Simultaneous Determination of Continental Surface Emissivity and Temperature from NOAA-10/HIRS Observations. Analysis of their Seasonal Variations.


Introduction

Continental surface infrared emissivity strongly depends on the frequency and on the type of the surface. Emissivity values are generally low and, as such, the time mean and seasonal (simultaneous) determination of surface temperature and emissivity is essential to greatly improve the accuracy of the longwave flux budget and, consequently, improving the performance of surface-atmosphere interaction models.

Research in this area has shown that a large part of the surface longwave radiation is directly hot in space without thermal infrared windows, surface as well as top of the atmosphere radiation budgets are significantly influenced by the surface emissivity. Surface emissivity and longwave net surface radiation are proportional, and to a 5% error in the emissivity (from 0.95 to 1.0, for example) approximately corresponds a 5% error in the longwave net radiations (about 15 W m⁻²).

It has also been shown that accounting properly for the surface emissivity in the solution of the inverse problem substantially and positively changes the retrieved meteorological profiles and cloud characteristics.

Surface "(air)" temperature and emissivity are strongly coupled through the radiation transfer equation and most studies aiming at retrieving one of these variables from satellite observations have used a prior information on the other. The method developed here is original in the sense that both variables are determined simultaneously through a non-linear regression inference scheme.

1. Methodology

Under clear sky conditions (i.e., no clouds, no aerosols) and under the assumption of local thermodynamic equilibrium, the calculation of the monochromatic radiance emitted by the atmosphere leads to the integration of the radiative transfer equation which may be written in the following way:

\[ L(\nu) = e^{-\tau(\nu,t)} \left[t(\nu,t) + (1-e^{-\tau(\nu,t)}) \right] \left(t(\nu,t) + (1-e^{-\tau(\nu,t)}) \right) \]

The emissivity of the surface is modelled by the radiative transfer equation and temperature is the fact that the number of data (or "pixels"), the number, n, of channels selected (see below), is smaller than the number of unknowns (or "parameters"), hence no clue the surface temperature. To overcome this difficulty, each "pixel" observed (here, a 1°×1° HIRS pixels box) is associated with two closest points (cone viewing angle) with the assumption that the surface temperature may vary, while the surface emissivity is the same for the "group of three" pixels. Then, there are 3n data for 3n unknowns and the system becomes over determined for n > 9007.

1.1. Thermodynamic Initial Guess Retrieval (TIGR)

1.1.1. Climatological Library

- About 2300 representative atmospheric conditions selected by statistical methods from 80 000 ex-situ events, and described on 40 loci from 1013 hPa to 0.0005 hPa.
- Cloud and transmissivity, brightness temperature and Julian days, spatial derivatives of the brightness temperature with respect to temperature, gas concentration, surface temperature and emissivity, etc., for all TOVS sounding channels are computed for each situation archived. Calculations are performed for 10 viewing angles, between 0° (direct) and 60° (maximum value for angular scanning). For 15 values of surface pressure (up to about 700 hPa) for elevated terrains, and for 5 surface types - land and sea, 5.5°x0.5° sea, the surface emissivity varies with frequency and viewing angle according to Nakada et al. [1988] and Harms-Erd and Sander's [1990]. A fixed emissivity is specified for all channels over land.

- For each atmospheric situation, a surface temperature is generated as the result of the temperature of the atmosphere at the lowest level and a random number with a mean value and a standard deviation of 4K.

1.1.2. Inference method

- Emissivity and surface temperature are retrieved through a non-linear regression inference scheme based on the multi-layer perceptron (MLP). Inputs are selected within TIGR, in consideration of the geographic area selected (5N-5S and 20W-60E). Each situation is associated with two closest situations to simulate the "group of three".

- The solution is constrained by adding the brightness temperatures of channels 6 (13.7 µm) and 7 (13.4 µm), as well as their differences with each key channel (8, 10, 18), giving 11 constraints for each TIGR situation selected.

Consequently, the total number of entries (input layer) comes to 33 (3x11x3). The output layer (the predictions) is made of 3 emissivities (one for each key window channel) and the three surface temperatures of the "group of three". Input brightness temperatures correspond to randomly drawn values of each channel entry on the range indicated above. Noise equivalent temperature (NET) is added to the input brightness temperatures in order to account for the instrument and model noises.

Conclusions and future works:

The work has presented the feasibility and usefulness of the method. Comparisons with bi-dimensional topography maps are encouraging, regarding its accuracy. The method is being extended to the Advanced Infrared Sounder (AIRS) on Board of Aqua platform. The large spectral coverage of the instrument should allow to fully characterise the type and the state of the surface and to follow its evolution. Surface emissivity and temperature are also essential for a better modelling of the energy and water vapor fluxes at the surface.