OBSERVATIONS OF CHANGES IN MARINE BOUNDARY LAYER CLOUDS

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Abstract

Recent research outlined by the Intergovernmental Panel on Climate Change (IPCC) highlights the response of marine boundary layer (MBL) clouds to warming associated with increasing greenhouse gases as a major contributor to uncertainties in model projections of climate change. Understanding how MBL clouds respond to increasing temperatures is hampered by the relative scarcity of marine surface observations and the difficulty of retrieving accurate parameters remotely from satellites. In this study we combine data from surface observations with that from the International Satellite Cloud Climatology Project (ISCCP), CloudSat and CALIPSO, with a view to investigating the spatial distribution and variations in MBL cloud fraction and cloud liquid water path (LWP). These results are then compared with the treatment of MBL clouds in the UK Met Office HadGEM models. Future work will assess how variations in LWP impact the top of atmosphere radiative energy balance using data from the Geostationary Earth Radiation Budget (GERB), in order to quantify the response of MBL clouds on interannual timescales to a changing climate

INTRODUCTION

The IPCC 4th Assessment Report identifies changes in Marine Boundary Layer cloud as one of the primary contributors to uncertainty in model predictions of climate change (Randall et al. 2007). Many models predict a decrease in MBL cloud with warming leading to increased absorbed solar radiation and a positive feedback. However there is still much disagreement between individual models (Bony and Dufresne 2005). Any trend is difficult to detect in the data due to the complexity of and substantial variation between datasets. This project aims to use long-term, well calibrated datasets to separate short term variability in MBL cloud properties from longer term trends, with particular focus on their radiative properties and Cloud Liquid Water. Evaluation of model representation of cloud properties will also be undertaken, with particular focus on UKMO HadGEM2.

Initial comparison of satellite- and ground-based Low Cloud Amount (LCA) retrievals reveals substantial disagreement. Figure 1 shows seasonal average LCA from the Extended Edited Cloud Report Archive (EECRA) and ISCCP datasets. Due to the different methods of data collection, the observed differences in absolute cloud amount are to be expected between the data. However, in general, the location of maximum cloud amount, extent of cloud deck and seasonal variability do agree. Additional care must be taken with satellite-based datasets due to known discontinuities and trends caused by changing satellite coverage over the lifetime of the dataset (e.g. Clement et al. 2009). Our initial studies therefore focus on variability within the large seasonal cycle of these cloud decks.

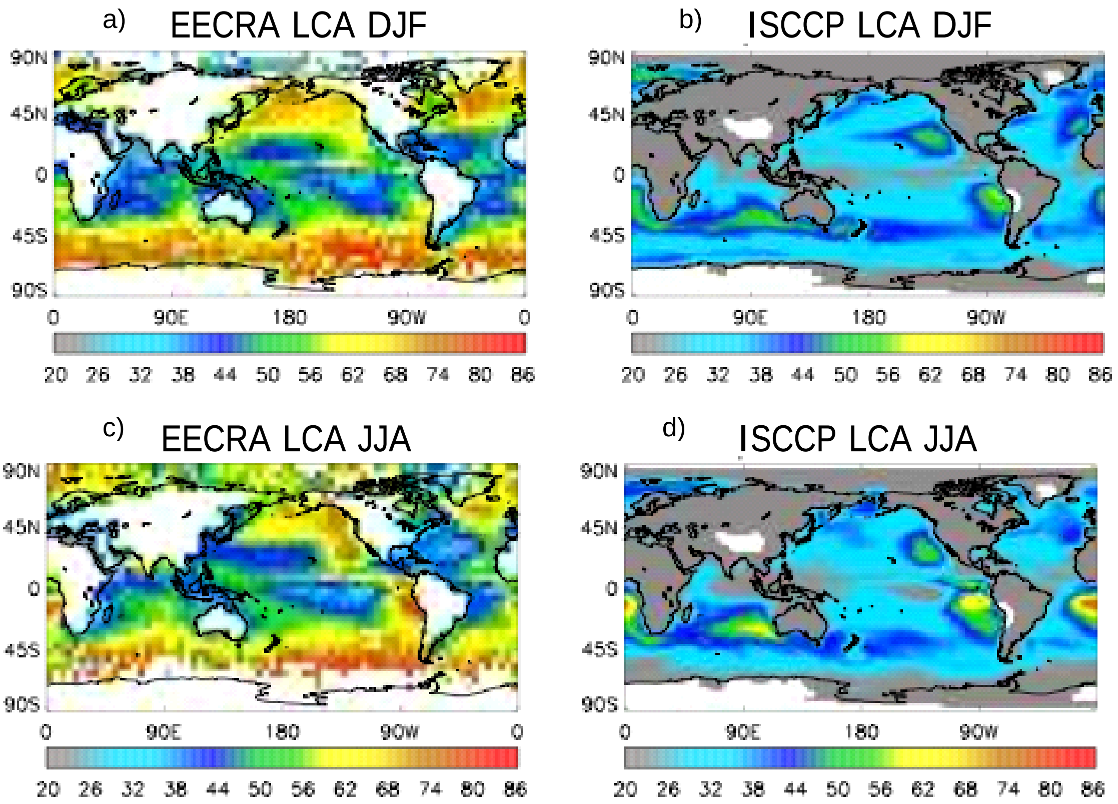

***Figure 1*: Comparison of surface- (a,c) and satellite-based (b,d) retrievals of Low Cloud Amount (%). Note the similar location and seasonal variation between datasets.**

MODEL DATA

We investigate the model treatment of MBL cloud regimes using data from an AMIP run of the UK Met Office HadGEM2 model (forced by SST) for the 20 years 1979-1998. Initial qualitative assessment reveals broad agreement with the data in terms of the large-scale position and seasonal movement of the cloud deck. However, the model tends to produce brighter clouds relative to observations, which is consistent with results from the global forecast model (Allan et al. 2007).

Figure 2 shows the model cloud amount field, averaged over the entire run, for the Stratocumulus cloud region off the west coast of Africa. The broad agreement with Figure 1 is apparent. This region has been selected to enable a more detailed future investigation of cloud radiative effects using the GERB instrument on board Meteosat-8 (Harries et al., 2005). The physical conditions giving rise to clouds with distinct radiative properties will be investigated and used to validate the model treatment of cloud regimes.

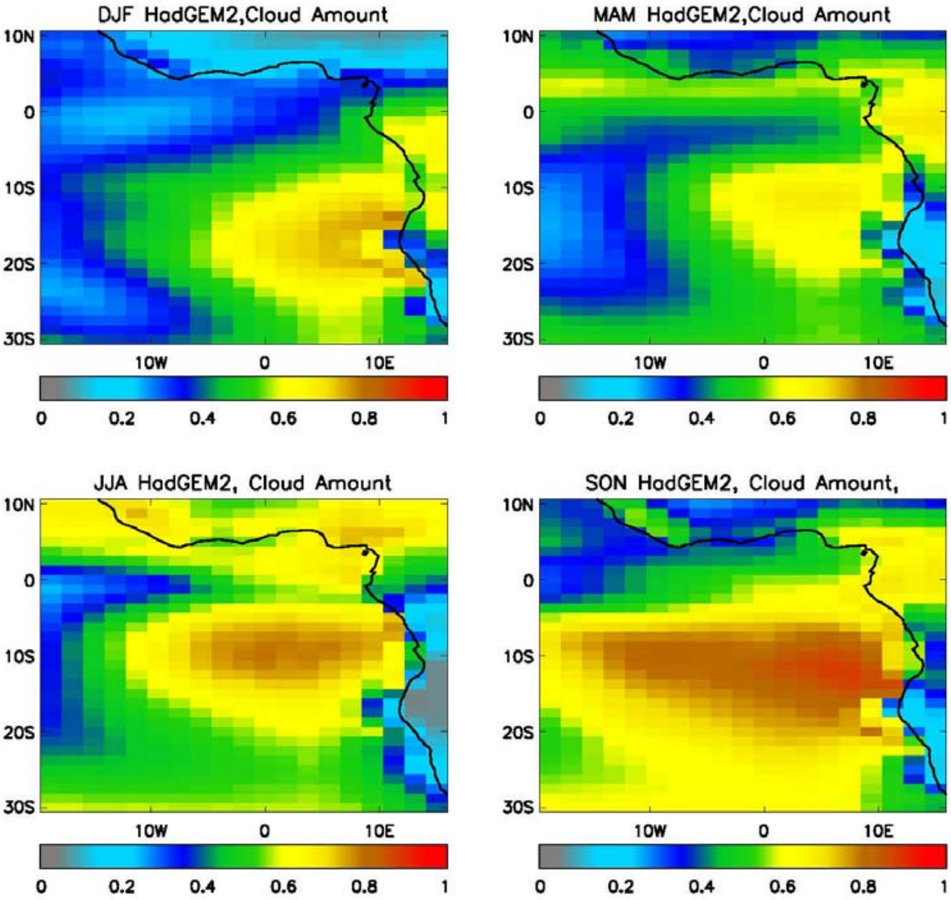

***Figure 2*: Seasonal Cloud Fraction, 1979-1998, HadGEM2 model field. The model displays qualitative agreement with both EECRA and ISCCP datasets, however, the seasonal movement of the cloud deck is not so pronounced in the model.**

RADIATIVE PROPERTIES

Small-scale cloud properties can have a large effect on the radiative properties of MBL clouds. In particular, droplet effective radius and rainfall frequency are known to significantly affect cloud albedo, however until recently, observational data was extremely sparse. CloudSat ,CALIPSO and the A-Train provide unprecedented data on vertical structure of clouds, with a high time and spatial resolution. Using information on e.g. rainfall, together with cloud radiative properties from GERB, a statistical picture of cloud properties can be built up. This information can then be used to validate model treatment of clouds.

Data from the high resolution GERB product (9kmx9km) was matched to CloudSat passes through the West African Stratocumulus (Sc) region (20W-15E, 30S-10N) for all passes during the period December 2006-February 2007. The selected GERB data are within +/- 0.1 degrees and 30 minutes of the CloudSat pass. Figure 3 shows radiative characteristics of the atmosphere in the West African Sc region. CloudSat scenes identified by CALIPSO as having a single layer of low cloud are separated into raining and non-raining scenes, with clear-sky and all single layer low cloud presented alongside.

Radiative characteristics of these scene types are presented as a frequency histograms, of the reflected shortwave radiation at Top of Atmosphere (TOA) from GERB. Figure 3 shows that, while raining scenes are vastly less common than non-raining scenes, they appear to reflect more incident solar radiation. Underlying mechanisms and potential effects of the diurnal cycle on these results are the subject of active ongoing work. This information can be fed back into the model analysis, to provide a further check on the representation of clouds.

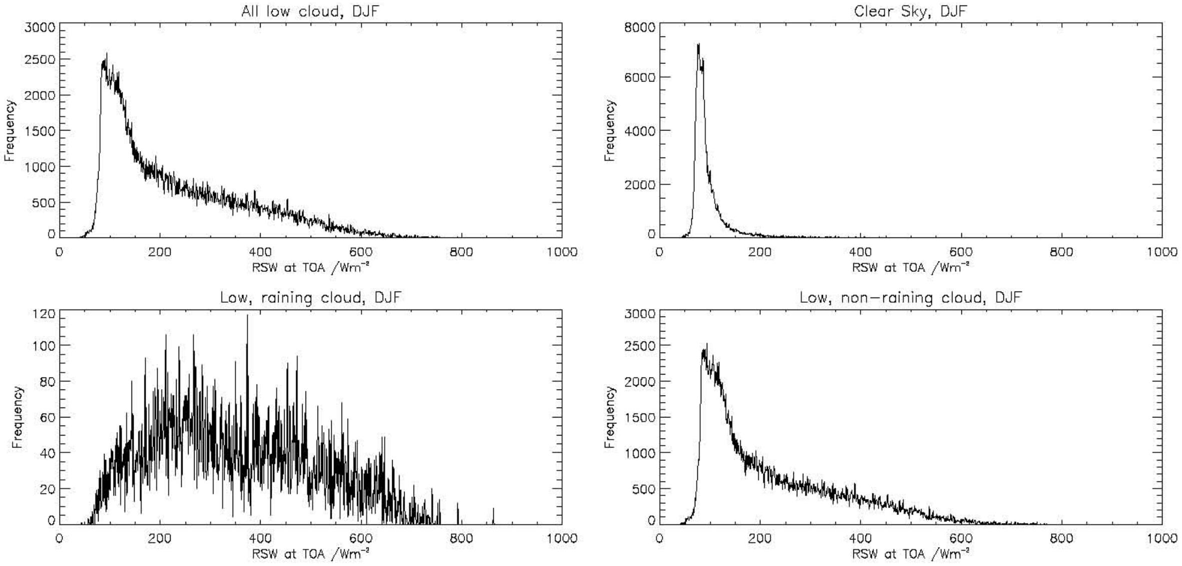

***Figure 3*: Marine Low Cloud separated into raining and non-raining regimes. Raining cloud (identified using CloudSat and CALIPSO) is in general more reflective although relatively rare. Some misclassification of cloud as clear sky, or very thin, broken cloud may be visible in the total cloud histogram.**

FUTURE WORK

The accurate representation of clouds in climate models remains an ongoing issue; however a clearer understanding of physical causes of variability in cloud properties is necessary for a more complete understanding. Future work will include investigations into the separability of physical causes of cloud variability. For example, Figure 4 shows frequency histograms describing cloud LWP for MBL clouds separated by their rainfall characteristics. A more quantitative approach to model-data comparisons will be instituted, with particular focus on statistical comparisons of cloud radiative effects under given conditions.

Figure 4 above uses LWP retrievals from MODIS on the *Aqua* satellite, which has been matched to CloudSat data. A logical extension to this work would be to include other liquid water datasets, such as those from the Special Sensor Microwave Imager (SSM/I), and to compare these results with those from recent HadGEM2 model runs.

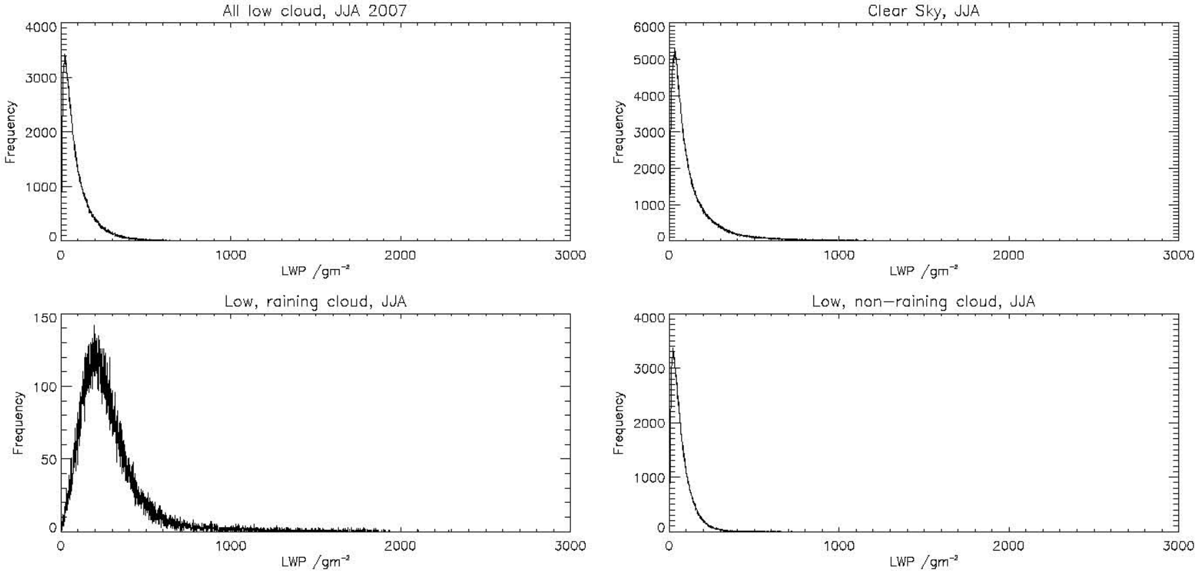

***Figure 4*: Cloud Liquid Water Path, showing the relative difference between raining and non-raining low cloud. The division criteria are the same as in Figure 3.**

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