

# The CERA-SAT reanalysis

Proof-of-concept for coupled DA in the satellite era

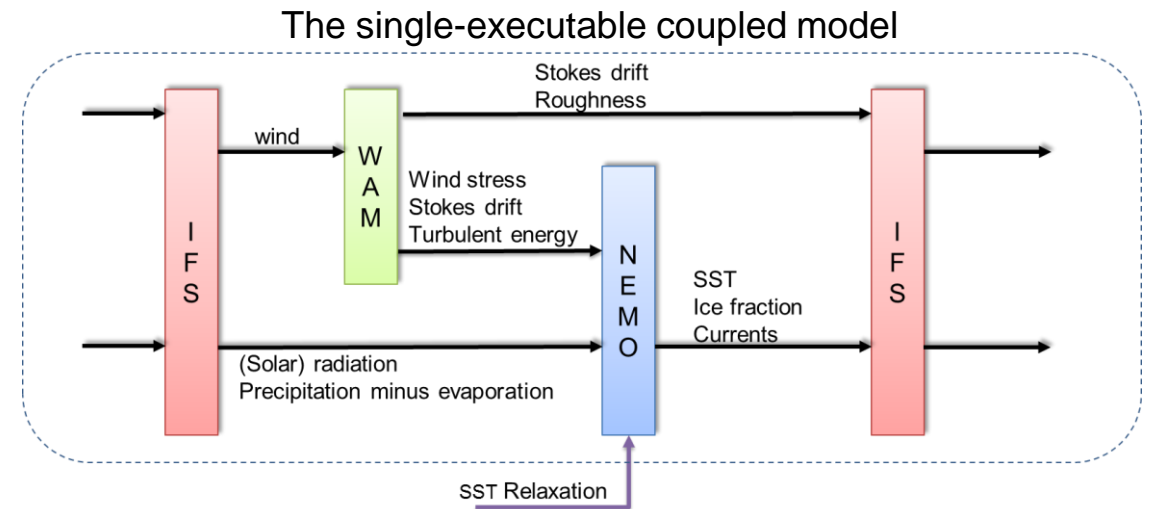
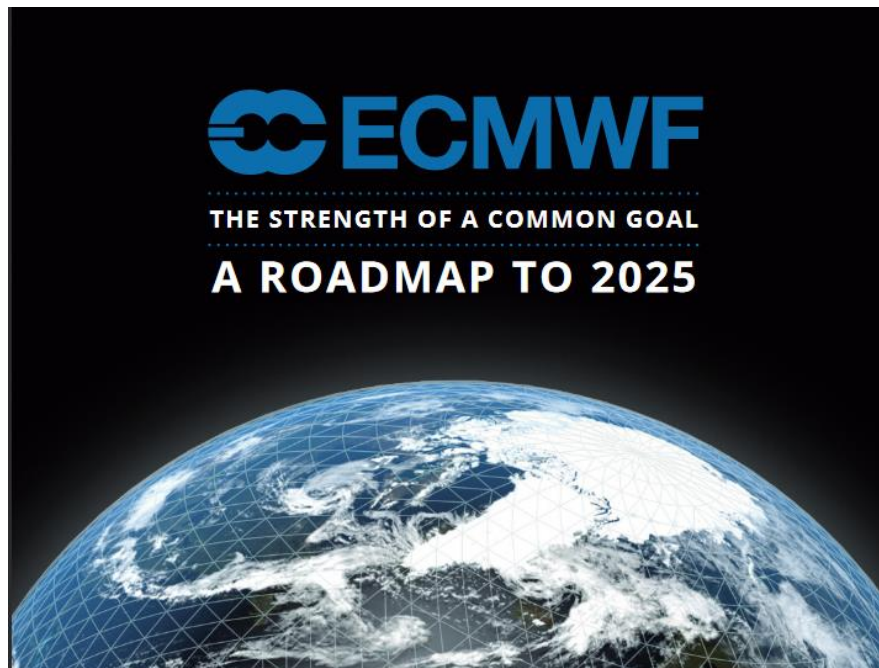
Dinand Schepers,  
Eric de Boisséson, Phil Browne, Roberto Buizza, Giovanna De Chiara, Per  
Dahlgren, Dick Dee, Reima Eresmaa, Yuki Kosaka, Patrick Laloyaux, Cristina  
Lupu, Patricia de Rosnay



# Towards an Earth system approach

*“Whilst Earth system modelling is already in its early stages, its application to data assimilation is very novel and results could be ground-breaking”*

*Roadmap to 2025*



# ERA-CLIM2 - Selected description of work

Produce global reanalyses to reconstruct the past climate/weather of the earth system

## **CERA-20C: A coupled reanalysis of the 20<sup>th</sup> century**

- based on conventional surface and subsurface observations
- deliver long time series of Essential Climate Variables (ECVs)

## **CERA-SAT: A coupled reanalysis at higher resolution**

- based on conventional and satellite observations
- evaluate the impact of a higher resolution on the coupled processes



# The CERA system



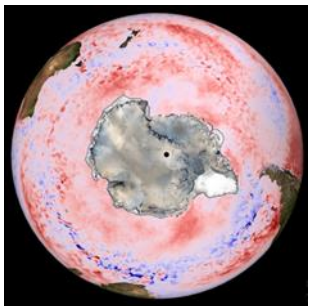
## Full observing system

- including reprocessed datasets



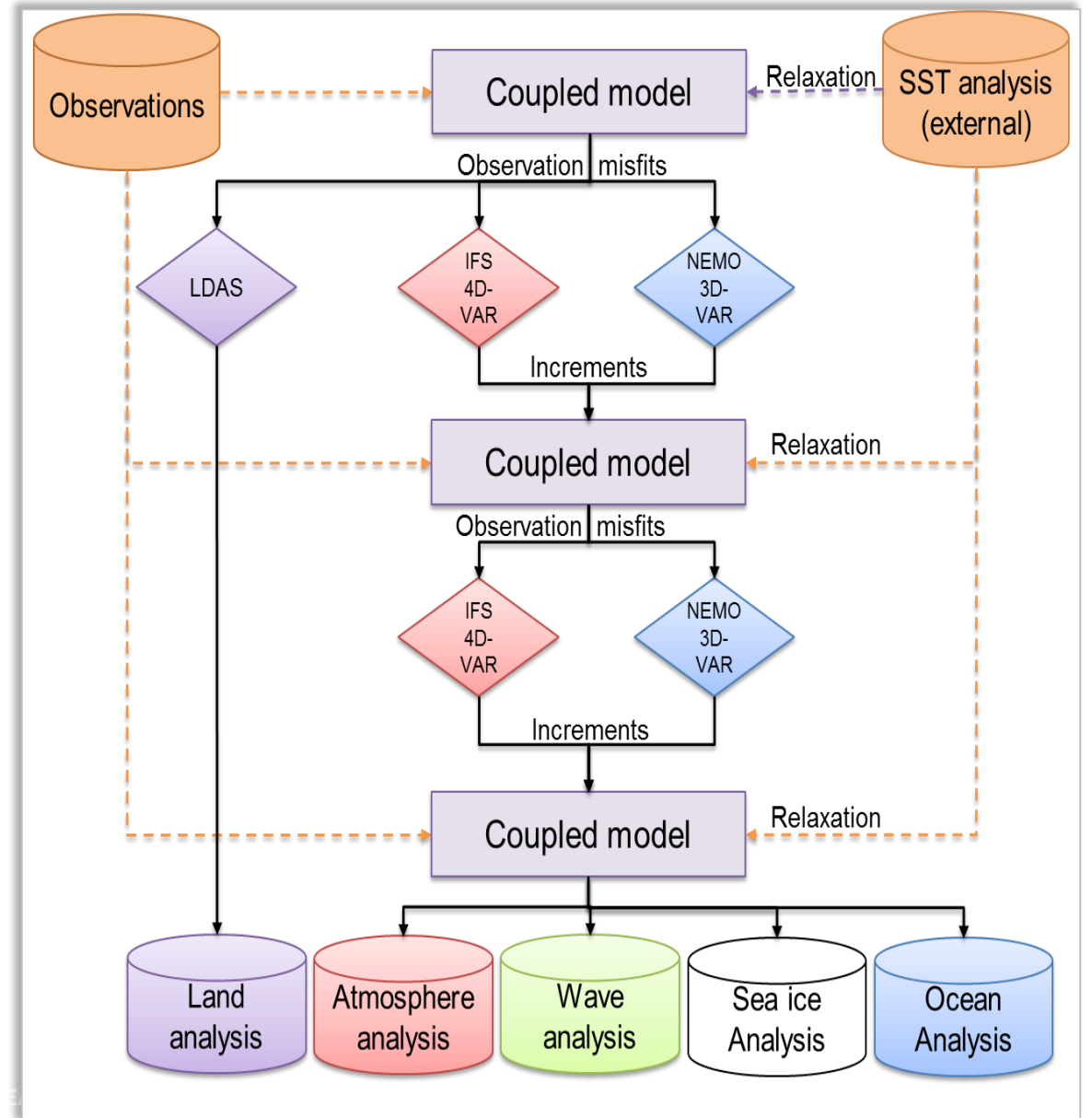
## Salinity and Temperature

- Subsurface profiles
- EN4.1.1 dataset



## SST and sea ice analysis

- OSTIA 0.05° product
- Used for
  - Sea ice assimilation
  - SST nudging



# CERA-SAT – A coupled reanalysis



## Atmosphere/Land

- **Model:** IFS (CY42R1\_esuite, April 2016)
- **Atmosphere Resolution:** TL319 (~60 Km); 137 levels
- **Assimilation:** 24-hour window 4D-Var
- **Full observing system** including reprocessed datasets
- **Land surface analysis** weakly coupled



## Ocean/Sea ice

- **Model:** NEMO / LIM2 (CY42r1\_nemo\_E28)
- **Resolution** (1/4 degree; ORCA025) ~30 km; 75 levels
- **Assimilation:** 24-hour window 3D-Var FGAT
- **Observations:** salinity and temperature profiles, SLA, SIC analysis (OSTIA L4)



## Wave

- **Model:** WAM (CY42R1\_esuite)
- **Resolution:** 0.5 degree
- **Assimilation:** 24-hour window
- **Observation:** ERA5 observing system

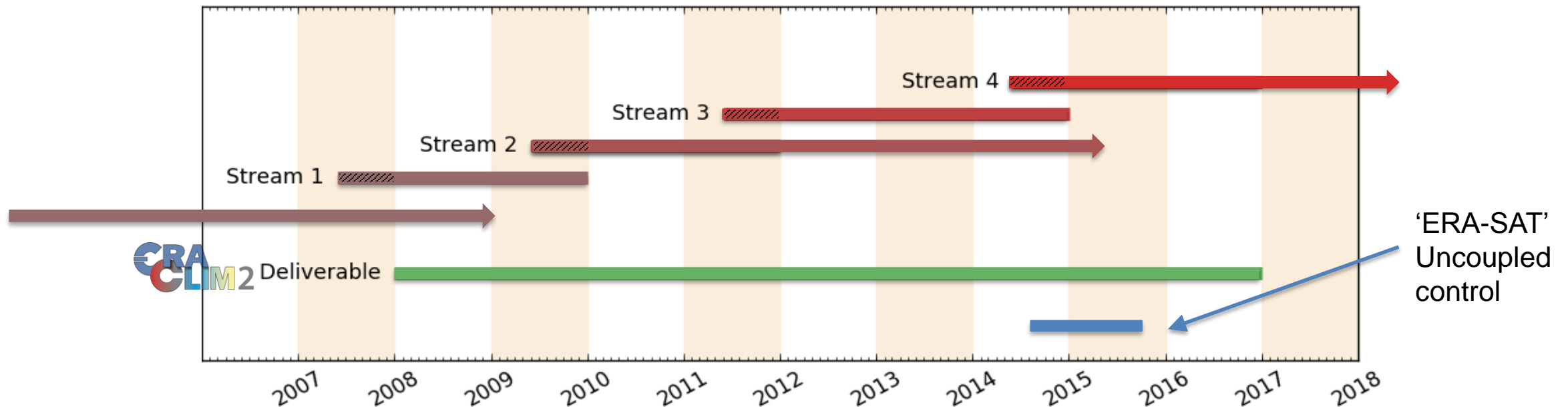


# CERA-SAT – Production & Delivery

## CERA-SAT was produced in 4 streams, merged into 1 deliverable

- 8 years research dataset (2008 - 2016)
- Produced in ~11 months
- Half year 'spin-up' per stream
- Extend beyond 2017
- Extend *stream 2* for spin-up studies
- Pre-extend from 2005

**ERA-CLIM2 delivered in Dec 2017**



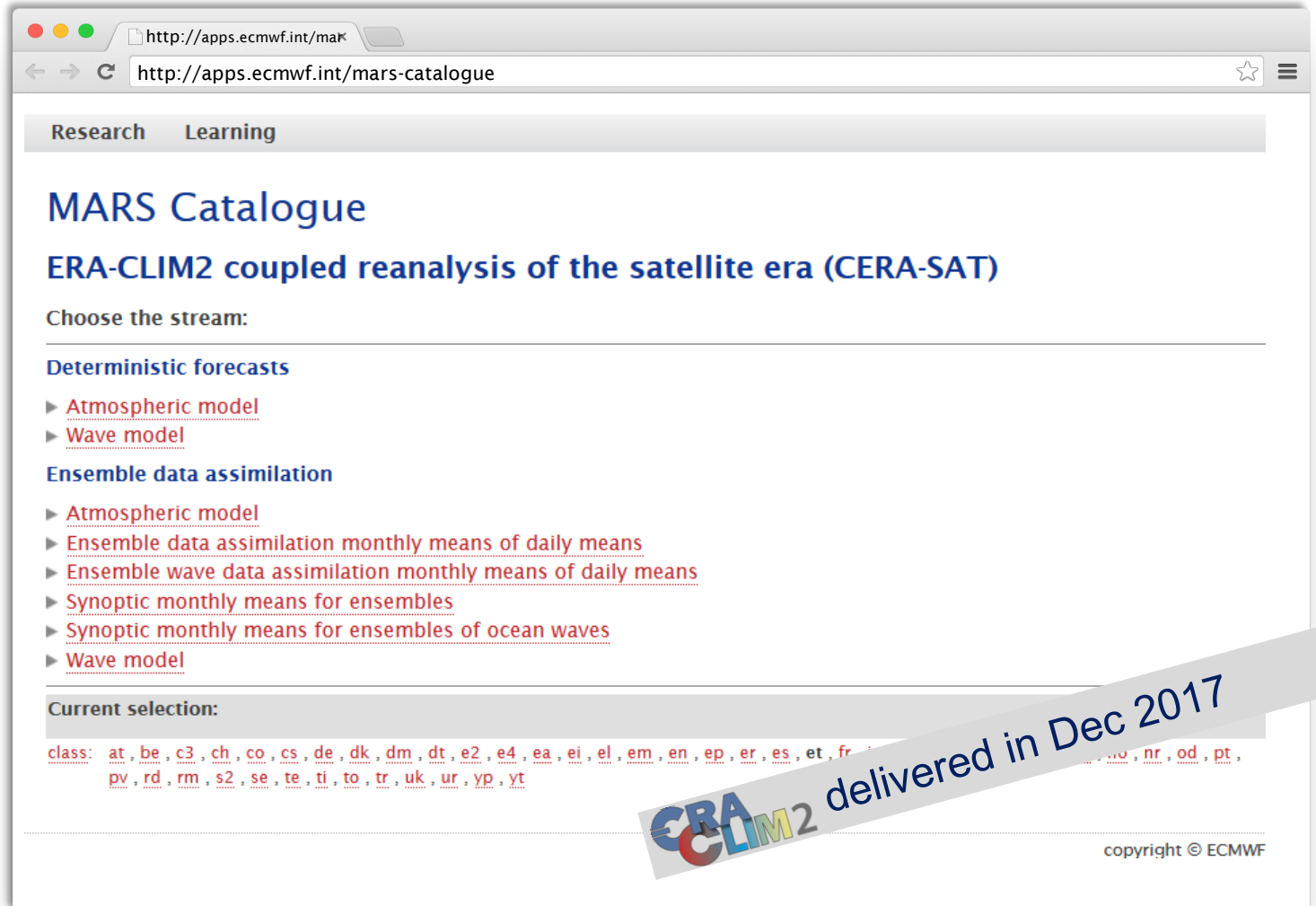
# CERA-SAT – Data access

## Fields in GRIB

- 3-hourly analysis, forecast fields
  - Atmosphere
  - Sea ice
  - Waves
  - Land surface
- Monthly mean fields

## Ocean fields in netCDF

## Observation feedback in ODB

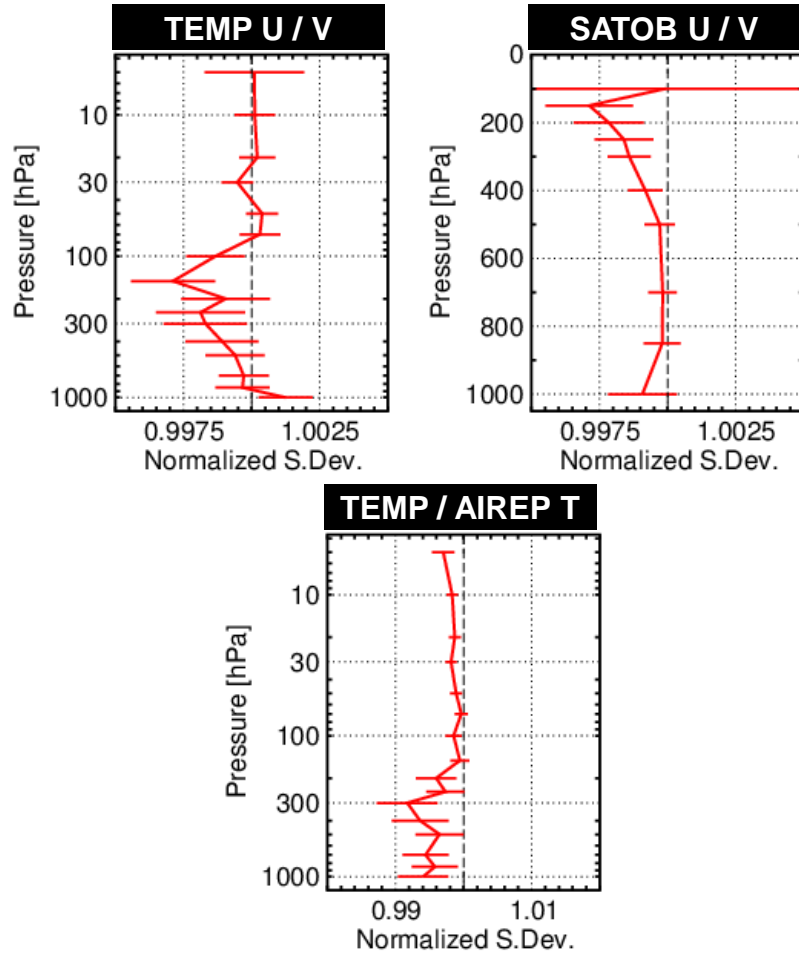


The screenshot shows a web browser window with the URL <http://apps.ecmwf.int/mars-catalogue>. The page title is "MARS Catalogue" and the main heading is "ERA-CLIM2 coupled reanalysis of the satellite era (CERA-SAT)". Below this, there is a section "Choose the stream:" followed by two main categories: "Deterministic forecasts" and "Ensemble data assimilation". Under "Deterministic forecasts", there are two links: "Atmospheric model" and "Wave model". Under "Ensemble data assimilation", there are five links: "Atmospheric model", "Ensemble data assimilation monthly means of daily means", "Ensemble wave data assimilation monthly means of daily means", "Synoptic monthly means for ensembles", and "Synoptic monthly means for ensembles of ocean waves". Below these links, there is a "Current selection:" section with a list of country codes: "class: at, be, c3, ch, co, cs, de, dk, dm, dt, e2, e4, ea, ei, el, em, en, ep, er, es, et, fr, ...". At the bottom right of the page, there is a logo for "ERA-CLIM2" and a copyright notice "copyright © ECMWF". A diagonal banner at the bottom right of the screenshot reads "ERA-CLIM2 delivered in Dec 2017".

# Coupled analysis – Background fit to tropospheric observations

## Change in standard deviation of B/G departures

(1 Sept 2015 – 31 Aug 2016; Global)

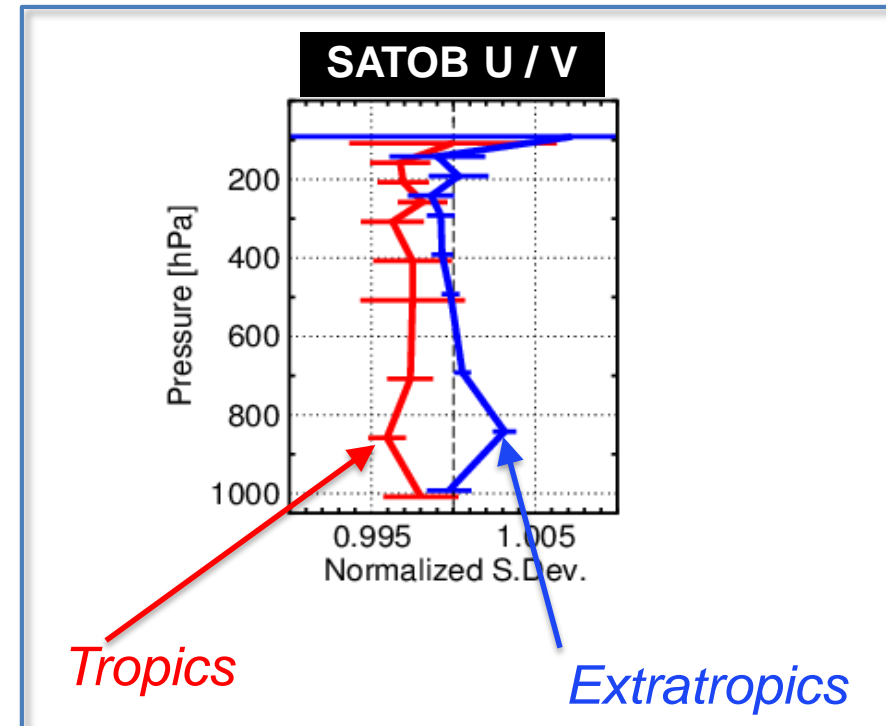


Improvement ←

→ Degradation

## Improved background fit to observations data

- Wind: 100—300 hPa
- Temperature: 300—1000 hPa



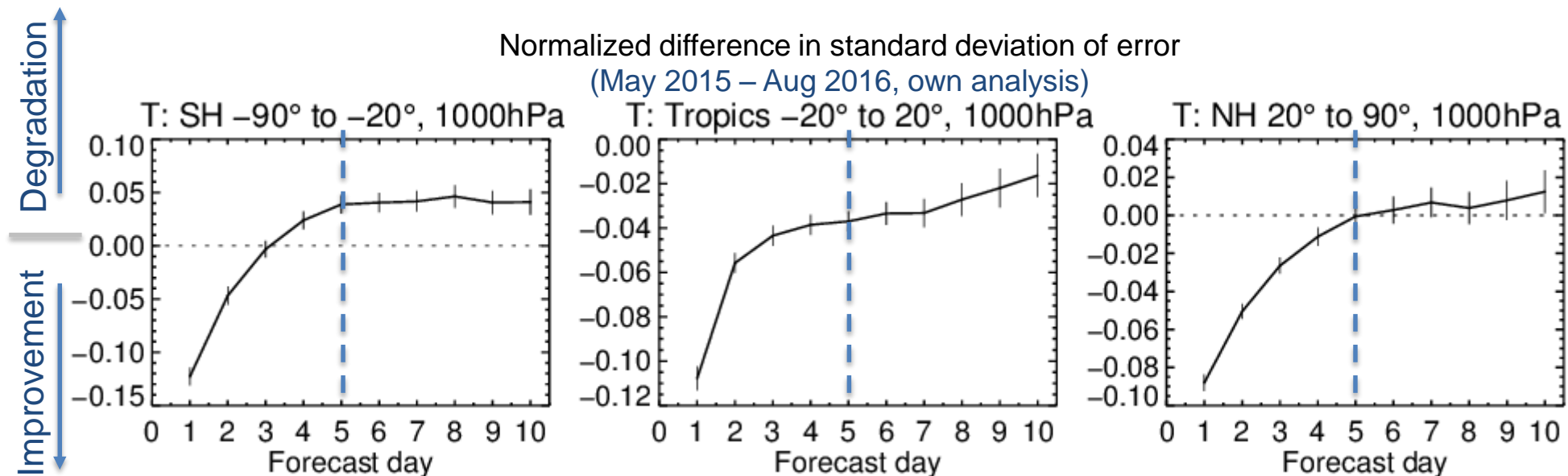
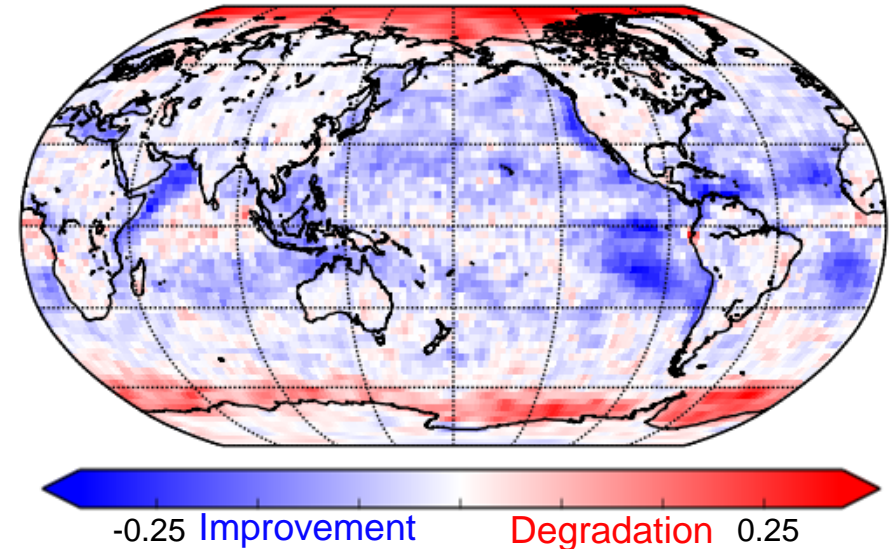


# Coupled assimilation & forecast – forecast scores

## Forecast improvements 1000hPa Temperature

- 15 months of daily forecasts
- Control: Uncoupled DA
- Reduced RMS over oceans
- Validation artifact: apparent degradation over sea ice

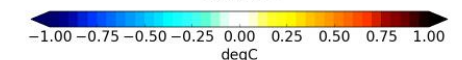
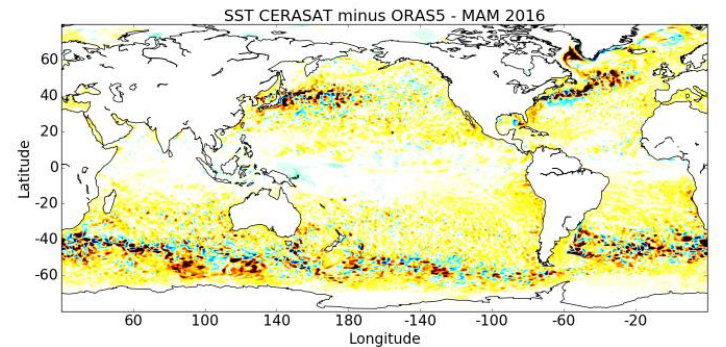
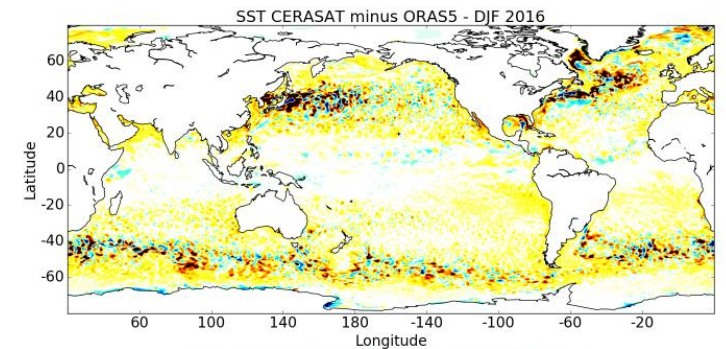
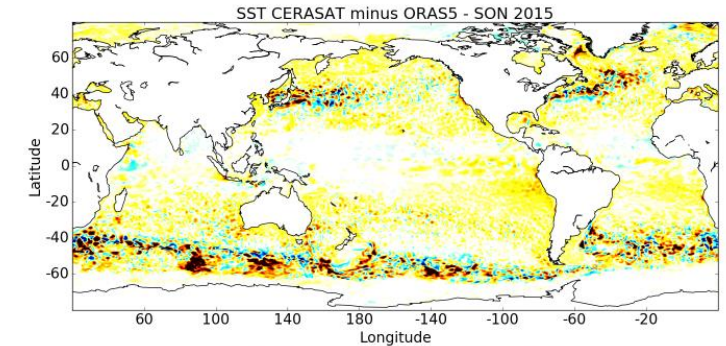
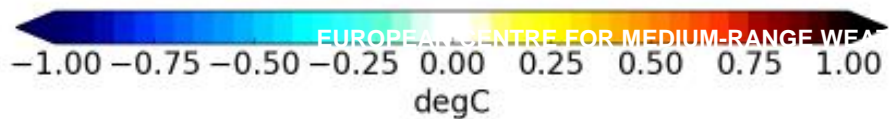
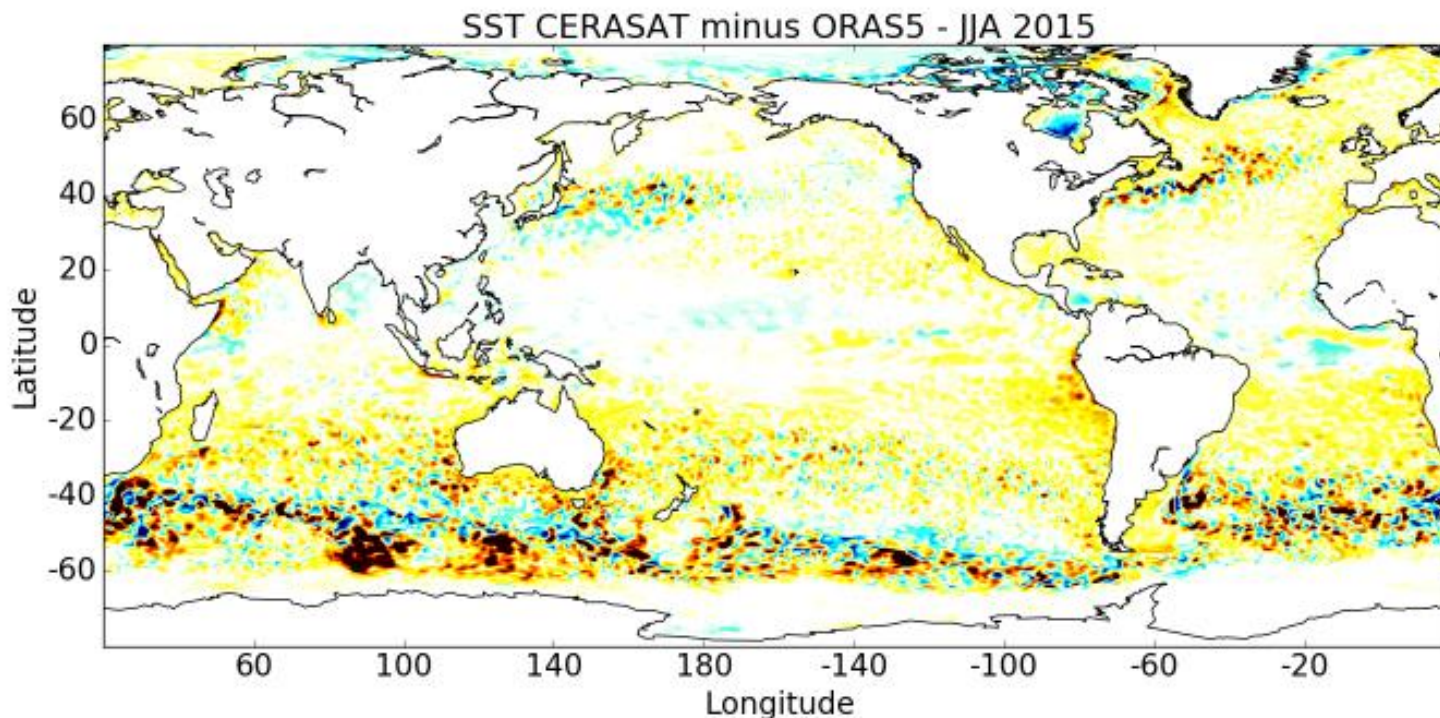
Normalised difference in RMS error  
T at 1000hPa T+120hrs



# CERA-SAT – Sea surface temperature (SST)

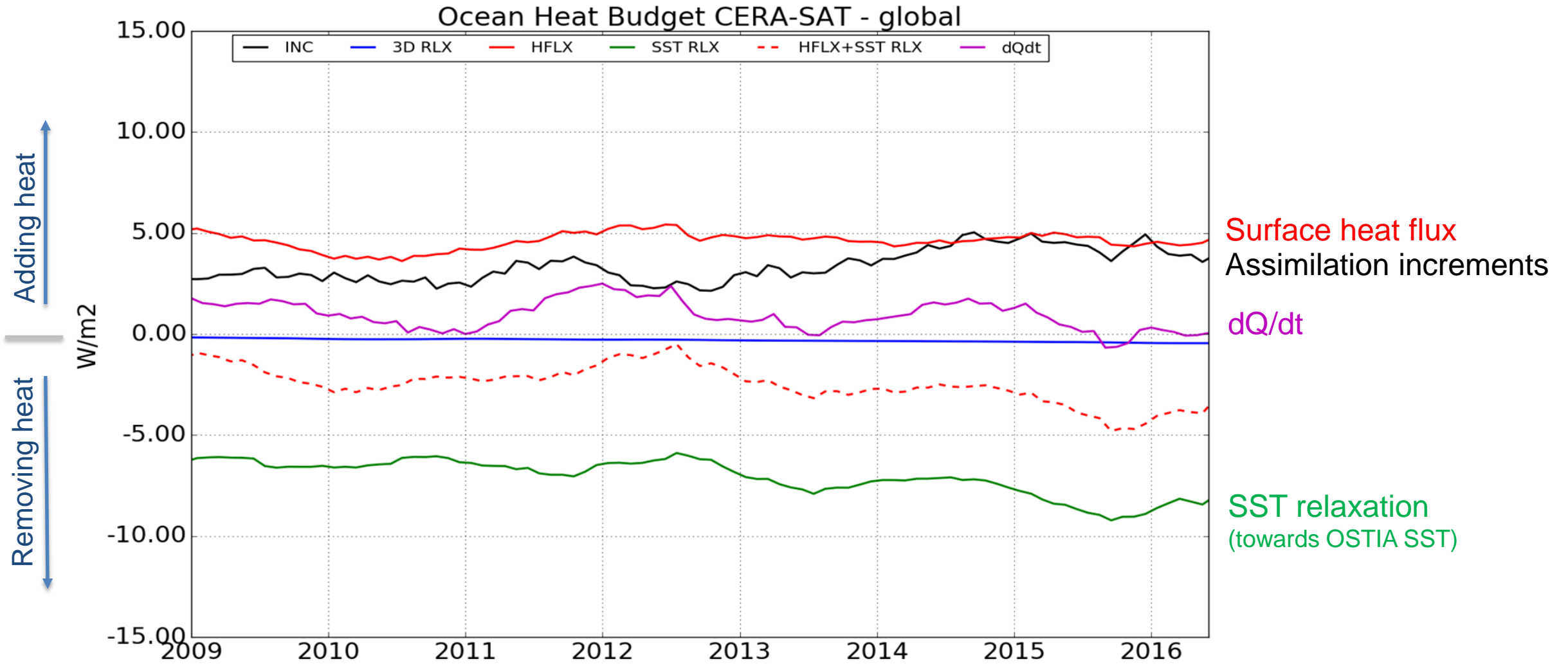
## Sea surface temperature vs. ORAS5

- Control: ORAS5; Ocean reanalysis forced by ERA-Interim



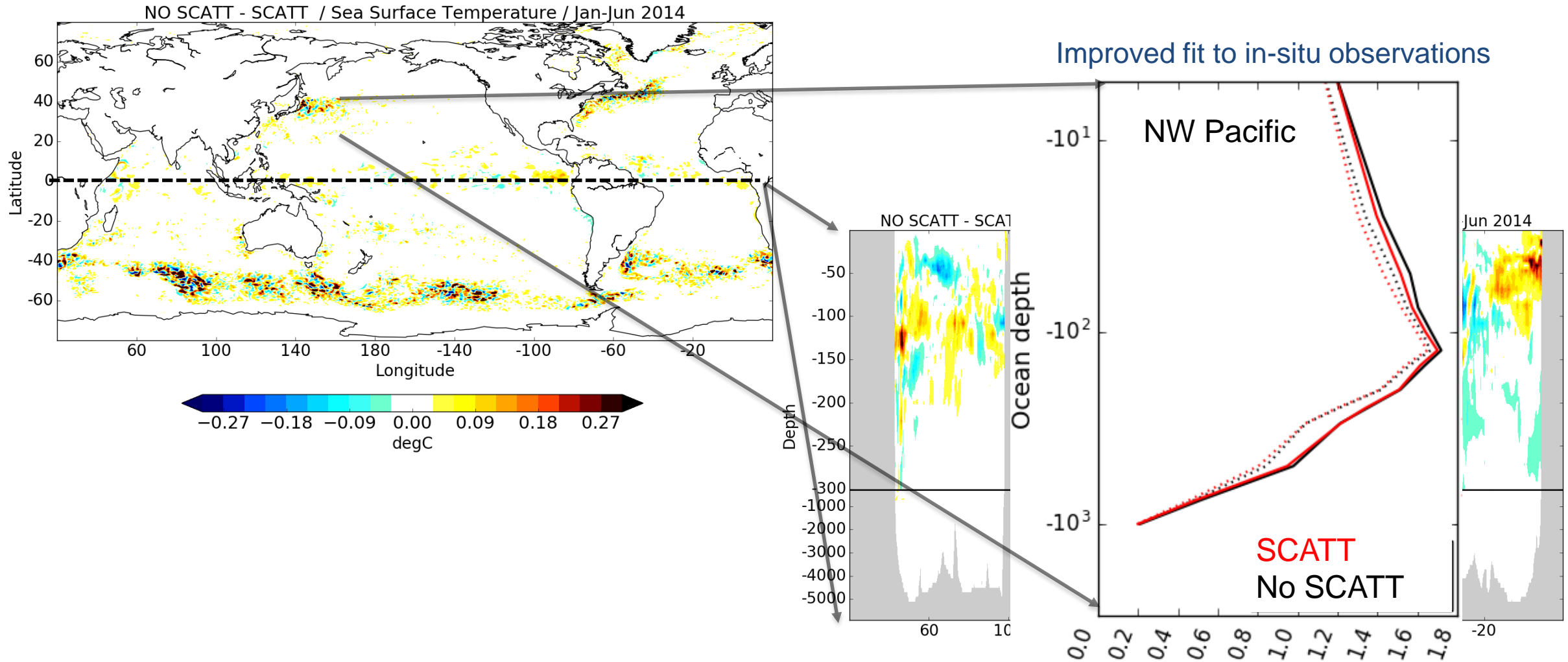
Courtesy of Eric de Boissesson

# CERA-SAT – Global ocean heat budget



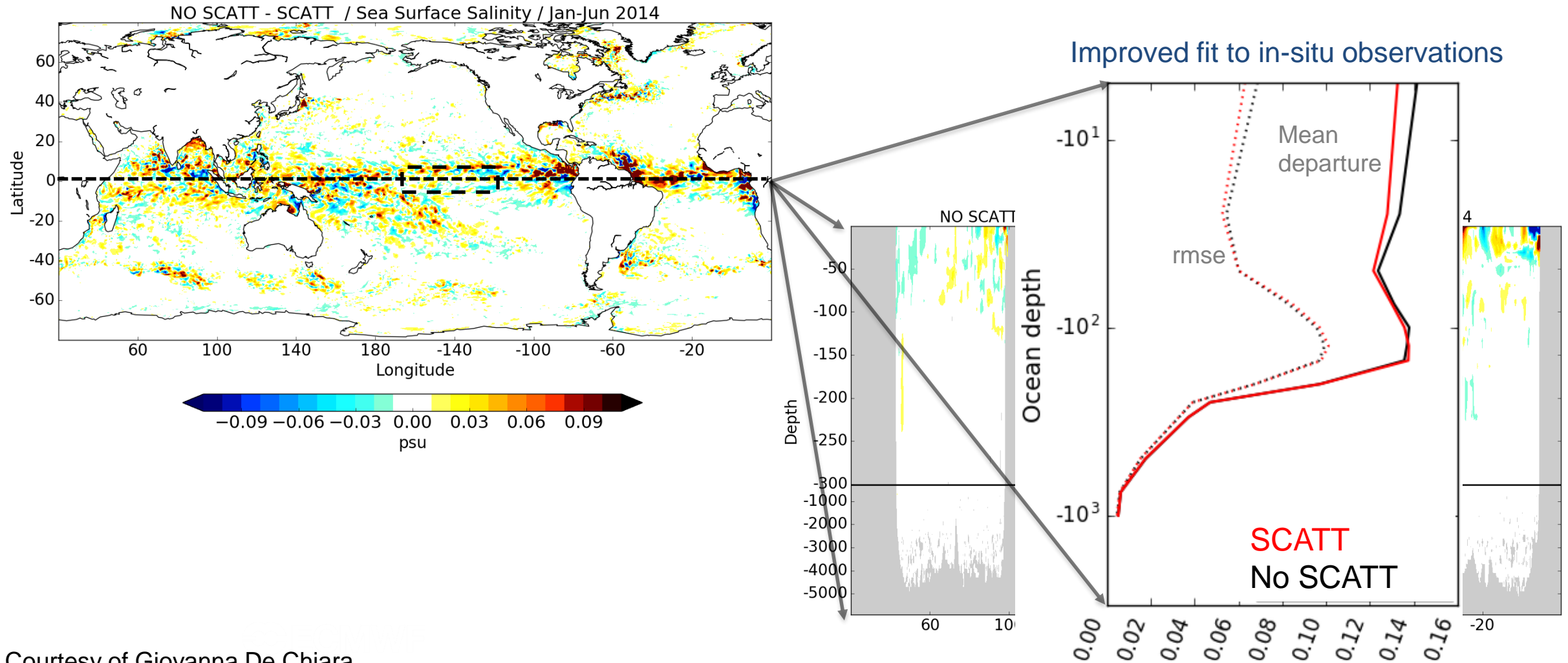


# Coupled analysis - Atmospheric winds impact ocean temperature



# Coupled assimilation - Atmospheric winds impact salinity

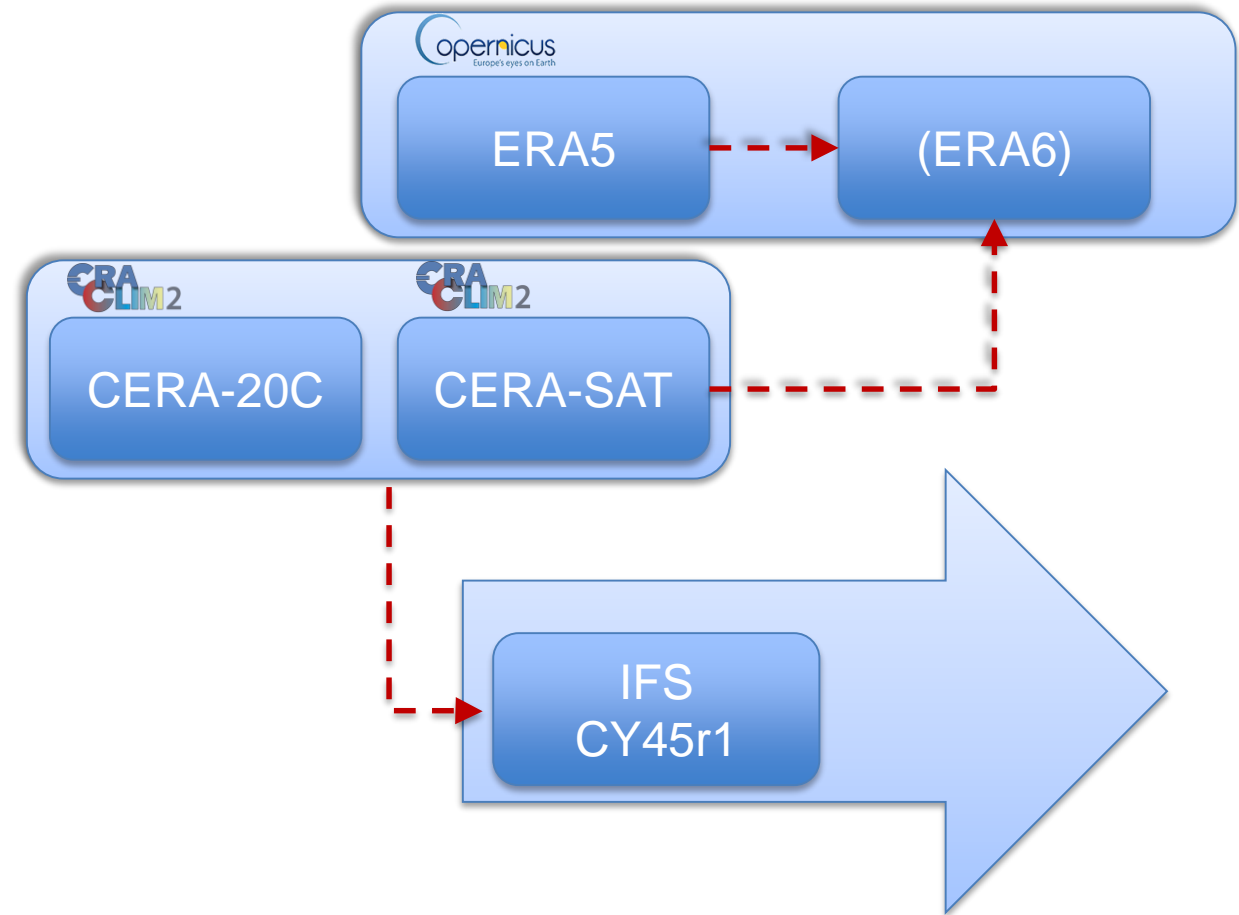
## Impact of scatterometer winds on ocean salinity



# CERA - Moving forward

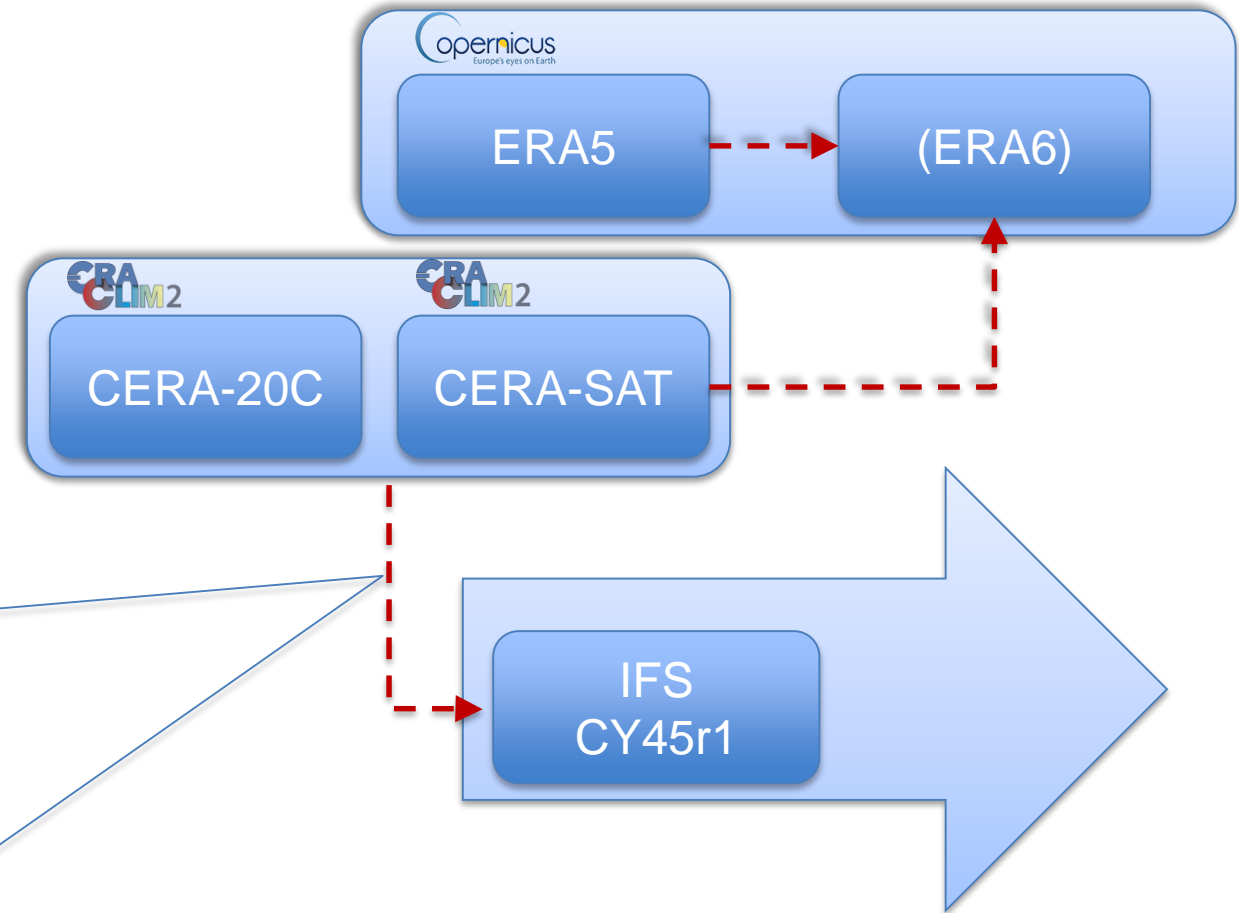
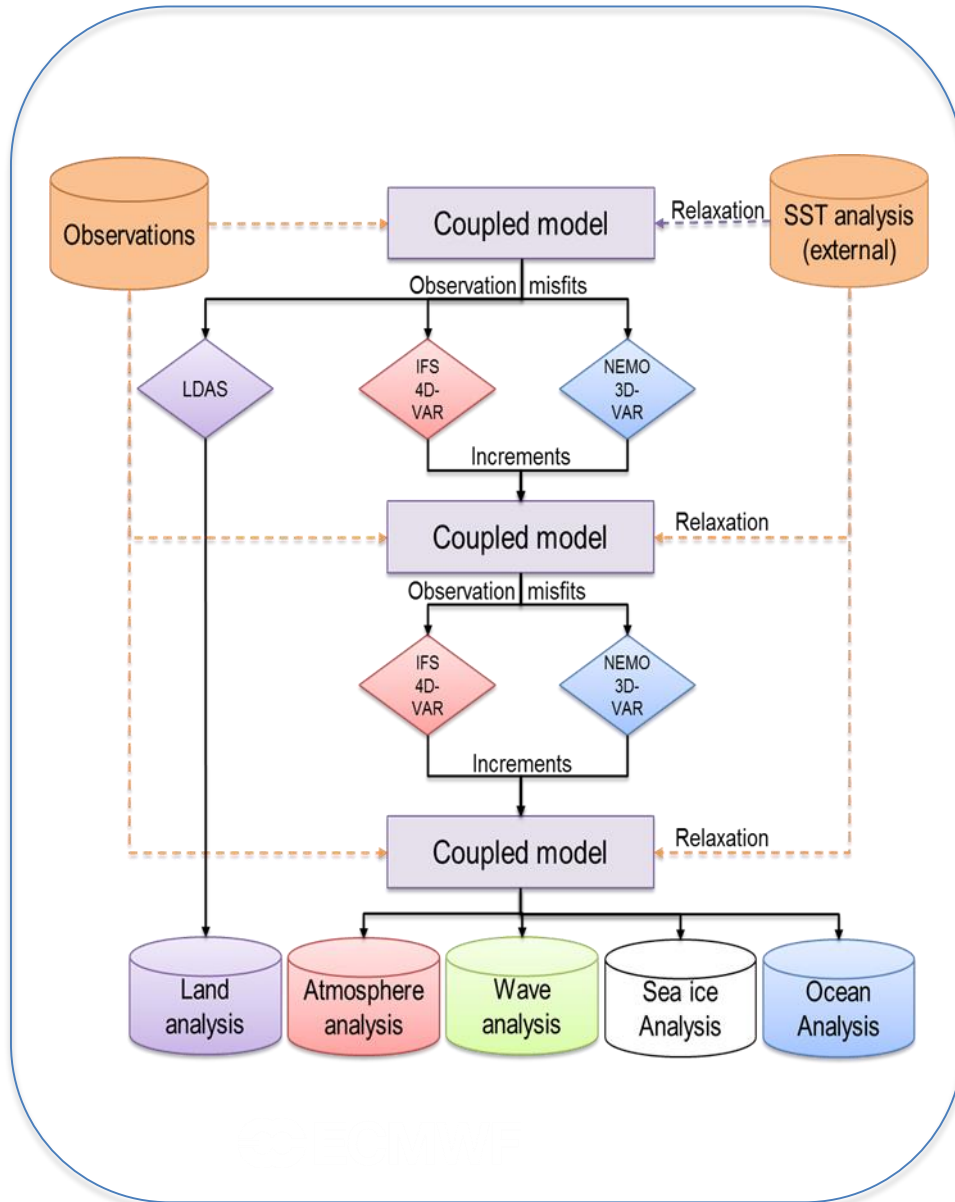
## CERA-SAT provides a *proof-of-concept* coupled reanalysis of the satellite era

- **Assess** the application of the CERA system for coupled data assimilation
- **Research** the effects of using the CERA system for coupled data assimilation
- **Aid further development** of coupled data assimilation





# CERA - Moving forward

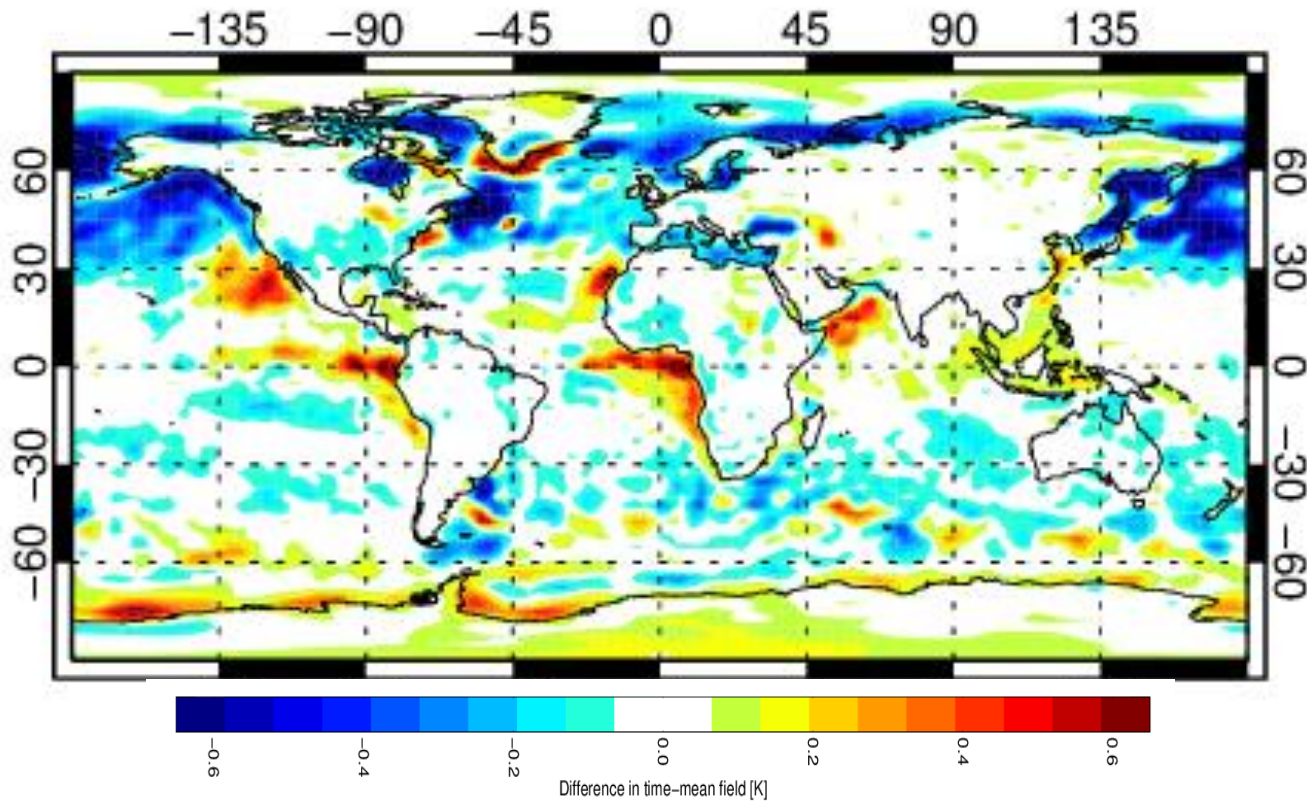


# CY45r1 – Impact of coupled DA: 1000hPa temperature

Difference in time-mean T (Summer analysis coupled assimilation – control)

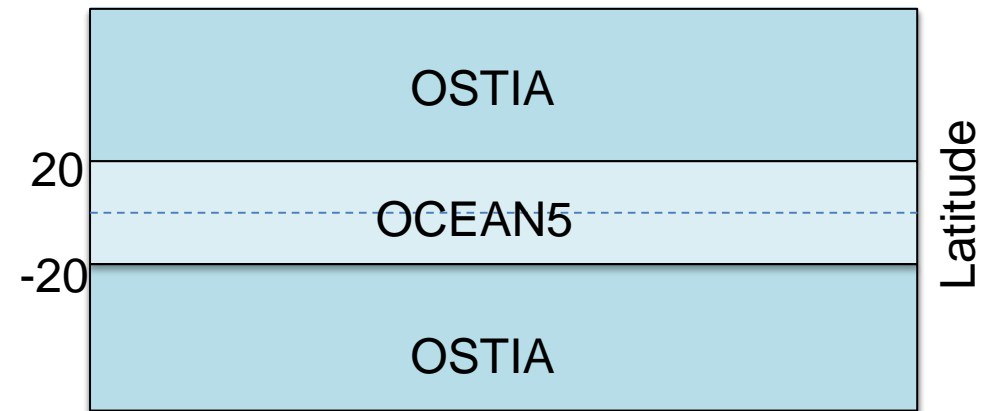
16-Jun-2017 to 31-Aug-2017 from 154 to 154 samples. Verified against own-analysis.

Analysis difference CERA - control



## Difference in 1000hPa temperature

- 2.5 months of forecasts
- Control: Blended SST (OSTIA / OCEAN5)



Courtesy of Phil Browne

Thank you

Dinand.Schepers@ecmwf.int

# Additional material

# Summary of the Description of Work

Produce global reanalyses to reconstruct the past climate/wheater of the earth system



*Atmosphere*



*Land*



*Wave*



*Ocean*



*Sea ice*

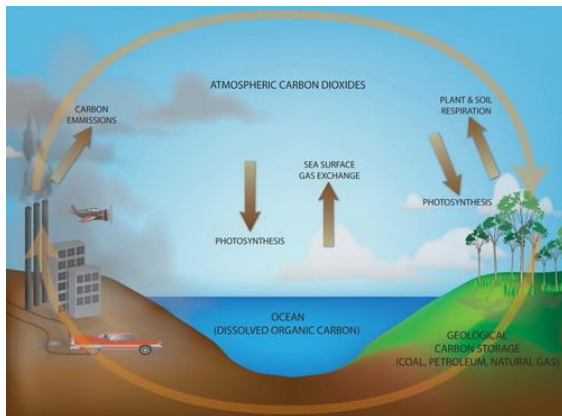
## **CERA-20C: A coupled reanalysis of the 20<sup>th</sup> century**

- based on conventional surface and subsurface observations
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## **CERA-SAT: A coupled reanalysis at higher resolution**

- based on conventional and satellite observations
- evaluate the impact of a higher resolution on the coupled processes

Produce associated reanalyses to reconstruct the evolution of the carbon fluxes



## **CERA-20C/Carbon: land & ocean carbon reanalyses**

- based on forcings from atmospheric/ocean reanalyses
- estimate carbon flux anomalies over the 20<sup>th</sup> century

## **CERA-SAT/Carbon: two land carbon reanalyses**

- produced online by the CTESSEL land model
- produced offline by the ORCHIDEE land model

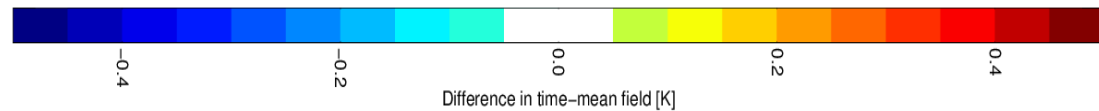
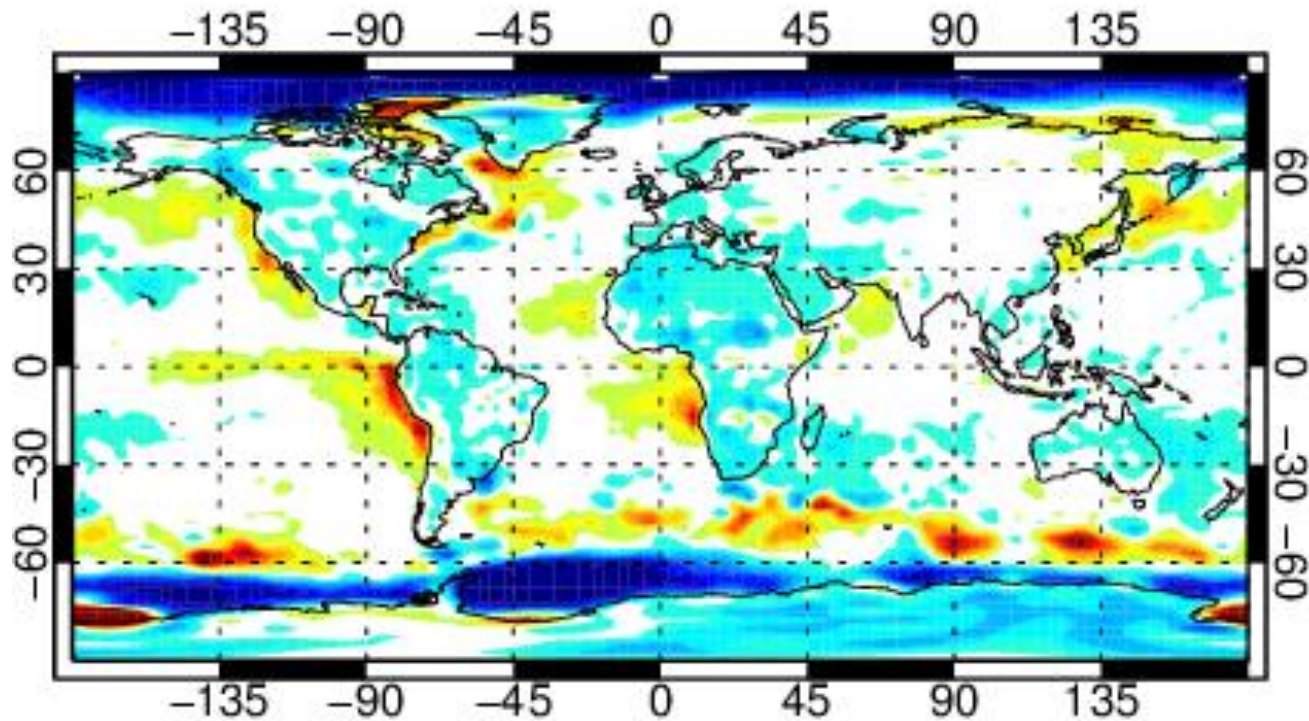


# CERA-SAT – 1000hPa temperature

Difference in time-mean T (coupled – uncoupled)

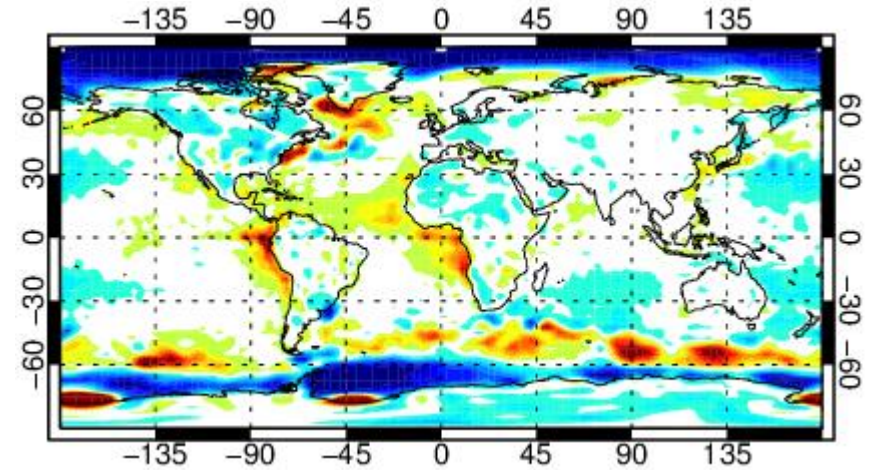
11-May-2015 to 31-Aug-2016 from 479 to 479 samples. Verified against own-analysis.

T+0; 1000hPa



Difference in time-mean field [K]

T+48; 1000hPa



T+96; 1000hPa

