# How ARM observations are improving cloud, precipitation and radiation prediction in the ECMWF global NWP model

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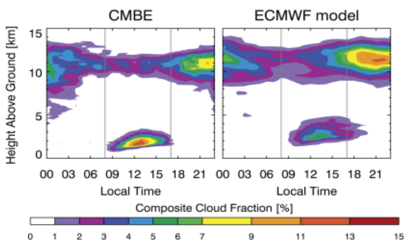
## 1. Introduction

The focus of ASR-funded work at ECMWF is process-oriented model evaluation of the global Numerical Weather Prediction model (known as the IFS) with ARM observations, to identify systematic and compensating errors relating to cloud and radiation and to inform model parameterization developments. ARM data provides the opportunity to probe the model representation of different cloud regimes in detail in different regions of the world. This is leading to increased realism of cloud, precipitation and radiation in the operational weather forecasts with relevance for other global NWP and climate models. Some of the key results from recent evaluation studies are summarized here.

## 2. Continental low clouds at SGP

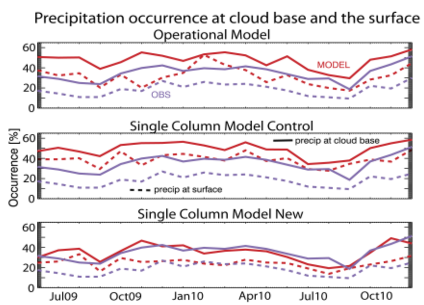



SGP observations are used to investigate a long-standing model problem of too high surface irradiance over the central U.S.A. Are low cloud errors the cause? A regime dependent evaluation for shallow Cu shows an underestimate of cloud occurrence (figure) but liquid water path that is too high, leading to good surface irradiance for the wrong reasons (a compensating error). A significant contribution to the bias instead comes from the overcast cloud regime where liquid water path is underestimated and the effective radius of cloud droplets is too high. (Ahgrimm and Forbes, 2012)

The results prompted parameterization changes to the boundary layer, shallow convection schemes and effective radius.

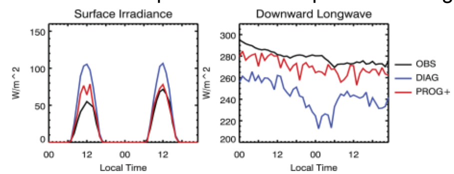
## 3. Low clouds and drizzle at Graciosa

It is common for global models to over predict the occurrence of light rain. Radar observations from Graciosa Island provide an estimate of precipitation occurrence at the surface as well as at cloud base. The figure to the right illustrates the light rain over-prediction in the IFS, and improved agreement with observations after changes to the parameterizations that control conversion from cloud water to rain, and subsequent rain evaporation. (Ahlgrimm and Forbes, 2014a)

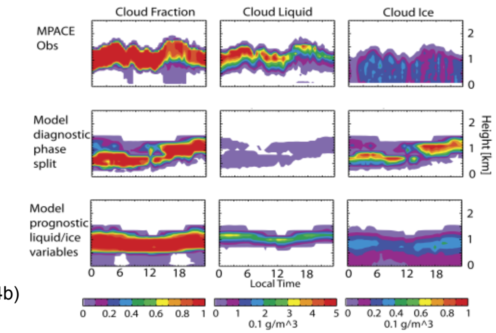



## 4. Arctic mixed-phase clouds at NSA

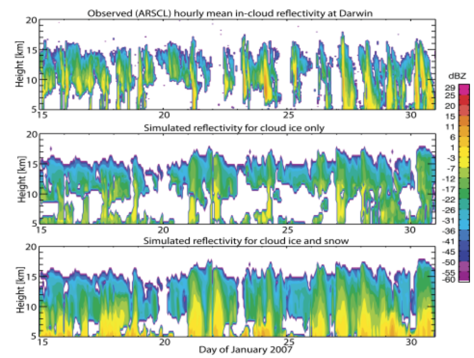
Supercooled liquid water topped boundary layer clouds are common in the higher latitudes (Arctic, N.Hem land and Southern Ocean), where radiative impacts can be large. Evaluation with NSA observations highlights the importance for radiation (fig. below) of more accurately representing the observed cloud structure with separate prognostic variables for liquid and ice compared to a single prognostic condensate variable with diagnostic phase partitioning (right figure).




(Forbes and Ahlgrimm, 2014b)




## 5. Tropical deep convective ice clouds at TWP




An accurate representation of both the cirrus anvil and precipitation in deep convection is vital for the correct radiative, hydrological and latent heating response in the tropics. In most global models cloud ice, stratiform snow and convective snow are treated as separate variables with different sub-grid fractions. TWP radar observations are used for a detailed analysis of the model (see example timeseries in figure) using several retrieval algorithms to explore uncertainty. The evaluation highlights deficiencies in the representation of ice water content, precipitation fraction, and snow evaporation. (Ahlgrimm and Forbes, 2014c)

## 6. Outlook - Variability

A recurring theme in the evaluation studies performed to date is the lack of a consistent treatment of cloud heterogeneity within a model grid box. Predicting a cloud fraction is a simple representation of grid box variability, but we need a better quantification of the heterogeneity of cloud and precipitation properties across different cloud regimes. The figure shows the fractional standard deviation dependence of cloud liquid and ice with horizontal scale and cloud fraction observed at Graciosa.