P3.4 SURFACE CLOUD-LONGWAVE RADIATION RELATIONSHIPS AT SHEBA SITE FROM A NEURAL NETWORK APPROACH

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## 1. INTRODUCTION

Clouds play an important role in the Arctic climate, especially in the ice-albedo and cloud-radiation feedback mechanisms. Those feedbacks are believed to be responsible for the polar amplification of global warming, and make the Arctic the most sensitive area to the global climate change. Some of the changes observed during recent decades in the oceanic and terrestrial northern high-latitudes are summarized in Serreze et al. (2000). There is significant warming in the central Arctic, downward trends in sea-ice cover, and negative snow anomalies over both continents. Arctic cloudiness has also changed in the last two decades based on the satellite derived data sets (Wang and Key, 2003; Comiso, 2003; and Schweiger, 2004).

Our understanding of the cloud-radiation interactions and feedbacks in the Arctic is, however, still limited by data sparsity and/or by poor spatial and temporal sampling. Recently available Arctic data from Surface Heat Budget of the Arctic Ocean (SHEBA) project offer new opportunities to evaluate the relationships between cloud properties and radiative forcing (Shupe and Intrieri, 2004). Even though the record length and spatial representation are limited, these observations are believed to be the most accurate and comprehensive measurements with a high temporal resolution in the Arctic.

In this study, we use the SHEBA data set to discuss the relationships between cloud parameters and longwave cloud radiative forcing obtained from a neural network (NN). The variables used here are cloud fraction (CLD), cloud base height (CBH), cloud base temperature (CBT), liquid water path (LWP) and longwave cloud radiative forcing ($CF_{LW}$). The preliminary results are presented briefly in this paper. Our NN derived sensitivities between $CF_{LW}$ and other cloud parameters are compared with those from Shupe and Intrieri (2004). These sensitivities are the controlling factors for feedbacks. Quantified relationships will help us to improve our understanding of future climate change. The principal objective of this study is to examine the sensitivity between longwave cloud forcing and cloud parameters and to quantify some of these relationships.

## 2. Methodology

Neural network model is a powerful statistical model which is widely used in classification, pattern recognition and other scientific areas. Most applications, however, have focused on the direct output of the NN. In this study, we are looking at the Jacobian matrix within the neural network, which contains the first derivatives of a given output variable with respect to a given input variable. This, by definition, can be interpreted as the sensitivity of longwave cloud forcing (output variable) to cloud parameters (input variables).

The advantage of this neural Jacobian is that it gives a direct statistical evaluation of the multivariate and nonlinear sensitivities, which depends on each situation of input and output variables (Aires and Rossow, 2003). To estimate the sensitivities of $CF_{LW}$ with respect to a given cloud parameter, we use a neural network model with one hidden layer.

## 3. RESULTS

In this section we present the relationships between each pair of $CF_{LW}$ and other cloud parameters. In Figure 1, the histograms of the Jacobians from a NN with $CF_{LW}$ as output and one of CLD, LWP, CBH, CBT as input are plotted. A distinguishable bimodal distribution of the sensitivities characterizes the relationships between each pair of the variables.

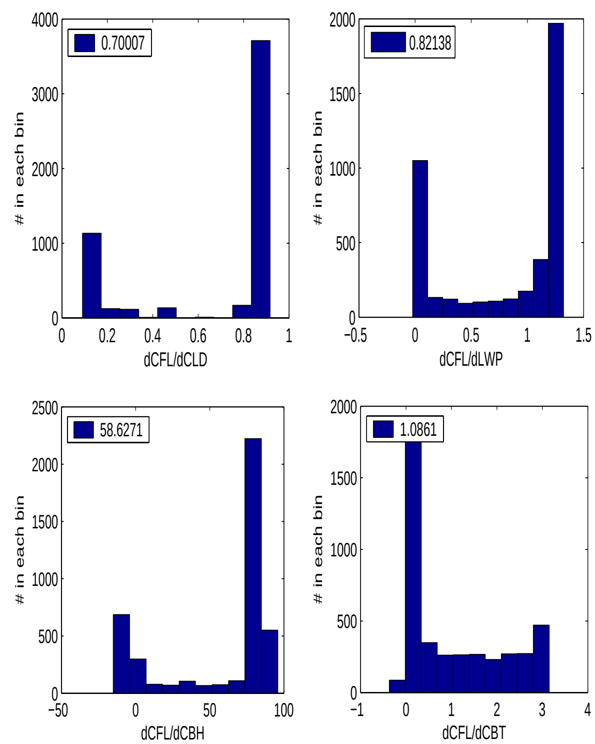


Fig. 1 Jacobian histograms from left to right, top to bottom: $CF_{LW}$ with respect to CLD, LWP, CBH and CBT.

The mean sensitivity is indicated by the number inside a box in each histogram plot. For example, mean $dCF_{LW}$/

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dCLD is 0.7 W $m^{-2}$ $\%^{-1}$ (i.e. each percent change in cloud fraction corresponds to a 0.7 W $m^{-2}$ change in longwave cloud radiative forcing). The bimodal distribution, however, indicates that this mean state does not exist very often.

The characteristics of each peak in the histogram are examined by looking at the distribution of data points in terms of the time of a year and of the absolute values of the input variable. The peak with low sensitivity near zero in the relation between $CF_{LW}$ and LWP corresponds to a high liquid water path regime mainly occurring during the warm season (Fig. 2 top panel). The minimum value of LWP in this regime is 55 g $m^{-2}$. The peak with high sensitivities is related to a low liquid water path regime during winter and spring seasons (Fig. 2 bottom panel). The negative values in LWP are due to calculation error. These two regimes with different sensitivities are consistent with the results in Shupe and Intrieri (2004). When liquid water path is high (> 55 g $m^{-2}$), clouds behave as blackbodies, and additional changes in LWP have little effect on longwave cloud forcing any more. On the other hand, however, the sensitivity is high when liquid water path is low, i.e. not saturated, and increases as liquid water path increases.

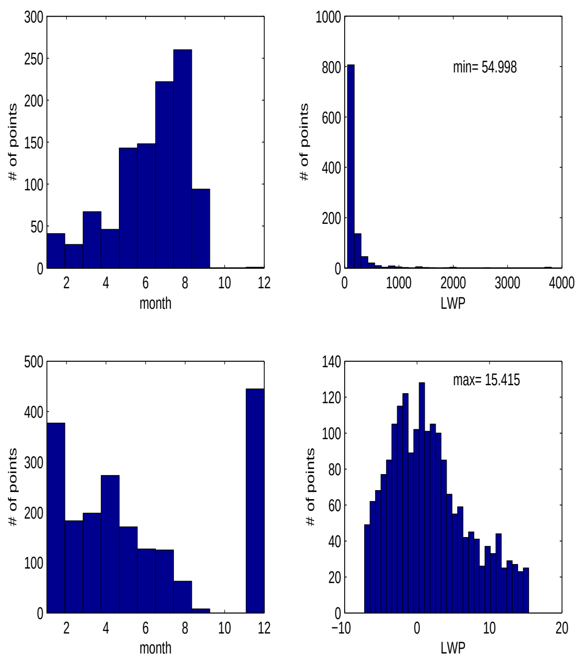


Fig. 2. Data point distributions for the peak with low sensitivity (top panel) and the peak with high sensitivity (bottom panel) corresponding to histogram of $dCF_{LW}$/dLWP in Fig. 1.

Similarly two distinct regimes are found in the relationships for the other three pairs of variables (Figures not shown). In general, clouds with low base height (< 1 km) and medium range of base temperature (-35 °C ~ -15 °C) has large impacts on longwave cloud radiative forcing. When clouds are high and cold, changes in those two cloud parameters do not affect $CF_{LW}$ much. Another group of cloud, those with high base temperature (-8 °C ~ 2 °C) mainly occurring in summer, also has a near zero sensitivity. We suspect that this is related to conditions in summer in which the lower 1~2 km atmosphere a nearly isothermal or at least neutrally stable, and low water cloud is the dominant cloud type.

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