P1.6 TURBULENT EXCHANGE OVER THE ARCTIC ICECAP

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1. INTRODUCTION

The central Arctic Ocean is a unique environment and is more sensitive to climate change than lower latitutes (e.g. Houghton et al. 2001). This is 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 (BL) 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 BL 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. 2005b).

The performance of the Met Office Unified Model over the Arctic Icecap is evaluated during the summer months using observations from the Arctic Ocean Experiment (AOE) 2001 (see Tjernström et al. 2004 for an overview). The accuracy of the surface energy budget (SEB) parameterization scheme is assessed, with a view of diagnosing problems and ultimately improving the scheme.

2. SCIENTIFIC BACKGROUND

The summertime Arctic BL is exceptional, in that the surface consists of only water, ice and snow and it experiences almost continuous daylight over this period. During AOE 2001 the BL was found to be well mixed and humid, with a surface layer close to neutral stability (Tjernström 2005a). A persistent capping inversion was found aloft, containing stratus cloud for a large proportion of the time. The BL stays at a fairly constant temperature as 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 did occur. Open leads and melt ponds have an undoubted effect on the BL. As well as being a possible source of cloud condensation nuclei, their turbulent surface fluxes differ widely from those over the ice surface (Ruffieux et al. 1995), probably helping to maintain the BL relative humidity near 100%. Entrainment from above may also act as a moisture source for these clouds.

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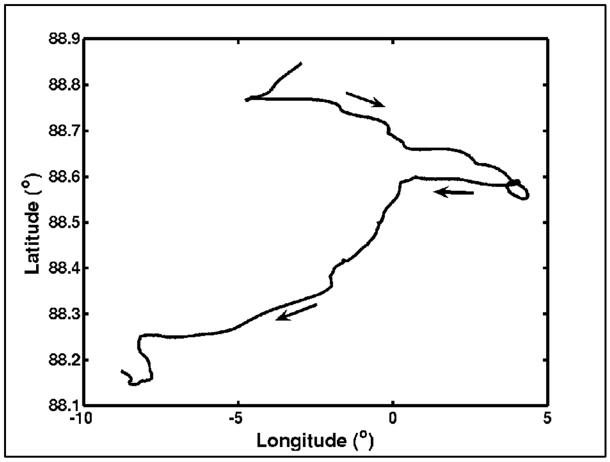

Figure 1. The drift track of the Oden during the AOE 2001 main observation period 2-21st August.

Figure 2. 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 Intercomparision Project (AMIP-II) and coupled global models from the IPCC and found an unsatisfactory amount of across model scatter, especially in relation to

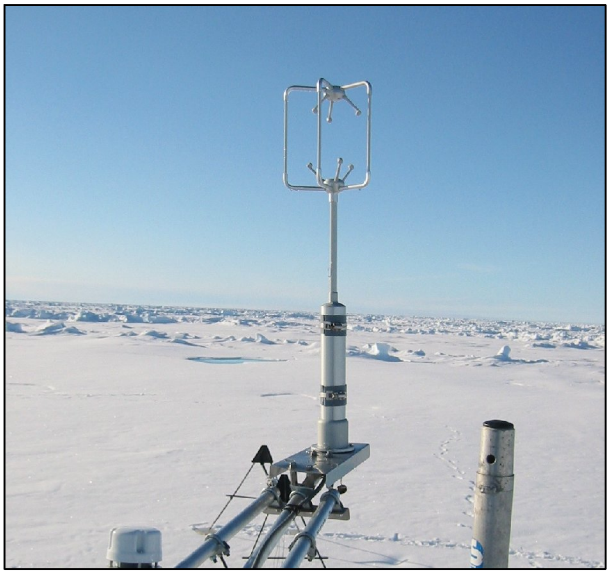

Figure 3. Sonic anemometer measurements on the icepack during AOE 2001 (Photo: M. Tjernström).

cloud cover and the SEB. 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.

Tjernström et al. (2005b) 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. The main measurement period was on drifting sea ice, over 3 weeks in August (see Figure 1). Figure 2 shows one of the meteorological measurement masts on the pack ice, with the Oden icebreaker in the background. High frequency measurements of wind, temperature and water vapor were made using sonic anemometers and krypton hygrometers (Figure 3). This data is used to calculate the surface turbulent fluxes of sensible and latent heat, along with measurements of shortwave and longwave radiation to build a complete picture of the SEB. Observations of temperature and wind profiles,

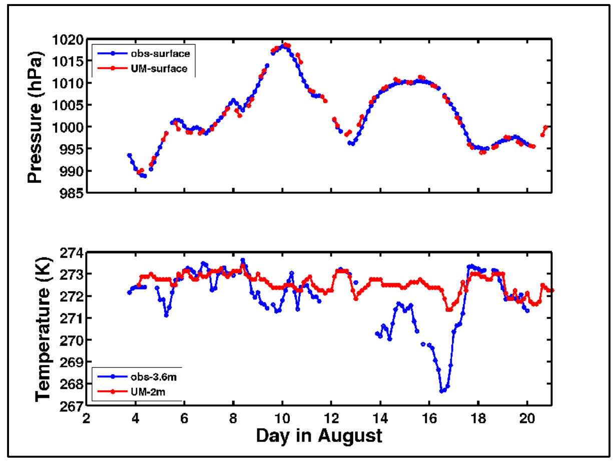

Figure 4. Comparison of Unified Model and AOE 2001 data during August 2001 - surface pressure (top panel) and near surface air temperature (bottom panel).

relative humidity and pressure were also made to assist in these comparisons.

3.2. Model data

The observations are compared to two sets of Unified Model data. The first data set is from the operational global NWP forecasts from 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 at T+3, 6, 9, 12 hours. Since 2001 the global operational NWP 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. It contains daily forecasts, out to 4 days, with a time step of 15 minutes.

Both data sets cover the entire August ice drift observation period. 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 SEB in the Arctic region.

4. MODEL EVALUATION

Initial comparisons using the 12 hour forecasts are shown in figures 4, 5 and 6. Comparisons with the re-run model data are planned for the coming months. The close correlation in the pressure field between the model and the observations indicates the model is capturing the large-scale dynamics very well. There are similarities been the model and observational near surface air temperature, but it is not as well simulated as the pressure field (Figure 4). For example, the dip in temperature on the 16^{th} is apparent in the model temperature, but the magnitude of the change is not well simulated. Relative humidity, wind speed and radiation

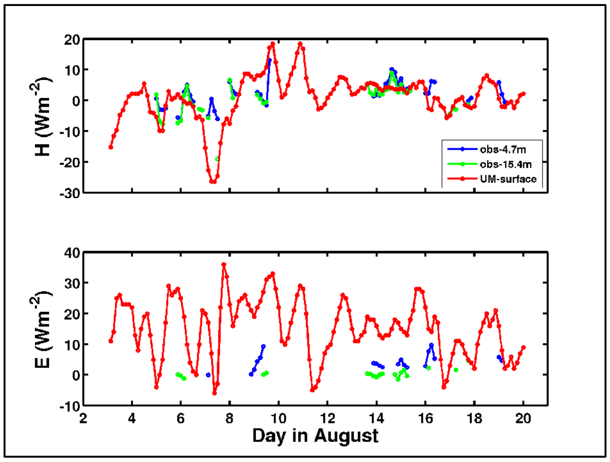

Figure 5. Comparison of Unified Model and AOE 2001 data during August 2001 - sensible heat flux (top panel) and latent heat flux (bottom panel).

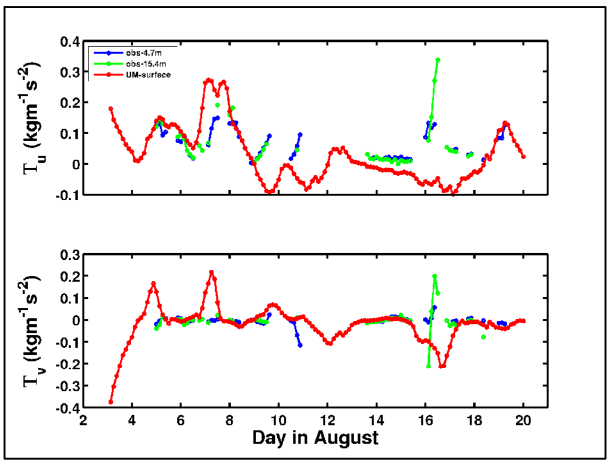

Figure 6. Comparison of Unified Model and AOE 2001 data during August 2001 - U direction wind stress (top panel) and V direction wind stress (bottom panel).

diagnostics show similar levels of accuracy (not shown).

Figure 5 shows the observed and simulated sensible and latent heat fluxes. The model simulates sensible heat fluxes of approximately the correct magnitude, but the flux variations are not well represented. The latent heat flux however seems to follow the trend in the observations quite closely, but the magnitudes of the simulated fluxes are much larger than the observations. Brunke et al. (2006) Tjernström et al. (2005b) both found that for at least some months the latent heat fluxes are vastly overestimated by models compared to the SHEBA data set. Overall, the wind stress comparisons (Figure 6) are of approximately the correct magnitude, but many of the simulated variations do not match the observations.

5. SUMMARY

The Arctic Ocean Experiment 2001 measurements are compared to output from the UK Met Office Unified Model. The observational data set includes measurements of turbulent fluxes and near-surface profiles of mean meteorological parameters over the Central Arctic ocean during the summer melt and autumn freeze-up period. The performance of the Unified Model over the central Arctic region is evaluated, with emphasis on the surface energy budget and flux parameterization schemes.

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