



Regional Reanalysis at UK Met Office

Richard Renshaw, Peter Jerney, Dale Barker

May 2014



with thanks

Stephen Oxley, Adam Maycock, Nigel Atkinson, Tom Green,
Jonah Roberts-Jones, Paul Dando, Rachel North, Ric Crocker,
and others



Outline

1. Why Regional Reanalysis ?
2. EURO4M Regional Reanalysis – Evaluation
3. Regional Reanalysis Plans
 - Uncertainty Estimation in Regional ReAnalysis (UERRA) project
 - Indian Monsoon Data Assimilation and Analysis (IMDAA) project
 - Other activities



1. Why Regional Reanalysis ?

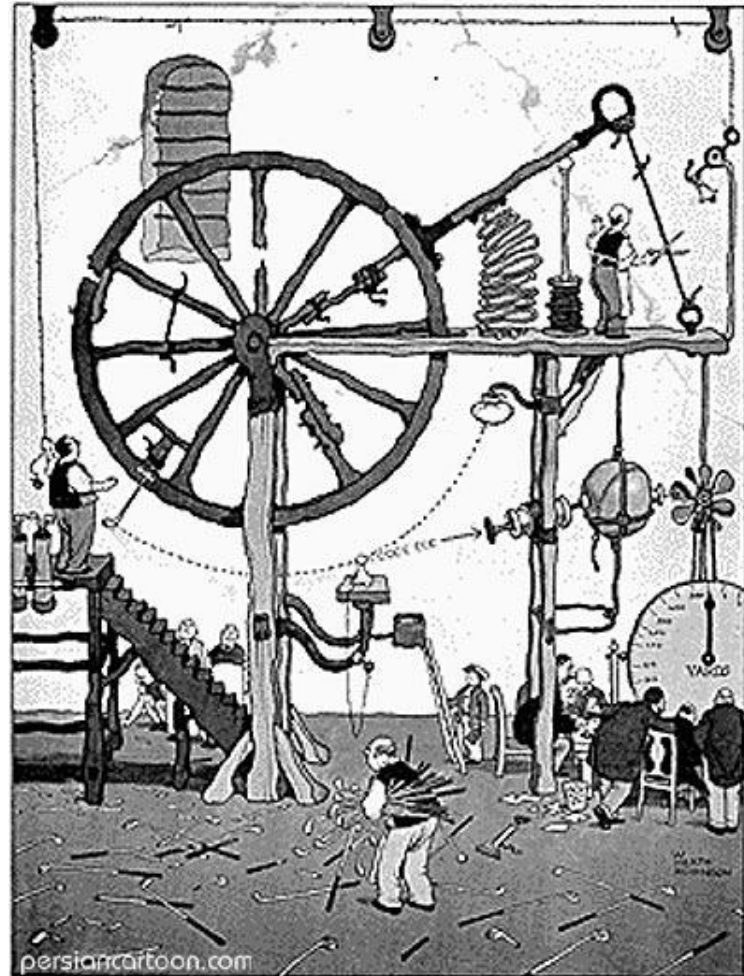


Met Office

What is a reanalysis ?

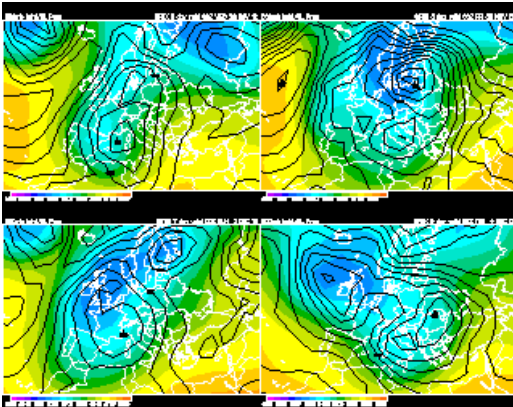
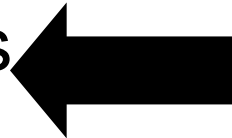


past observations



state-of-the-art NWP

gridded analyses



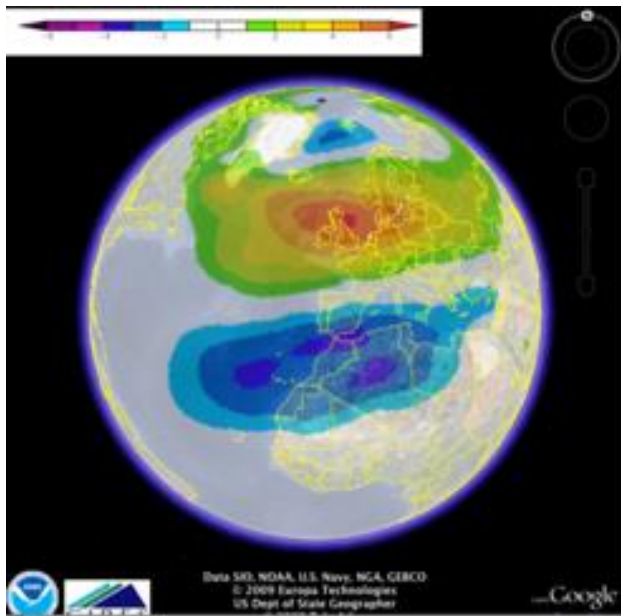
Why would anyone want a reanalysis ?



- Gridded data
- Based on observations
- Incorporates model equations
- Physically and dynamically coherent
- Full set of meteorological fields
- Consistent in time and in space
- We can estimate accuracy

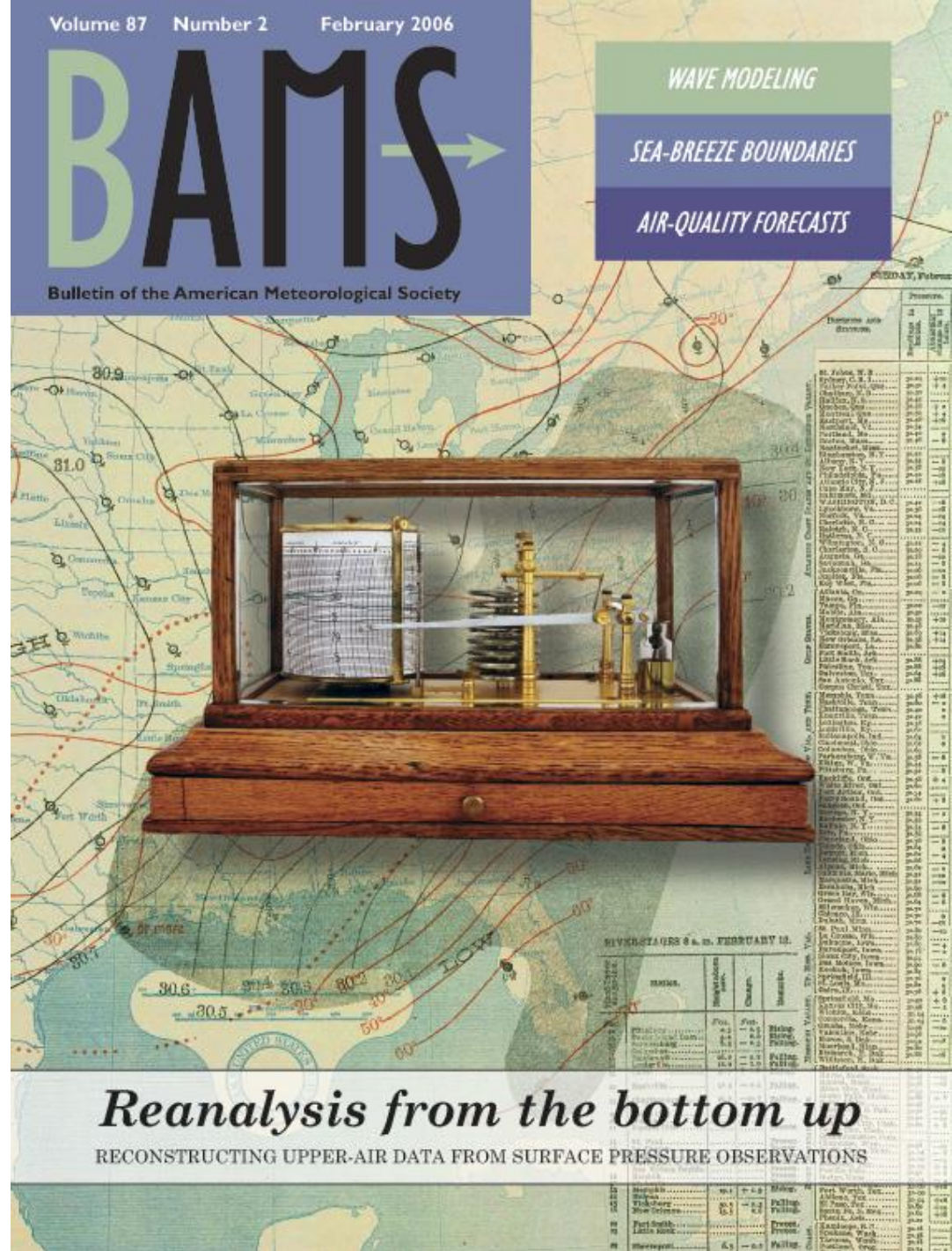


Global Reanalyses



- NCEP-NCAR (1995) 250km
- ECMWF ERA-40 (2004) 130km
- ECMWF ERA-Interim (2010) 80km
 - JMA JRA-55 (2013) 60km
 - ...

The 20th Century Reanalysis Project



*Jeff Whitaker, Gil Compo, Nobuki Matsui
and Prashant SardesmuKh*

NOAA/ESRL and Univ. of
Colorado/CIRES

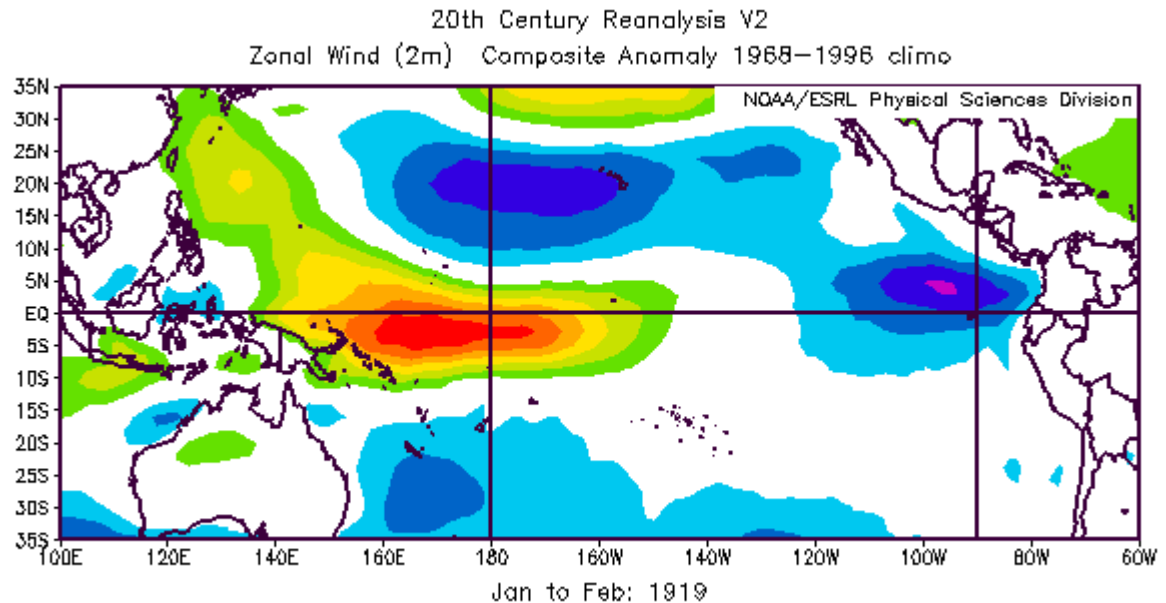


NOAA 20th Century (v2)

Gil Compo

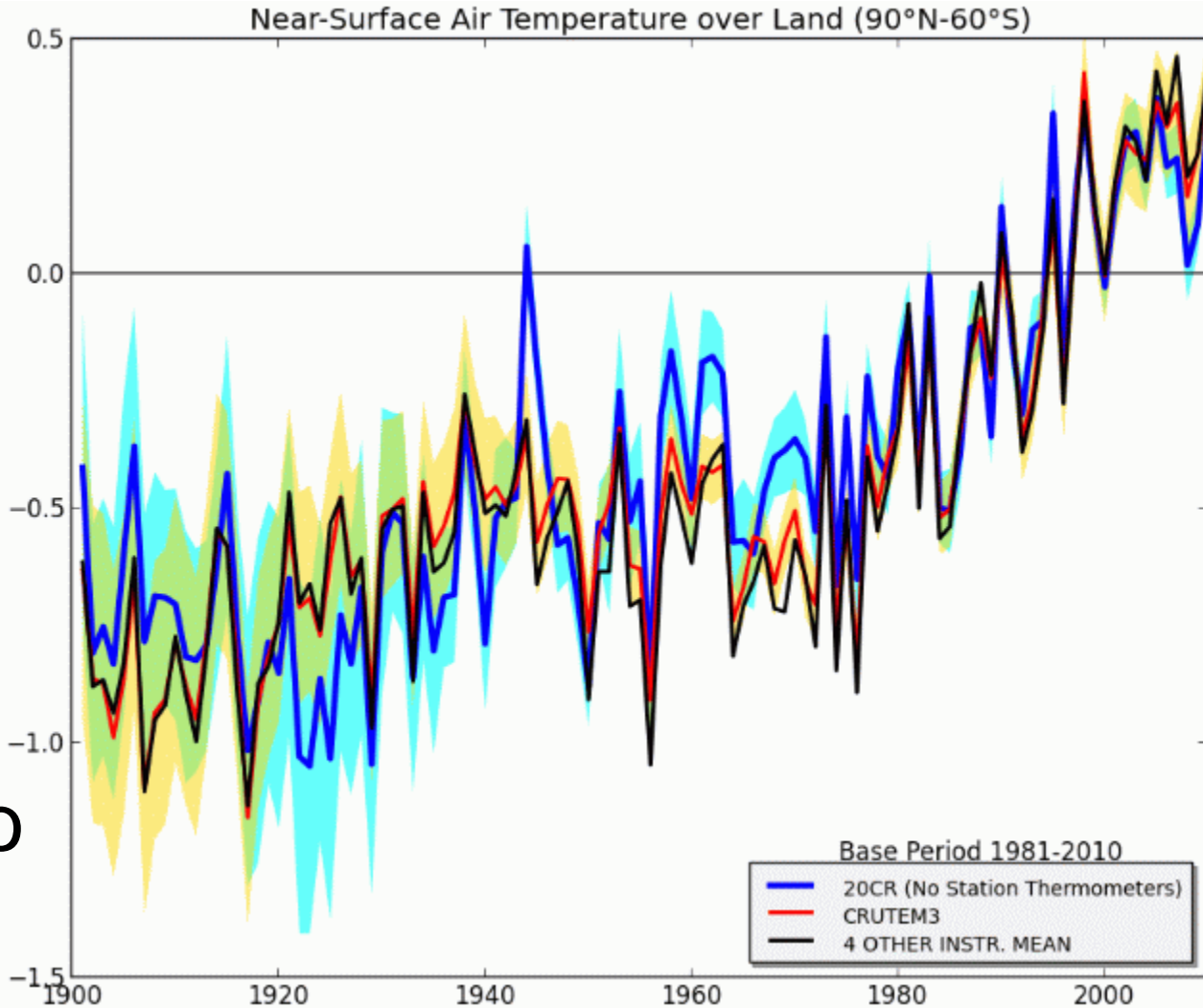
1870 – 2010, 200km
Surface pressure obs
56-member ensemble, EKF

El Nino, 1919
Wind anomalies





20th Century Reanalysis: land temperature trend

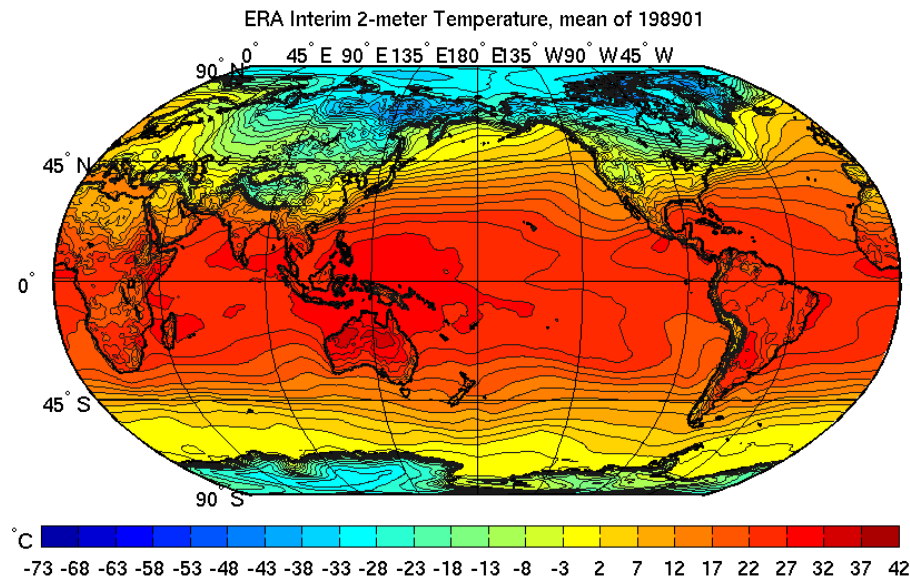


Gil Compo
et al



ERA Interim Reanalysis Dee et al, 2011

- Global atmosphere, T255 (80km), 60 vertical levels
- 12-hour 4D-Var
- 1979 - present

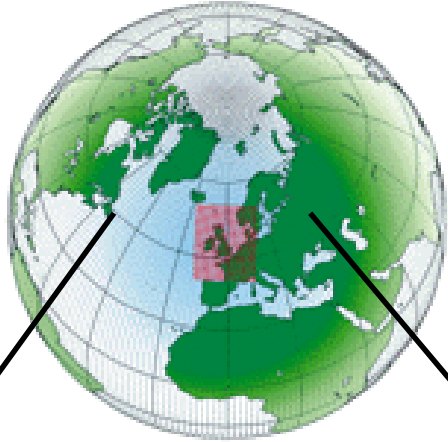




Regional reanalysis - why bother ?!

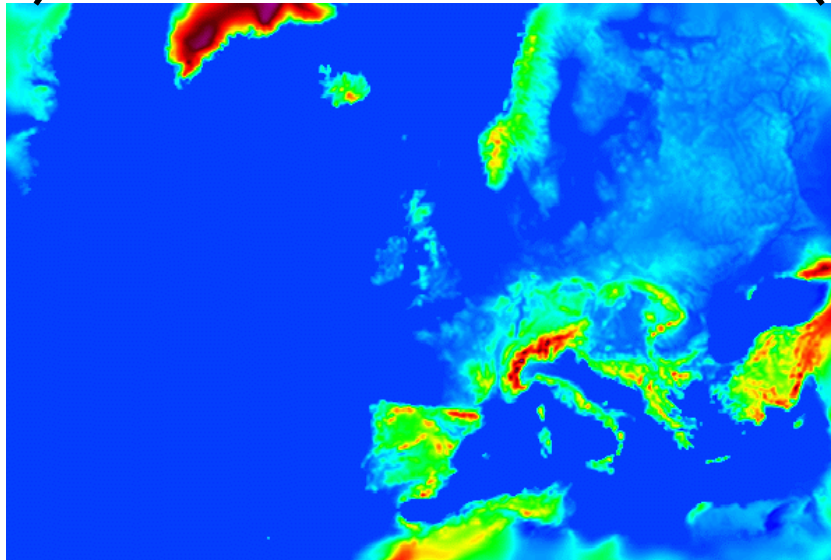


Evidence from operational NWP



25km Global

VS

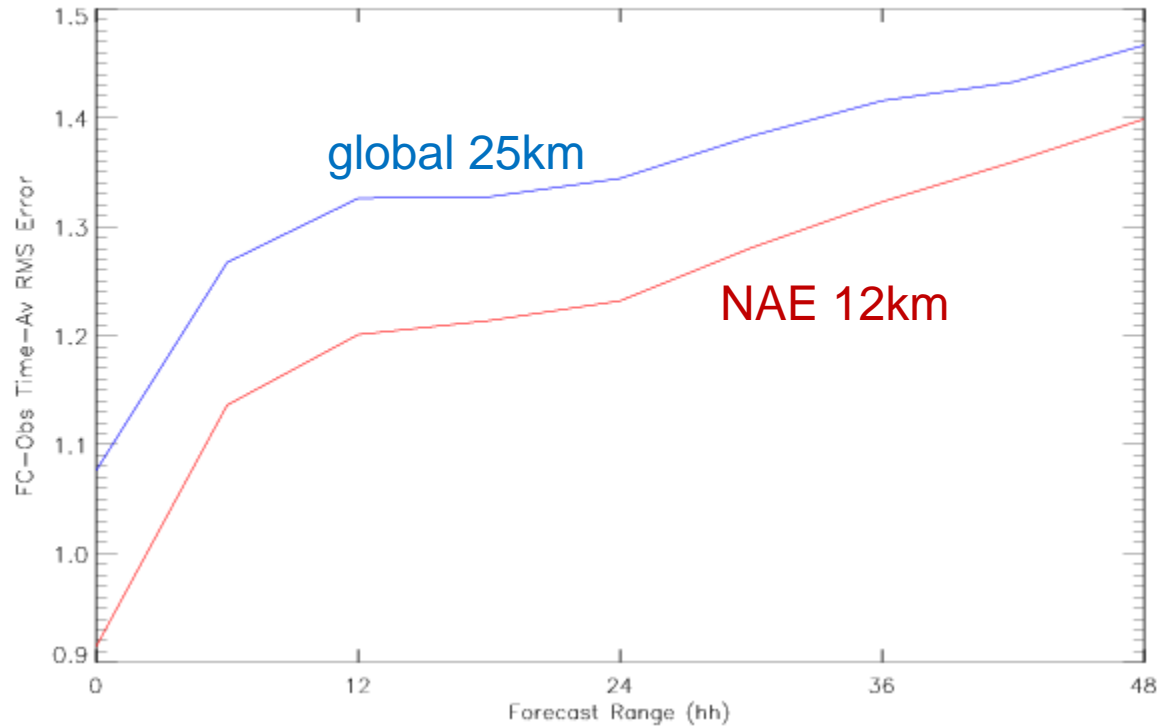


12km NAE



...the benefits of resolution

Temperature (Kelvin) at Station Height: Surface Obs
WMO Block 03 station list
Equalized and Meaned from Mar 2011 00Z to Feb 2012 18Z



↑
screen
temperature
rms error (K)

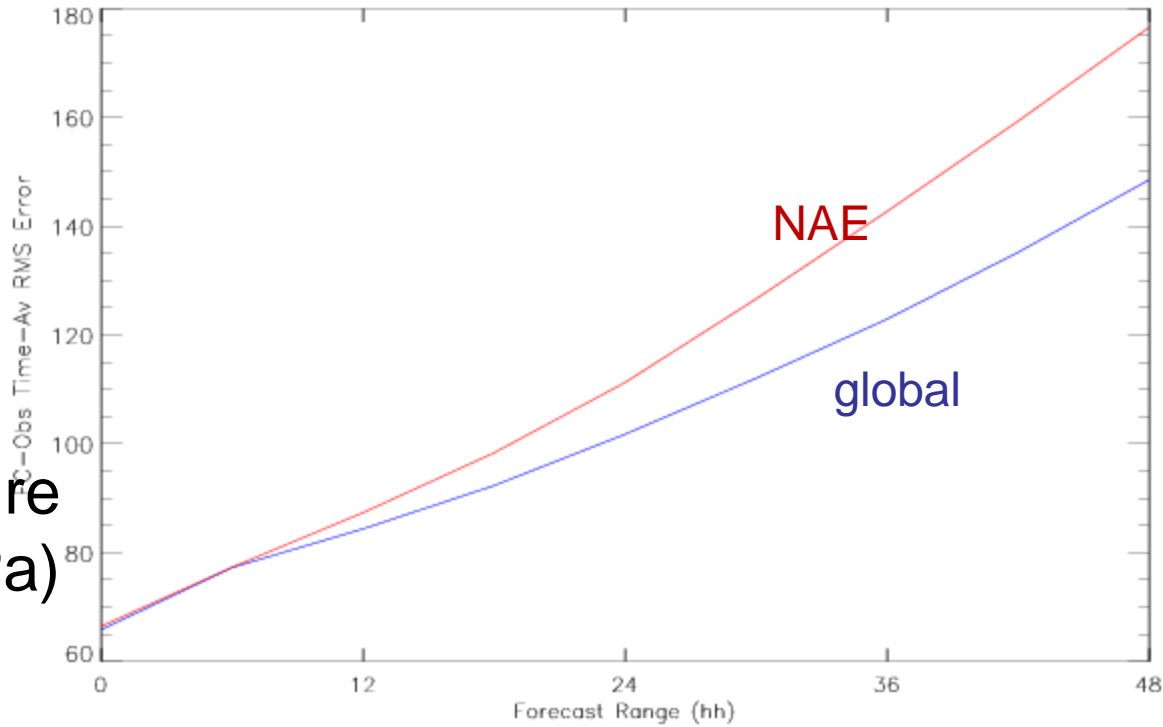
forecast range →



...and the disadvantage of boundaries!

↑
mean sea
level pressure
rms error (Pa)

Mean Sea Level Pressure (Pa): Surface Obs
Reduced Mesoscale Model area
Equalized and Meaned from Mar 2011 00Z to Feb 2012 18Z



forecast range →

EUROPEAN REANALYSIS AND OBSERVATIONS FOR MONITORING

Tracking changes in European climate

- EU-project, April 2010 – March 2014, 9 partners
- Goal: **LONG-TERM CLIMATE DATASETS + ASSESSMENTS OF CHANGE**
 - ...describing climate variability and change at the European scale
 - ...placing high-impact extreme events in a historical context

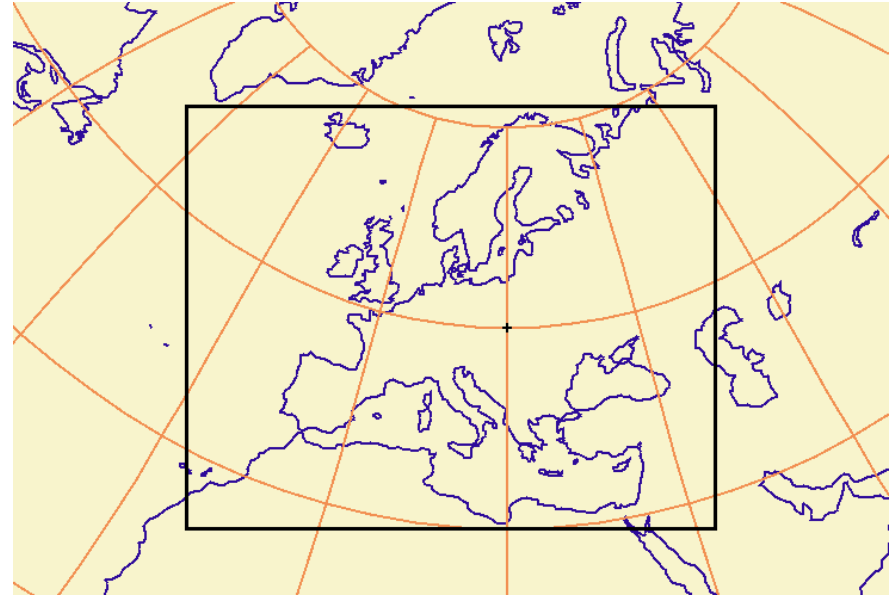




Met Office

European Regional Reanalysis: EURO4M project

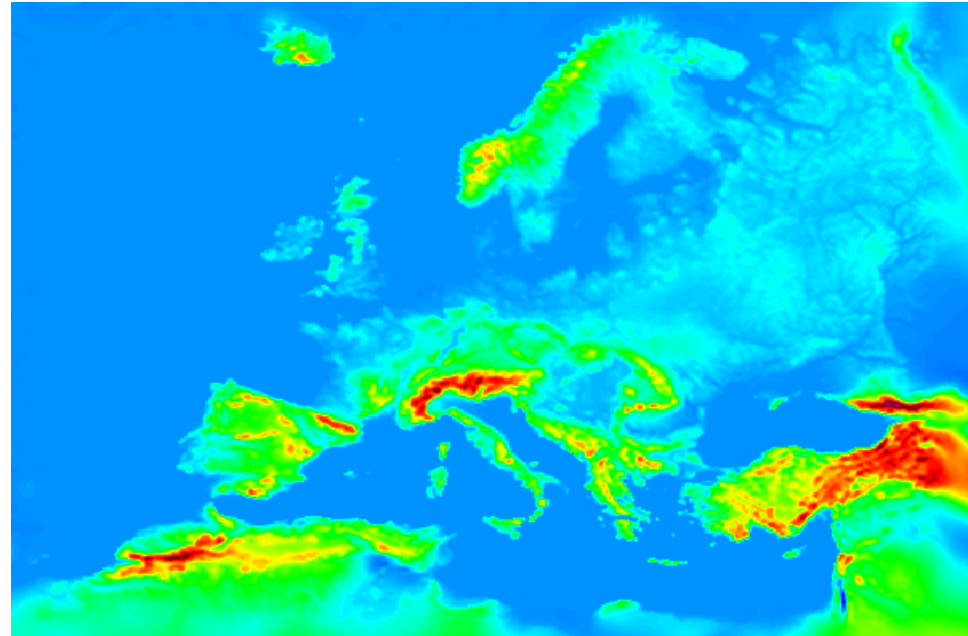
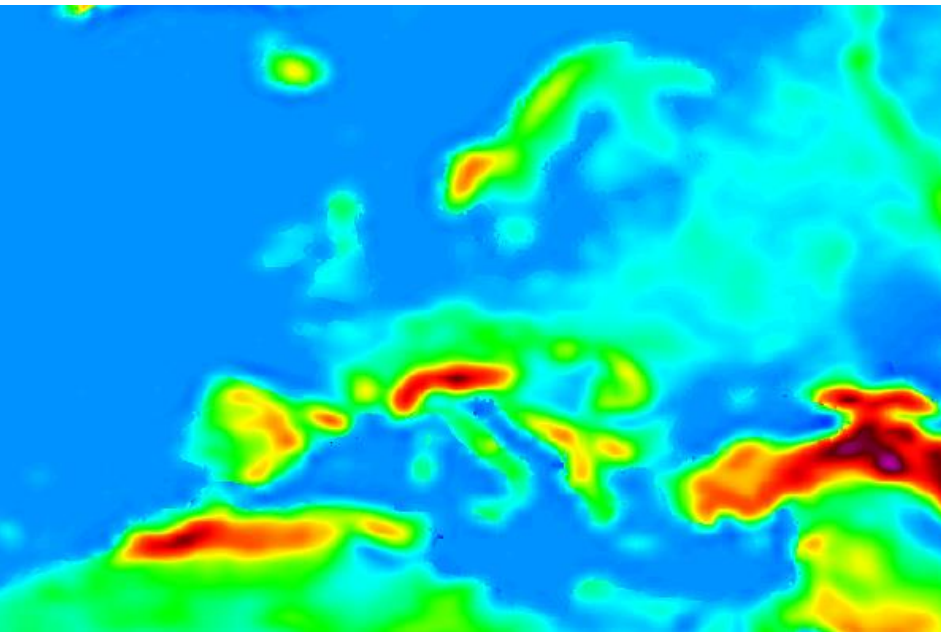
- EURO4M project (2010-2014) developed DA UM regional reanalysis, tested in pilot 2 year period (2008-2009).



- Resolution: 12km model, 24-36km DA (4D-Var, hybrid EnDA)
- Lateral boundary conditions: ERA (-Interim). ERA observations.



Increase in resolution



ERA-Interim: Model/DA 80/125km

EURO4M: Model/DA: 12/24km

Observations

- Surface (SYNOP, buoy, etc)
- Upper air (sonde, pilot, wind profiler)
 - Aircraft
 - AMV ('satwinds')
- GPS-RO and ground-based GPS
 - Scatterometer winds
 - ATOVS
 - AIRS
 - IASI
 - MSG clear sky radiances



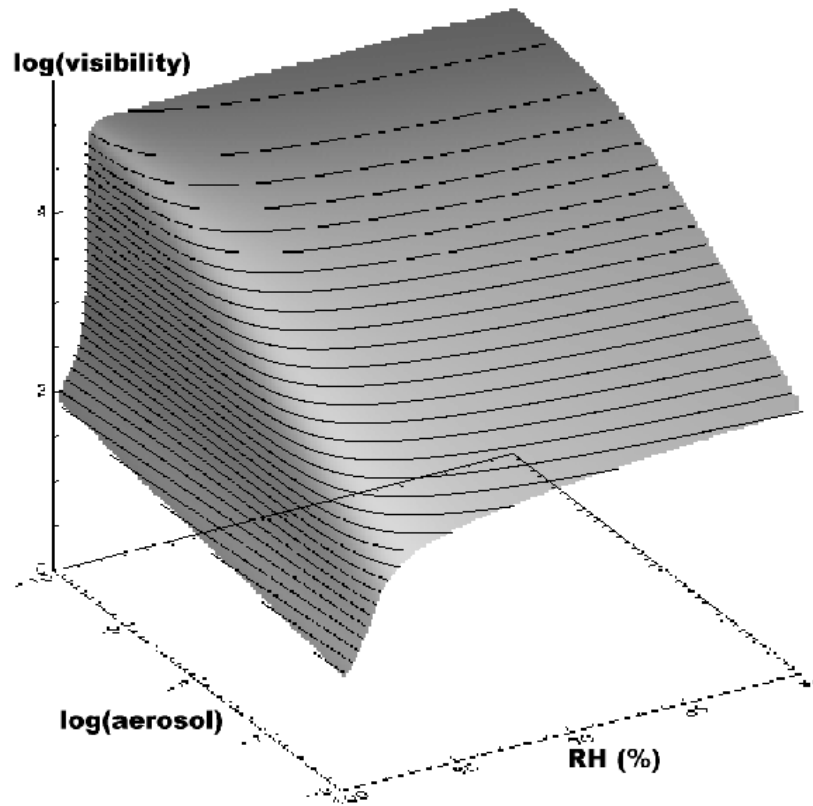


Getting more from surface obs...

- Visibility
- Cloud
- Rainfall



Visibility assimilation



Visibility = f(aerosol concentration, humidity)



Cloud from SYNOP reports

Peter Francis



Cloud base assimilated as function of relative humidity

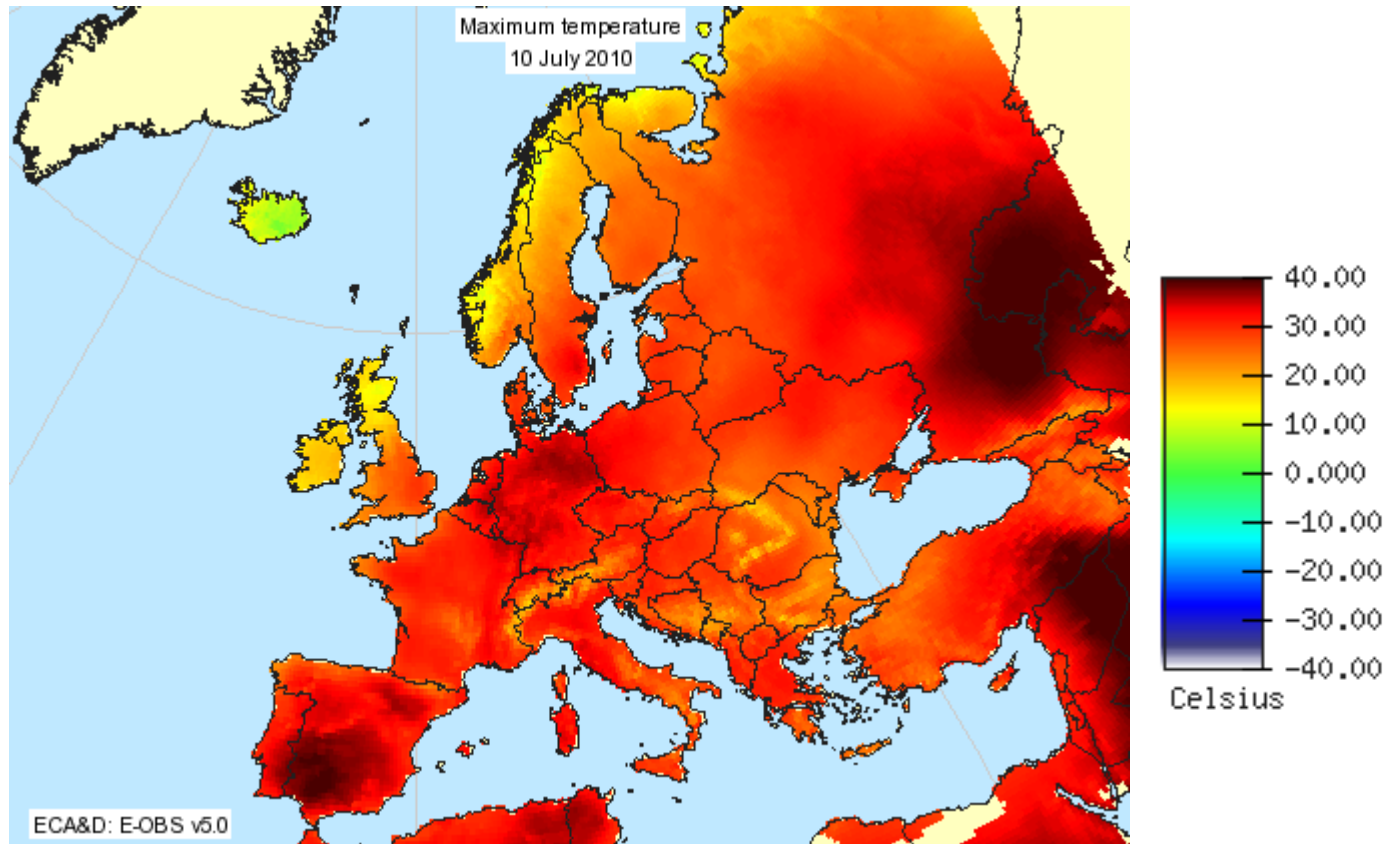


2. EURO4M Regional Reanalysis Evaluation

Peter Jermey

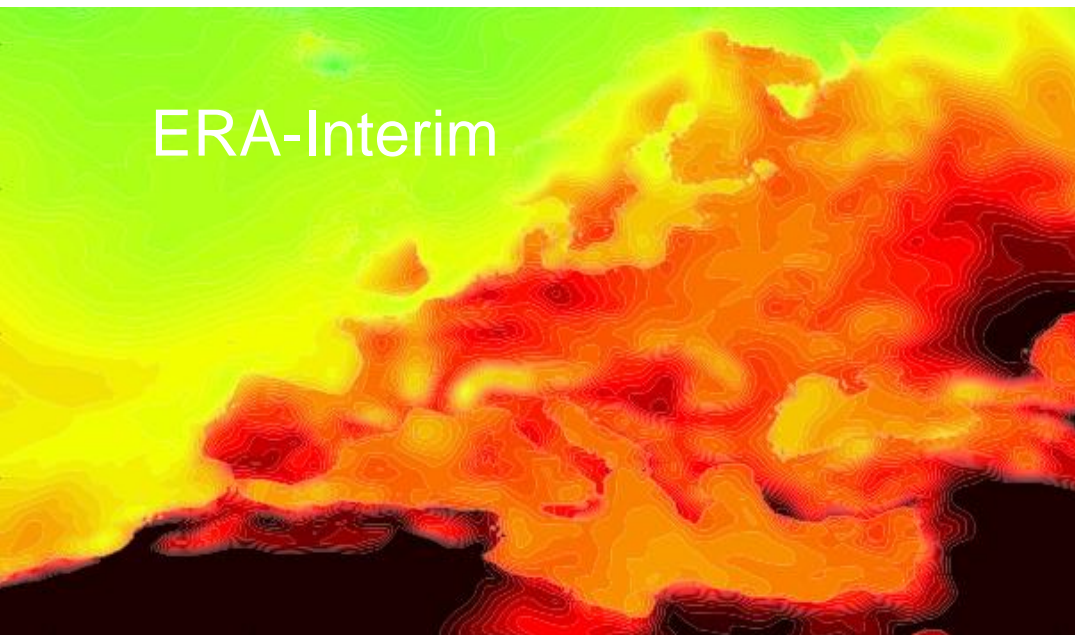
Russian heatwave, July 2010

e-obs

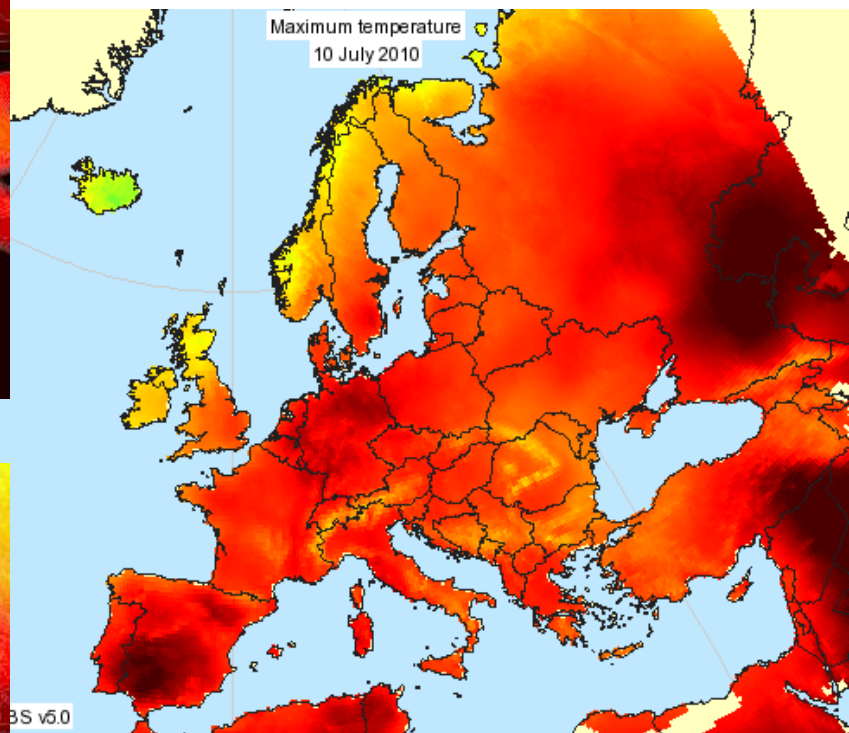


Tmax, 10-07-2010

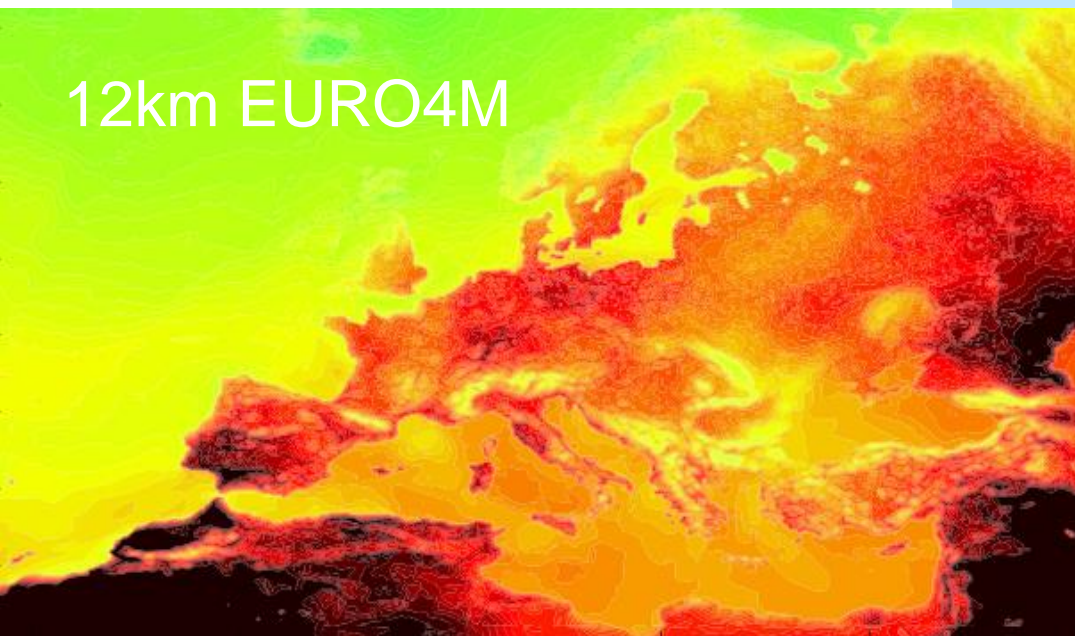
ERA-Interim



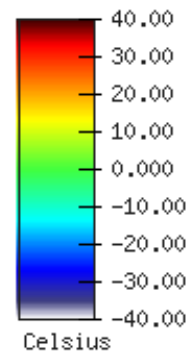
obs



12km EURO4M

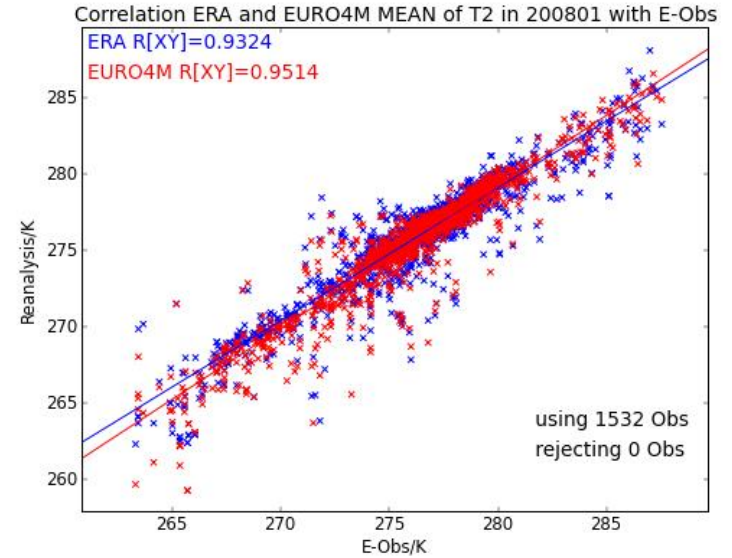
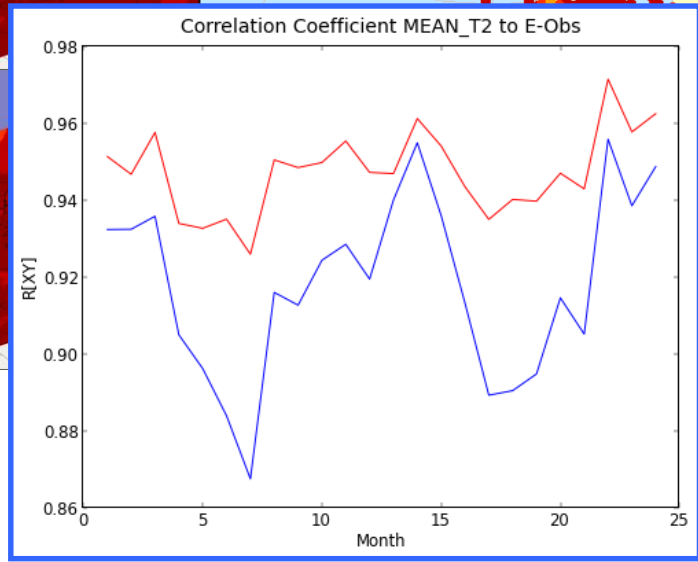
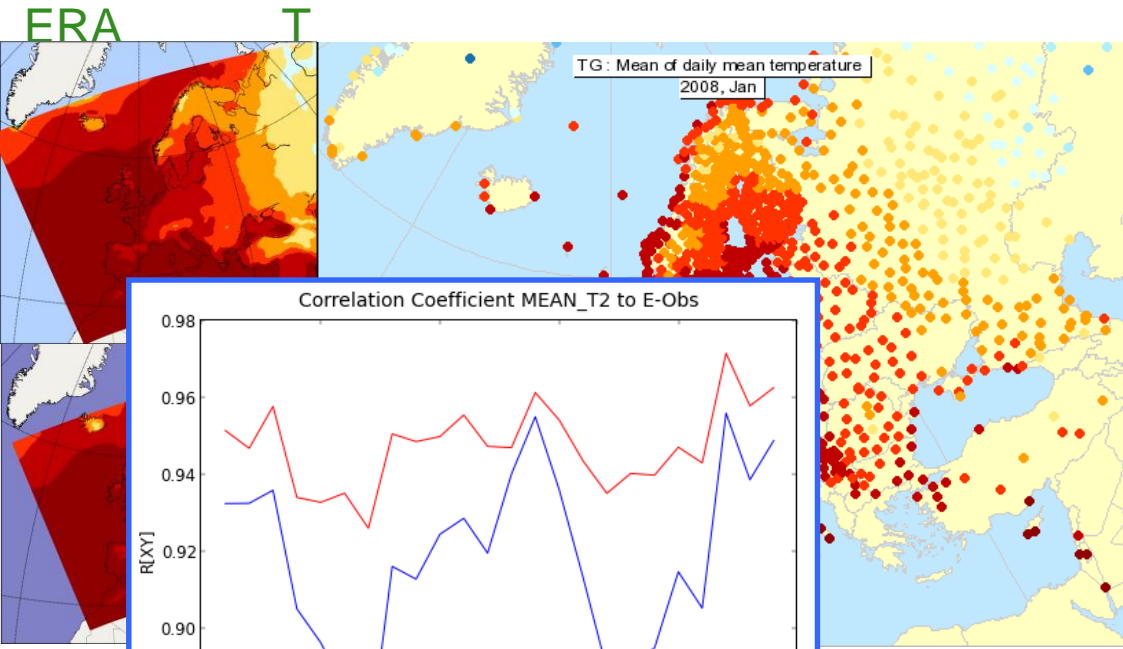


Tmax
10-07-10



Monthly Means

Compare with ECA&D statistics from obs stations



MO

Compare with ECA&D statistics from obs stations

Mean	Max of Min Temp	Dry Days	
Mean of Min Temp	Mean Precip	Wet Days	
Mean of Max	Icing Days	Frost Days	MO better in...
Mean Wind Speed	Total Wet Precip		24/24 months
Max of Min Temp	Mean Temp		23/24 months
Max of Max Temp	Tropical Nights		22/24 or 21/24
Min of Min Temp	Mean Wet Precip		20/24 or 19/24
Max Precip 5	Mean Cloud		10/24 months
Summer Days	Mean Rel Hum		
Calm Days	Maximum Gust		
Days	Max Daily Precip		
Days	Wind Days	Mean PMSL	



Climate Statistics

Climate statistics are useful for monitoring the European climate.

Regional models represent 12/28 stats better than ERA-Interim for the full period.

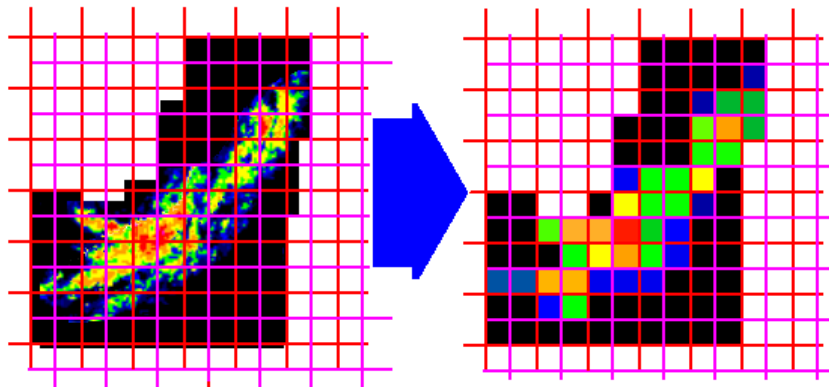
Regional models represent 27/28 stats better than ERA-Interim for most of the period.

Large scale variables (e.g. pressure) are better represented in the global ERA-Interim.

Covers wide range of intensities, periods and scales

Flooding in central Europe in 2013 caused 25 deaths and 12bn Euros damage

Higher resolution should lead to improved representation of extremes



Floods July 2008

ROMANIA



9000 houses damaged
20,000ha ag. land flooded
5 dead
\$100 million

MOLDOVA



300 houses destroyed
7500ha ag. land flooded
3 dead
\$300million

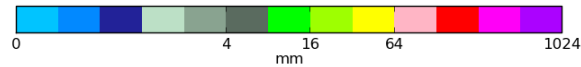
UKRAINE



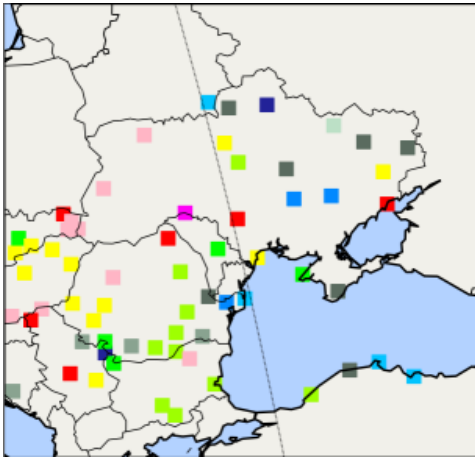
50,000 houses flooded
300,000 people affected
38 dead
cost \$700million

Floods July 2008

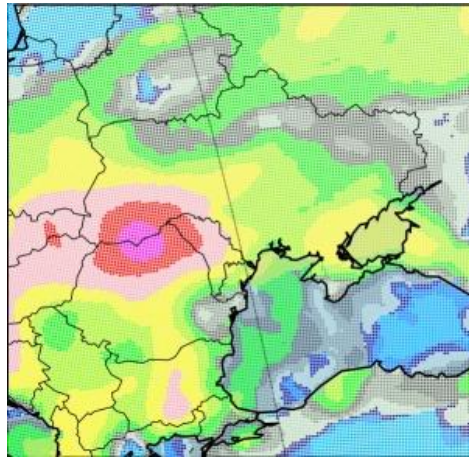
23-26th July
Accumulations



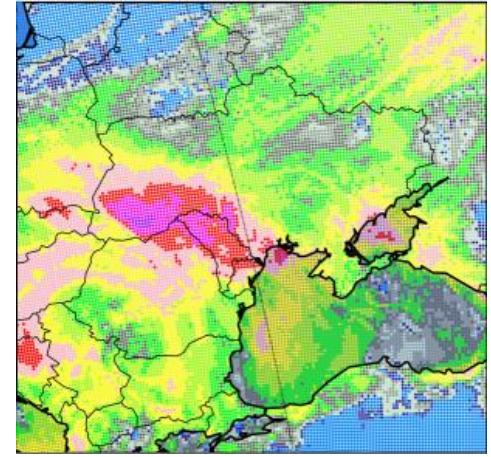
SYNOP



ERA-Interim



UKMO



Mean abs
error

15mm

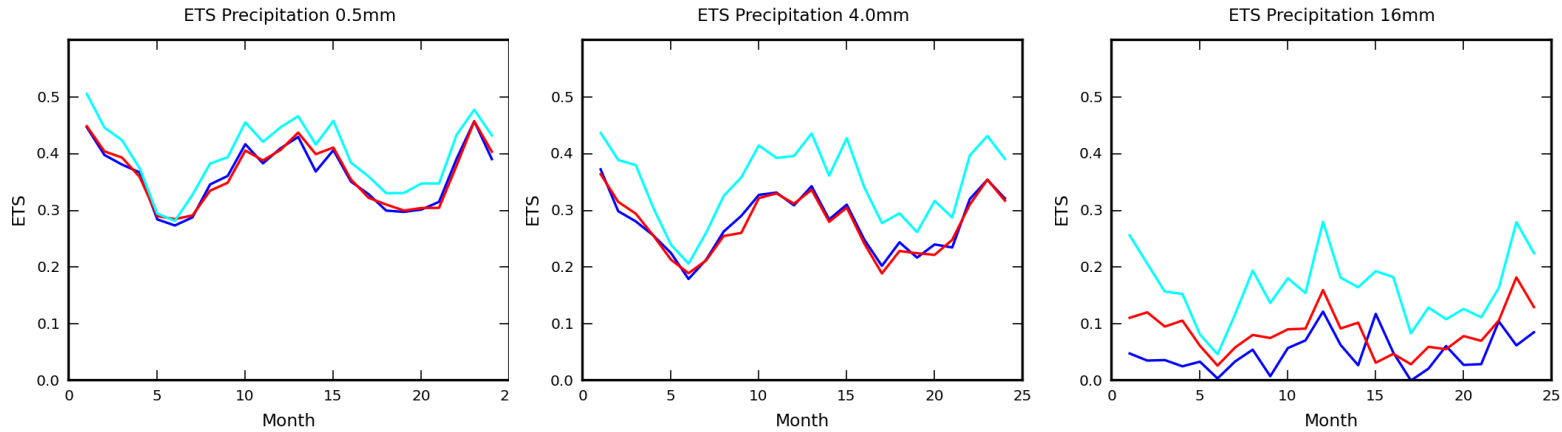
13mm



ETS precip scores



Truth is SYNOP rain gauge data

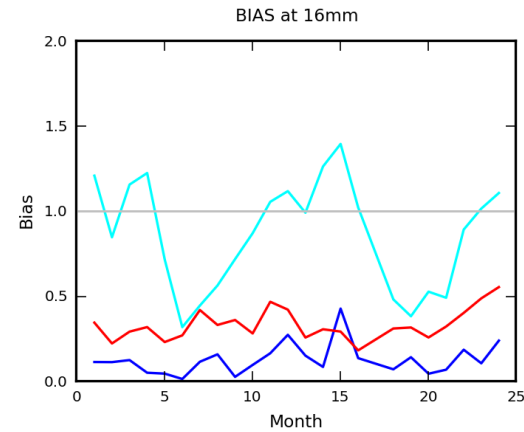
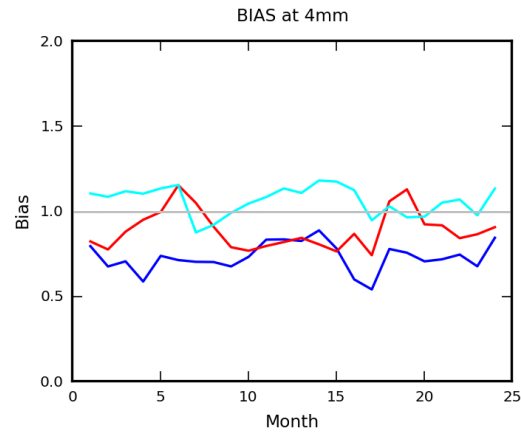
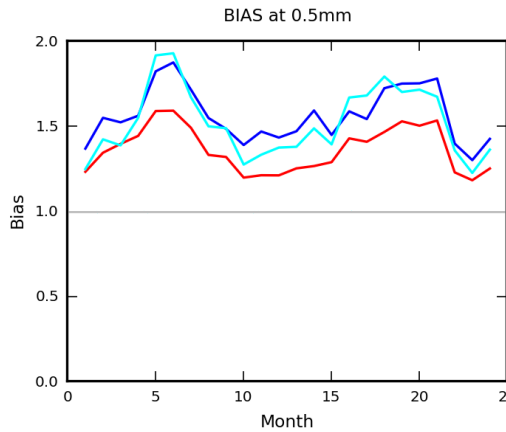


6hr

ERA-Interim

HIRLAM

Met Office



6hr

At high thresholds models under-represent, but ...
... bias is reduced by increased resolution & 4DVAR assimilation

Validation

- Reanalysis is only useful if we know the errors
- Validation datasets need to be independent
- Reanalysis fields are already of good quality
- Datasets need to be good quality, with error estimates
- Conventional obs have limited coverage
- Some variables difficult to validate



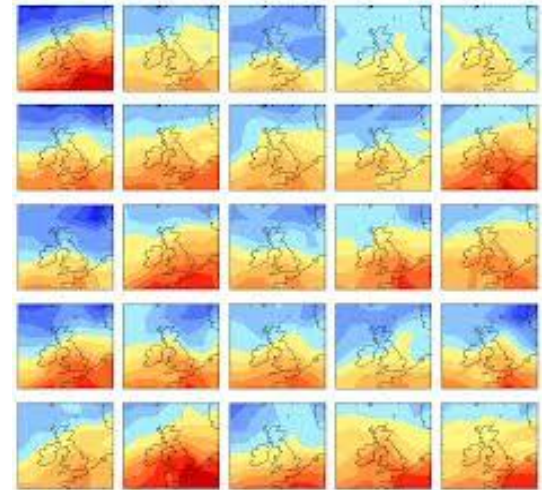


3. Regional Reanalysis Plans



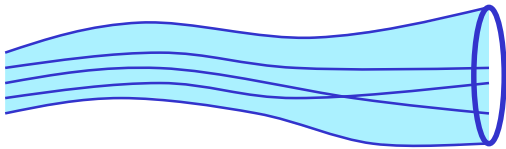
Uncertainty Estimation in Regional ReAnalysis (UERRA) Project

- EURO4M represents just an initial step towards a full regional reanalysis capability.
- UERRA (2014-2018) will provide a **multidecadal, multivariate dataset of essential climate variables (ECVs) for the satellite era (1978-present)**.
- UERRA will include both deterministic and **the first ensemble regional reanalysis** (leveraging techniques developed for global NWP).
- UERRA described as a component of a 'pre-operational' climate service, preparing the way for reanalysis as a central pillar of the **Copernicus Operational Climate Service**.

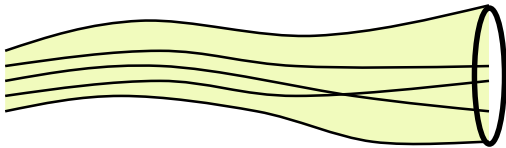
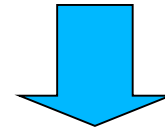




Uncertainties from ensembles



Calibrate for variables
we can validate



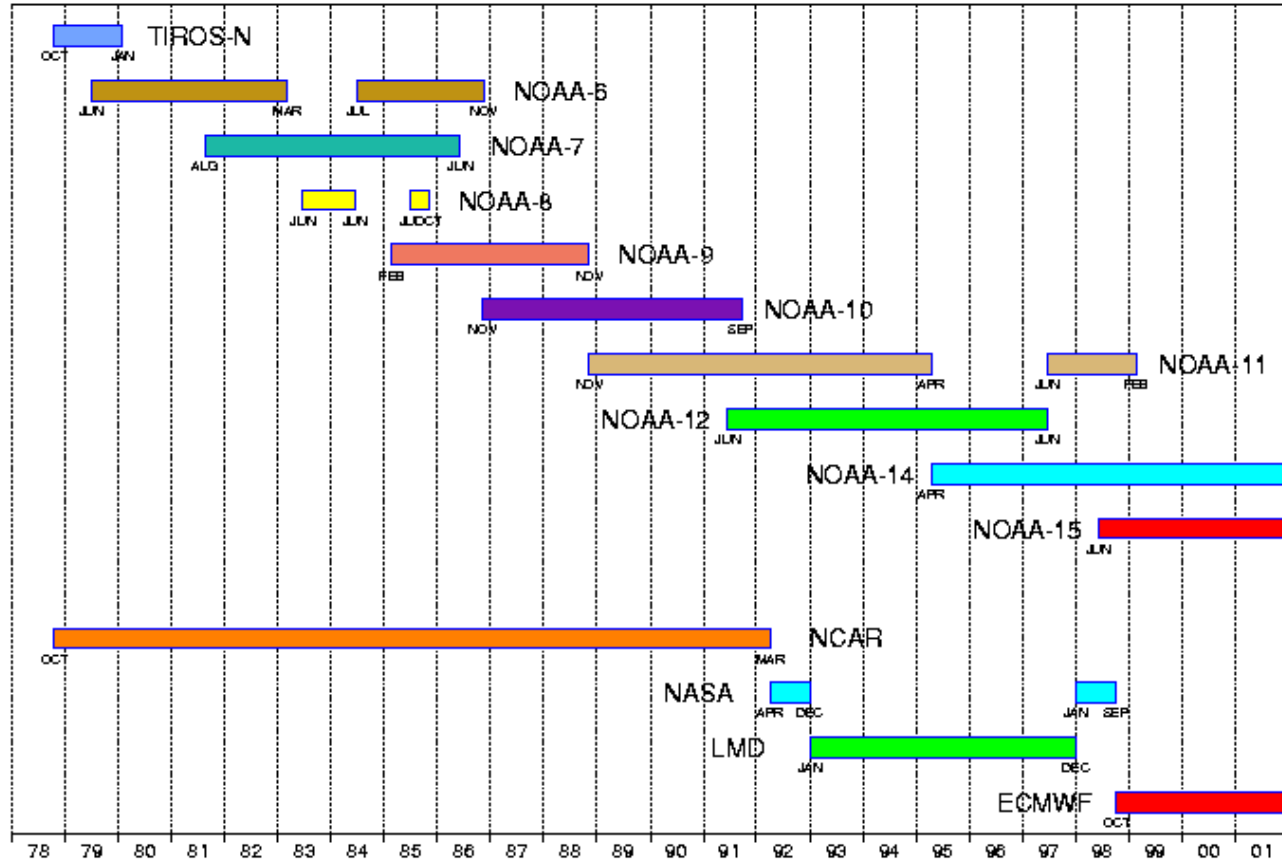
Get uncertainties for
variables we can't
validate



Reanalysis challenges...



TOVS sounding instrument



1978

2001

(Amy Doherty)



Variational Bias Correction

Airmass-dependent bias correction of satellite radiances
(based on Harris and Kelly, 2001)

$$bias = c^{scan} + \sum_{i=1}^n ci^{air} f(x_b)$$

VarBC will give smooth and automatic updating

Challenge: tune for a regional model

(DingMin Li, Andrew Lorenc , Dale Barker)



Precipitation assimilation

Target

Use E-Obs gridded daily precipitations

System to disaggregate 24hr accumulations to 6hrs

4D-Var has linearised precipitation processes

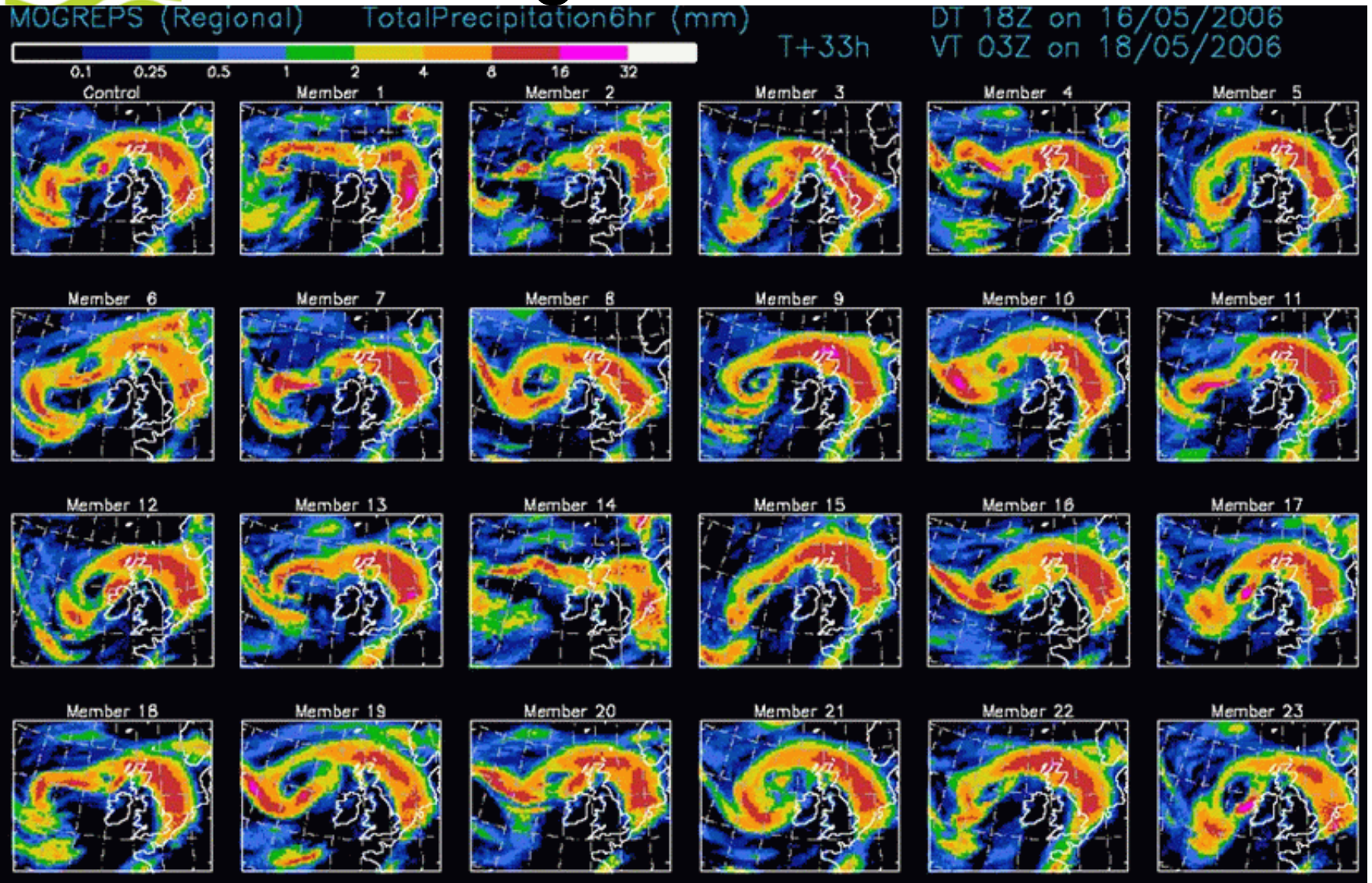
Use Var outer loop (UM-Var-UM-Var-UM)

to cope with non-linearity





Regional Ensemble

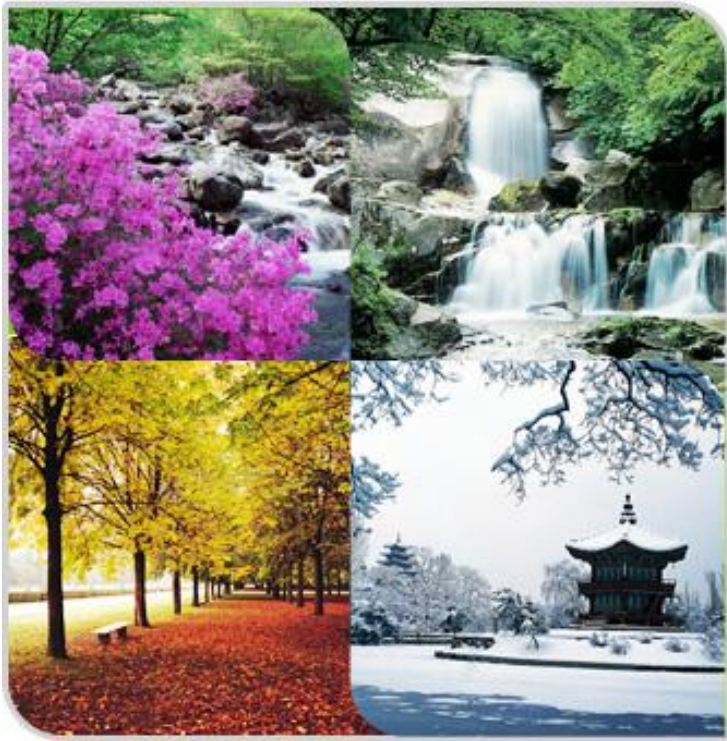




Met Office

Summary

1. Reanalysis benefits both weather and climate services.
1. Motivations for regional reanalysis similar to those for regional NWP.
1. Very promising results from EURO4M pilot 2008-2009 study.
1. Focus now on 'production' regional reanalyses (1978-present).
1. Collaboration with UM partners



Korean East Asia Reanalysis



Thank you for listening...

<http://www.euro4m.eu/>
<http://www.uerra.eu/>



Extra slides...



Cloud assimilation

Operational NAE assimilates 3D cloud fields
from nowcasting system

(combines satellite imagery + surface reports)

EURO4M reanalysis uses surface reports directly





Cloud from SYNOP report

Wattisham, 00Z 2012/03/13

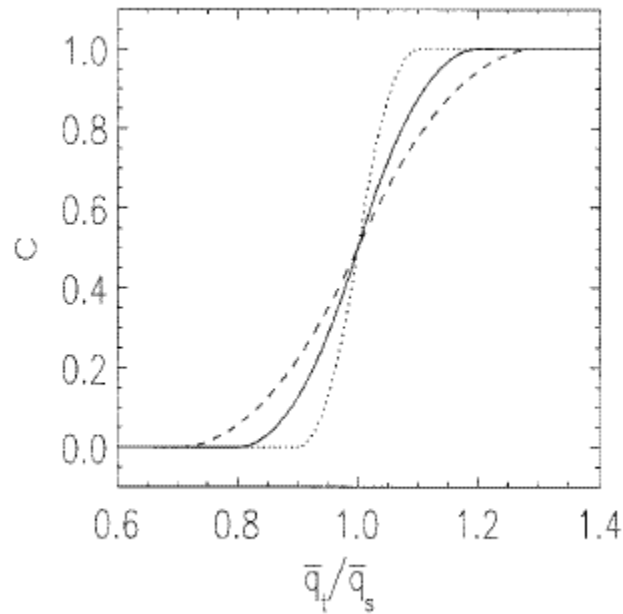
AAXX 13004 03590 11238 83504 10064 20060 30240 40352 53002 60001 71022
886// 92350 333 55/// 20411 84703 86706 88708

- 84703 4 oktas Stratus from 90m
- 86706 6 oktas Stratus from 180m
- 88708 8 oktas Stratus from 240m



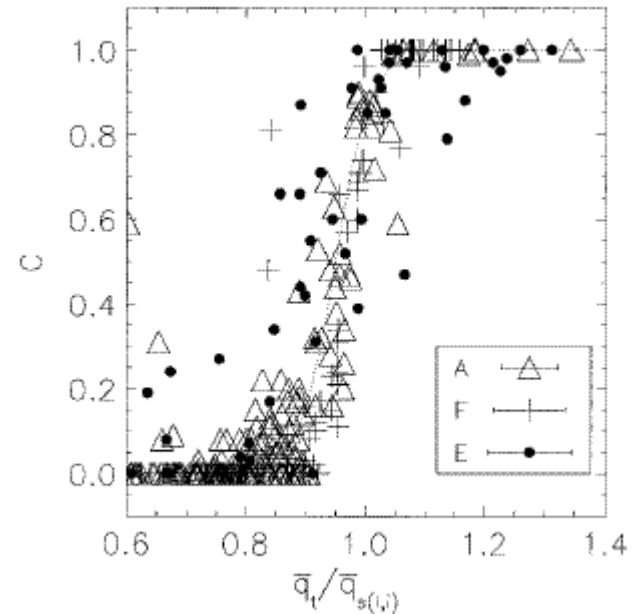
Pete Francis

Cloud-RH diagnostic



Smith scheme

QJRMS 1990

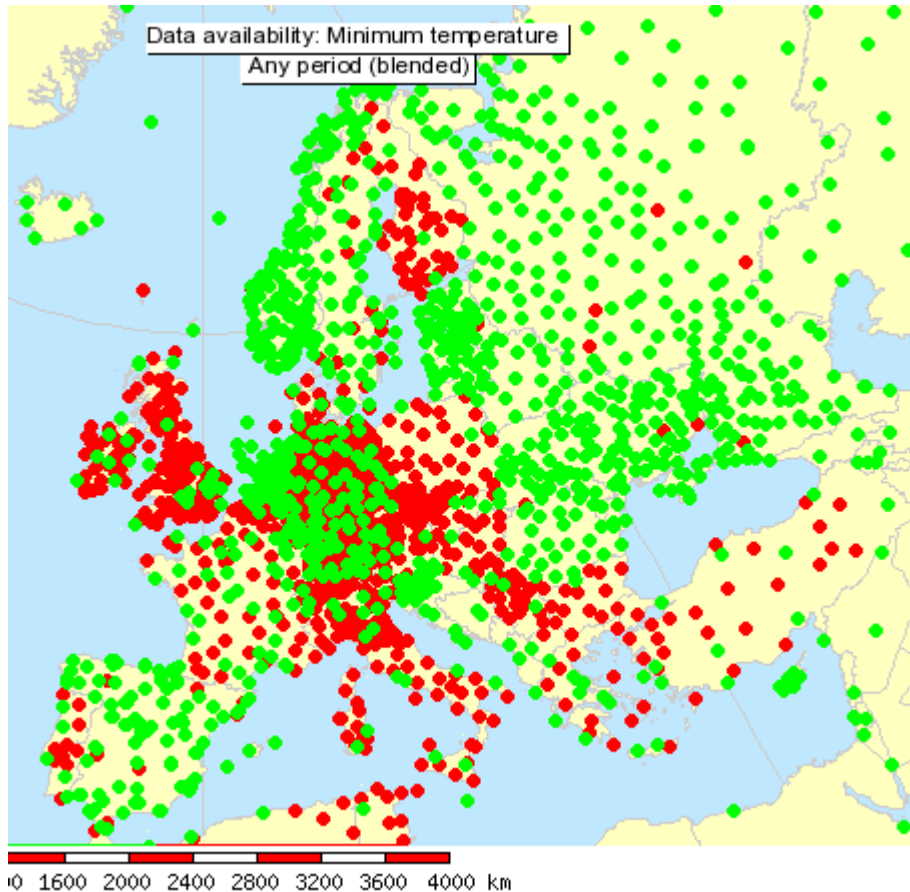


aircraft data

Wood & Field, JAS 2000



ECAD: European Climate Assessment and Dataset



www.ecad.eu

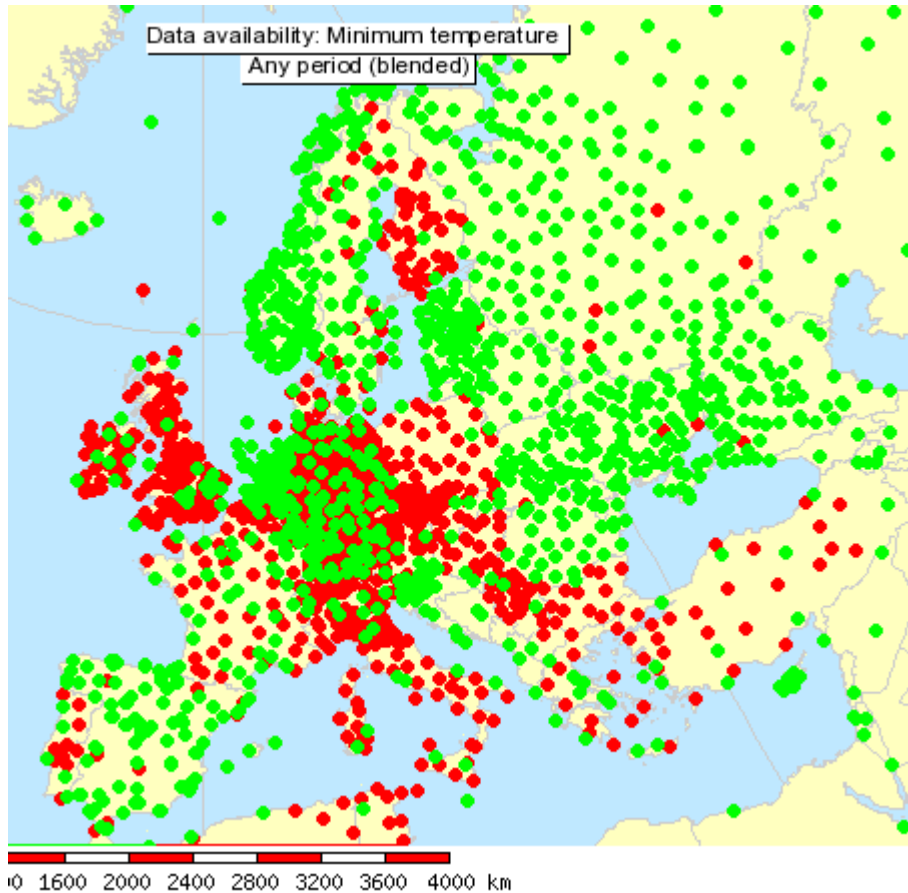
Daily data from 1950 -



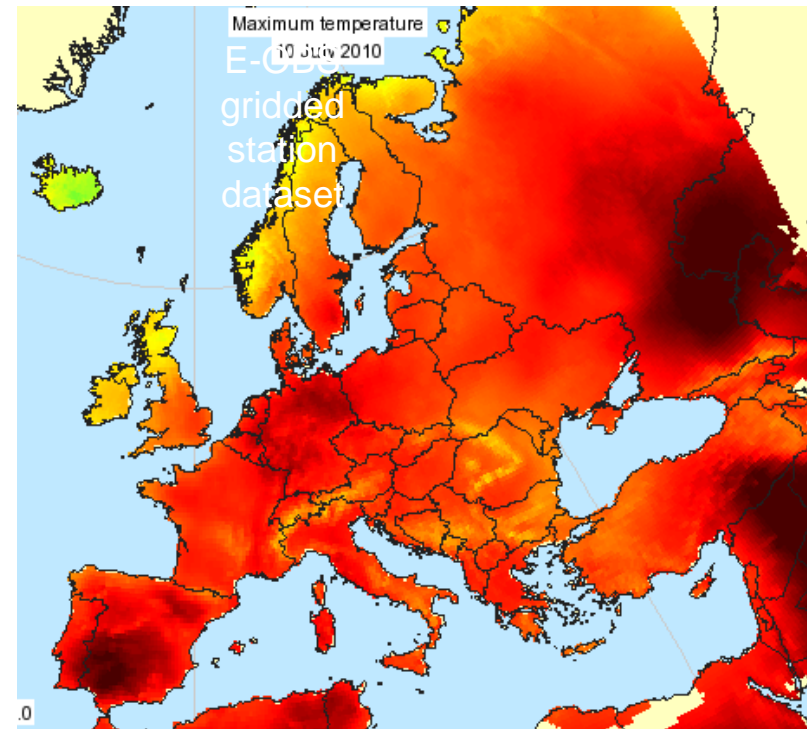
“E-Obs”

obs

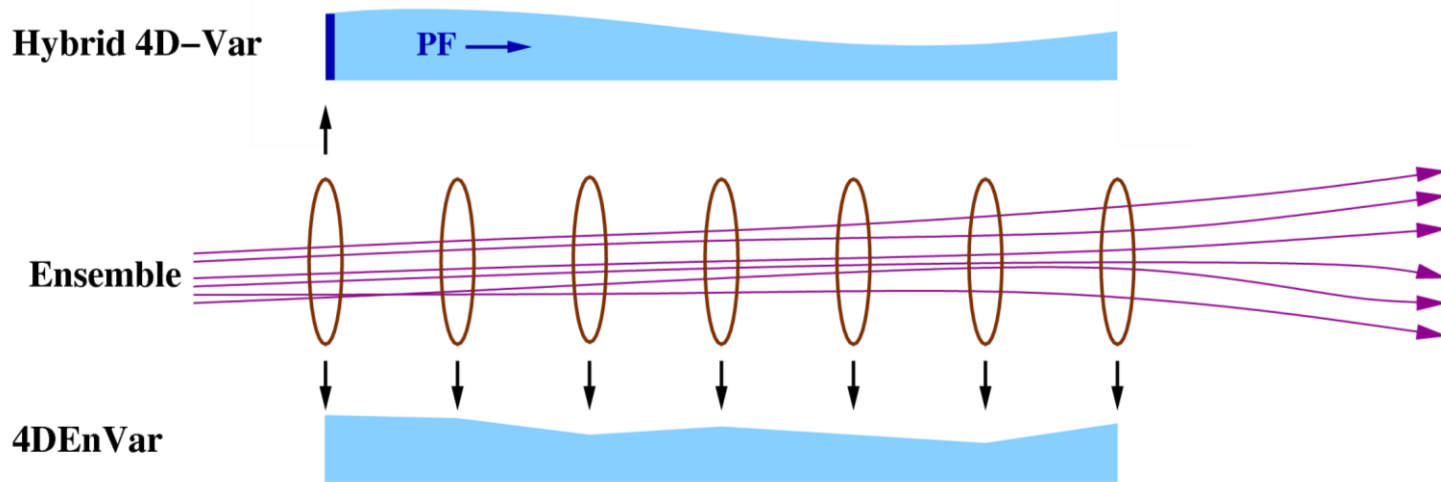
daily 25km grid



Maximum temperature on 10 July 2010
(during the Russian heat wave)



4D-Ensemble-Var (4DEnVar): 4D ensemble covariances without using a linear model



- Should be much more efficient on next-generation supercomputers with much larger numbers of processors.
- Ensemble forecasts can be run in parallel before obs arrive rather than sequentially during the 4D-Var iterations. (No PF model.)
- Much higher I/O costs in 4DEnVar.
- Generalises to a unified deterministic / ensemble analysis system.



A possible ensemble system

