



Climate Change

News from C3S : ERA5

Climate Change Service

Hans Hersbach, ECMWF,
and many, many colleagues





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Overview

- Rationale behind reanalysis
- Overview of ECMWF reanalysis products
- Copernicus Climate Change Service (C3S)
- ERA5, the follow up of ERA-Interim
public release of segment 2010-2016 is coming soon
- Concluding remarks

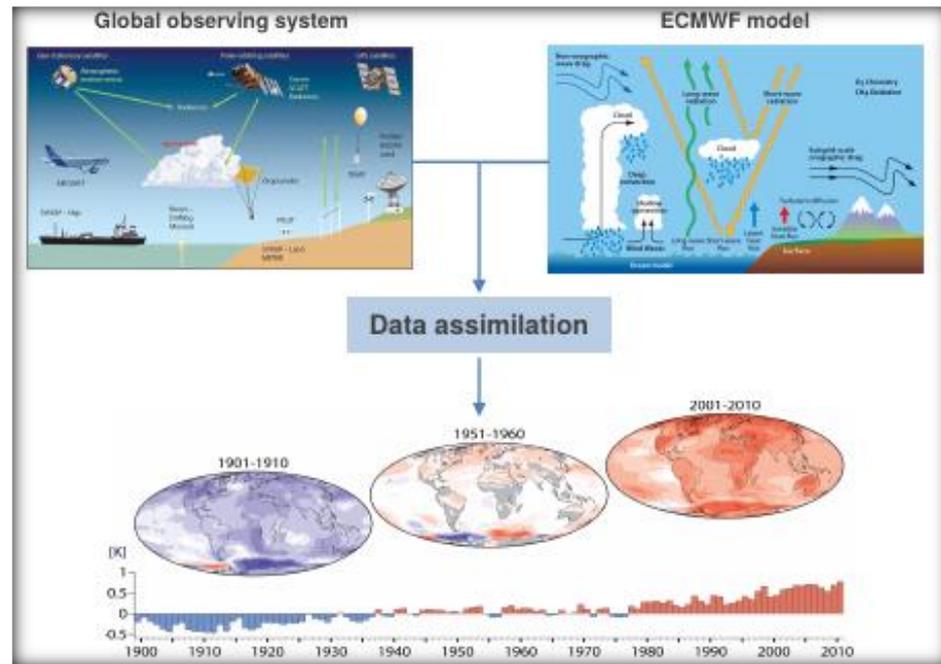


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Why Reanalysis?

Reanalysis offers a detailed overview of the past atmosphere

- **Complete:** combining vast amounts of observations into global fields
- **Consistent:** use the same physical model and DA 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 (e.g. rising Arctic surface temperature)*
- **ERA5** will provide a large number of essential climate variables within the C3S Climate Data Store





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Reanalyses Produced at ECMWF

Atmosphere/land

including ocean waves

1) 1979 - 1981
FGGE

2) 1994 - 1996
ERA-15

3) 2001 - 2003
ERA-40

4) 2006 - ...
ERA-Interim

5) 2016 - ...
ERA5

Ocean

including sea ice

2006
ORAS3

2010 - ...
ORAS4

2016 - ...
ORAS5



Centennial

2013 - 2015
ERA-20CM/20C

2016
CERA-20C

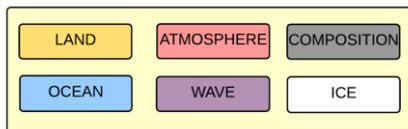
Enhanced land

2012
ERA-Int/Land

2014
ERA-20C/Land

2017 - ...
ERA5L

Towards a coupled earth system



Atmospheric composition

2008 - 2009
GEMS

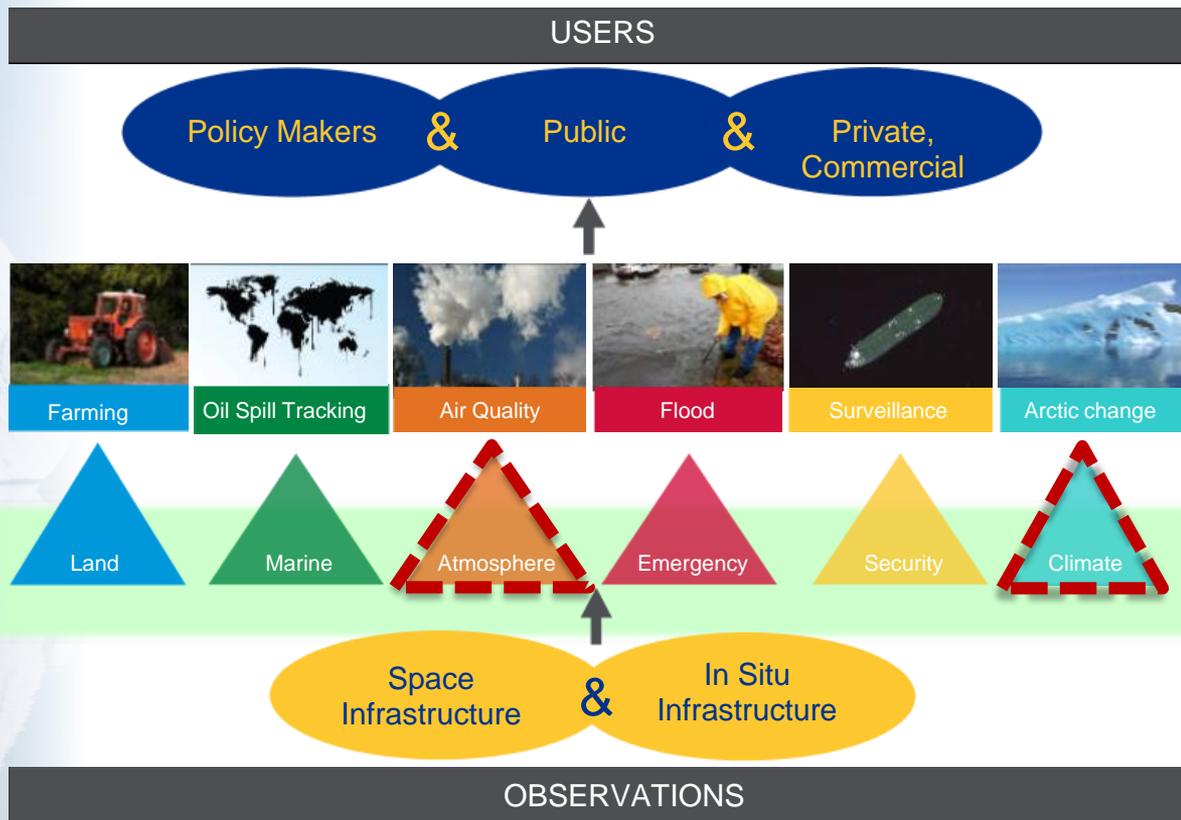
2010 - 2011
MACC

2017 - ...
CAMS



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Copernicus Services



Different Needs

Examples of areas covered

6 Information Services

Sustainable observation capabilities

ECMWF operates the *Copernicus Climate Change Service (C3S)* and *Copernicus Atmosphere Monitoring Service (CAMS)* on behalf of the European Commission.





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Climate Change Service: Vision

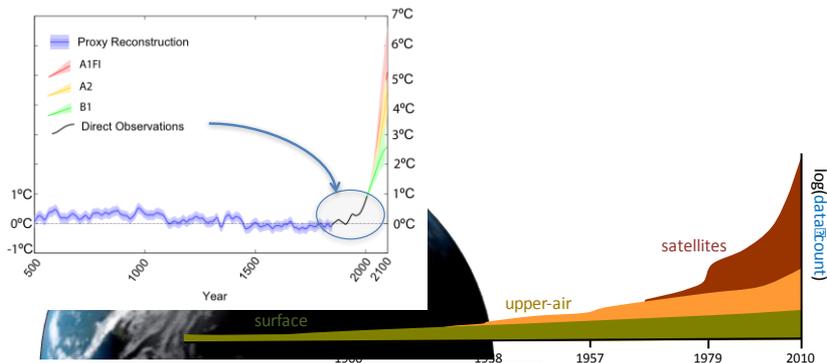
- Be an authoritative source of climate information for Europe
- Build upon massive European investments in science and technology
- Service
- Enable the market for climate services



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Climate Change Service: Solutions

Global Temperature Relative to 1800-1900 (°C)



• How is climate changing?

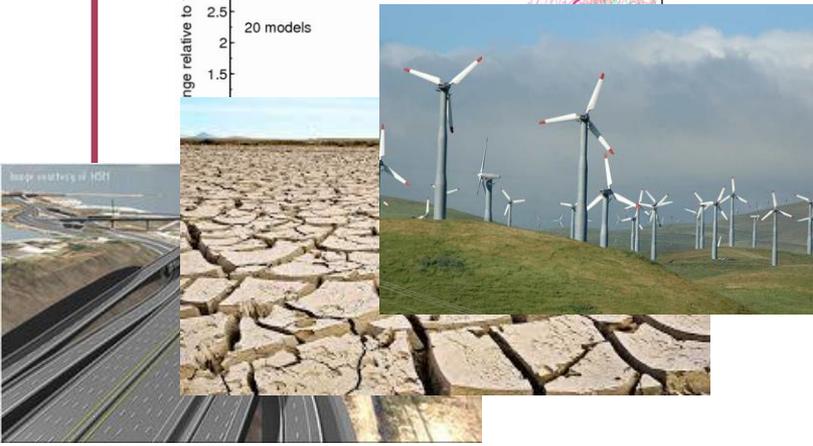
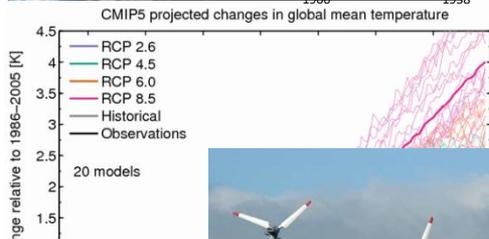
- Earth observations
- Reanalyses

• Will climate change continue/accelerate?

- Predictions
- Projections

• What are the societal impacts?

- Climate indicators
- Sectoral information





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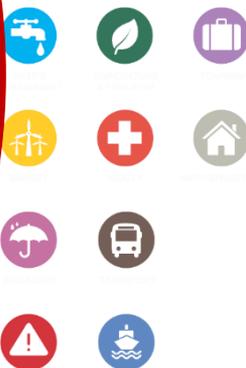
Components of C3S

Climate Data Store

Essential Climate Variables (ECVs) for atmosphere, ocean, land and Climate Indicators:

- Observed, reanalysed and simulated
- In support of adaptation & mitigation policies at global and European level
- On a distributed system, single access portal
- Toolbox

Sectoral Information System



Evaluation & QC

- Ensures C3S delivers state-of-the-art climate information to end-users
- Identifies gaps in the Service
- Bridges Copernicus with Research Agenda in Europe (e.g. H2020, national research projects)
- Monitors continually, quality of C3S products and services
- “Quality Assurance” body

Outreach Dissemination

- Web content provision & management
- Public outreach
- Coordination with national outreach efforts
- Liaison with public authorities
- Events (conferences, seminars...)
- Training and education service

Focus of this presentation: ERA5

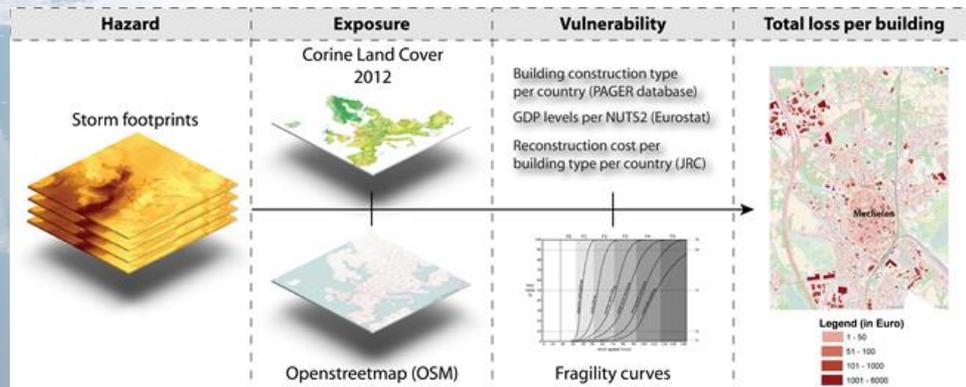
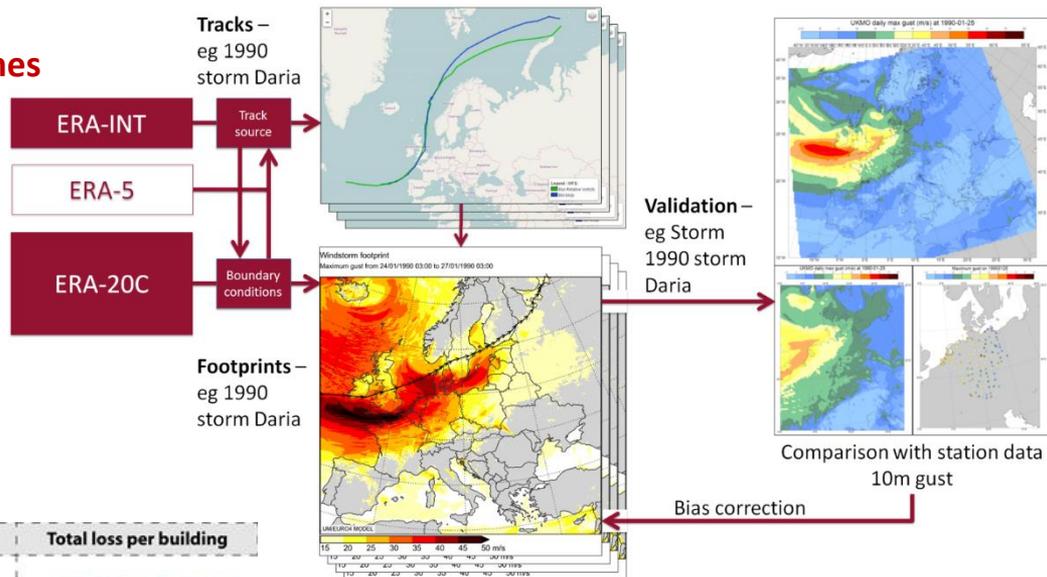


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WISC – Storm Tracks and Footprints

1) Track and downscale Extratropical Cyclones

- From global reanalysis
- With UKMO Unified Model over Europe
- 10-second wind gust



2) Make detailed Loss assessment

- In freely available database
- Useful for e.g. insurance industry



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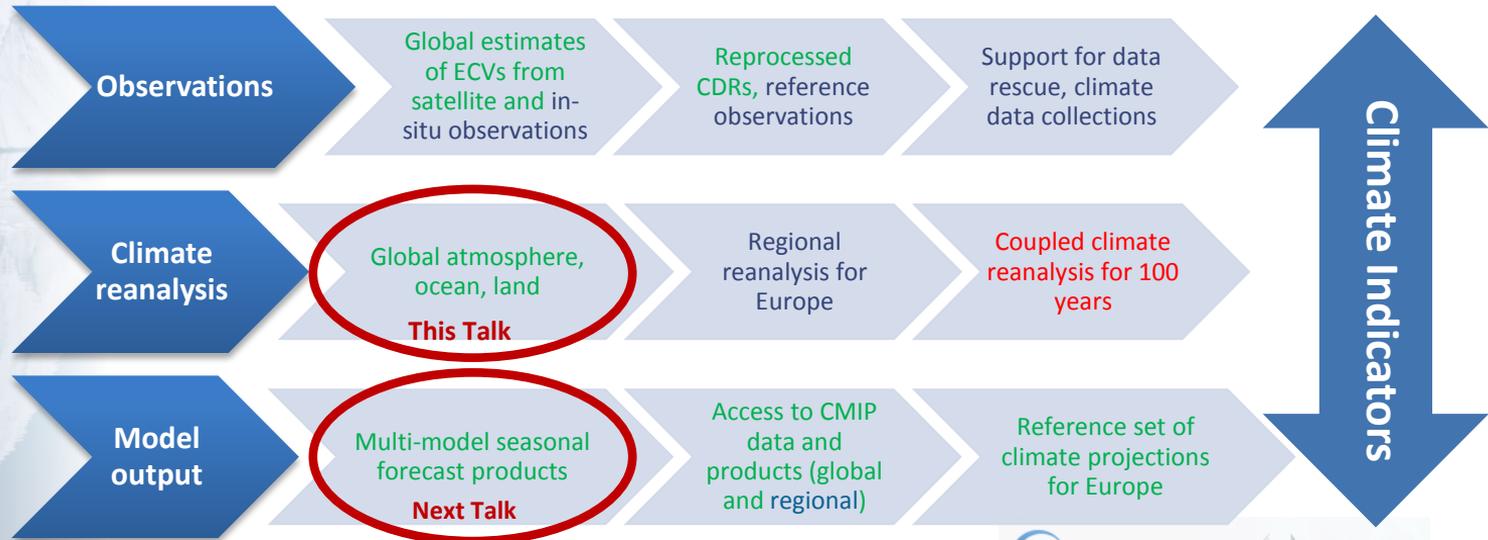
Developing the CDS portfolio



Scientific basis:

- Essential Climate Variables as defined by GCOS
- GCOS Status Report and Implementation Plan
- IPCC, CMIP

- Action engaged
- In preparation (PIN or ITT out)
- Not started





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<https://climate.copernicus.eu/>

CLIMATE SERVICES FOR YOUR OPERATIONS

IN FOCUS

Monthly sea-ice maps
04 May 2017

MONTHLY MAPS

Average surface air temperatures for April 2017
April 2017

NEWS

- 03 Mar 2017
#OpenDataHack @ECMWF - explore creative uses of open data
- 03 Mar 2017
C3S holds its inaugural General Assembly
- 26 Jan 2017
Copernicus at the 4th International Conference on Energy & Meteorology (ICEM)

EVENTS

- 13 Nov 2017
5th International Conference on Reanalysis
- 30 Jun 2017

TENDERS

C3S_312b Essential Climate Variable products derived from observations - Prior information notice

PROJECTS

- SWICCA - Service for Water Indicators in Climate Change Adaptation
- EDGE - End-to-end Demonstrator for improved

Monthly updates: based on Reanalysis



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Seasonal forecasts - first release 12/2016

home > products

Seasonal forecasts

Graphical forecast products

The Copernicus Climate Change Service (C3S) is developing seasonal forecast products, with a target publication date of 15th of each month. These products are based on data from several state-of-the-art seasonal prediction systems.

The current proof-of-concept phase includes graphical forecast products for a number of variables (air and sea-surface temperature, atmospheric circulation and precipitation); the forecasts are updated every month and cover a time range of 6 months. The interface to the list of products offers links to maps or timeseries for the forecast variables, and the facility to navigate the full set of graphics. Multi-system combinations, as well as predictions from the individual component systems, are available.

The centres currently providing forecasts to C3S are ECMWF, The Met Office and Météo-France; at a later stage Deutscher Wetterdienst and Centro Euro-Mediterraneo sui Cambiamenti Climatici will be added to the list.

- AVERAGE SURFACE AIR TEMPERATURE MONTHLY MAPS
- CLIMATE REANALYSIS
- SEASONAL FORECASTS

NEWS

13 Dec 2016
#OpenDataHack: @ECMWF - explore creative uses of open data

06 Dec 2016
Report Reassesses Variations in Global Warming

28 Nov 2016
Copernicus at Wissenswerte

17 Nov 2016
C3S and CAMS at COP22

01 Nov 2016
ODI Summit and Awards 2016

[More News](#)

EVENTS

13 Nov 2017
5th International Conference on Reanalysis

06 Mar 2017
C3S General Assembly

22 Feb 2017
Copernicus Symposium on Climate Services for

An example of C3S service:
multi-system seasonal
forecasts

Météo-France
UK Met Office
ECMWF

(CMCC & DWD)

<http://climate.copernicus.eu/seasonal-forecasts>





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ERA-Interim users worldwide

ERA-Interim had more than 20,000 unique users in 2015-2016 alone.

Users and stakeholders:

- Climate monitoring & provision of climatologies
- ECMWF member states
- Research and education, over 7,000 citations
- Public sector
- Space agencies
- Commercial applications

However, ERA-Interim is 10 years old and needs replacement

Unique registered users in 2016





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What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 – present	Initially 1979 – present, later addition 1950-1978
Streams	1979-1989, 1989-present	Parallel streams, one per decade
Assimilation system	2006, 4D-Var	2016 ECMWF model cycle (41r2), 4D-Var
Model input (radiation and surface)	As in operations, (<i>inconsistent sea surface temperature</i>)	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		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 ~ 5 Peta Byte (1979-NRT)
Extra Observations	Mostly ERA-40, GTS	Various reprocessed CDRs, latest instruments
Variational Bias correction	Satellite radiances	Also ozone, aircraft, surface pressure



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ERA5 Release Plan

A two-months *test data set* is available

- Jan-Feb 2016
- <https://climate.copernicus.eu/climate-reanalysis>

Soon !!: public release 2010 – 2016

Access: initially similar to ERA-Interim (Web-API)
later (Jan 2018) via the **C3S Climate Data Store**

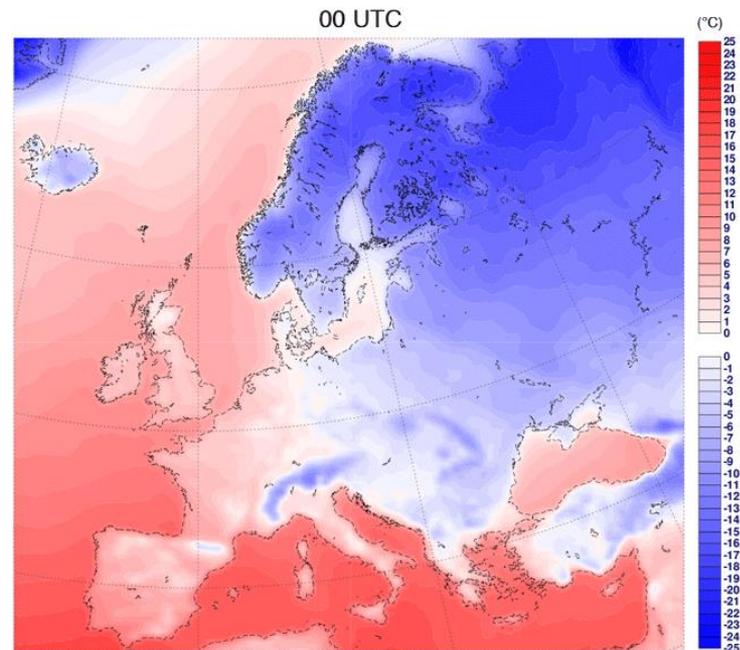
Q3/4 2017: 2017 – timely updates

- ERA5: Updates with about 2-months delay (final product)
- ERA5T: Updates with short delay (<1 week, preliminary product)

Q1/2 2018: Release 1979 – 2009:

- Continue ERA5 timely updates
- Continue ERA-Interim for another 6 months

2018: integration of ERA5 segment from 1950





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The evolving observing system

Newly reprocessed data sets

Radiances: SSM/I brightness temp from CM-SAF
METEOSAT from EUMETSAT

Atmospheric motion vector winds: METEOSAT, GMS/GOES-9/MTSAT, GOES-8 to 15, AVHRR METOP and NOAA

Scatterometers: ASCAT-A, ERS 1/2 soil moisture

Radio Occultation: METOP GRAS, COSMIC, CHAMP, GRACE, SAC-C, TERRASAR-x

Ozone: NIMBUS-7, EP TOMS, ERS-2 GOME, ENVISAT SCIAMACHY, Aura MLS, OMI

Altimeter: ERS1/2, ENVISAT, Jason-1

Extra data (not used in ERA-Interim)

lack of infrastructure ERA-Interim

IASI, ASCAT, ATMS, Cris, MWHS2, Himawari-8 ...

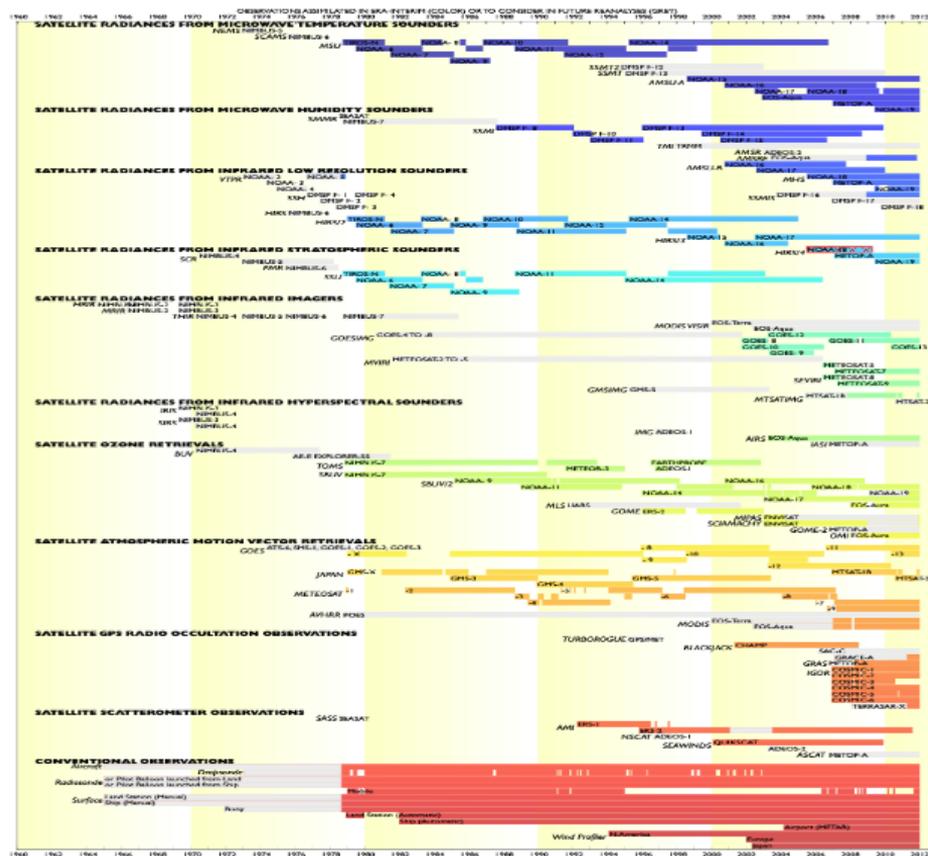
Typically the latest instruments:

ERA5 is more future proof!

Improved data usage

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

...





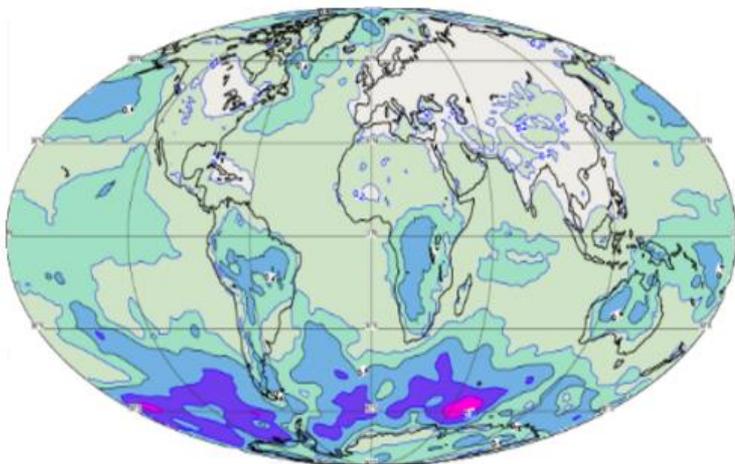
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ERA5 provides an estimate for uncertainty

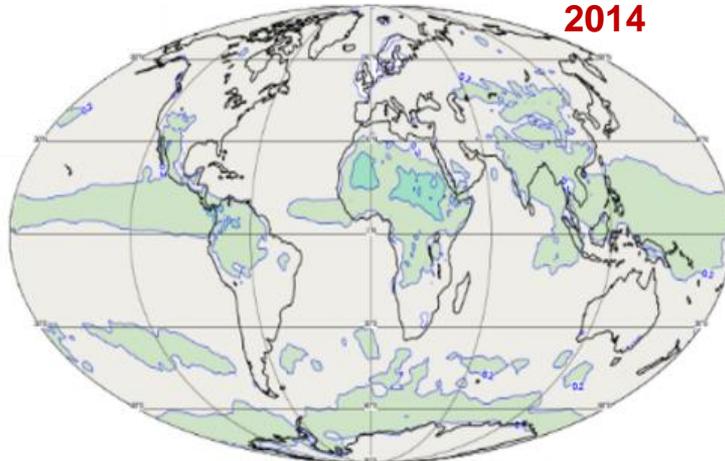
ERA5 is based on a 10-member EDA system

Spread in Surface Pressure (hPa)

January 1979



July
2014





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Hourly data and access to observations

Hourly reanalysis fields

ECMWF Home Chart dashboard Contact Search ECMWF

About Forecasts Computing Research Learning

Navigation

- Job list
- MARS activity

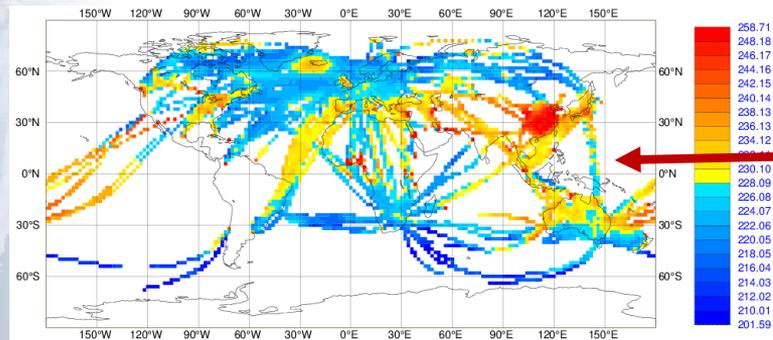
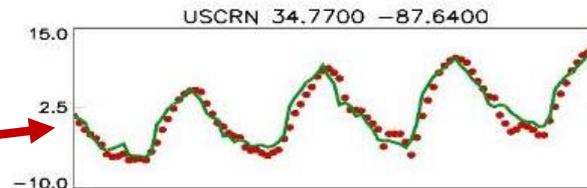
See also...

- FAQ
- Accessing forecasts
- GRIB decoder

MARS Catalogue

Date (30 values)	Time (24 values)	Parameter (121 values)
2014-06-01	00:00:00	2 metre dewpoint temperature
2014-06-02	01:00:00	2 metre temperature
2014-06-03	02:00:00	10 metre U wind component
2014-06-04	03:00:00	10 metre V wind component
2014-06-05	04:00:00	100 metre U wind component
2014-06-06	05:00:00	100 metre V wind component
2014-06-07	06:00:00	Albedo
2014-06-08	07:00:00	Angle of sub-grid-scale orography
2014-06-09	08:00:00	Anisotropy of sub-grid-scale orography
2014-06-10	09:00:00	Boundary layer height

ERA5 2-metre temperature compared to independent data



Observation feedback archive

ECMWF Home Chart dashboard Contact

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MARS Catalogue

Date (30 values)	Time (2 values)	Observation platform (102 values)
2014-06-01	00:00:00	37007
2014-06-02	12:00:00	50001
2014-06-03		ACARS
2014-06-04		AIREP
2014-06-05		AMDAR
2014-06-06		AQUA AIRS Radiances
2014-06-07		AQUA AMSUA Radiances
2014-06-08		AQUA MODIS AMV
2014-06-09		AURA MLS O3
2014-06-10		AURA OMI O3

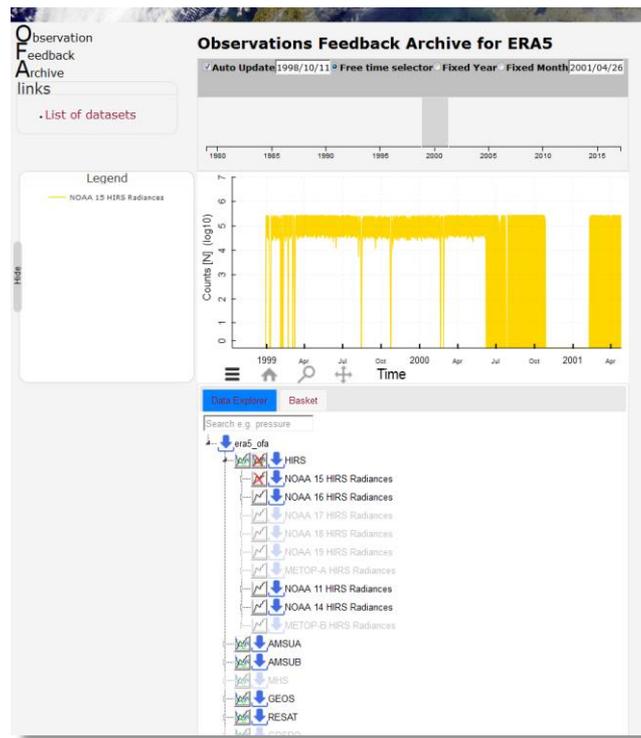
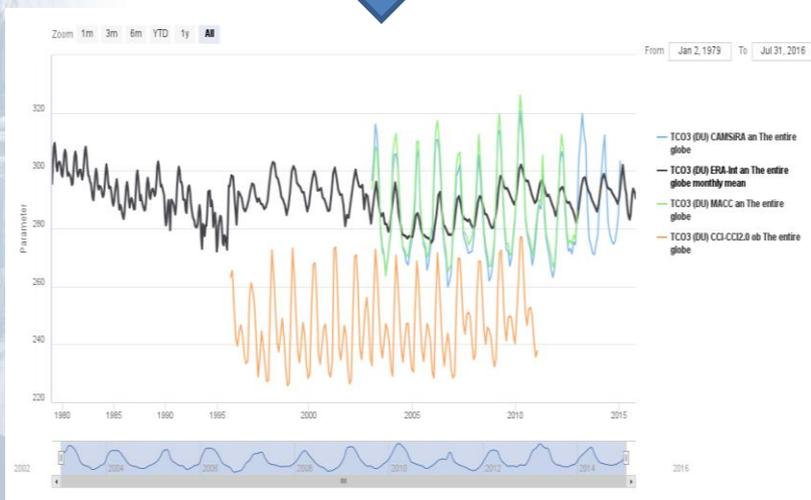


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Climate Reanalysis Data Access Tool

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

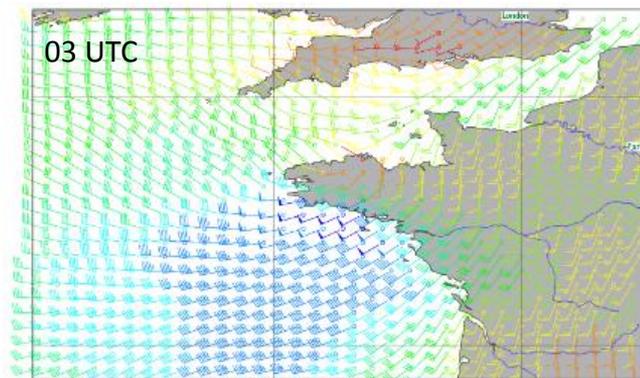
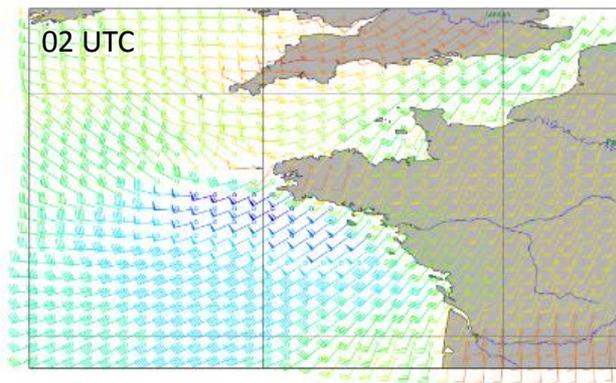
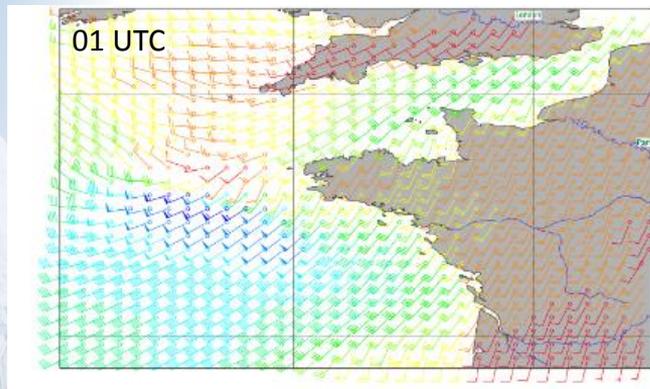
Climate Monitoring Facility: Explore, compare, plot ECV estimates from multiple sources





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Lothar 26 December 1999

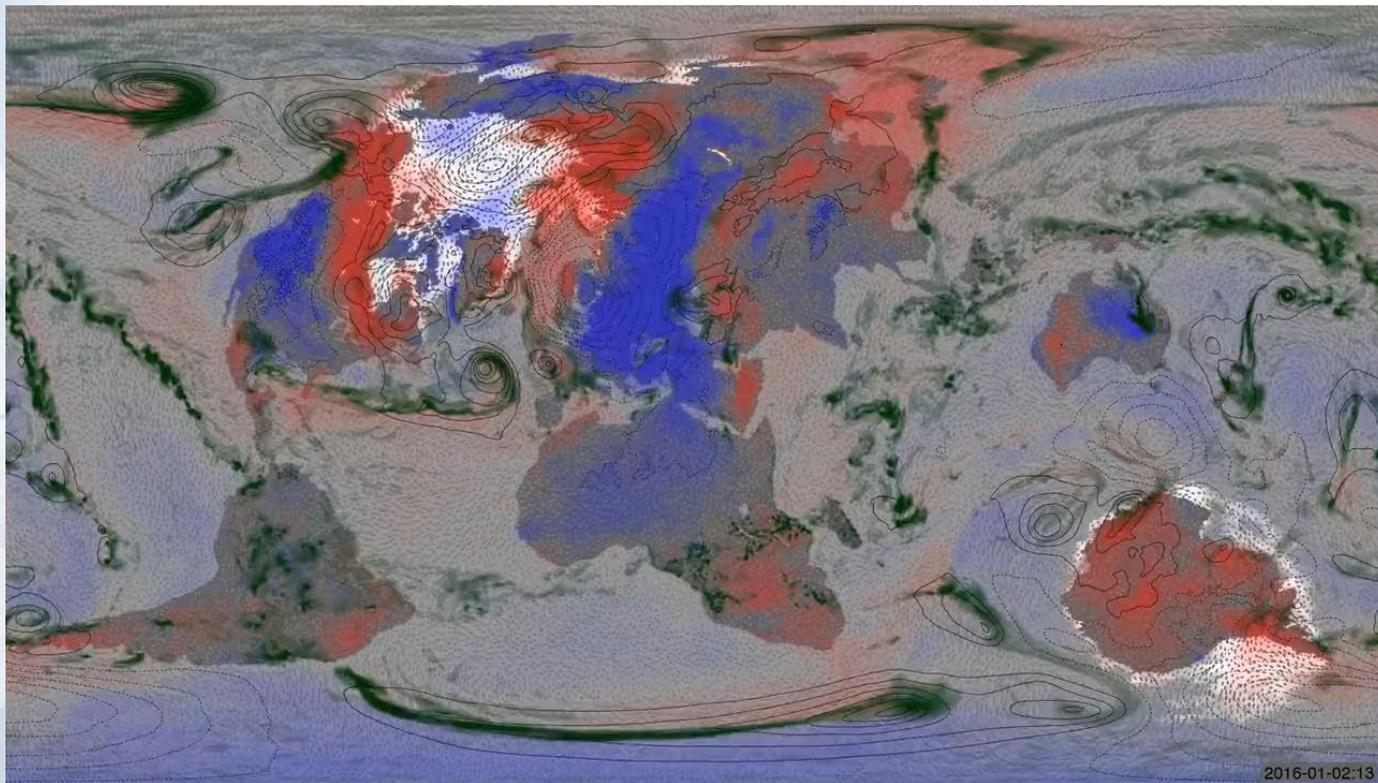




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ERA5 Test data set

Two months test data set (Jan-Feb 2016), *animation: Philip Brohan*

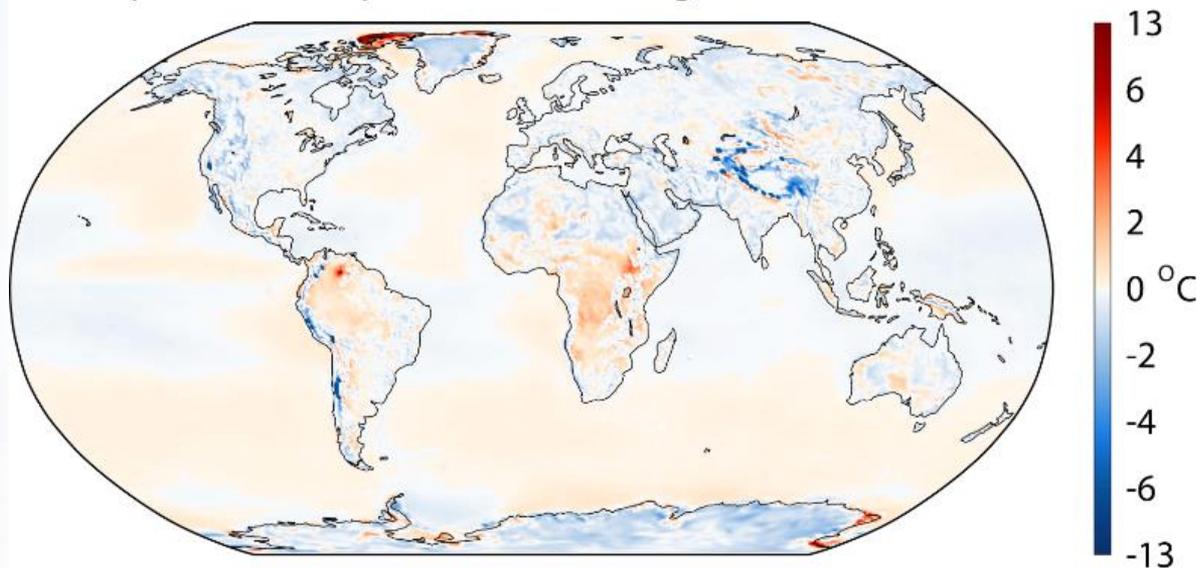




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ERA5 mean temperature vs ERA-Interim

2m temperature for September 2009 to August 2010: ERA5 - ERA-Interim



Differences in global-mean values are very small

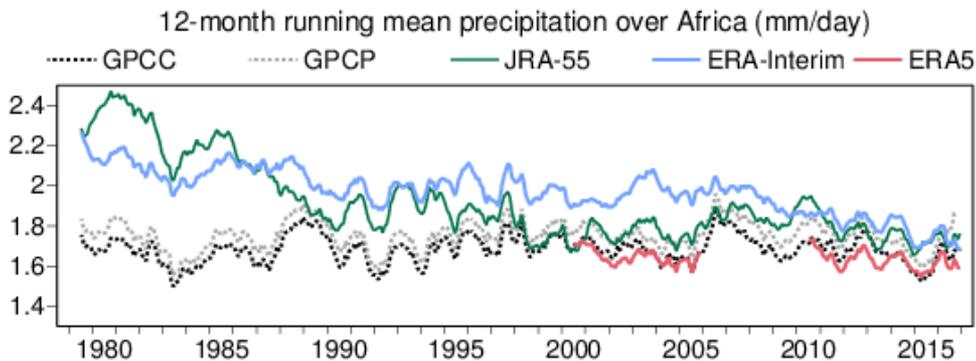
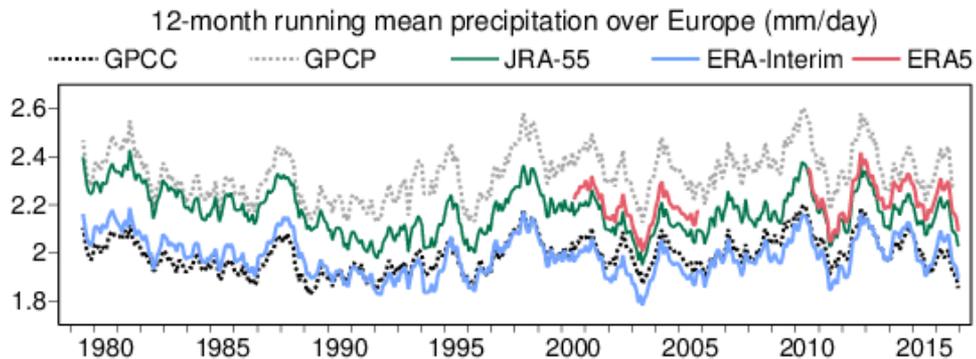
Largest local difference is over Ellesmere Island: Background error (background-observation) at Alert Climate station is -5.1°C for ERA-Interim and -1.8°C for ERA5

ERA5 is colder over Antarctic plateau, where ERA-Interim has warm bias (Fréville *et al.*, 2014)



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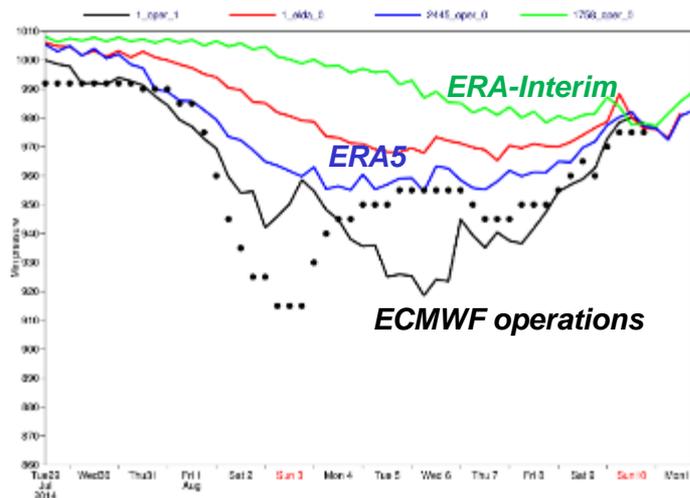
Comparison with other long data sets



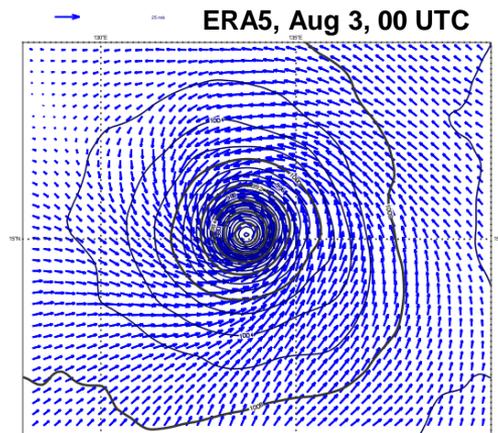
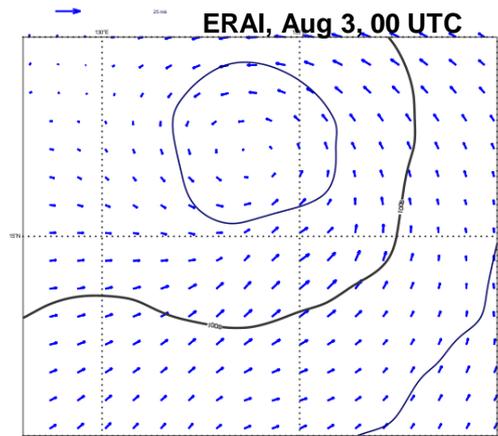


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Super Typhoon Halong (August 2014)



- ERA5 much better than ERA-Interim,
- but not as good as ECMWF operations

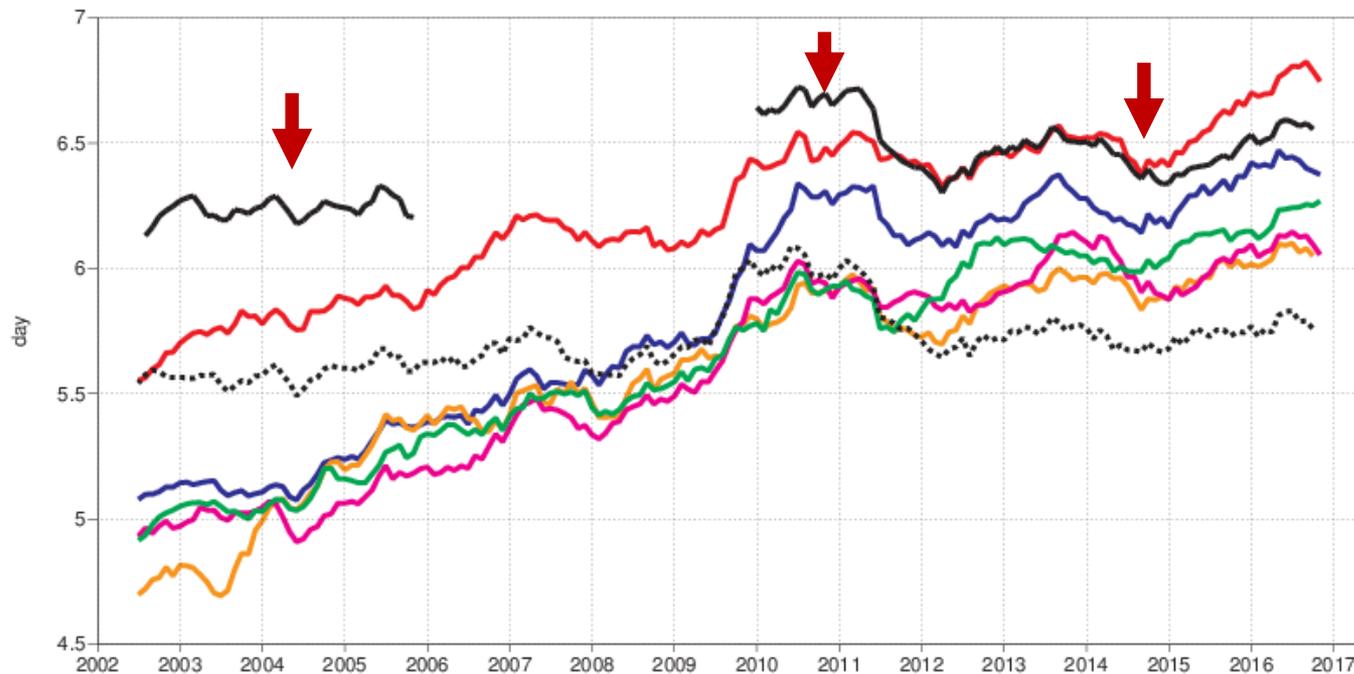




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Comparison of forecast scores

500hPa geopotential
Anomaly correlation Reaching 80%
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)





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Concluding Remarks

ERA-Interim is 10 years old and needs replacement

The production of ERA5 is well underway:

- Higher resolution, hourly output, uncertainty estimate.
- Funded within the C3S Copernicus program
- Produced in parallel streams
- Public Release for 2010-2016 is expected July 2017

The performance of ERA5 is very promising in the troposphere.

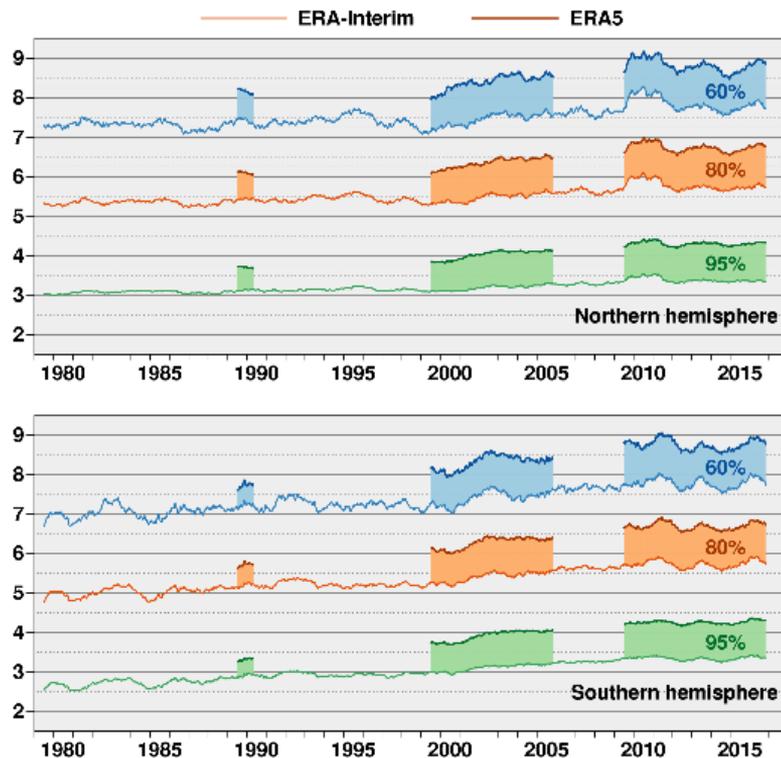
There are some imperfections, though

- Temperature bias upper stratosphere
- Too strong tropical jet mesosphere
- Initially there were quality issues over the southern hemisphere in the 1980s (delay in production stream)

At ECMWF activities are focused towards a coupled Earth system

- Benefit to reanalysis as well: ERA6

Range (days) when 365-day mean 500hPa height AC (%) falls below threshold





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C3S - Development timeline

Stage 0/1 - Proof of Concept/Pre-operational

Stage II - Operational ~20 ECVs, ~5-6 Sectors

Stage III - Operational ~30 ECVs, ~8-10 Sectors

