



Met Office

Land surface developments at the Met Office

Imtiaz Dharssi

(presented by Bruce Macpherson)



Contents

This presentation covers the following areas

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- Soil Moisture Nudging
- Summer warm bias
- New soil hydraulic properties
- New soil thermal conductivity
- Future work

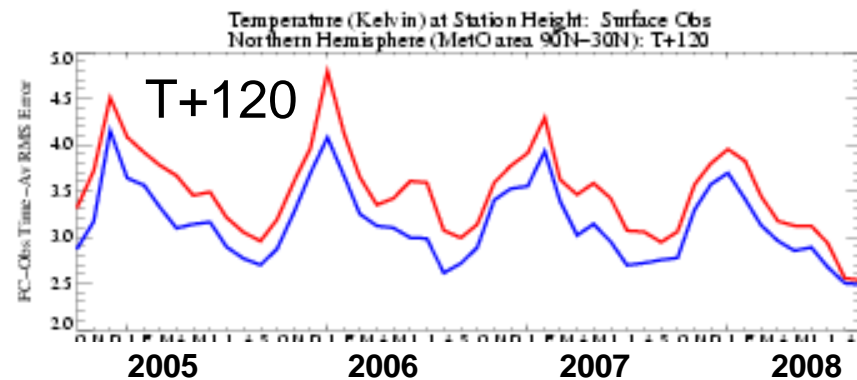
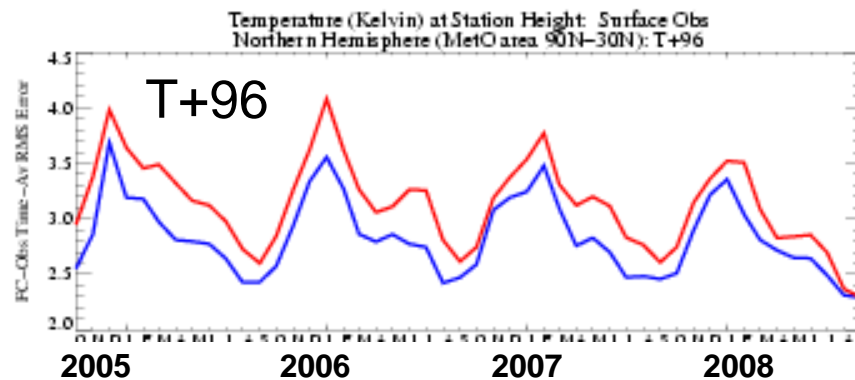
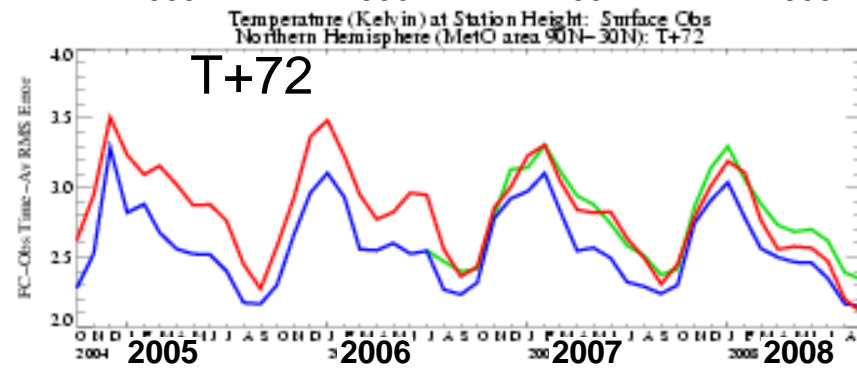
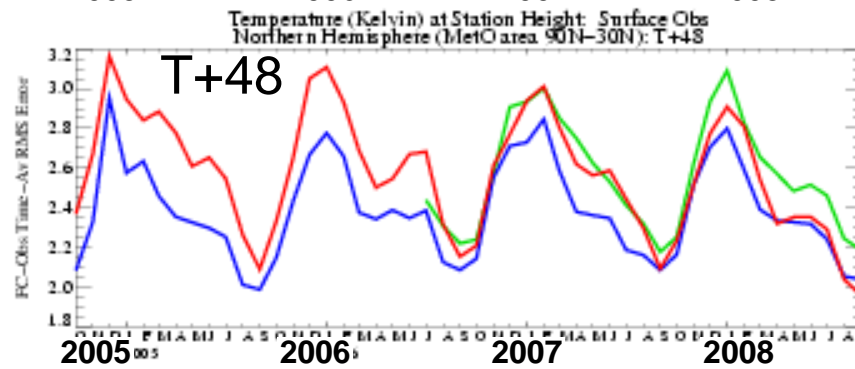
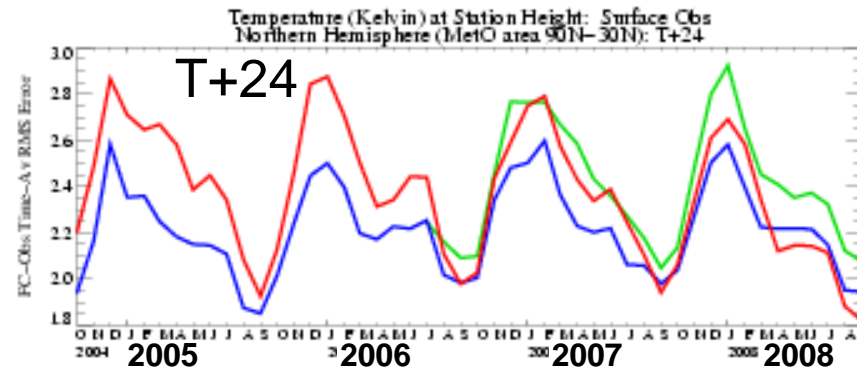
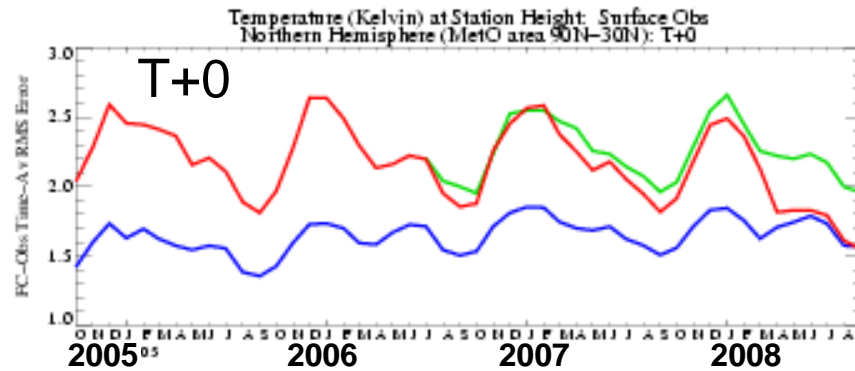
Screen Temperature RMS errors – comparison between Met centres Northern Hemisphere 30N to 90N



UKMO

ECMWF

NCEP



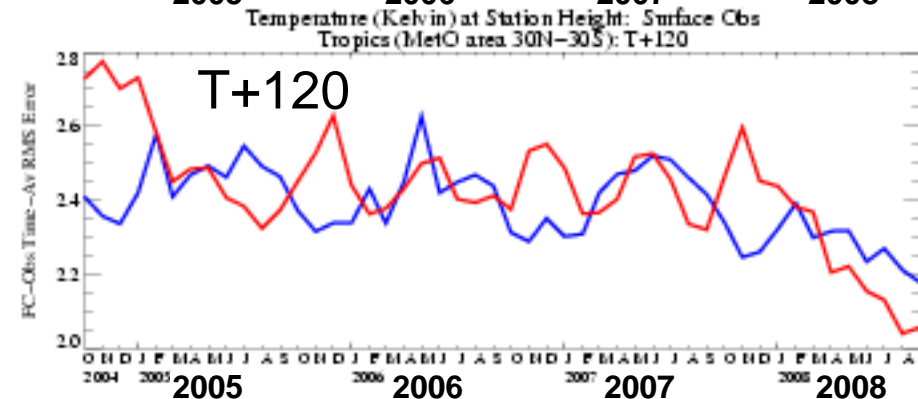
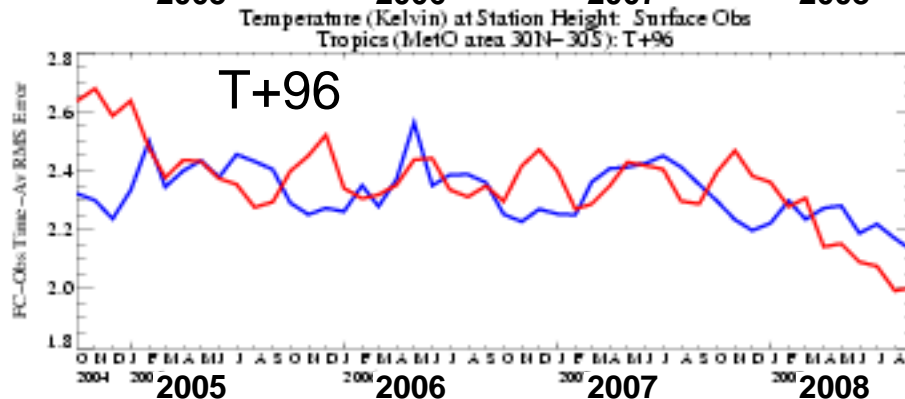
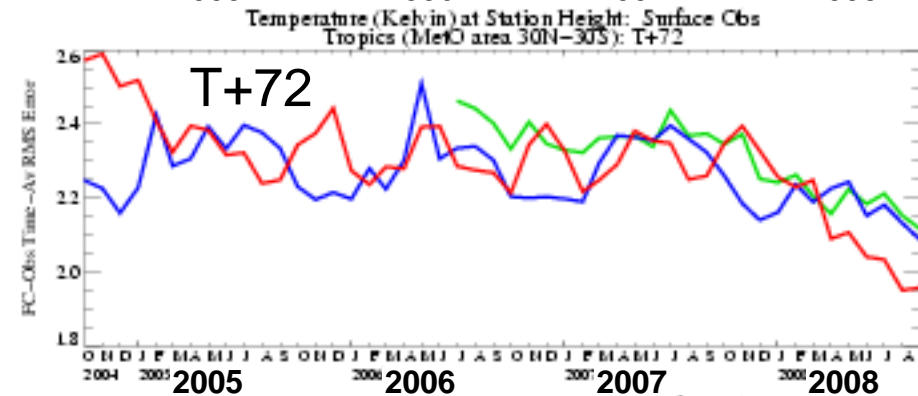
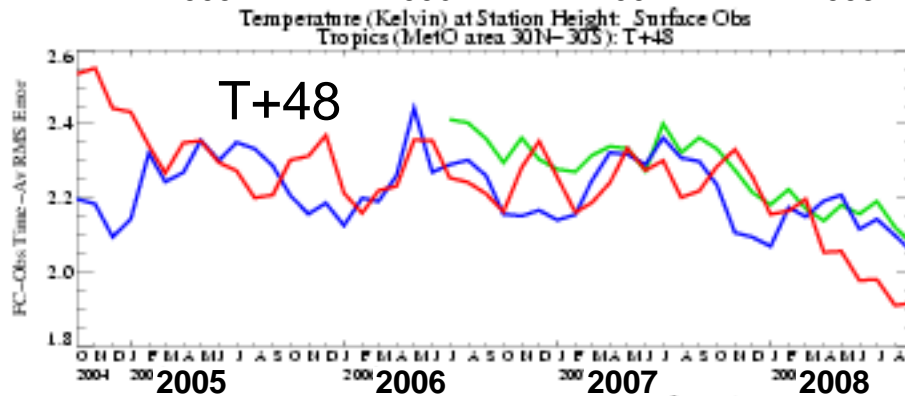
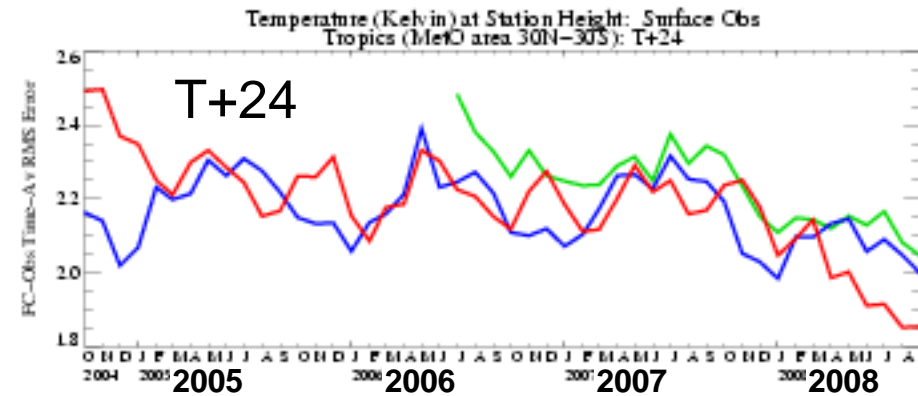
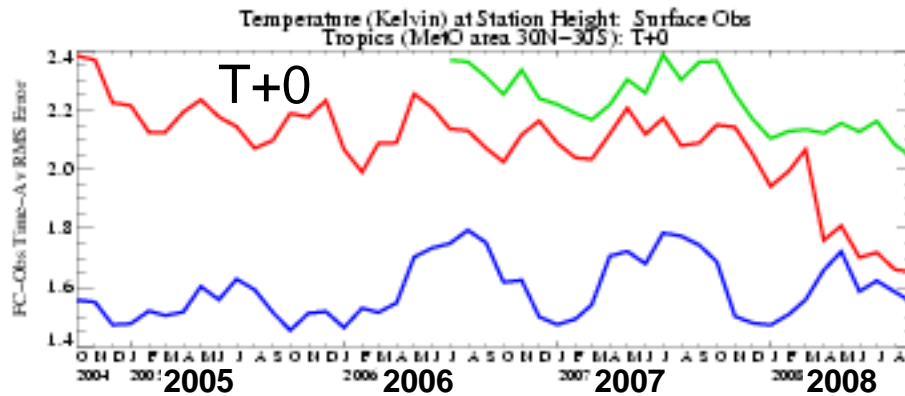
Screen Temperature RMS errors – comparison between Met centres Tropics 30S to 30N



UKMO

ECMWF

NCEP

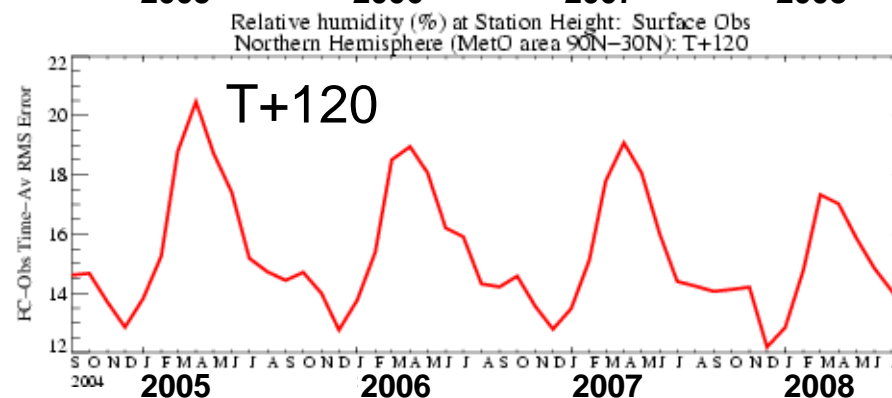
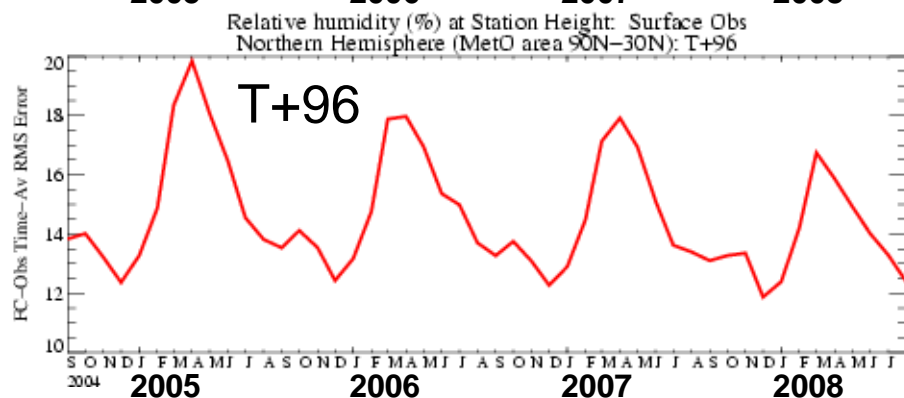
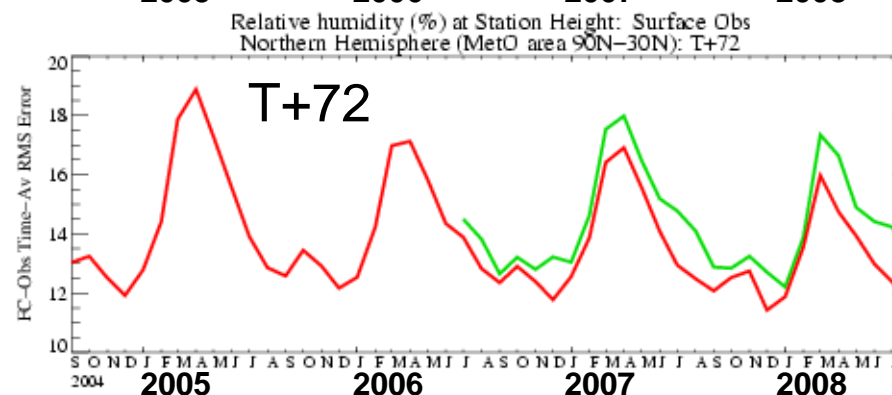
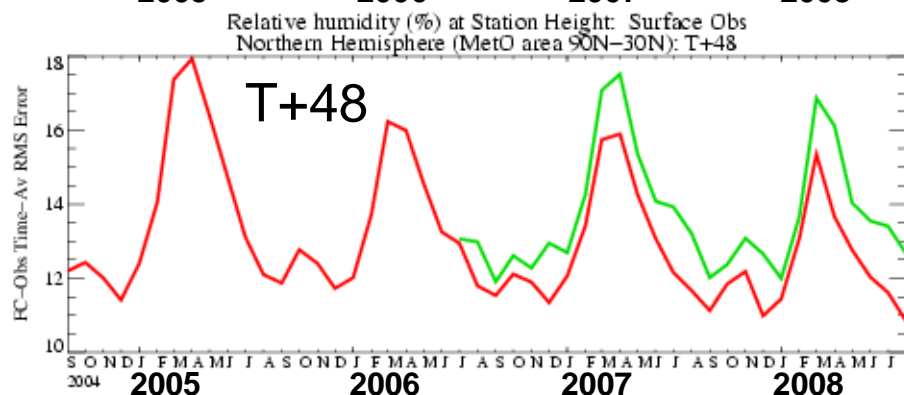
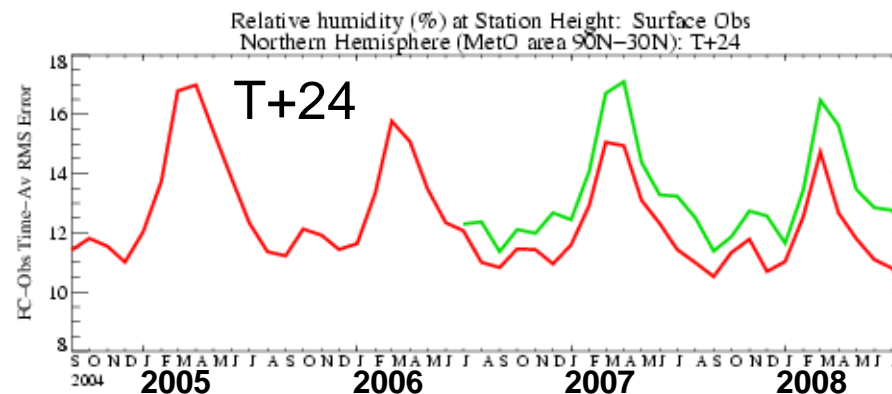
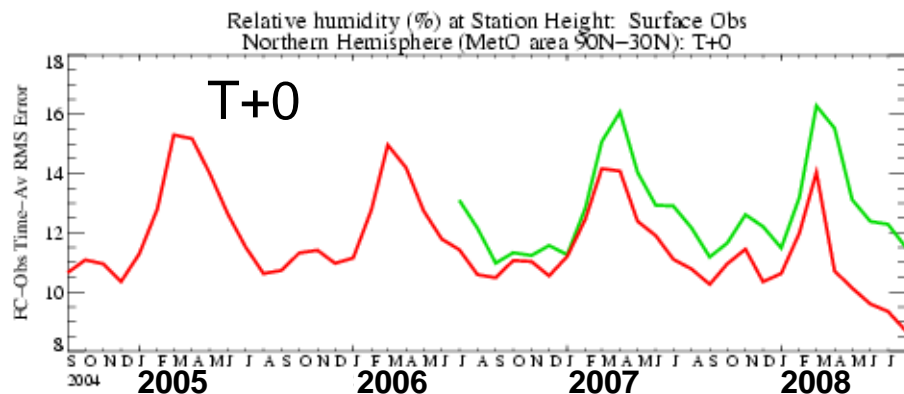


Screen RH RMS errors – comparison between Met centres Northern Hemisphere 30N to 90N

Cases:  **UKMO**

 **ECMWF**

 **NCEP**

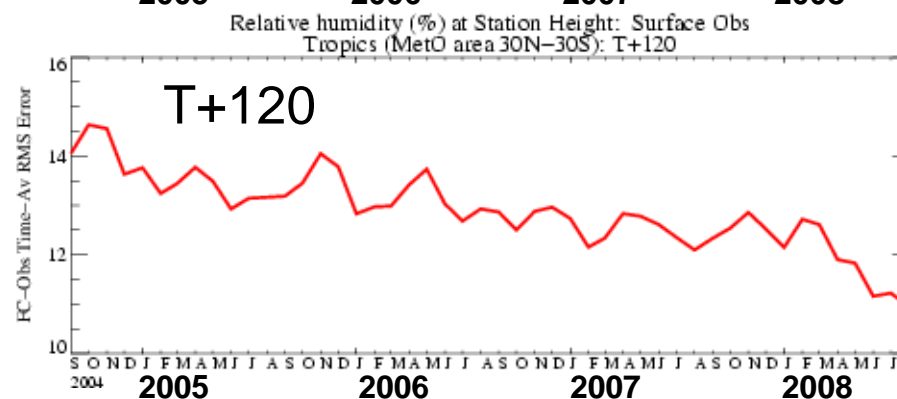
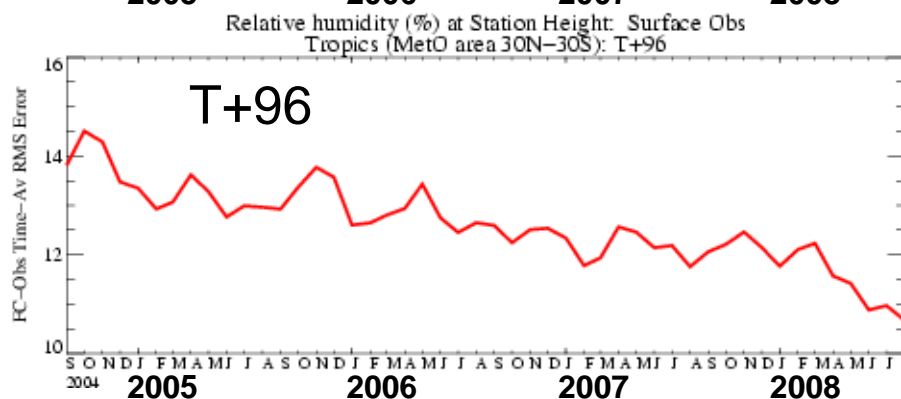
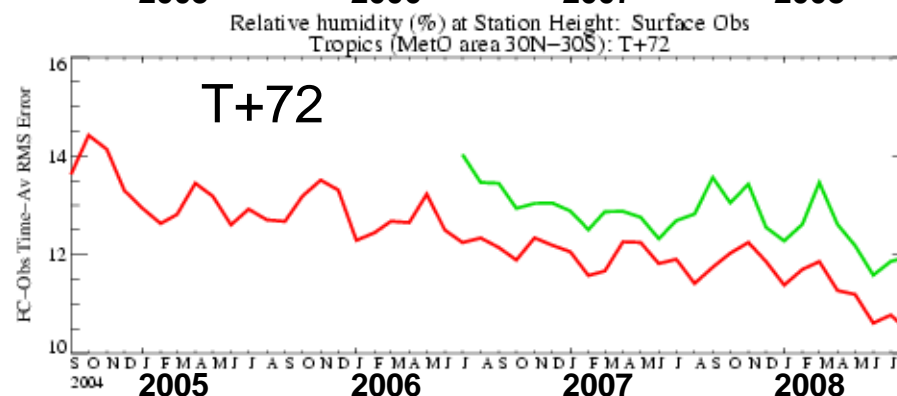
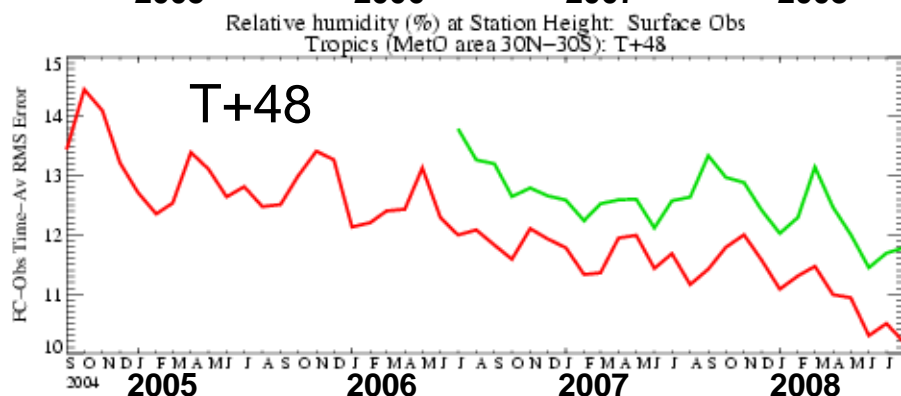
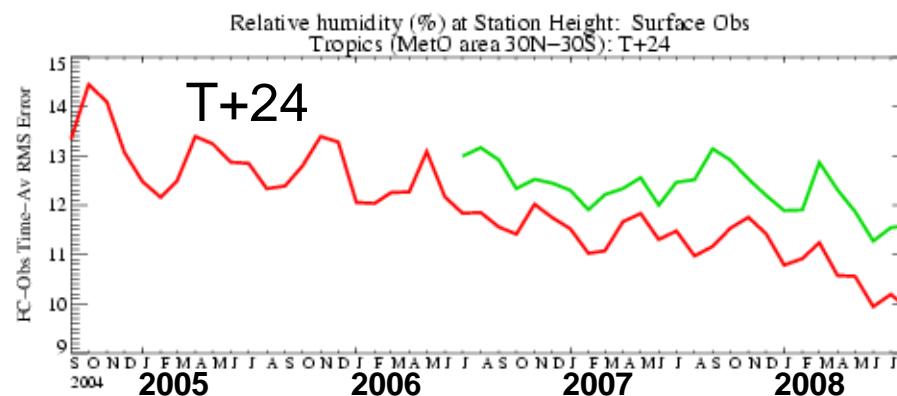
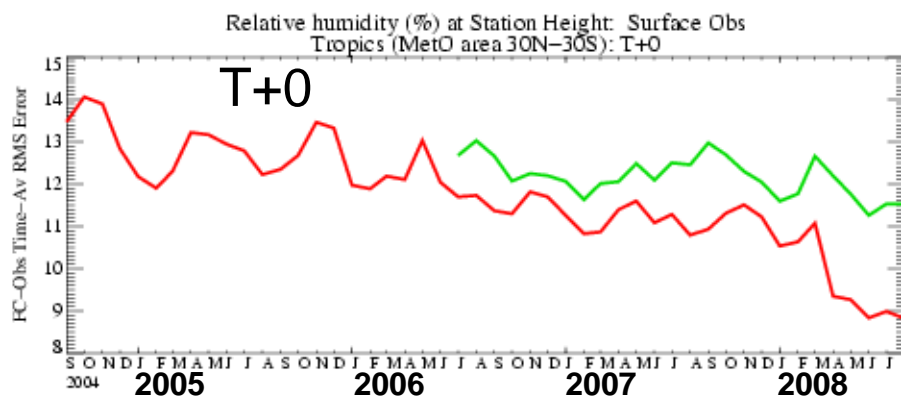


Screen RH RMS errors – comparison between Met centres Tropics 30S to 30N

Cases:  **UKMO**

 **ECMWF**

 **NCEP**





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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.



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UM summer warm bias

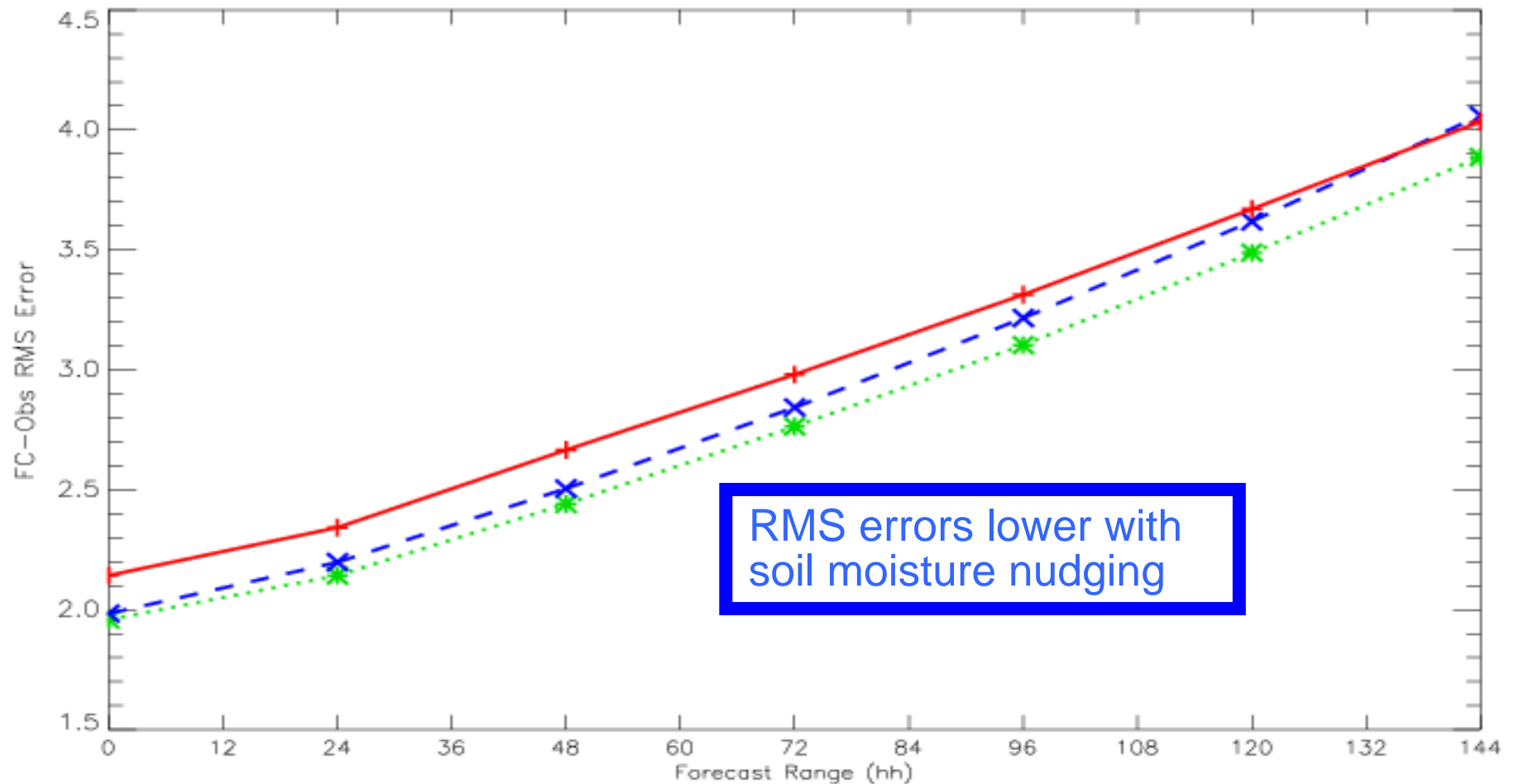
- The UM soil moisture nudging scheme:
 - reduced the RMS errors in screen humidity and temperature.
 - BUT made the UM too warm and dry during the summer.
- The scaled Willmott, Rowe and Mintz (1985) soil moisture climatology is too moist and hid other problems in the UM.
- The May 2007 package of changes 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

Temperature (Kelvin) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N–20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

Cases: + PS11 + soil moisture climatology x PS11 + soil moisture nudging
* PS15 + soil moisture nudging



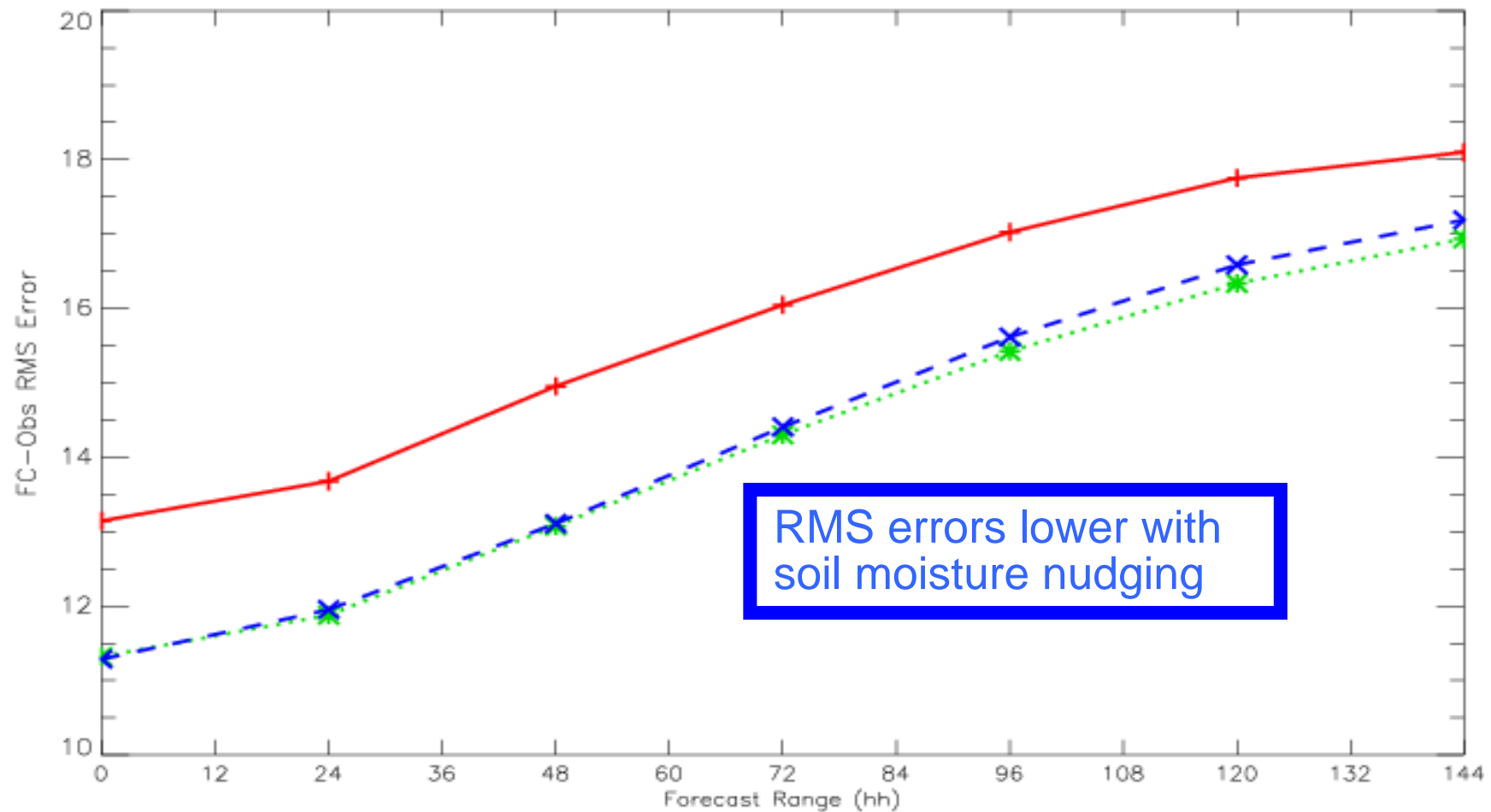
RMS errors lower with soil moisture nudging



RMS errors in screen RH JJA 2006

Relative humidity (%) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N–20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

Cases: + PS11 + soil moisture climatology x PS11 + soil moisture nudging
* PS15 + soil moisture nudging



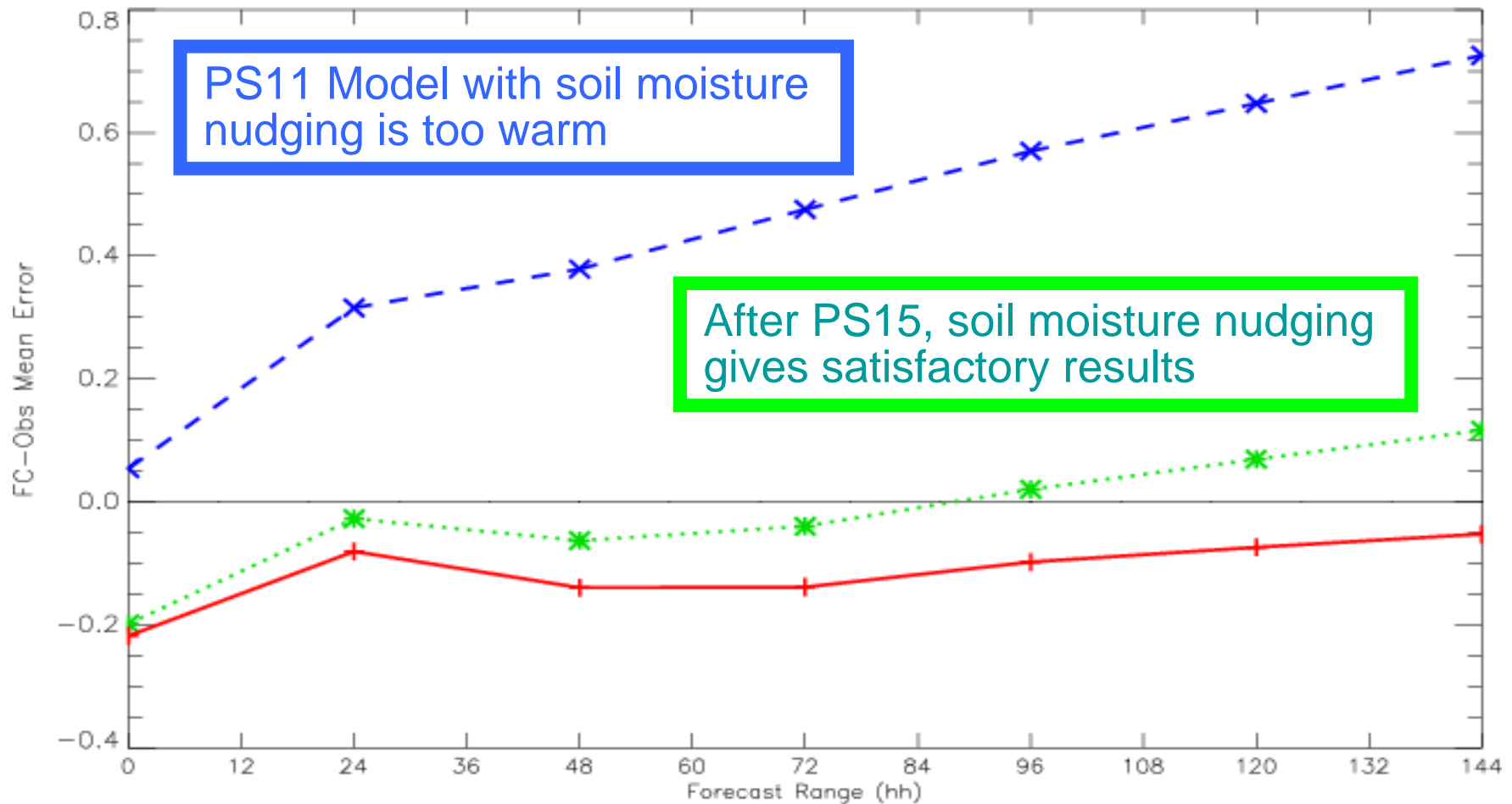
RMS errors lower with soil moisture nudging



Bias in screen T JJA 2006

Temperature (Kelvin) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N–20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

Cases: + PS11 + soil moisture climatology * PS11 + soil moisture nudging
* PS15 + soil moisture nudging

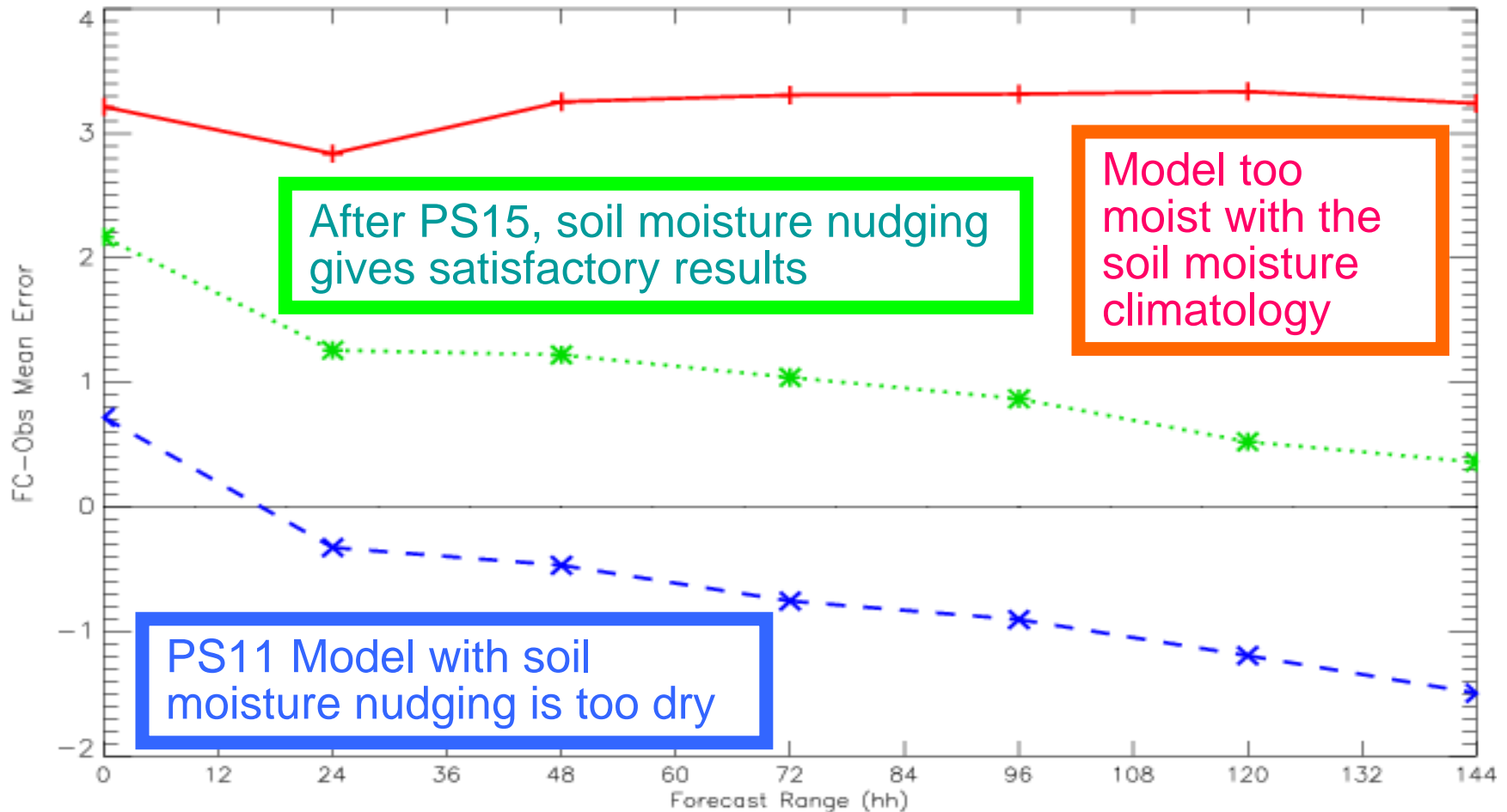




Bias in screen RH JJA 2006

Relative humidity (%) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N–20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

Cases: + + PS11 + soil moisture climatology x x PS11 + soil moisture nudging
* * PS15 + soil moisture nudging





***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

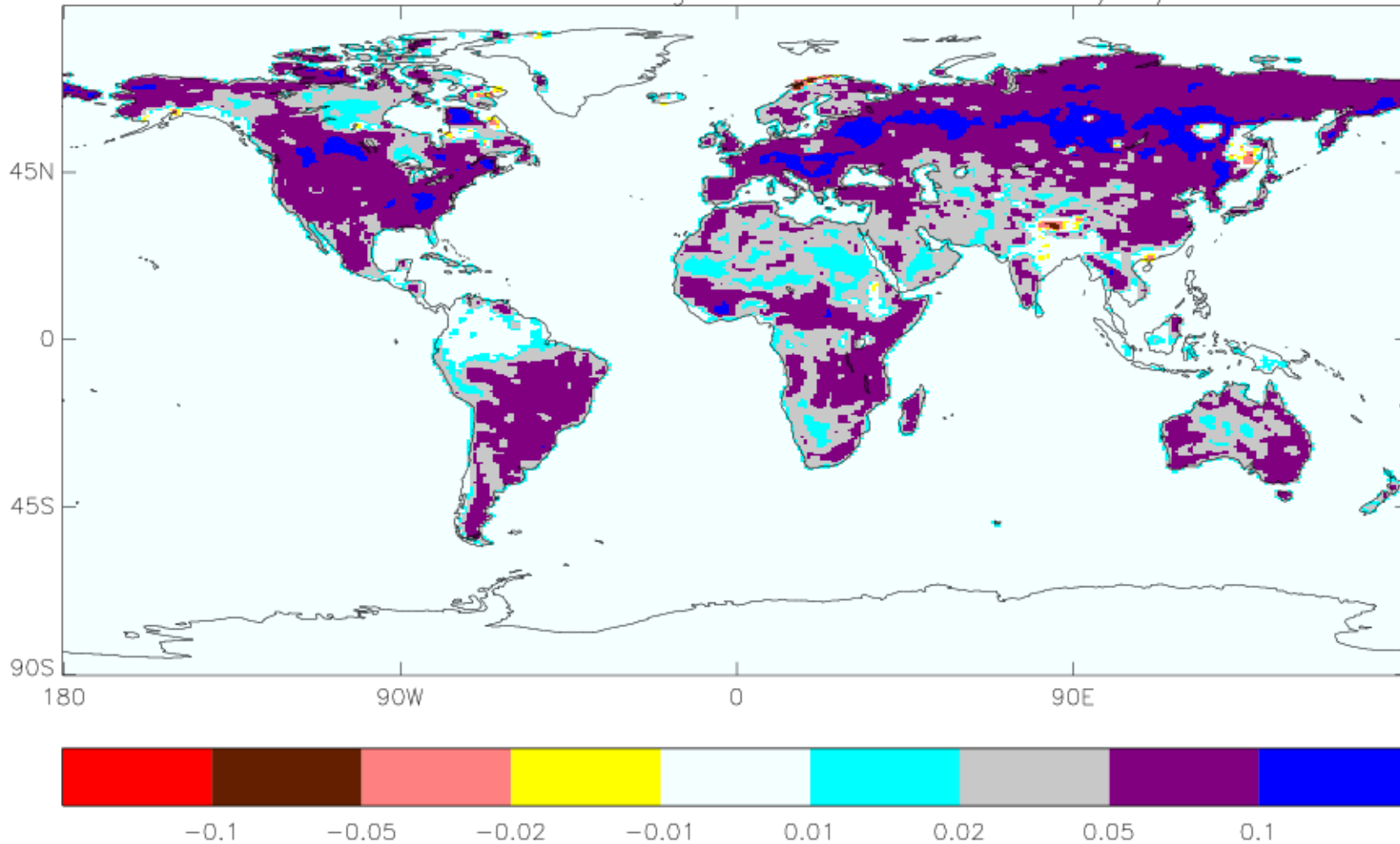
- April 2007 – error discovered in the code to calculate UM soil hydraulic properties.
 - Correction results in significantly higher wilting and critical points.
 - The new wilting and critical points are in much closer agreement with those used at ECMWF, other Met centres and observations.
 - Correction 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



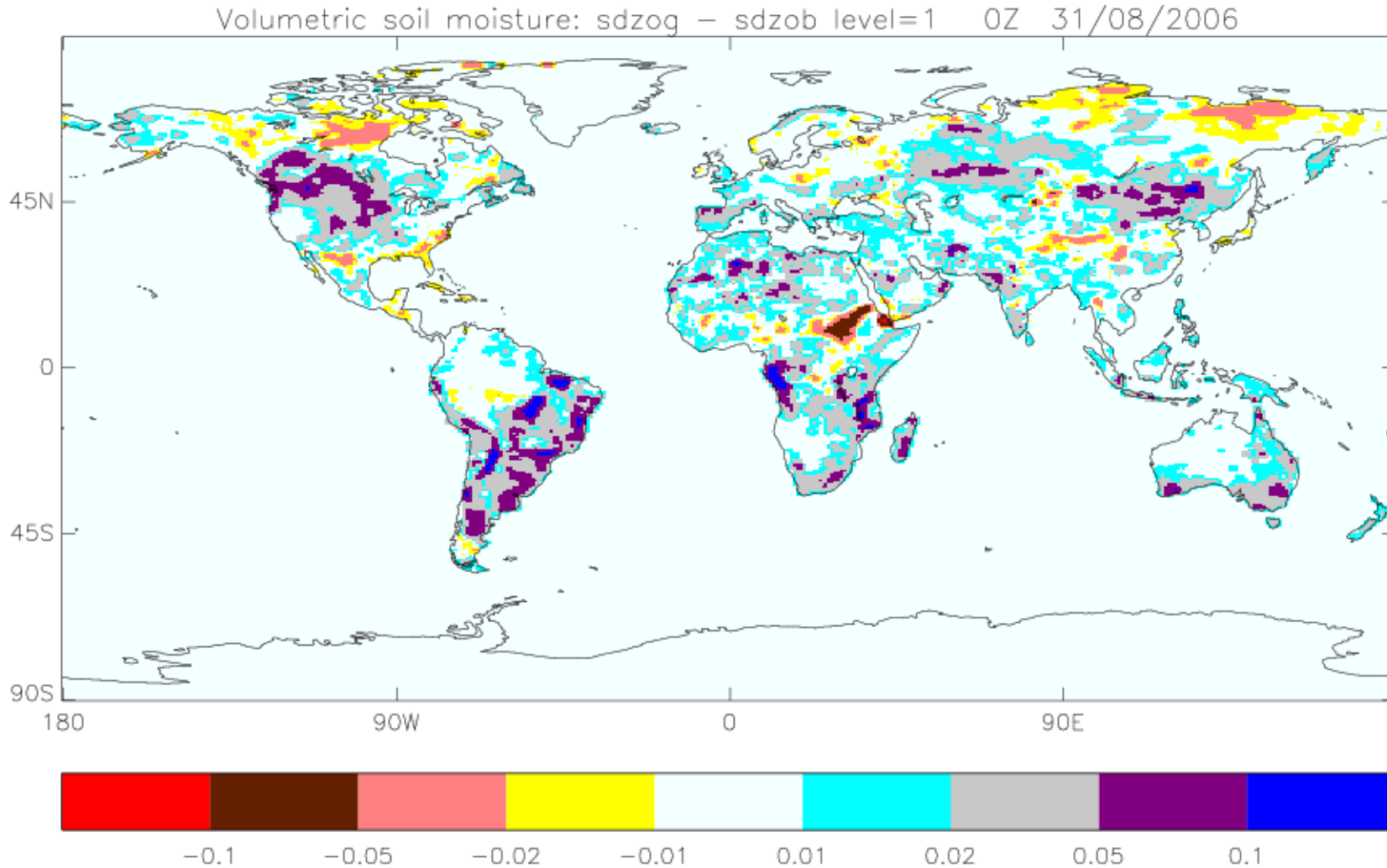
New hydraulic soil properties – old hydraulic soil properties Difference in volumetric soil moisture for the **bottom** soil level

Volumetric soil moisture: sdzog – sdzob level=4 OZ 31/08/2006





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





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New soil hydraulic parameters – Impact on Forecasts

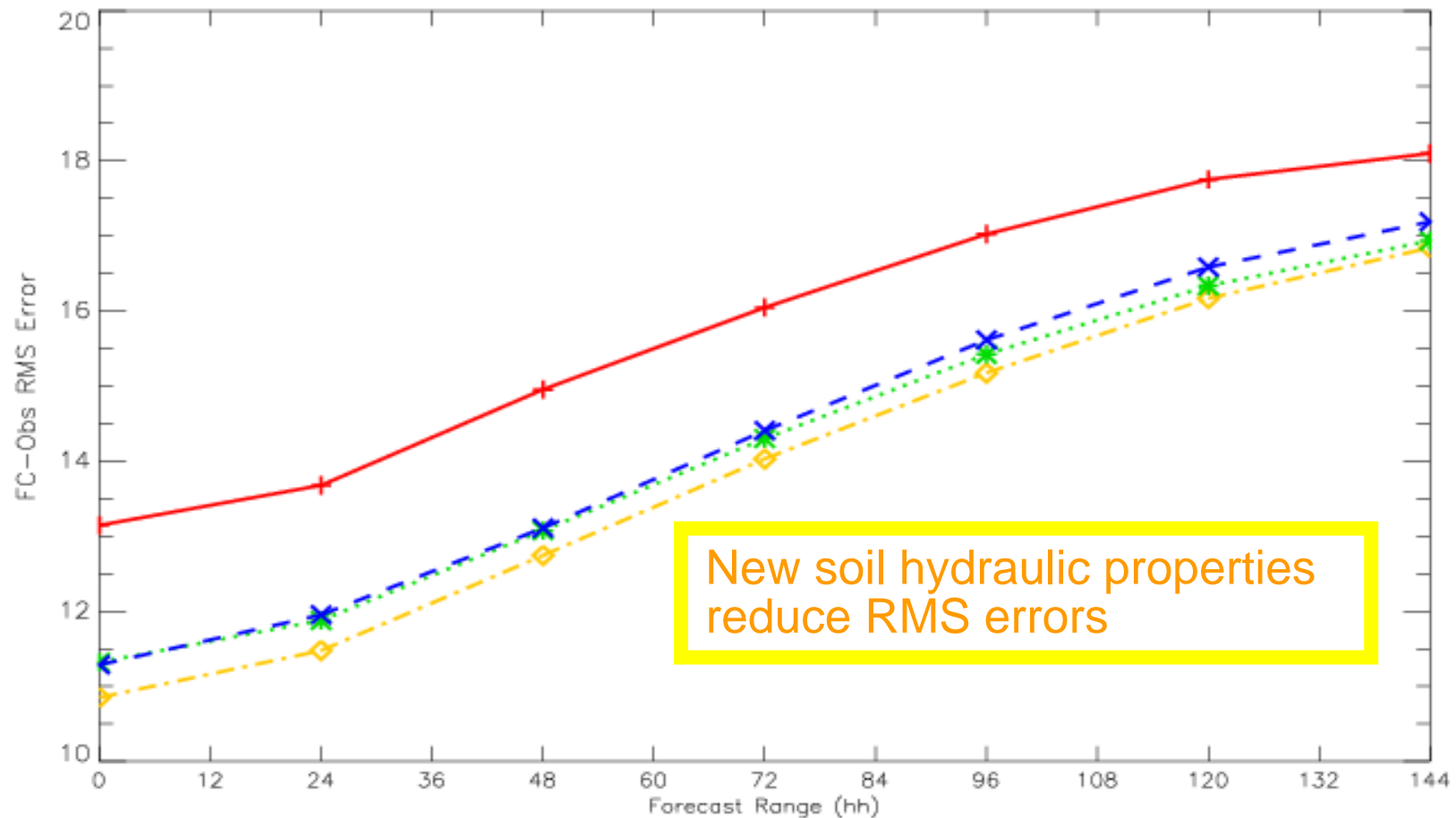
- **reduced RMS errors** in screen temperature and humidity.
- New soil hydraulic properties increase the soil moisture but now the soil binds more tightly to the soil water (increased wilting and critical points) so
 - soil moisture availability actually decreases
 - evaporation decreases
 - **NH summer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

Relative humidity (%) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N-20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

- Cases:
- PS11 + soil moisture climatology
 - PS11 + soil moisture nudging
 - PS15 + soil moisture nudging
 - PS15 + soil moisture nudging + new soil hydraulic properties

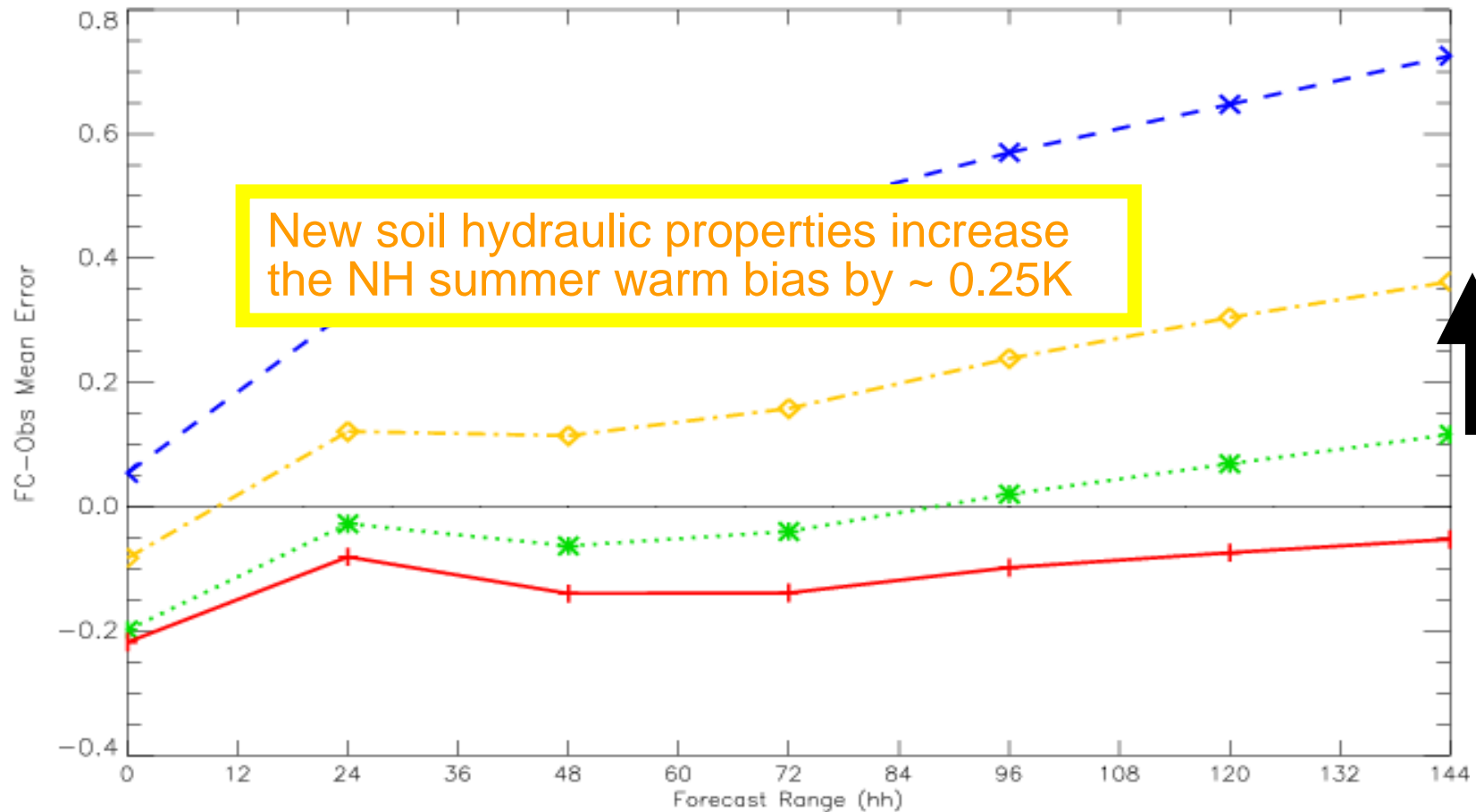




Bias in screen T JJA 2006

Temperature (Kelvin) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N–20N) (land points only)
Equalized and Meaned from 1/6/2006 12Z to 1/9/2006 12Z

- Cases:
+ PS11 + soil moisture climatology
x PS11 + soil moisture nudging
* PS15 + soil moisture nudging
◇ PS15 + soil moisture nudging + new soil hydraulic properties



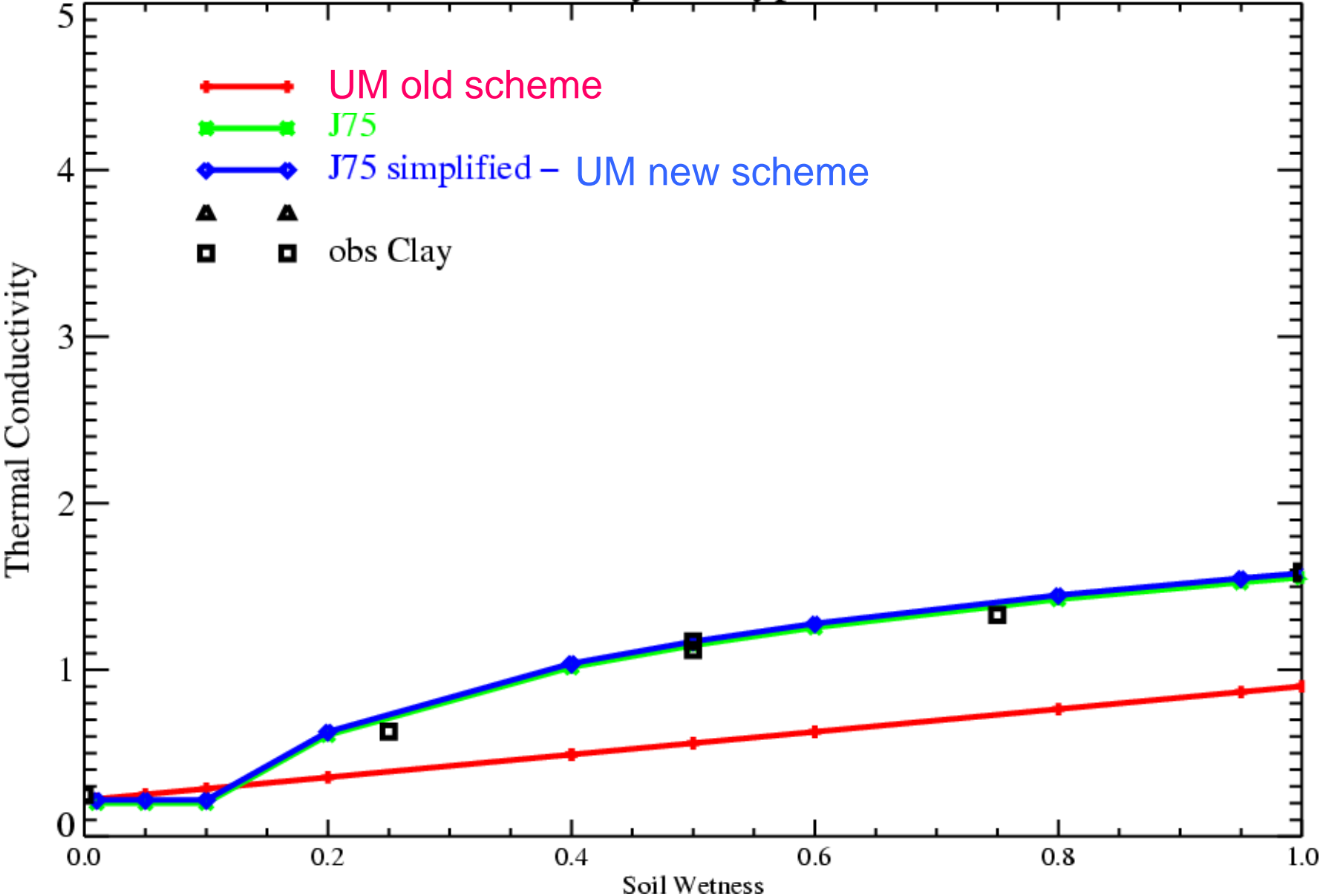


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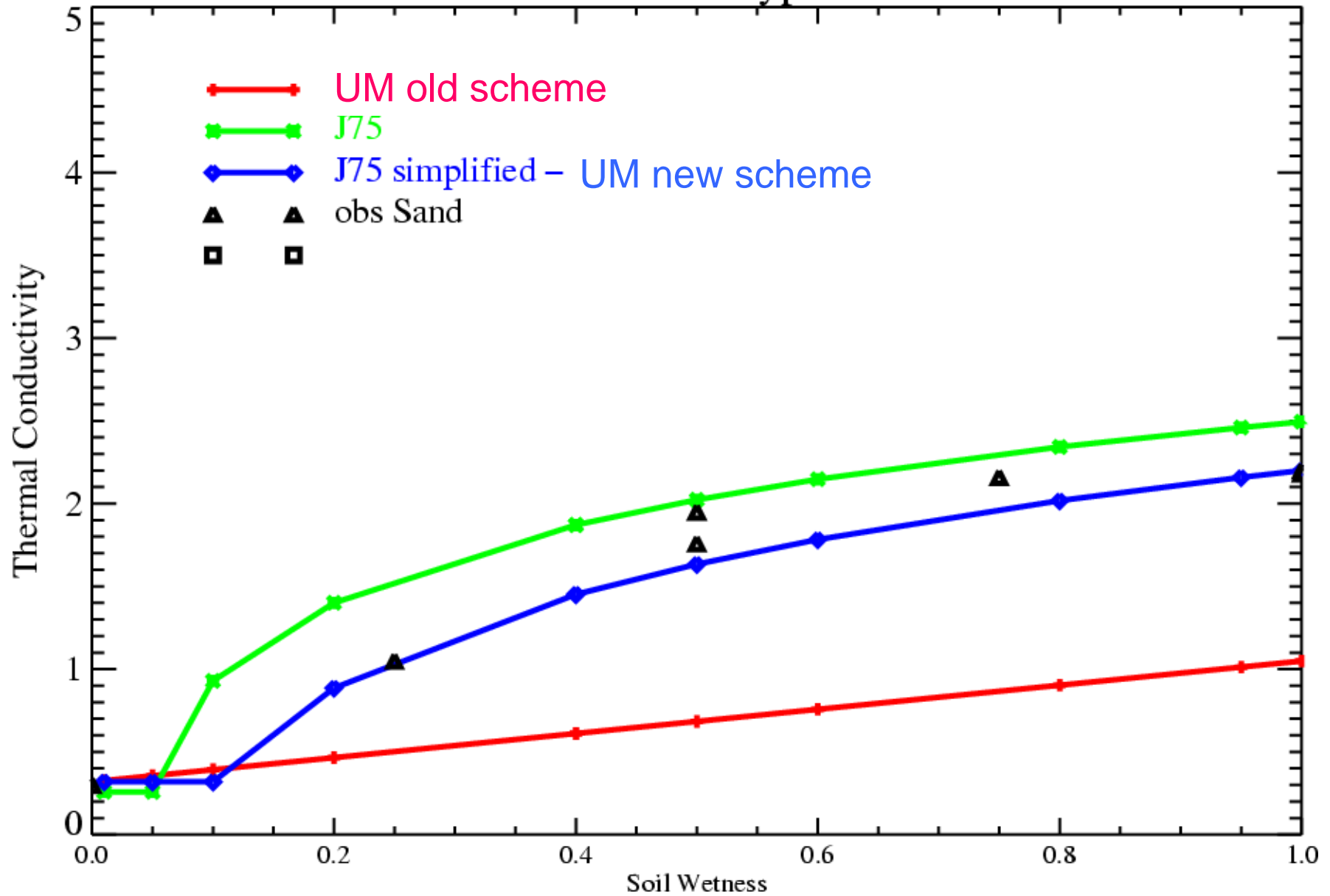
Soil Thermal Conductivity

- 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.

Clay soil type



Sand soil type





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Impact of new soil thermal conductivity parameterisation

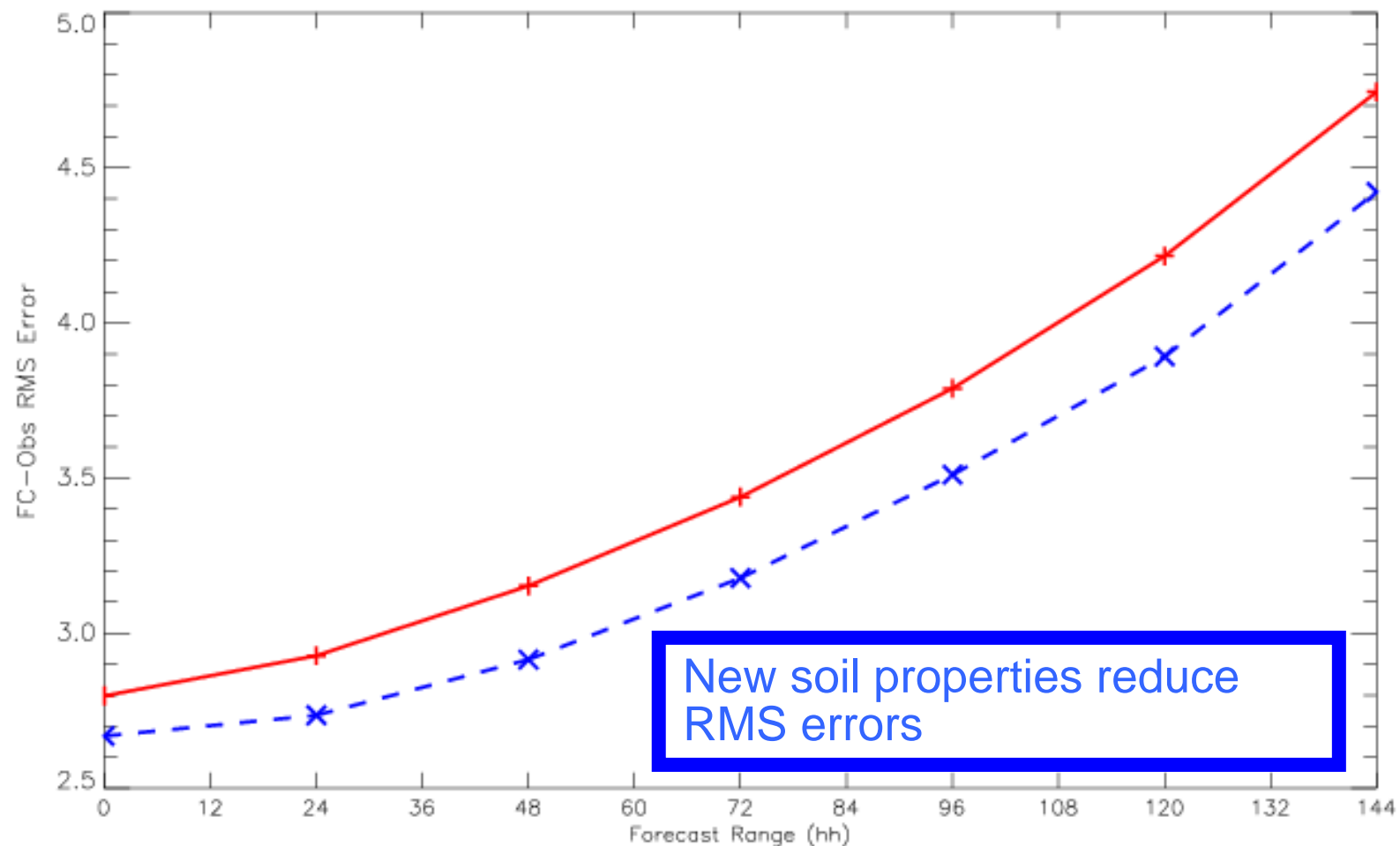
- Climate runs, Global, NAE and 4km trials show significant reduction in biases and RMS errors in screen temperature.
- Impact greatest in winter (reduces cold bias by ~ 0.6 K). RMS errors in screen temperature reduced by ~ 10%.
- In summer, warm bias reduced by ~ 0.2 Kelvin. RMS errors in screen temperature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



RMS errors in screen T for Dec 2006

Temperature (Kelvin) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N-20N) (land points only)
Equalized and Meaned from 27/11/2006 12Z to 31/12/2006 12Z

- Cases: + PS15 + SMC nudging + old soil properties
x PS15 + SMC nudging + new soil hydraulic properties + new soil thermal conductivity

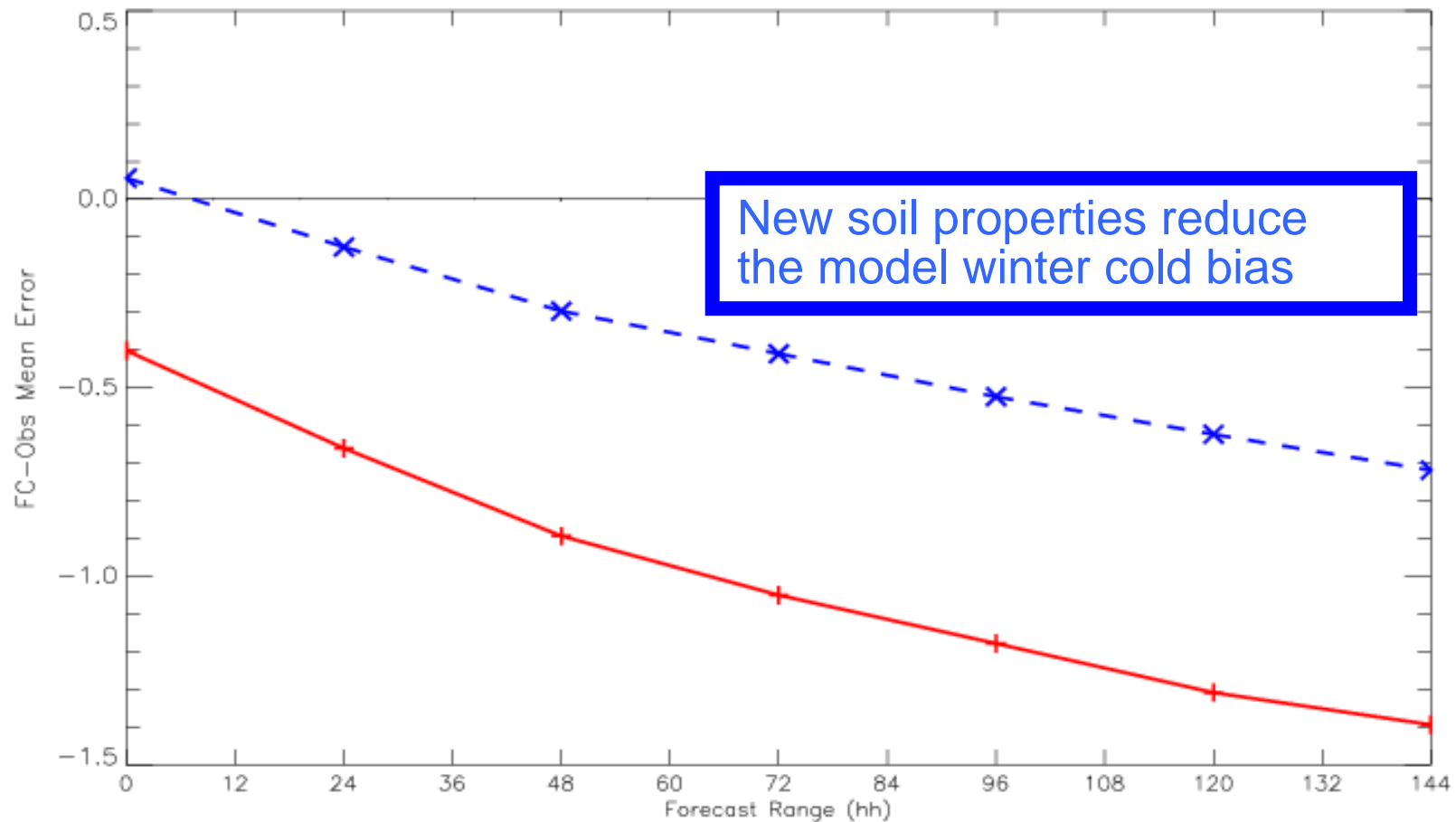




Bias in screen T for Dec 2006

Temperature (Kelvin) at Station Height: Surface Obs
Northern Hemisphere (CBS area 90N-20N) (land points only)
Equalized and Meaned from 27/11/2006 12Z to 31/12/2006 12Z

- Cases: + PS15 + SMC nudging + old soil properties
x PS15 + SMC nudging + new soil hydraulic properties + new soil thermal conductivity





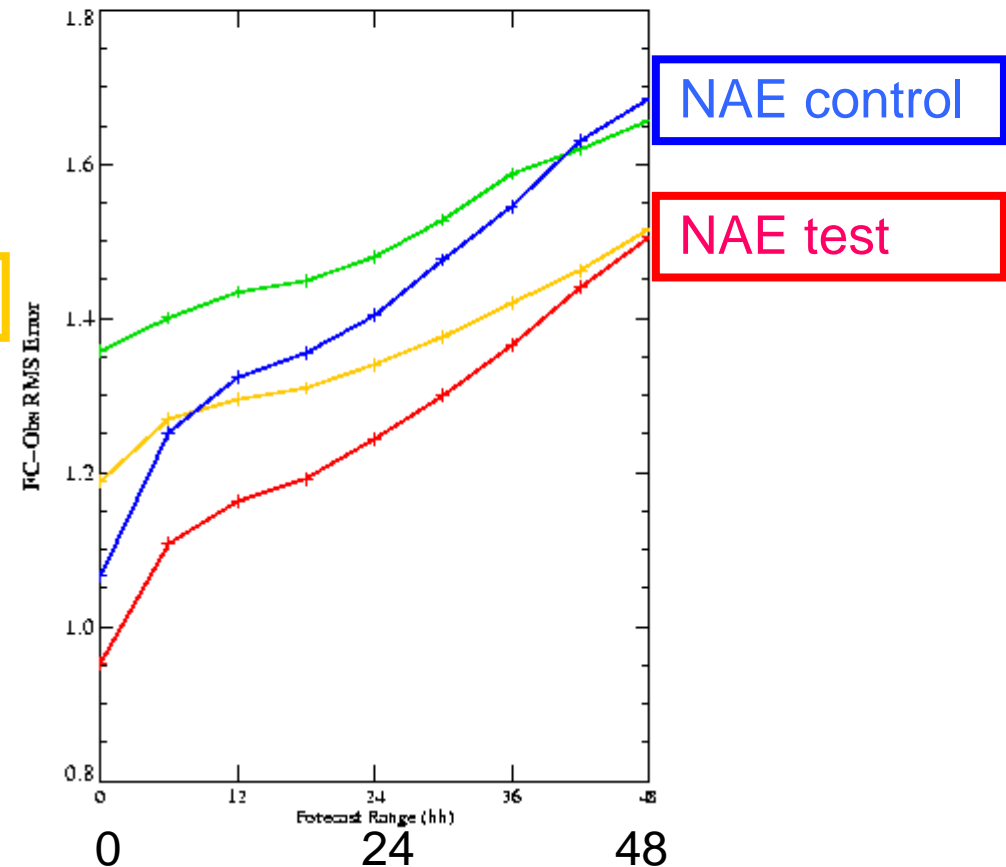
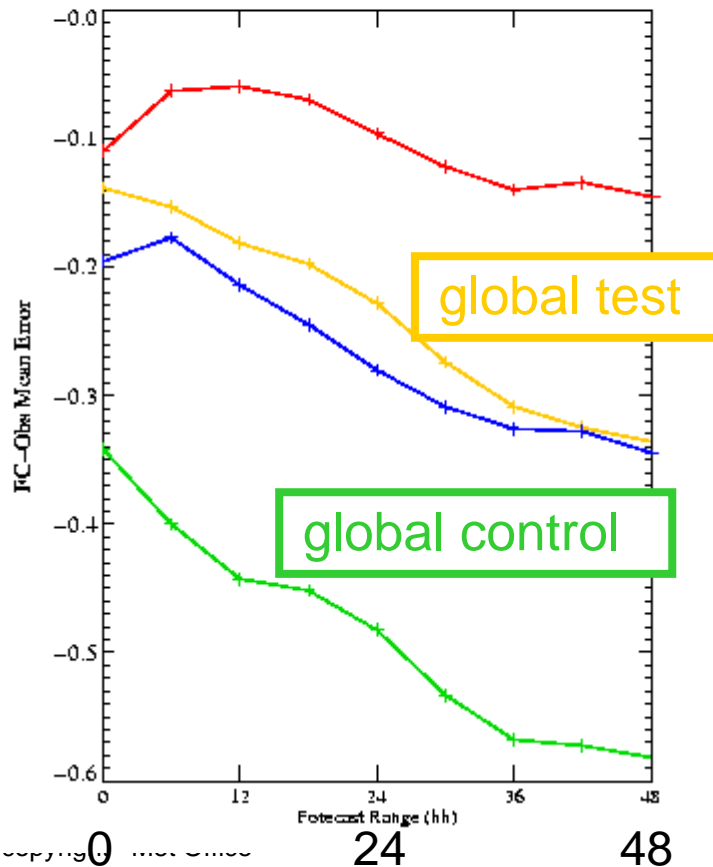
screen T impact in global/NAE models Mar 2008

mean

rms

Temperature (Kelvin) at Station Height: Surface Obs
 Meaned from 19/2/2008 00Z to 31/3/2008 18Z

Cases: — NAE Parallel — NAE Oper — Global Oper — Global Parallel
 Areas: + —+ Reduced Mesoscale Model area

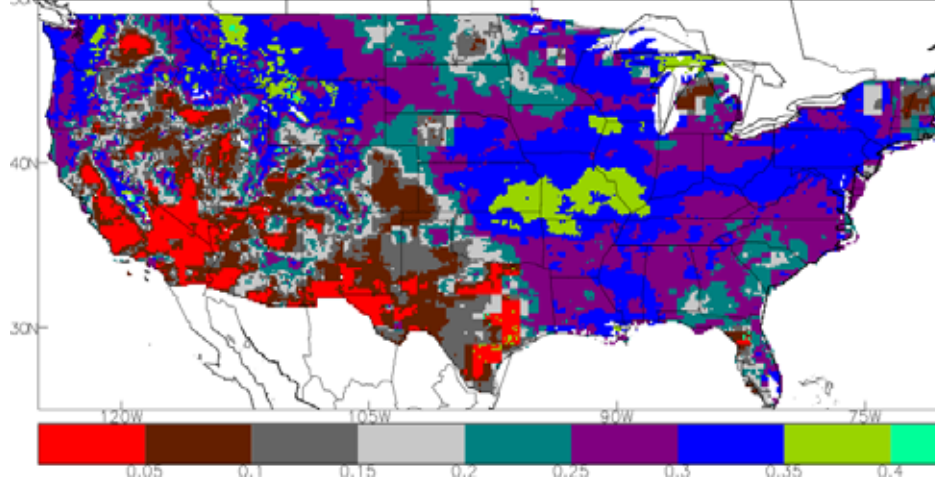




UM land surface model (**JULES**) run offline with
North American Land Data Assimilation System (**NLDAS**) driving data
<http://www.jchmr.org/jules/>
<http://ldas.gsfc.nasa.gov/drought/>

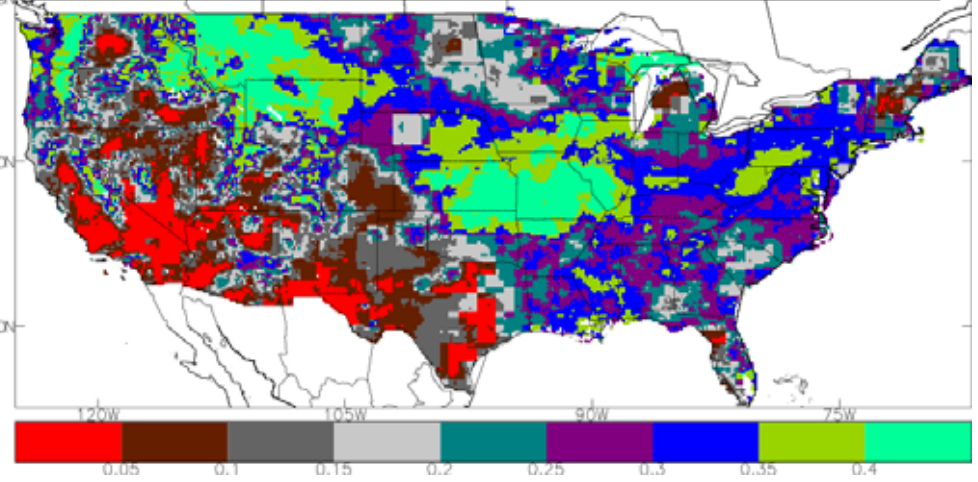
M 4 smcl Gridbox moisture content of each soil layer (kg/m²), for 4 soil lay
Level=1 20080527_02

JULES – NLDAS with Clapp & Hornberger soil hydraulics



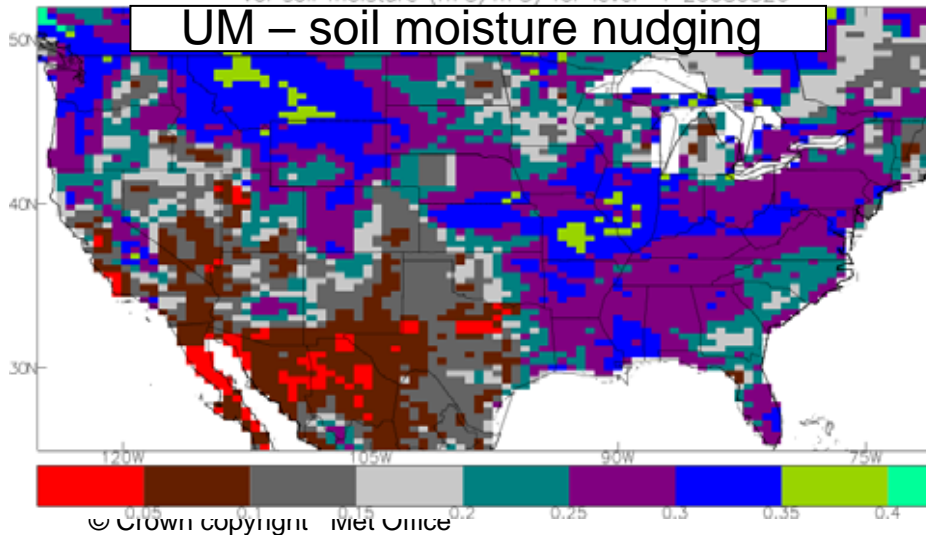
M 4 smcl Gridbox moisture content of each soil layer (kg/m²), for 4 soil layers
Level=1 20080527_02

JULES – NLDAS with van Genuchten soil hydraulics



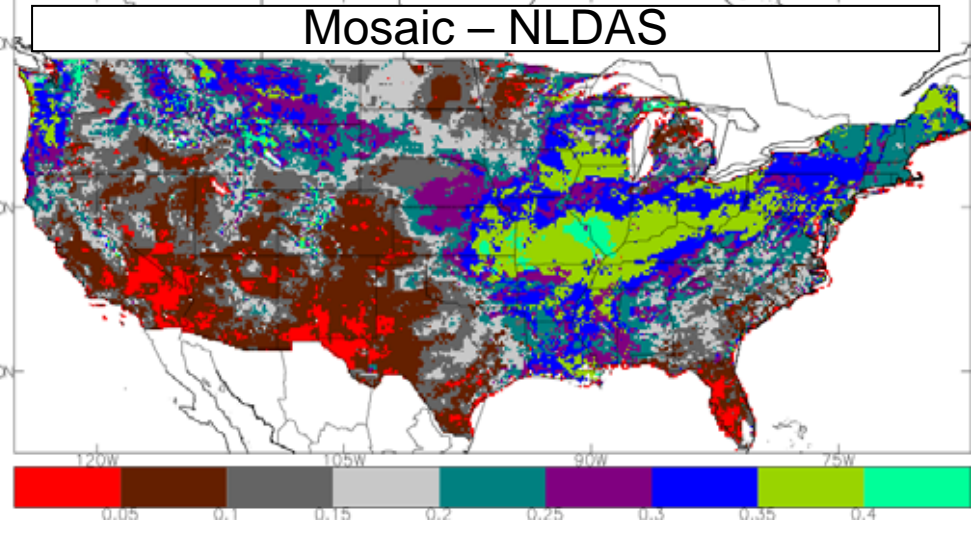
Vol soil moisture (m³/m³) for level 1 20080526

UM – soil moisture nudging



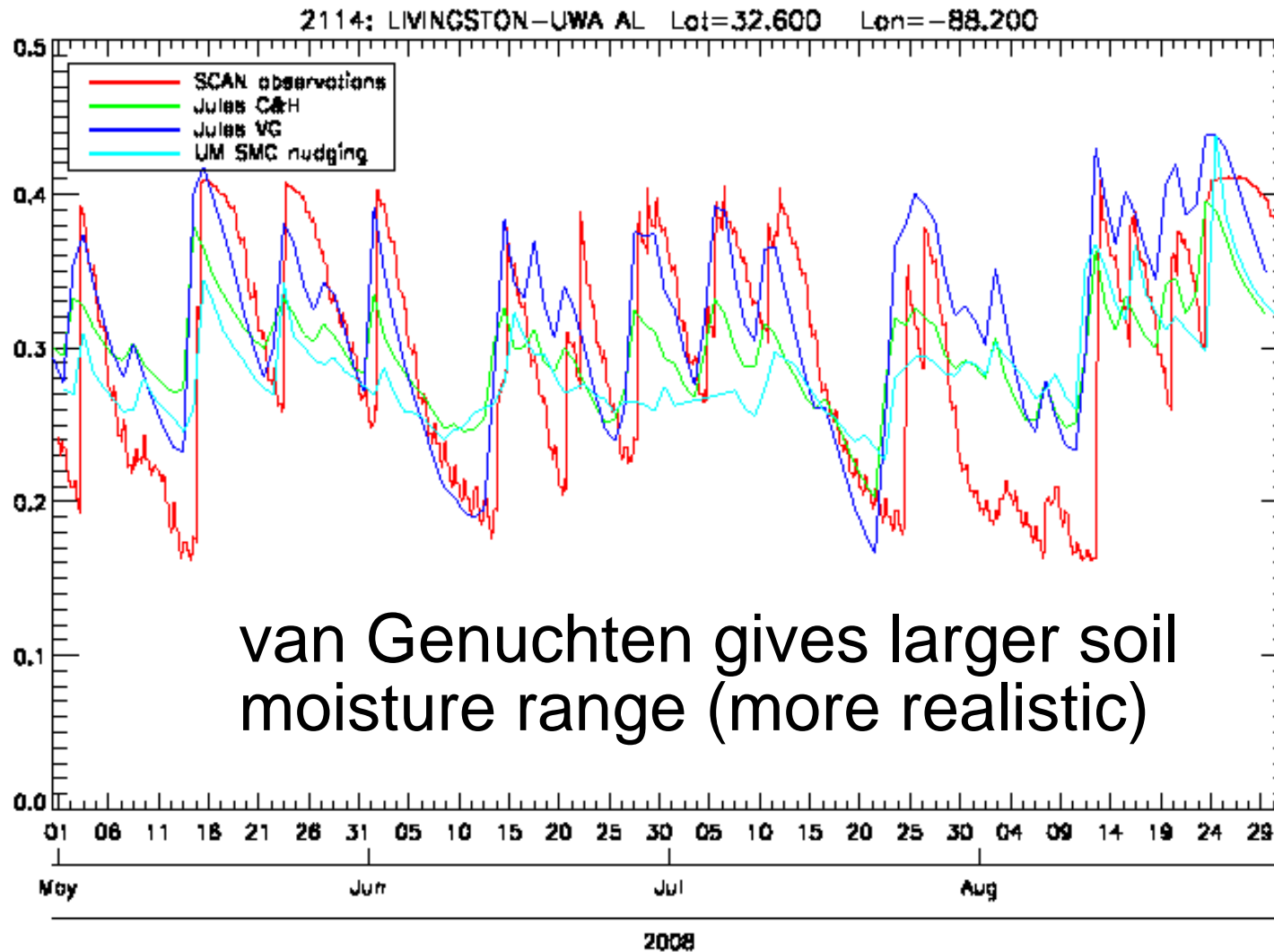
2008052612.grb
MOSAIC: Vol soil moisture (m³/m³) on soil level 1

Mosaic – NLDAS





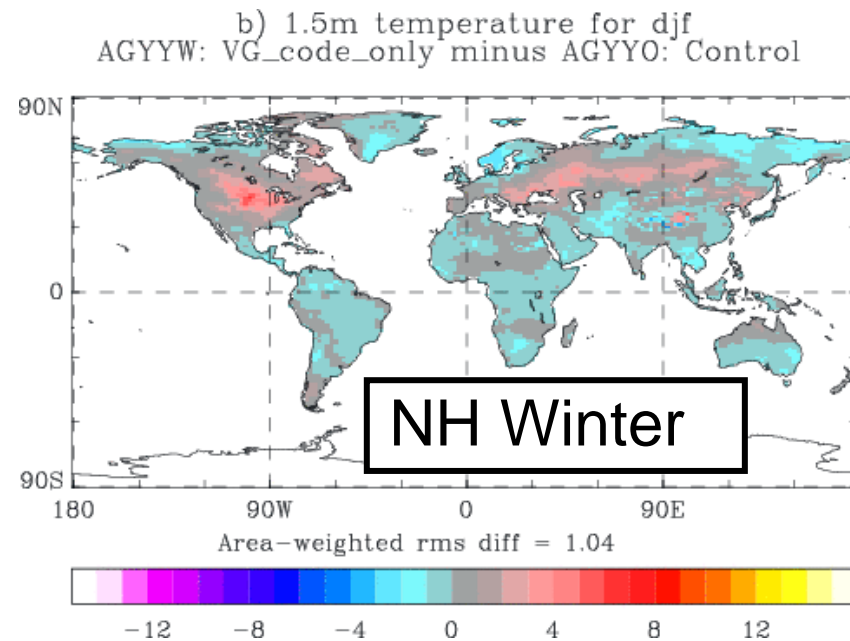
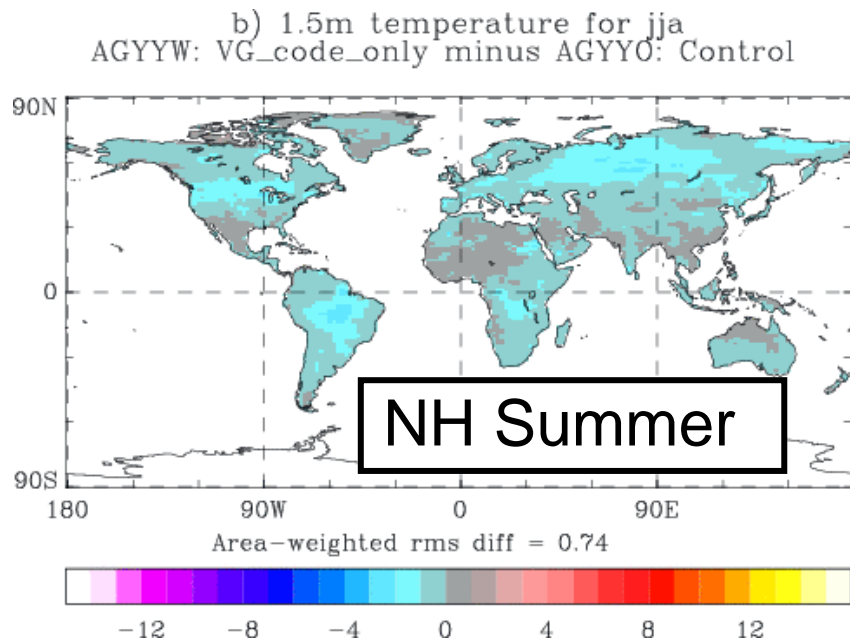
Soil moisture time series (Alabama)





Impact of van Genuchten soil hydraulics

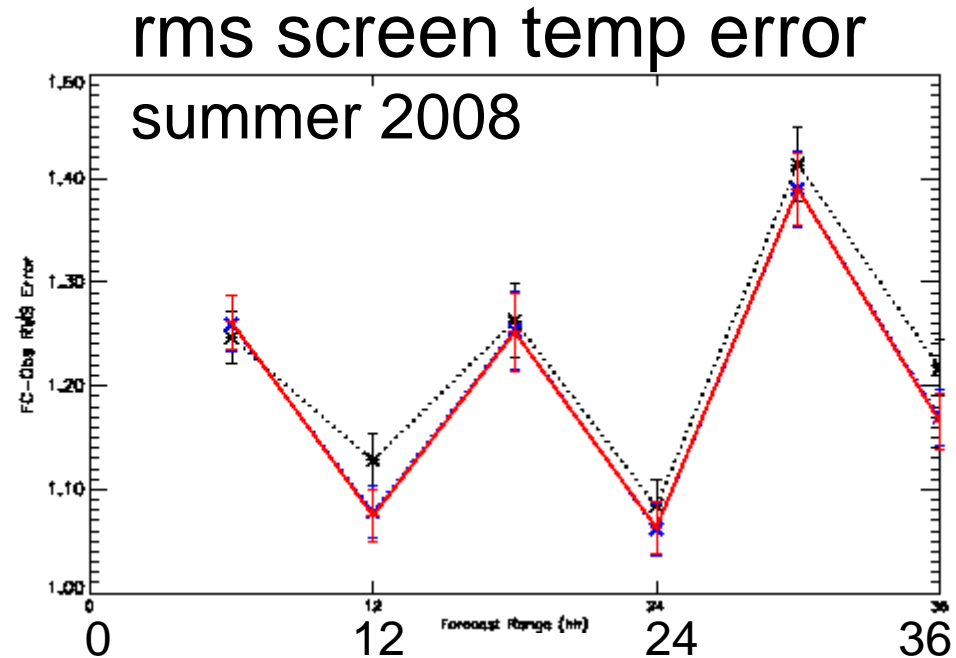
- Results from a 5 year climate run shows a significant cooling of the screen level during the NH summer and a general NH warming during the NH winter.
- The model soil moisture (not shown) is higher in both the NH summer and NH winter.
- Results courtesy of Dan Copsey.





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



— Offline analysis – MOSES-PDM
..... Soil moisture nudging
..... Climatology – GSWP2

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.



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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.



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Questions?