Using satellite remote sensing data for evaluating Earth system models: Plans for UKESM1 evaluation

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The National Centre for Earth Observation (NCEO) is a NERC research centre with more than 80 scientists distributed across leading UK universities and research organisations. NCEO provides the UK with core expertise in Earth Observation science, data sets and merging techniques, and model evaluation to underpin Earth System research and the UK's international contribution to environmental science.

NCEO is a member of the UKESM Long-Term Science Multi-Centre (LTSM) project and will lead the model evaluation component of the project. This will involve evaluation and assessment of the model in such areas as greenhouse gas emissions, land/atmosphere interactions, atmospheric chemistry, land surface energy balance and atmospheric aerosols. Here we focus on two examples of ongoing evaluation being performed by NCEO within the context of the UKESM project.

Land Surface Energy Balance - ***Phil Harris,** NCEO-CEH*

In many regions of the world soil moisture plays a central role in the partition of net radiation at the land surface into sensible and latent heat flux. This partition can also be thought of in terms of whether spring and summer evapotranspiration (ET) is limited by either soil moisture or net radiation. The GCMs in CMIP3 and CMIP5 largely agree on the locations of the extreme climatological cases, in which ET limitation is dominated by either radiation or severe soil moisture deficits. But there are large areas of inter-model disagreement in the transition regions between these two cases. Unfortunately, global evaluation of these model processes has been hindered by the lack of reliable, large-scale observations of ET and root-zone soil moisture.

One way to address this is to use satellite observations of land surface temperature (LST) in combination with atmospheric reanalyses of near-surface air temperature. As the land surface dries during rain-free periods, ET may decrease day-by-day due to declining soil moisture availability. This is accompanied by a warming land surface, and the rate at which LST increases relative to 2m air temperature is an indicator of changes in the surface energy partition and increasing sensible heat flux.

The observational side of this analysis has been carried out using 15 years of satellite LST from MODIS Terra and Aqua and ERA-Interim 2m air temperature, along with a combination of satellite precipitation products (TRMM, CMORPH, PERSIANN) to identify rain-free dry spells. Observations are averaged over many (1000s of) dry spells to quantify the surface behaviour in different regions, seasons and - most importantly - as a function of antecedent precipitation, a proxy for root-zone soil moisture availability. This diagnostic has also been calculated from AMIP simulations (atmosphere-land model simulations using prescribed sea surface temperatures) of ten CMIP5 models, including HadGEM2-A, using model-simulated dry spells. It is anticipated that this analysis will complement the evaluation of precipitation in UKESM1.

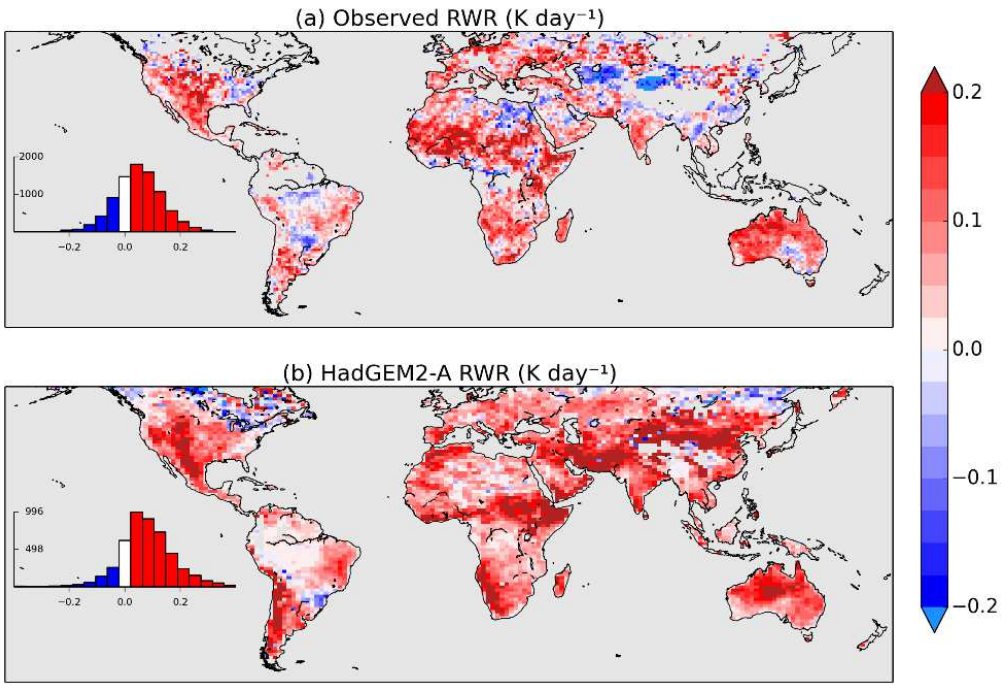

Figure 1. The relative warming rates (RWRs) between the land surface and screen level (i.e.~2m above the land surface) during 10-day dry spells calculated (a) from MODIS satellite land surface temperature (LST) and ERA-Interim 2m air temperature data on a 1° grid and (b) from the HadGEM2-A output on a 1.875° by 1.25° grid. Grid boxes are coloured grey if they have less than one dry spell event per year. Inset histograms show the frequency of different RWR values within the global domain.

Atmospheric Aerosols - ***Adam Povey,*** *NCEO-Oxford*

The ESA Climate Change Initiative (ESA-CCI) has produced various long-term data records from existing and ongoing satellite observations that are intended to evaluate climate and Earth system models. NCEO researchers are strongly involved in the production of many of these Essential Climate Variables (ECVs), including sea surface temperature, atmospheric concentrations of greenhouse gases (carbon dioxide and methane), atmospheric ozone concentrations and atmospheric aerosol.

The CCI-Aerosol project uses the ATSR-2 and AATSR sensors to produce a record of aerosol optical depth and fine-mode particle fraction from 1995 to 2012 at 10km resolution, including pixel-level uncertainties. A round robin exercise evaluated seven aerosol retrieval algorithms and found that none is universally sufficient. Hence, the project has used three algorithms to evaluate the 17-year data record, resulting in a small ensemble. The ensemble mean has been found to be more accurate than any individual algorithm while maximising coverage and providing a qualitative assessment of the systematic uncertainty due to algorithm assumptions. This data is expected to play an important role in evaluating the representation of key aerosol processes in UKESM1.

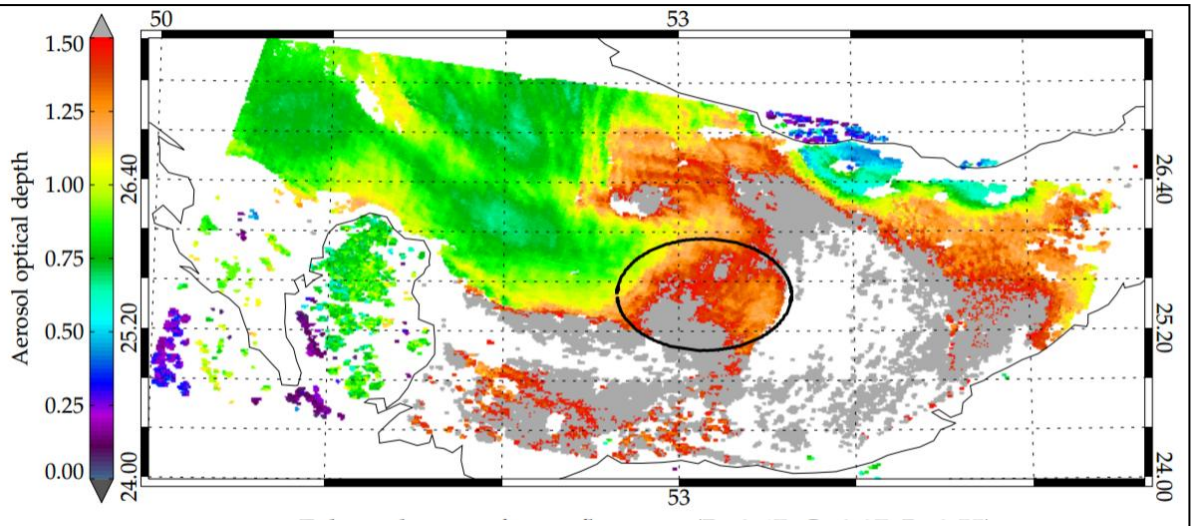

Figure 2. Aerosol optical depth (AOD) at 1km resolution over the Persian Gulf on 16 Sep 2008 as observed by AATSR. The radius 50km circle is centred on a concurrent Aeronet observation, which is used to validate the product.