Regional Reanalysis: Why Bother?

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Overview

1. Motivations
2. Regional NWP – Why Bother?
3. The EURO4M project
4. Regional Reanalysis – Why Bother?: Initial results
5. Conclusions

1. Motivations

a. *Requirement to provide timely, accurate, user-focussed high-impact climate [**variability/extreme**/change] indicators.*
b. *Advanced data assimilation capable of effectively assimilating a wide range of observation types.*
c. *Large database of 'unused' observations of past climate available for DA (e.g. surface, precip, cloud).*
d. *Long time-series of DA-reanalysis invaluable to weather/ climate model evaluation, calibration, and development.*

2. Regional NWP – Why Bother (Barker et al, AMS 2011)

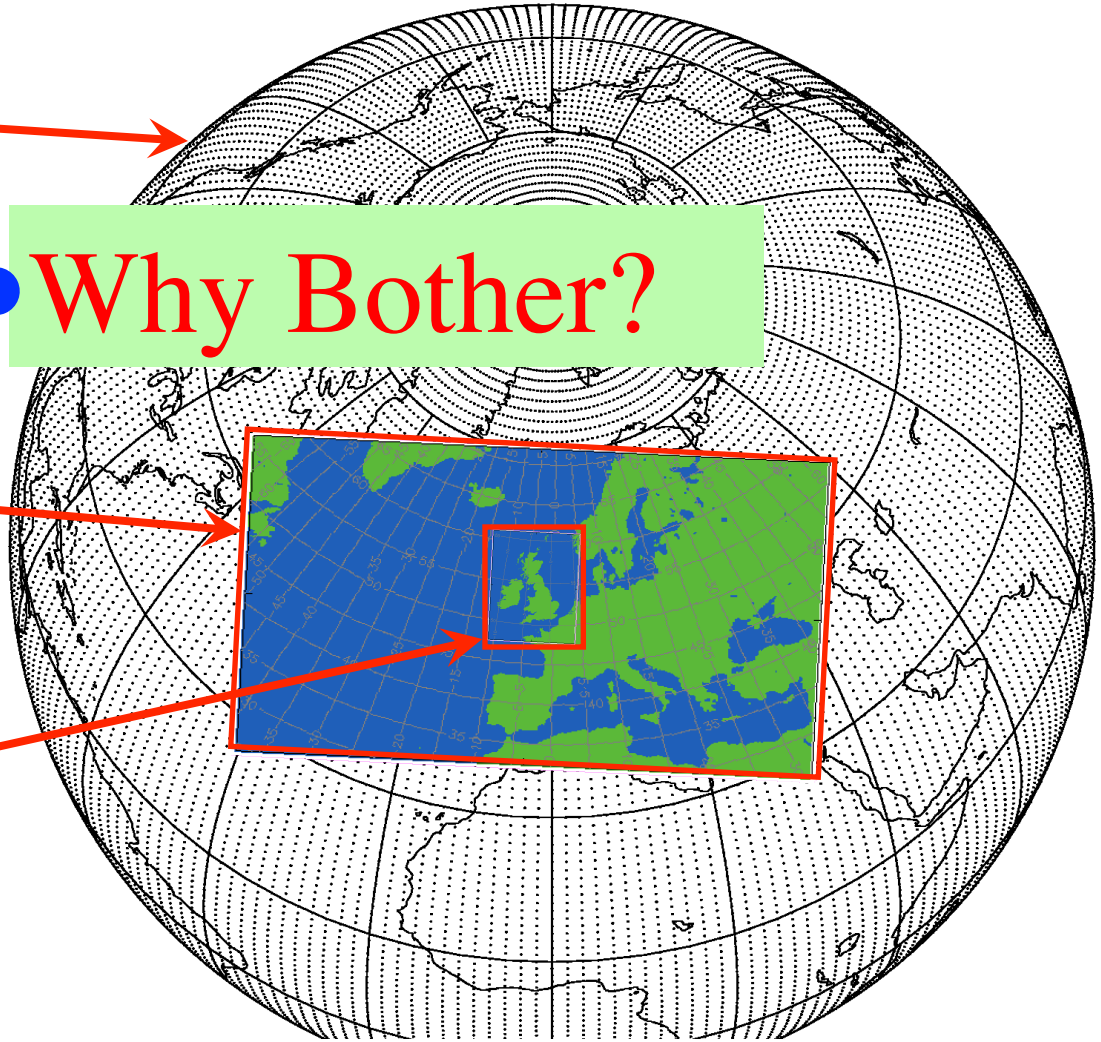
Operational NWP Models: April 2012

Global
- 25km 70L
- Hybrid 4DVAR – 60km inner loop
- 60h forecast twice/day
- 144h forecast twice/day
- *+12member EPS at 60km 4x/day*

NAE
- 12km 70L
- 4DVAR – 36km inner loop
- 60h forecast
- 4 times per day
- *+12member EPS at 18km 4x/day*

UK-V *(& UK-4)*
- 1.5km 70L
- 3DVAR (3 hourly)
- 36h forecast
- 4 times per day

Why Bother?



Met Office Global Regional Ensemble Prediction System = MOGREPS

T+24 Verification Vs. Sondes: Temperature

NAE from 40km GM

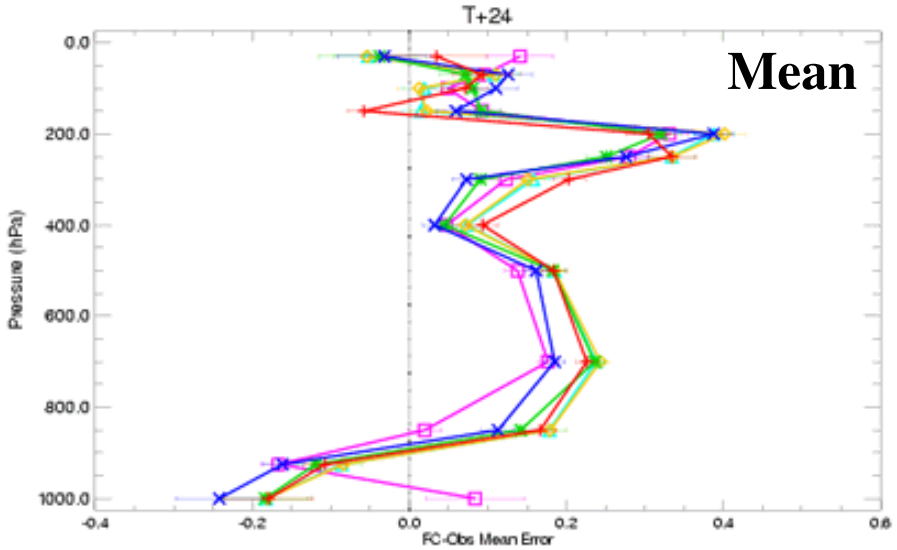
NAE from 25km GM

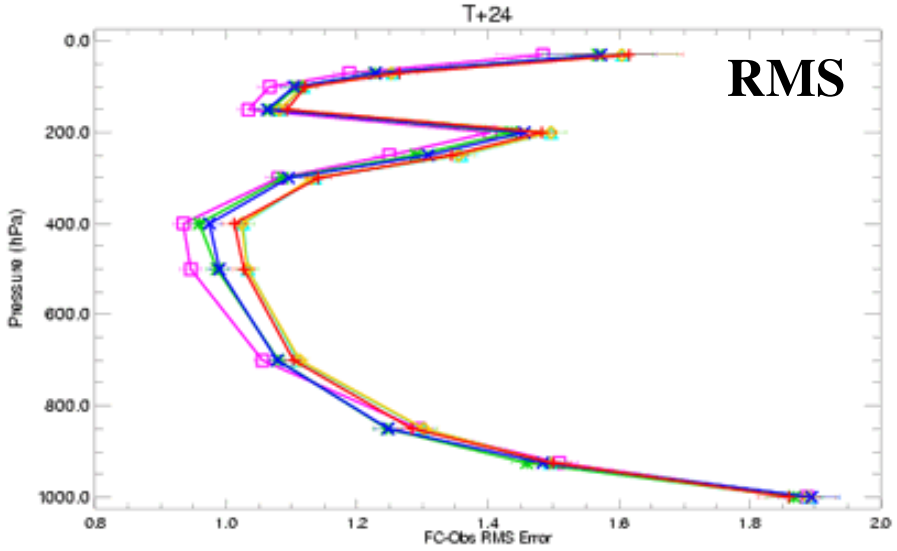
Cycling NAE DA

1 cycle NAE DA no cloud

1 cycle NAE DA with cloud

25km GM

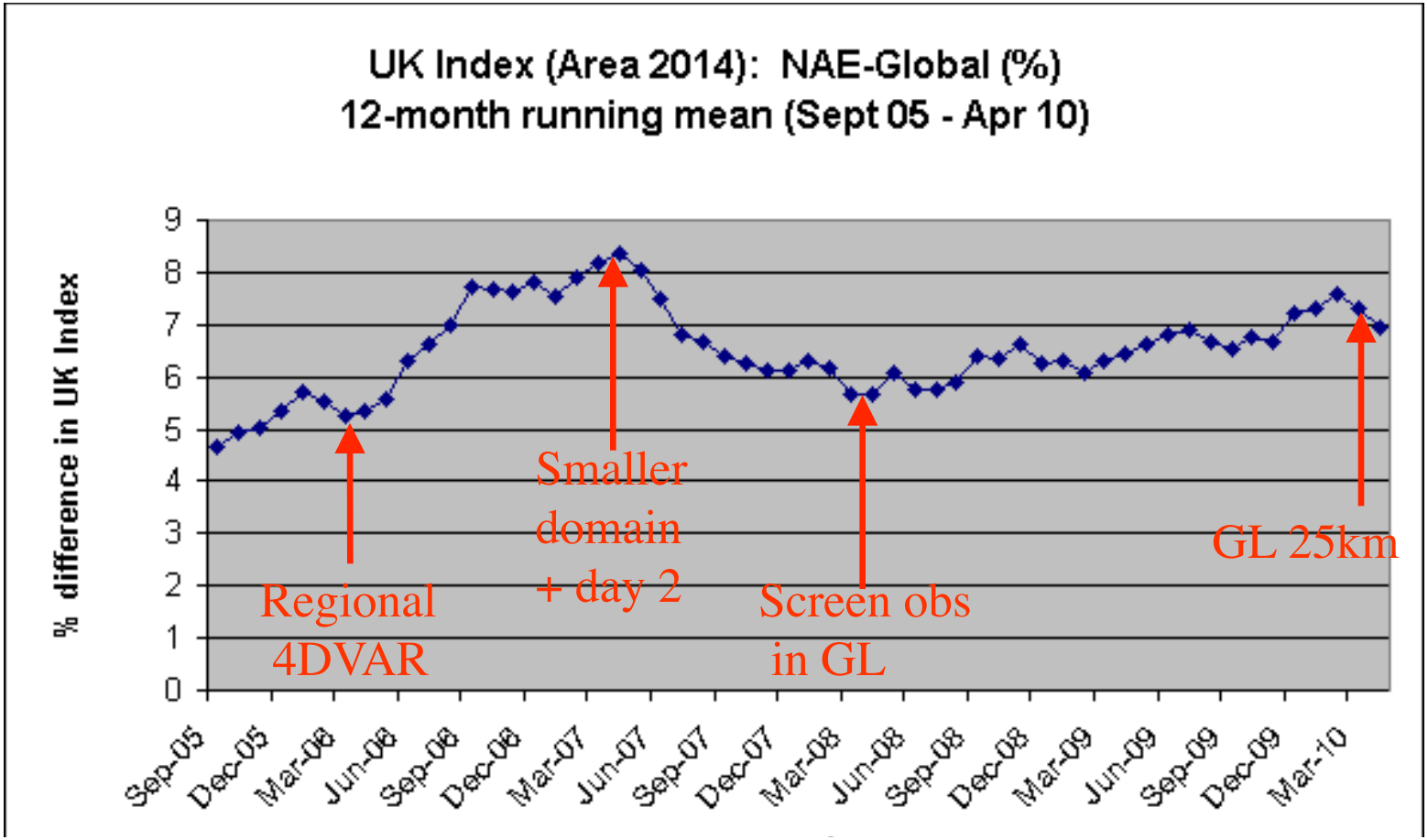




NAE Area Verification:
1 Jan to 7 Mar 2010

Benefit of Regional NWP Vs Global

UK index = Weighted skill score for surface weather (temp, wind, cloud, precipitation, and visibility). Includes T+6 to T+48.



~40% difference due to prognostic visibility in NAE (too expensive for global).

UK Area

Verification Vs. Surface Obs: Surface T

NAE from 40km GM

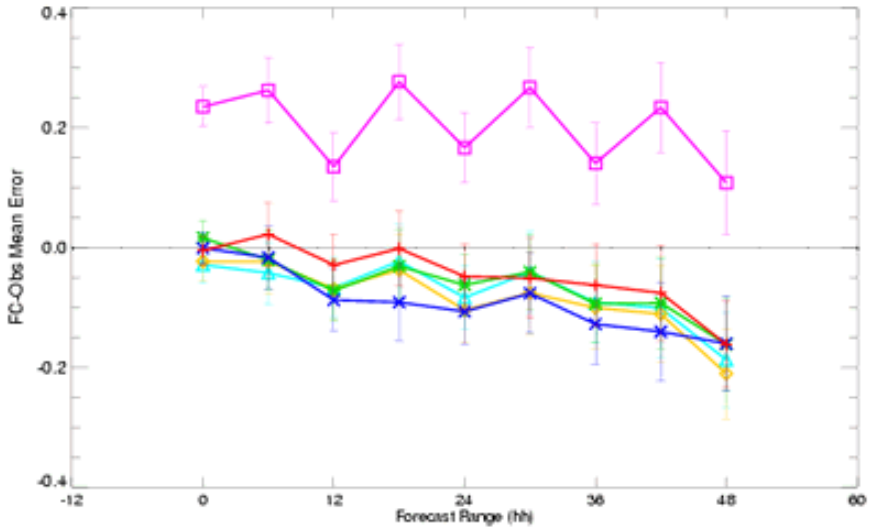
NAE from 25km GM

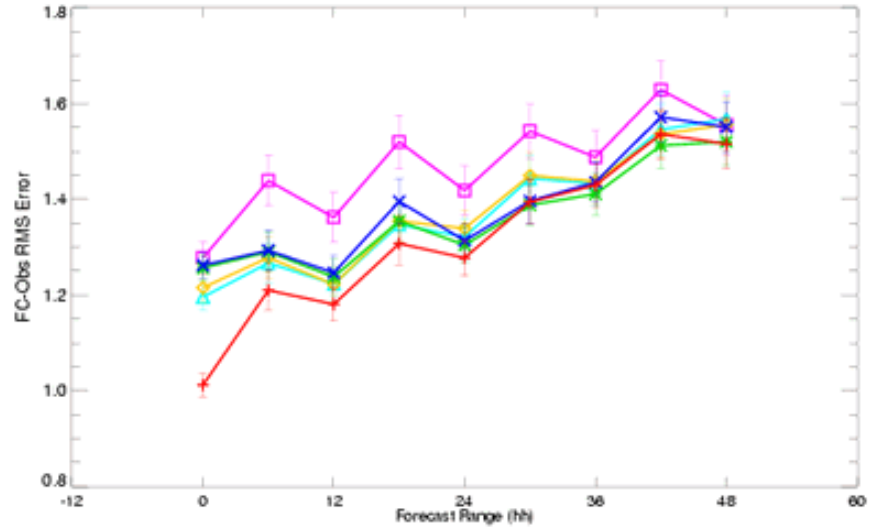
Cycling NAE DA

1 cycle NAE DA no cloud

1 cycle NAE DA with cloud

25km GM

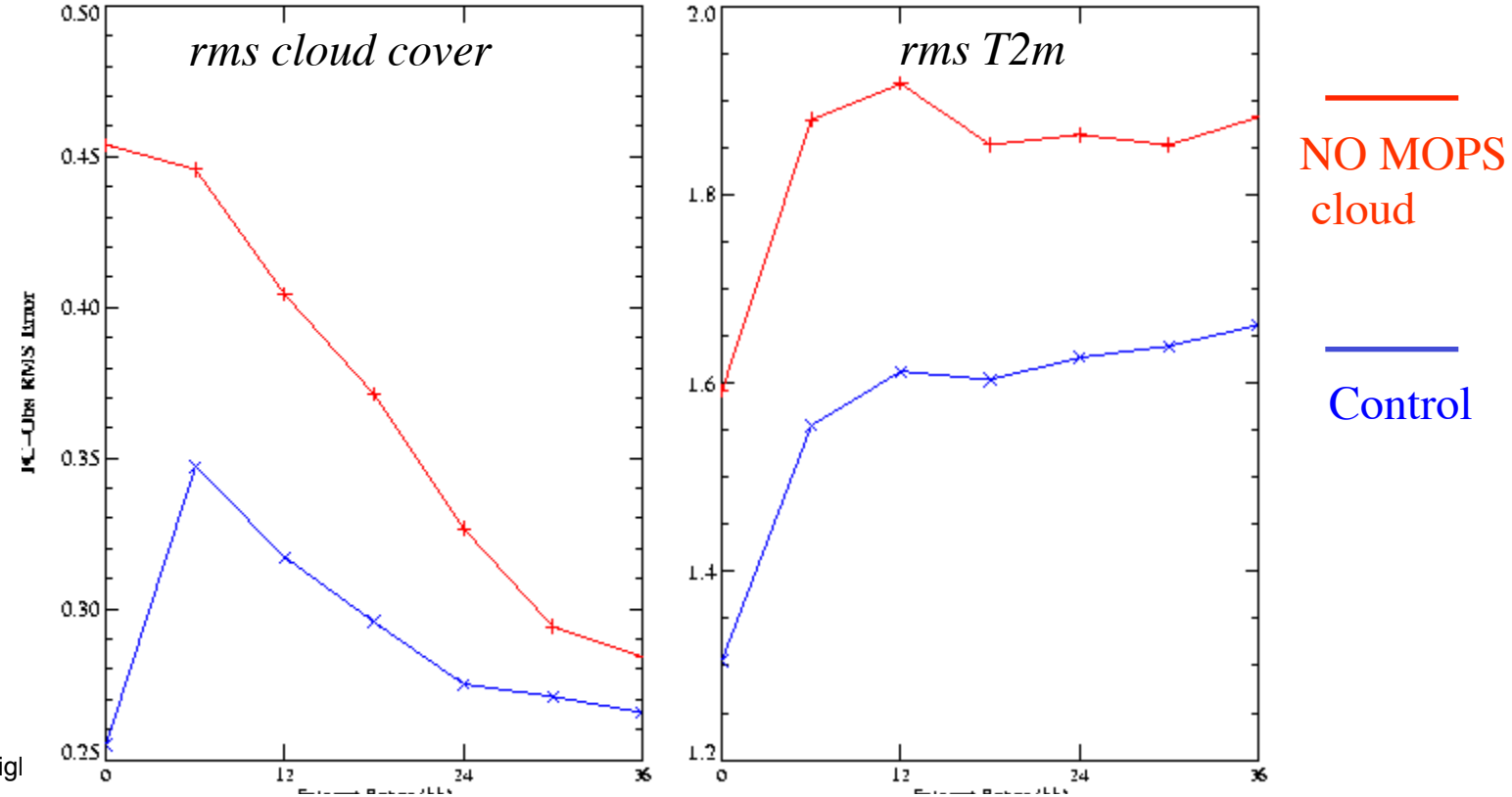




UK Area Verification:
1 Jan to 7 Mar 2010

Cloud assimilation

- Cloud observations analysed in EuroPP system (input imagery+surf reports).
- 3D Cloud fraction is assimilated as proxy relative humidity profile.
- Model's RH is nudged proportionally to the model-analysis cloud difference.
- Significant benefit in Sc episodes (eg Feb '06)

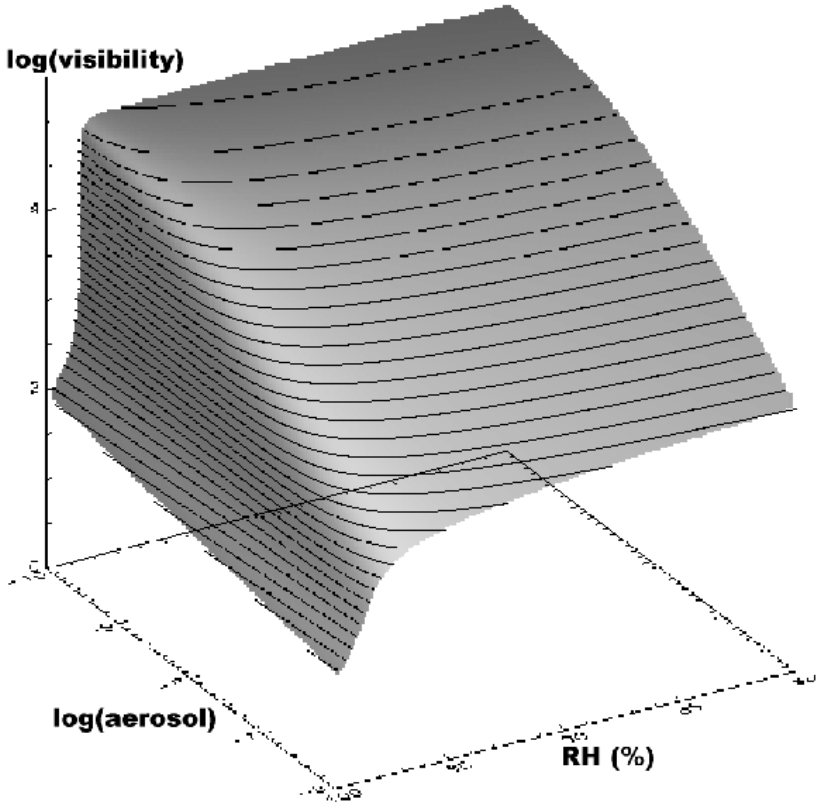


Visibility forecasting and assimilation

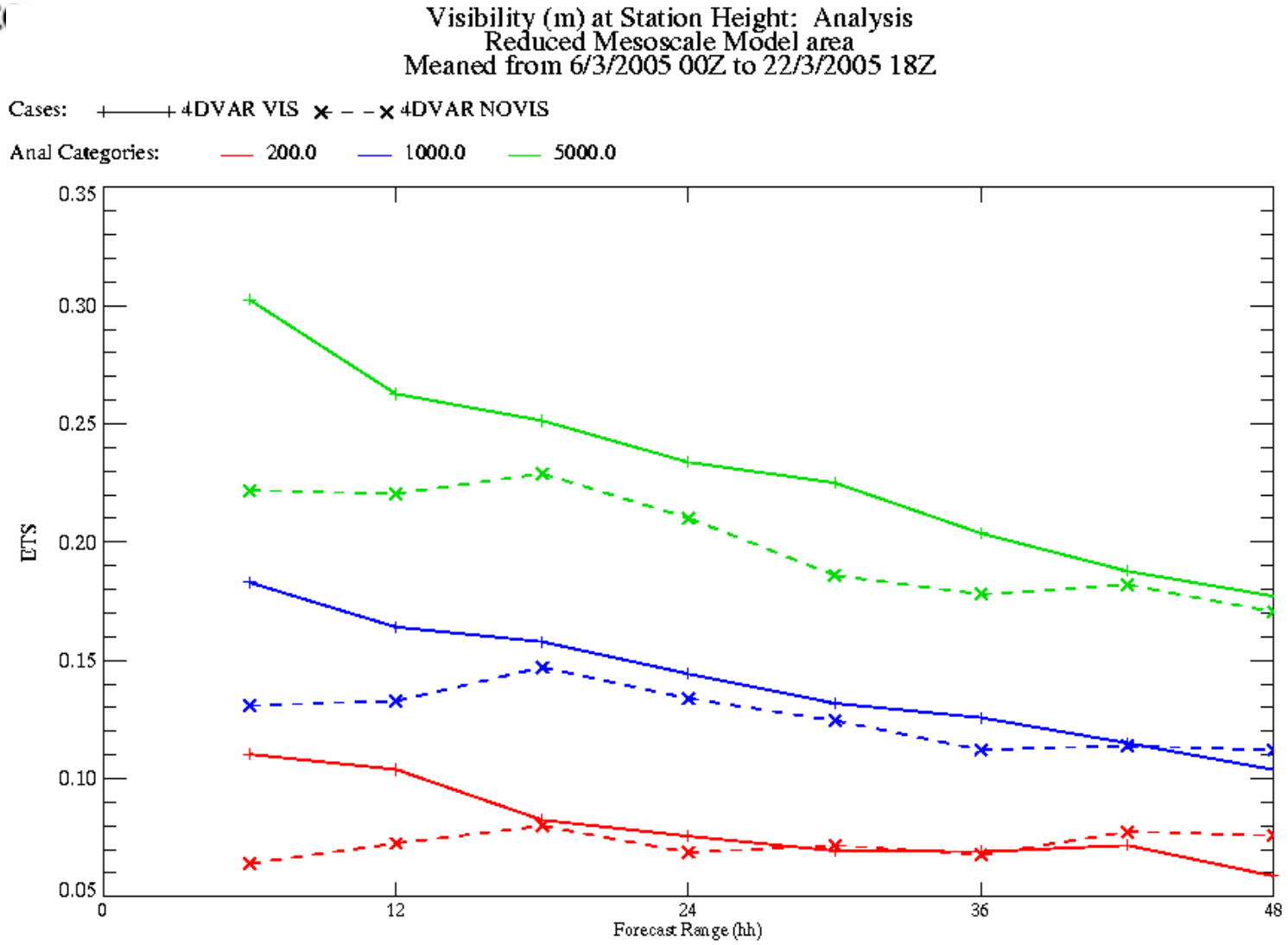
- **UM aerosol**
  - single aerosol mass mixing ratio m
  - tracer advection
  - boundary layer mixing
  - sources
  - removal by precipitation

- **Visibility diagnosis**
  - humidity
  - aerosol
  - temperature
  - precipitation rate

- **4D-Var Assimilation**
  - PF advection of log(m)'



4D-Var: VIS vs NO VIS



Regional NWP – Why Bother?

Benefit Of European Regional NWP vs 25km global model (UM):

	Regional NWP	+ Regional DA
Upper-Air Temperature	✗	✗
Upper-Air Wind Speed	✗	✗
PMSL	✗	✗
6hrly Acc. Precipitation	✗	✗
Surface Wind-Speed	T+6 – T+48	T+0 – T+6
Cloud Amount	T+0 – T+48	T+0 – T+6
Visibility	T+0 – T+48	T+0 – T+12
Surface Temperature	T+0 – T+48 (UK only)	T+0 – T+12/24 (NAE/UK)

3. The EURO4M Project

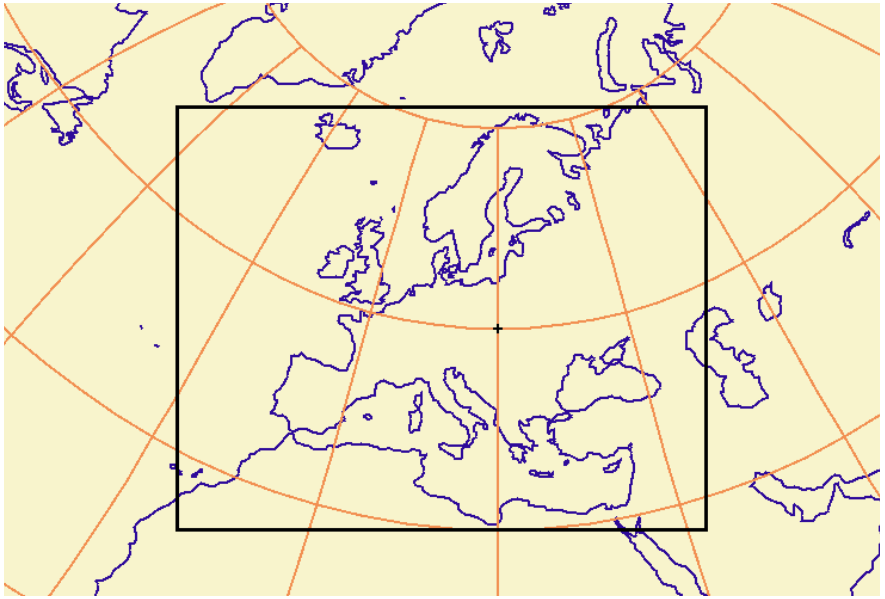
http://www.euro4m.eu

See also poster by Tank and Verver

EURO4M Regional Reanalysis

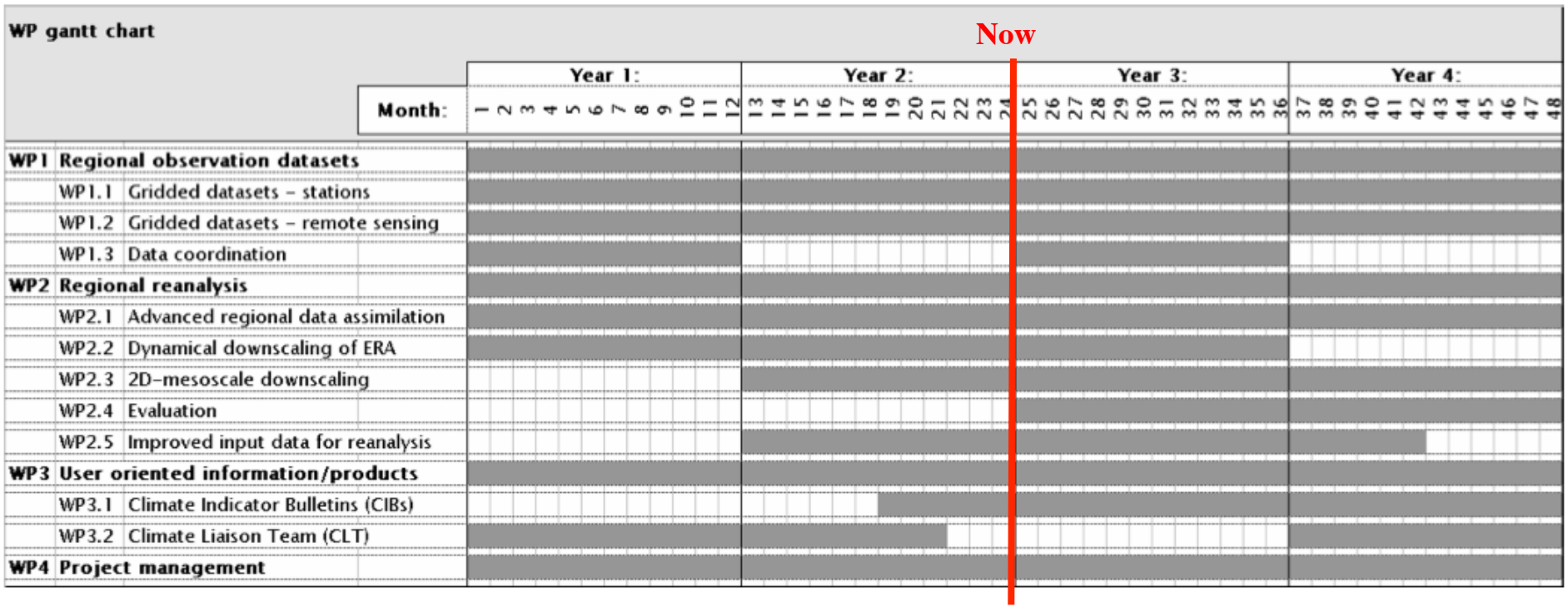
- Abstract: “EURO4M will develop the capacity for, and deliver the best possible and most complete (gridded) climate change time series and monitoring services covering all of Europe. These will describe the evolution of the Earth system components by seamlessly combining two different but complementary approaches: regional observation datasets of Essential Climate Variables (ECVs) on the one hand and model based regional reanalysis on the other….”

EURO4M/MetO 4D-Var Domain



- Participants: KNMI , MetO, URV, NMA-RO, MS, DWD, SMHI, UEA, MF.
- MetO leads 4D-Var model based regional reanalysis (12km 4D-Var).
- Project duration April 2010 – March 2014.

EURO4M Work Packages



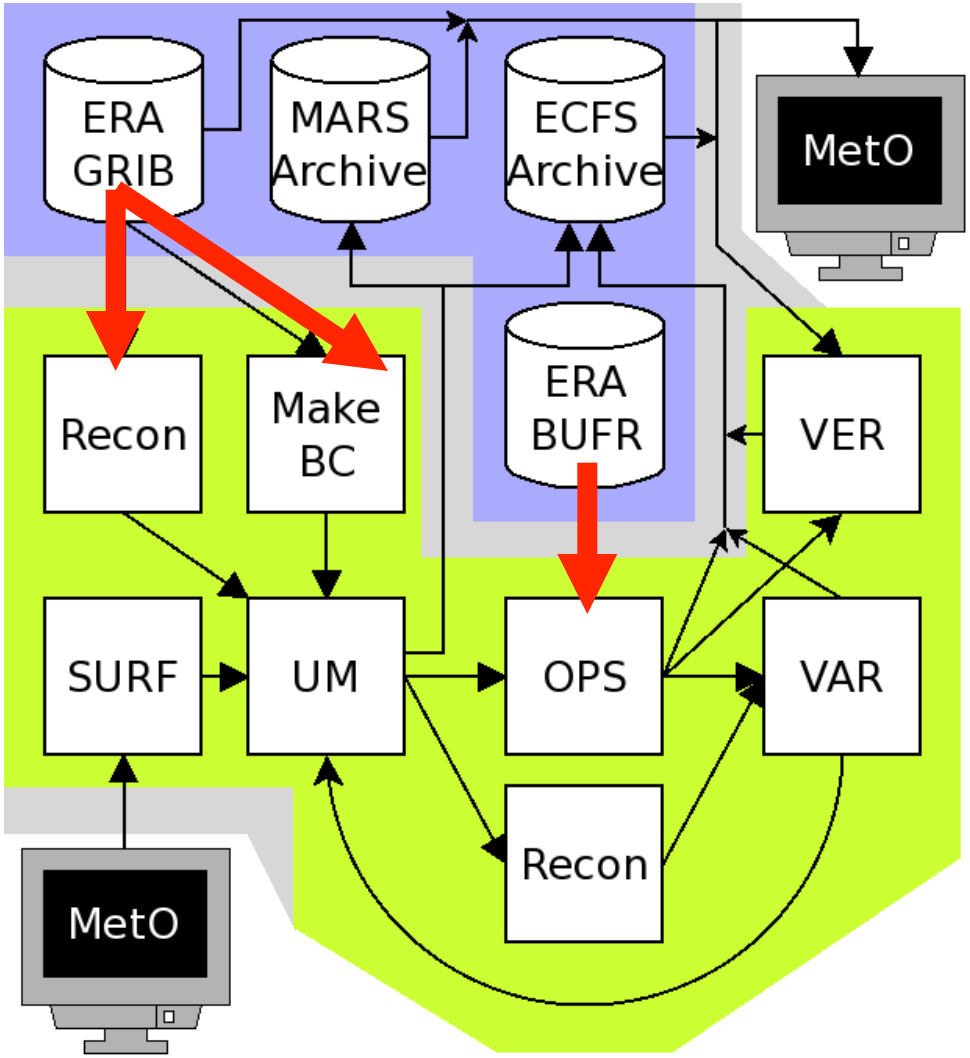
- WP2.1 Building capacity for advanced regional data assimilation (MetO)
- WP2.2 Dynamical downscaling of ERA (SMHI).
- WP2.3 2D mesoscale downscaling (Météo France).
- WP2.4 Evaluation (MeteoSwiss).
- WP2.5 Improvement of input data for reanalyses (UEA)

ERA/EURO4M Interface

ECMWF

"interface"

Met Office

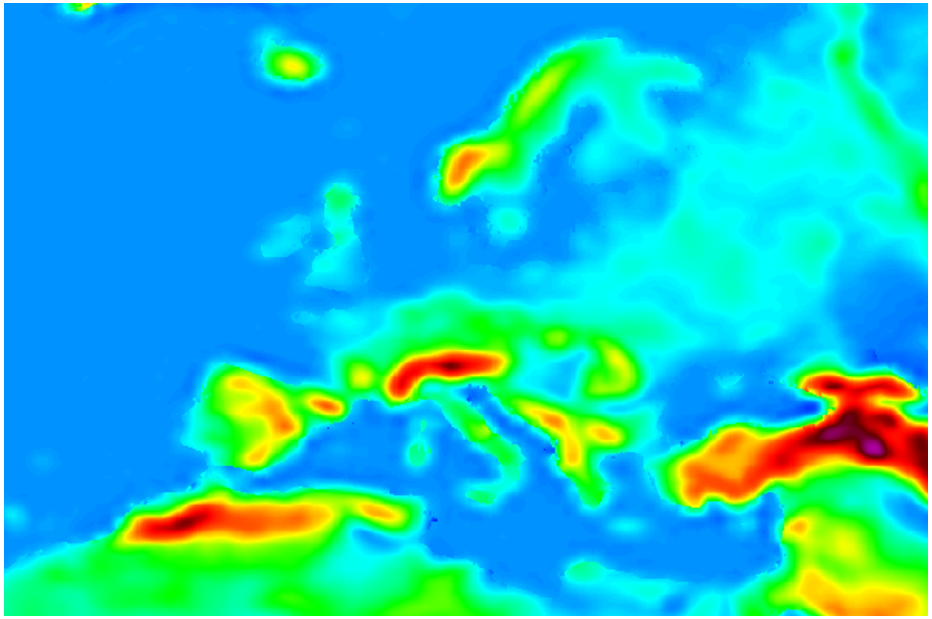


EURO4M WP2 (NWP-reanalysis): What can we add to ERA?

- Resolution.

ERA-Interim:

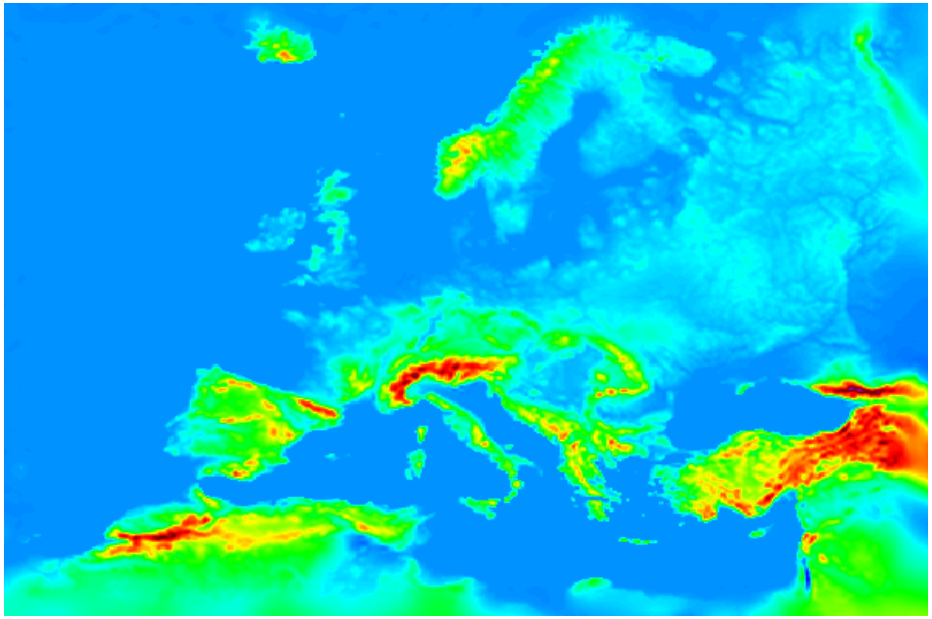
Model T255 (**80km**), Var T159 (125km)



* Note ERA-Clim up to T511 (~40km)

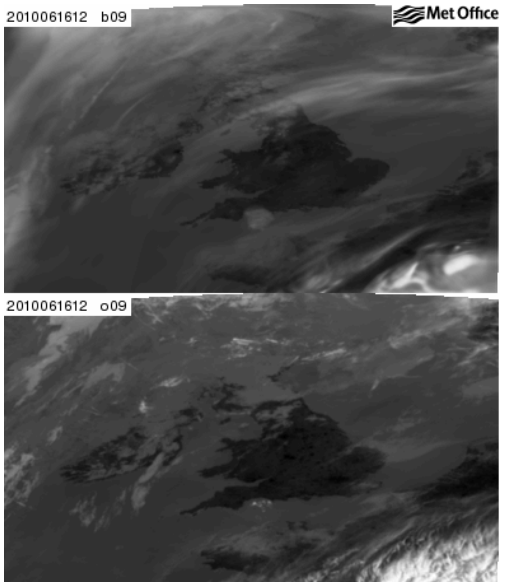
EURO4M 4D-Var

Model **12km,** Var 36km

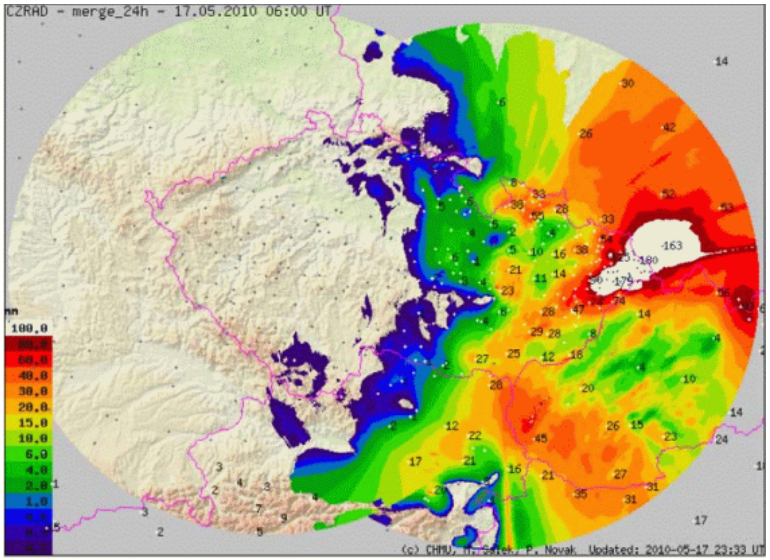


* Note EURO4M Var up to 12km

EURO4M WP2 (NWP-reanalysis): What can we add to ERA?



- Resolution.
- Observations: All standard global obs, included radiances assimilated, plus:
  - Additional high-resolution surface, sat. data:
  - Precipitation (accumulations, radar)
  - Cloud fraction
  - Visibility
- Statistical post-processing of surface fields:
  - Introduces local effects of orography.
  - Inclusion of additional surface mesonet obs.
  - Correct model bias through e.g. Kalman Filter.
- Raw data for tailored European climate information bulletins (WP3. users).



Courtesy of T. Landelius (SMHI)

Dynamical downscaling and reanalysis over Europe (WP2.2 – 2.3)

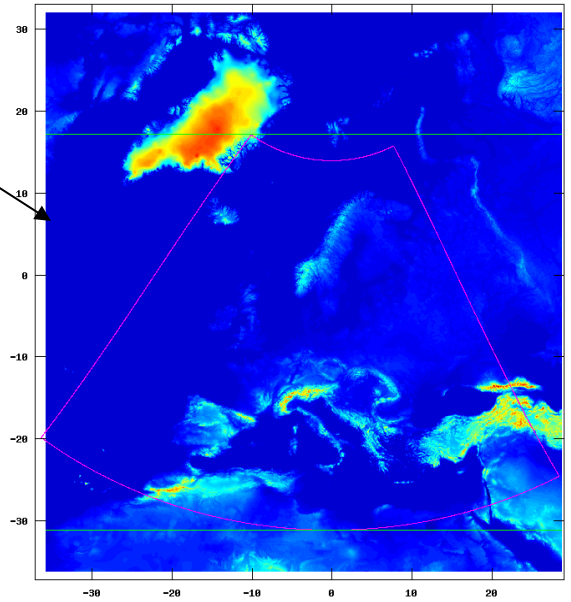
3D-Var Re-analysis at 22 km,
60Levels over Europe (SMHI)

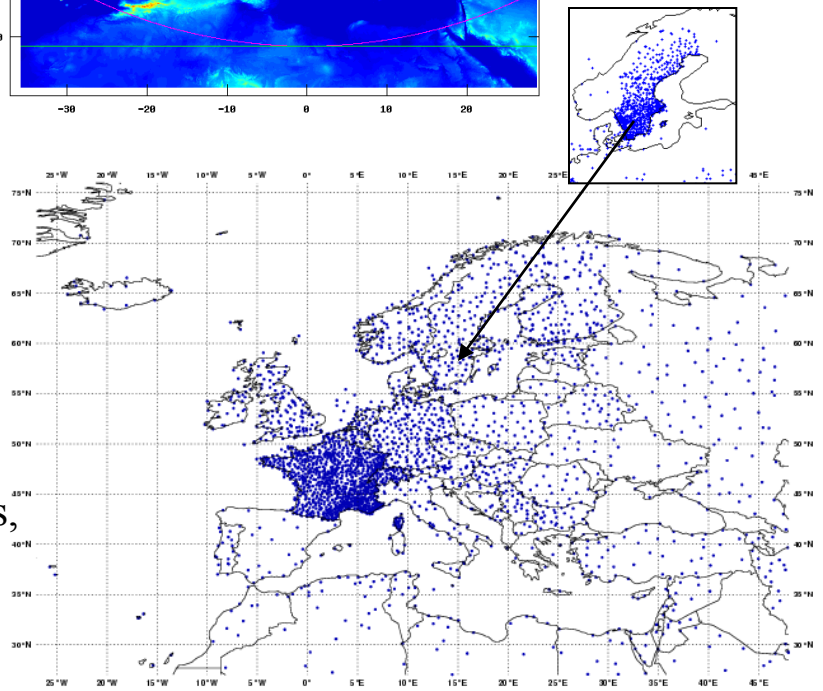
Downscaling

Δx ~ 5 km over Europe

More observations

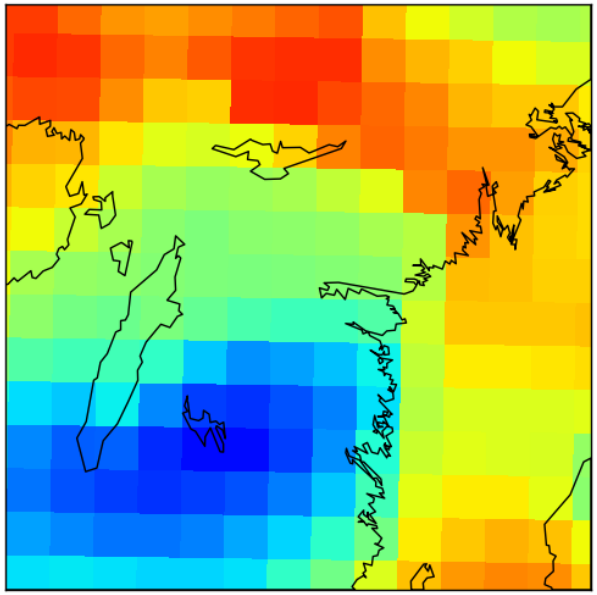
2D analysis at Δx ~5 km



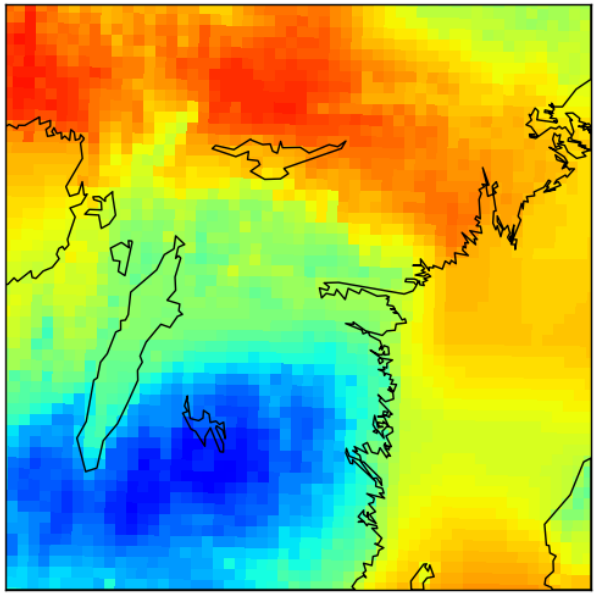


By adding details with topography and more observations, the quality of the analysis should improve … ~ 4000 obs (1200 over France)

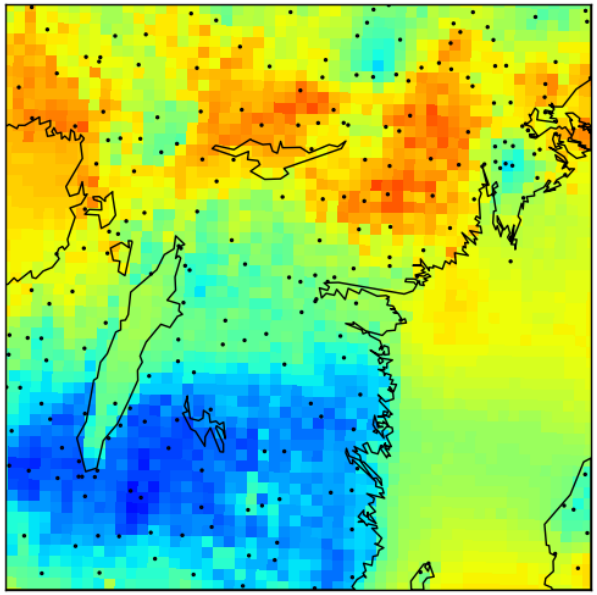
WP2.3 2D Reanalysis Postprocessing (SMHI, Meteo France)



HIRLAM 22 km



Downscaled to 5 km



MESAN T2m analysis
(observations as black dots)

WP2.4 Evaluation (MeteoSwiss)

- Formally begins April 2012.

- MeteoSwiss: precipitation variations in Alpine regions.

  Met Office: Reanalysis sensitivity to resolution, technique. Observation innovations (O-B), residuals (O-A), increments (A-B), sensitivities.
- SMHI: compare MetO/HIRLAM reanalyses.
- Meteo France: Evaluate MESAN/SAFRAN 2D analysis.
- DWD: verify WV, cloud, precip, radiation with CM-SAF Investigate satellite radiance calibration.

Using existing datasets, reanalyses, and datasets developed in WP1

4. Regional Reanalysis: Why Bother? Initial Results

First attempt at reanalysis...

May 2010

- Floods in Poland, eastern Europe

June 2010

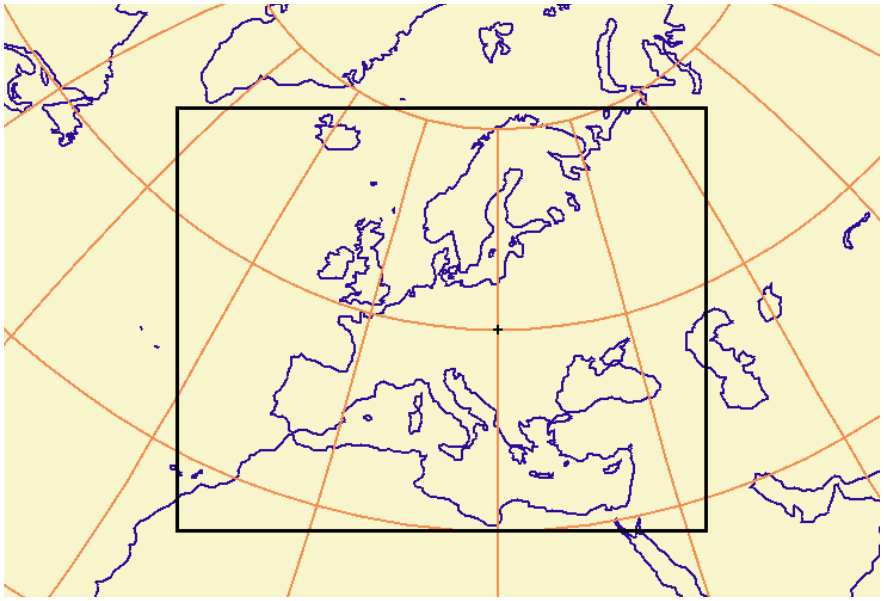
- Severe storms France/Spain

July 2010

- Russian heatwave spreading West, forest fires

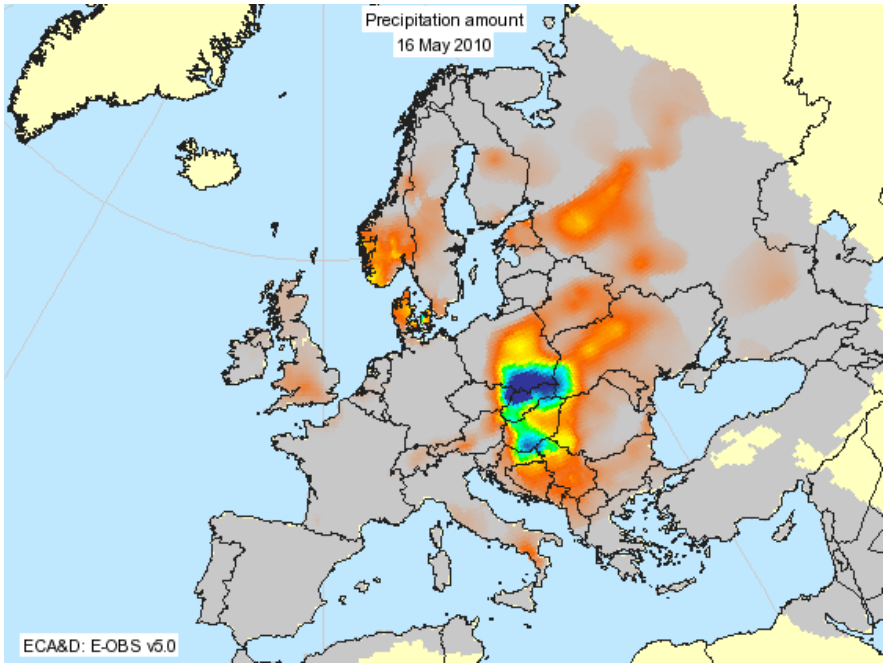
EURO4M 4DVar Configuration

- EURO4M project (2010-2014) promises only 1-2yr 4D-Var 'proof-of concept'.
- Resolution: 12km model and 36km 4D-Var data assimilation.
- 4 six-hour cycles per day (00, 06, 12, 18UTC). 1-2hr period.

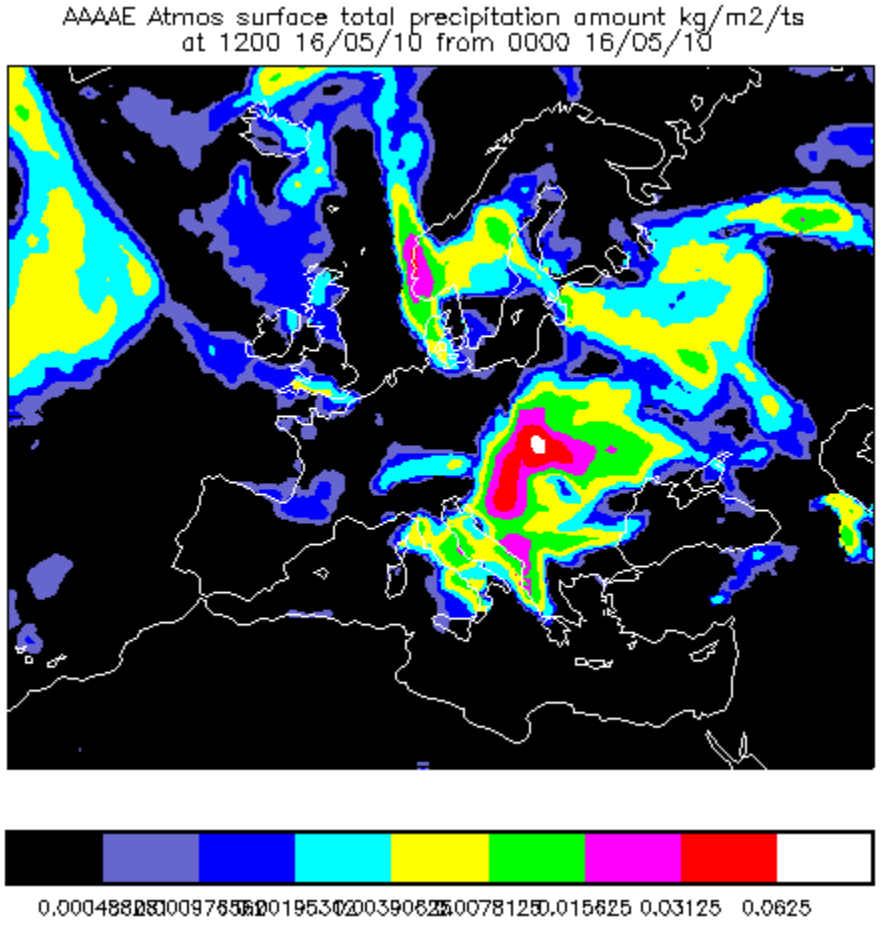


- Observations: Supplement ERA-CLIM MARS archive (e.g. precip obs).
- Lateral boundary conditions from ERA-INTERIM, then ERA-P3.
- Forecast to T+48 once per day (12UTC) to verify against NWP metrics.

Poland floods, 16th May 2010



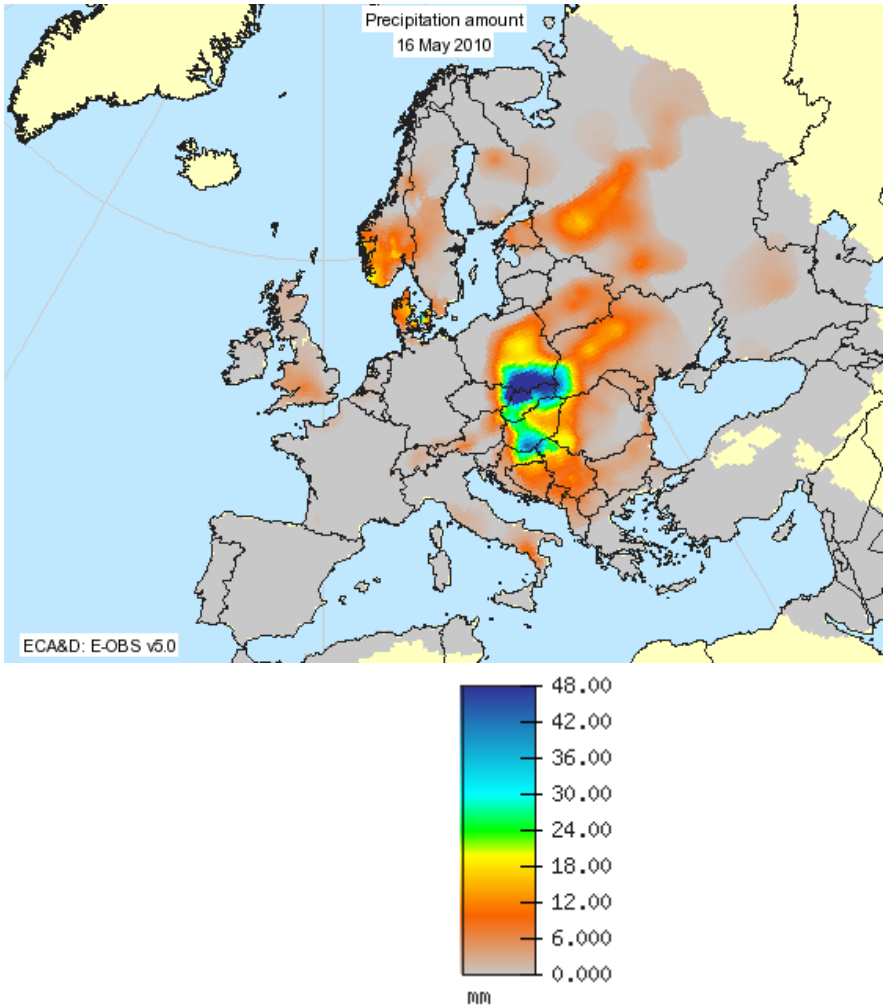
e-obs



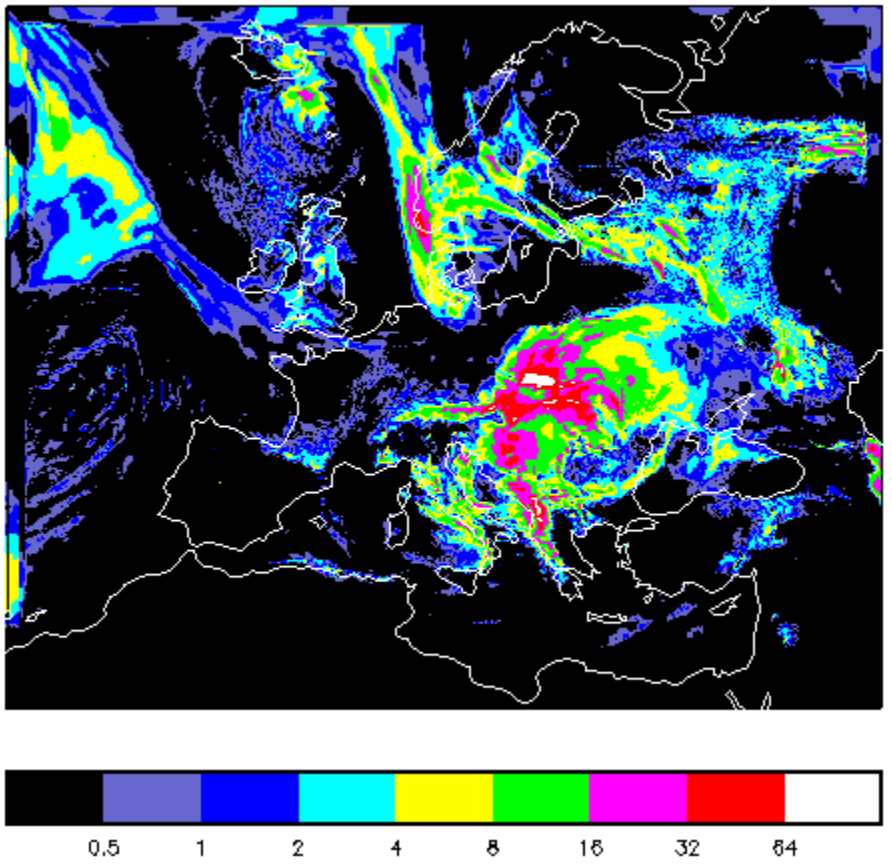
ERA-Interim

Poland floods, 16th May 2010

E-obs Gridded 24hr Rainfall

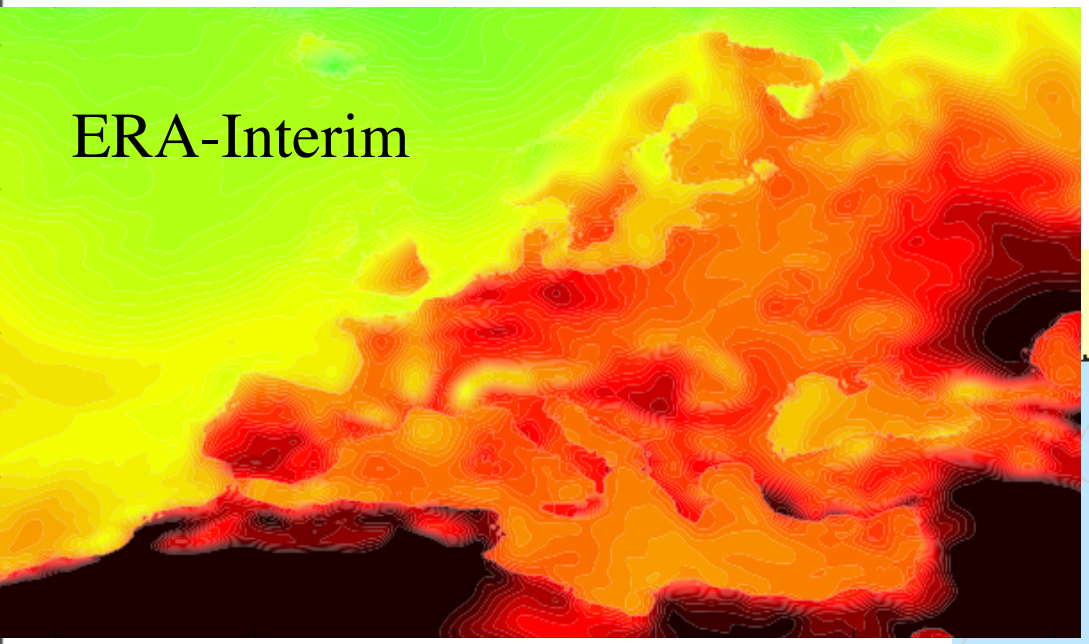


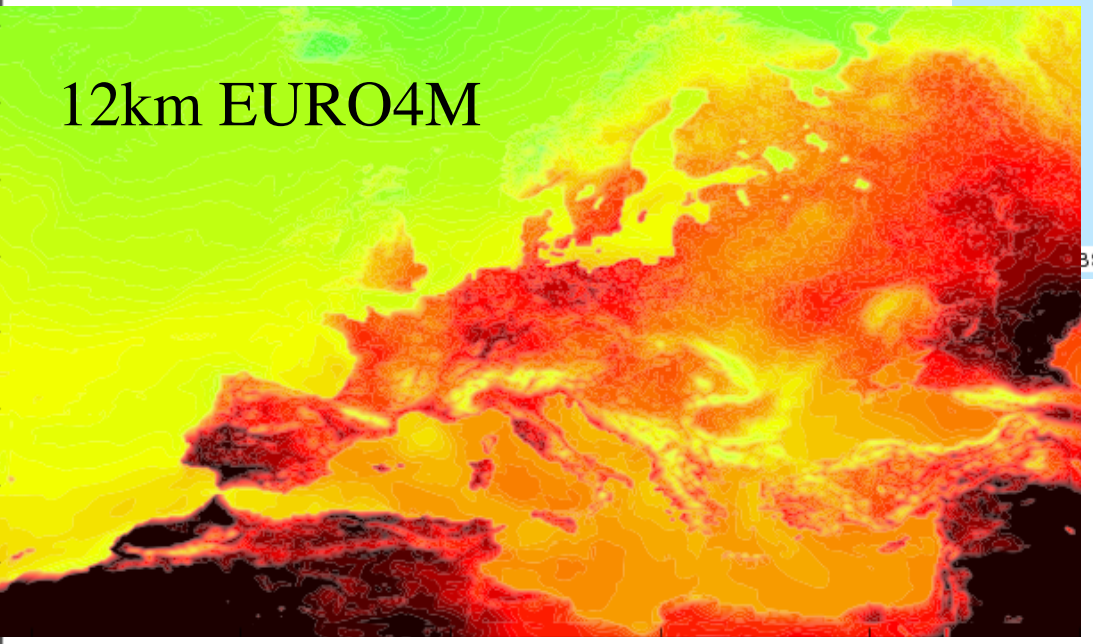
UMEUF Time mean
Atmos surface total precipitation amount kg/m2/ts
15/05/2010 21:00 –> 16/05/2010 12:00

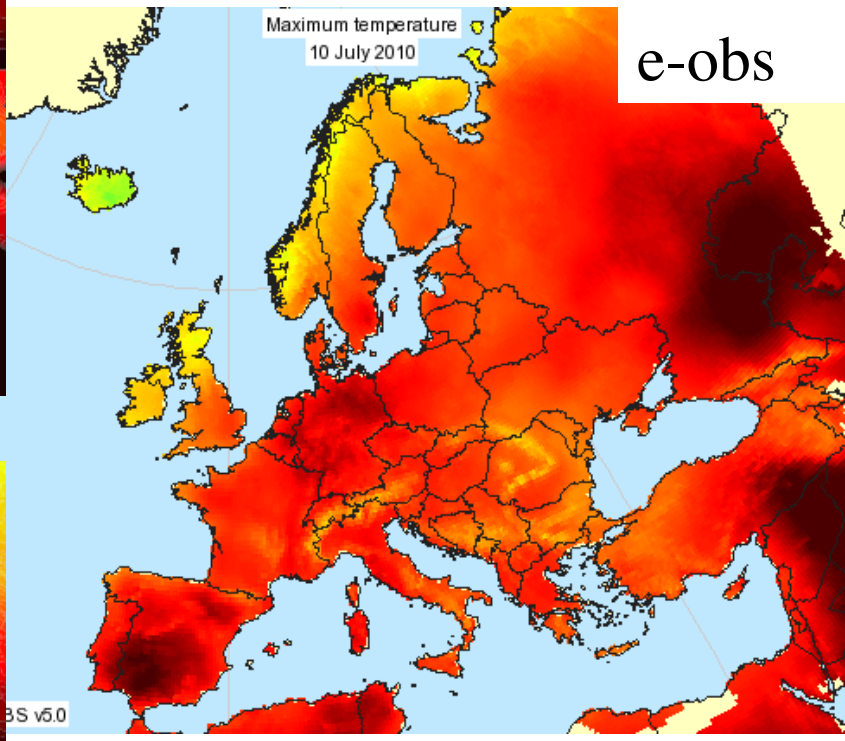


12km reanalysis

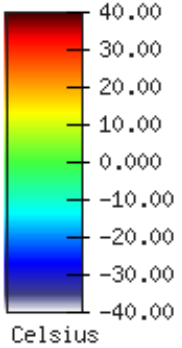
Russian heatwave, July 2010







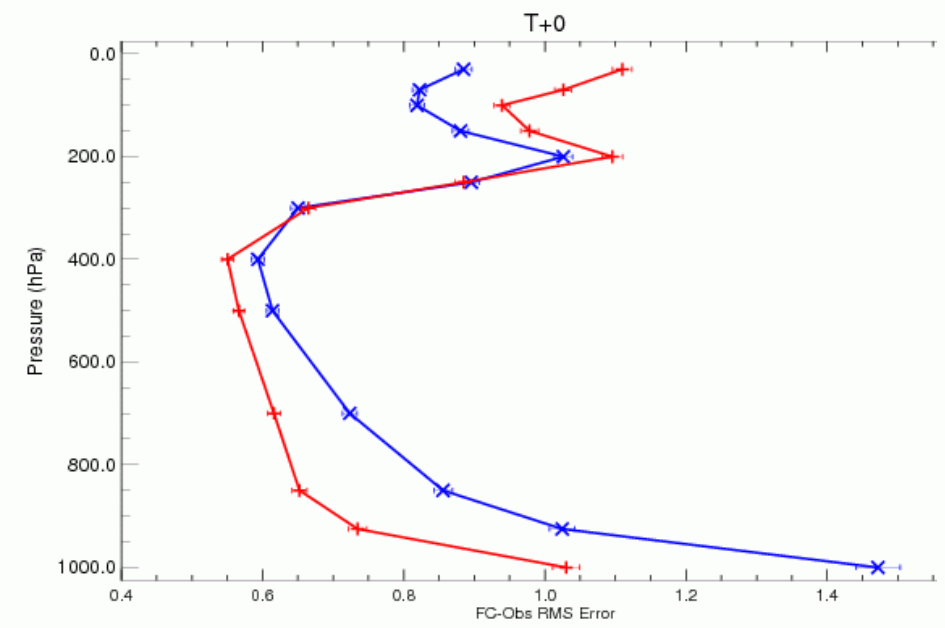
Tmax
10-07-10



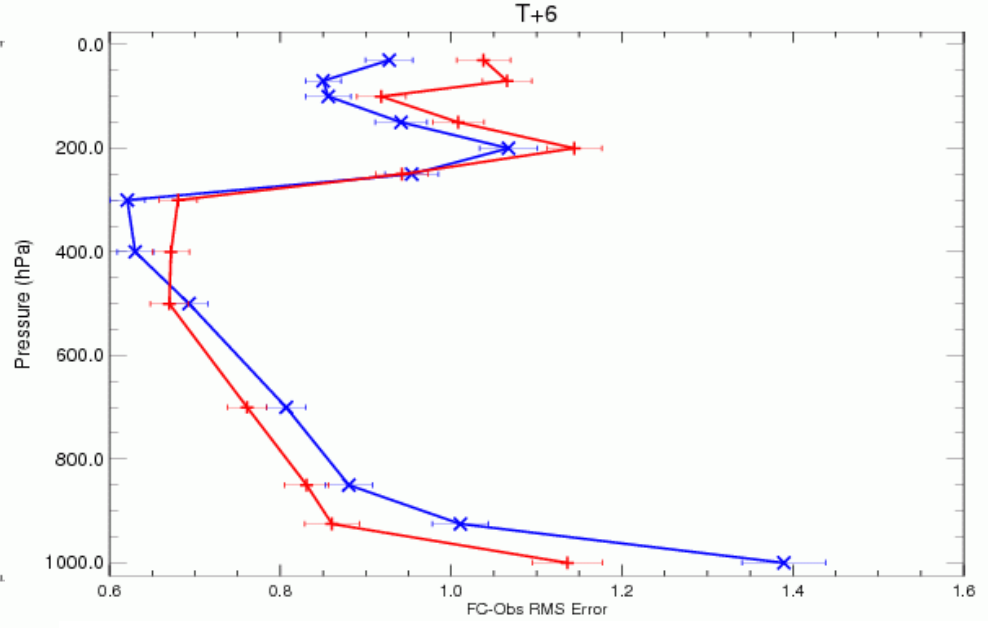
Verification vs Radiosonde

European Temperature rms error: May-July 2010

T+0



T+6



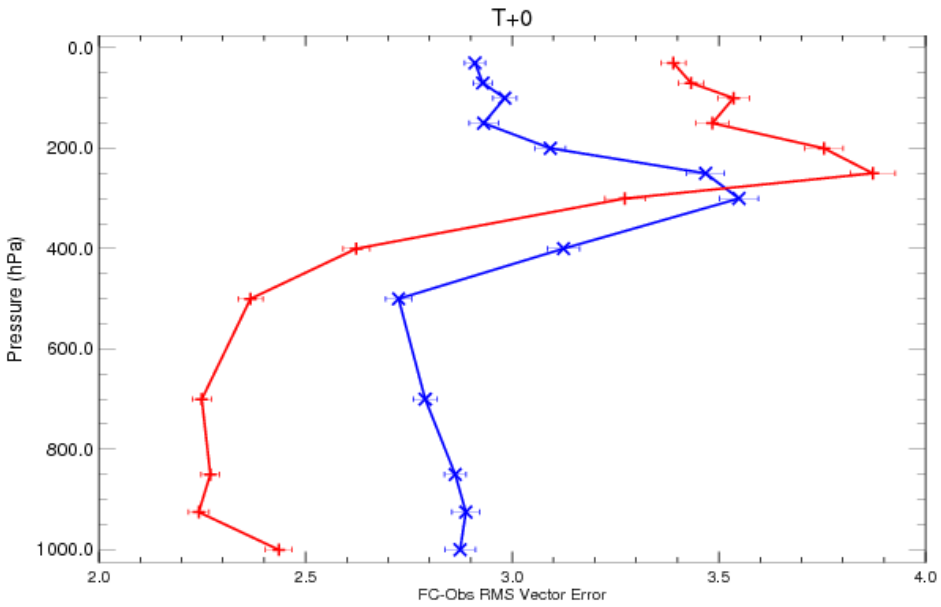
ERA-Interim

EURO4M 12km

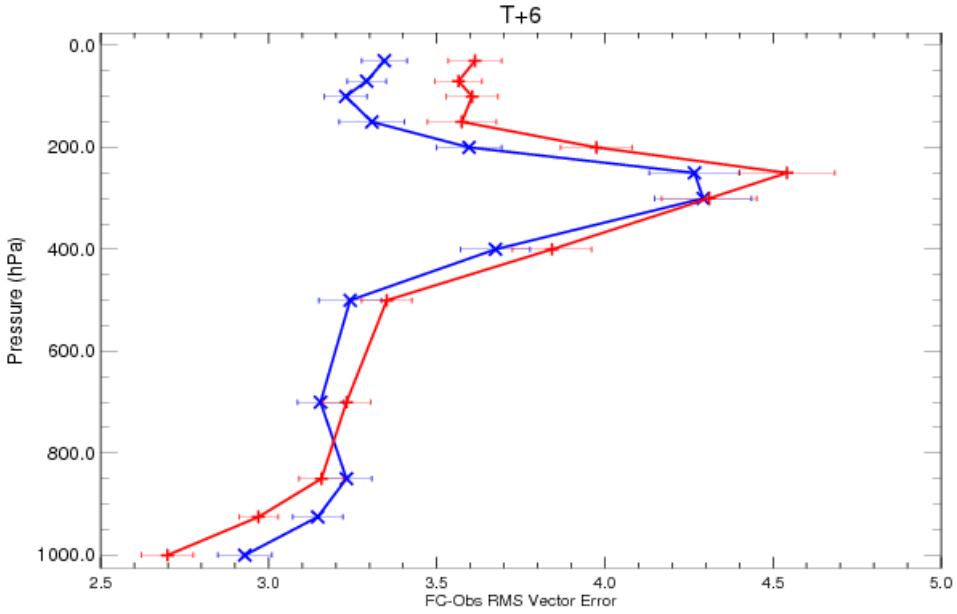
Verification vs Radiosonde

European Wind Vector rms error: May-July 2010

T+0



T+6



ERA-Interim

EURO4M 12km

5. EURO4M 4D-Var reanalysis: Next Steps

EURO4M WP2.1: 2012-2014 Plans

- Variational bias correction
- ODB – obs monitoring. ECMWF collaboration.
- Extend observations dataset (link to WP1, WP2.5)
- Cloud and Precipitation assimilation
- Validation – extreme statistics
- Collaborate on cross-validation

- ‘Pre-Production’ Reanalysis: 2 years, recent period.
- Impact of 4D-Var assimilation resolution (12-36km)

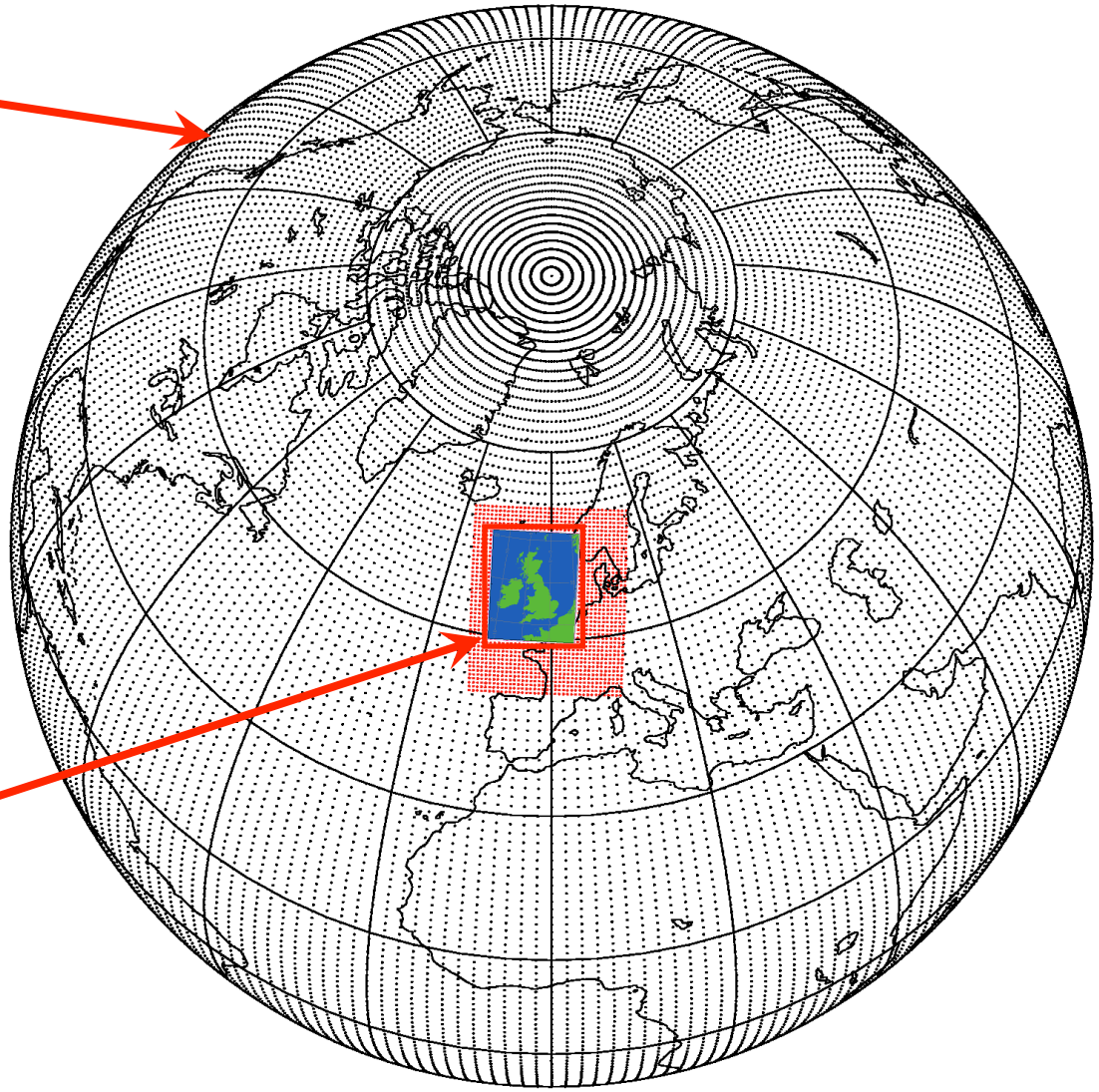
Near-Future NWP Configuration (2012-2013)

Global

- 16-20km 70L (80km top)
- Hybrid 4DVAR (50km inner-loop)
- 60 hour forecast twice/day
- 144 hour forecast twice/day
- 44/12member 33km MOGREPS-G 4*/day

UKV

- 1.5km 70L (40km top)
- 3DVAR (hourly)
- 36 hour forecast, 4 times per day
- 12 member 2.2km MOGREPS-UK



Future: Convective-Scale Reanalysis?

EURO4M

Damaging winds

Birmingham Tornado
13/07/2005

Flash floods

Boscastle: 16/08/2004

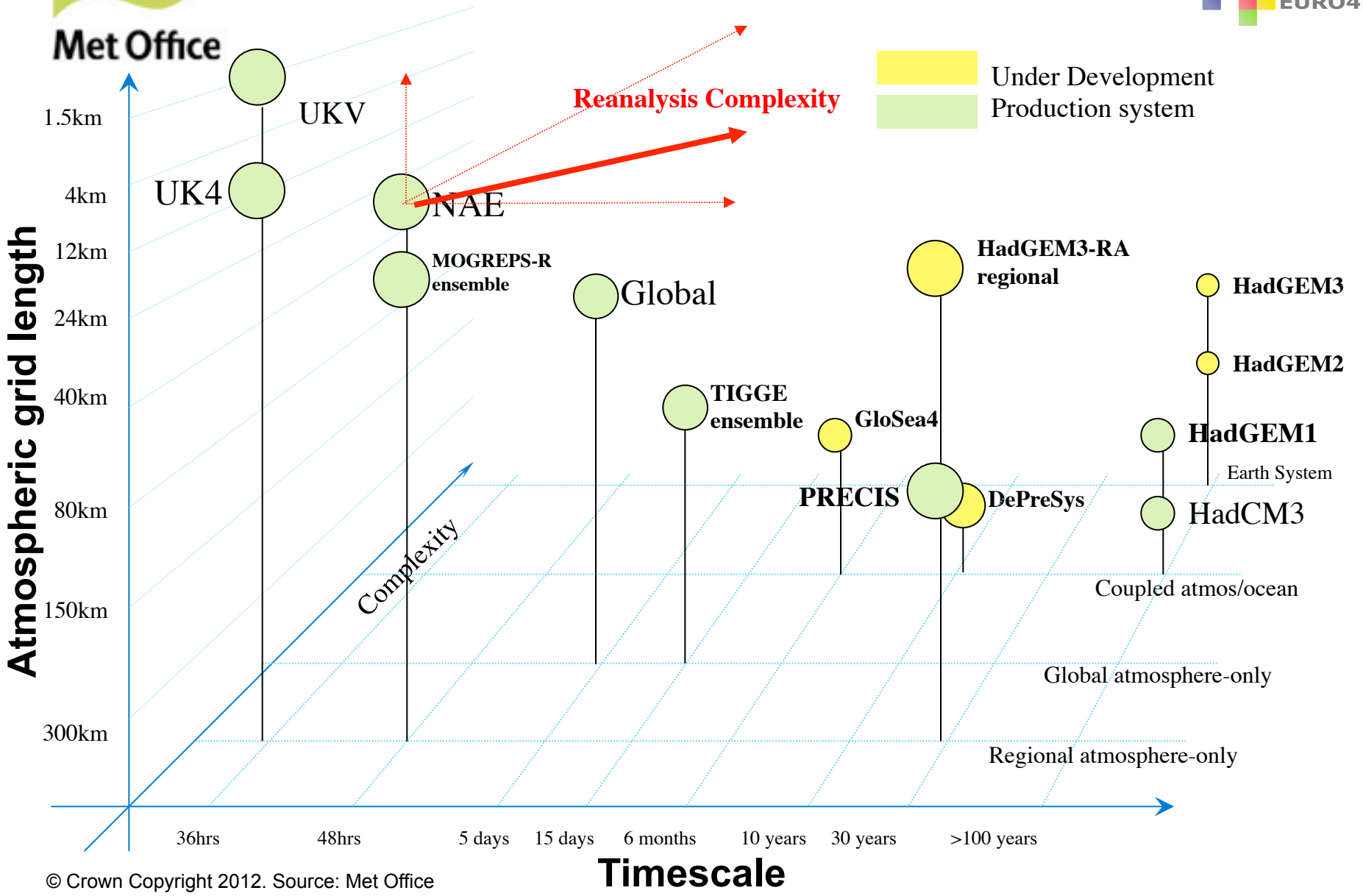
Fog, low cloud

Luxair crash
06/11/2002 – 18 dead

Accident on M4
near Cardiff 10/1
2/2003

‘Weather’ varies over small scales, especially when extreme – ongoing need for regional reanalysis

Seamless Weather/Climate Modelling



Regional Reanalysis Questions

1. Securing funding (e.g. EURO4M 4 year project, but 4D-Var only 1-2yr proof of concept).

2. Profligation of regional reanalyses (4 in Europe, SARR (India), ASR (arctic), etc.

3. Next-generation regional reanalysis:
    1. Ensemble (for DA, uncertainty estimates, etc)
    2. Role for statistical post-processing?
    3. Role for complementary observation-based reanalysis (verification, independence, etc).
    4. Increased coupling ocean-atmosphere-land.

Met Office

EURO4M

Questions/Discussion?

Validation plans

- Monitor O-B stats
- Use small subset of stations to assess analysis accuracy, not used in the analysis
- Comparison against ERA-CLIM and SMHI reanalyses
- Comparison against gridded reanalysis datasets (e.g. GPCC).
- Verify T+48 forecast, once a day

Satellite data used in NWP (1)

August 2011

Observation type	Satellites	NWP variables	NWP models *
AMSU/MHS radiances	4 NOAA + Metop	temp., hum.	G, R
HIRS clear radiances	2 NOAA + Metop	temp., hum.	G, R
IASI and AIRS clear+cloudy radiances	Metop + Aqua	temp., hum.	G, R
SSMIS radiances	1 DMSP	temp., hum.	G, R
Geo imager clear IR radiances	MSG, GOES	humidity	G, R, UK
GPS RO bending angles	5 COSMIC, Metop/GRAS, GRACE-A, TerraSAR-X	temp., hum.	G,R
GPS ZTDs	~350 European stations	humidity	(G), R, UK

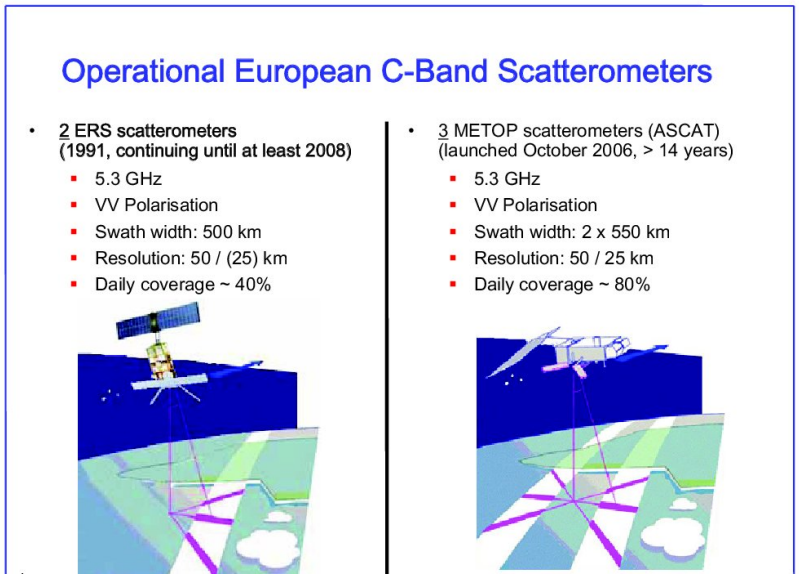
* G=global, R=regional=N.Atlantic+Europe, UK=UK area

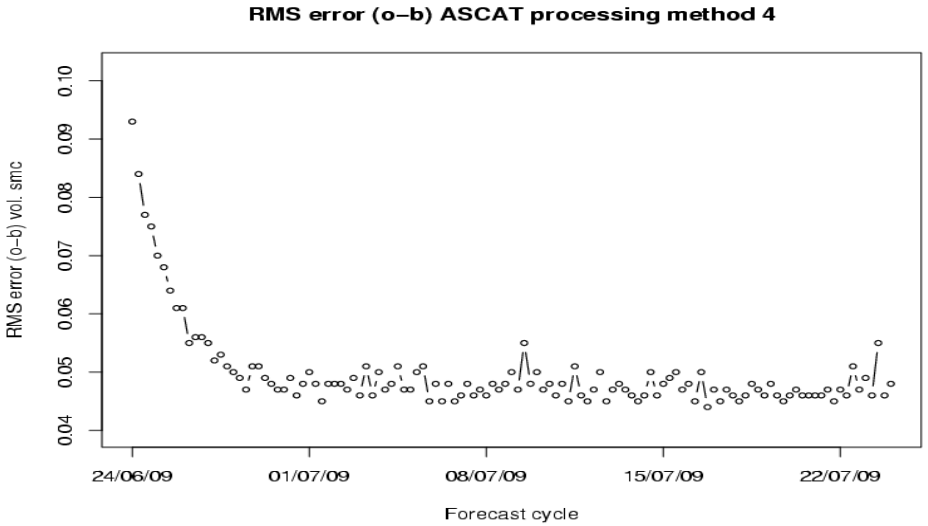
Satellite data used in NWP (2)

August 2011

Observation type	Satellites	NWP variables	NWP models *
AMVs – geo	5 geo satellites	wind	G, R, UK
AMVs – MODIS and AVHRR	Aqua, Terra, NOAA, Metop	wind	G, R
Scatt. sea-surface winds: ASCAT	Metop	surface wind	G, R, UK
MW imager sea-surface winds: Windsat	Coriolis	surface wind	G, R
SEVIRI cloud height/amount	MSG	cloud	R, UK
SSTs: AVHRR, AATSR, …	NOAA, Metop, ENVISAT, Aqua	sea surf. temp.	G, R, UK
Soil moisture: ASCAT	Metop	soil moisture	G, R, UK
Sea ice: SSM/I, SSMIS	DMSP	sea ice	G, R
Snow cover	various	snow cover	G, R

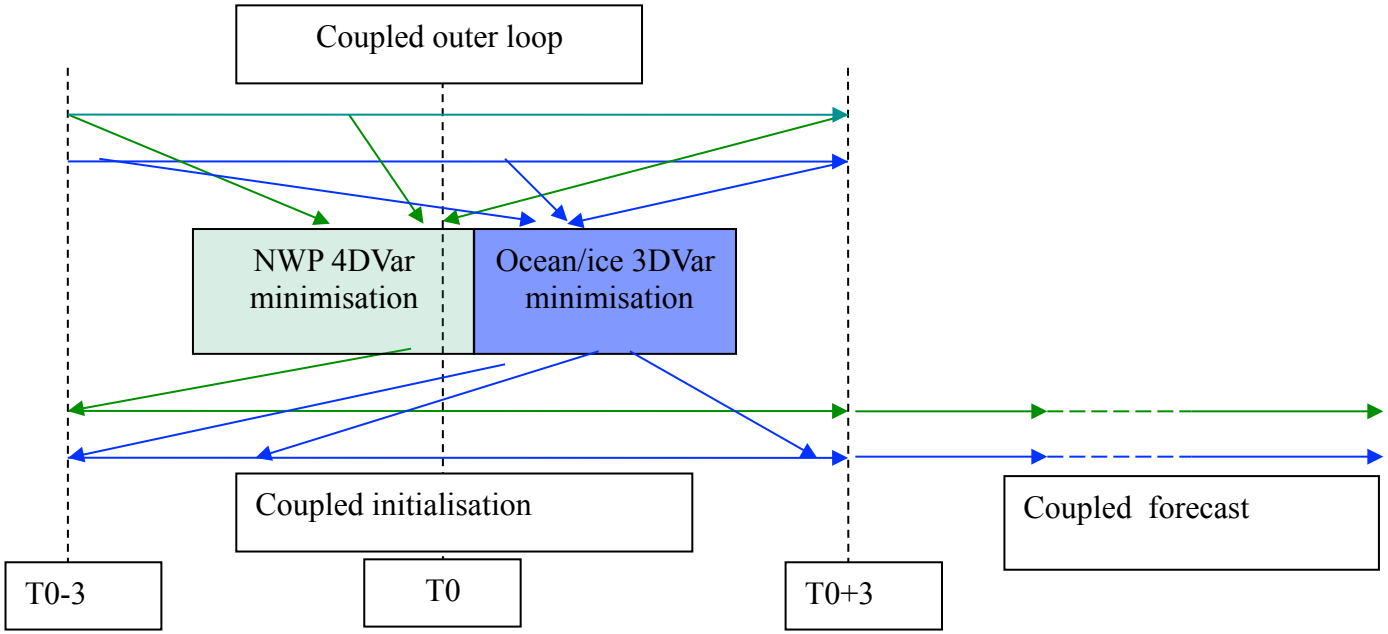
DA Frontiers 2: Land DA





- ASCAT soil wetness assimilation implemented May 2010 (first major Met Centre to operationally use satellite derived soil moisture in NWP).
- Simple/cheap method to assimilate measurements of ASCAT soil wetness:
  - Nudge level 1 soil moisture is nudged. Surface T etc corrected through 4D-Var.
- Initial trials indicates ASCAT soil wetness assimilation improves forecasts of screen temperature and humidity in tropics (neutral in Europe so far).
- Next stages: Build new EKF Land DA algorithm (collaboration with ECMWF, etc)

DA Frontiers 3: Coupled DA for ESM



- Not full coupled DA, but initialisation shocks should be reduced.
- Atmospheric trajectory will change in ocean IAU step.
- On-line model bias correction schemes could be developed to correct model drifts (rather than doing *a posteriori* calibration as in GloSea).
- Longer-term: develop fully coupled O-A DA, and extend to other ESM components

Matt Martin

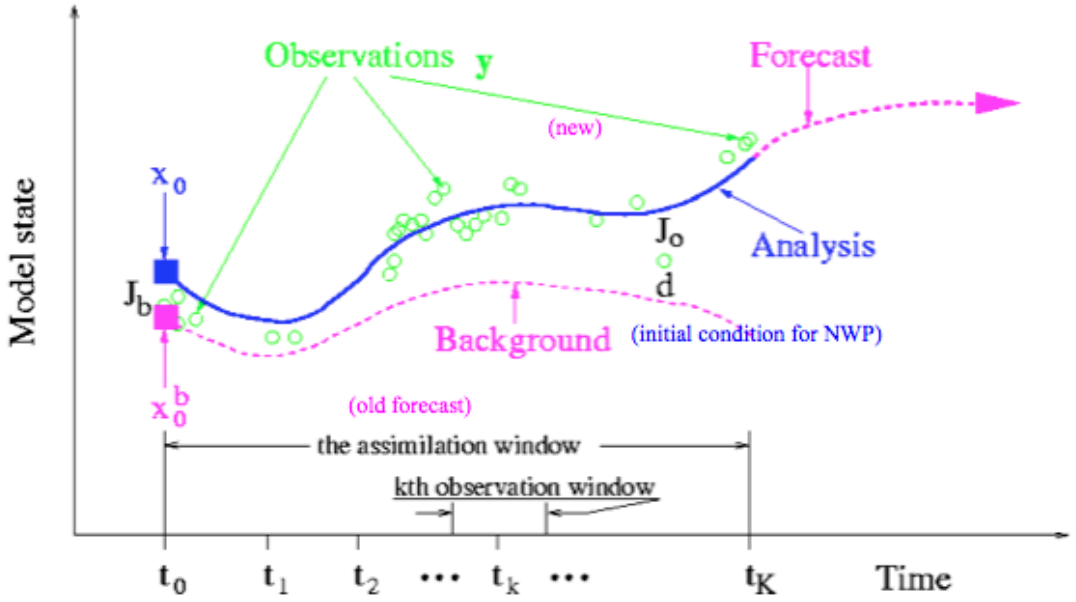
Satellite DA In Convective-Scale NWP

(Tubbs, Kelly, Lean)

- SEVERI radiances (thinned to 24km):
  - One timeslot/3hours in UKV DA 3D-Var.
  - Channel 5 (clear sky, all surface).
  - Channel 6 (land/sea – not highland, sea-ice).
  - Channels 7-10 (over sea).

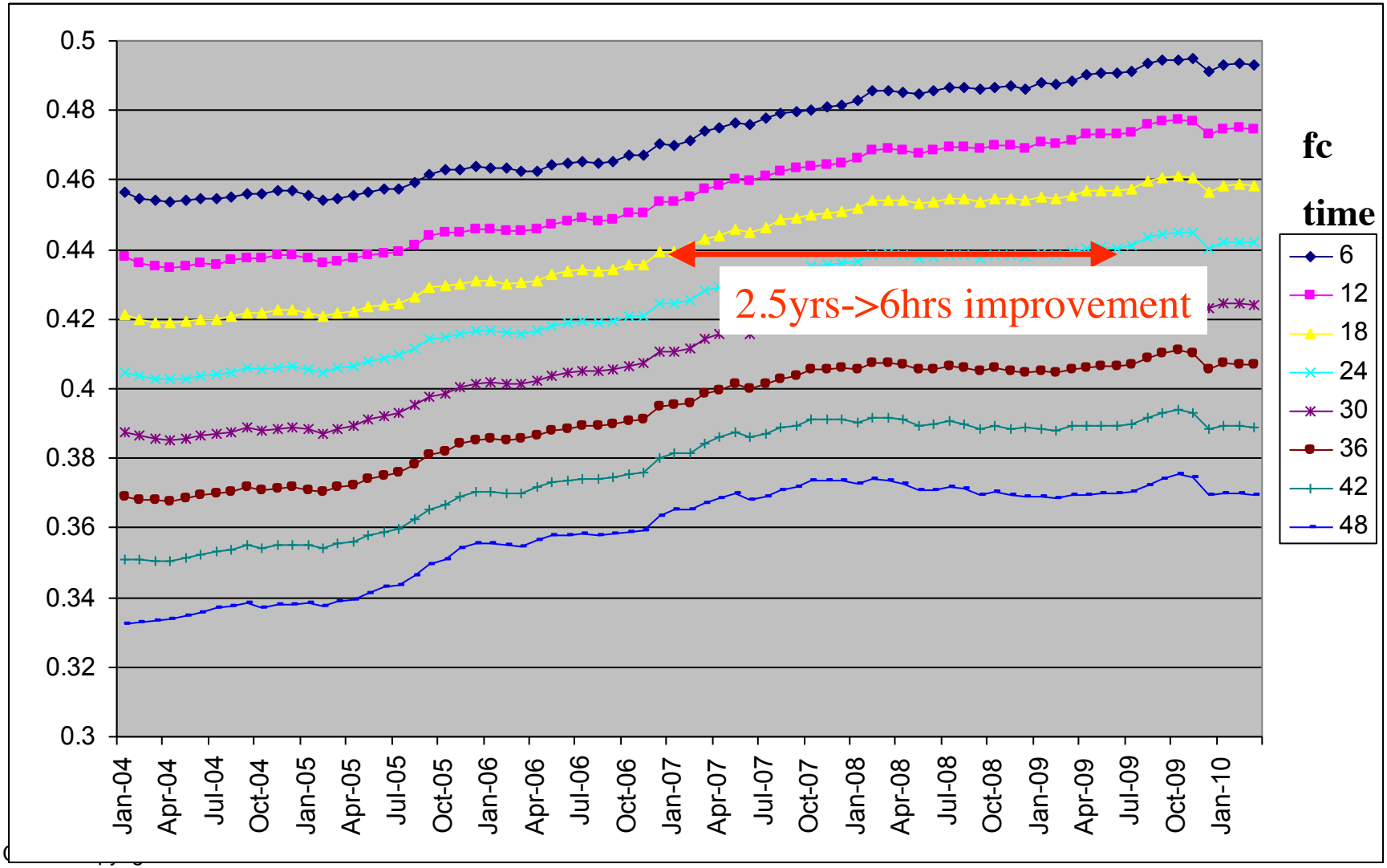
- Plans:
  - Higher-resolution AMVs.
  - Correct land surface skin temp to allow SEVERI ch7-9,10 over land
  - Trialling SEVERI ch5 over low cloud + high-resolution AMSU-B.
  - Results to date (7/2/2012-1/3/2012 trial): UK Index: British Isles (WMO 03): 0.184 (0.74%)

Precipitation assimilation



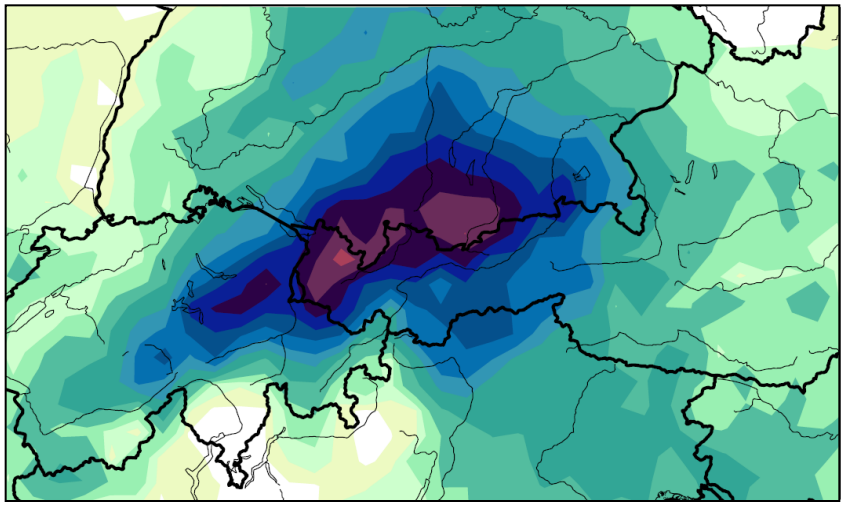
- Current NWP approach uses latent heat nudging ‘retrieval’.
- 4D-Var PF model includes linearised microphysics (large-scale precipitation) and convection. Potential to adjust dynamics to fit rainfall.
- Currently trialling with radar surface rainrate BUT reanalysis will have to use surface reports of 24hr raingauge accumulations.
  - Need to disaggregate 24hr accumulations into 4x6hrs for assimilation.

Improvement of NAE UK Index

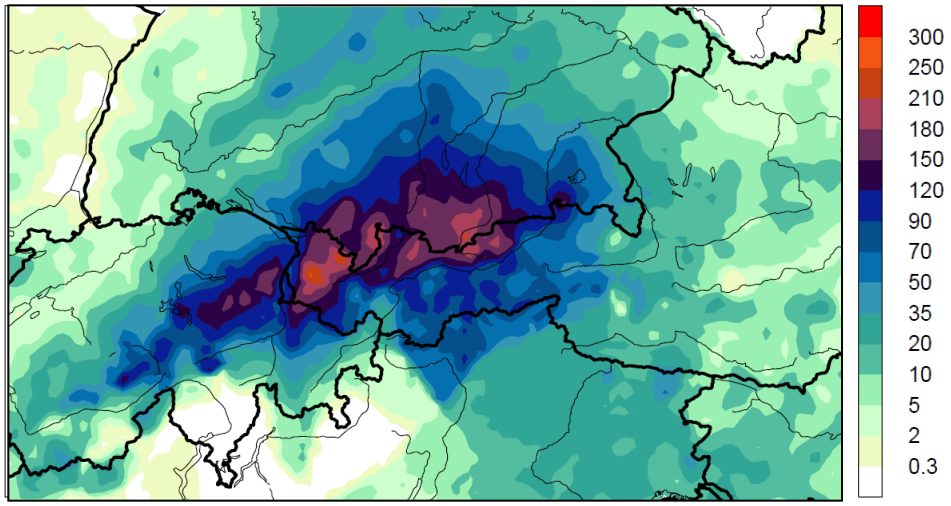


WP2.4 Evaluation (MeteoSwiss)

20 km grid



5 km grid



Precipitation at meso-scale in complex topography (Alpine region)

Consistency between obs. datasets (spatial pattern, annual cycle) for precip extremes?

High-resolution regional reanalyses vs. global reanalysis?

Representation of interannual to decadal variations by regional reanalyses?

GA3: See Frei discussion