The ERA5 reanalysis: a detailed record of the climate and weather for the past 70 years

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Raluca Radu,

and many others

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Overview

- Overview of ERA5
- Observations used in the back extension
- One synoptic case for the back extension
- The ERA5 extended climate
- Towards an improved version of the back extension
- Plans for ERA6, the next C3S global reanalysis
- Summary

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C3S Global Reanalysis: ERA5 and its back extension

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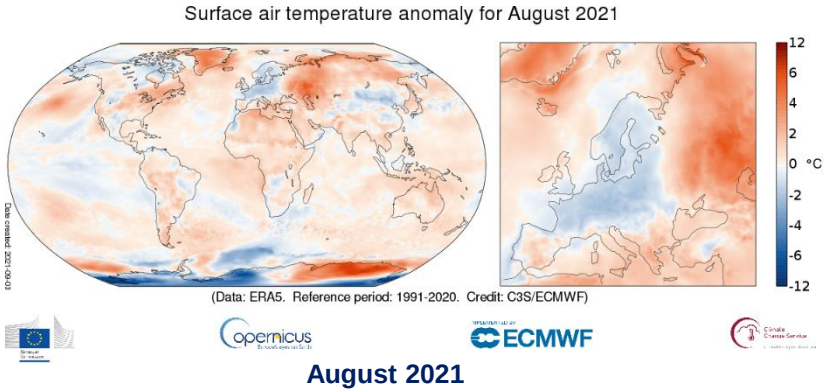
ERA5: *A full-observing-system global reanalysis for the atmosphere, land surface and ocean waves*

- Daily updates **5 days behind real time from 1979 onwards**
- **59,000 users; order of 400 Tb weekly downloads**
- Hourly snapshots at 31km resolution up to about 80km height
- Uncertainty estimate from a 10-member ensemble at reduced resolution
- About 100 billion observations have been used so far



ERA5.1: stratosphere 2000-2006

Improves on the mean state in the stratosphere

Access via the C3S Climate Data Store (CDS)

- **Fast:** on spinning disk (around 1.8 petabyte; not ERA5.1)
- **Slow:** ERA5-complete on tape (MARS, around 10 petabyte)

ERA5 Back extension: 1950 - 1978

Has in general good characteristics, suitable for many users
However sub-optimal for tropical cyclones (extremes)

Made available in the CDS as a separate, preliminary dataset
The production of the improved version is well underway

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Observations used in the ERA5 back extension (1950-1978), Bell et.al., 2021, accepted

1950: around 53,000 per day
1978: around 570,000 per day
2021: around 26 million per day

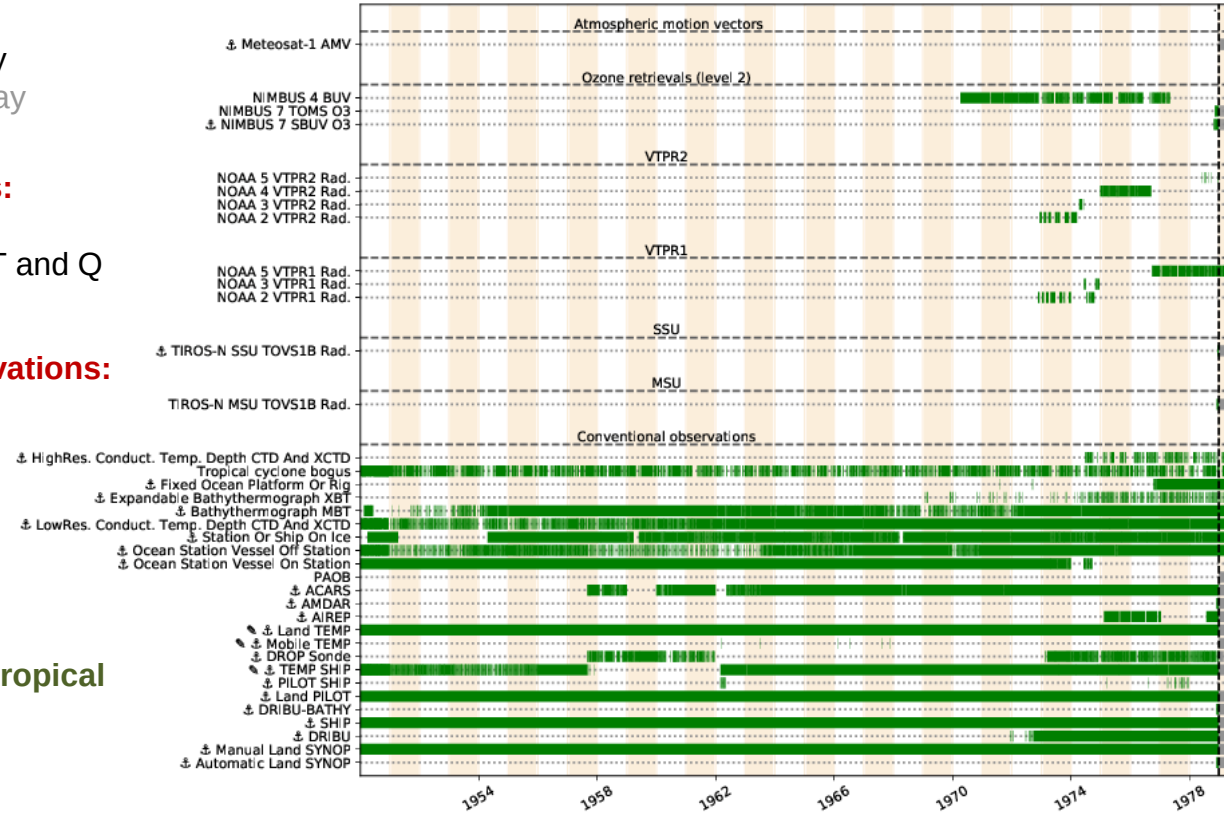
Some satellite observations:
BUV: partial column ozone
VTPR: sensitive to upper-air T and Q

Lots of conventional observations:
Including from extra sources

Upper air:
weather balloons, aircraft:
T, U/V, Q

Surface:
Land, ship, buoy, IBTrACS tropical cyclone bogus:
Ps, 10m wind, Rh2m,
T2m, snow depth

No wave-height observations



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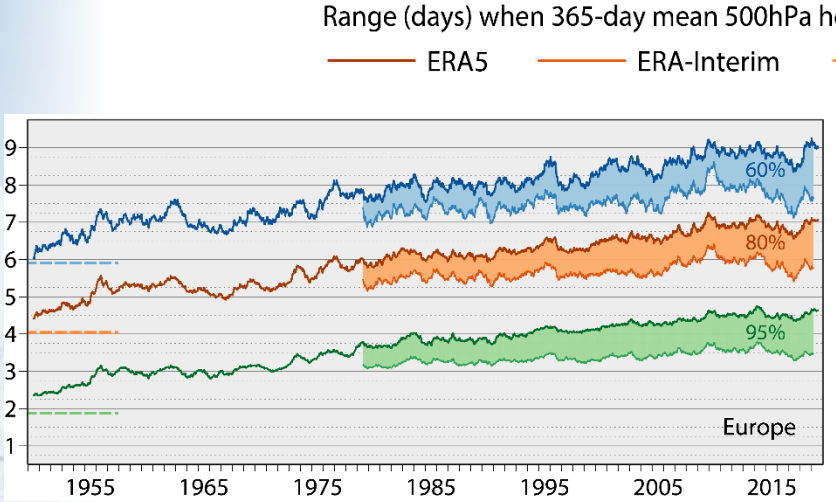
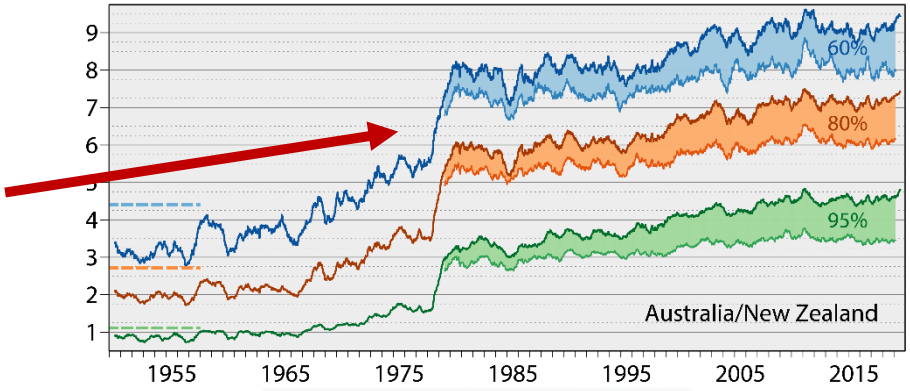
And the quality of re-forecasts issued from reanalysis evolves accordingly



ERA5 back extension:
NHEM (especially Europe) skill is promising, Thanks to radiosondes and many surface observations.

Over SHEM there is a dramatic improvement following the introduction of TOVS satellite data in late 1978.



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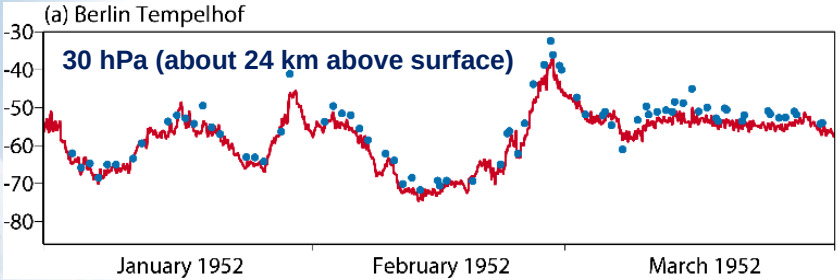
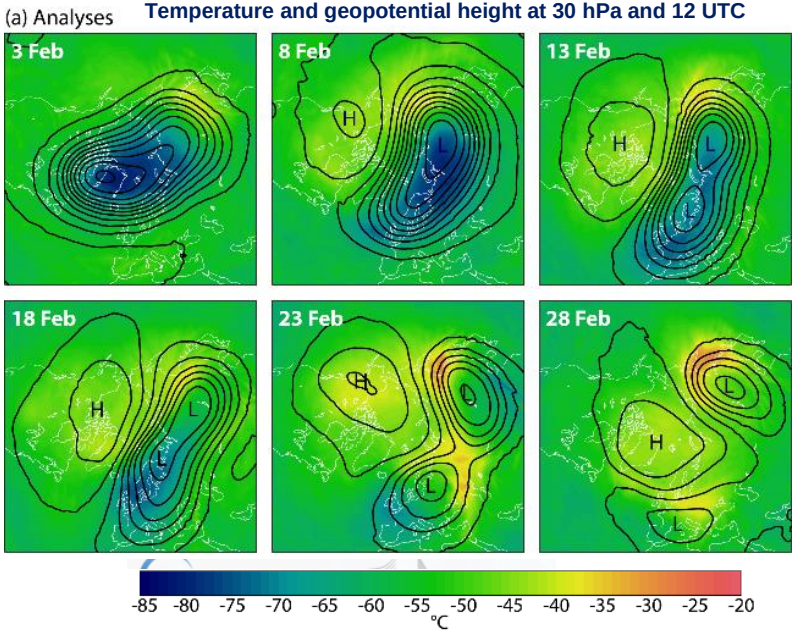
Stratospheric Sudden Warming, February 1952



The discovery of the stratospheric sudden warming phenomenon, was made by Scherhag (1952) by studying radiosonde ascents from Tempelhof Airport, Berlin, many of which were assimilated by ERA5.

In addition, ERA5 shows the full three-dimensional picture of the related split of the stratospheric polar vortex.



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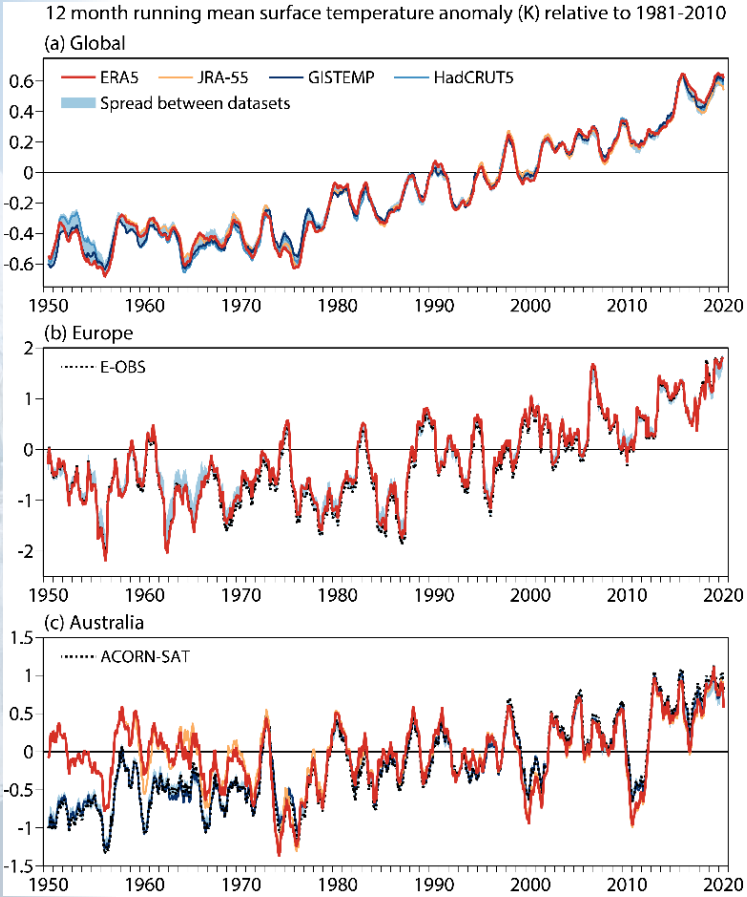
Climate change: evolution of 2m temperature and comparison with other datasets



Temperature trends:

- The global mean temperature shows little trend from 1950 to the mid 1970s.
- After that global warming becomes clearly visible with a global trend of around
  - 0.18 K/decade for 1981-2010
  - 0.24 K/decade for 1991-2020

Consistency between datasets:

- reanalyses and more direct observation-based datasets.

- In general, quite good and reassuring,
  - especially over Europe,
- However, there are some discrepancies,
  - especially over Australia

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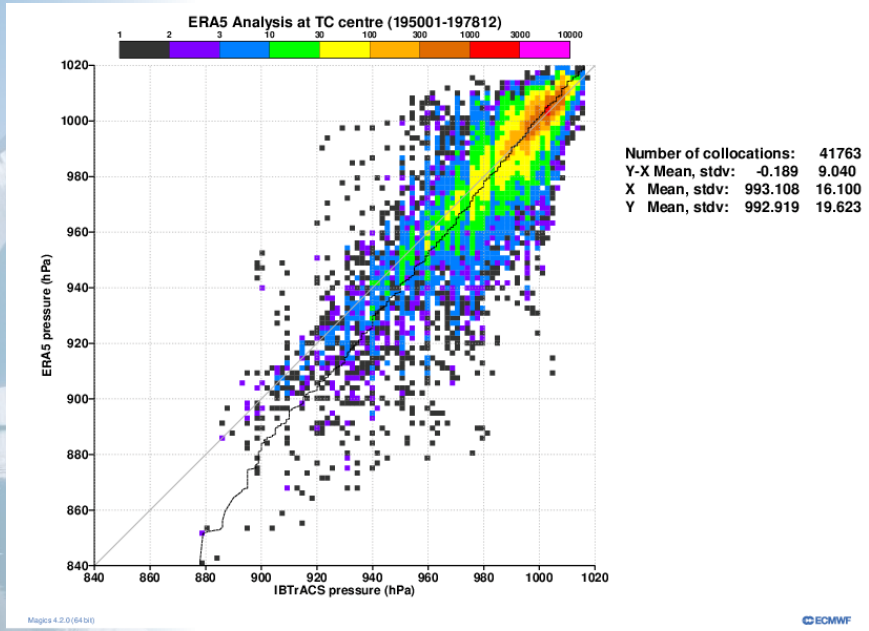
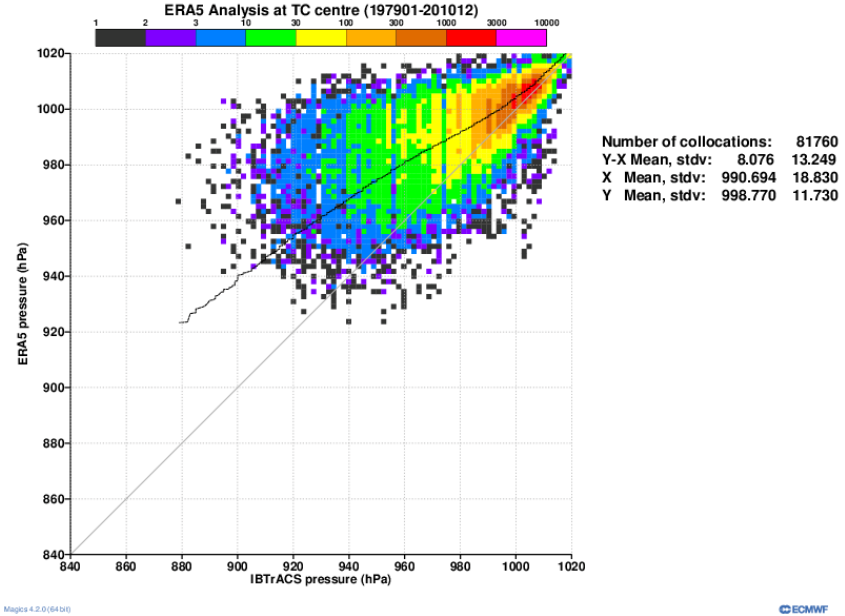
IBTrACS bogus observations were overfitted in the preliminary ERA5 back extension.





Back extension: No QC, no VarQC, high weight

Lowest pressure 840 hPa
Ocean waves up to 31 meters!

IBTrACS are not assimilated from 1979 onwards

Ocean waves up to 20 meters.

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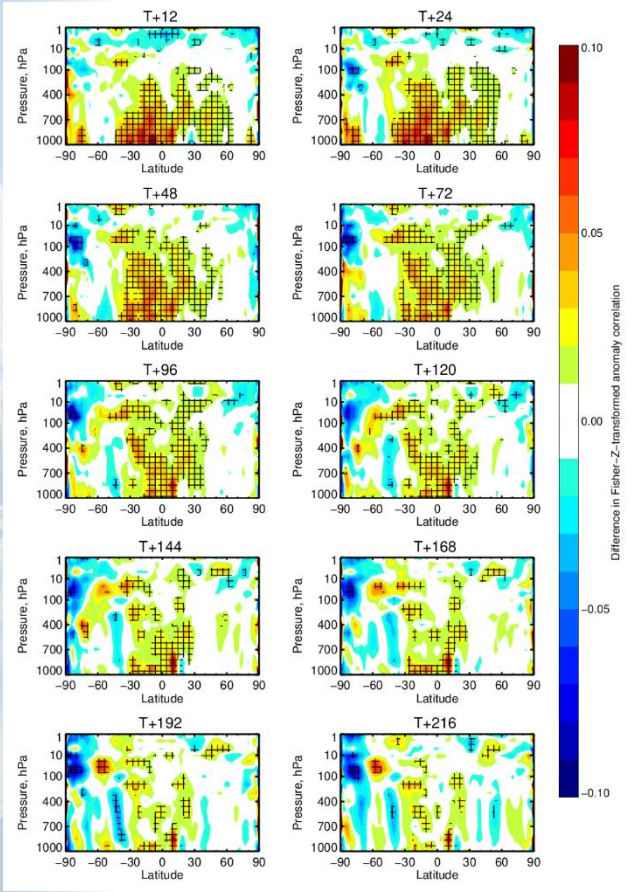
Development work for the improved back extension



ACC Temperature: **Better** **Worse**

The assimilation of IBTrACS was made safer:

- ✓ Reintroduce the Huber VarQC norm
- ✓ Reintroduce the first-guess check
- ✓ Retune obs weight from 0.78 hPa to 2.0 hPa
- ✓ Introduce cap at 910 hPa

A bug in VarBC for surface pressure that had been fixed half-way is now in place throughout

The new production streams start from the well-spun up preliminary product

- ✓ Smaller jumps in soil moisture and stratospheric humidity

A test run (Jan 1967- Mar 1968) showed many improvements:

- ✓ No more over-assimilation of TC's
- ✓ Significantly better forecast skill
- ✓ More observations used plus better departure statistics

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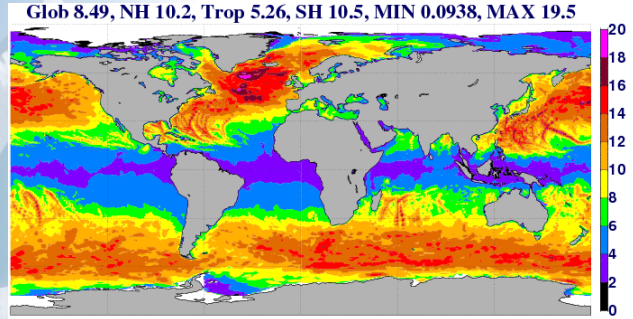
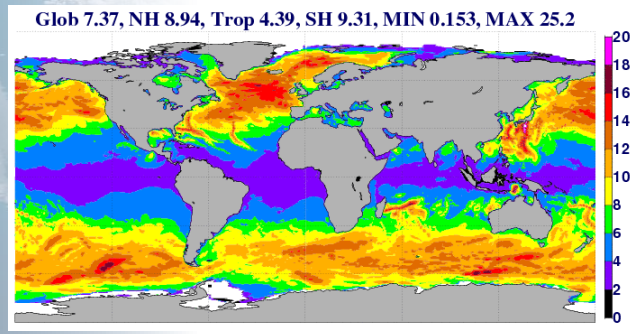
Ultimate stress test: the local maximum of all significant wave heights

Final version

Released data from 1979-2010

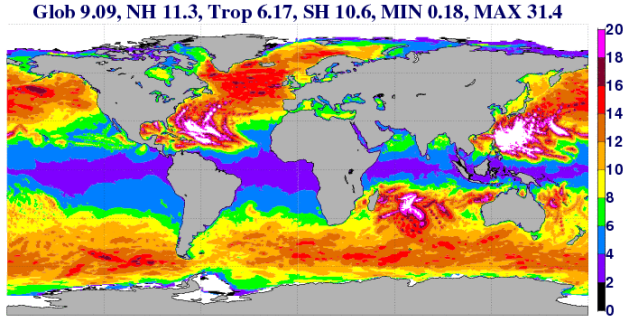


New product (not public yet), 134 months so far

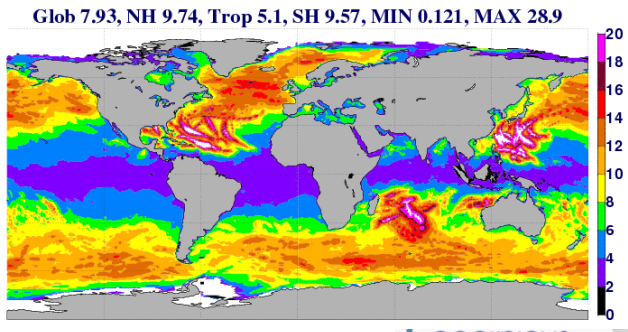


Preliminary version

Preliminary product 1950-1978



Preliminary product, same 134 months



The new back extension is much more in line with the released ERA5 version from 1979 onwards

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Preparations for ERA6

Start production of **ERA6** in 2024

- Higher resolution (TBC), from 1950 or earlier

- Coupled with the ocean, based on the latest IFS cycle:
  additional 8 years of ECMWF R&D like improved stratosphere, new ozone model, etc.

- Improved observations from our C3S providers:
  - Reprocessed (EUMETSAT) and newly-rescued satellite data (see presentation by Bill Bell later today)
  - In-situ observations

ERA5 is to be maintained into the late 2020s

In addition we aim for **improvement of the following methodologies**:

- Self-updating static part of the background error covariance matrix
- Counteract on model error by using weak-constraint 4D-Var retrospectively
- Improve the uncertainty estimate, in particular for the mean state.

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Summary

The **ERA5** reanalysis provides hourly snapshots of the atmosphere, land surface and ocean waves for over 70 years

- Very popular dataset, including ERA5-Land (see presentation by Joaquin Munoz-Sabater later today)
- Compared to ERA-Interim: much higher resolution, in general better performance

- There are, of course several known issues (see ERA5 online documentation, or ERA5 paper)
- Questions/feedback: https://climate.copernicus.eu/help-and-support

In many ways the **ERA5 back extension** is a high-quality product and suits many users,

- However, the analysis of tropical cyclones was sub optimal
- The production of an improved version is well underway
- 1959-1978 first, then 1940-1958

Further reading:

- The ERA5 journal paper (Hersbach et. al, 2020 in QJRMS)
- Bell et. al, accepted in QJRMS: the ERA5 back extension paper
- The ERA5 online documentation
- Simmons et. al, 2020: Global stratospheric temperature bias and other stratospheric aspects of ERA5 and ERA5.1
- Simmons et. al, 2021: on ERA5 surface temperature and humidity
- Many, many journal papers.