**P4.2** THE PERFORMANCE OF A GLOBAL AND MESOSCALE MODEL OVER THE CENTRAL ARCTIC OCEAN

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## 1. INTRODUCTION

Recent evidence has shown that temperatures in the Arctic are rising at almost twice the rate of the global average (Solomon et al. 2007) and that this increase corresponds to a decrease in both sea ice thickness and extent (Parkinson et al. 1999; Nghiem et al. 2007). This trend is predicted to continue and probably increase in the future (Holland et al. 2008), largely due to processes such as the ice-albedo feedback (Curry et al. 1996). It is important that models can simulate this region accurately and thus predict future changes in climate with confidence. The Arctic boundary layer during the summer melt and autumn freeze-up period often contains low-level cloud or fog, often with several cloud layers and associated inversions. The boundary layer processes controlling the cloud cover are not well understood and both global and regional scale climate models perform poorly over the Arctic Icecap, especially in terms of the surface flux parameterization schemes and the cloud processes (Brunke et al. 2006; Tjernström et al. 2005a).

The performance of the Met Office Unified Model (UM) and the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) is evaluated over the Arctic Icecap, during the summer months using observations from the Arctic Ocean Experiment (AOE) 2001 (Tjernström et al. 2004). The accuracy of the modeled basic meteorological parameters, the terms of the surface energy budget and cloud representation is assessed, with a view of diagnosing problems and ultimately solving them.

## 2. SCIENTIFIC BACKGROUND

The Arctic boundary layer is exceptional, in that the surface consists of only water, ice and snow and that it experiences almost continuous daylight over the summer months. During AOE 2001 the boundary layer was found to be well mixed and humid, with a surface layer close to neutral stability (Tjernström 2005b). A persistent capping inversion was found aloft, containing stratus cloud for a large proportion of the time. The boundary layer remains at a fairly constant temperature because the water and ice surface acts as a buffer against changes in air temperature. Frontal activity and wind speeds are relatively weak, although intrusions of warm, moist air from lower latitudes do occur. Open leads and melt ponds have an undoubted effect on the boundary layer. As well as being a possible source of cloud condensation nuclei, their turbulent surface fluxes differ greatly from those over the ice surface (Ruffieux et al. 1995), probably helping to maintain boundary layer relative humidity close to 100%. Entrainment from above may also act as a moisture source for these clouds.

**Figure 1**. Measurements on the icepack during AOE 2001, with the Swedish icebreaker, Oden in the background (Photo: M. Tjernström).

Several studies have highlighted the deficiencies in model simulations of the Arctic region. Walsh et al. (2002) compared Arctic climate simulations by uncoupled models from the Atmospheric Model Intercomparison Project (AMIP-II) and coupled global models from the Intergovernmental Panel on Climate Change (IPCC) and found an unsatisfactory amount of across model scatter, especially in relation to cloud cover and the surface energy budget. Brunke et al. (2006) compared bulk aerodynamic algorithms used over sea ice with data from the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment. Deficiencies were found relating to the wind stress and surface fluxes produced by the different algorithms, which caused big differences in the flux annual and diurnal cycles.

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Tjernström et al. (2005a) also used data from SHEBA to evaluate 6 Arctic Regional Climate Model Intercomparison Project (ARCMIP) models. They found only small errors in simulated surface pressure, 2m air temperature and low-level specific humidity; wind speed however, showed greater errors. The surface radiation fluxes were reasonable considering that cloud cover needs to be simulated correctly for this to be accurate. However, the turbulent heat fluxes did not correlate well at all with the observations.

## 3. DATA SETS

### 3.1. Observational data

AOE 2001 took place in the central Arctic Ocean, on the Swedish icebreaker Oden, during the summer and autumn months of 2001 (Tjernström et al. 2004). The main measurement period was on drifting sea ice, between 2-21 August 2001 (Figure 1). High frequency measurements of wind, temperature and water vapor were made using sonic anemometers and krypton hygrometers. This data was used to calculate the surface turbulent fluxes of sensible and latent heat, which along with measurements of shortwave and longwave radiation builds a complete picture of the surface energy budget. Near-surface and radiosonde observations of temperature, wind, relative humidity and pressure were also made to assist in these comparisons.

### 3.2. Model data

This investigation uses two data sets from the UM. The first was obtained from the operational global numerical weather prediction forecasts produced in 2001 (model cycle G25). It consists of 12 hour forecasts using 3 hourly observations, run from 00UTC and 12UTC analyses and sampled at 3 hour forecast intervals. Since 2001 the model has undergone a number of improvements to the numerics and physical parameterizations. The second data set contains re-runs of the forecasts using a newer version of the model (cycle G42), with initial conditions from the European Centre for Medium-Range Weather Forecasts (ECMWF) 40 year reanalysis (ERA-40). It contains daily forecasts, out to 4 days, with a time step of 15 minutes. Using both data sets in the evaluation will give an insight into whether the new version of the model has improved the simulations of the surface energy budget in the Arctic region.

The mesoscale model, COAMPS was run over the Arctic on three nested grids. The outer-most grid covers the entire Arctic region and was forced at the boundaries by ERA-40 data. The inner-most grid covers the AOE 2001 observation locations.

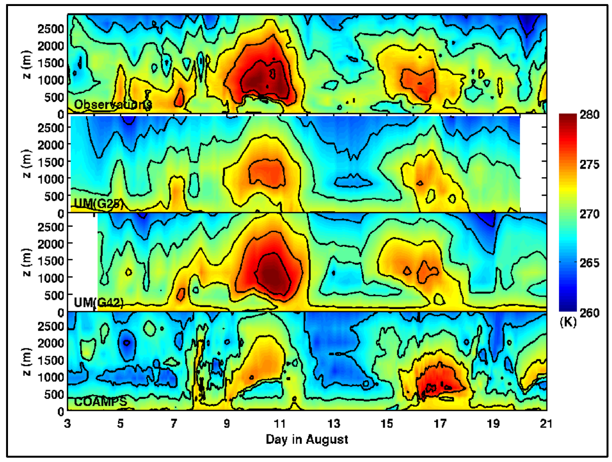


**Figure 2**. Observed and modeled air temperature, up to 3000m. Contours are at 3K intervals.

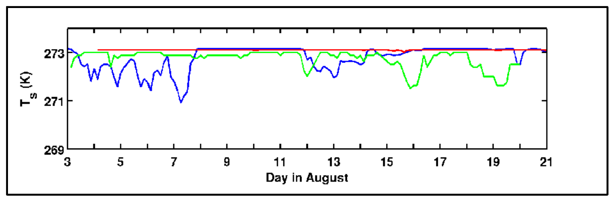


**Figure 3**. Surface ice temperature from UM(G25), UM(G42) and COAMPS.

## 4. MODEL EVALUATION

The observations show two warm periods between days 9-11 and 15-17 (Figure 2). UM(G42) and UM(G25) have captured these events with reasonable accuracy. COAMPS is less successful since the magnitude of the first warming is too low and the second one arrives too late. A cooler spell was observed between days 12-17. All models indicate cooler air aloft during this period but none adequately represent the observed surface cold period on day 15. COAMPS shows a very short-lived cold region and both versions of the UM show no decrease in temperature at all (also see Figure 4). The ice surface temperature in UM(G42) never decreases below 273.1K (the freezing point of water) however, in COAMPS it can (Figure 3), indicating inaccuracies in the UM(G42)'s near-surface air temperature are likely to be caused by its surface scheme.

The surface pressure and near-surface wind fields are reproduced with high accuracy in UM(G25) and UM(G42), indicating the large-scale weather systems are well represented (Figure 4). In COAMPS, these fields are reproduced adequately but with greater errors than in the UM due to the representation of large-scale dynamics in a mesoscale model rather than errors in model parameterizations. The two versions of the UM show very different cloud fractions and although UM(G42) is an improvement on the previous version neither reproduce the periods of clearer skies

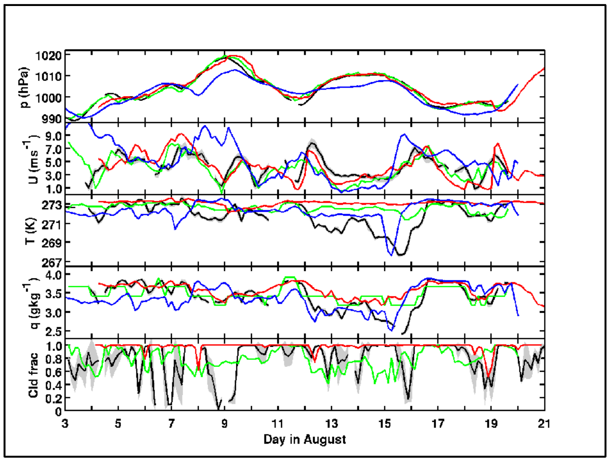


**Figure 4**. Observations and model comparisons of near-surface pressure, wind speed, air temperature, specific humidity and cloud fraction, observations (black line), UM(G25), UM(G42) and COAMPS. Cloud data is unavailable from COAMPS.

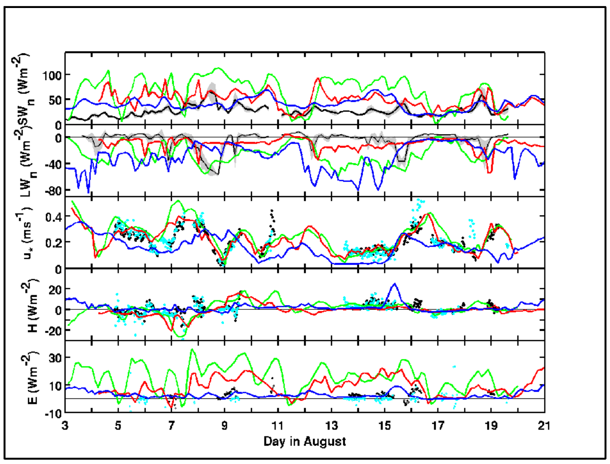


**Figure 5**. Surface flux observations and model comparisons of shortwave and longwave net radiation, friction velocity, sensible and latent heat fluxes, showing the observations (black line or black/light blue dots), UM(G25), UM(G42) and COAMPS. Positive = energy into the ground

particularly accurately.

In all three models, the surface radiation fluxes are too large in magnitude, although the sign is generally correct (Figure 5). The friction velocity and sensible heat fluxes produced by the models are reasonable but the latent heat flux in both versions of the UM is too high, indicating problems with the UM surface flux parameterization scheme.

## 5. SUMMARY

Observations from the Arctic Ocean Experiment 2001 are compared to prognostics from the UM and COAMPS. The pressure, humidity and wind fields are satisfactorily represented. The representation of cloud is unsatisfactory in both models and the latent heat flux is too large in the UM. There are also problems with the UM's representation of the ice surface and near-surface air temperatures.

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