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ERA5: STATE-OF-THE-ART GLOBAL ATMOSPHERIC REANALYSIS AT ECMWF

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Why reanalysis?

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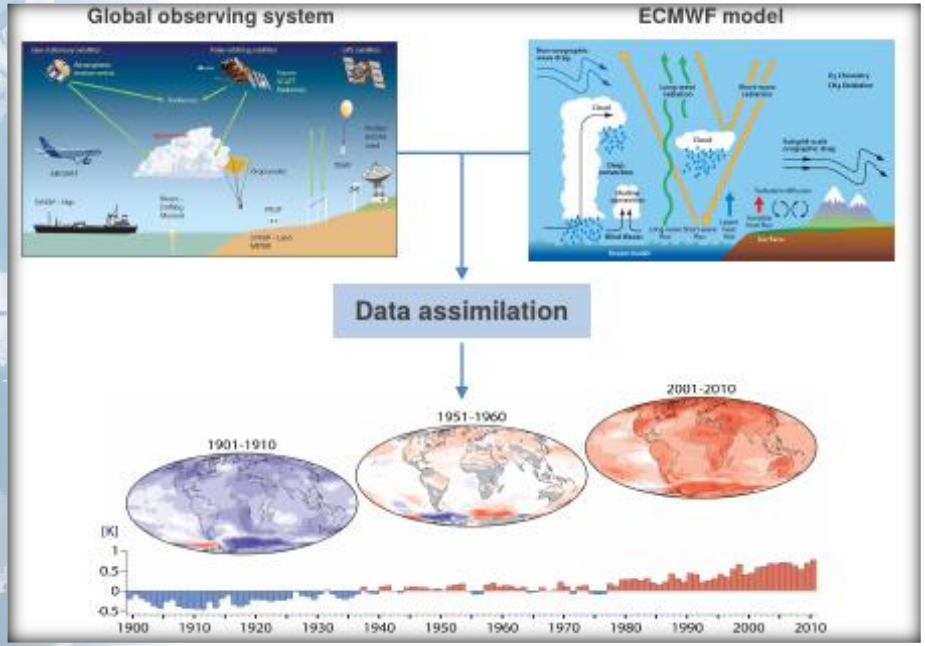
Reanalysis offer a detailed overview of the past Earth's climate even if direct observations are sparse



- Complete: combining vast amounts of observations into (global) fields
- Consistent: use the same physical model and DA system throughout
- Convenient: "maps without gaps", always available in the same way

- However The observing system has evolved considerably and so the quality of the reanalysis products that rely on this!

➢ ERA5 is based on a 10-member Ensemble 4D-Var data assimilation system

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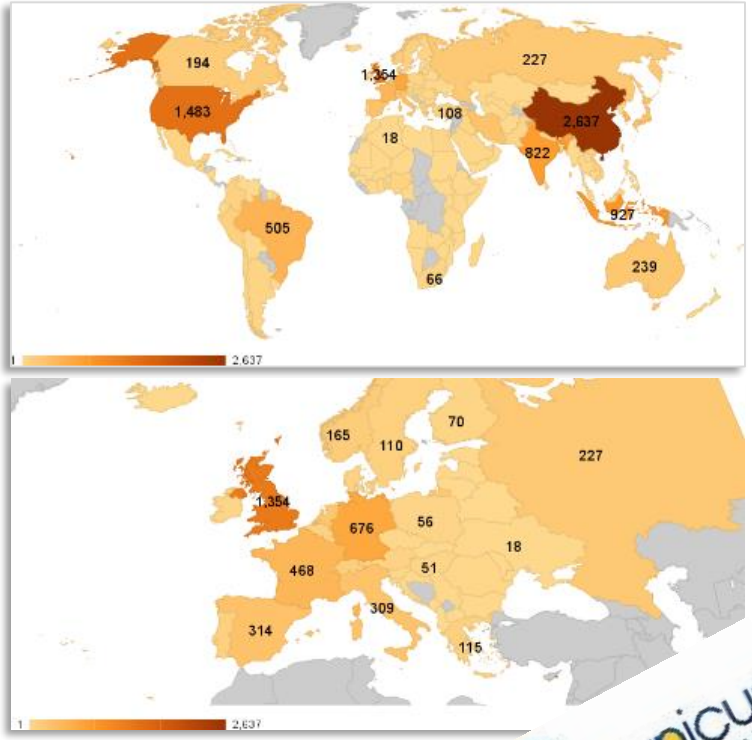
ERA-Interim users world wide

ERA-Interim had more than 33,000 unique users between Jan 2016- Apr 2018 alone.

Users and stakeholders:

- Climate monitoring & provision of climatologies
- ECMWF member states
- Research and education, over 10,000 citations (Dee et al, QJRMS)
- Public sector
- Space agencies
- Commercial applications

Unique registered users in 2016



However, ERA-Interim is 10 years old and needs replacement (on top … latest observations are not used) → A new reanalysis (ERA5) is nee…

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What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 – present	***1950 – present***, produced in 2 phases
Availability behind real time	2-3 months	2-3 months (final product) ***2-5 days*** (ERA5T)
Assimilation system	2006 (31r2), 4D-Var	***2016*** (41r2), ***4D-Var, hybrid EDA providing B***
Model input (radiation and surface)	As in operations, *(inconsistent SST and sea ice)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** 137 levels to 1 Pa
Uncertainty estimate		***from*** 10-member ***EDA at 62 km***
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), Extended list of parameters ~ 9 Peta Byte (1950 - timely updates)
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias control radiosondes	Satellite radiances, RAOBCORE	Also ozone, aircraft, surface pressure, RISE
Land downscaling product	ERA-Interim land, 79km	ERA5L, ***9km*** (forced by ERA5)

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The ERA5 observing system

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0.75 (1979) – 24 Million (2019) obs per day
Over 200 types of reports

Reprocessed data sets

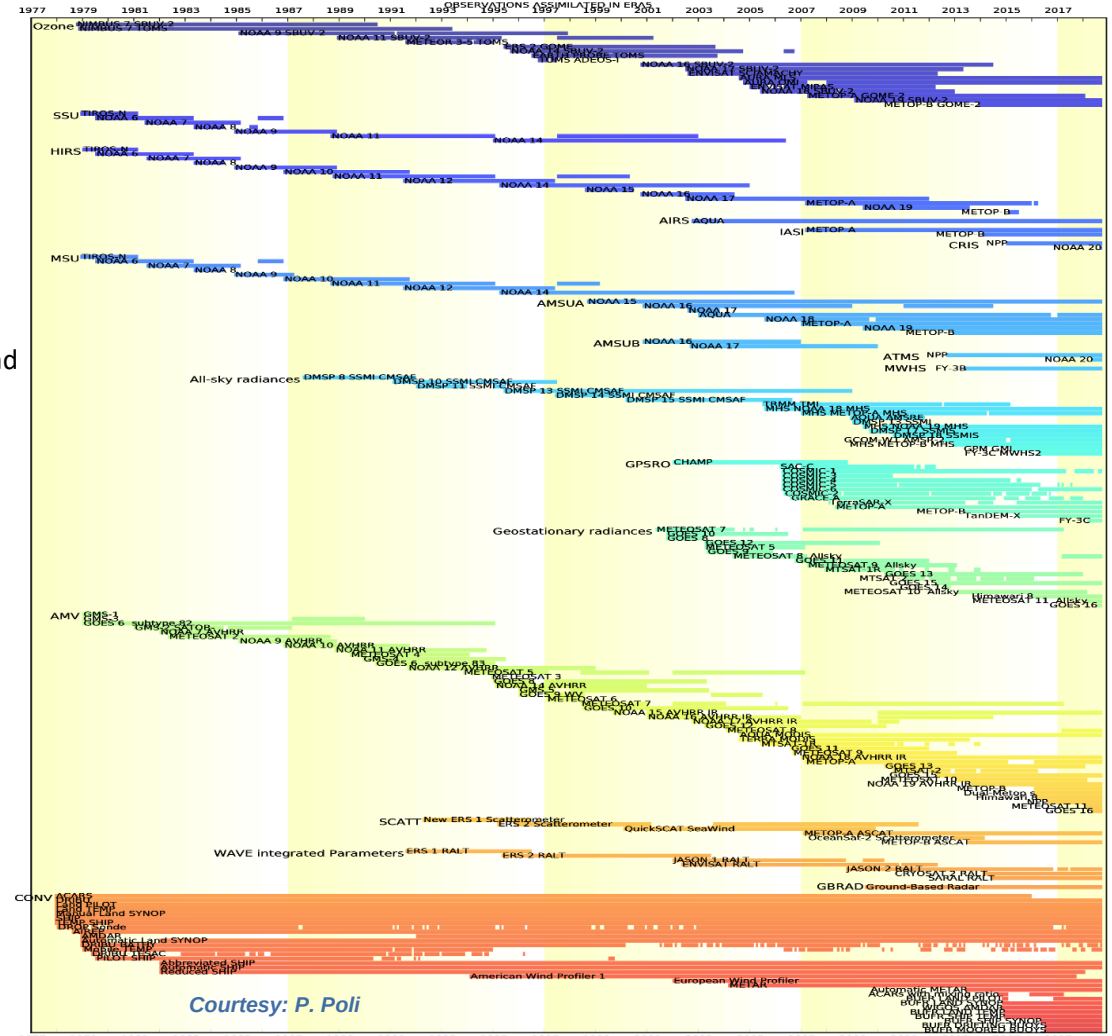
- **Radiances**: SSM/I brightness temp from CM-SAF MSG from EUMETSAT
- **Atmospheric motion vector winds**: METEOSAT, GMS/GOES-9/MTSAT, GOES-8 to 15, AVHRR METOP and NOAA
- **Scatterometers**: ASCAT-A (EUMETSAT), ERS 1/2 soil moisture (ESA)
- **Radio Occultation**: COSMIC, CHAMP, GRACE, SAC-C, TERRASAR-x (UCAR)
- **Ozone**: NIMBUS-7, EP TOMS, ERS-2 GOME, ENVISAT SCIAMACHY, Aura MLS, OMI, MIPAS, SBUV
- **Wave Height**: ERS-1,ERS-2, Envisat, Jason

Latest instruments

IASI, ASCAT, ATMS, CrIS, MWHS, Himawari, …

Improved data usage

all-sky vs clear-sky assimilation,
latest radiative transfer function, corrections,
extended variational bias control



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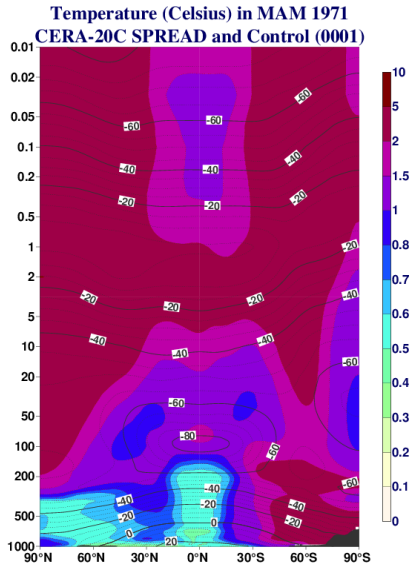
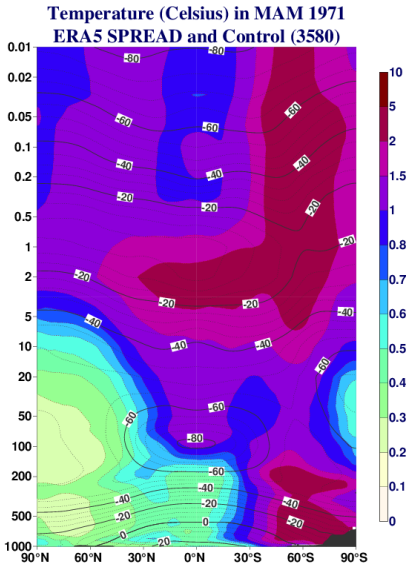
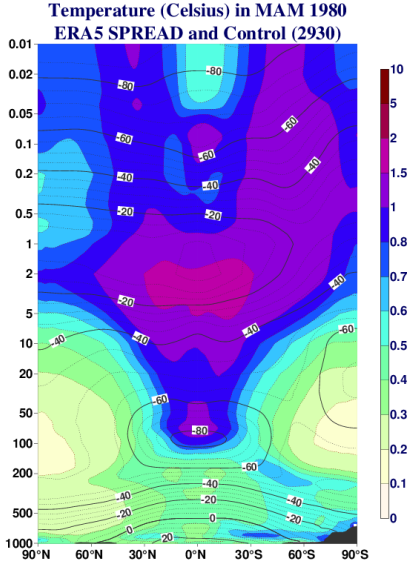
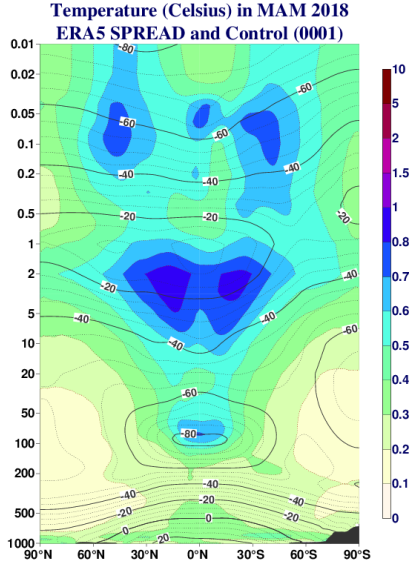
Ensemble spread as a measure for the *synoptic* ERA5 uncertainty









1971 CERA-20C:
Surface pressure, marine wind, only

1971 ERA5:
Upper-air data

1980 ERA5:
Early-satellite era

2018 ERA5:
Current observing system

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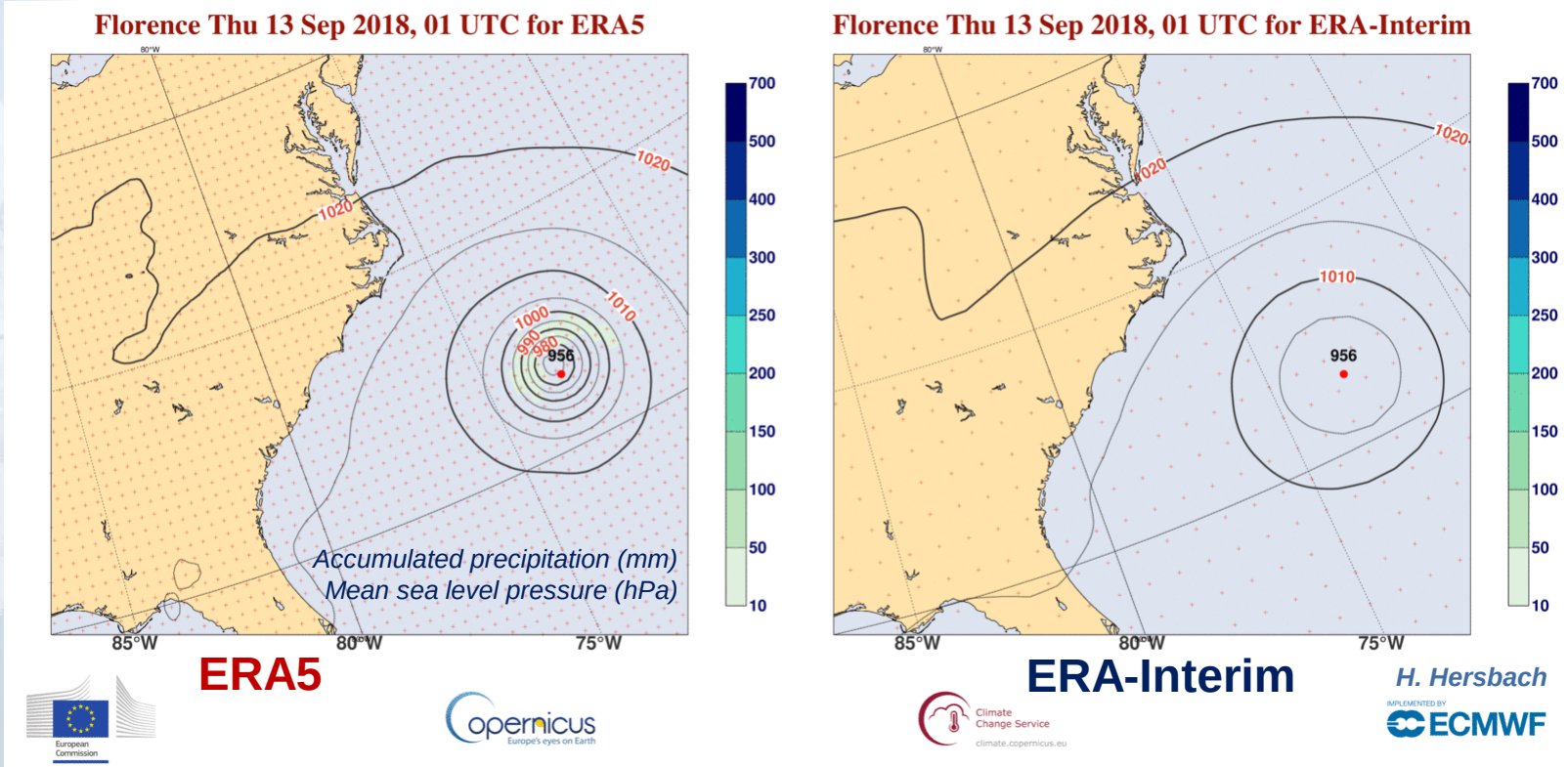
Better model, more and better observations, higher resolution, hourly output



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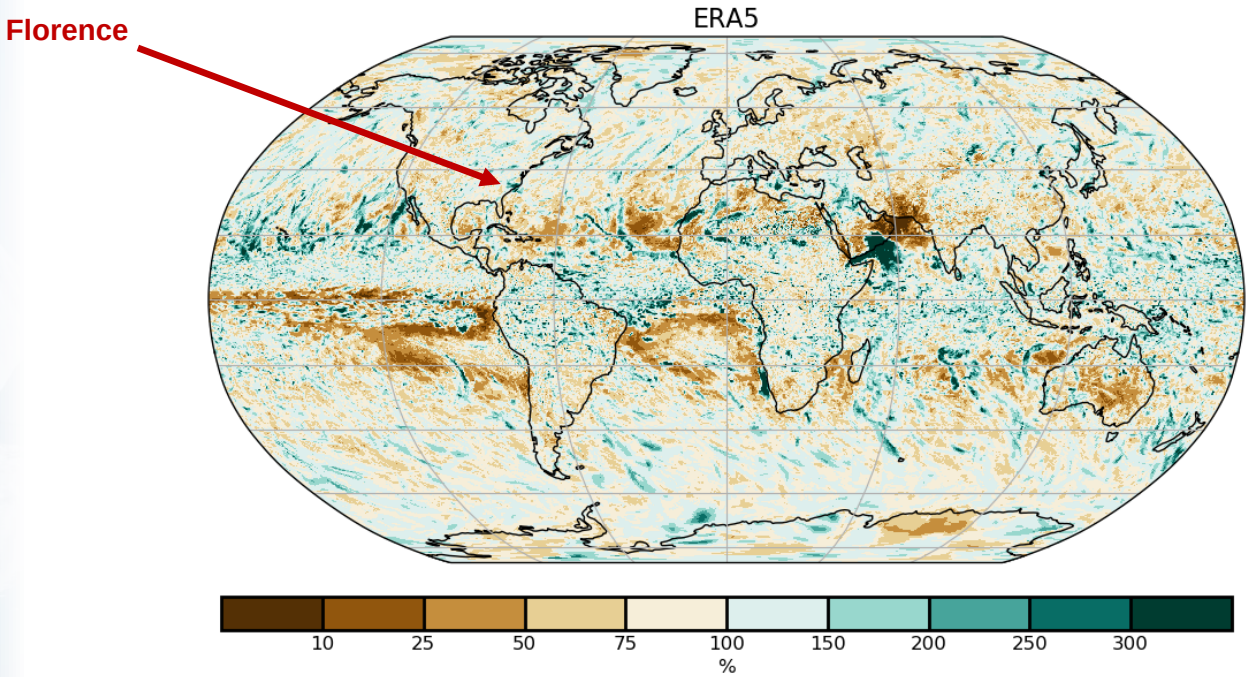
Maximum of daily ERA5 precipitation in 2018 relative to the 1981-2010 climatology



Courtesy of Adrian Simmons; to appear in BAMS SOC 2019

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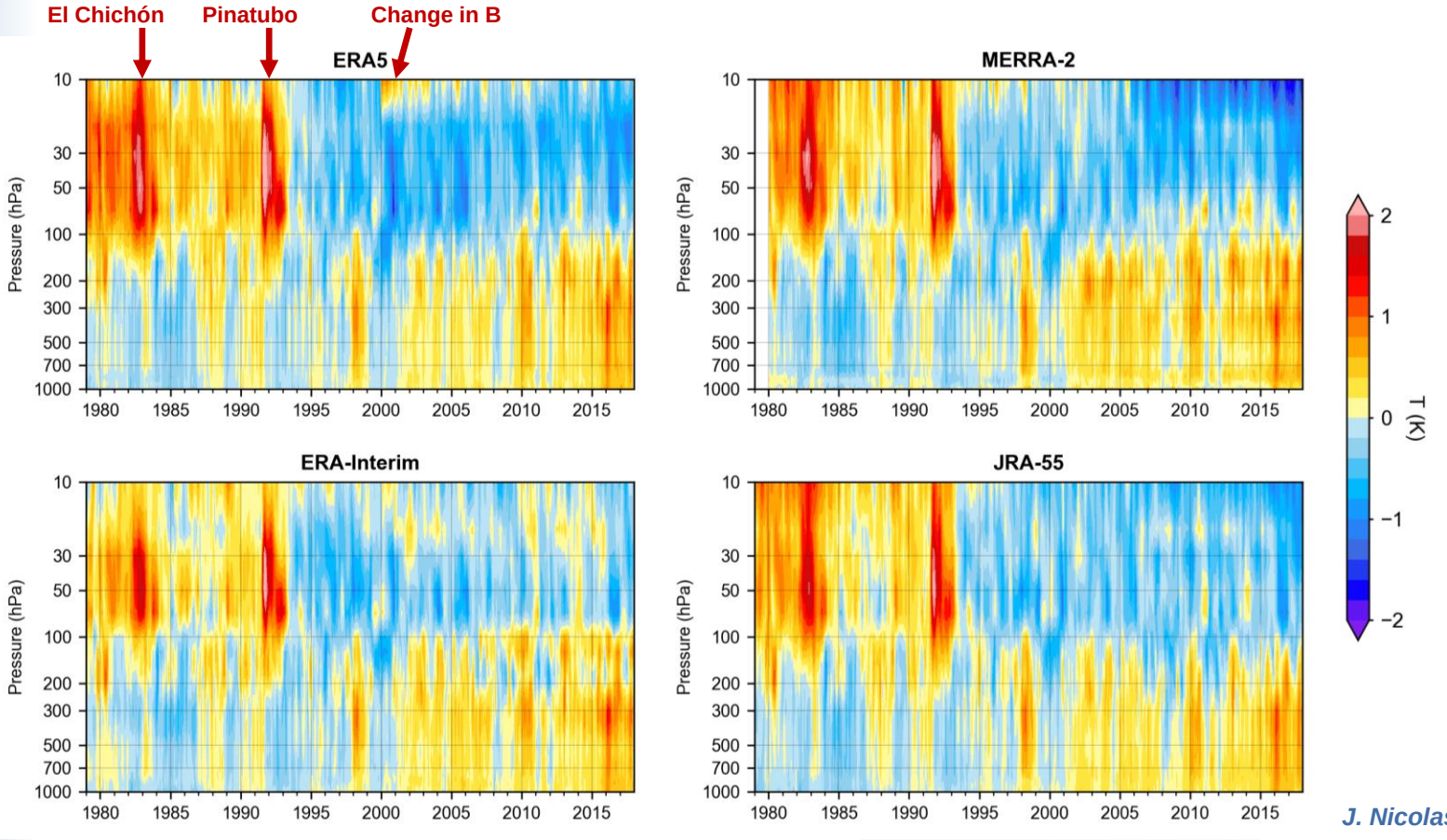
Global mean anomaly temperature compared to 1981-2010



J. Nicolas

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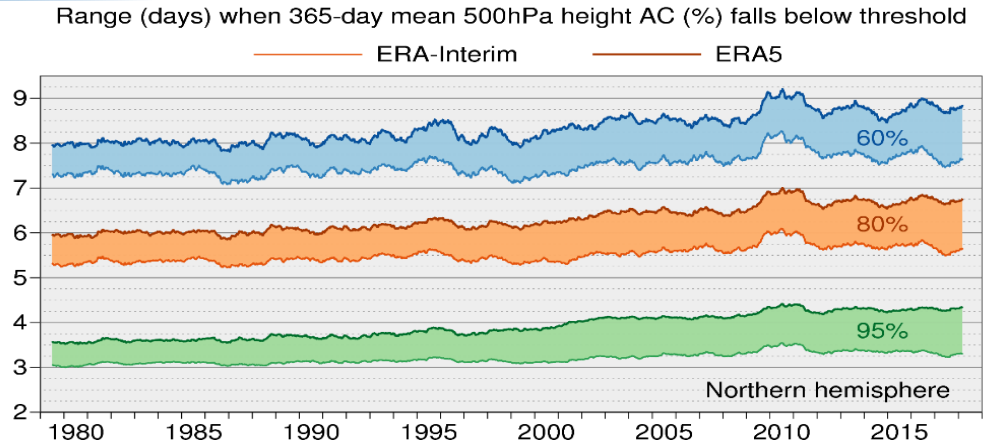
Skill from re-forecasts as a measure for the accuracy of reanalysis products



Re-forecasts from ERA5 have higher skill than those from ERA-Interim

The (forecast) model is an integral part of the assimilation system

Also: better analyses produce better forecasts

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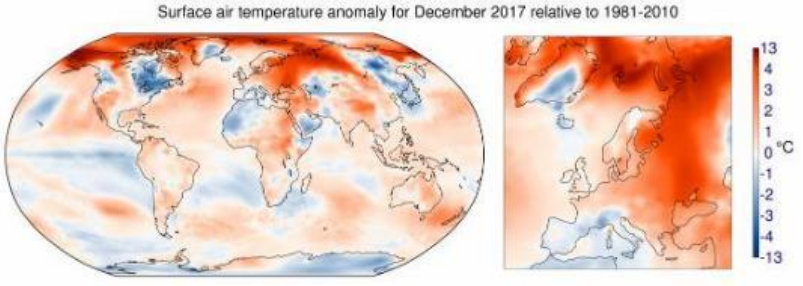
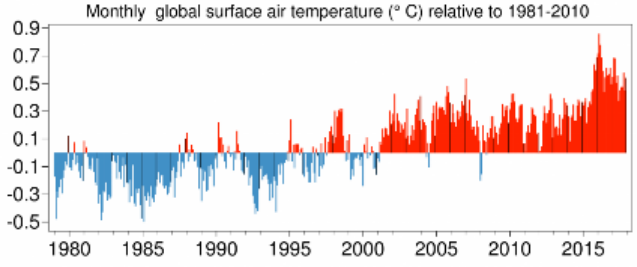
Monthly climate monitoring

The Copernicus Climate Change Service (C3S) includes in its product portfolio, reanalyses and a climate monitoring facility. These two products are being used to monitor the climate by providing monthly updates for several Essential Climate Variables (ECVs). The monthly updates are posted onto the Copernicus website (https://climate.Copernicus.eu/monthly-maps-and-charts) within a few days of the end of each month. In the future it will be extended, but currently the main source of content is the ERA-Interim global reanalysis.





Globally, the warmest and second warmest instances of each month of the year occurred between October 2015 and December 2017, with the warmest instances of each month of the year occurring from October 2015 to September 2016. Consequently, this latter period is the warmest twelve months on record and had a temperature 0.64°C above the average for 1981-2010. 2016 is by far the warmest calendar year on record: its global temperature of 0.62°C above average compares with the value of 0.53°C for 2017, the second warmest calendar year, and 0.44°C for 2015, the third warmest calendar year. The spread in the global averages from various temperature datasets has been unusually large in 2016 and 2017, and some datasets rank 2017 colder than 2015. The main reason for the spread stems from differences in the coverage of the polar regions and from differences in the estimates of sea-surface temperature. All datasets agree that the last three years were the warmest on record.

F. Vamborg

https://climate.copernicus.eu/climate-bulletins

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ERA5-Land, a high-resolution downscaling of the land-surface component

- Rerun of a single stand-alone simulation of the land component
- No data assimilation
- Uncoupled run with the atmosphere

- Physics of the IFS in cy45r1 (includes all modeling used in ERA-Interim/Land)
- Surface dynamical downscaling (allows capturing details associated to processes as topographic forcing)
- Daily lapse-rate correction
- Revision of soil thermal conductivity and water balance,
- Bug-fixes (rain over snow, infinitesimal fraction of convective rainfall, accumulation fluxes of CO2, etc.)
- Potential evapotranspiration fluxes bugged in ERA5, corrected in ERA5-Land and added to the catalogue,
- More customized data set for users in different economic sectors

J. Muñoz-Sabater

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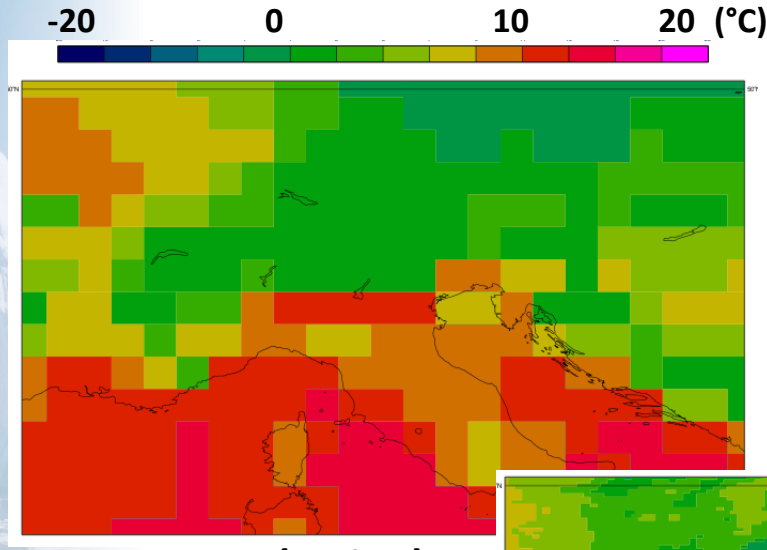
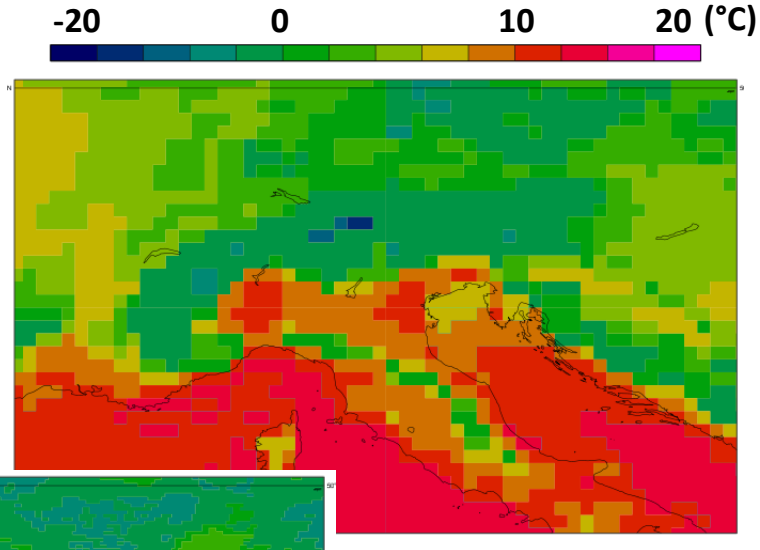
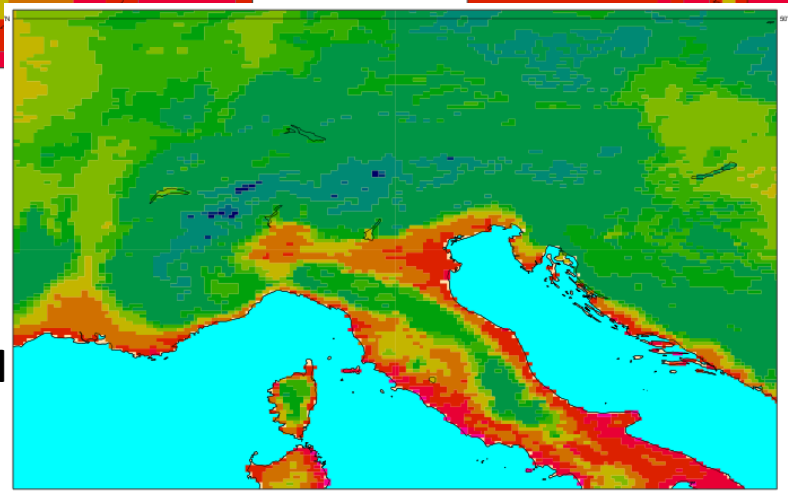
Add value of higher resolution; Soil Temperature (15 March 2010)



ERA-Interim (79 km)



ERA5 (31 km)



ERA5-Land (9 km)

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Status of ERA5 (and ERA5-Land)

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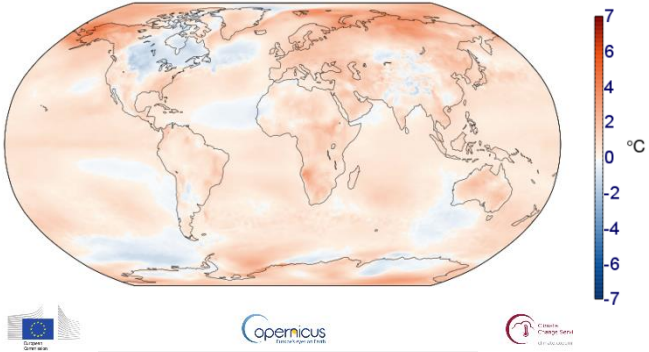
Full-observing-system global reanalysis for atmosphere, land and ocean waves.



T2m, **June 2018 - May 2019**
relative to 1981-2010

ERA5 is replacing ERA-Interim: end date ERA-I **31 August 2019**

To date ERA5 is publicly available from **Jan 1979 - May 2019**
(ERA5-Land from **Jan 2001 - March 2019)**

Improvements compared to ERA-Interim:

- Benefit from 10 years model development
- Much higher resolution; **31km** versus 79km
  (**9km** ERA5-Land)
- More and better input data
- Hourly output
- Uncertainty estimate (at 63km)

CDS Public Release plan for 2019/2020:

- **Currently:** updates 2-3 months behind real time
- **Available:** ERA5-Land from 2001 (9km)
- **soon:** updates 2-5 days behind real time: ERA5T
- 2nd release of ERA5-Land (1979-2000)
- **Next:** access to ERA5 observations
- **Early 2020:** 1950-1978.

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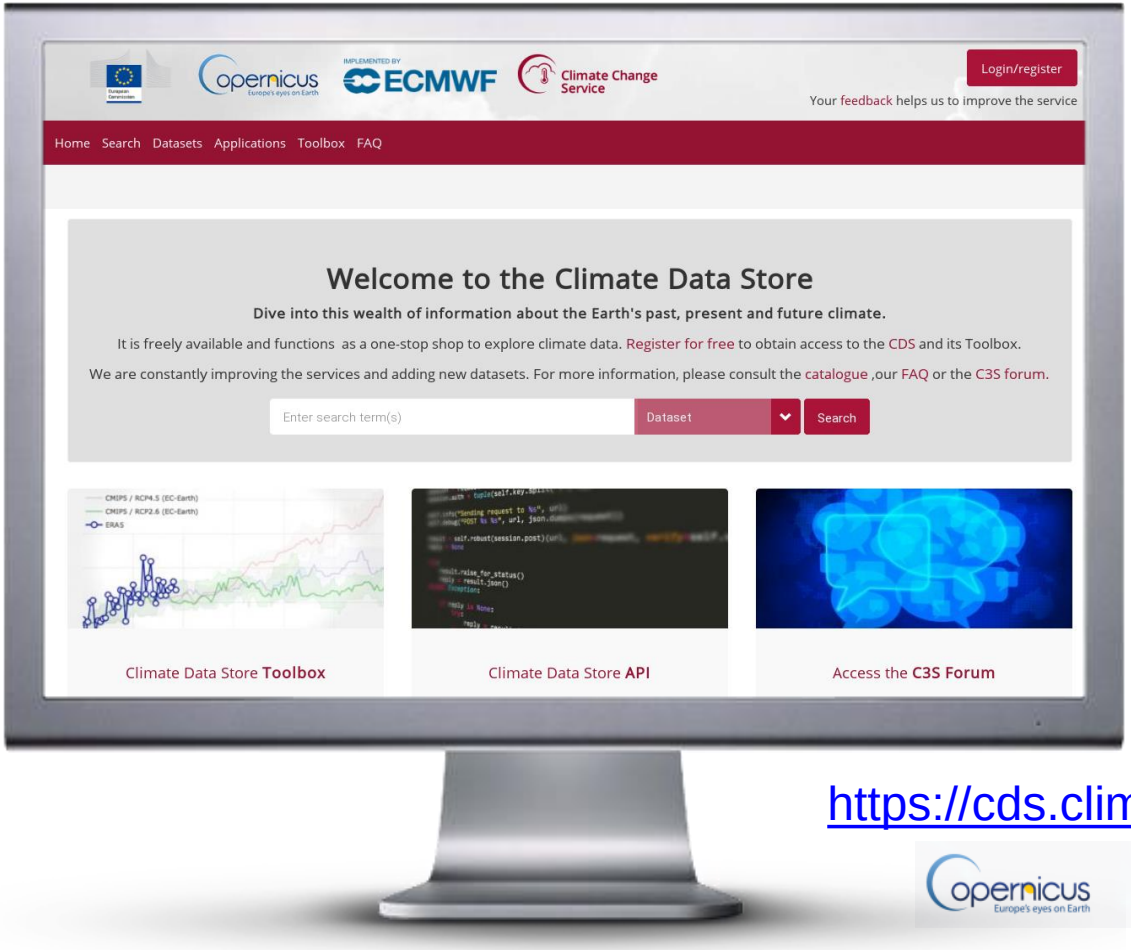
ERA5 in the Climate Data Store



https://cds.climate.copernicus.eu/

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Access ERA5 data and support

Online data sets:

- Regridded to regular lat-lon (ERA5: 0.25x0.25°, ERA5-Land: 0.1x0.1°)
- Pressure levels and single levels
- Hourly and monthly averages
- Simplified structure (best estimate)

Data on tape: ERA5 complete via CDS_API

User support (Copernicus-support@ecmwf.int)**:**

- Copernicus Knowledge Base portal: https://confluence.ecmwf.int/display/CKB/
- How to download data
- Online documentation
- C3S forum: https://confluence.ecmwf.int/display/CUSF/forum

References:

- ECMWF Newsletter (Spring 2019)
- ERA report
- Peer-reviewed: in preparation (2019)

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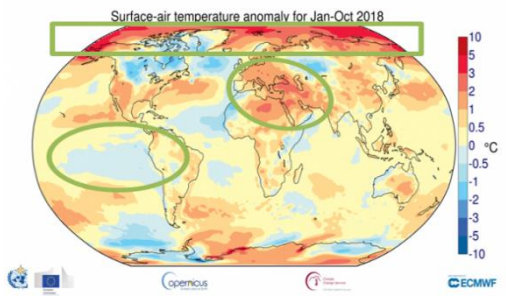
Final remarks and outlook

WMO climate statement: past 4 years warmest on record



Reanalysis provides a physically complete view of the recent climate.

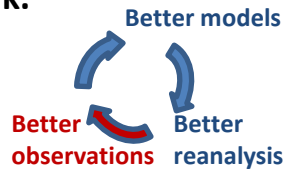
- Reanalysis is now fully integrated into international assessments of climate change as delivered by, for example, the WMO, and the European State of the Climate.

ERA5 is available from 1979 and is replacing ERA-Interim.

- Much higher resolution, better model, better and more observations
- The ensemble provides information on the evolving confidence of its products

The ongoing production of ERA5 is undertaken within the Copernicus C3S framework.

- At ECMWF as part of the C3S operational service
- Many reanalysis-related tasks are being carried out by C3S outsourced providers:
  - satellite reprocessing (EUMETSAT), data rescue, consolidation of historical datasets
  - the production of two high-resolution regional reanalyses, for Europe and the Arctic



The ERA5 data product portfolio is growing:

- Next: ERA5-Land 2nd release, timely updates 2 days behind real time, access to observation feedback, back extension to 1950
- Evolution of the CDS, increasing versatility of the toolbox, implementation of quality assurance stamps (EQC)

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THE END

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Climate data Store: https://cds.climate.copernicus.eu/

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