JCSDA Infrared Sea Surface Emissivity Model Status

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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).

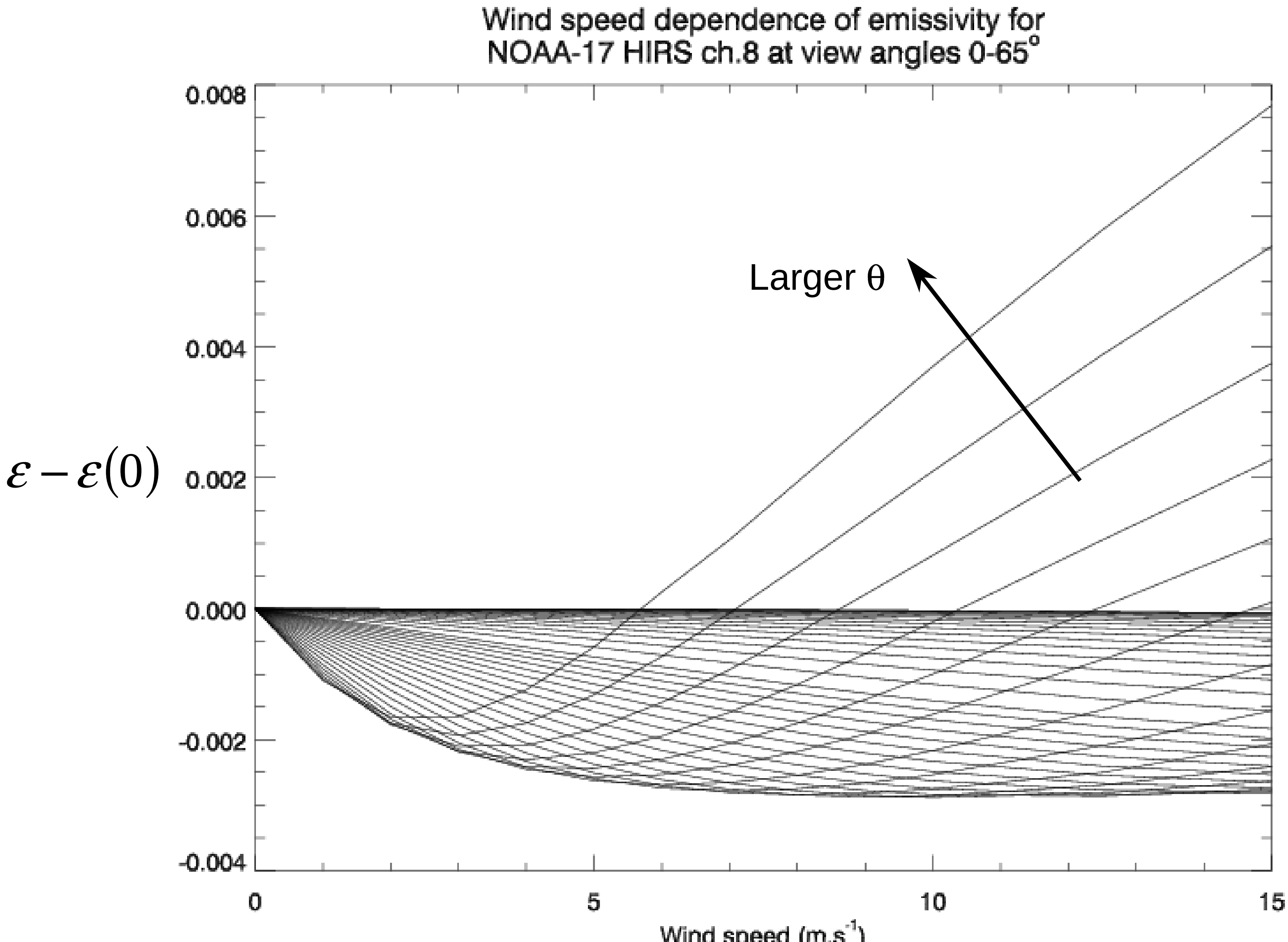
$$\varepsilon(\theta) = c_0 + c_1\hat{\theta}^{N_1} + c_2\hat{\theta}^{N_2} \qquad (1)$$

where $\hat{\theta} = \dfrac{\theta}{60^\circ}$ 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



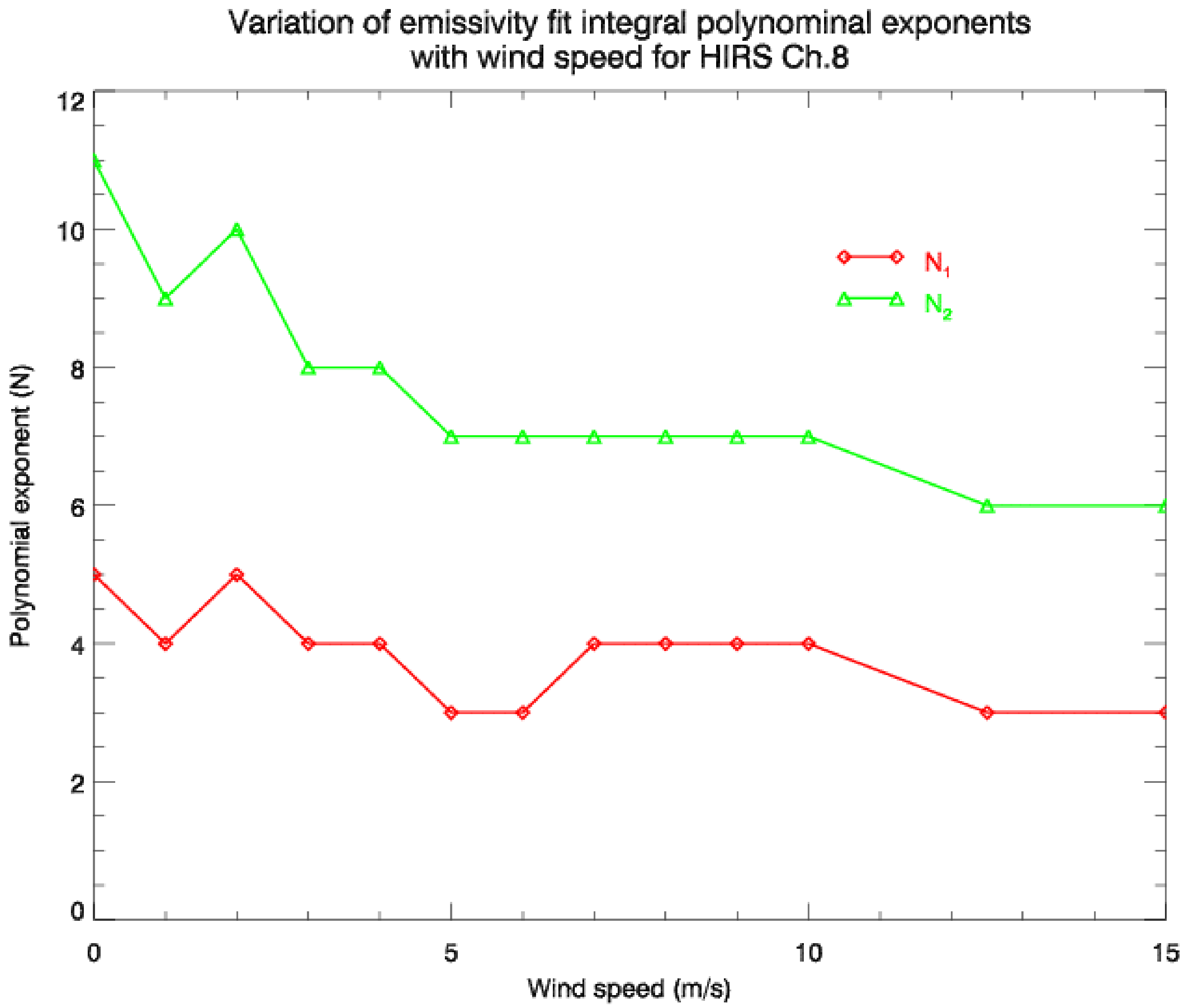
IRSSE Model (2)

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.

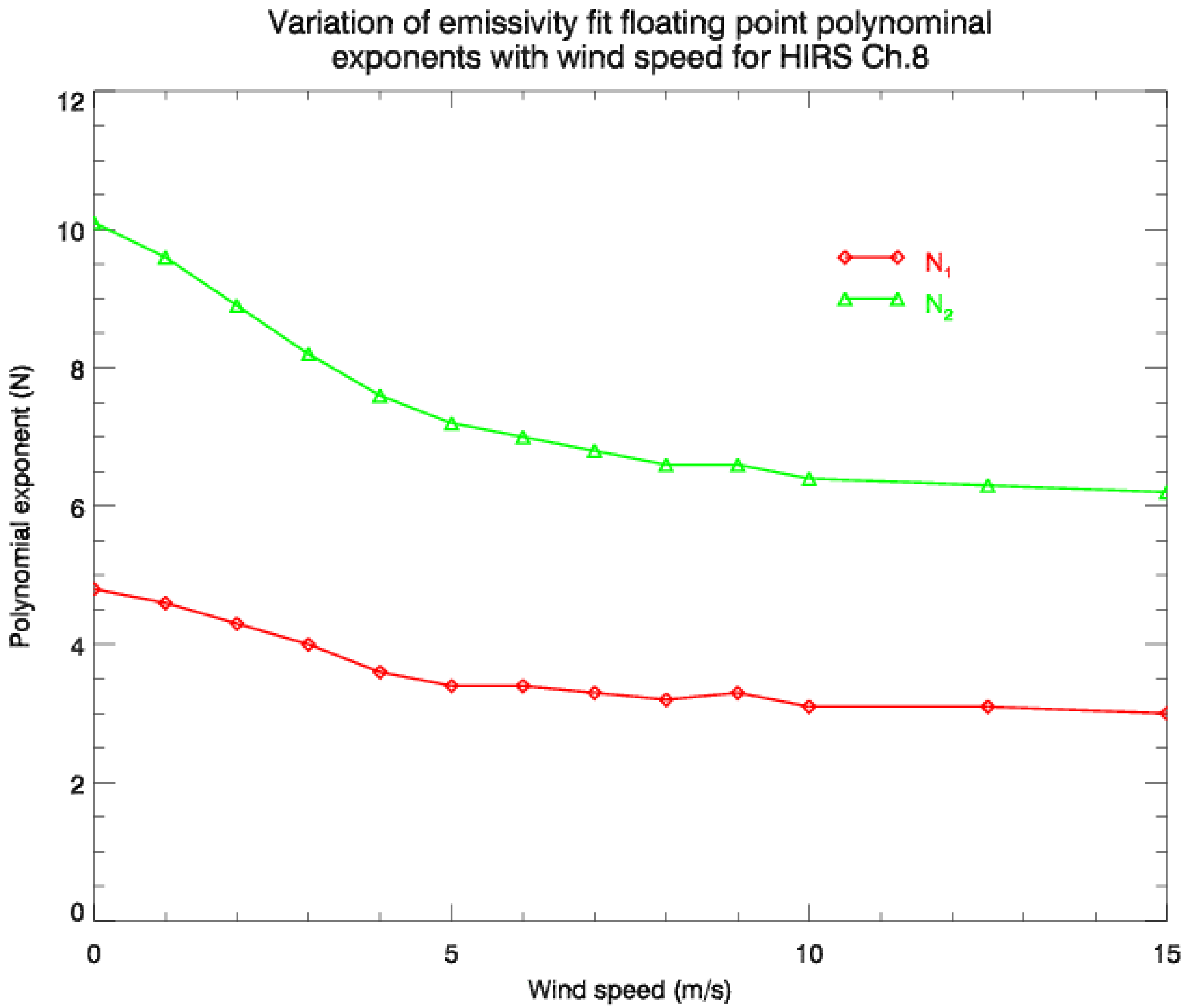
For integral values of N_1 and N_2 their variation with wind speed suggested inverse relationships for both.

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



Wind Speed Dependence of Real Exponents



IRSSE Model (3)

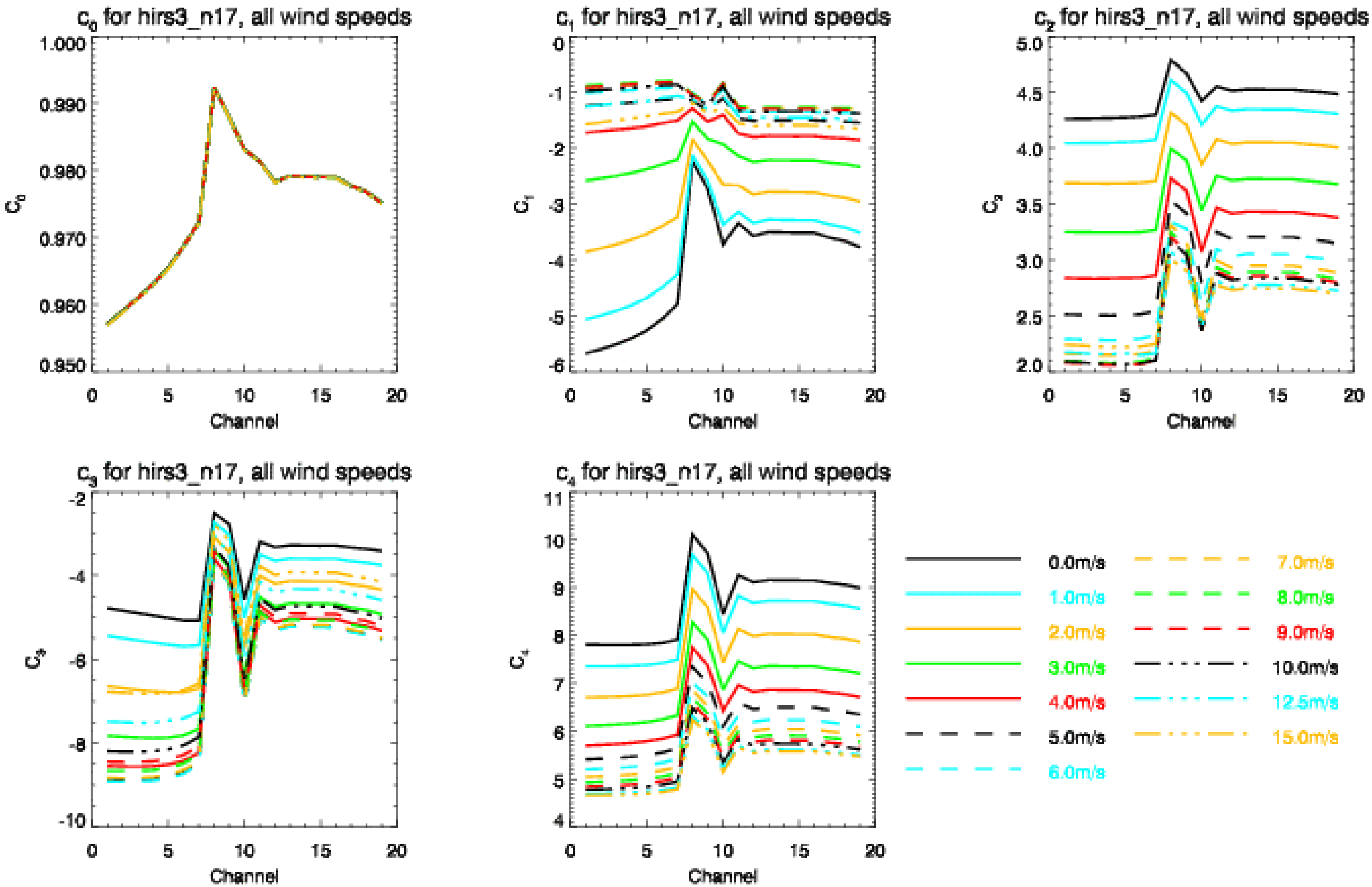
The model was slightly changed to,

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

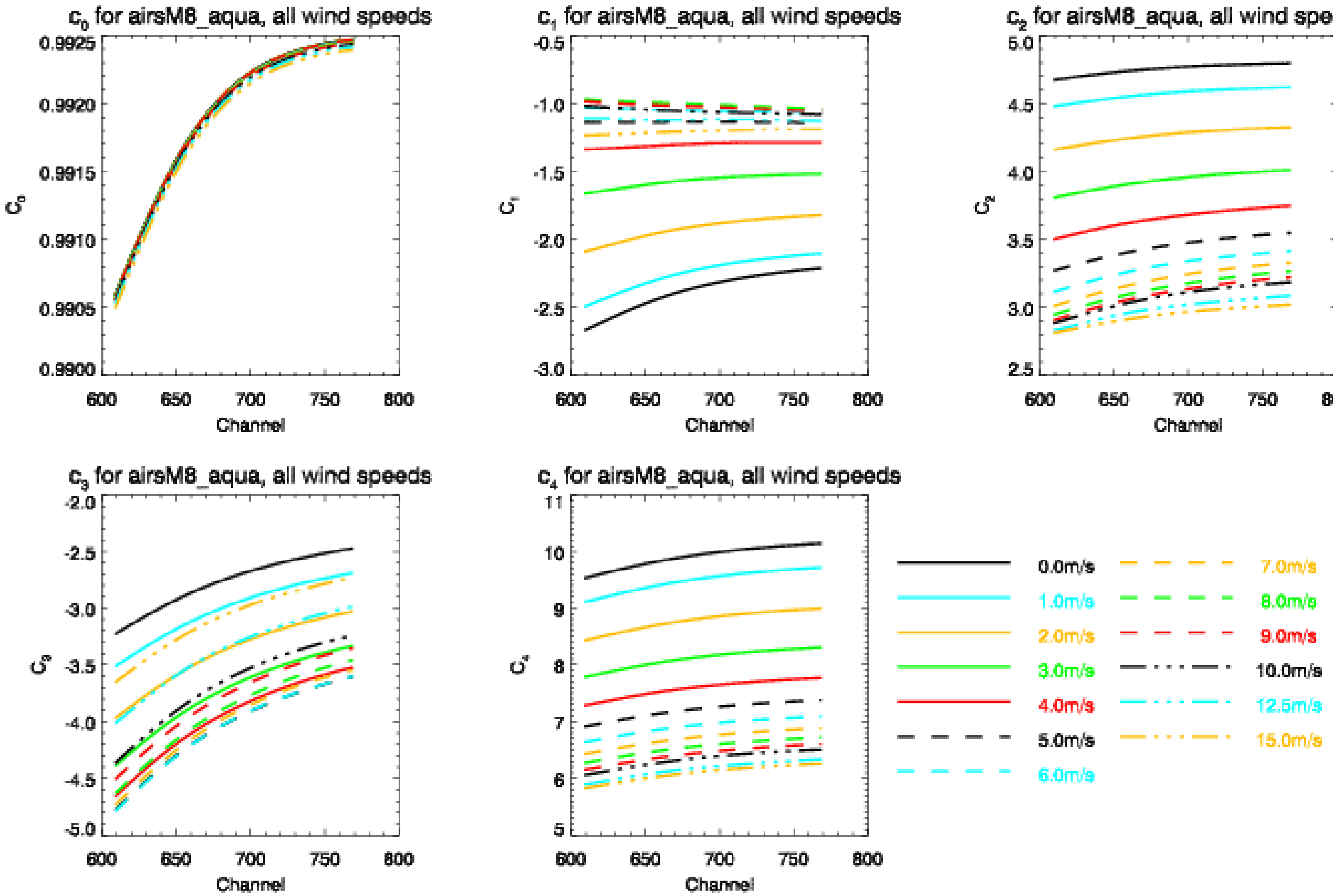
where v is the wind speed in ms^{-1}.

- 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

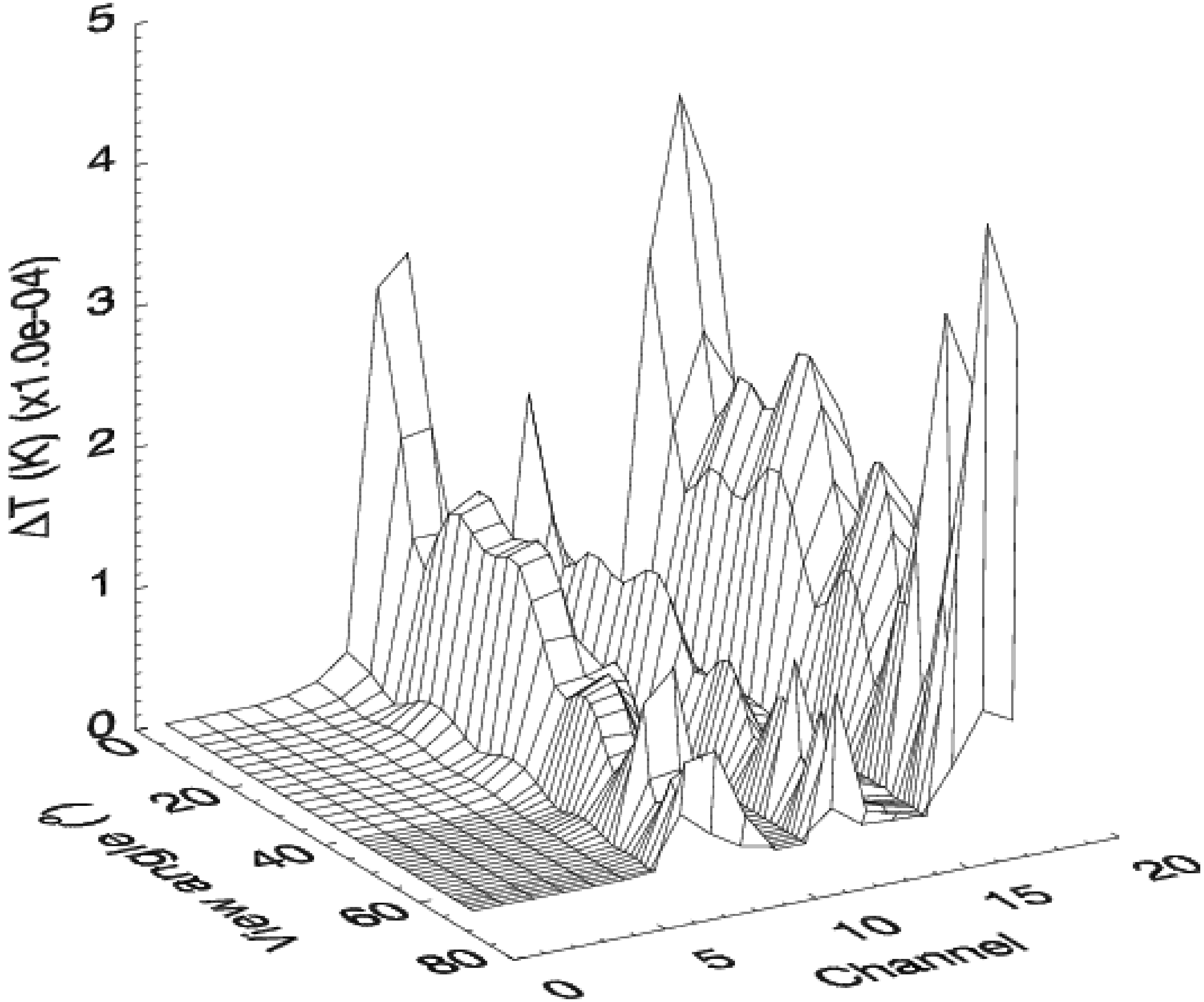
Emissivity Coefficient Variation By Channel for NOAA-17 HIRS/3



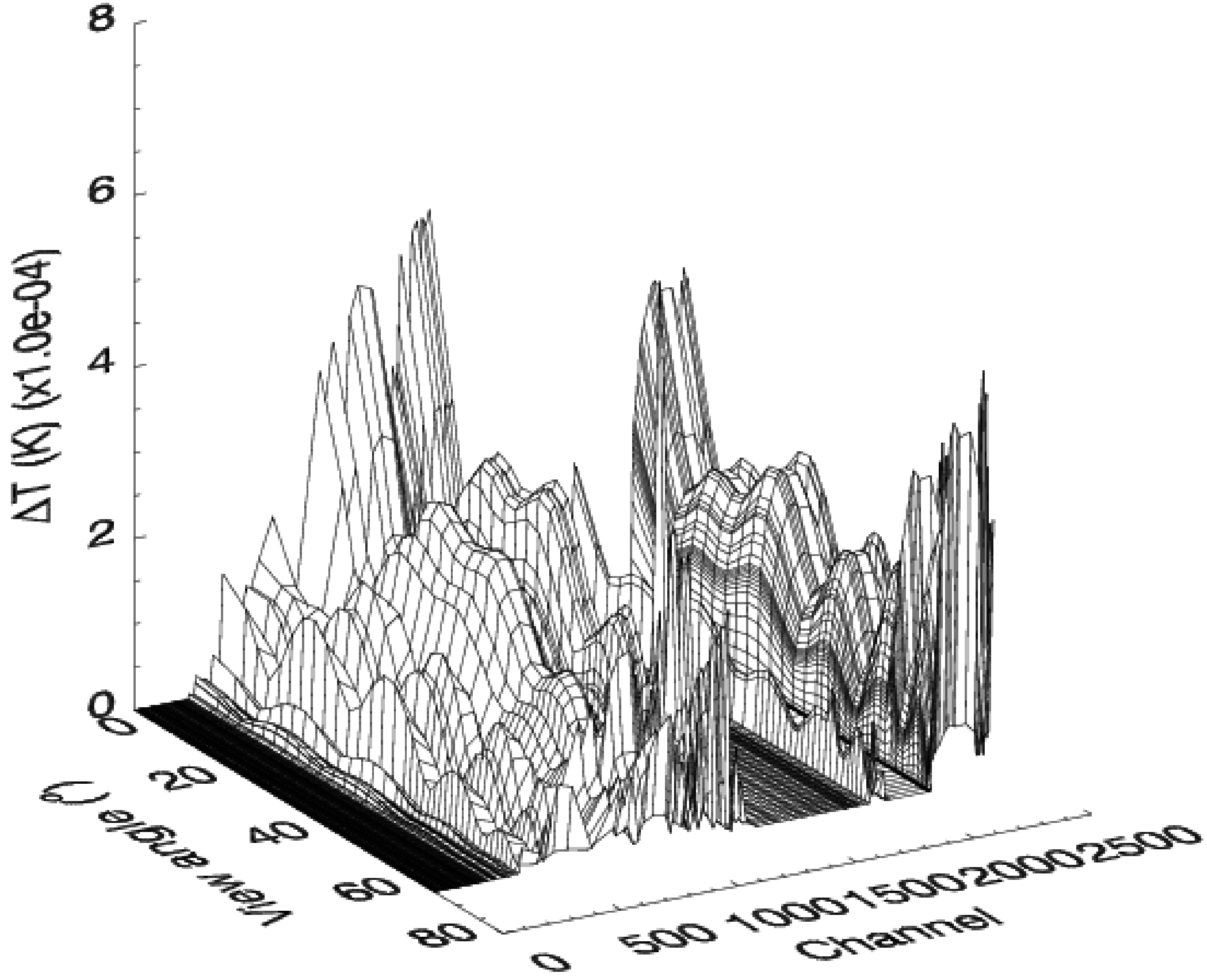
Emissivity Coefficient Variation By Channel for AIRS M8 (~850-900cm^{-1})



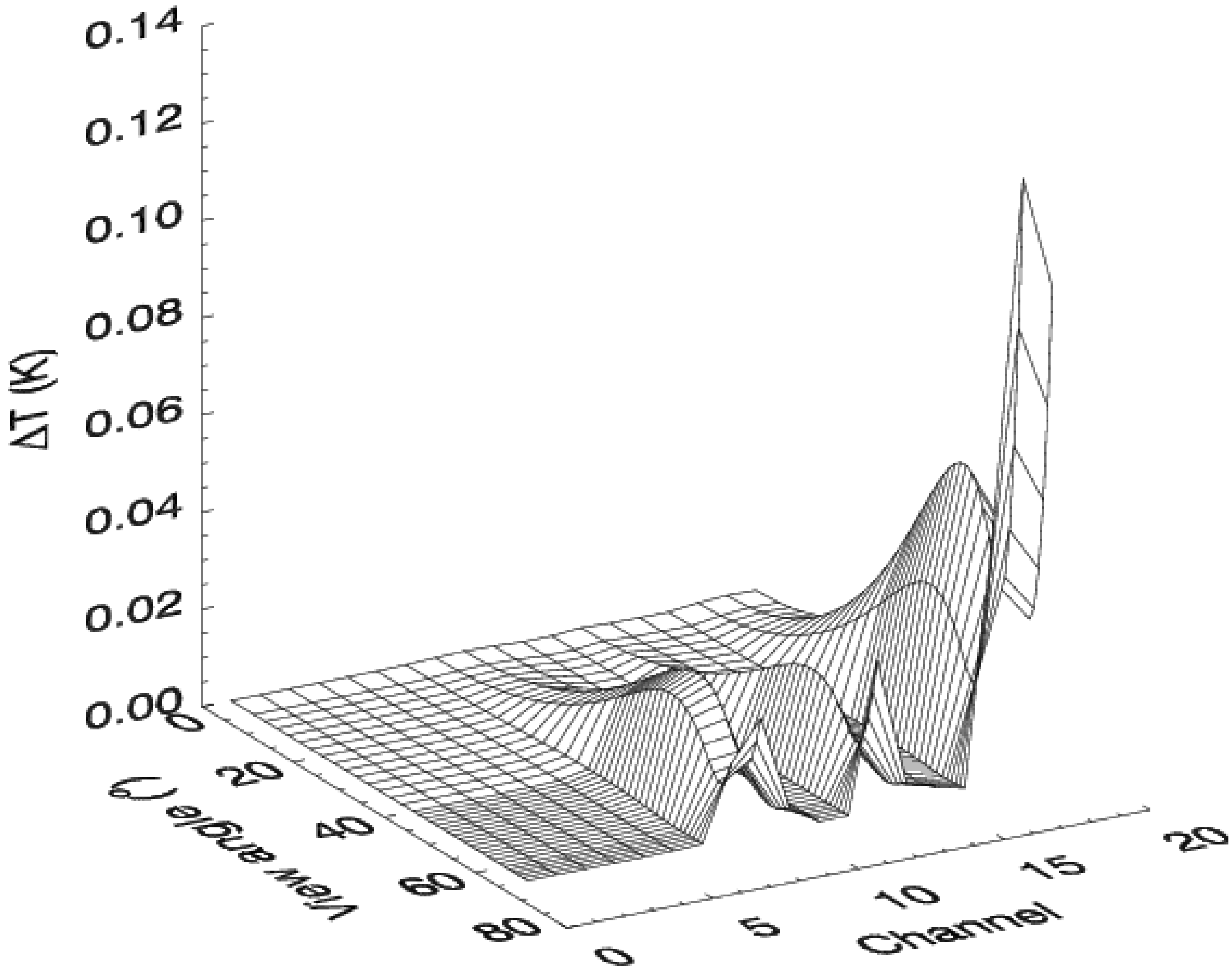
TOA T_B Residuals for NOAA-17 HIRS. RMS for all wind speeds



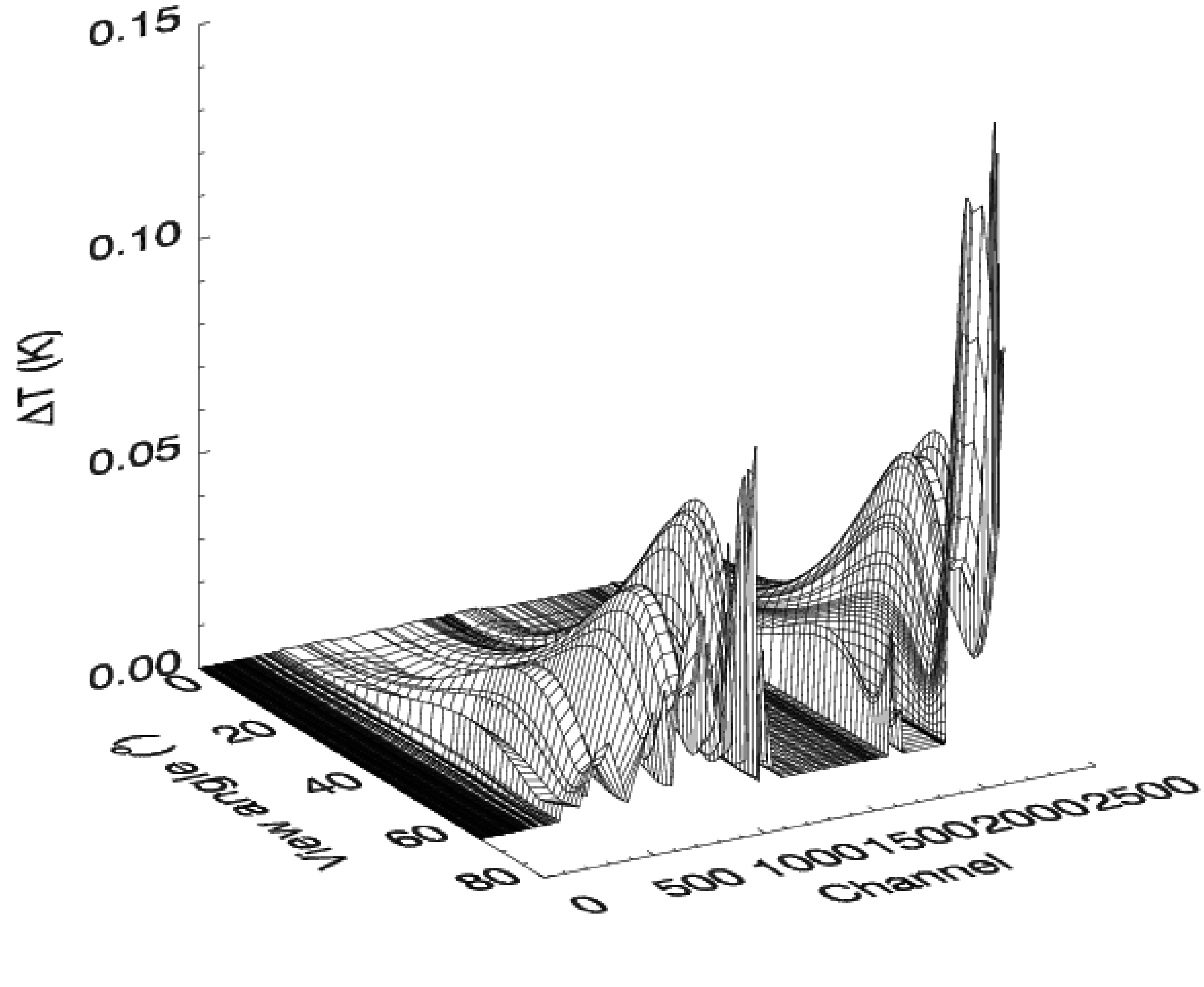
TOA T_B Residuals for AIRS 281 subset.
RMS for all wind speeds



TOA T_B Residuals for NOAA-17 HIRS. RMS for all wind speeds; only 0ms^{-1} ε predicted



TOA T_B Residuals for AIRS 281 subset.
RMS for all wind speeds; only 0ms^{-1} ε 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 ~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.

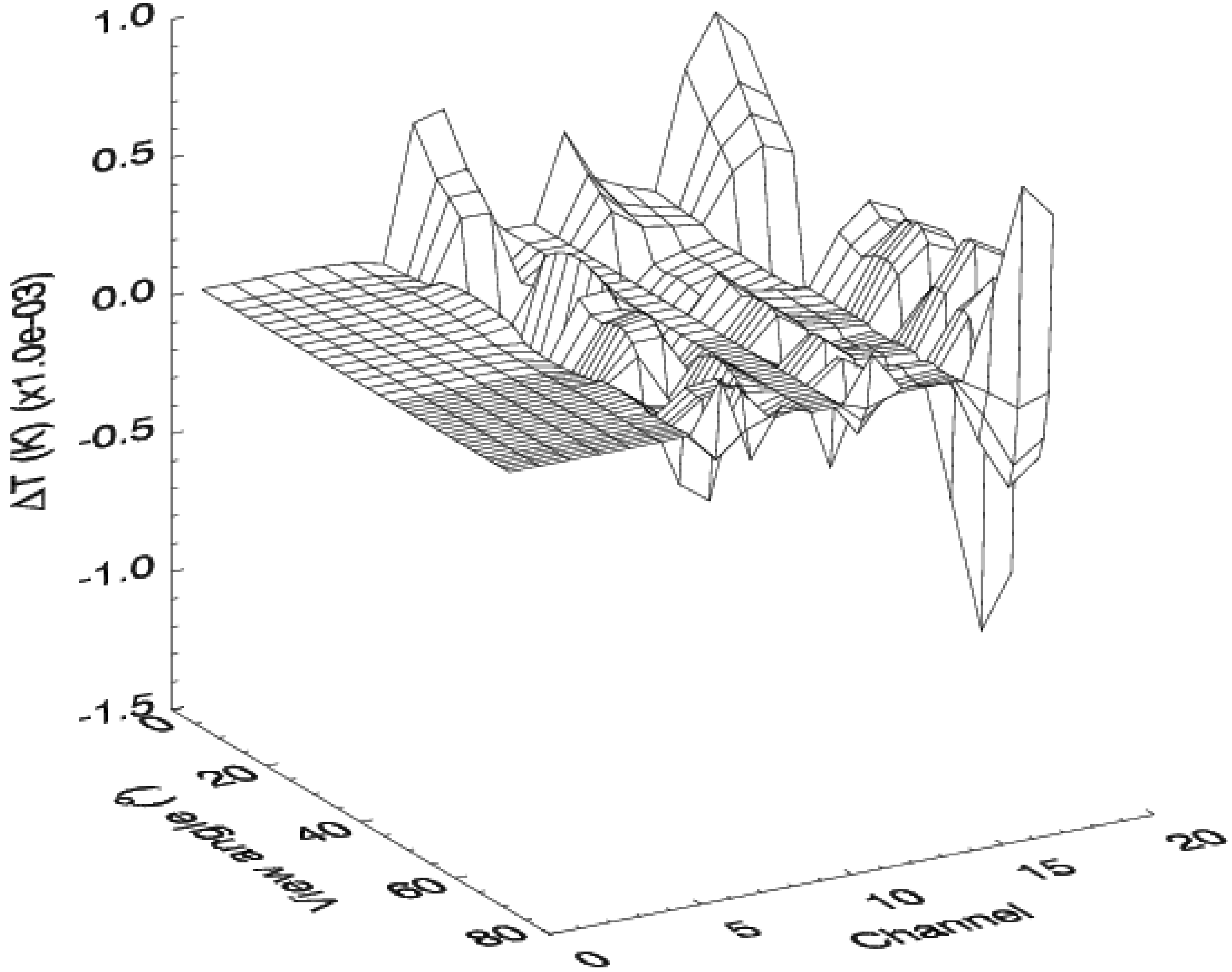
Code Availability

- 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.)

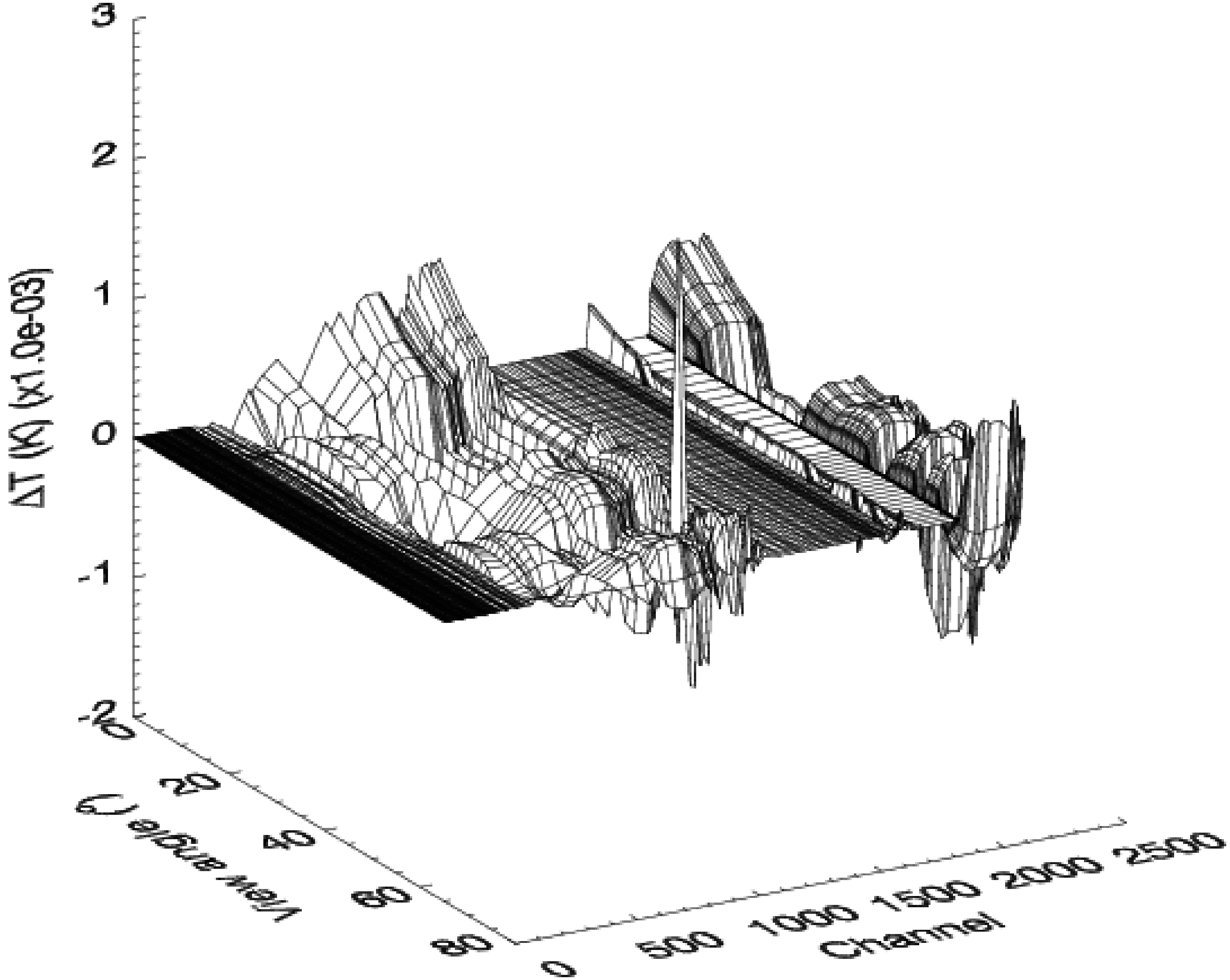
- ITSC group will be notified when code and data has been posted at a download web page/ftp site.

Extra Stuff

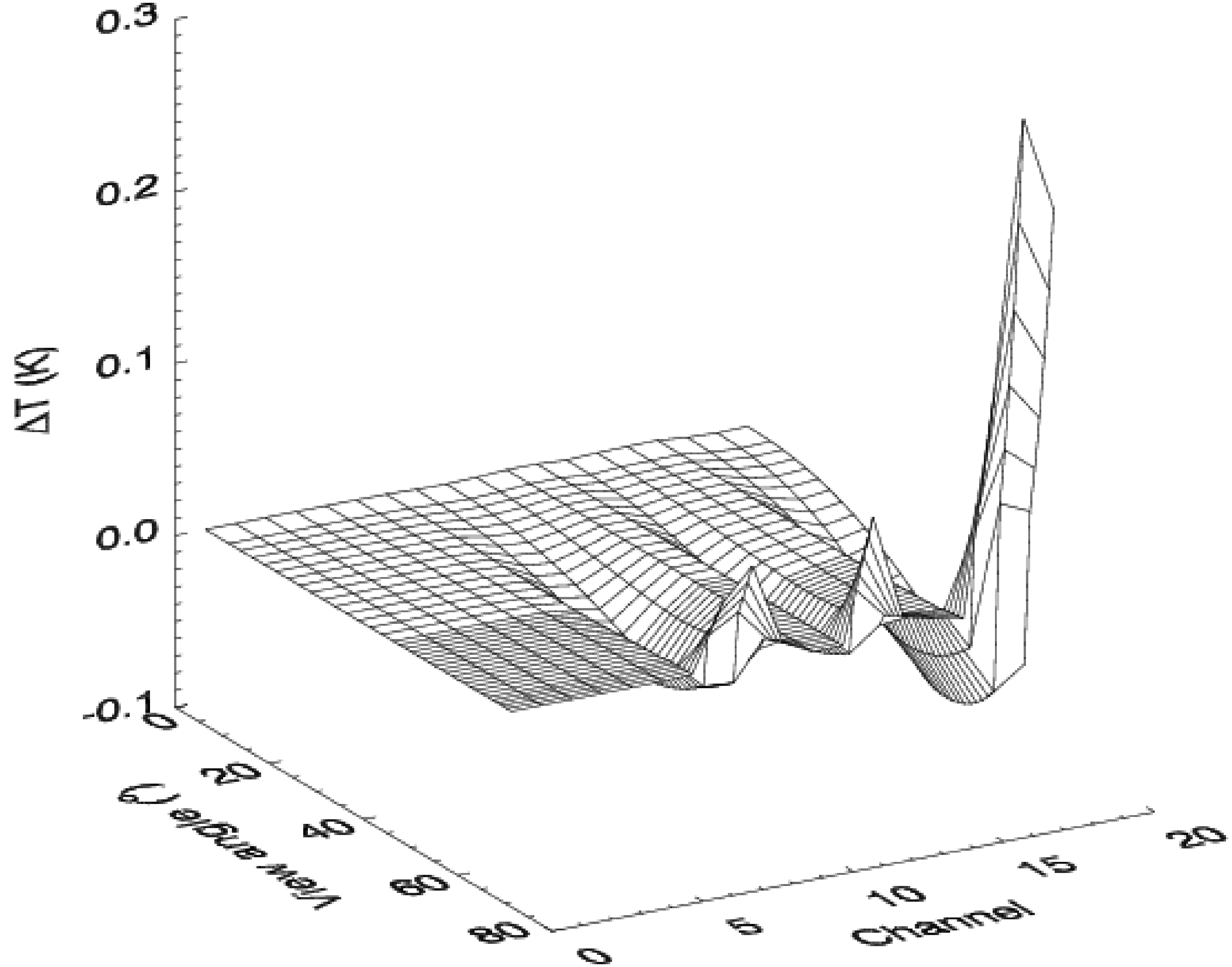
TOA T_B Residuals for NOAA-17 HIRS. MAX for all wind speeds



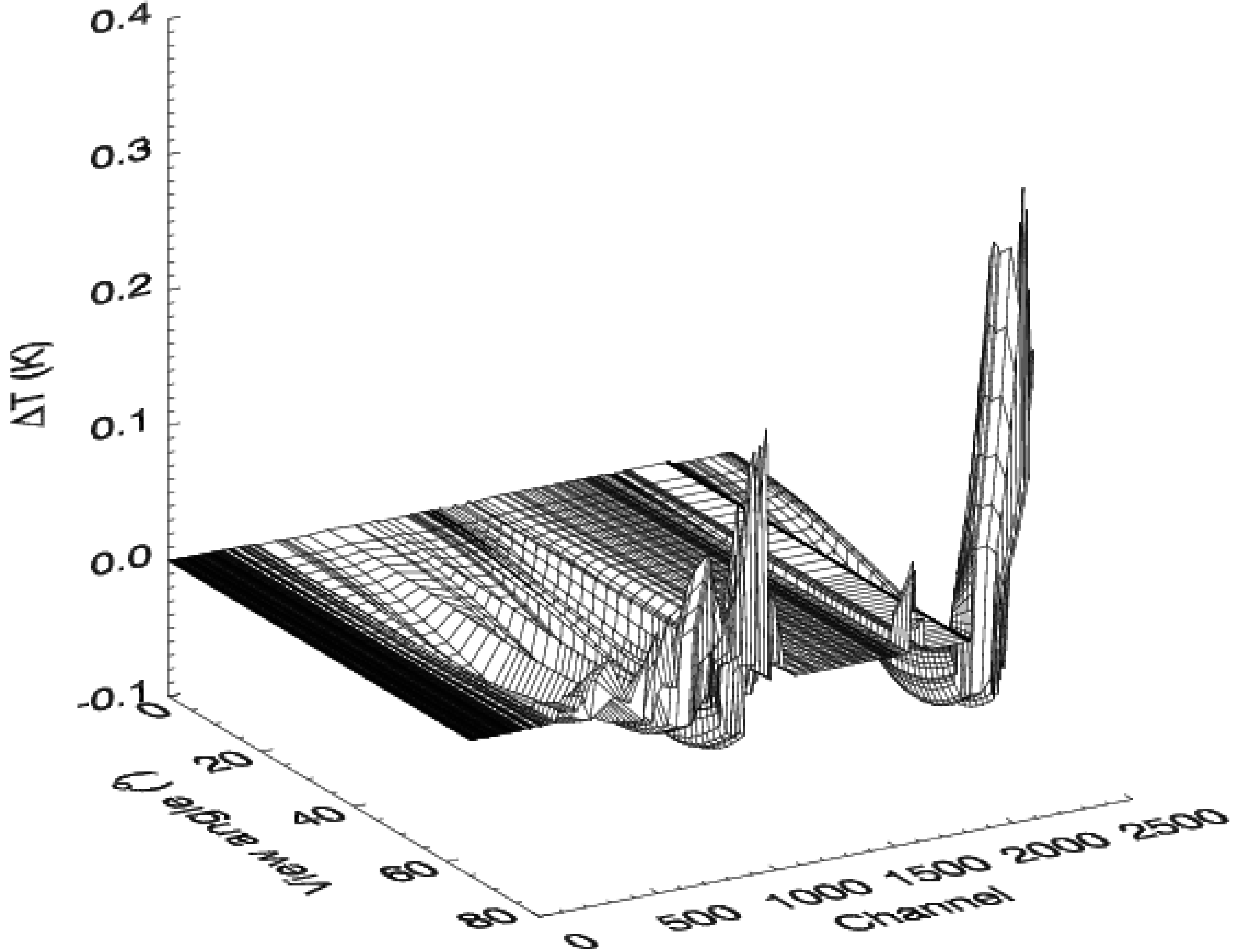
TOA T_B Residuals for AIRS 281 subset. MAX for all wind speeds



TOA T_B Residuals for NOAA-17 HIRS.
MAX for all wind speeds; only $0ms^{-1}$ ε predicted



TOA T_B Residuals for AIRS 281 subset. MAX for all wind speeds; only 0ms^{-1} ε predicted



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, δ.

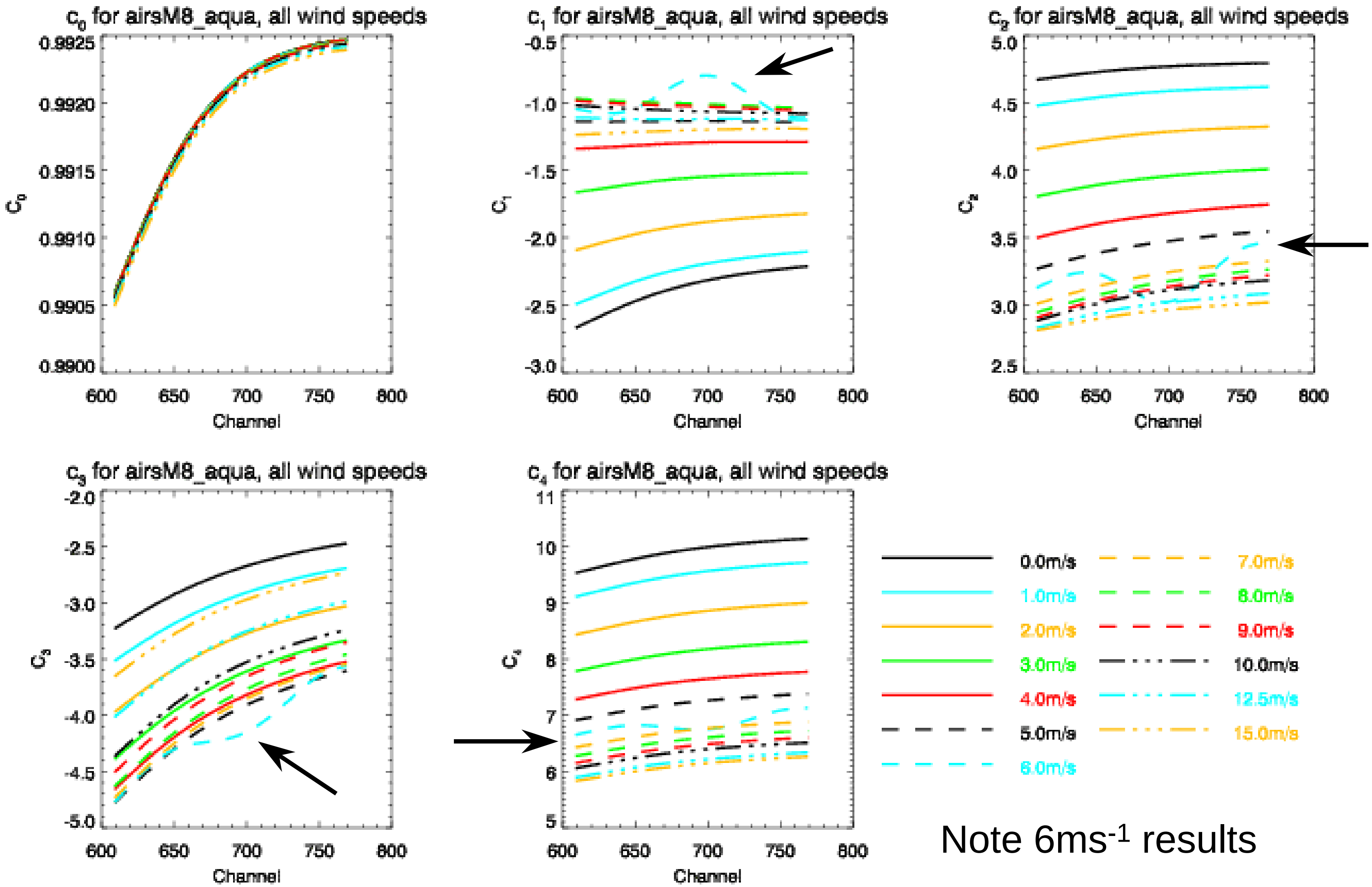
In most cases $\delta = 10^{-5}$ was sufficient. $\delta = 10^{-6}$ was used for all computation except for frequencies around 880cm^{-1} where $\delta = 10^{-7}$ was needed.

Lower accuracy == Faster computation

For the affected frequencies/wind speeds at a single angle, computation time increased from 6m30s to 4h03m18s!

Integration accuracy (2)

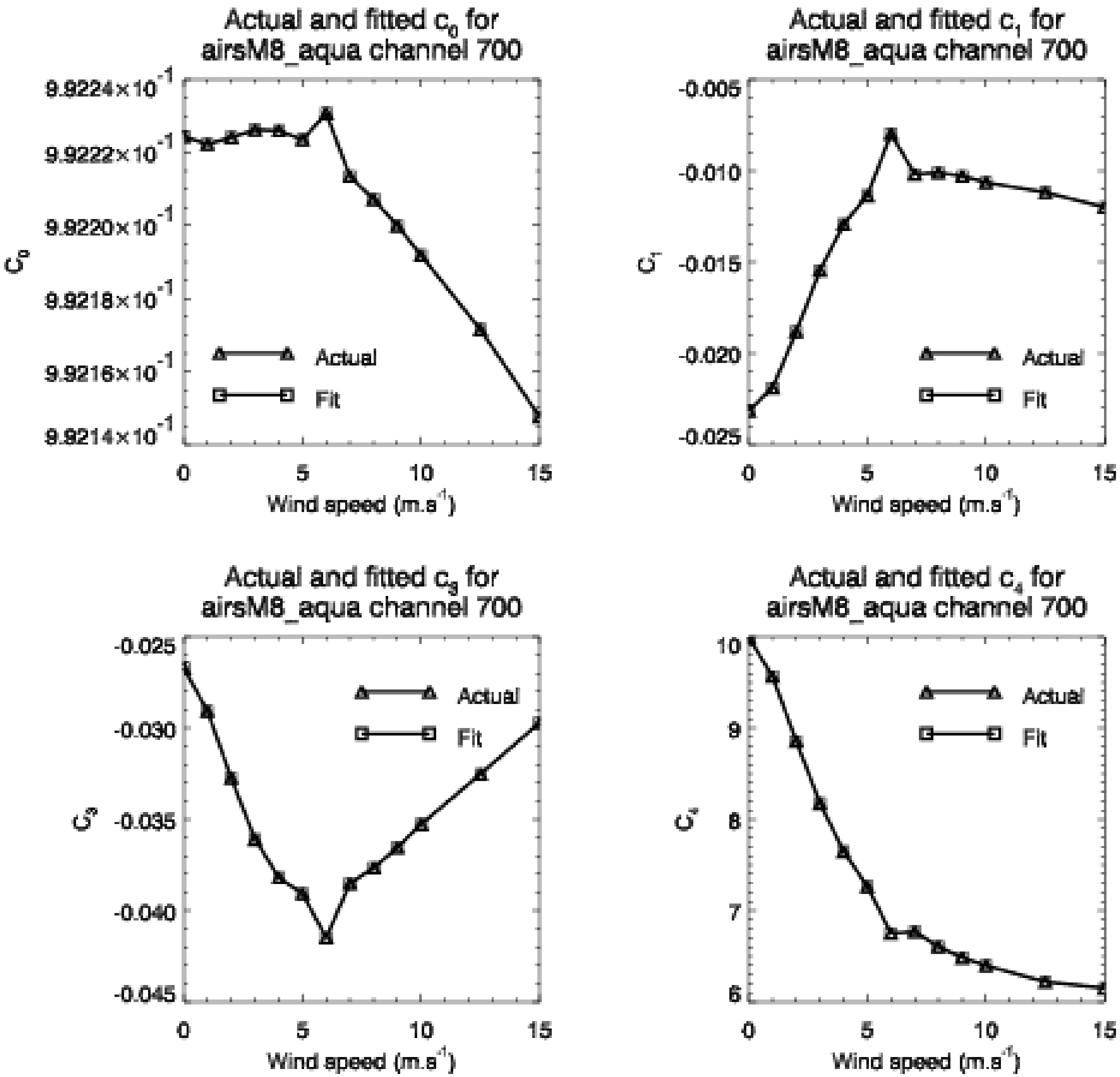
AIRS M8 (~850-900cm-1) coefficients



Note 6ms^{-1} results

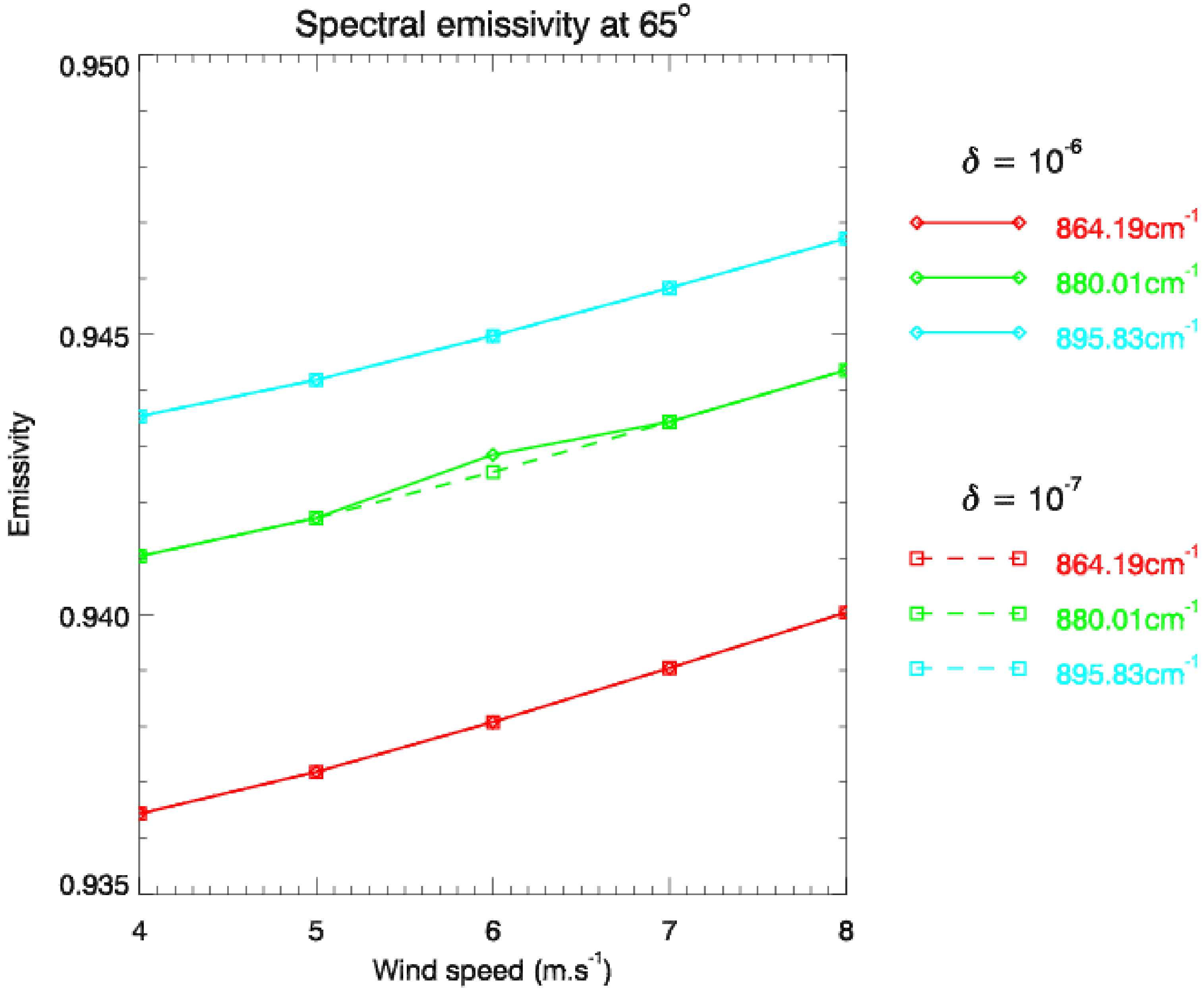
Integration accuracy (3)

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)



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 ~0.0003. This is small (effect on T_B is also small), but is about 2x the typical RMS emissivity residual.

International TOVS Study Conference, 13th, TOVS-13, Sainte Adele, Quebec, Canada, 29 October-4 November 2003. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2003.