Reanalysis Needs for Reference Data

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Key points

- Reference-quality observational data are essential for many aspects of reanalysis
- Useful for validation and/or assimilation, but also via their contribution to improving satellite-based products
- Priority 1 and 2 ECVs all highly relevant
- Look forward to jointly making progress via WG-ARO & GRUAN

Outline

- Current reanalysis activities
- ESA's Climate Change Initiative
- Recap, outlook, ways to work together

Stating the obvious

- There's no such thing as the perfect dataset – applies to observations, models and reanalyses
- Caution should be applied when using any dataset
- Especially true when examining trends in reanalyses
- At any point in time, we can improve on what we've got – via better instruments and/or reprocessing

Outline

- **Current reanalysis activities**
  - **Expanding the ERA-Interim reanalysis**

  - **Developing the ERA-CLIM reanalyses**

  - **MACC-II for atmospheric composition – operational + reanalysis**
  - **Ocean reanalyses**

- **ESA's Climate Change Initiative**

- **Recap, outlook, ways to work together**

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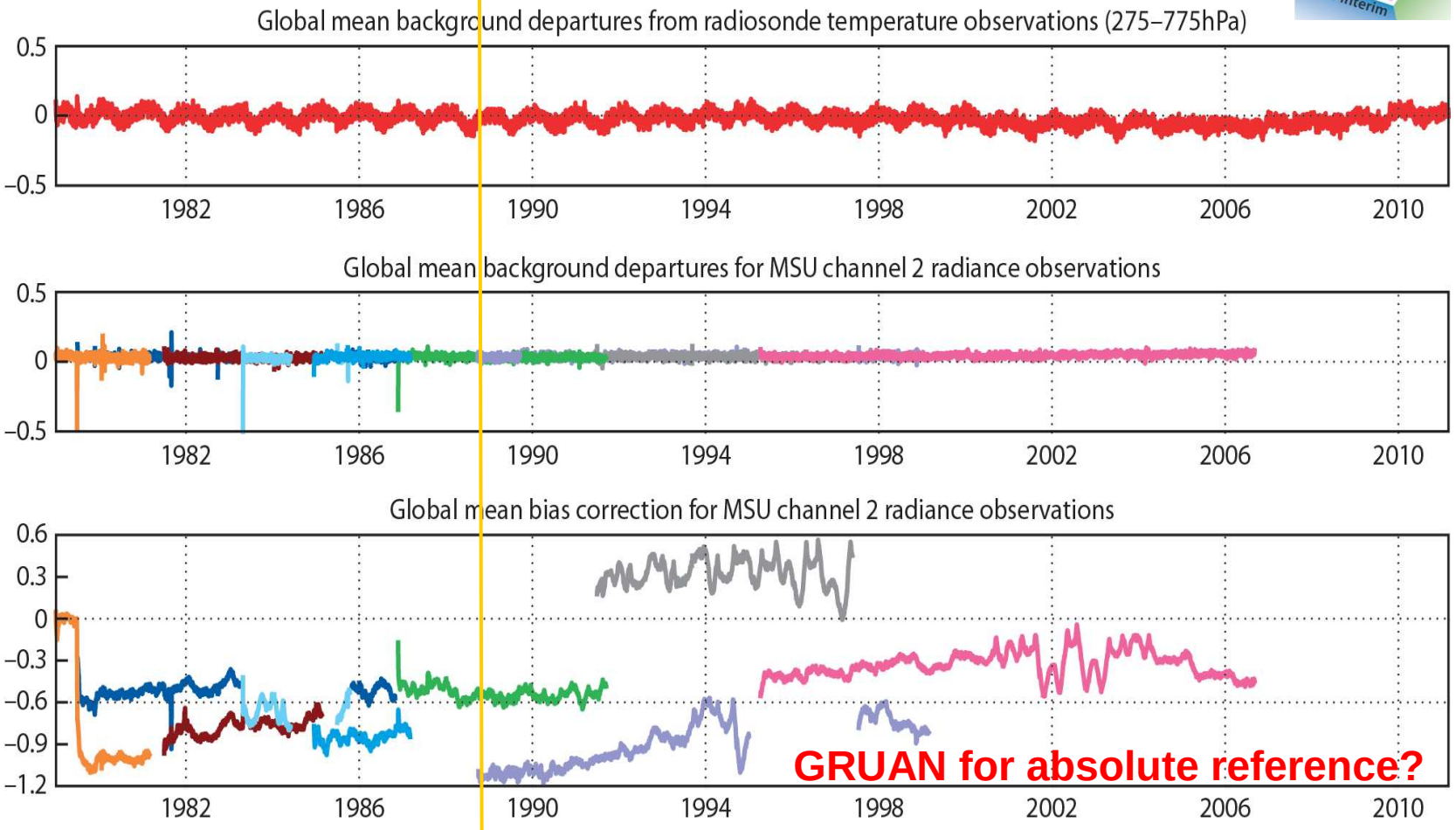
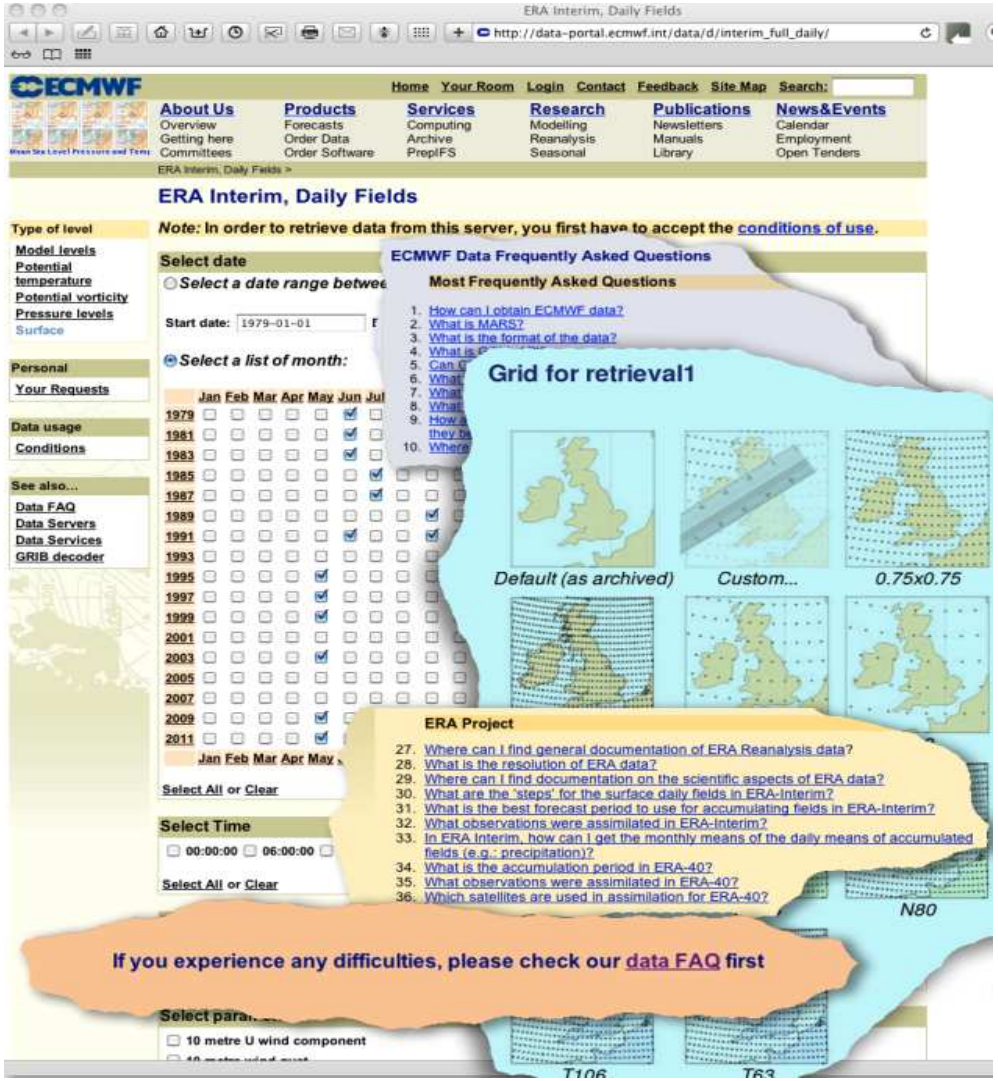
Expanding the ERA-Interim reanalysis



Back-extension

Services: access, diagnostics, …

ERA-Interim full-resolution data server



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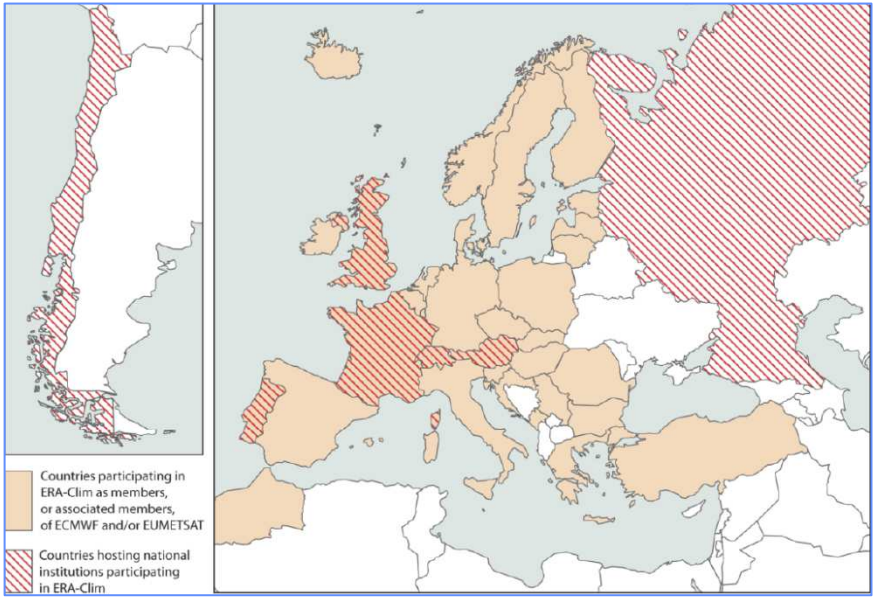
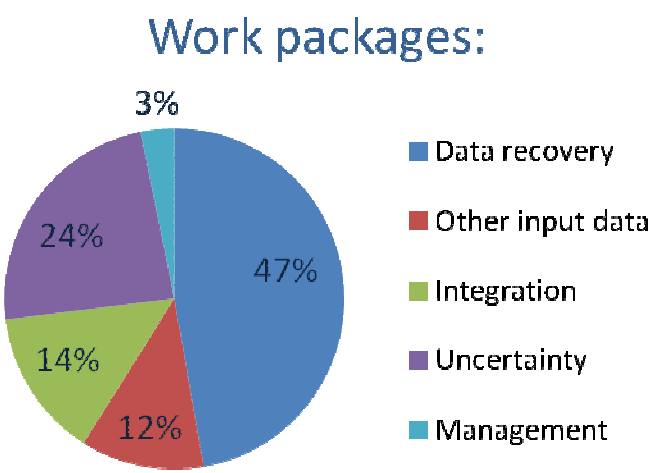
Autumn 2011

The ERA-CLIM Project

- ERA-CLIM: European Reanalysis of Global Climate Observations
- 3-year collaborative research project, start date 01/01/2011
- Funded by EU research FP7, Environment theme
- Total cost €4.9M; EC contribution €3.5M
- 8(9) partners, 47.5(59) person-years, 50 deliverables





ERA-CLIM Deliverables

Objectives	Key deliverables	
Development of the observational record for the early 20th century	Inventories; database for metadata, web-based digitising tools	WP1
	Digitized, quality-controlled instrumental records for the early 20th century	
	Access to observations and metadata via international data centres	
Preparation of reprocessed satellite observations, boundary conditions, and forcing data	Reprocessed satellite data sets for input to reanalysis; early satellite records	WP2
	Ensemble of consistent sea-surface boundary conditions for the 20th-century	
	Atmospheric forcing data (solar, aerosols, GHG, land surface…) for ERA-20C	
Development of an Observation Feedback Archive (OFA)	Database facility for input observations with quality feedback from reanalyses	WP3
	A series of long test reanalyses at various resolutions to prepare for ERA-20C	
Production of pilot reanalyses and data quality information	All reanalysis products and input observations available via web services	
Assessment and reduction of data uncertainties	Homogenized in-situ data and bias correction techniques	WP4
	Improved ocean observations for reanalysis	
	Tools for quality assessment of reanalysis products	

ERA-CLIM pilot reanalyses

ERA-CLIM

	What	Period	Resolution	Ens	When	Vol
ERA-Int	Interim reanalysis	1989-NRT	T255L60	1	ongoing	33 Tb
ERA-P0	AMIP ensemble	1900-2011	T159L91	10	Jun 2011 (9M)	
ERA-P1	EDA using sfc obs only	1900-2011	T159L91	10	Sep 2011 (15M)	655 Tb
ERA-S1	Land surface using ERA-P1	1900-2011	T799	1	Sep 2012 (9M)	77 Tb
ERA-P2	Reanalysis using all obs	2 early decades	T511L91	1	Sep 2012 (9M)	180 Tb
ERA-E2	As ERA-P2 but with SST/sea-ice perturbations	2 early decades	T159L91	10	Jan 2013 (9M)	180 Tb
ERA-P3	To replace ERA-Interim	1979-NRT	T511L91	1	Jan 2012 (24M+)	234 Tb
ERA-20C	20th-century reanalysis	1900-NRT	T511L91	1	2014 (36M+)	1062 Tb

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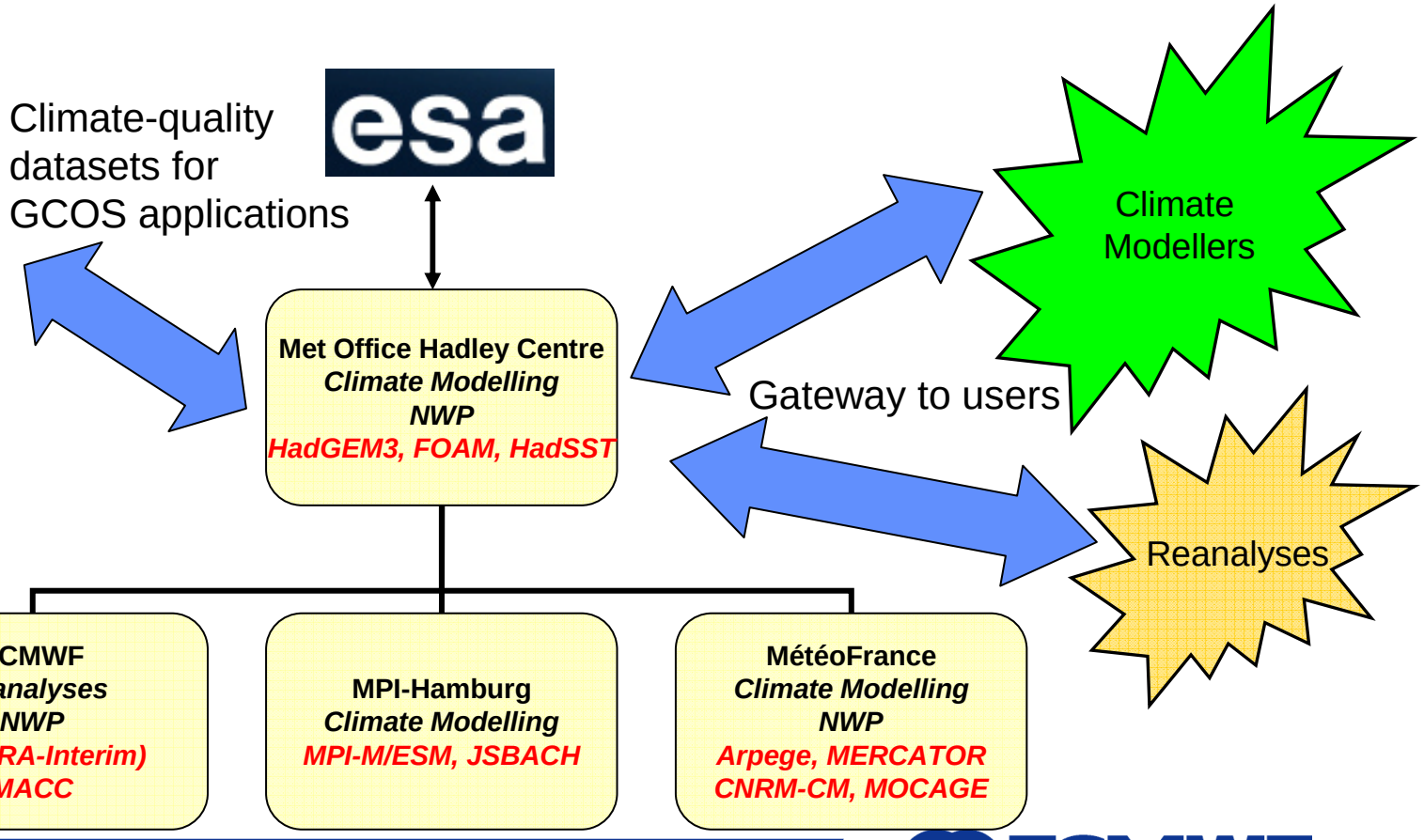
- **ESA's Climate Change Initiative**

- Recap, outlook, ways to work together

ESA's CCI & Climate Modelling User Group

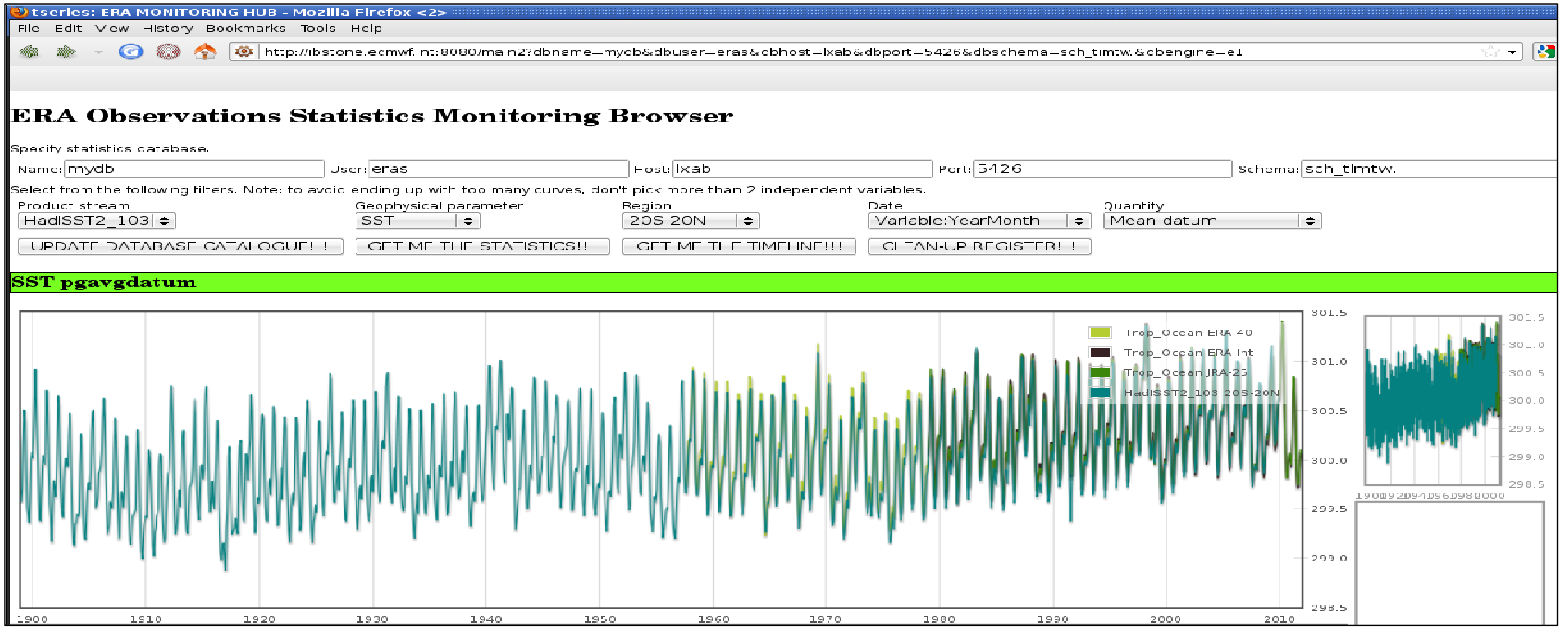
- 6 year program, 2010-2016, approx 75M Euros
- Phase 1, 2010-2013, involves ~ 250 persons

ECV projects
Sea-level
Sea surface temperature
Ocean Colour
Sea-ice
Ice-sheets
Glaciers and ice caps
Land Cover
Fire disturbance
Soil moisture
Cloud properties
Ozone
Aerosols
Greenhouse Gases



ECMWF within Climate Modelling User Group

- **Facilitate reanalysis usage** (ancillary input, comparison)
- Our experience is **contributing to product development**:
  - Requirements, definitions, uncertainty characterization, consistency/homogeneity, validation – **role for GRUAN!**
- **Building database system to evaluate L3 products**



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- **Recap, outlook, ways to work together**

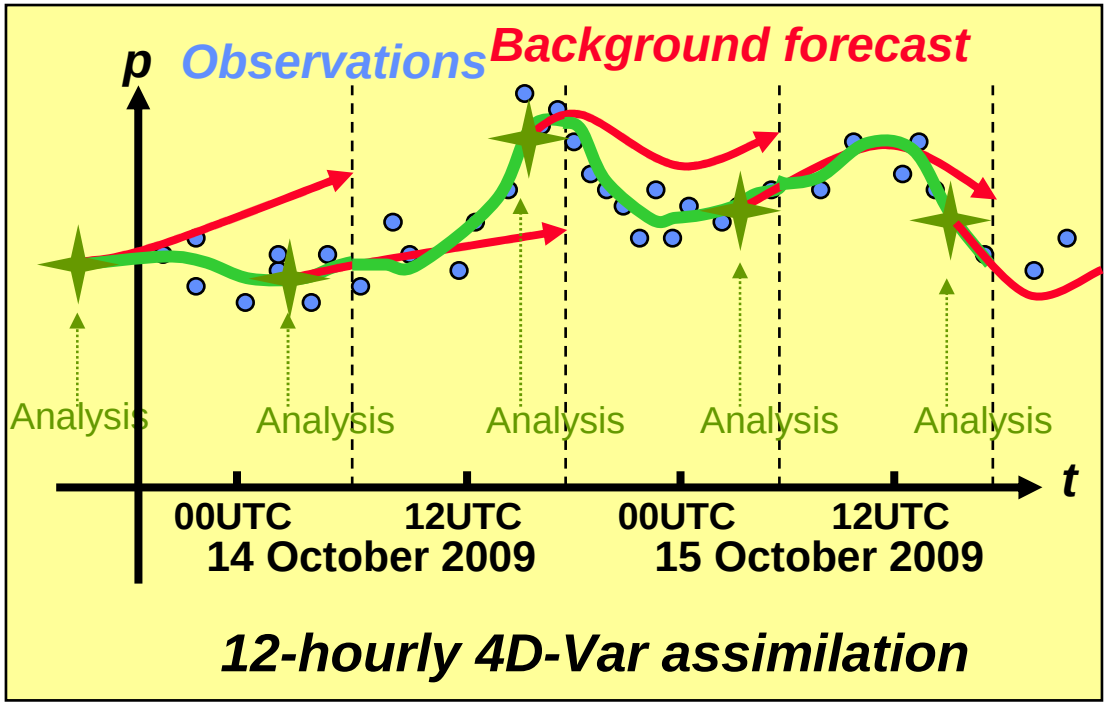
Recap, outlook, ways to work together

- Reference-quality observational data are essential for many aspects of reanalysis
- Useful for validation and/or assimilation, but also via their contribution to improving satellite-based products
- Priority 1 and 2 ECVs all highly relevant
- Look forward to jointly making progress via WG-ARO & GRUAN
- Strengthen awareness and links between communities

Backup slides

Brief Primer on Data Assimilation

- **Combine information from**
  - Observations
  - Background forecast (propagates the information extracted from prior observations)
  - Error statistical models
  - Relationships to build-in dynamical and physical consistency between various meteorological parameters
- **To produce the "most probable" estimate of the atmospheric state**
  - And some estimate of uncertainty



Data assimilation systems incorporate observations in an optimal way with a model to improve knowledge of the atmospheric state

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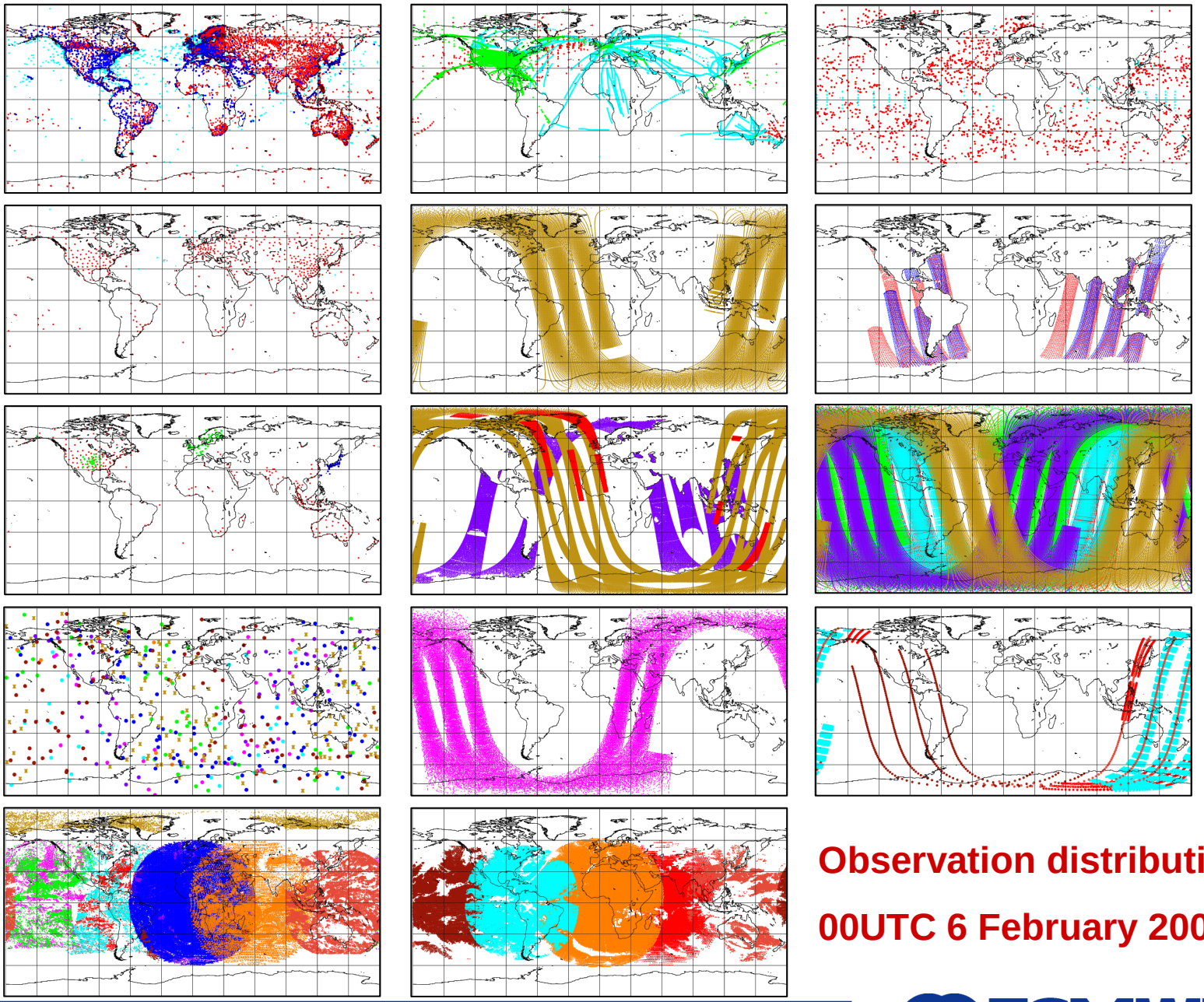

Observation distributions

00UTC 6 February 2009 ±3h

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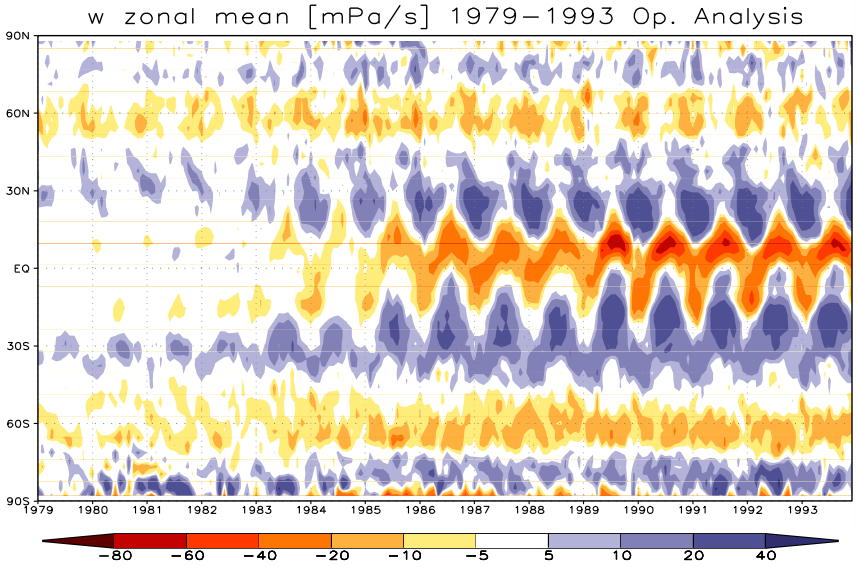
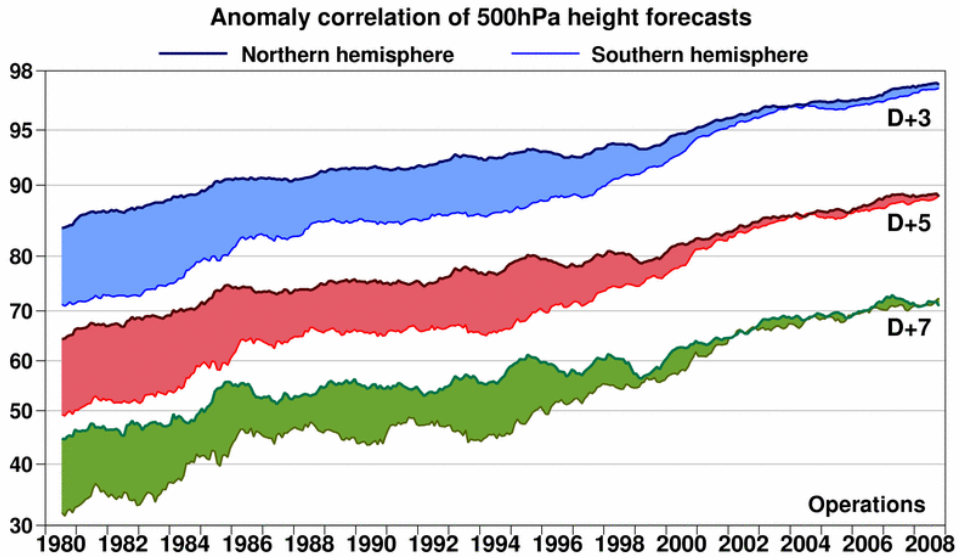
Why not use operational analysis products?

Zonal mean vertical velocity at 500 hPa



- ECMWF operational system 1979-1993

3 to 7-day Forecast skill

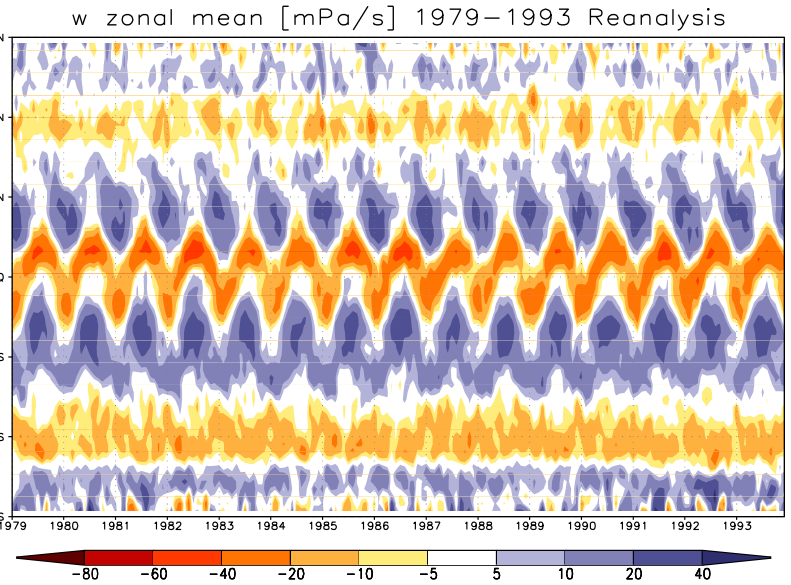


- ECMWF operational system 1979-2009

Quality of operational analysis products changes in time

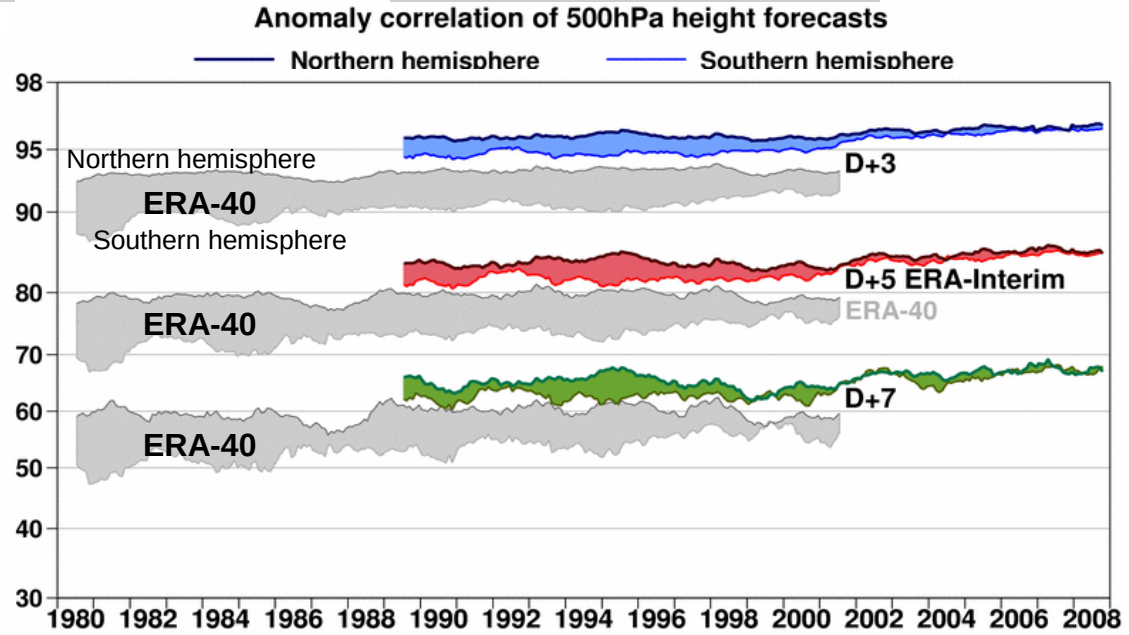
ECMWF Reanalyses

Zonal mean vertical velocity at 500 hPa



- ERA-15 (1979-1994)

3 to 7-day Forecast skill



- ERA-40 (1957-2002)
- **ERA-Interim: from 1989 to near-real-time**

Reanalysis quality more "uniform" in time*

**** but still subject to changes in the observing system***

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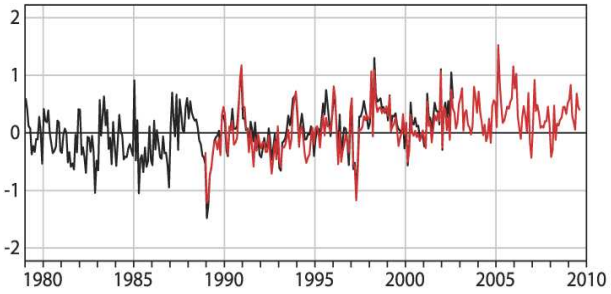
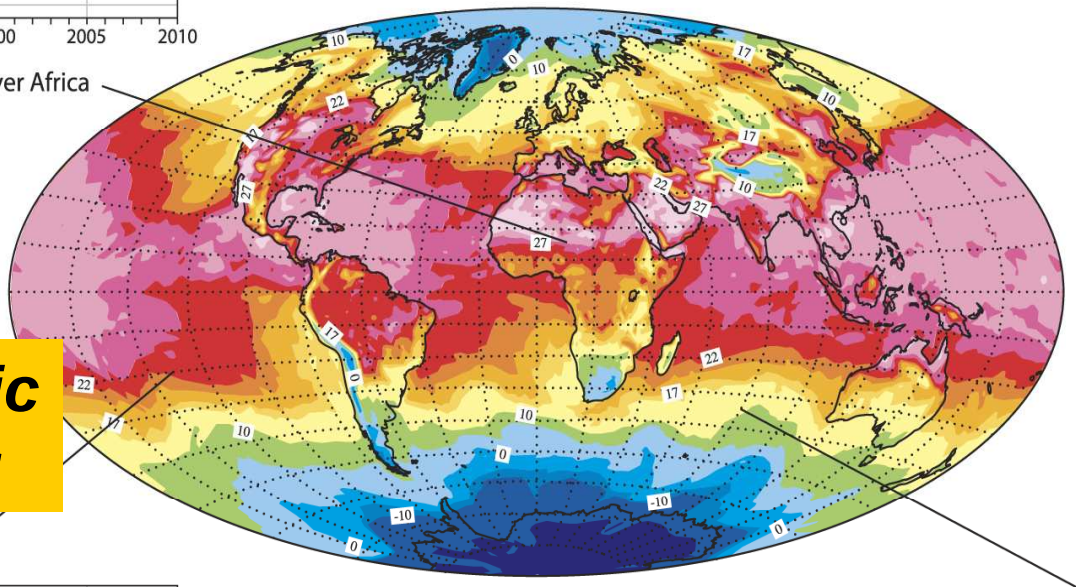
Reanalyses offer consistent multi-dimensional views of the atmosphere



2-metre temperature anomaly (°C) over Africa

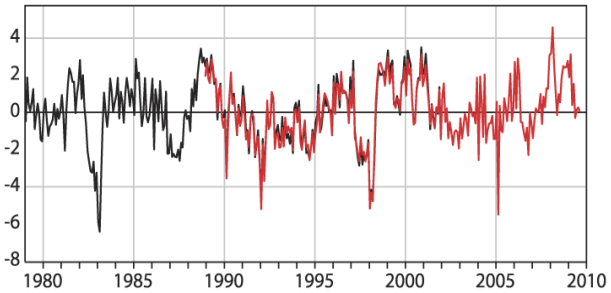
Time

ERA-Interim 2-metre temperature (°C)
15 August 2003 03 UTC

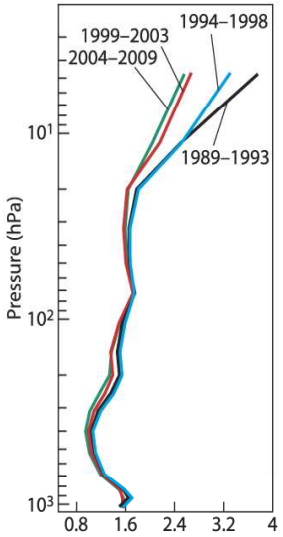


Atmospheric parameter

Southern Oscillation Index (hPa)



Horizontal



Standard deviation of differences between ERA-Interim and radiosondes temperature (°C) in the southern hemisphere

Vertical

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ERA-Interim products

- 20+-year period January 1989- July 2009 completed
- Extending forward in time (5 days behind real-time)
- Monthly updates of the product archive
- Resolution: T255L60, 6-hourly (3-hourly for surface)

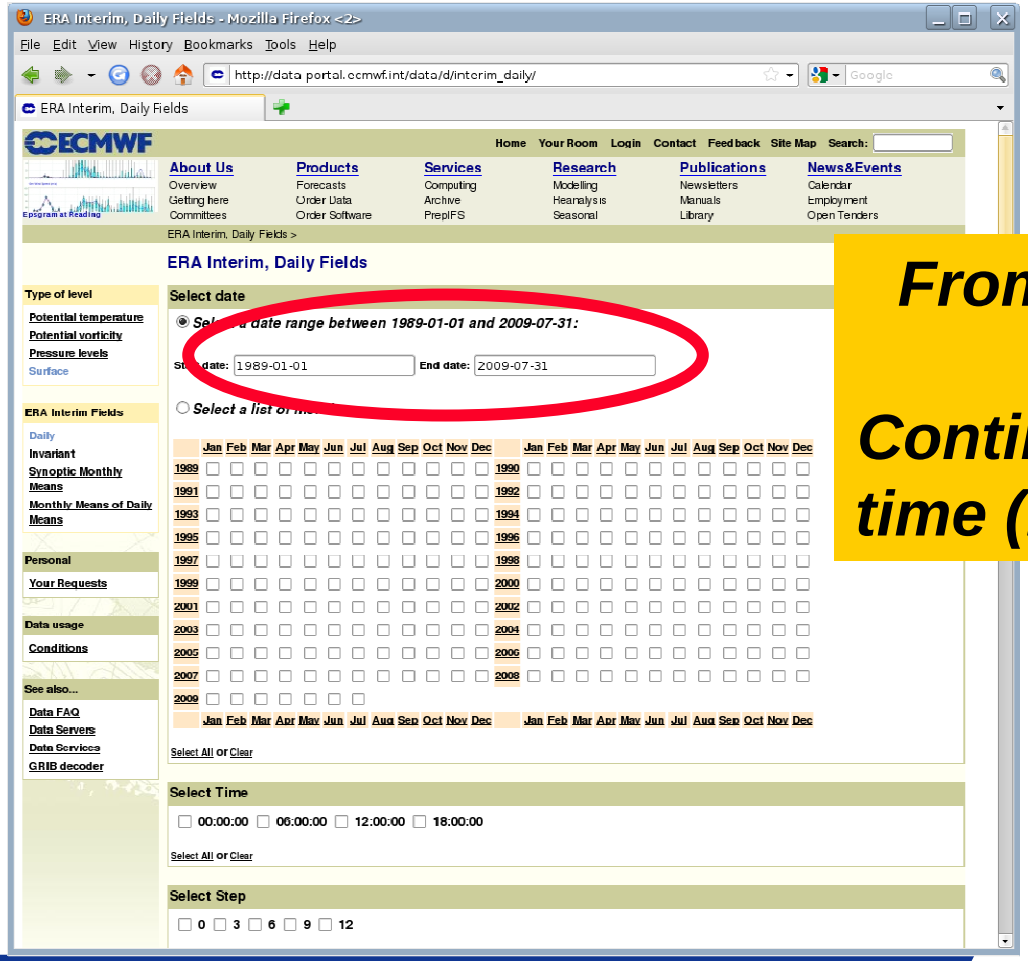
- Analysis + forecast products, and monthly averages
- Products from coupled ocean-wave and land-surface models

- Member state users: full access via MARS
- All users: web access via ECMWF Data Server

ERA-Interim Public Data Server

Information: http://www.ecmwf.int/research/era

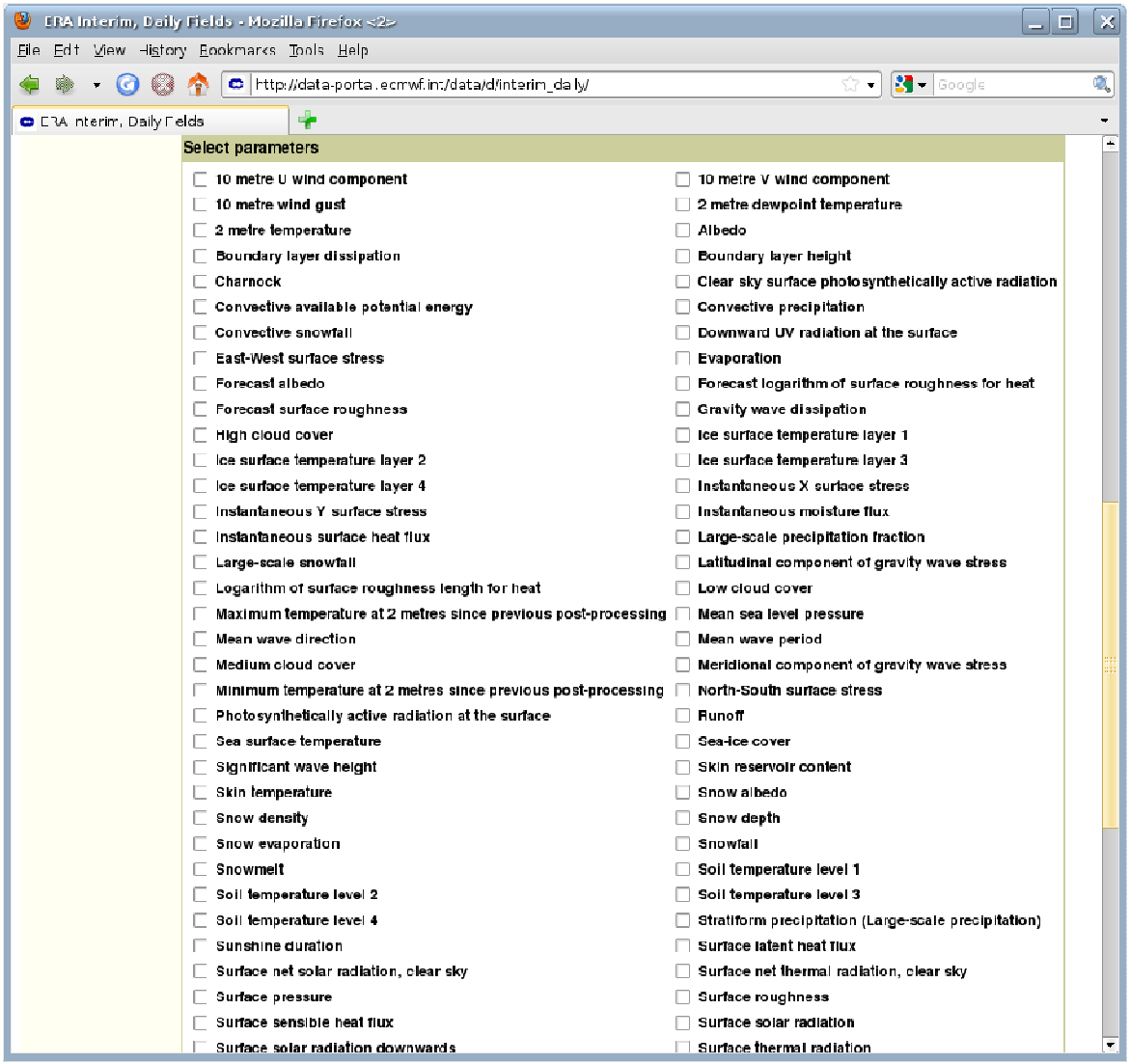
Products: http://data-portal.ecmwf.int/data/d/interim_daily/



From 1989 onwards.

Continued in near-real-time (monthly updates)

Surface (2D) parameters
3-hourly resolution, and monthly averages



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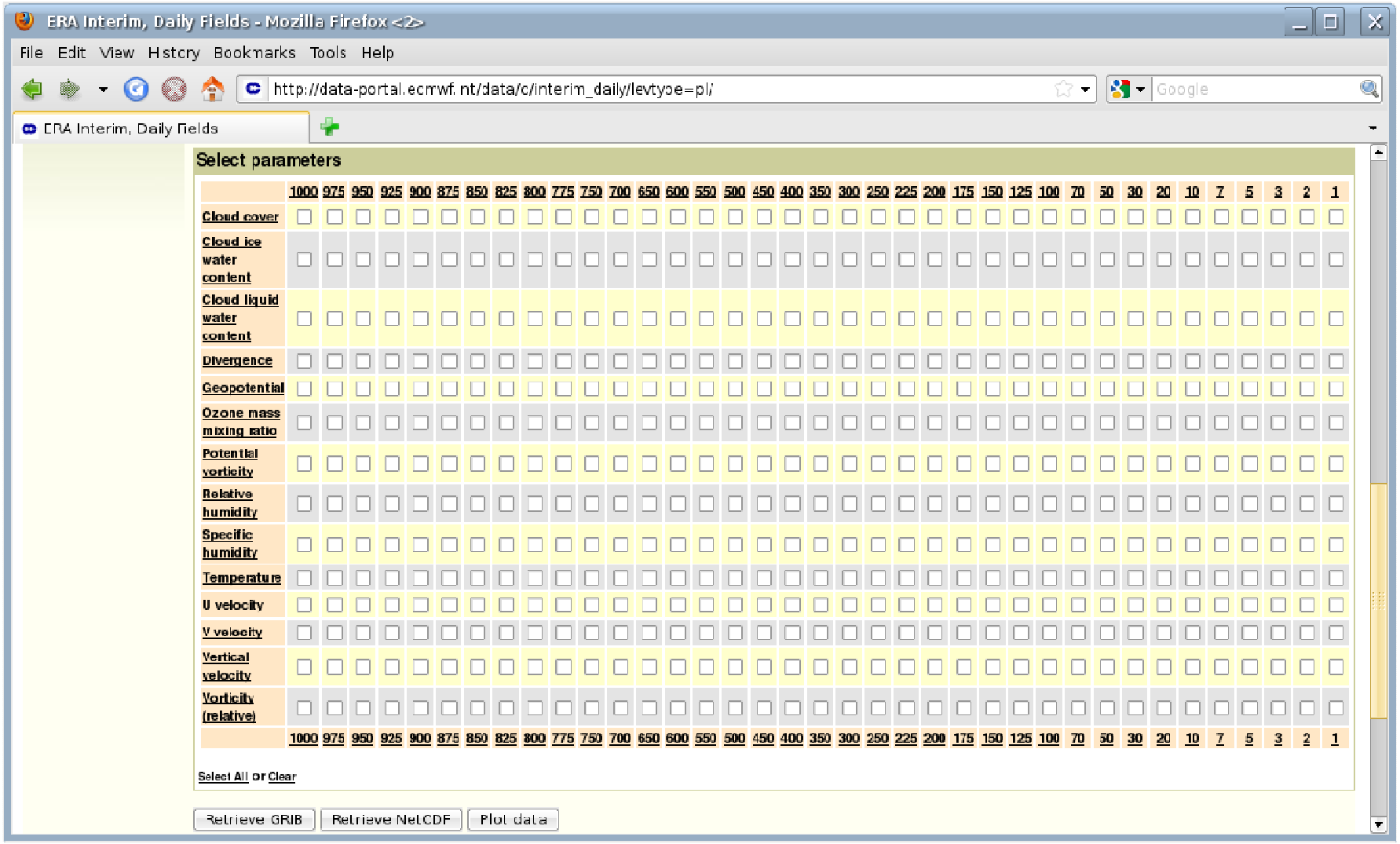
Upper-air (3D) parameters
6-hourly resolution, and monthly averages



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Reanalyses are worth repeating

- All ingredients evolve thanks to research and development in the science community
  - Models are getting better
    - Dynamics, physics, resolution
  - Data assimilation methods are getting better
    - Optimal interpolation → 3DVAR → 4DVAR …
  - Observations are getting better
    - Past observations are re-processed with new techniques, datasets can be homogeneized, …
- Each new generation of reanalysis integrates all these efforts for the benefit of a wide user community

Potential role of reanalysis for integration and validation of ECV products

- Bring in products under one unified framework, to compare
  - with full reanalysis system
  - with other observations
- Identify / estimate uncertainties
- Assess impact via withholding experiments or sensitivity analyses
- Assess homogeneity and time consistency
- Identify discrepancies between physically-related parameters

Conclusions

- **Most (if not all) of the ECV projects will require some information on the atmospheric parameters at the time and location of the satellite observation**

- **ECMWF already has a production system in place (based on the state of science as of 2006) to generate atmospheric auxiliary data in a time-continuous way**
  - **ERA-Interim reanalysis (1989-July 2009), continued in near-real-time**

- **These products are freely available on the web:** http://www.ecmwf.int/research/era

- **Potential for integrating future ECV products in ECMWF reanalyses for evaluation and assessment**

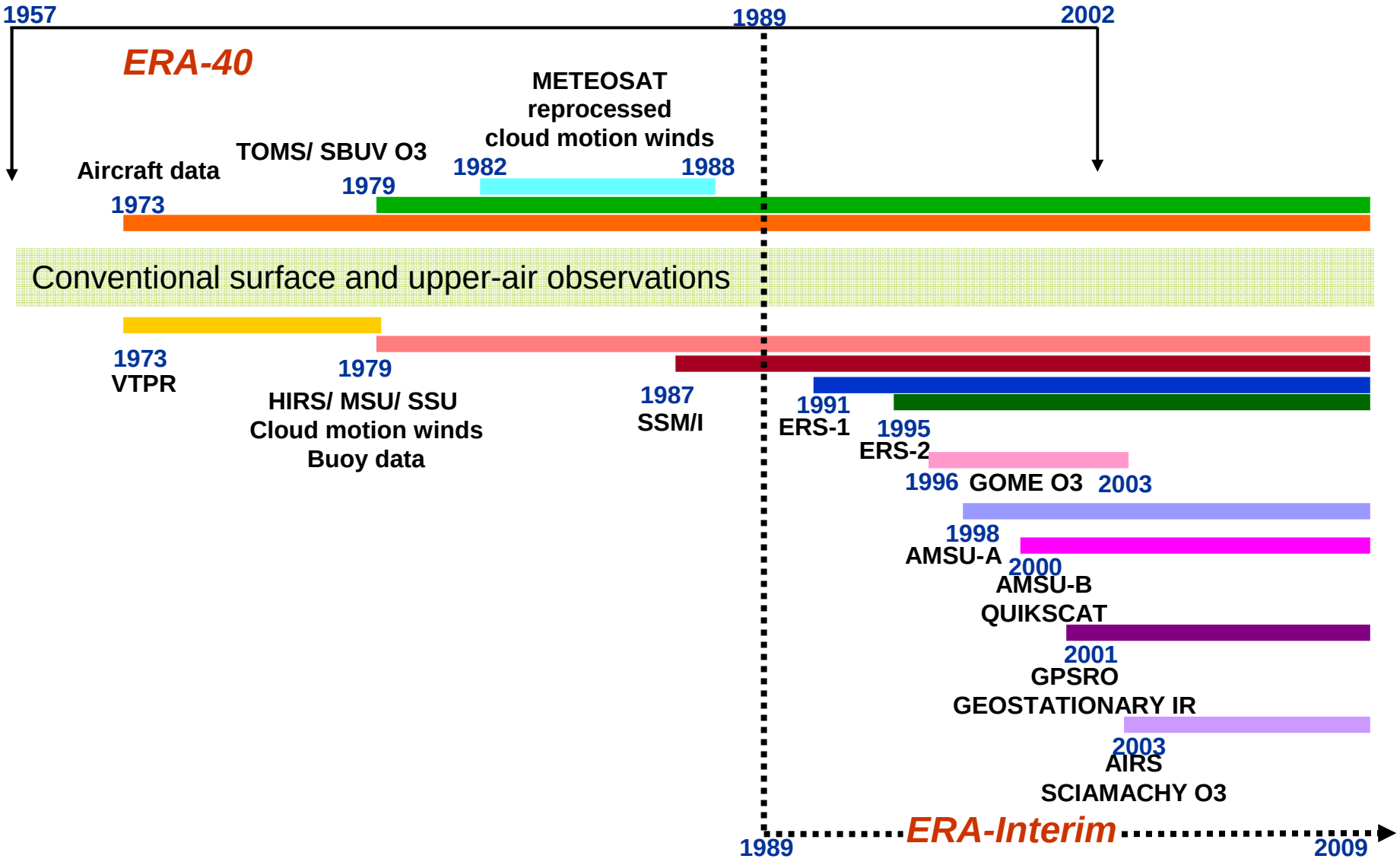
Some applications of reanalysis

- **Gridded proxy for "Observations", for verification and diagnosis**
  - Forecast model development, calibration of seasonal forecasting systems, climate model development; use of data assimilation increments for identifying model errors
- **Input data for model applications**
  - for smaller-scales (global→regional; regional→local), ocean circulation, chemical transport, nuclear dispersion, crop yield, health warnings, …
- **Study of short-term atmospheric processes and influences**
  - process of drying of air entering stratosphere, bird migration, …
- **Providing climatologies**
  - ocean waves, resources for wind and solar power generation, …
- **Assessment of the observing system**
  - providing feedback on observational quality, bias corrections and a basis for homogenization studies; contributing to data reprocessing activities
- **Study of longer-term climate variability and trends**
  - used with caution in conjunction with observational studies

When will ERA-Interim be replaced?

- **Challenges for a future reanalysis project:**
  - An extended reanalysis project such as ERA-40 takes 7-10 years to complete
    - Complex technical and scientific adventure (computing, monitoring, archiving)
    - Integration of expertise of various communities
  - Need to acquire 'new' observations
    - Not fully dealt with in ERA-Interim – few additional datasets
    - Several `new' datasets now available after digitization and clean-up – more datasets coming up
  - Scientific challenges:
    - Better handle the model error (bias)
    - Coupling with ocean
  - Funding

Observing systems used in ERA-40 and ERA-Interim



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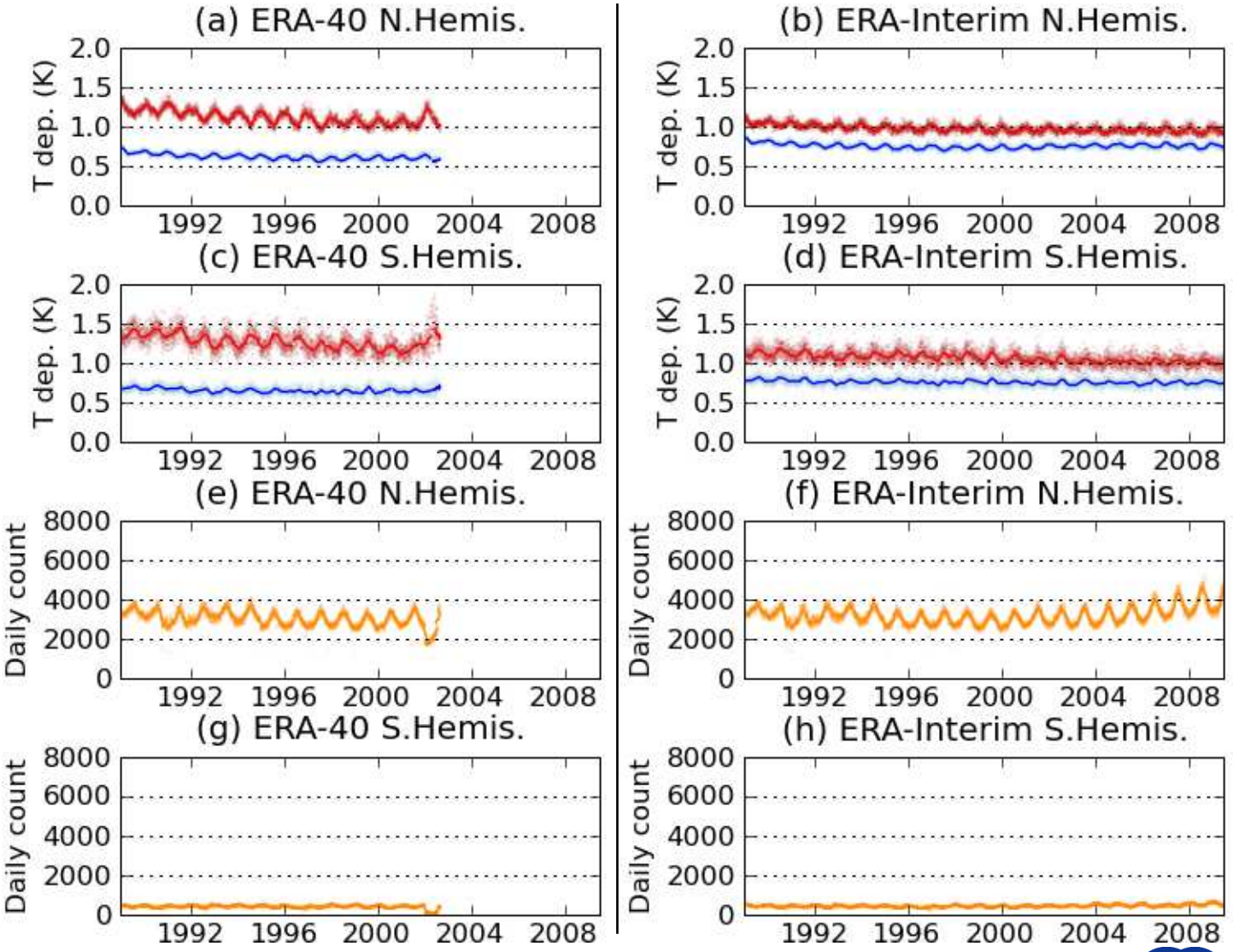
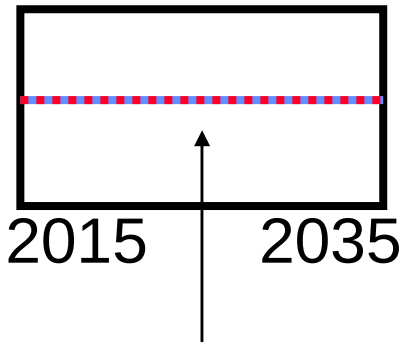
Validation with radiosonde temperatures at the "middle" of the troposphere (500 hPa)



Ideal case

(perfect model)



Analysis and *a priori* have the same statistics as compared to observations (observation error)

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