News from C3S: ERA5

Climate Change Service

Hans Hersbach, ECMWF, and many, many colleagues
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
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
<table>
<thead>
<tr>
<th>Atmosphere/land</th>
<th>including ocean waves</th>
<th>Ocean</th>
<th>including sea ice</th>
</tr>
</thead>
<tbody>
<tr>
<td>3) 2001 - 2003 ERA-40</td>
<td>4) 2006 - ... ERA-Interim</td>
<td>2016 - ... ORAS5</td>
<td></td>
</tr>
<tr>
<td>5) 2016 - ... ERA5</td>
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**Centennial**

<table>
<thead>
<tr>
<th>Enhanced land</th>
<th>Atmospheric composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 ERA-Int/Land</td>
<td>2008 - 2009 GEMS</td>
</tr>
<tr>
<td>2014 ERA-20C/Land</td>
<td>2010 - 2011 MACC</td>
</tr>
<tr>
<td>2017 - ... ERA5L</td>
<td>2017 - ... CAMS</td>
</tr>
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</table>

Towards a coupled earth system
ECMWF operates the Copernicus Climate Change Service (C3S) and Copernicus Atmosphere Monitoring Service (CAMS) on behalf of the European Commission.
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
How is climate changing?
- Earth observations
- Reanalyses

Will climate change continue/accelerate?
- Predictions
- Projections

What are the societal impacts?
- Climate indicators
- Sectoral information
**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
**W I S C – S t o r m T r a c k s a n d F o o t p r i n t s**

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
Scientific basis:

- Essential Climate Variables as defined by GCOS
- GCOS Status Report and Implementation Plan
- 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 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 (global and regional)
- Reference set of climate projections for Europe

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

This Talk: Global atmosphere, ocean, land
Next Talk: Multi-model seasonal forecast products
Monthly updates: based on Reanalysis
An example of C3S service: multi-system seasonal forecasts

Météo-France
UK Met Office
ECMWF
(CMCC & DWD)

http://climate.copernicus.eu/seasonal-forecasts
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
## What is new in ERA5?

<table>
<thead>
<tr>
<th></th>
<th>ERA-Interim</th>
<th>ERA5</th>
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<tbody>
<tr>
<td><strong>Period</strong></td>
<td>1979 – present</td>
<td>Initially 1979 – present, later addition 1950-1978</td>
</tr>
<tr>
<td><strong>Streams</strong></td>
<td>1979-1989, 1989-present</td>
<td>Parallel streams, one per decade</td>
</tr>
<tr>
<td><strong>Assimilation system</strong></td>
<td>2006, 4D-Var</td>
<td>2016 ECMWF model cycle (41r2), 4D-Var</td>
</tr>
<tr>
<td><strong>Model input</strong></td>
<td>As in operations, (inconsistent sea surface temperature)</td>
<td><strong>Appropriate for climate</strong>, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice</td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td>79 km globally, 60 levels to 10 Pa</td>
<td><strong>31 km globally</strong>, 137 levels to 1 Pa</td>
</tr>
<tr>
<td><strong>Uncertainty estimate</strong></td>
<td></td>
<td>Based on a 10-member <strong>4D-Var ensemble</strong> at 62 km</td>
</tr>
<tr>
<td><strong>Land Component</strong></td>
<td>79km</td>
<td>ERA5L, 9km (separate, forced by ERA5)</td>
</tr>
<tr>
<td><strong>Output frequency</strong></td>
<td>6-hourly Analysis fields</td>
<td><strong>Hourly</strong> (three-hourly for the ensemble), <strong>Extended list of parameters</strong>, ~ 5 Peta Byte (1979-NRT)</td>
</tr>
<tr>
<td><strong>Extra Observations</strong></td>
<td>Mostly ERA-40, GTS</td>
<td>Various <strong>reprocessed CDRs, latest instruments</strong></td>
</tr>
<tr>
<td><strong>Variational Bias correction</strong></td>
<td>Satellite radiances</td>
<td>Also ozone, aircraft, surface pressure</td>
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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
The evolving observing system

Newly reprocessed data sets

- Radiance: 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
ERA5 provides an estimate for uncertainty

ERA5 is based on a 10-member EDA system

Spread in Surface Pressure (hPa)

January 1979

July 2014
Hourly reanalysis fields

Observation feedback archive

ERAS 2-metre temperature compared to independent data
Observation Feedback Archive: Explore, select, plot and download observations used in ERA5

Climate Monitoring Facility: Explore, compare, plot ECV estimates from multiple sources
ERA5 Test data set

Two months test data set (Jan-Feb 2016), animation: Philip Brohan
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)
Comparison with other long data sets

12-month running mean precipitation over Europe (mm/day)

12-month running mean precipitation over Africa (mm/day)
• ERA5 much better than ERA-Interim,
• but not as good as ECMWF operations
Comparison of forecast scores

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

CMC  JMA  UKMO  ECMWF  ERA5  ERA-Interim  NCEP

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
C3S - Development timeline

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<th>Year</th>
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