Validation of Global Weather Forecast and Climate Models Over the North Slope of Alaska Under the CCPP-ARM Parameterization Testbed (CAPT) Framework

S. Xie, S. Klein, J. Boyle, M. Fiorino, J. Hnilo, T. Phillips, and G. Potter

Lawrence Livermore National Laboratory

A. Beljaars

European Center for Medium-Range Weather Forecasts

Abstract

Data collected from the ARM Mixed-Phase Arctic Cloud Experiment (M-PACE) field campaign over the North Slope of Alaska (NSA) in October 2004 have been used to validate Arctic clouds and radiation simulated by the ECMWF weather forecast model and by two U. S. climate models, the NCAR Community Atmosphere Model (CAM3) and the GFDL Atmosphere Model (AM2). The two climate models were diagnosed in a comparable weather-forecasting framework developed for the CCPP-ARM Parameterization Testbed (CAPT), a joint effort of ARM and DOE's Climate Change Prediction Program (CCPP).

All the models show skill in predicting various cloud types observed during M-PACE; however they underpredict cloud amount in the early period of the experiment when both multilayered and boundary-layer mixed-phase clouds are present. During this period, the simulated cloud bases by the two climate models (CAM3 and AM2) are too low compared to the observations. Large error is also seen in the simulated cloud microphysical properties.

The ARM M-PACE data also reveal deficiencies in the model simulations of radiative fluxes at the surface and the top of the atmosphere that are associated with the errors in their predicted cloud fields. At the times of the boundary layer clouds, CAM3 and ECMWF considerably overestimate the outgoing longwave radiation at the top of the atmosphere and substantially underestimate the downwelling longwave radiation at the surface while AM2 shows a good agreement with the observations in these fields. Errors in the model cloud and radiation fields also can have a large impact on the simulated surface energy budget. For example, the ECMWF model exhibits a much larger energy loss (-21 W/m2) than the observed (-9.6 W/m2) at the surface during the M-PACE period.

The ARM NSA M-PACE: Oct. 5 – 22, 2004

Figure 1 Experimental layout. The two ARM sites are located at Barrow and Atqasuk; the two supplemental sites will be at Oliktok Point and the NSF Toolik Lake Field Station.

Measurements

Clouds and Cloud Microphysical Properties

- Millimeter-wavelength cloud radar
- Micropulse Lidars
- Laser Ceilometers
- Aircrafts
- Microwave Radiometers

Surface Radiation

- Radiometric Instrument Systems

TOA Radiation

- NASA-Terra and NOAA-15, -16 Satellites

Only data collected at Barrow were used in this study

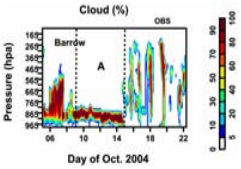
Models

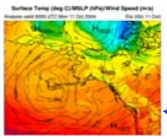
- ECMWF T511L60 Weather Forecast Model
- NCAR CAM3 T85L26 Climate Model
- GFDL AM2 Climate Model with $1.25^0 \times 1^0$ and 24 Levels

- For the climate models, a series of 72-hour runs is initialized with the NASA GSFC Data Assimilation System (DAO) at 00Z every day, which covers the period Oct. 5-22, 2004, the MPACE IOP
- A composite of 12-36 hour forecasts from the 72-hour runs is analyzed to reduce model spin-up problems and to give time for model clouds to develop
- Results at the model ocean grid closest to the Barrow site are compared with the observations

Synoptic Conditions

Barrow was covered with multilayered clouds in the mid-and low-levels in the early few days. For the period 9-14 October, persistent mixed-phase boundary layer clouds formed over ocean and advected into NSA. Scattered deep frontal clouds are seen after 15 October.





The ETA model analysis shows that the NSA was mainly affected by a high pressure system centered to the northeast of the Alaskan coast for the period when the persistent mixed-phase boundary layer clouds occurred.

Cloud Microphysical Properties

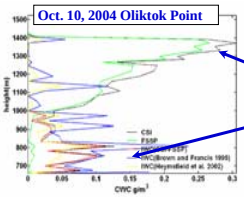


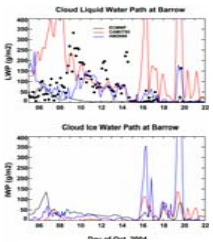
Figure 6 Comparison of bulk measurements of IWC (CSI-FSSP) against IWC estimated from 2DC using variety of habit identification and mass calculation techniques

(From G. McFarquhar et al. 2005)

- CSI: Cloud Spectrometer and Impactor probe
- FSSP: Forward scattering spectrometer probe
- 2DC: two dimensional cloud probe

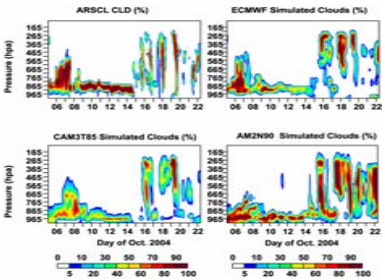
Cloud Liquid Water Path and Ice Water Path

Results show large intermodel differences in the produced LWP and IWP. CAM3 produces significantly larger LWP and smaller IWP than AM2 for the multilayered clouds and deep frontal clouds. This might be related to the difference in their microphysical parameterizations as mentioned earlier.



In the presence of single-layer clouds, both CAM3 and AM2 agree fairly well with the observations in LWP while ECMWF largely underestimates the observed LWP

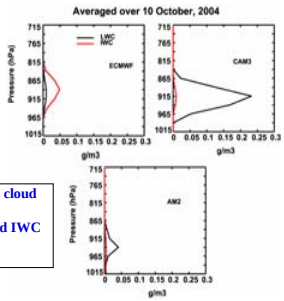
Model Simulated Clouds



- All models show skill in predicting various clouds observed during M-PACE
- Cloud bases are too low in CAM3 and AM2, and cloud amounts are largely underestimated by ECMWF and CAM3 for the boundary layer clouds
- Model frontal clouds last longer than observed

Simulated LWC and IWC

CAM3 and ECMWF use one prognostic equation to predict cloud liquid water/ice content. The distinction between water and ice phase is made as a function of temperature. In contrast, AM2 uses separate prognostic equations for predicting cloud liquid and ice. This might partially cause the intermodel difference in the simulated cloud microphysical properties.

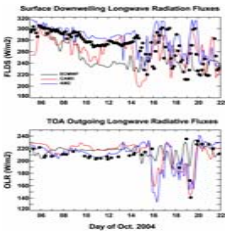


- Significant differences are seen in the cloud physical properties among the models
- The vertical distributions of LWC and IWC are significantly different from the observations

Cloud fraction seems to be decoupled from cloud waters. For example, AM2 produces much more boundary layer clouds than CAM3 while AM2 shows much smaller cloud water content than CAM3. This is probably because cloud fraction is largely dependent on RH in the models.

Downwelling Surface LW and TOA OLR

Errors in the radiation fields are closely related to errors in clouds and cloud microphysical properties. In the presence of the boundary layer clouds, ECMWF and CAM3 considerably underestimate the observed downwelling surface LW and overestimate the observed OLR while AM2 agrees well with the observations in these fields.



Future Work

- Focus on the single-layer mixed phase clouds and evaluate model microphysical schemes using aircraft data and retrieved cloud microphysical properties from cloud radar measurements
- Collaborate with parameterization developers to test new cloud microphysical schemes in both CAM3 and AM2 during the MPACE IOP under the CAPT framework

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