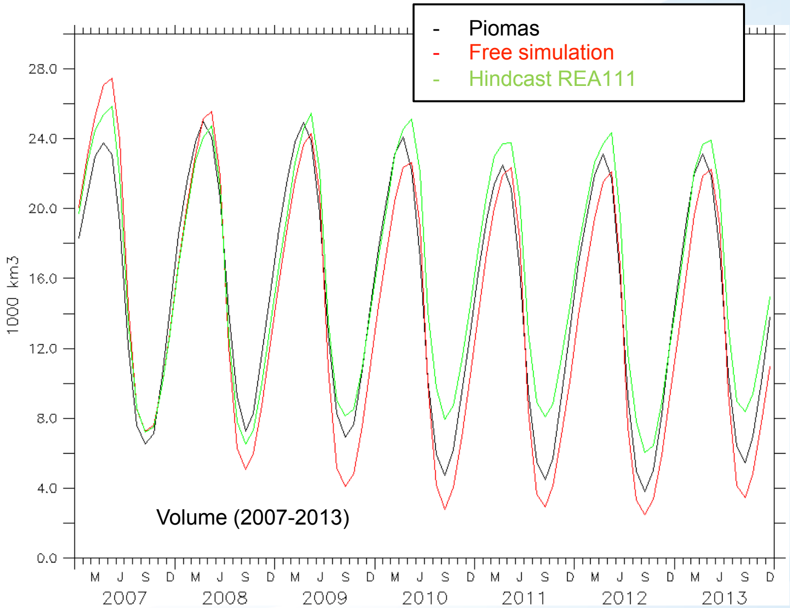

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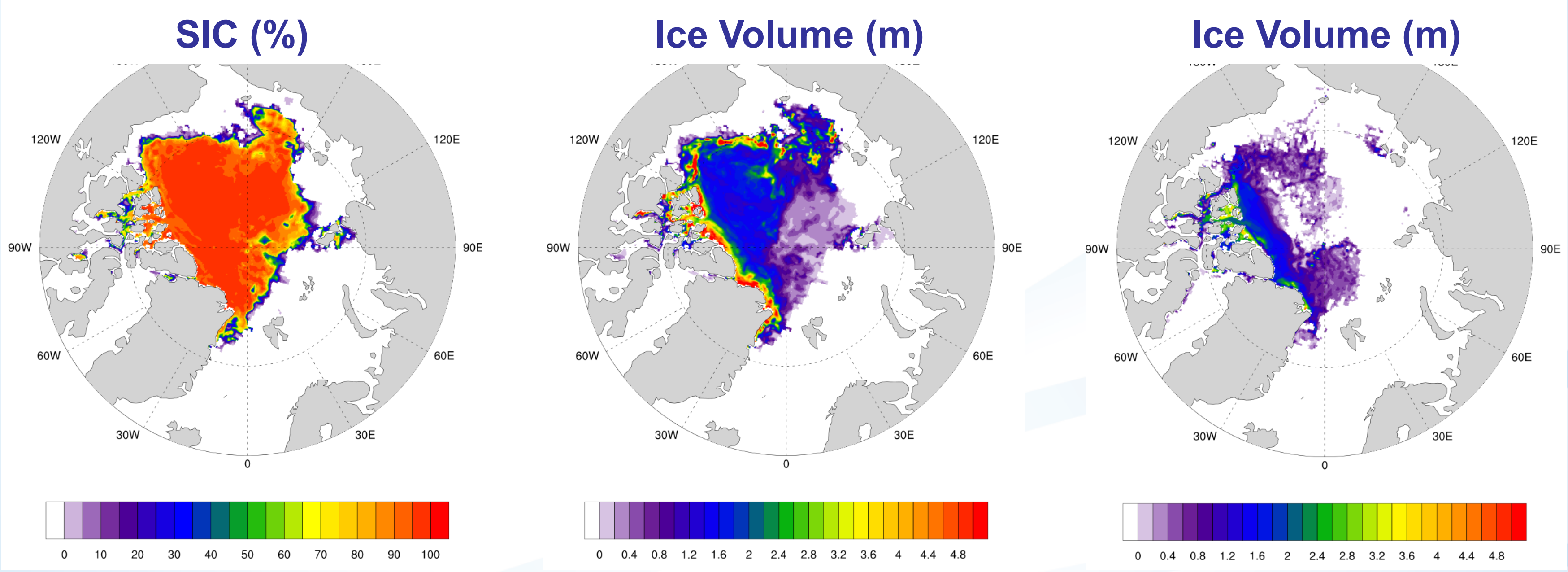

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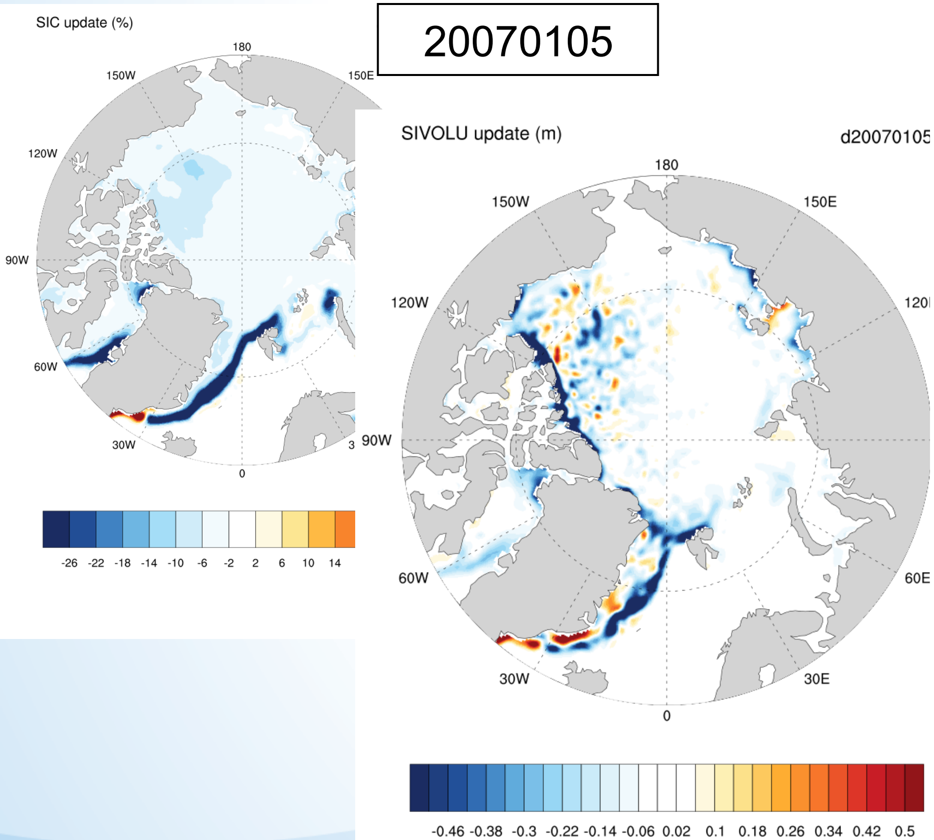
20070105



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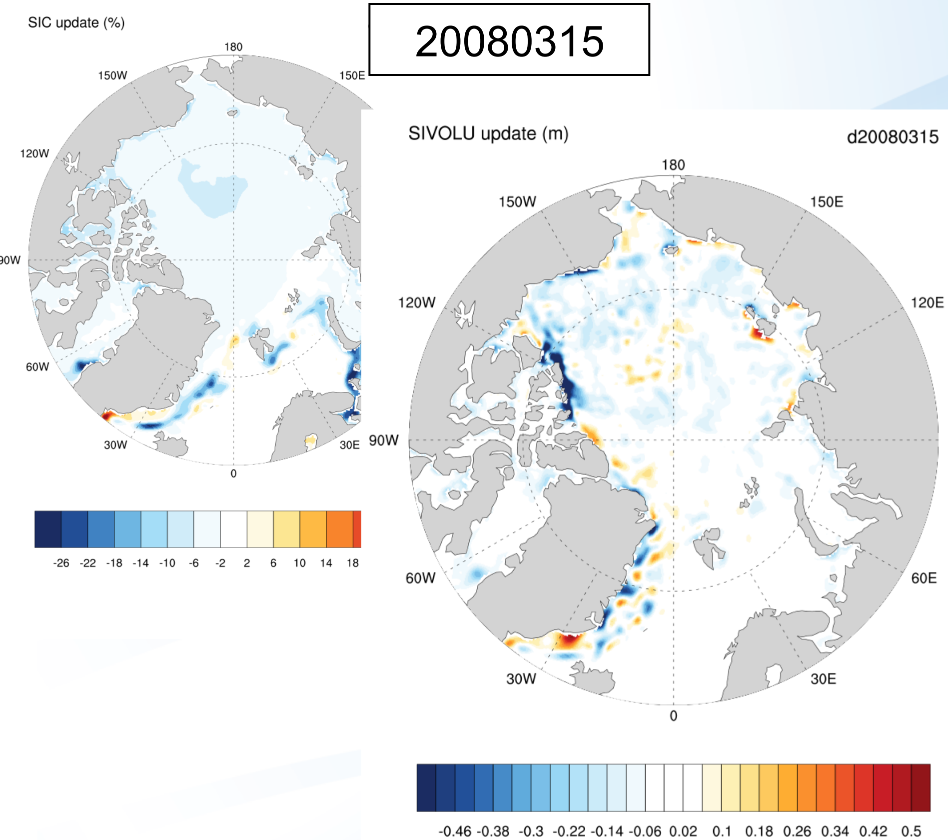

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Ocean Forecasters

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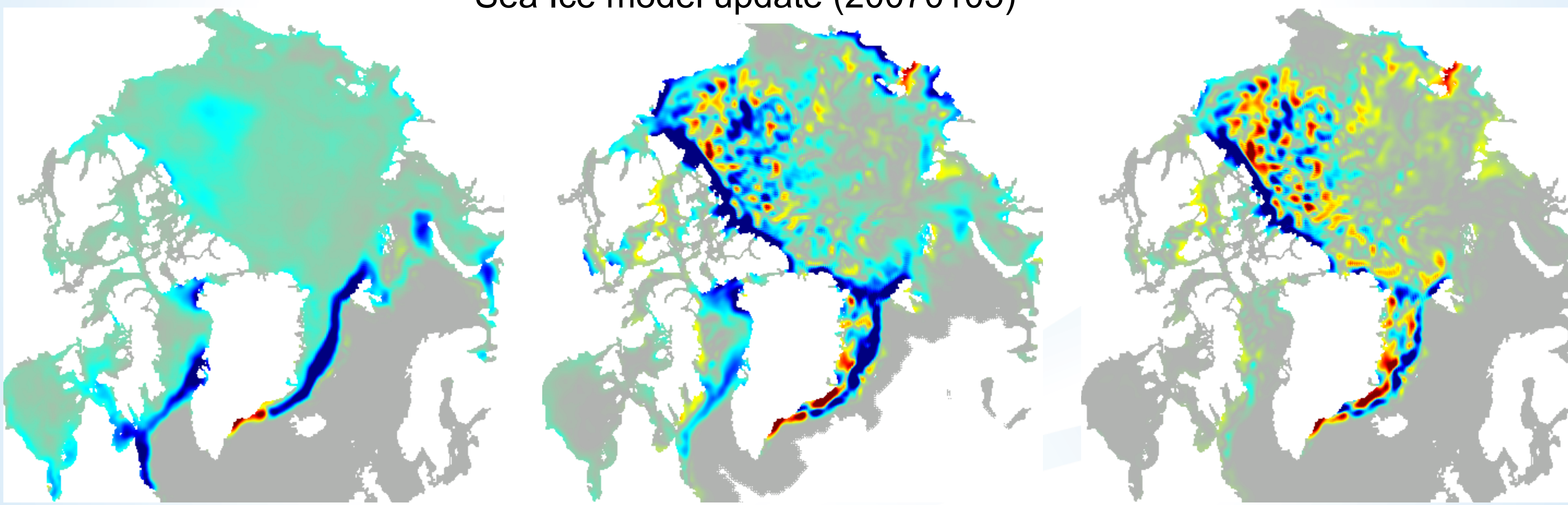
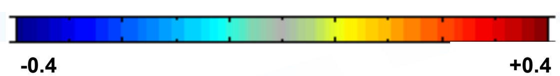
Sea Ice model update (20070105)



SIC update
REA111

SIVOLU update
REA111

SIVOLUCAT update (cat. 5)
REA111



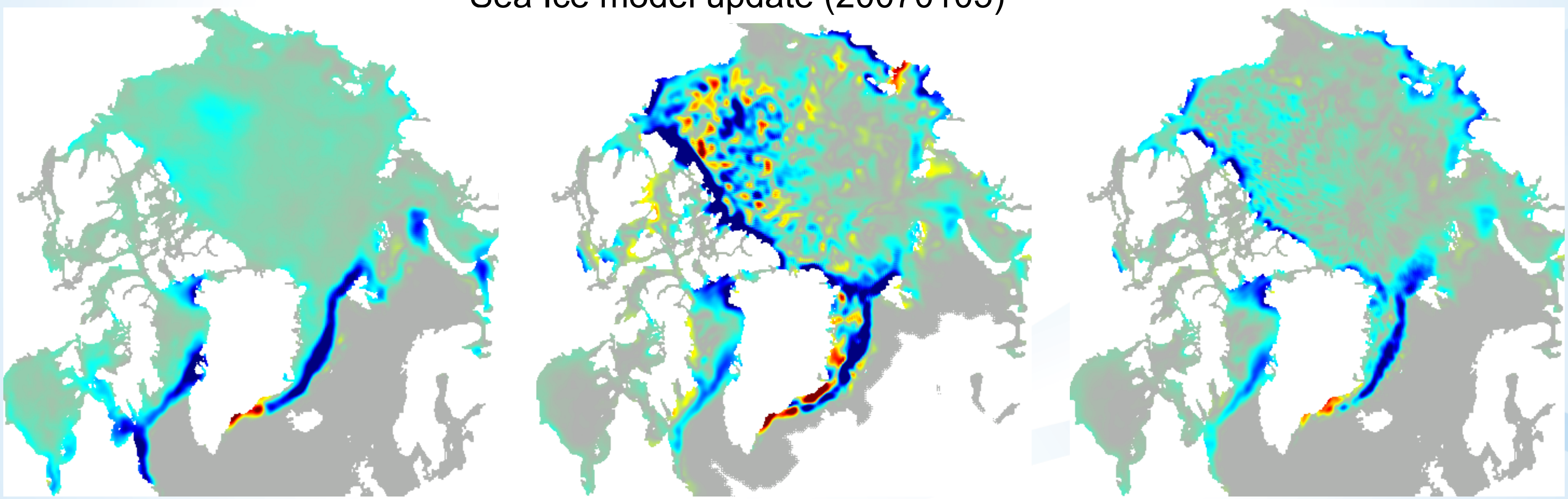
CREG4 Mercator ocean and sea-ice near real-time system
(2007-2013 hindcast experiment assimilating OSI-SAF SIC Observations) Starting from 20070102

REA113

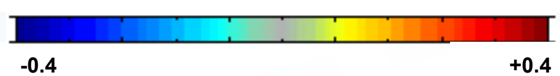
Model update from analysis : [siconc,siconcat,sivolucat]

(Δsiconcat(1:5), Δsivolucat(1:5)) estimated from analysis based on OSI-SAF SI and null innovations on SICONCAT(5) and SIVOLUCAT(5)

Sea Ice model update (20070105)



SIC update **REA113** | SIVOLU update **REA111** | SIVOLU update **REA113**



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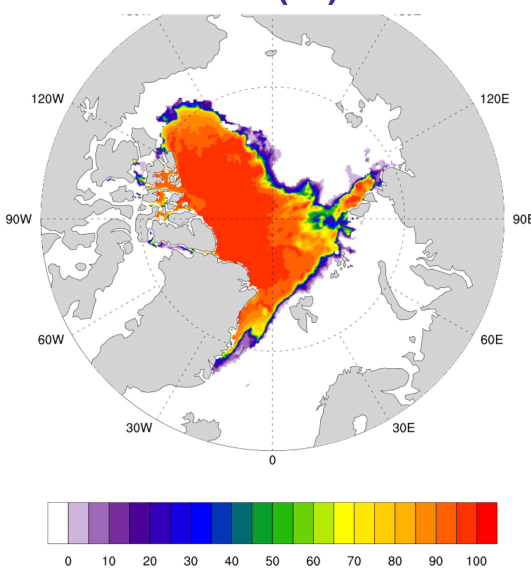
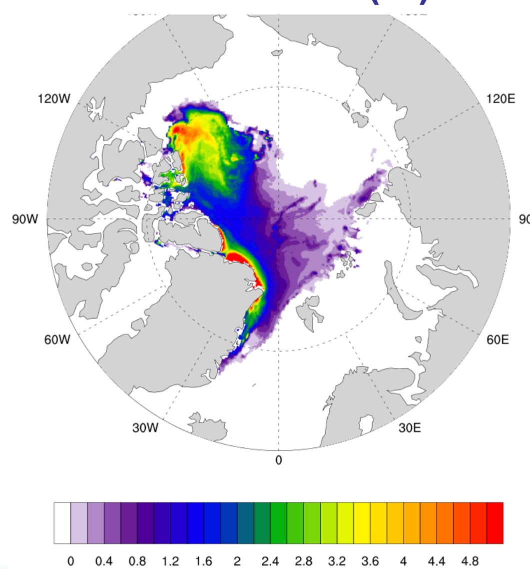
SIC (%)



Ice Volume (m)



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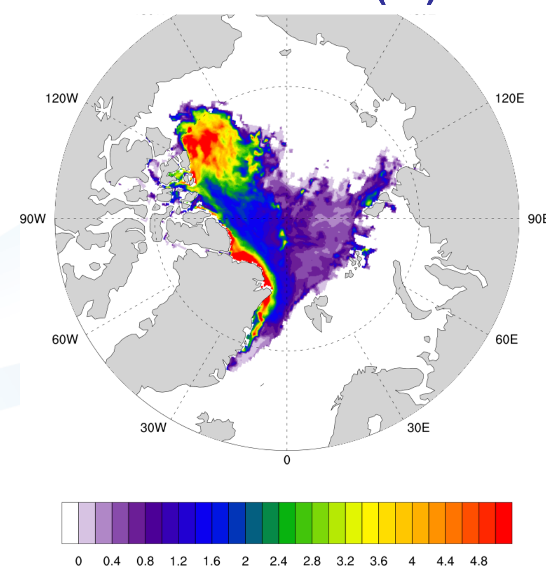

REA113 Hindcast experiment

REA111

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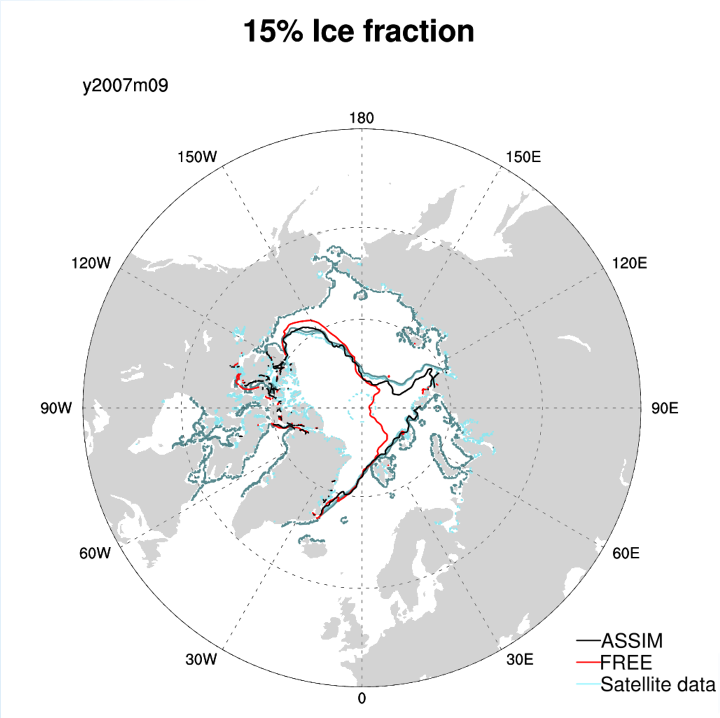

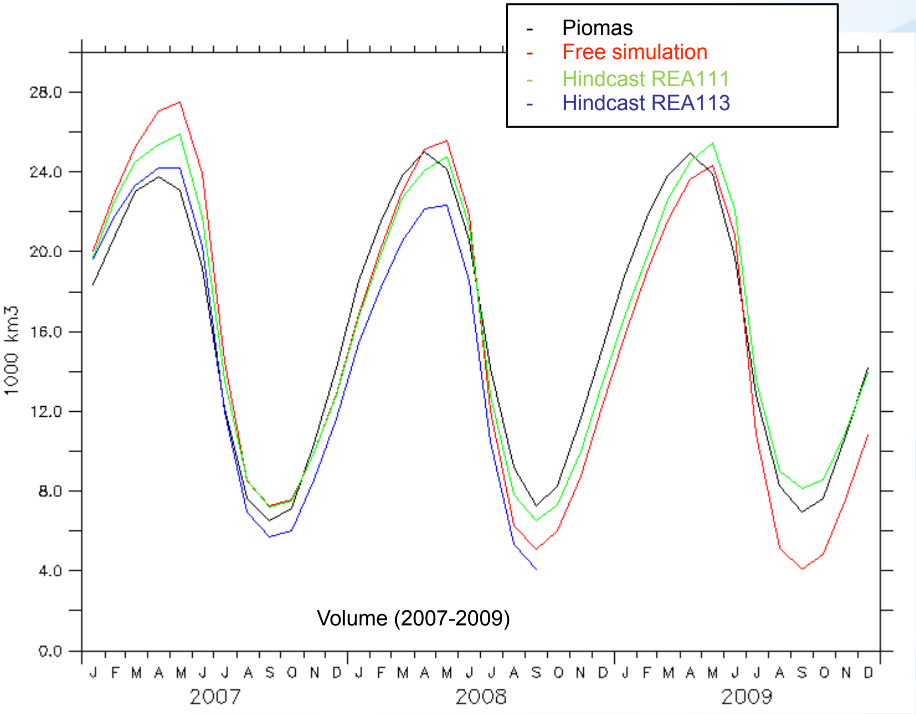

Mercator activities in the ERA-CLIM2 Project
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→Production of reference simulation using **multivariate sea ice analysis** with CREG4/NEMO3.6/LIM3

We have realized various multi-years reanalysis using different tuning for the state vector and we are working on the identification of an optimal set up for sea ice analysis.

2 - Development of libraries dedicated to the anamorphosis approach

→ First version of libraries and tools dedicated to gaussian transformation

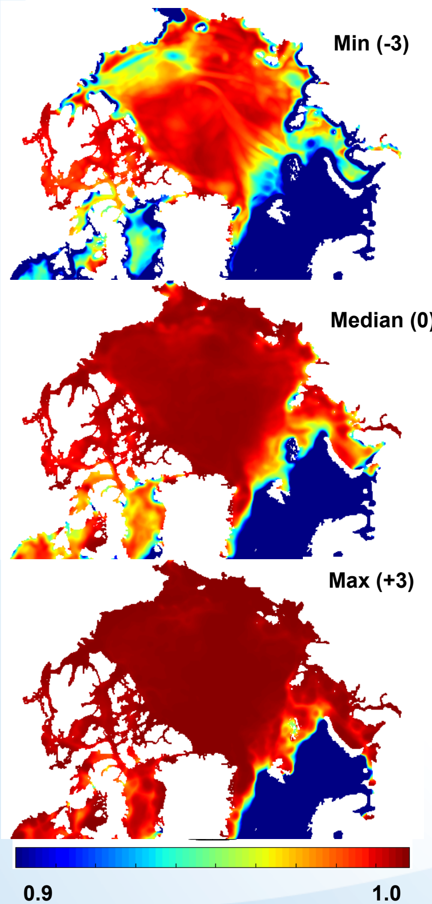
→ First application through a very simple method considering a post analysis 1D extrapolation of the SIC update to the others variables

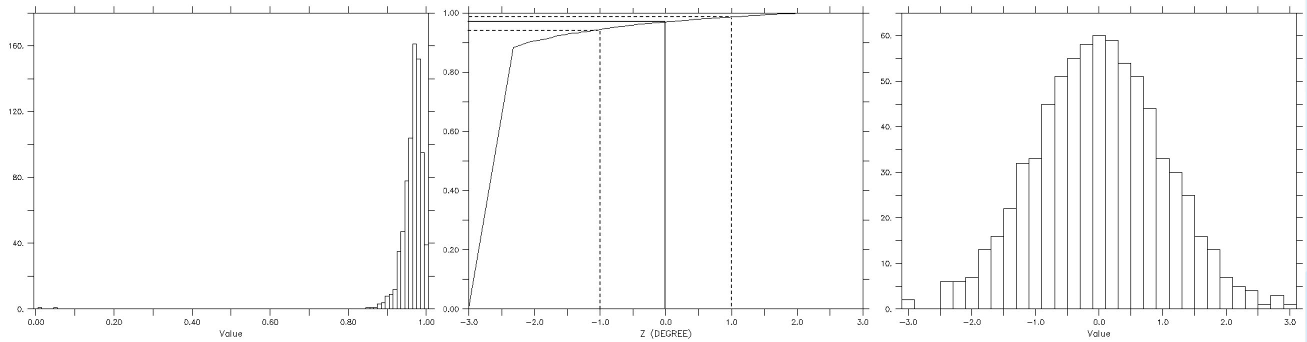
→Production of multi-year hindcast using this post analysis 1D extrapolation :… **Work in Progress…**

The Gaussian Anamorphosis approach

Anamorphosis Transformation based on 2006-2013 CREG4 Free simulation model states

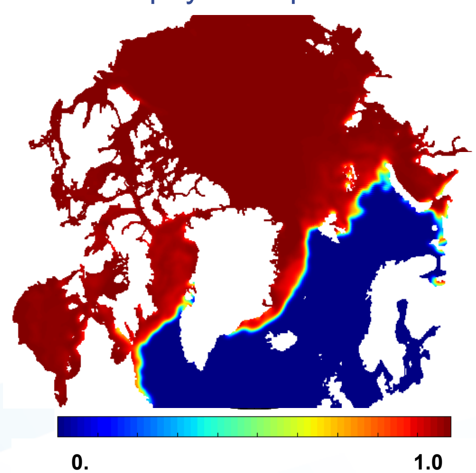
SIC Percentile map





We build local (space and time) transformation for each variable of the state vector (SIC, SIVOLU, SICONCAT(1:5), SIVOLUCAT((1:5))

SIC (20070105)
physical space



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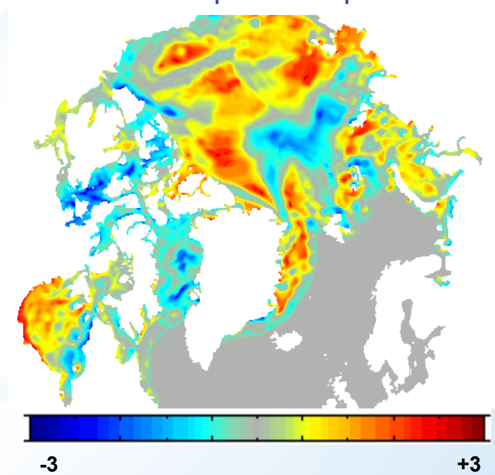
SIC (20070105)
anamorphosed space



The Gaussian Anamorphosis approach

Spatial correlation using background error based on 2006-2013 CREG4 Free simulation model states

<u>To build a background error in the anamorphosed space</u>

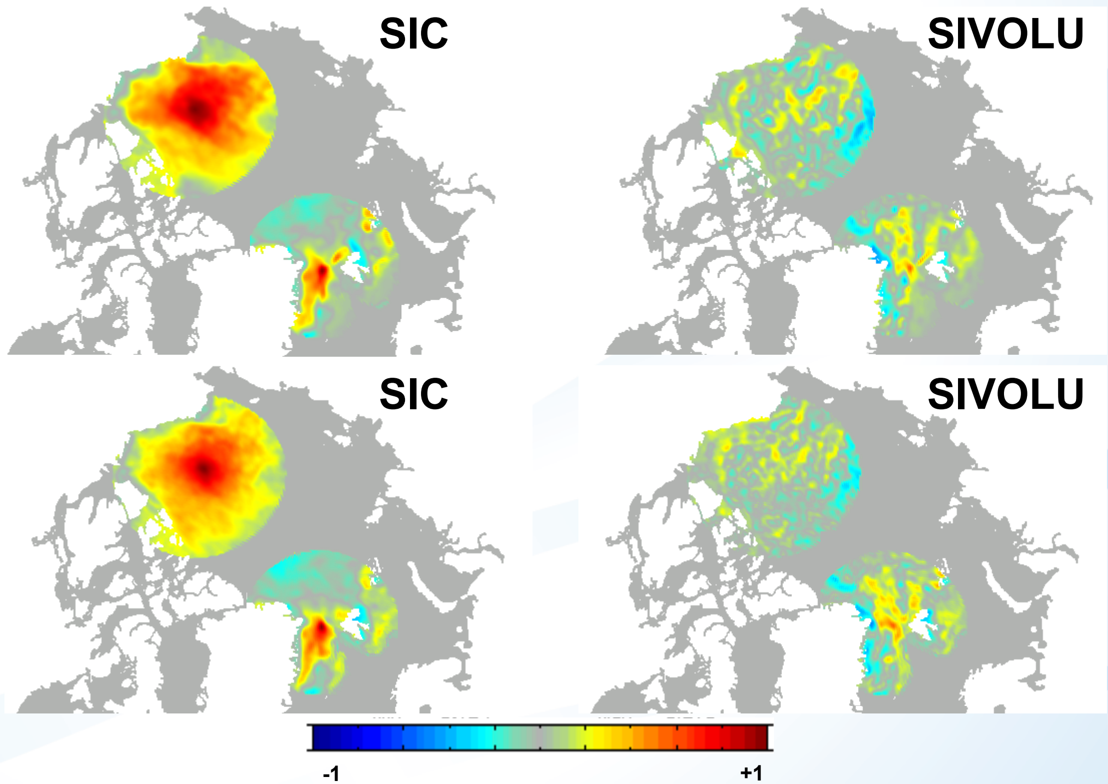
1 – we transform each state of the **2006-2013 CREG4 Free simulation in the anamorphosed space using their own transformation**

2 – we build the background error as an ensemble of anomalies to the median (0 in practise)

Spatial correlation to SIC build from background error in anamorphosed space using anamorphosed states

20070105

Spatial correlations to SIC build from background error using physical states



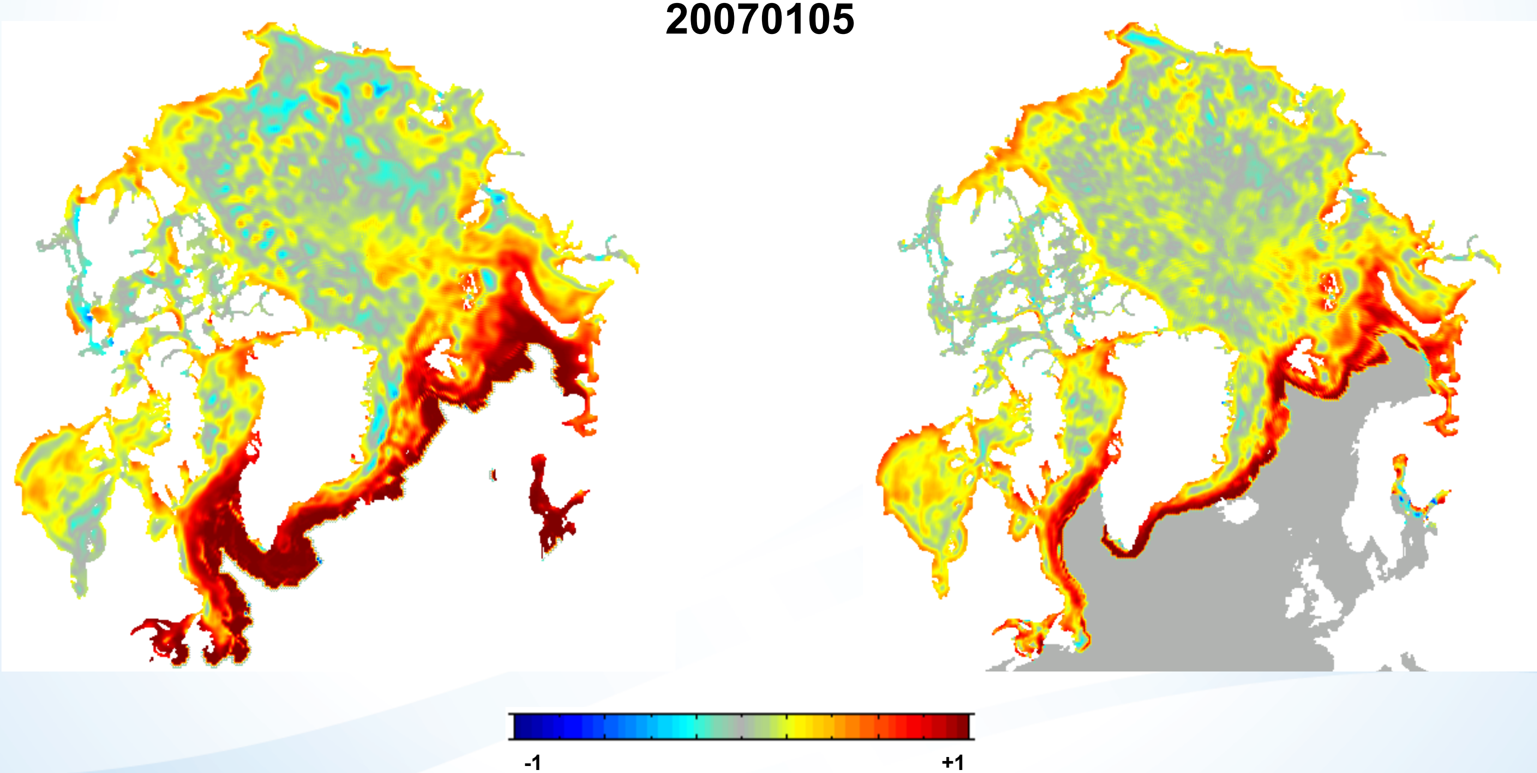
The Gaussian Anamorphosis approach

1D correlation using background error based on 2006-2013 CREG4 Free simulation model states

SIVOLU map of 1D correlation to SIC build from background error using physical states

SIVOLU map of 1D correlation to SIC build from background error in anamorphosed space using anamorphosed states

20070105



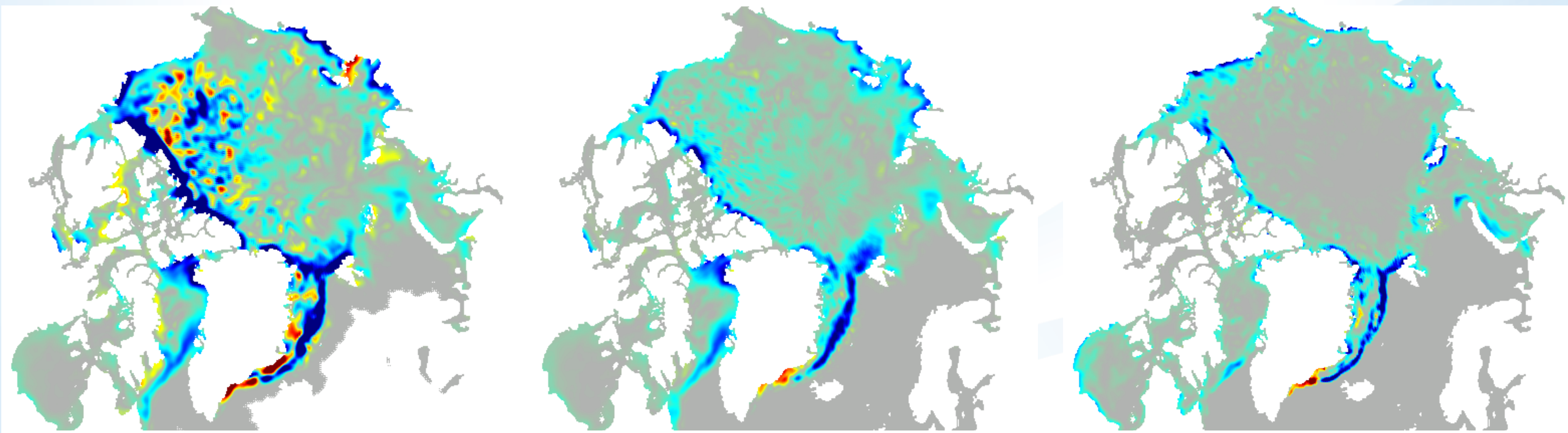
The Gaussian Anamorphosis approach

Development of a simple sea ice analysis
using a post analysis 1D extrapolation in the anamorphosed space

Post analysis 1D extrapolation method

1 - launch of an unidata/univariate sea ice analysis to produce SIC update
2 - transformation the SIC update in anamorphosed SIC update considering the background SIC state
3 - 1D extrapolation to anamorphosed SIVOLU update
4 - back in physical space considering the background SIVOLU state

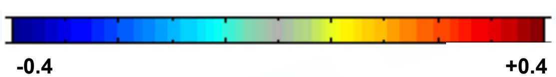
SIVOLU update (20070105) for different sea ice analysis set up



REA111 Sea ice analysis
No constraint on SIVOLUCAT(5)

REA113 sea ice analysis
Constraint on SIVOLUCAT(5)

1D extrapolation of REA111 SIC update in anamorphosed space



The Gaussian Anamorphosis approach

Development of a simple sea ice analysis using a post analysis 1D extrapolation in the anamorphosed space

Mercator Ocean
Ocean Forecasters

Main defaults :

- Well posed in unidata analysis case only. It is not possible to consider several type of observations in the 1D extrapolation. It is also preferable to observe all the domain.
- No consideration of the spatial and or time covariance between SIC and SIVOLU as it is done during the multivariate analysis.

Main advantages :

- Simple implementation after the analysis and before the restart of the model.
- Independent from the analysis scheme which could be a kalman filter or a variational approach.
- Permits to explore anamorphosis approach before an on-line implementation in the analysis

Limitation :

- Needs ensemble of state (to build the transformation) consistent with the physic of the days. It is well posed if an ensemble scheme is used.

This method seems to be appropriate to the unidata sea ice analysis case as it has been developed in several group (NEMOVAR, SAM2, …)

However ,this method is only a first step before a full on-line implementation and should be considered as an exploration approach

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