Recent progress in land surface modelling and assimilation at the Met Office

Presented by Bruce Macpherson

Slides created by Imtiaz Dharssi, Gabriel Rooney, Sam Pullen, John Edwards and Margaret Hendry

September 2009

Contents

- Assimilation of ASCAT soil wetness
- New soil properties
- JULES surface scheme
- Snow analysis

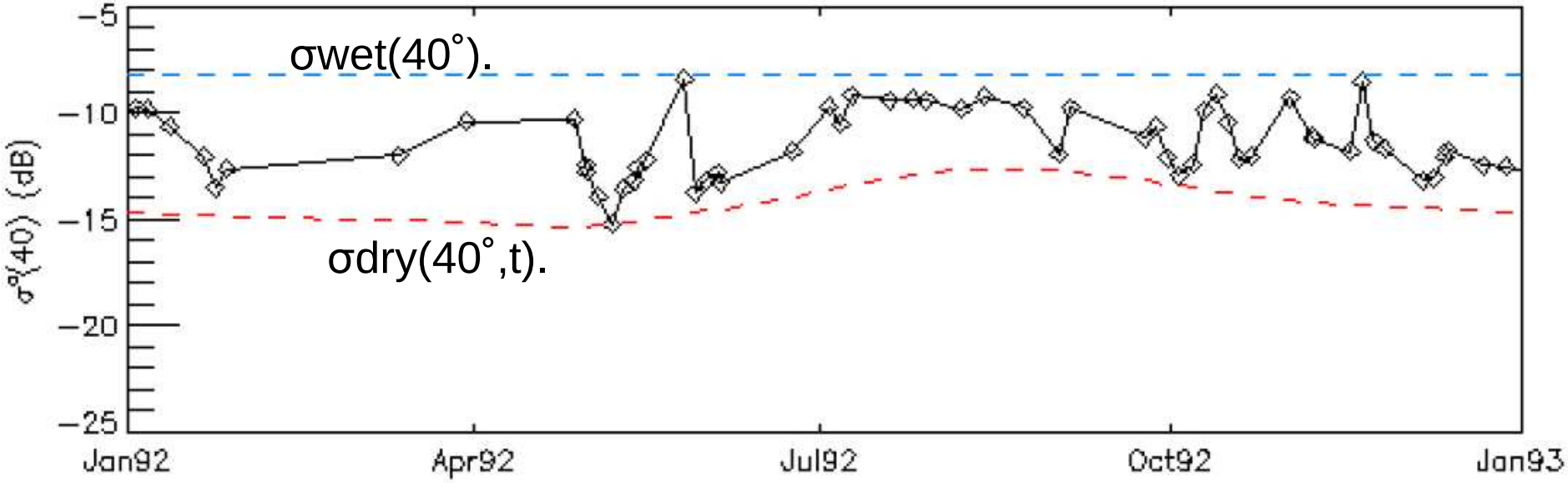
Assimilation of ASCAT soil wetness

Work by Imtiaz Dharssi, Keir Bovis, Bruce Macpherson and Clive Jones

ASCAT Soil Wetness

- ASCAT soil wetness is actually a normalised backscatter

$$SW_{\sigma}(t) = \frac{\sigma(40^{o},t) - \sigma_{dry}(40^{o},t)}{\sigma_{wet}(40^{o}) - \sigma_{dry}(40^{0,}t)}$$



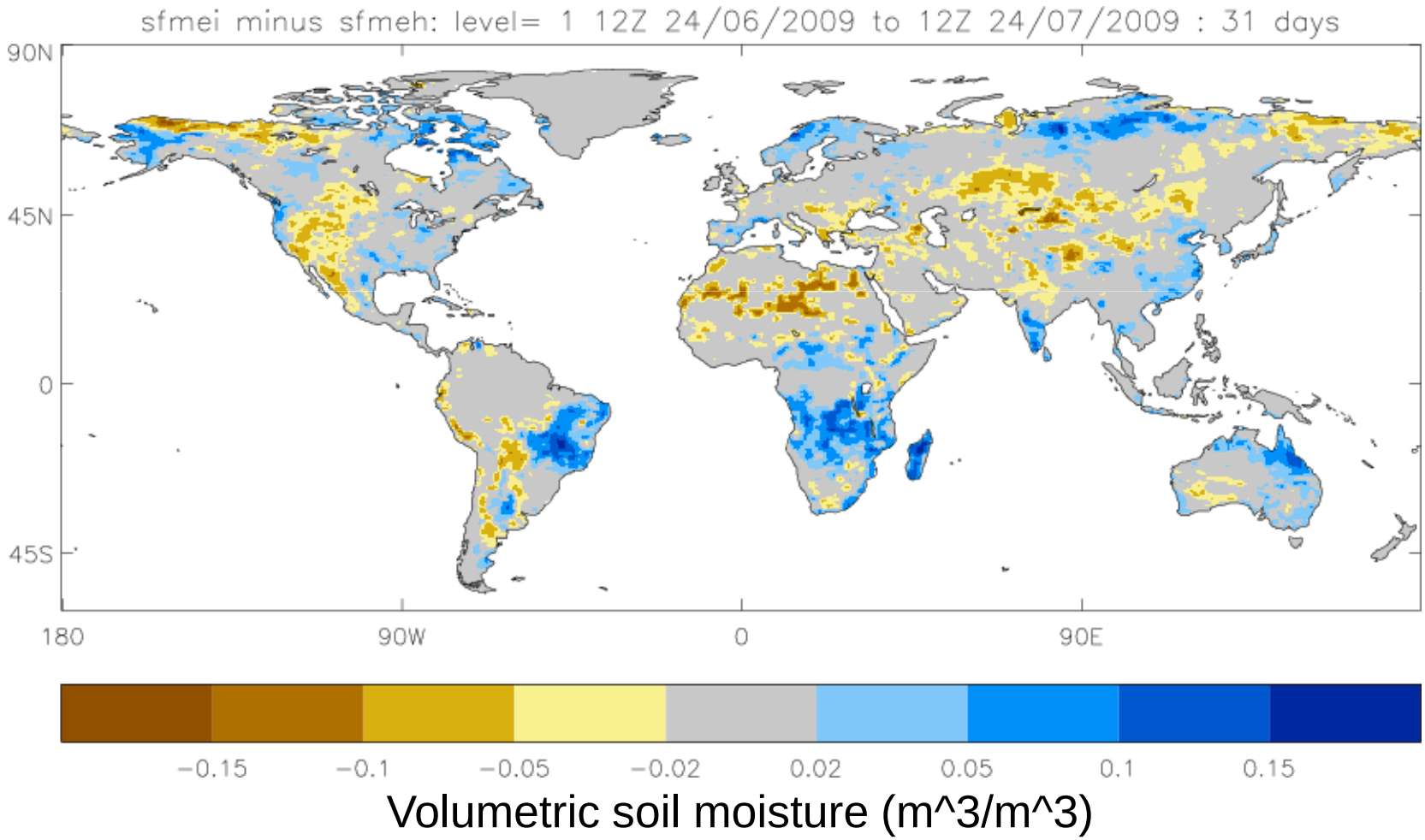
Converting ASCAT soil wetness to soil moisture

- Match the ERS SCAT soil wetness climatology to the JULES/GSWP2 soil moisture climatology.
  - The matching parameters vary spatially.
- A soil wetness climatology has been created using measurements from ERS SCAT for the years 1992 to 2000.
- Soil moisture climatologies have been created by driving the Met Office off-line land surface model, JULES, with GSWP2 global driving data (period 1986 to 1995).
  - GSWP2 = Global Soil Wetness Project 2.
    - Driving data = precipitation, surface SW and LW radiation, near surface air temperature, humidity, wind speed and surface pressure.
  - A JULES/GSWP2 soil moisture climatology is cheap to create – takes a weekend on a Linux PC.

Global trial on impact of assimilation of ASCAT soil wetness

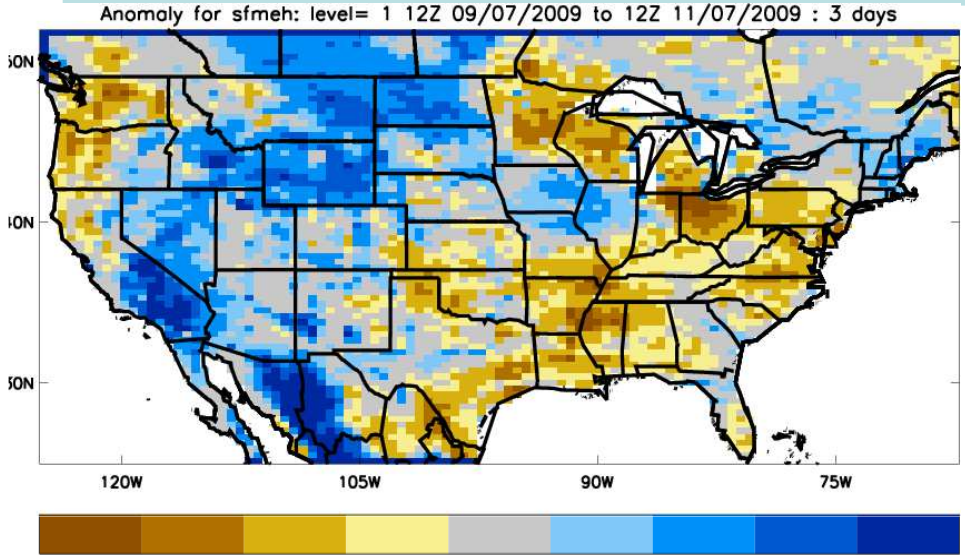
- **Control**
  - June/July 2009
  - Operational model.
    - 4 Soil layers: 0-10cm, 10-35cm, 35cm-1m, 1m-3m.
    - Observations of screen temperature and humidity are used to nudge the model soil moisture in all soil layers.
- **Test**
  - As control plus ASCAT soil wetness to nudge the **top level** soil moisture.
    - We QC the ASCAT soil wetness data.
    - ASCAT soil wetness data replaces the models existing level 1 soil moisture.
    - ASCAT data applied AFTER soil moisture nudging on all layers

Difference in time averaged top level volumetric soil moisture from ASCAT

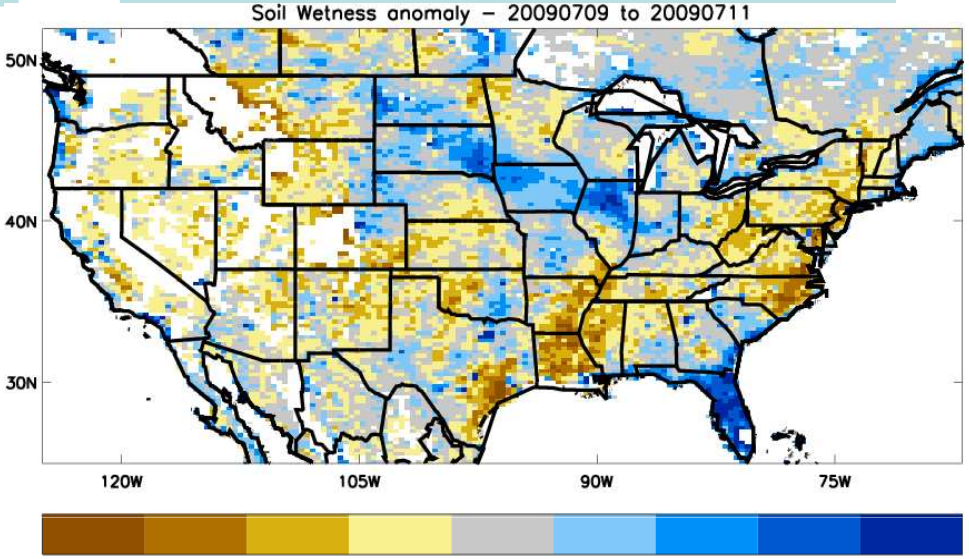


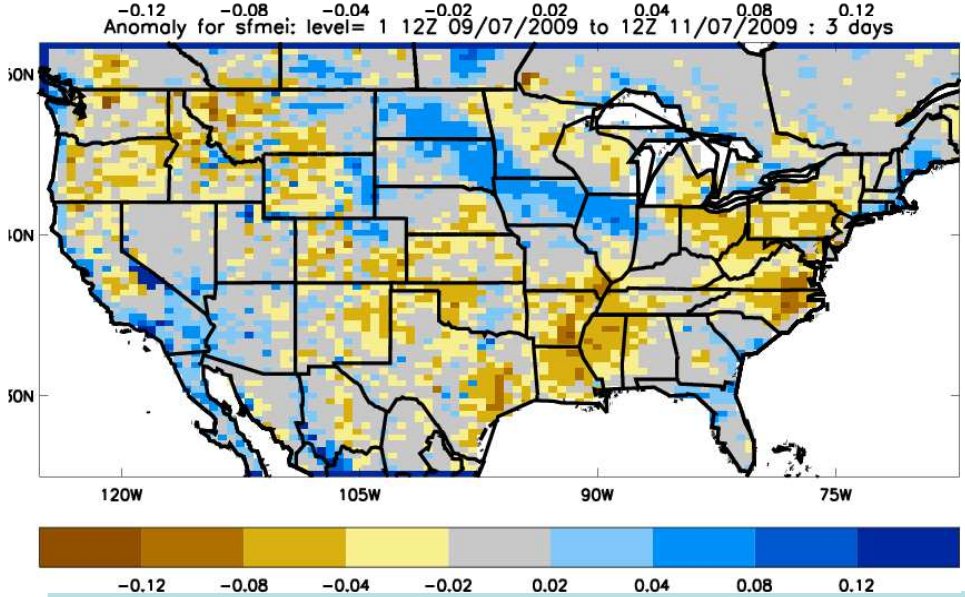
Water anomalies: 9 to 11 July 2009

Control run: top 10cm soil moisture anomaly

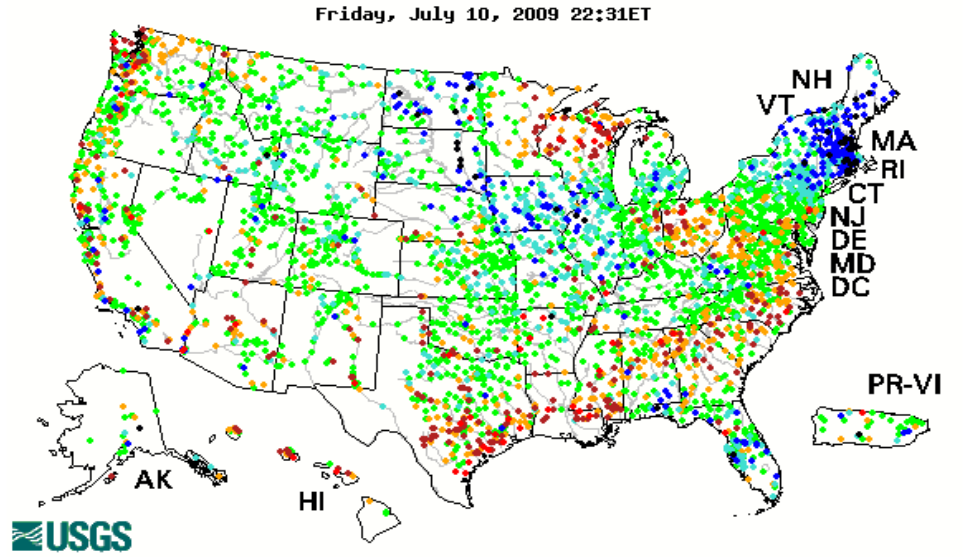


ASCAT surface soil wetness anomaly





Test run: top 10cm soil moisture anomaly

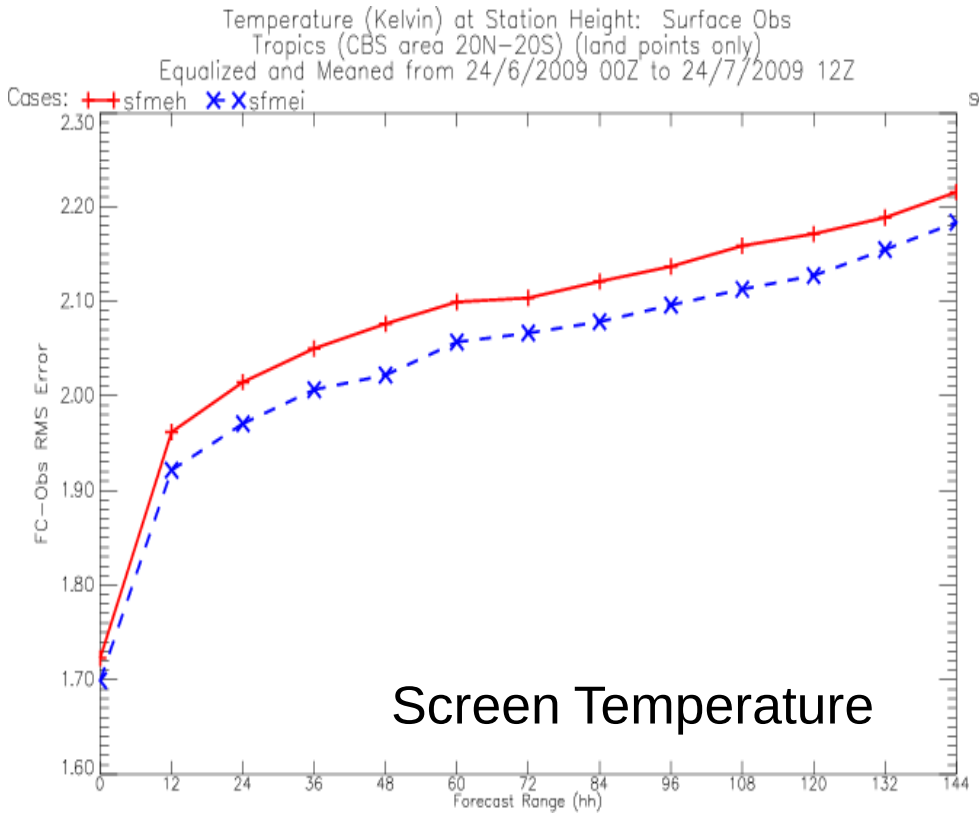


River Flow anomaly

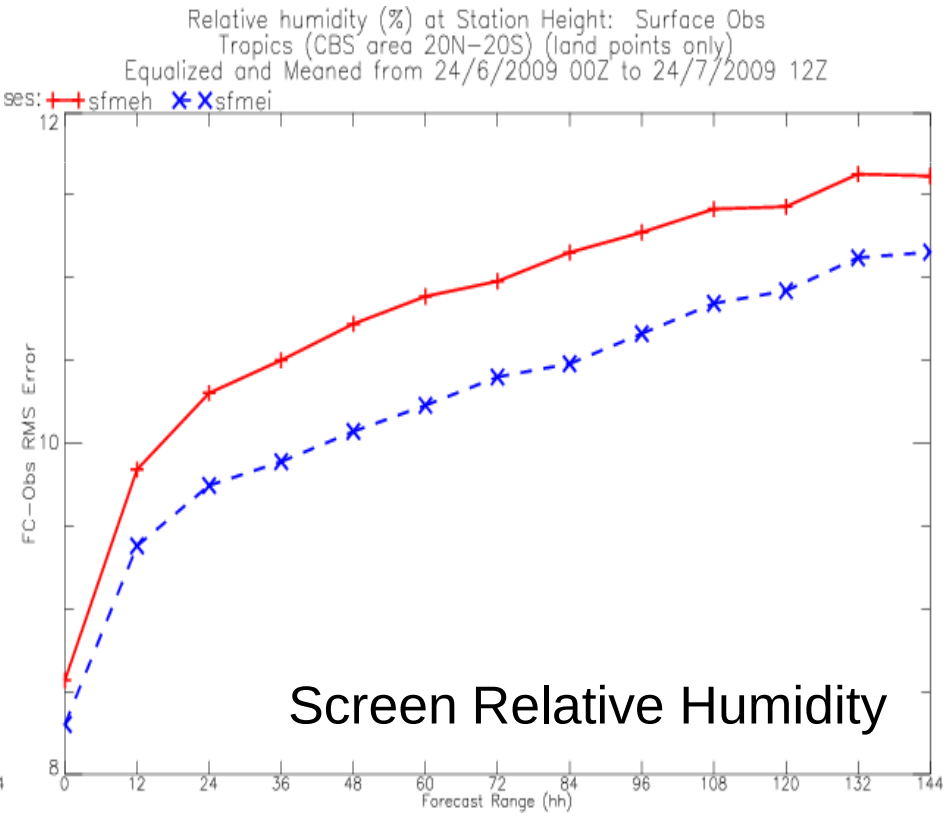
Tropics: RMS errors in screen T and RH

Control

Test with ASCAT soil wetness assimilation



Screen Temperature

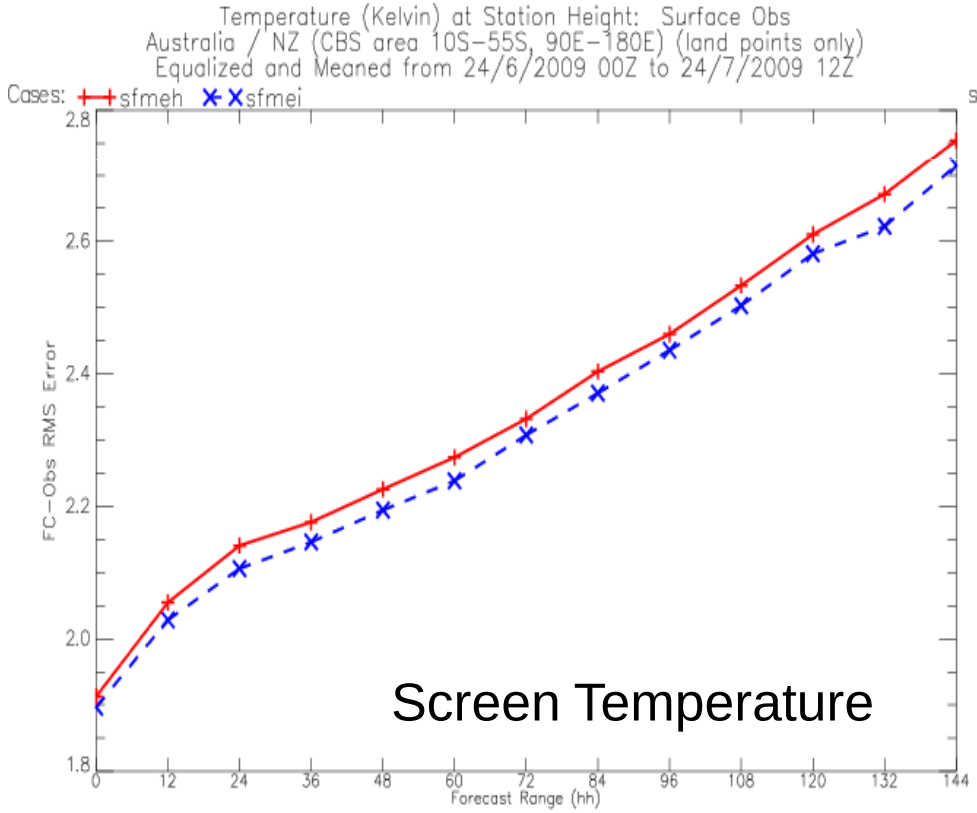


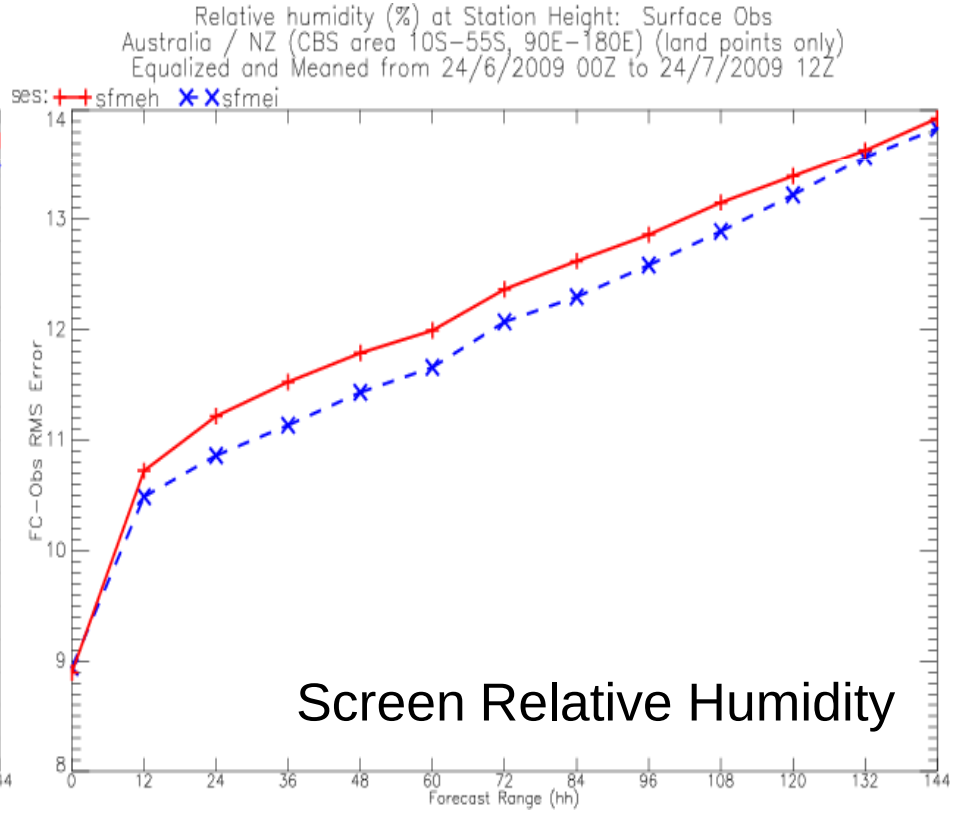
Screen Relative Humidity

Australia: RMS errors in screen T and RH

Control

Test with ASCAT soil wetness assimilation

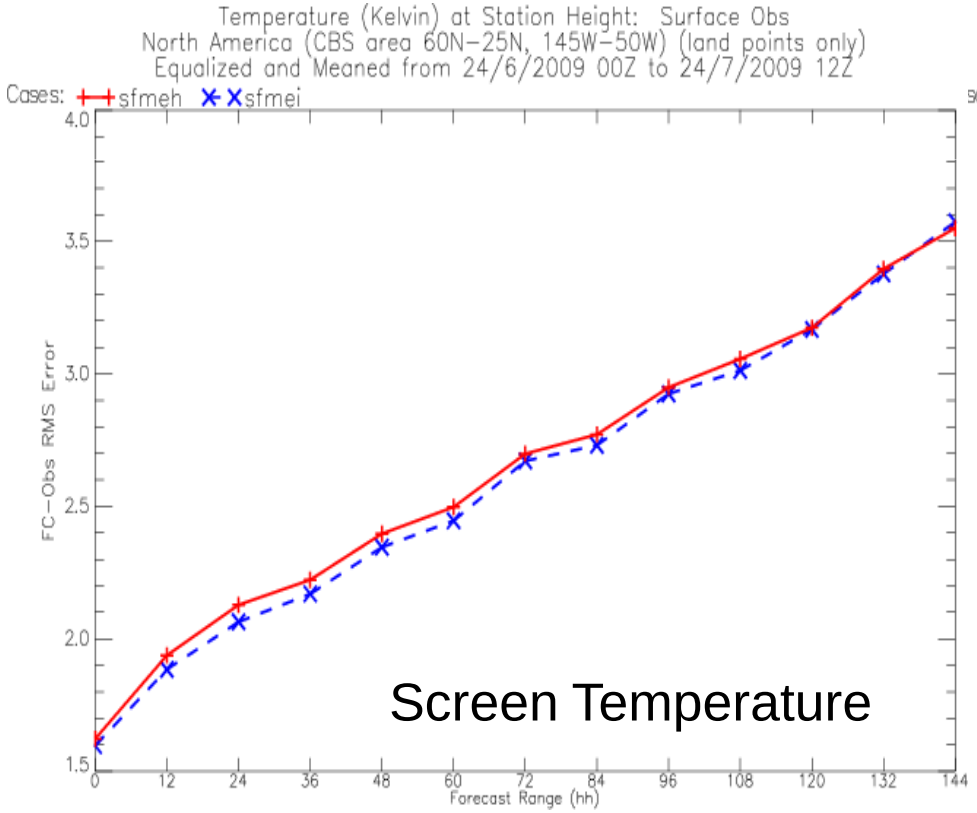


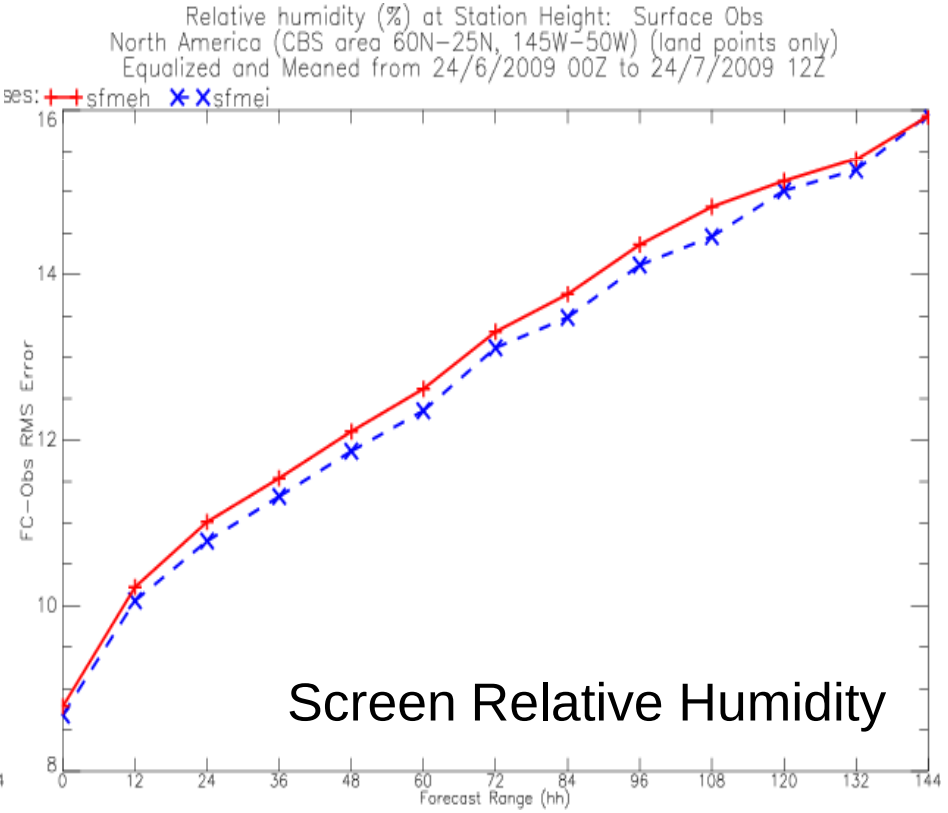


North America: RMS errors in screen T and RH

Control

Test with ASCAT soil wetness assimilation

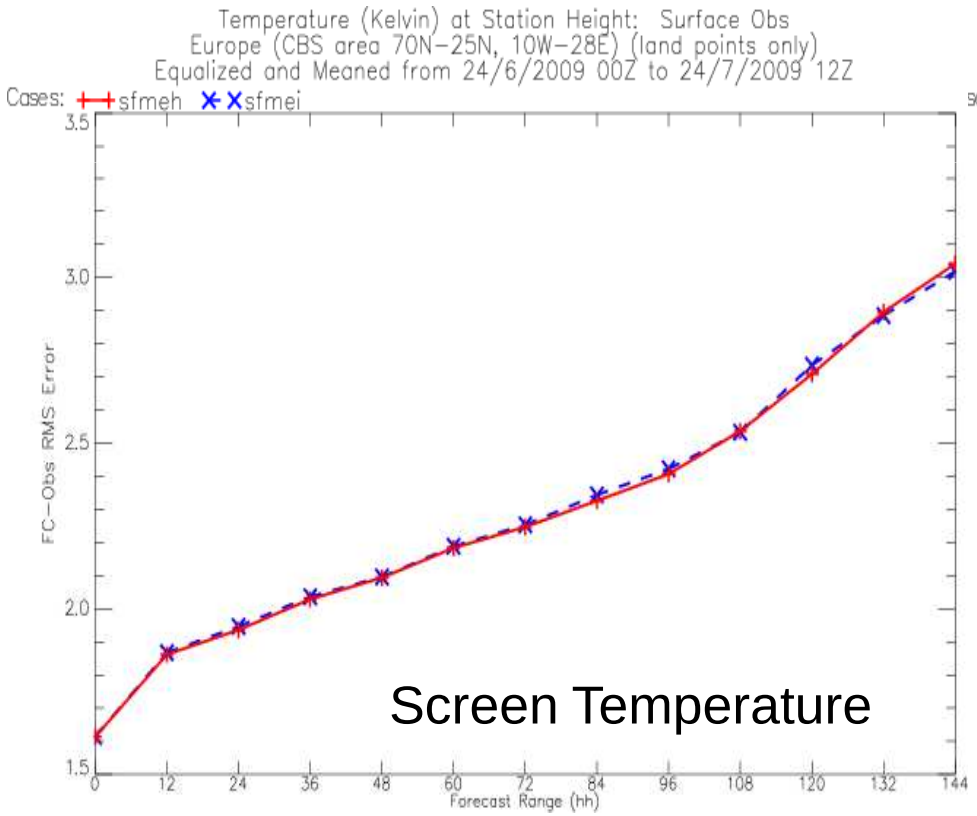


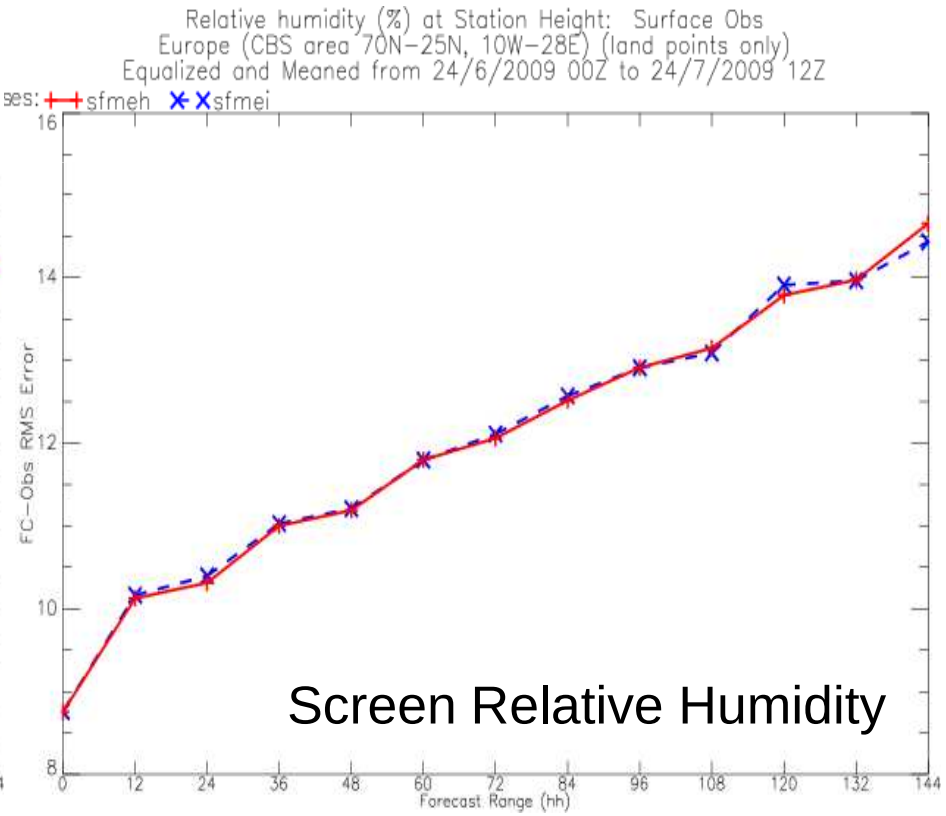


Europe: RMS errors in screen T and RH

Control

Test with ASCAT soil wetness assimilation





Summary

- We have tested a simple and cheap method to assimilate measurements of ASCAT soil wetness.
- Our first trial indicates that ASCAT soil wetness assimilation improves forecasts of screen temperature and humidity for the tropics. Impact in other regions is slightly positive or neutral.
- Future work: develop an Extended Kalman Filter (EKF) land data assimilation scheme that can assimilate both screen level observations and satellite measurements.

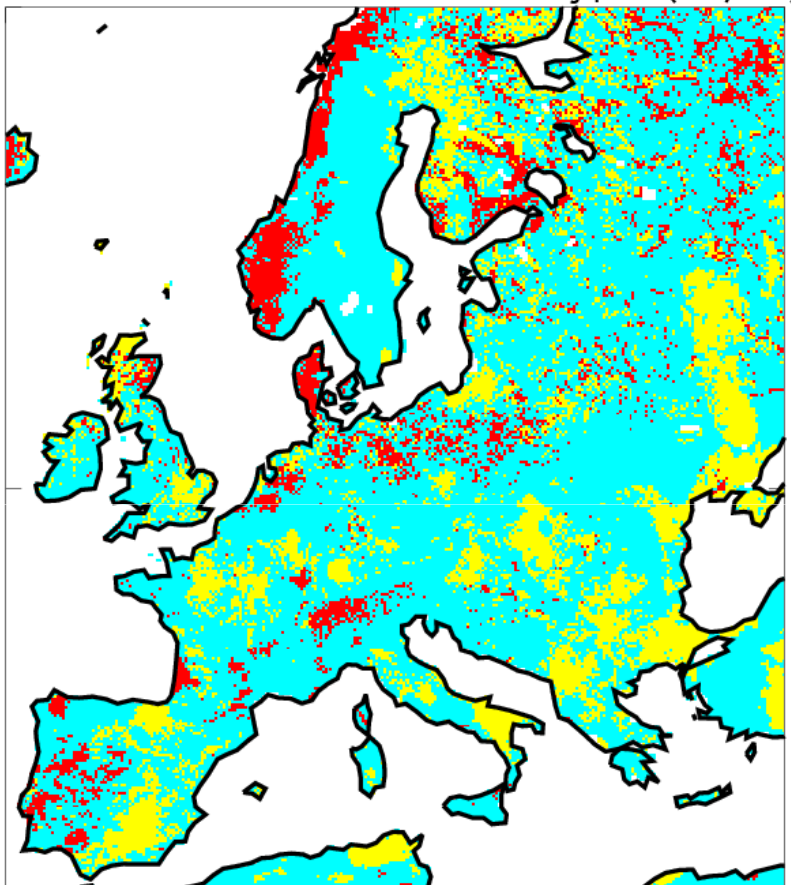
New soil properties

Work by Imtiaz Dharssi, Clive Jones, Bruce Macpherson and Keir Bovis

New soil properties:

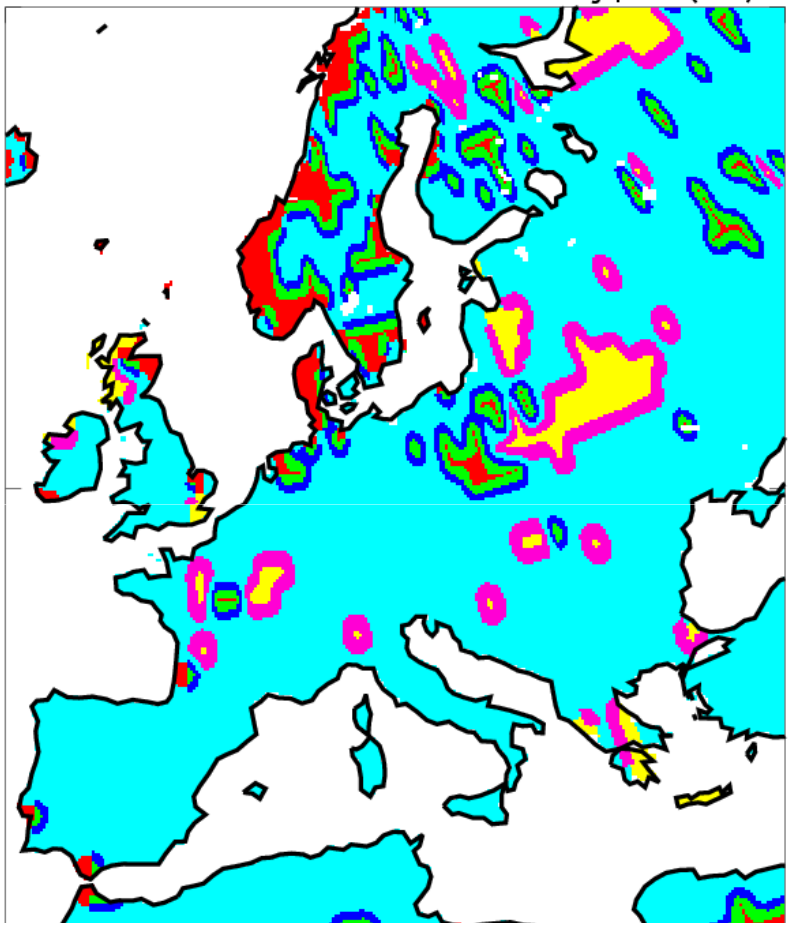
Comparison of the wilting points

New Soil: Volumetric soil moisture at the wilting point (m^3/m^3).

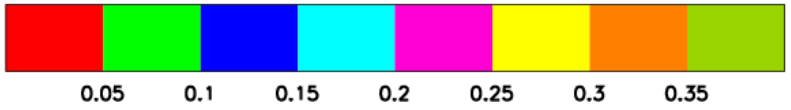


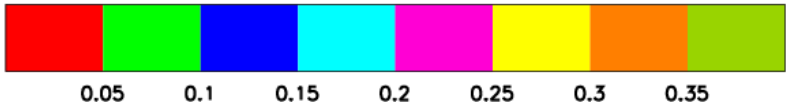
Based on the soil sand, silt, clay and organic carbon data from the Harmonised World Soil Database (HWSD, 2008) and other sources.

Current Soil: Volumetric soil moisture at the wilting point (m^3/m^3).



Current soil properties based on 1 degree x 1 degree data of Wilson and Henderson-Sellers (1985).





Coarse Medium Fine

New soil properties

- With the new soil properties we use van Genuchten soil hydraulics
  - Instead of Clapp and Hornberger soil hydraulics
- Global trials have been run for a summer and winter case
  - The van Genuchten soil hydraulics reduces the vertical flow of water and tends to make the soil wetter.
    - This reduces the model's summer warm bias by about 0.1K.
  - Otherwise the impact of the new soil properties is broadly neutral.

JULES: a new surface scheme

Joint UK Land Environment Simulator

JULES and the Unified Model

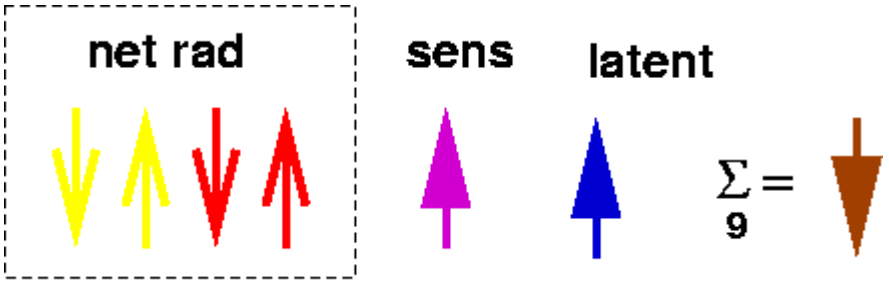
- The Met Office Unified Model (UM) is used for both climate and NWP.
- The land surface in the UM is modelled by the Met Office Surface Exchange Scheme, MOSES (e.g. HCTN 30, or Rooney & Claxton, QJRMetS 2006)
- A stand-alone version of MOSES was produced at UM Version 5.5.
- This led to the release of the academic community resource JULES, **http://www.jchmr.org/jules/**

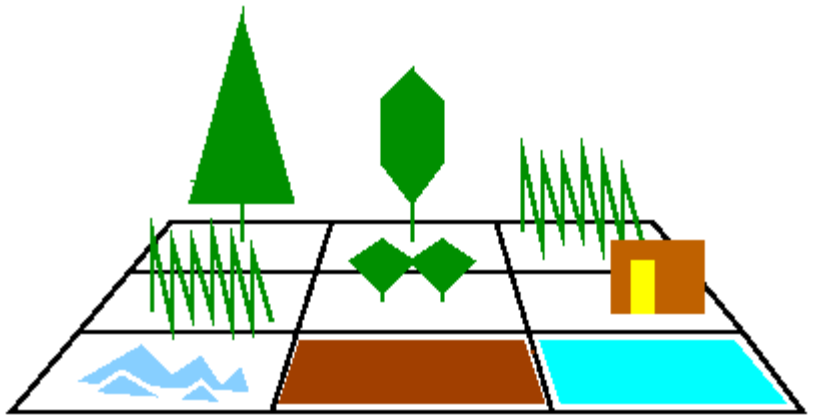
Overview of JULES

9 tiles, 5 veg + 4 non-veg

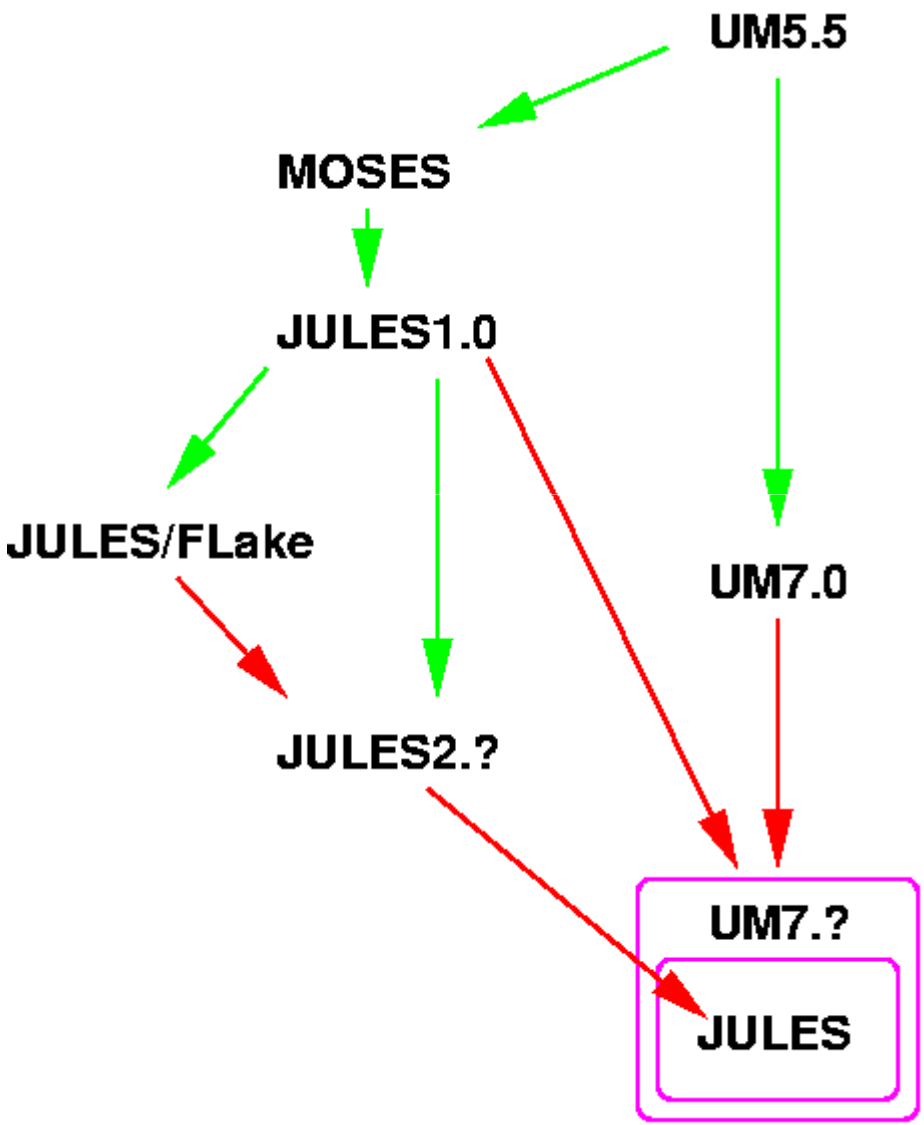
Forced with observables:
T, P, q, DWSW, DWLW,
windspeed, rain, snow

Yields:
surface (canopy) T,
sensible + latent heat fluxes,
soil temperature and moisture





Re-integrating JULES

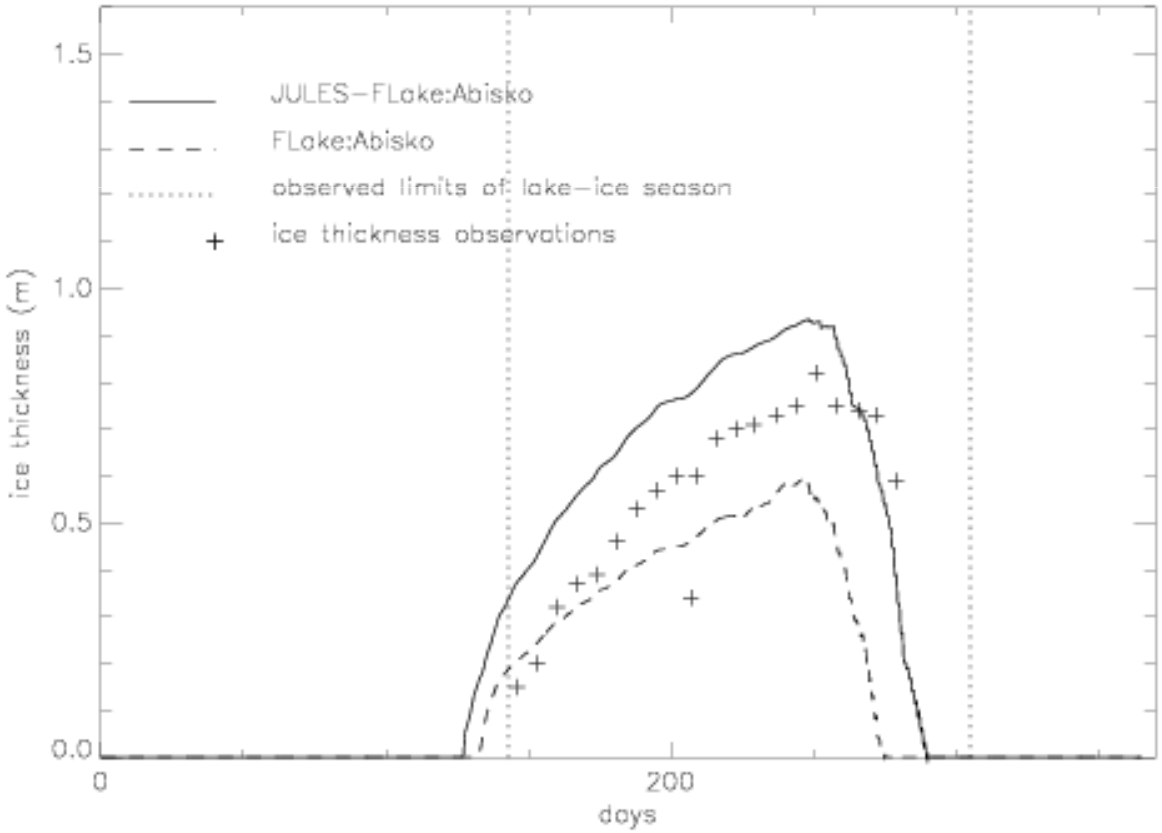


Multi-layer snow scheme

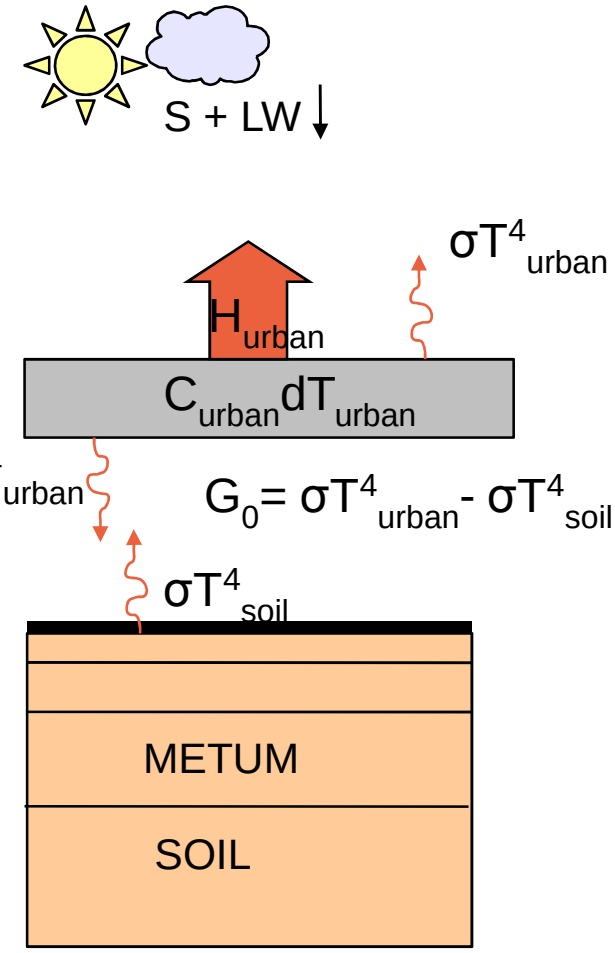
- Main new science going into the UM through JULES
- Developed by Richard Essery, Univ of Edinburgh
- Specify maximum number of snow layers
- Model compacts and relayers

Other developments

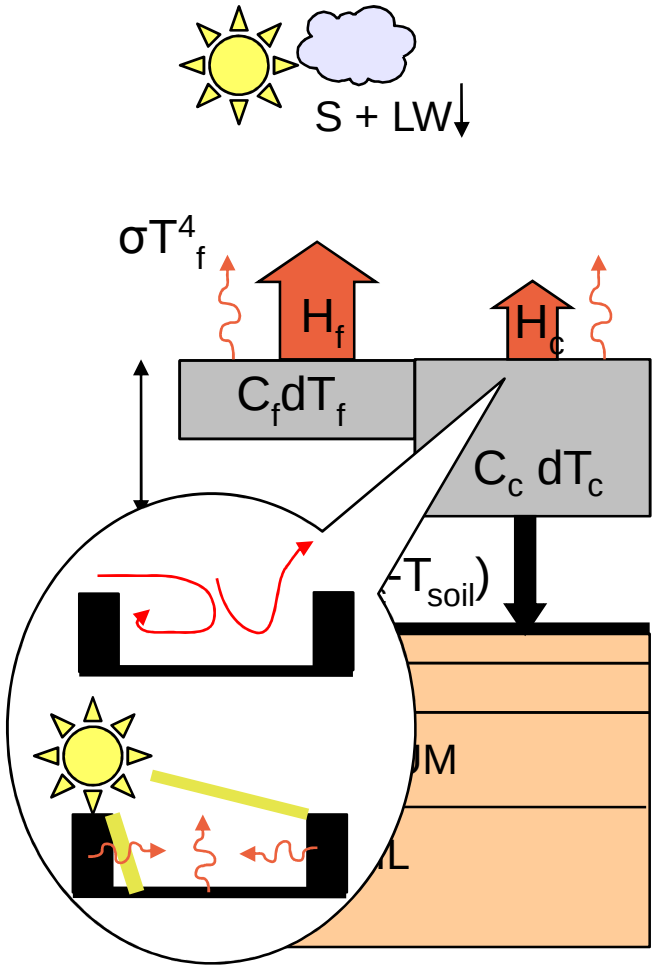
- FLake in JULES
- Urban extensions



Met Office Reading Urban Surface Exchange Scheme



Best et al., 2006, Boundary-layer Meteorol., 118 (3): 503



Porson et al., 2009, Q. J. R. Meteorol. Soc., (submitted)

A snow analysis for the global model

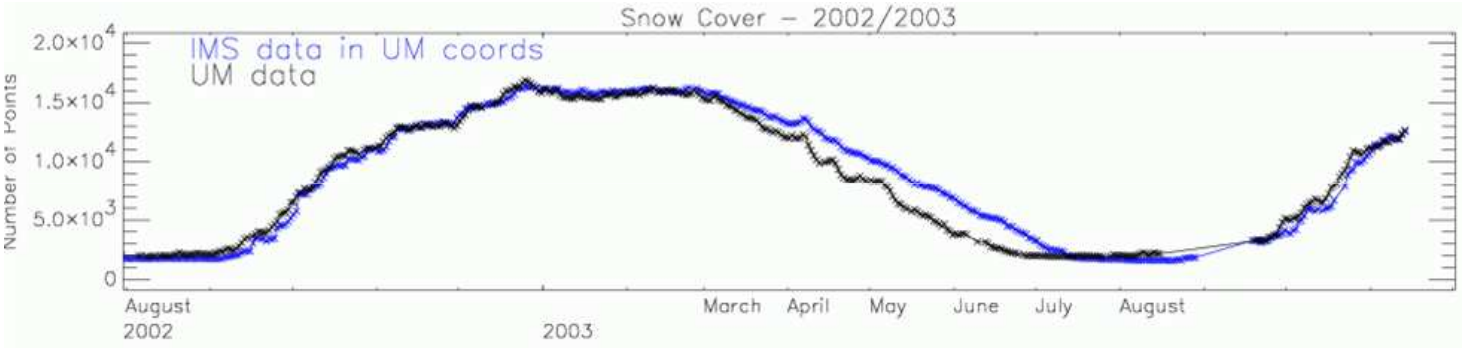
Work by Samantha Pullen, Gabriel Rooney and Clive Jones

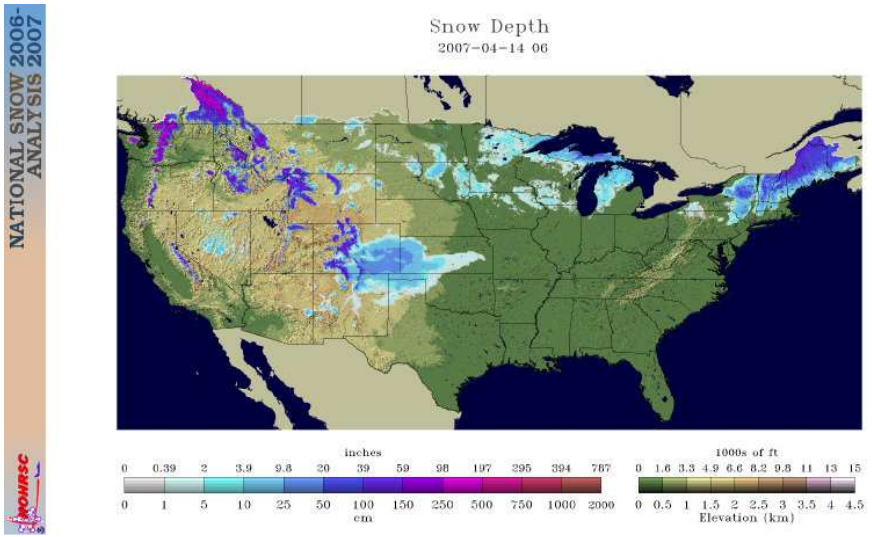
Motivation

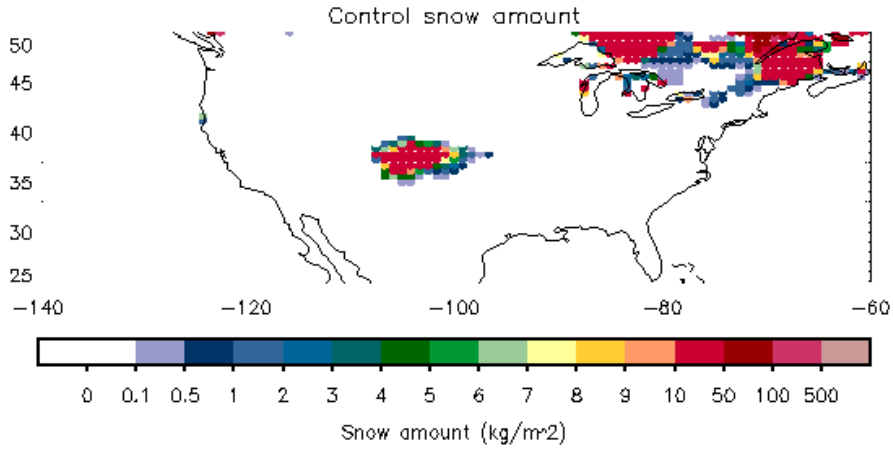
Freely evolving snow amounts → Not enough

Too much variability

Early snowmelt





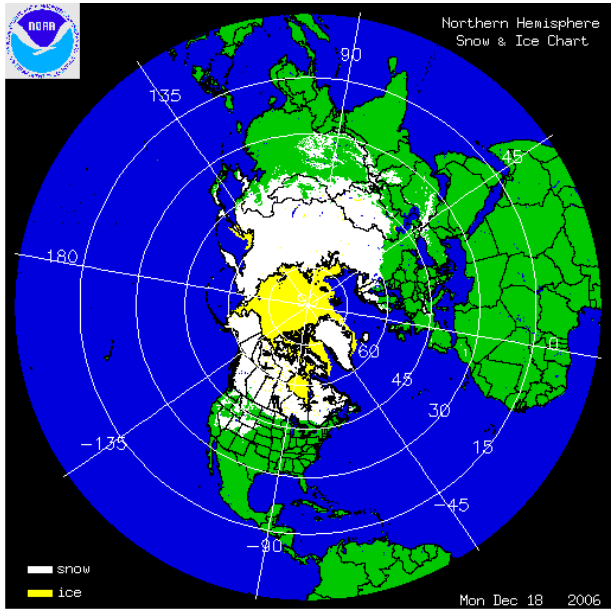


Satellite data

NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS)

- GEO, LEO (GOES, Meteosat, MTSAT, AVHRR, MODIS, SSM/I, AMSU)
- Derived products (e.g. USAF Snow and Ice Analysis Product)
- In situ data
- Analyst

- Daily, 4km resolution, NH
- Polar stereographic 6144 X 6144
- Snow cover (0 or 100), ice (0 or 1)
- Resampled to model grid to produce fractional snow cover product



The snow analysis scheme

Observations | Background | Analysis

frac. cover = 0

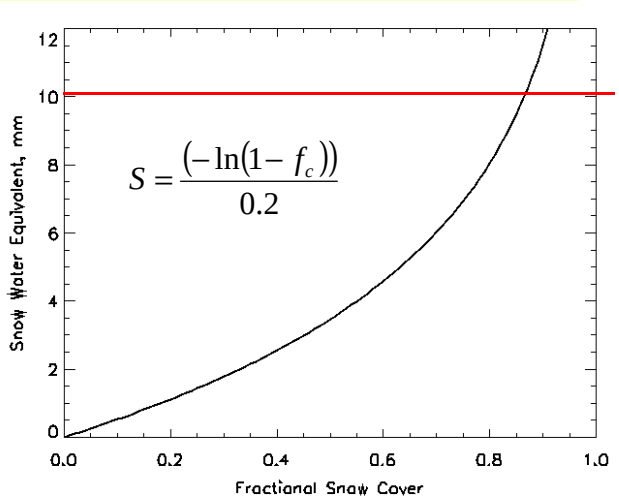
analysed snow = 0

model snow > 0

analysed snow = model snow

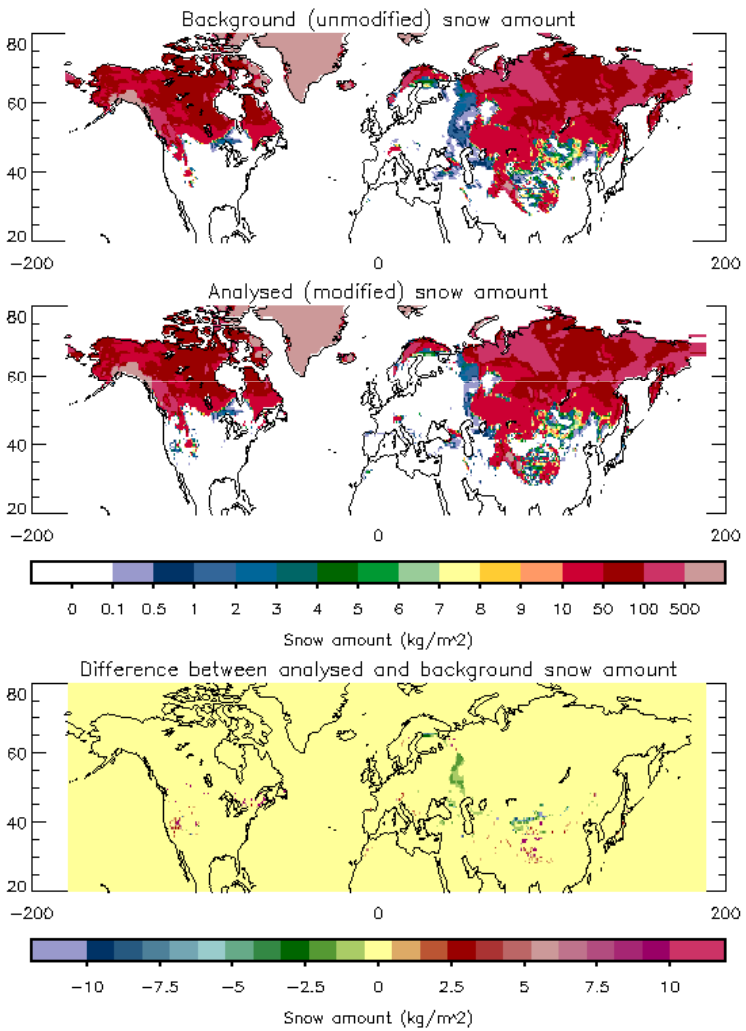
frac. cover > 0

model snow = 0



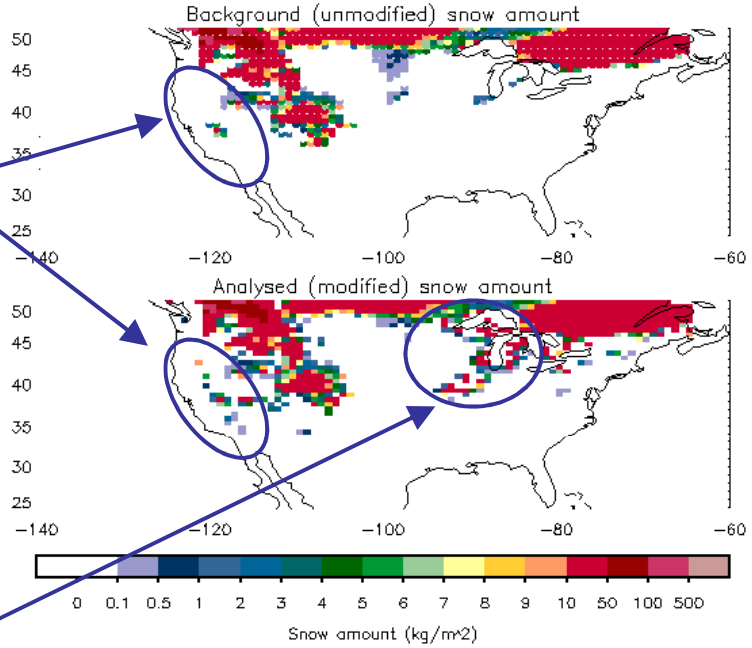
Winter season trial (Dec06)

15-12-06

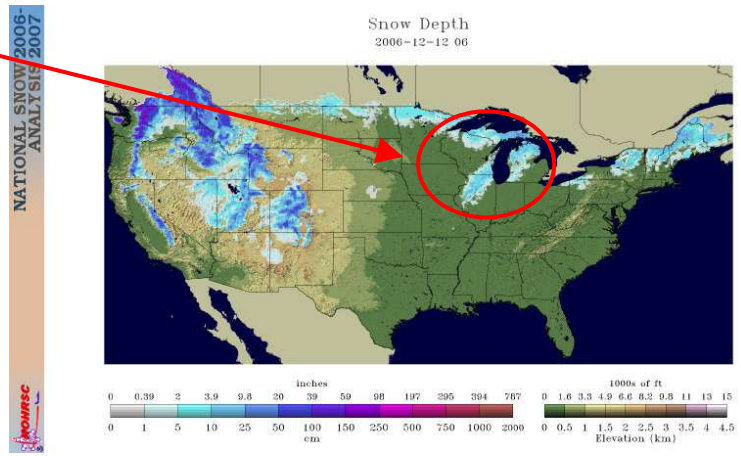


12-12-06

Sierra Nevadas



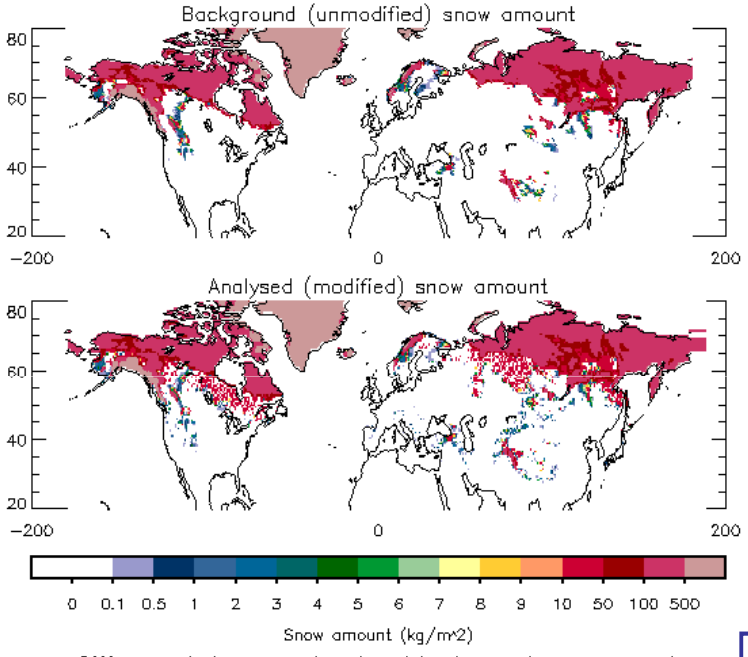
Great Lakes



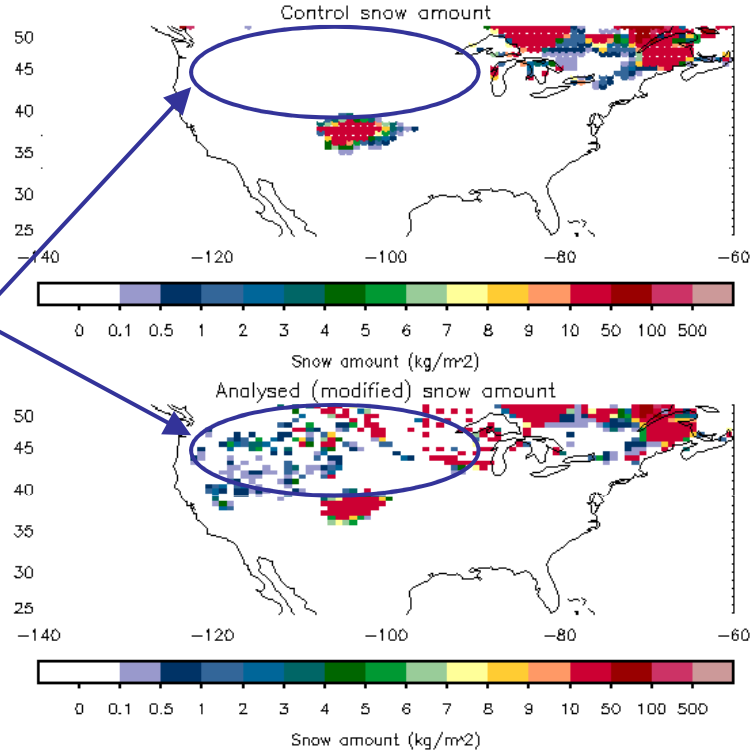
Spring season trial (MAM07)

Met Office

20-04-07



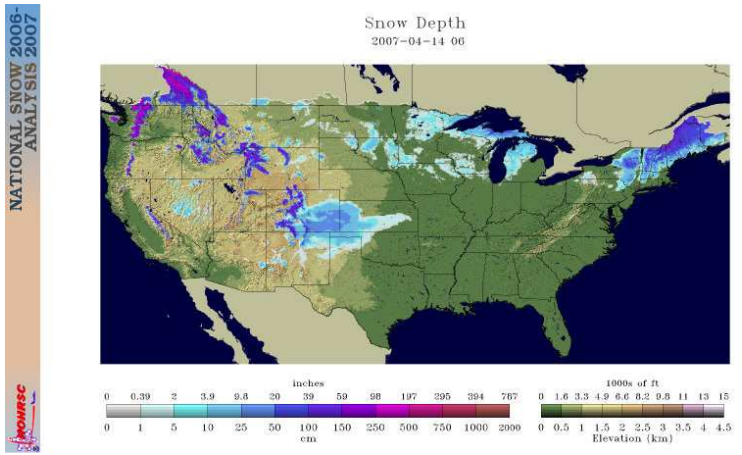
14-04-07



Analysis replaces snow that has been melted too early

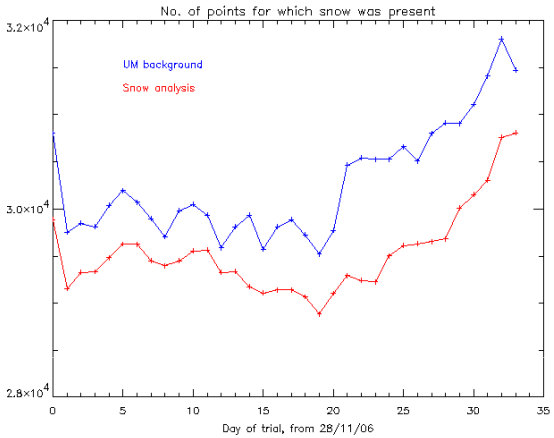
Large-scale additions of snow over US, Canada and Eastern Europe

Removal over Central Asia



Verification of snow-covered points

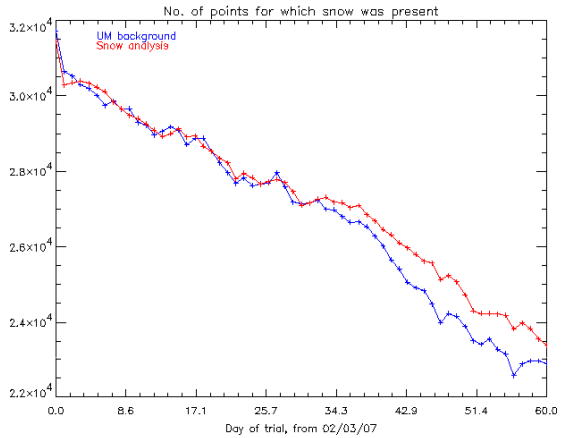
Winter



Dec 06

Snow removed overall

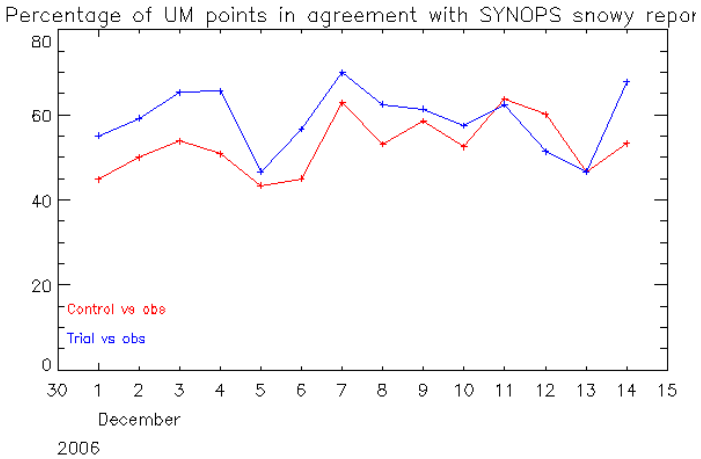
Spring

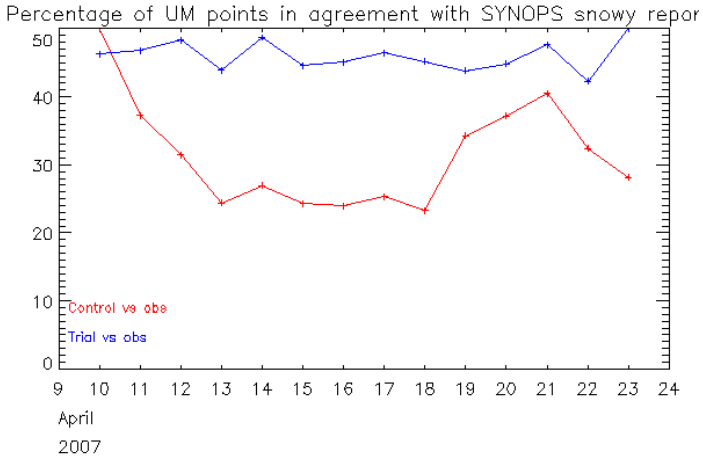


March/April 07

Snow added overall

Improvement in agreement between SYNOP snow reports and presence of snow in model compared with control run with no snow analysis





Summary of snow trials

- The Northern Hemisphere snow analysis has been operational in the Met Office's global NWP model since November 2008.
- There is clear evidence that the snow analysis improves the analysed snow field, in terms of presence/non-presence of snow
- There is some evidence of improvements in surface/low level T and RH, especially where snow is predominantly removed by the analysis.
- Little of the information introduced by the analysis is retained in subsequent forecasts, especially where snow has been added.
- An upgrade to the snow analysis is currently being tested to mitigate the effects of time delays in the IMS data, which can lead to exclusion of snowfall events from the analysis.

Questions?