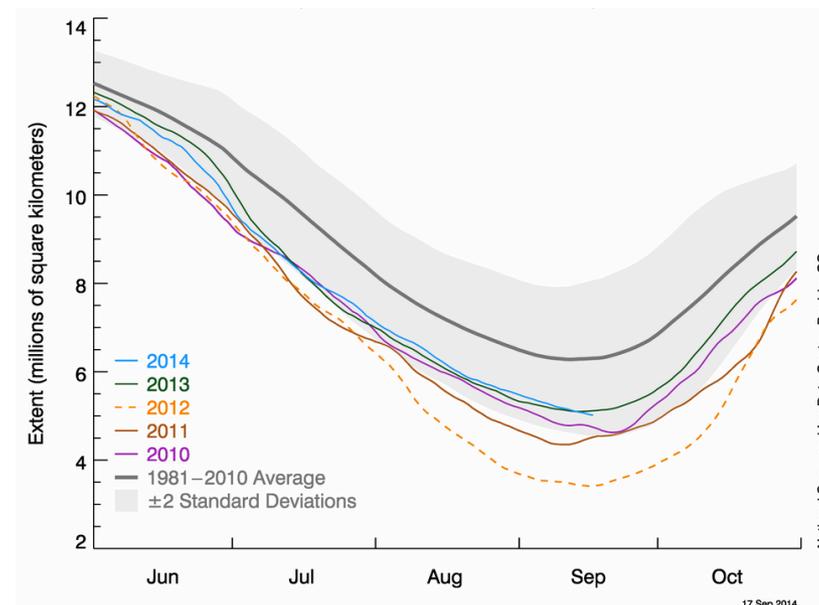
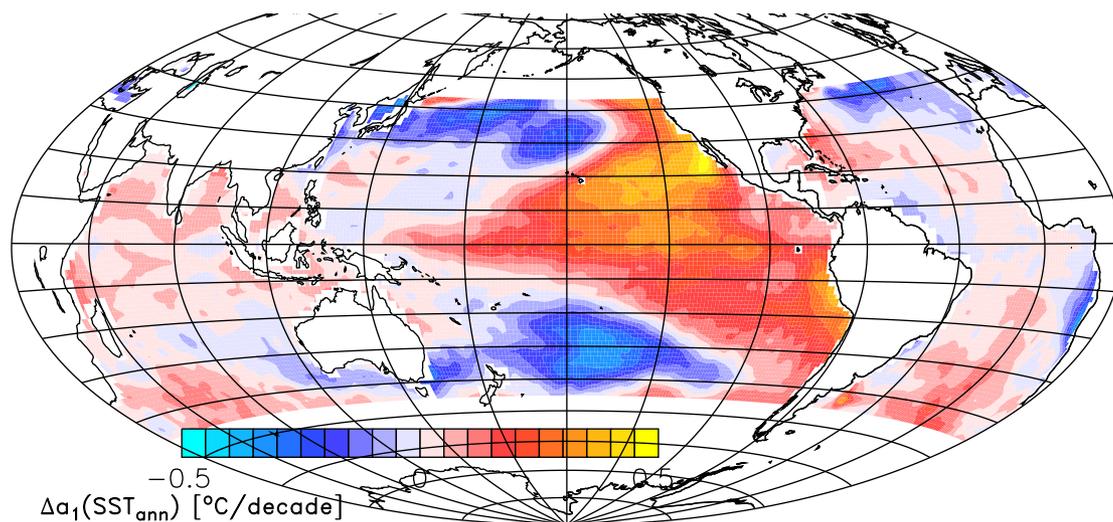


Ocean and sea ice initialization and prediction activities at Climate Forecasting Unit (CFU), Catalan Institute of Climate Sciences (IC³)

Neven S. Fučkar¹, Virginie Guemas^{1,2}, Muhammad Asif¹, Chloe Prodhomme¹, Omar Bellprat¹, Eleftheria Exarchou¹, and Francisco J. Doblas-Reyes^{1,3}

¹Institut Català de Ciències del Clima (IC3), Barcelona, Spain, ²Centre National de Recherches Météorologiques/Groupe d'Etude de l'Atmosphère Météorologique, Météo-France, CNRS, Toulouse, France, ³Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain.

EC-Earth2.3 lin. trend - ERSSTv3b lin. trend (1979-2012)



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

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_m01w
- * **ORCA025L46** : m01w, at ECFS ec:/c3y/restarts_m01w
- * **ORCA1L46** : m01x, at ECFS ec:/c3y/restarts_m01x

Source: ORAS4 reanalysis (1958-2013) ORCA1L42

From ORAS4 restarts:

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

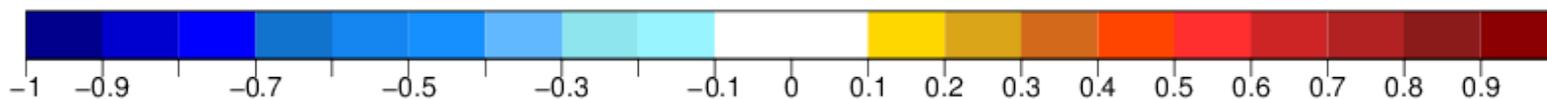
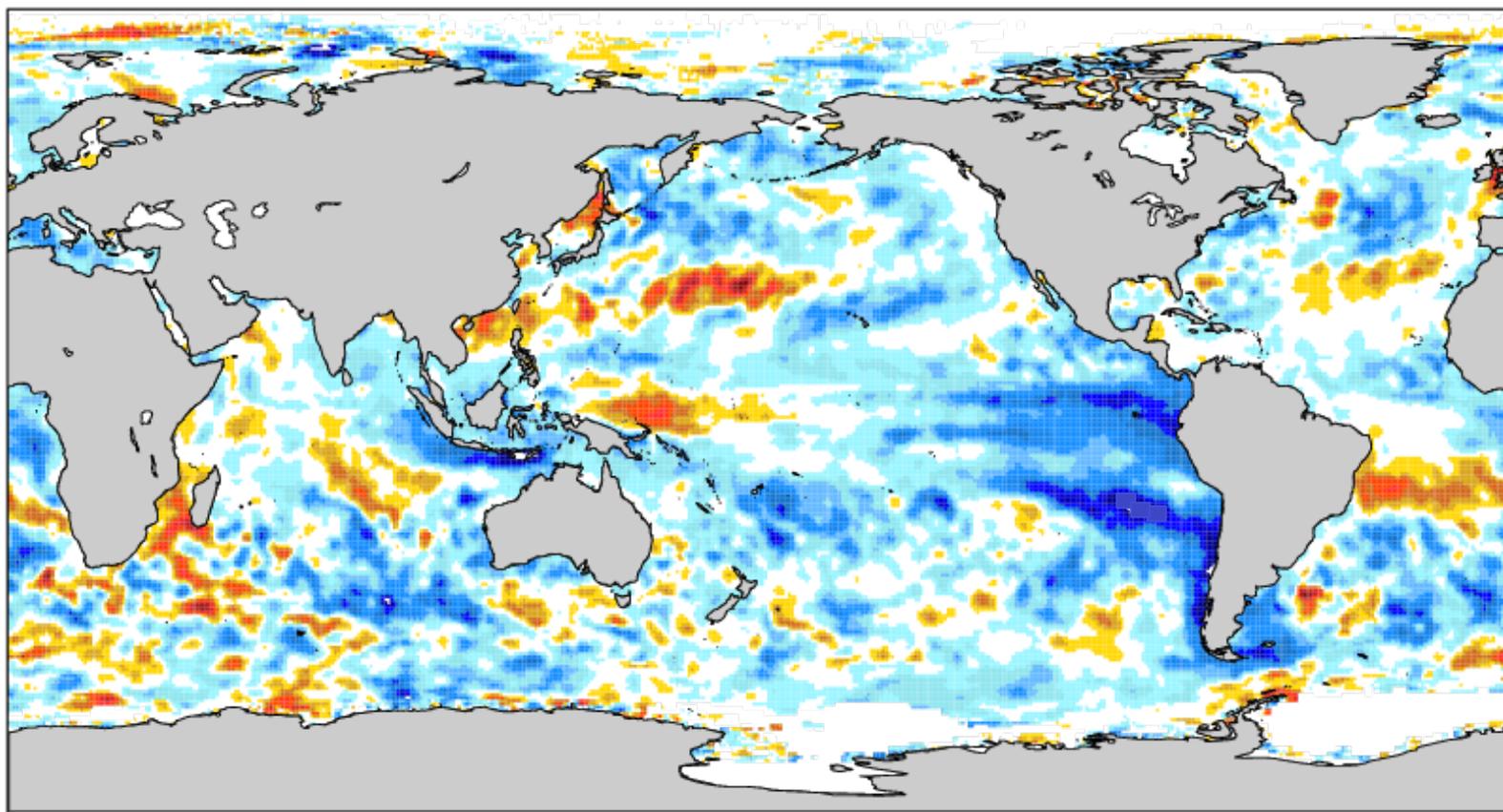
More information : https://dev.ec-earth.org/projects/ecearth3/wiki/Ocean_initial_conditions_for_climate_predictions

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

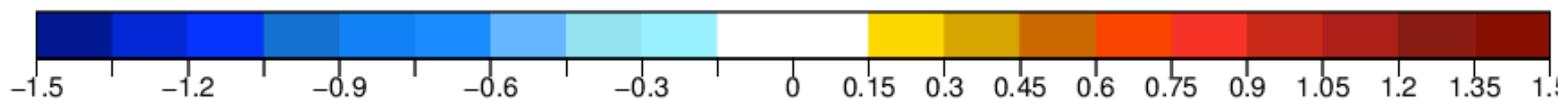
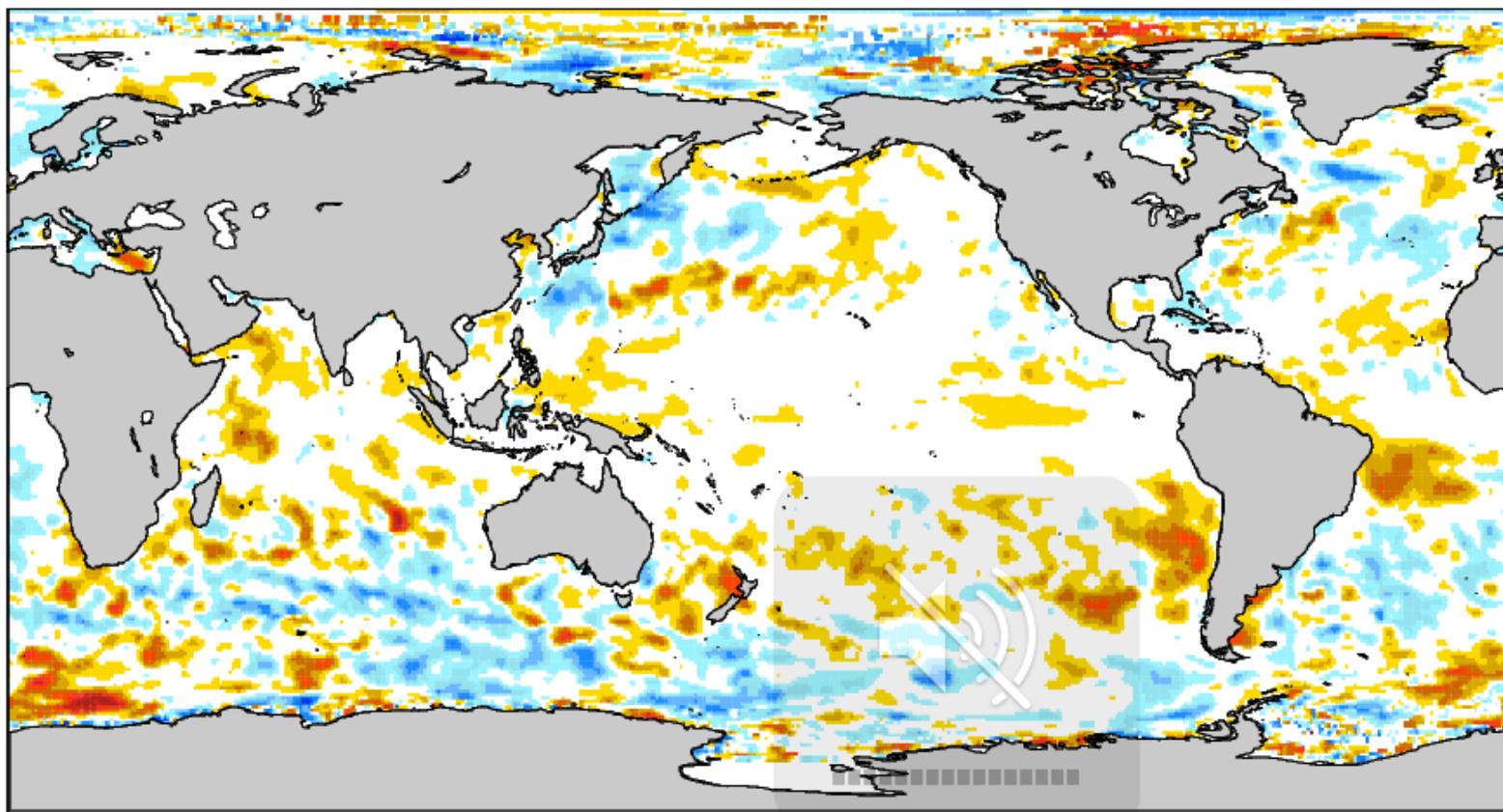
Testing the ocean initial conditions

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



Testing the ocean initial conditions

ORAS4 – GLORYS2v1 correlation skill for JJA from 1st May. Reference: HadISST



Ocean initial conditions for EC-Earth3.1 climate predictions

Source: GLORYS2v1 reanalysis (1993-2009) ORCA025L75

From GLORYS2v1 restarts:

- * **ORCA025L75** : original restarts
- * **ORCA024L46** : 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 , at ECFS ec:/c3y/restarts_m01w
- * **ORCA025L46** : m01w, at ECFS ec:/c3y/restarts_m01w
- * **ORCA1L46** : m01x, at ECFS ec:/c3y/restarts_m01x

Source: ORAS4 reanalysis (1958-2013) ORCA1L42

From ORAS4 restarts:

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

More information : https://dev.ec-earth.org/projects/eearth3/wiki/Ocean_initial_conditions_for_climate_predictions

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

Source: GLORYS2v1 reanalysis (1993-2009) ORCA025L75

From GLORYS2v1 restarts:

- * **ORCA025L75** : original restarts
- * **ORCA024L46** : 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** : original restarts
- * **ORCA024L46** : 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** : original restarts
- * **ORCA024L46** : vertical interpolation + extrapolation + empty seas filled with climatology
- * **ORCA1L46** : vertical and horizontal interpolation + extrapolation + empty seas filled

Future 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 will be performed.

Source: Ocean - GLORYS2v1 reanalysis (1993-2009)

Atmosphere – ERA-Interim reanalysis (1993-2009)

From GLORYS2v1 monthly means and ERA-Interim 6-hourly means

* IFST255L91ORCA1L46 : default nuding configuration

* IFST255L91ORCA1L46 : tuned nudging parameters

**A 20-Century coupled experiment nudging the atmosphere component only.
What is the skill when only the atmosphere is nudged?**

Source: Atmosphere – ERA-20C (1900-2010)

From ERA-20C sea-level pressure and surface winds

* IFST255L91ORCA1L46

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**

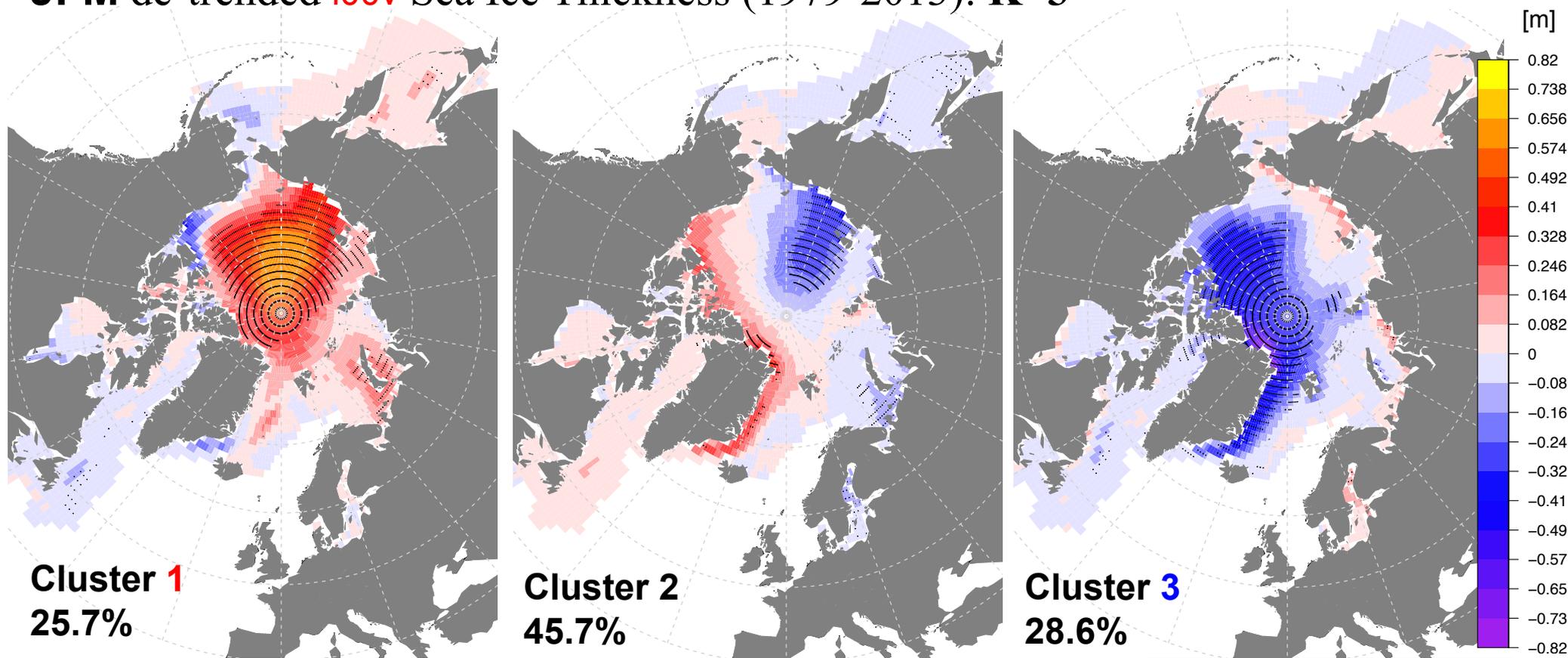
LIM3 – 1 category:

- * **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

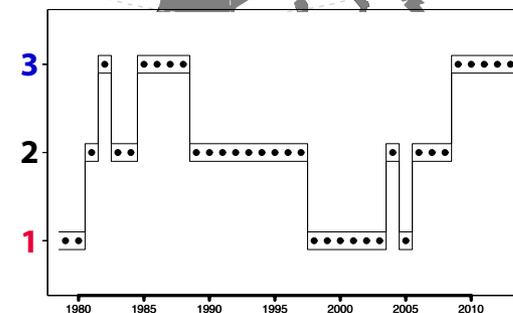
More information : https://dev.ec-earth.org/projects/ecearth3/wiki/Sea_Ice_initial_conditions_for_climate_predictions

K-means cluster analysis of IC3 sea ice reconstruction: PICA-ICE

JFM de-trended **i00v** Sea Ice Thickness (1979-2013): **K=3**



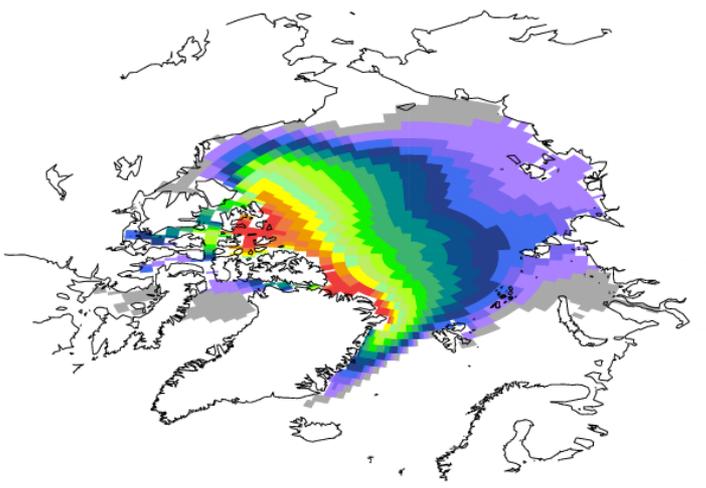
JAS cluster patterns have similar structures



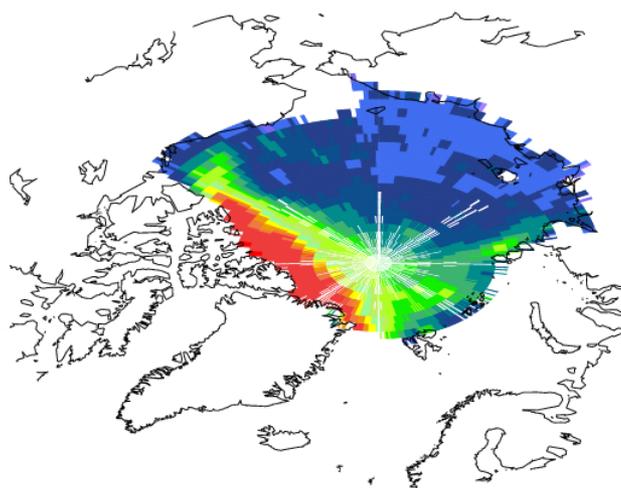
Validation of IC3's LIM3 reconstruction

2003-2007 October-November sea ice thickness

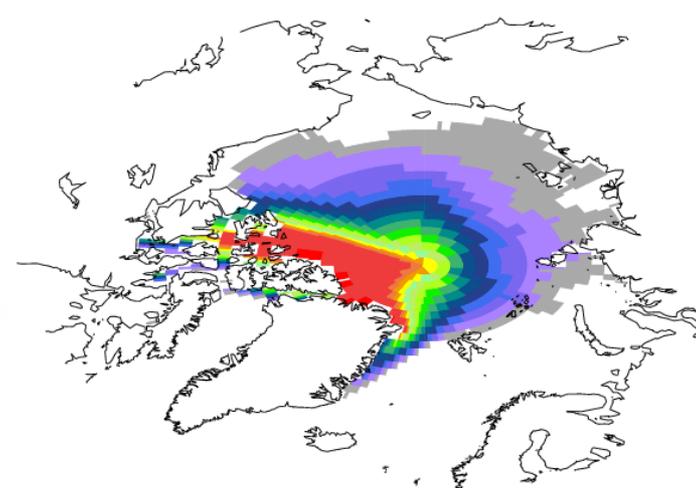
LIM2 reconstruction



IceSat



LIM3 reconstruction



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:

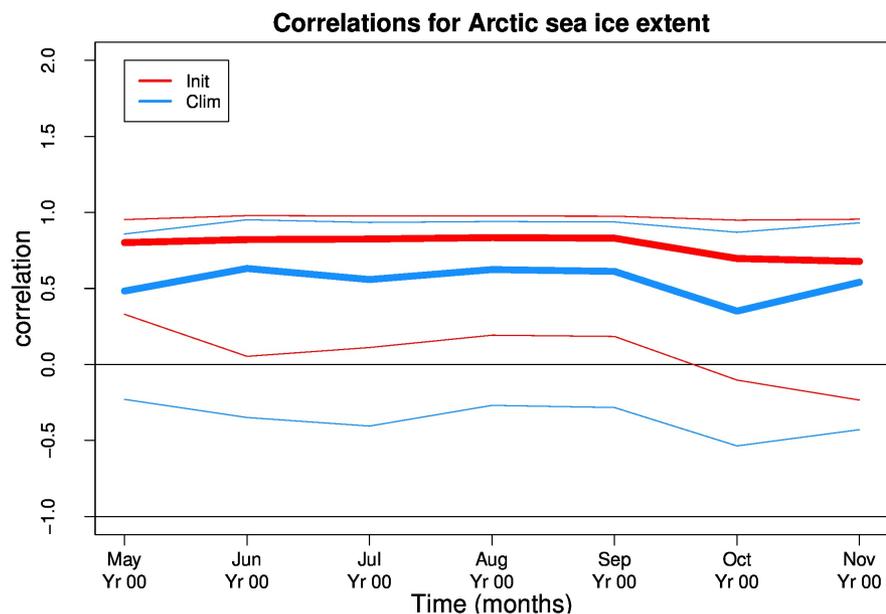
- * **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 monthly-mean 3D T and S and forced by
 1. DFS4.3 over the 1958-2006 period = **i056**
 2. ERA-interim over the 1979-2013 period = **i057**
- * **ORCA025** : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 forced by DFS4.3 and ERA-interim

LIM3 – 5 categories:

- * **ORCA1** : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 and forced by DFS4.3 and ERA-interim

Impact of sea ice initialization : contribution to SPECS

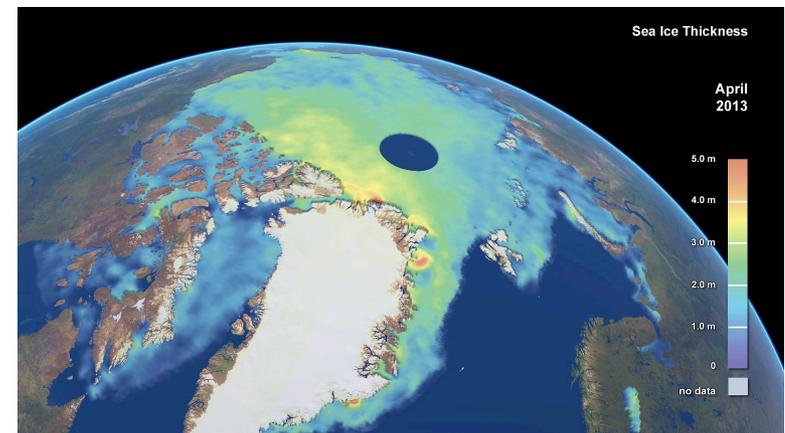
- EC-Earth2.3 in T159L62-ORCA1L42-LIM2 configuration
- Initialization on 1st May and 1st November every year from 1979 to 2012
- 1-year forecasts (5 members)
- IFS initialized from ERA-interim with singular vectors to obtain 5 members
- Ocean initialized from ORAS4
- LIM2 initialized from i00v = HistEraNudg in **Init**
i00v climatology in **Clim**



Clear added-value of sea ice initialization on the Arctic sea ice prediction skill when initialized in May (but with mitigating impact on the atmosphere)

Concluding remarks

- Sets of ocean and sea ice IC are already available (see details on the EC-Earth development portal) → we plan to make even wider spectrum of further improved IC available to the community next year
- Interpolated ocean IC currently enable better climate forecasts than ocean nudging technique, however also including atmospheric nudging and tuning may reverse this
- ORAS4 is better IC source for ORCA1 configuration than GLORYS2v1
- New and improved LIM3 (single category) sea ice reconstruction and the associated IC are available
- K-means cluster analysis of sea ice fields reveals robust pan-Arctic patterns without assumptions constraining PCA
- Added value of realistic sea ice IC in summer are evident in sea ice predictions



Contribution to PREFACE (Enhancing Prediction Of Tropical Atlantic Climate And Its Impacts)

Model: ORCA1L46 initialized from GLORYS2v1.

Simulations: ensemble hindcasts initialized every May and November (4-month integrations).

Goals are to:

→ **Identify biases (with respect to different observational datasets)**

→ **Investigate possible bias generating mechanisms**

