P2.8 HIGH LATITUDE SURFACE TEMPERATURE FOR CLEAR FIELDS OF VIEW FROM THE AIRS ADVANCED SOUNDER

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1. INTRODUCTION

In order to facilitate the routine NWP assimilation of operational advanced infrared sounder data (IASI on MetOp and CrIS on NPOESS) over high latitude land regions of the globe, we demonstrate a method for preparing the input to 1-D var data assimilation. The method involves the identification of clear sounder fields of view over snow/ice in winter conditions and the determination of the skin temperature and infrared emissivity appropriate for each sounder field of view. The method is demonstrated using NASA AIRS and MODIS data over snow covered land and sea ice. MODIS data collocated within AIRS fields of view are used to estimate the uniformity of the scene. A clear filter is applied to the AIRS data which uses both the MODIS sub-pixel uniformity and consistency with the expected snow emissivity within certain limits. A surface temperature is estimated from the clear AIRS fields of views using the peak of the snow emissivity. Examples are provided from a case study over the Greenland ice sheet for all of the EOS Aqua AIRS overpasses for the months of January 2005 and January 2006.

2. DATA

The data used in this study are from the Atmospheric InfraRed Sounder (AIRS) and the Moderate Resolution Imaging Spectroradiometer on the NASA Earth Observing System (EOS) Aqua platform. The data was acquired from the NASA Goddard DAAC in mid-2006 and consists of L1B AIRS radiances (PGE version 4) and the MYD03 and MYD021km geolocation and 1-km IR products (collection 5).

Data was ordered from the Goddard DAAC within a bounding box (60N, 70W) to (85N, 10W) containing the Greenland continent for the months of January 2005 and January 2006. An example image of the MODIS 12 μm brightness temperature collocated within AIRS fields of view is shown in Fig. 1. The dark blue colors indicate both cold cloud tops and clear regions over the Green ice sheet. The red colors are warmer scenes over the surrounding oceans.

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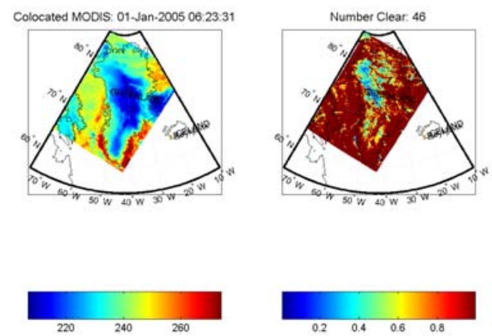

Figure 1: Colocated MODIS mean (left) and standard deviation (right) within AIRS fields of view at 12 μm .

The MODIS infrared data is at a nominal 1-km spatial resolution (at nadir) while the AIRS infrared data is at a nominal 15-km (at nadir). Only the 12 μm MODIS L1B radiances have been used in this analysis. The AIRS data consists of 2378 spectral channels for every 15-km footprint. An example AIRS observation over the Greenland ice sheet is shown in Fig. 2 after application of PCA noise filtering (Tobin, et al., 2006). The AIRS observation indicates the presence of warm air above a very cold surface (i.e. a low level temperature inversion) in both the CO_2 and H_2O emission bands. Note also a discontinuity in the AIRS brightness temperature near 4 μm which is a symptom of an instrument correlated noise error that is most apparent at these very cold scene temperatures (< 230 K).

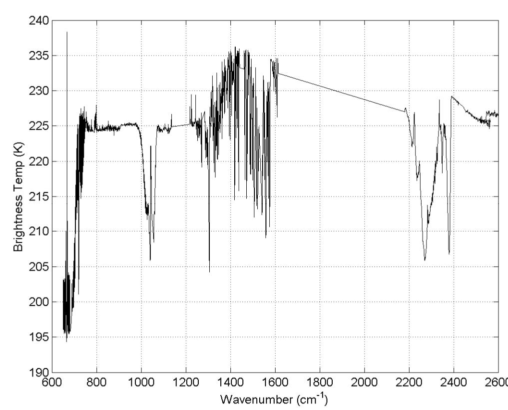

Figure 2: AIRS brightness temperature observation collected over the Greenland Ice Sheet at about 06:27 UTC on 01 January 2005 from the file AIRS.2005.01.01.064.L1B.AIRS_Rad.v4.0.9.0.

3. METHODOLOGY

The methodology described in this section is intended to be useful for the assimilation of advanced sounder data (AIRS on EOS, IASI on METOP, or CrIS on NPOESS) into numerical weather prediction models. Most data assimilation methods require L1B radiances from a cloud-free scene as input to a 1-D var, 3-D var, or 4-D var variational method. They also require knowledge of the surface radiative properties (skin temperature and surface infrared emissivity). The method proposed in this paper satisfies both of these data assimilation criteria for a particularly challenging geographic situation; polar (high latitude) winter (solar zenith angles > 90 degrees).

In order to identify clear AIRS fields of view, we make the assumption that a sufficiently strict criterion on the uniformity of the MODIS pixels collocated within an AIRS footprint can be used to reject cloud contaminated scenes. A standard deviation criterion of 0.2 K for temperatures less than 230 K was used to identify the clear AIRS FOVs for this study.

An important advantage of the high spectral resolution infrared observations of AIRS, IASI, and CrIs is the ability to selectively choose wavelengths appropriate to the geographic conditions. This is particularly true of the observations over snow and ice surfaces where the emissivity of these surfaces has a peak value near 960 cm^{-1} of 0.9952 as shown in Fig. 3.

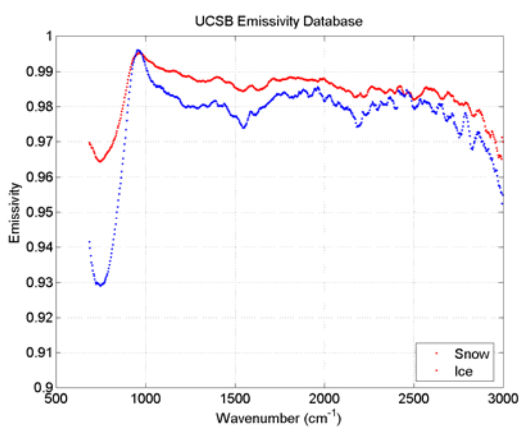

Figure 3: UCSB snow and ice emissivity (Mammoth Lakes; SNOW_1 and ICE01). The peak emissivity is about 0.9955 at 965 cm^{-1} for both snow and ice. A value of 0.9952 at 960 cm^{-1} was used in this study.

Analysis fields from the European Center for Medium range Weather Forecasting (ECMWF) were used as input to the UMBC SARTA radiative transfer model to compute the atmospheric radiative transfer terms in Eqn. 1. Figure 4 shows ECMWF profiles for the uniform scenes over the Greeland Ice Sheet from one AIRS data granule. Note that the elevation of the ice sheet varies from an average height of about 2 km to a peak of 3.2 km in a gradual slope.

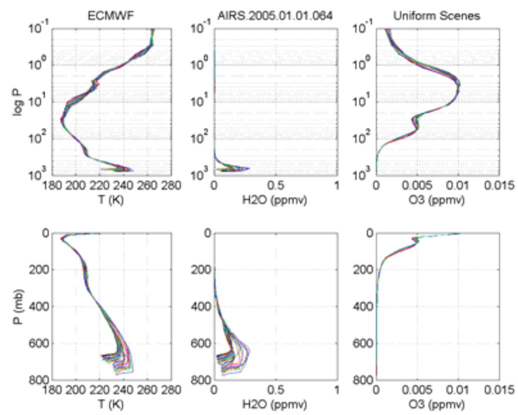

Figure 4: ECMWF profiles for uniform AIRS scenes over the Greenland ice sheet (2005.01.01.064).

4. RESULTS

Figures 5-11 demonstrate application of the method previously described for the determination of clear scenes and estimation of surface skin temperature to all AIRS overpasses of the Greenland ice sheet for January 2005 and 2006.

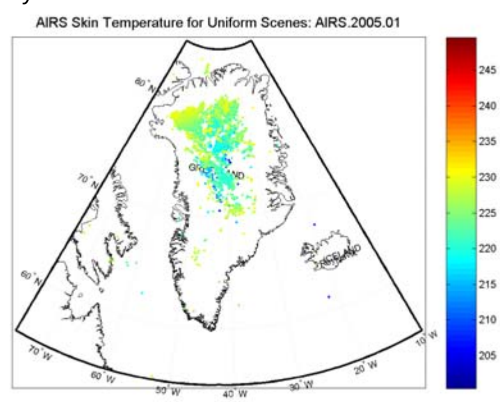

Figure 5: AIRS skin temperature derived from uniform scenes for each satellite overpass during the month of January 2005.

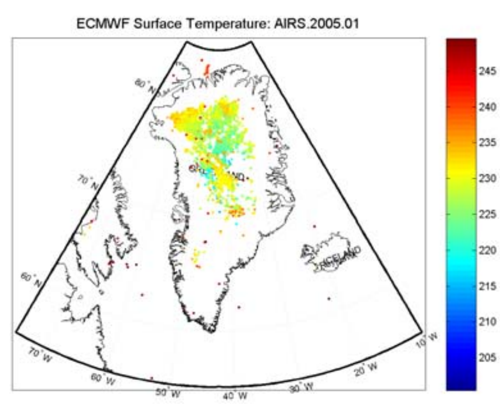

Figure 6: ECMWF analysis surface temperatures for the same AIRS scenes shown in Fig. 5.

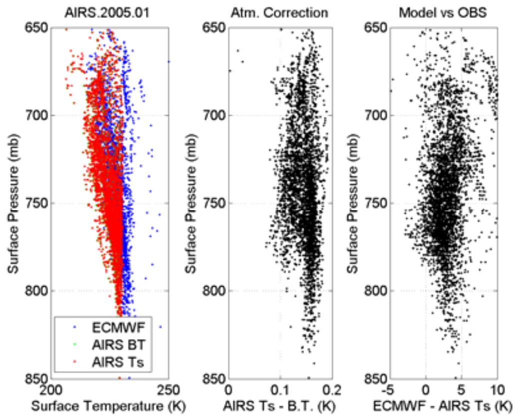

Figure 7: Surface temperatures versus surface pressure over the Greenland ice sheet for the month of January 2005.

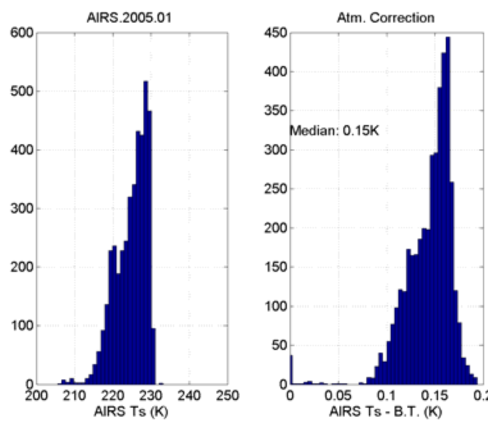

Figure 8: AIRS derived surface temperature histogram (left) for January 2005 over the Greenland ice sheet and for the difference between the AIRS observed brightness temperature and the derived skin temperature (right).

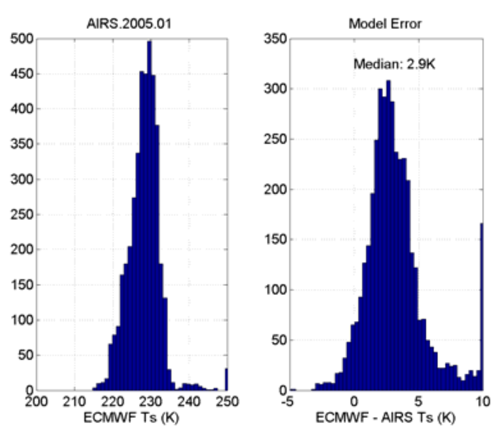

Figure 9: ECMWF derived surface temperature histogram (left) for January 2005 over the Greenland ice sheet and the difference from AIRS (right).

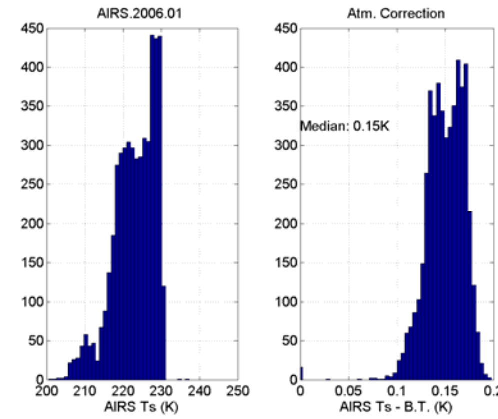

Figure 10: Same as Fig. 8 except for January 2006.

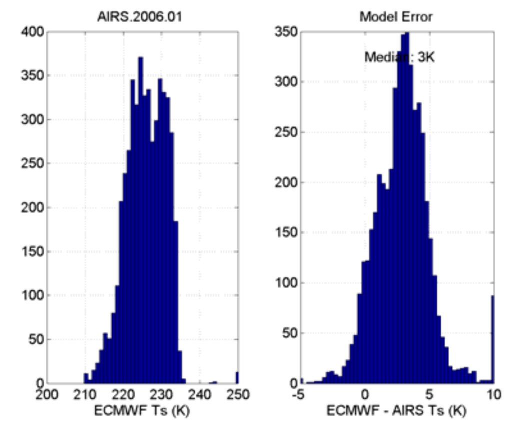

Figure 11: Same as Fig. 9 except for January 2006.

5. CONCLUSIONS and FUTURE PLANS

A methodology has been presented for the successful identification of clear sounder fields of view and the accurate estimation of surface temperature. The MODIS sensor demonstrates the sensitivity and geolocation accuracy necessary for the identification of uniform AIRS fields of view. Although the correlated errors in the AIRS sensor are exacerbated at the low brightness temperatures found in the high latitude winter surface temperatures, the high spectral resolution allows the selection of spectral channels at the peak of the snow and ice emissivity. The ECMWF analysis fields are shown to be reasonably good over the Greenland ice sheet as evidenced by the relatively small obs minus calc forward model residuals (using the UMBC SARTA model). The atmospheric correction and surface emissivity of the AIRS data is shown to be less than 0.2 K for all clear scenes over Greenland in the months of January 2005 and 2006. The difference between the ECMWF model surface temperature and the derived surface temperature from AIRS ranged between zero and 10 degrees with a median difference of 3.0 K (ECMWF minus AIRS) for both January 2005 and 2006. Future work involves the determination of surface emissivity across the infrared spectrum and the inversion of the radiance residuals into perturbations on the ECMWF profiles used as a first guess. A list of prior efforts related to the use of high spectral resolution for surface remote sensing is given in the references.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Knuteson, R., F. Best, D. DeSlover, B. Osborne, H. Revercomb, and W. Smith, Sr., 2004: Infrared land surface remote sensing using high spectral resolution aircraft observations, Adv. Space Res., Vol. 33, (2004), pp 1114-1119.

Knuteson, R., Ackerman, Revercomb, H., Tobin, D., 2004: Infrared Land Surface Remote Sensing Using High Spectral Resolution Satellite Observations, 35th COSPAR Scientific Assembly, Paris, France, 18 - 25 July 2004.

Knuteson, R. O. and H. E. Revercomb, 2004: Land Surface Temperature And Emissivity From Advanced Sounders, 2004 EUMETSAT Meteorological Satellite Conference, Prague, Czech Republic, 31 May – 4 June, 2004.

Knuteson, R., Ackerman, S., Antonelli, P., Revercomb, H., Smith, W., Tobin, D., 2004: Infrared Surface Reflection At High Spectral Resolution: Theory And Observations, International Radiation Symposium (IRS2004), Busan, Korea, 23-28 August 2004.

Knuteson, R., Revercomb, H., and Tobin D., 2004: Use of High Spectral Resolution Infrared Observations by Ground-based, Aircraft, and Satellite Instruments to Simulate HES Radiances over a Land Site, 3rd GOES-R Users Conference, May 10-13, 2004, Broomfield, CO.

Knuteson, R., Lee, S.C., Revercomb, H., and Tobin, D., 2004: Validation of AIRS Land Surface Temperature and Infrared Emissivity Products, Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract A51B-0757, December 2004.

Knuteson, R., Feltz, W., Revercomb, H., Tobin, D., 2005: Seasonal Dependence of the Infrared Land Surface Emissivity in the Vicinity of the ARM SGP Central Facility, Atmospheric Radiation Measurement (ARM) Science Team Meeting, 15th, Daytona Beach, FL, 14-18 March 2005. Proceedings. Washington, DC, US Department of Energy, Office of Energy Research, Office of Health and Environmental Research, Environmental Sciences Division.

Knuteson, R., Cychosz, J., Lee, S.Z., Revercomb, H., Tobin, D., and Vinson, K., Comparison Of LST From AIRS And MODIS From The EOS Aqua Platform, 2005: Eos Trans. AGU, 86(52), Fall Meet. Suppl., Abstract B51B-0208, December 2005.

Knuteson, R., Cychosz, J., Lee, S.Z., Revercomb, H., Tobin, D., and Vinson, K., Comparison Of LST From AIRS And MODIS From The EOS Aqua Platform, 2006: Extended Abstracts, 10th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Atlanta, GA, Amer. Meteor. Soc., January 2006.