The new global reanalysis ERA5

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European Centre for Medium-Range Weather Forecasts (ECMWF)

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Overview

- Introduction: reanalysis in C3S
- ERA5 and its major improvements with respect to ERA-Interim
- Some aspects of the performance of ERA5
- Summary and conclusions

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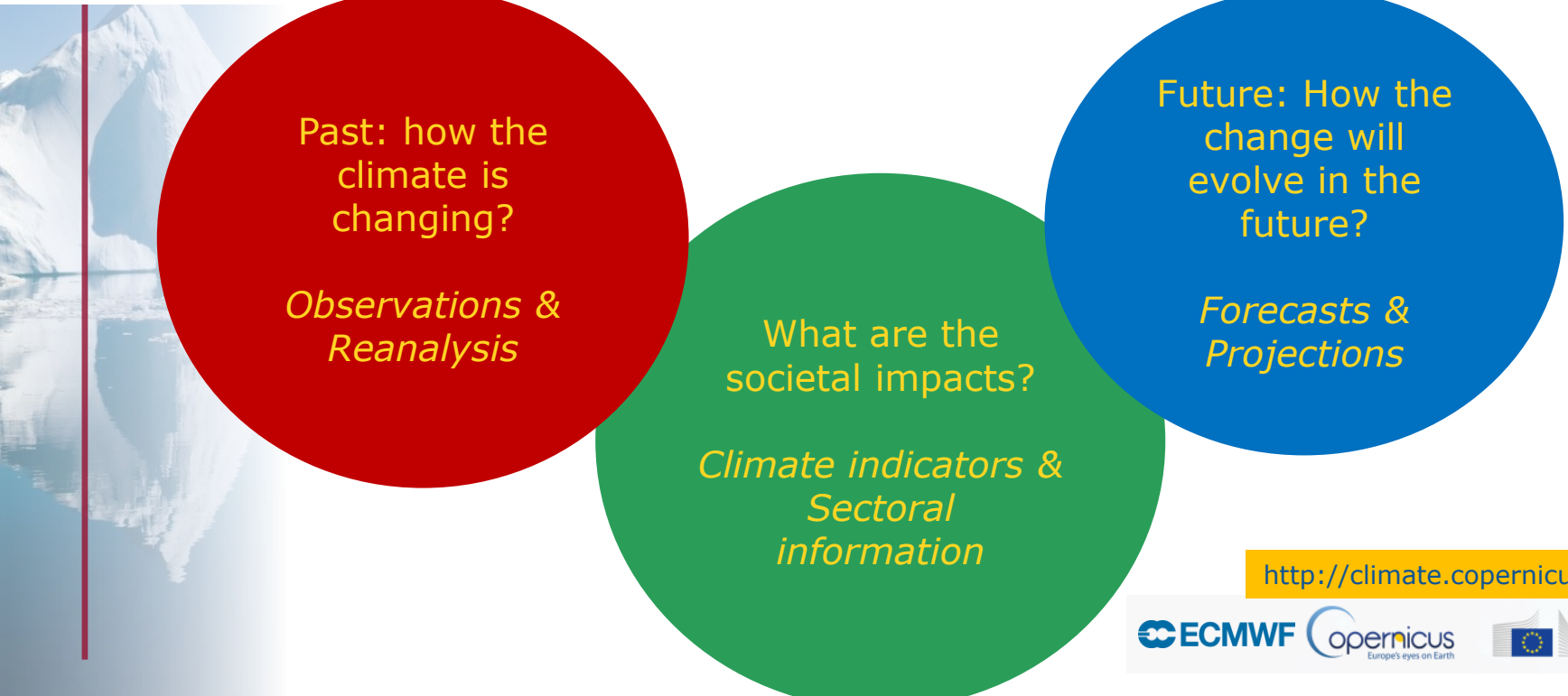
Copernicus Climate Change Service (C3S)

Aim: to be an authoritative source of climate information for Europe
(building on national investments and complement national climate service providers



http://climate.copernicus.eu/

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Content of the Climate Data Store

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Scientific basis:

- Essential Climate Variables as defined by GCOS
- GCOS Status Report (GCOS-195)
- **IPCC, CMIP**

Observations	Global estimates of ECVs from satellite and in-situ observations	Reprocessed CDRs, reference observations	Support for data rescue, climate data collections	Climate Indicators
Climate reanalysis	Global atmosphere, ocean, land	Regional reanalysis for Europe	Coupled climate reanalysis for 100 years	
Model output	Multi-model seasonal forecast products	Access to CMIP data and products	Reference set of climate projections for Europe	

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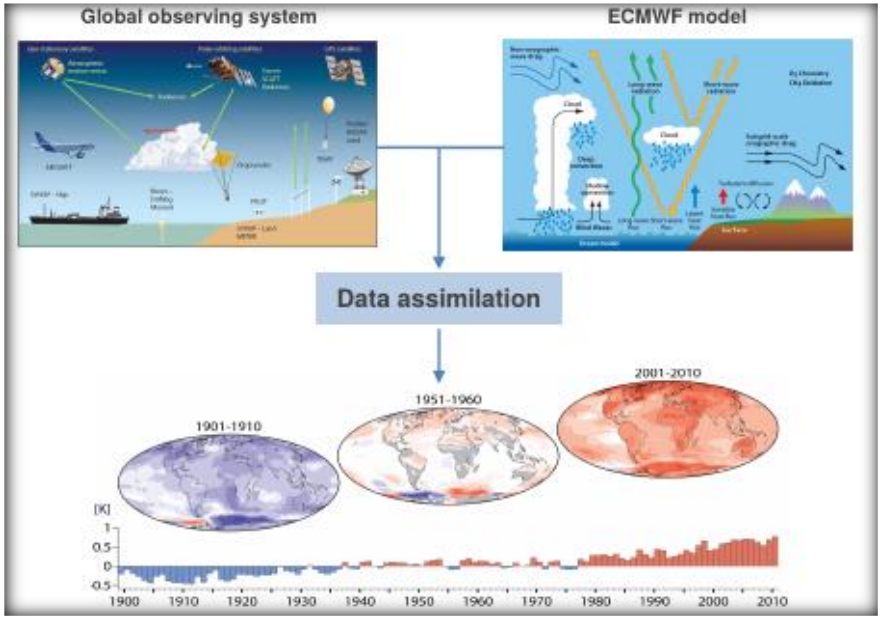
What is reanalysis?

Reanalysis offers a detailed overview of the past atmosphere (and other components of the climate system)

- **Complete**: combining vast amounts of observations (including reprocessed ones) into (global) fields
- **Consistent:** use the same physical model and data assimilation system throughout
- **State-of-the-art:** use the best available observations and model at highest feasible resolution
- ***Reanalysis allows for a close monitoring of the Earth's climate system also where direct observations are sparse***



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Global Climate Reanalysis Service: ERA5

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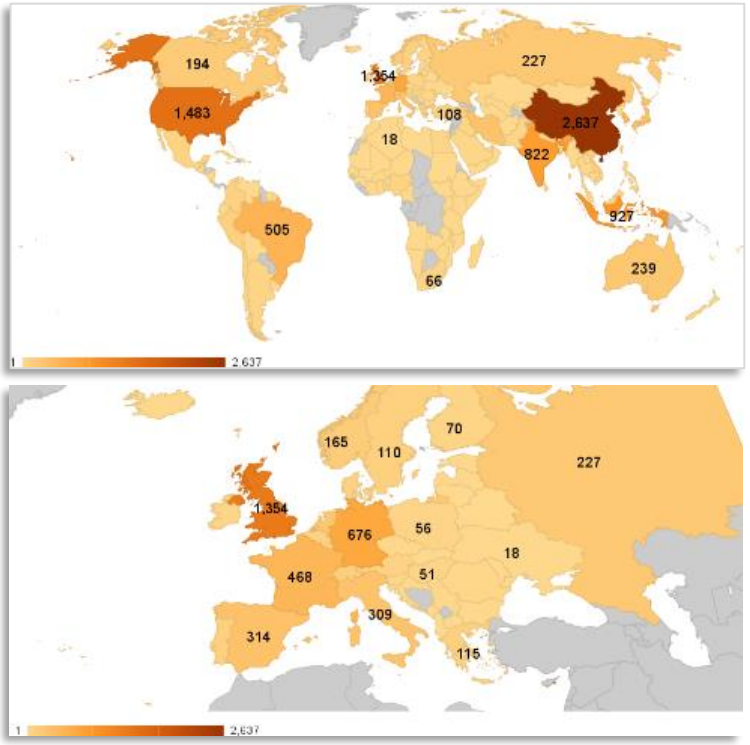
SO FAR: ERA-Interim: a success story

ERA-Interim had more than 33,000 unique users in 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., 2011, QJRMS)
- Public sector
- Space agencies
- Commercial applications

Unique registered users in 2016



However, ERA-Interim is more than 10 years old and needs replacement (on top of that the latest observations are not used) → a new reanalysis (ERA5) is needed!!

What is new in ERA5 (compared to ERA-Interim)?

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	ERA-Interim	ERA5
Period	1979 – present	Initially 1979 – present, ***then 1950-1978***
Streams	1979-1989, 1989-present	Parallel streams, one/two per decade
Assimilation system	2006, 4D-Var	***2016 ECMWF model cycle*** (41r2), 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, consistent 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		Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	***ERA5L, 9km*** (separate, forced by ERA5)
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 correction	Satellite radiances, radiosondes predetermined	Also ozone, aircraft, surface pressure, newly predetermined for radiosondes.

Newly 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

Data not used by ERA-Interim

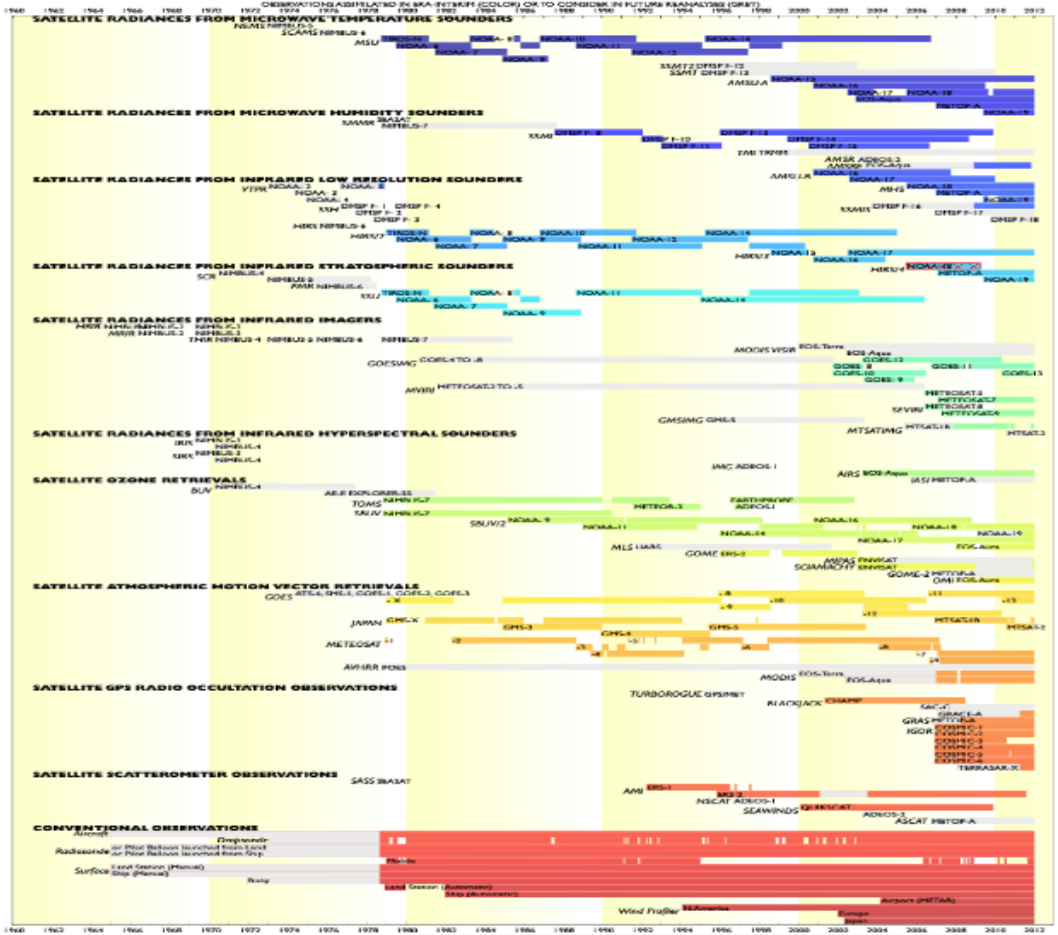
IASI, ASCAT, ATMS, Cris, Himawari, …

Typically the latest instruments:

ERA5 is more future proof!

and improved data usage

all-sky vs clear-sky assimilation,
latest radiative transfer function …



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Uncertainty estimation in ERA5

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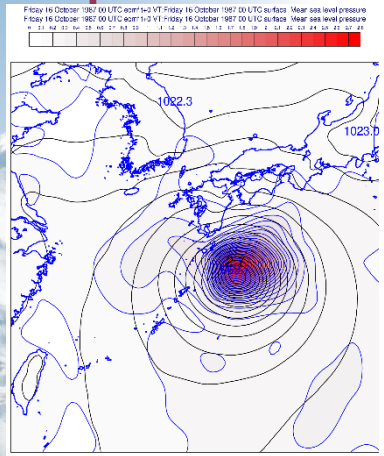
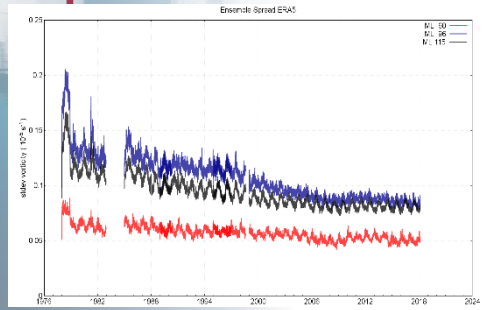
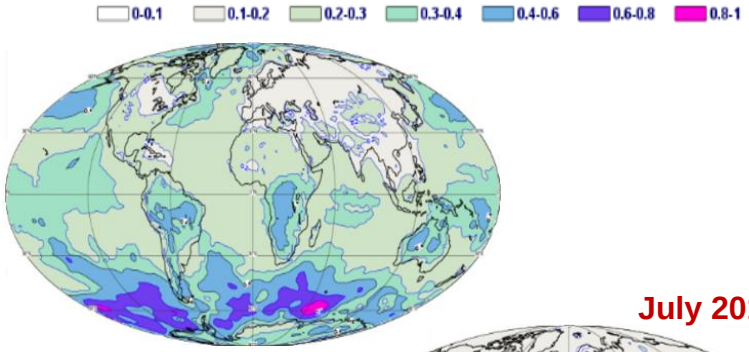
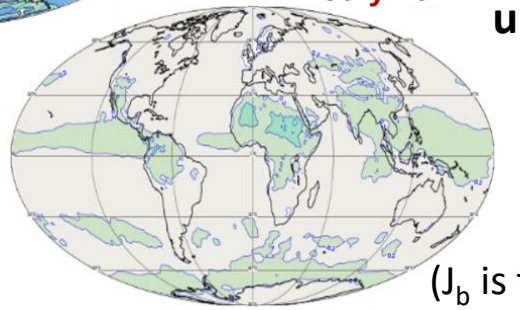




Spread in Surface Pressure (hPa)



January 1979



July 2014

- 10 member ensemble (EDA)
- Tailored for data assimilation background errors: (J_b in ERA5: 85% static, 15% from EDA)
- Ensemble spread and mean
- Spread indicates the relative uncertainty
  - in space and time
  - only accounts for random error (except SST)

(J_b is the background error covariance matrix)

Reflects variations in:

- ingested observing system
- flow-dependent sensitivity

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Additional Climate Reanalysis Data Access Tools are also available as part of the Climate Data Store

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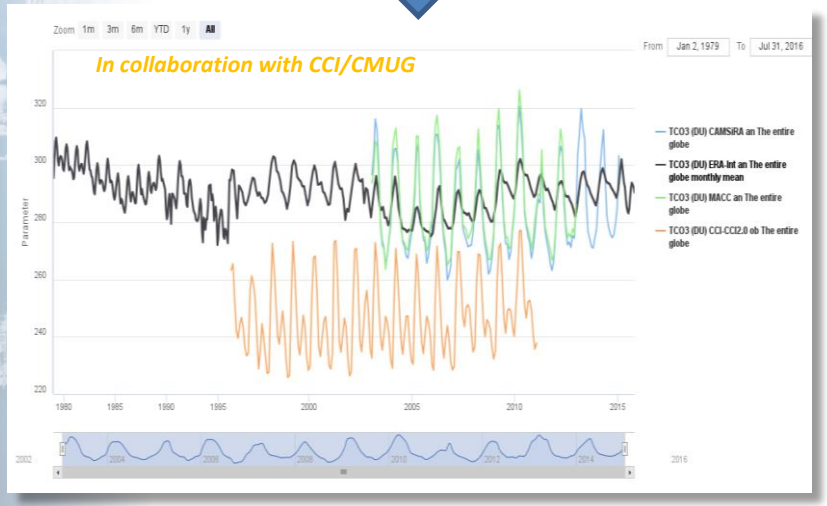
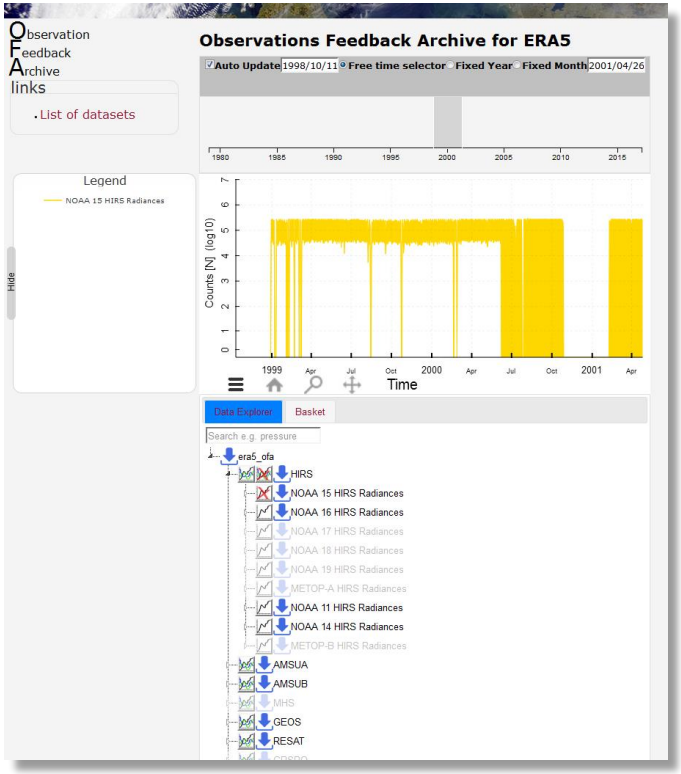
Observation Feedback Archive: Explore, select, plot and download observations used in ERA5

Climate Monitoring Facility: Explore, compare, plot Essential Climate Variables (ECV) estimates from multiple sources





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Monthly climate monitoring: climate.copernicus.eu

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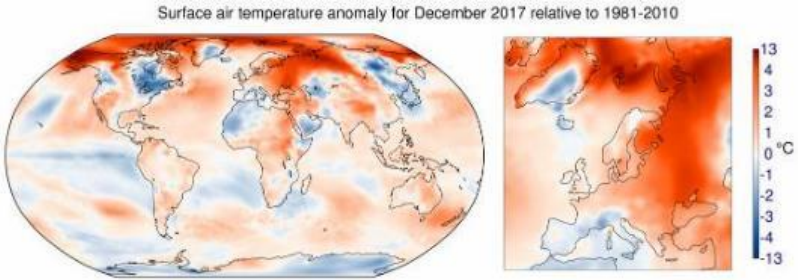
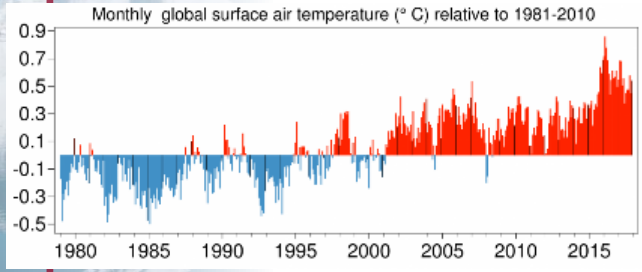
The Copernicus Climate Change Service (C3S) includes in its product portfolio, reanalyses and a climate monitoring facility. These two products are being used to monitor the climate by providing monthly updates for several Essential Climate Variables (ECVs). The monthly updates are posted onto the Copernicus 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.

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Status of ERA5 production

Parallel production streams:

Speed: 7-9 days/day per stream

'NRT': running 2-3 days behind real time

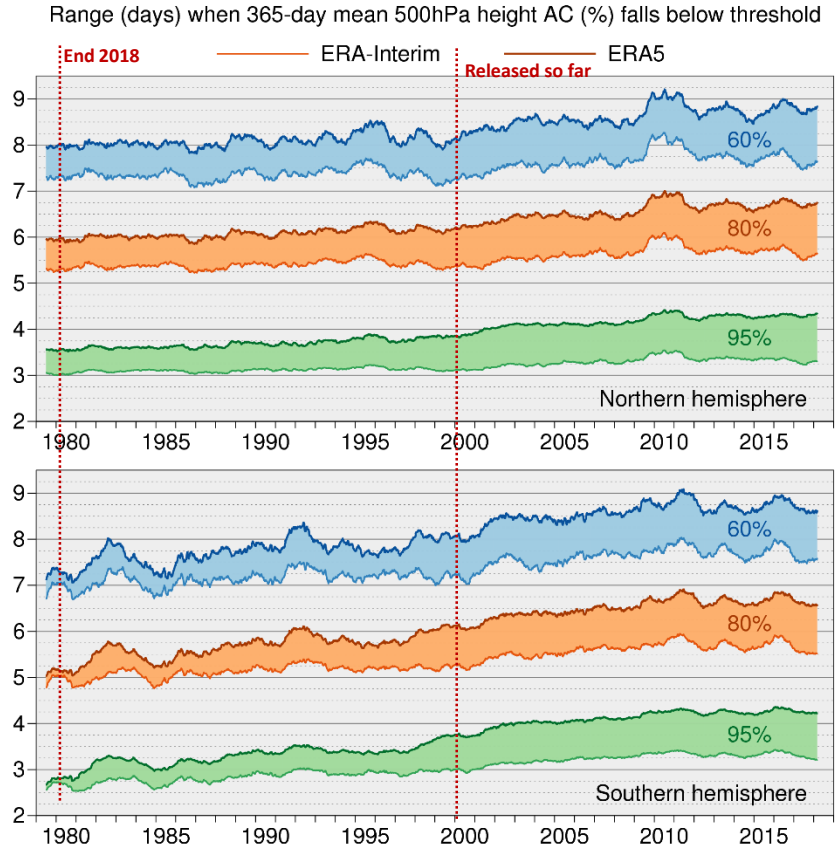
- *so far, released 2-3 months later*
- *Soon: released 1 week behind real time*

2000 onward has been released to date

1979-1999: to be available by end 2018

Back-extension from 1950: to be started soon

Integration ERA5 land has just started



Courtesy: Adrian Simmons

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Quality of ERA5: some snapshots

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ERA5: general evaluation

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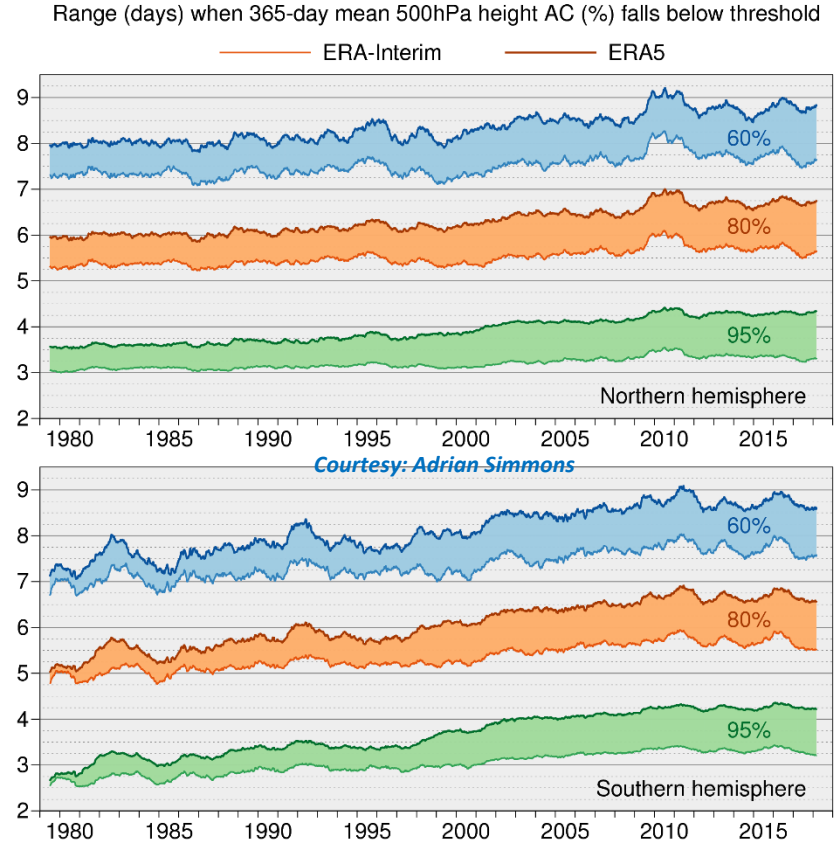
ERA5 and ERA-Interim, NH and SH: forecast range, where the mean 500 hPa geopotential height anomaly correlation falls below a given (60%, 80% and 95%) threshold



Some remarks:

1. The score evolution is quite „flat" showing that the system is consistent (unchanged) and the improvements are coming only from improvements in the Global Observing System.
2. The improvement is in the order of 1 day/40 years instead of the 1 day/decade improvement of the ECMWF operational system.
3. There is a robust „1 day" predictability improvement of ERA5 with respect to ERA-Interim particularly at the NH (it is consistent with the fact that ERA5 is 10 years younger than ERA-Interim).
4. The gap between ERA5 and ERA-Interim is increasing.
5. Though in 1979 at Southern Hemisphere ERA5 and ERA-Interim are very similar (no satellite data).
6. There are similar predictability „highs" and „lows" in the two systems (see particularly around 2010).

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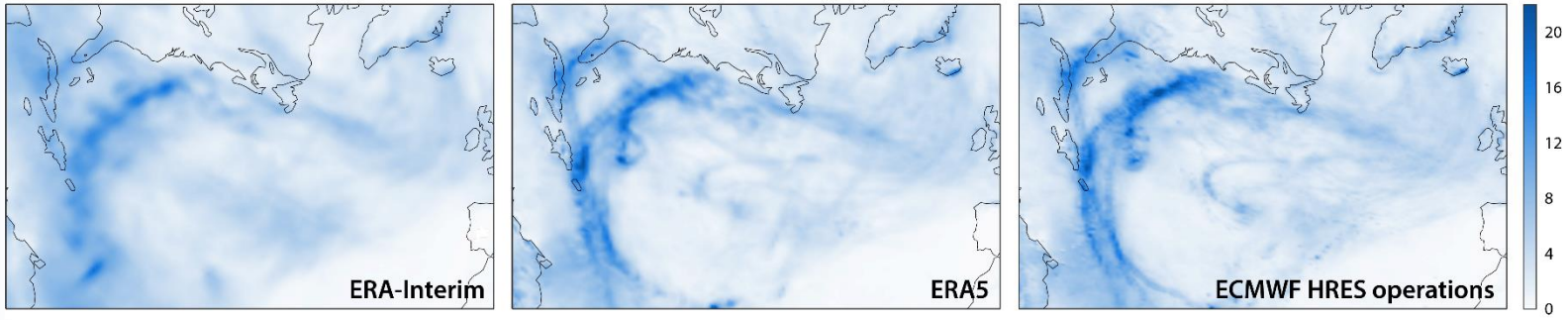
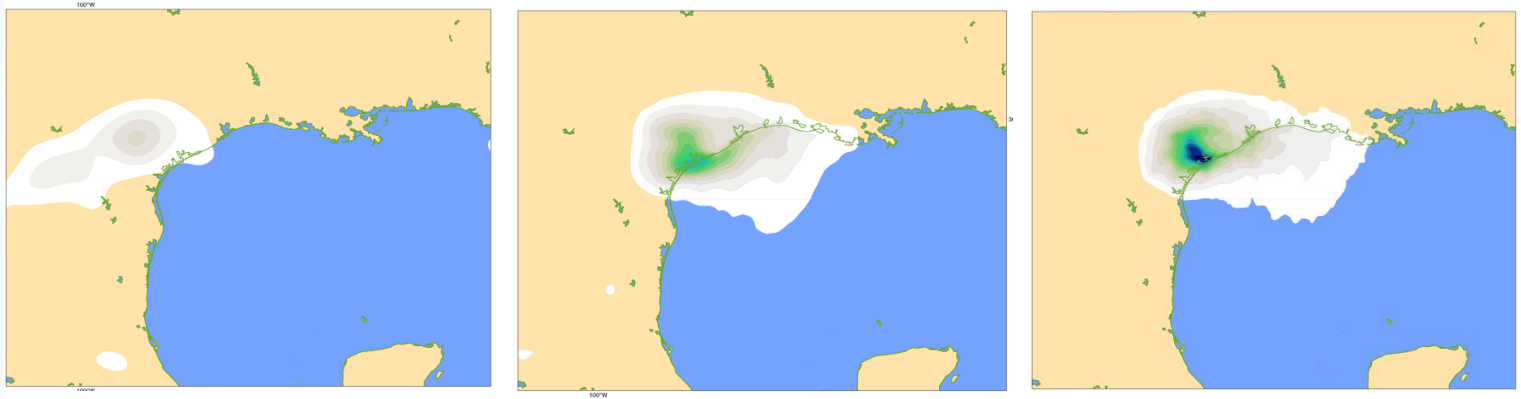
Horizontal resolution and depiction of tropical cyclones

Mean precipitation rate (mm/day) for September 2017



Horizontal resolutions: ~80km ~30km ~10km

5-day precipitation for Harvey



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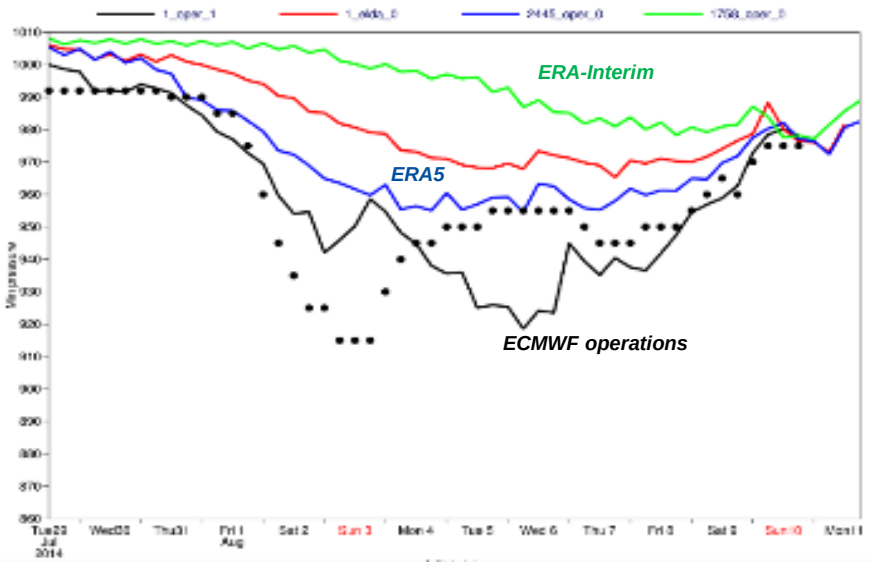
Tropical cyclone Halong



Tropical cyclone "Halong" (Aug, 2014): evolution of the minimum pressure
OPER, ERA5, EDA, ERA-INTERIM

→ much improved with respect to ERA-Interim
→ but slightly less good than operations

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Evolution of global mean surface temperature (wrt 1981-2010)

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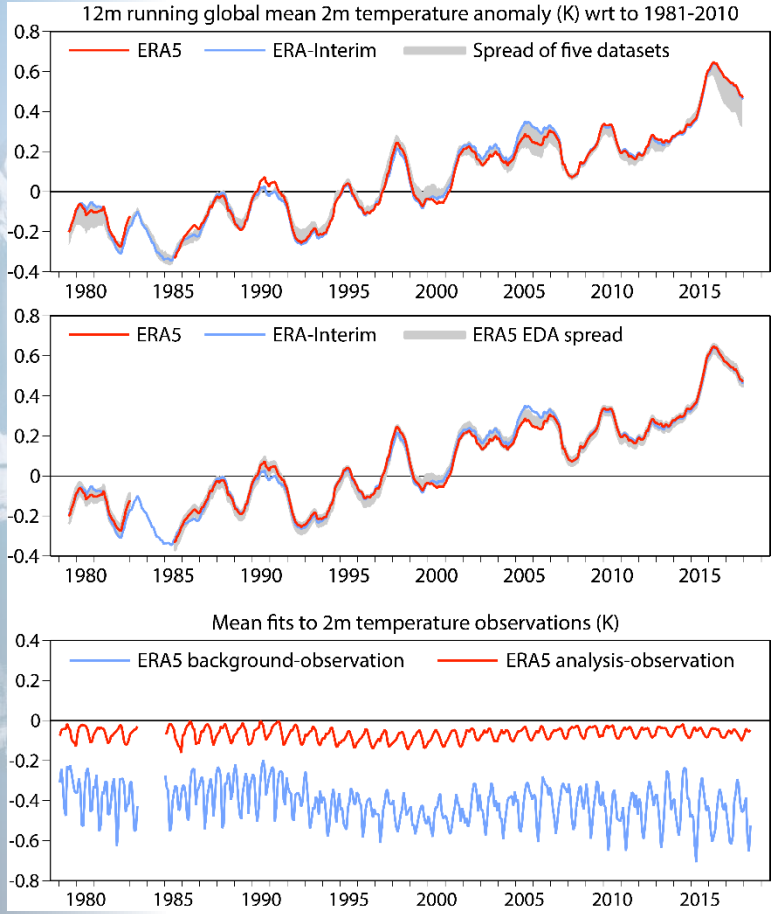

1. **The overall global temperature increase is very similar to ERA-Interim and ERA5**
2. **More uncertainty with respect to external datasets particularly for the periods around 1980, 2005 and the last few years (in EDA it is mostly around 2005)**
3. **Generally speaking the EDA spread is small**
4. **Good fit to observations with a small cold bias**

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Final remarks

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Summary and final remarks

ERA-Interim will be replaced by ERA5 very soon (and ERA-Interim will be stopped latest at the end of 2019)

As part of the Copernicus Climate Change Service:

- ERA5 has: 31km global resolution, from 1950, hourly output, uncertainty estimate.
- **At the moment ERA5 2000-2017 is publicly available**
- Release of other periods will be done in stages and data will be available via the **Climate Data Store**.
- By end 2018: 1979 onwards.
- Also: C3S User service Desk, Knowledge Base, FAQ's, user support

The performance of ERA5 is very promising particularly in the troposphere.

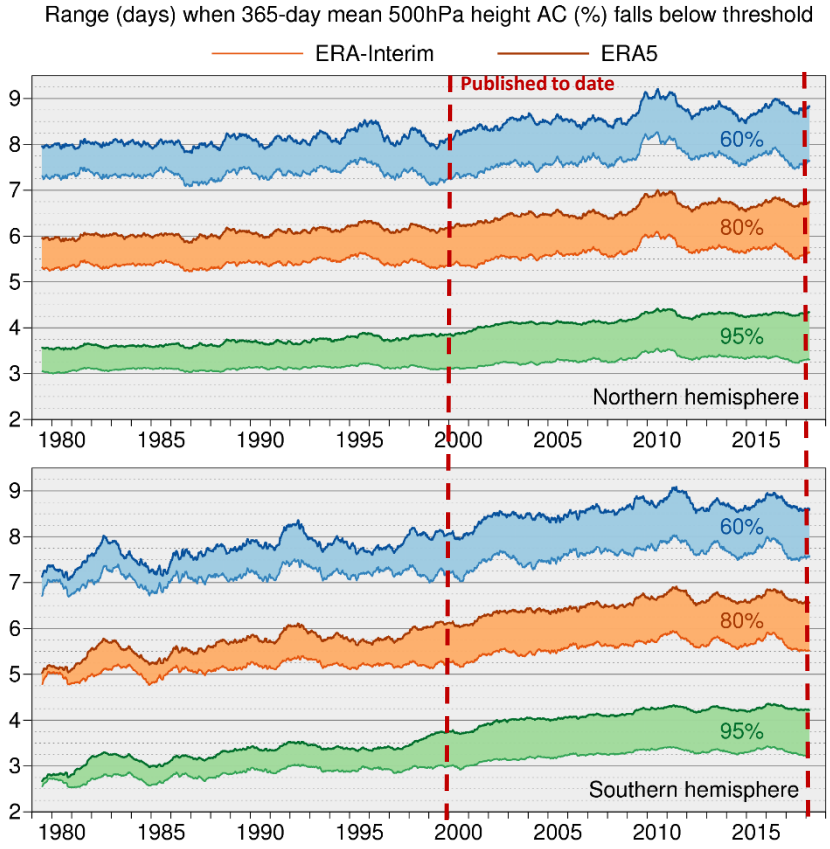
- improved global hydrological and mass balance
- reduced biases in precipitation,
- refinement of the variability and trends of surface air temperature.

In parallel, at ECMWF reanalysis activities are focused towards a coupled Earth system

- Benefit to reanalysis (ERA6)
- and the ECMWF system as a whole

Next reanalyses:

- Coupled Earth system reanalysis
- Centennial reanalysis around 2021
- ERA6 for the satellite era around 2023



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