

# ERA-CLIM2 Review

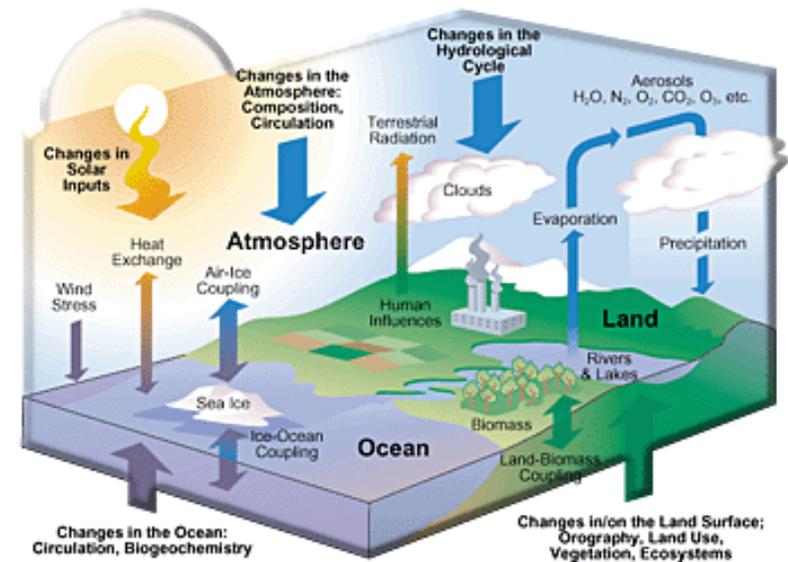
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*European Centre for Medium-Range Weather Forecasts*

# The FP7 ERA-CLIM2 project (2014-2017)



**Goal: Production of a consistent 20<sup>th</sup>-century reanalysis of the coupled Earth-system: atmosphere, land surface, ocean, sea-ice, and the carbon cycle**



*Main components:*

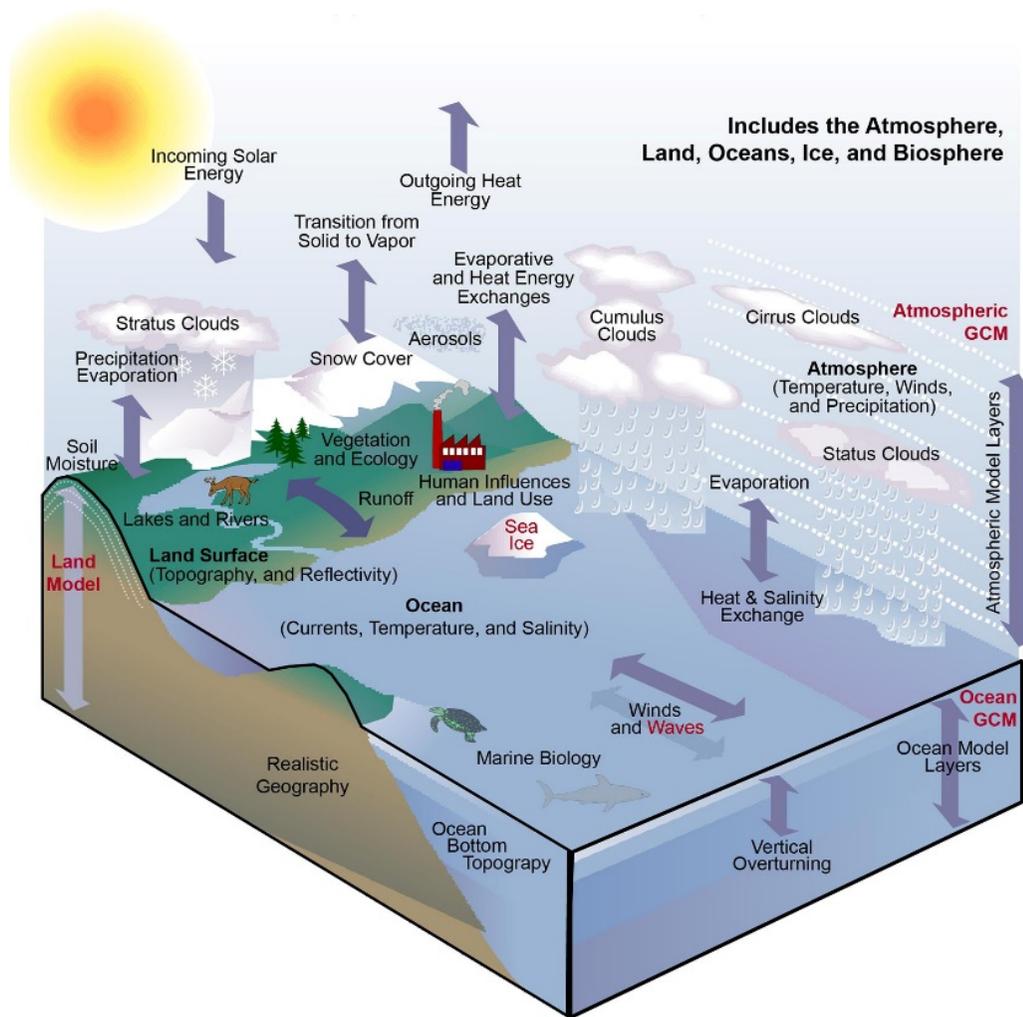
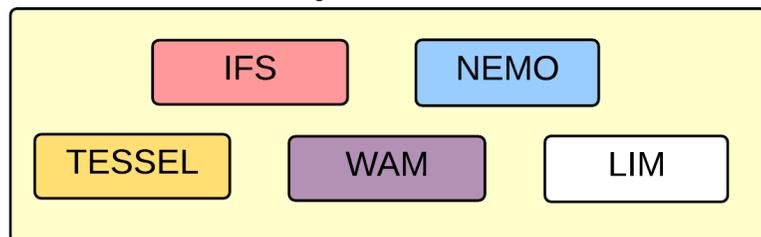
- *Production of coupled reanalyses, for 20C and the modern era (WP1)*
- *Research and development in coupled data assimilation (WP2)*
- *Earth system observations for extended climate reanalyses (WP3)*
- *Evaluation of uncertainties in observations and reanalyses (WP4)*
- *Improving access to reanalysis data and input observations (WP5)*
- *Management and coordination (WP6-9)*

# A key building block: the CERA system

CERA: the Coupled ECMWF Reanalysis assimilation system:

- Based on the ECMWF coupled model
- Assimilates atmospheric and ocean observations simultaneously
- Ocean observations can impact atmospheric estimate and conversely

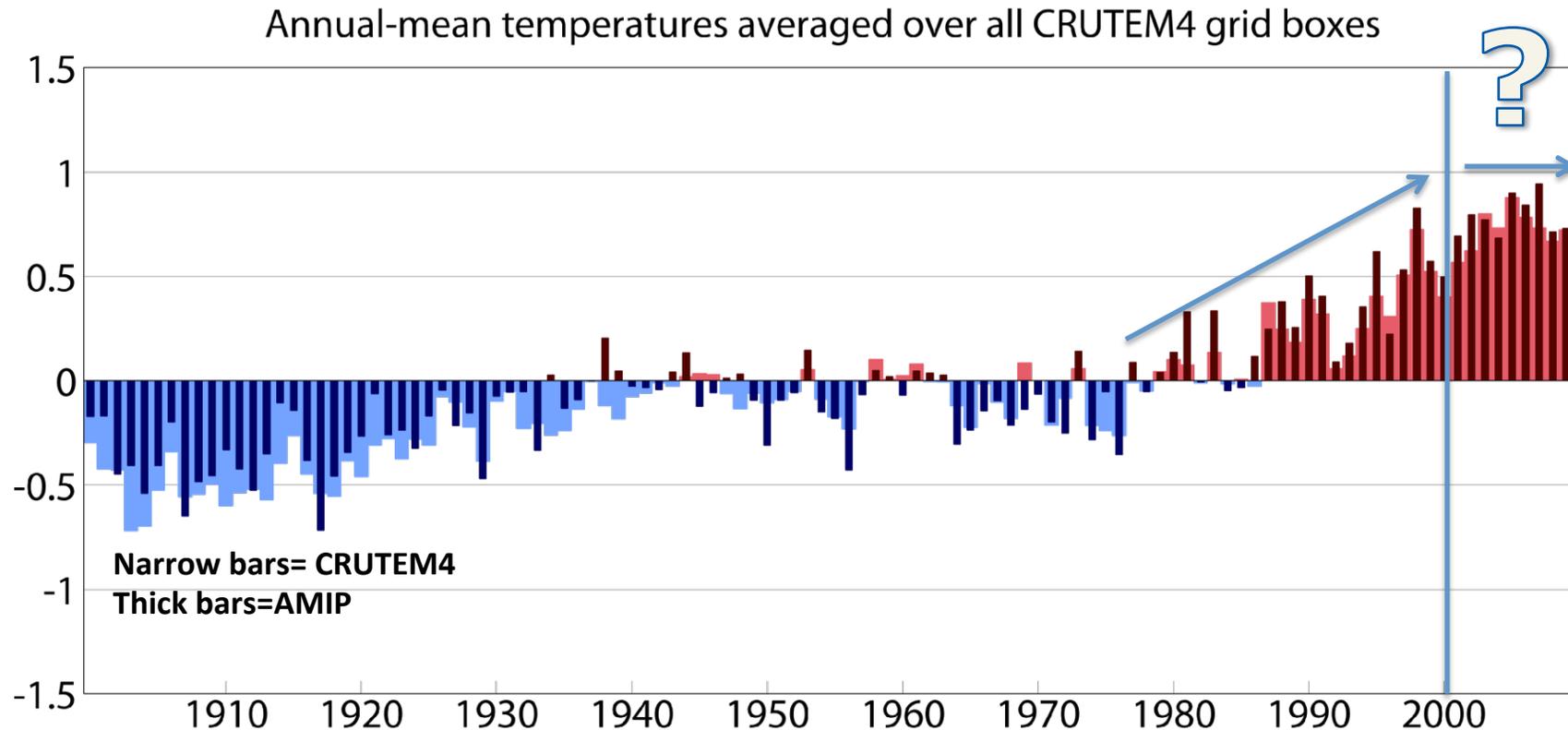
## ECMWF coupled Earth model



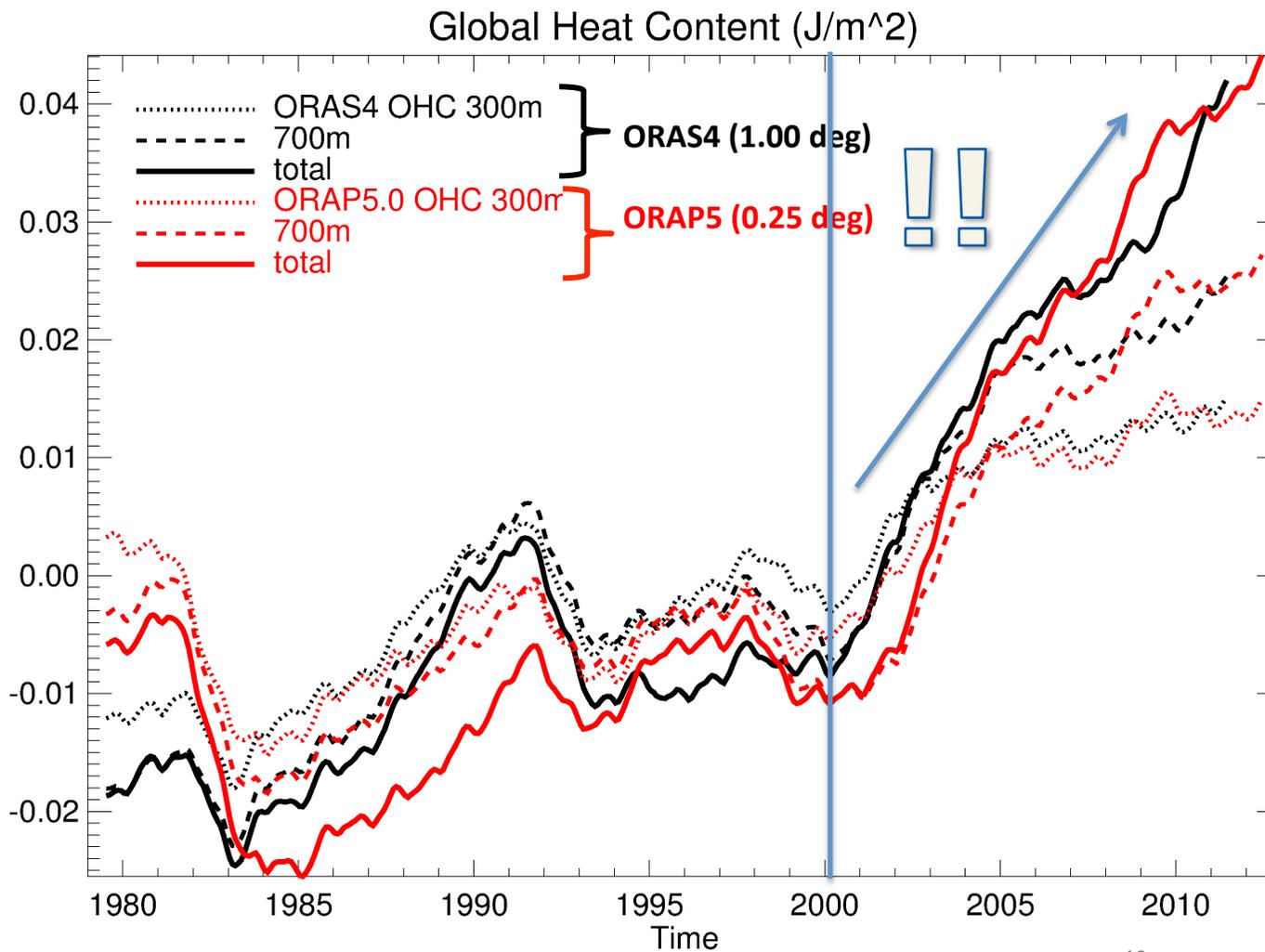
(from Patrick Laloyaux)

# Why do we need coupled models/DA?

To understand climate change, and how different Earth-system components interact, we need to have a fully coupled approach. We need to take all Earth-system observations into account, and assimilate them to create a full, 5-dimensional (3 space, time and component) picture of the climate evolution.



# Because they can help us understanding change



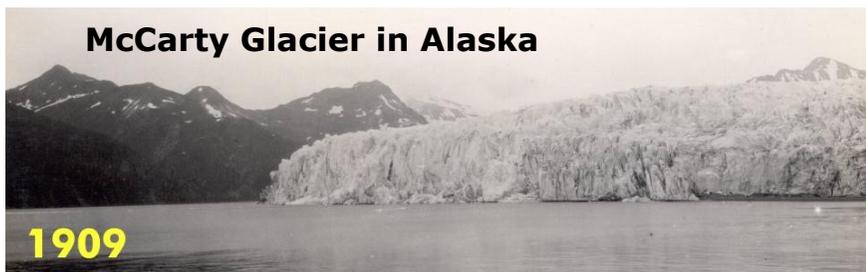
(from Magdalena Balmaseda)

# CERA-20C: the 1<sup>st</sup> European coupled reanalysis



A complete reconstruction of the 20<sup>th</sup> century global weather based on observations to monitor the low-frequency climate variability for atmosphere, land, ocean and sea-ice, and provide long time-series of gridded Essential Climate Variables (ECVs).

It use only a restricted set of observations (whitelisting approach selecting datasets suitable for climate application), modern data assimilation methods (the CERA system) and a coupled model to transform these heterogeneous observations into a consistent view of the global Earth climate.



# The CERA-20C and CERA-SAT reanalyses



## Observation selection for climate reanalysis:

- Consistent datasets with long time series of weather observations

## To produce CERA-20C we need observations:

- Atmosphere: conventional pressure and marine wind observations (ICOADS/ISPD)
- Ocean: temperature and salinity profiles (EN4)
- Air-sea interface: sea surface temperature analysis product (HADISST2)

## Resolution of the CERA-20C and CERA-SAT reanalyses:

- Atmosphere  $T_L159L91$  (~120 km) and  $T_L319L137$  (~65 km)
- Ocean: NEMO model with ORCA100z42 and 025z75 (coupling O $\leftrightarrow$ A every hour)
- In CERA-SAT: weakly coupled land and wave assimilation
- 10 member ensemble to estimate uncertainty

## Assimilation method::

- Atmosphere: 4-dim. var. method with a 24-h window
- Ocean: 3-dim. var. method with First Guess at Appropriate Time (FGAT) method
- Land: Optimum Interpolation (OI) and Simplified Ensemble Kalman Filter (SEKF)
- Wave: OI

# Work is progressing well and as planned



1. WP1 - **CERA-20C** production has been completed; work on **CERA-SAT** is progressing.
2. WP2 - Research into **more fully coupled data assimilation** is advancing.
3. WP3 - **Observation data rescue** work is on track; a registry for metadata established.
4. WP4 - Preliminary **validation of CERA-20C** with early upper air data suggest equal or better quality compared to ERA-20C or NOAA-20CR.
5. WP5 - Work is progressing to **provide users access to CERA20C products**.
6. WP6/9 – **Lean and effective management and coordination** with similar projects has been proceeding well. ‘Gaps’ between R&D and C3S operational production identified.



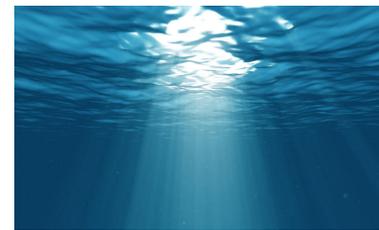
*Atmosphere*



*Land*



*Wave*

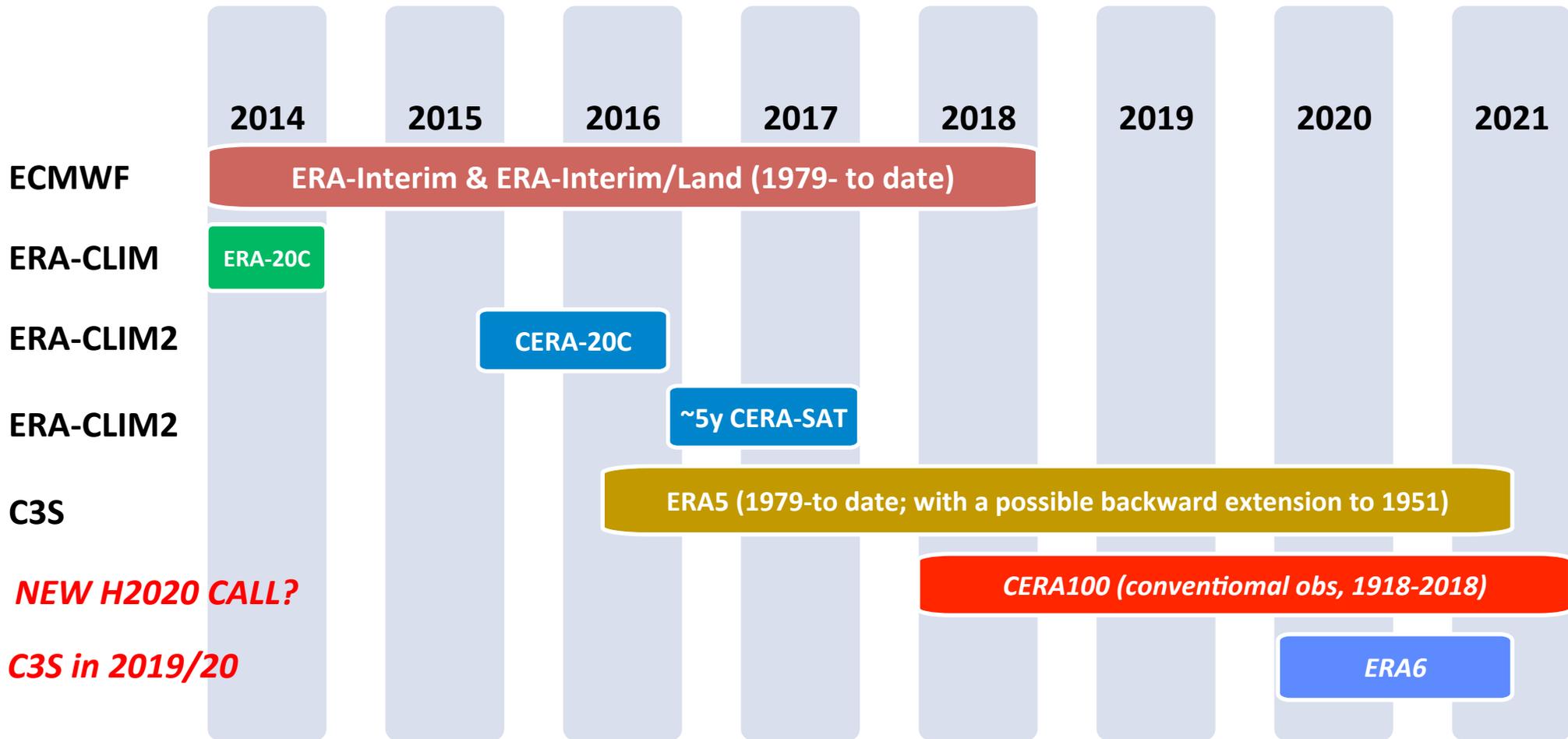


*Ocean*



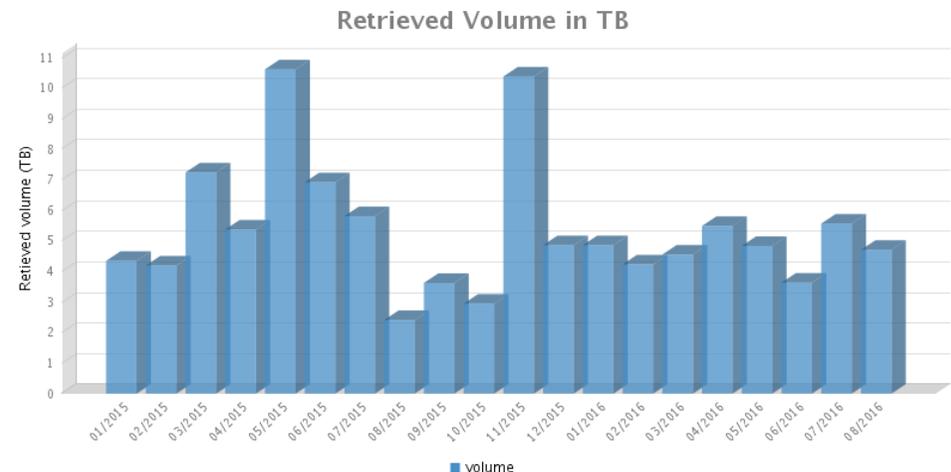
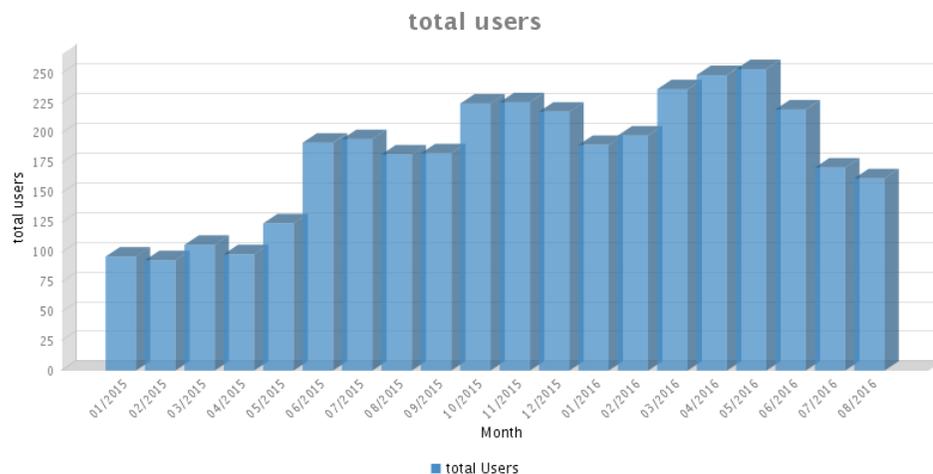
*Sea ice*

# Looking ahead in global reanalysis production



# Q1: Oper. products/services completed

- ERA-CLIM2 did not generate any operational product or service, but it has been funding R&D activities that could lead to operational production.
- C3S could in the near future (2021?) generate the first European operational global coupled reanalysis of the satellite era (ERA6) using an upgraded version of the CERA assimilation system developed and improved by the CERA, ERA-CLIM and ERA-CLIM2 projects.
- We expect CERA-20C to be very well valued by the community, even more than ERA-20C since early diagnostics suggest it has a higher quality). Here are some statistics on ERA-CLIM reanalysis ERA-20C:



## Q2: Oper. products/services requiring work?



ERA-CLIM2 data although they are not going to be part of any operational service, they are going to be very valuable to understand climate variations:

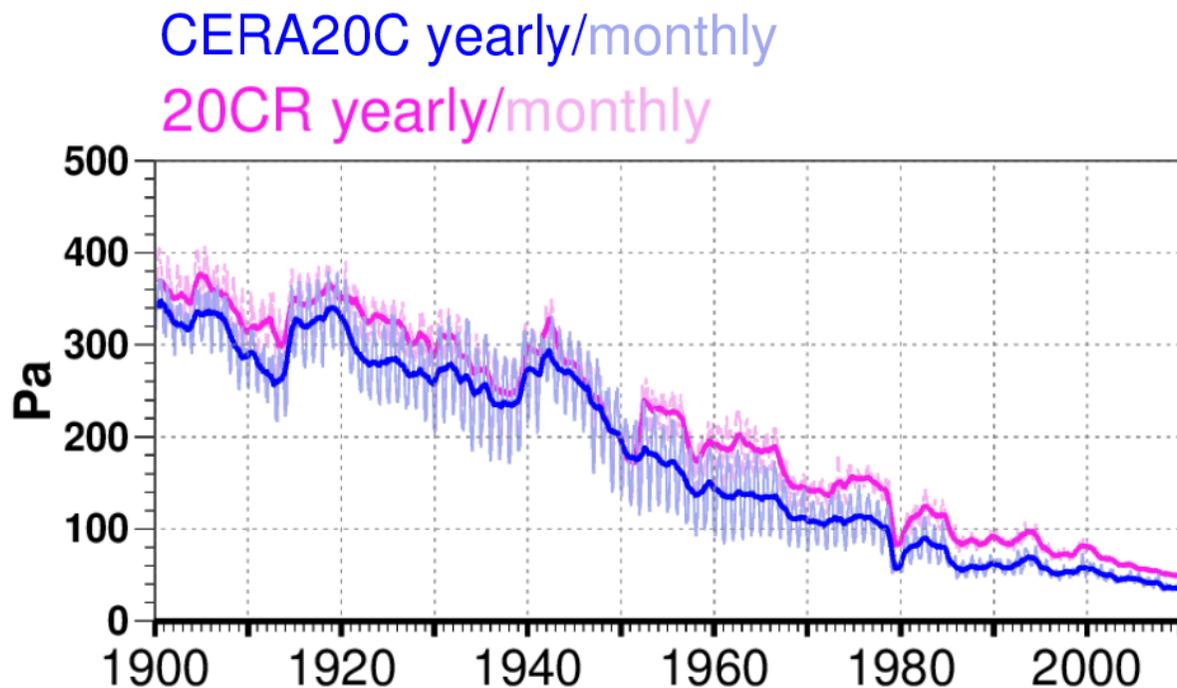
1. **CERA-20C** - The first European coupled reanalysis of the 20<sup>th</sup> century will provide a more complete picture of ocean/land/atmosphere variations.
2. **CERA-SAT** – The prototype higher-resolution coupled reanalysis of the satellite era will move us a step forward towards a more complete and better integrated DA system.
3. **Observation Feedback Archive** – It will improve access to observations.

Looking ahead: building on ERA-PreSAT work (*Hershback et al*, 2016 submitted), a possible very valuable product/service that could be generated by **a follow-on project (2018-2021)** could be:

3. **CERA100** – A pre-satellite era reanalysis: users expressed the interest in having a coupled reanalysis that uses all conventional data (i.e. also radio-sondes and 2mT), spanning a period of say 1918 to 2018. Further R&D work is required to develop such a system.

## Q3: Further research needs

1. **Further R&D work on coupled DA** is required to generate a high-resolution, coupled DA of the satellite era that includes also more reliable uncertainty estimate. The CERA system used so far only includes partial coupling.
2. **Data rescue and observation quality control of past data** should continue if we want to further improve the quality and reliability (uncertainty estimation) of future reanalyses for (a) climate monitoring and (b) skill assessment of extended-range predictions.



(from Per Dahlgren)

## Q3: Further research needs



**There is a gap. If we want that C3S provides a more accurate service in the future, we need to do more R&D work and observation data rescue.** These activities could be done in a follow-on project (Jan 2018 to end of 2020/21) to prepare the data and the system that could be used by C3S to generate the next climate reanalysis (ERA6):

1. More data rescue (e.g. of ocean observations)
2. Further improvements to the generation methodology, assessment, and use of ocean and land ensembles in data assimilation as part of the coupled system.
3. Further development of assimilation of surface ocean variables (particularly SST), in order to allow more coupling between ocean-atmosphere. Could include work to assess and improve diurnal cycle of SST representation within the reanalysis.
4. Research into more strongly coupled data assimilation so that more benefit can be made from observations, with the addition of other relevant components (e.g. aerosols).

# A new H2020 project (2018-2021)?



A new project, building on the CERA, ERA-CLIM and ERA-CLIM2 projects, **could deliver:**

- **More recovered observations** of a century-long period (say 1918-2018);
- **CERA100:** a century-long (1918-2018) global coupled climate reanalysis using surface and upper-air conventional observations only;
- **CERA-v3:** an improved coupled data assimilation system.

More observations (both from surface stations and radio-sondes), recovered within the ERA-CLIM and ERA-CLIM2 projects but not yet used in reanalyses, will be used in this project.

CERA100 will be the first coupled climate reanalysis generated including surface and upper air radio-sondes observations for the past 100 years.

CERA-v3 will be ready to be used by C3S to produce the next operational reanalysis (ERA6).

... further supporting material

# ERA-CLIM2 Consortium: 16 partners



1. EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS (ECMWF Europe)
2. MET OFFICE (METO United Kingdom)
3. THE EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES (EUMST Europe)
4. UNIVERSITAET BERN (UBERN Switzerland)
5. UNIVERSITAET WIEN (UNIVIE Austria)
6. FUNDACAO DA FACULDADE DE CIENCIAS DA UNIVERSIDADE DE LISBOA (FFCUL Portugal)
7. ALL-RUSSIAN RESEARCH INSTITUTE OF HYDROMETEOROLOGICAL INFORMATION-WORLD DATA CENTRE (RIHMI Russian Federation)
8. MERCATOR OCEAN (MERCOC France)
9. METEO-FRANCE (METFR France)
10. DEUTSCHER WETTERDIENST (DWD Germany)
11. CENTRE EUROPEEN DE RECHERCHE ET DE FORMATION AVANCEE EN CALCUL SCIENTIFIQUE (CERFAC France)
12. CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI SCARL (CMCC Italy)
13. ILMATIETEEN LAITOS (FMI Finland)
14. THE UNIVERSITY OF READING (UREAD United Kingdom)
15. INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE (INRIA France)
16. UNIVERSITE DE VERSAILLES SAINT-QUENTIN-EN-YVELINES. (UVSQ France)

# WP1: production of coupled reanalysis - update



1. The **CERA-20C** production has been completed. After quality control and diagnostic, the dataset is being consolidated and given full access by the end of the year.
2. Work has started to develop and test the **CERA-SAT** system: a prototype suite has been established and is being debugged. The plan is to start production in Q1-2017, with the final aim is to complete few years of the satellite era (possibly from 2010 to date) with a ( $\frac{1}{4}$  degree, z75) NEMO ocean and a T<sub>L</sub>319L137 (~65 km) atmosphere (closer to the ERA5 resolution).

## WP2: R&D in coupled data assimilation - update



1. Work on improvements to the SST and sea-ice assimilation is progressing well. NEMOVAR developments to allow use of ensemble information, and improvements to the efficiency of the 4DVar capability have been completed.
2. Improvements to the land carbon model parameters have been made and a 20<sup>th</sup> century run of the ocean biogeochemistry has been completed.
3. Research into the possibilities for more fully coupled data assimilation is progressing well.
4. Progress on these various research themes will be discussed with the whole community at an International WS in October 2016 in Toulouse.

## WP3: Earth-system obs for reanalysis - update



1. The data rescue work is well on track; most of the prioritized data have been digitized. Since many interesting new sources came to light during the project, data rescue work is continuing. A global registry for metadata has been established by the Univ. of Lisbon.
2. With respect to boundary constraints, all deliverable are on track or have been delivered. A prototype version of the snow course data has been published.
3. The recovery of historical observations for reanalysis and the creation of inventories is progressing, and a web-based global registry for metadata and for information on data rescue is being built.

# WP4: evaluation of uncertainties - update



1. Preliminary validation of CERA-20C with early upper air data suggest equal or better quality compared to ERA-20C or NOAA-20CR.
2. Discussions on the possibility to develop and produce an experimental assimilation of the early upper air period 1939-1967 (ERA-preSAT) has been continuing.
3. Precipitation validation – HOMPRA vs CERA-20C comparison ongoing at DWD.
4. Inter-comparison of Carbon Fluxes TESSEL vs Orchidee is ongoing – representation of land surface coupling is an important future reanalysis product.
5. Coupled energy cycle evaluations for the tropics and the Arctic show high value of reanalysis based products for system analysis/model validation (Mayer et al. 2016a,b).

## WP5: improving access to reanalysis - update



1. Work is progressing to have the possibility to archive/retrieve NetCDF files in MARS. A prototype tool (shown at the Review meeting) is under testing. Work is expected to be completed by month 36.
2. Work is progressing to consolidate the atmospheric, wave and ocean part, in order to provide users with CERA20C products.
3. Work has started to look at the functionality of the data portal for CERA20C, specially with serving a data in (native) GRIB and (native) NetCDF.

## WP6-9: update



1. In Jan 2016, following a request the project has been extended to end of 2017.
2. General Assemblies are being organized and planned:
  - Dec 2016: GA2 was organized at EUMETSAT
  - Jan 2017: GA3 is being organized in Wien
  - Q4-2017: GA4 will be organized at ECMWF
3. Review Meetings:
  - The 27M Meeting was organized at ECMWF IN April
  - The 36M Meeting is being organized in conjunction with the GA3 in Wien, in Jan 2017
4. The gap between the end of ERA-CLIM2 and the operational activities in reanalysis foreseen within the Copernicus Climate Change Service (C3S has been discussed in a document shared with Dr M Kacik. The document also discussed the potential value of having a follow-on project in 2018-2020/21.
5. For more information, see the web site hosted at ECMWF:  
<http://www.ecmwf.int/en/research/projects/era-clim2>

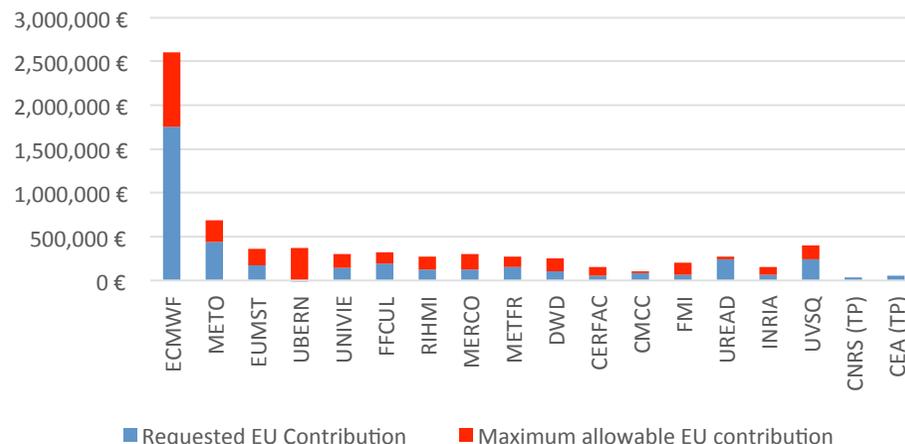
# Financials (situation at June 2015)



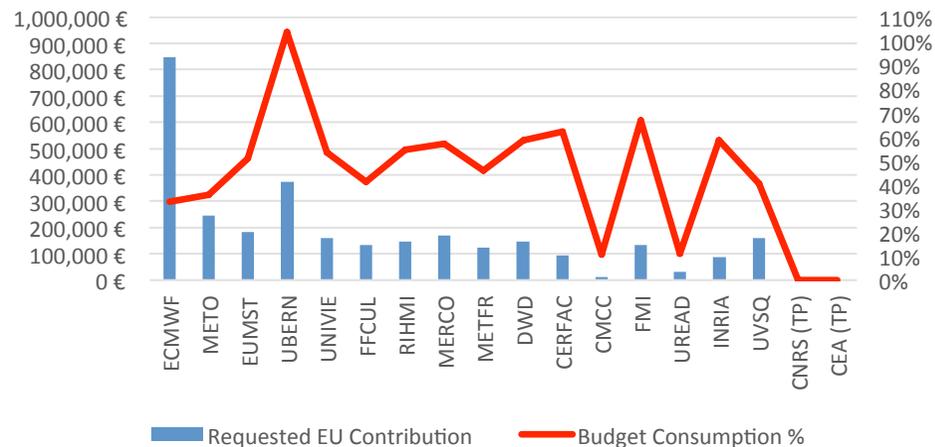
The following graphs illustrate the budget consumption at 30/06/2015, when partners reported to Coordinator.

*The next reporting update is expected in Feb 2017, with consumptions up to 31/12/2016.*

Partners' total and consumed budget (30/6/15)



Partners' consumption - 30/06/2015



# ERA-CLIM2 2016/2017 meetings



## ERA-CLIM2 WSs and GAs held in 2016:

- 25 Apr 2016: ERA-CLIM2 27M Review Meeting (ECMWF);
- 26 Apr 2016: Progress meeting (ECMWF);
- 22 Jun 2016: User WS on observations for reanalyses – Organized as part of the Conference on historical data for reanalysis by L Haimberger and S Broennimann, jointly with ACRE Meeting (Maynooth, Ireland)

## ERA-CLIM2 WSs/GAs planned for the future:

- 18-21 Oct 2016 - WS on Coupled Data-Assimilation, jointly organized by ERA-CLIM2 with WMO/DAOS in 2016 (Toulouse, Météo France; <http://www.meteo.fr/cic/meetings/2016/CDAW2016/>)
- 16-18 Jan 2017 - ERA-CLIM2 3<sup>rd</sup> General Assembly – (Wien, organized by L Haimberger)
- 19 Jan 2017 - ERA-CLIM2 36M Review Meeting – (Wien)
- Q4-2017 - ERA-CLIM2 4<sup>th</sup> General Assembly (2017 – M48) – (ECMWF)