Spatial variability of the atmosphere over southern England under clear skies: magnitude and impact

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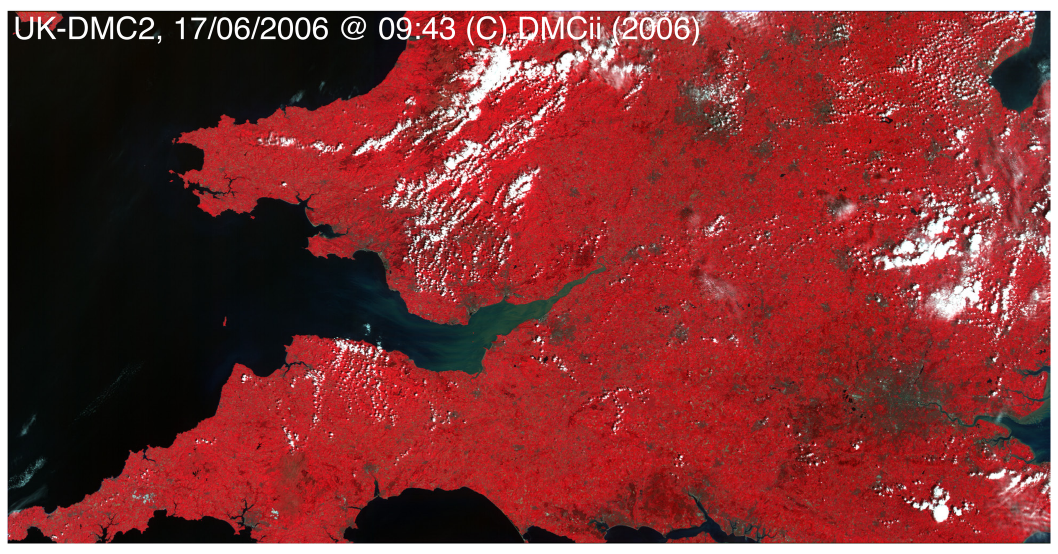
Background

Remote sensing techniques provide an important synoptic view of the planet, essential for the analysis of environmental change. A UK Environmental Change Observatory has been proposed using images from the DMC sensor which have a swath of 600km with a resolution of 22m. This data provides unparalleled large-area coverage at a resolution appropriate for analysing environmental change, but there are challenges with using data such as these.

Atmospheric correction must be performed before these images can be analysed, and this is often performed using standard techniques which assume that the atmosphere is uniform across the image.

This is unlikely to be true for large images!



Aim and Data Sources

Aim: To assess the spatial variability of the atmosphere over southern England on a clear day, its significance, and the errors caused by applying a uniform atmospheric correction over the entire area.

The 17th June 2006 was chosen as it was a typical clear day across most of the area (see image above) and coincided with the NCAVEO Field Campaign (see Milton et al., 2008).

The key spatially-variable atmospheric parameters are **Aerosol Optical Thickness (AOT)** and **Precipitable Water Content (PWC)**. This study focuses on AOT values because water vapour effects should be minimal as there are no water absorption features within the DMC bands.

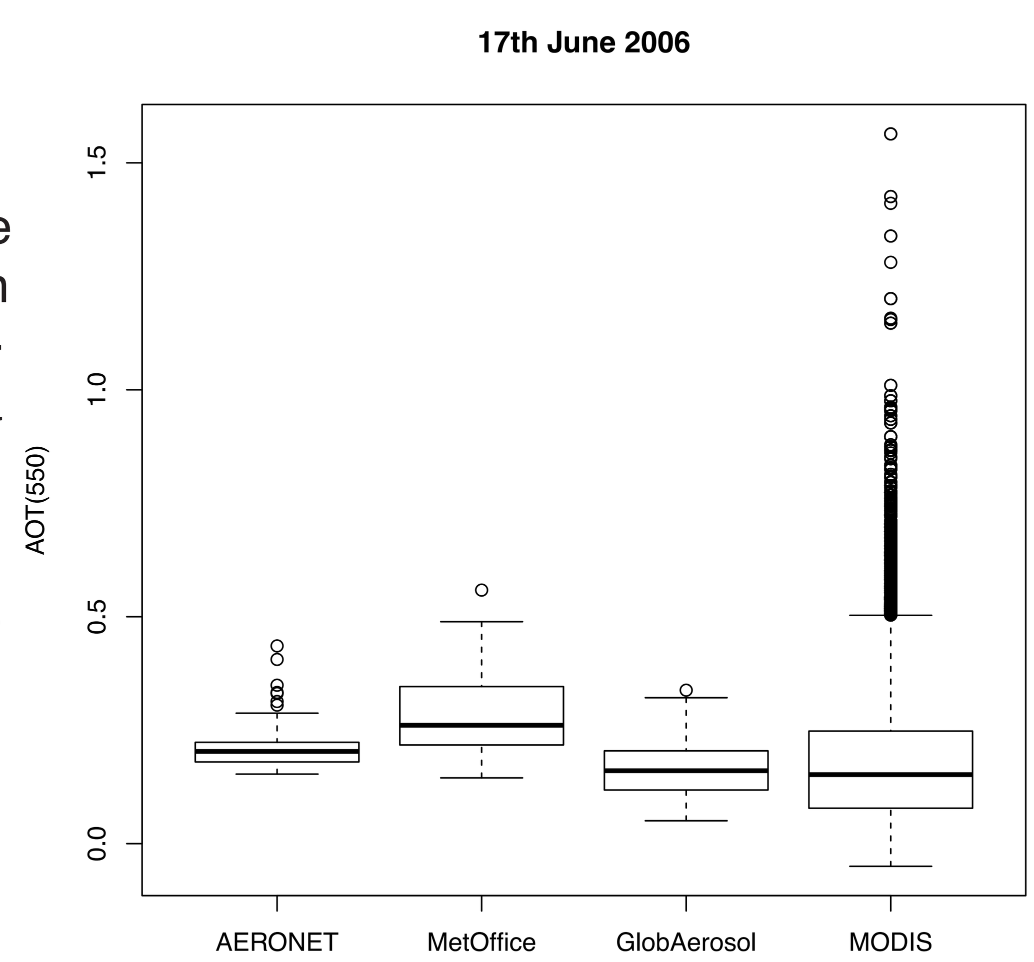
The data sources used are described below:

Source	Type	Spatial Resolution	Temporal Resolution	Assessed error	Closest acquisition to 09:43
AERONET	Ground	One location	Every 15 minutes, in good weather	0.01-0.02	09:37
Met Office	Ground	36 stations across study area	Hourly	—	10:00
MODIS (MOD04)	Satellite	10km	Daily merged OR once per orbit	$\pm 0.2 \pm 0.2\tau$	10:38
GlobAerosol	Multi-Satellite	10km	Daily	RMSE: 0.12	N/A (Daily)

Spatial Variability

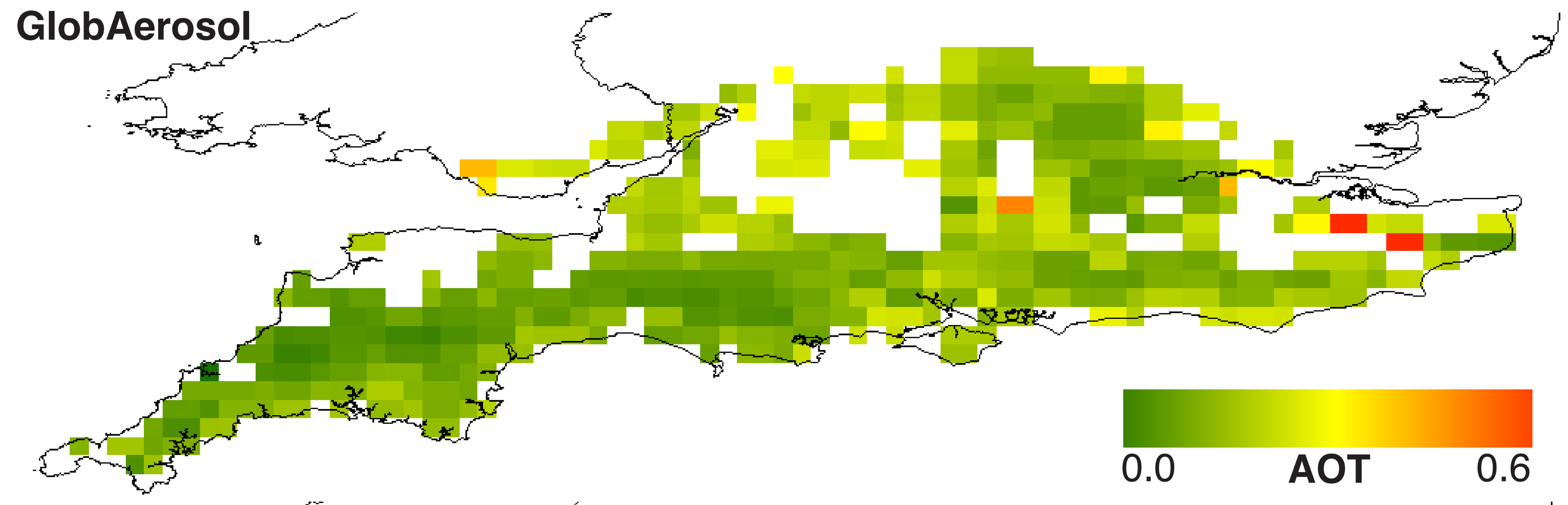
Although there is a lot of data available, establishing the spatial variability of the atmosphere is difficult as most of the data with a good spatial resolution has high error. AERONET data has the highest temporal resolution and can therefore provide values very close to the DMC overpass time, but only provides values at one location, severely limiting its use in studying spatial variability.

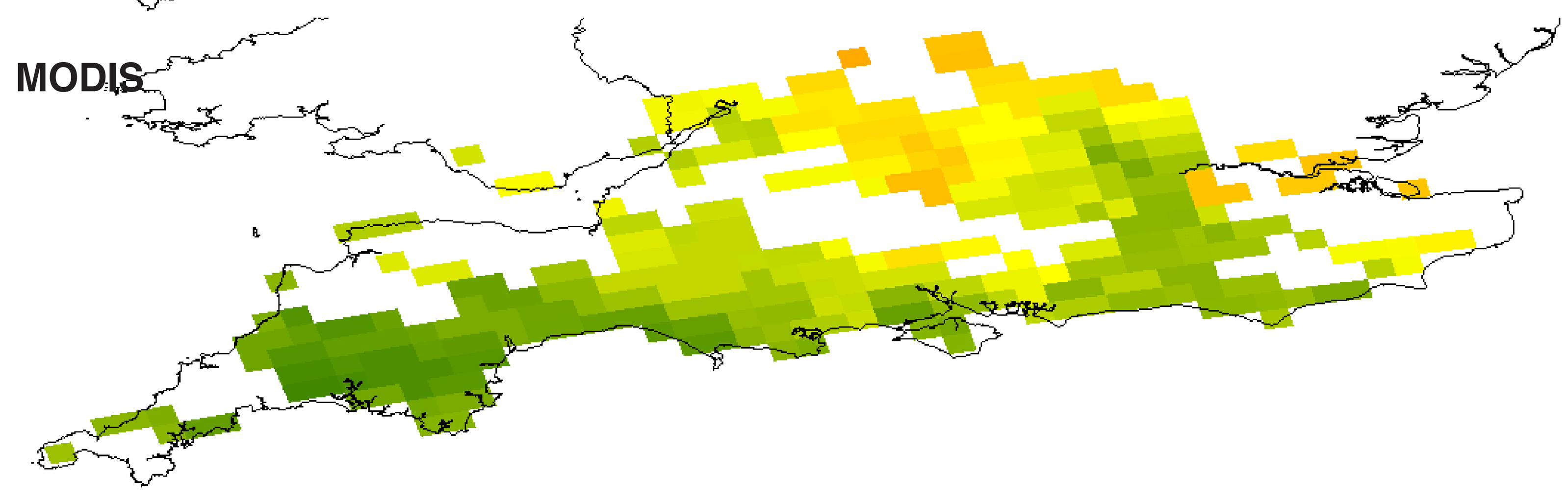
The distribution of data from each of the sources at the closest acqusition time to the DMC image are compared in the boxplot (right). The AERONET data shown is using a time-for-space substitution, assuming that, due to the movement of airmasses etc, the AOT over the AERONET site over a day will roughly equate to the AOT over the whole study area.



Overall, the range appears to be approximately 0.1-0.5, which is a significant variation for a generally clear day; the variation could be expected to be much higher for days with more varied weather. Although the MODIS data was cloud-screened, it appears to have a far larger range than the other data sources, which could be caused by subvisual clouds. As expected, the AERONET data had the smallest range, as it consisted only of measurements at one point, and thus all values were subject to the conditions at that point and do not give a good overview of conditions across the study area.

Ignoring the MODIS outliers, the data seems to suggest that the lowest and highest reasonable ranges of AOT on the 17th were 0.15-0.28 (AERONET) and 0.07-0.50 (MODIS) respectively. All further analysis below was performed using the 5% and 95% quantiles rather than the maximum and minimum of the datasets as it allows us to assume that 10% of the pixels in the DMC image are affected by these extreme values, and thus make statistical deductions about the significance of any errors.





Effects on NDVI

The 6S model was used via the Py6S interface to investigate the effects of performing a uniform atmospheric correction on data that had been derived from a heterogenous atmosphere, by running the model bi-directionally using different AOTs for the calculation of TOA radiance and the correction of that radiance. NDVI was calculated from each of the results, and these were compared to the true NDVI values for the input green vegetation spectrum. **The maximum difference found was 7.9% (MODIS), with a minimum change of 2.2% (AERONET).** Using the method of Ruimy et al. (1994) this was found to correspond to a change in NPP of 1.45 g/m^2. Thus, even using the most conservative estimate of AOT range over southern England (AERONET), applying a uniform correction could result in an NDVI error of 2.2% for around 10% of the pixels in an image, possibly up to 5% or even 8%.

Conclusions

Variability is significant (AOT of 0.1–0.5), and could cause an NDVI error of 2–8%

Even during clear skies, AOTs across southern England, as measured by a number of data sources, ranged from approximately 0.1-0.5. This is significant variation, which would not be represented by a single value from the sole AERONET site in the area. Simulations have shown that performing an atmospheric correction assuming a uniform atmosphere could cause errors of 2-8% in NDVI for around 10% of the pixels within a DMC image of the area.

Robin Wilson is studying for a PhD at the University of Southampton supervised by Prof. E. J. Milton and Dr J. M. Nield. His work focuses on improving pre-processing methods to enable higher-quality scientific data to be produced from satellite images, primarily in the context of monitoring environmental change. This work was supported by an EPSRC Doctoral Training Centre grant (EP/G03690X/1). Contact him at `r.t.wilson@soton.ac.uk`.