JCSDA Infrared Sea Surface Emissivity Model Status

Paul van Delst
Introduction

- Global Data Assimilation System (GDAS) at NCEP/EMC uses IRSSE model based on Masuda.
  - Doesn’t include effect of enhanced emission due to reflection from sea surface. Only an issue for larger view angles.
  - Coarse frequency resolution.
- Upgrade the model
  - Use Wu-Smith methodology to compute sea surface emissivity spectra.
  - Reflectivity is average of horizontal and vertical components. Assume that IR sensors are not sensitive to the different polarisations.
  - Refractive index data used:
    - Hale & Querry for real part (pure water)
    - Segelstein for imaginary part (pure water)
    - Friedman for salinity/chlorinity correction
  - Instrument SRFs used to produce sensor channel emissivities. These are the predicted quantities.
IRSSE Model (1)

Started with model used in ISEM-6 (Sherlock, 1999).

\[ \varepsilon(\theta) = c_0 + c_1 \hat{\theta}^{N_1} + c_2 \hat{\theta}^{N_2} \quad (1) \]

where \( \hat{\theta} = \frac{\theta}{60^\circ} \) and \( N_1, N_2 \) are integers.

The coefficients \( c_0, c_1, \) and \( c_2 \) for a set of \( N_1 \) and \( N_2 \) are determined by regression with a maximum residual cutoff of \( \Delta \varepsilon = 0.0002 \). Only wind speeds of 0.0ms\(^{-1}\) were fit in ISEM-6.

The variation of emissivity with wind speed (for HIRS Ch8) was found to be much more than 0.0002.
Wind Speed Dependence of Emissivity

Wind speed dependence of emissivity for NOAA-17 HIRS ch.8 at view angles 0-65°

\[ \varepsilon - \varepsilon(0) \]

Larger \( \theta \)
Since the variation with wind speed was greater than 0.0002, the exponents, $N_1$ and $N_2$, of the emissivity model were also allowed to vary.

For integral values of $N_1$ and $N_2$ their variation with wind speed suggested inverse relationships for both.

The exponents were changed to floating point values, and the fitting exercise was repeated. The result shows a smooth relationship.
Wind Speed Dependence of Integral Exponents

Variation of emissivity fit integral polynomial exponents with wind speed for HIRS Ch.8

Polynomial exponent (N)

Wind speed (m/s)
Wind Speed Dependence of Real Exponents

![Graph showing the variation of emissivity fit floating point polynomial exponents with wind speed for HIRS Ch.8. The graph displays two curves, one with diamonds labeled \(N_1\) and another with triangles labeled \(N_2\).]
IRSSE Model (3)

The model was slightly changed to,

$$\varepsilon(\theta, v) = c_0(v) + c_1(v) \hat{\theta}^{c_2(v)} + c_3(v) \hat{\theta}^{c_4(v)}$$  \hspace{1cm} (2)$$

where $v$ is the wind speed in ms$^{-1}$.

- **Generating the coefficients**
  - For a series of wind speeds, the coefficients $c_i$ were obtained.
  - Interpolating coefficients for each $c_i$ as a function of wind speed were determined. These are stored in the model datafiles.

- **Using the model**
  - For a given wind speed, the $c_i$ are computed.
  - These coefficients are then used to compute the view angle dependent emissivity.
Emissivity Coefficient Variation By Channel for NOAA-17 HIRS/3
Emissivity Coefficient Variation By Channel for AIRS M8 (~850-900 cm\(^{-1}\))
TOA $T_B$ Residuals for NOAA-17 HIRS. RMS for all wind speeds
TOA $T_B$ Residuals for AIRS 281 subset. RMS for all wind speeds
TOA $T_B$ Residuals for NOAA-17 HIRS. RMS for all wind speeds; only $0\text{ms}^{-1}$ ε predicted.
TOA $T_B$ Residuals for AIRS 281 subset. RMS for all wind speeds; only 0ms$^{-1}$ $\varepsilon$ predicted.
TOA $T_B$ Residuals

When wind speed is taken into account:
- Residuals are relatively independent of view angle and channel.
- Magnitudes (Ave., RMS, and Max) are $\sim 10^{-4}$–$10^{-3}$K.

When only 0.0ms$^{-1}$ emissivities are predicted:
- Residuals peak for largest view angles.
- Shortwave channels appear to be more sensitive.
- Magnitudes can be > 0.1K for high view angles. For angles < 40-45°, residuals are typically <0.02K.
Further work

- Investigate impact of JCSDA IRSSE model in the GDAS.
  - Initial tests with the new model show more data is making it past quality control.

- Further validation of the model with measurements.
  - AERI measurements from 1995 field experiment show that the new model is better at larger angles.
  - More AERI measurements from the CSP tropical western Pacific cruise (1996) will be used for further validation.

- Investigation of using bicubic spline interpolation to extract IRSSE data from wind speed/view angle database.
  - Surface of emissivities as a function of wind speed and view angle is very smooth, so fit equation may be overkill.

- Investigation of integration accuracy issue.
  - A very few frequency/wind speed/view angle combinations in the emissivity spectra calculations have shown sensitivity to the integration accuracy over azimuth angle.
  - Solved by higher integration accuracy, but at a computational cost.
Code Availability

● Three parts of the code
  - Code to compute spectral emissivities (Fortran90) and refractive index netCDF datafiles
  - Code to fit model and produce coefficients (IDL)
  - IRSSE model code (Fortran90) and coefficient datafiles. (Operational code used in the GDAS.)

● ITSC group will be notified when code and data has been posted at a download web page/ftp site.
TOA $T_B$ Residuals for NOAA-17 HIRS. MAX for all wind speeds
TOA $T_B$ Residuals for AIRS 281 subset. MAX for all wind speeds
TOA $T_B$ Residuals for NOAA-17 HIRS. MAX for all wind speeds; only $0\text{ms}^{-1}$ ε predicted
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Integration accuracy (1)

It was noticed that anomalous “bumps” appeared in some coefficients. AIRS module 8 (M8) was affected most.

Caused by integration accuracy in code that produces the emissivity spectra. Lower limit of integration over azimuth angle is determined by the accuracy, $\delta$.

In most cases $\delta = 10^{-5}$ was sufficient. $\delta = 10^{-6}$ was used for all computation except for frequencies around 880 cm$^{-1}$ where $\delta = 10^{-7}$ was needed.

Lower accuracy == Faster computation

For the affected frequencies/wind speeds at a single angle, computation time increased from 6m30s to 4h03m18s!
Integration accuracy (2)
AIRS M8 (~850-900cm\(^{-1}\)) coefficients

Note 6ms\(^{-1}\) results
Integration accuracy (3)

E.g.: AIRS M8 ch700 (880.409cm⁻¹)

Note anomalous values at 6ms⁻¹. For all affected channels, it’s caused by one “bad” point in the emissivity spectra.
Integration accuracy (4)

Spectral emissivity at $65^\circ$

For $\delta = 10^{-6}$:
- $864.19 \text{ cm}^{-1}$
- $880.01 \text{ cm}^{-1}$
- $895.83 \text{ cm}^{-1}$

For $\delta = 10^{-7}$:
- $864.19 \text{ cm}^{-1}$
- $880.01 \text{ cm}^{-1}$
- $895.83 \text{ cm}^{-1}$

Wind speed (m.s$^{-1}$)
Integration accuracy (5)

It is not clear why computed emissivities at certain frequencies/wind speeds/angles are sensitive to the integration accuracy.

May be due in part to limited precision of the refractive index and salinity/chlorinity correction data – these are functions of frequency only. So, one would think this should affect results at more than a few isolated wind speeds and view angles.

Effect of anomalous model coefficients produces an emissivity error of \( \sim 0.0003 \). This is small (effect on \( T_B \) is also small), but is about 2x the typical RMS emissivity residual.