CERA-20C: a 20th century record of consistent ocean-atmosphere states

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ECMWF

ERA-CLIM projects

Main purpose is the production of extended climate reanalyses for climate reconstruction and monitoring involving:

- Data rescue activities (recovery and digitisation of past climate observations)
- Preparation of climate-quality atmospheric forcing data and boundary conditions
- Preparation of the data assimilation system for extended climate reanalysis

The first ERA-CLIM project (2011-2013) led to a 20th century atmospheric reanalysis called ERA-20C (Poli et al, 2016) assimilating surface conventional observations only

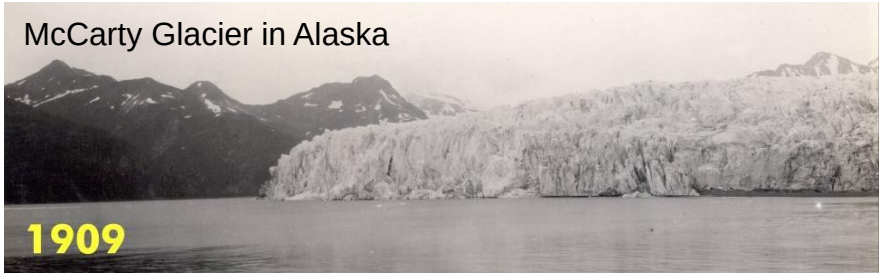
ERA-CLIM2 has been on going since 2014 and leading to the production and dissemination of an extended climate reanalysis of the 20th century at moderate resolution: CERA-20C

CERA-20C: objective

A complete reconstruction of the 20th century global weather to monitor the low-frequency climate variability and provide long time-series of Essential Climate Variables (ECVs).

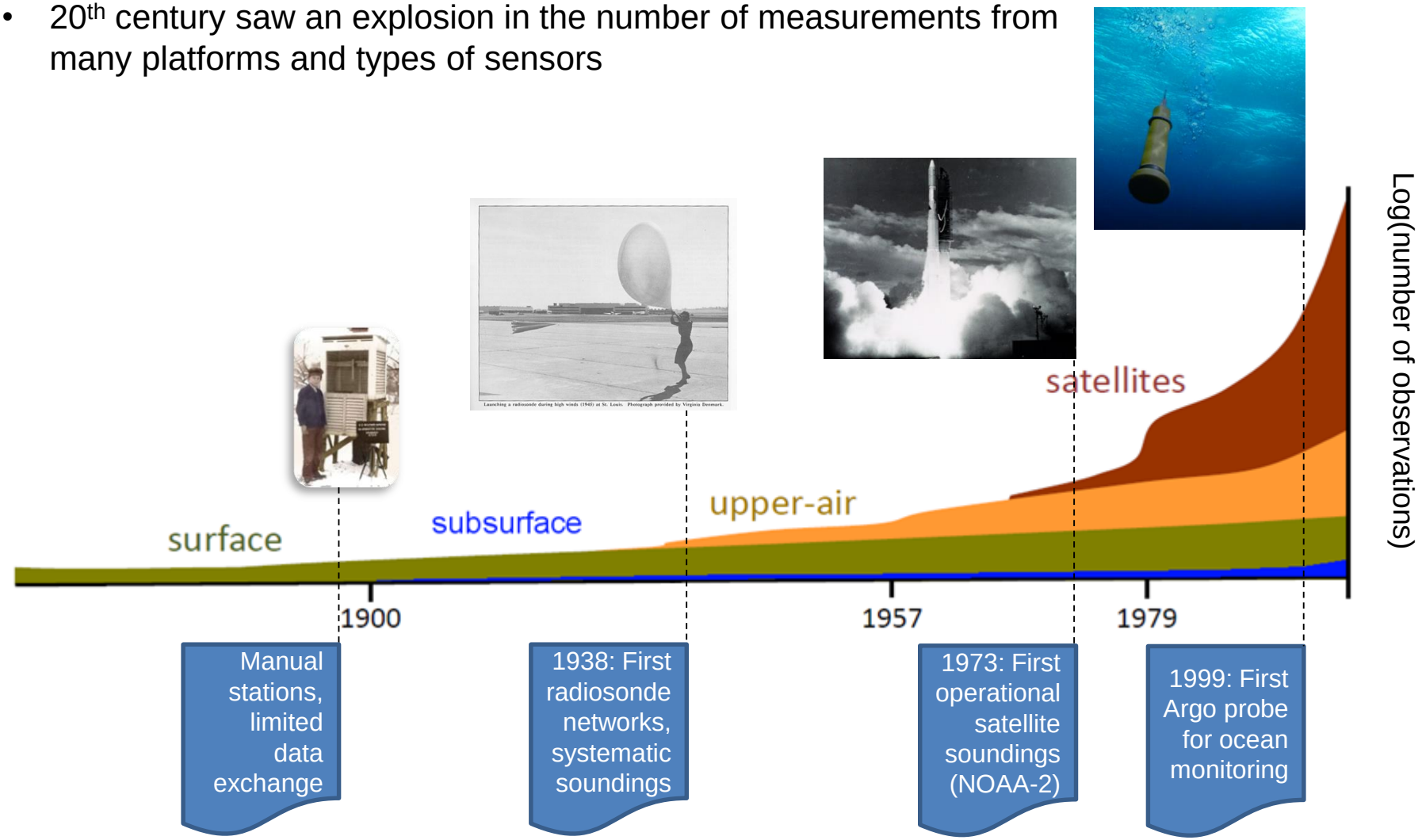
Key components:

- ✓ conventional observations
- ✓ modern data assimilation methods
- ✓ coupled Earth system model
- ➢ A consistent view of the global climate



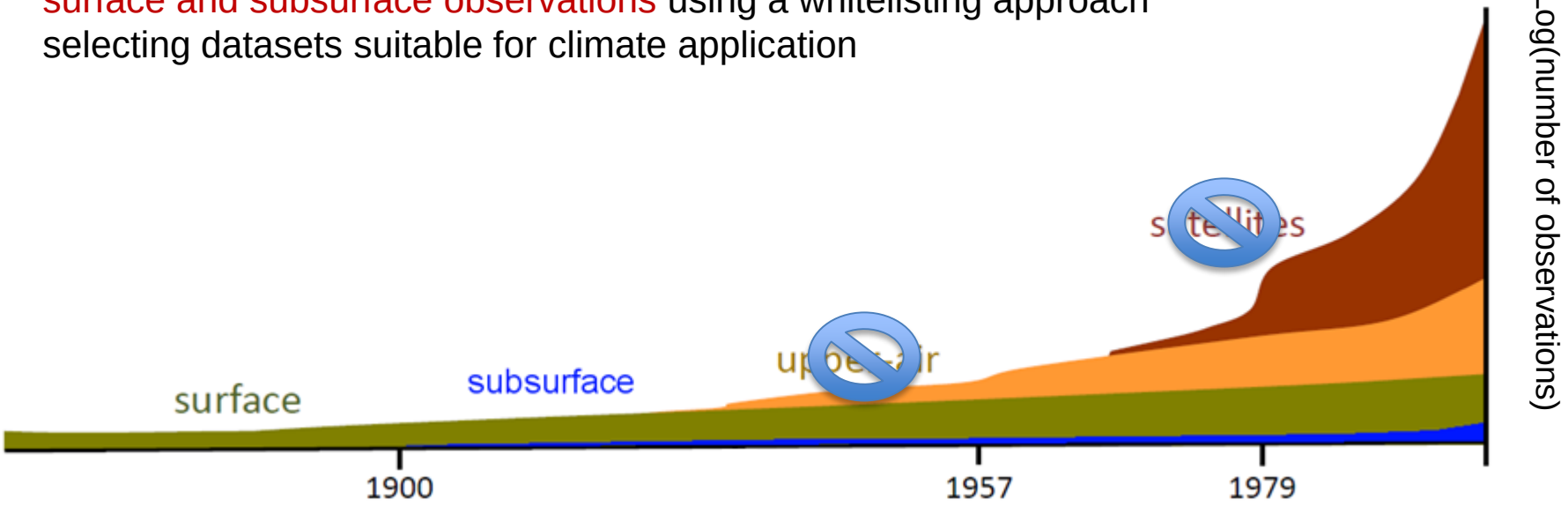
The observing system

- 20th century saw an explosion in the number of measurements from many platforms and types of sensors



The observing system

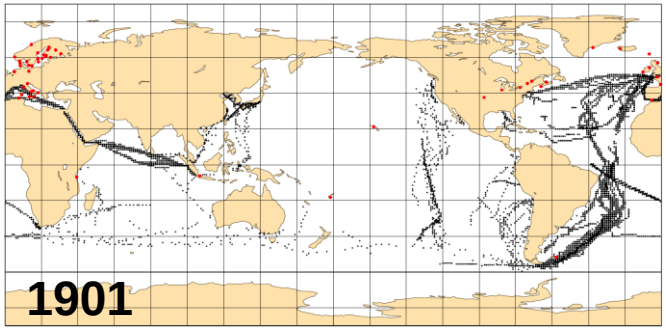
- 20th century saw an explosion in the number of measurements from many platforms and types of sensors
- For consistency CERA-20C assimilates only a restricted set of surface and subsurface observations using a whitelisting approach selecting datasets suitable for climate application

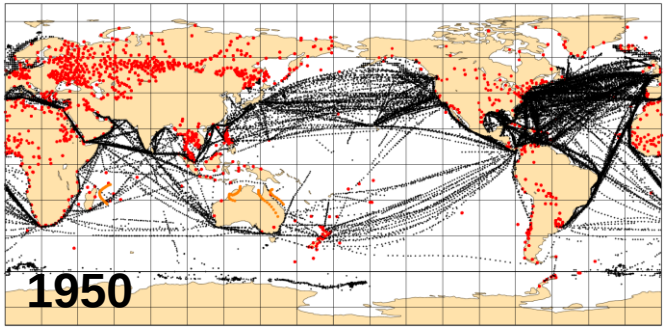


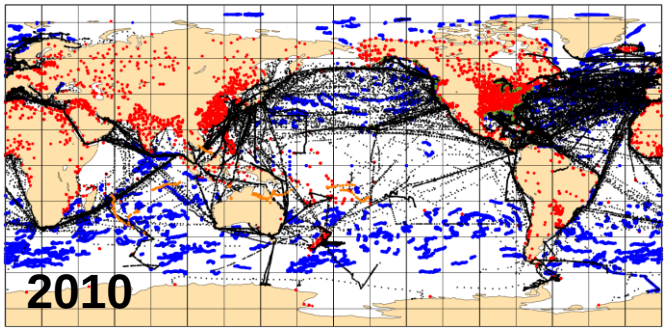
- Atmosphere: surface pressure and marine wind observations (ICOADS/ISPD)
- Ocean: temperature and salinity profiles (EN4)
- Air-sea interface: Sea Surface Temperature analysis product (HADISST2.1-monthly)

The observing system

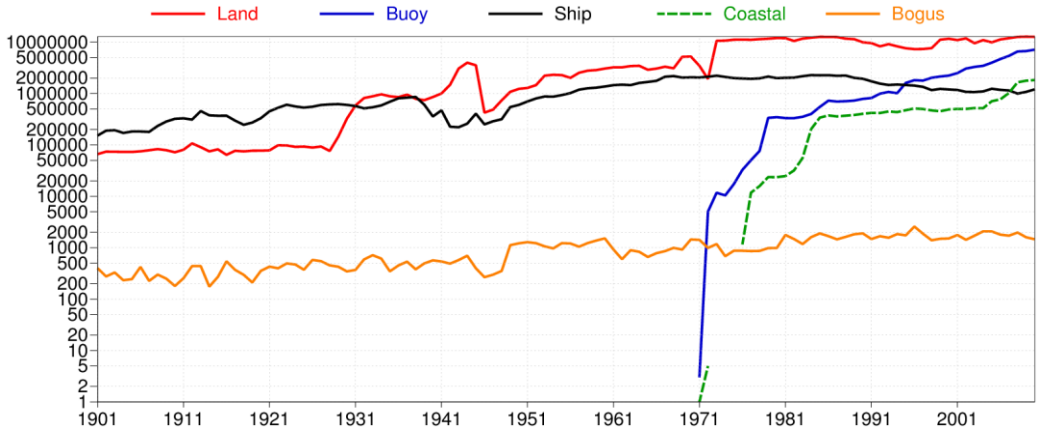
Mean sea level pressure observations (ISPD and ICOADS)





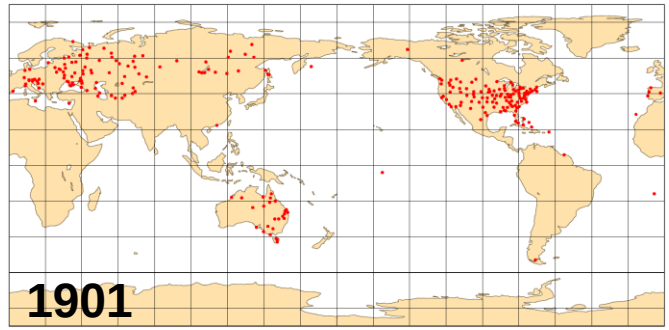


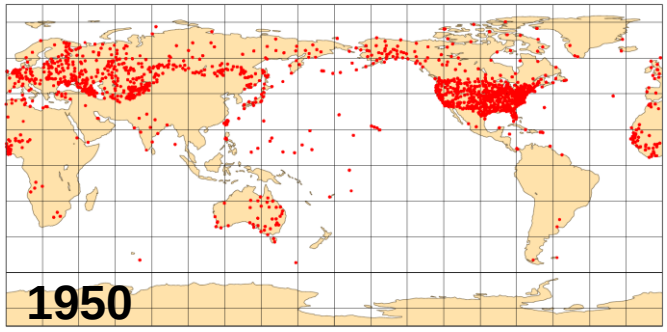
Yearly count of assimilated observations (logarithmic scale)

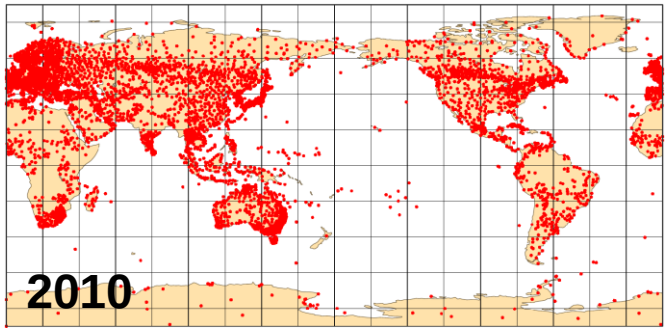


The observing system

Surface pressure observations (ISPD)







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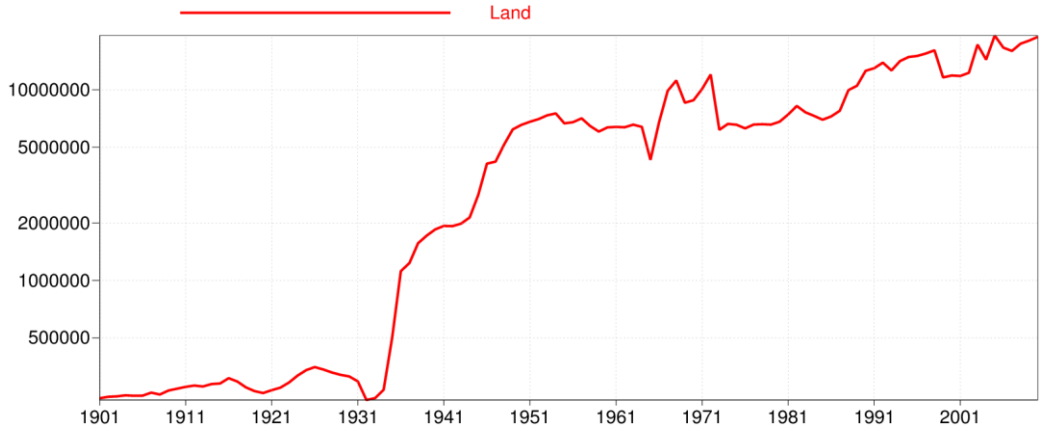
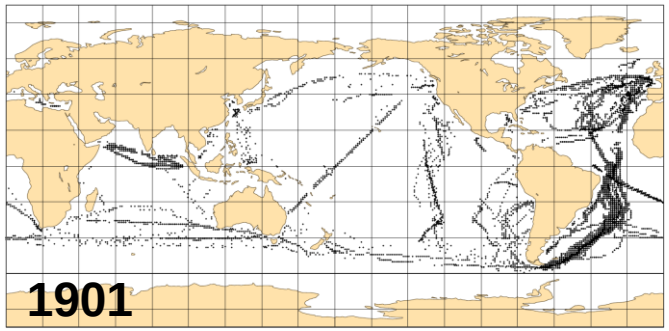
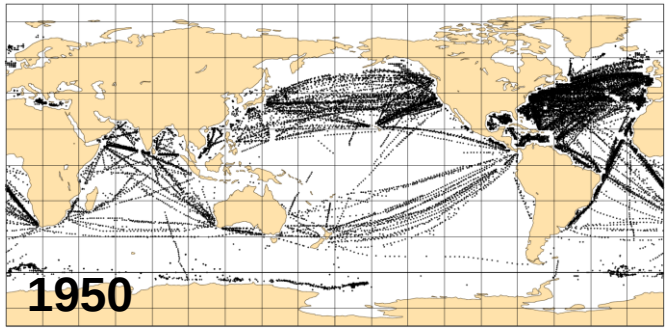
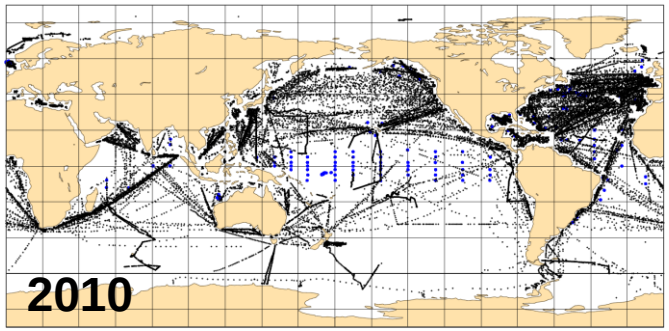


The observing system

Surface marine wind observations (ICOADS)







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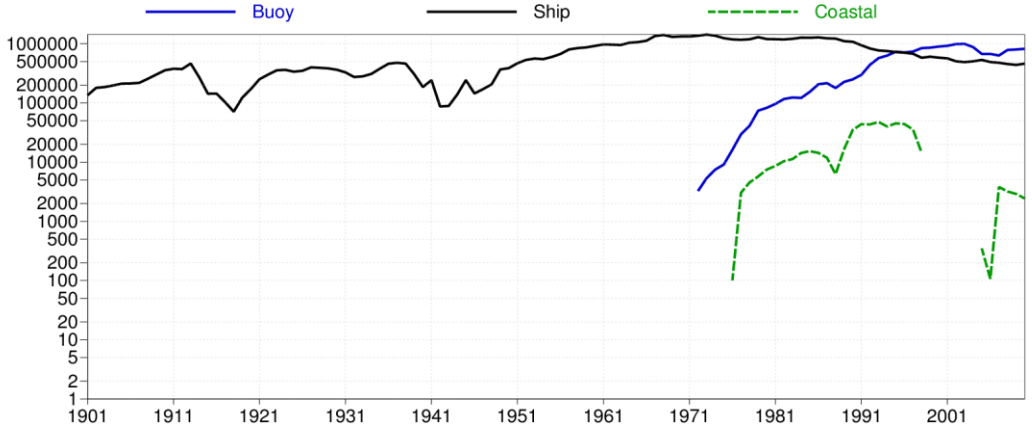
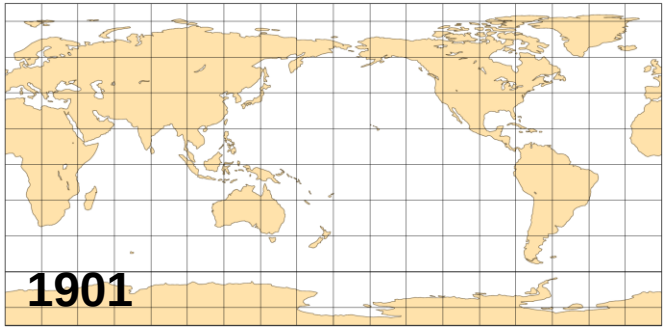
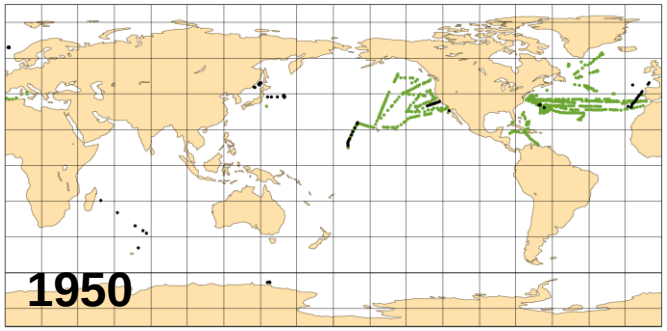
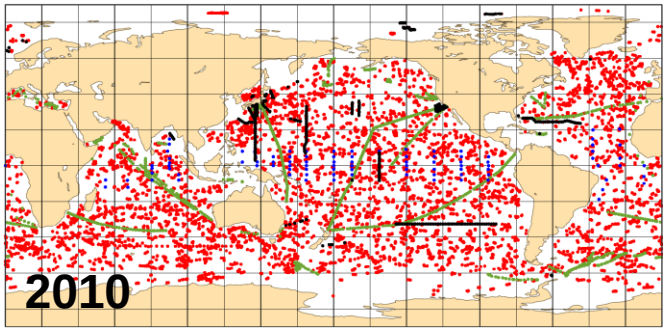


The observing system

Ocean temperature observations (EN4)







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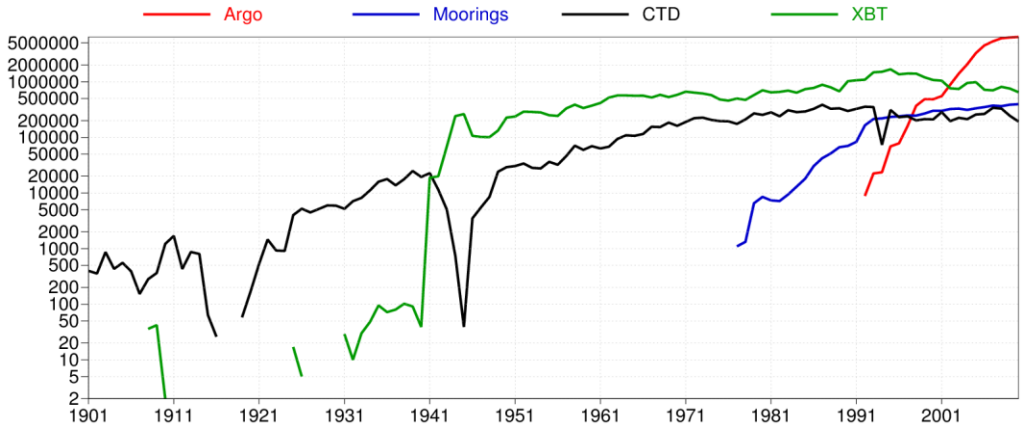
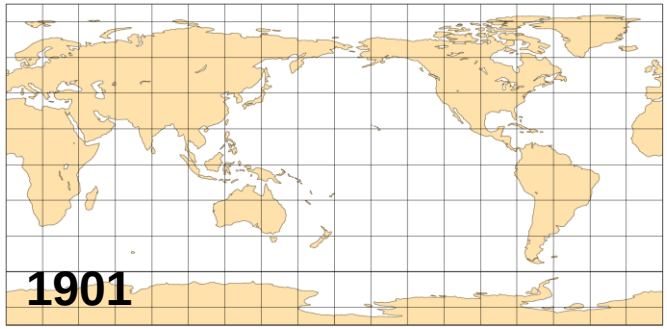
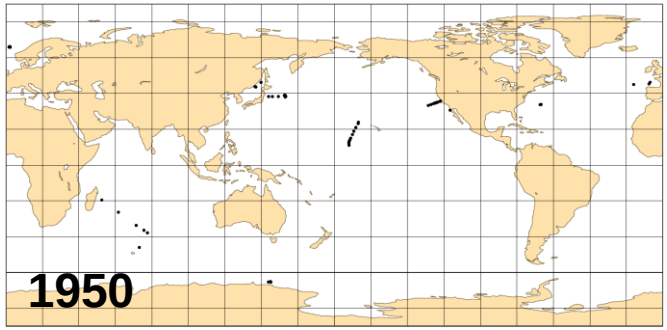
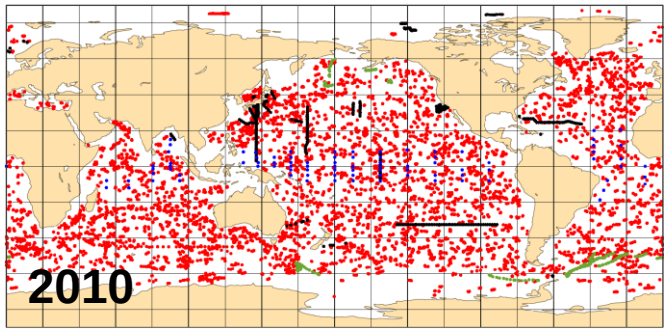


The observing system

Ocean salinity observations (EN4)







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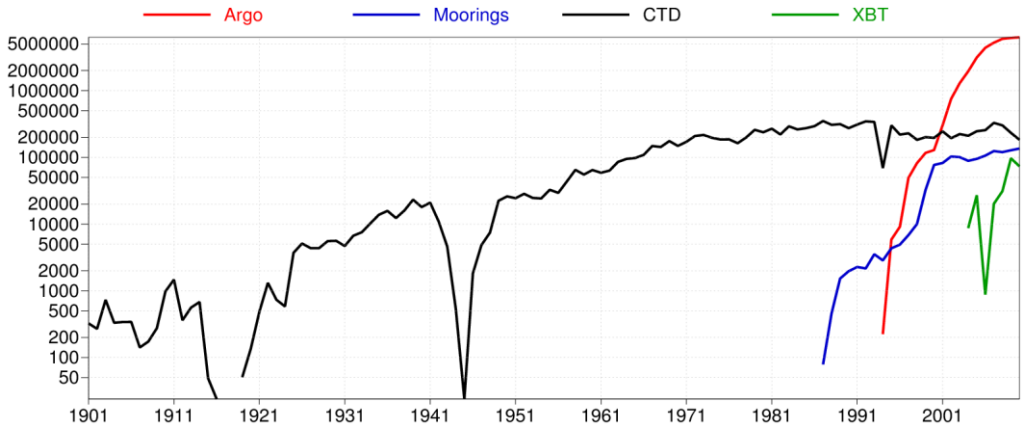
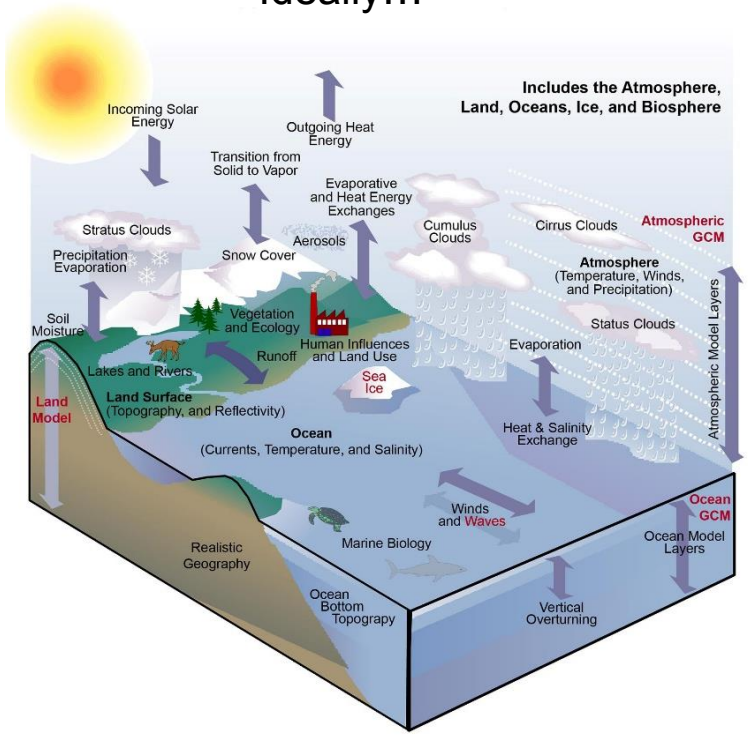


The coupled DA system

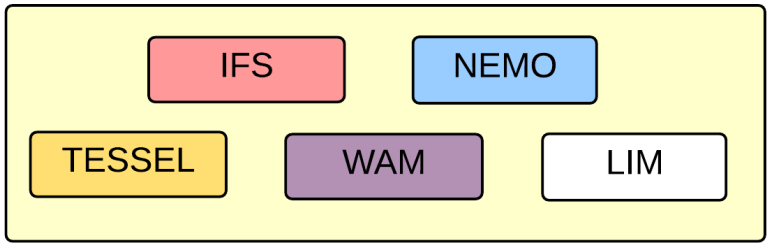
The ocean and atmospheric observations are ingested by a coupled DA system based on the ECMWF coupled model that aims to link the various components of the Earth system

Ideally…



In practice…

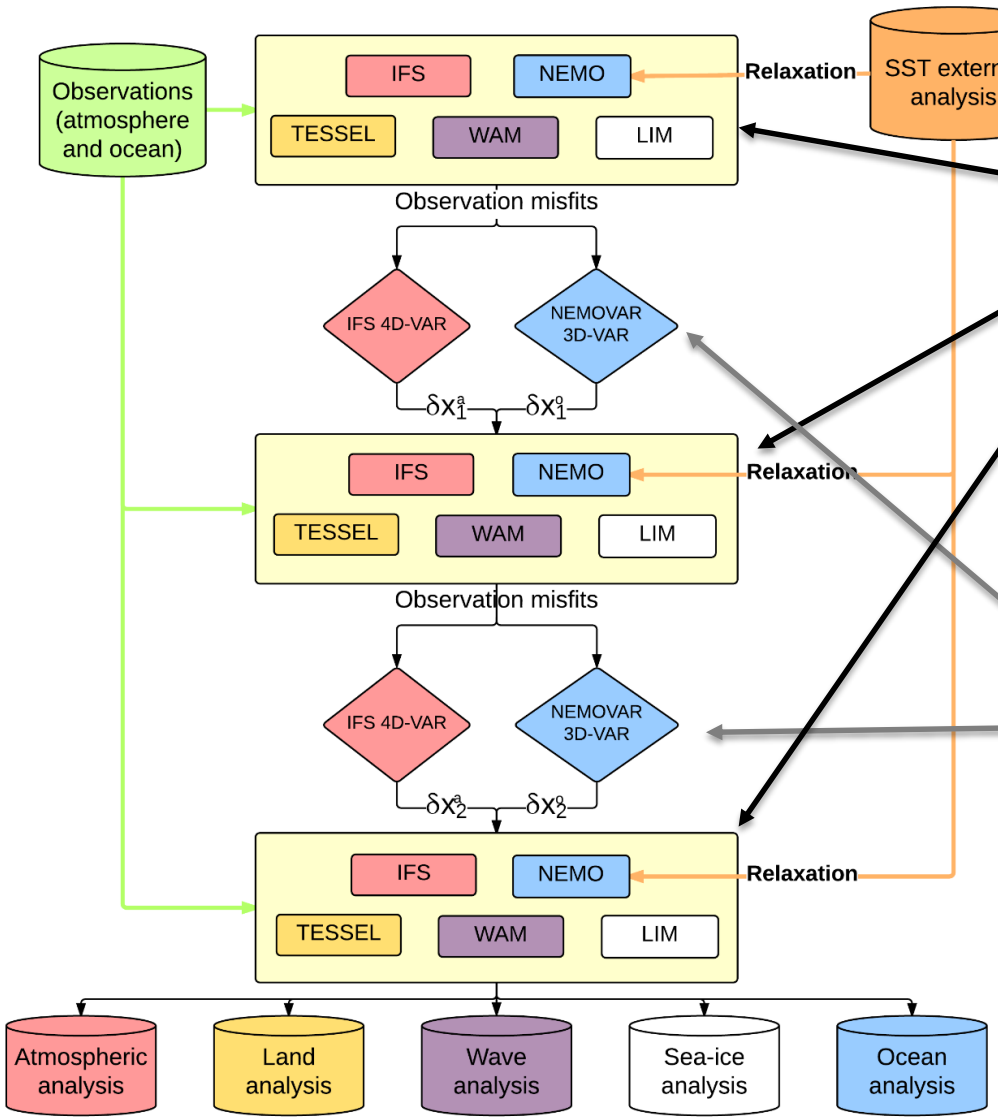
ECMWF coupled system



Configuration

- Atmosphere, wave and land: IFS CY41R2 T159L91 (~120km)
- Ocean and sea-ice: NEMO ORCA1Z42 (1deg, 10m first layer)

The coupled DA system



Coupled model computes observation misfits within a 24-hour window in each outer iteration

SST computed in NEMO and constrained by relaxation

Atmospheric and ocean increments are computed in parallel to correct the initial state

The two iterations allow ocean observations to impact the atmospheric state and conversely

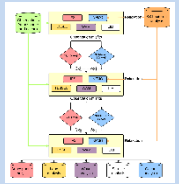
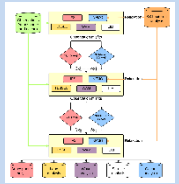
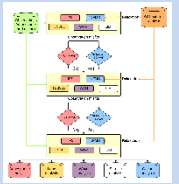
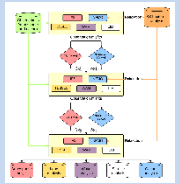
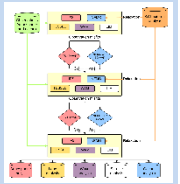
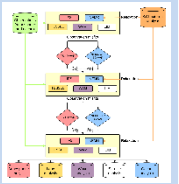
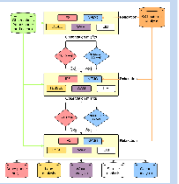
Analysis dynamically consistent with respect to the coupled model

The coupled DA system

CERA-20C has been generated with a 10-member EDA with perturbations on atmospheric and ocean observations, surface forcing and SST and stochastic physics in the atmosphere.

The ensemble provides a measurement of uncertainty in the climate reconstruction, and flow-dependent background error statistics.

Observation uncertainties + **Model uncertainties** + **Model forcing uncertainties** = **Reanalysis uncertainties**

CTRL	MEM1	MEM2	MEM3	MEM4	MEM5	MEM6	MEM7	MEM8	MEM9
									

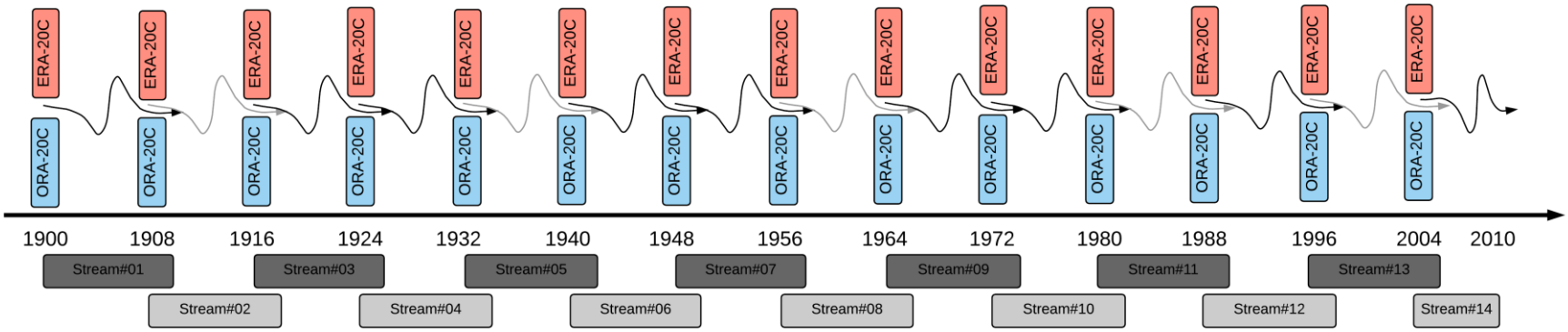
CERA-20C production

CERA-20C is a 10-member ensemble of 20th century climate reanalysis

- period 1900-2010 divided in 14 streams of 10 years
- all the streams are running in parallel
- 2-year overlap for consistency in the final product

Uncoupled initial conditions for each stream

- ERA-20C for the IFS component
- ORA-20C for the NEMO component: a 10-member ensemble of 20th century ocean reanalyses forced by ERA-20C and using EN4 data and HadISST2.1



CERA-20C finished in June 2016 after 7 months of production

CERA-20C production

Computational cost

7 months of production
400 Nodes (20,000 cores, 5% of ECMWF HPC system)
500,000 4D-Var problems to solve (one every 30 sec.)
optimised production suite with dedicated HPC support

Archiving

1400 Tb of atmospheric data
200 Tb of ocean data
dedicated data service

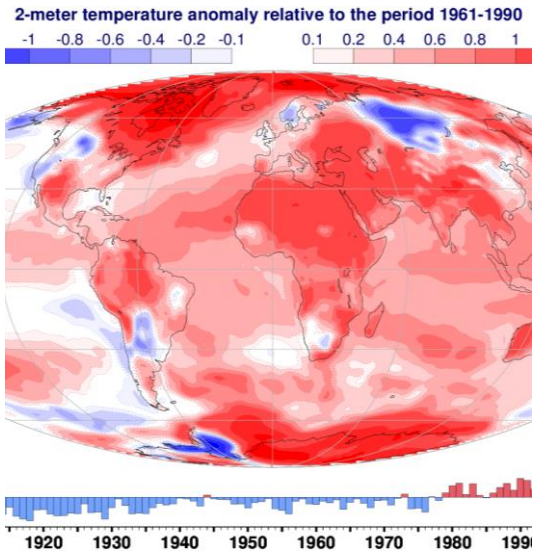
Manpower & teamwork

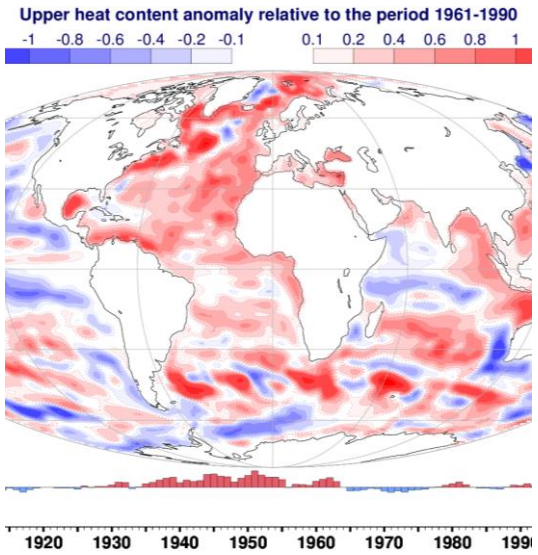
12/7 monitoring with required manual actions:

- related to observation inputs
- related to technical issues (HPC, filesystems, …)
- scientific monitoring

CERA-20C first results

Production of timeseries of climate variables in both the atmosphere and the ocean





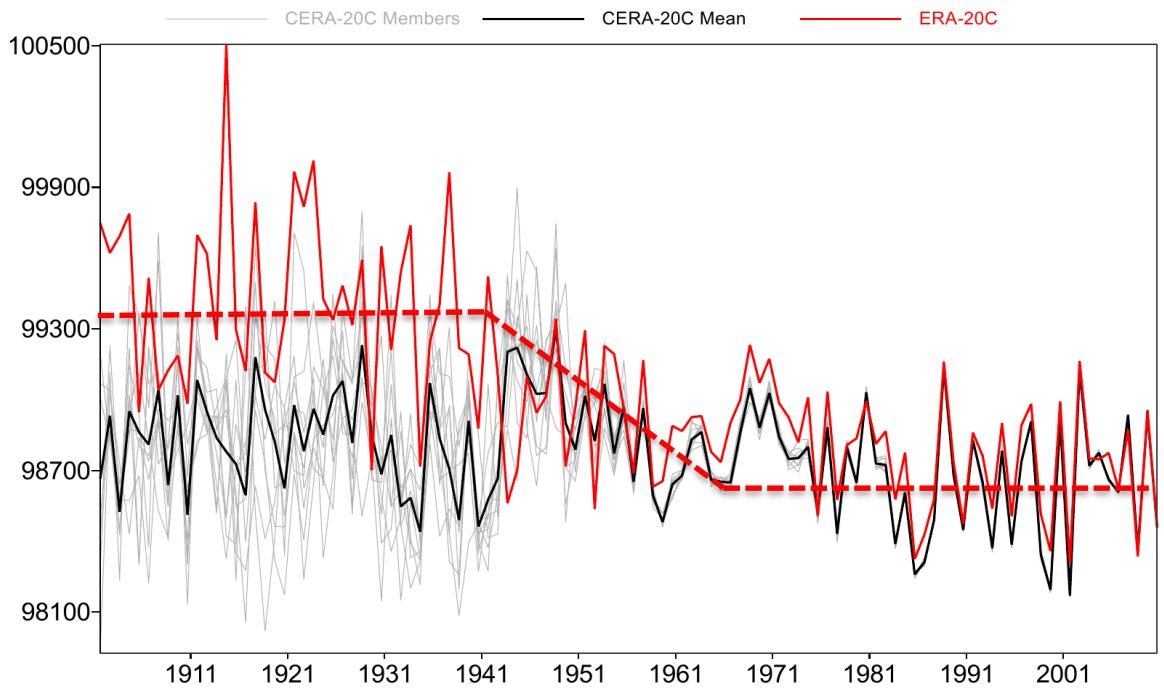
To be compared to extended records from both observations and other reanalyses

But also comparisons with ERA-20C and ORA-20C

CERA-20C first results

Low frequency and long term trends

MSLP analysis in CERA-20C (black) and in ERA-20C (red) over Antarctica for the SON period



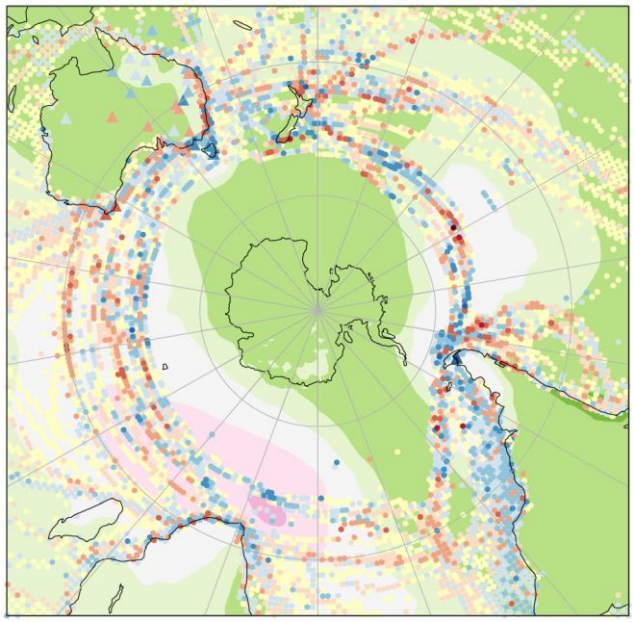
→ spurious trend in ERA-20C (8hPa higher before 1940) corrected in CERA-20C

CERA-20C first results

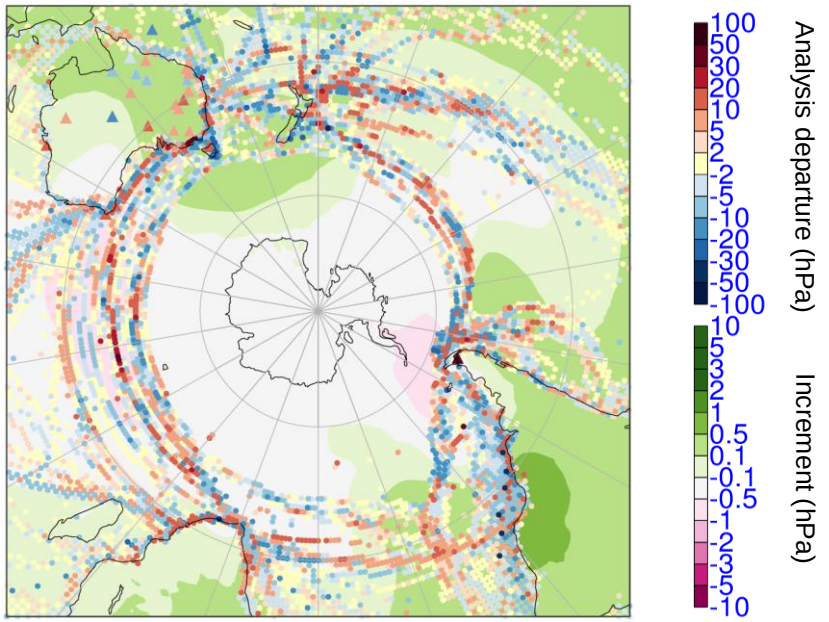
Low frequency and long term trends

Mean MSLP increment for the year 1924 (green positive increment, pink negative increment)

ERA-20C



CERA-20C



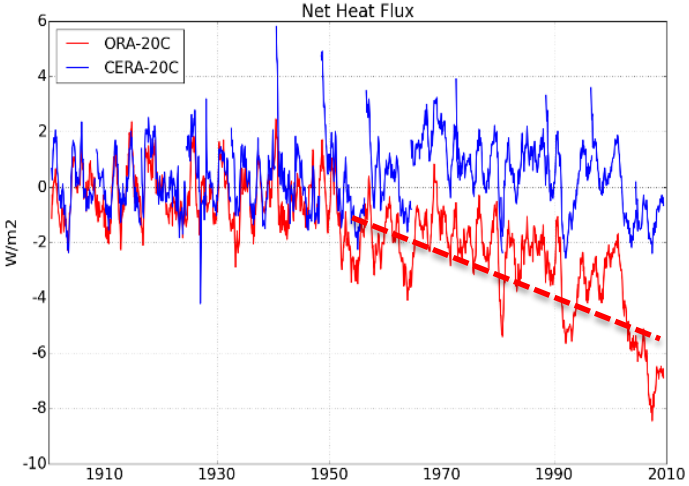
Comes from the observation error specification

- ERA-20C overfits the observations with a too small observation error → large increment → spurious trend
- Revised in CERA-20C using a time-varying Desroziers' diagnostic (P. Poli et al., ERA-20C Deterministic, ERA Report Series, 48, 2015) → correct the trend

CERA-20C first results

Air sea interface

Net heat flux downward



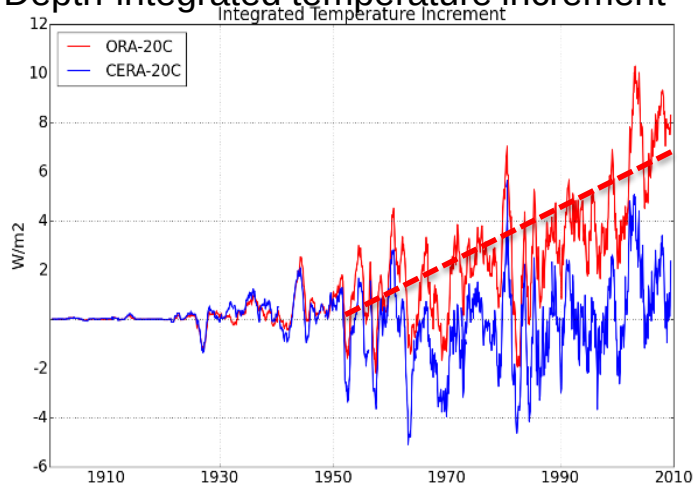
ORA-20C forced by ERA-20C

→ negative trend probably due to rapid increase of the ERA-20C wind speed after the 40s in the NH

→ this increase might be due to a change in the observing system. TBD

No such trend in CERA-20C. Wind observations better handled? TBD

Depth-integrated temperature increment



The ocean temperature increment in ORA-20C is compensating for the trend in heat fluxes

CERA-20C increment shows more stability

CERA-20C appears as a much more balanced system at the air-sea interface

Conclusion

- CERA-20C is the first ensemble of 20th century climate reanalysis
- It uses historical records of ocean and atmosphere surface and subsurface observations as consistently as possible
- CERA-20C provides 3-hourly estimates of the coupled ocean-atmosphere state available from 1901 to 2010
- So far compare positively to ERA-20C in terms of long term trends
- CERA-20C solved problems noticed in ERA-20C proving that reanalysis is an exercise that needs to be repeated over and over in order to improve the system
- Some aspects still need to improve: data QC, atmosphere/ocean ICs, sea-ice, …

Next …

- Potential uses of CERA-20C:
  - past climate reconstruction
  - climate monitoring
  - the detection of signals of decadal variability
  - initial conditions (and verification states) for extended-range forecasts
  - insights into the impacts of the various observing systems on the reanalysed climate states
  - Etc…

- Needs evaluation wrt other reanalyses and independent observational products

- CERA-20C will be made available to the research community to identify its strengths but also its weaknesses and ways forward to address them

- Dissemination should be completed by the end of 2016