# 61349 A NEW APPROACH FOR OBTAINING ADVECTION PROFILES: APPLICATION TO THE SHEBA COLUMN

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## 1. Introduction.

The Surface Heat of the Arctic Ocean (SHEBA) field experiment was designed to provide a comprehensive dataset for studying the sea ice-albedo and cloud-radiation feedbacks over the central Arctic using a column approach. Due to the prohibitive cost, the advective tendencies required to close these budgets were not observed. To address this need, advective tendencies of temperature and water vapor from operational forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF) were archived for use in SHEBA single-column model (SCM) simulations.

The adequacy of the ECMWF SHEBA advection dataset has not been rigorously analyzed up to this point. Bretherton et al. (2001) showed that the monthly-averaged physical and advective tendencies were generally in balance, indicating there was no large systematic drift in the model variables. However, this balance does not guarantee that errors in the advective tendencies are small, as biases in the physical and advective tendencies may offset.

In this study, we demonstrate deficiencies in using the ECMWF SHEBA advections to directly force SCM simulations. We develop a technique to nudge the predicted ECMWF advective tendencies to observed time-averaged vertically-integrated (TAVI) heat and moisture budgets. This approach is similar tothat of Zhang and Lin (1997), who constrained a network of measurements to observed vertically-integrated budgets. However, the approach here interfaces predicted advective tendencies with the observed budgets, and thus requires additional techniques to temporally and vertically distribute errors in the TAVI ECMWF advections. We then demonstrate how using the corrected advections allows for a less ambiguous evaluation of SCM results.

## 2. Evaluation of the ECMWF advections.

Profiles of predicted temperature, T, and water vapor mixing ratio, q, were archived from successive runs of the ECMWF model version 13R4 for the SHEBA year (which was improved Feb. 2000 to produce the equivalent of a “reanalysis”). A continuous timeseries was developed by concatenating the 12-35 hour forecast for each day. A check for self-consistency within the timeseries reveals deficiencies.

Monthly TAVI total, physical, and 3-D advective T and q tendencies are derived as a residual from observed heat and moisture budgets and used to evaluate and correct the ECMWF advective tendencies. These budgets are determined from an array of SHEBA observations. The ECMWF 3-D T and q advections are similarly time-averaged and vertically-integrated for a direct comparison with the advections inferred from observations. A comparison of these advective terms is given in Table 1. The monthly TAVI ECMWF advections have a warm, moist bias relative to the derived advections during the April-July period of SHEBA.

## 3. Correction of the ECMWF advections.

An algorithm is developed to correct the ECMWF advections that varies temporally and vertically while constraining the advections to the observed budgets. Since the observed budgets are time-averaged and vertically-integrated, a method for partitioning the correction temporally and vertically is determined. This approach is based on the relation that the error in the total tendencies is equal to the sum of the error in the physical and advective tendencies.

A new data set of SHEBA 3-D T and q advections is calculated by adding a correction term to the original ECMWF advections. The correction term is a function of time and vertical level and is given by the difference between errors in the ECMWF physical and total tendencies. Errors in the total tendencies are directly calculated from SHEBA sounding measurements. Errors in the physical tendencies are determined by assuming that the error in the TAVI ECMWF physical tendencies is proportional to the magnitude of the instantaneous ECMWF physical tendency.

## 4. Evaluation of the corrected advections.

Simulations are conducted with the Arctic Single-Column Model (ARCSCM; Morrison et al., 2003). Prognostic variables include temperature and water vapor, cloud water, cloud ice, rain, and snow mixing ratios. Tendencies resulting from cloud microphysics, convection, shortwave and longwave radiative transfer, and turbulent mixing are predicted. Initial and boundary conditions are specified from SHEBA observations.

Month-long simulations are performed with ARCSCM for April, May, June, and July using the original ECMWF advections and the corrected data set, these

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*Corresponding author address:* Hugh Morrison, Program in Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO 80309; e-mail: hugh@monsoon.colorado.edu two sets of simulations are referred to as “baseline” and “corrected”, respectively. The baseline results are generally too warm and moist with the exception of the June simulation. These results are in overall agreement with the biases found in the ECMWF advections given in Table 1. Plots of RMS T and q error (Figure 1) show that, with only a few exceptions, the biases are reduced across the profile in each month using the corrected advections. A general reduction of biases regardless of their sign suggests that the vertical and temporal distribution of the advection is improved with the correction. Biases in the precipitation and liquid water path (LWP) are also reduced, with the exception of the mean LWP in April and May (Table 2).

**Discussion and conclusions.**

An inherent difficulty encountered in using an SCM is differentiating biases associated with the physical parameterizations from biases associated with the model forcing. Using the corrected advections to reduce uncertainty in evaluating the model parameterizations is demonstrated by an analysis of the simulated LWP (see Table 2). The monthly mean LWP obtained from the baseline and corrected simulations reveals two interesting results. In spring (i.e. April and May), the simulated LWP in the corrected run is degraded compared to the baseline values, even though errors in the predicted T and q profiles and precipitation are reduced, thereby revealing deficiencies in the model that would otherwise appear to be less substantial. In contrast, use of the corrected advections markedly improves the predicted LWP in July. This suggests that much of the bias in the baseline simulation is associated with the advective forcing, rather than the model physics, since the T and q profiles and precipitation are simultaneously improved along with the LWP.

Nudging the advection towards the observed budgets eliminates a first order source of error in the model and subsequently reduces model drift. By constraining drift, the physical parameterizations are allowed to respond to a more realistic set of conditions. Since the advection terms are being nudged, rather than the T and q directly, the model profiles are allowed to vary more freely in response to the physical parameterizations. Direct nudging of the temperature and water vapor profiles introduces a term with no corresponding physical process and limits feedbacks between the parameterizations. If the nudging of the predicted T and q towards observations is coupled to the model physics and treated as an advective term, this problem is circumvented, but then model drift is allowed to feedback on the forcing, resulting in large errors in rate-driven processes (e.g. precipitation). The corrected advections presented here do not depend on the predicted T and q profiles. Use of these advections simultaneously reduces model drift and tendency inputs (i.e. rates), as evidenced by the improved precipitation. Minimizing both of these sources of error is necessary in SCM simulations, since many of the physical parameterizations depend on both the state variables and their associated tendencies.

This correction algorithm may be applied to any numerical weather prediction model output, but requires an extensive observational data set. The algorithm may also be modified to correct the 2-D (horizontal) advection. The corrected advections described here are best suited for long-term simulations. Potential applications include coupled sea ice-atmosphere simulations over an annual cycle or the evaluation of model parameterizations in a statistical context.

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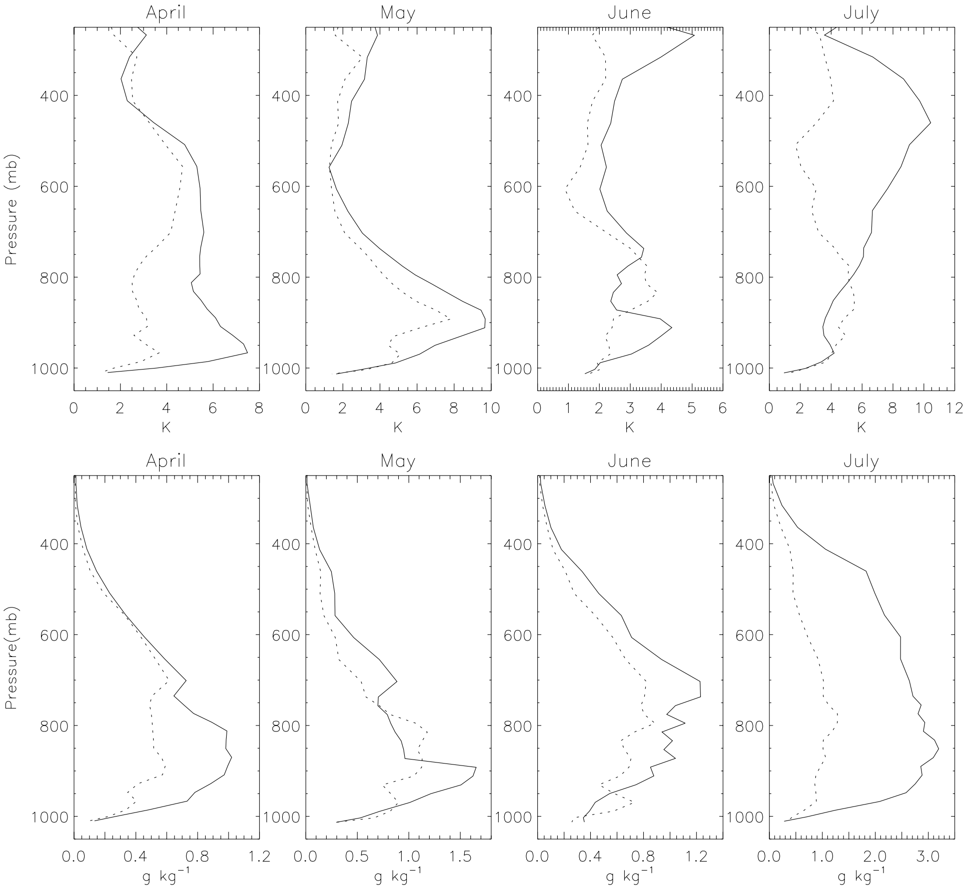
**Table 1.** Comparison of TAVI 3-D T (W m$^{-2}$) and q (10$^{-3}$ g m$^{-2}$ s$^{-1}$) advection. “Observed” indicates the advections derived from the observed budgets.

| Month | Tadv Observed | Tadv ECMWF | Tadv Error | qadv Observed | qadv ECMWF | qadv Error |
|---|---|---|---|---|---|---|
| April | 92.92 | 114.59 | 21.67 | 6.23 | 8.33 | 2.10 |
| May | 106.63 | 108.14 | 1.51 | 5.80 | 8.50 | 2.70 |
| June | 69.00 | 76.44 | 7.44 | 4.51 | 5.01 | 0.50 |
| July | 36.31 | 52.62 | 16.31 | 11.38 | 26.90 | 15.52 |

**Table 2.** A comparison of modeled and retrieved/obs. mean LWP (g $m^{-2}$) and liq.-equivalent precipitation (cm).

| | LWP | | | Precipitation | | |
|---|---|---|---|---|---|---|
| Month | Retrieved | Baseline | Corrected | Observed | Baseline | Corrected |
| April | 20.7 | 8.0 | 0.8 | 1.47 | 1.84 | 1.37 |
| May | 35.4 | 32.7 | 21.5 | 1.00 | 1.92 | 1.08 |
| June | 62.7 | 64.5 | 63.0 | 1.34 | 2.59 | 2.31 |
| July | 70.0 | 194.7 | 94.5 | 3.52 | 7.36 | 4.97 |

**Figure 1.** RMS error in the predicted T and q profiles for the baseline (solid) and corrected (dotted) simulations.



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