Status of the reanalysis activities at ECMWF

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Reanalysis productions at ECMWF

Atmosphere/land **including ocean waves**

1979 - 1981 FGGE	1994 - 1996 ERA-15	2001 - 2003 ERA-40	2006 – ERA-Interim	2016 - … ERA5

Ocean **incl sea ice**

2006 ORAS3	2010 - … ORAS4	2016 - … ORAS5

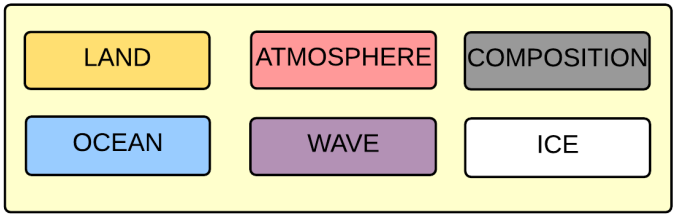
Enhanced land

2012 ERA-Int/Land	2014 ERA-20C/Land	2017 - … ERA5L

Atmospheric composition

2008 - 2009 GEMS	2010 - 2011 MACC	2017 - … CAMS

Towards a coupled earth system



Centennial

2013 - 2015 ERA-20CM/20C
2016 - … CERA-20C

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Content

- ***ERA5*** ➔ *See Adrian's talk this afternoon!*
  - *Brief introduction*
  - *Assessment of the ERA5 ozone*
  - *Release plan*
- ***Towards ERA6***
  - *The CERA system and CERA-SAT reanalysis*

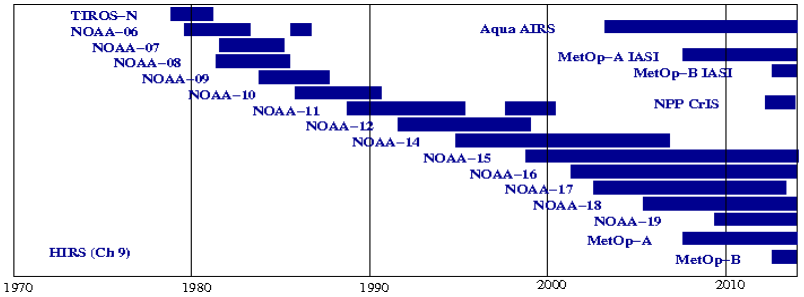
What's new in ERA5?

	ERA-Interim	ERA5
Period	1979 – present	Initially 1979 – present, later **1950**-1978
Streams	1979-1989, 1989-present	Parallel streams, one per decade
Assimilation system	2006 cycle (31r2), 4D-Var	**2016** ECMWF model cycle (41r2), 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent SST)*	***Appropriate for climate***, e.g., evolution GHG, volcanic eruptions, SST and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** **137 levels to 1 Pa**
Uncertainty estimate	/	Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	ERA5L, 9km (separate, forced by ERA5)
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters*** ~ 5 Peta Byte (1979-NRT)
Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias correction	Satellite radiances	Also ozone, aircraft, surface pressure

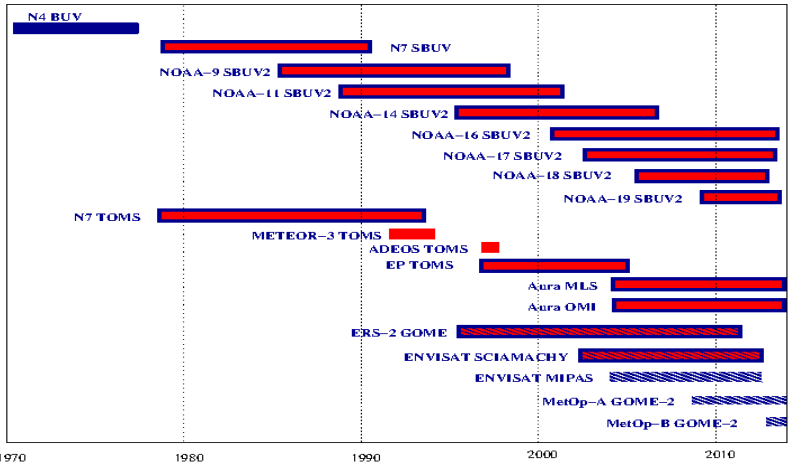
The evolving observing system

- **Improved data usage**
  - all-sky vs clear-sky assimilation,
  - latest radiative transfer model,
  - …
- ***ERA5 is more future proof!***
  - Lack of infrastructure in ERA-Interim to include new observations (IASI, ASCAT, ATMS, CrIS, MWHS2, Himawari-8)
- **Newly reprocessed data sets**
  - **Radiances:** SSM/I brightness temp from CM-SAF
  - **METEOSAT** from EUMETSAT
  - **Altimeter:** ERS1/2, ENVISAT, Jason-1
  - **Scatterometers:** ASCAT-A, ERS 1/2 soil moisture
  - **GPS RO:** METOP GRAS, COSMIC, CHAMP, GRACE, SAC-C, TERRASAR-x
  - **AMV winds:** METEOSAT, GMS/GOES-9/MTSAT, GOES-8 to 15, AVHRR METOP and NOAA
  - **Ozone:** NIMBUS-7, EP TOMS, ERS-2 GOME, ENVISAT SCIAMACHY, Aura MLS, OMI

Level 1b



Level 2



Used / same version

Used / new version

Never used

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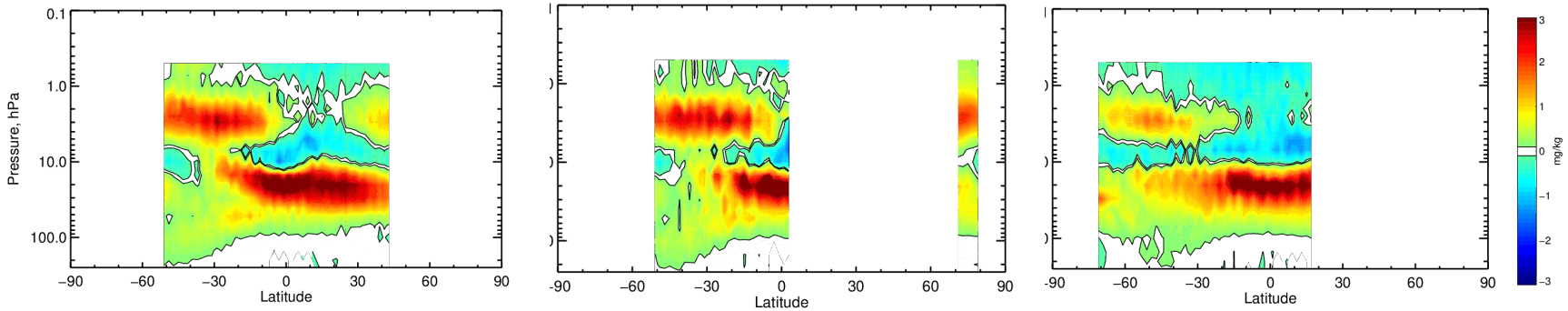
Quality of the ERA5 O_3 reanalysis: SAGE II

SAGE-ERA

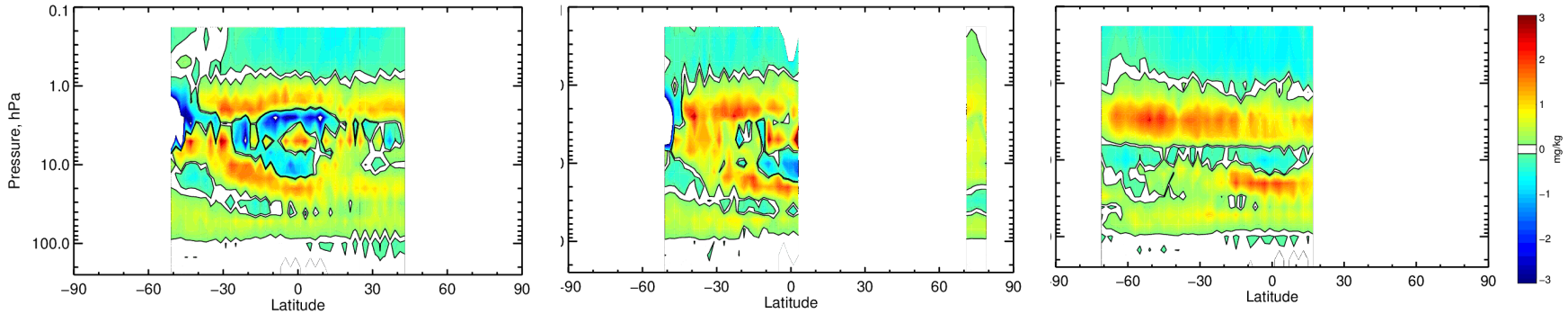
1989

May | **August** | **October**

ERA-Interim



ERA5



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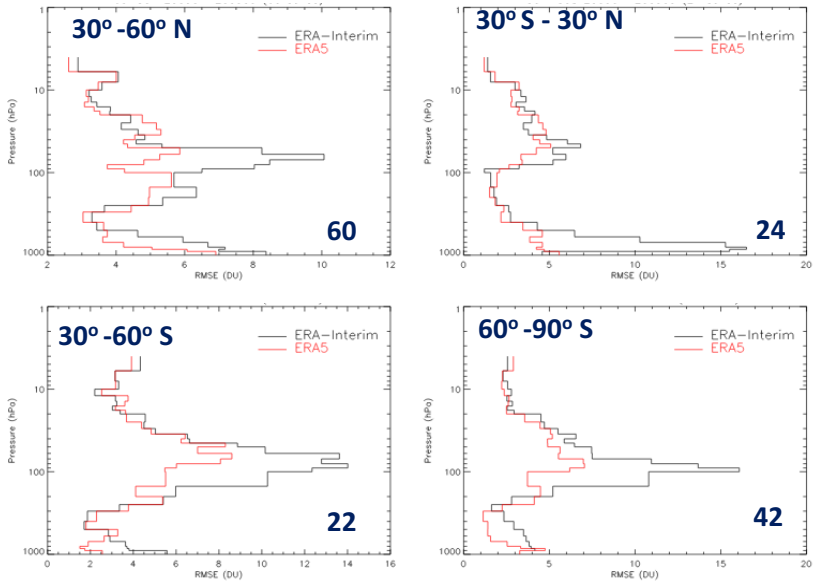
Quality of the ERA5 O_3 reanalysis: WOUDC O_3 Sondes

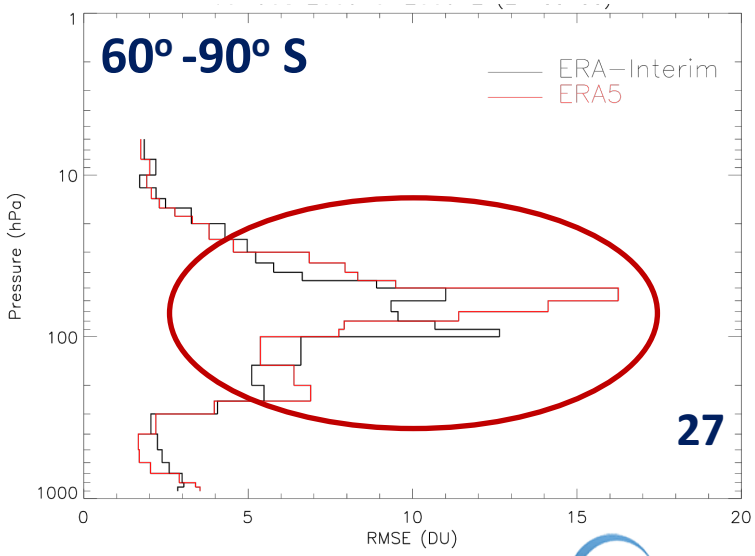
2009

July-September



Similar results found in JFM, and AMJ at all available latitudes, as well as between 60ºS and 60ºN during OND.

October-December



Investigation of the impact of various ozone changes using the same model version (ozone model, and assimilation) **might show a small degradation from v8.6 SBUV data in October.**

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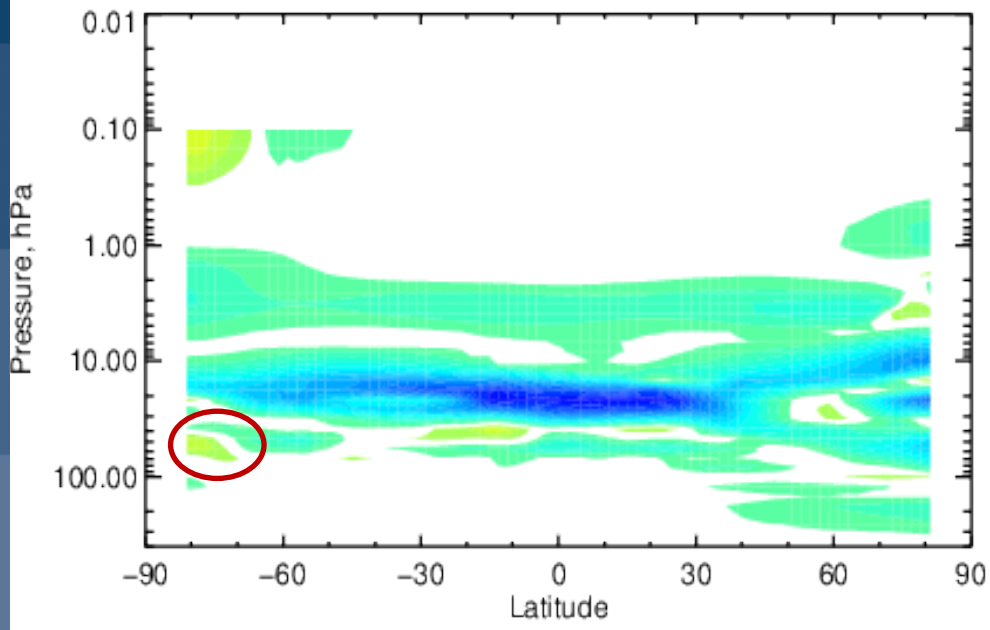
Impact of the assimilation of SBUV: v8.6 [21 lev] vs v8.0 [6 lay]

October



The assimilation of the full vertical resolution (v8.6) SBUV profiles seems to cause a small "degradation" in the fit to MLS during Oct compared to that of a coarser product (6 layers, bottom one covering the region surface-16hPa).

$$\Delta = \left|\overline{MLS - An_{O_3}^{(21\ Lev)}}\right| - \left|\overline{MLS - An_{O_3}^{(6\ Lay)}}\right|$$

- **> 0 ➔ SBUV(21 Levels) degrades fit to MLS**
- **< 0 ➔ SBUV(21 Levels) improves fit to MLS**

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ERA5 preliminary assessment

The performance of ERA5 is very promising in some aspects, e.g.:

- ✓ improved global hydrological and mass balance;
- ✓ reduced biases in precipitation;
- ✓ refinement of the variability and trends of surface air temperature;
- ✓ Ozone reanalyses are generally better than those from ERA-Interim.

There are some imperfections, though

- ✗ Temperature bias in the stratosphere;
- ✗ Tropical jet in the mesosphere too intense;
- ✗ Initially there were quality issues over the SH in the 1980s (delay in production stream).
- ✗ Ozone in the ozone hole region slightly degraded compared to E-I due to assimilation of high vertical resolution SBUV profiles.

See Adrian's talk later today.

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ERA5 release plan

- **Q2 2017: public release of 2010 – 2016**

- **Q4 2017 / Q1 2018: 2017 – timely updates**
  - **ERA5:** Updates with about 2-months delay (final product)
  - **ERA5T:** Updates with short delay (<1 week, preliminary product)

- **Q1/2 2018: Release of 1979 – 2009:**
  - Continue ERA5 timely updates
  - **Continue ERA-Interim for another 6 months**

- **2018: integration of ERA5 segment from 1950**

***Access*:**
- Initially similar to ERA-Interim (Web-API)
- From Q1 2018 via the **C3S Climate Data Store**

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From ERA5 to ERA6

- As part of its long-term strategy, ECMWF is developing an Earth System Model (atmosphere, including composition, ocean, waves, sea ice, and land).
- Part of these developments will be exploited in the next global reanalysis, ERA6.
- Funded through the ERA-CLIM2 project, a pilot reanalysis based on coupled system has almost been completed. It couples the atmosphere, ocean, wave, SI and (weakly) land components.
- The ocean coupling is important for:
  - seasonal forecasting: it provides better SST forecasts for ENSO predictions;
  - short range forecasting: it improves the Tropical Cyclone forecasts

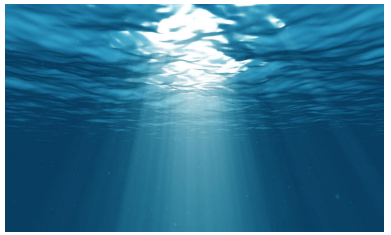
ERA-Clim2

CERA-20C: the first ECMWF coupled reanalysis of the 20th century


Atmosphere


Land


Wave

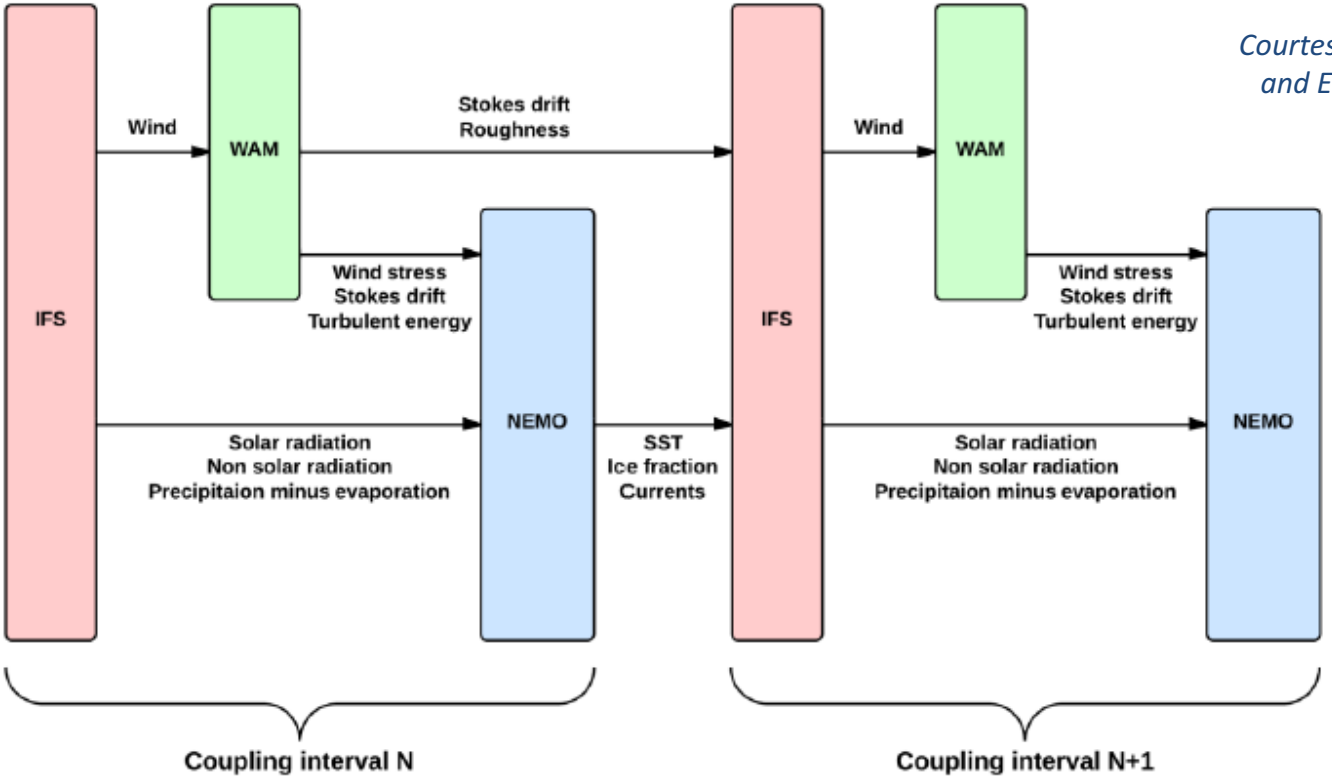

Ocean


Sea ice

Model: IFS/NEMO/LIM2 (CY41R2, Mar 2016)
Forcing: SST nudged (HADISST2)
Observation: surface conventional, salinity and temperature profiles
Assimilation: new CERA system (10-member ensemble coupled hybrid DA)
Resolution: T159L91/ORCA1 Z42
Period: 1901-2010

P. Laloyaux et al. A coupled data assimilation system for climate reanalysis. Quarterly Journal of the Royal Meteorological Society, 142(65-78), 2016.

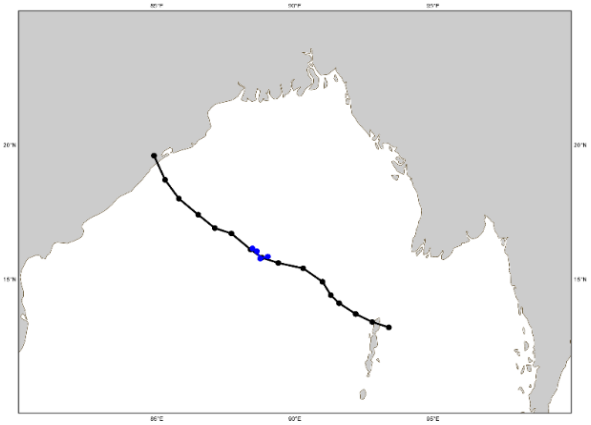
Towards a Coupled ECMWF ReAnalysis (CERA) system



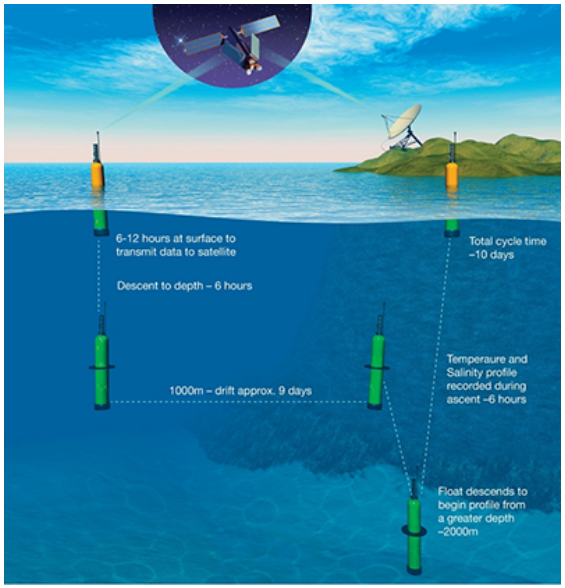
Courtesy of P. Laloyaux and E. de Boisseson

Atmosphere-ocean interactions need to be taken into account, not only during the forecast but also for the definition of the initial conditions of the forecasts.

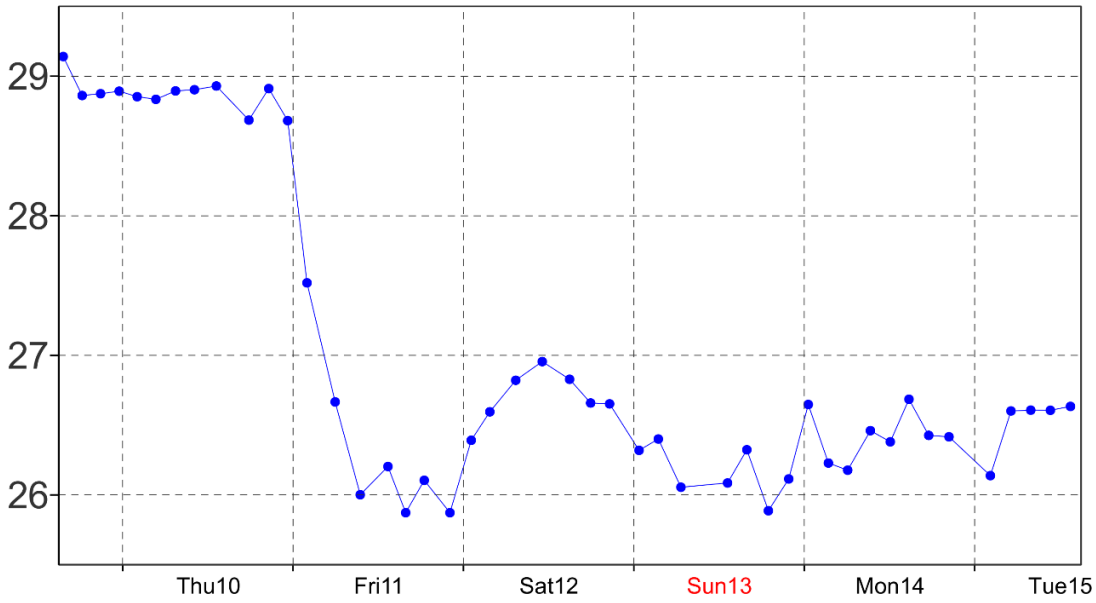
Coupled vs. uncoupled during a Tropical Cyclone (TC) event



TC Phailin formed on October, 4th 2013 in the Bay of Bengal



Temperature observations from Argo probe

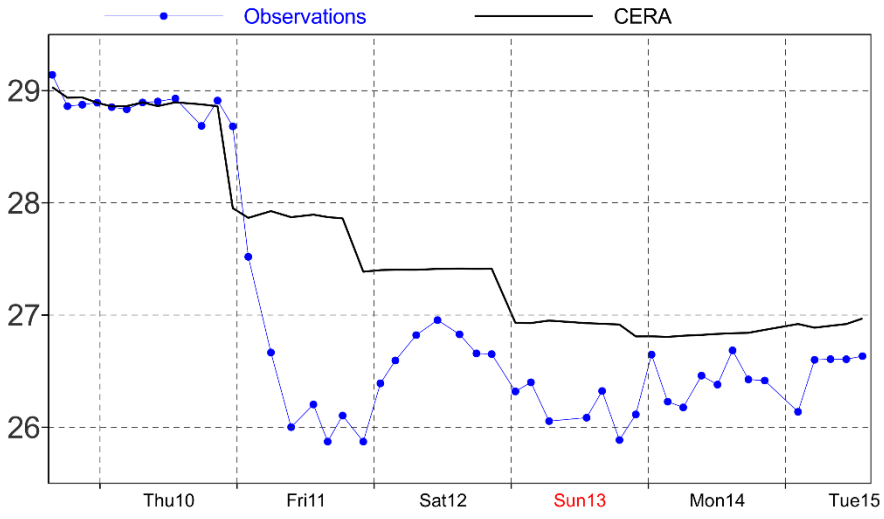


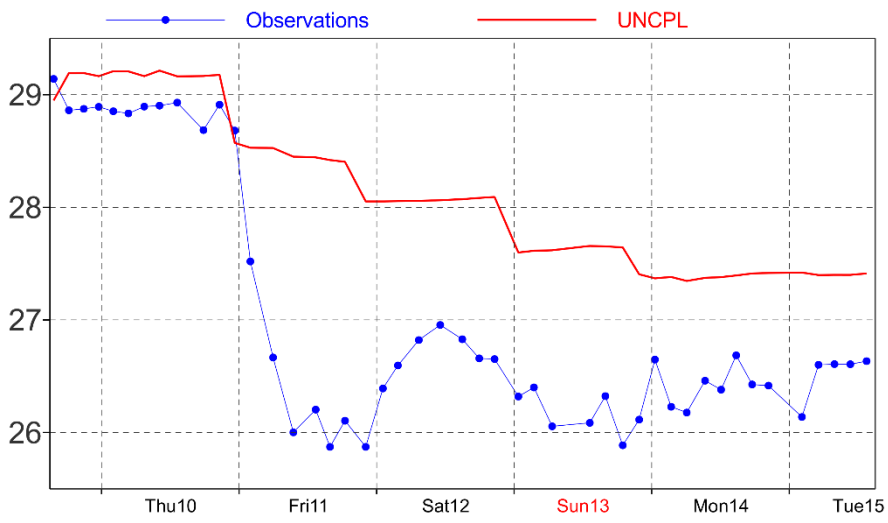
Coupled vs. uncoupled during TC Phailin

CERA: Coupled ECMWF Re-Analysis
UNCPL: Uncoupled

Atmo Res ~ 128km / 137 L
Ocean Res 1 deg/42 L
24h Assimilation Window

Temperature observations and analyses



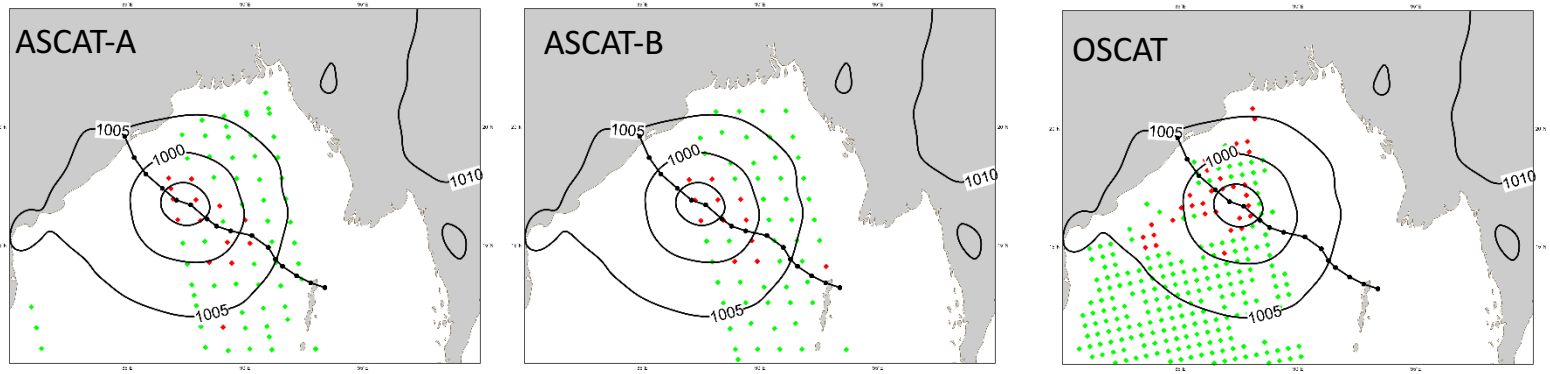


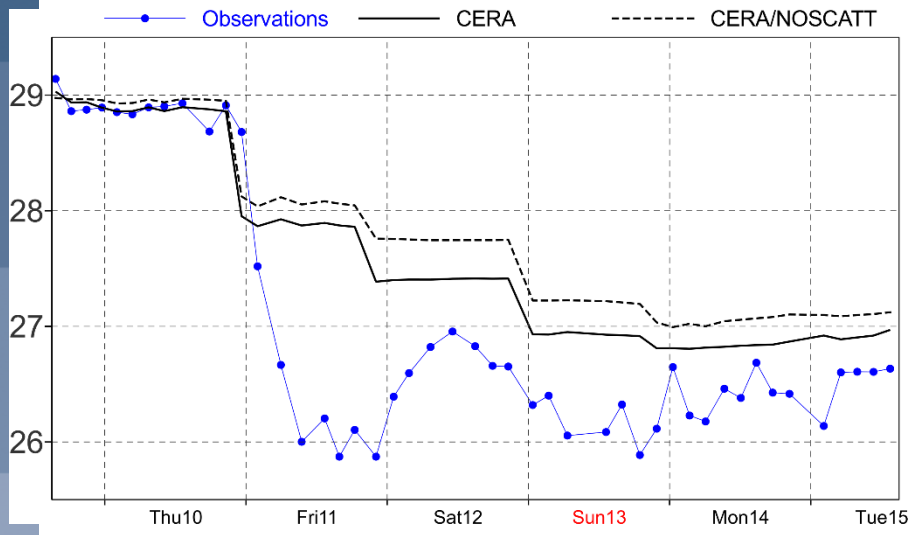
Coupled analysis is closer to the observations with a stronger cold wake

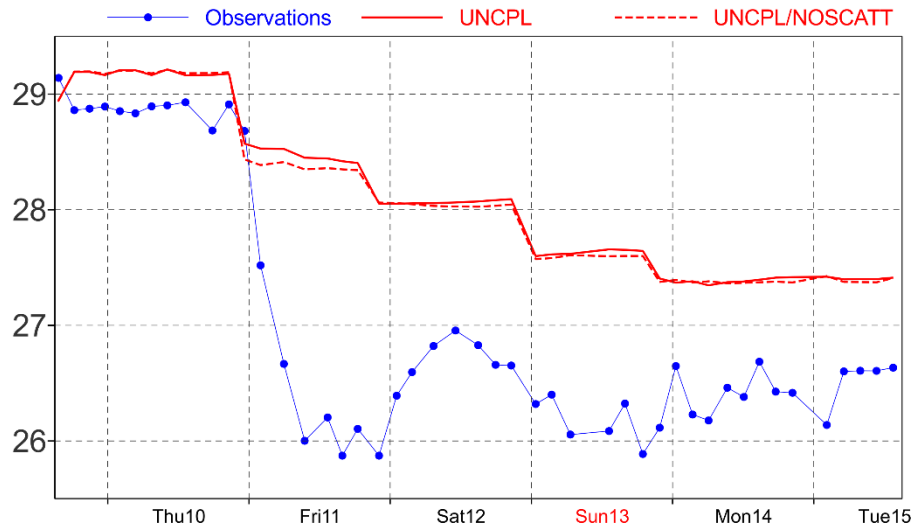
P. Laloyaux, J-N Thépaut and D. Dee, Impact of scatterometer surface wind data in the ECMWF coupled assimilation system. MWR, 2016.

Crucial role of SCAT data

Wind measurements from scatterometers (ascending pass, 11 October 2013)







CERA-SAT: a proof-of-concept coupled reanalysis for the period 2008-2016

Atmosphere/Wave/Land

- **Model:** IFS (**CY42R1**_esuite, April 2016)
- **Atmosphere Resolution: TL319** (~60 Km); **137 levels**
- **Wave Resolution**: 0.5 deg
- **Assimilation:** 24-hour window
- **Full observing system** (including reprocessed datasets)

Ocean/Sea ice

- **Model:** NEMO / LIM2 (CY42r1_nemo_E28)
- **Resolution** (**1/4 degree; ORCA025**) ~30 km; **75 levels**
- **Assimilation:** 24-hour window 3Dvar FGAT
- **Observations:** salinity and temperature profiles, **SSH, SI analysis** (OSTIA L4)

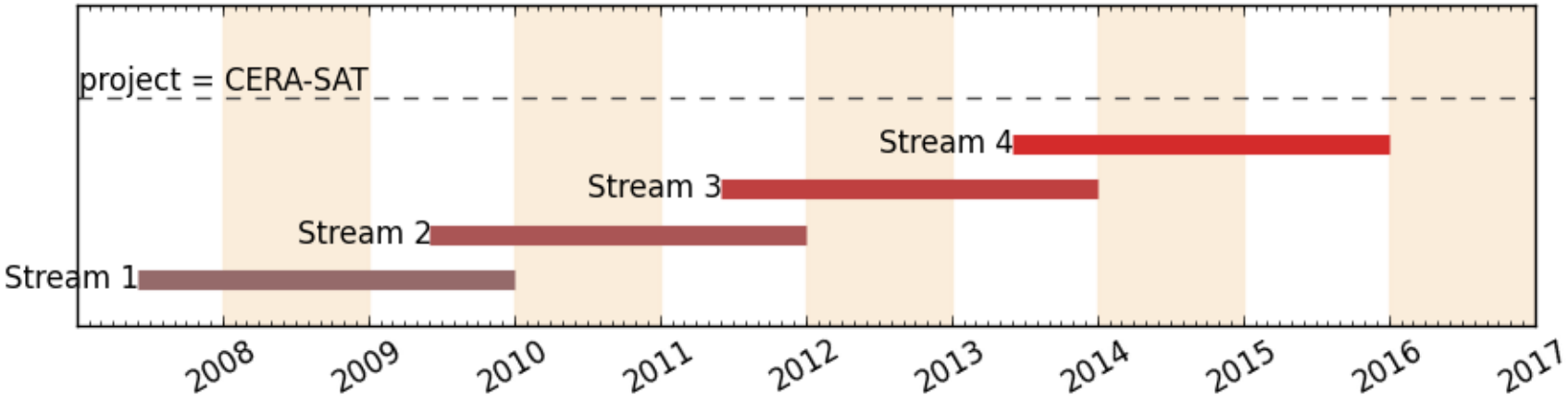
Wave

- **Model:** WAM (CY42R1_esuite)
- **Resolution:** 0.5 degree
- **Assimilation:** 24-hour window
- **Observation: ERA5 observing system**

ERA-CLIM2 deliverable in Dec 2017

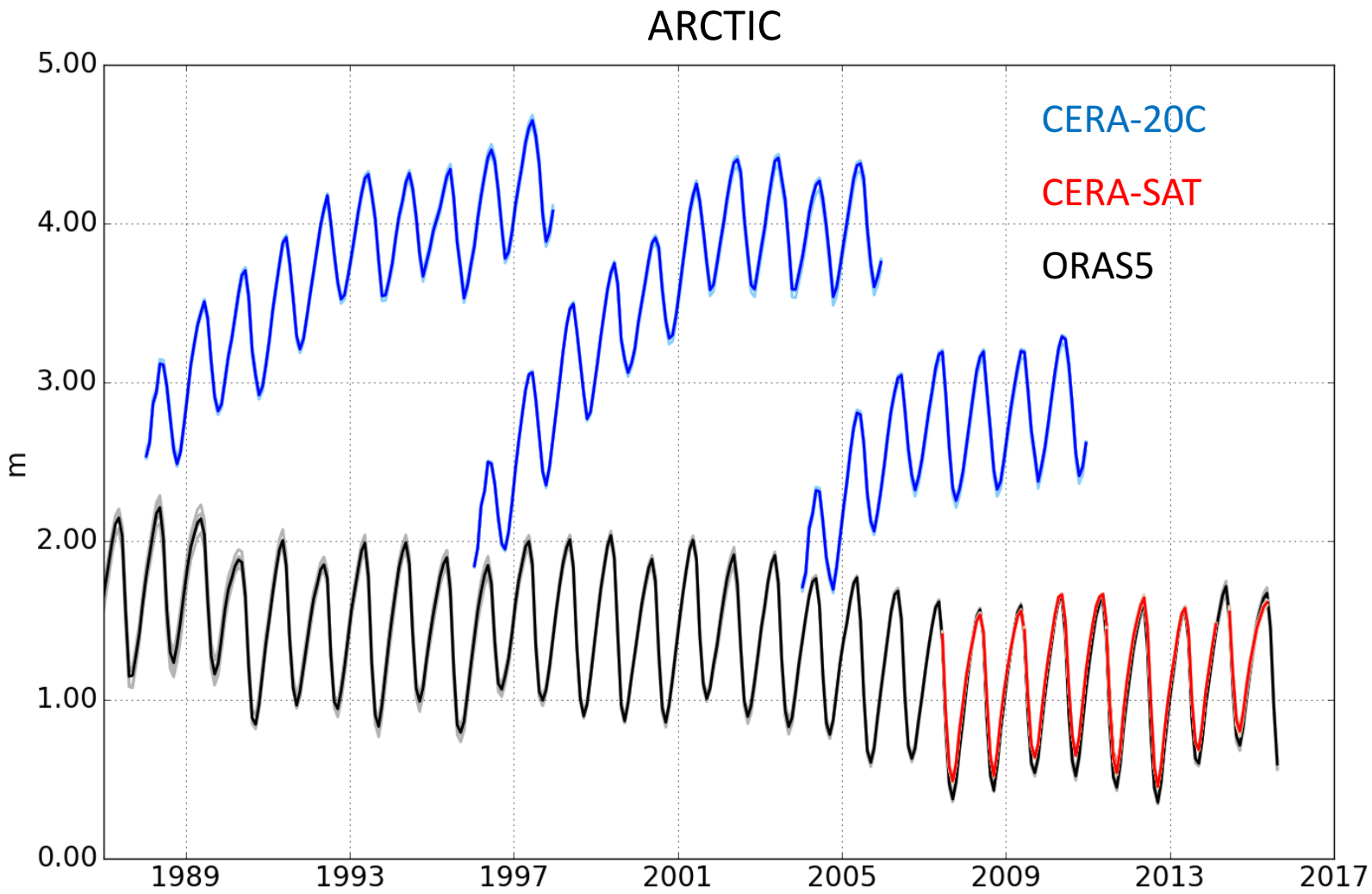
CERA-SAT schedule and data availability

- Period: 2008-2016
- Production:
  - ❖ Started at the end of Dec 2016, to be completed by mid-November
  - ❖ 4 streams; 2.5+ years each (0.5+ year overlap)
- Provide CERA-SAT system in uncoupled mode – for clean impact studies



- The data are available in the ECMWF MARS archive, and it is being consolidated in a single experiment ID.

Preliminary assessment of Sea-Ice thickness



Conclusions

- **The production of ERA5 is well underway:**
  - Higher resolution than ERA-Interim;
  - It provides hourly output, uncertainty estimates, and the feedback archive.

- **Preliminary assessment of ERA5 show good performance** particularly in the troposphere, but some issues in the upper stratosphere and mesosphere.

- **Data release has started** (backlog to be finished in Q2 2018).

- Work is on-going to move **towards a fully coupled Earth System Model**.

- Preliminary work exploiting the **coupling with the ocean model show promising results**, and highlight the importance of some elements of the observing system, in particular the scatterometers.

- As part of the ERA-CLIM2 project, **a proof-of-concept reanalysis has been produced for the 2008-2016 period** using the coupled system and the full observing system with encouraging preliminary assessment.