Land surface developments at the Met Office

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(presented by Bruce Macpherson)

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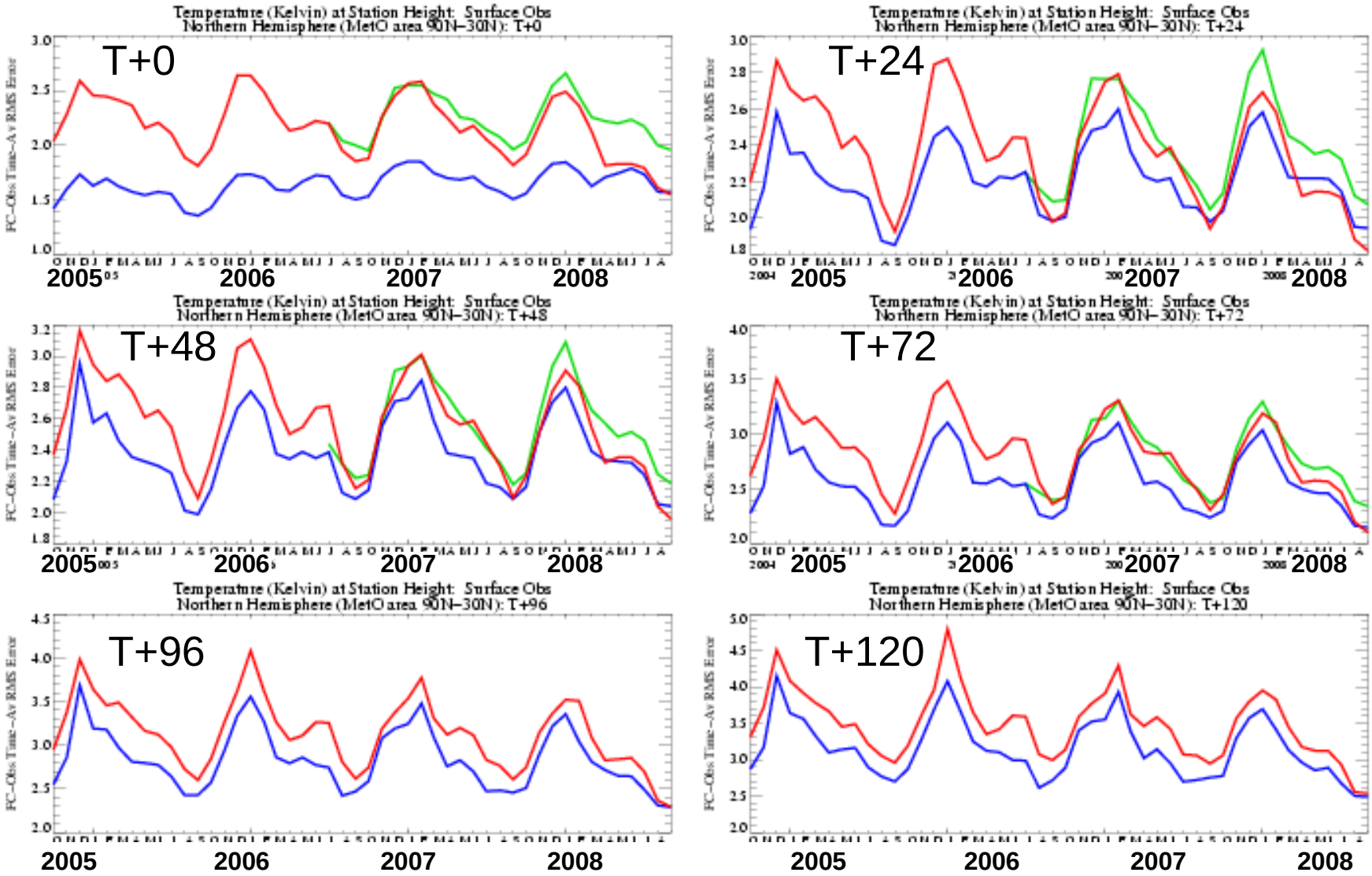
Screen Temperature RMS errors – comparison between Met centres

Northern Hemisphere 30N to 90N

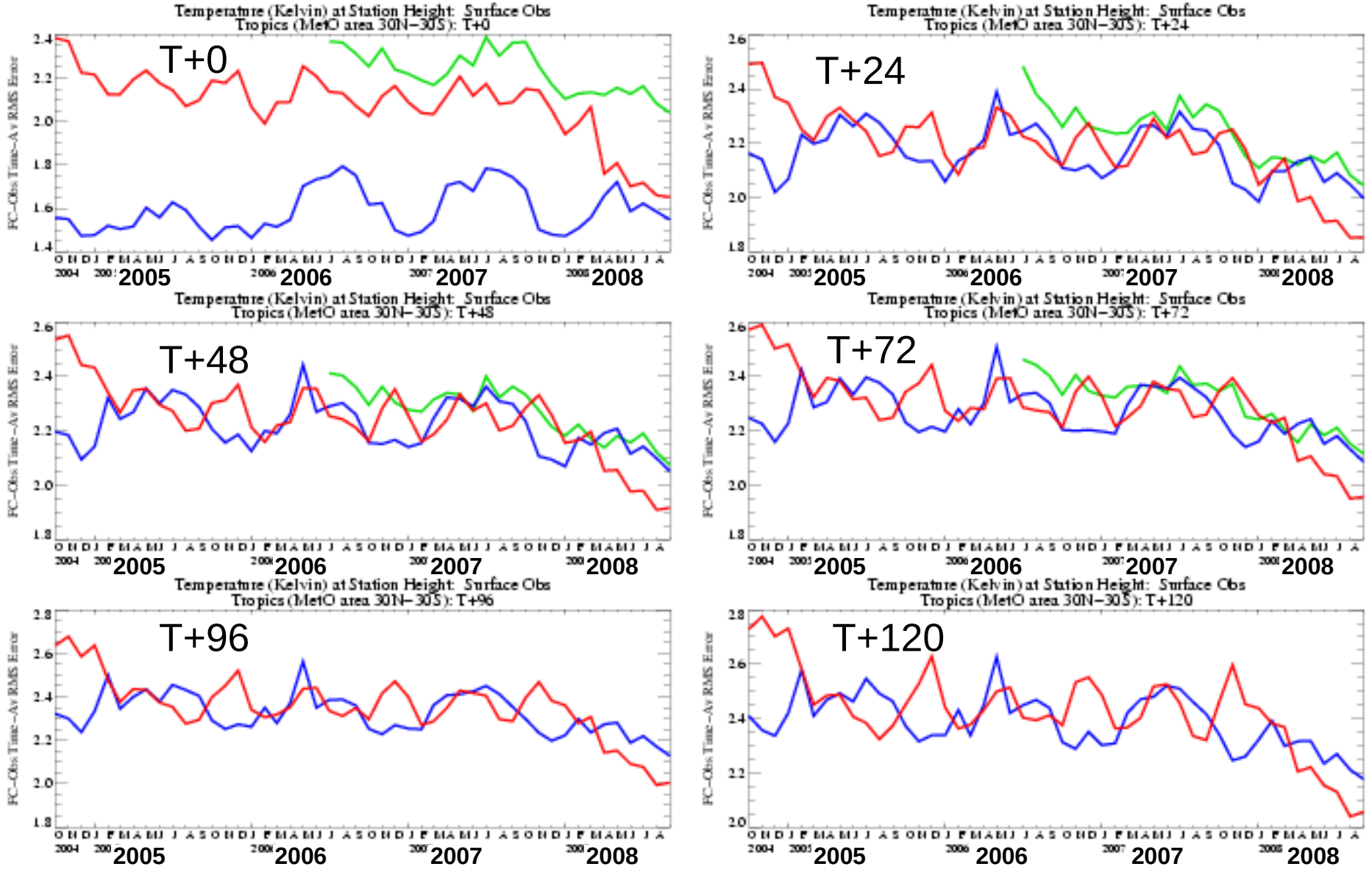
UKMO ECMWF NCEP



Screen Temperature RMS errors – comparison between Met centres

Tropics 30S to 30N

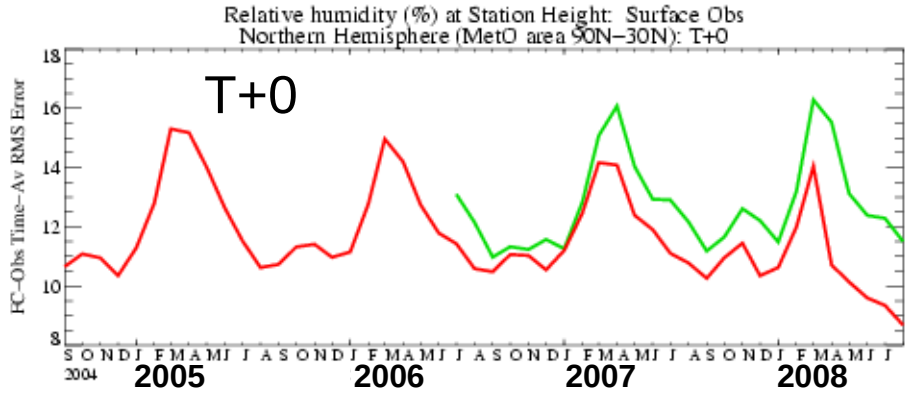
UKMO ECMWF NCEP

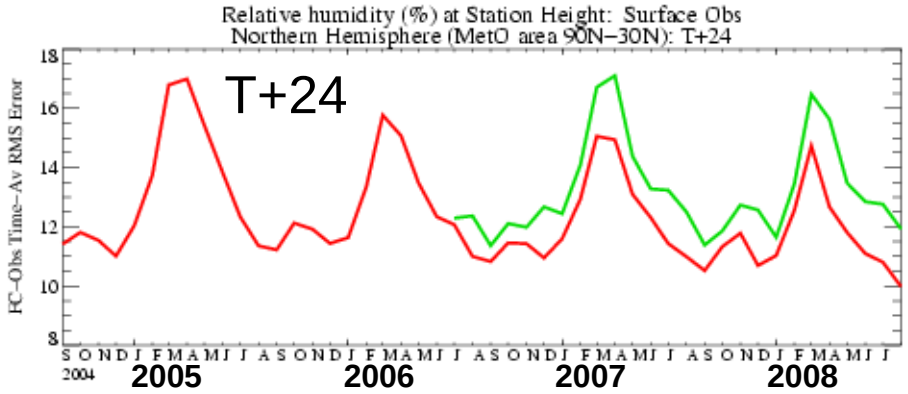


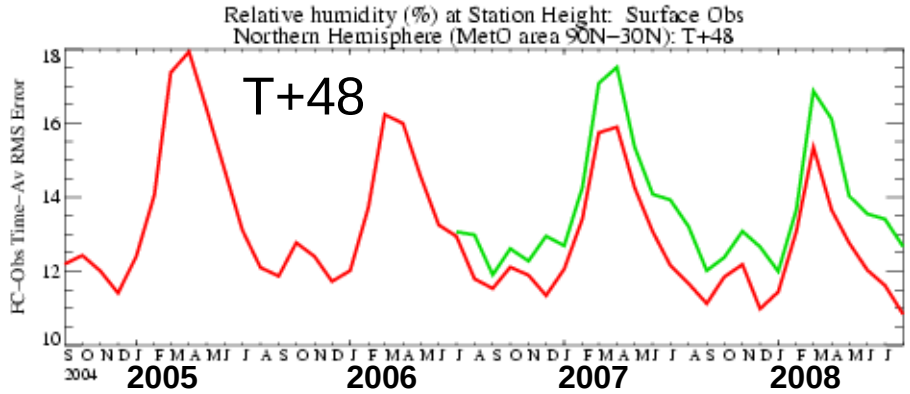
Screen RH RMS errors – comparison between Met centres

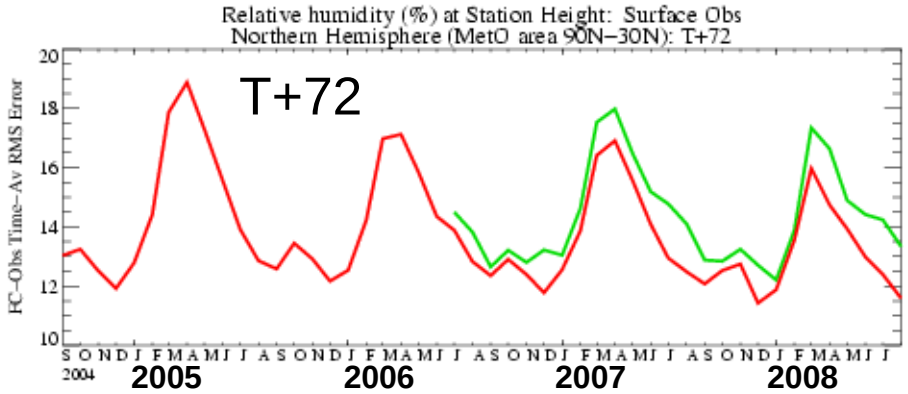
Northern Hemisphere 30N to 90N

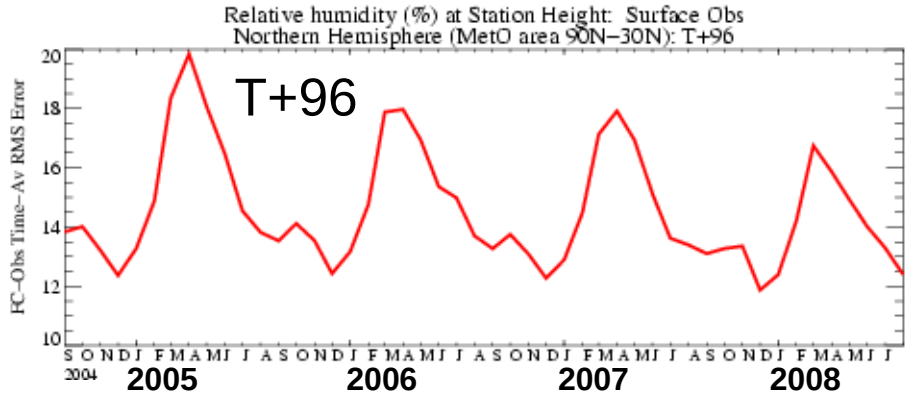
Cases: — UKMO — ECMWF — NCEP

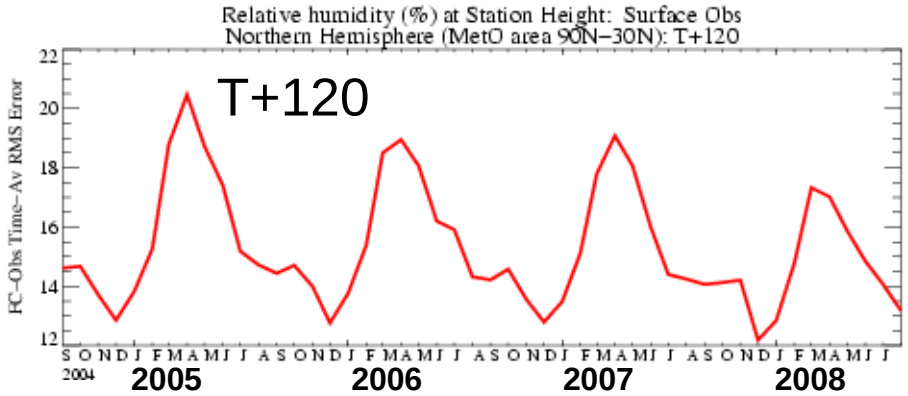












Screen RH RMS errors – comparison between Met centres

Tropics 30S to 30N

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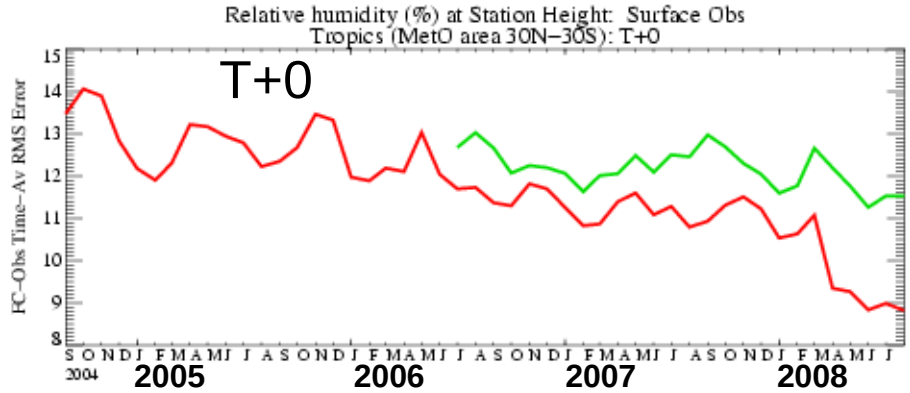
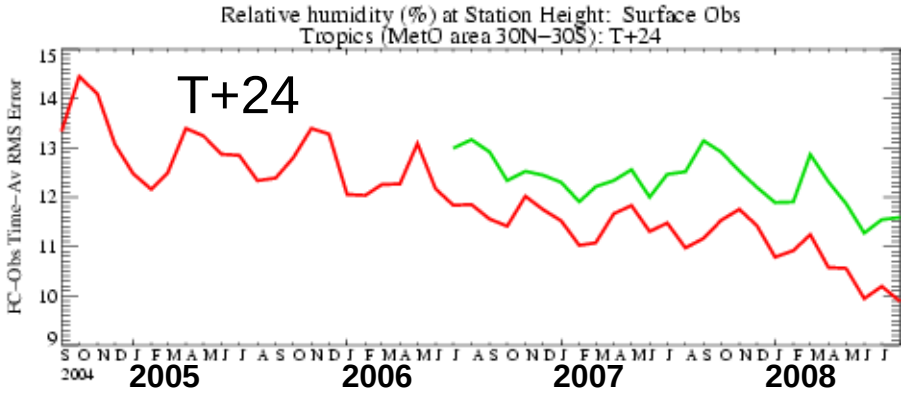
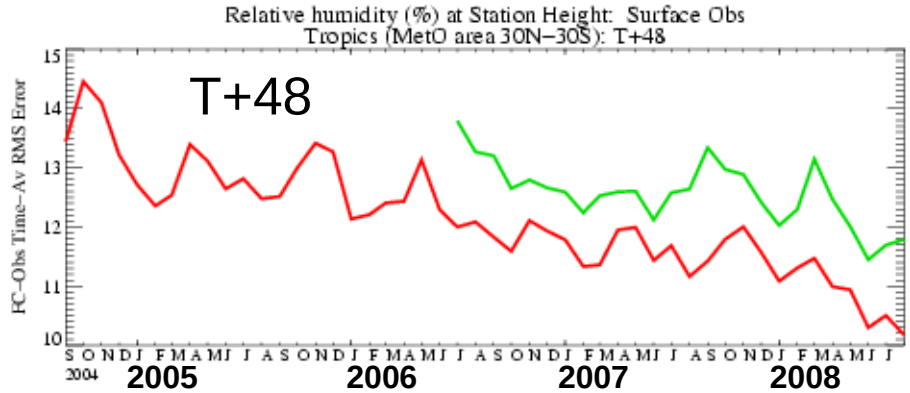
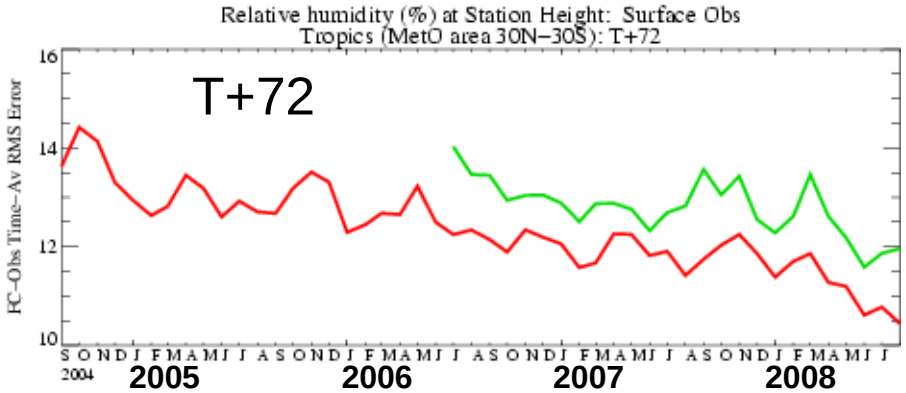
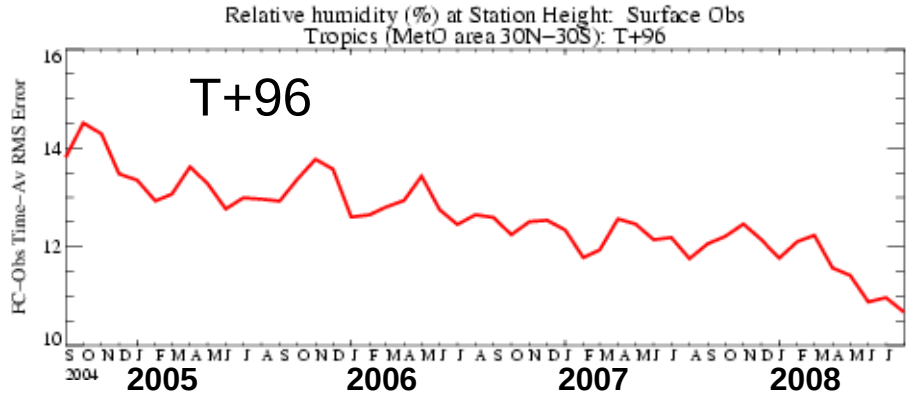
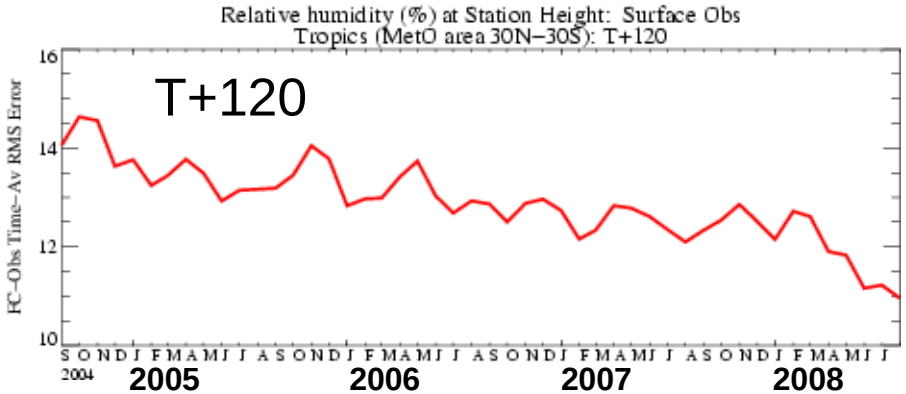












Timeline of land surface changes

- **August 2005. Global Unified Model (UM) starts using a soil moisture nudging scheme.**
  - previously reset weekly to a scaled climatology (Willmott, Rowe and Mintz, 1985).
- June 2006. Allow UM soil moisture to fall below the wilting point, consistent with the bare soil evaporation scheme. Fix bug causing soil moisture nudging scheme to switch off in certain situations).
- September 2006. Global UM uses the IGBP vegetation dataset.
- November 2006. Inclusion of a bare soil evaporation term in the UM soil moisture nudging scheme – previously the UM soil moisture freewheels below the wilting point.
- **May 2007. Package of changes to reduce the UM summer warm bias.**
  - Convective cloud decay (PS13), biogenic aerosols, MODIS surface albedos, new runoff scheme for snow-melt and seasonally varying leaf area index (LAI).
- November 2007. Switch off UM soil moisture nudging under snow.
- **April 2008. New soil properties and SYNOP assimilation.**
- November 2008. New snow analysis scheme.

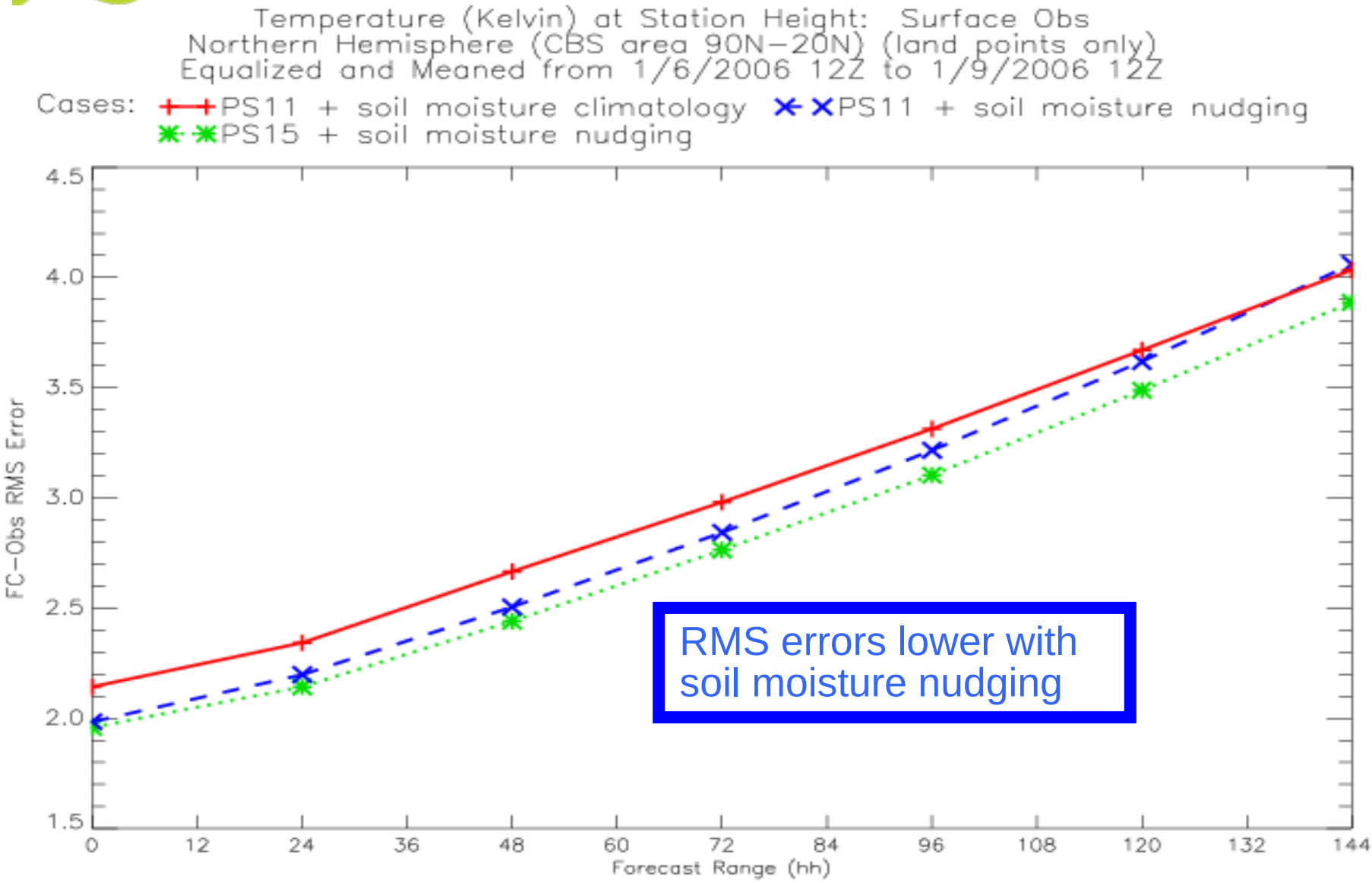
Soil Moisture Nudging Scheme

- A Physically Based Soil Moisture Nudging Scheme.
  - http://www.met-office.gov.uk/research/hadleycentre/pubs/HCTN/HCTN_35.pdf
- Uses screen level (2m) observations of temperature and humidity (T/q).
- Assumes that under certain conditions, model screen T/q errors at T+6 hours are due to model errors in soil moisture.
  - Richardson number < 0 (unstable conditions).
  - Negative correlation between model T/q errors.
    - screen level too cold and moist:
      - → model soil too moist – nudging scheme dries model soil.
    - screen level too warm and dry:
      - → model soil too dry – nudging scheme moistens model soil.
    - No soil moisture nudging if:
      - model screen level too warm and moist.
      - model screen level too cold and dry.

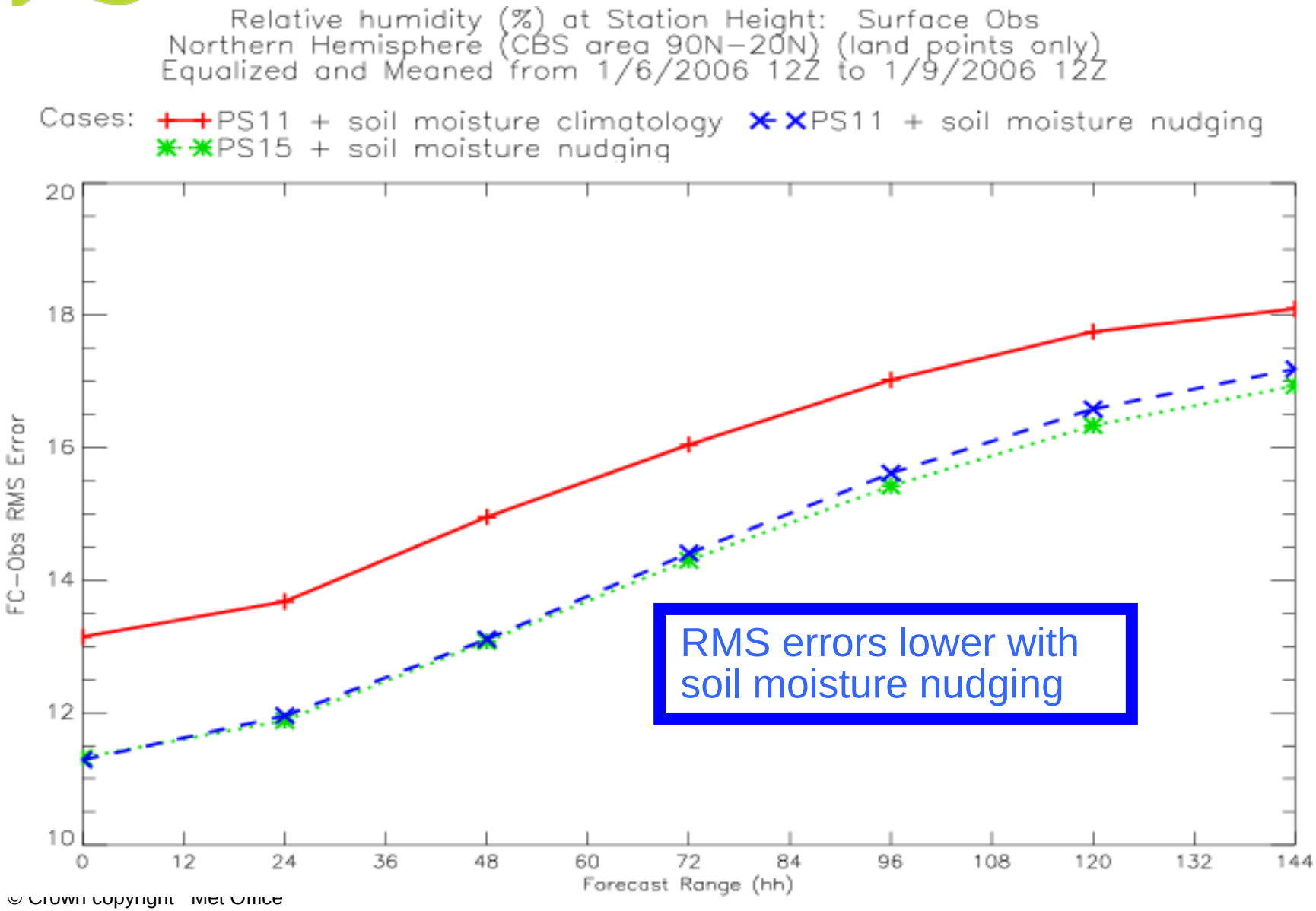
UM summer warm bias

- The UM soil moisture nudging scheme:
  - reduced the RMS errors in screen humidity and temperature.
  - BUT made the UM too warm and dry during the summer.
- The scaled Willmott, Rowe and Mintz (1985) soil moisture climatology is too moist and hid other problems in the UM.
- The May 2007 package of changes substantially reduced the UM summer warm/dry bias.
  - Convective cloud decay – the radiation scheme sees more convective cloud with less intermittency.
  - Biogenic aerosol climatology.
  - New MODIS surface albedos.
  - New runoff scheme for dealing with snow-melt over frozen soils. New scheme results in less surface runoff and moister soils.
  - Seasonally varying leaf area index (LAI).

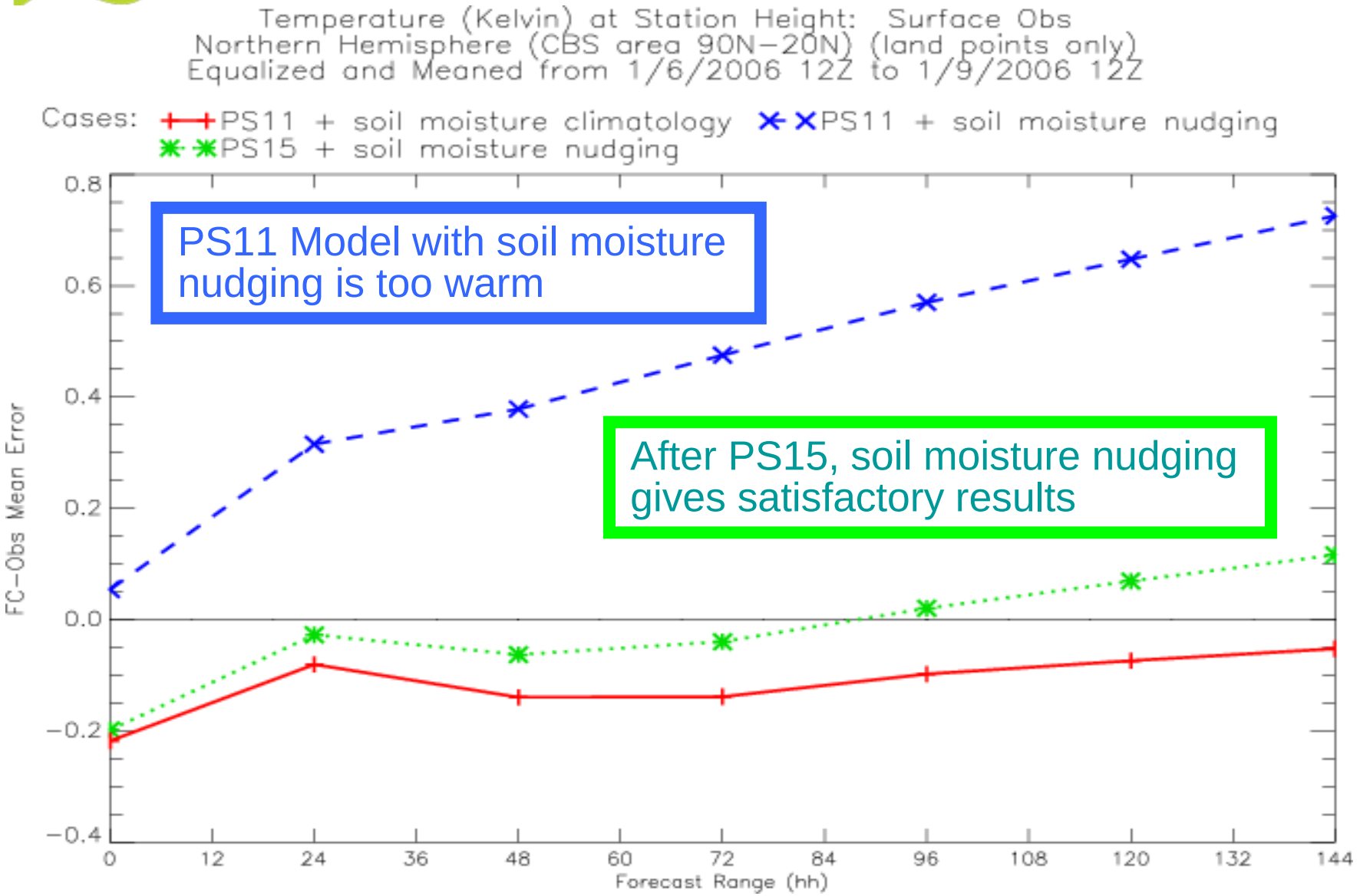
RMS errors in screen T JJA 2006



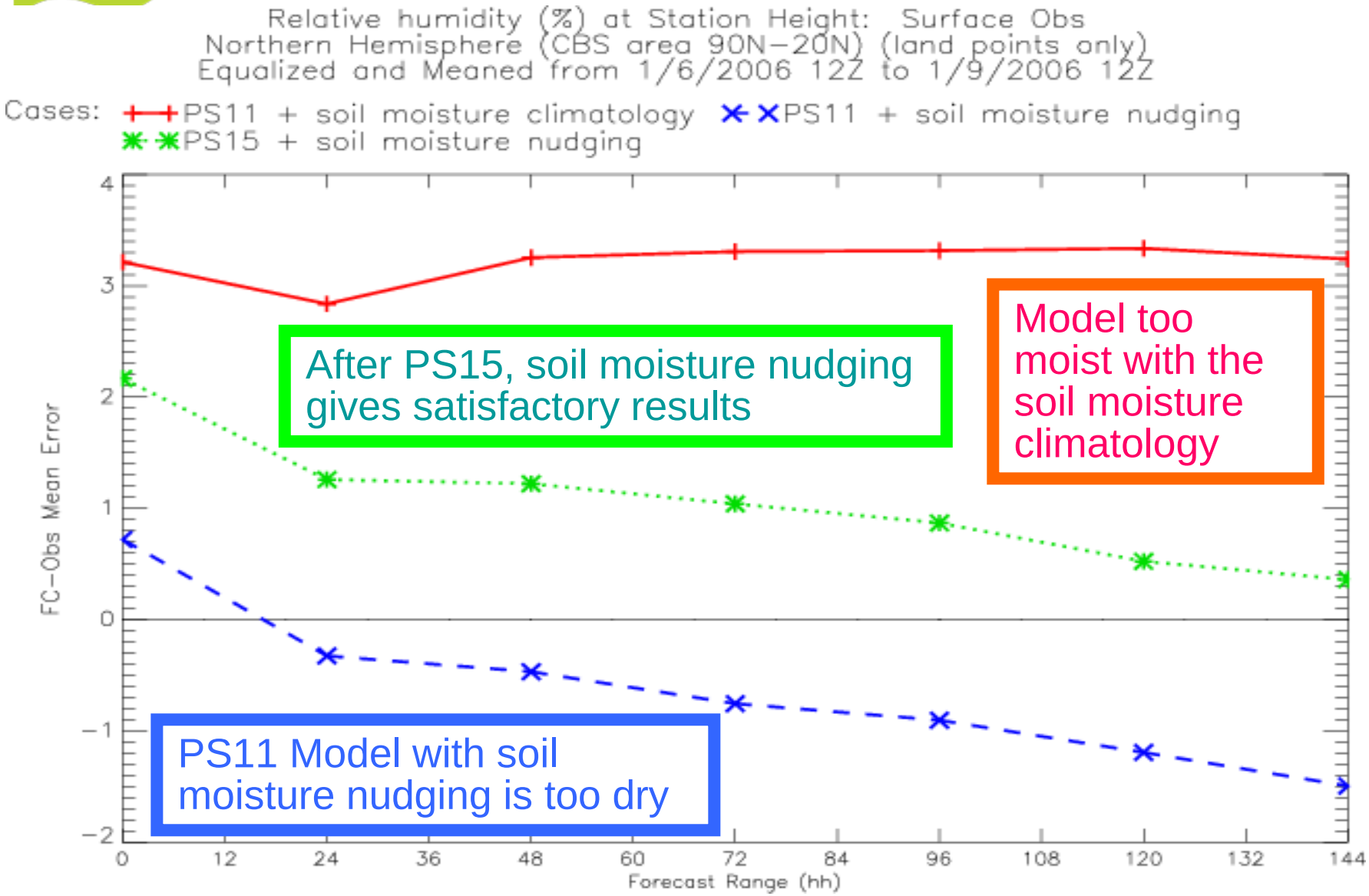
RMS errors in screen RH JJA 2006



Bias in screen T JJA 2006



Bias in screen RH JJA 2006



April 2008:
New soil properties and SYNOP assimilation.

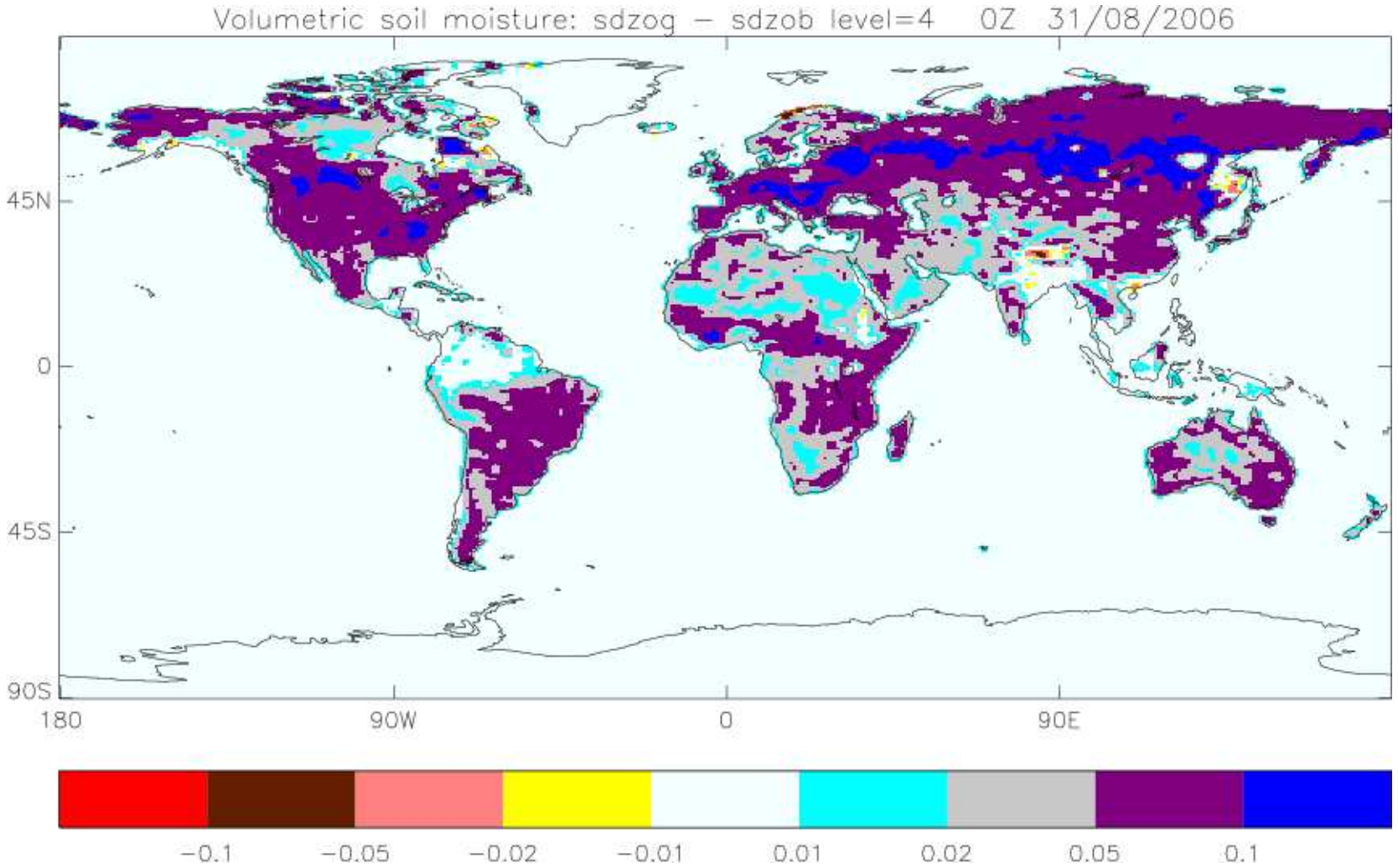
- New soil hydraulic properties – wilting and critical points.
  - A longstanding error in the UM code to calculate soil hydraulic properties is corrected.
- New soil thermal conductivity.
  - New scheme based on Johansen (1975).
- Assimilation of SYNOP T/RH/Wind data in global model.
  - already used in regional models.
- Soil temperature nudging in global model
  - already in regional models

Errors in UM soil hydraulic properties

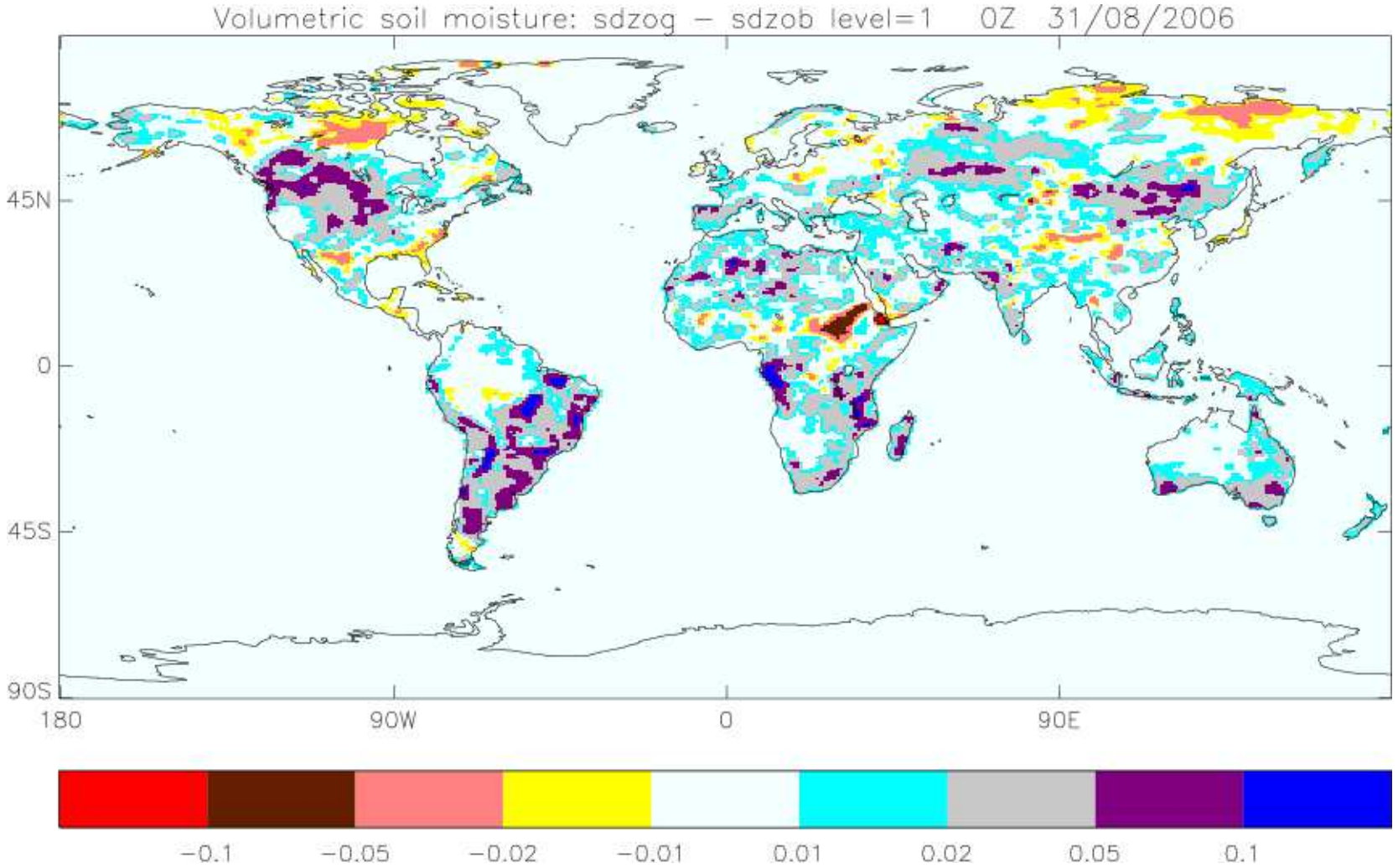
- April 2007 – error discovered in the code to calculate UM soil hydraulic properties.
  - Correction results in significantly higher wilting and critical points.
    - The new wilting and critical points are in much closer agreement with those used at ECMWF, other Met centres and observations.
  - Correction also results in lower values for the saturated hydraulic conductivity.
- Trials with NWP models, climate models and offline land surface models all show that the new soil properties result in much higher soil moisture content.

	Wilting Point (m^3/m^3)	Critical Point (m^3/m^3)	Saturated Hydraulic Conductivity (mm/s)
UKMO medium soil - Old	0.14	**0.24**	0.0047
UKMO medium soil - New	0.19	**0.33**	0.0028
ECMWF - 2007	0.17	0.32	0.0056
ECMWF medium soil - 2008	0.15	0.35	0.0012

New hydraulic soil properties – old hydraulic soil properties
Difference in volumetric soil moisture for the **bottom** soil level



New hydraulic soil properties – old hydraulic soil properties
Difference in volumetric soil moisture for the **top** soil level



New soil hydraulic parameters – Impact on Forecasts

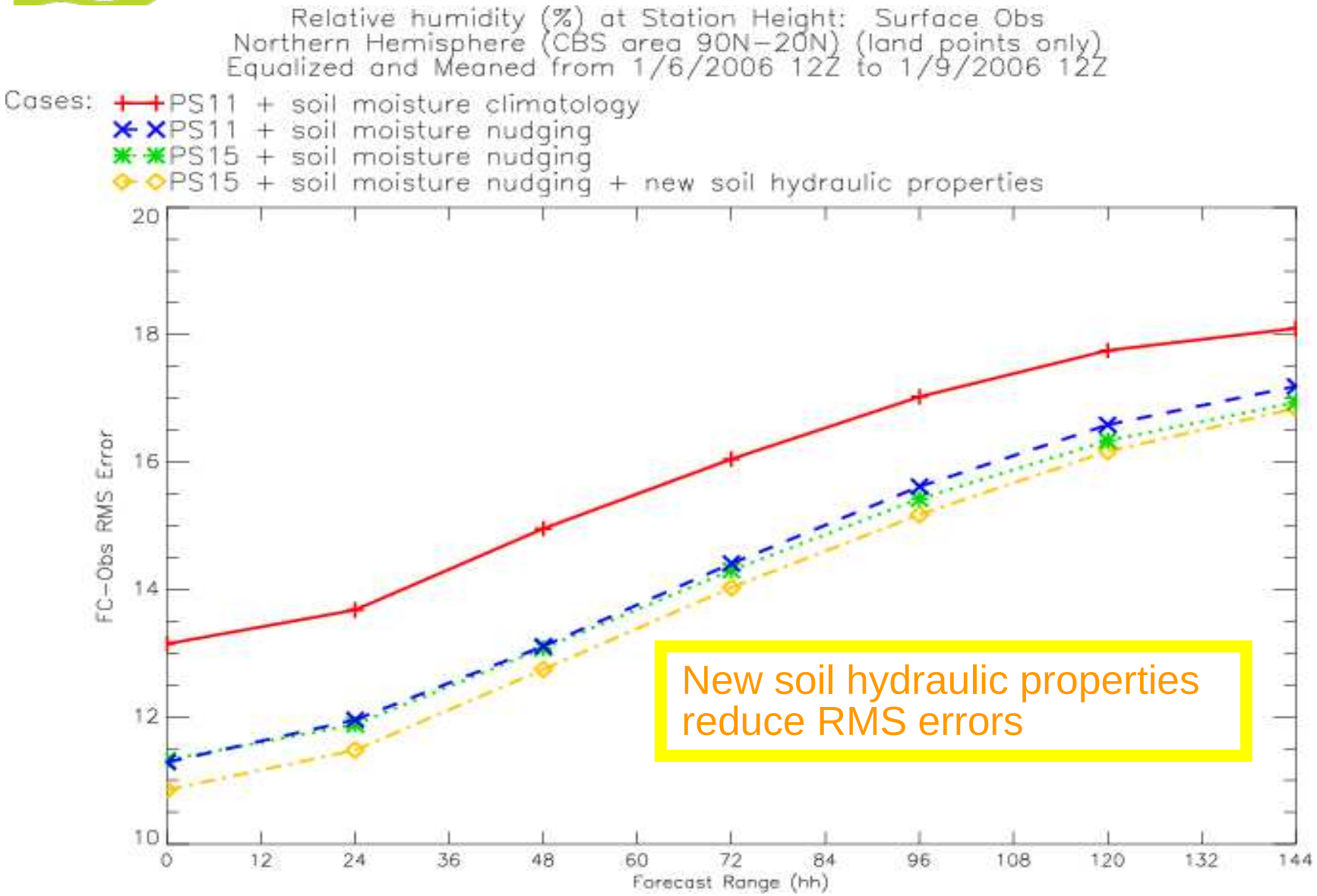
- **reduced RMS errors** in screen temperature and humidity.
- New soil hydraulic properties increase the soil moisture but now the soil binds more tightly to the soil water (increased wilting and critical points) so ….

  → soil moisture availability actually decreases

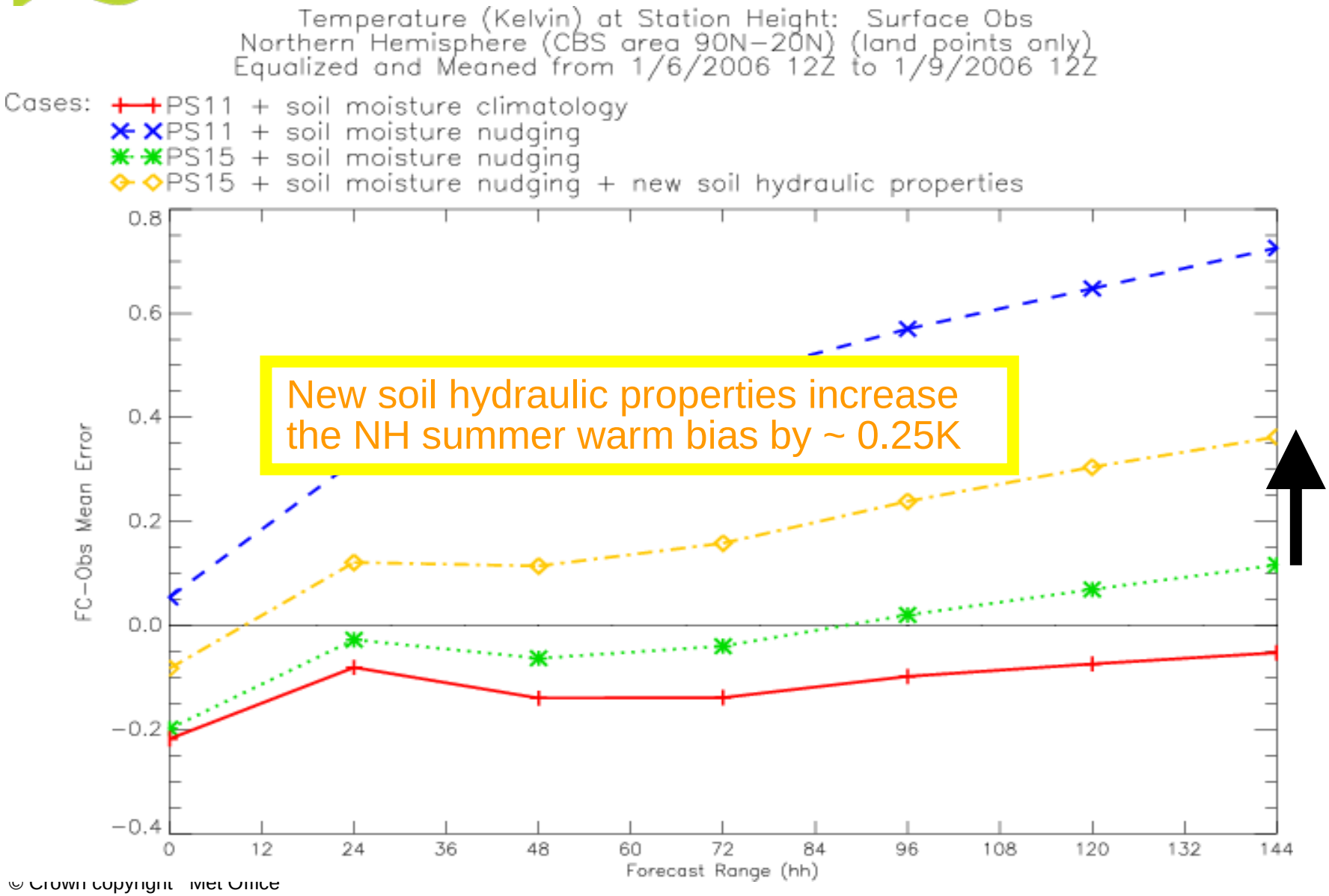
  → evaporation decreases

  → **NH summer warm bias actually becomes worse**!
- Climate runs and offline land surface model runs show the same warming/reduced evaporation.

RMS errors in screen RH JJA 2006

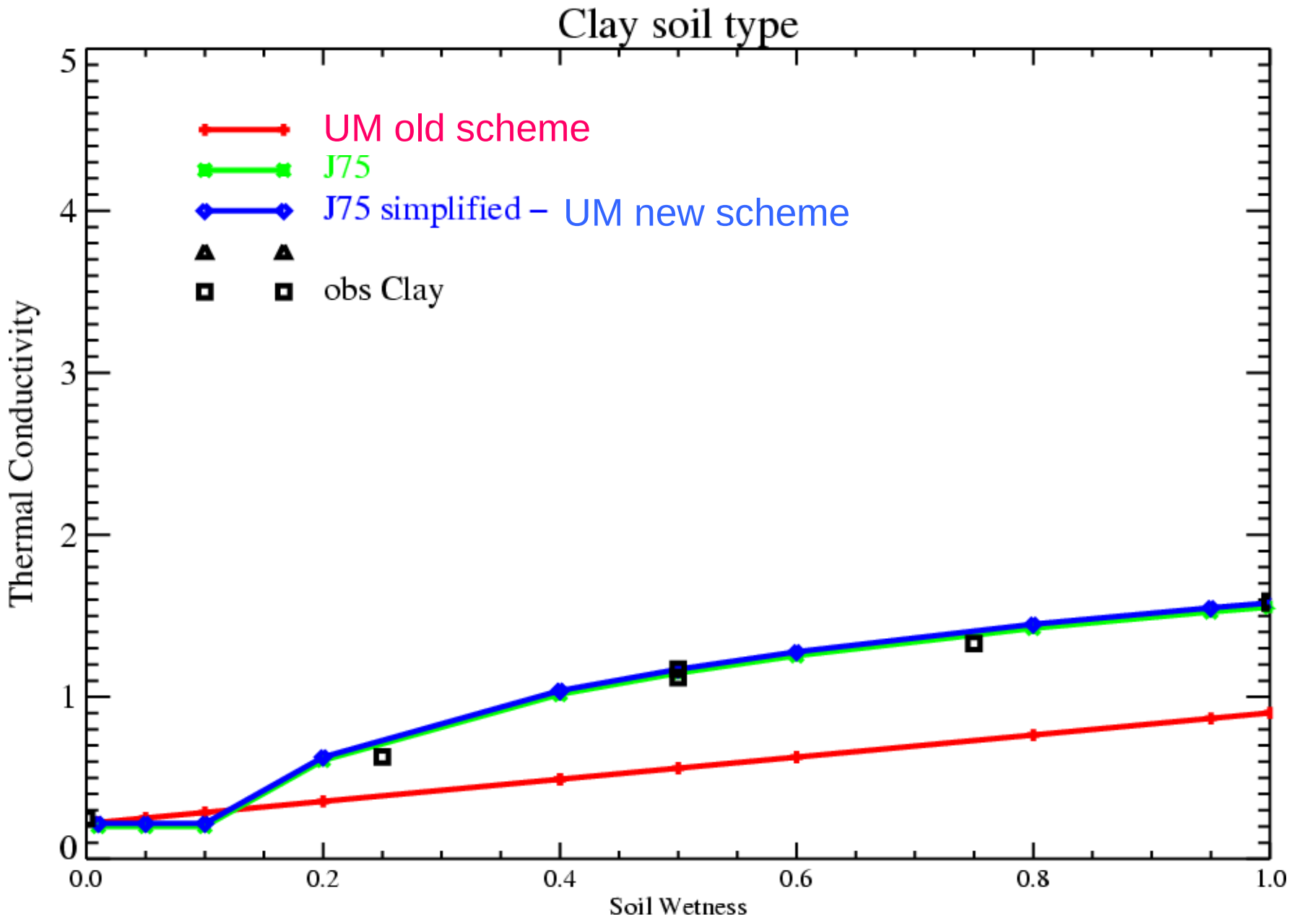


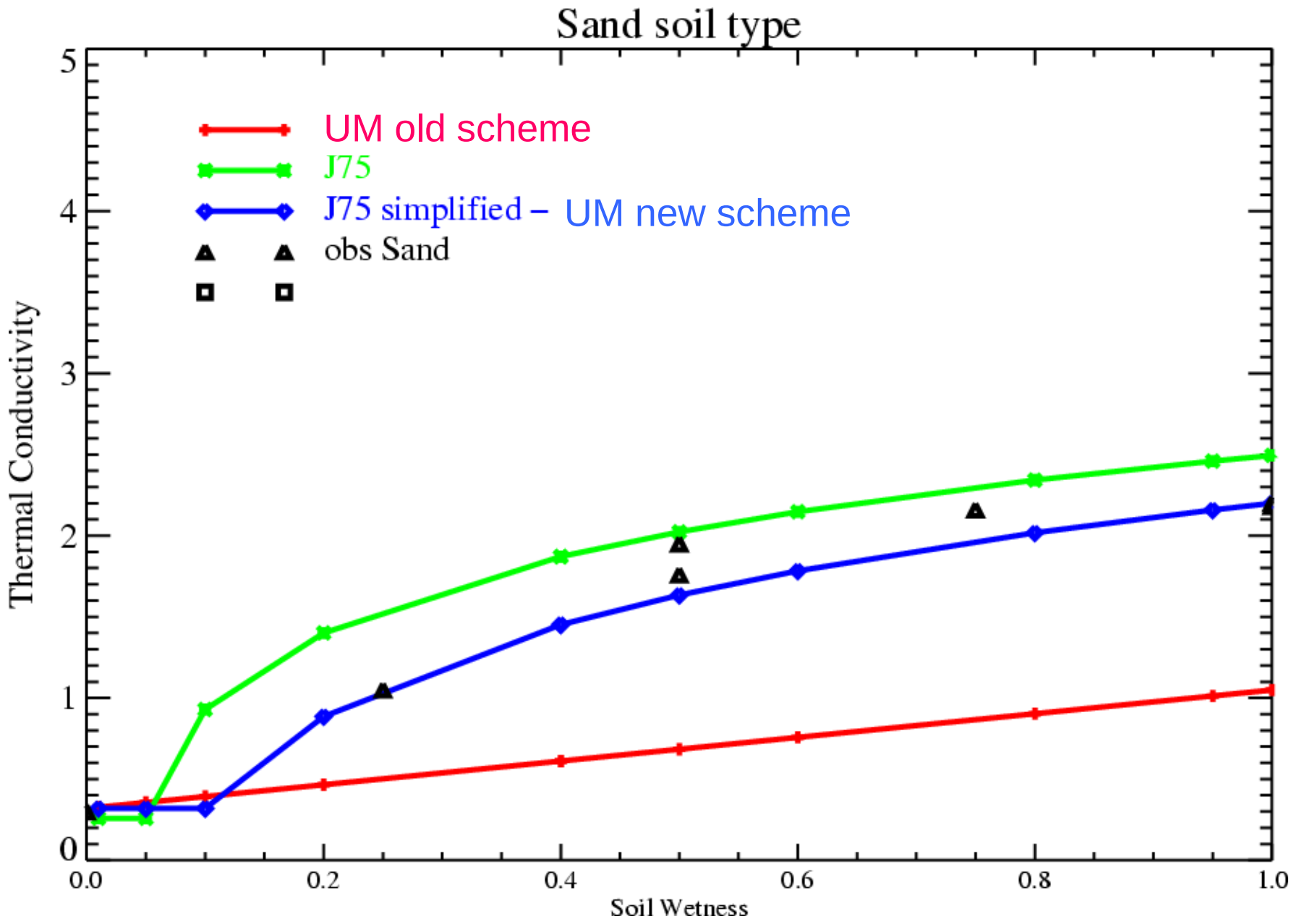
Bias in screen T JJA 2006



Soil Thermal Conductivity

- Anne Verhoef and Pier Luigi Vidale at Reading University suggested that the UM soil thermal conductivity was too low and that parameterisations based on Johansen (1975) were more accurate.
- Increasing the thermal conductivity will increase the heat flow between the ground and the atmosphere.
- Heat flow will still be from warmer to colder
  - Summer day – cooling of the boundary layer
  - Summer night – warming of the boundary layer
  - Winter – warming of the boundary layer
- The Johansen parameterisation requires knowledge of soil sand/silt/clay fractions so we have implemented a simplified version of the Johansen parameterisation which doesn't require this information.

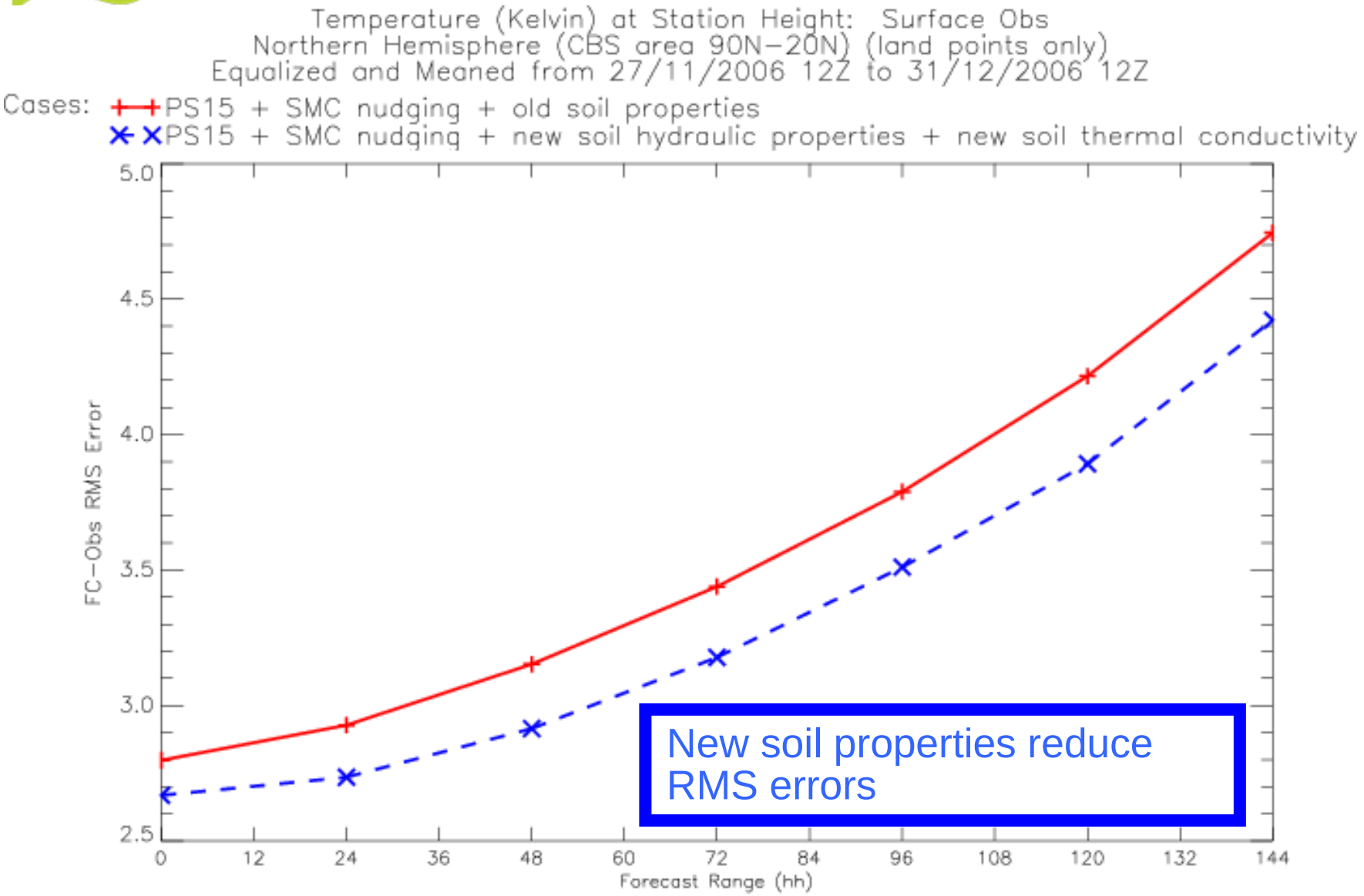




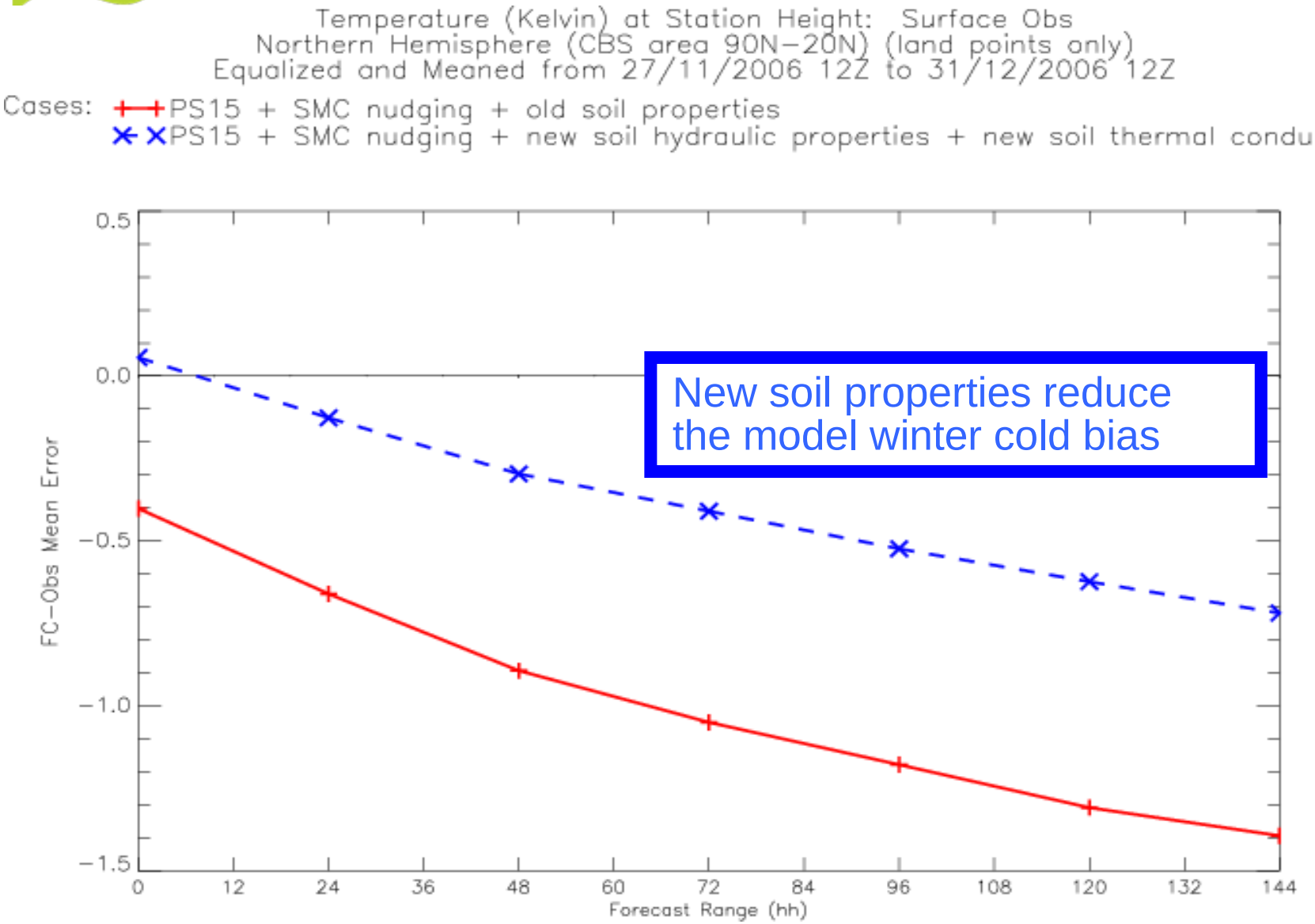
Impact of new soil thermal conductivity parameterisation

- Climate runs, Global, NAE and 4km trials show significant reduction in biases and RMS errors in screen temperature.
- Impact greatest in winter (reduces cold bias by ~ 0.6 K). RMS errors in screen temperature reduced by ~ 10%.
- In summer, warm bias reduced by ~ 0.2 Kelvin. RMS errors in screen temperature also reduced.

RMS errors in screen T for Dec 2006

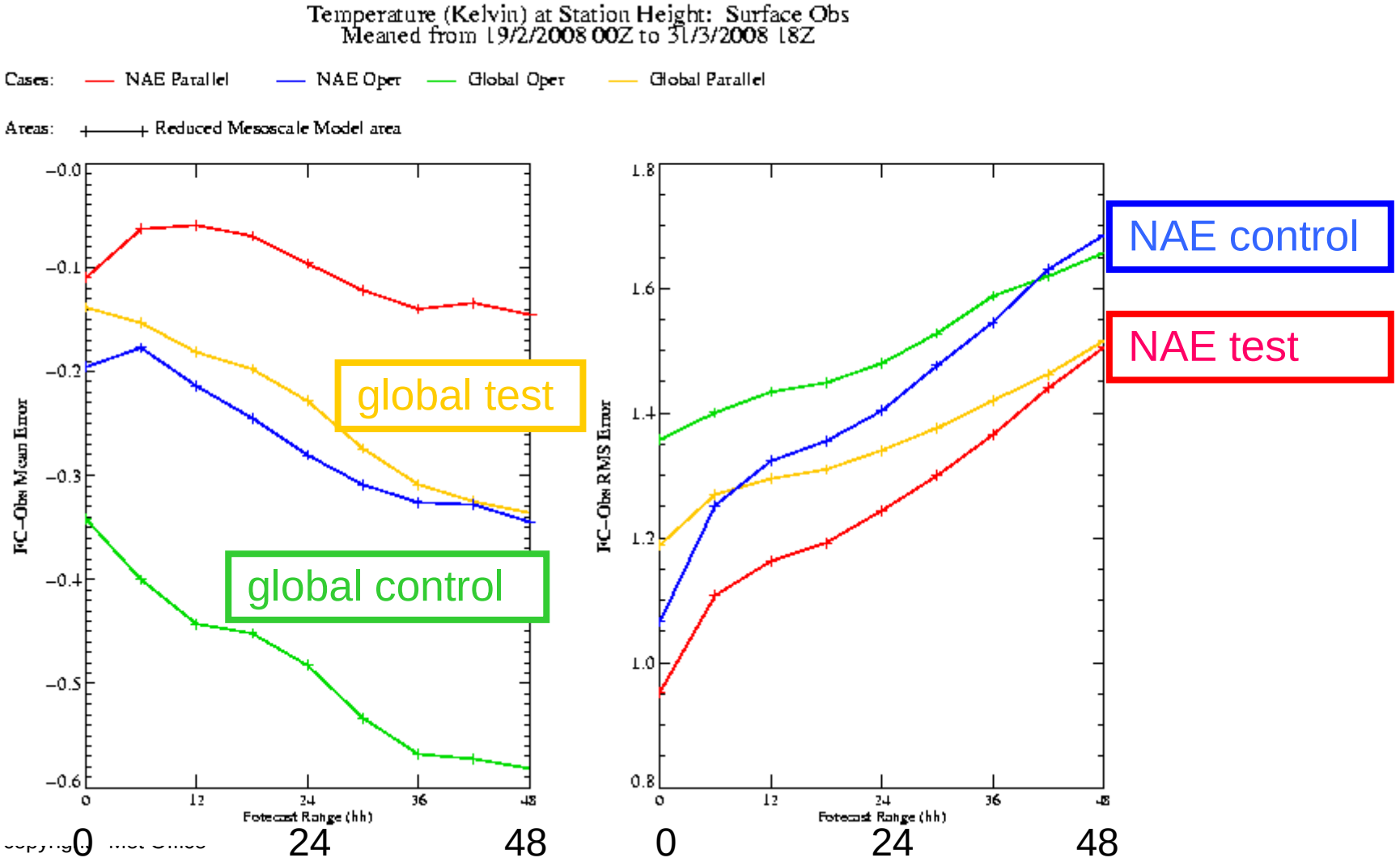


Bias in screen T for Dec 2006

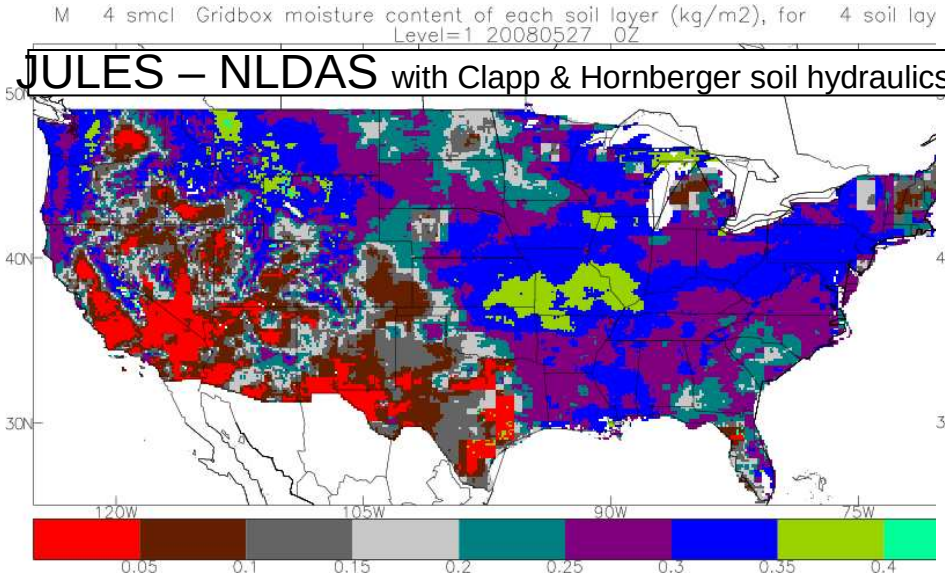


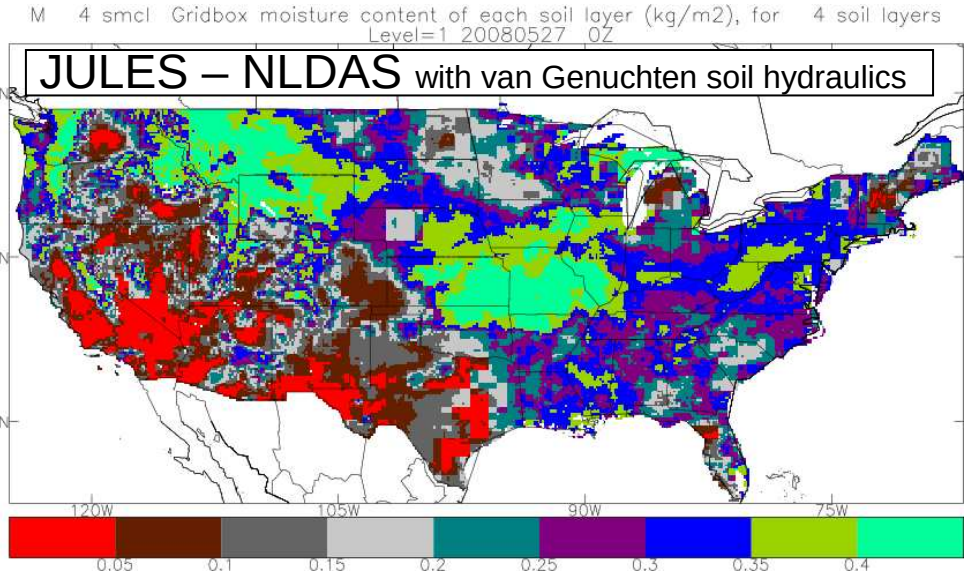
screen T impact in global/NAE models Mar 2008

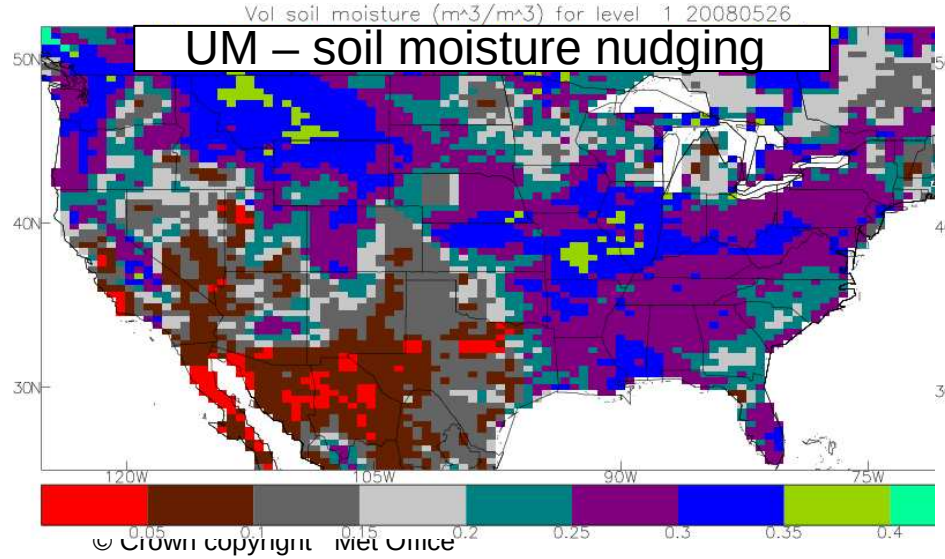
mean rms

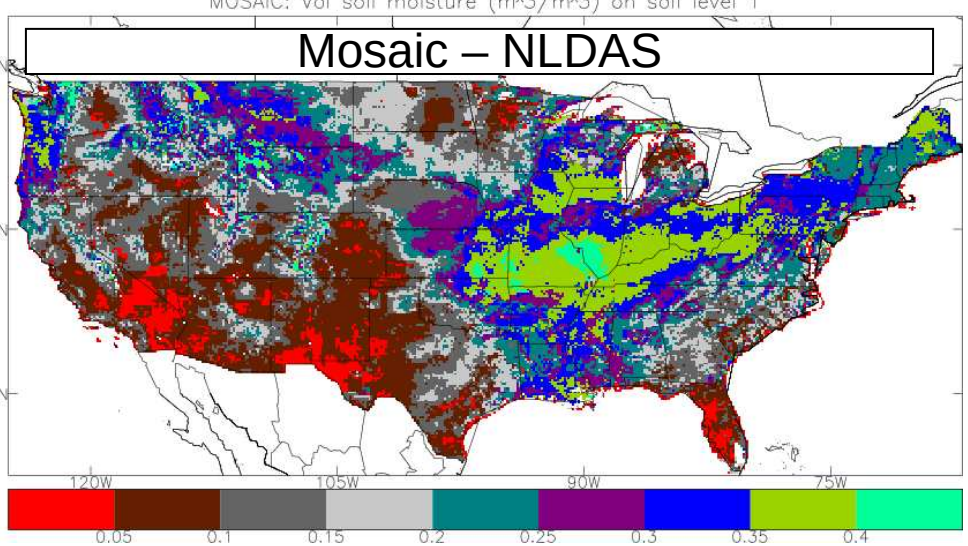


UM land surface model (**JULES**) run offline with
North American Land Data Assimilation System (**NLDAS**) driving data
http://www.jchmr.org/jules/
http://ldas.gsfc.nasa.gov/drought/

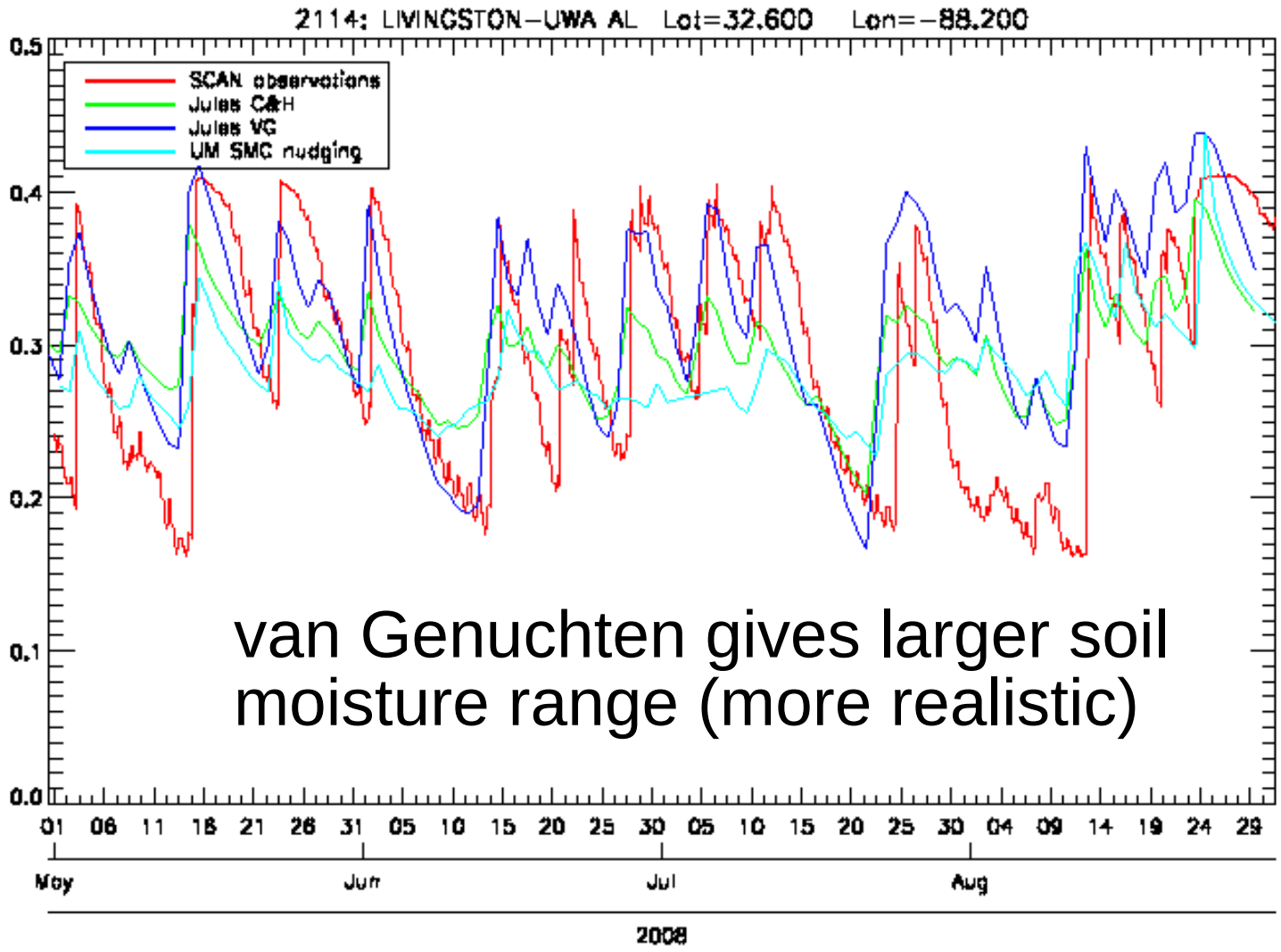








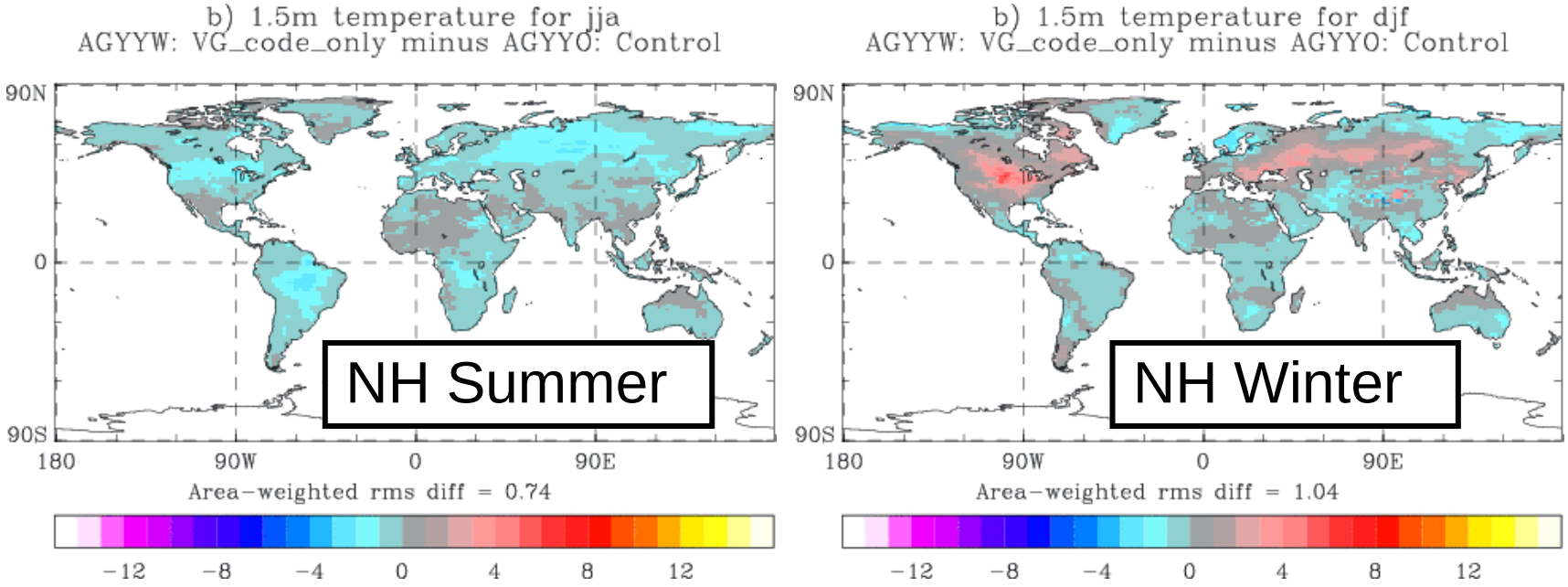
Soil moisture time series (Alabama)



van Genuchten gives larger soil moisture range (more realistic)

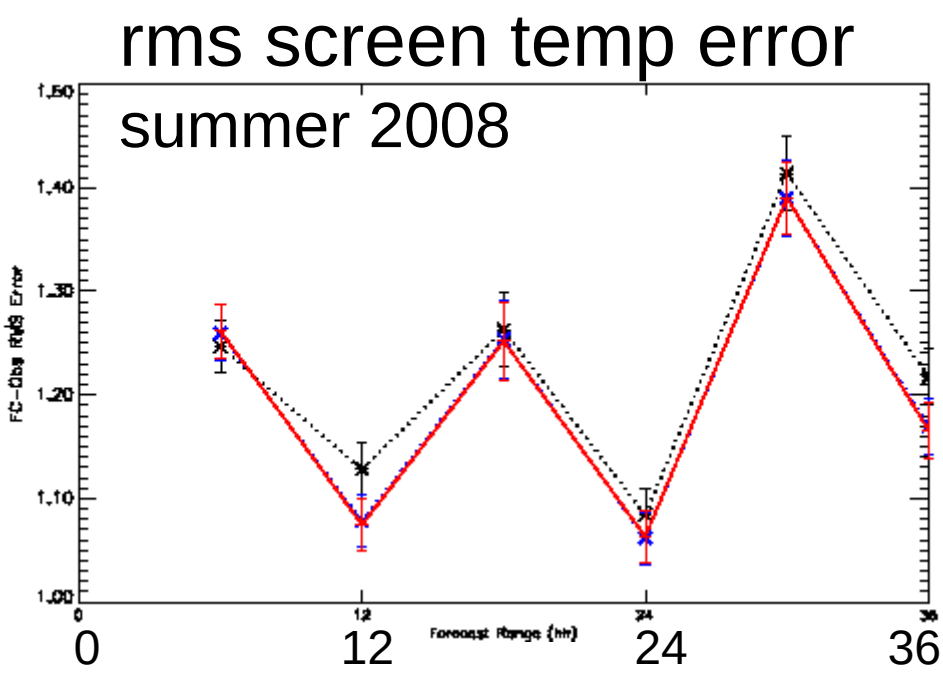
Impact of van Genuchten soil hydraulics

- Results from a 5 year climate run shows a significant cooling of the screen level during the NH summer and a general NH warming during the NH winter.
- The model soil moisture (not shown) is higher in both the NH summer and NH winter.
- Results courtesy of Dan Copsey.



Soil moisture nudging vs Offline soil moisture analysis

- **Soil Moisture nudging**
  - Global UM soil moisture analysis interpolated onto UK 4km grid
- **Offline soil moisture analysis** – MOSES-PDM (Smith et al, 2006)
  - Offline 4km land surface model driven by observation based data
    - Precipitation – radar data calibrated with rain gauges
    - Downward surface radiation - satellite derived
- Screen temperature RMS errors almost identical between soil moisture nudging and MOSES-PDM.
  - climatology up to 5% worse



Results courtesy of Keir Bovis.

New UM snow analysis scheme

Samantha Pullen, Gabriel Rooney, James Cameron, Clive Jones

- Currently the Unified Model (UM) snow amounts evolve freely.
  - Early snowmelt, too much variability, not enough snow.
- The UM snow analysis scheme uses the NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS) snow cover data.
  - GEO, LEO (GOES, Meteosat, MTSAT, AVHRR, MODIS, SSM/I, AMSU).
  - Derived products (e.g. USAF Snow and Ice Analysis Product).
  - In situ data.
  - Analyst.
- The UM snow analysis scheme analyses snow amount (kg/m^2).
- There is clear evidence that the snow analysis improves the analysed snow field, in terms of presence/non-presence of snow.
- Some evidence of improvements in screen level T and RH, especially where snow is predominantly removed.
- Little of the information is retained, especially where snow is added.
- A time lag of up to 36 hours in the IMS data is potentially problematic.
- The UM snow analysis scheme will become operational during November 2008.

Future Work

- Derive global soil hydraulic properties using the recently released Harmonized World Soil Database.
- Use van Genuchten soil hydraulics instead of Clapp and Hornberger.
- Assimilate ASCAT derived surface soil wetness.
  - ASCAT (advanced scatterometer) is carried on board the meteorological operational (MetOp) satellite.
- Drive our land surface model (JULES) with near real-time observation based forcing data.

Questions?