ERACE: The environmental response to aerosols observed in CCI ECVs

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Motivation

Atmospheric aerosols can interact directly with radiation and indirectly alter the properties and albedo of clouds, both of which affect the climate. Driven by the great diversity of aerosol loading and properties, these interactions have been highlighted as the two most uncertain influences of climate change by the Intergovernmental Panel on Climate Change [1]. The ESA CCI is producing a global and long-term record of aerosol and cloud properties using cutting edge techniques, providing a new opportunity to evaluate the interaction and variation of aerosol and cloud. The aim of this project is to quantify the radiative and climate effects of specific anthropogenic aerosol pollutants using this new data.

Project

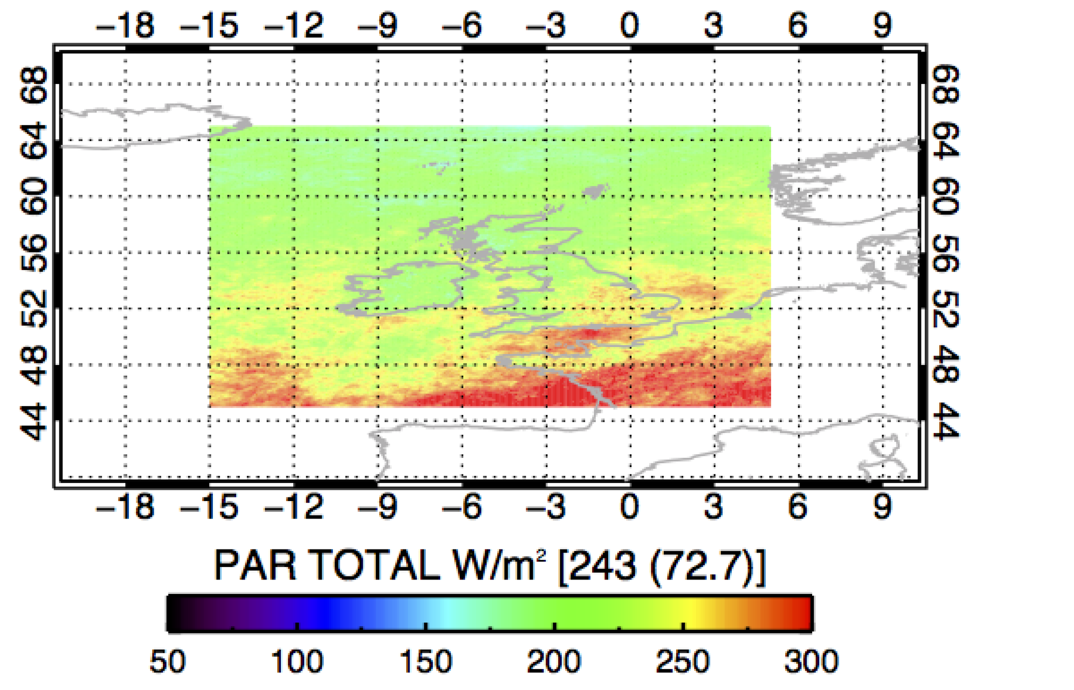
It can be difficult to isolate the impact of aerosol from natural variability and demonstrate a statistically significant signal. A common approach is to composite satellite data to improve the signal-to-noise ratio. [2] considered multiple years of satellite observations to examine the effect of passive volcanic emissions on aerosol and cloud properties. These were averaged after rotation about the source volcano according to the wind direction to discriminate observations before and after the introduction of aerosol. Mutually orienting measurements throughout the time series strives to not combine the two in long-term averages, which could mask interactions. In the next stage of the project this technique will be extended to other localised sources of aerosol in the CCI data set, such as industrialised islands, wild fires, and geographically-constrained cities.

To assess the radiative perturbation resulting from these and other aerosol sources, a post-processor for CCI data is under development to output the up and downwelling radiance and direct-to-diffuse ratio at the surface. The former can be used to constrain the range of possible radiative forcings resulting from aerosol interactions by comparing the radiance observed up and downwind of various sources. The evaluation currently focuses on regional averages to consider the extent to which the observed local effects can explain regional trends in surface radiance. The direct-to-diffuse ratio can contribute to the ongoing debate on the impact of enhanced aerosol levels on uptake of carbon dioxide by vegetation. This will bring significant added value to the CCI cloud and aerosol products by providing direct measures of the radiative impact of aerosol, simplifying their comparison to models and use in evaluating the global energy budget.

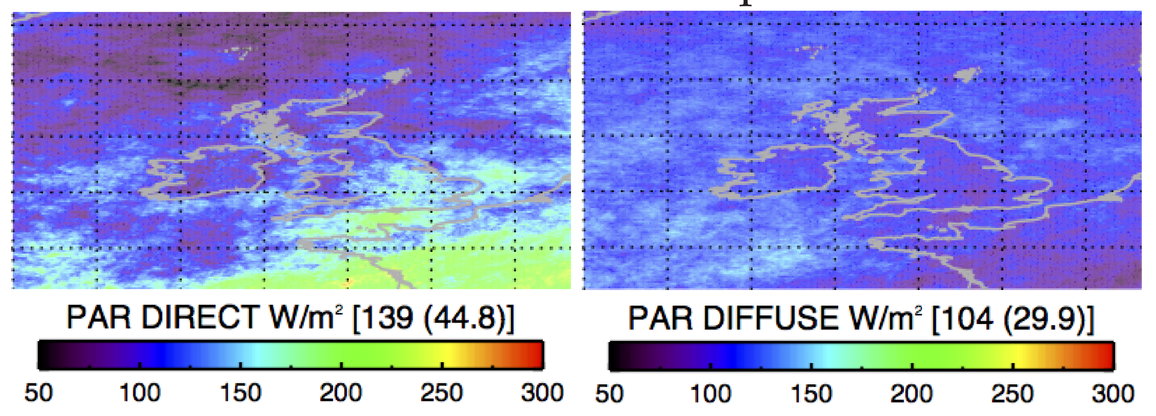
Broadband radiative flux

Broadband radiative fluxes are computed in a post-processing step using BUGSrad [3]. BUGSrad is based on the two-stream approximation and correlated-k distribution methods of atmospheric radiative transfer. It is applied to a single-column atmosphere for which the cloud or aerosol layers are assumed to be plane-parallel. Application of this code to satellite data has shown excellent agreement between Cloud-Sat/MODIS with CERES measured broadband fluxes. Here, we adopt a similar strategy as that used in [4] to compute the top- and bottom-of-atmosphere broadband radiative fluxes using the Level 2 cloud and aerosol optical properties from (A)ATSR instruments. With the growing demand for PAR (Photosynthetic Active Radiation) in land surface modelling and agriculture studies, we also derive this quantity using a similar methodology to that described in [5]. Primary inputs to BUGSrad are the particle effective radius (ER), optical thickness (OT), solar zenith angle, surface albedo, and the vertical profiles of temperature, humidity, and ozone. Validation efforts of this new radiation product with GERB and ground-based sensors are currently underway.

Photosynthetic Active Radiation



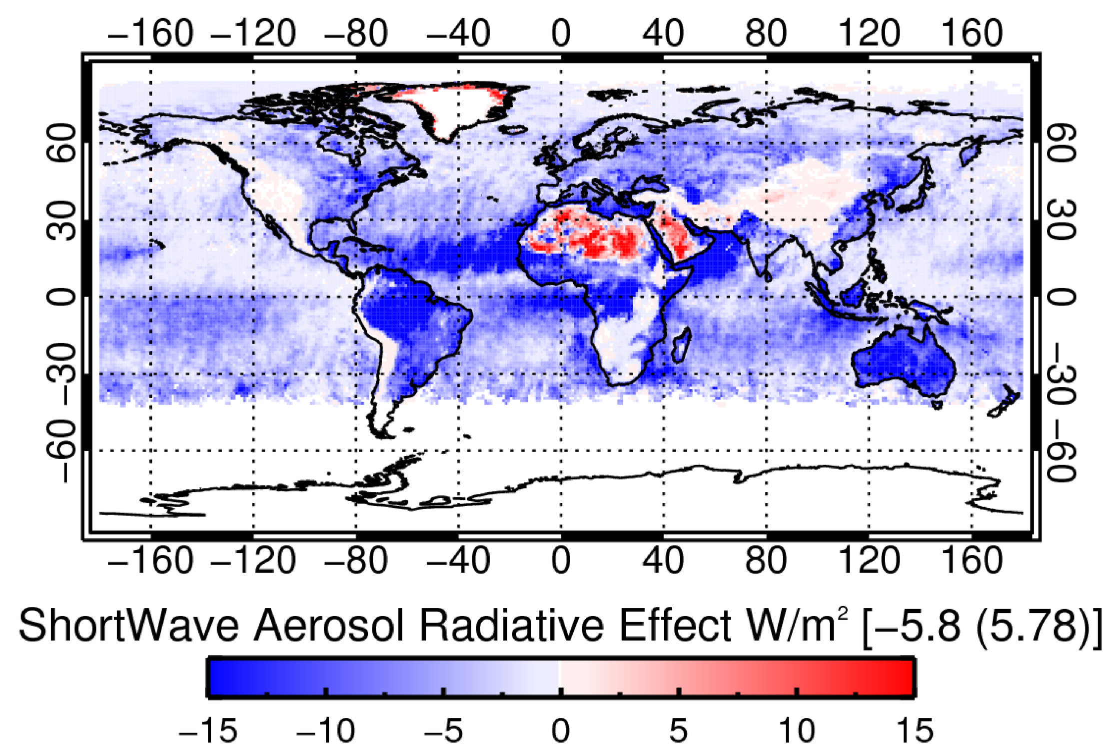
Above: Total PAR over the UK in JJA 2008 at 5×5 km resolution derived from integration over 400–700 nm. **Below**: The direct and diffuse components of that.

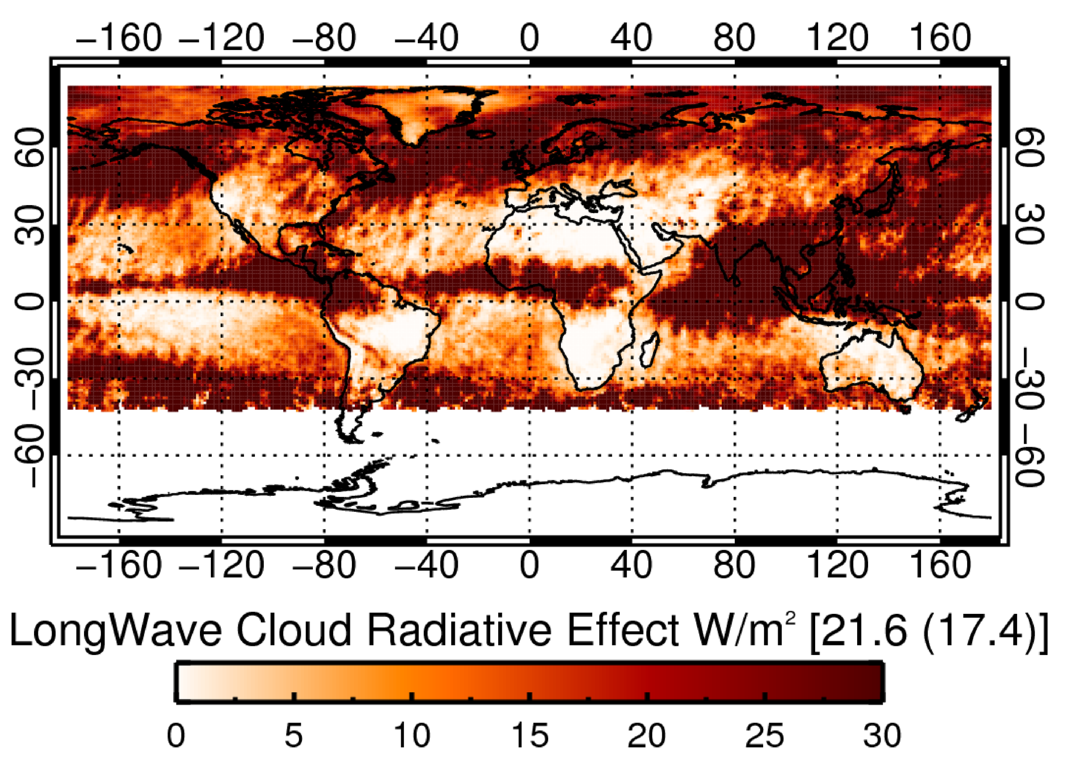


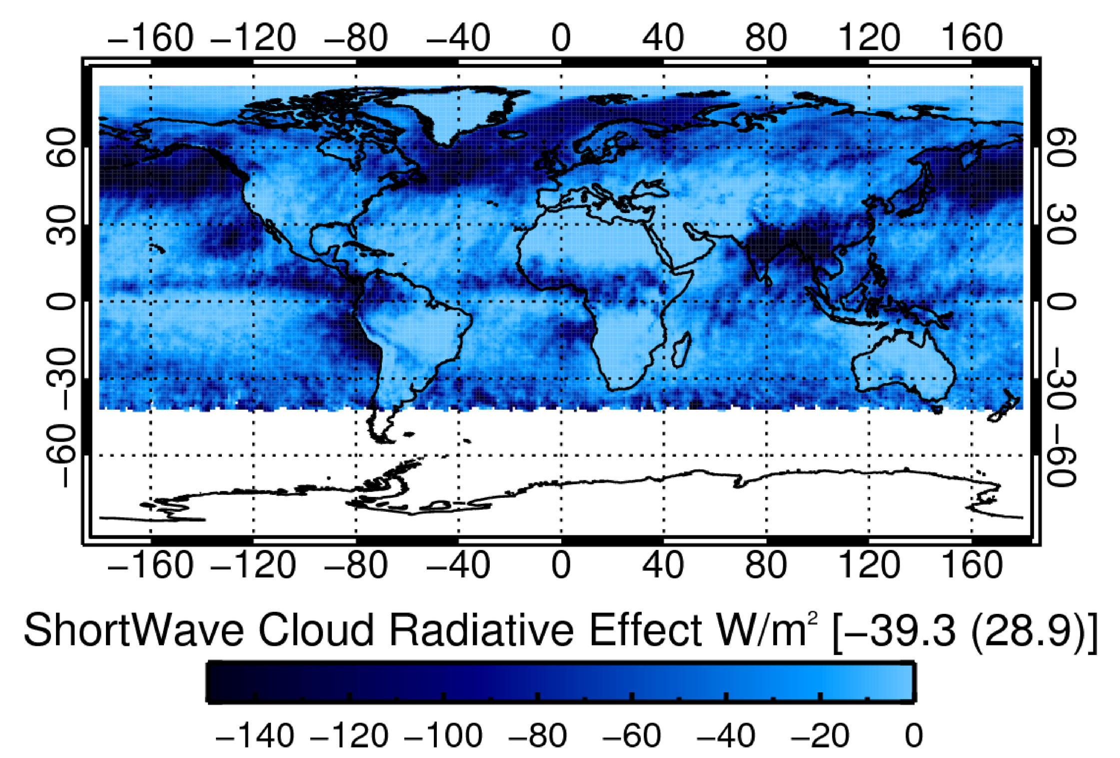
Preliminary flux estimation

BUGSRAD computes radiative fluxes at the 1-km pixel scale resolution of the satellite retrieval first assuming no clouds (clear-sky) and then using the optical property retrievals for cloud and aerosol (observed). These data are then aggregated onto a $1^\circ \times 1^\circ$ grid and averaged over JJA for 2008.

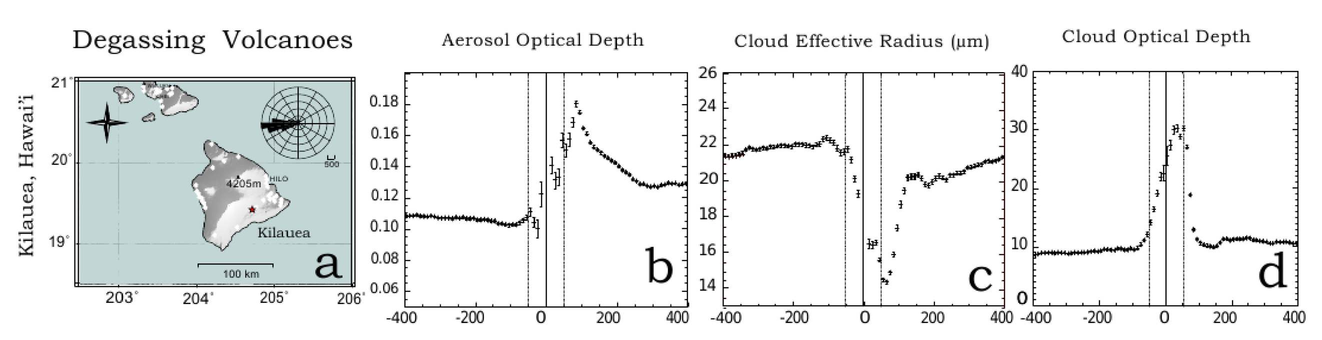
Below: Cloud radiative effect, $CRE = F_{\text{clear}} - F_{\text{observed}}$, the difference in outgoing top of atmosphere broadband radiation between clear- and all-sky conditions in the long and shortwave (left and right, respectively). Global mean values and standard deviations weighted by latitude are provided in brackets. **Right**: The same, but for a first approximation of the aerosol radiative effect.



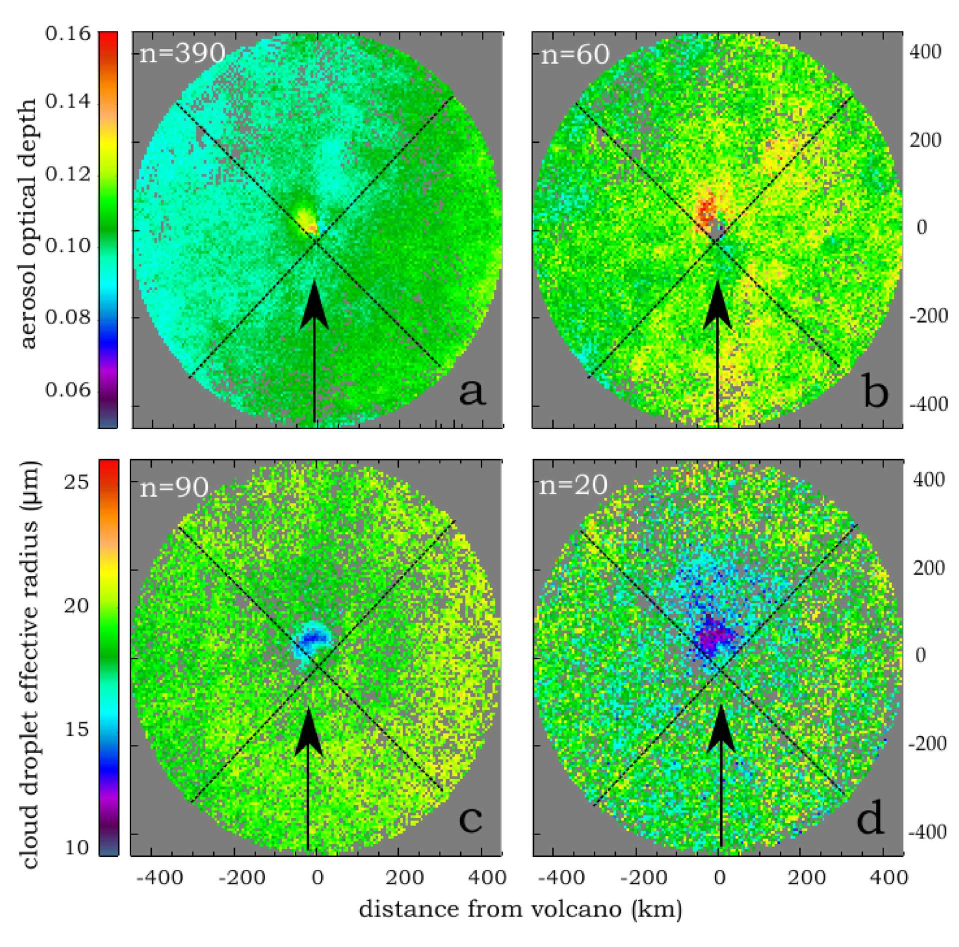




Wind-corrected aerosol fields



Above; Variation of aerosol OT (b), cloud OT (d), and cloud ER (c) up and downwind (left and right, respectively) of Kilauea, Hawai'i (a). Averages are over an arc of $\pi/2$ about the volcano vent with MODIS Aqua data for 2002–2008. Error bars show one standard error for this average. A variation on Fig. 3 from [2].
Right: Average MODIS aerosol OT (a,b) and cloud ER (c,d) around Piton de la Fournaise during inter-eruptive (a,c) and eruptive (b,d) periods, 2002–2008. The summit is the origin and arrows indicate wind direction. Originally Fig. 9 of [2].



Discussion

The two primary outputs of this project are broadband radiative fluxes and PAR. PAR is used in many applications, such as driving land-surface models, evaluating agriculture investment potential, and to calculate euphoric depth in the ocean. Broadband fluxes are used to study the climate system by quantifying the radiative effects of greenhouse gases, clouds, and aerosols. We intend to extend this product to SLSTR in an effort to continue to monitor and deepen our understanding of the Earth's climate system.

The flux fields shown are above are very preliminary and validation activities are in progress. The next step is to explore the impact of using alternative radiative transfer codes, such as [6] and DISORT [7]. These evaluations will be used to select an appropriate method for post-processing all three aerosol CCI datasets. Work on the wind-correction algorithm will begin after an issue with data coverage in urban areas has been investigated. The intention is to evaluate the full 17-year (A)ATSR data record.

References

[1] IPCC, Climate Change 2013: The Physical Science Basis.
[2] S. Ebmeir et al. (2014), doi:10.5194/acp-14-10601-2014.
[3] G. Stephens et al. (2001), doi:10.1175/1520-0469(2001)058<3391:POARTP>2.0.CO;2.
[4] D. Henderson et al. (2013), doi:10.1175/JAMC-D-12-025.1.
[5] W. Su et al. (2006), doi:10.1029/2006JG000290.
[6] J. Edwards and J. Slingo (1996), doi:10.1002/qj.49712253107.
[7] K. Stamnes et al. (1988), doi:10.1364/AO.27.002502.