New Reanalyses for Society: How to reconstruct the past climate?

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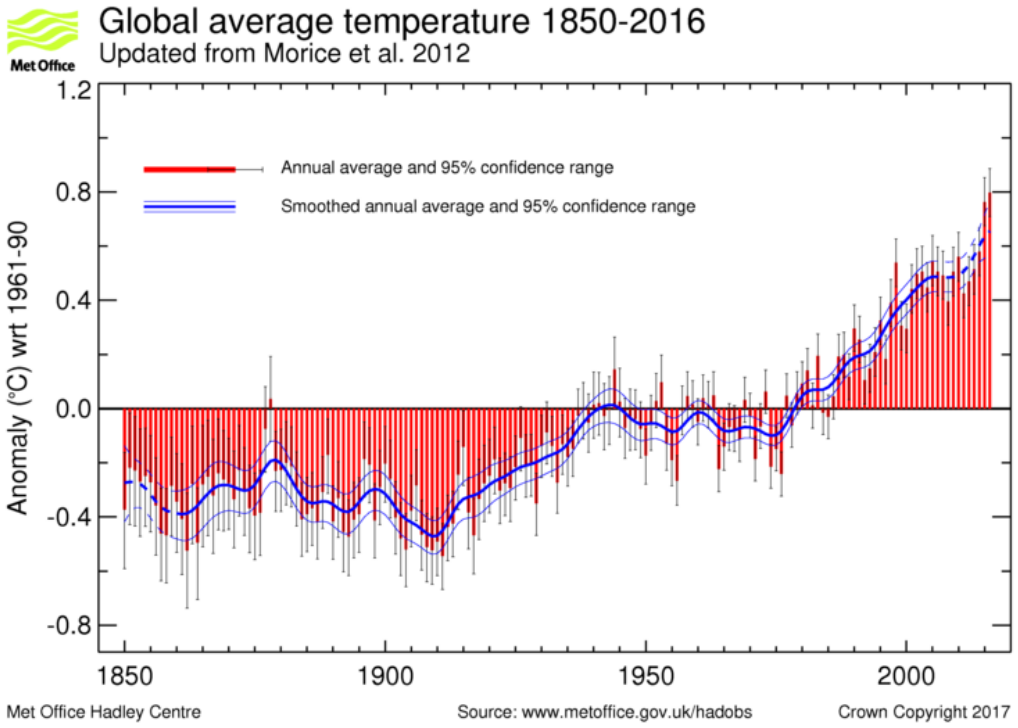
ERA-CLIM2 - Climate Reanalyses and Services for Society
14 December 2017
University of Bern

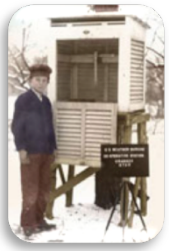
ECMWF
EUROPEAN CENTRE FOR MEDIUM RANGE WEATHER FORECASTS

ERA CLIM 2

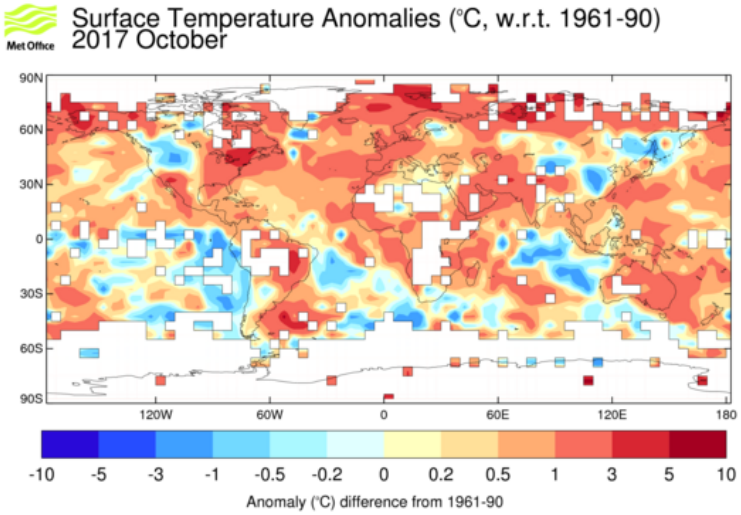
SEVENTH FRAMEWORK PROGRAMME

Reconstructing the past climate from observations





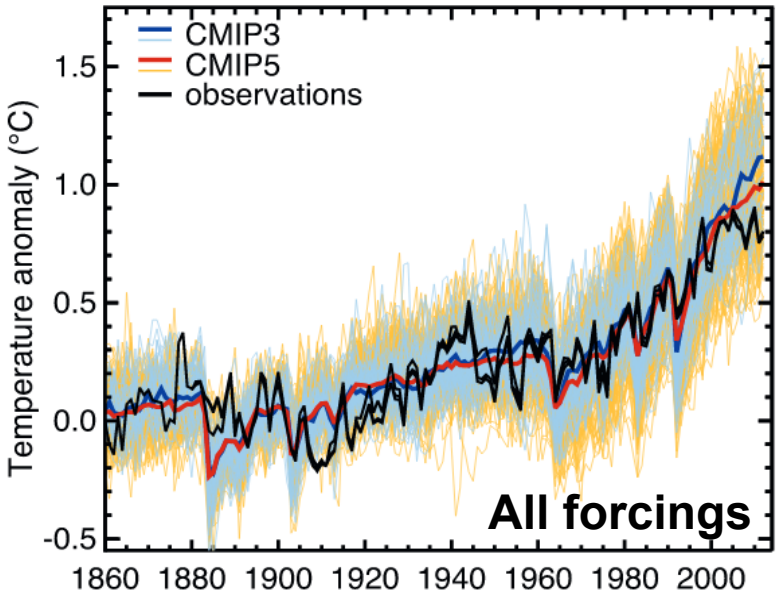
Many weather stations, ships and buoys distributed around the world report weather measurements (e.g. temperature) since 1850.



Limitations

- availability (spatial and temporal gaps)
- uncertainties and biases in the observations

Reconstructing the past climate from models



$$\frac{\partial u}{\partial t}+\dot{\sigma}\frac{\partial u}{\partial \sigma}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-fv-\frac{uv}{r}\tan\phi+g\frac{\partial z}{\partial x}+c_p\theta\frac{\partial \pi}{\partial x}+F_x=0$$

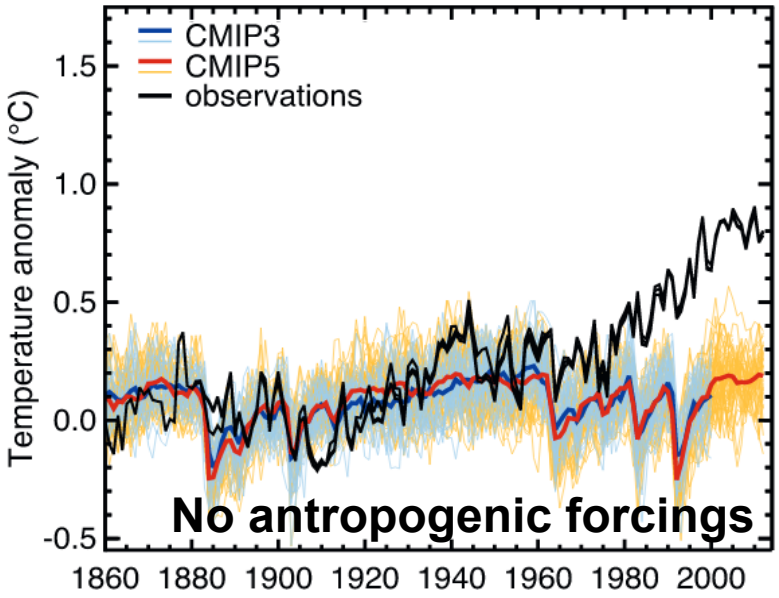
$$\frac{\partial v}{\partial t}+\dot{\sigma}\frac{\partial v}{\partial \sigma}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+fu+\frac{u^2}{r}\tan\phi+g\frac{\partial z}{\partial x}+c_p\theta\frac{\partial \pi}{\partial y}+F_y=0$$

$$\frac{\partial (gz)}{\partial \sigma}+c_p\theta\frac{\partial \pi}{\partial \sigma}=0,$$

$$\frac{\partial \theta}{\partial t}+\dot{\sigma}\frac{\partial \theta}{\partial \sigma}+u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+H=0,$$

$$\frac{\partial p_\sigma}{\partial t}+\frac{\partial}{\partial \sigma}(\dot{\sigma}p_\sigma)+\frac{\partial}{\partial x}(up_\sigma)+\frac{\partial}{\partial y}(vp_\sigma)-\frac{vp_\sigma}{r}\tan\phi=0, \qquad \pi=\left(\frac{p}{P}\right)^\kappa.$$

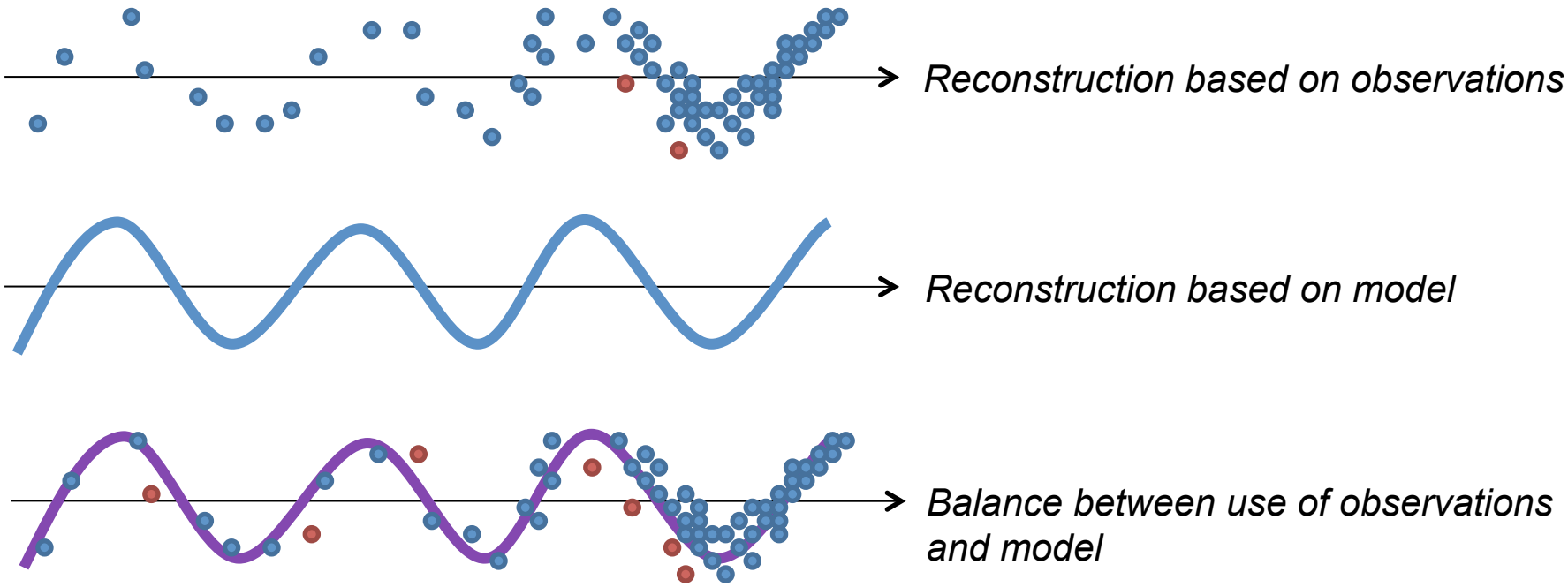
Many different models based on equations describes the motion of atmosphere and ocean



Limitations

- cannot reproduce a synoptic weather situation
- uncertainties and biases in the model
- Sensitivity to the model forcings (concentration of greenhouse gases has changed due to human activity)

Reconstructing the past climate from observations and model



Reanalysis: use a NWP model constrained by forcings and observations (data assimilation)

Reanalysis uses a NWP model which allows to:

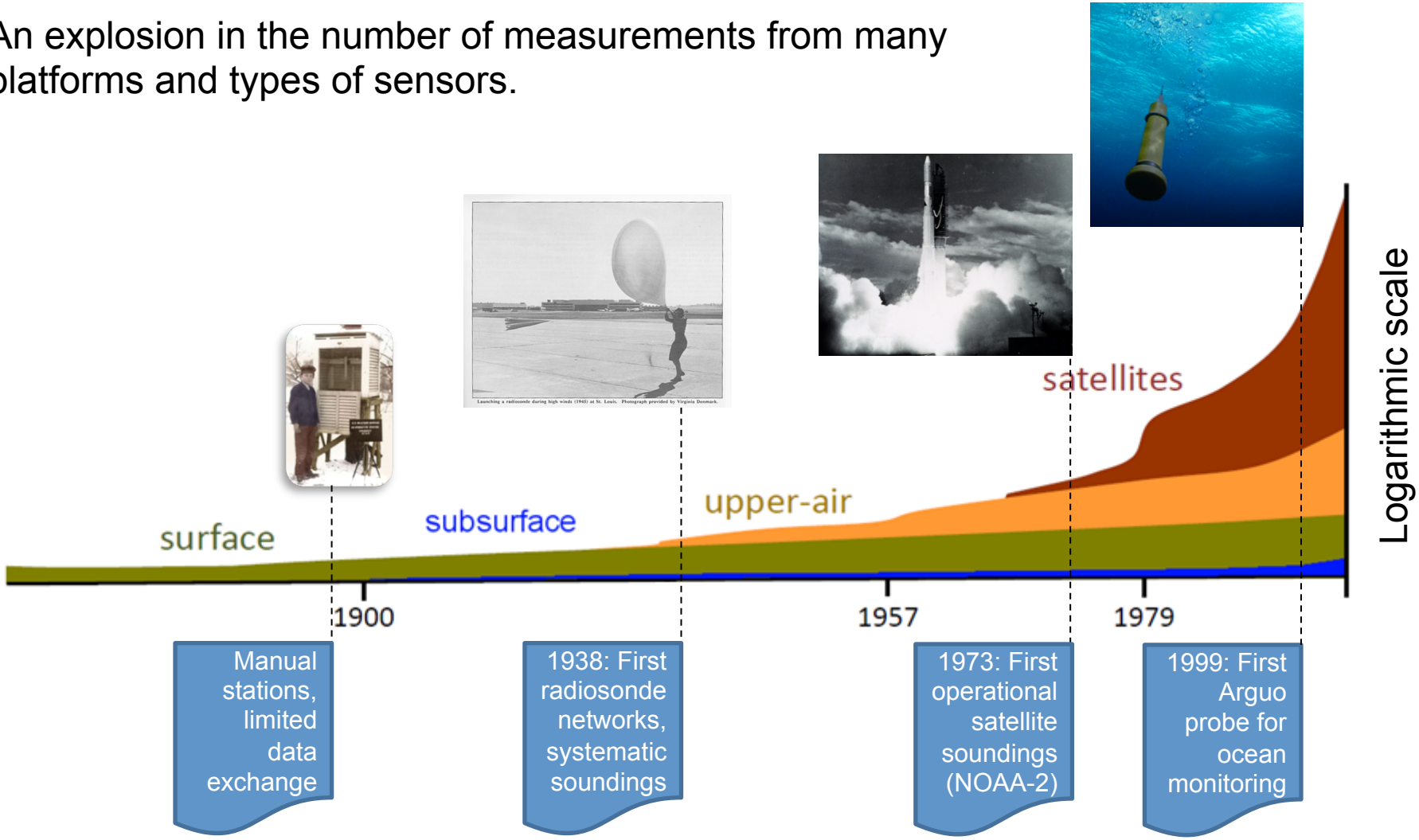
- ensure consistency across geophysical variables
- ensure consistency in horizontal and vertical dimensions (fill in the blanks)

Reanalysis uses observations which allows to:

- reduce systematic errors in the model
- represents weather synoptic situation

Reconstruct the climate over the 20th century with reanalysis

An explosion in the number of measurements from many platforms and types of sensors.



20th century climate reanalyses need a consistent observing system (use only a subset of surface/subsurface observations)

Surface pressure observations are available through the whole 20th century

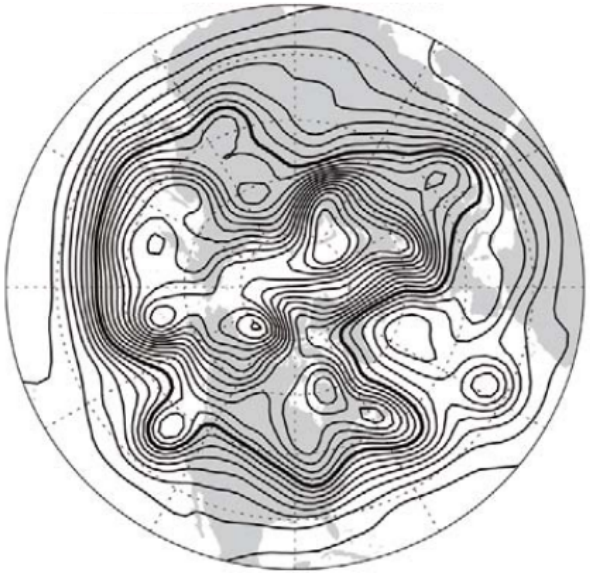
Are surface pressure observations enough to represent weather?

FEASIBILITY OF A 100-YEAR REANALYSIS USING ONLY SURFACE PRESSURE DATA

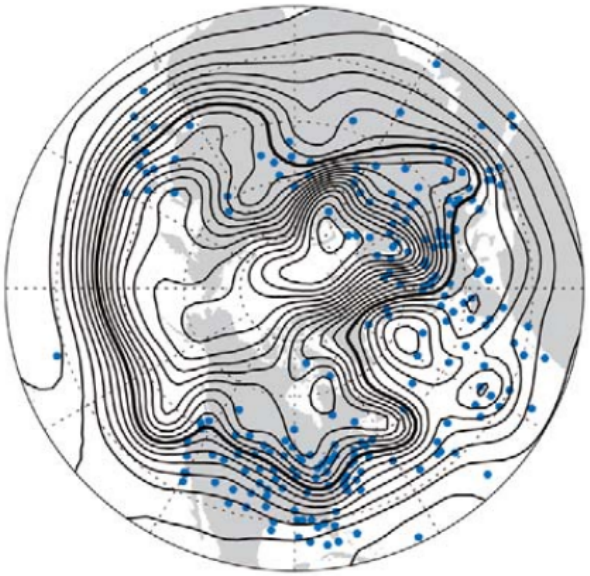
BY GILBERT P. COMPO, JEFFREY S. WHITAKER, AND PRASHANT D. SARDESHMUKH

A modern data assimilation system could use available surface pressure observations to produce a consistent dataset of the daily extratropical circulation from the late-nineteenth century to the present.

500hPa geopotential height analysis (20th of December 2001)



All observations including upper-air and satellite



Only surface pressure observations, simulating the 1895 network (308 stations)

20th century reanalysis datasets

A new family of climate reconstruction

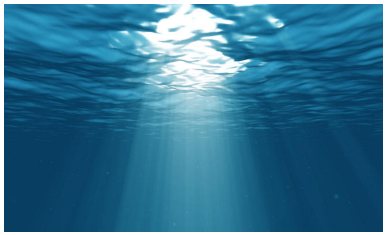
- NOAA/CIRES 20CR
- ERA-20C Atmosphere only
- CERA-20C Coupled atmosphere-ocean

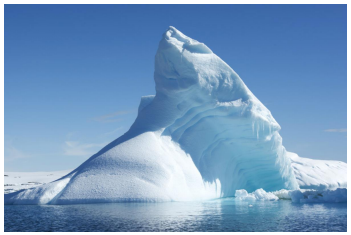
CERA-20C


Atmosphere


Land


Wave


Ocean


Sea ice

→ ECMWF coupled model used for NWP

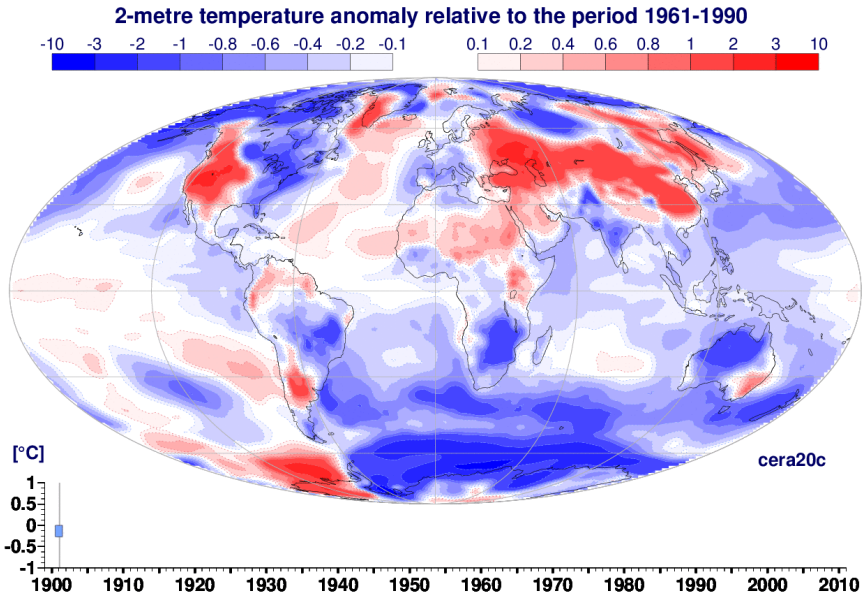
→ pressure and marine wind observations

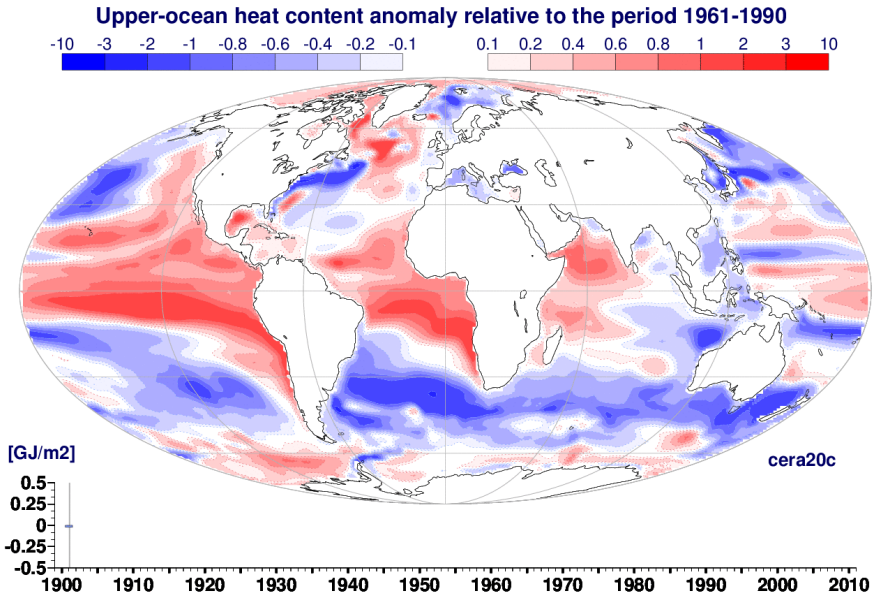
→ salinity and temperature ocean profiles

→ a new coupled assimilation system

→ 10-member ensemble to represent uncertainties

Climate signals in CERA-20C



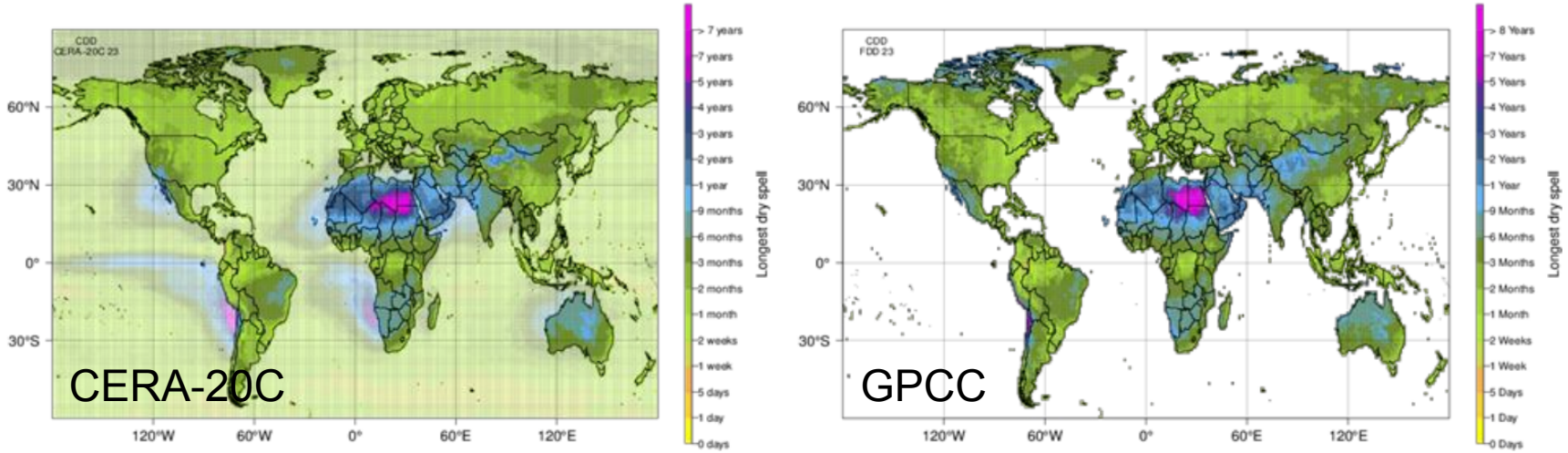


CERA-20C global average temperature anomaly with respect to 1961-1990 period

- no gaps in the datasets
- spacial and temporal consistency ensured by the NWP model
- climate signal consistent with observations and model based reconstructions

Climate signals in CERA-20C

Longest period of consecutive dry days between 1988 and 2010

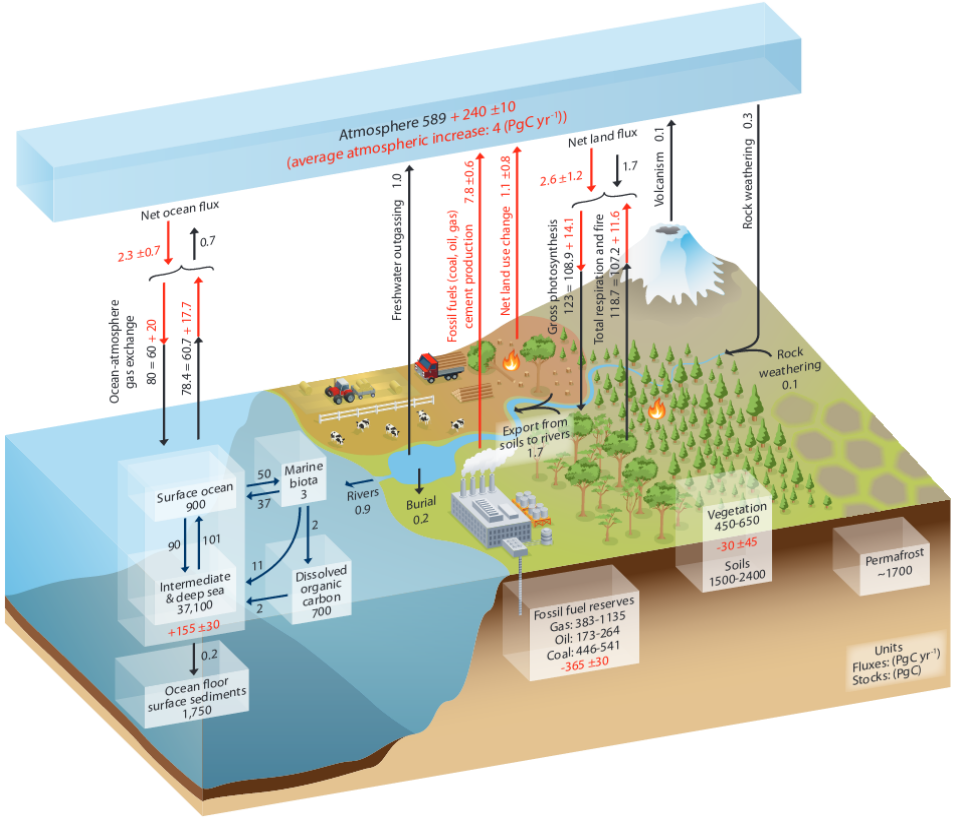


CERA-20C precipitation agrees well with independent observations

- no precipitation measurements are used in CERA-20C
- produced by the NWP model constrained by surface pressure observations

Courtesy of Elke Rustemeier

Associated reanalyses: ocean and land carbon cycle

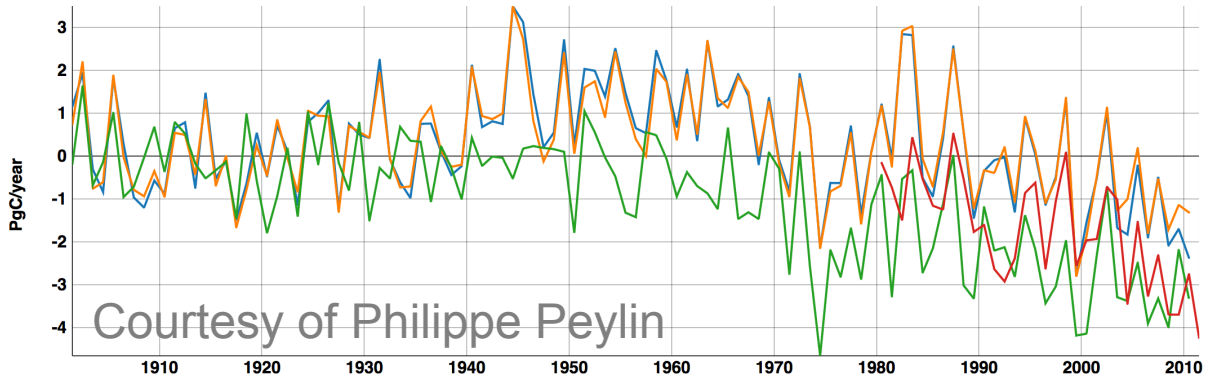


Intergovernmental Panel on Climate Change (IPCC) report shows that over 2000-2010

- 2.3 PgC/yr stocked in the ocean
- 2.6 PgC/yr stocked in the land
- 4 PgC/yr stays in the atmosphere

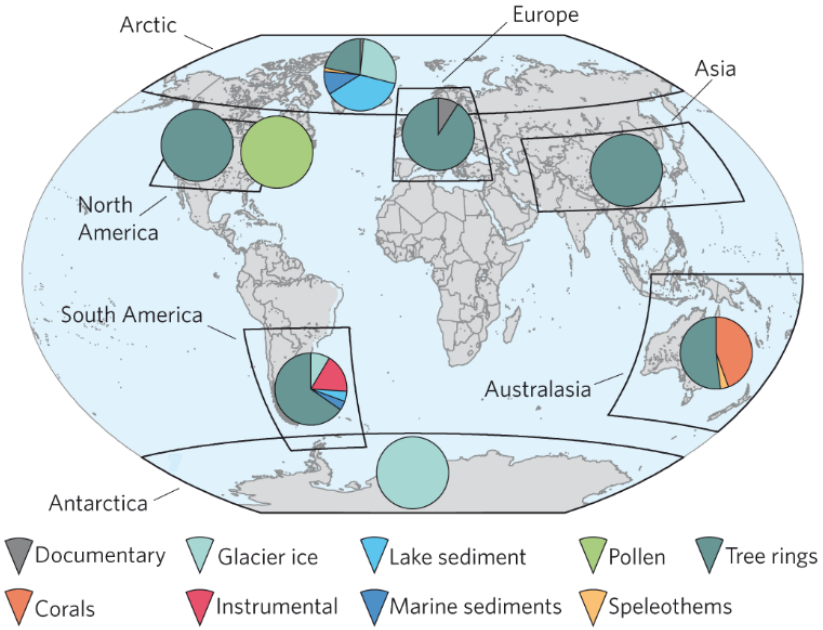
How did the carbon exchange fluxes evolve over the 20th century?

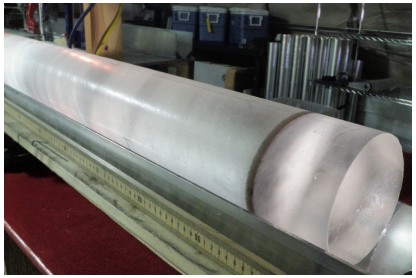
Total land carbon net flux between the atmosphere and the land



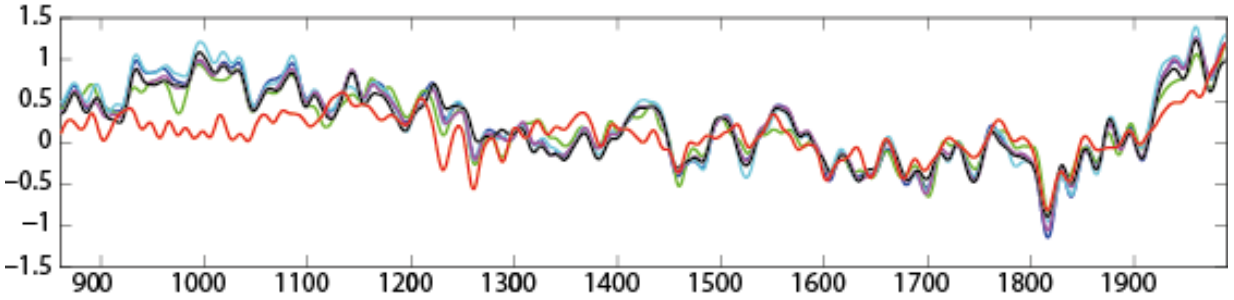
Going further back in time: paleoclimate reconstruction

Extremely sparse observing system (100-1000 per season/year), no direct observations, new data assimilation technique





Temperature anomaly in Artic



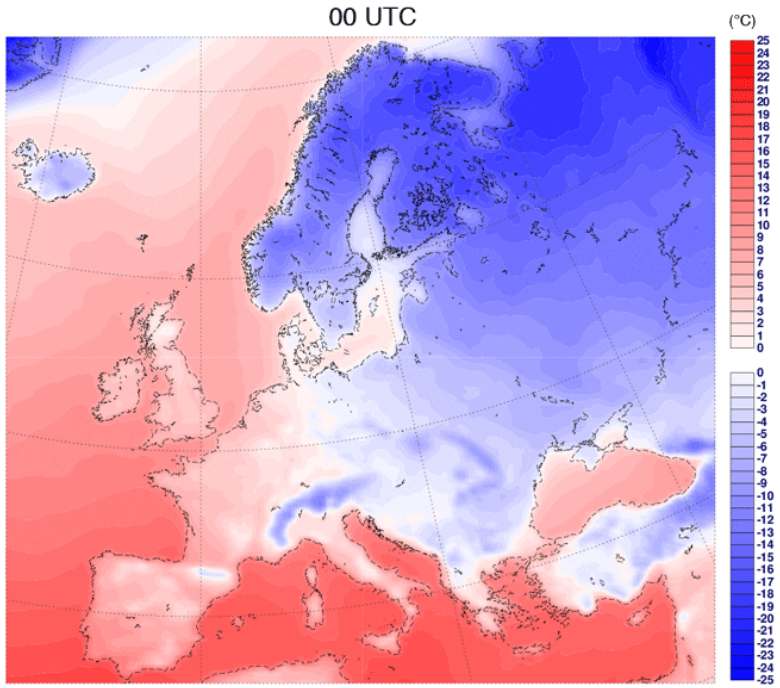
Observation only

Model only

Reanalysis

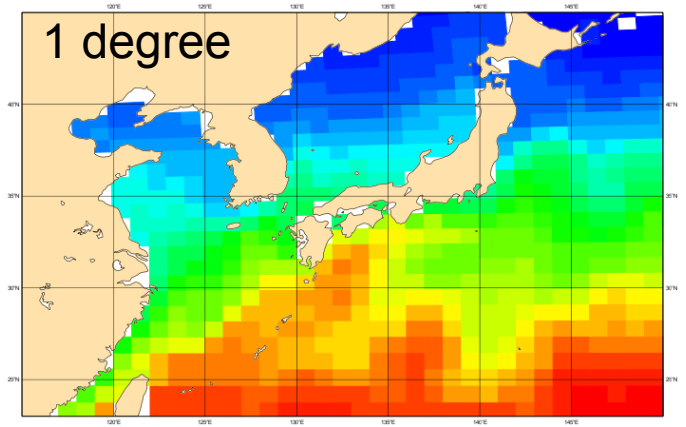
Courtesy of Hugues Goosse

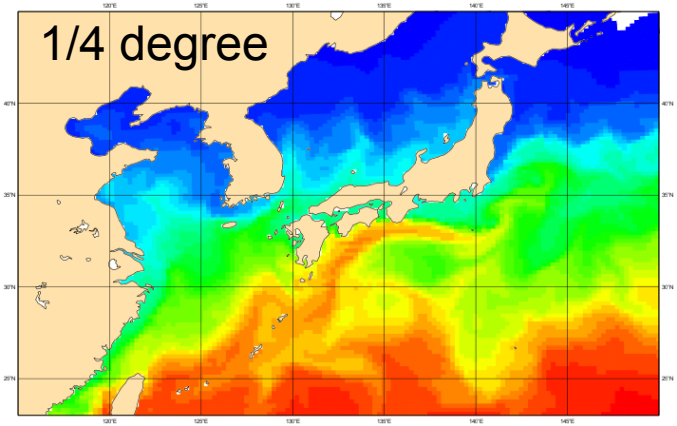
More detailed over recent years: satellite era reanalysis



ERA5

- Resolution of 31 km globally
- Hourly output
- Assimilating upper air and satellite



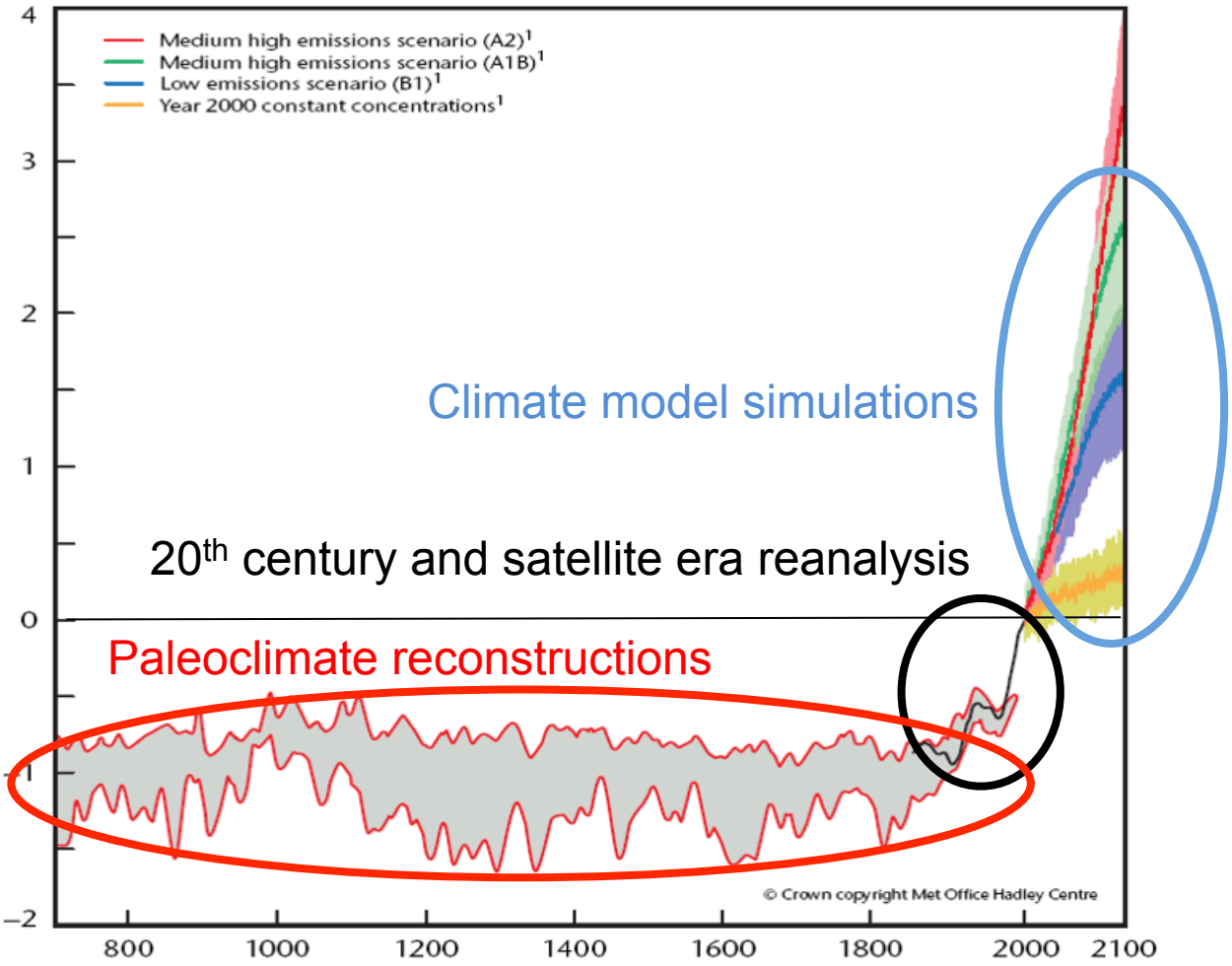


CERA-SAT

- Resolution of 65 km globally
- Assimilating upper air and satellite

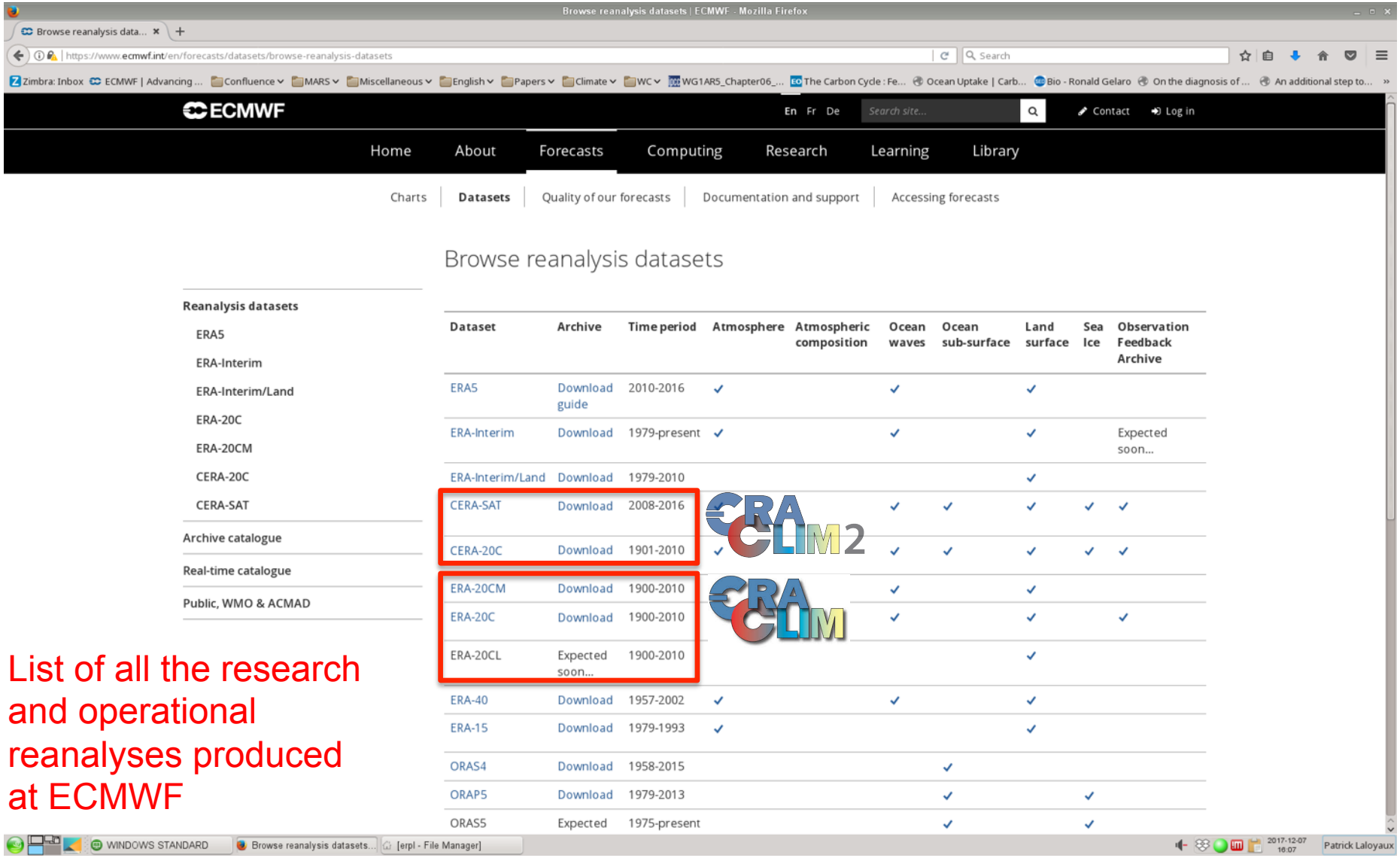
Conclusions

Global surface temperature change relative to 2000



- Reanalysis combines observation and model information to provide climate information
- 20th century and satellite era reanalyses are the short link between paleoclimate reconstructions and climate model simulations

Conclusions



List of all the research and operational reanalyses produced at ECMWF

https://www.ecmwf.int/en/forecasts/datasets/browse-reanalysis-datasets