Climate Forecasting Unit

MINISTERIO
DE ECONOMÍA
Y COMPETITIVIDAD

SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Initialisation of the EC-Earth climate forecast system

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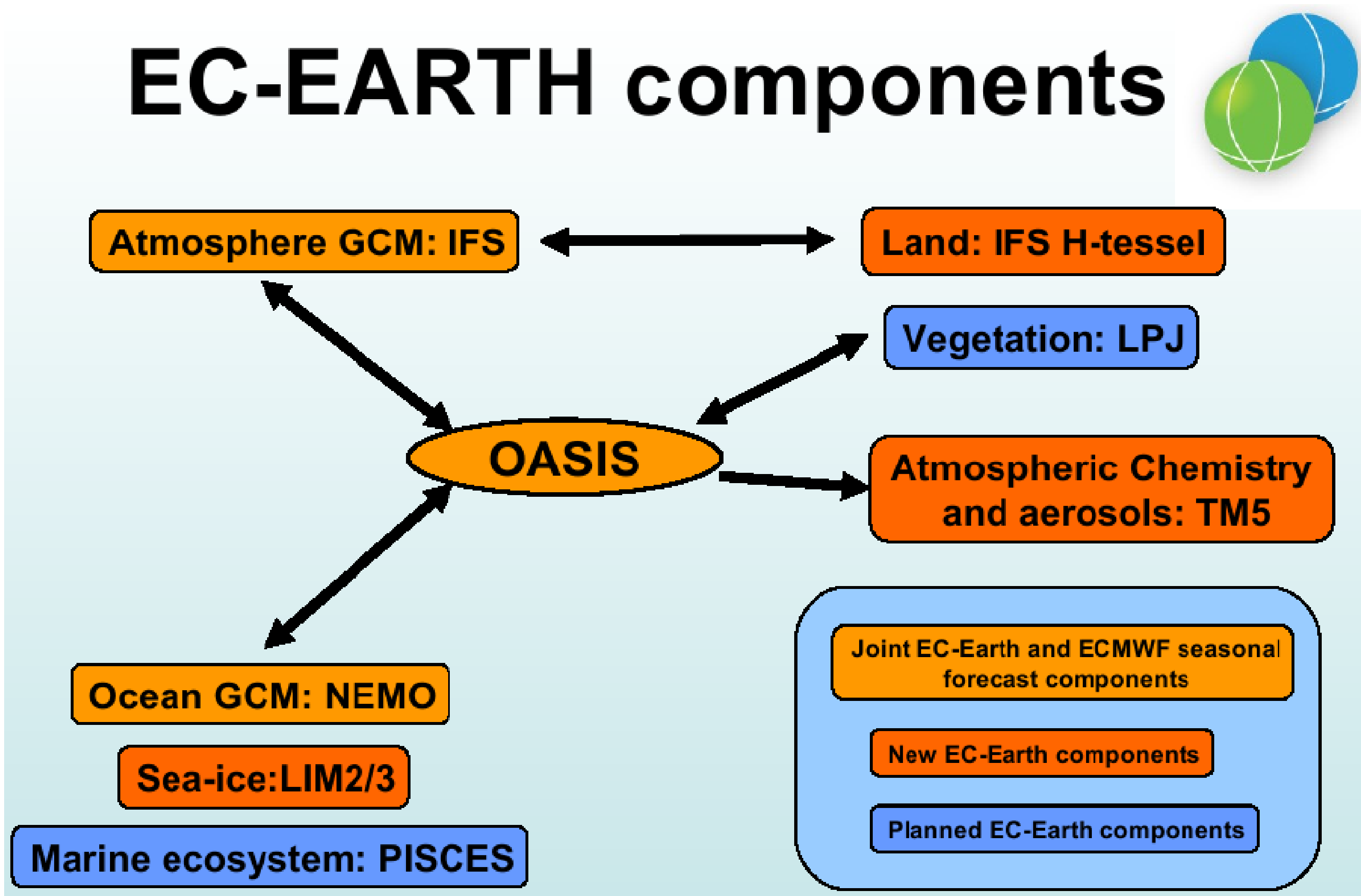
Climate system predictability

- Memory on interannual to centennial timescales in the **ocean**

- Memory on seasonal to interannual timescales in the **sea ice** and **land surface**

- External radiative forcings (solar activity, greenhouse gases, aerosols)

Model


EC-EARTH components
Atmosphere GCM: IFS
Land: IFS H-tessel
Vegetation: LPJ
OASIS
Atmospheric Chemistry and aerosols: TM5
Ocean GCM: NEMO
Sea-ice:LIM2/3
Marine ecosystem: PISCES
Joint EC-Earth and ECMWF seasonal forecast components
New EC-Earth components
Planned EC-Earth components

Objectives

1. Initialize each model component (atmosphere, ocean, sea ice) with the best possible estimate of the observed climate state

2. Ensure an optimal consistency between the initial states of all the model components

3. Account for the initial state uncertainty through the generation of ensembles

Initialization of EC-Earth2.3 – CMIP5

Ocean: NEMOVAR-ORAS4 5-member ORCA1L42 ocean reanalysis developed by the ECMWF

Atmosphere: ERA40 (before 1989) and ERAInt (after 1989) atmospheric reanalysis developed by the ECMWF; use of singular vectors to generate initial perturbations

Sea ice: in-house 5-member LIM2 ORCA1 reconstructions

In-house sea ice reconstructions (1/5)

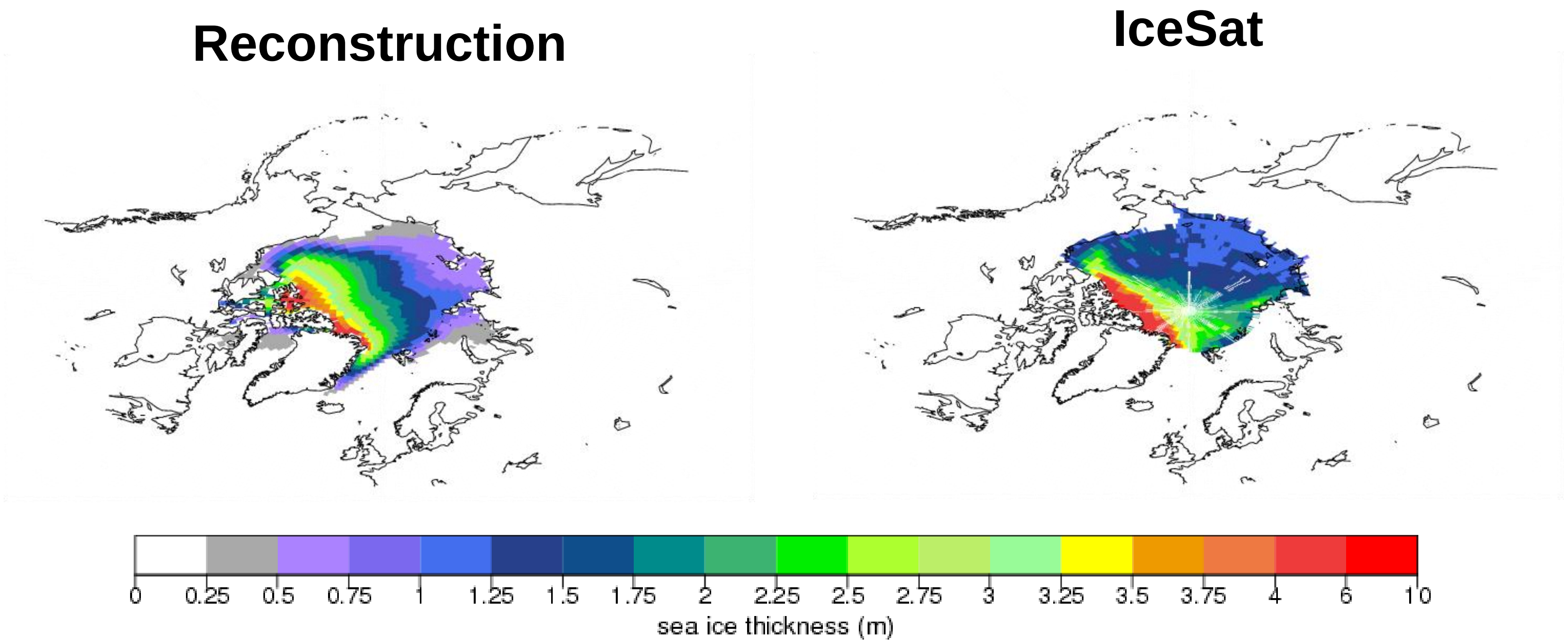
- **<u>NEMO3.2</u> ocean model + <u>LIM2</u> sea ice model**
- **<u>Forcings :</u> 1958-2006 DFS4.3 or 1979-2013 ERA-interim**
- **<u>Nudging :</u> T and S toward ORAS4, timescales = 360 days below 800m, and 10 days above except in the mixed layer, except at the equator (1°S-1°N), SST & SSS restoring (-40W/m2, -150 mm/day/psu)**
- **<u>Wind perturbations + 5-member ORAS4</u> - - - > 5 members for sea ice reconstruction**

5 member sea ice reconstruction for 1958-present consistent with ocean and atmosphere states used for initialization

Guemas et al (2014) Climate Dynamics

In-house sea ice reconstructions (2/5)

October-November Arctic sea ice thickness



Too much ice in central Arctic, too few in the Chukchi and East Siberian Seas

Guemas et al (2014) Climate Dynamics

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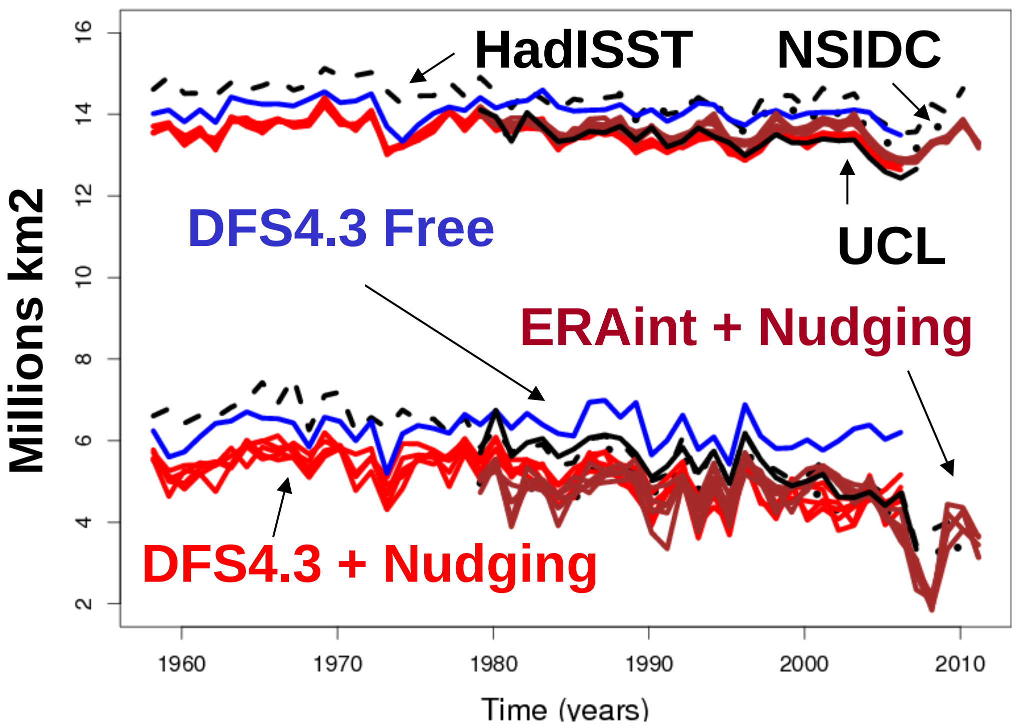
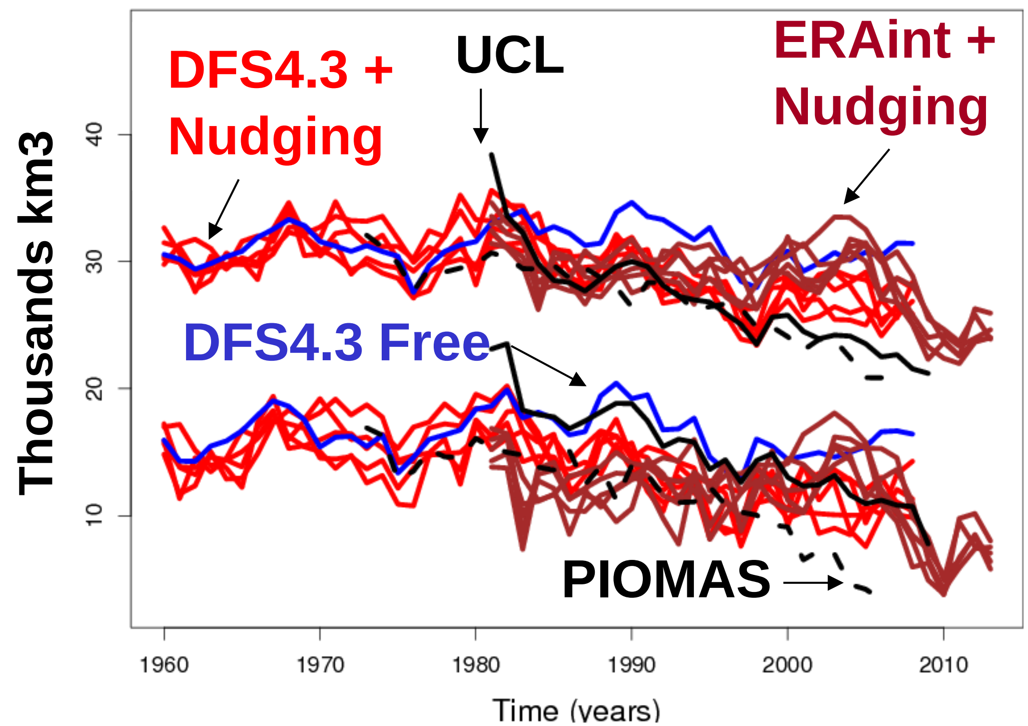
In-house sea ice reconstructions (3/5)

March and September Arctic sea ice

Sea ice area



Sea ice volume



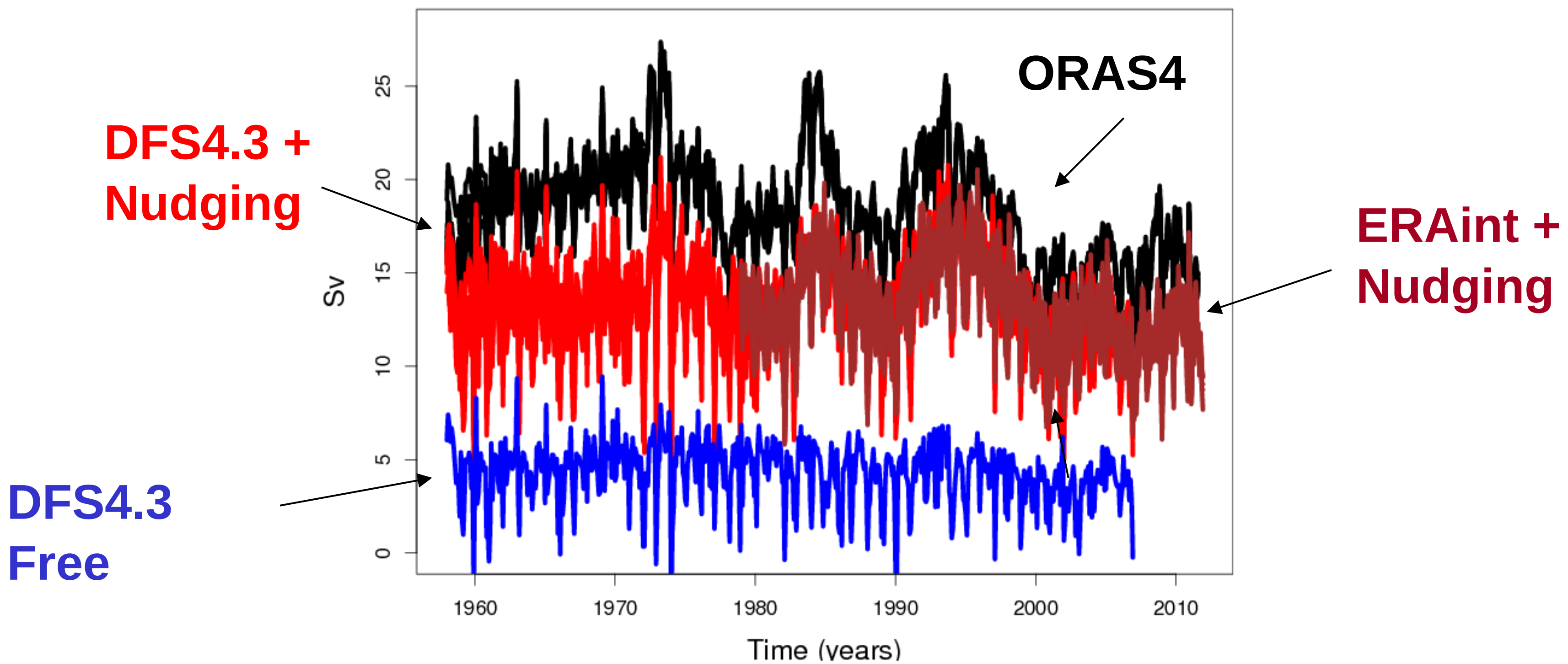
Bias but reasonable agreement in terms of interannual variability

Guemas et al (2014) Climate Dynamics

In-house sea ice reconstructions (4/5)

Atlantic Meridional Overturning Circulation

Overturning Streamfunction 40-55N, 1-2km



Ocean nudging allows capturing decadal variability in AMOC and warm inflow in the Barents Sea

Guemas et al (2014) Climate Dynamics

Initialization of EC-Earth3.1 – CMIP6

Ocean: GLORYS2v1 ORCA025L75 1-member ocean reanalysis developed by MERCATOR, NEMOVAR-ORAS4 ORCA1L42 5-member ocean reanalysis developed by the ECMWF

Atmosphere: ERA40 (before 1989) and ERAInt (after 1989) atmospheric reanalysis developed by the ECMWF; use of singular vectors to generate initial perturbations

Sea ice: GLORYS2v1 ORCA025, in-house 5-member ORCA1 LIM2 and LIM3 reconstructions

How to handle the various resolutions?

Ocean initialization

EC-Earth3.1

ORCA1L46

ORCA025L46

ORCA025L75

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions

ORAS4 ORCA1L42	GLORYS2V1 ORCA025L75

EC-Earth3.1

ORCA1L46	ORCA025L46	ORCA025L75

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions

ORAS4
ORCA1L42

GLORYS2V1
ORCA025L75

Horizontal/vertical interpolation

Horizontal/vertical extrapolation

Empty seas filled with climatology

EC-Earth3.1

ORCA1L46

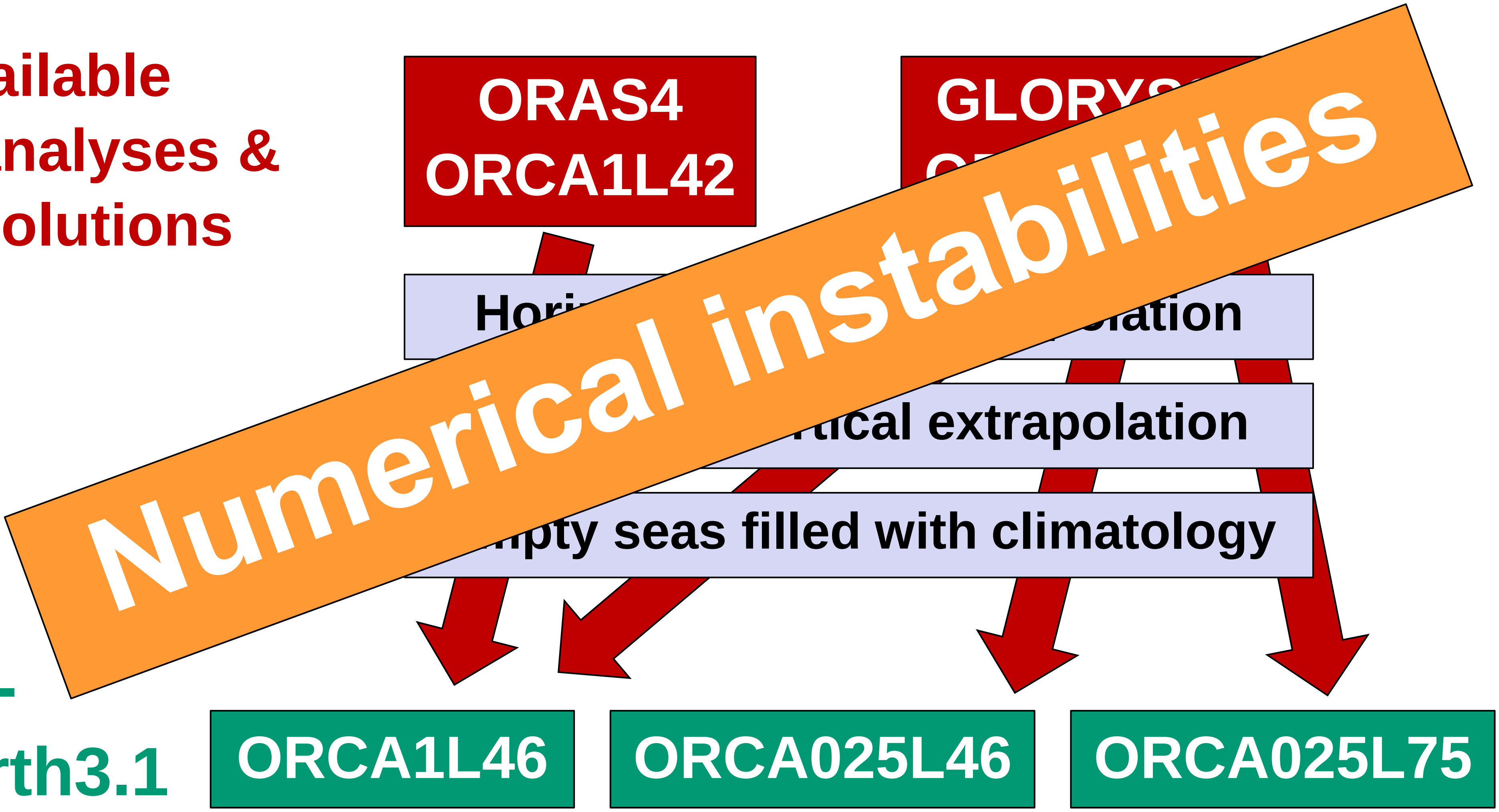
ORCA025L46

ORCA025L75

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions



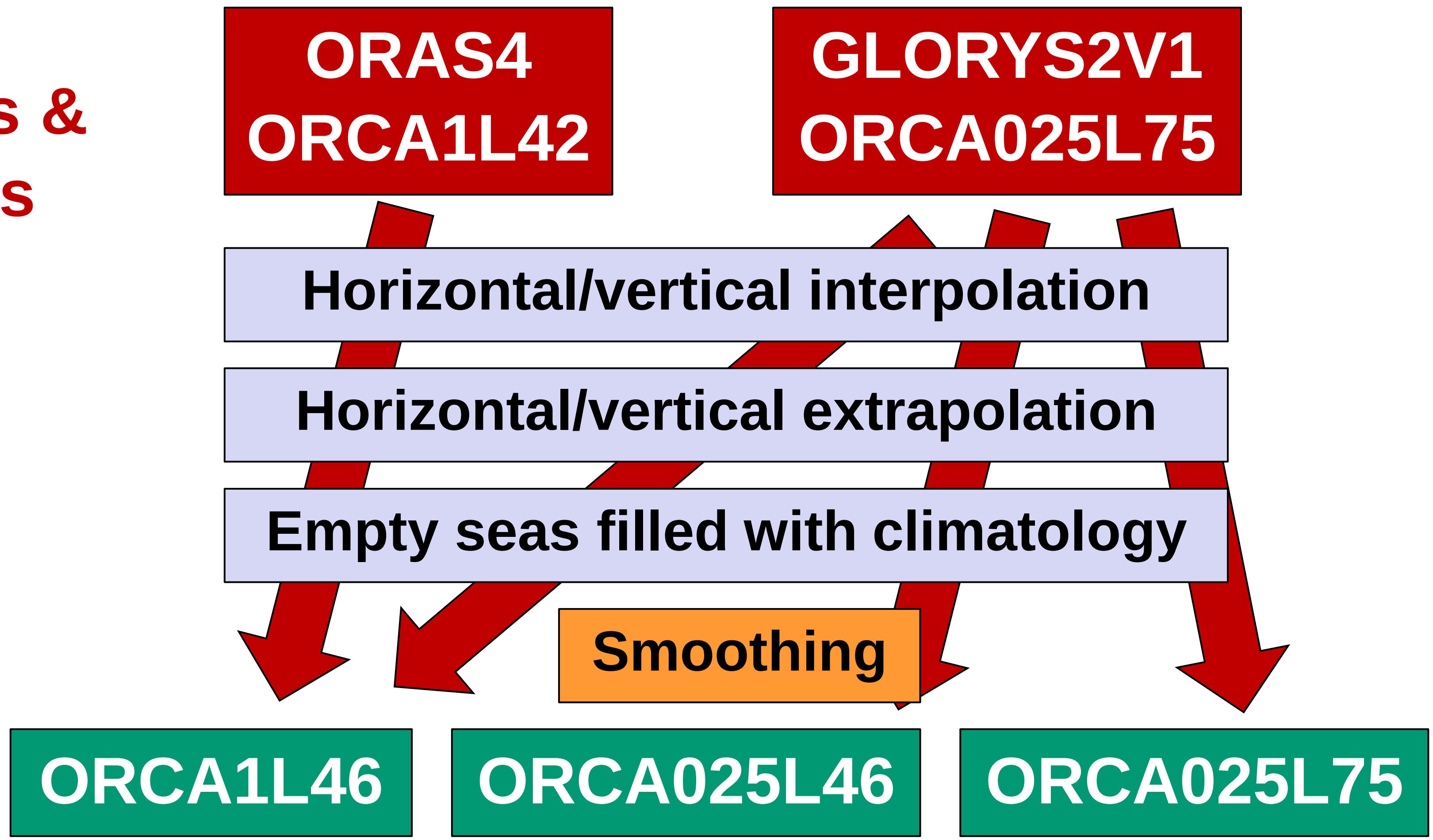
EC-Earth3.1

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions

EC-Earth3.1



Can we improve the internal consistency of our ocean initial state to avoid smoothing?

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions

ORAS4
ORCA1L42

GLORYS2V1
ORCA025L75

Horizontal/vertical interpolation/extrapolation of monthly temperature and salinity

Coupled simulations with 3D T and S nudged toward monthly-mean reanalysis (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)

EC-Earth3.1

ORCA1L46 | **ORCA025L46** | **ORCA025L75**

Testing the ocean initial conditions

- EC-Earth3.0.1 - T255L91-ORCA1L46-LIM2
- Initialization on 1st May and 1st November every year from 1993 to 2009
- 4 month forecasts
- 5 members
- LIM2 initialized from interpolated GLORYS 2v1
- Ocean initialized from

  interpolated GLORYS2 v1 restarts = **Interp**

  or restarts from nudged simulation = **Nudg**

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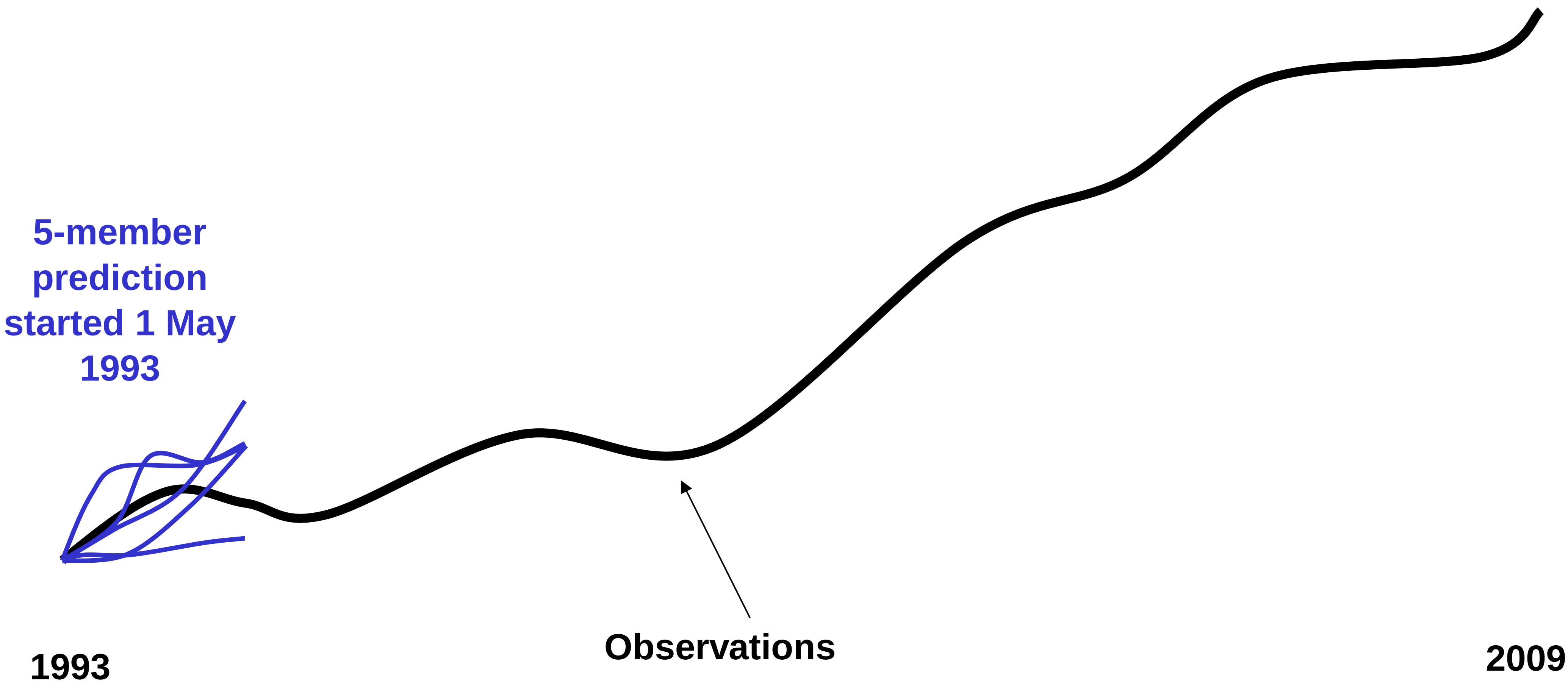
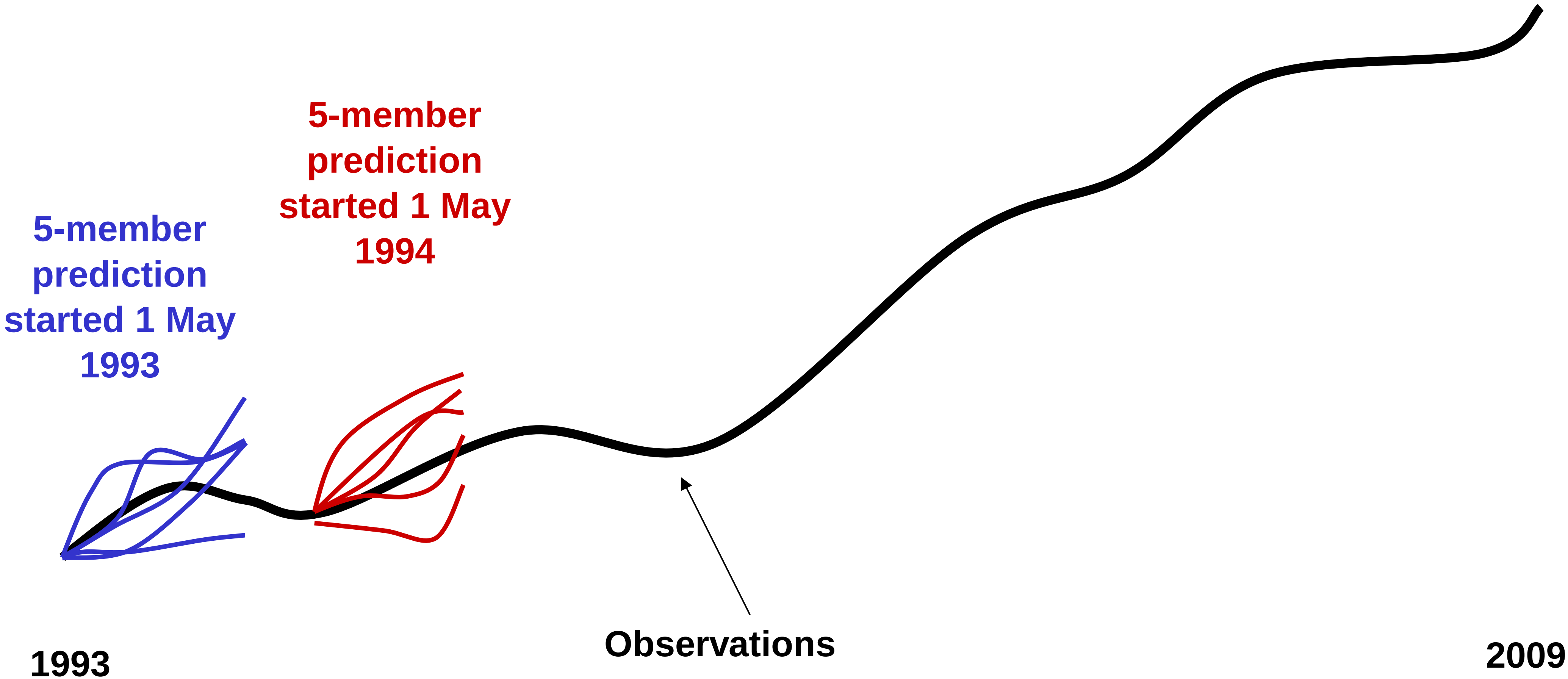
Methodology

Experimental setup : 1 grid-point



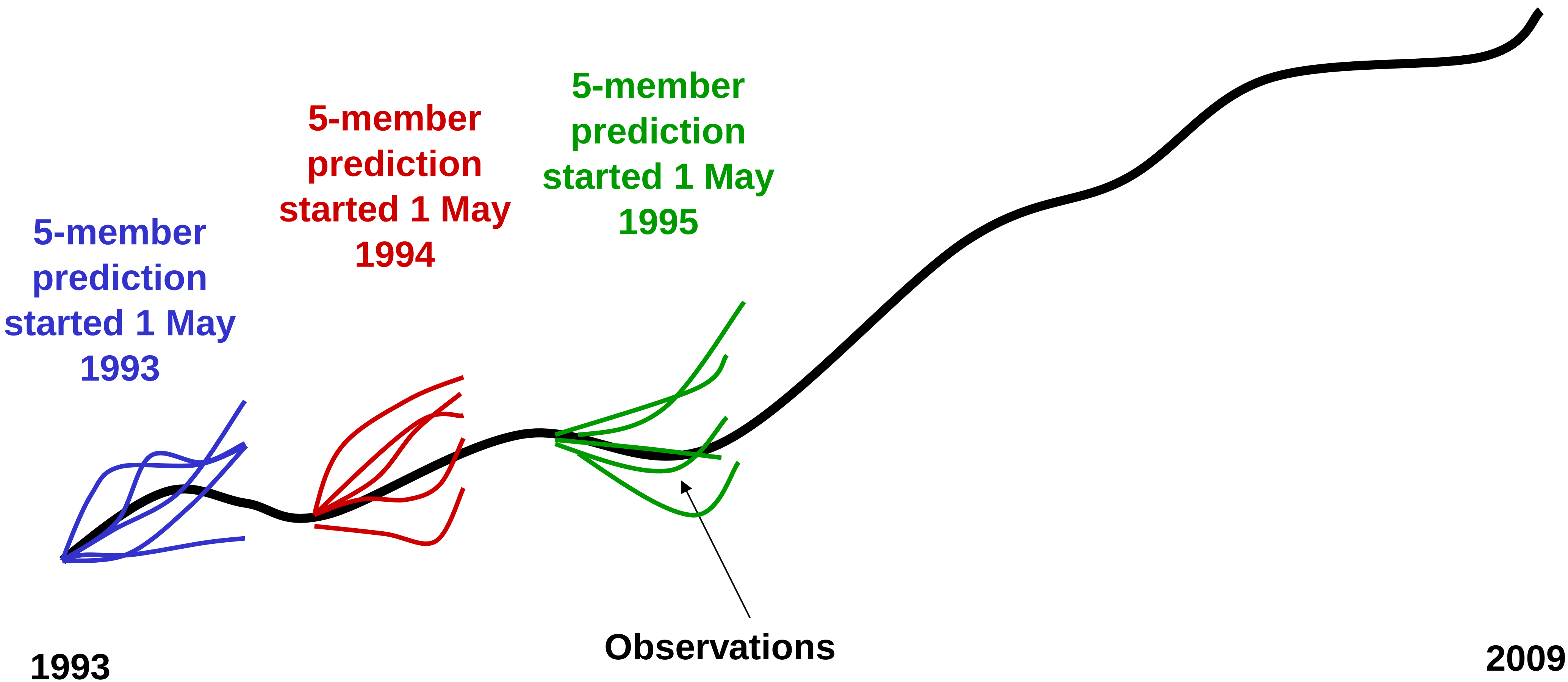
Methodology

Experimental setup : 1 grid-point



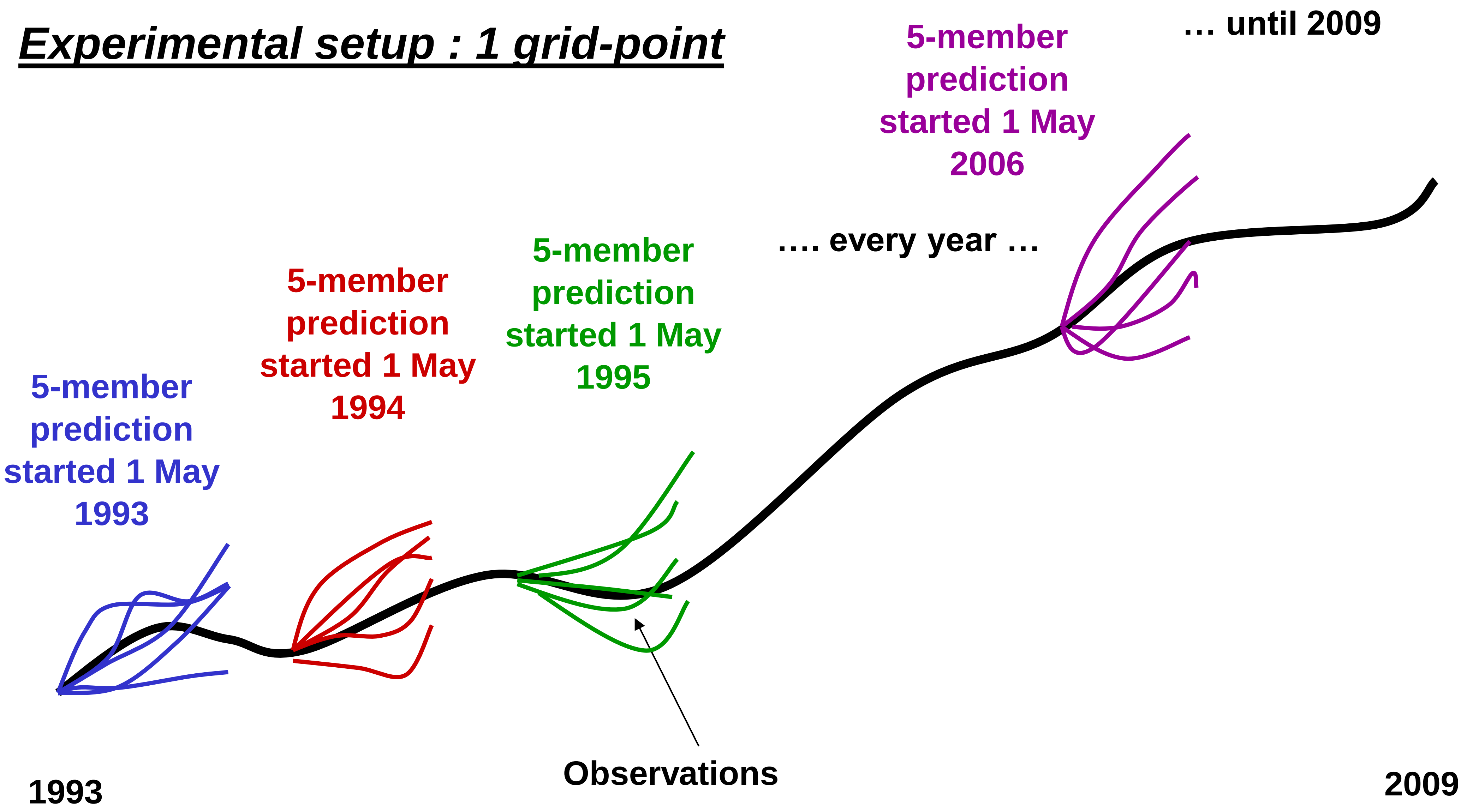
Methodology

Experimental setup : 1 grid-point



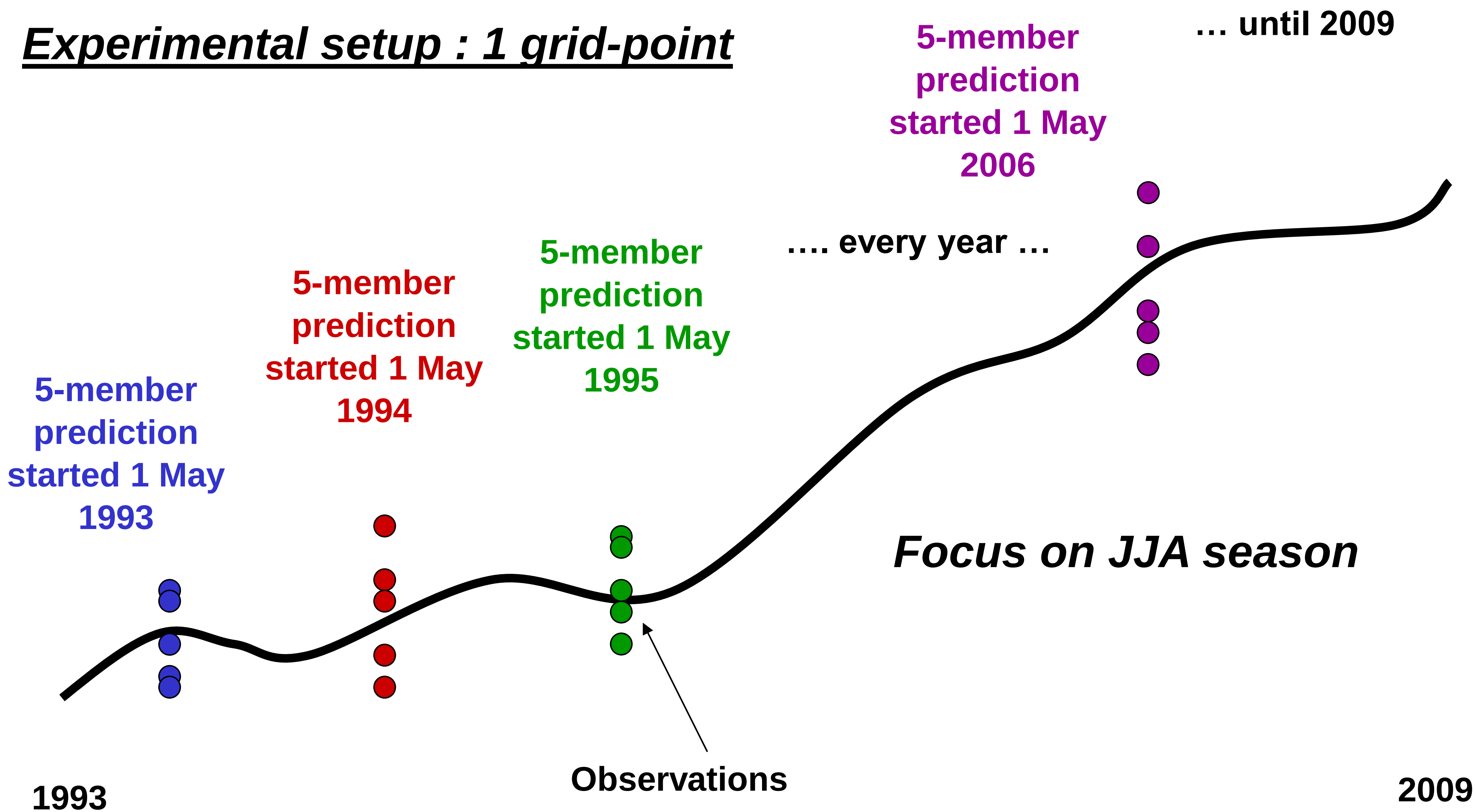
Methodology

Experimental setup : 1 grid-point



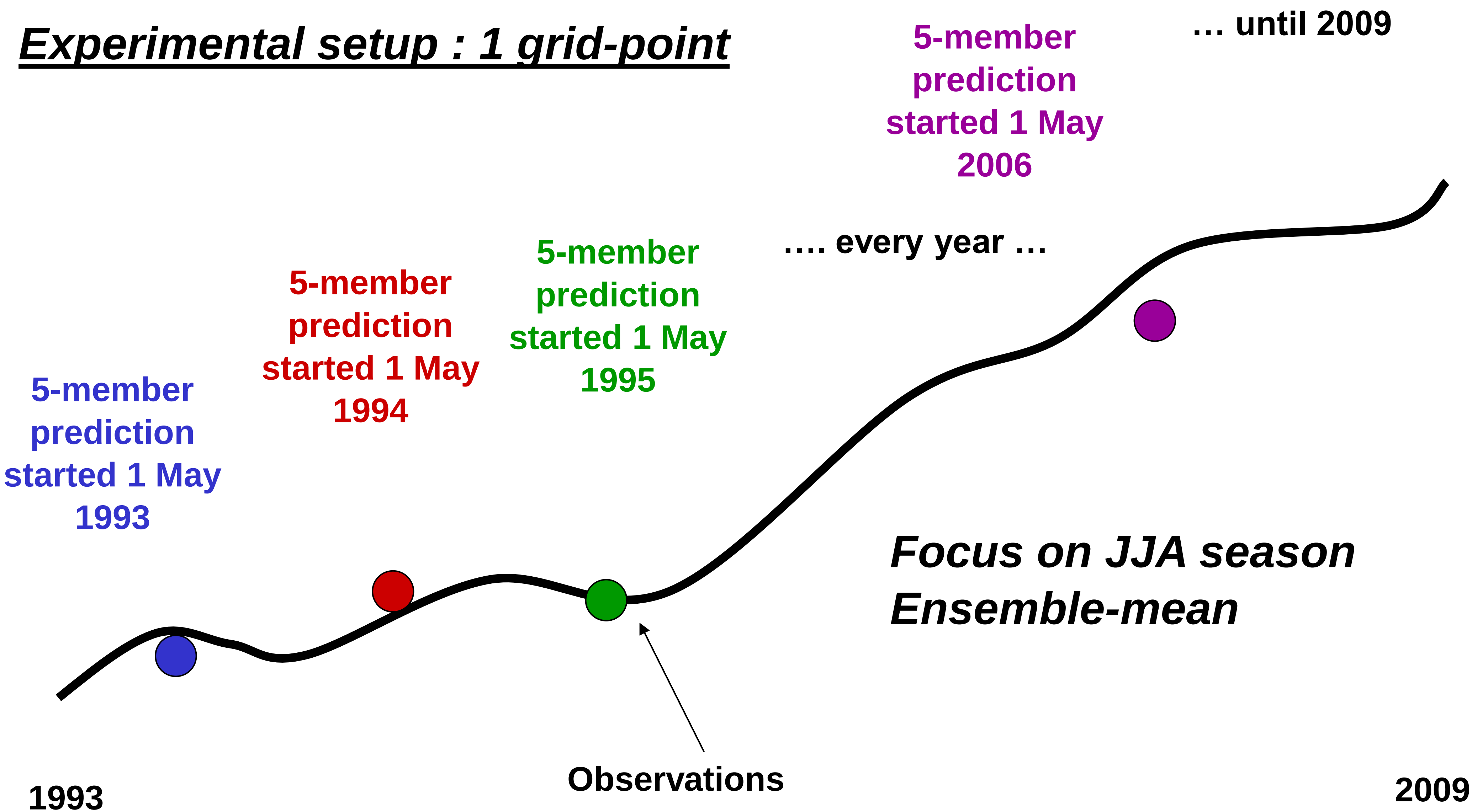
Methodology

Experimental setup : 1 grid-point



Methodology

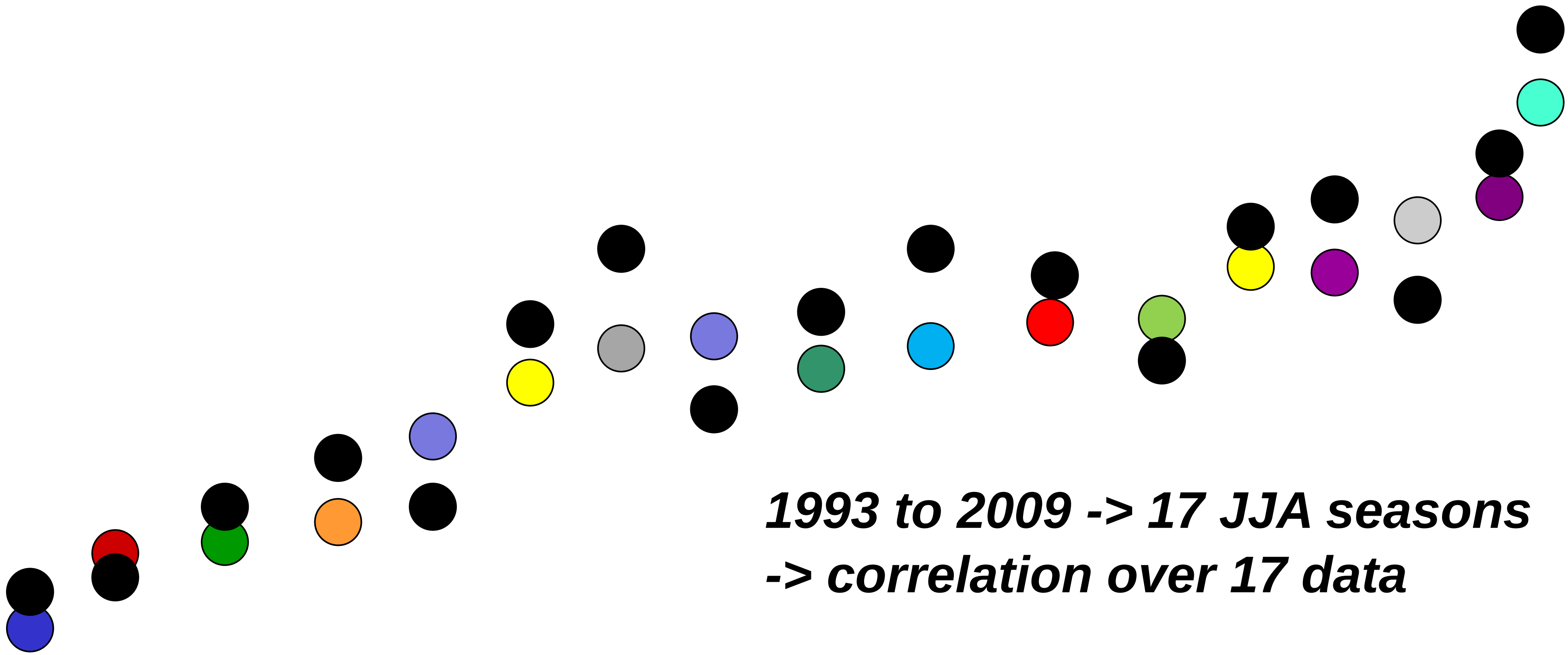
Experimental setup : 1 grid-point



Focus on JJA season
Ensemble-mean

Methodology

<u>Experimental setup : 1 grid-point</u>

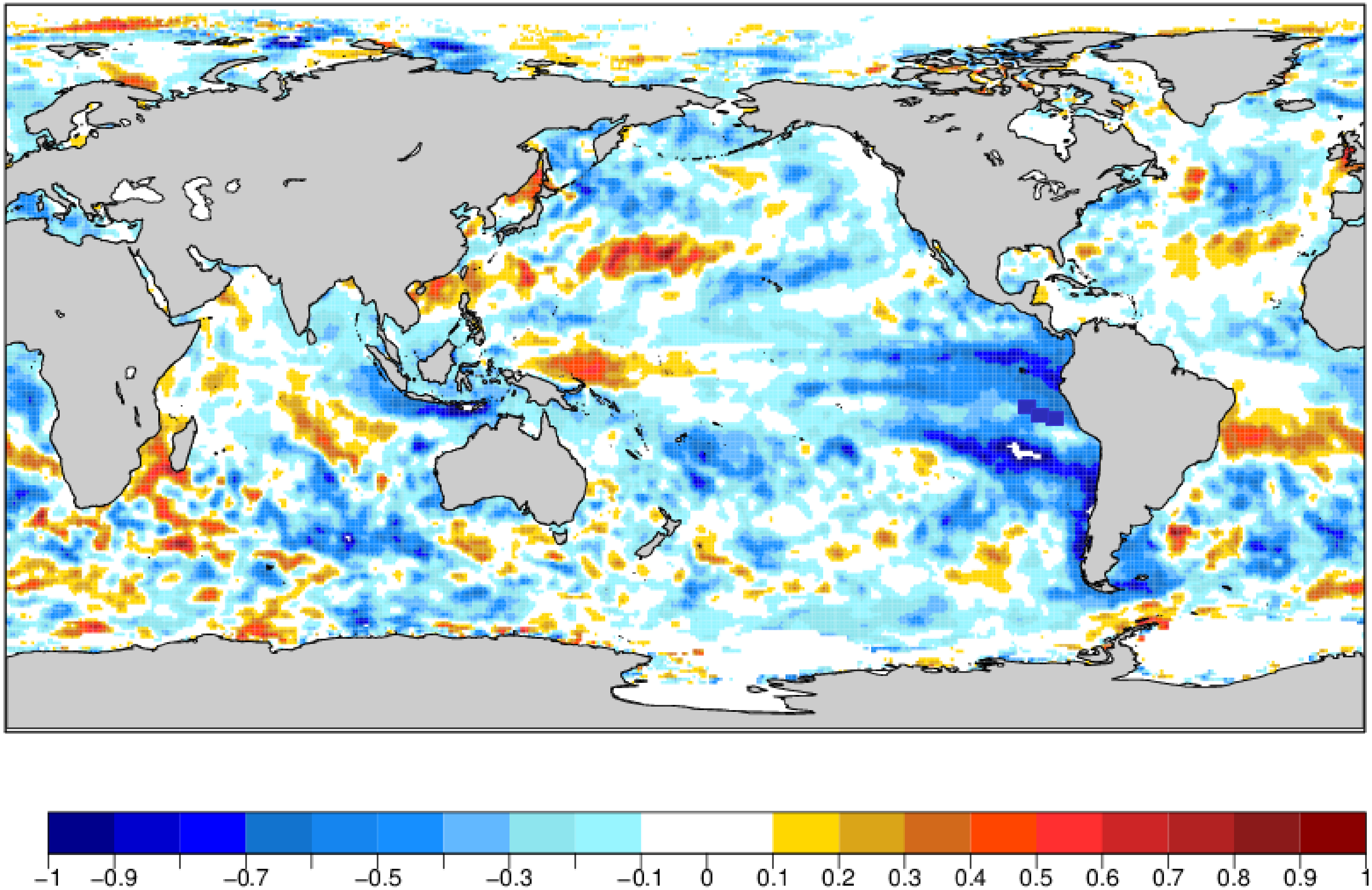


1993 to 2009 -> 17 JJA seasons
-> correlation over 17 data

1993 **2009**

Testing the ocean initial conditions

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



Interp better skill *chloe.prodhomme@ic3.cat* **Nudg better skill**

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How to handle the various resolutions?

Ocean initialization

Av[illegible]ilable rea[illegible]s & resolution[illegible]

ORAS4 ORCA1L42

GLOR[illegible]V1 O[illegible]025L75

Horizo[illegible]tical in[illegible]lation/extrapolation of month[illegible]ature and salinity

Coupled [illegible]ations w[illegible] and S nudged toward [illegible]nly-mean reanalysis ([illegible]elow 800m, 10 da[illegible] 800m except in the mixed layer + SST & [illegible]ing -40W/m2, -150 mm/day/psu except along 1°S-1°N)

EC-Earth[illegible]

ORCA1L46

ORCA025L46

ORCA025L75

How to handle the various resolutions?

Ocean initialization

Available reanalyses & resolutions

ORAS4
ORCA1L42

GLORYS2V1
ORCA025L75

Coupled simulations with nudging in the atmosphere and in the ocean ? With a stronger strength of the nudging ?

?

EC-Earth3.1

ORCA1L46

ORCA025L46

ORCA025L75

How to handle the various resolutions?

Ocean initialization

ORAS4	GLORYS2V1	GLOSEA5	ORAP5
ORCA1L42	ORCA025L75	ORCA025L75	ORCA025L75

Horizontal/vertical interpolation

Horizontal/vertical extrapolation

Empty seas filled with climatology

Smoothing

EC-Earth3.1

ORCA1L46	ORCA025L46	ORCA025L75

Which sea ice product ?

EC-Earth3.1- LIM2

In-house ORCA1 reconstruction

GLORYS2V1 ORCA025

GLORYS2V1 interpolated to ORCA1

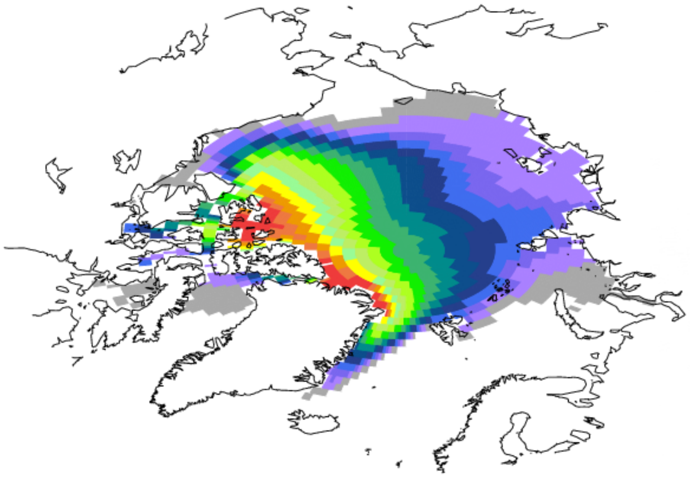
EC-Earth3.1- LIM3

In-house ORCA1 reconstruction

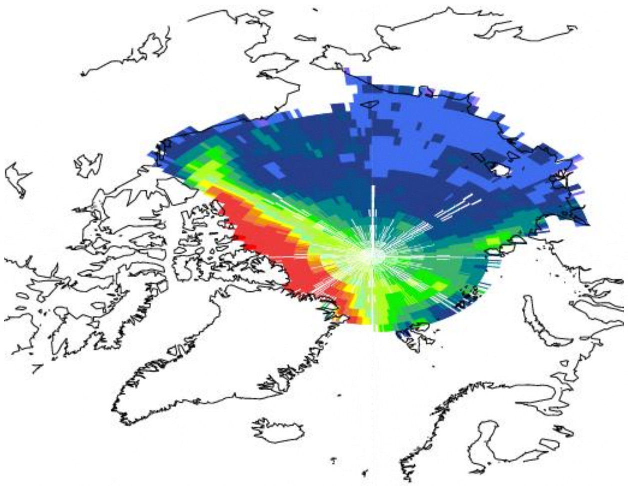
In-house sea ice reconstructions (5/5)

2003-2007 October-November sea ice thickness

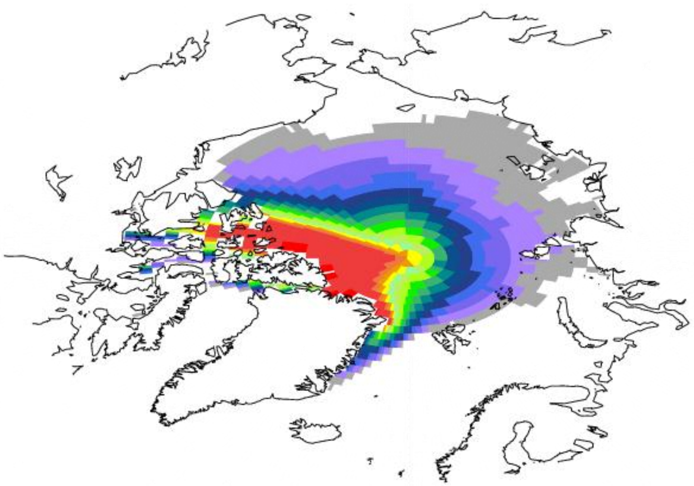
LIM2 reconstruction

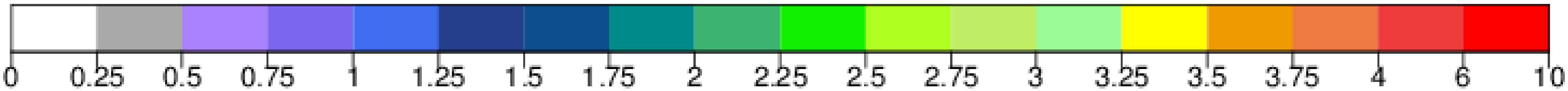


IceSat



LIM3 reconstruction





Sea ice reanalysis to come

- 1979-present
- **Ensemble Kalman Filter** : Assimilation of satellite sea ice concentration, in-situ and satellite sea ice thickness
- Arctic and Antarctic sea ice
- ORCA1/NEMO3.6/LIM3, 25 members

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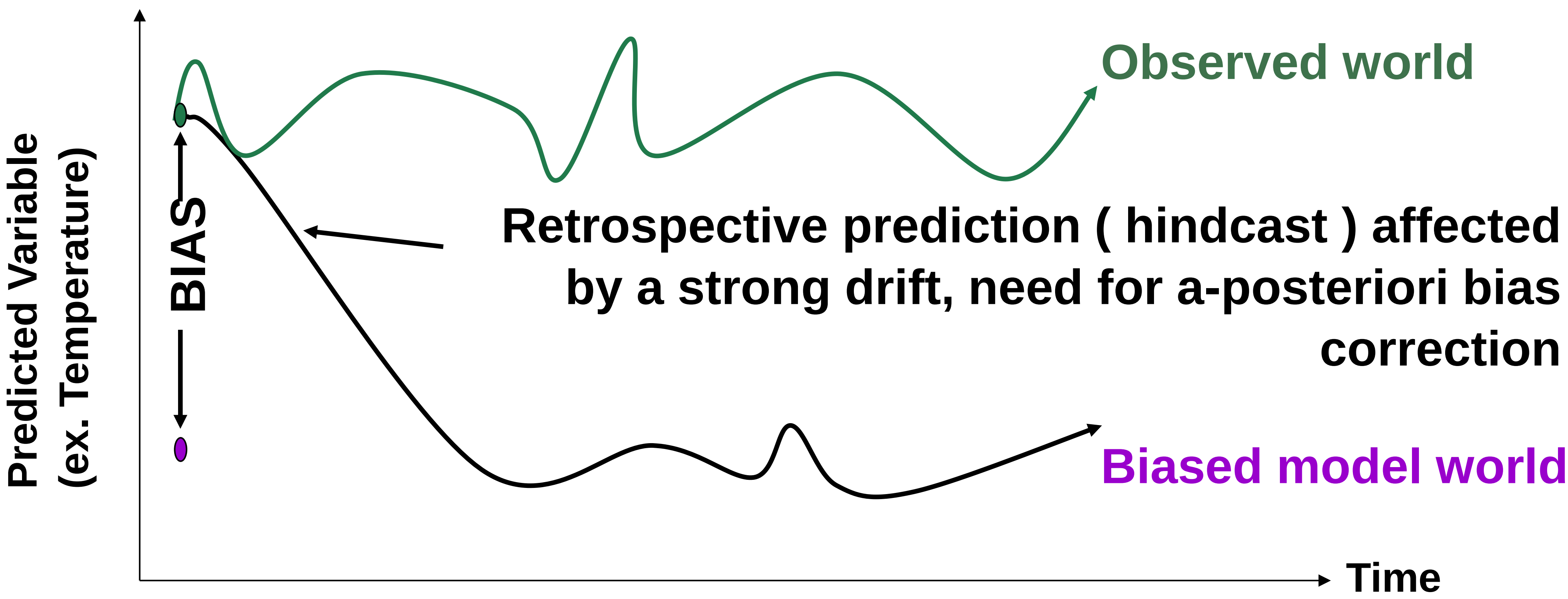
The climate prediction drift issue



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The climate prediction drift issue

- Issue : Distinction between climate drift and climate signal
- Hypothesis : If the model climate is stable (no drift), the simulated variability is independent of the model mean state within the range of current model biases and closer to the observed variability than when mixed with the drift
- Testing the hypothesis : Allowing the climate model biases but constraining the phase of the simulated variability toward the contemporaneous observed one at the initialization time : Anomaly Initialization (AI)

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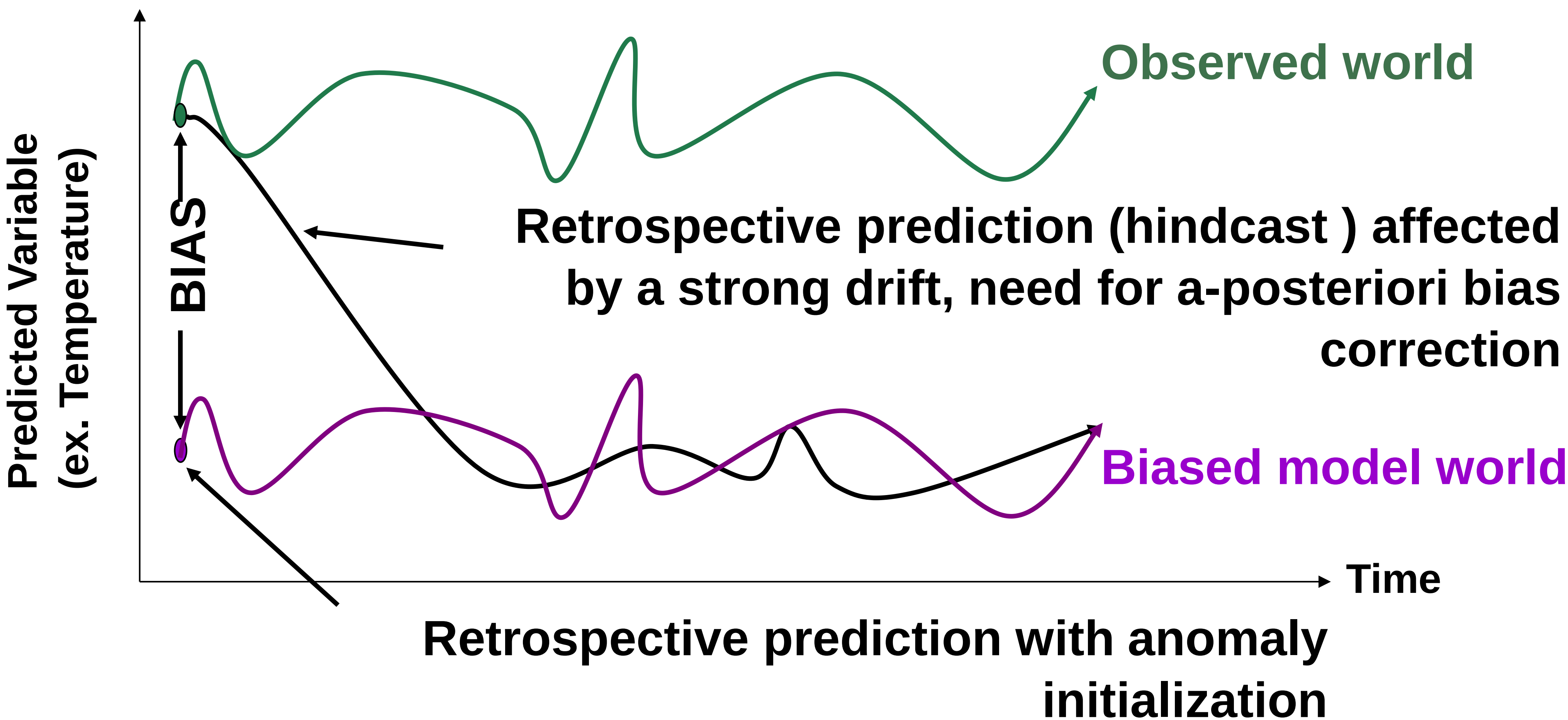
The climate prediction drift issue



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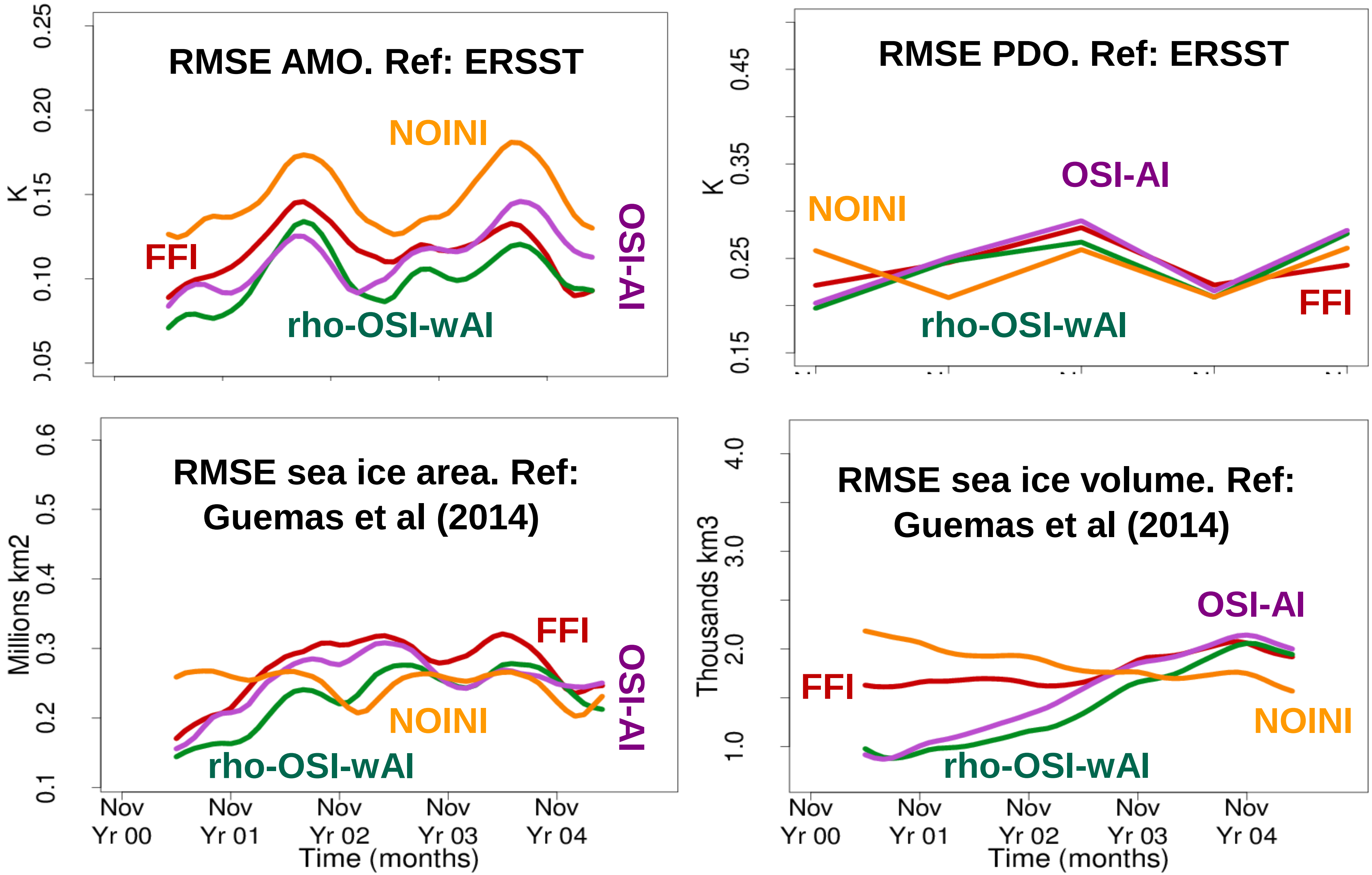
Anomaly versus Full Field Initialization

EC-Earth2.3, 5 members, start dates every 2 years from 1960 to 2004



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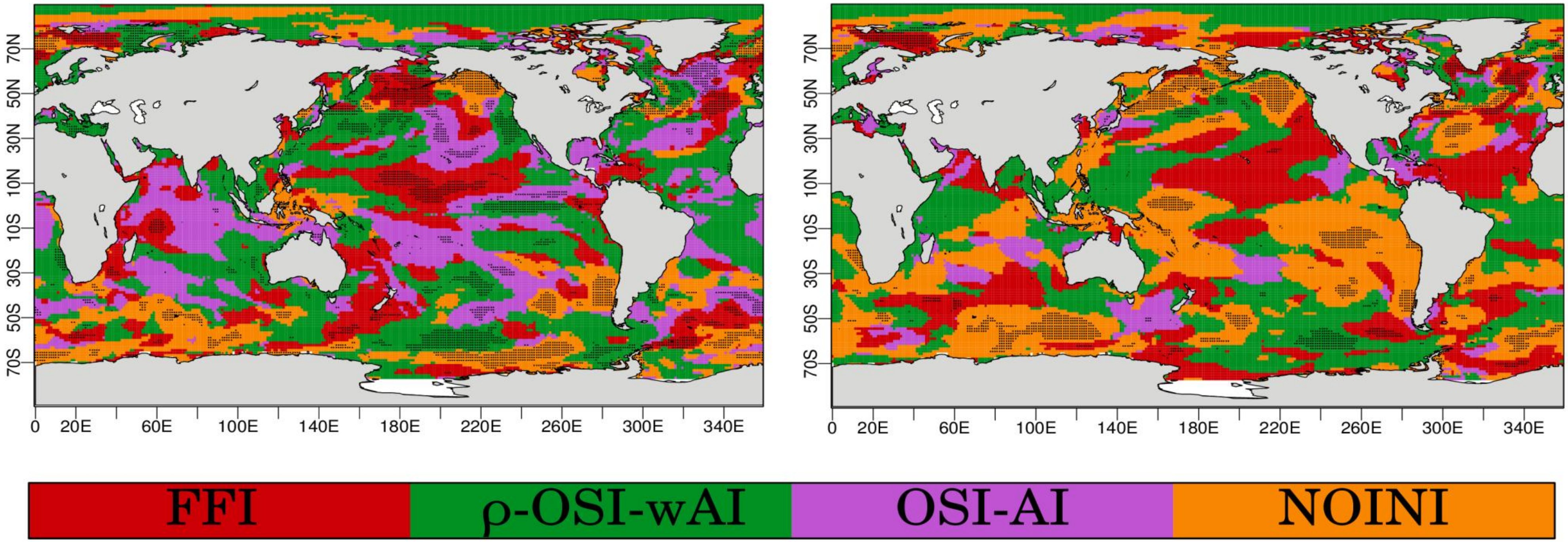
Anomaly versus Full Field Initialization

Experiment with the minimum SST RMSE

Forecast year 1 **Forecast years 2-5**



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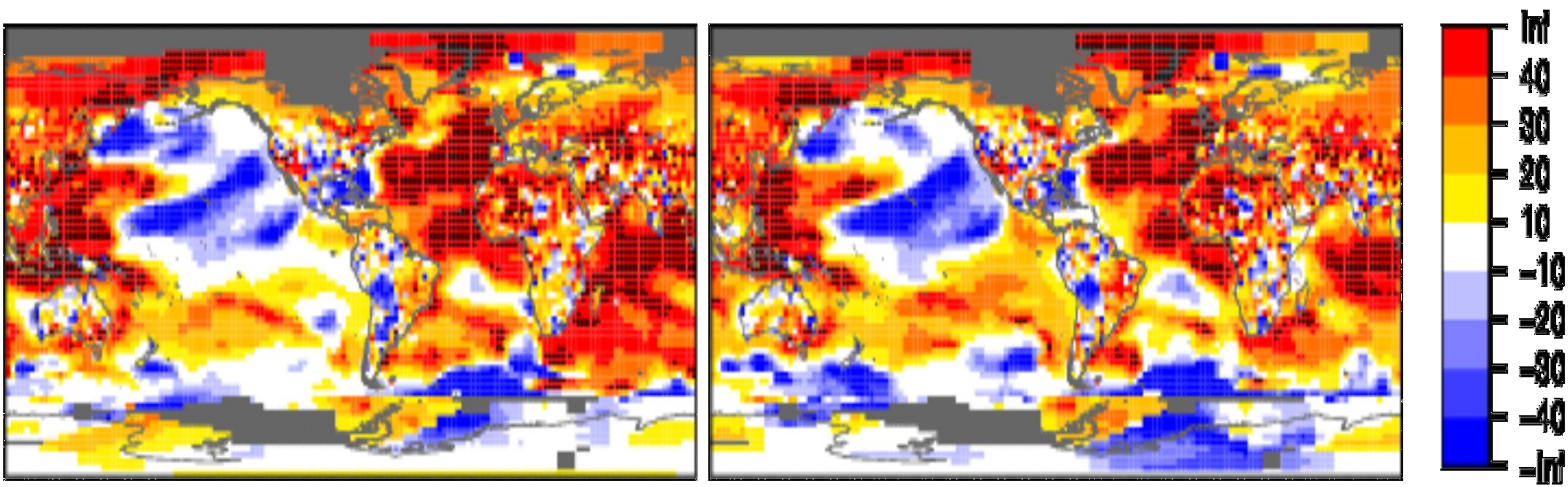
How do we use our predictions ?

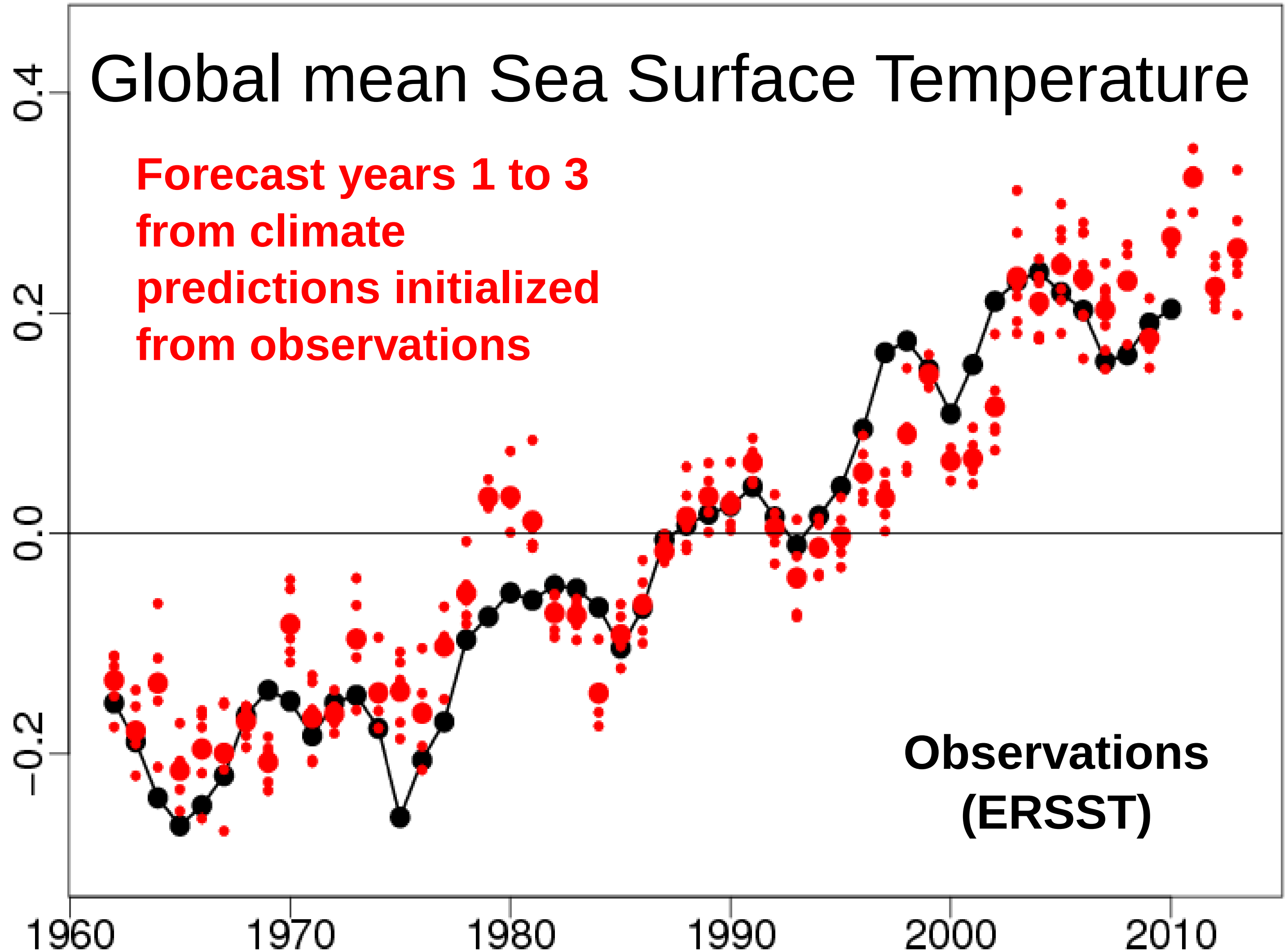
IPCC AR5 decadal predictions

Root mean square skill score (RMSSS) of the ensemble mean predictions for the near-surface temperature from the multi-model experiment produced for the 5th Assessment Report of Intergovernmental Panel on Climate Change (1960-2005) for (left) 2-5 and (right) 6-9 forecast years. Five-year start date interval.



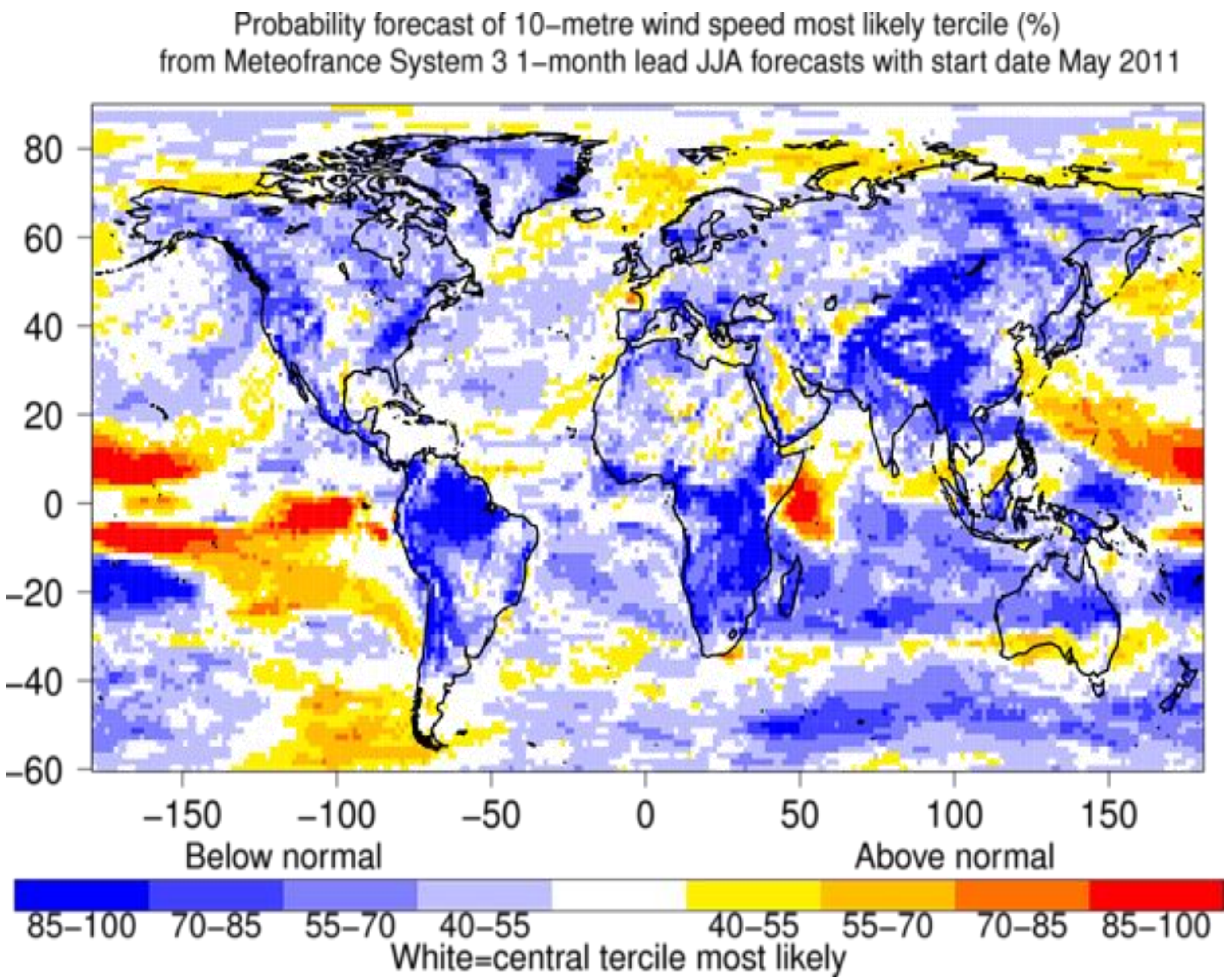
Doblas-Reyes et al. (2013), Nature Communications

Predictions of the XXIst century hiatus



Guemas et al. (2013), Nature Climate Change

Climate services: renewable energy



Lienert and Doblas-Reyes (2013)

Conclusions

- Use of a wide variety of reanalyses which need to be adapted to various resolutions: best methodology still under investigation
- Need for suitable sea ice data assimilation development
- Need for sampling of the initial condition uncertainties