Ocean and sea ice initialization and prediction activities at Climate Forecasting Unit (CFU), Catalan Institute of Climate Sciences (IC³)

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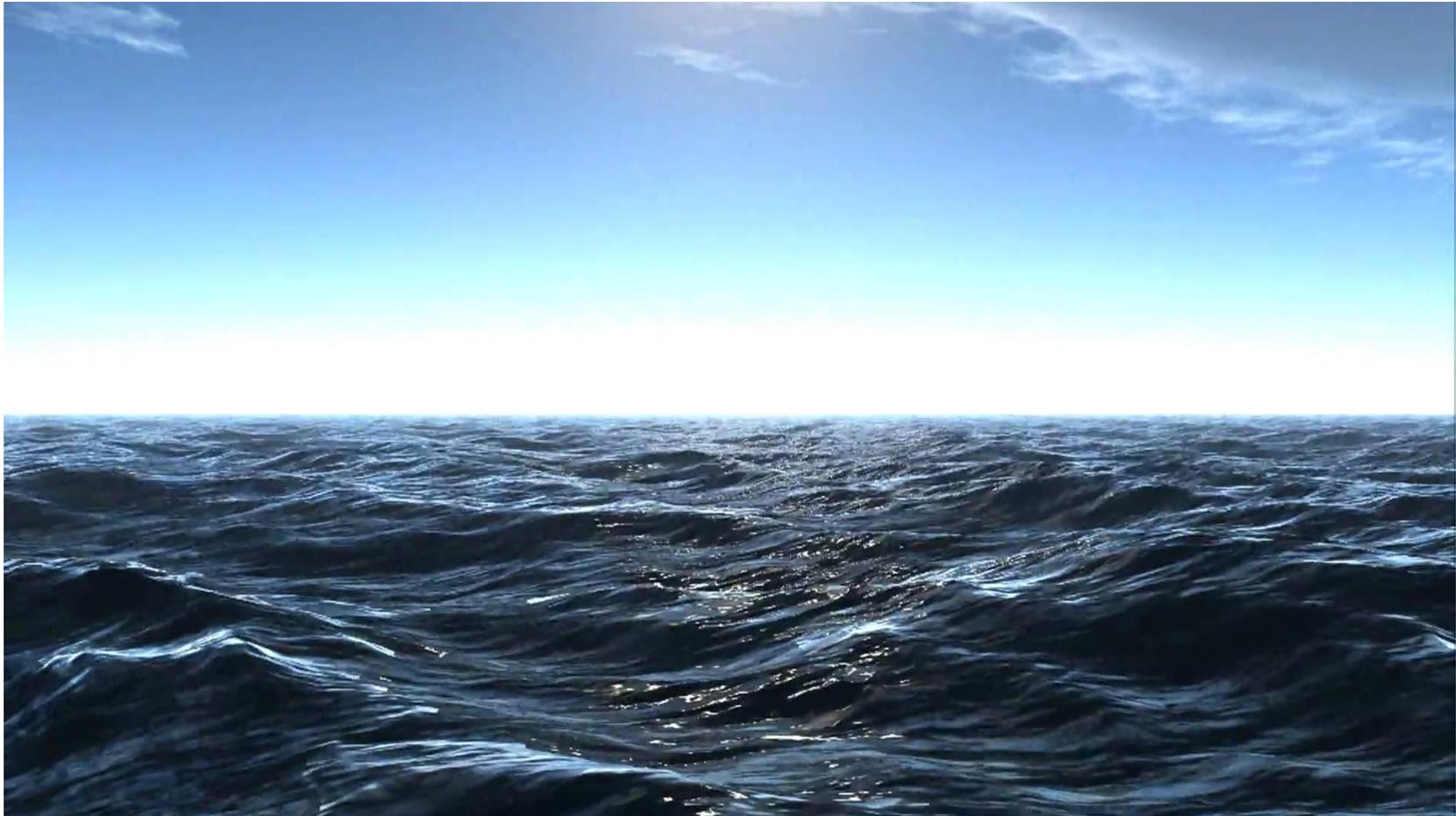[2]*Université Catholique de Louvain-La-Neuve (UCL), Belgium,*
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I. Ocean initialization

Ocean initial conditions for EC-Earth3.1 climate predictions

<u>Source:</u> GLORYS2v1 reanalysis (1993-2009) ORCA025L75

From GLORYS2v1 restarts:

* **ORCA025L75** : original restarts

* **ORCA025L46** : vertical interpolation + extrapolation + empty seas filled with climatology

* **ORCA1L46** : vertical and horizontal interpolation + extrapolation + empty seas filled

From GLORYS2v1 monthly means:

Coupled EC-Earth3.0.1 with 3D T and S nudged toward monthly-mean GLORYS2v1
(360 days below 800m, 10 days above 800m except in the mixed layer + SST & SSS restoring - 40W/m2, -150 mm/day/psu except along 1° S-1° N)

* **ORCA025L75** : m01u , et ECFS ec:/c3y/restarts_m01u

* **ORCA025L46** : m01w, at ECFS ec:/c3y/restarts_m01w

* **ORCA1L46**   : m01x, at ECFS ec:/c3y/restarts_m01x

<u>Source:</u> ORAS4 reanalysis (1958-2013) ORCA1L42

From ORAS4 restarts:

* **ORCA1L46** : vertical interpolation and extrapolation + empty seas filled

More information : https://dev.ec-earth.org/projects/ecearth3/wiki/Ocean_initial_conditions_for_climate_predictions

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Testing the ocean initial conditions

- EC-Earth3.0.1 in T255L91-ORCA1L46-LIM2 configuration

- Initialization on 1st May and 1st November every year from 1993 to 2009

- 4 month forecasts

- 5 members

- IFS initialized from ERA-interim with singular vectors to obtain 5 members

- LIM2 initialized from GLORYS 2v1

- Ocean initialized from interpolated GLORYS2 v1 restarts   = Interp
             or from restarts from nudged simulation toward GLORYS = Nudg

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Testing the ocean initial conditions

Nudg - **Interp** correlation skill for JJA from 1st May. Reference: HadISST
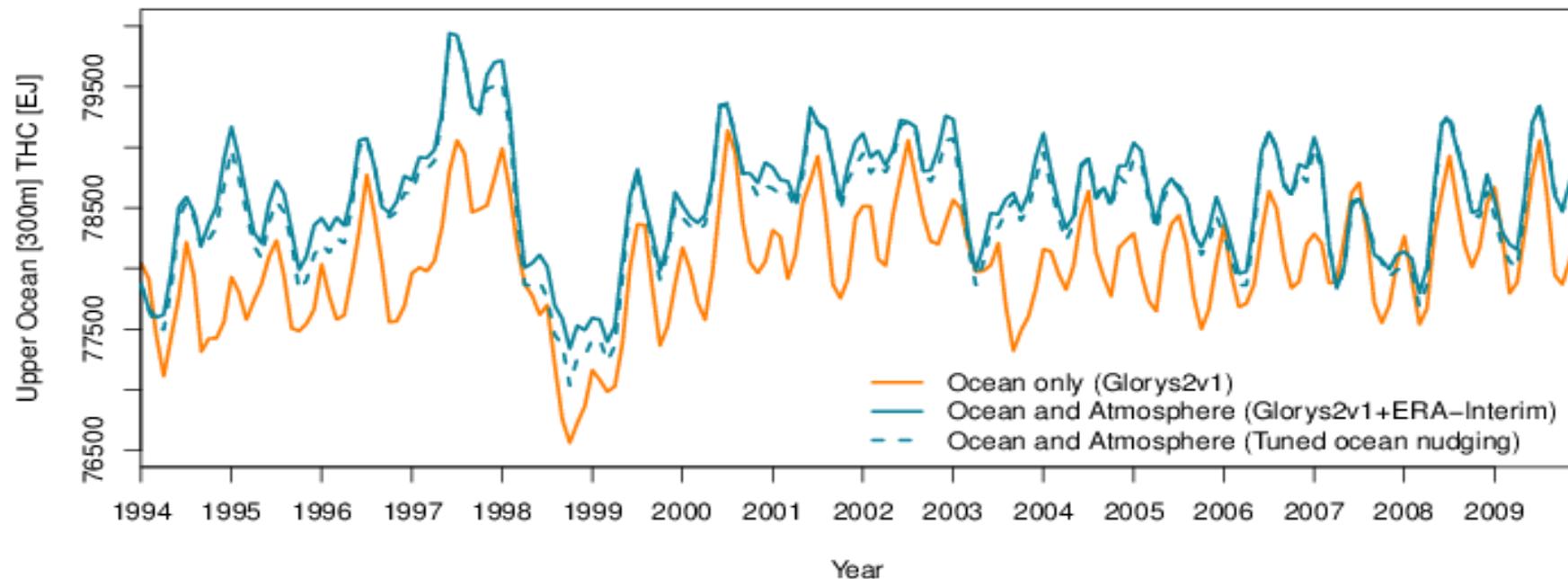

chloe.prodhomme@ic3.cat
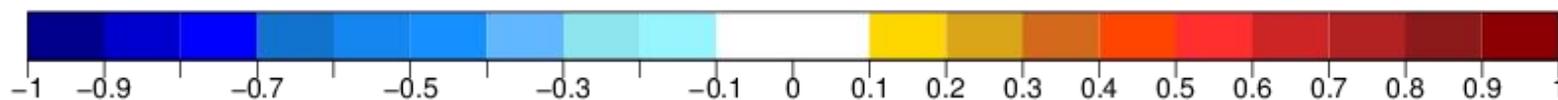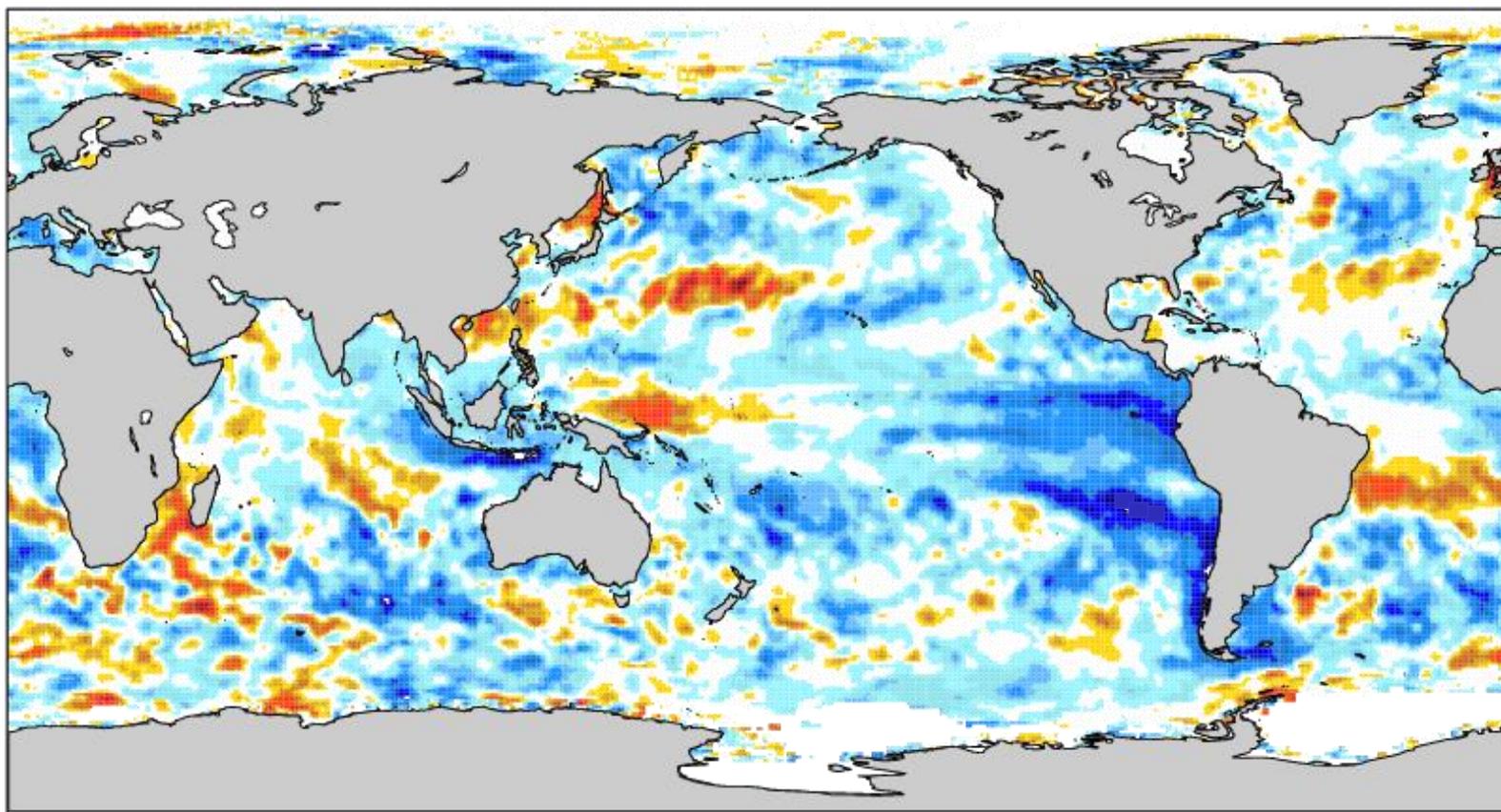
Ocean initial conditions nudging ocean *and* atmosphere

Nudging atmospheric dynamics in coupled mode could improve ocean initial conditions due to improved wind stress.

Low skill of current nudged ocean initial conditions might result from long time scale of relaxation (1 year in the deep ocean and 10 days in the upper ocean). Tuning of the nudging parameter in progress.

EC–Earth Nudging Simulations

Legend:
- Ocean only (Glorys2v1)
- Ocean and Atmosphere (Glorys2v1+ERA–Interim)
- Ocean and Atmosphere (Tuned ocean nudging)

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Future ocean initial conditions for EC-Earth3.1 climate predictions

Source: GLORYS2v1 reanalysis (1993-2009) ORCA025L75

From GLORYS2v1 restarts:

* **ORCA025L75** : original restarts

* **ORCA025L46** : vertical interpolation + extrapolation + empty seas filled with climatology

* **ORCA1L46** : vertical and horizontal interpolation + extrapolation + empty seas filled

Source: ORAS4 reanalysis (1958-2013) ORCA1L42

From ORAS4 restarts:

* **ORCA1L46** : vertical interpolation and extrapolation + empty seas filled

Source: GLOSEA5 reanalysis (1990-2012) ORCA025L75

From GLOSEA5 restarts:

* **ORCA025L75** : extrapolation + empty seas filled with climatology

* **ORCA025L46** : vertical interpolation + extrapolation + empty seas filled with climatology

* **ORCA1L46** : vertical and horizontal interpolation + extrapolation + empty seas filled

Source: ORAP5 reanalysis ORCA025L75

From ORAP5 restarts:

* **ORCA025L75** : extrapolation + empty seas filled with climatology

* **ORCA025L46** : vertical interpolation + extrapolation + empty seas filled with climatology

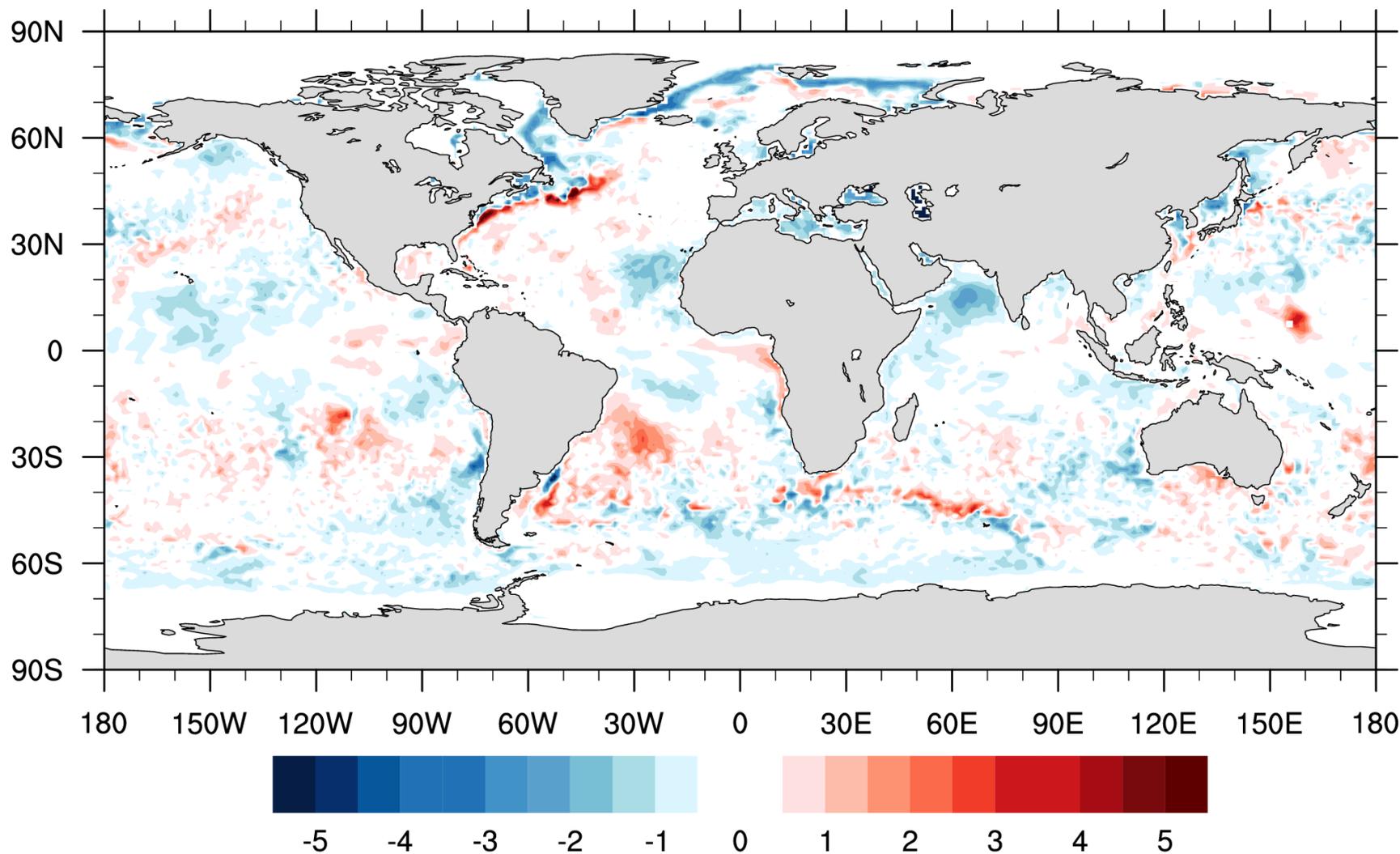* **ORCA1L46** : vertical and horizontal interpolation + extrapolation + empty seas filled

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Generation of GLOSEA5 initial conditions in progress

May SST error % HadISST in a prediction initialized in May 1993 from GLOSEA5

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II. Sea ice initialization

Sea ice initial conditions for EC-Earth3.1 climate predictions

Source: GLORYS2v1 reanalysis (1993-2009) ORCA025

    From GLORYS2v1 restarts:

    * **ORCA025** : original restarts

    * **ORCA1** : horizontal interpolation + extrapolation

Source: IC3 reconstructions

    LIM2:

    * **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM2
        nudged toward ORAS4 monthly-mean 3D T and S and forced by

        1. DFS4.3 over the 1958-2006 period   = **b02s**
        2. ERA-interim over the 1979-2013 period = **i00v**

    LIM3 – 1 category:

    * **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM3
        nudged toward ORAS4 monthly-mean 3D T and S and forced by

        1. DFS4.3 over the 1958-2006 period   = **i056**
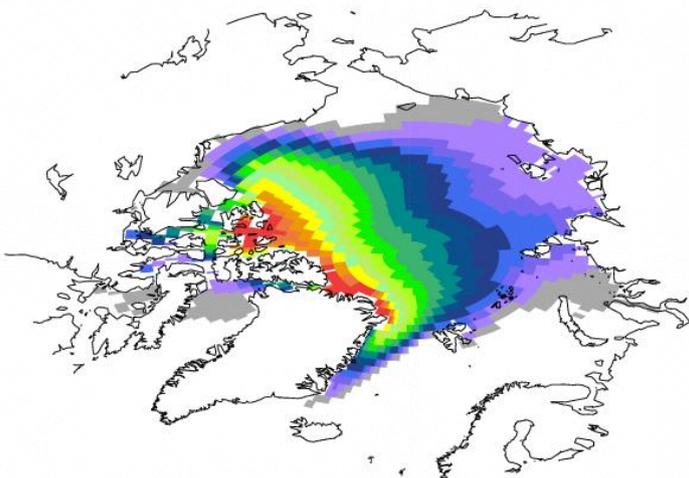   2. ERA-interim over the 1979-2013 period = **i057**

* Obsolete: i03r & i03s – without ocean nudging toward ORAS4

More information : https://dev.ec-earth.org/projects/ecearth3/wiki/Sea_Ice_initial_conditions_for_climate_predictions
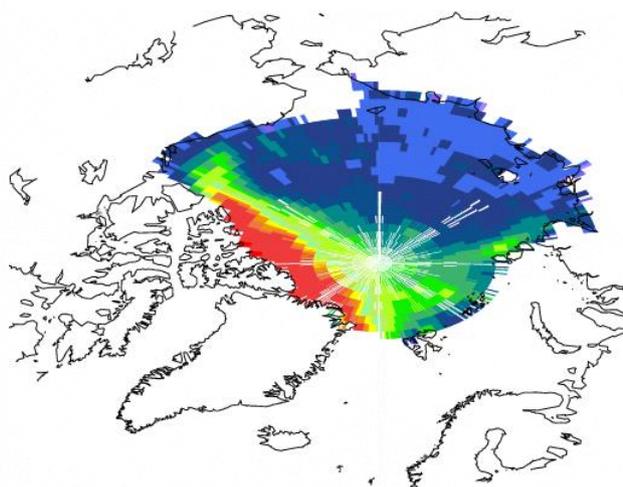
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Validation of IC3's LIM3 reconstruction

2003-2007 October-November sea ice thickness

LIM2 reconstruction   IceSat   LIM3 reconstruction

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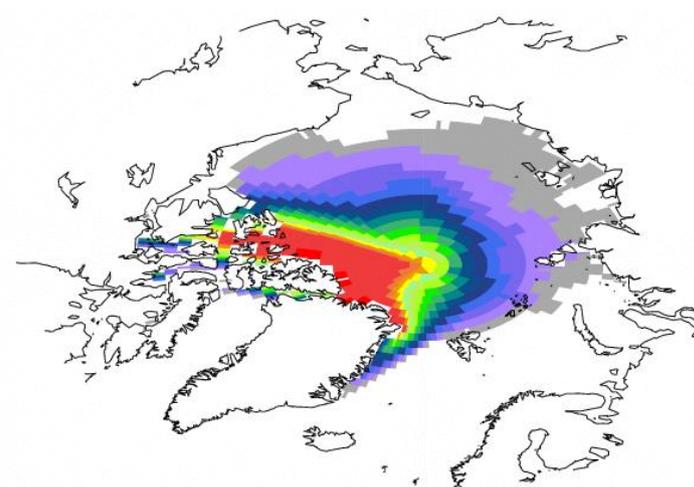
Future sea ice initial conditions for EC-Earth3.1 climate predictions

Source: GLORYS2v1 reanalysis (1993-2009) ORCA025

From GLORYS2v1 restarts:

* **ORCA025** : original restarts

* **ORCA1** : horizontal interpolation + extrapolation

Source: IC3 reconstructions

LIM2:

* **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM2 nudged toward ORAS4 monthly-mean 3D T and S and forced by

    1. DFS4.3 over the 1958-2006 period   = **b02s**
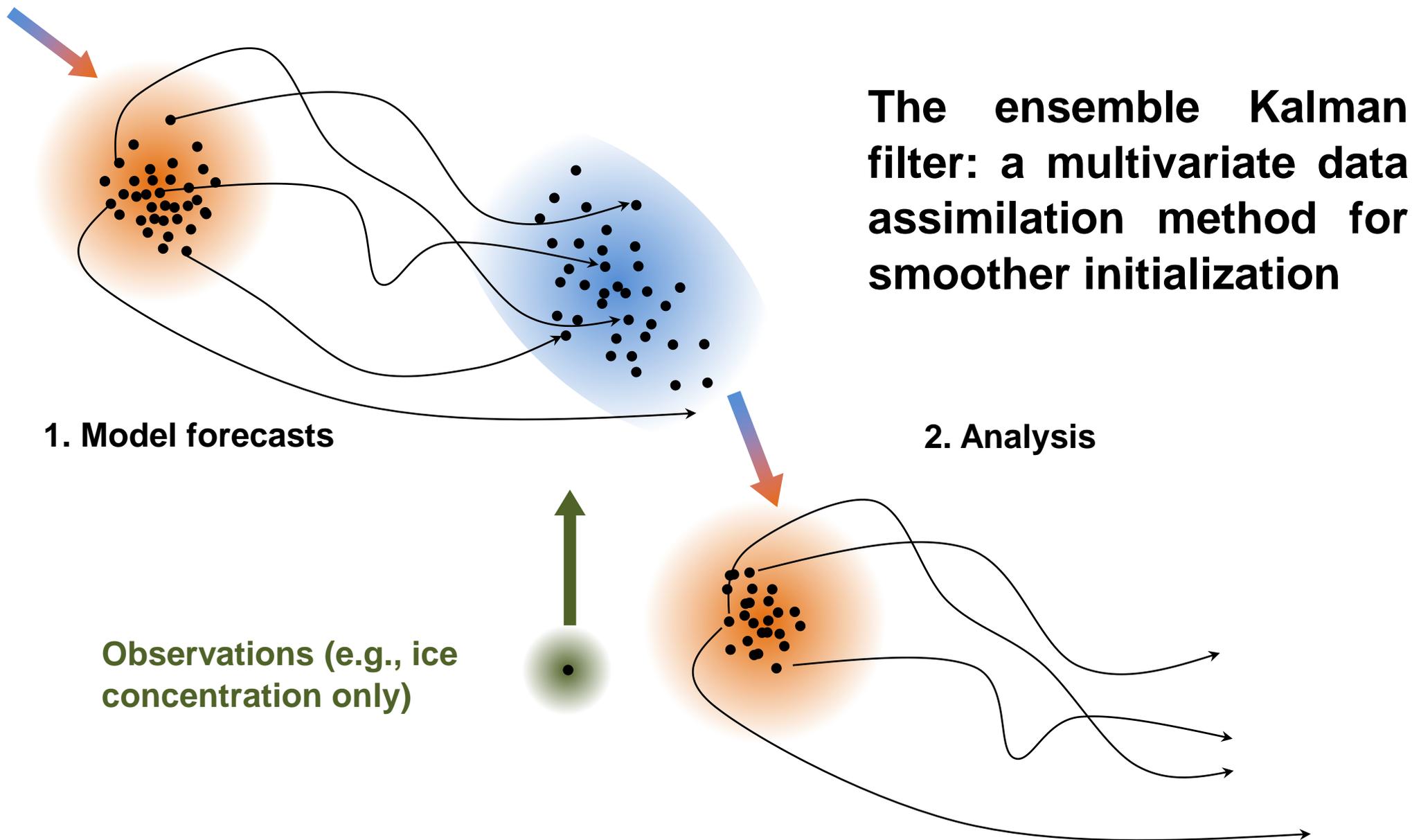   2. ERA-interim over the 1979-2013 period   = **i00v**

LIM3 – 1 category:

* **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 monthly-mean 3D T and S and forced by

    1. DFS4.3 over the 1958-2006 period   = **i056**
    2. ERA-interim over the 1979-2013 period   = **i057**

* **ORCA025** : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 and forced by DFS4.3 and ERA-interim

* **ORCA1 and ORCA025:** Reanalyses using the Ensemble Kalman Filter and sea ice concentration and sea ice thickness observations from the European Space Agency Climate Change Initiative

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Sea Ice Initialization: sea ice data assimilation

The ensemble Kalman filter: a multivariate data assimilation method for smoother initialization

1. Model forecasts

2. Analysis

Observations (e.g., ice concentration only)

Massonnet et al (2014) Ocean Modelling

Sea Ice Initialization: sea ice data assimilation

Importance of multivariate initialization for seasonal sea ice prediction

Massonnet et al (2014) Ocean Modelling
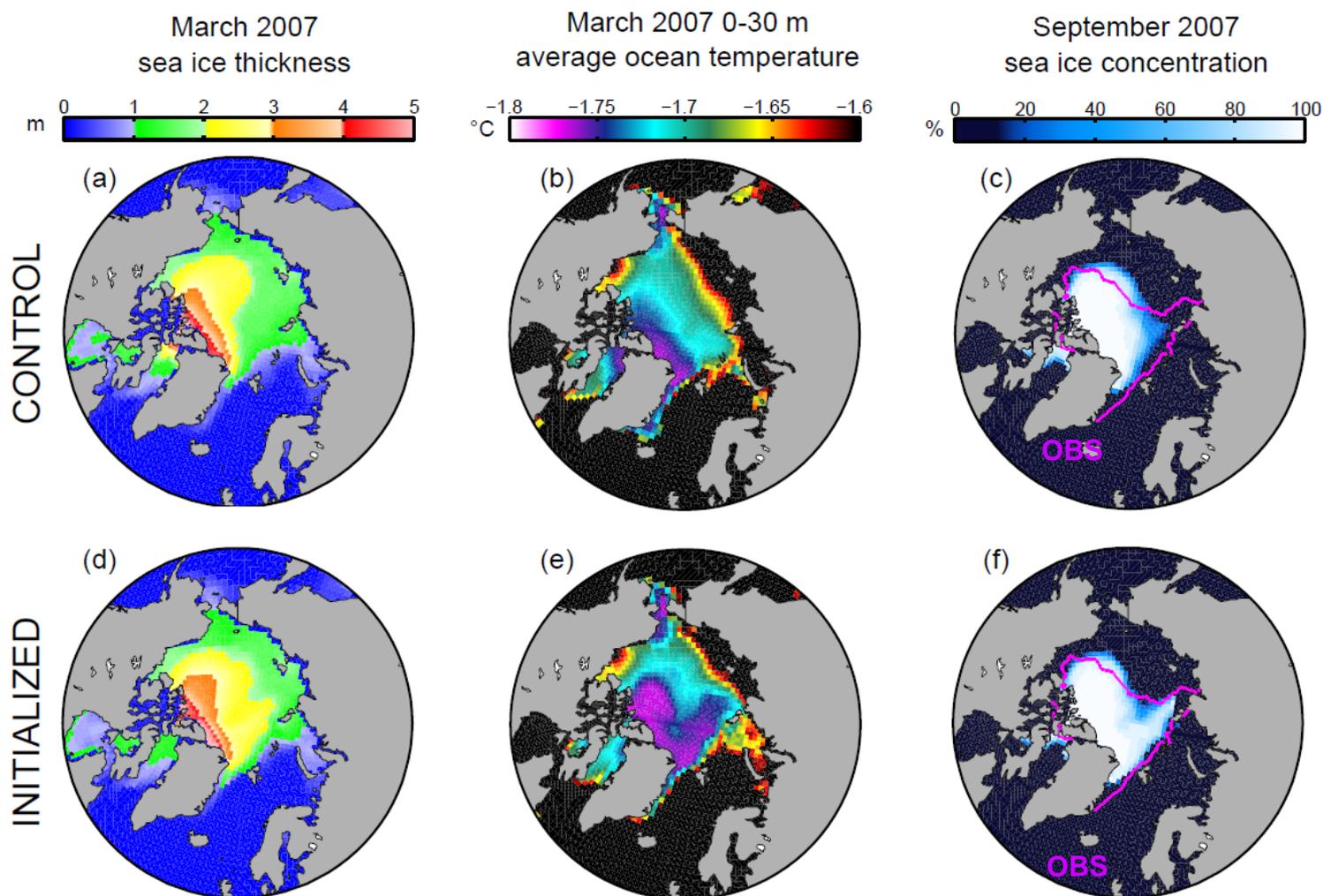
Sea Ice Initialization: sea ice data assimilation

Fully-coupled sea ice data assimilation in EC-Earth: the next challenge

- **What are the perturbations required to generate adequate spread in EC-Earth during the forecast steps of the assimilation run ?**

- **Should the atmosphere be updated when sea ice observations are assimilated?**

- **Can we afford to run the EnKF with less members (CPU time is limited) ?**

Massonnet et al (2014) Ocean Modelling

Conclusions

● **Large set of ocean and sea ice initial conditions (IC) for climate predictions already available (see details on the EC-Earth development portal) → on-going work to extend further this set : GLOSEA5, ORAP5, GLORYS2v3, new ORCA05 sea ice reconstruction**

● **Currently, a better skill is obtained when using interpolated ocean IC than using ocean nudging but including the atmospheric nudging tends to substantially change the ocean heat content → assessment of the role of atmosphere nudging and tuning of the ocean nudging parameters on the climate prediction skill in the coming months**

● **Generation of sea ice reanalysis at the ORCA1 and ORCA025 configurations based on the Ensemble Kalman Filter planned for the next months**