CERA: The Coupled ECMWF ReAnalysis System

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In the context of the **ESA DA** projects, ECMWF has been developing a coupled data assimilation system for re-analysis called **CERA**.

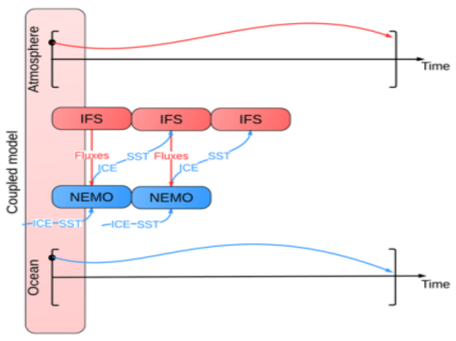
- **Context**: uncoupled IC far from the natural state of coupled model. Initialization shocks and drift.
- **Purpose**: building a coupled atmosphere-ocean data assimilation framework to generate consistent climate system state for climate studies and forecasts
- **CERA system**: coupled model in the outer loop + separate ocean-atmosphere inner loops

The coupled model

Atmosphere: IFS 38R1 T159L91

Ocean Model: NEMO V3.4 ORCA1 and 42 levels

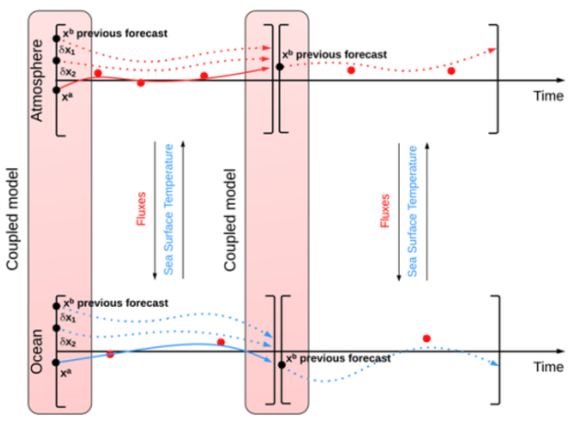
3-hour sequential coupling in a single executable environment



The coupled data assimilation system

General design

- Misfit with observations computed in **coupled mode**.
- Atmos. and Ocean increments computed **in parallel: 4D-var** in the Atmos, **3D-var FGAT** in the Ocean
- Variational minimization **do not use** cross model covariance
- **Multiple outer iterations** allow ocean observations to have an immediate effect on the atmospheric analysis.



Observations

Atmosphere	
Land Surface (weather stations)	Surface Pressure 2 m Temperature 10 m Wind Direction/Force Precipitation Information
Sea Surface (ships and buoys)	Surface Pressure 10 m Wind Direction/Force 2 m Temperature
Upper Air Sounding (balloons)	10m Upper Air Wind Direction/Force 2m Upper Air Temperature Geopotential Height
Satellite Sounding	Upper Air Wind Direction/Force Mean Layer Temperature Precipitable Water Content Brightness Temperature Backscatter
Aircraft report	Aircraft Upper Air Wind Direction/Force Temperature

Ocean	
XBT	Temperature
CTD/ARGO/Moorings	Temperatue Salinity
Altimeters	Sea level anomalies
SST maps	(via nudging)

Relaxation toward SST observations in the ocean component

Constraining the SST

Purpose: constrain the long-term mean while allowing high-frequency variability. Particularly relevant in **poorly-observed periods**.

- In the NEMO code the relaxation is an **additional flux term**:

$$X = SST - SST_{obs}$$
$$constraint = -\lambda X$$

1 timescale
λ daily

In coupled mode: **need strong λ** to avoid the drift … may inhibit high freq. variability

- Alternative = **2 constraints**: strong on low freq. and weak on high freq.

$$\bar{X} = \overline{SST} - \overline{SST_{obs}}$$
$$new\ constraint = -\lambda_1(X - \bar{X}) - \lambda_2 \bar{X}$$

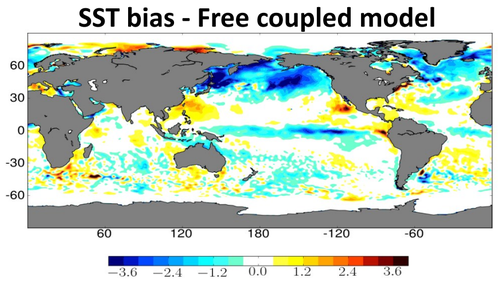
2 timescales: λ_1 daily - λ_2 monthly

An **additional timescale** may be necessary to avoid aliasing issues

CERA preliminary results

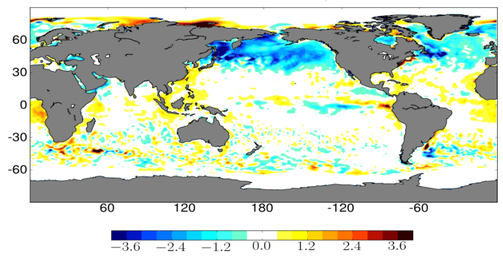
- **Test**: 2-month run from 01/08/10 to 30/09/10. Study of the impact of the different components of the coupled data assimilation on **the SST bias** (resp. NCEP RTG SST) for September 2010.

SST bias - Free coupled model



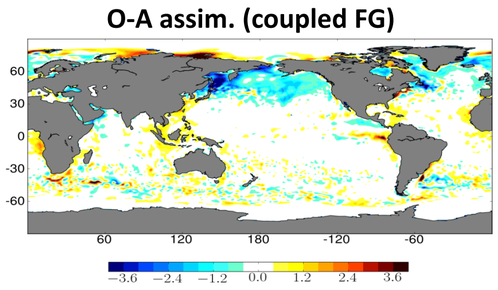
- The free coupled model shows a cold SST bias in the summer hemisphere due to **too strong mixing**. Other biases (equa. cold tongue, WBC)

Atmos. assim. (coupled FG)



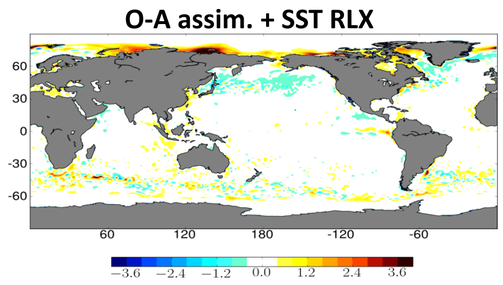
- The atmospheric 4D-var **reduces** consistently the SST biases

O-A assim. (coupled FG)



- Adding the ocean DA further **reduces** the SST biases

O-A assim. + SST RLX



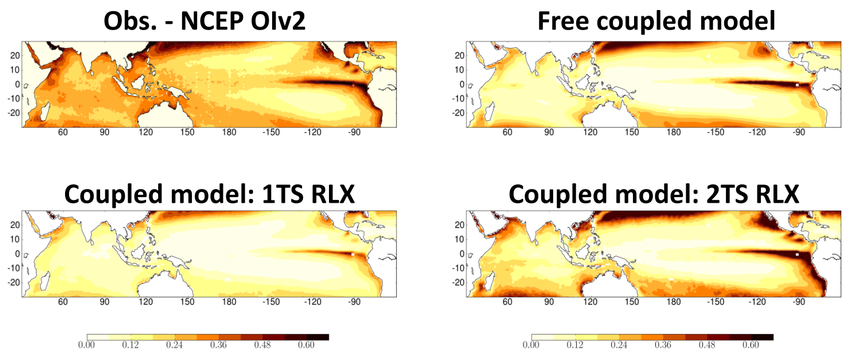
- The SST relaxation **constrains** efficiently the coupled data assimilation

The CERA system is doing a good job in **reducing the SST biases**

Why a multi-timescale SST relaxation ?

- The relaxation should avoid the **damping** of the intraseasonal variability (**ISV**) of the SST
- Tests.: 1991-2000 coupled runs using SST relaxation towards NCEP OIv2 (Reynolds, 2007): free run, 1-timescale relaxation, 2-timescale relaxation

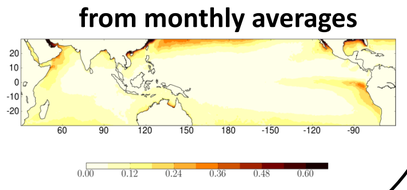
Intensity of the ISV of SST (1991-2000)



The coupled model captures some of the observed ISV but it is **damped** when relaxing **with 1 timescale**. Using **2 timescales enhances** the ISV.

A multi-timescale SST relaxation will matter in **poorly-observed periods** where, at best, **monthly SST** are available. Products as HadISST2 (left panel), used to force ERA-20C, **cannot capture** the ISV. In that case, **2 timescales** - at least – will be **necessary** to represent some of the ISV.

ISV in HadISST2 – daily SST derived from monthly averages



Conclusions

- Building of the CERA framework with a 4D-var in the atmos. and 3D-var FGAT in the ocean
- First results shows that the system is working as expected
- Improvement of the SST relaxation scheme in order to capture the intraseasonal signals

On-going & future works

- Longer CERA runs and case studies where coupling matters
- SST relaxation: toward an additional timescale and tests in poorly-observed periods
- Diagnostics on coupled processes at different timescales