New soil physical properties implemented in the Unified Model

Met Office

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Introduction

Knowledge of soil is essential for meteorological, climatological, agronomic and hydrological applications. The properties of soil can have a significant impact on near surface temperature and humidity, low clouds and precipitation by influencing the exchange of heat and water between the land surface and the atmosphere.

The soil hydraulic properties affect the soils ability to hold water and the rate at which water moves through the soil. The soil moisture together with the soil hydraulic properties control transpiration from plants and direct evaporation from bare soil. Also, the soil thermal conductivity and heat capacity both depend on soil moisture and soil texture, so that these properties in turn influence the land surface temperature. Thus, soil moisture and the soil physical properties control the partitioning of net surface radiation into sensible, latent and ground heat fluxes.

Soil Hydraulic Properties

The Unified Model (UM) has three soil textural types; coarse, medium and fine. The soil hydraulic properties are calculated using the Cosby et al (1984) regression relationships from the soil sand/silt/clay fractions. The sand/silt/clay fractions are derived from the 1° x 1° soil classes data of Wilson and Henderson-Sellers. The Clapp and Hornberger equations are used to describe the soil water retention curve and the relationship between soil moisture and soil hydraulic conductivity.

In early 2007, a long-standing error was found in the way that Met Office programs use the Cosby et al (1984) equations to calculate the soil hydraulic parameters. At the time, it was thought that this error might significantly contribute to the summer warm bias of the global Unified Model. Correcting the error causes a large change to the UM soil hydraulic properties, as shown in tables 1 and 2. Note the order of magnitude increase in SATHH (soil suction at saturation) and the large increase to Θ_c - Θ_w of the medium soil type. The new values of SATHH are now in much better agreement with observations (for example see Table 2 of Clapp and Hornberger, 1978). Note that the UM sand/silt/clay fractions have not been changed.

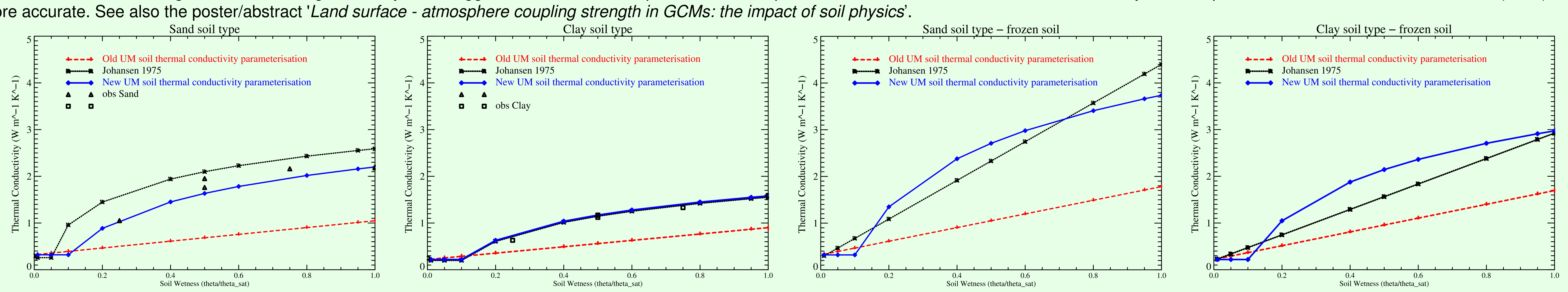
OLD	Critical point Θ_c	Wilting point Θ_w	Critical minus Wilting $\Theta_c - \Theta_w$	SATHH (m) $-\psi_s$	K_s (mm/s)
Fine	0.310	0.221	0.090	0.045	0.0036
Medium	0.242	0.136	0.106	0.049	0.0047
Coarse	0.096	0.033	0.062	0.022	0.0110

NEW	Critical point Θ_c	Wilting point Θ_w	Critical minus Wilting $\Theta_c - \Theta_w$	SATHH (m) $-\psi_s$	K_s (mm/s)
Fine	0.370	0.263	0.107	0.324	0.0015
Medium	0.332	0.187	0.145	0.397	0.0028
Coarse	0.128	0.045	0.083	0.062	0.0195

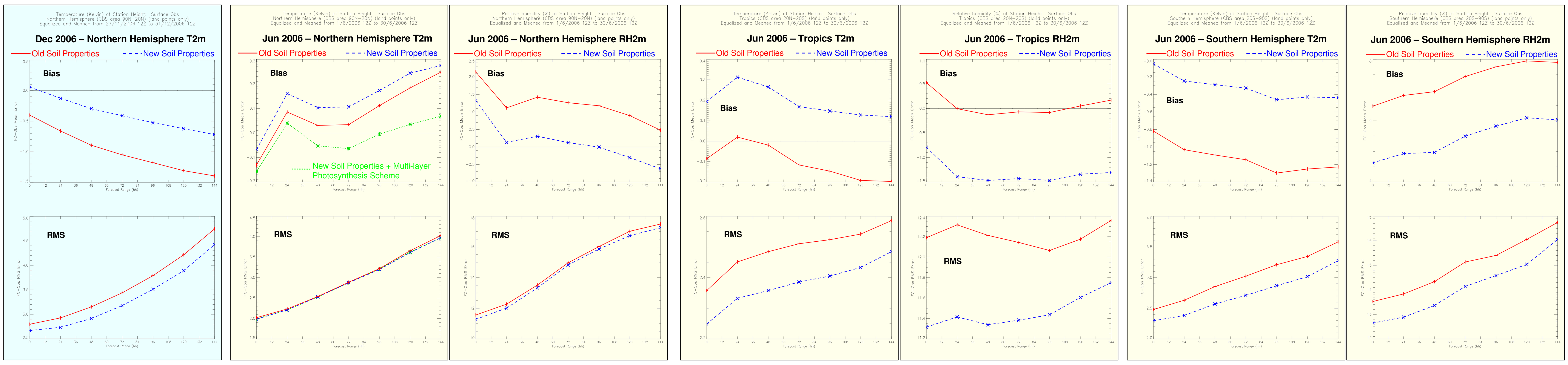
Hydraulic properties, for the three UM soil textural types. SATHH is the soil suction at saturation, K_s is the hydraulic conductivity at saturation, the critical point Θ_c is the volumetric soil moisture for a soil suction of 3.364 m, the wilting point Θ_w is the volumetric soil moisture for a soil suction of 152.9 m.

Soil Thermal Conductivity

Anne Verhoef and Pier Luigi Vidale at Reading University have suggested that the old UM parameterisation predicts too low values of soil thermal conductivity and that parameterisations based on Johansen (1975) are more accurate. See also the poster/abstract '*Land surface - atmosphere coupling strength in GCMs: the impact of soil physics*'.



Pre-operational Trials

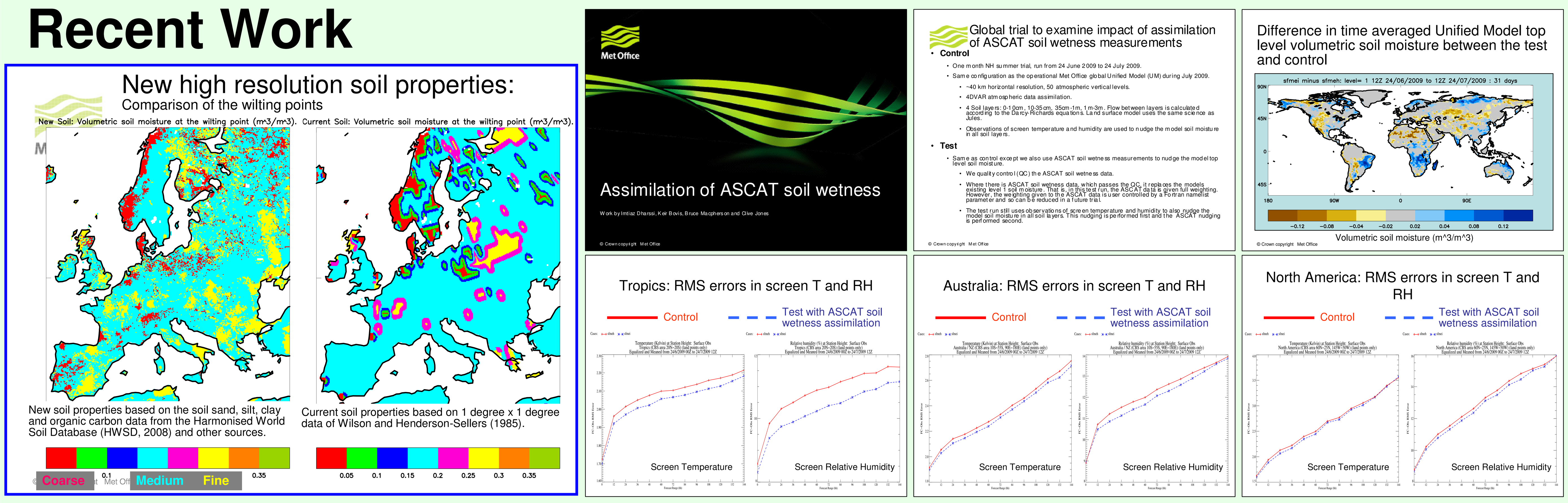


Operational Implementation

The improved UM soil physical properties were implemented operationally in the global UM, the North Atlantic European (NAE) and United Kingdom 4km (UK4) models at Parallel Suite 18 (PS18) that started mid-February 2008 and became operational at the start of April 2008. PS18 shows that all models benefit significantly from the new UM soil physical properties.

Operational verification shows that there has been a clear improvement in operational UM forecasts of screen temperature and relative humidity since April 2008 and that the operational UM performance for screen temperature forecasts is now as good as, or better than, other leading NWP centres. The magnitude of the improvement seen in the operational verification is similar to the magnitude of the improvement shown by the pre-operational trials. The biggest improvements are at the longer forecast times and for the extra-tropics winter hemisphere.

Recent Work



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