Annual Report for Period: 01/2001 - 12/2001
Principal Investigator: Key, Jeffrey R.
Organization: U of Wisconsin Madison
Title:
Antarctic Cloud Properties and Their Effect on the Surface Energy Budget

Submitted on: 12/26/2001
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Project Participants

Senior Personnel

Name: Key, Jeffrey
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Pavolonis, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
Mr. Pavalonis came to the University of Wisconsin from Penn State University in September 2000 (last project year) to pursue a Master's degree. He is involved in modeling the the effect of clouds on the surface energy balance, using a radiative transfer model and a regional climate model.

Name: Wang, Xuanji
Worked for more than 160 Hours: Yes
Contribution to Project:
Xuanji Wang is a PhD student and is assisting with the processing of our long-term satellite data set, including a climatological analysis of cloud and surface properties.

Undergraduate Student

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Two graduate students at Boston University were involved in the project until it was tranferred to Wisconson nine months into the first year. Adeline M. Wong investigated the effects of clouds on the surface temperature of sea ice from the perspective of remote sensing applications. Yufang Jin studied the influence of heat advection on surface temperature of coastal Antarctica. These two students remained at Boston University and are no longer involved in the project.

Activities and Findings

Research and Education Activities:

Note: This is an annual report for the third project year. This is officially the final year, though we have requested a one-year no-cost extension because of delays when the project was transferred from Boston University to the University of Wisconsin-Madison in the fall of 1999.

Research performed to date has focussed on the acquisition of surface meteorological and radiation data for Antarctic stations, comparison of surface radiation to satellite-derived quantities, the role of heat advection in explaining the differences between the clear and cloudy sky surface temperature, a comparison of two satellite-derived cloud and radiation data sets, the theoretical and observed radiative effects of clouds on the

surface radiation budget, and the assimilation of satellite-derived cloud and surface properties in a regional climate model. The region of interest is the continent of Antarctica and the surrounding ocean.

Surface observations of the energy budget components are essential for validating models and satellite retrievals. We have obtained a variety of meteorological station data from scientists around the world. Most of the meteorological stations are located along the Antarctic coast, except for South Pole Station and the Automatic Weather Stations. In all, data have been acquired for 34 meteorological stations on the Antarctic continent.

One goal of the project is to compile a climatology of cloud properties such as cloud amount, height, phase, and optical depth based on satellite data (AVHRR). We have evaluated the polar portion of the International Satellite Cloud Climatology Project (ISCCP) cloud product through comparisons to surface observations and to our own satellite retrievals of cloud and surface properties. We previously identified a number of deficiencies in the ISCCP product at high latitudes, but have also found that the new 'D' data set is a significant improvement over the original 'C' product.

Surface and top of the atmosphere radiative fluxes and cloud forcing have been computed from the ISCCP D1 product for the period 1986-1994. Ancillary data include temperature and humidity profiles from the TOVS Path-P Polar Pathfinder data set, when and where available.

We have extended the standard AVHRR Polar Pathfinder data set (available through the National Snow and Ice Data Center) to include cloud properties and radiative fluxes. To date we have processed data for 1982-1993; processing of 1994-1999 is underway. Comparisons are being made with the ISCCP-based flux product described above.

We have recently developed a near real-time product from the AVHRR similar to the extended AVHRR Polar Pathfinder product. Surface, cloud, and radiative properties are computed once-daily at a 25 km resolution, centered on 12Z, for both polar regions. Plots of all parameters are now available on the web.

Our primary data product will be a multi-year suite of surface energy budget parameters generated with a regional climate model that incorporates satellite-derived cloud and surface properties. We have chosen the ARCSyM model for this task. Modifications of the model for satellite data assimilation are underway. The task is complicated by the fact that the satellite product provides data at two local solar times each day rather than at two fixed GMT hours. We anticipate completing model modifications in the next 2-3 months, after which a multi-year data set of the surface energy budget over Antarctica will be generated.

Findings:

Our hypothesis is that the primary effect of clouds on the surface energy budget is a result of their radiative effect, often called 'cloud forcing', rather than associated changes in heat and moisture advection. This has recently been shown to be true for data collected during the Surface Heat Budget of the Arctic (SHEBA) experiment (O. Persson, pers. comm.). Daily synoptic and radiation data from Neumayer Station have been investigated to better understand the relationship between surface air temperature, cloud fraction, and wind speed. The following observations have been made:

* Generally, the surface air temperature increases with an increase in cloud amount during the winter, illustrating the warming effect of clouds in the absence of solar radiation.

* The temperature-cloud relationship is more complicated in summer with competing cooling and warming effects of clouds. Both positive and negative correlations can occur. The surface temperature is also affected by cloud optical depth, cloud height, heat and moisture advection.

* A strong positive correlation exists between the surface air temperature and wind speed, especially in winter. It is also obvious that cloud fraction increases with increasing wind speed, which explains (in part) the strong temperature-wind relationship.

* The pattern of changes in net radiation does not agree with that of surface temperature, though it was observed that the surface temperature responds to changes in surface net radiation after approximately one day.

Both heat and moisture advection exhibit a positive correlation with cloud fraction, which is evidence of the fact that at high latitudes cloud formation is controlled primarily by the large-scale horizontal transport of heat and moisture. So while the cloud radiative effect may be the dominant process in controlling surface temperature and the energy budget overall, the relative contribution of advection must also be considered.

Sensitivity studies done with a radiative transfer model showed that cloud fraction, cloud optical depth, and surface reflectance have a significant influence on the surface radiation budget of Antarctica. Any changes in these parameters can mean the difference between clouds

having a warming or a cooling effect on the surface.

Cloud forcing computed using both the ISCCP cloud product and the extended AVHRR Polar Pathfinder data set have shown that clouds have a warming effect on the surface (positive cloud radiative forcing) at all times of the year over the Antarctic continent, at least on a monthly time scale. This is in contrast to the global effect of clouds, which on the average is one of cooling. The warming effect occurs even in the summer months, and can be attributed to the bright surface and low sun angle.

However, there is a significant uncertainty in the ISCCP-based fluxes. Comparisons of surface observations of the downwelling shortwave flux at South Pole Observatory to modeled fluxes using the ISCCP D1 cloud data reveal errors of 5-20% for instantaneous observations. Errors approaching 10% for monthly averages are typical. Longwave fluxes are currently under investigation. Preliminary results indicate that the uncertainty in the downwelling longwave flux is much larger than for the shortwave flux. We believe that the extended AVHRR Polar Pathfinder data set is more accurate than the ISCCP-based flux product.

Training and Development:

The project has provided the opportunity for two graduate students to learn how to perform basic scientific research including, but not limited to, data processing, model use and development, and scientific programming.

Outreach Activities:

Some of the research findings were presented at the Space Science and Engineering Center/Atmospheric and Oceanic Sciences Department Summer Workshop 2000 in a session on climate modeling and change.

A number of conference presentations have been made, as listed in the publications section below.

Journal Publications

Key, J., P. Yang, B. Baum, and S. Nasiri, "Parameterization of shortwave ice cloud optical properties for various particle habits", Journal of Geophysical Research, p. , vol. , (2001). Accepted

Schweiger, A.J., R. Lindsay, J. Key, and J. Francis, "Arctic clouds in multiyear satellite data sets", Geophysical Research Letters, p. 1845, vol. 26(13), (1999). Published

Wang, X. and J. Key, "Aggregate-area radiative flux biases", Annals of Glaciology, p. , vol. , ( ). Accepted

Wang, X. and J. Key, "Spatial variability of the sea ice radiation budget and its effect on aggregate area fluxes", Annals of Glaciology, p. , vol. , ( ). Accepted

Maslanik, J., J. Key, C. Fowler, T. Nyguyen, X. Wang, "Spatial and temporal variability of surface and cloud properties from satellite data during FIRE-ACE", Journal of Geophysical Research, p. 15233, vol. 106(D14, (2001). Published

Key, J., X. Wang, J. Stroeve, C. Fowler, "Estimating the cloudy sky albedo of sea ice and snow from space", Journal of Geophysical Research, p. 12489, vol. 106(D12, (2001). Published

Books or Other One-time Publications

Wong, A.M., "Estimating the cloudy sky surface temperature of sea ice from space", (2000). Thesis, Published
Bibliography: Department of Geography, Boston University, Boston, MA.

Key, J., D. Slayback, C. Xu, and A. Schweiger, "New climatologies of polar clouds and radiation based on the ISCCP 'D' products", (1999). Conference proceedings, Published
Editor(s): American Meteorological Society
Collection: Proceedings of the Fourth Conference on Polar Meteorology and Oceanography
Bibliography: Dallas, TX, January 10-15, 227-232

Key, J. and A.M. Wong, "Estimating the cloudy sky surface temperature of sea ice with optical satellite data", (1999). Conference proceedings, Published

Editor(s): American Meteorological Society
Collection: Proceedings of the Fourth Conference on Polar Meteorology and Oceanography
Bibliography: Dallas, TX, January 10-15, 227-232

Wang, X. and J. Key, "Aggregate-area Radiative Fluxes", (2001). Conference proceedings, Published
Editor(s): American Meteorological Society
Collection: Proceedings of the Sixth Conference on Polar Meteorology and Oceanography
Bibliography: pp. 293-296

Pavalonis, M. and J. Key, "The influence of Antarctic cloud and surface properties on cloud radiative forcing at the surface", (2001). Conference proceedings, Published
Editor(s): American Meteorological Society
Collection: Proceedings of the 11th Conference on Satellite Meteorology and Oceanography
Bibliography: pp. 172-175

Web/Internet Site

URL(s):

http://stratus.ssec.wisc.edu,
http://stratus.ssec.wisc.edu/research/d1fluxes/d1fluxes.html, http://stratus.ssec.wisc.edu/products/rtcaspr

Description:

This site provides highlights of the research and provides access to the data sets generated by the project.

Other Specific Products

Product Type: Data or databases

Product Description:

We have computed surface and top of the atmosphere radiative fluxes for both polar regions based on the International Satellite Cloud Climatology Project (ISCCP) three-hourly cloud product ('D1') for the period 1986-1994. The data set is comprised of upwelling and downwelling shortwave and longwave fluxes and cloud forcing at a grid cell size of 280 x 280 km.

The AVHRR Polar Pathfinder project product set is being extended to include cloud properties and radiative fluxes. The spatial scale is 25 km with a twice-daily temporal sampling. To date the years 1982-1993 have been processed. The processing of 1994-1999 is underway.

A new near real-time product comprised of surface, cloud, and radiative properties derived from the Advanced Very High Resolution Radiometer (AVHRR) has been developed and is available on the Web. It is done once each day at 12Z for both polar regions.

Sharing Information:

Data products are shared with the scientific community and general public via the World Wide Web. Daily and monthly average ISCCP-based fluxes are available for download. Near real-time surface, cloud, and radiative properties from satellite can be viewed on the web. Other products will be made available for download as they are generated.

Contributions

Contributions within Discipline:

To date, our findings have increased our understanding of how clouds affect the surface radiation budget. This was exemplified by the cloud forcing calculations that showed the warming effect of clouds even during the summer (high-sun) period.

Our data products (ISCCP-based fluxes, extended AVHRR Polar Pathfinder, and near real-time surface and cloud properties) products are available to the scientific community. It provides an idea tool for validation/verification of regional climate models.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

This project has provided the opportunity for training three graduate students to date.

Contributions to Resources for Research and Education:

The project has provided funds for a workstation that is used by a graduate student. It has also provided the resources necessary for the development data dissemination tools via the Internet.

Contributions Beyond Science and Engineering:

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: less than 20 percent of current funds

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Organizational Partners

Contributions: To Any Other Disciplines

Contributions: To Any Beyond Science and Engineering