Near-surface observations for coupled atmosphere-ocean reanalysis

Patrick Laloyaux

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ECMWF

Outline

- Current status and future plans of reanalysis at ECMWF
- Challenges for near-surface observations to support climate reanalysis
- Impact of near-surface observations in coupled assimilation
- Conclusions and requirements for future observing systems

Current status and future plans of reanalysis at ECMWF

Type 1: Reanalyses of the modern observing period (~30 - 50 years)

- Use a single model and data assimilation method
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Operational ECMWF products: ERA-Interim (atmosphere) & ORAS4 (ocean)

Key Strengths:

Support the development and the evaluation of Numerical Weather Prediction

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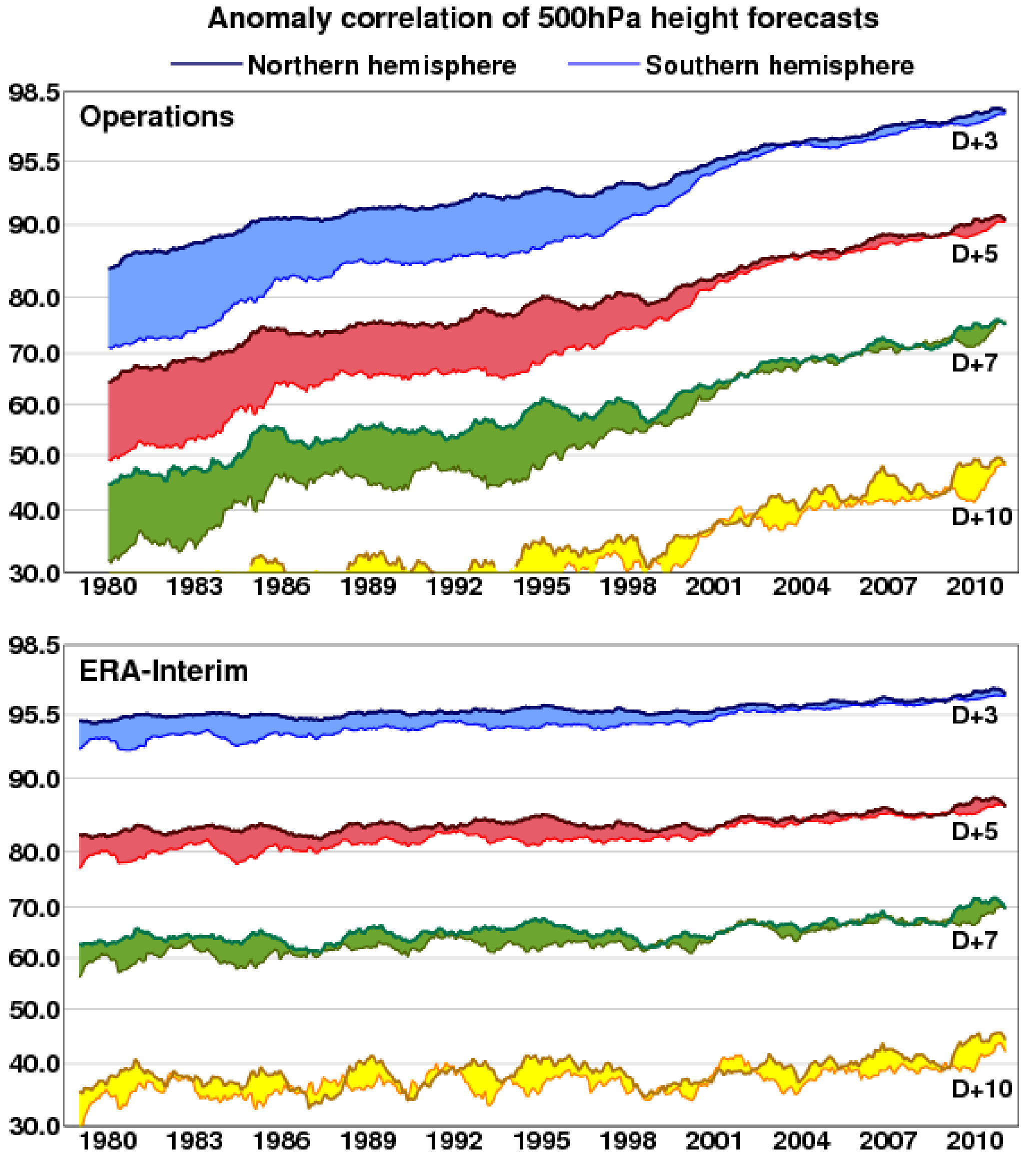

Operations: improvements in

- model
- data assimilation
- observing system

Reanalysis: improvements in

- observing system

→ The comparison shows that most of the improvements in operational forecast skills comes from a better model and data assimilation system

→ ERA-Interim allows to evaluate NWP forecast skills

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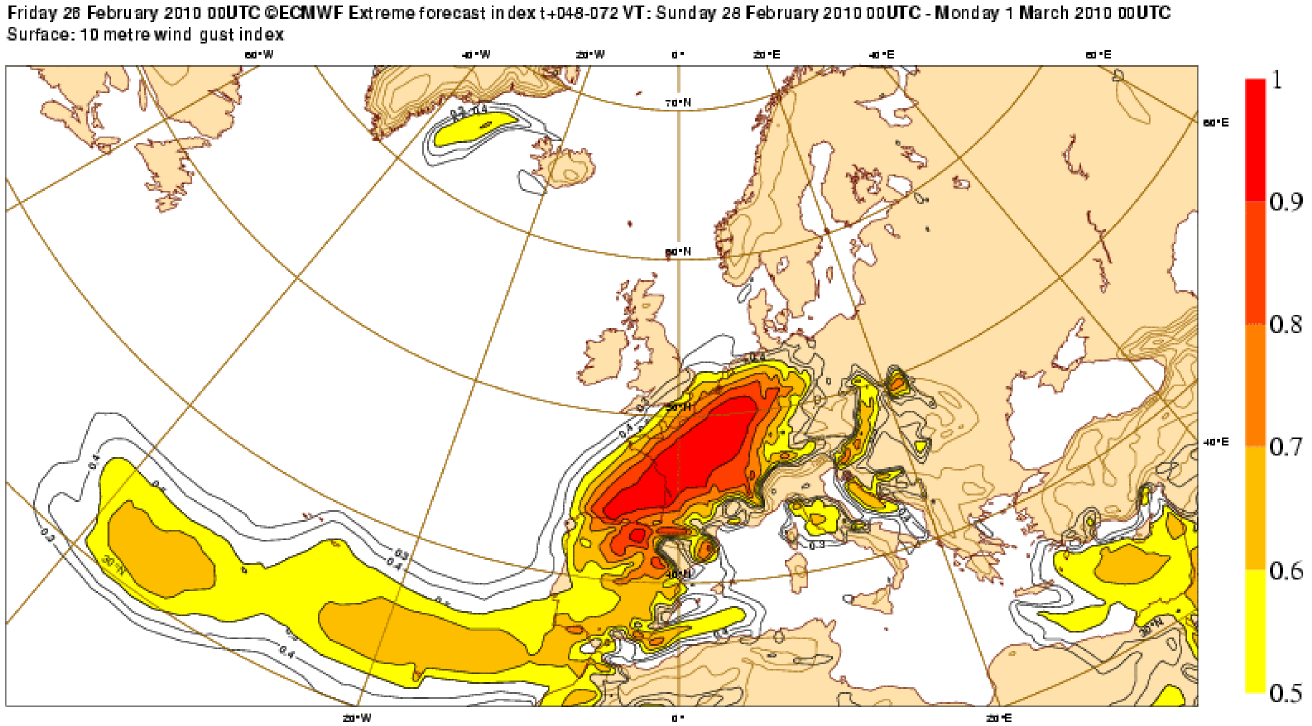
Extreme Forecast Index (EFI) detects extreme events in a given ensemble forecast.

Difference between the ensemble forecast distribution and a reference distribution (M-climate)

- an ensemble re-forecast for the most recent 20 years
- initial conditions taken from ERA-Interim



EFI for 10-meter wind gust for 1 March 2010
2-day warning for windstorm Xynthia

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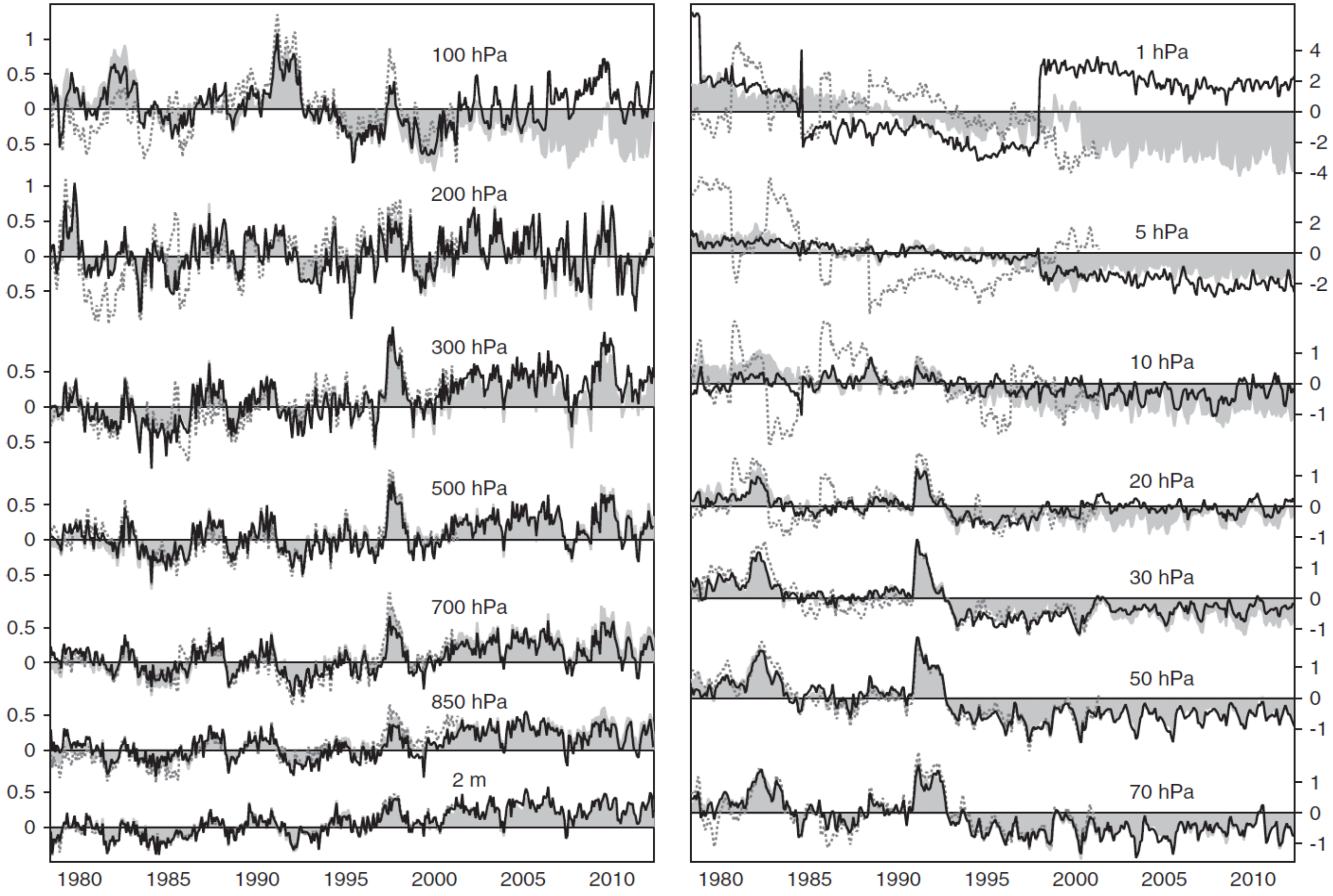
Solid line: ERA-Interim temperature anomalies relative to 1979–2001 (monthly and globally averaged)



Good trends for surface temperature (compared to gridded dataset)

El-Nino, El Chichon and Pinatubo events

Issue at 1hPa with the introduction of a new satellite (AMSU-A)
→ Improve the use of these observations to reduce the jumps

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- Use a single model and data assimilation method
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ECMWF product: ERA-20C (atmosphere)

→ Assimilate only surface pressure and ocean surface winds from conventional instruments

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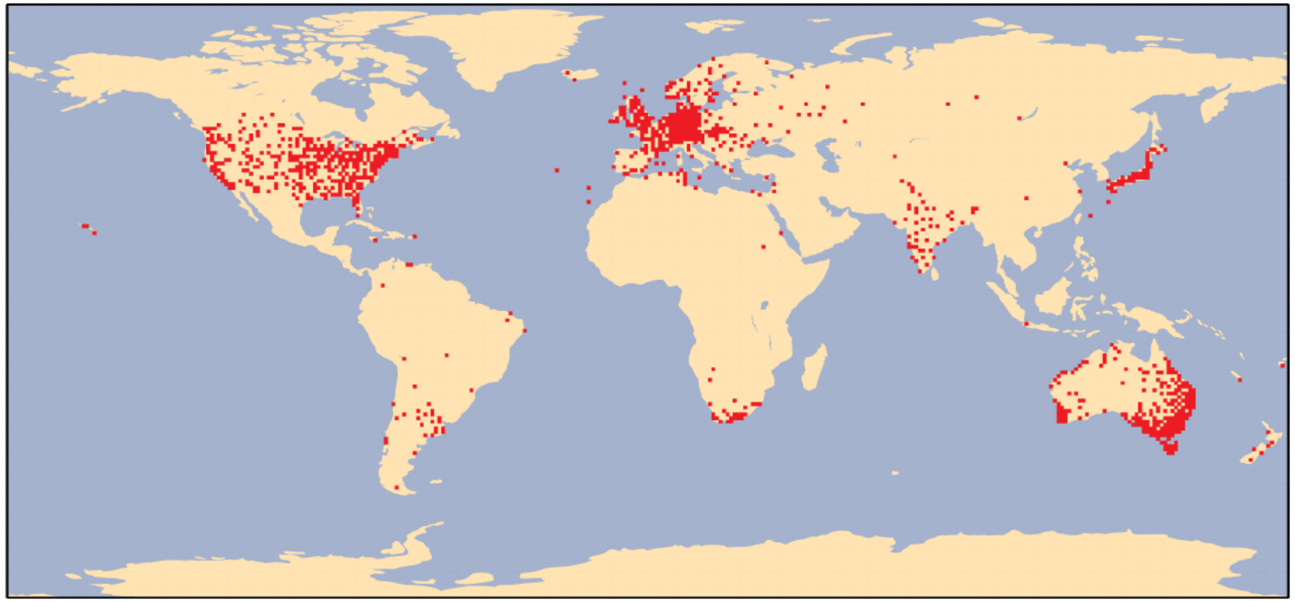

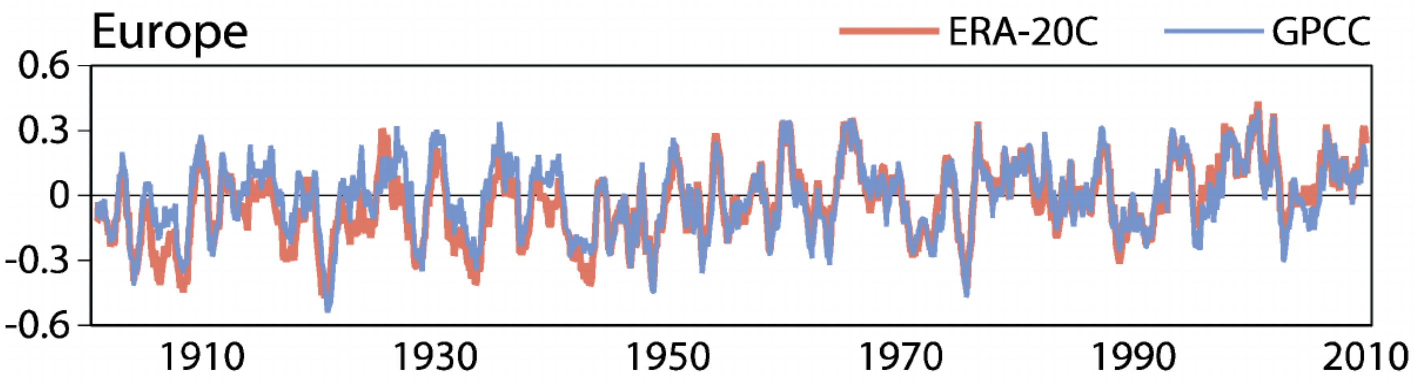

GPCC precipitation gridded dataset

- 1°x1° grid resolution
- Independent

Precipitation anomaly averaged over Europe in mm/day
(12-month running mean, anomalies relative to 1961-1990)

→ ERA-20C represents well the inter-annual fluctuations for the whole century, especially from 1945 onwards

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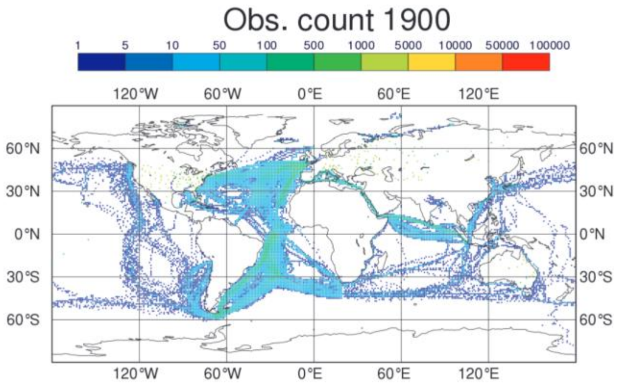
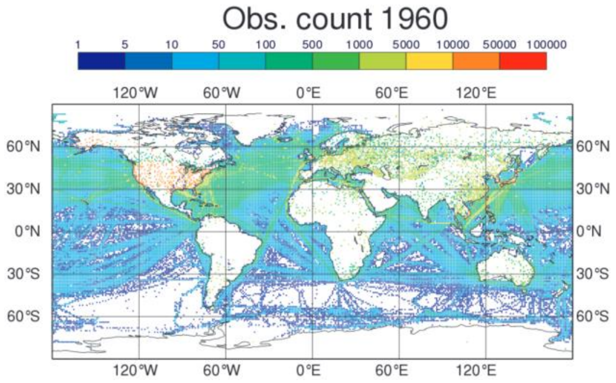
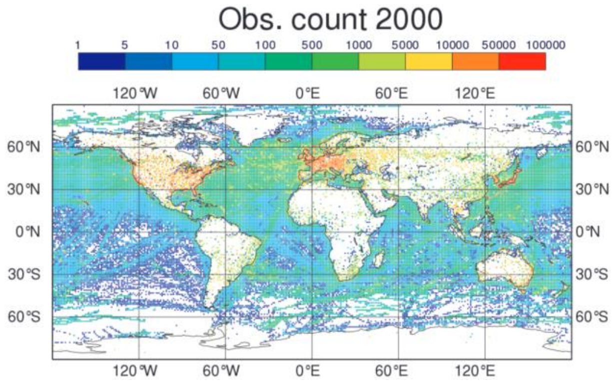
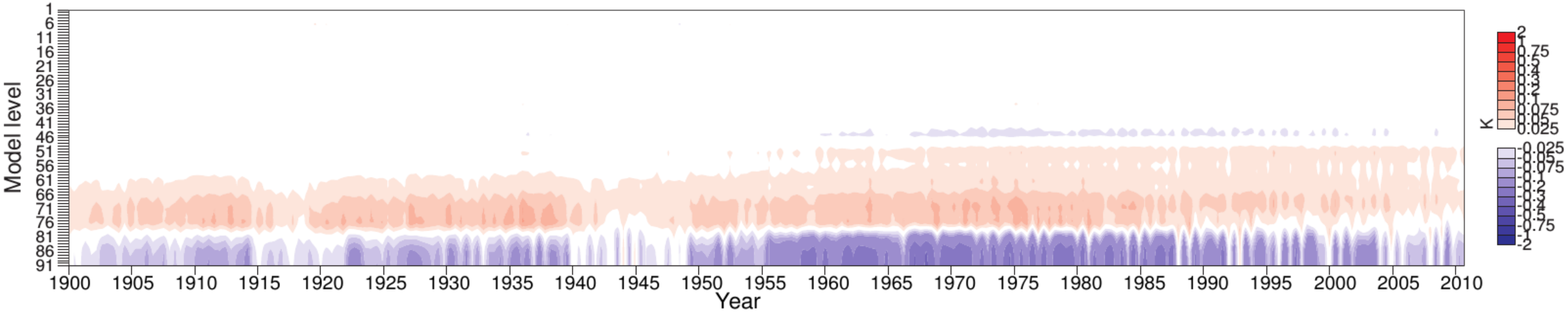






Timeseries of the model correction in ERA-20C (due to the assimilation of observations)



→ Consistent model correction over the 20th century
→ Some room for improvement to deal with the increasing number of observations

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Future plans for reanalysis

Uncoupled assimilation systems in operations:

Atmospheric reanalysis:
Computed by IFS
Prescribed sea surface temperature
Assimilation of atmospheric observations

Ocean reanalysis
Computed by NEMO
Constrained by atmospheric forcing
Assimilation of temperature and salinity profiles (EN4)

- ERA-Interim replaced by ERA-5
- ORAS4 replaced by ORAS5

Coupled assimilation system in research (CERA):

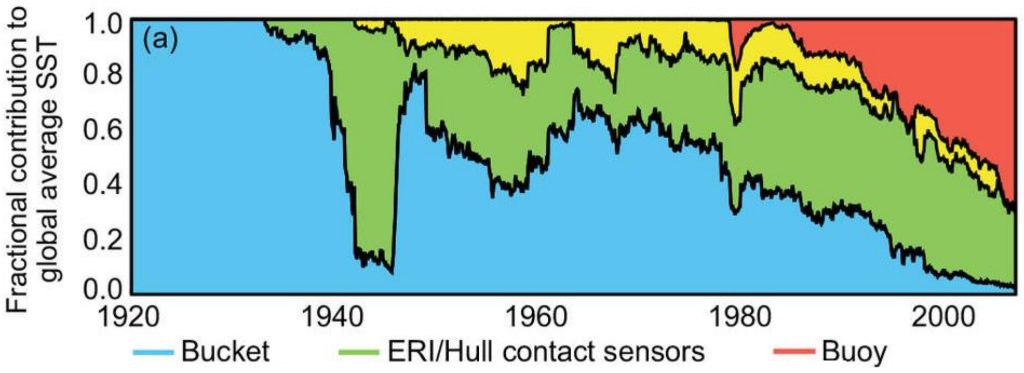
Coupled atmosphere-ocean reanalysis
Computed by the coupled IFS-NEMO model
One-hour coupling frequency
Simultaneous assimilation of atmospheric and ocean observations

- CERA-20C: extended climate reanalysis
- CERA-SAT: reanalysis of the modern observing period

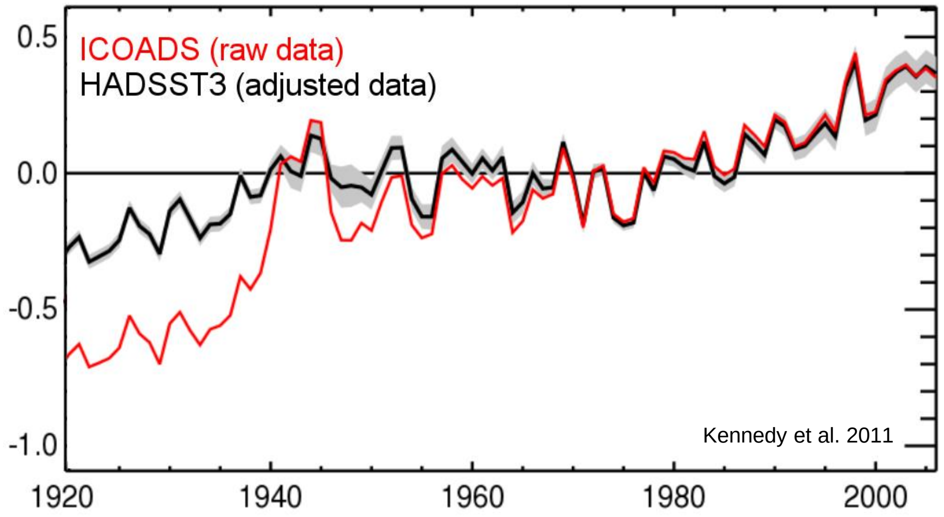
Challenges for near-surface observations to support climate reanalysis

Adjustment of past measurements – Sea Surface Temperature

SST is a key variable for coupled assimilation system
- observations are needed to avoid large biases at air-sea interface
- observations not yet assimilated at ECMWF, rely on external gridded dataset



Different instruments and sampling methods lead to different observation biases
→ Buckets have cold biases
→ ERI have small warm biases

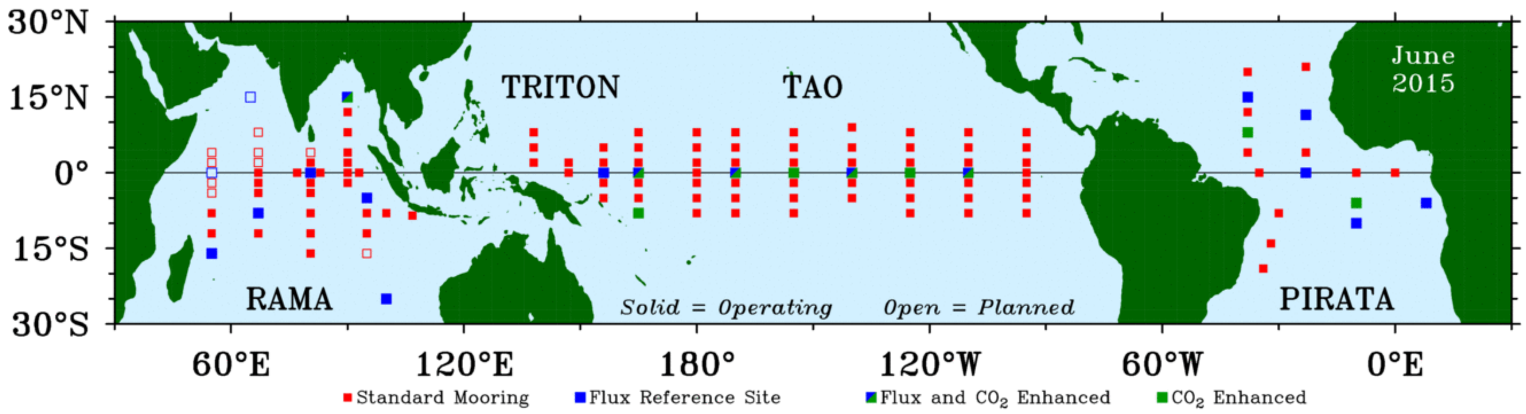


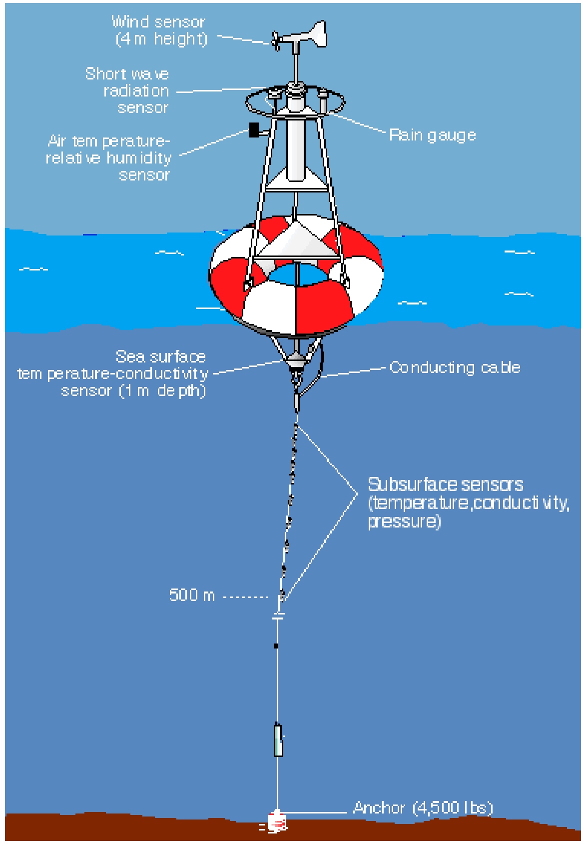
Annual SST anomalies (relative to 1961-1990)

ICOADS (raw data) adjusted in HADSST3

Adjustments suffer from
→ inadequate documentation of sampling characteristics
→ no proper overlap for intercomparison

Long term observation records - Global tropical moored buoy array



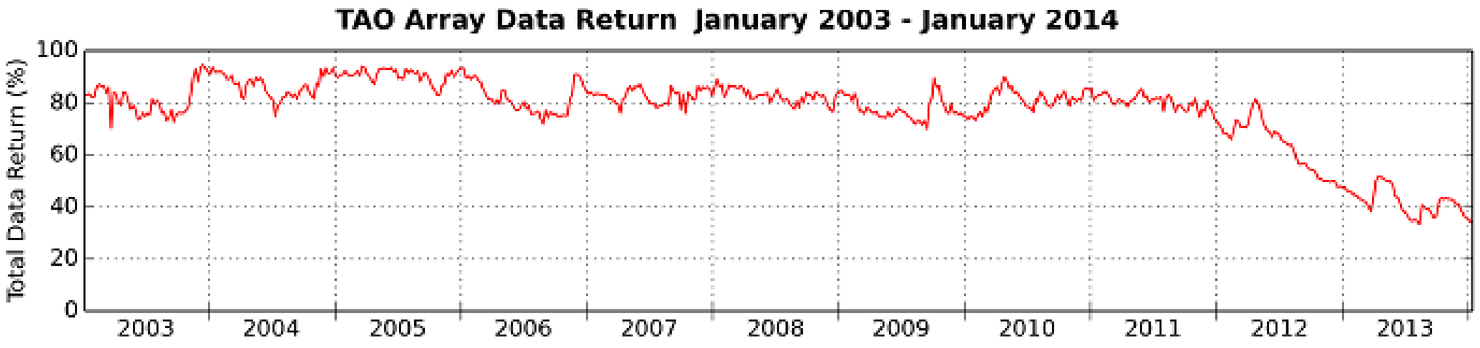


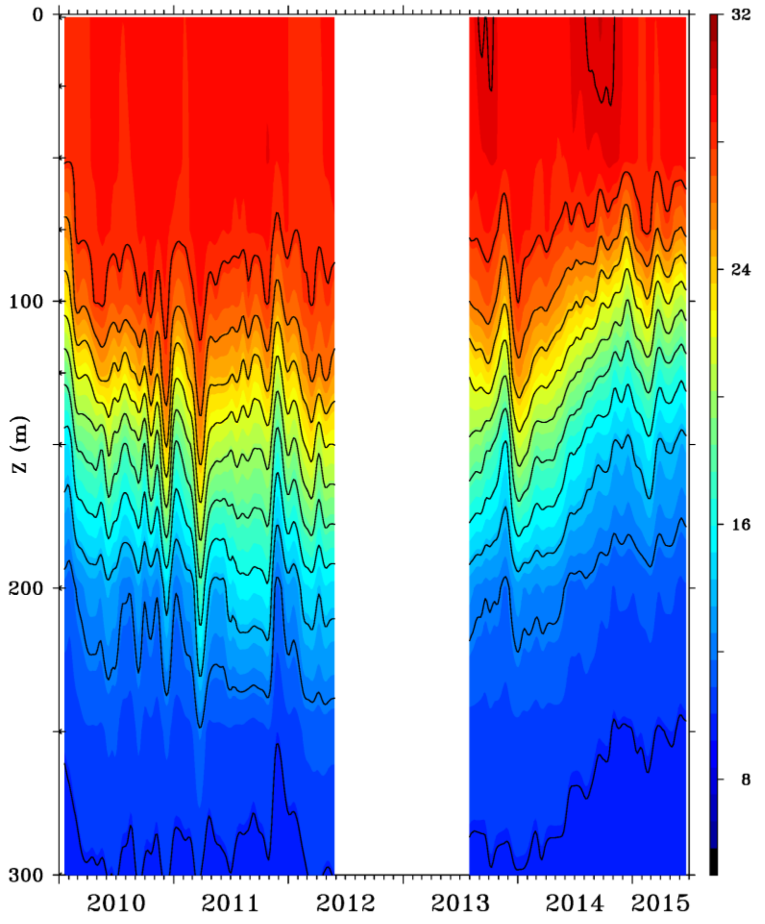
Collocated ocean and atmosphere measurements:

- study coupled phenomena (e.g. tropical cyclone)
- study climate variations related to ENSO

Long term observation records - Global tropical moored buoy array

Budget cuts pushed NOAA to retire a ship dedicated for the service
→ $3 million cut
→ half of all measurements lost
→ Produce serious gaps in the climate records

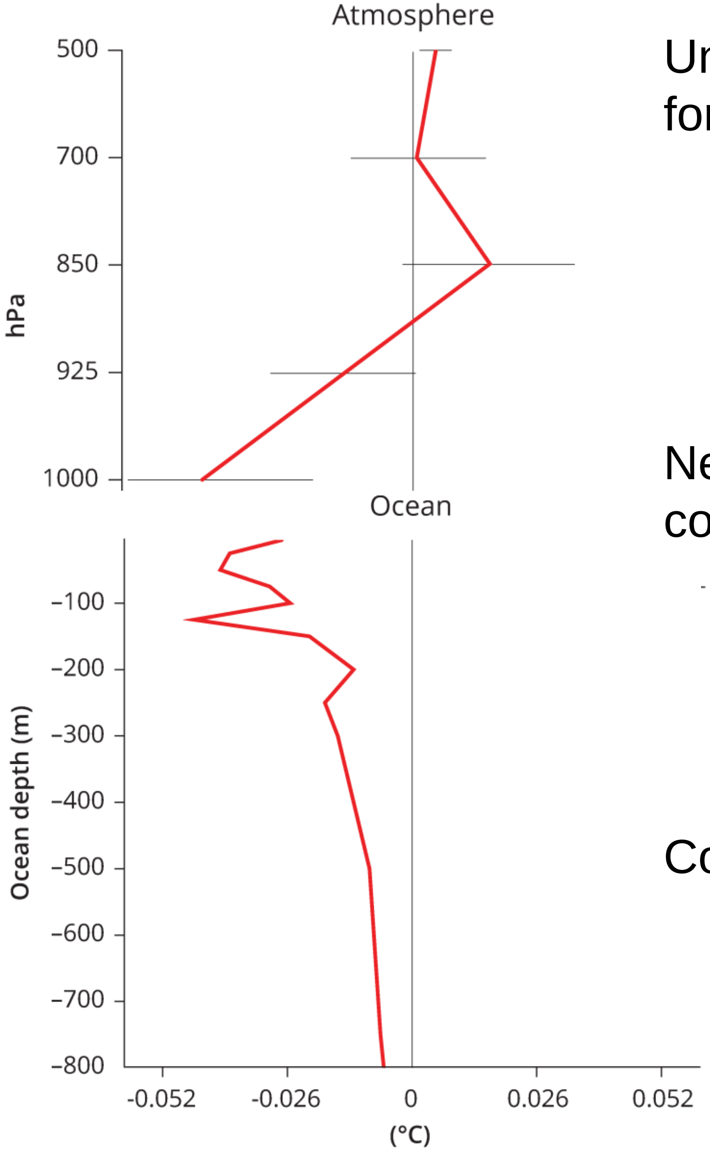




Timeseries from one TAO mooring for temperature

Impact of near-surface observations in coupled assimilation

Positive impact of the coupled assimilation

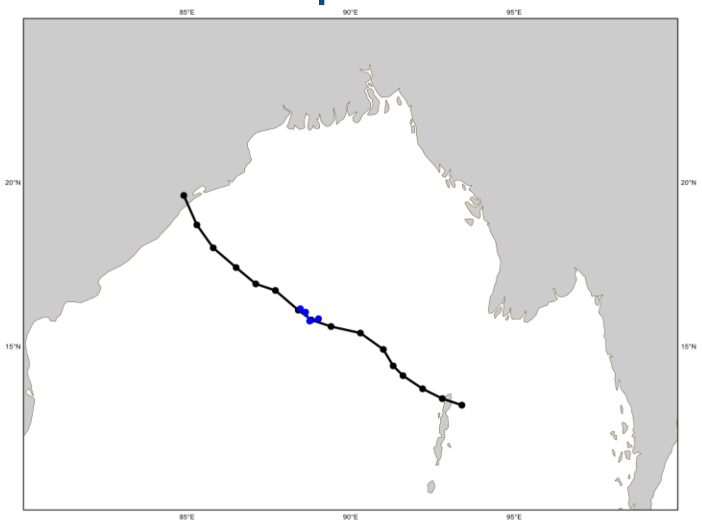


Uncoupled and coupled assimilation systems compared over Tropics for September 2010

Negative values means that background temperature RMSE is smaller in the coupled assimilation system (with respect to conventional observations)

Coupled assimilation allows a better use of near-surface observations

Positive impact of the coupled assimilation - Tropical cyclone Phailin



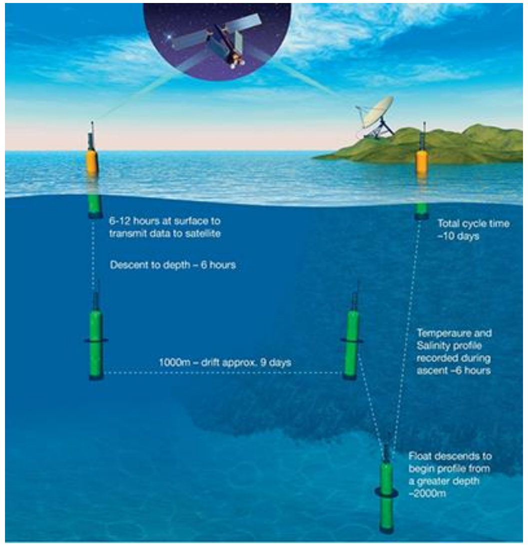
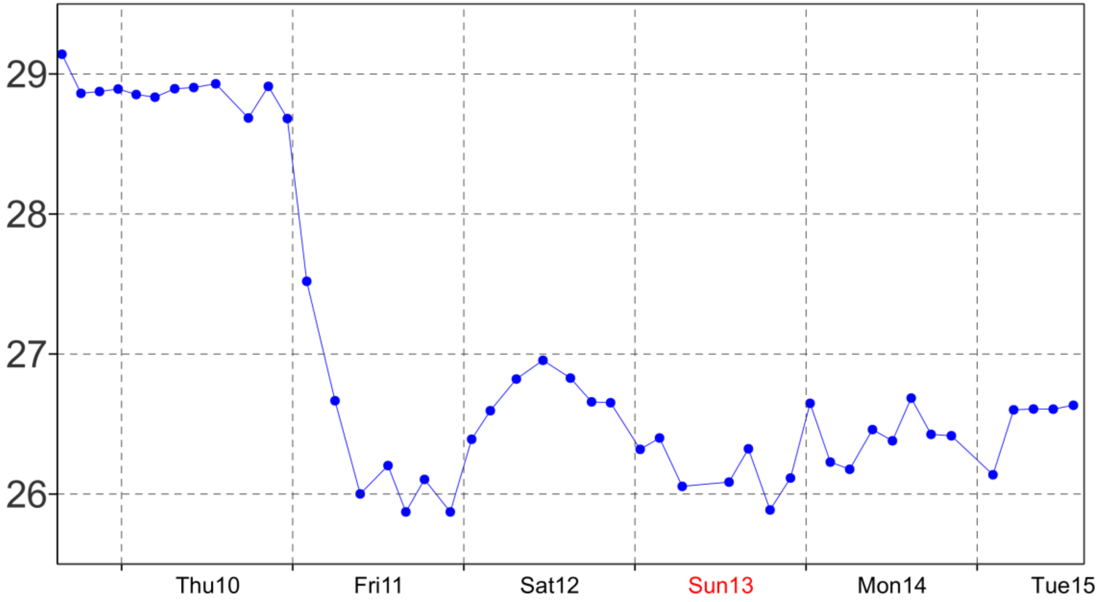


Illustration of a specific weather event:

- Bay of Bengal
- formed on the 4th October 2013
- Argo probe with high-frequency measurements

Temperature measurements at 40-meter depth



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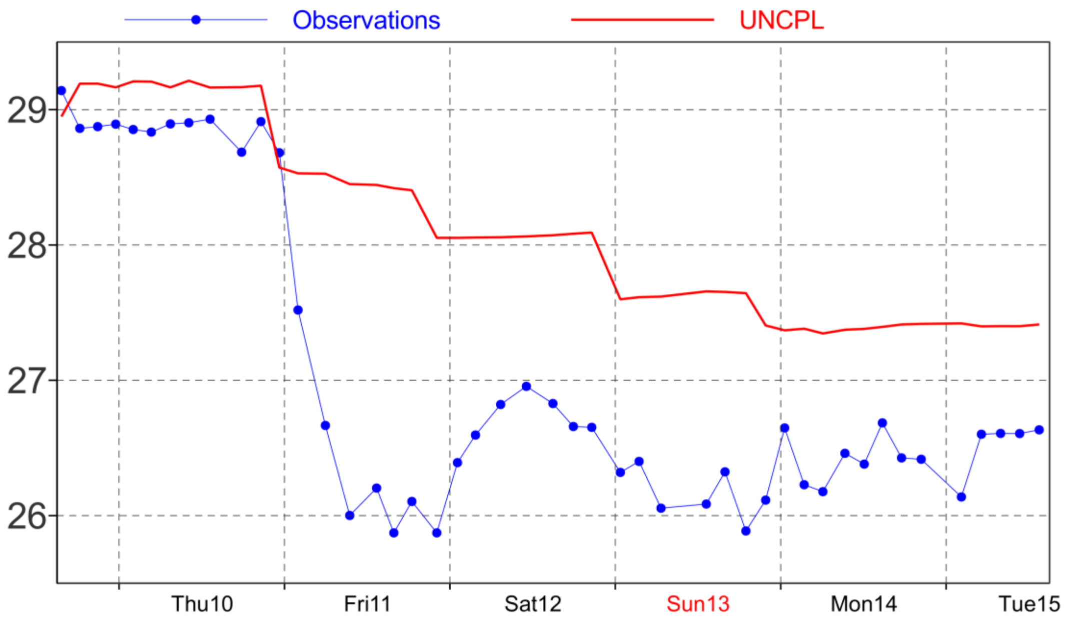
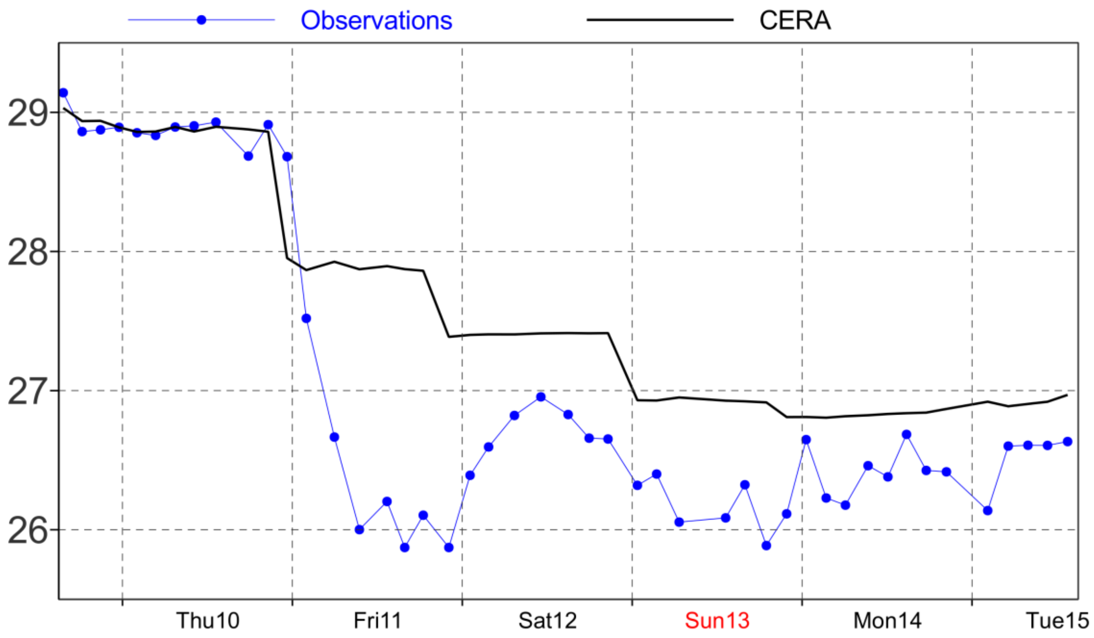
Ocean temperature analysis at 40-meter depth

Uncoupled assimilation



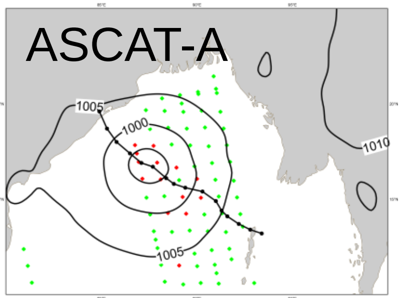
Coupled assimilation

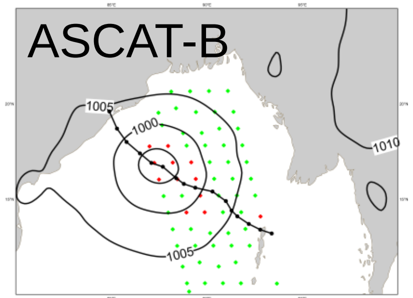


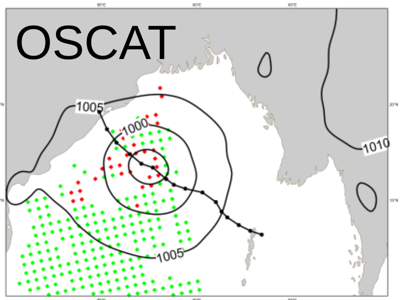
→ Coupled analysis has a stronger cold wake (closer to observations)

Positive impact of the coupled assimilation - Tropical cyclone Phailin

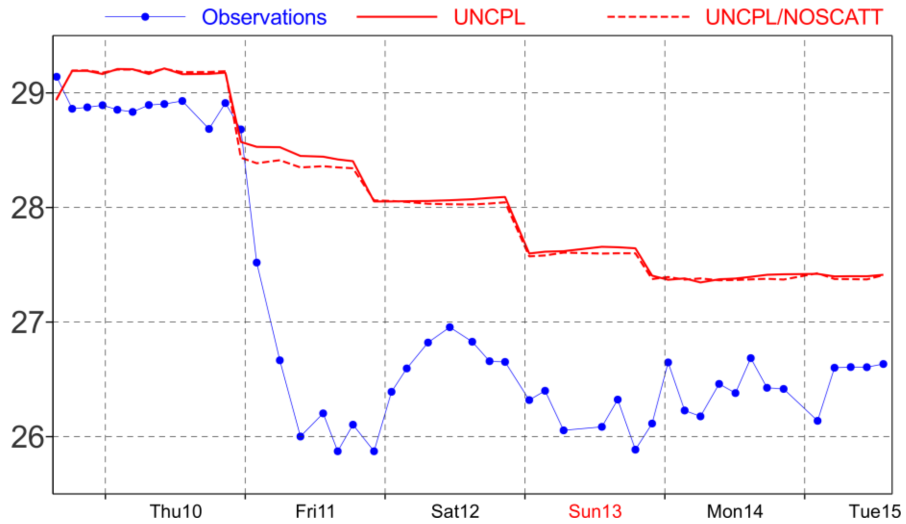
Wind measurements from scatterometers

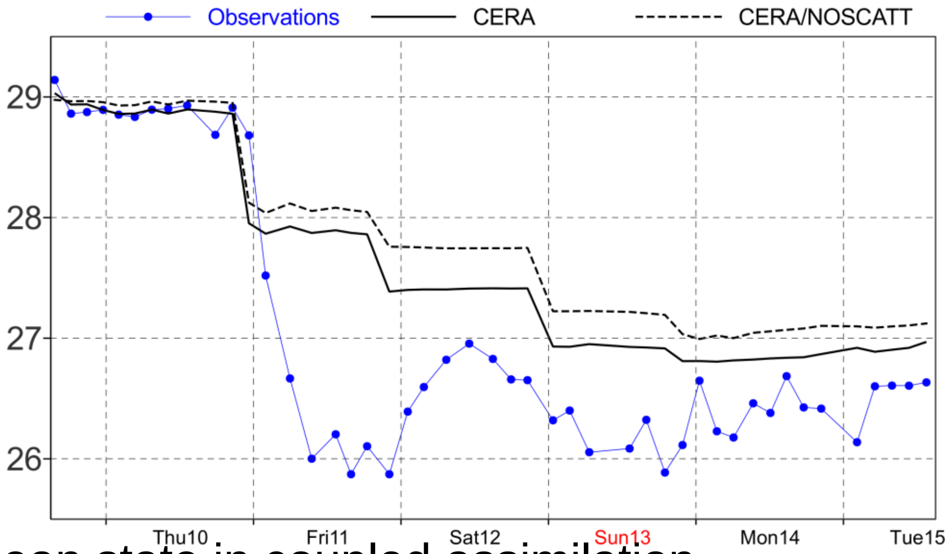






Ocean temperature analysis at 40-meter depth (no scatterometer data in dashed)



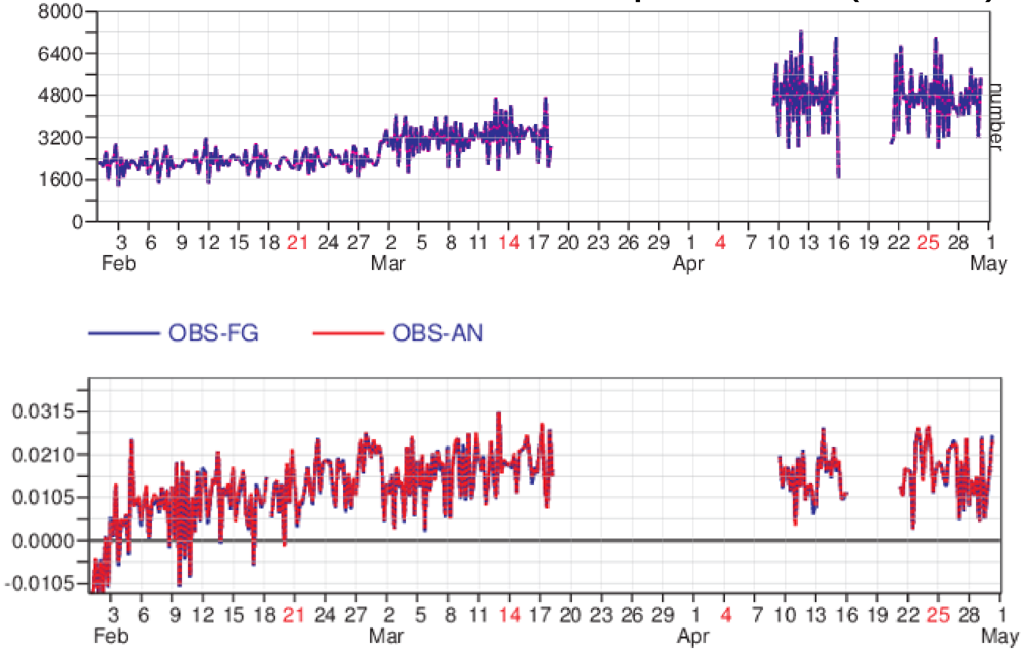


→ Crucial role of scatterometer data to estimate the ocean state in coupled assimilation

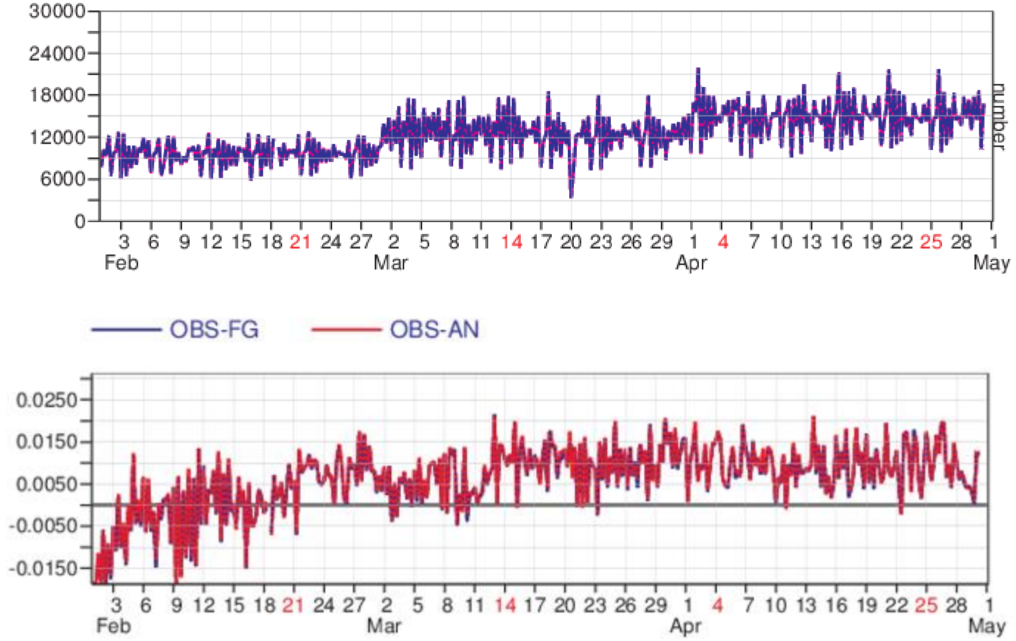
→ Atmospheric observations have the potential to improve ocean analysis

Benefits of data reprocessing: ASCAT for soil moisture analysis (2010)

ASCAT data assimilated in operations (CTRL)



Reprocessed ASCAT data (REPROC)



→ 4 times more assimilated observations in REPROC

→ Background and analysis mean departure errors reduced by 30%

Conclusions and requirements for future observing systems

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Do not repeat the mistakes made in the past in the production of observation records

- poor documentation about instruments and sampling methods
- changes in observing system without adequate overlap and intercomparison
- gaps in observation records

Continue to improve the use of observations

- data assimilation methods (coupling, better representation of the diurnal cycle)
- reprocessing the datasets

Provide uncertainties with observations

- a set of interchangeable realisations of the observation dataset (e.g. HADISST2)