THE ASSIMILATION OF RADIANCE DATA OVER LAND AND ICE SURFACES

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ABSTRACT

The importance of an accurate characterization of the land surface is usually discussed in terms of its direct impact on the forecast model physics and dynamics. However, the land (and ice) surface also influences the assimilation of radiance data. The mechanism of this indirect impact is explained in terms of the quality control of radiance data and the contribution of the surface to so called "sounding radiances". It is shown that the magnitude of the indirect impact of the surface on the NWP system is significant.

1.0 VARIATIONAL ANALYSIS OF OBSERVATIONS

We essentially use observations to adjust or correct a background state of the atmosphere X_b (a single state in **3DVAR** or a time series of states in **4DVAR**) subject to a number of prior constraints.

The adjustment process finds an optimal state Xa (the analysis) that minimizes a **COST FUNCTION** defined:

$$J(X) = (X-X_b)\, B^{-1}\, (X-X_b)^T + [Y_m-H(X)]\, O^{-1}\, [Y_m-H(X)]^T + \ldots$$

where:

Y_m are the observed data
H is the observation operator (maps from model > obs)
O is the combined error covariance of Y_m and H
B is the error covariance of X_b

For radiance data the observation operator H involves an integration of the radiative transfer equation

$$H(X) = \varepsilon . R[X_{sfc}] . \tau_{sfc} + \int R[\, X\,]\, d\tau + \ldots$$

where:
ε is the surface emissivity
R is the Planck function
τ is the transmittance

2.0 SURFACE CONTRIBUTION TO SOUNDING CHANNELS

Apart from the radiance data measured in "window channels", many of the "sounding channels" (i.e. those we would like to use to adjust the background tropospheric temperature and humidity) have significant contributions from the surface. eg. the following have a sensitivity of > **10 %**

HIRS: channels 4 / 5 / 6 / 7 / 14 / 15 / 16
MSU: channels 2 (and 3 over high orography)
AMSU-A channels 4 / 5 / 6 / 7
AMSU-B channels 3 / 4 / 5 (in dry conditions)

Over sea (where the SST can be known to better than 1K) we typically observe atmospheric signals [Ym - H(X)] < 0.5K in mid-tropospheric (dry) sounding channels (e.g. HIRS-5 or MSU-2).

However, over land and ice surfaces (where the background skin temperatures and emissivity can have large errors) we can observe much larger signals.

Thus over surfaces where background skin temperatures (and / or emissivity) errors are large, contributions from the surface can **dominate the atmospheric signal** we are looking for.

3.0 QUALITY CONTROL OF SOUNDING CHANNELS

The radiance observed in sounding channels may be sensitive to atmospheric phenomena that we do not (or cannot) currently analyze.

e.g. clouds in IR channels and precipitation in mw channels

These cases **MUST** be detected and removed before the analysis. This is currently done by applying a threshold to background radiance departures in the channels most sensitive to the phenomena (window channels).

e.g. HIRS window channel 8 for clouds
MSU window channel 1 for precipitation

The validity of such an approach depends crucially upon **an accurate estimate of skin temperature and surface emissivity**.

This check is currently applied successfully over sea, but **cannot be used over land or ice** where:

i) We may reject good data or worse:

ii) Pass contaminated data as "good" due to compensation (e.g. cloud and a warm T* error)

4.0 OBJECTIVE ASSIMILATION OF SURFACE SENSING RADIANCE DATA

We could include variables such as T* and emissivity in the analysis control vector and allow them to be adjusted **simultaneously** with other analysis variables (e.g. temperature and humidity) using the radiance data.

However,

i) Ambiguities between T* and emissivity would have to be resolved by the background error covariance and our knowledge of the errors in these parameters is currently poor.

ii) We would also have to understand (and model) any correlation between surface errors and those of atmospheric temperature and humidity.

iii) We expect the background errors to be extremely variable (depending on location, time and atmospheric state) and are unlikely to be gaussian.

iv) We would have to understand how "representative" the observed radiance is of the model surface parameter (i.e. spatial and temporal scales).

v) We still have the problem of how to screen the radiance data for clouds and precipitation over land and ice.

Thus objective simultaneous analysis of the surface parameters is currently feasible.

5.0 SUBJECTIVE ASSIMILATION OF SURFACE SENSING RADIANCE DATA

We can simply observe model land (and ice) surface problem (passively) in terms of radiance departure statistics.

Initially we are concentrating on large discrepancies between the model and observations (in radiance space).

i) geographical distribution
ii) diurnal distribution (soon with GOES)
iii) seasonal distribution

And are trying to understand (subjectively) the source of the problems.

e.g. large departures in the IR channels suggest problems with the model T*

e.g. large departures in the MW channels suggest problems with our emissivity model (snow cover/ soil moisture / ice age etc..) or the input parameters.