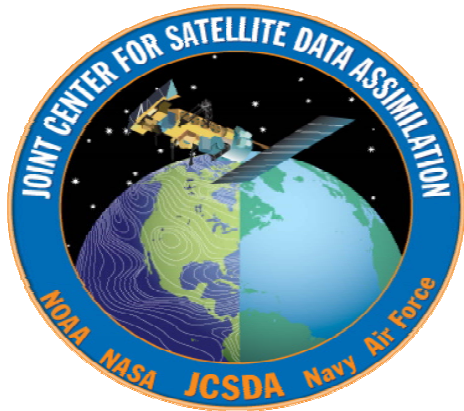




# JCSDA Infrared Sea Surface Emissivity Model Status



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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).

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

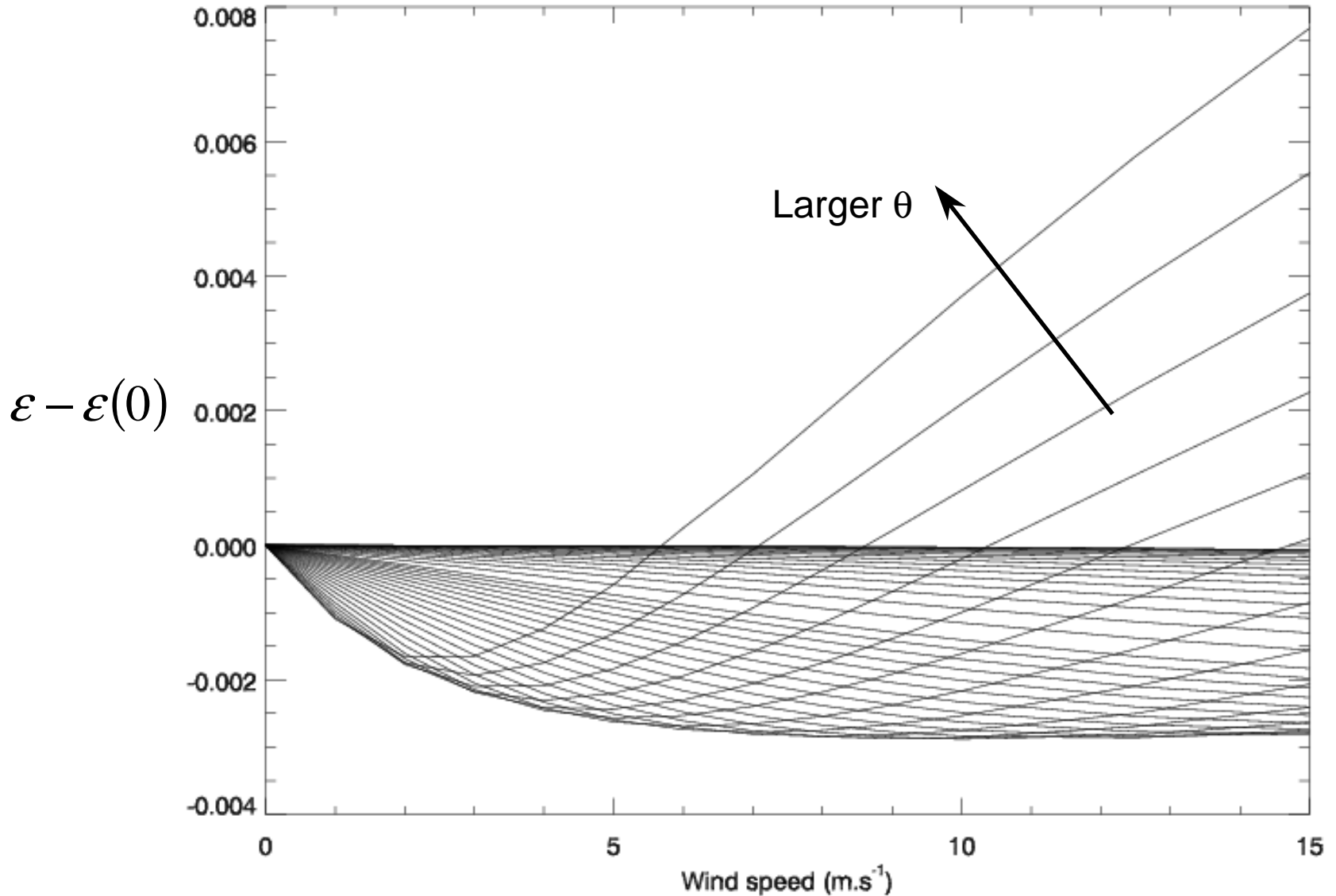
where  $\hat{\theta} = \frac{\theta}{60^\circ}$  and  $N_1, N_2$  are integers.

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  $0.0\text{ms}^{-1}$  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°



## IRSSE Model (2)

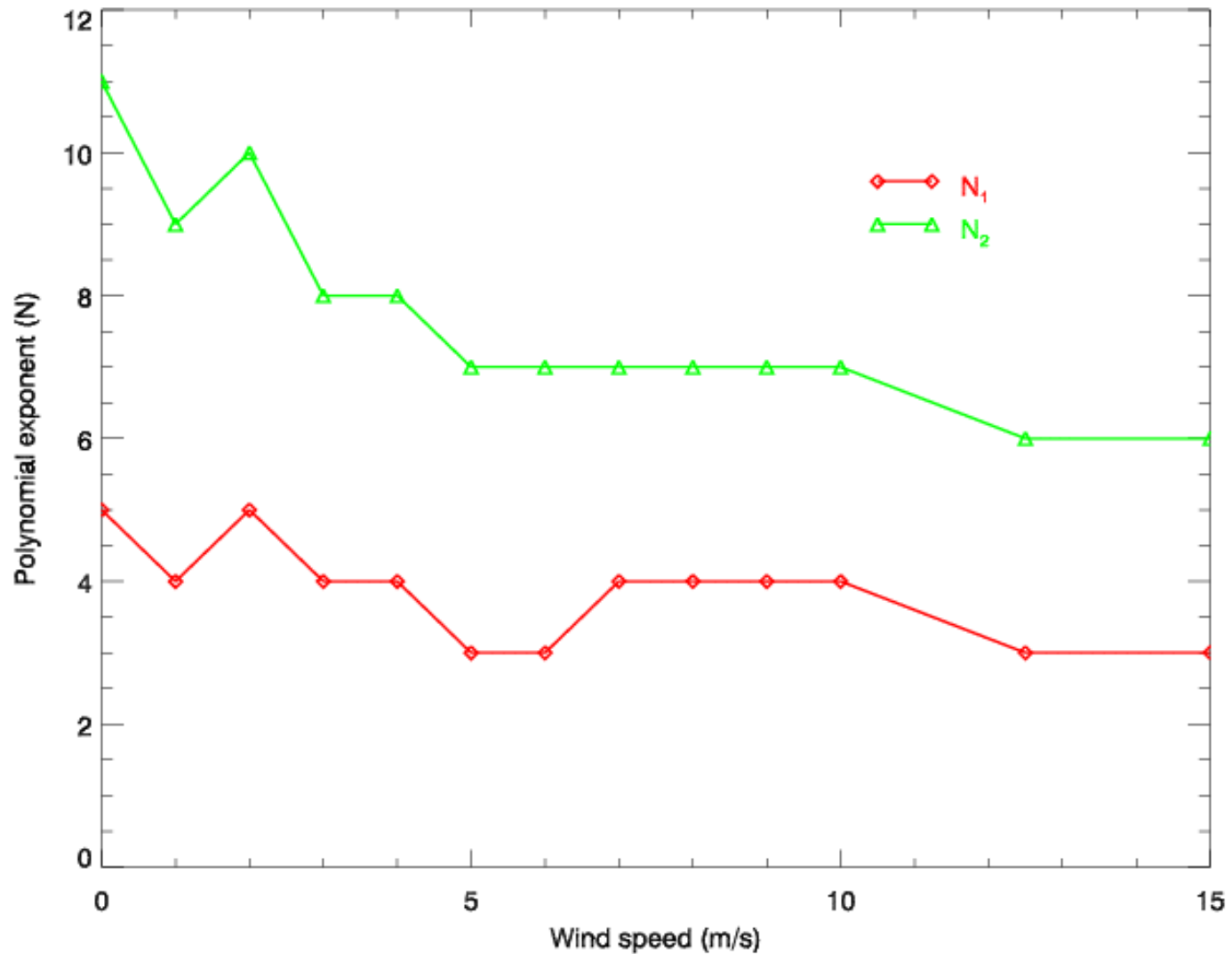
Since the variation with wind speed was greater than 0.0002, the exponents,  $N_1$  and  $N_2$ , of the emissivity model were also allowed to vary.

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.

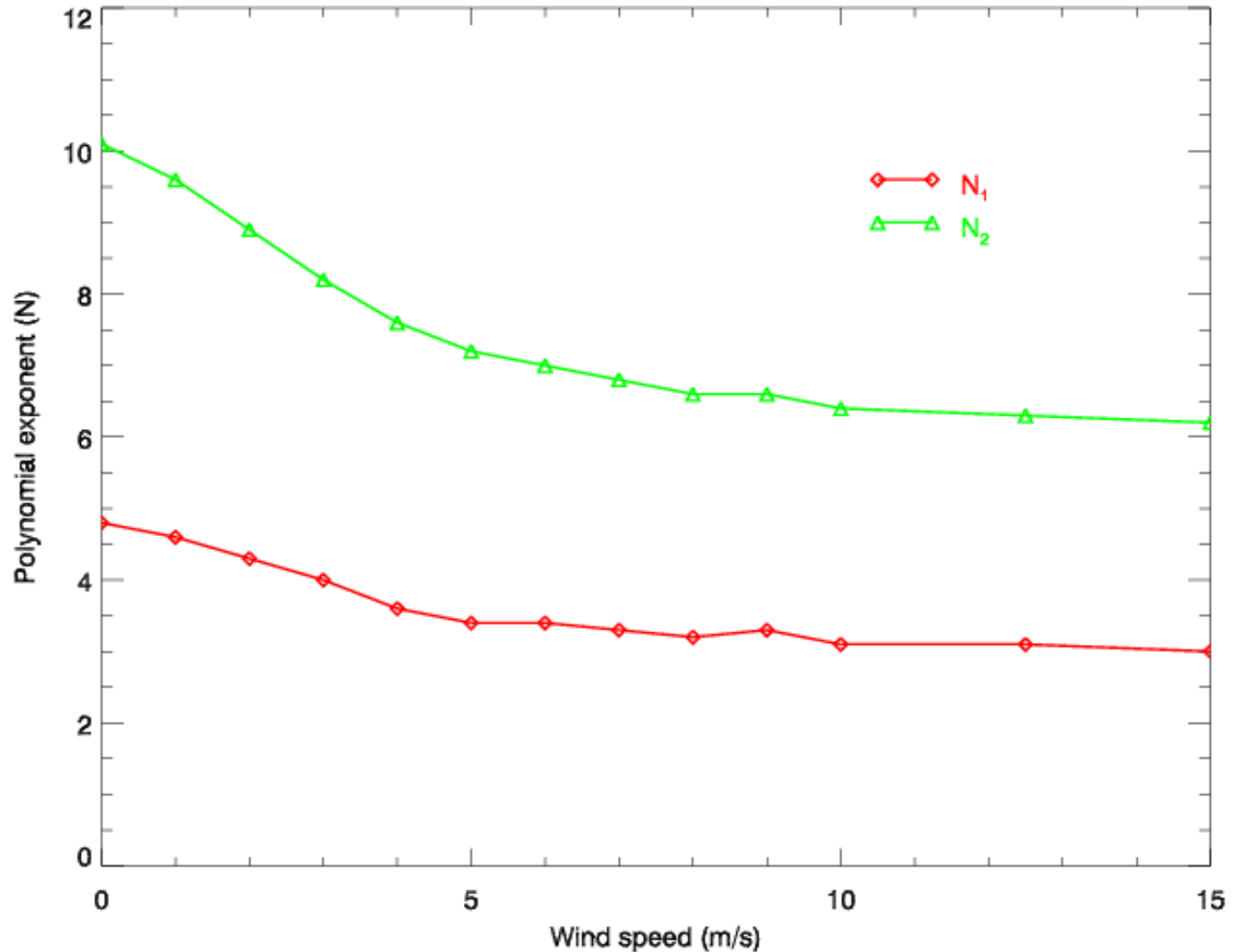
# Wind Speed Dependence of Integral Exponents

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



# Wind Speed Dependence of Real Exponents

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



# IRSSE Model (3)

The model was slightly changed to,

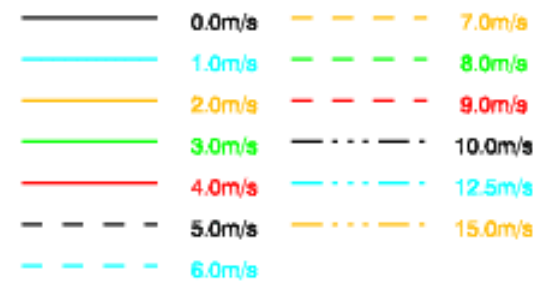
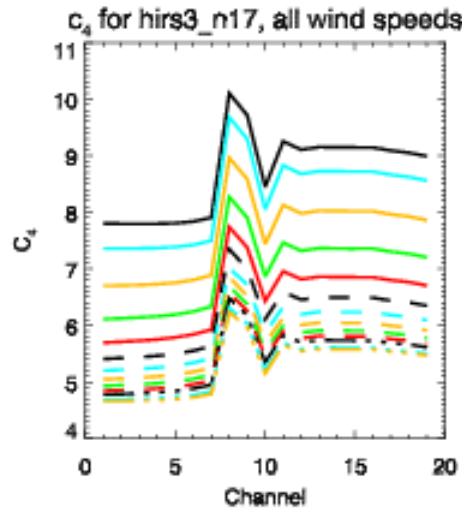
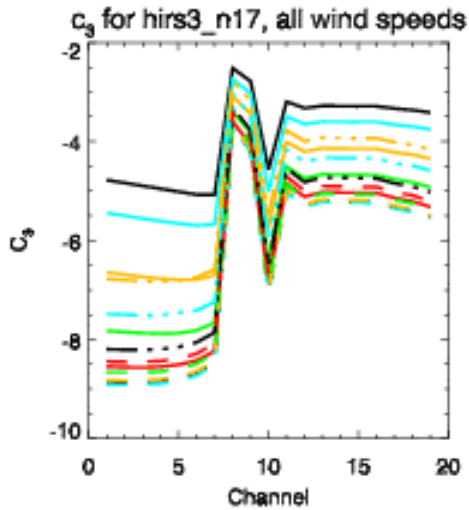
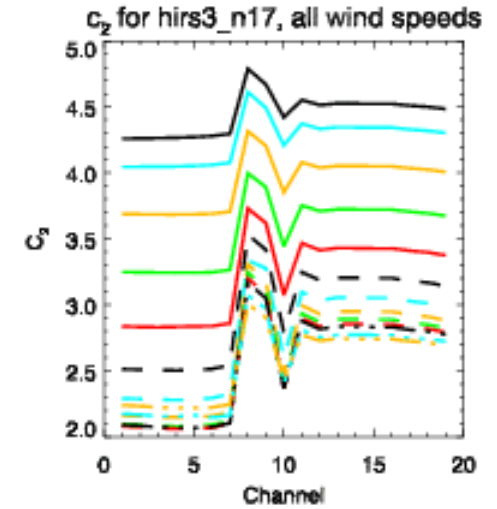
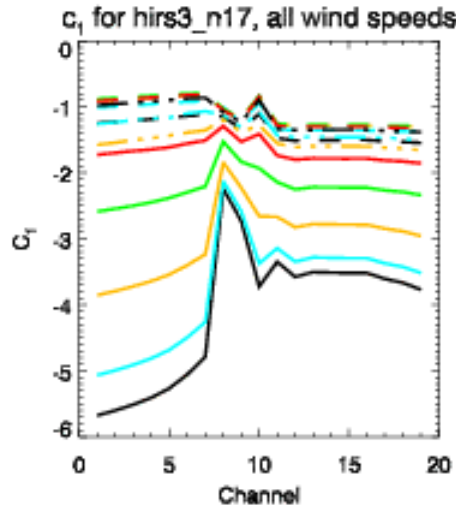
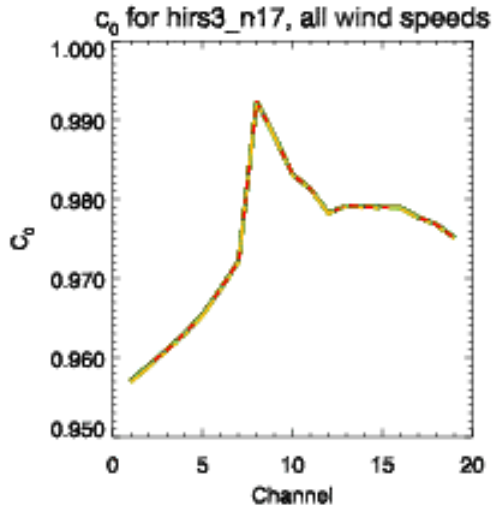
$$\varepsilon(\theta, \nu) = c_0(\nu) + c_1(\nu)\hat{\theta}^{c_2(\nu)} + c_3(\nu)\hat{\theta}^{c_4(\nu)} \quad (2)$$

where  $\nu$  is the wind speed in  $\text{ms}^{-1}$ .

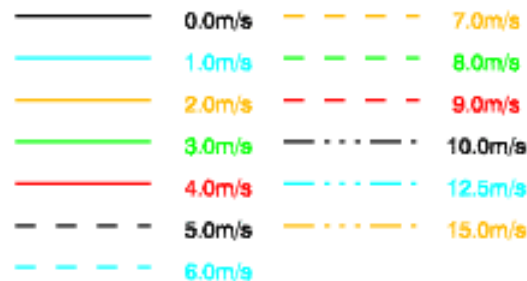
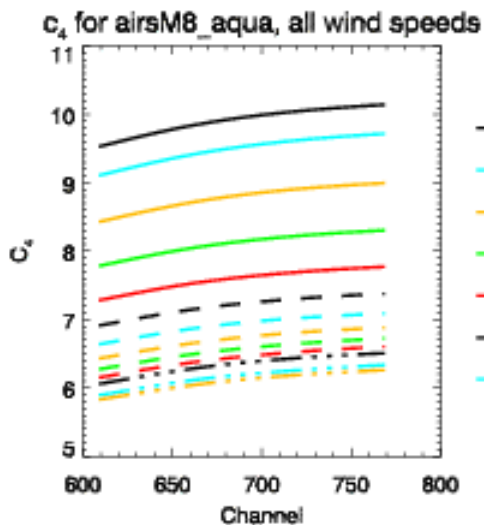
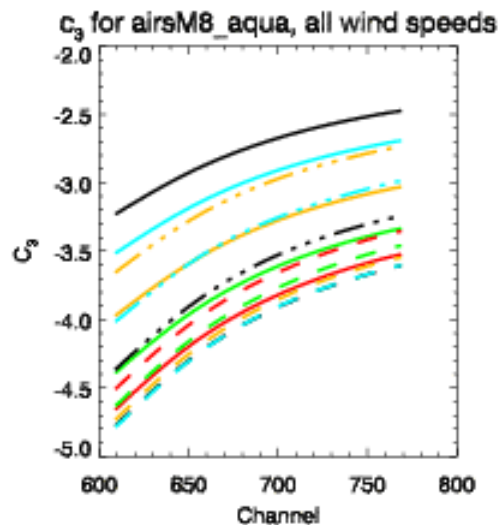
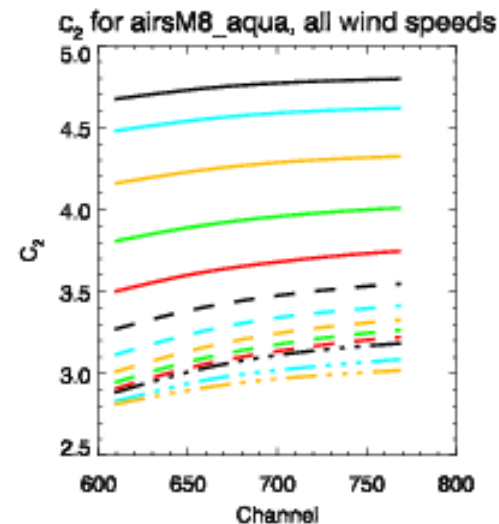
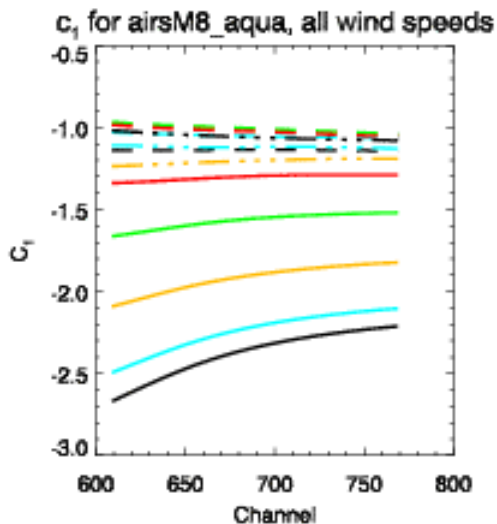
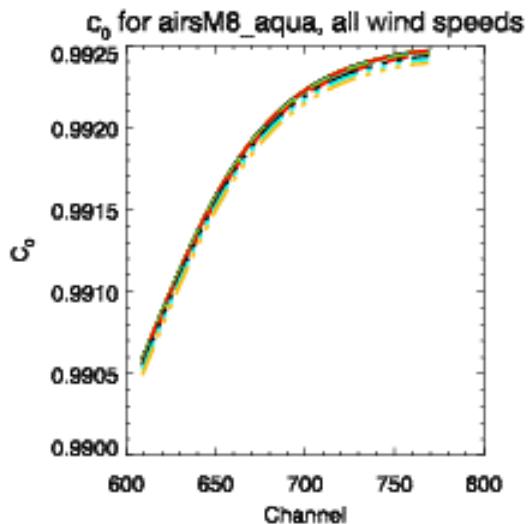
- Generating the coefficients
  - For a series of wind speeds, the coefficients  $c_i$  were obtained.
  - Interpolating coefficients for each  $c_i$  as a function of wind speed were determined. These are stored in the model datafiles.
- Using the model
  - For a given wind speed, the  $c_i$  are computed.
  - These coefficients are then used to compute the view angle dependent emissivity



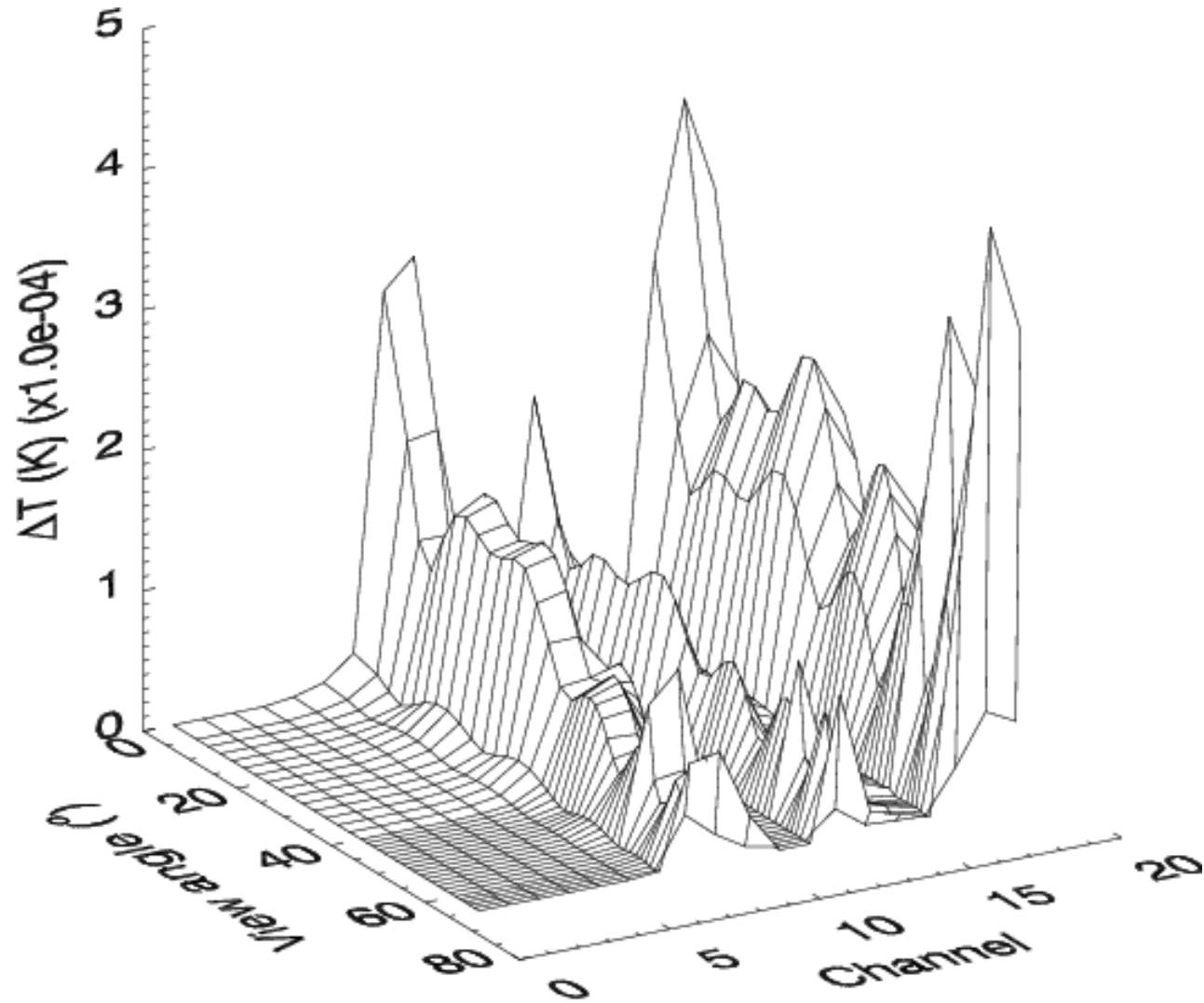
# Emissivity Coefficient Variation By Channel for NOAA-17 HIRS/3



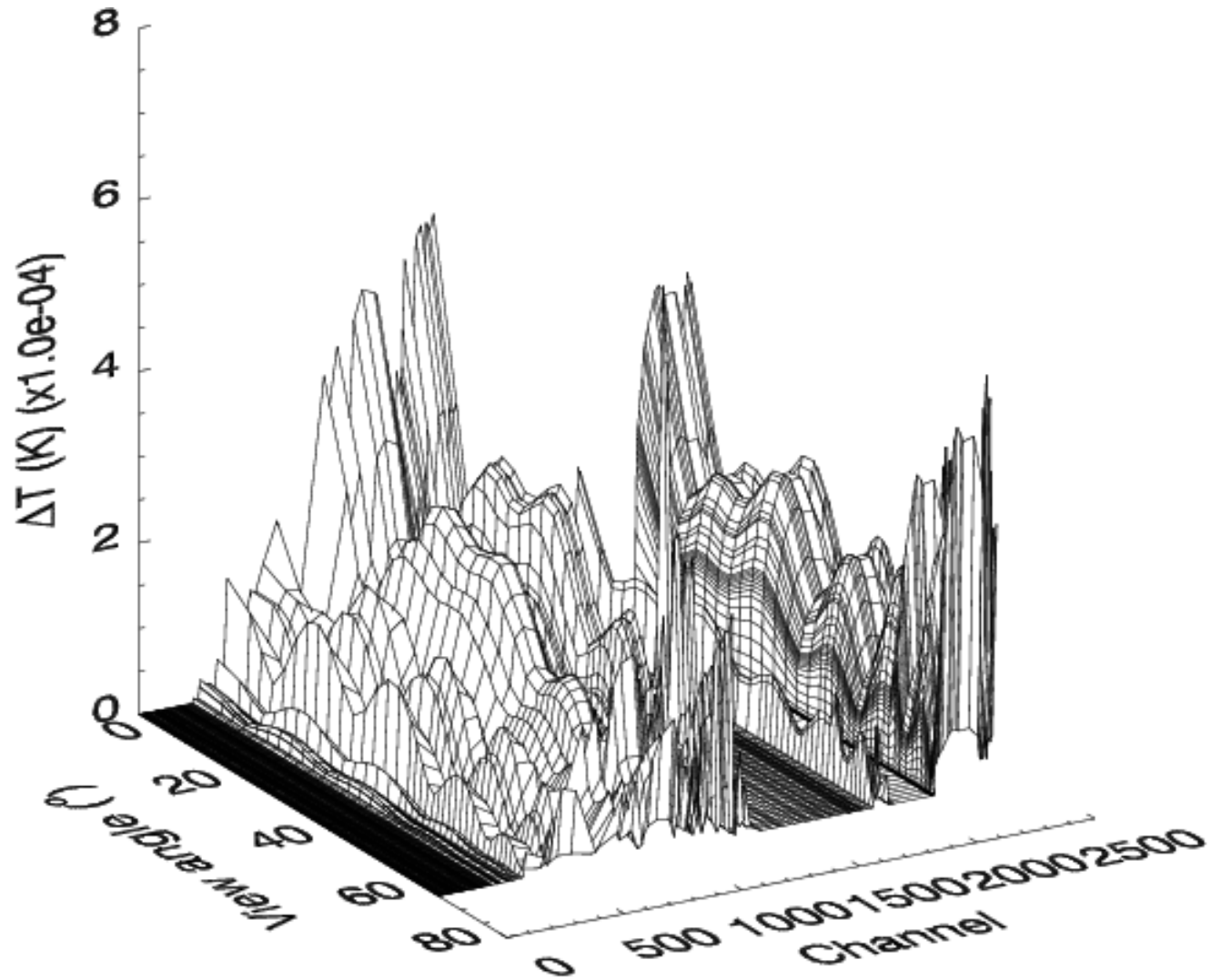
# Emissivity Coefficient Variation By Channel for AIRS M8 ( $\sim 850\text{-}900\text{cm}^{-1}$ )



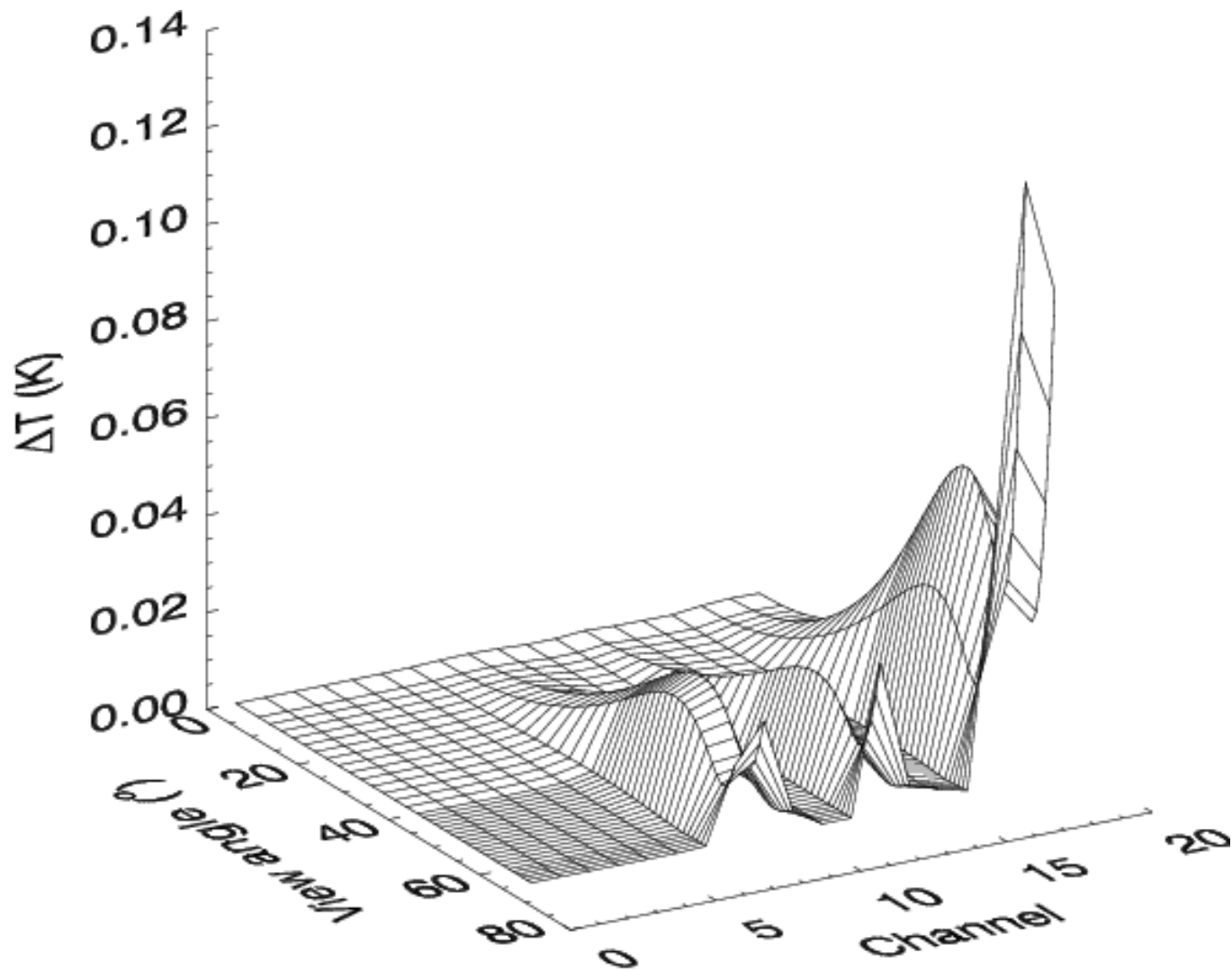
# TOA $T_B$ Residuals for NOAA-17 HIRS. RMS for all wind speeds



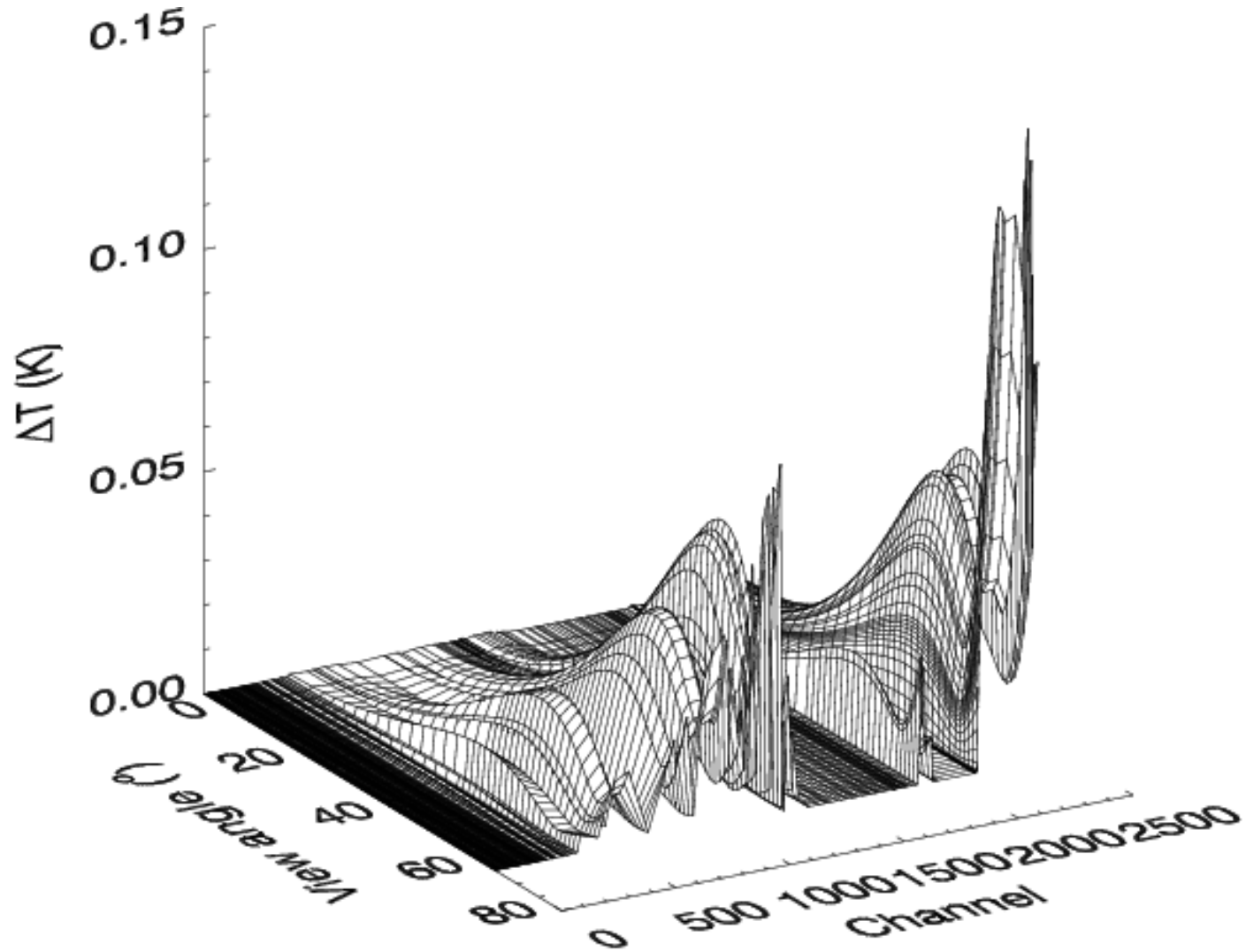
# TOA $T_B$ Residuals for AIRS 281 subset. RMS for all wind speeds



# TOA $T_B$ Residuals for NOAA-17 HIRS. RMS for all wind speeds; only $0\text{ms}^{-1}$ $\epsilon$ predicted



# TOA $T_B$ Residuals for AIRS 281 subset. RMS for all wind speeds; only $0\text{ms}^{-1}$ $\varepsilon$ 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  $0.0\text{ms}^{-1}$  emissivities are predicted:

- Residuals peak for largest view angles.
- Shortwave channels appear to be more sensitive.
- Magnitudes can be  $> 0.1$ K for high view angles. For angles  $< 40$ - $45^\circ$ , residuals are typically  $< 0.02$ K

# 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.

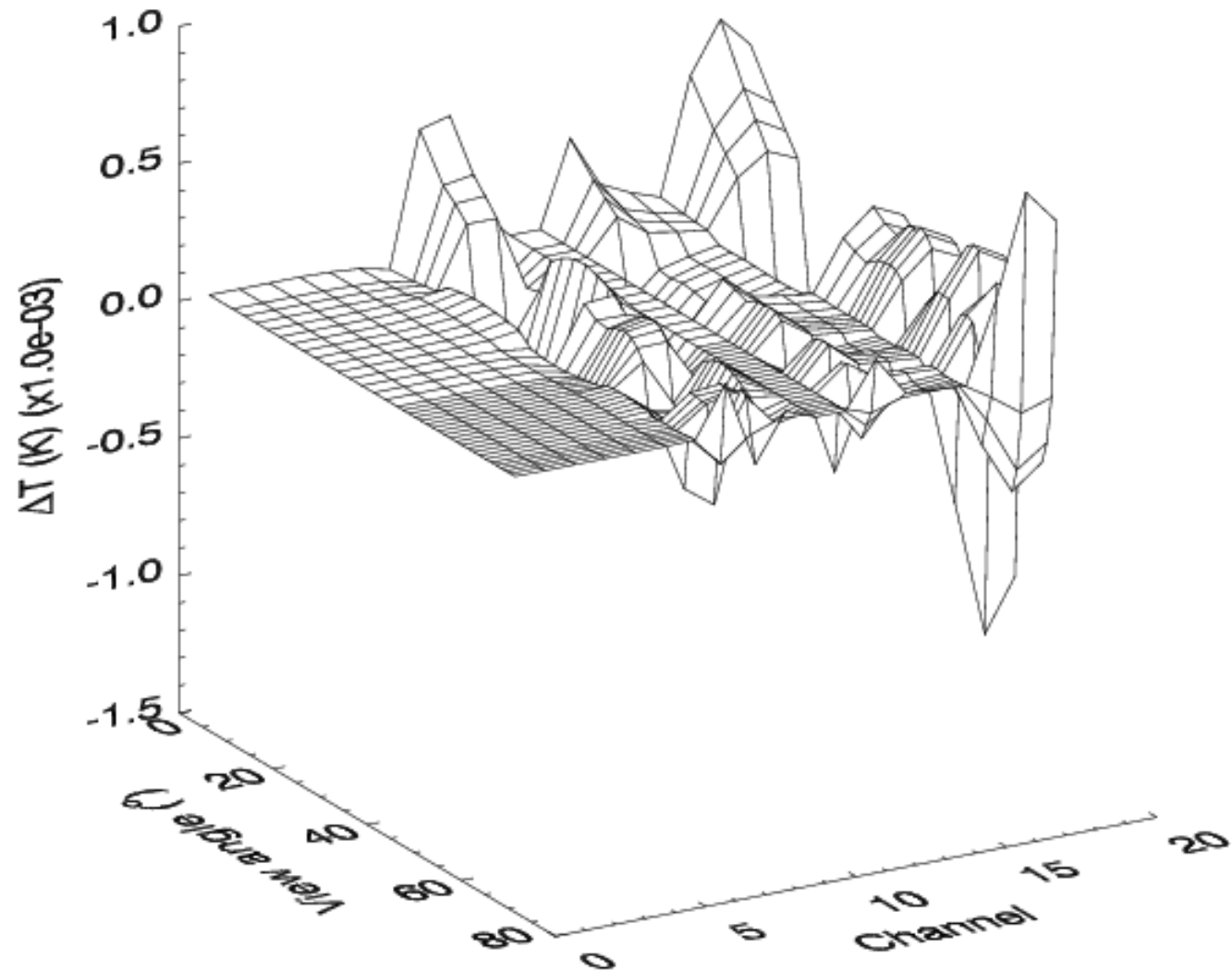


# Code Availability

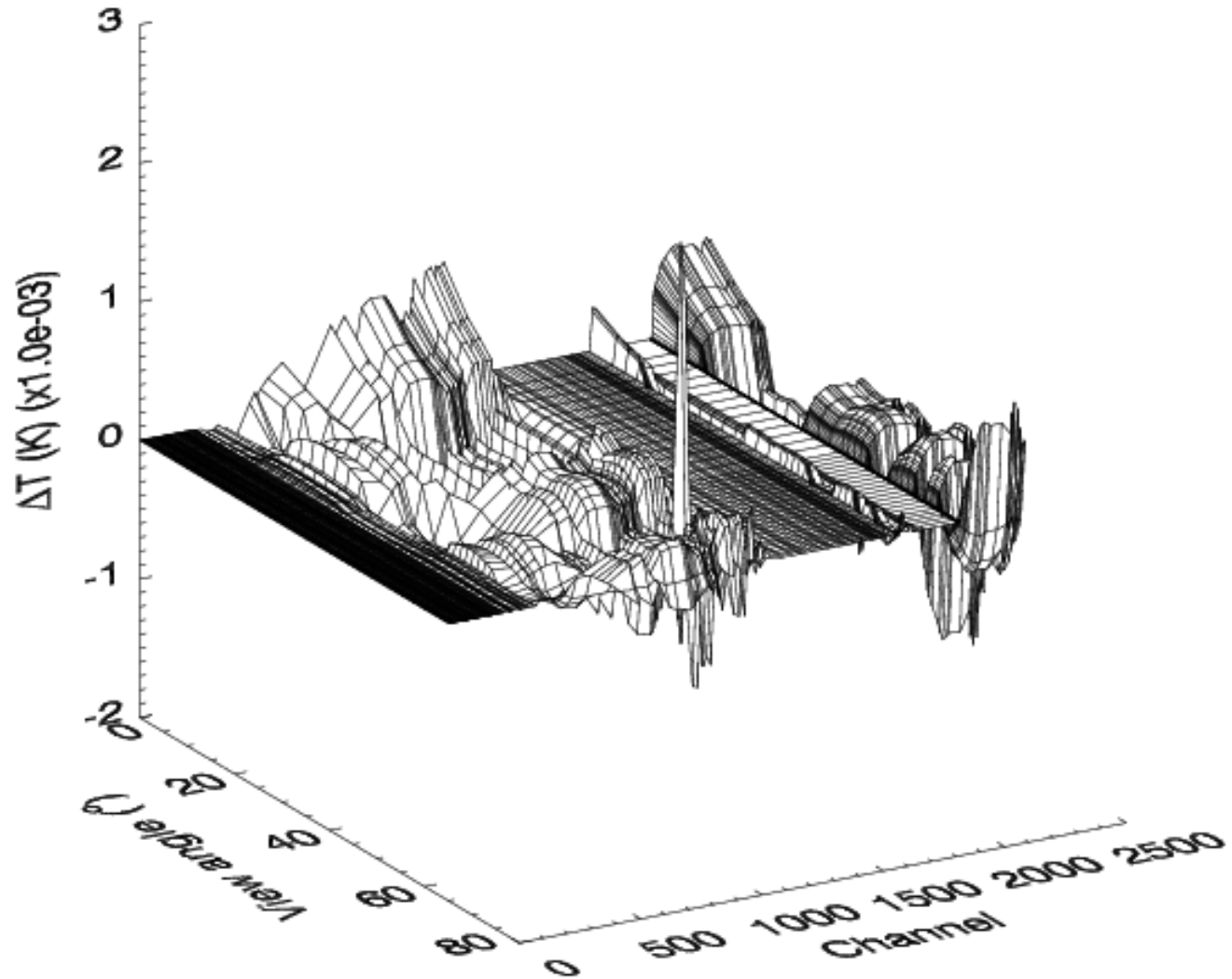
- Three parts of the code
  - Code to compute spectral emissivities (Fortran90) and refractive index netCDF datafiles
  - Code to fit model and produce coefficients (IDL)
  - IRSSE model code (Fortran90) and coefficient datafiles. (Operational code used in the GDAS.)
- ITSC group will be notified when code and data has been posted at a download web page/ftp site.

**Extra Stuff**

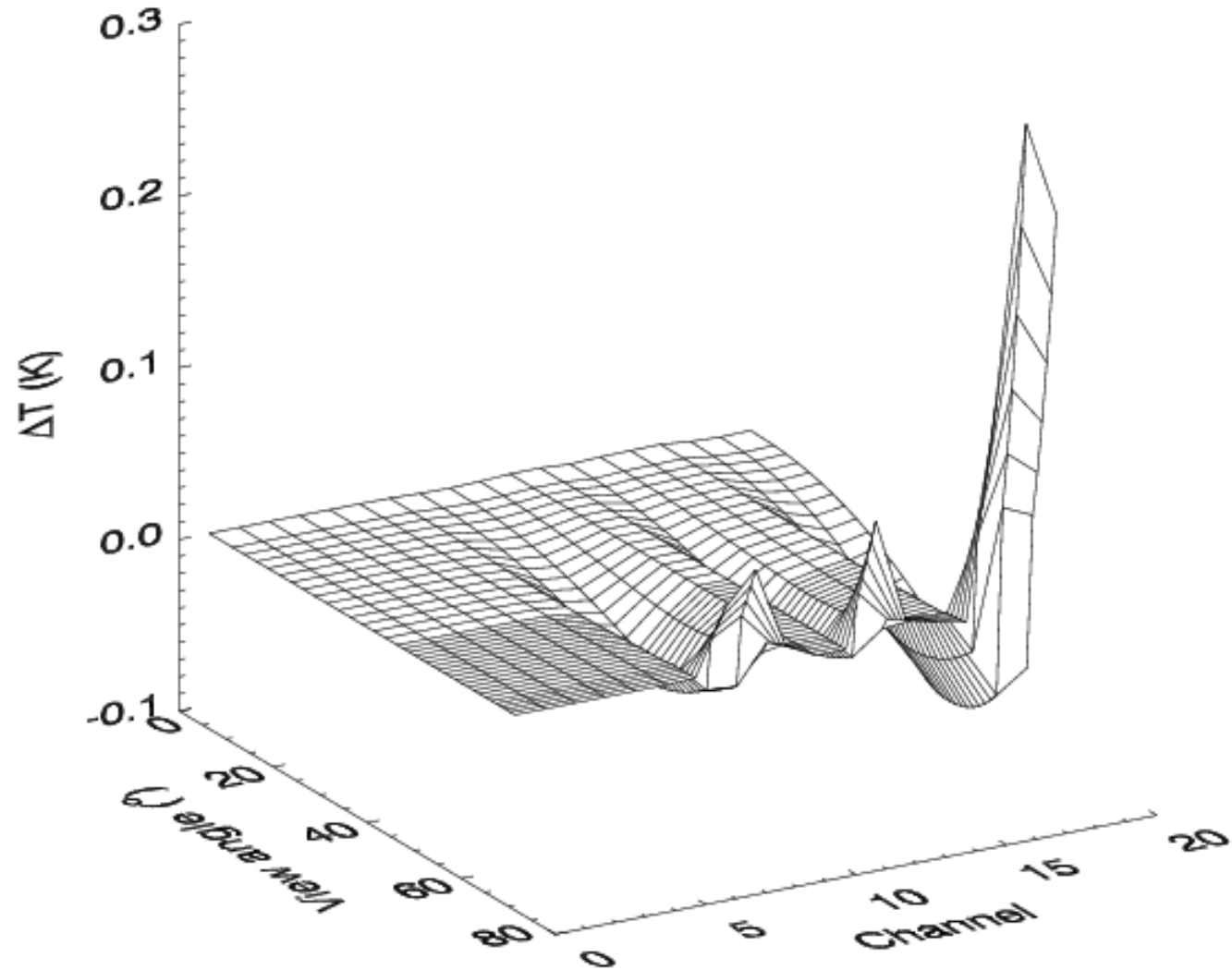
# TOA $T_B$ Residuals for NOAA-17 HIRS. MAX for all wind speeds



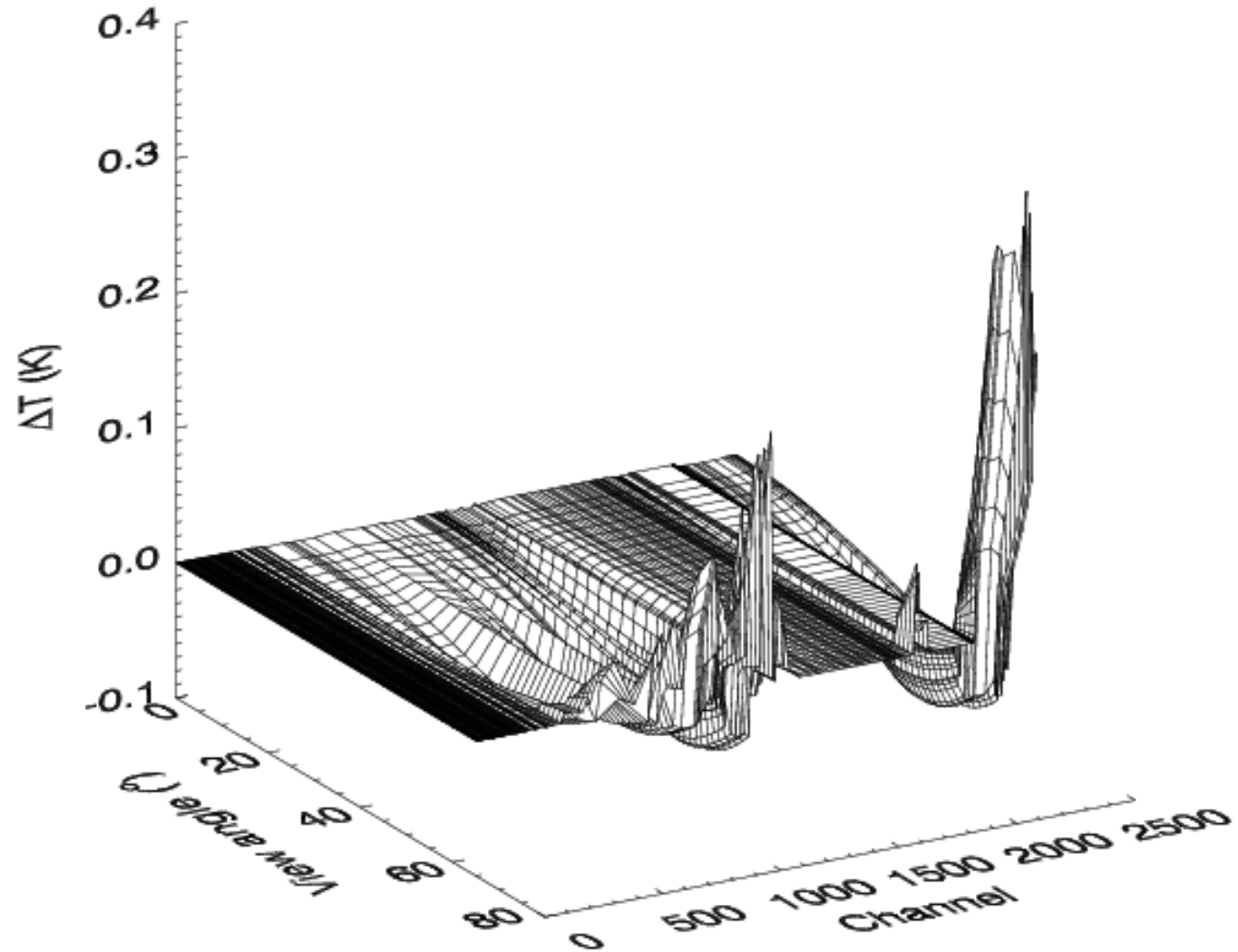
# TOA $T_B$ Residuals for AIRS 281 subset. MAX for all wind speeds



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



# TOA $T_B$ Residuals for AIRS 281 subset. MAX for all wind speeds; only $0\text{ms}^{-1}$ $\epsilon$ 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,  $\delta$ .

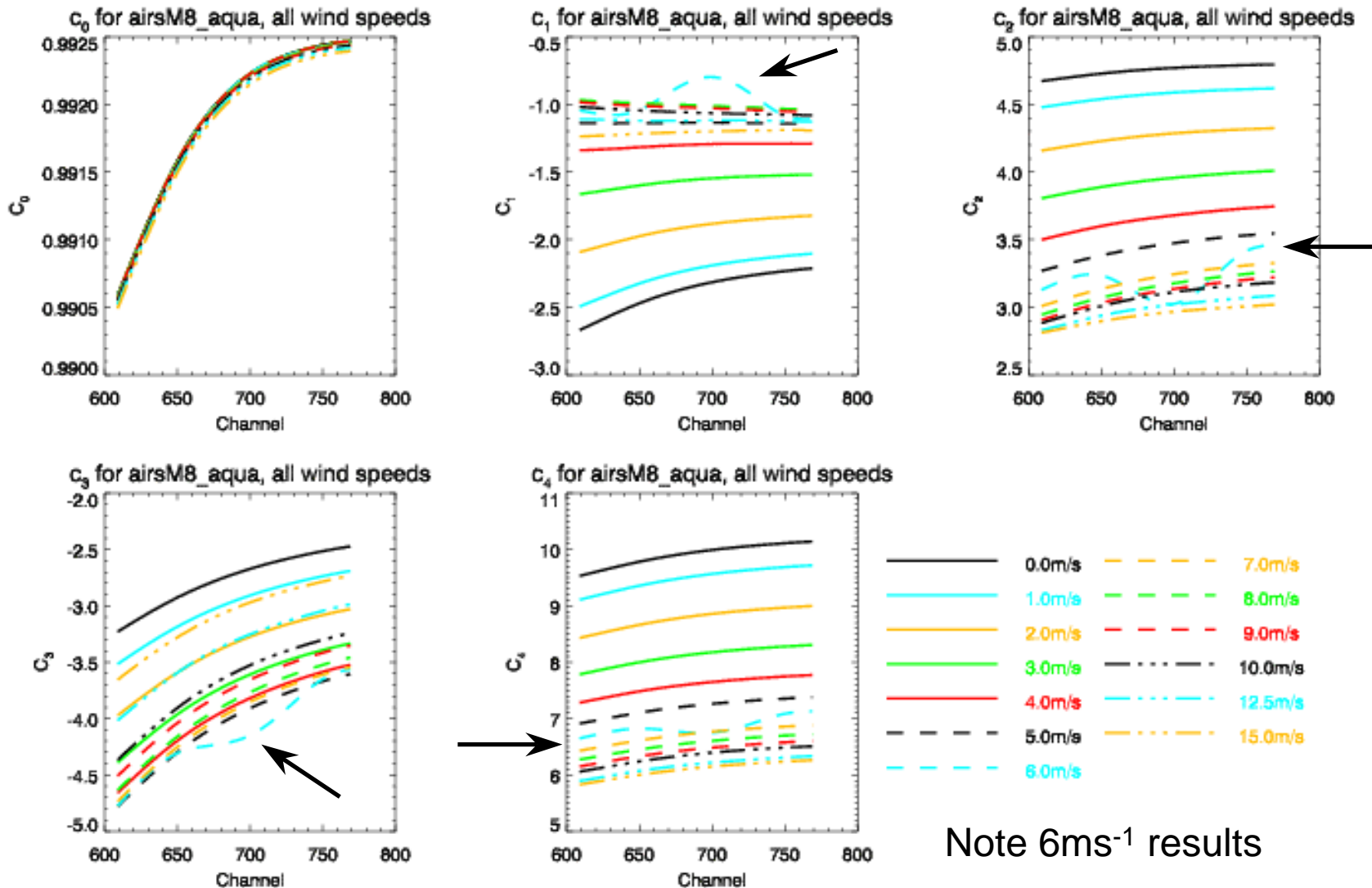
In most cases  $\delta = 10^{-5}$  was sufficient.  $\delta = 10^{-6}$  was used for all computation except for frequencies around  $880\text{cm}^{-1}$  where  $\delta = 10^{-7}$  was needed.

Lower accuracy == Faster computation

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

# Integration accuracy (2)

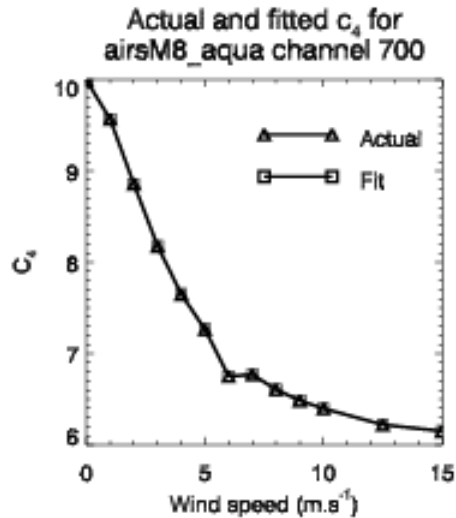
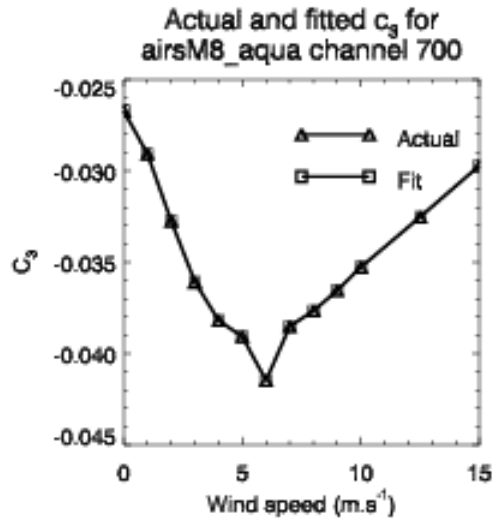
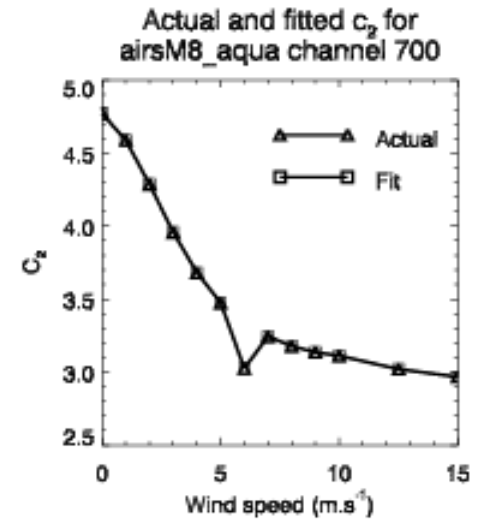
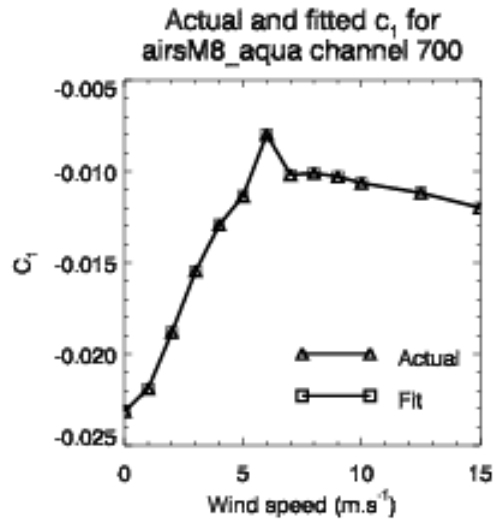
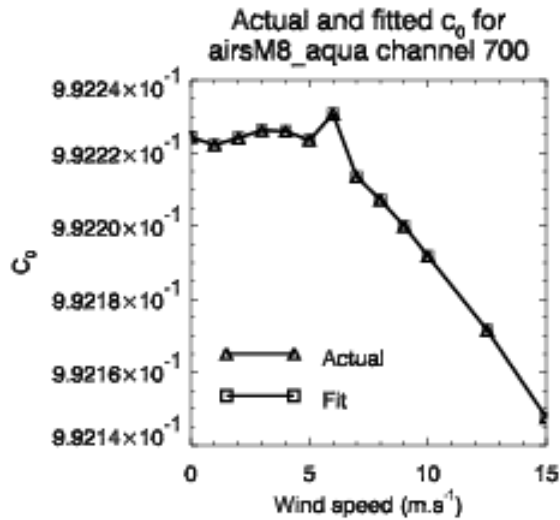
## AIRS M8 (~850-900cm<sup>-1</sup>) coefficients





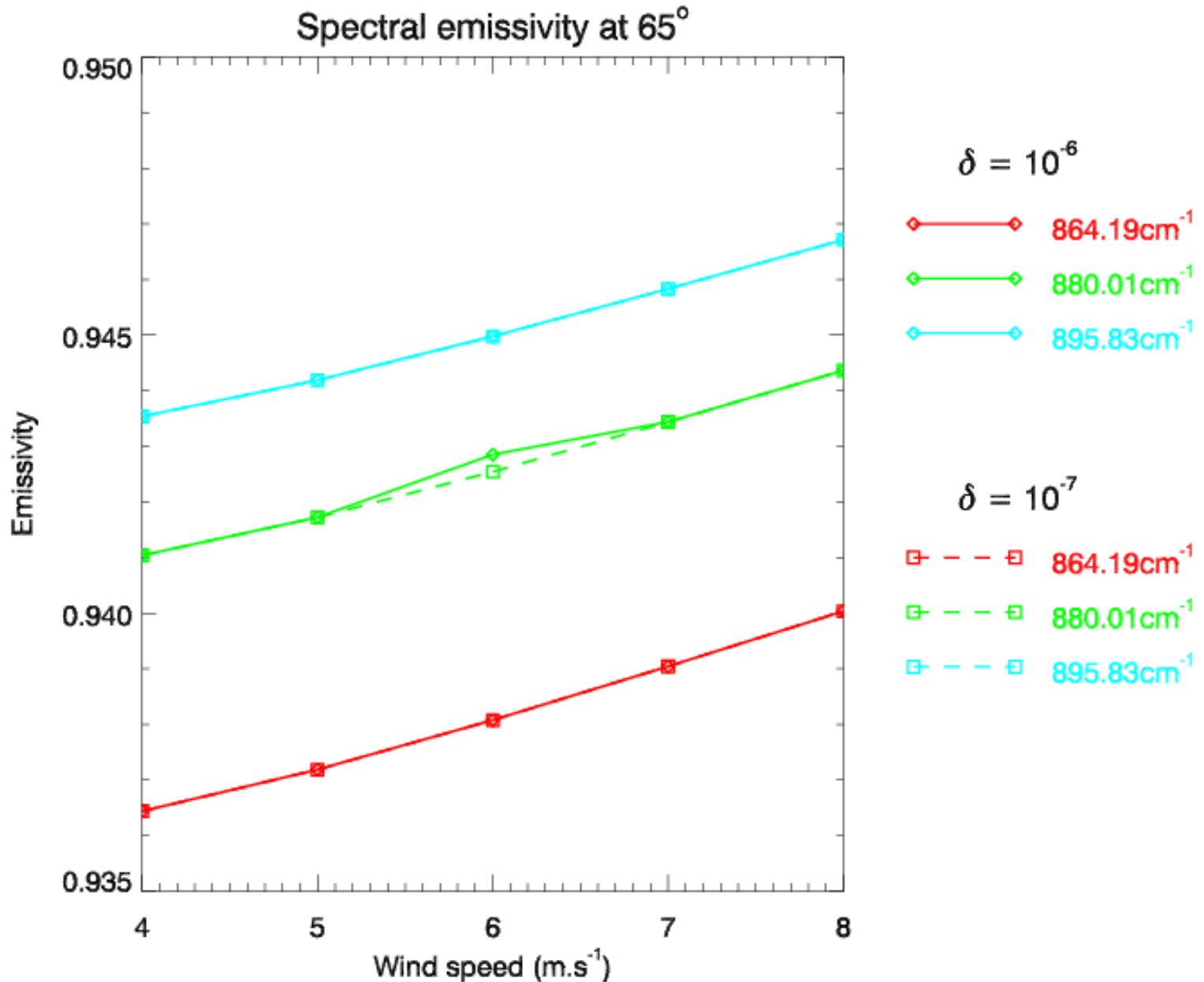
# Integration accuracy (3)

E.g.: AIRS M8 ch700 (880.409cm<sup>-1</sup>)



Note anomalous values at 6ms<sup>-1</sup>. 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  $\sim 0.0003$ . This is small (effect on  $T_B$  is also small), but is about 2x the typical RMS emissivity residual.