Implementation of a new infrared sea surface emissivity model in the Community Radiative Transfer Model (CRTM)

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2nd Workshop on Remote Sensing and Modeling of Surface Properties
9-11 June 2009, Météo France, Toulouse, France

Outline

- Introduction
- Description of infrared sea surface emissivity models (IRSSEMs) used in the CRTM
- Comparison of model emissivities
- Comparison of CRTM calculations using different emissivity models
- Comparison of Observed – Calculated brightness temperature differences using different emissivity models.
- Summary
- Further work

Introduction

- CRTM is used in the NCEP/EMC data assimilation systems to simulate satellite radiance observations.
- Infrared water reflection is treated as Lambertian in the CRTM.
- Current emissivity model in CRTM is based on the Wu-Smith [1997] model in which the reflected sea surface emission is taken into account.
- Work by Hanafin and Minnett [2005] and Nalli et al. [2008a,b] has shown this methodology will underestimate the effective emissivity at larger zenith angles due to the quasi-specular reflection of downwelling atmospheric radiance into the sensor field-of-view.
- Difference between Wu-Smith and Nalli model emissivities in the longwave IR window region can be as high as 1%.

Infrared sea surface emissivity models (IRSSEM)

- Wu-Smith model (currently operational).
  - Uses Hale-Querry (Real part) and Segelstein (Imaginary part) for refractive indices.
  - Cox-Munk wave slope probability density function.

- Nalli model.
  - Choice of any of the available refractive index data sets (will show Hale-Querry and Wieliczka) as well as the Hale-Querry/Segelstein hybrid.
  - Choice of Cox-Munk or Ebuchi-Kizu wave slope probability distribution function.
  - Downwelling surface incident radiances are computed for climatological profiles. These downwelling radiances are used in RTE minimisation to derive an effective incidence angle to account for reflected atmospheric radiation.

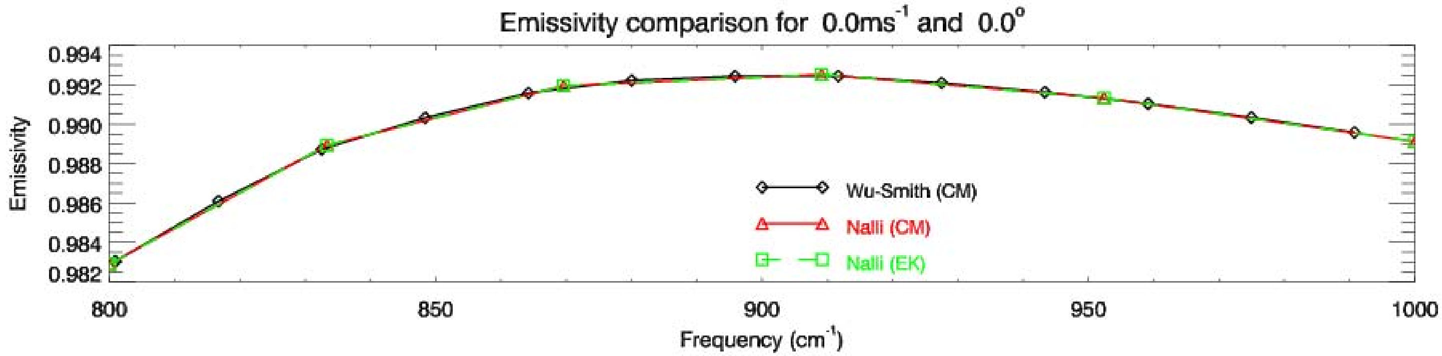
- Implemented as a lookup-table (LUT) of effective emissivities as a function of frequency, zenith angle, and wind speed.

- Linear interpolation performed between LUT points.

Emissivity comparison.

Hale-Querry refractive index; nadir

0ms^{-1}



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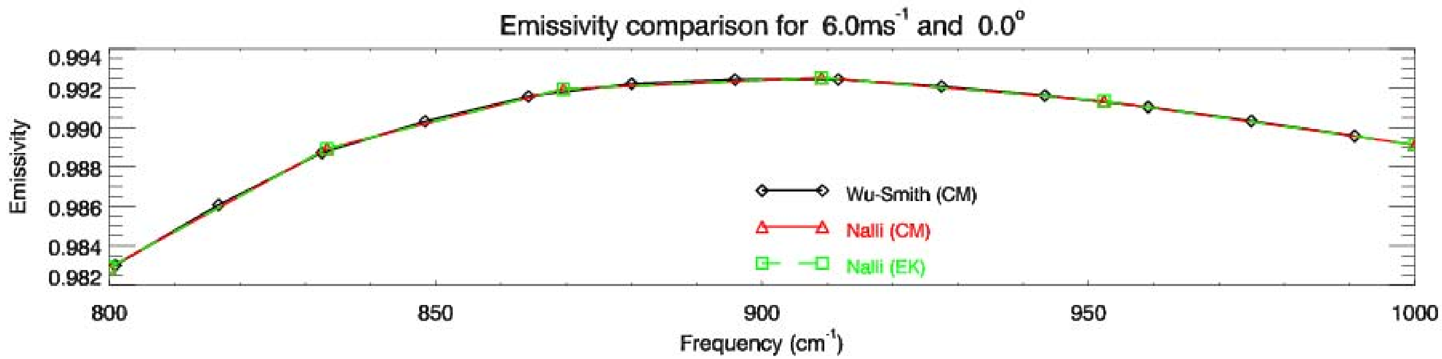

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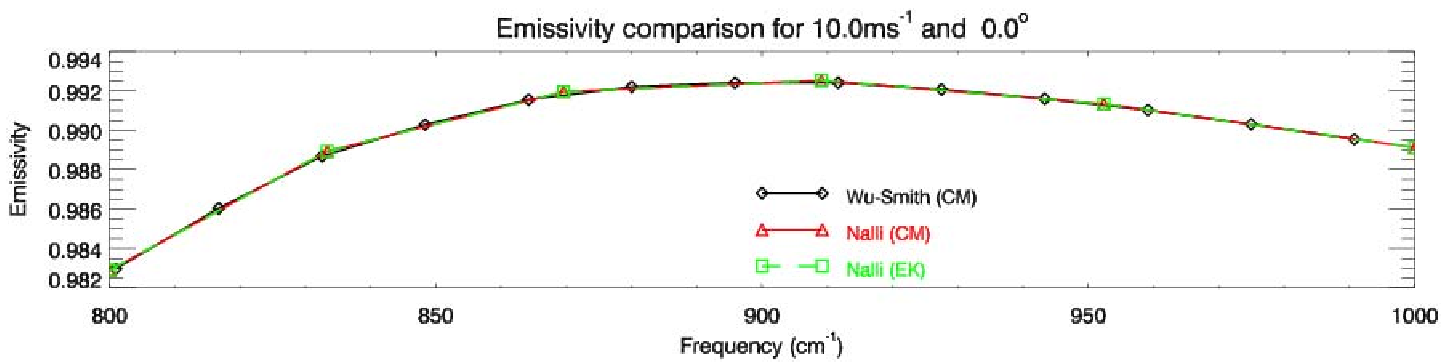
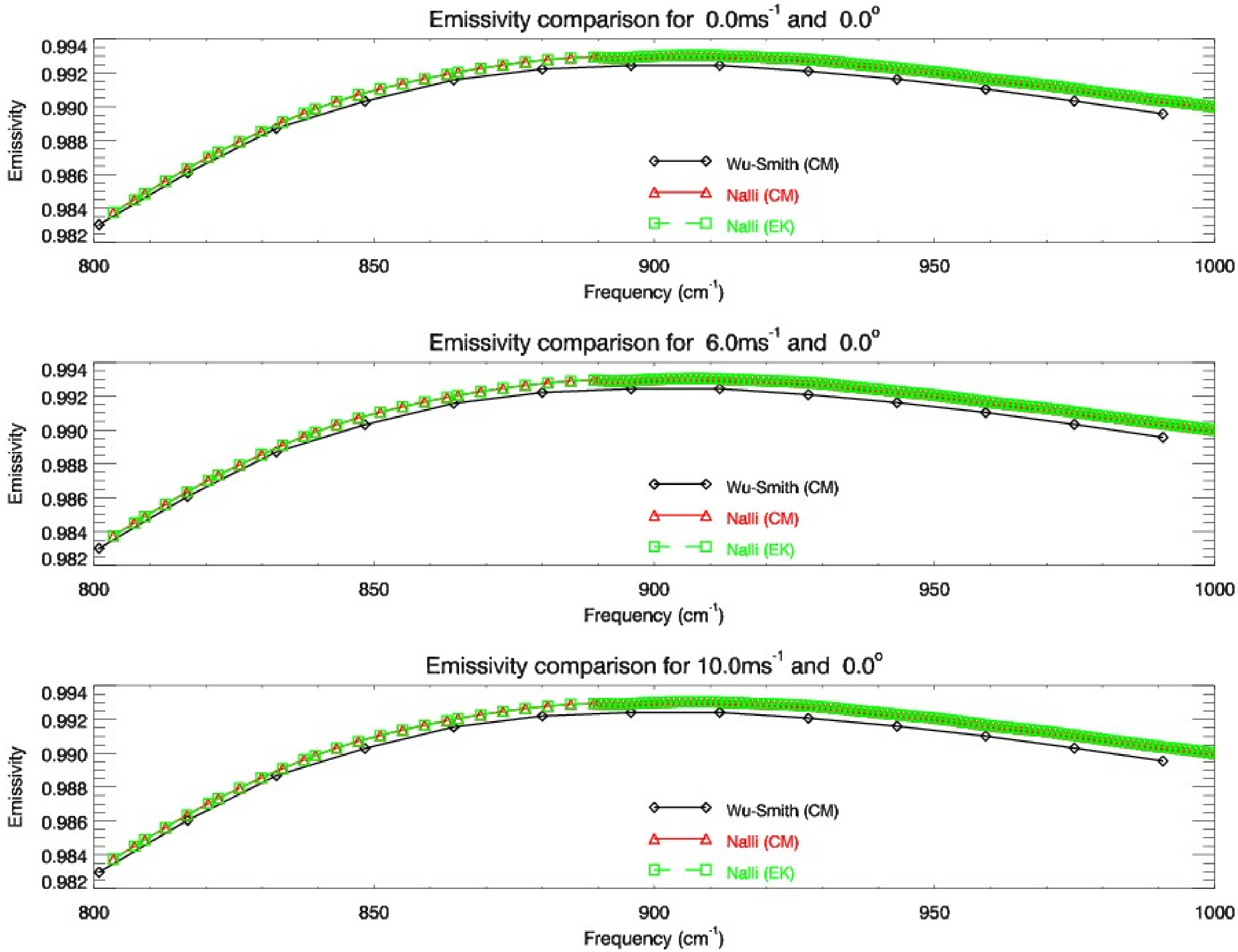


Emissivity comparison.
Wieliczka refractive index; nadir

0ms-1

0ms-1

0.0ms-1



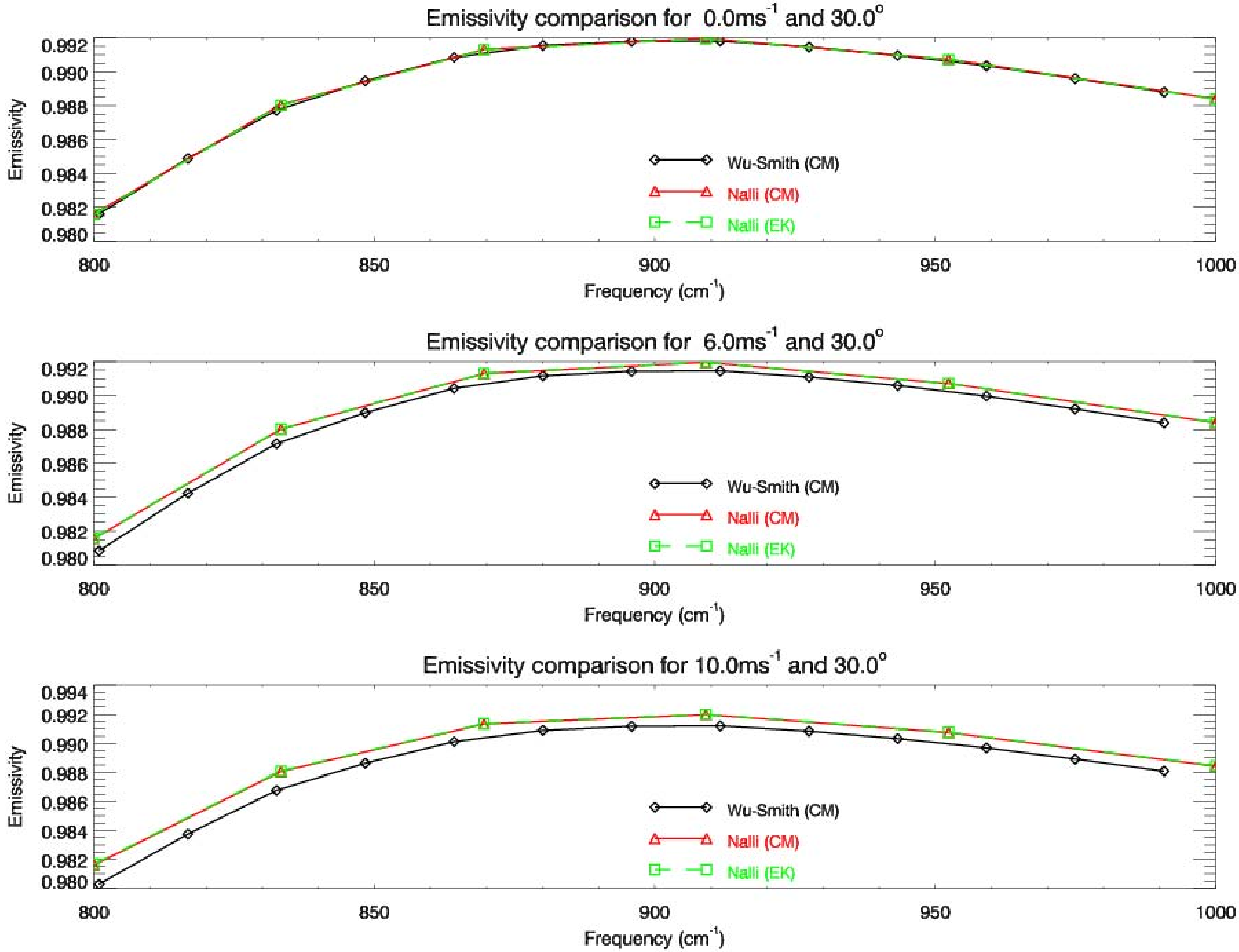
Emissivity comparison.

Hale-Querry refractive index; 30°

0ms^{-1}

0ms^{-1}

0.0ms^{-1}



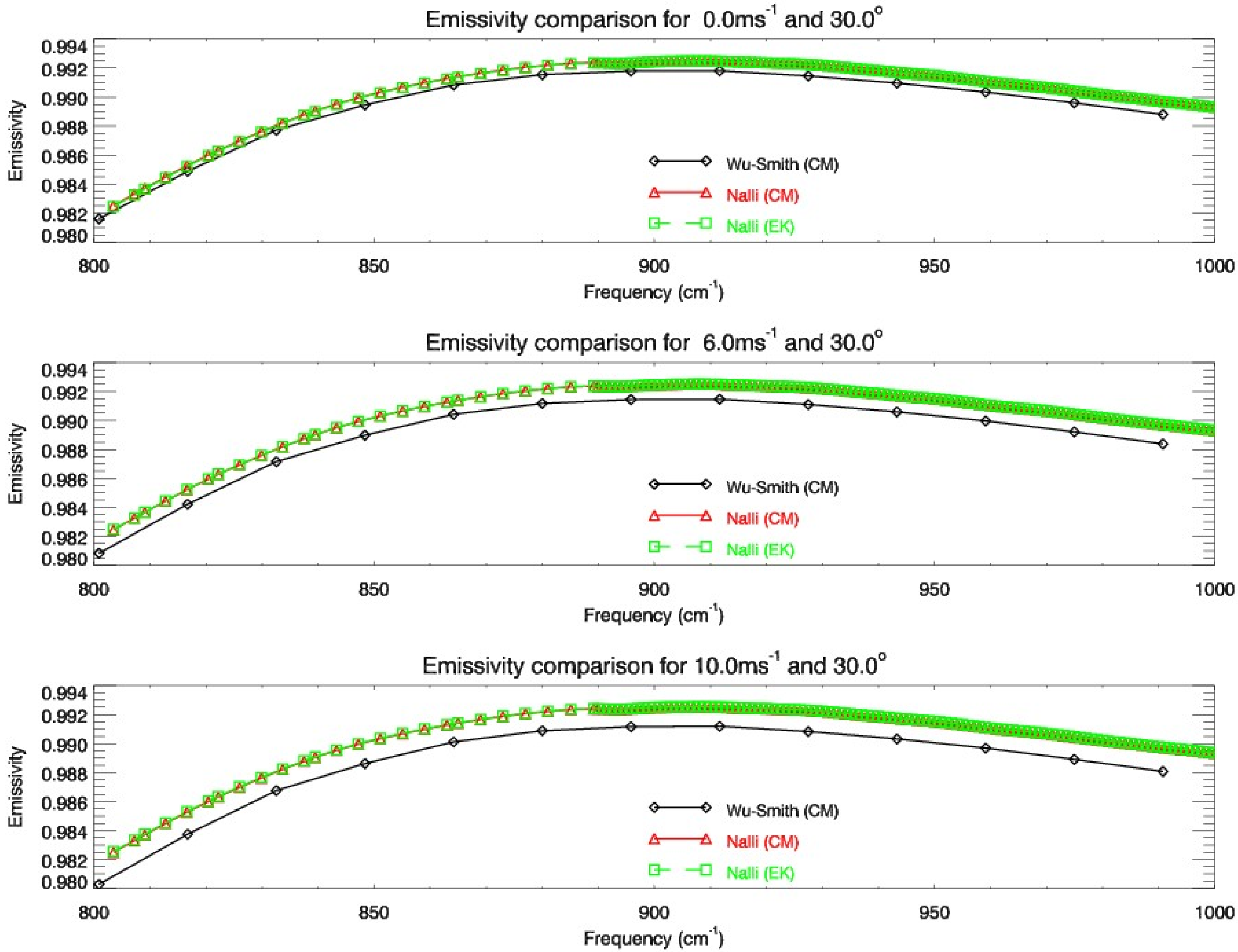
Emissivity comparison.

Wieliczka refractive index; 30°

0ms^{-1}

0ms^{-1}

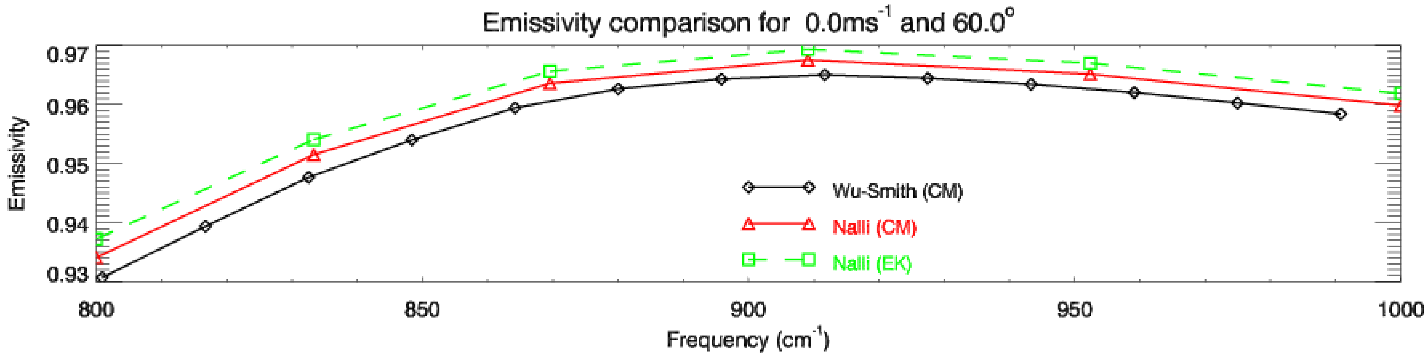
0.0ms^{-1}



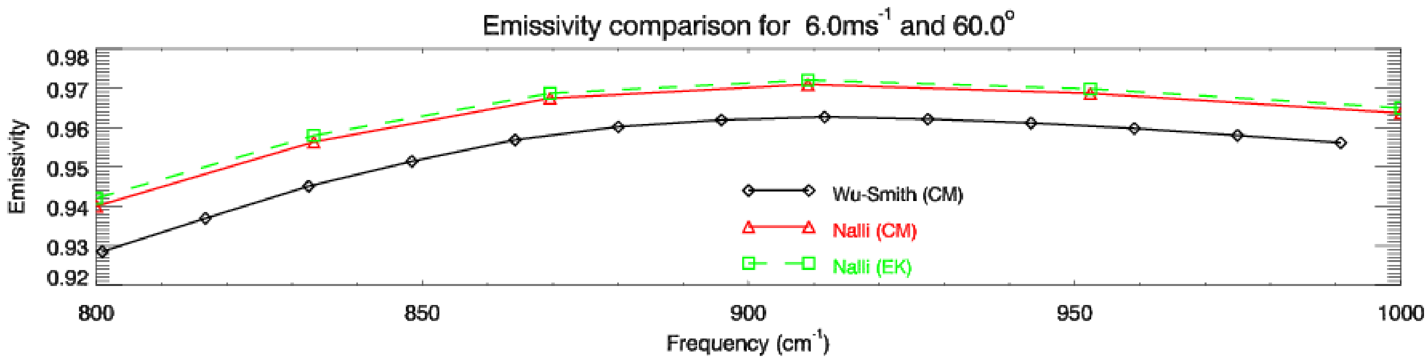
Emissivity comparison.

Hale-Querry refractive index; 60°

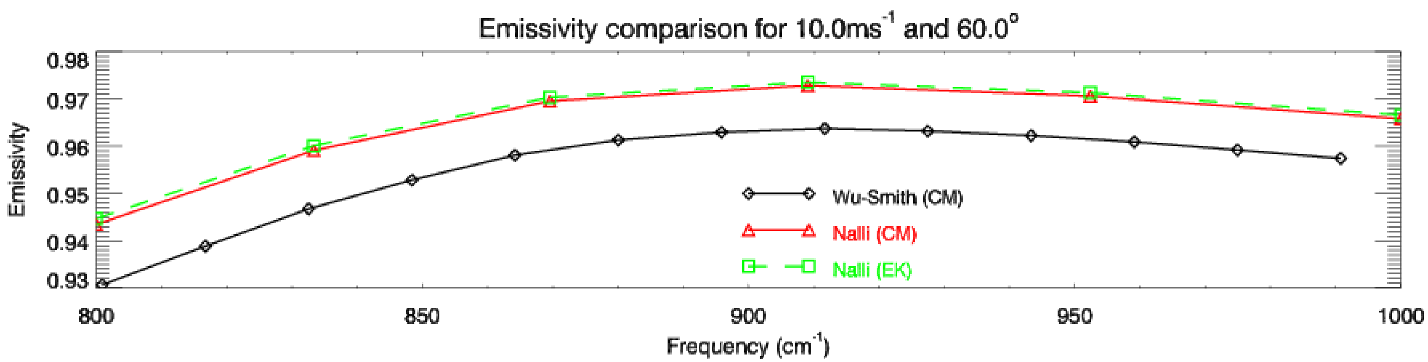
0ms^{-1}



0ms^{-1}



0.0ms^{-1}

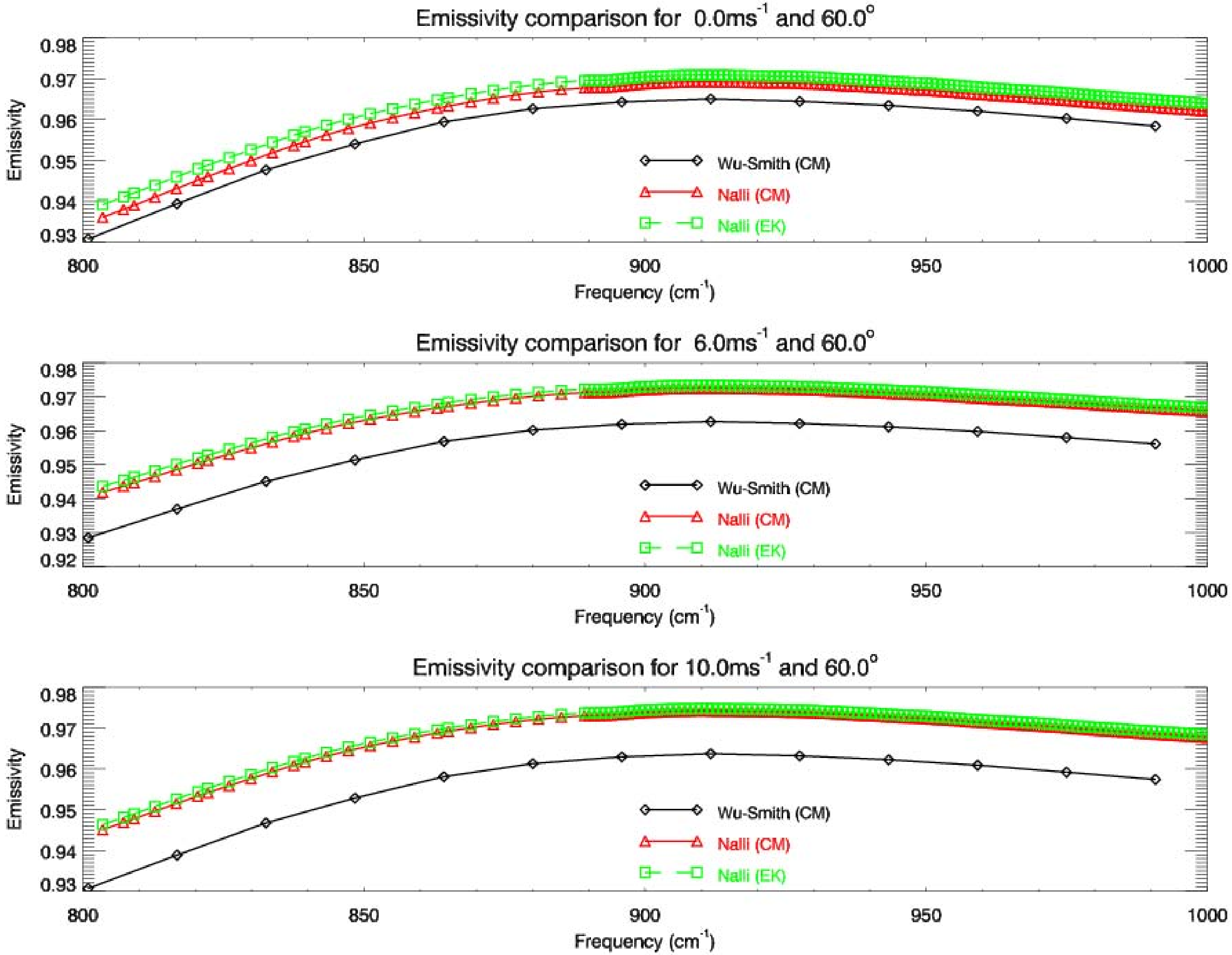


Emissivity comparison.
Wieliczka refractive index; 60°

0ms-1

0ms-1

0.0ms-1



CRTM ΔT_B comparisons

- Used two profile datasets to perform CRTM comparisons.
  - ECMWF datasets produced via NWP-SAF (provided by Tom Greenwald/Ralf Bennartz at UWisconsin through Peter Bauer at ECMWF).
- Summer-ocean dataset
  - 24000 profiles
  - Wind speeds range from 0 to ~20ms^{-1}
  - Zenith angles set to vary from 0 to 60°
- Winter-ocean dataset
  - 8703 profiles
  - Wind speeds range from 0 to ~30ms^{-1}
  - Zenith angles set to vary from 0 to 60°
- Computations performed for MetOp-A IASI band 1 – I'll only show results for the 800-1000cm^{-1} longwave window region.
  - Nalli minus Wu-Smith should yield +ve differences, especially at larger angles.
- For Nalli model, used the Ebuchi-Kizu PDF and both the Hale-Querry and Wieliczka refractive index data sets.

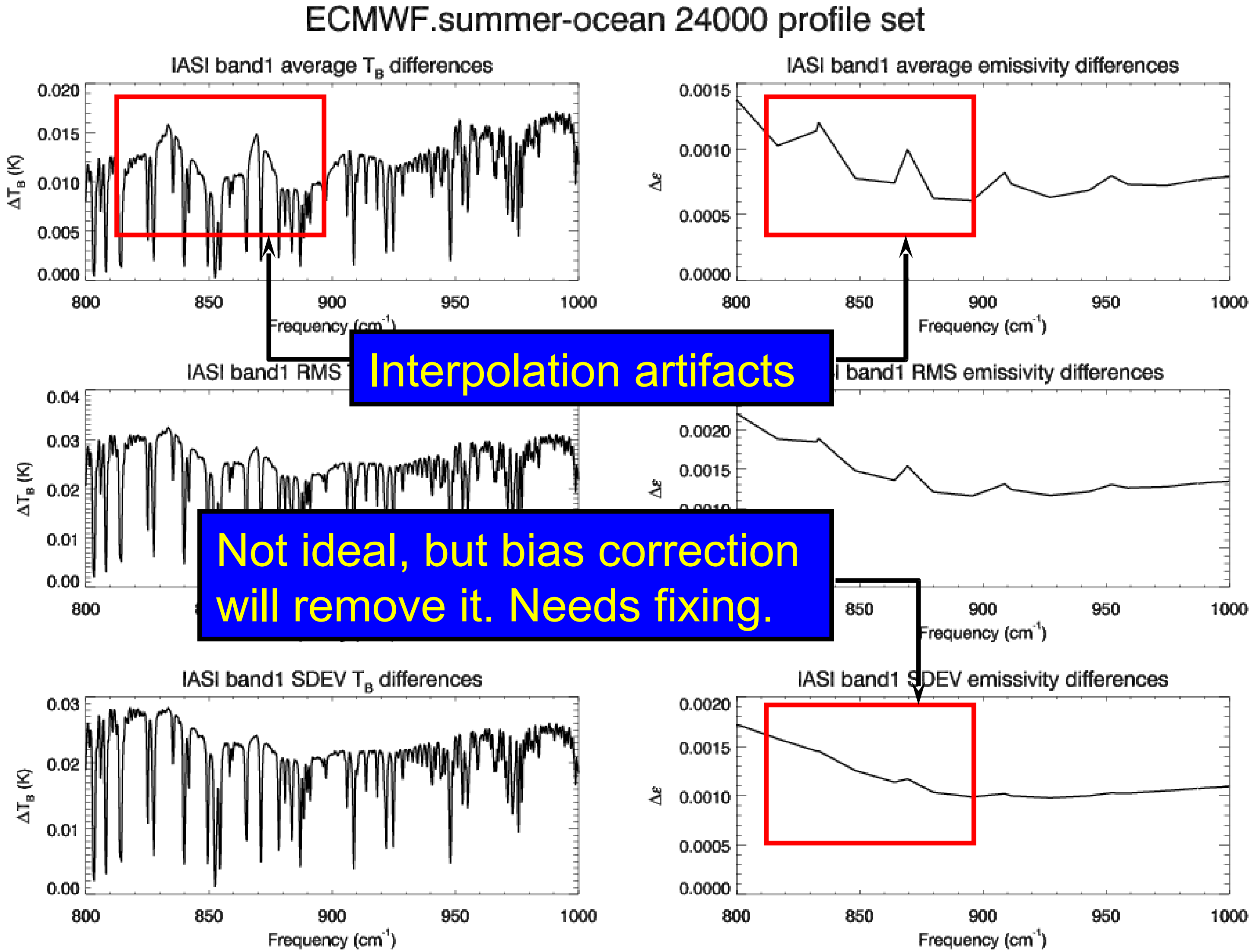
CRTM ΔT_B comparisons

Stats for *all* θ_z and ν; Hale-Querry RefIndex

verage

MS

DEV



CRTM ΔT_B comparisons

Stats for *all* θ_z and ν ; Wieliczka RefIndex

verage

MS

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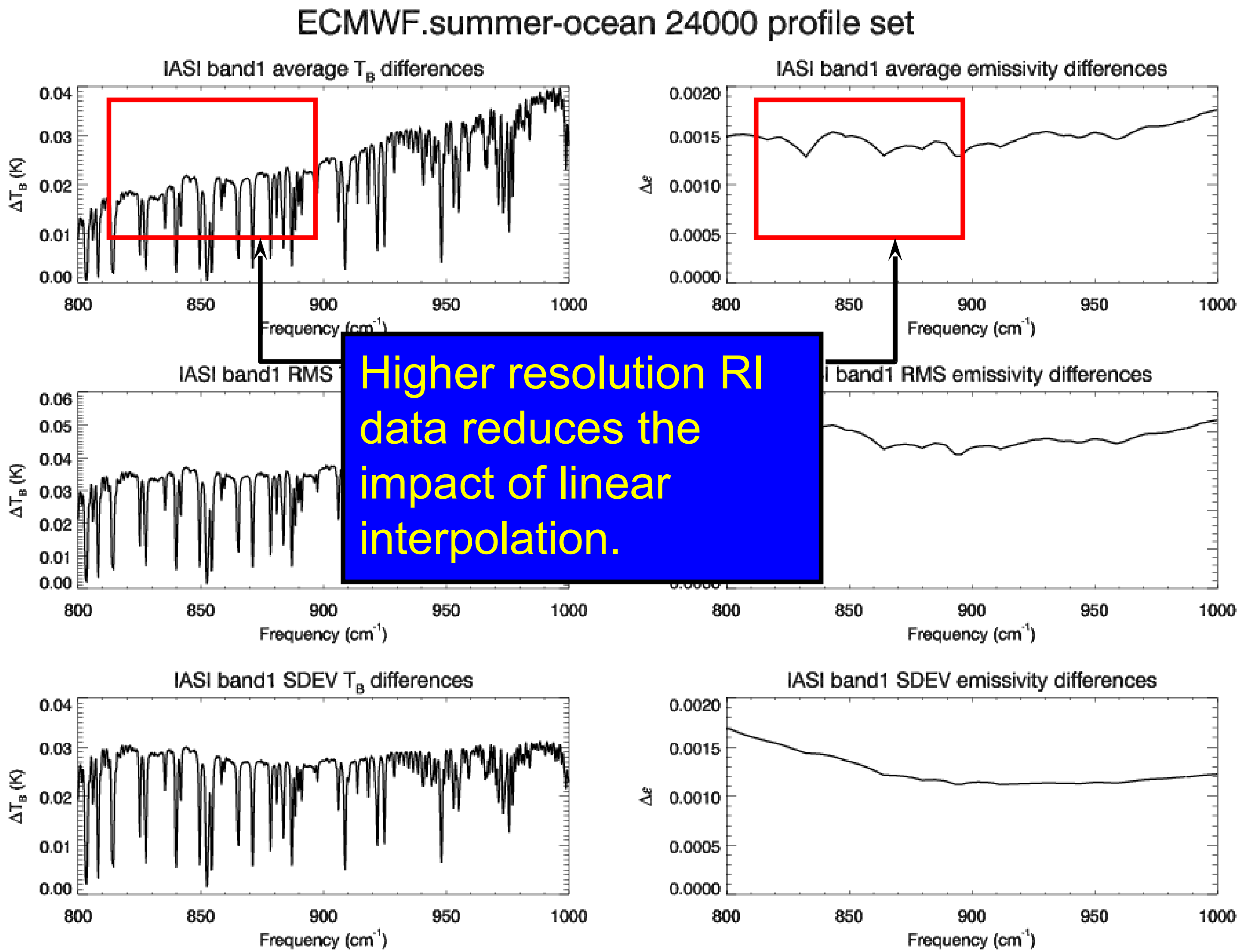
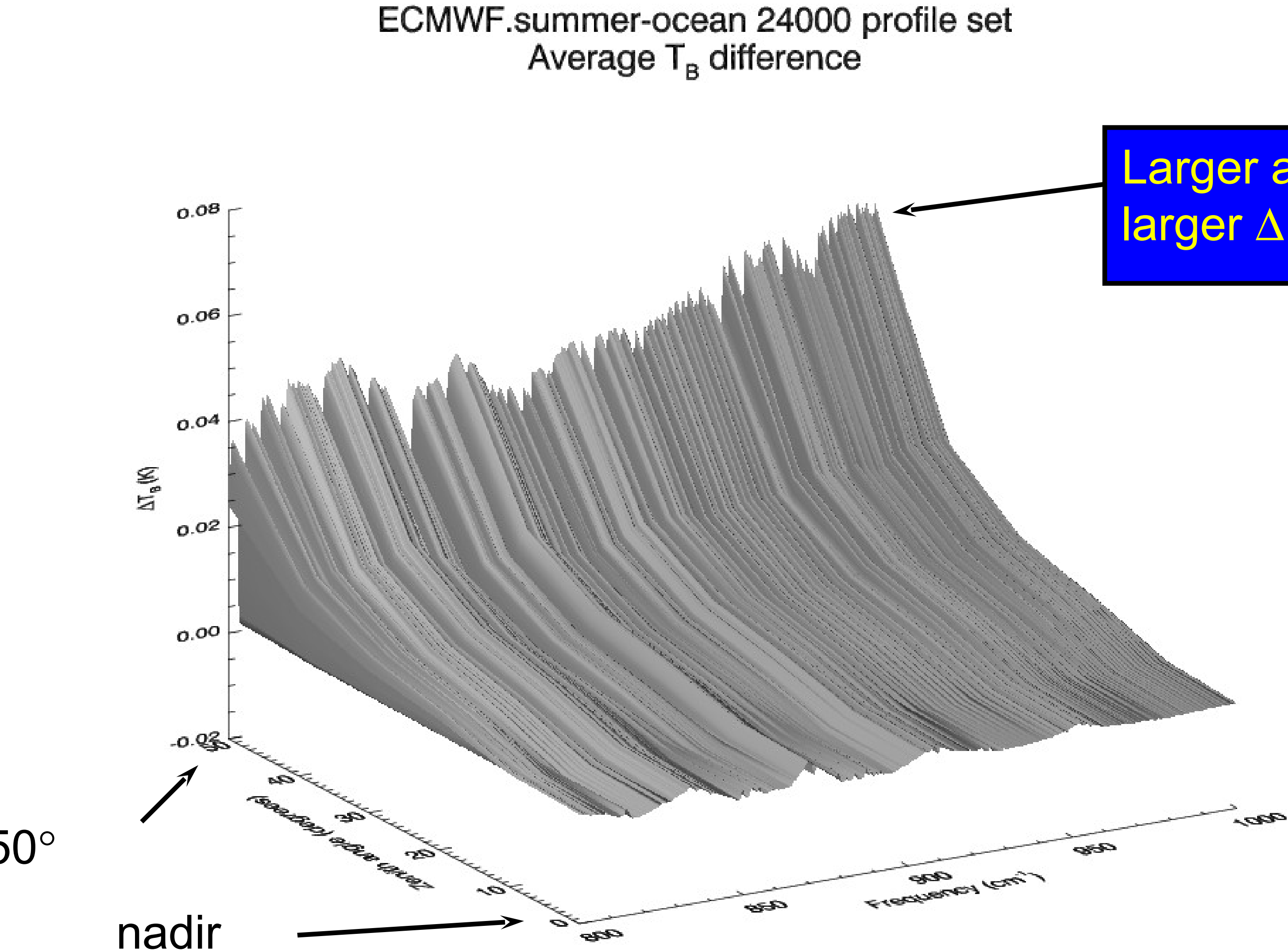


CRTM ΔT_B comparisons

Average $\Delta T_B(\theta_z)$ surface; Hale-Querry RefIndex



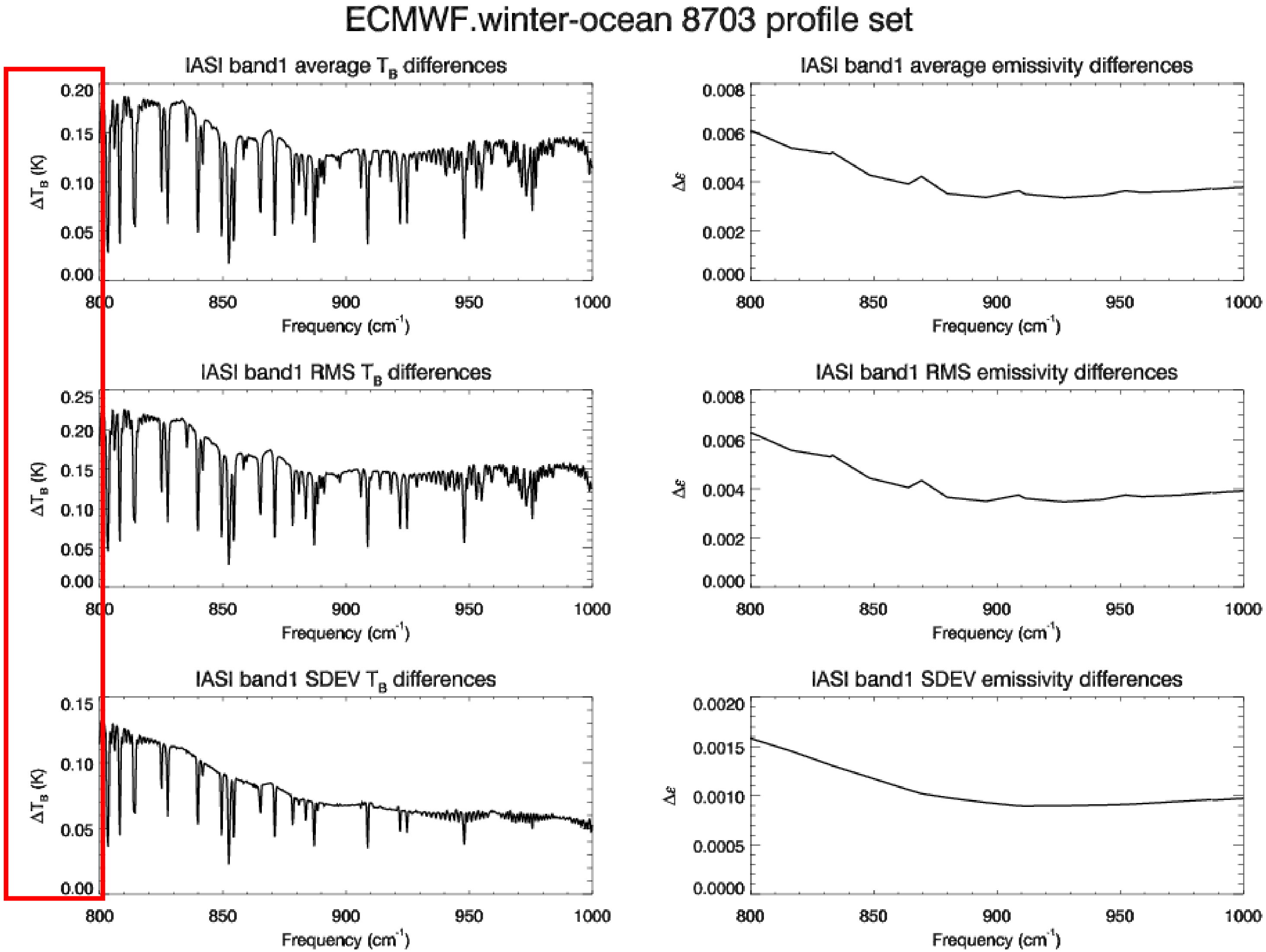
CRTM Δ T_B comparisons

Stats for *all* ν, and θ_z=50°; Hale-Querry RefIndex

verage

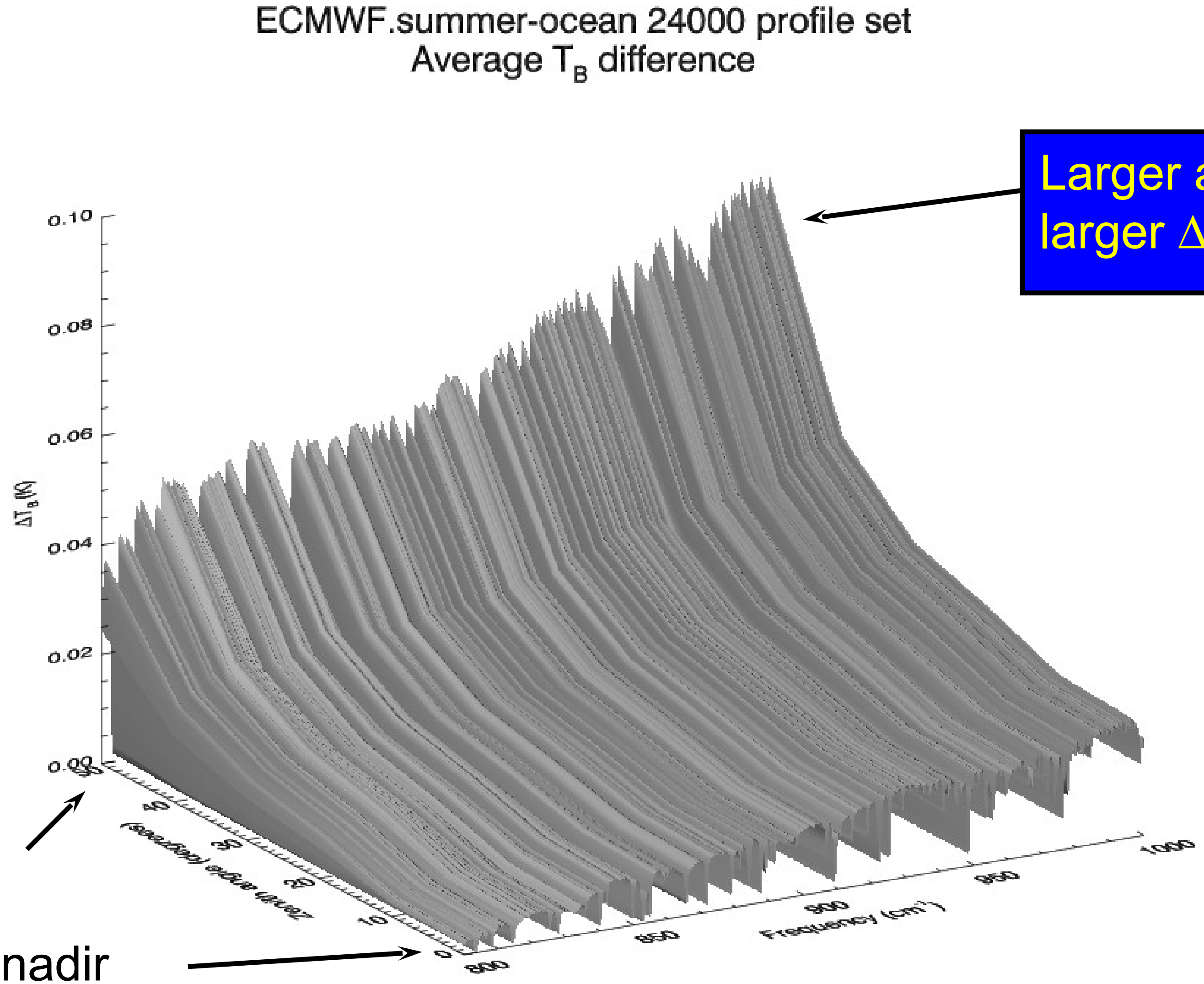
MS

DEV



CRTM Δ T_B comparisons

Average Δ $T_B(\theta_z)$ surface; Wieliczka RefIndex



Larger angles yield larger Δ T_B as expected.

50°

nadir

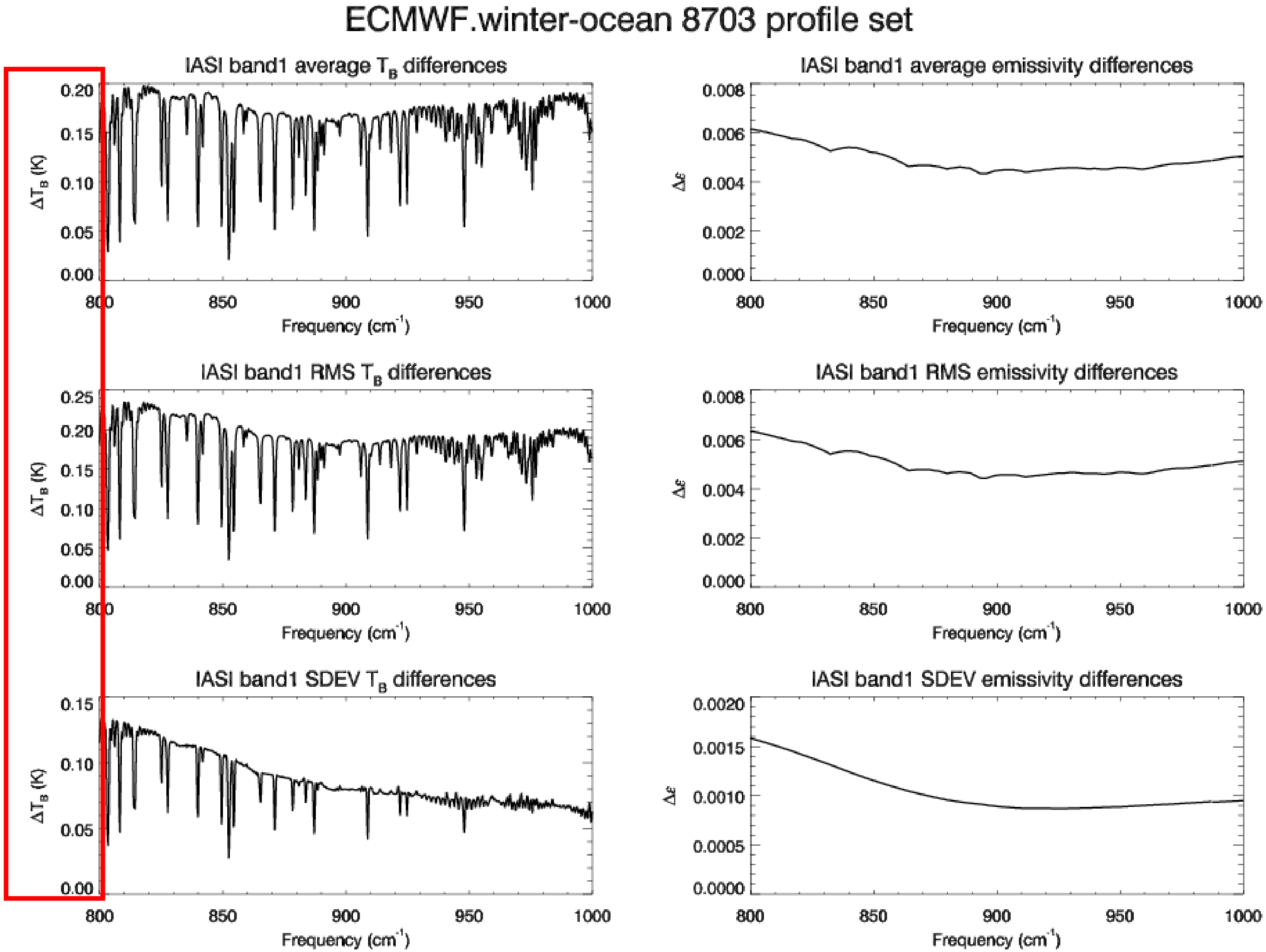
CRTM ΔT_B comparisons

Stats for *all* ν, and θ$_z$=50°; Wieliczka RefIndex

verage

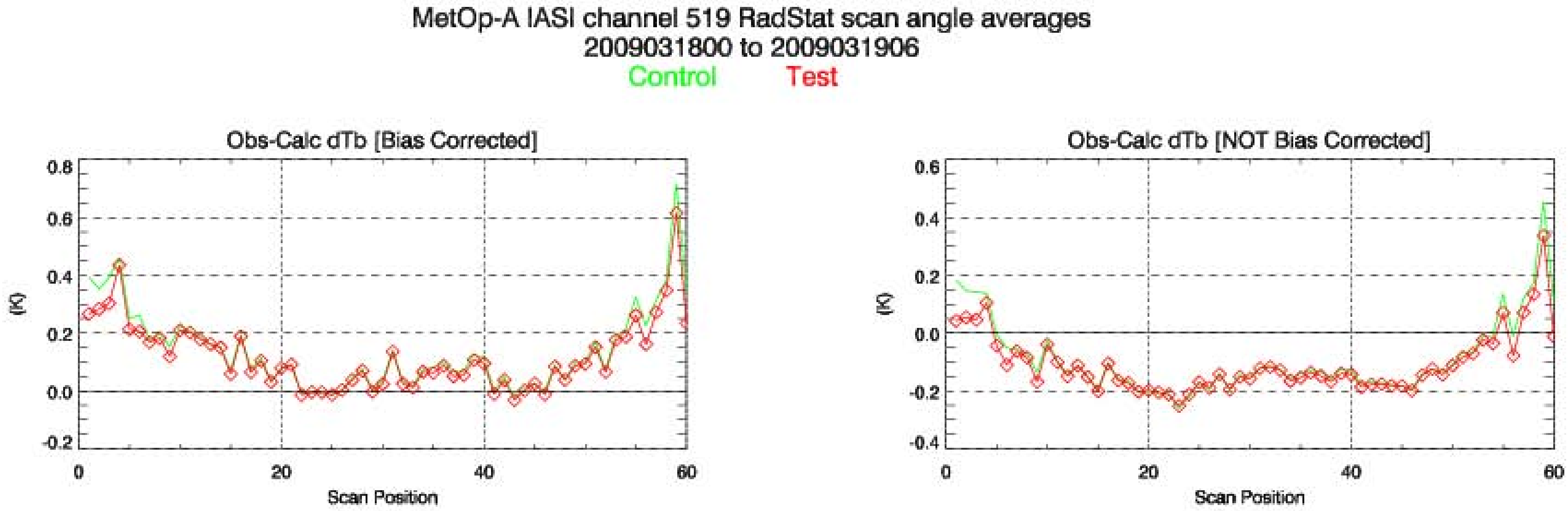
MS

DEV



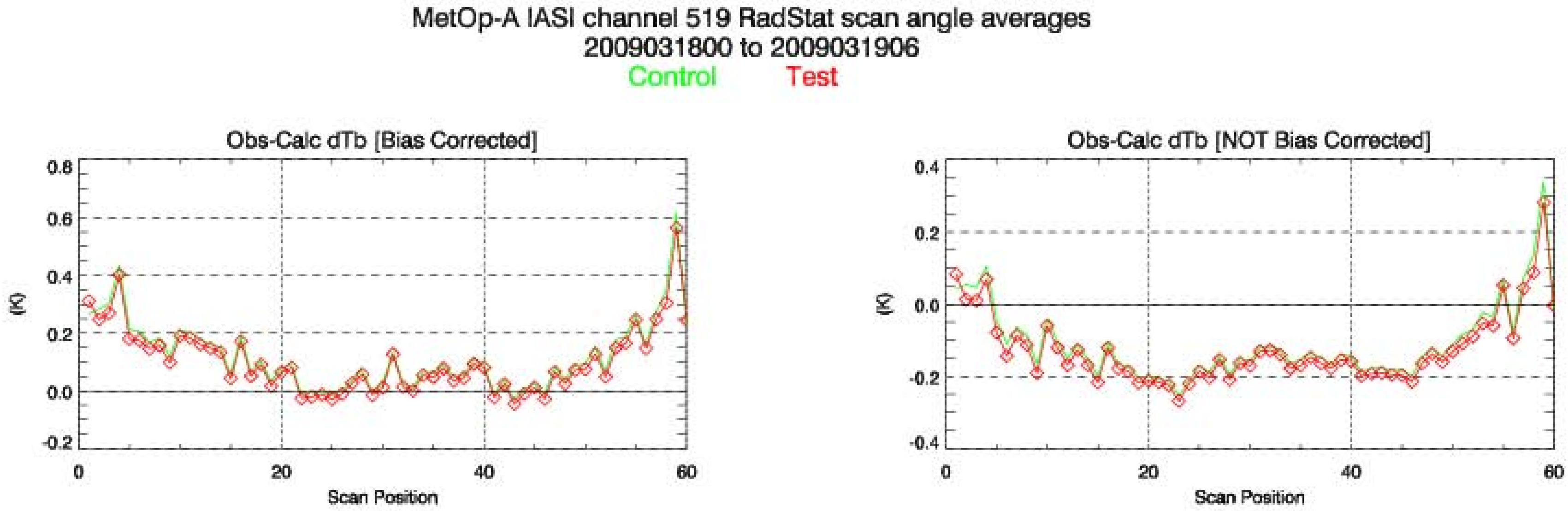
GSI Obs-Calc ΔT_B comparisons

IASI 1766 channel subset; Hale-Querry RefIndex



- Scan angle differences. Control = Wu-Smith model; Test = Nalli(HQ) model.
- Ch490 is 849.75cm^{-1}; Ch519 is 900.0cm^{-1}.
- 100000+ observations.
- The Obs-Calc ΔT_B decrease at higher scan angles indicates the higher effective emissivity of the Nalli model is indeed compensating for the reflected downwelling radiance.
- Bias correction is for control in both runs.

GSI Obs-Calc ΔT_B comparisons
IASI 1766 channel subset; Impact of RefIndex



- Scan angle differences. Control = Nalli(HQ) model; Test = Nalli(W) model.
- Ch490 is 849.75cm-1; Ch519 is 900.0cm-1.
- 100000+ observations.
- The Obs-Calc ΔT_B difference is small, but noticeable.
- Bias correction is for Wu-Smith model in both runs.

Summary

- Emissivity differences between Wu-Smith and Nalli models are quite significant in the longwave window.
  - Differences are at the 1% level for higher angles and wind speeds.
- Computed IASI brightness temperature difference statistics (average and sdev) for test profile sets can get to 0.2K for IR longwave window.
- Impact on IASI obs-calc statistics in the GSI is of the same order for the high scan angle FOVs.
- Current implementation of IRSSEMs in the CRTM is not ideal.
  - In particular, linear interpolation introduces artifacts.

Further work

- Improve the interpolation scheme in the IRSSEM.
  - Other CRTM LUT interpolations use an averaged quadratic scheme to preserve derivatives across LUT hingepoints.
  - Will implement that module in the IRSSEM.

- Better characterisation of the impact of refractive index data sets.
  - Currently, the differences are overwhelmed by the interpolation differences due to the varying spectral resolutions of the datasets.
  - Maybe pre-interpolate the RI datasets before computing the effective emissivities?

- Characterise the impact of wave slope PDF model.

- Impact of IRSSEM methodology when using a BRDF model.
  - Yong Han (NESDIS/STAR) has implemented an infrared sea surface BRDF model to handle sun glint in solar-affected IR channels.
  - Will use this throughout the IR spectral region to consistently model the surface reflection for multiple downwelling streams (e.g. aerosol-laden atmospheres)