Modeling of Inhomogeneous Surface Properties for the Advanced Technology Microwave Sounder

Thomas J. Kleespies
NOAA/NESDIS
Problem

- Radiative transfer with channels that ‘see’ the surface is problematic because of emissivity and skin temperature uncertainties.
- This is especially true of inhomogeneous backgrounds, including coastlines, large rivers, mountainous regions, and even regions of high ocean temperature gradients (e.g. north wall of Gulf Stream).
Inhomogeneous surface over ocean
Possible Solution

- The ability to integrate high resolution databases within a given field-of-view, and perform multiple radiative transfer within the field of view, weigh that according to the antenna beam power, and integrate.
Normalized antenna patterns by adding (negative) maximum value of each pattern to all values. (red along track, blue crosstrack)
Got best fit to the eye with a 7\textsuperscript{th} order polynomial (black solid crosstrack, dashed along track)

50\% power is at -3dB
95\% power is at -13dB
99\% power inside the fov is at -20 dB.

The solid fit line fits almost exactly over the data. The dashed fit line is almost as good.
50% power has a dB reduction of \(-10 \log_{10} 0.50 = -3.01\) m=1.0
95% power has a dB reduction of \(-10 \log_{10} 0.05 = -13.01\) m=2.0
99% power has a dB reduction of \(-10 \log_{10} 0.01 = -20.00\) m=3.0

\[
P_x = C_0 + \sum_{i=1}^{7} C_i x^i \quad \text{Along track power}
\]
\[
P_y = D_0 + \sum_{i=1}^{7} D_i y^i \quad \text{Cross track power}
\]
\[
P = -(P_x + P_y) \quad \text{Total power}
\]
\[
Pr = 10^{-P/10} \quad \text{Power expressed as fraction of full power}
\]
Right now ignoring the 45º and 135 º slices
Sample ATMS scan line with relative antenna power to 50%.
Sample ATMS scan line with relative antenna power to 99%.
Digital Elevation Model for this Study

- GTOPO30 from USGS
- 0.008333º resolution
- translates to .93km at equator
“Radiative Transfer”

• Integrate power/land fraction over fov
• Assume land and sea skin temperature and emissivity homogeneous
"Radiative Transfer" continued

\[ T_B = \frac{\int_A \Phi(A) T_R(A) dA}{\int_A \Phi(A) dA} \]

\[ \Phi = \frac{1}{\int_A \Phi(A) dA} \]

\[ = \Phi \int_L \Phi(L) T_R(L) dL + \Phi \int_S \Phi(S) T_R(S) dS \]

\[ = T_{RL} \Phi \int_L \Phi(L) dL + T_{RS} \Phi \int_S \Phi(S) dS \]

Land Power Fraction \hspace{1cm} Ocean Power Fraction

Power Fraction = Fraction of total antenna power within fov allocated to each surface type
5.2 degree fov
1.1 degree fov
## Example Tb Differences

\[
\begin{align*}
\text{TB\_land} &= 280 & \text{TB\_sea} &= 210 \\
\% & \quad \text{Land} & \quad \text{Sea} & \quad \text{Land} & \quad \text{Sea} & \quad \text{Tb} \\
\text{Power} & \quad \text{Fraction} & \quad \text{Fraction} & \quad \text{Power} & \quad \text{Fraction} & \\
50\% & \quad 0.476 & \quad 0.524 & \quad 0.491 & \quad 0.509 & \quad 244.39 \\
95\% & \quad 0.329 & \quad 0.671 & \quad 0.405 & \quad 0.595 & \quad 238.36 \\
99\% & \quad 0.269 & \quad 0.731 & \quad 0.397 & \quad 0.603 & \quad 237.80
\end{align*}
\]

Thanks to Paul vanDelst for suggesting this comparison.
What does this look like just using GDAS within the fov?

• Use the above described methods to determine the various land/ water/ snow/ sea ice fractions and pass to CRTM

• Preliminary results in the following slides from George Gayno, NCEP/EMC/JCSDA/SAIC
IMPACT: ACCOUNTING FOR FOV
Power not included
EX: NOAA-15 AMSU-A, CHANNEL 2

CONTROL:
OBS. MINUS GUESS $T_b$

IMPACT: CHANGE IN
OBS. MINUS GUESS $T_b$

NORTHERN CANADA NEGATIVE IS IMPROVEMENT
Potential Improvements

• Work shown here uses the nominal fov centroid zenith angle. It would be better to use the actual angles within the fov.
• Fit as a function of scan position
• ...

This is preliminary work
Summary and Discussion

• A method has been presented to use sub-fov radiative transfer to improve radiances over inhomogeneous surfaces
• Usefulness of this technique is limited by the quality and resolution of available model state/ancillary databases
• Usefulness also limited by the expense of fov integration and multiple RT calculations
• Future application of Moore’s law and other hardware development may ease these restrictions
Back up slides
Mixed temperature
This is a first attempt with idl, using it's lores coastline (we don't have the CIA hires coastline, and using the F:\landsea\global.eighth, which is clearly not up to the task.
NOAA-17 AMSU-A and AMSU-B scan pattern in cylindrical coordinates. Coastline is North New Guinea.
International TOVS Study Conference, 17th, ITSC-17, Monterey, CA, 14-20 April 2010.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2011.