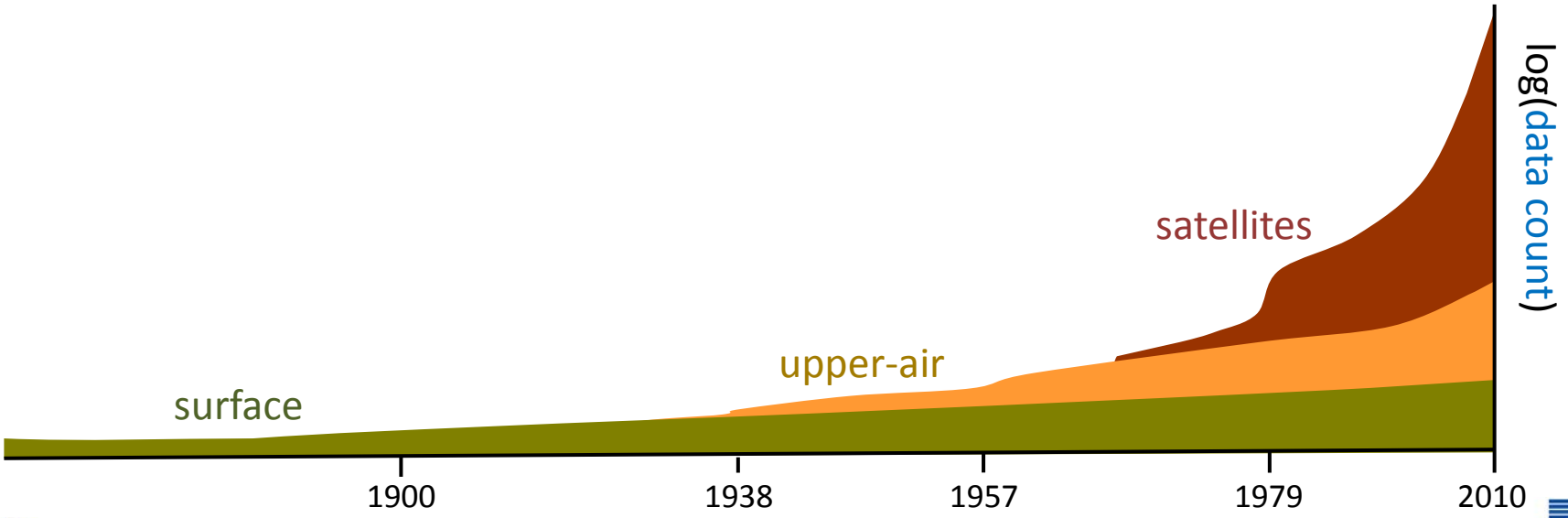
The ERA-CLIM and ERA-CLIM2 projects
and
Production of ERA5

Dick Dee, ECMWF

Reanalysis developments at ECMWF

Reanalysis of the modern observing period: **ERA-Interim → ERA5**

- Produce the best state estimate at any given time
- Use as many observations as possible, including from satellites
- Closely tied to forecast system development (NWP and seasonal)
- Near-real time product updates for climate monitoring



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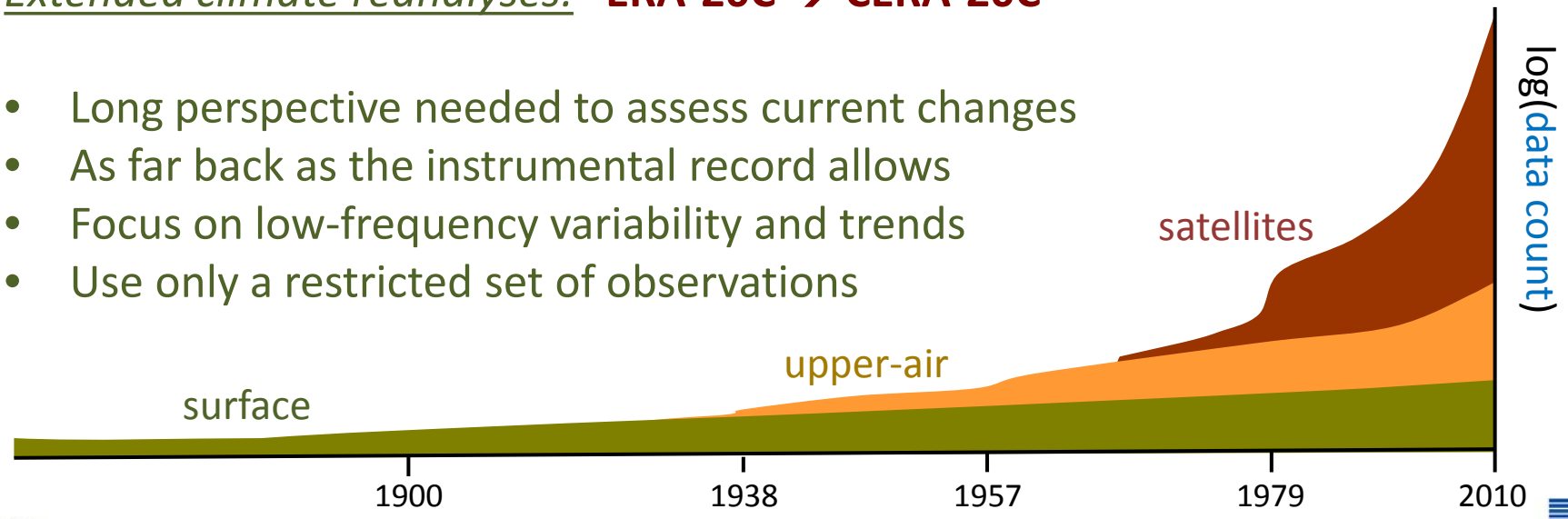
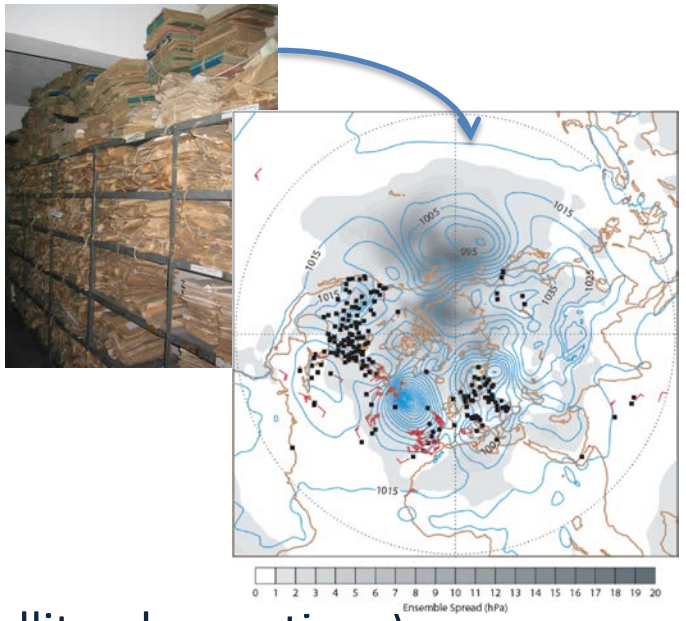
Extended climate reanalyses: **ERA-20C → CERA-20C**

- Long perspective needed to assess current changes
- As far back as the instrumental record allows
- Focus on low-frequency variability and trends
- Use only a restricted set of observations



ERA-CLIM

FP7 collaborative research, 9 institutions, 2011-2013

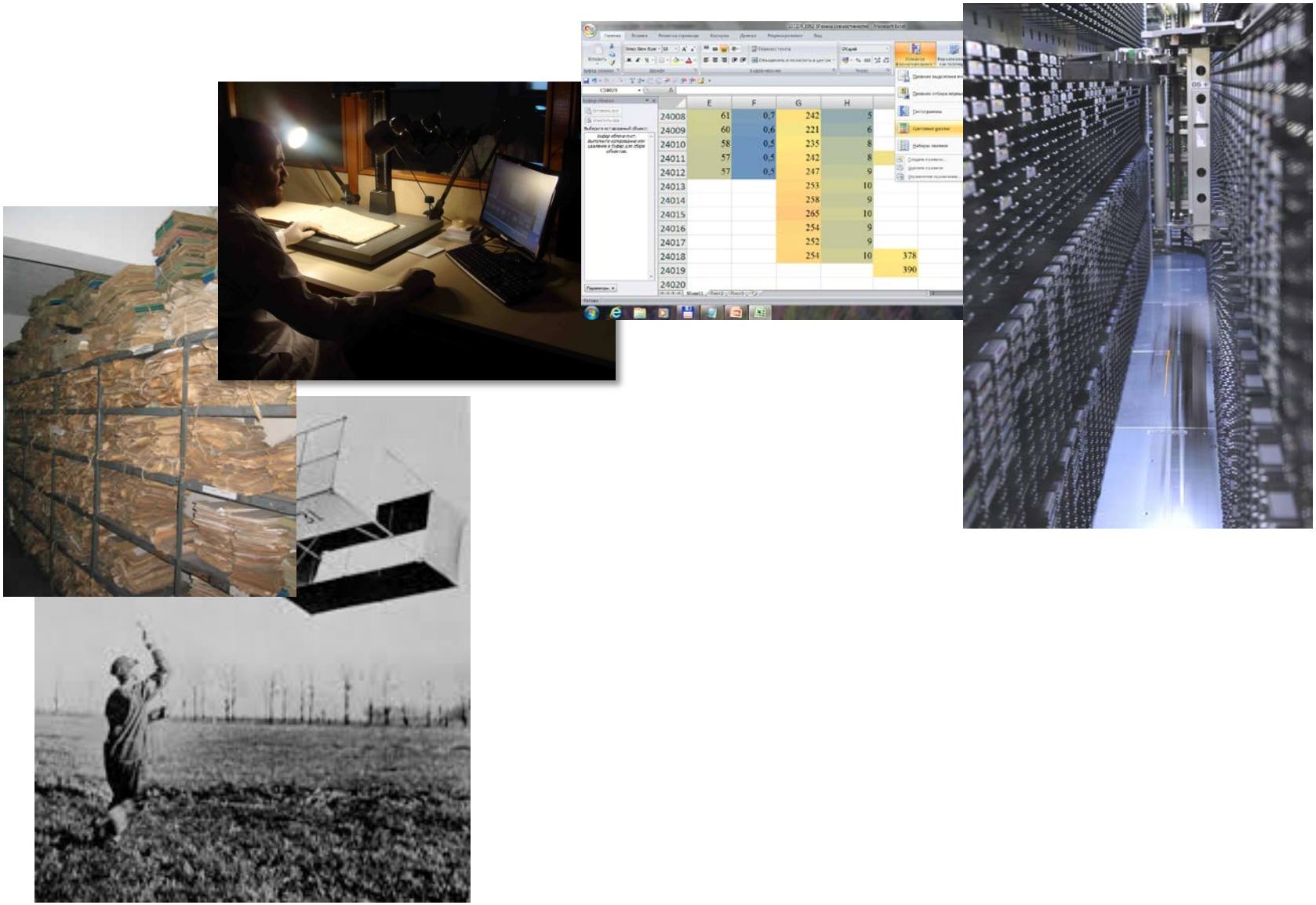


Goal: Preparing input observations, model data, and data assimilation systems for a global atmospheric reanalysis of the 20th century

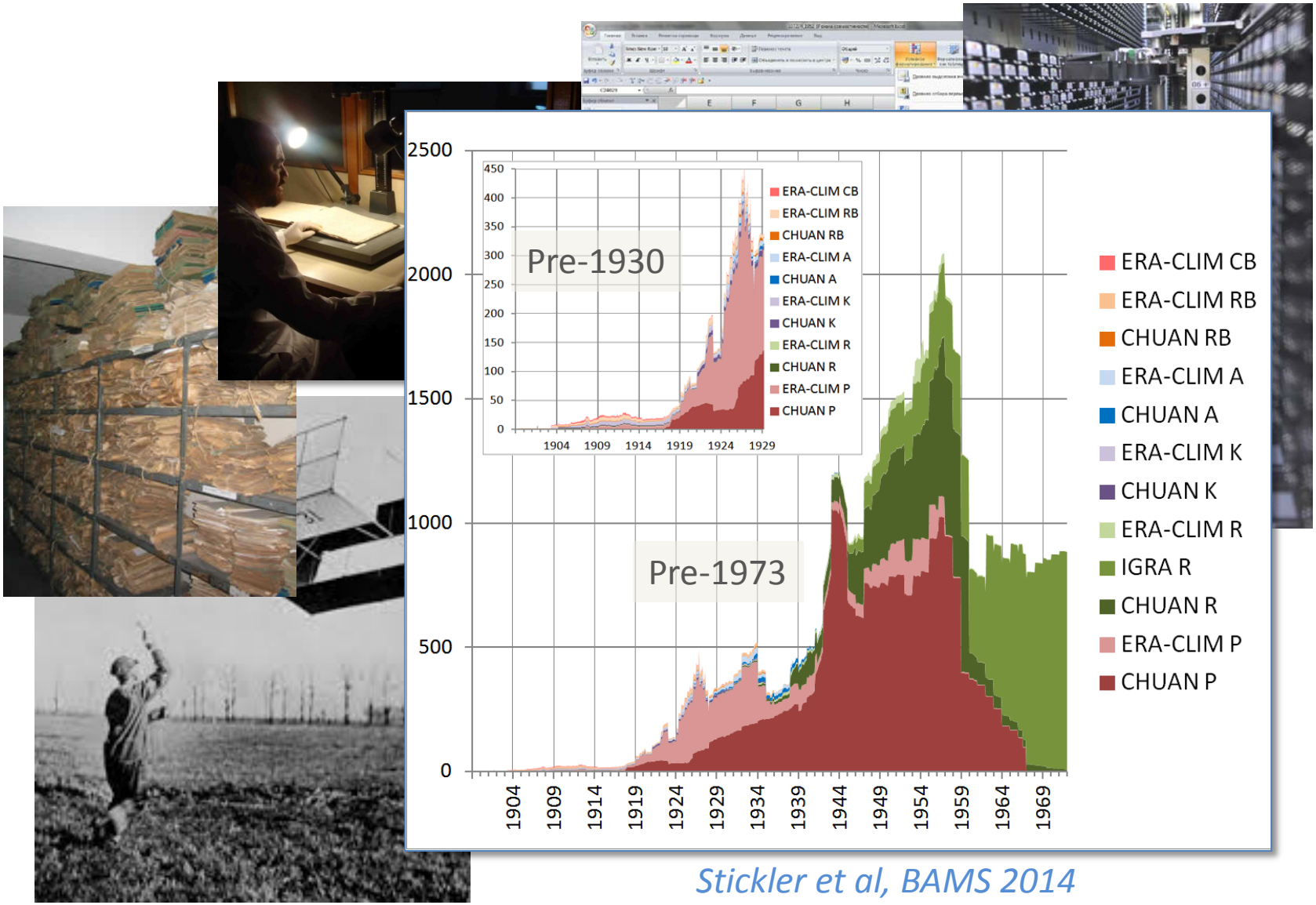
Main components:

- Data rescue (in-situ upper-air and satellite observations)
- Incremental development of new reanalysis products
- Use of reanalysis feedback to improve the data record
- Access to reanalysis data and observation quality information

Data rescue: *Upper-air observations pre-1957*



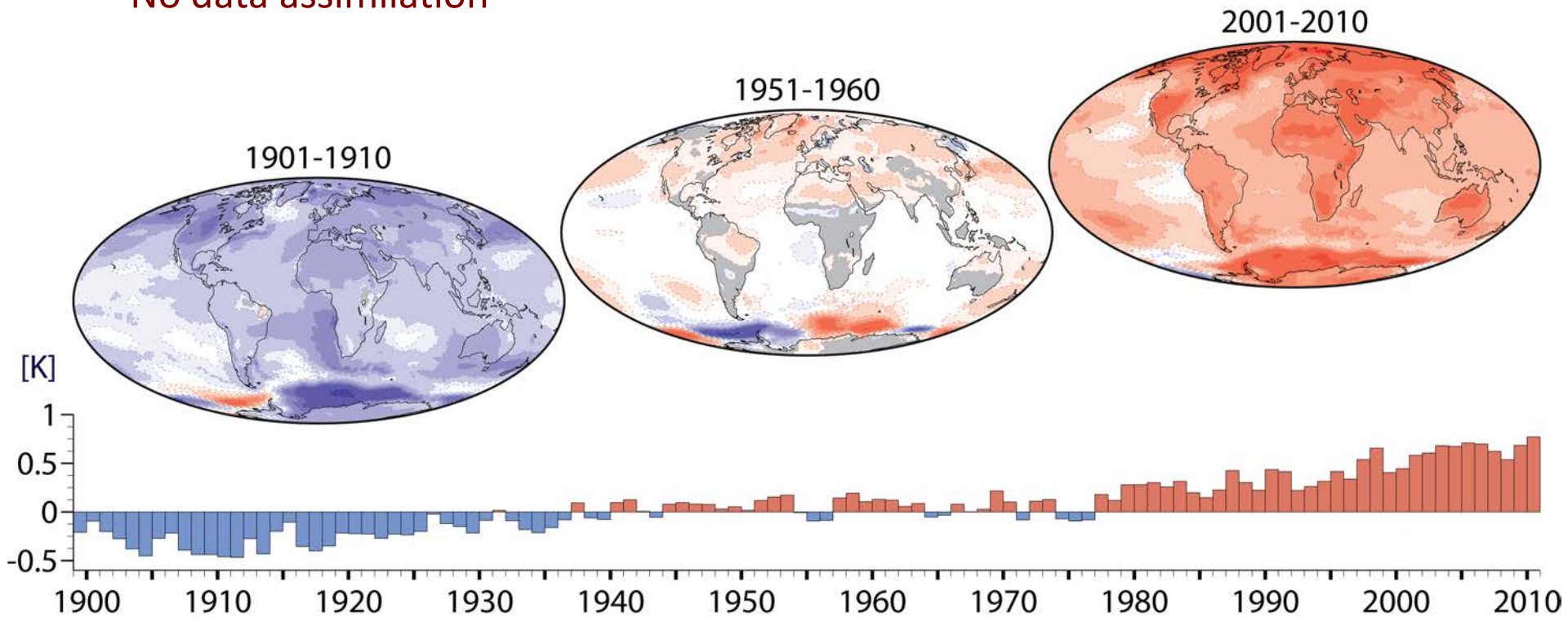
Data rescue: *Upper-air observations pre-1957*



Stickler et al, BAMS 2014

ERA-20CM: Ensemble of model simulations

- Model input: HadISST2, CMIP5 (volcanic aerosols, CO2, …)
- No data assimilation



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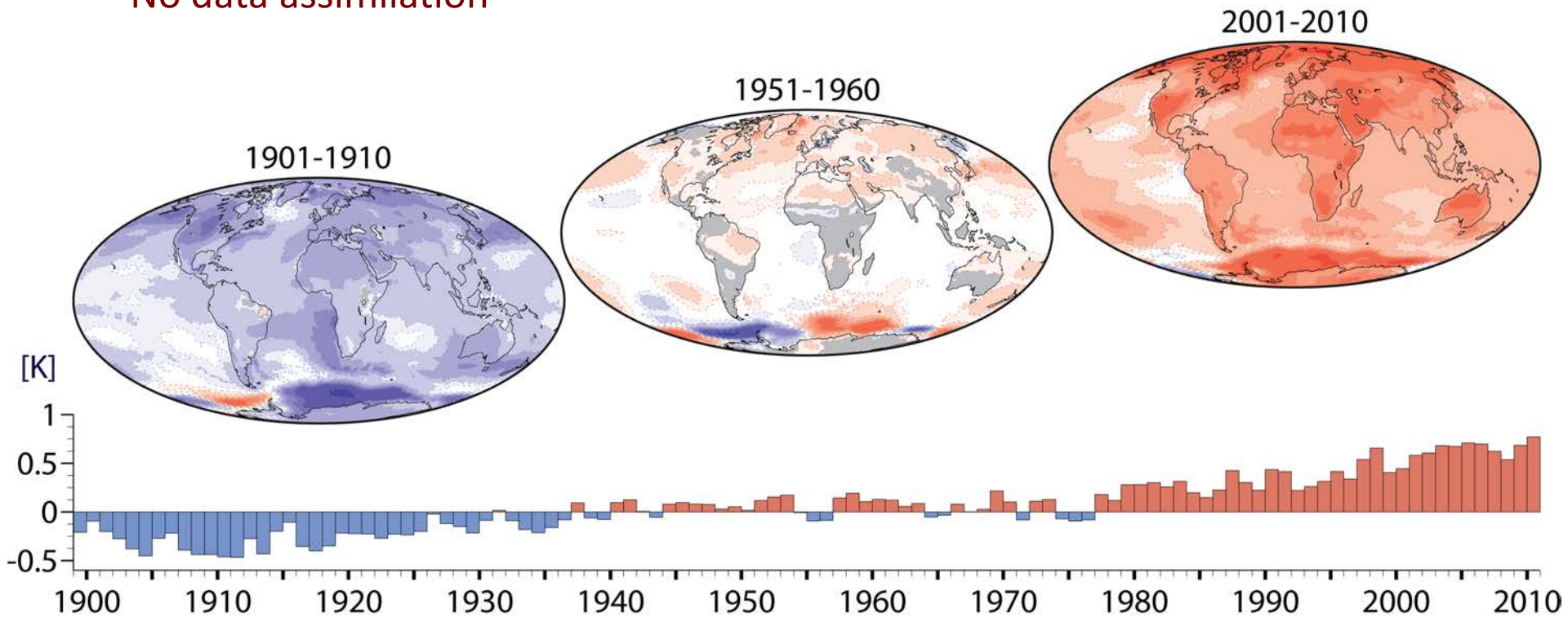
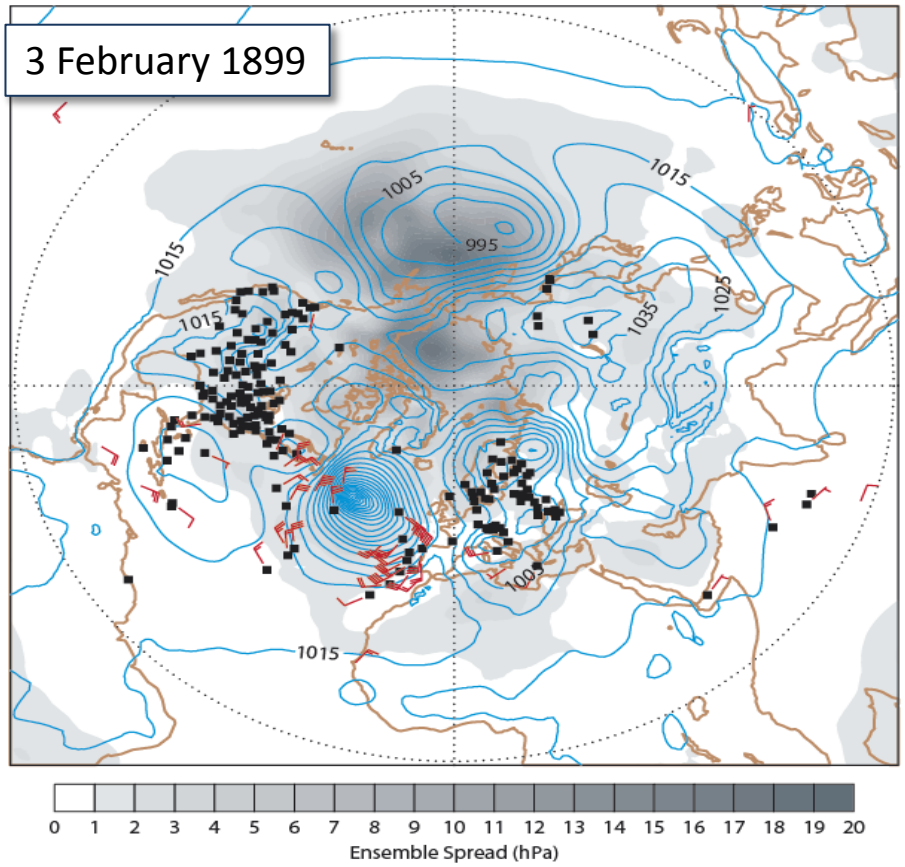


- Hersbach et al 2015, QJRMS
- Output available at `www.ecmwf.int/research`

ERA-20C: Assimilation of surface observations



TERRIFIC STORMS AT SEA

Steamships from All Quarters Report Extremely Rough Voyages.

ALL MORE OR LESS BATTERED

Vessels Sighted in Distress and Abandoned — Blinding Snow and Waves Like Mountains.

All the steamers that came in yesterday were coated with ice from the tops of the masts down to the water line, and all had passed through storms of blinding snow and mountainous waves. The British steamer Ethelgonda, from Bristol and Swansea, which left the latter port on Jan. 19, ran into a gale of hurricane force, and seas swept her decks repeatedly. So fierce was the wind that the boat drifted before the gales and was barely able to keep steerage way. She anchored outside the bar late Sunday afternoon. The cable parted and she lost her anchor, together with 100 fathoms of chain. Then the great snowstorm drove her 150 miles off the shore. She succeeded in getting back late on Tuesday night.

The French liner La Bretagne, from Havre, came in a little before noon yesterday, with 58 cabin and 225 steerage passen-

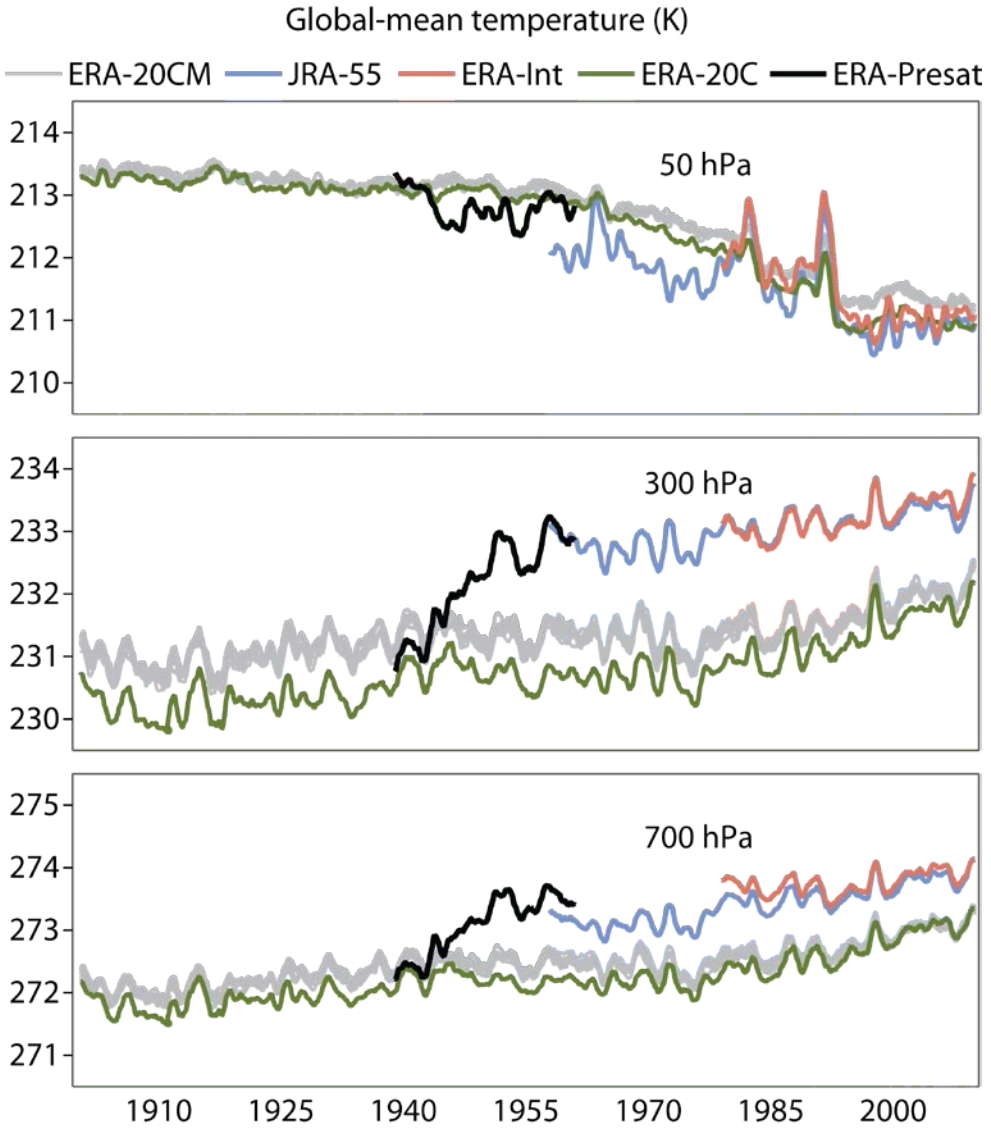
The New York Times
Published: February 16, 1899
Copyright © The New York Times

- Output available at `www.ecmwf.int/research`

(including observation feedback)

Impact of data assimilation on trends

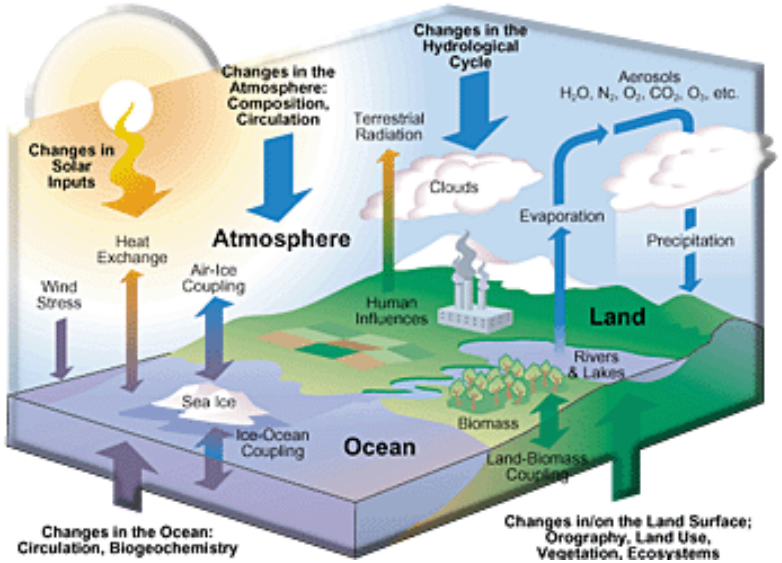
- ERA-20C slightly worse than ERA-20CM *(relative to CRUTEM4)*
- More warming than ERA-Interim in lower troposphere *(differences in model biases + SST data)*
- Promising results from first experiment with ERA-CLIM upper-air observations *(ERA-Presat, 1939-1959)*



ERA-CLIM2

FP7 collaborative research, 16 institutions, 2014-2016

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



Main components:

- Production of coupled reanalyses, for 20C and the modern era
- Research and development in coupled data assimilation
- Earth system observations for an extended climate reanalysis
- Evaluation of uncertainties in observations and reanalyses

ERA-CLIM2 Objectives

- Production of an **ensemble of 20th-century reanalyses** at moderate spatial resolution, **using a coupled atmosphere-ocean model**, to provide a consistent data set for atmosphere, land, ocean, cryosphere, including, for the first time, the carbon cycle across these domains;

- Production of a **coupled reanalysis of the satellite era** at improved spatial resolution, to provide a climate monitoring capability **with near-real time data updates**;

- Further **improvement of earth-system reanalysis capability** by implementing a coherent research and development program in **coupled data assimilation** targeted for climate reanalysis;

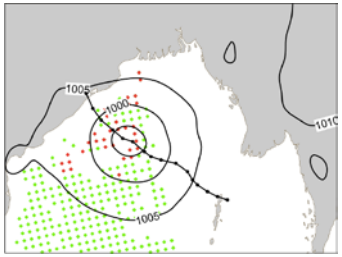
- Continued **improvement of observational data sets** needed for reanalysis**, in-situ as well as satellite-based**, with a focus on temporal consistency and reduction of uncertainties in estimates of essential climate variables;

- Development of tools and resources for users to help **assess uncertainties in reanalysis products,** such as the **Observation Feedback Archive.**

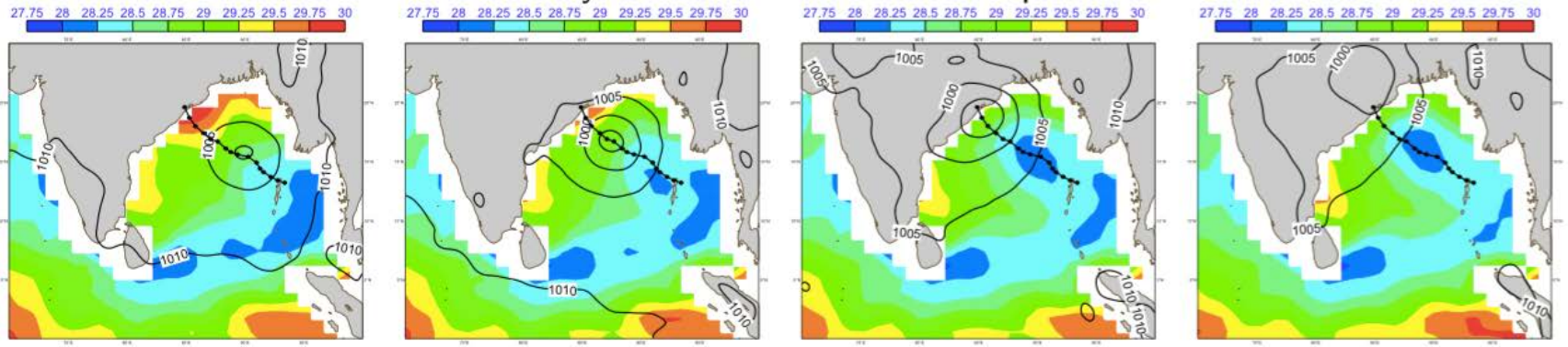
CERA system: Atmosphere-ocean coupling

Case study:

- Tropical Cyclone Phailin
- Assimilating scatterometer winds



CERA analysis of the Sea Surface Temperature



10 October 2013 | 11 October 2013 | 12 October 2013 | 13 October 2013

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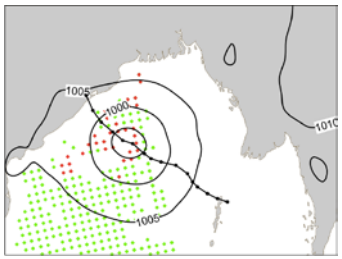
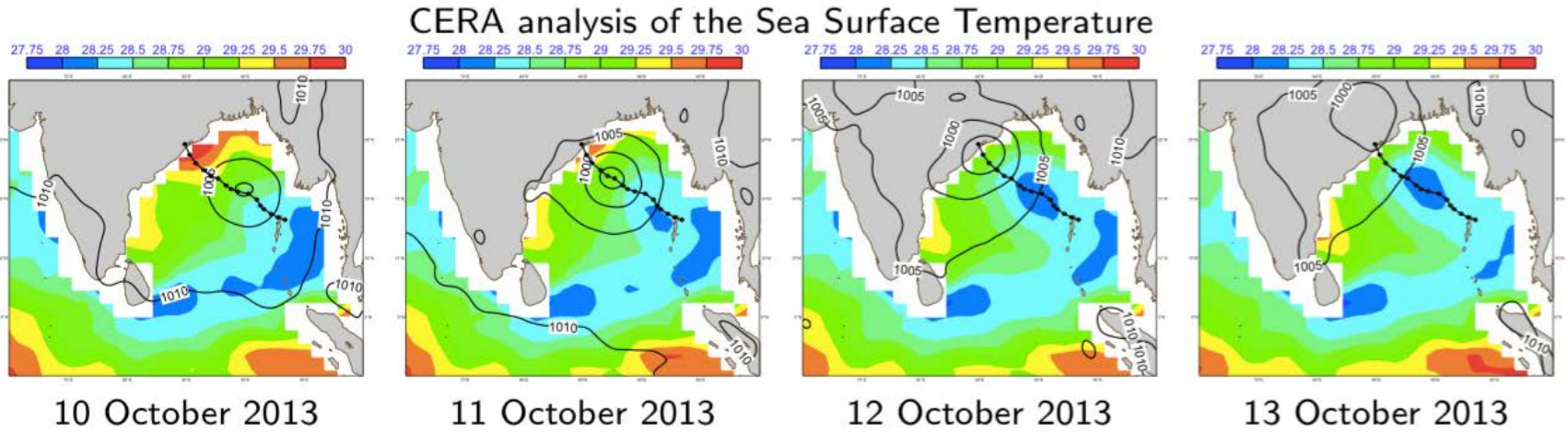




Long-term goals for reanalysis:

- Physically plausible representation of the sea surface even if unobserved
- Consistent fluxes at the atmosphere-ocean interface; improved energy budgets

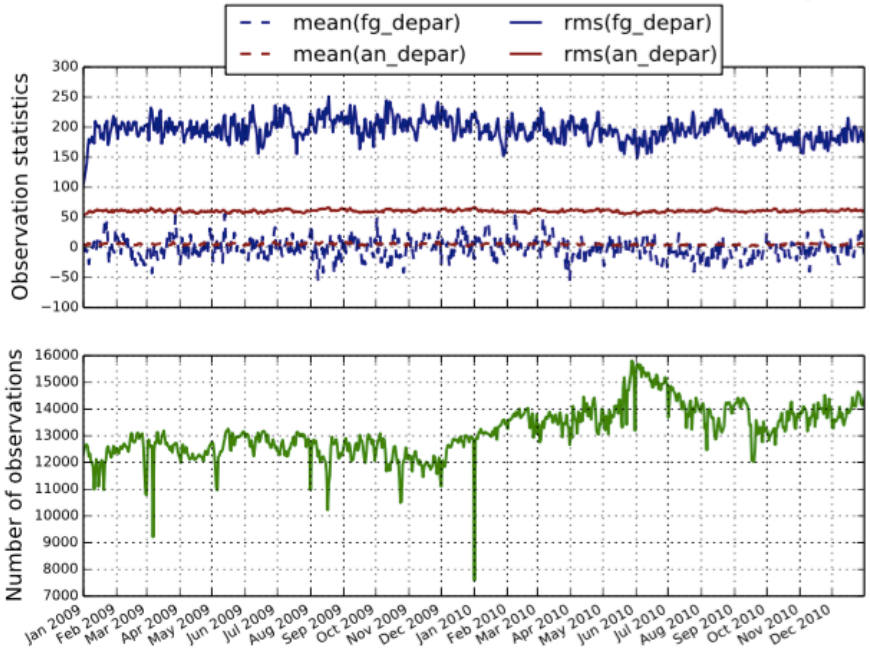
CERA-20C: Test productions

Configuration:

- 1°CERA system
- assimilation of 10-meter winds, mslp, temperature and salinity profiles
- HadISST2 for the SST nudging
- from 1900 to 2010

Test run over 2 years (2009-2010) providing forcing fields for offline CARBON reanalyses

Tools to monitor the CERA20C production (e.g. mslp statistics from buoys)



- Full production to start late 2015
- Carbon (ocean + land) to follow

Preliminary test results for ocean carbon

Annual mean of **carbon flux** (gC/m^2/yr) from ocean to atmosphere :

- Observation (Takahashi)
- Simulation with filtered Kz

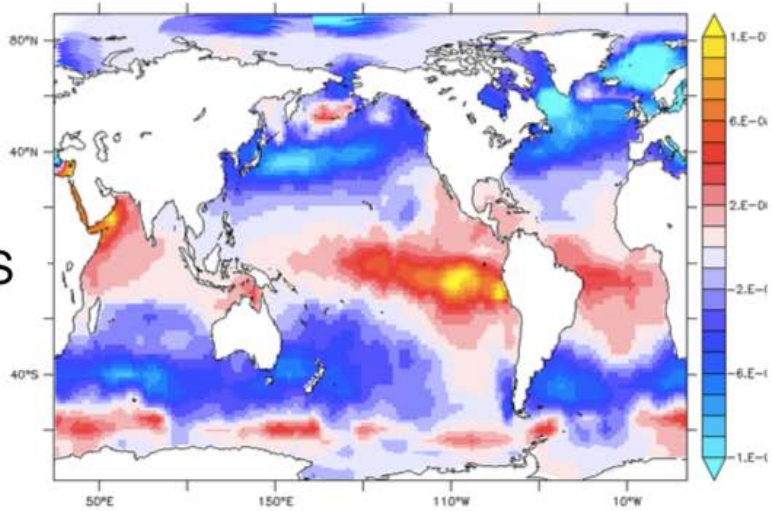
Simu vs Obs :

- general good direction of the flux
- carbon sources to atmosphere too big
- very small carbon sink in North Atlantic & Austral Ocean

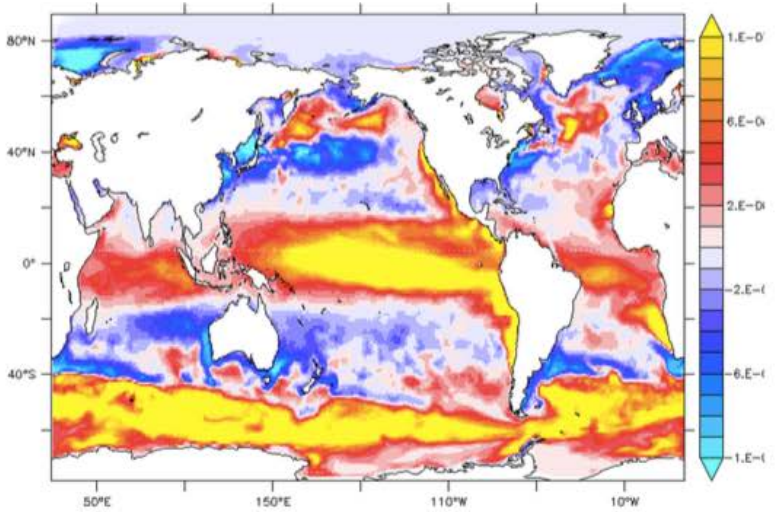
- Based on PISCES biogeochemical model using CERA-20C output
- *Courtesy Aurélie Albert (Mercator)*

⇨ A lot of work to do !

OBS



Filt SIMU



Retiring ERA-Interim: **ERA5**

	ERA-Interim	ERA5
Start of production	August 2006 IFS Cy31r2	June 2015 IFS Cy41r1
Model input	As in operations *(inconsistent SST)*	Appropriate for climate (CMIP5, HadISST.2)
Spatial resolution	79 km global 60 levels to 10 Pa	31 km global 137 levels to 1 Pa
Time period	1979 - present	1979 - present (extension to ~1950)
Dissemination	Monthly	Monthly for ERA5; daily for ERA5T
Observations	Mostly ERA-40, GTS	Various reprocessed CDRs
Radiative transfer	RTTOV7	RTTOV11
Analysis method	4D-Var 1D+4DVar rain	10-member ensemble 4D-Var (EDA) All-sky MW
Variational bias corrections	Satellite radiances	Also ozone, aircraft, surface pressure (radiosondes)

Satellite data used in ERA-Interim

Microwave radiances
- temperature sounding
- water vapor sounding

Infrared radiances
- temperature and water vapor sounding
- stratospheric temperature sounding

Imagery — visible, near infrared, water vapor

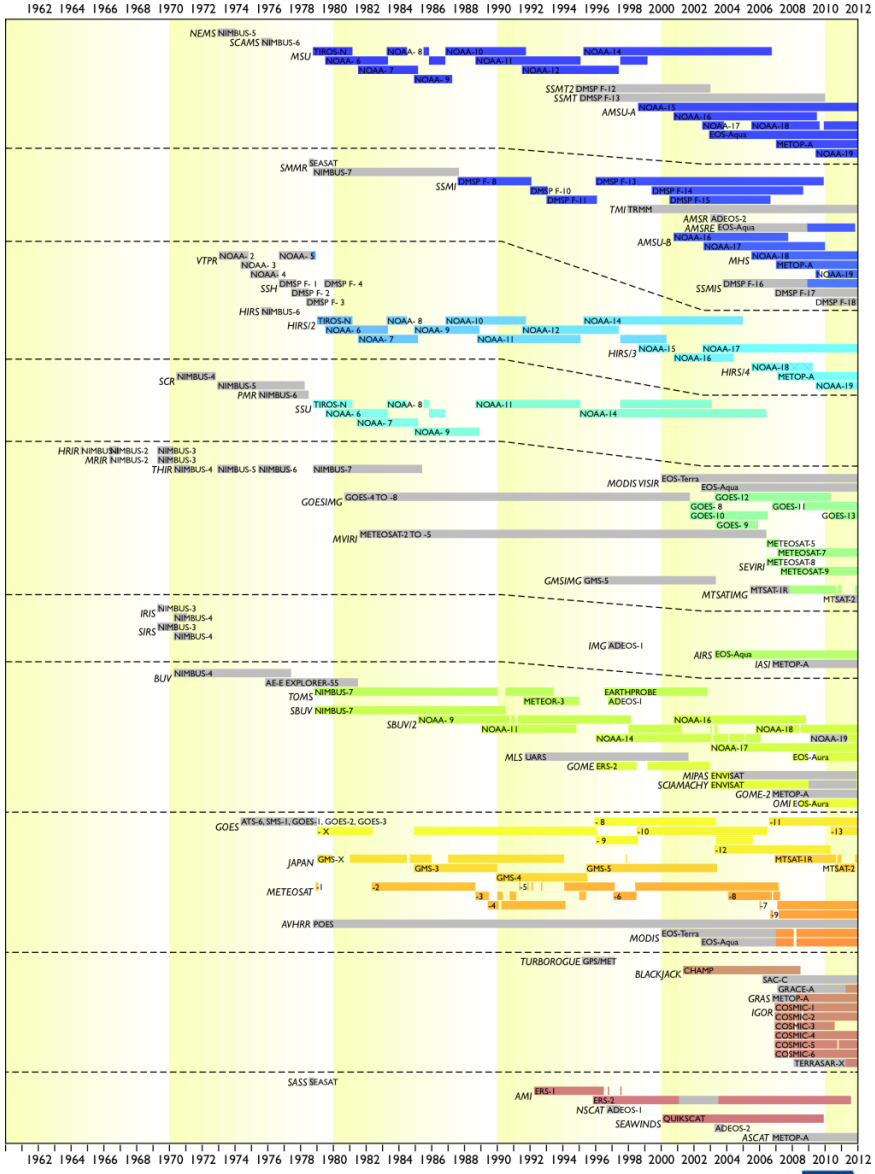
Hyper-spectral infrared

Ozone — mostly ultra-violet, some limb-viewing infrared

Atmospheric motion vectors
- geostationary (GEO)
- low-earth orbit (LEO)

Bending angles from GPS radio occultation

Backscatter — near-surface wind above ocean



New input data sets for ERA5

- METEOSAT AMV (EUMETSAT)
- GOES AMV (CIMSS 1995-2013)
- GMS and GOES-9 AMV (Japan)
- AVHRR NOAA AMV (CIMSS 1982-2010)
- AVHRR METOP AMV (EUMETSAT)

- METEOSAT radiances (EUMETSAT)
- ASCAT L1 Sigma0 (EUMETSAT)
- SSM/I radiances (CM-SAF)

- SBUV and TOMS ozone (NASA v8.6)

- Upper-air in situ observations (NCAR DS 370.0)
- Surface pressures (ISPD 3.2.6)
- Marine surface reports (ICOADS 2.5.1)

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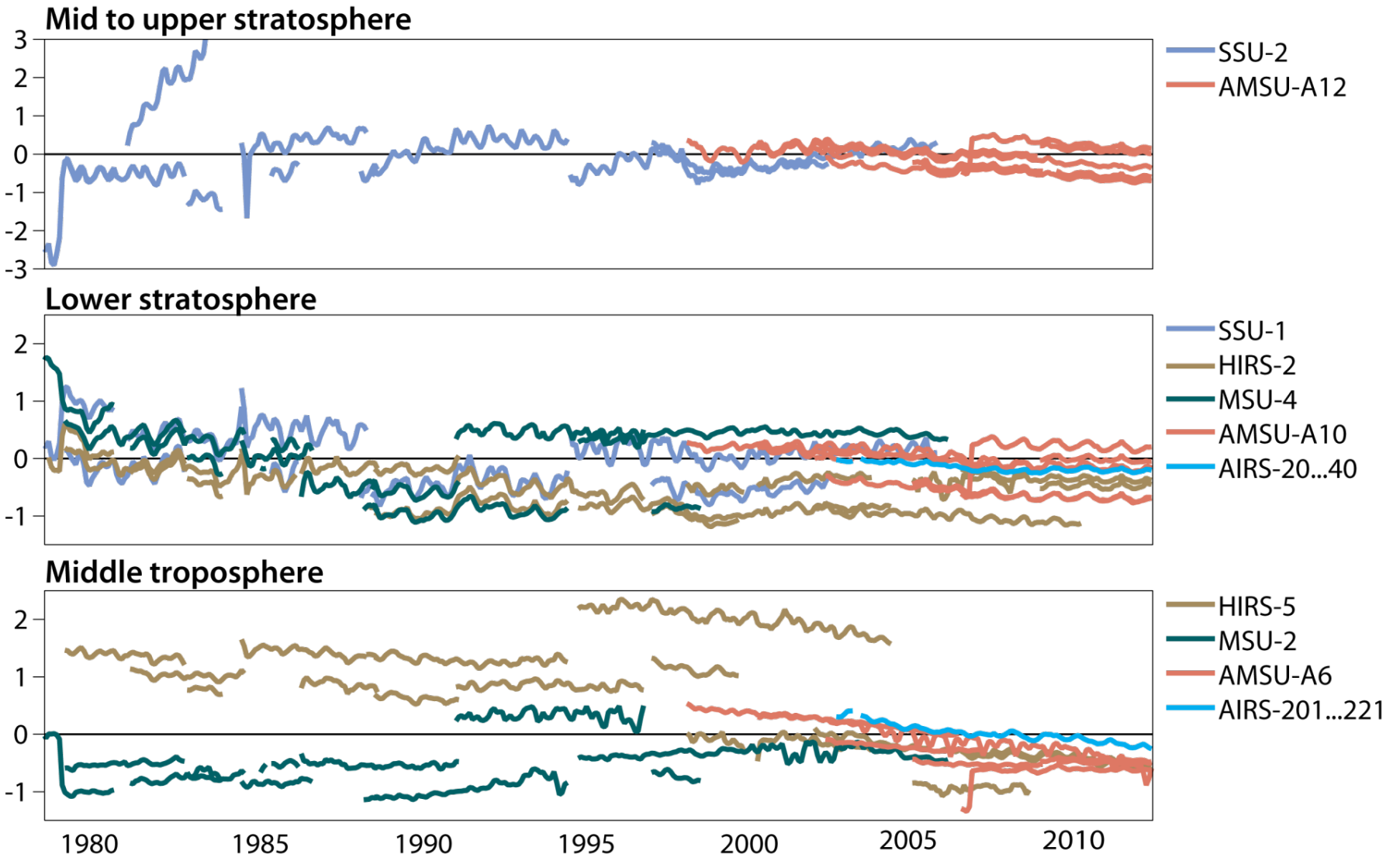
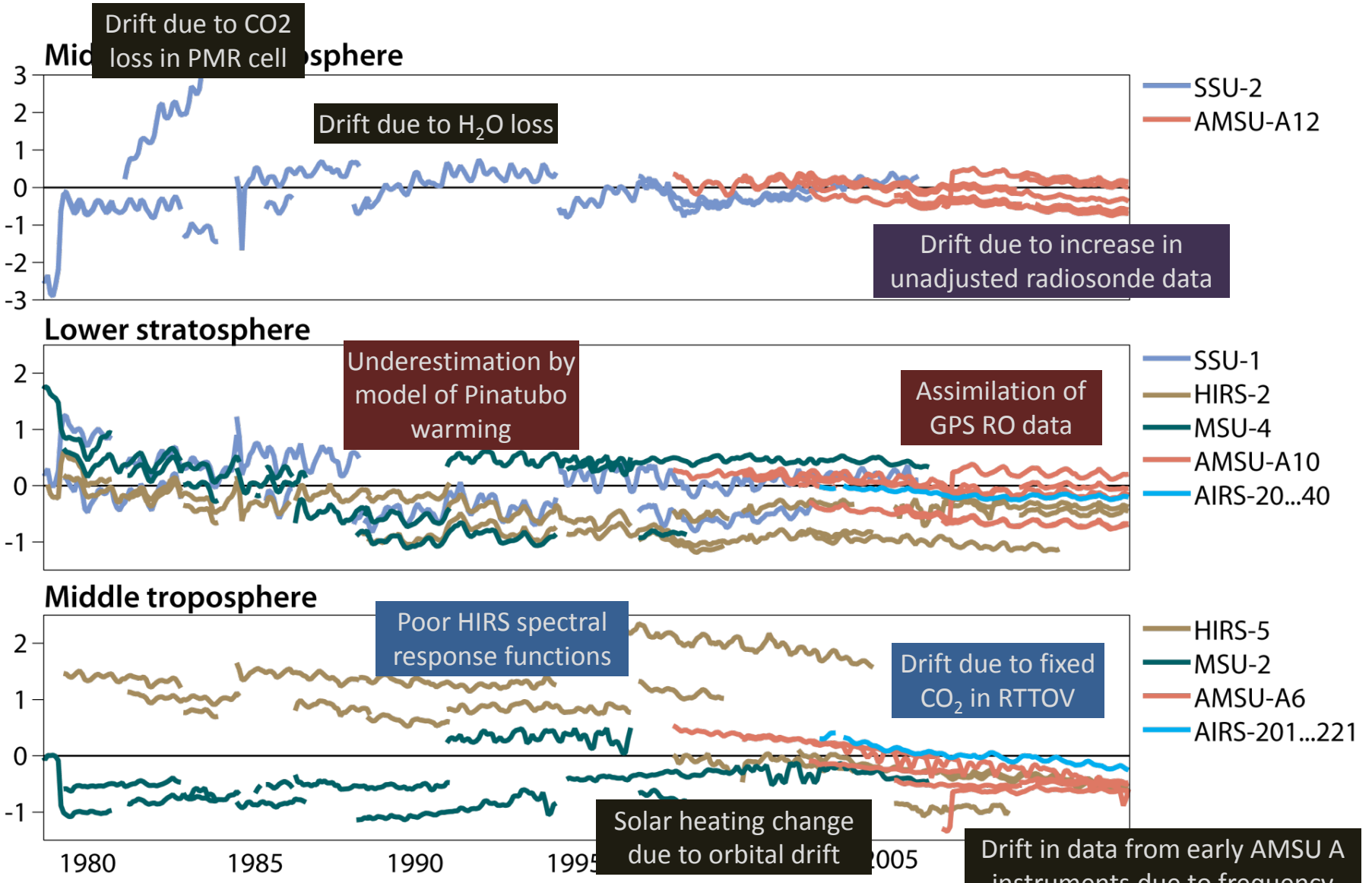
Improved radiative transfer modelling:

- Microwave and infrared frequency shifts
- Time-varying SSU cell pressure
- Time-varying atmospheric CO2 concentration

Feedback: ERA-Interim radiance biases [K]



Some lessons learned



ERA-CLIM / ERA-CLIM2: Potential impact on C3S

Short term:

- Better input data sets for ERA5
- Better data services, including NetCDF support
- Observation Feedback Archive and associated tools
- Coordination of in-situ data rescue : A global data rescue registry ?
- Stimulation and coordination of activities in satellite data rescue
- A coupled reanalysis for the satellite era : ERA6 ?

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Longer term:

- Improved extended climate reanalyses : ERA-20Cv2; CERA-20C; + carbon ?
- Meaningful information about uncertainties in reanalysis products
- A coupled reanalysis for the satellite era : ERA6 ?