Calculating Latent Heat Fluxes Over the Labrador Sea Using SSM/I Data

Bernard Walter
NorthWest Research Associates
P. O. Box 3027
Bellevue, WA 98009
phone: (425) 644-9660, x-320; fax: (425) 644-8422; e-mail: walter@nwra.com

Award #: N00014-97-C-0152
http://www.onr.navy.mil/sci_tech/ocean/onrpgahj.htm

LONG-TERM GOAL

To develop a methodology for remotely measuring the spatial and temporal variability of the atmospheric surface latent and sensible heat fluxes over the Labrador Sea using passive microwave imagery (SSM/I).

OBJECTIVES

(1) To test existing algorithms for calculating integrated water vapor (IWV) and surface wind speed and compare these calculations to shipboard measurements made from the Knorr during the 1997 experiment. Calculate surface flux fields over the Labrador Sea.

(2) Develop algorithms optimized for use in the Labrador Sea using the 1997 data and apply these to the 1998 data set.

APPROACH

It has been well proven that one can estimate atmospheric integrated water vapor (IWV) and surface wind speed using SSM/I data. Algorithms have been developed by using oceanic sounding data sets and buoys in conjunction with radiative transfer models and multiple regression techniques to relate brightness temperatures (Tb's) from different SSM/I channels and IWV and wind speed at 19.5 m height. The SSM/I instrument on the DMSP series of satellites operates at 4 frequencies (19, 22, 37 and 85 GHz), and at horizontal (H) and vertical (V) polarizations at 19, 37 and 85 GHz and at V polarization at 22 GHz. Spatial resolution is nominally 50 km at 19, 22 and 37 GHz and 25 km at 85 GHz.

Using over-the-ocean radiosondes Liu (1986) showed that IWV was highly correlated with surface mixing ratio (q_a) on a monthly averaged basis. Subsequently, Hsu and Blanchard (1988) showed this relationship held for individual soundings. Previous studies have shown that latent heat fluxes can be estimated from quantities (IWV and wind speed) that can be estimated from SSM/I data (Claud et al, 1992; Clayson and Curry, 1996).

Claud et al (1992) developed an empirical relationship between SSM/I brightness temperatures, an independent estimate of T_{sfc}, and (q_s-q_a), where q_s is the saturation mixing ratio at the ocean surface temperature T_{sfc}, q_a is the mixing ratio of the air near the ocean surface. Having (q_s-q_a) and wind speed allows us to calculate a value of the latent heat flux, LHF, using the bulk method:

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Calculating Latent Heat Fluxes Over the Labrador Sea Using SSM/I Data**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **NorthWest Research Associates,P. O. Box 3027,Bellevue,WA,98009**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

$$LHF = L_v*\rho*C_E*u*(q_s-q_a), \quad (\text{in } W/m^2).$$

WORK COMPLETED

I followed the above approach in developing a technique for estimating LHF over the Labrador Sea during the 1997 field program. The 212 radiosondes launched from the Knorr during February 2 - March 13, 1997 provided the in situ data from which I developed the algorithms for calculating IWV and wind speed and ultimately LHF.

I developed the relationship between IWV and T22v and T19v by regressing the values of the integrated water vapor calculated from the Knorr soundings and the brightness temperature values of T22v and T19v at the Knorr location. All the following relationships were developed on a daily-averaged basis. The resulting IWV algorithm is:

$$IWV\ (g/kg) = -16.4415 + .9302*T22v - .8563*T19v.$$

I followed the form of the wind speed algorithm developed by Goodberlet et al (1989) where

$$u = a_0 + a_1*T19v + a_2*T22v + a_3*T37v + a_4*T37h,$$

where the constants a_0 - a_4 are obtained from a regression analysis.

Using the values of the wind speed adjusted to a height of 10 m measured on the Knorr and the SSM/I values of T19v, T22v, T37v and T37h at the location of the Knorr I developed the following wind speed algorithm:

$$u\ (m/s) = 193.557 + .3777*T19v - .0276*T22v + 1.7815*T37v + .8195*T37h$$

Following the approach of Claud et al (1992), using the calculated value of q_a (at 10 m) from the sounding data and q_s calculated from the measured values of T_{scf} at the Knorr I similarly developed the following algorithm for (q_s-q_a):

$$(q_s-q_a) = 3.213 - .2605*IWV + .33104*T_{sfc}.$$

In summary the procedure to calculate LHF is as follows:

(1) IWV = f(T22v, T19v)
(2) u = f(T19v, T22v, T37v, T37h)
(3) $(q_s-q_a) = f(IWV, T_{sfc})$
(4) $LHF = L_v*\rho*C_E*u*(q_s-q_a)$, (in W/m^2)

SSM/I brightness temperature fields were obtained for the area 51^0 N - 67 ^{0} N and 67 ^{0} W - 43 ^{0} W, containing the Labrador Sea. Using the above algorithms for IWV, (q_s-q_a) and u, I then calculated LHF fields for this area.

An estimate of the sensible heat flux, SHF, can also be made from SSM/I data using the fact that the air temperature T_a is related to the value of the integrated water vapor (Jourdan and Gautier, 1995).

Using the daily averaged values of T_a from the Knorr and IWV from the radiosondes I obtained the following relationship between T_a and IWV:

$$T_a = -25.27*\exp(-.305*IWV) + 2.0.$$

Using the bulk flux method the SHF can then be calculated from:

$$SHF = \rho*C_p*C_H*u*(T_{sfc}-T_a), \quad \text{(in W/m}^2\text{)}.$$

RESULTS

A methodology has been developed for estimating latent and sensible heat flux fields over the Labrador Sea using remote sensing passive microwave data from SSM/I. This allows the specification of spatial and temporal changes in the surface heat budget over the wintertime Labrador Sea at spatial scales (~ 50 km) much higher than is possible with NCEP reanalysis fields. Having these higher resolution flux fields is critical for studying the scales of oceanographic processes important to deep convection in the Labrador Sea.

Latent heat flux fields have been calculated for the Labrador Sea and qualitatively show spatial variations that one would expect. This is also true of the sensible heat flux fields. The average Bowen ratio (SHF/LHF) for the measurements on the Knorr was 1.02 whereas the Bowen ratio for the predicted fluxes was 1.24.

The correlation coefficient between latent heat fluxes obtained from the in situ measurements on the Knorr and those obtained from the SSM/I algorithm was r = 0.907. The correlation coefficient between the Knorr’s sensible heat flux and that from the SSM/I algorithm was r = 0.88.

The latent and sensible heat flux fields have been obtained from the NCEP reanalyses for the same time period (Feb.2 - Mar. 13) and will be compared to the flux fields estimated from the SSM/I data. The fluxes will also be calculated for the period and location of the Knorr during the 1998 cruise and will be compared to the bulk estimates made from the in situ ship measurements. Spatial fields of fluxes will also be calculated for 1998 and these fields compared to the NCEP reanalysis flux fields for the same time period.

IMPACT/APPLICATION

If this method of remotely estimating surface turbulent sensible and latent heat flux fields proves robust it would provide a method for supplying data for initializing oceanographic numerical models, and for the analysis/interpretation of oceanographic measurements. Having these higher resolution (~50 km) flux fields is critical for studying the scales of oceanographic processes important for deep convection in the Labrador Sea.

TRANSITIONS

The above technique can be applied to other geographic areas for similar wintertime cold air outbreak conditions.

RELATED PROJECTS

(1) I have been working with Kent Moore at the University of Toronto in the interpretation and analysis of the NCEP reanalysis fields. He is also supplying me with AVHRR imagery over the Labrador Sea recorded during the 1997 field program.

(2) I will be comparing the heat flux fields that I obtain with those that Russ Davis at SIO obtained from his drifter measurements.

(3) I will also be comparing my fluxes with those Eric D'Asaro at APL, University of Washington obtained from his Lagrangian floats.

REFERENCES

Claud, C., K. Katsaros, G. Petty, A. Chedin and N. Scott, 1992: A cold air outbreak over the Norwegian Sea observed with the TIROS-N Operational Vertical Sounder (TOVS) and the Special Sensor Microwave /Imager (SSM/I), *Tellus, 44A*, 100-118.

Clayson, C. and J. Curry, 1996: Determination of surface turbulent fluxes for the Tropical Ocean-Global Atmosphere Coupled Ocean-Atmosphere Response Experiment: Comparison of satellite retrievals and in situ measurements, *J. Geophys. Res. 101*, 28515-28528.

Goodberlet, M., C. Swift, and J. Wilkerson, 1989: Remote sensing of the ocean surface winds with the Special Sensor Microwave/Imager, *J. Geophys. Res., 94*, 14547-14555.

Hsu, S. and B. Blanchard, 1989: The relationship between total precipitable water and surface-level humidity over the sea surface: A further evaluation, *J. Geophys. Res., 94*, 14539-14545.

Jourdan, D. and C. Gautier, 1995: Comparison between global latent heat flux computed from multisensor (SSM/I and AVHRR) and from in situ data, *J. Atmos. Oceanic Technol., 12,* 46-72.

Liu, W., 1986: Statistical relation between monthly mean precipitable water and surface-level humidity over the global oceans, *Mon. Wea. Rev. 114*, 1591-1602.