FIRST Results from Cerro Toco, Chile

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Outline

- Review of FIRST Project to Date
  - Background
- Comparison of Results from FIRST's Two Ground-Based Field Campaigns
  - Table Mountain, CA and Cerro Toco, Chile
  - Significantly less water at Cerro Toco than Table Mountain
- Results from Cerro Toco Closure Study
  - Comparing measurements, model calculations from LBLRTM, and assessing their uncertainties

FIRST Milestones

2001 → 2005 – FIRST built at SDL

2005 and 2006 – Balloon flights at Ft. Sumner, NM

Reconfigured as ground based

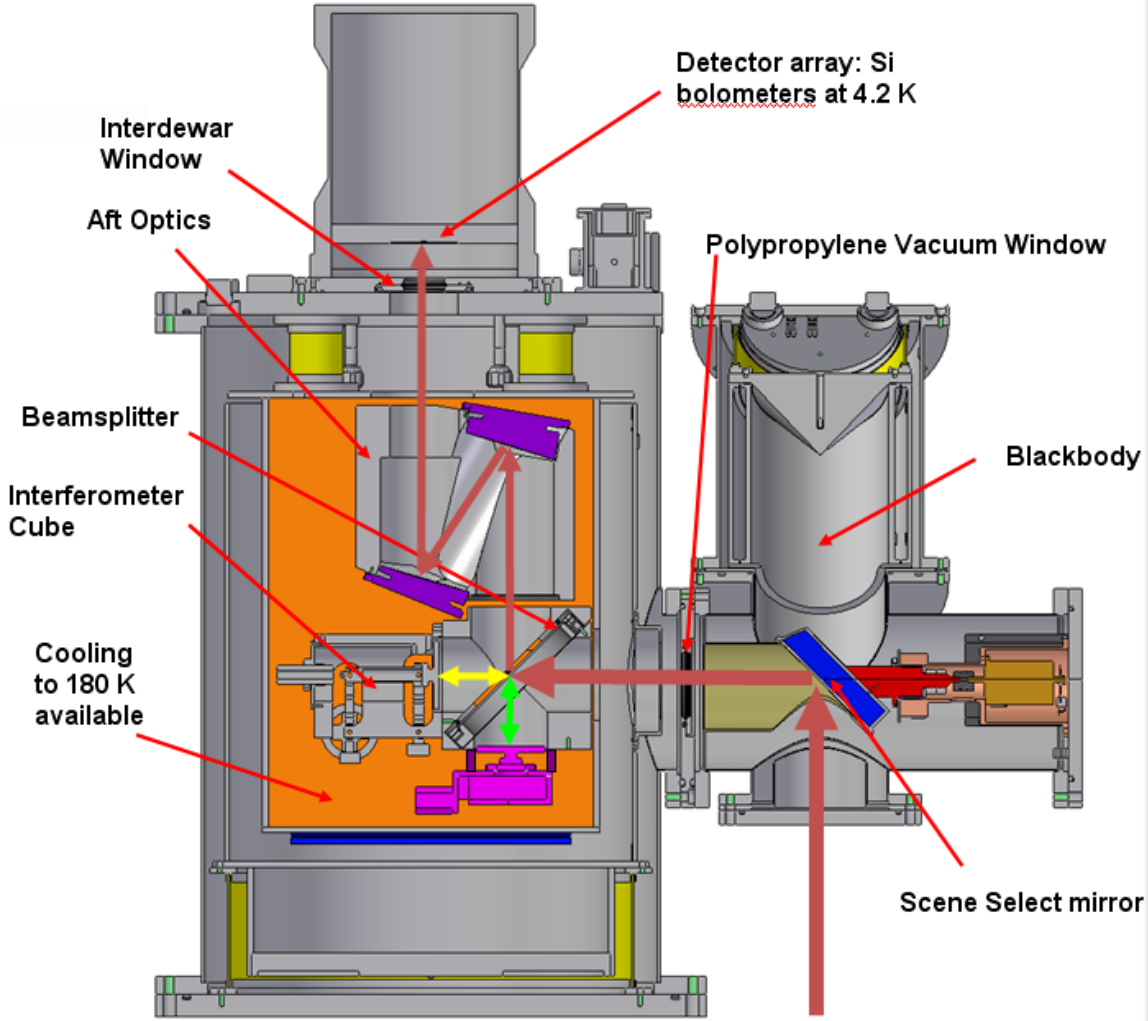
2009 – RHUBC-II Campaign, Cerro Toco, Chile

2012 – Deployment to Table Mountain, CA

2014 – Final delivery of Cerro Toco atmospheric dataset

2015 – Submission of Table Mountain article to JQSRT

FIRST Instrument



Instrument Characteristics

- Plane mirror FTS
- 100 – 1000 cm^{-1}
- 0.643 cm^{-1} resolution
- Calib. BB @ 296 K & 325 K
- 10 LHe bolometers
- Ge on polypropylene beamsplitter
- 11.5 sec scan

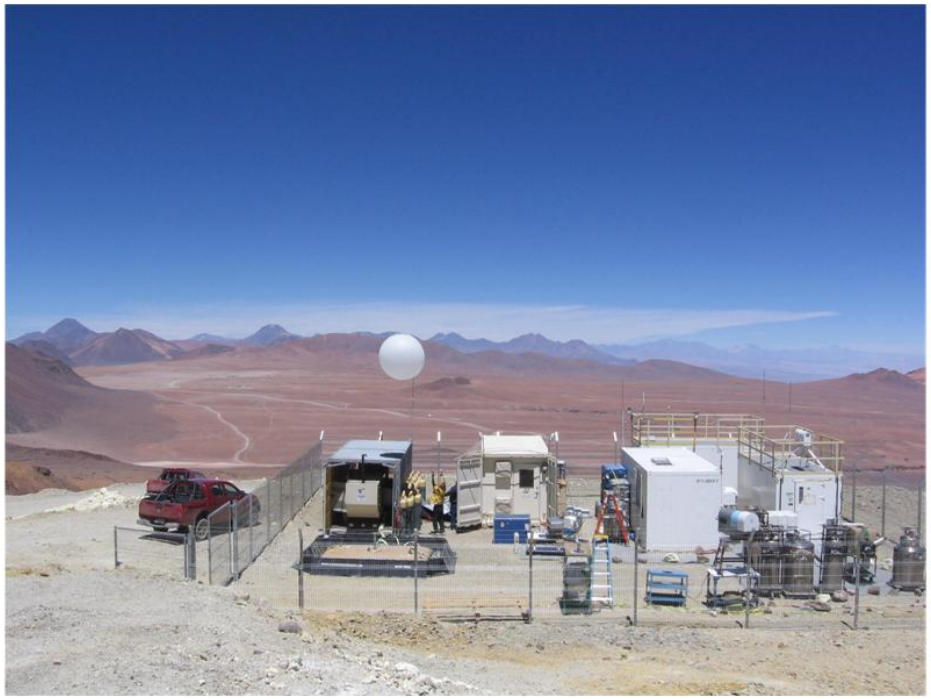
FIRST Ground-Based Calibration Results
Laboratory Calibration, 1-sigma values

Scene Temp (K)	Uncertainty
310.35	0.2 K
270.55	0.3 K
247.42	1.0 K
225.18	1.5 K
209.41	2.6 K
189.33	3.5 K
169.05	4.5 K

FIRST calibration measured across range of geophysical scene temperatures

Results reported in Latvakoski et al., 2013; 2014, Applied Optics

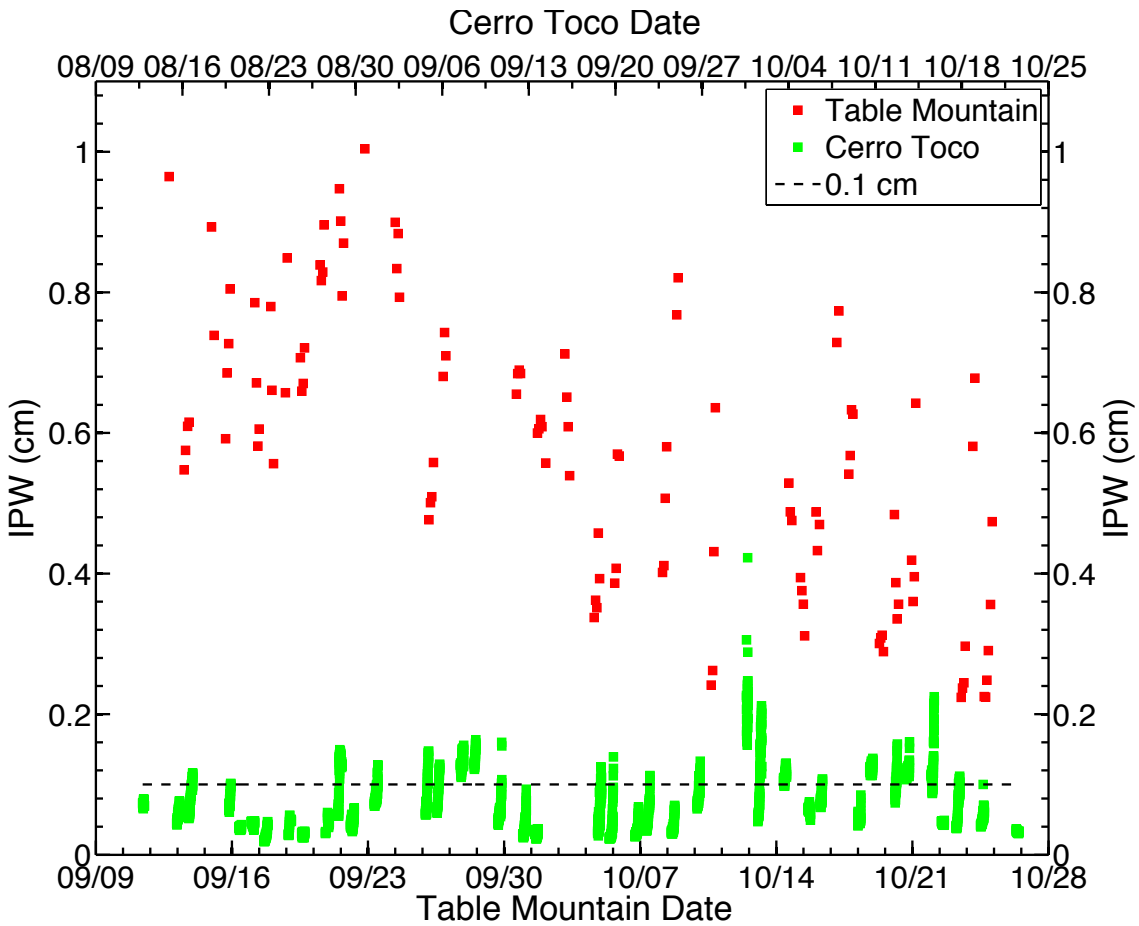
The Two Ground-based Field Campaigns



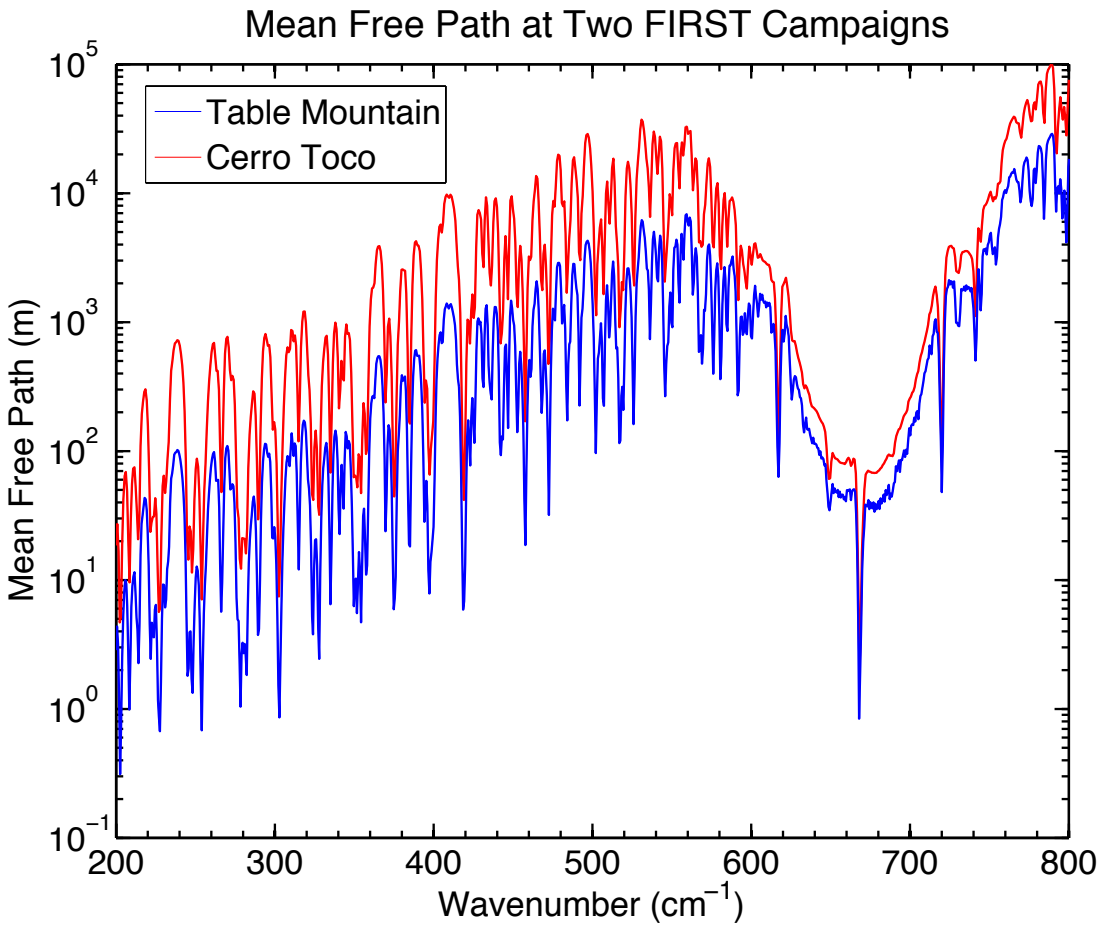
Cerro Toco, Chile
Very Cold and Very Dry
August – October 2009
17,500 feet
p = 550 hPa
IPW ~ 0.03 cm

Table Mountain, California
Cool and Dry
September – October 2012
7500 Feet
p = 775 hPa
IPW ~ 0.3 cm

IPW at Table Mountain, CA and Cerro Toco, Chile

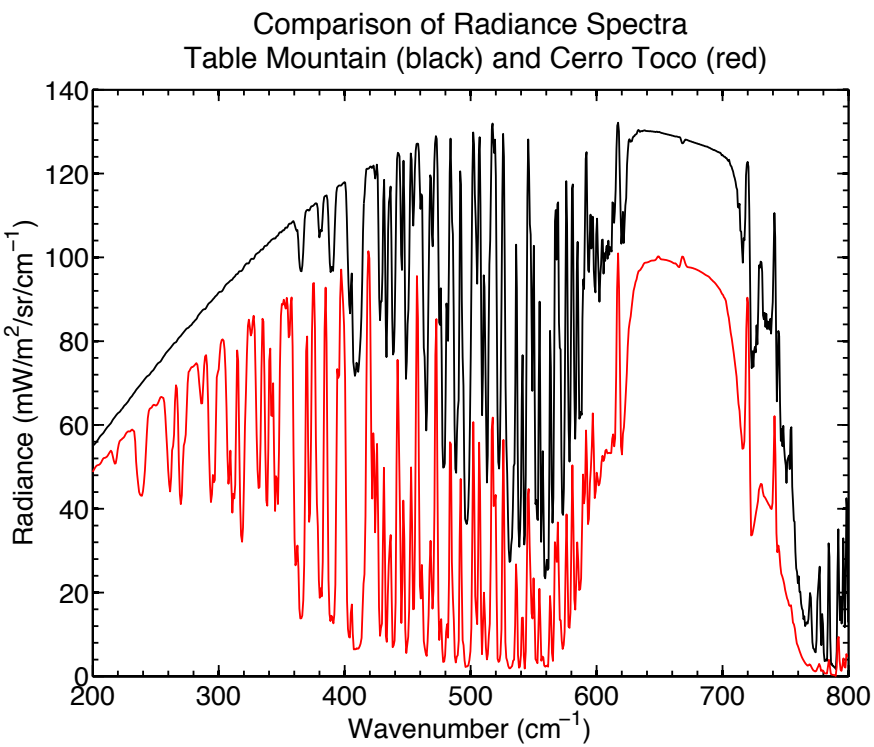


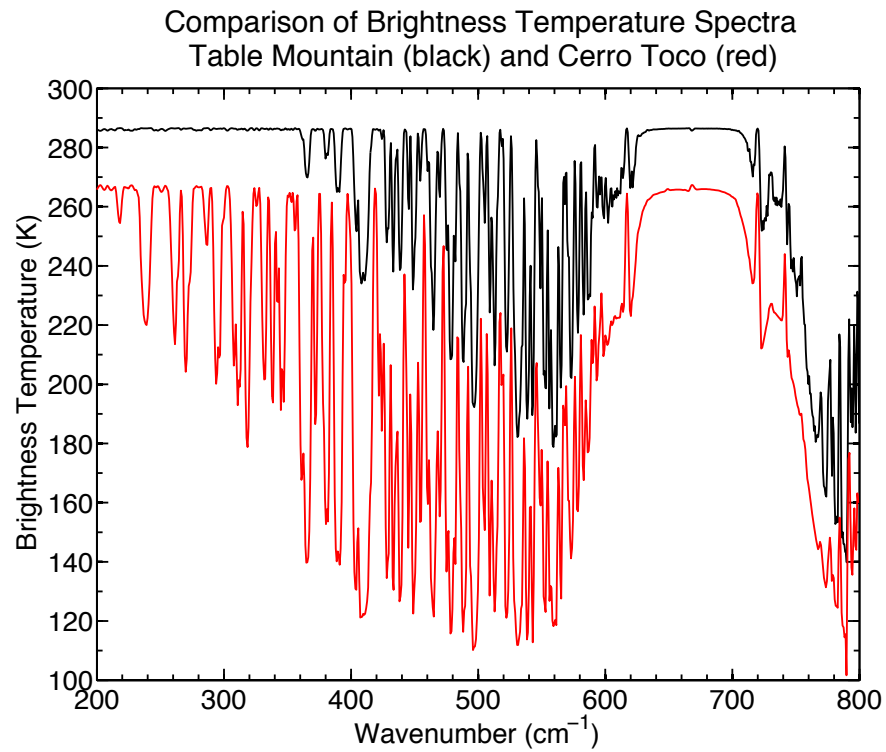
Where Does Radiance Measured by FIRST Come From?



Log scale on Y axis

Much longer mean free path at Cerro Toco





TMF IPW = 0.3 cm

CT IPW = 0.03cm

Scene Temp (K)	Ground Based
310.35	0.2 K
270.55	0.3 K
247.42	1.0 K
225.18	1.5 K
209.41	2.6 K
189.33	3.5 K
169.05	4.5 K

Cerro Toco Closure Study

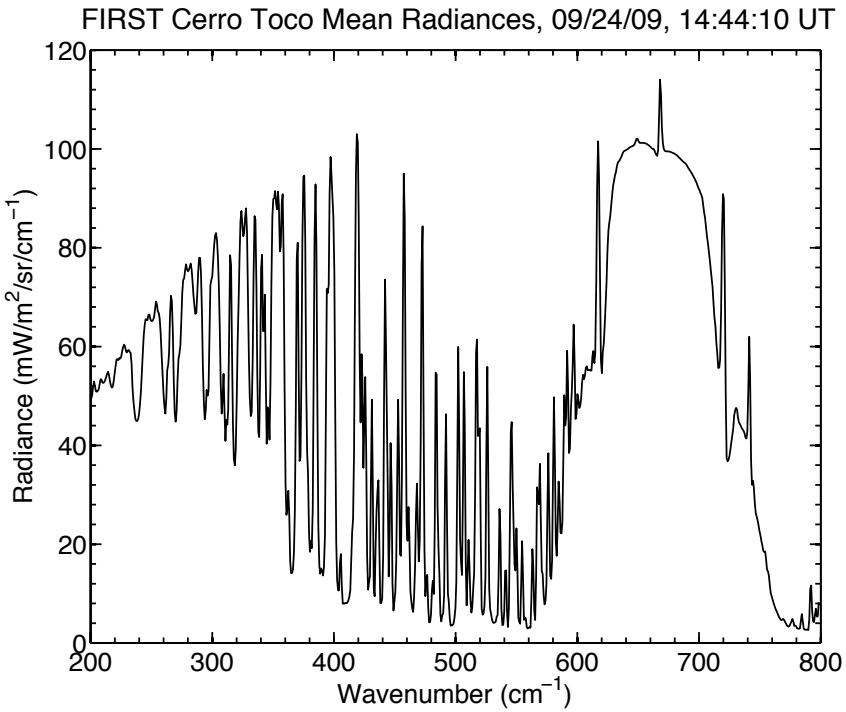
- Compare FIRST measurements with calculated line-by-line spectra
- FIRST ground-based measurements
  - Spectra shown here are 30 minute means
    - Predefined scan period
    - Reduce noise
  - Spectra shown between 200 – 800 cm^{-1}
- Calculated spectra from LBLRTM by AER Inc.
  - Line database is AER v3.2
  - Radiosonde water and temperature vertical profiles available at 5 minute intervals
    - Profiles processed with LBLRTM then spectra averaged

Uncertainties

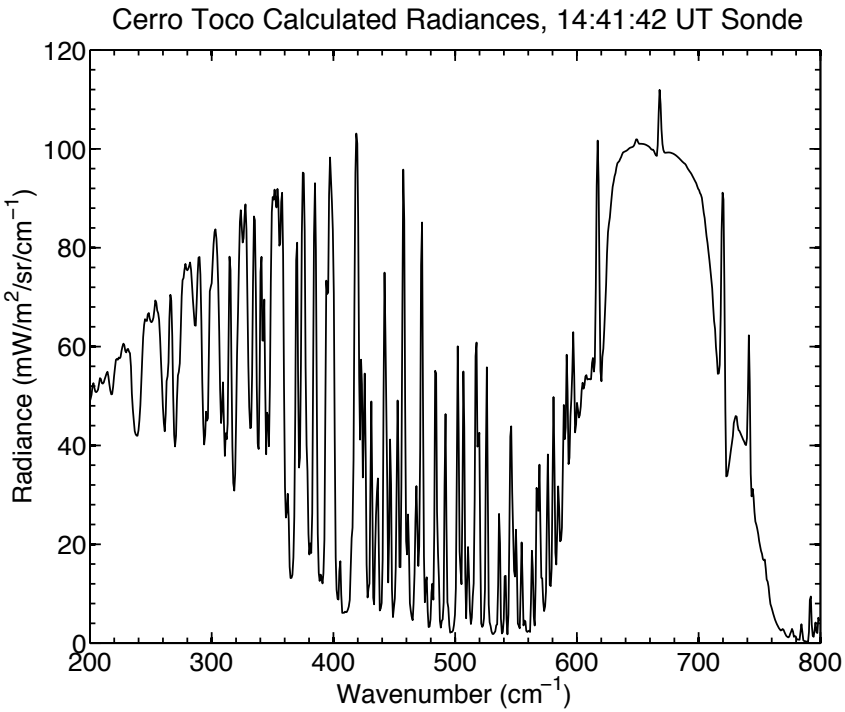
- Model Uncertainties
  - Line parameter database uncertainties
    - H_2O and CO_2
    - Available for line strength and half-width
  - Radiosonde LBLRTM inputs
    - Water vapor – 5%
    - Temperature – 0.25K
  - Uncertainty in the water vapor continuum as calculated by the continuum model in LBLRTM
    - From correspondence with Eli Mlawer
      - Foreign: 80-300 cm^{-1} – 25%; 300-400 cm^{-1} – 20%; 400-600 cm^{-1} – 15%
      - Self - 80–350 cm^{-1} – 25%; 350-600 cm^{-1} - 20%
  - RSS of these is the Model Uncertainty
- Include measurement uncertainty
  - Sky uncertainty
    - Standard deviation of the approximate 155 spectra recorded in 30 minutes
  - Uncertainty from laboratory calibration
    - From Applied Optics publications by Harri Latvikoski
  - RSS of these is the Measurement Uncertainty
- Calculated combined uncertainty
  - RSS of measurement uncertainty and model uncertainty

Example Closure Study Results from September 24, 2009

Measured

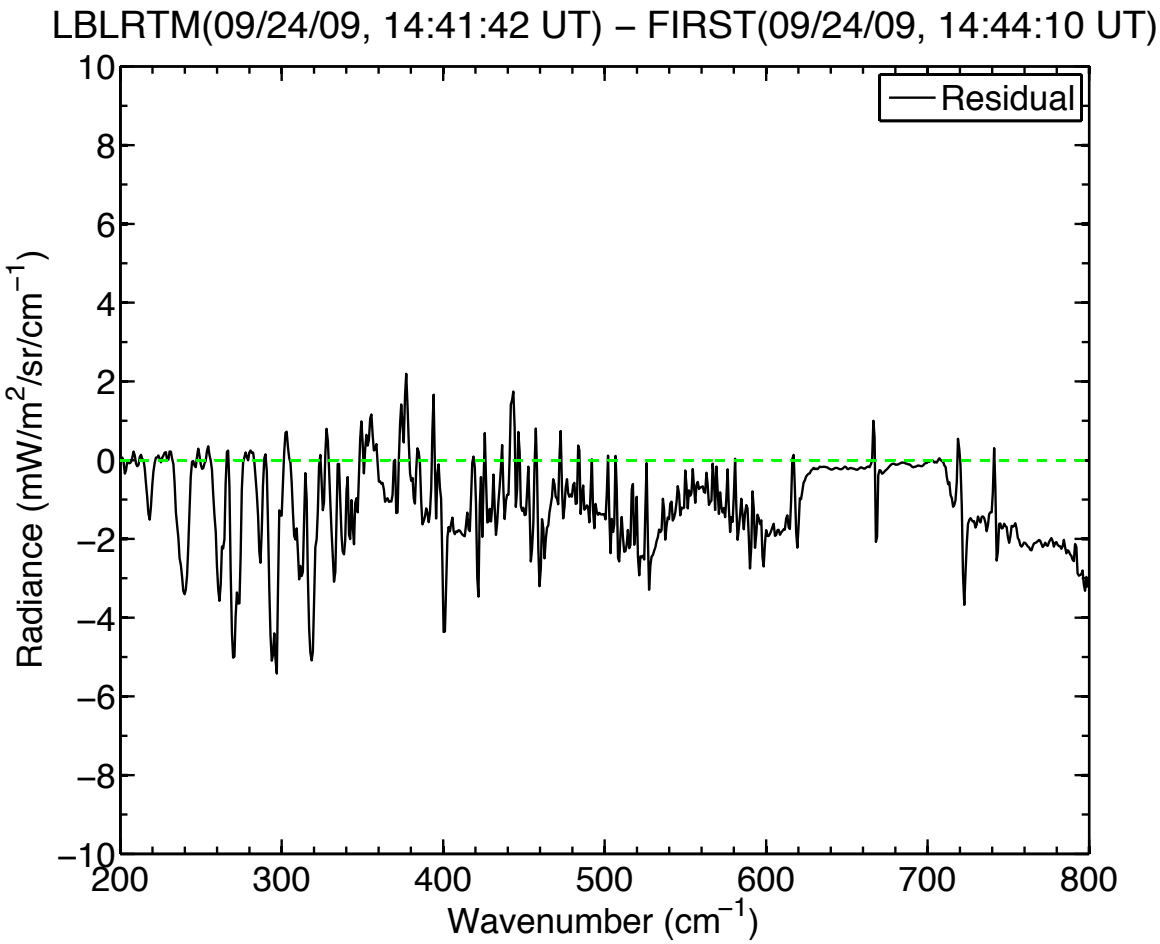


Calculated

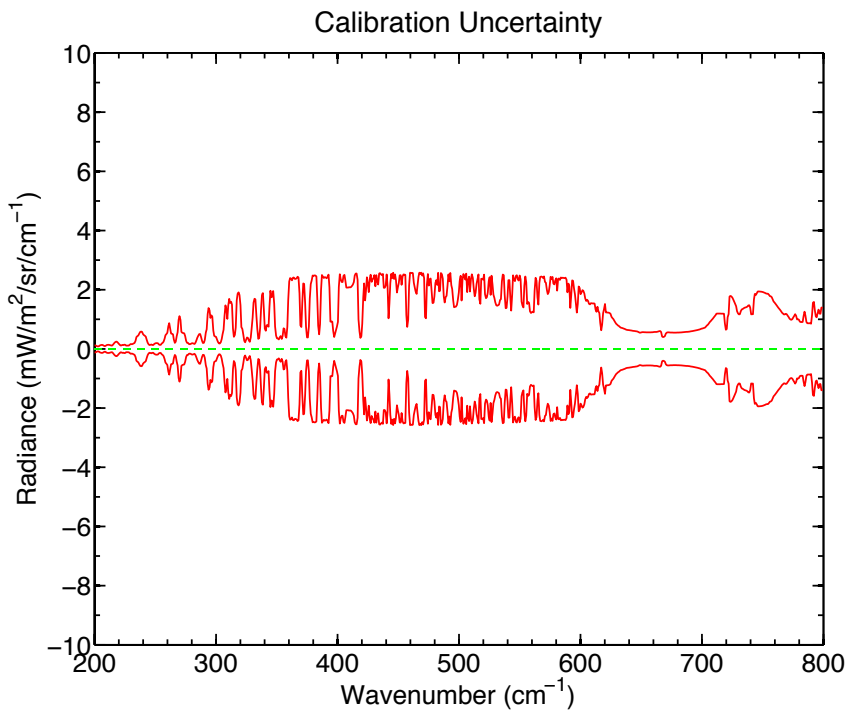


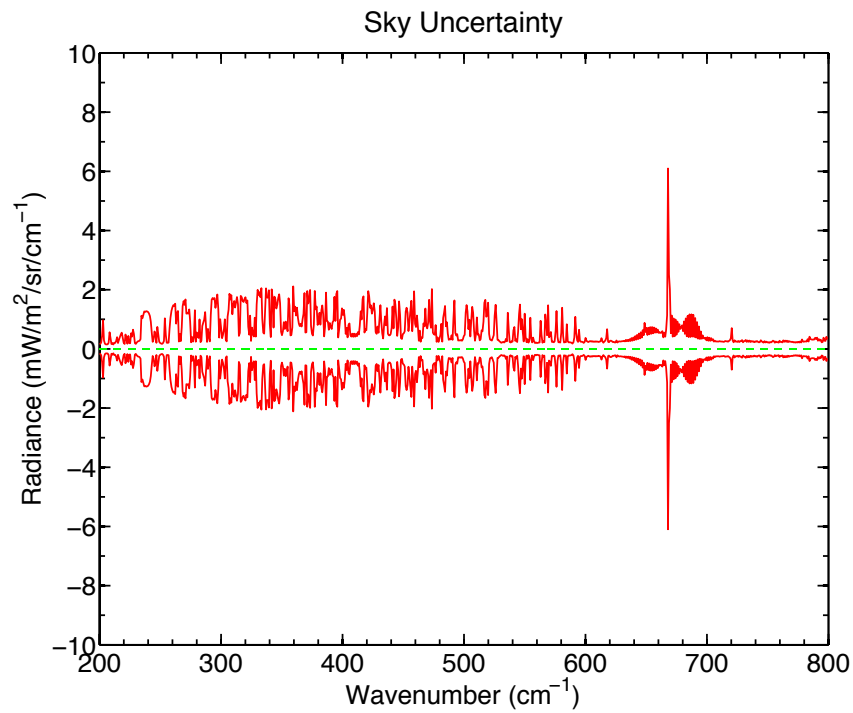
- Figures not on same plot as they would overlap and be difficult to discern.
- Y-scale in above figures: 0 RU – 120 RU, the following slides: -10 RU – 10 RU

LBLRTM – FIRST, 9/24 cont.

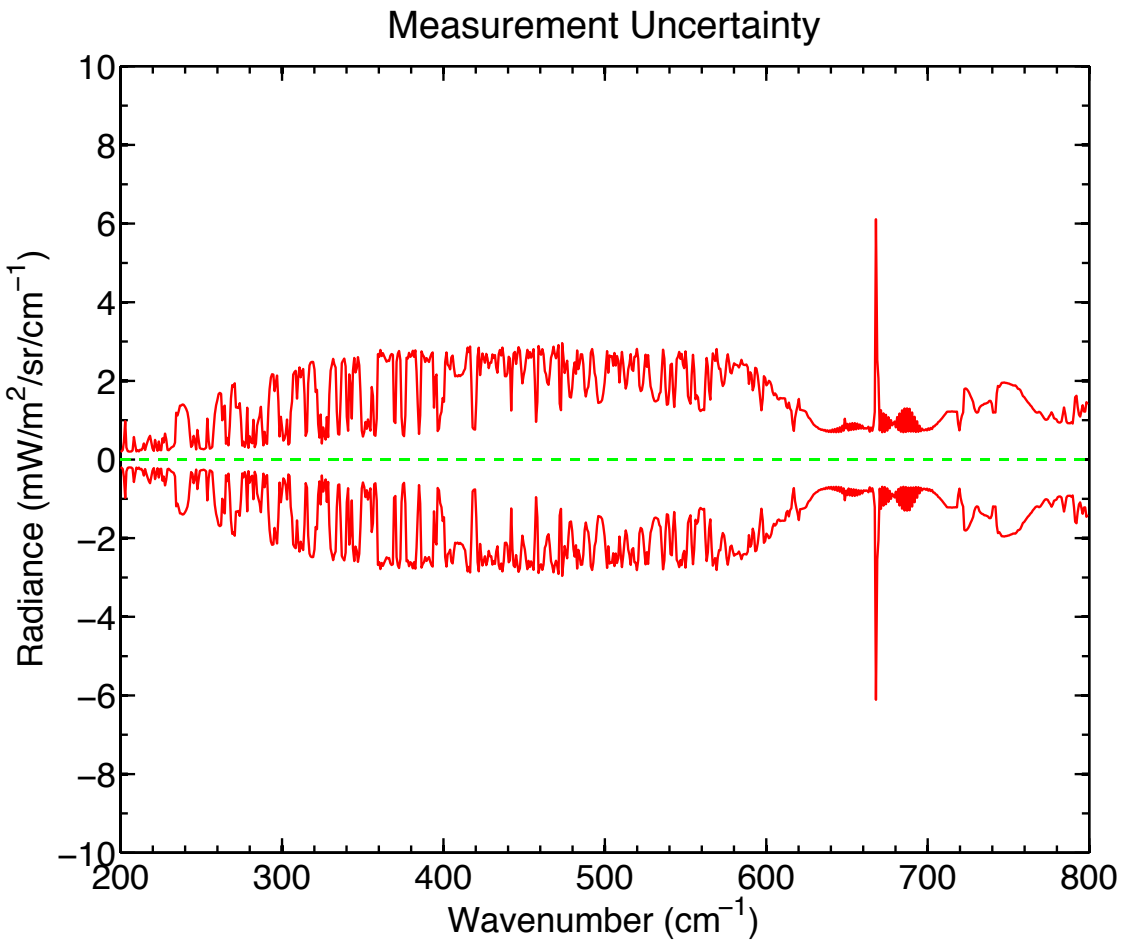


Uncertainties of Measured Spectra, 9/24 cont.

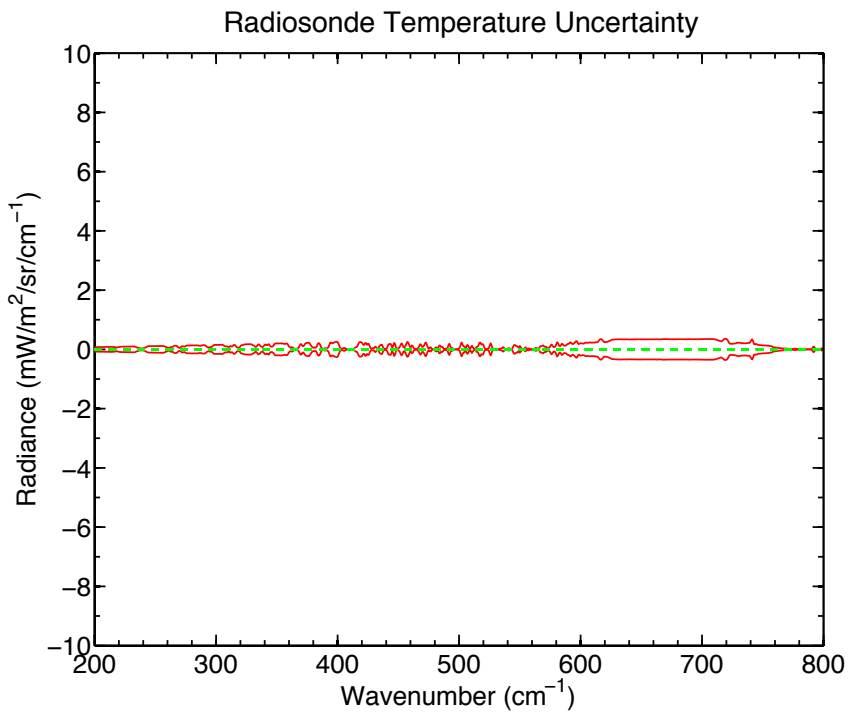


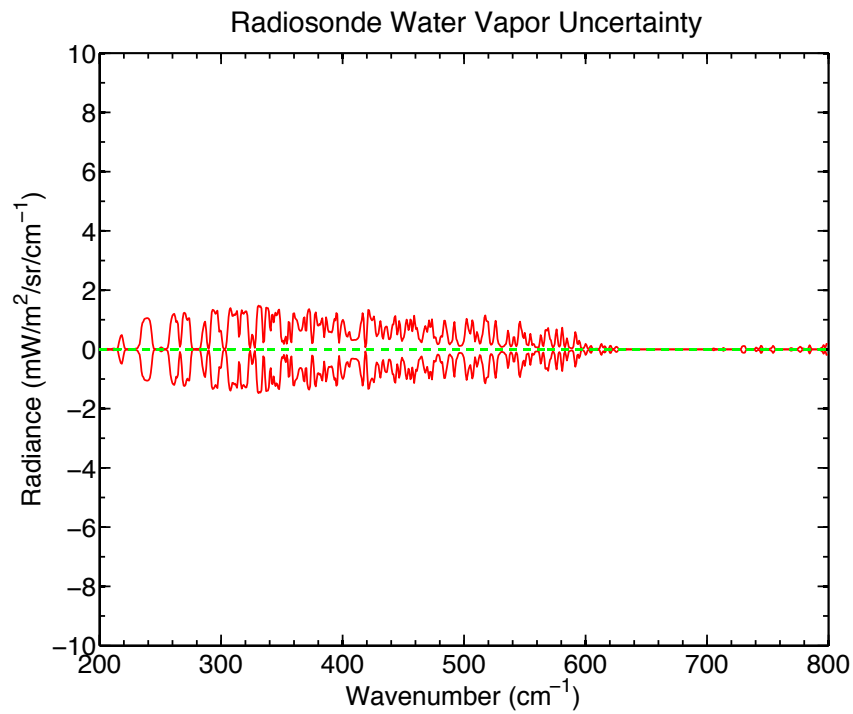


RSS of Measurement Uncertainties, 9/24 cont.

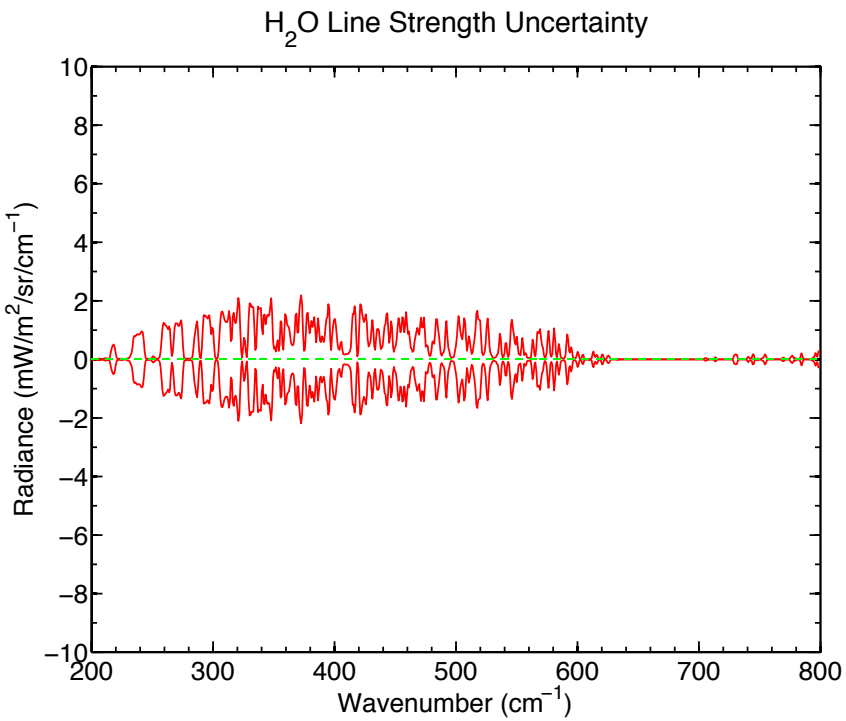


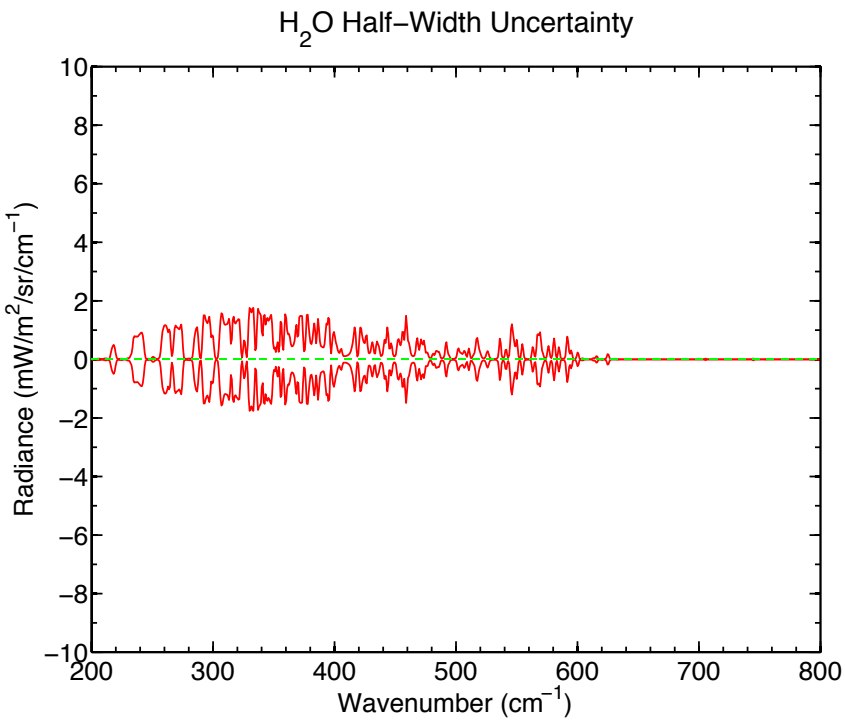
Uncertainties in LBLRTM Model Inputs, 9/24 cont.



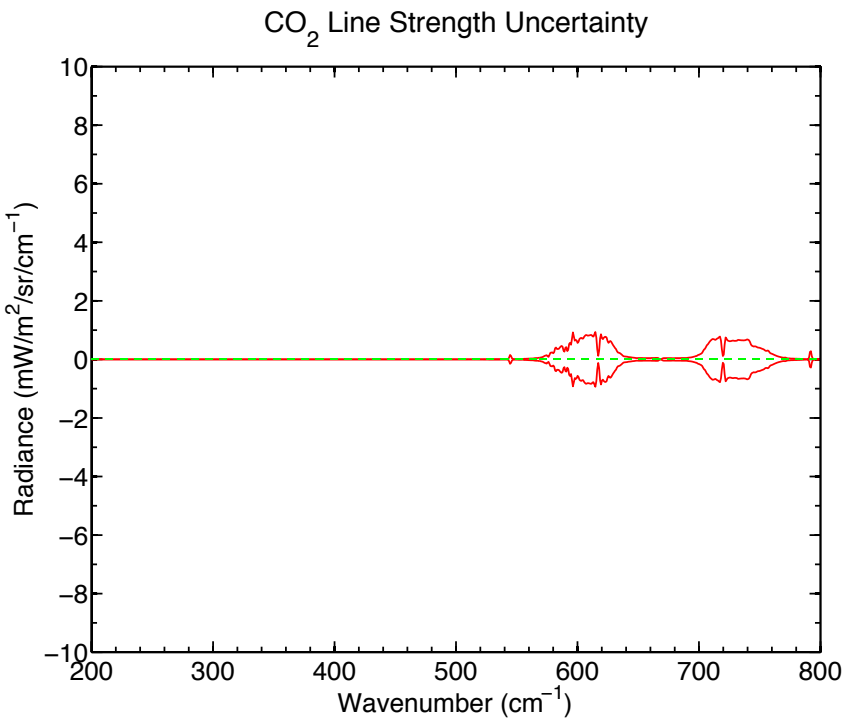


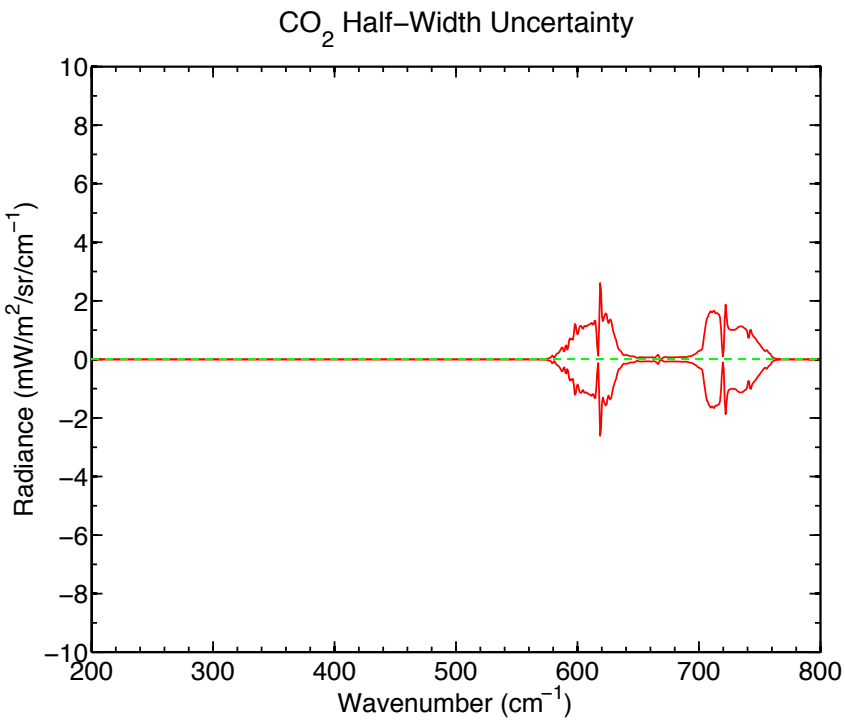
Uncertainties in LBLRTM Line Parameter Inputs, 9/24 cont.



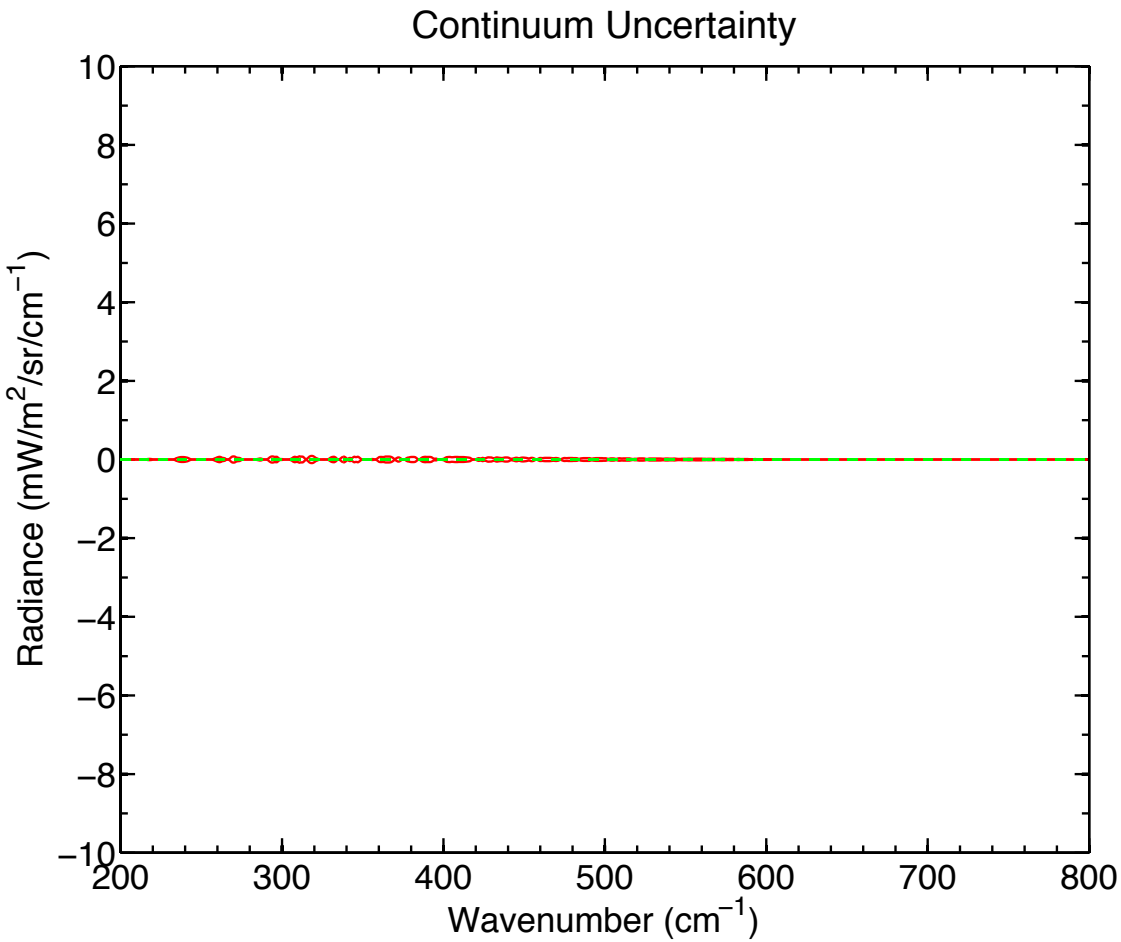


Uncertainties in LBLRTM Line Parameter Inputs, 9/24 cont.

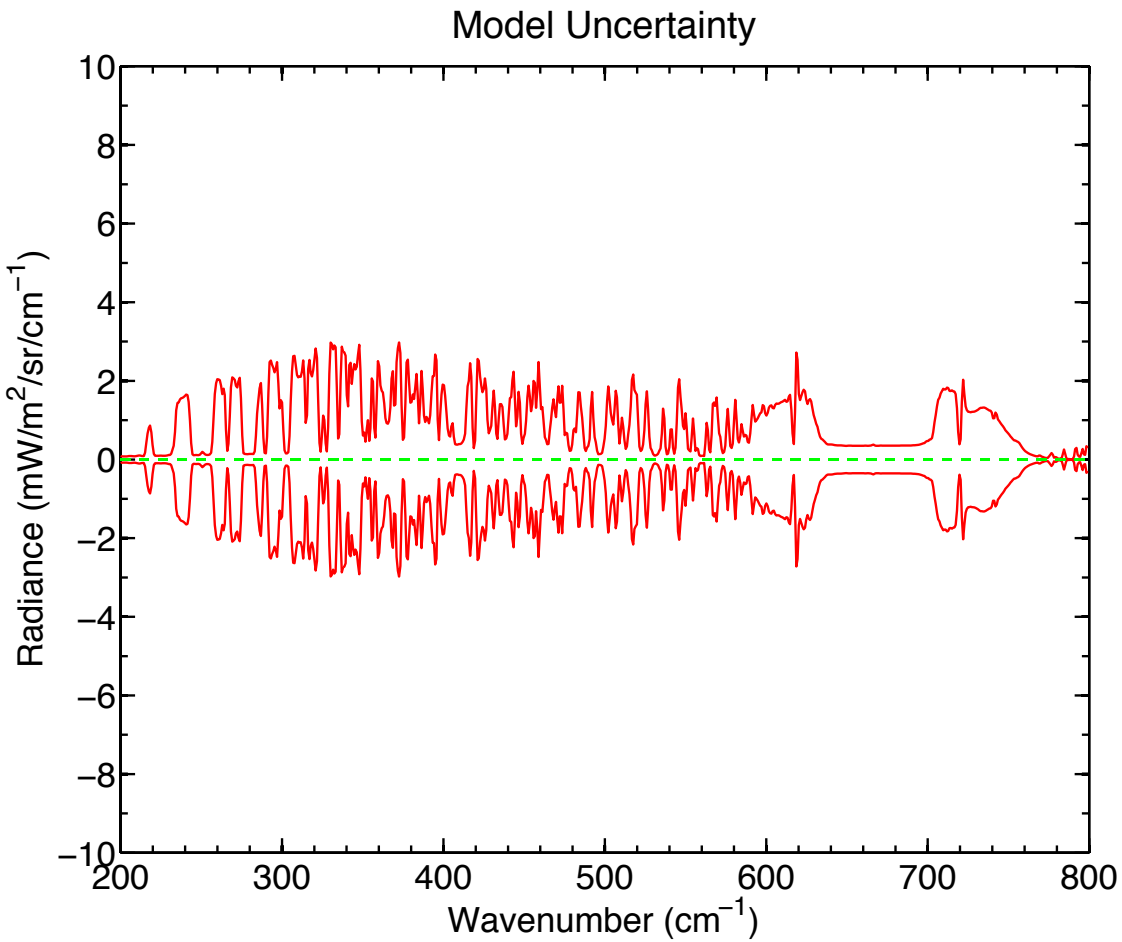




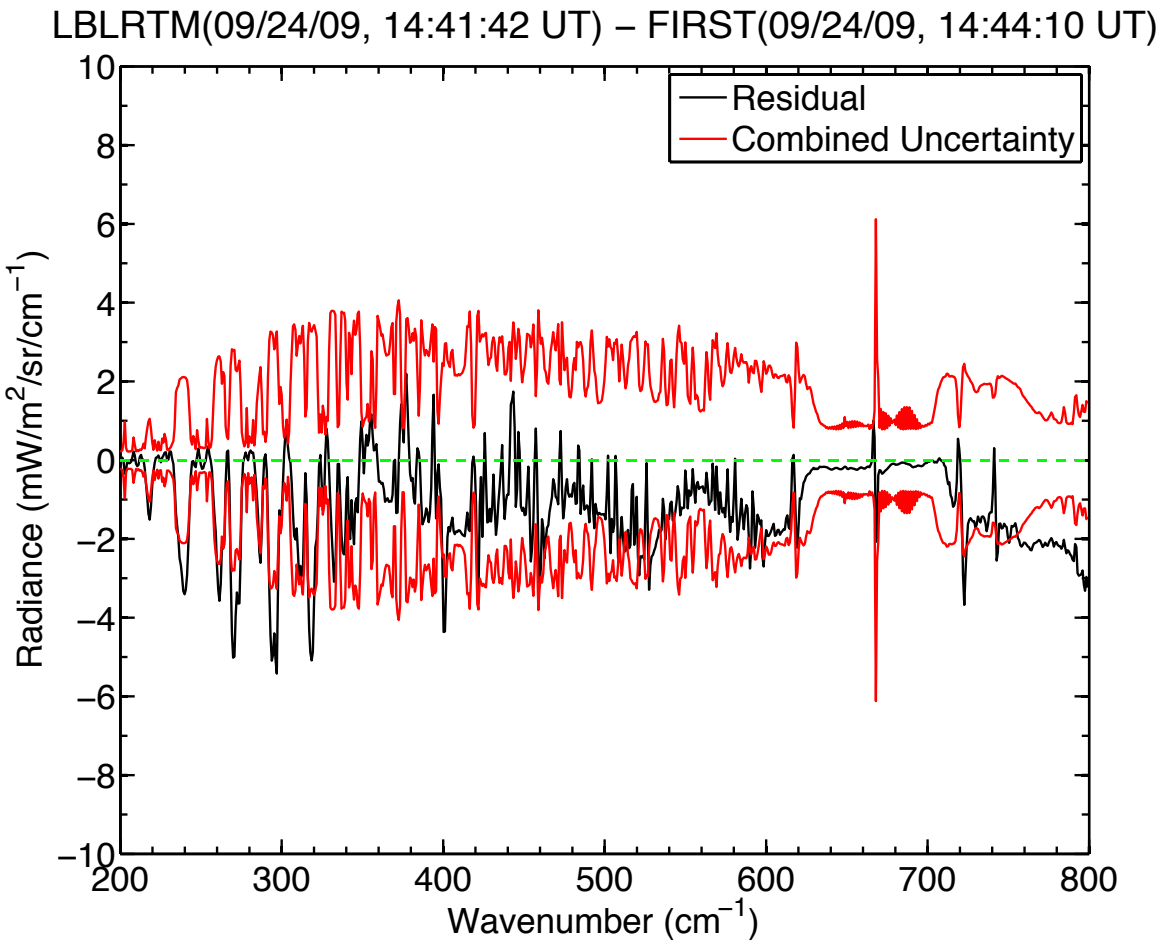
Water vapor continuum uncertainty, 9/24 cont.



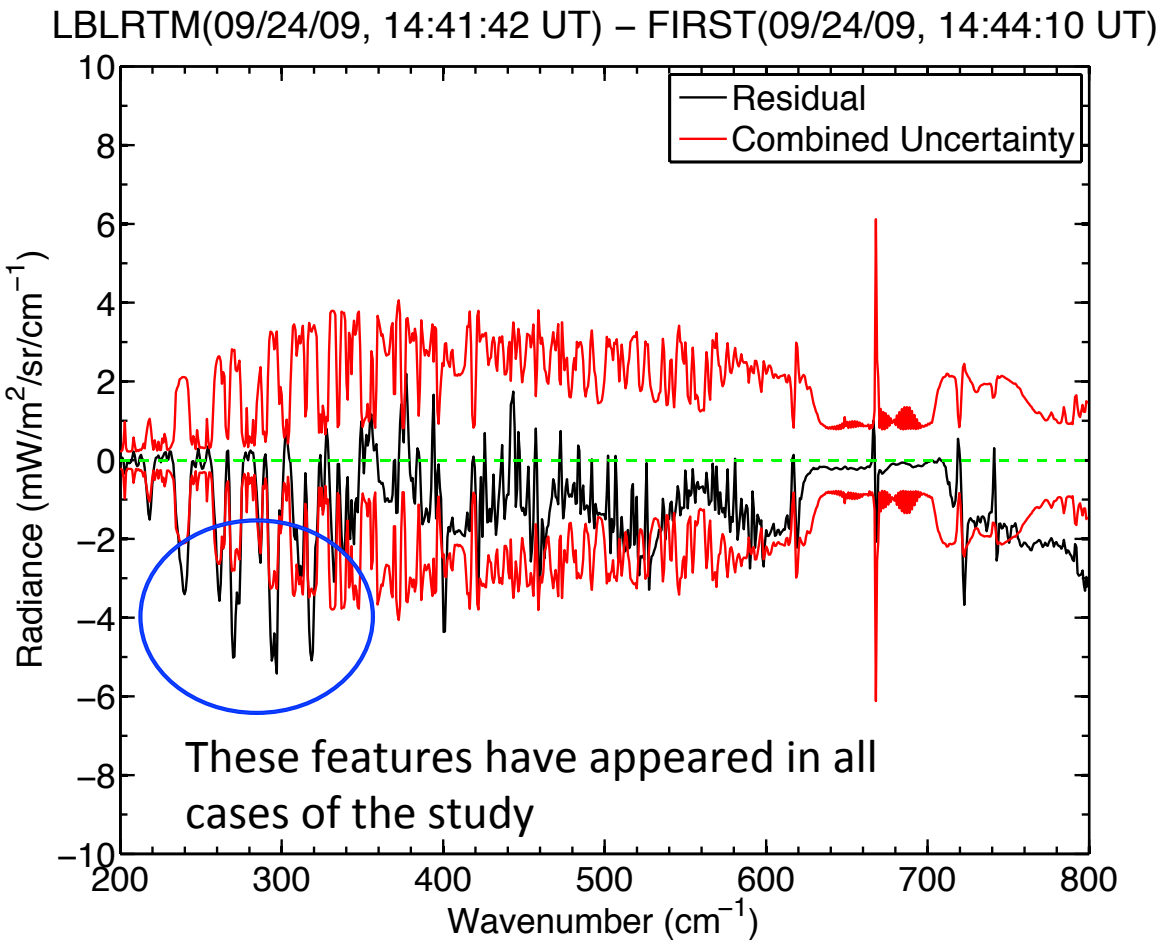
RSS of the Previous Uncertainties Pertaining to LBLRTM Model, 9/24 cont.



Combined Uncertainty = RSS of Model and Measurement

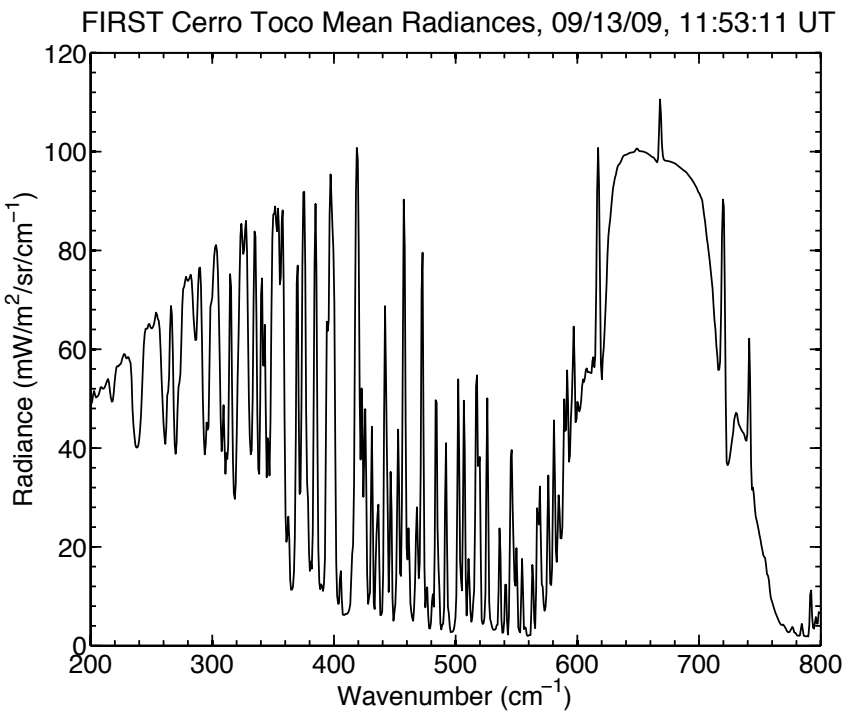


Combined Uncertainty = RSS of Model and Measurement

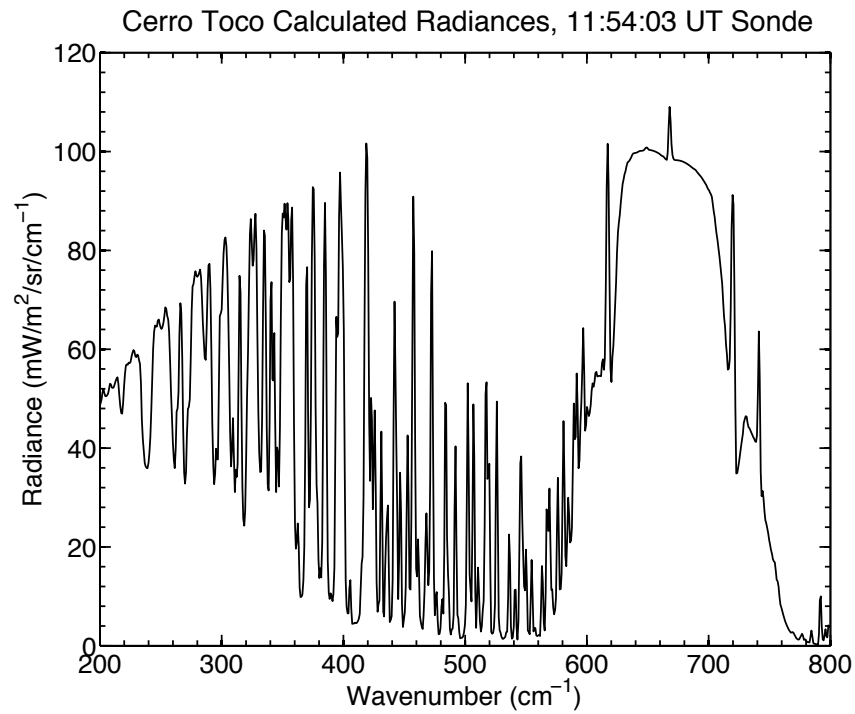


Example Results from September 13, 2009

Measured

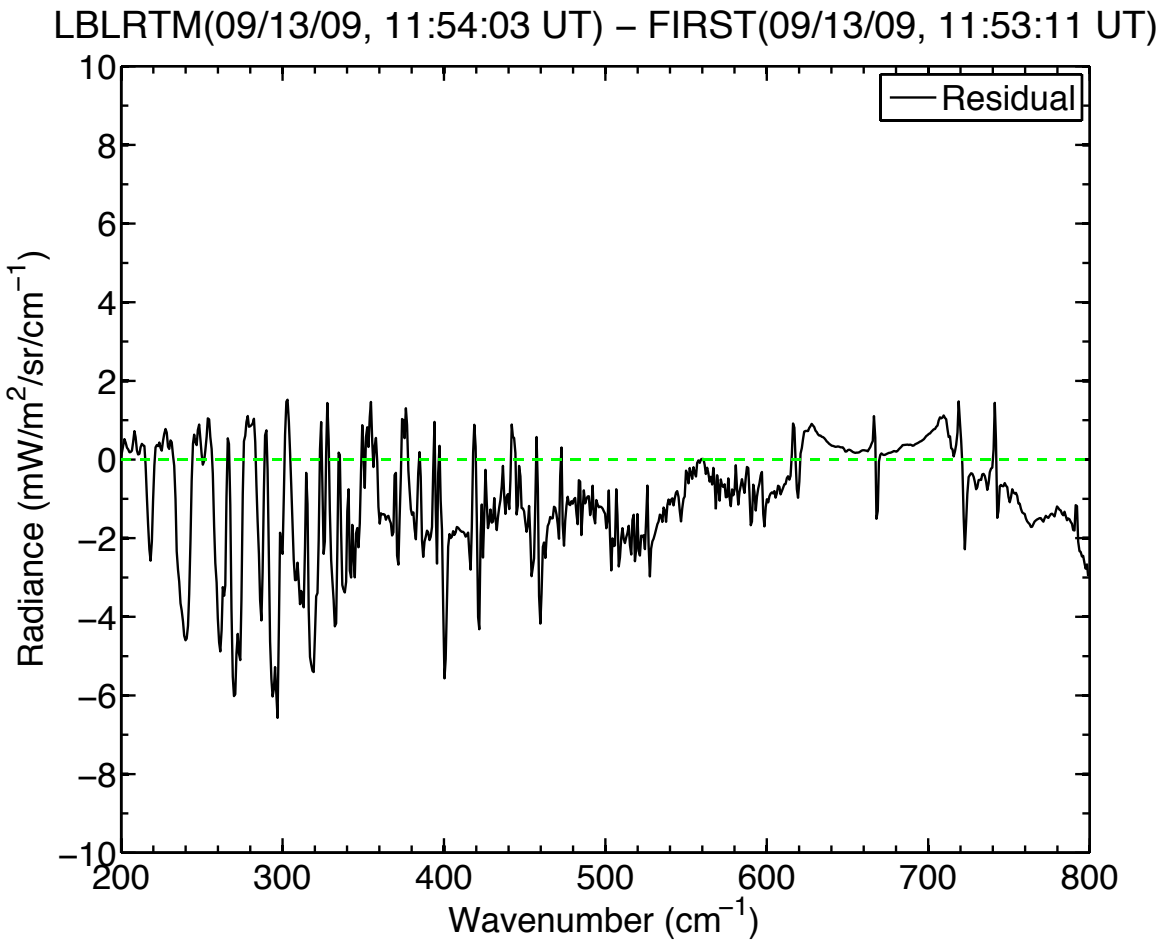


Calculated

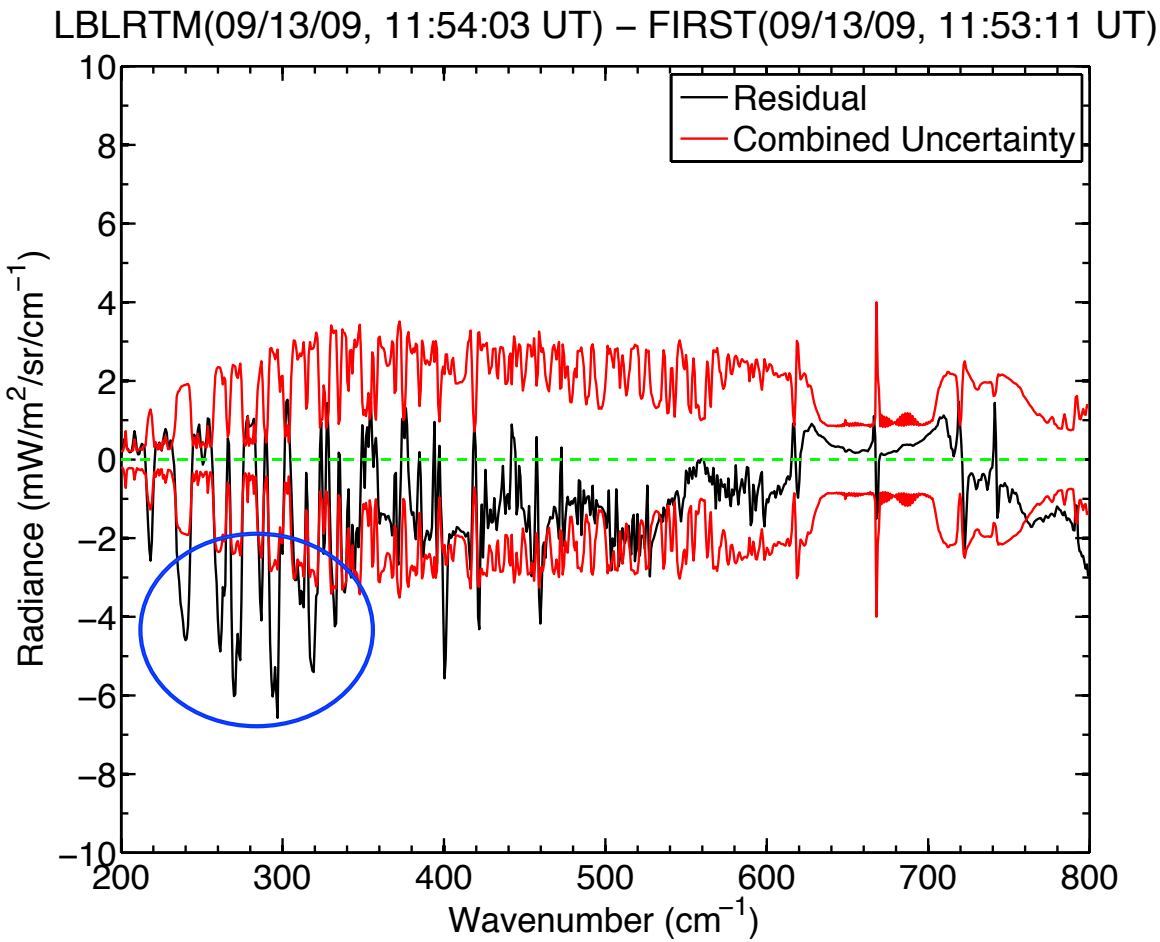


- Y-scale in above figures: 0 RU – 160 RU, the following slides: -10 RU – 10 RU
- Will quickly go through this second set to show the presence of the features between 200 and 350 cm-1.

LBLRTM – FIRST, 9/13 cont.



Combined Uncertainty

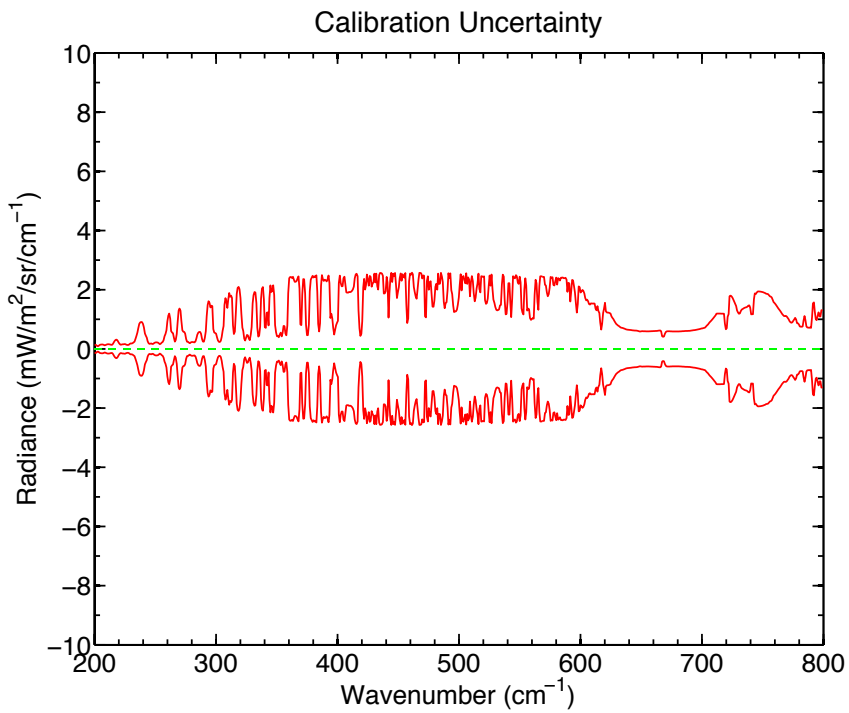


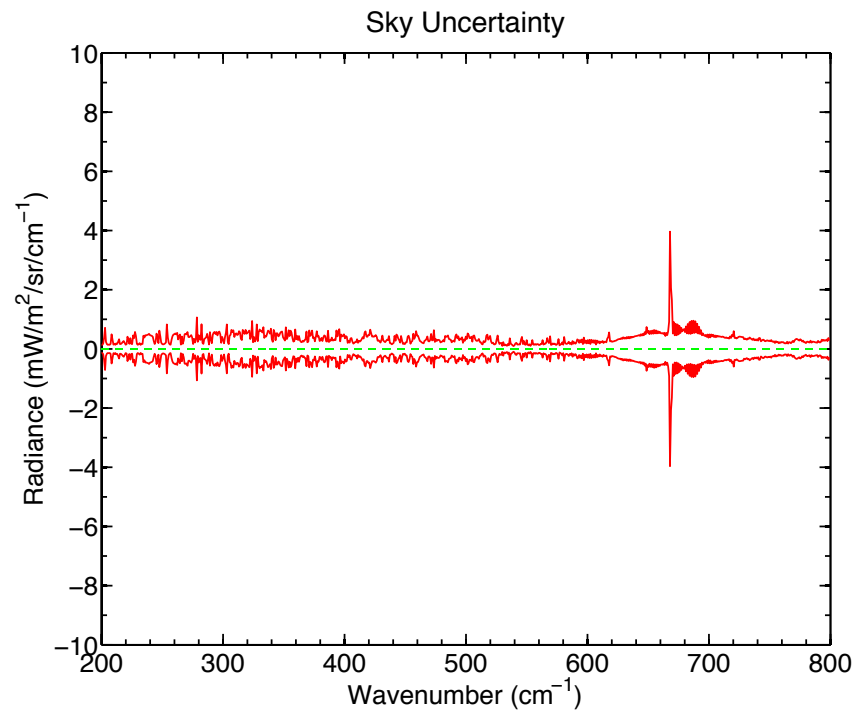
Summary

- Measurements taken by FIRST at two ground-based field campaigns
  - Table Mountain analysis winding down results submitted to JQSRT
  - Working through several days of Cerro Toco results
- FIRST measurements at Cerro Toco compared to LBLRTM calculations
  - Uncertainties for model and measurement components calculated
  - Difference (LBLRTM-FIRST) agrees within combined uncertainties except for some undetermined features

Backups

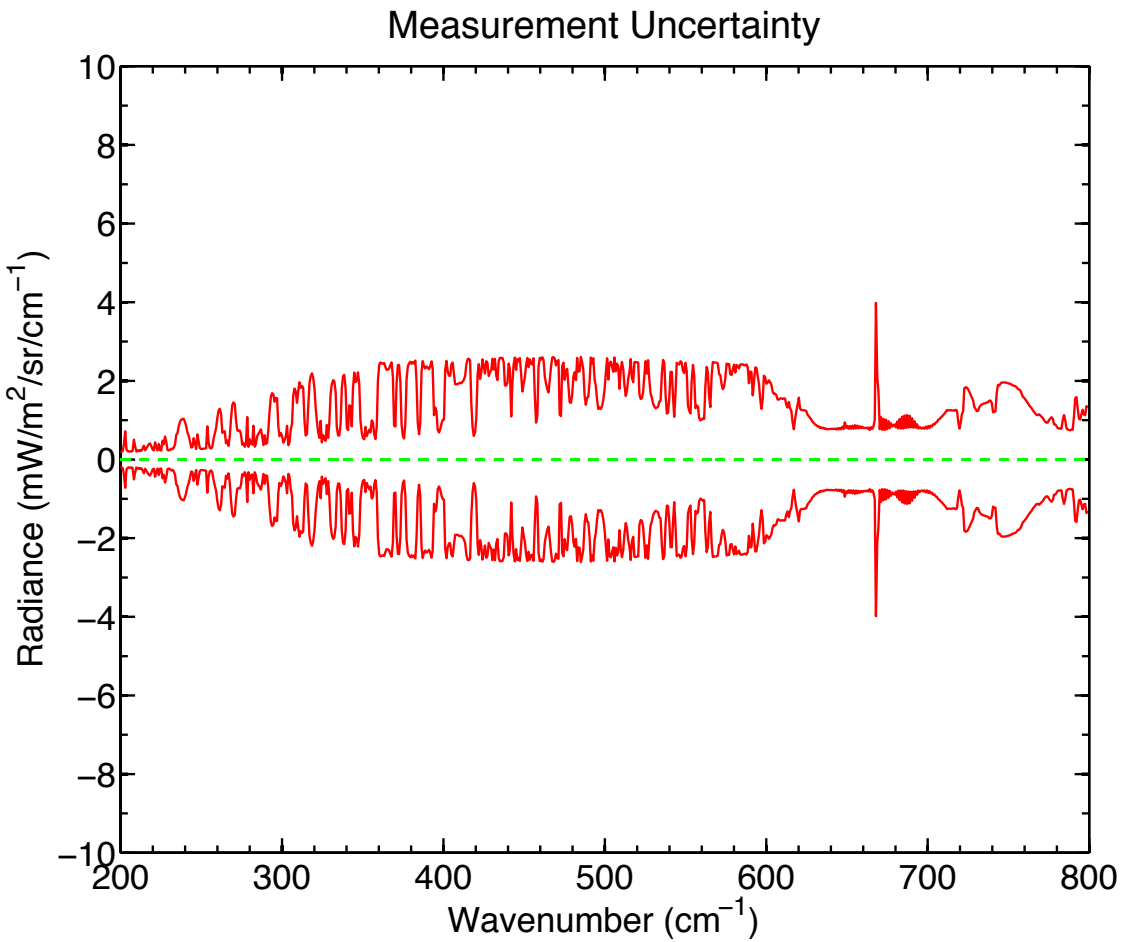
Uncertainties in Measured Spectrum, 9/13 cont.



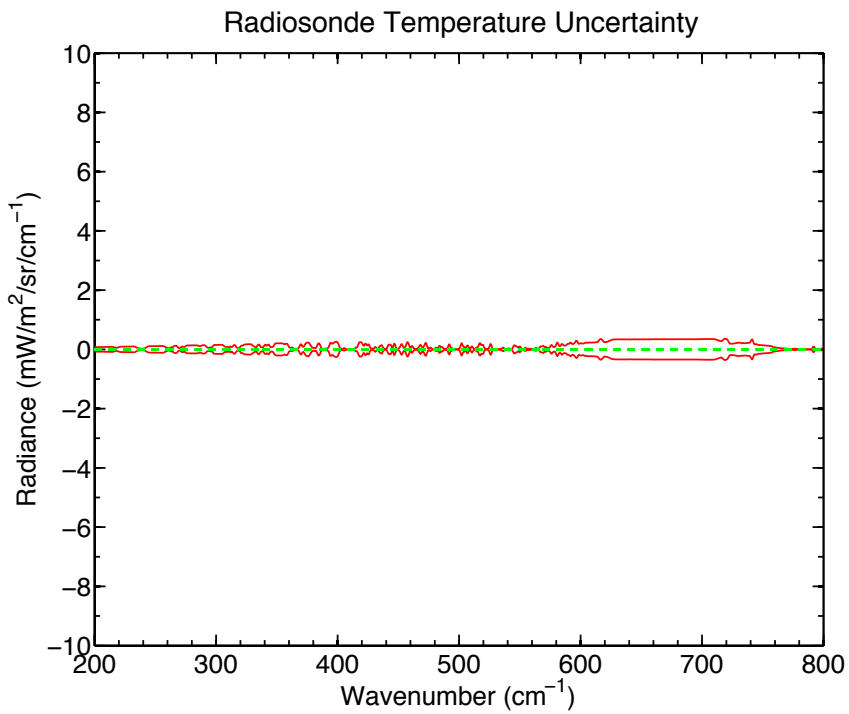


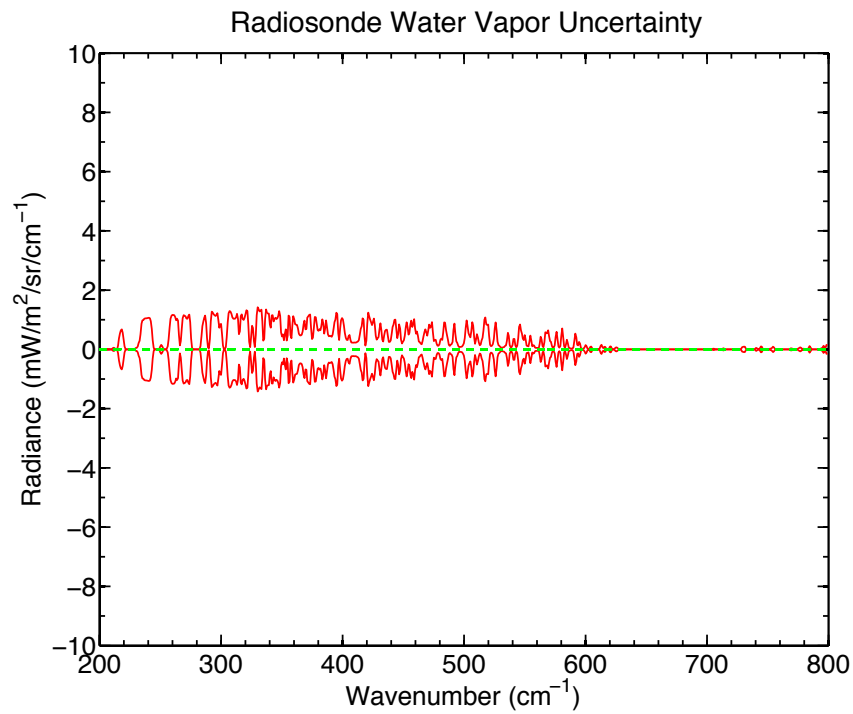
Calibration uncertainty similar to 9/24 day, sky uncertainty different.

RSS of Measurement Uncertainties, 9/13 cont.

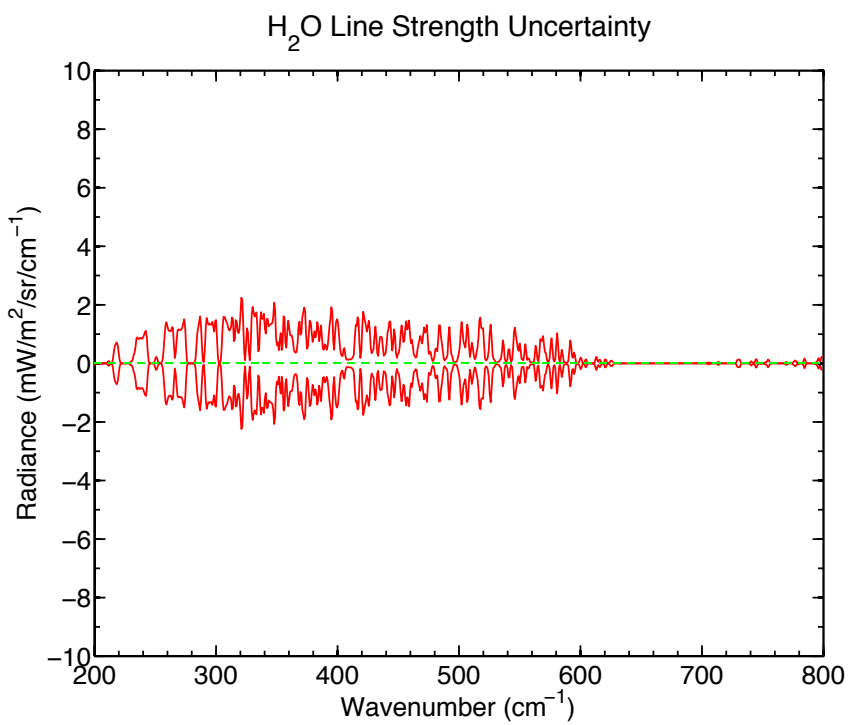


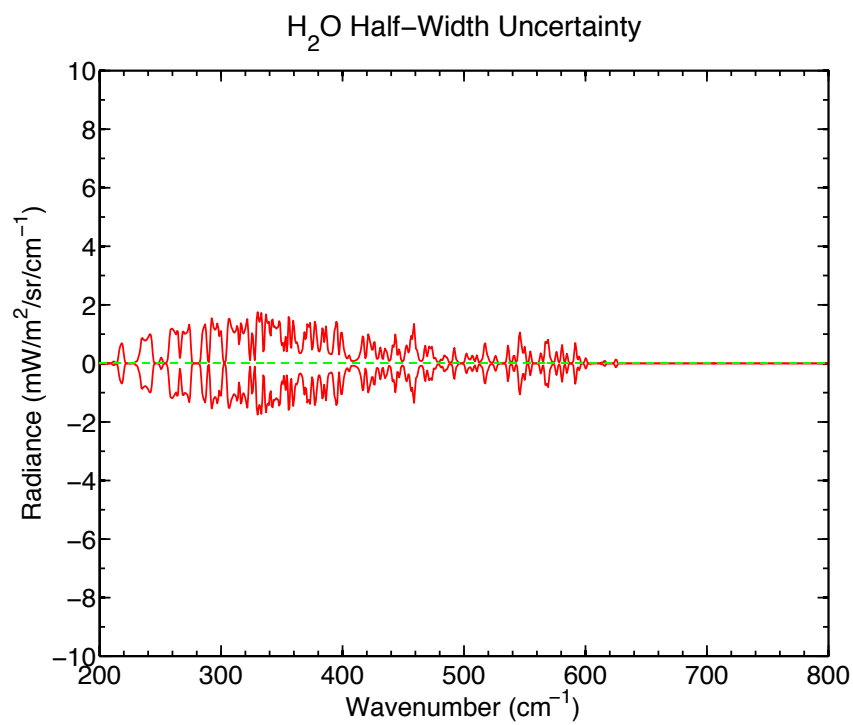
Uncertainties in LBLRTM Model Inputs, 9/13 cont.



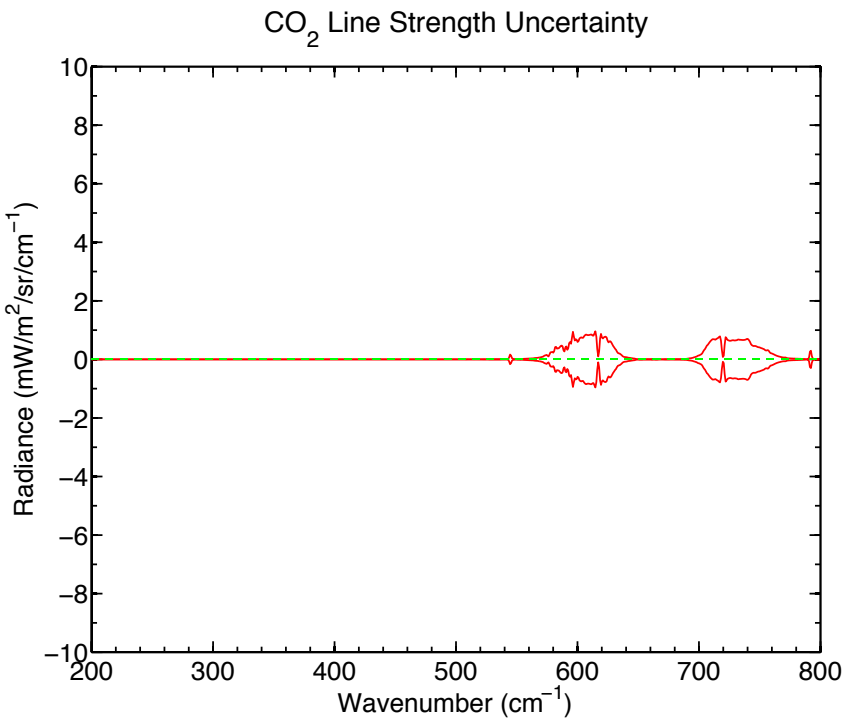


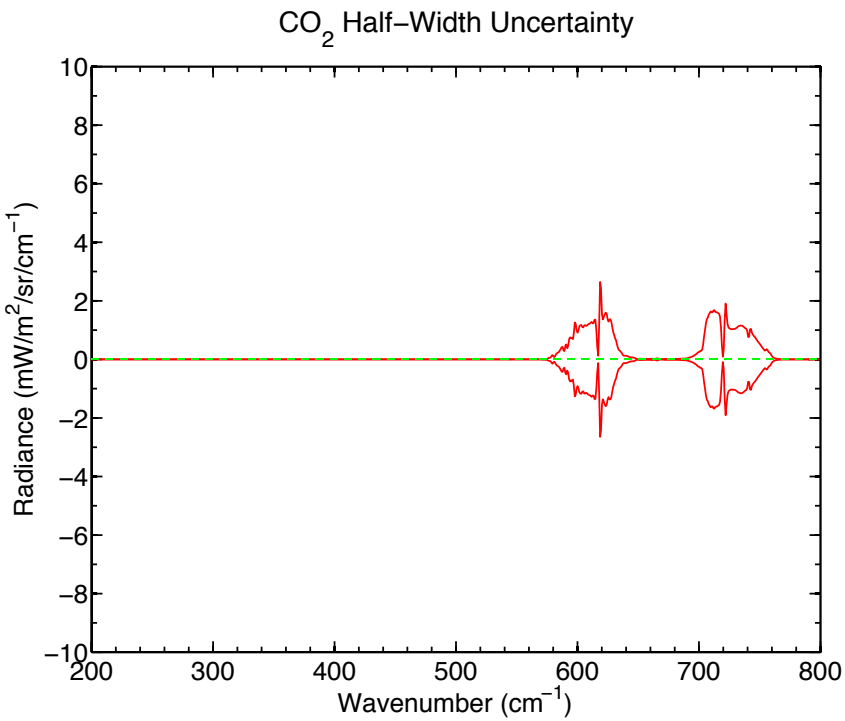
Uncertainties in LBLRTM Line Parameter Inputs, 9/13 cont.



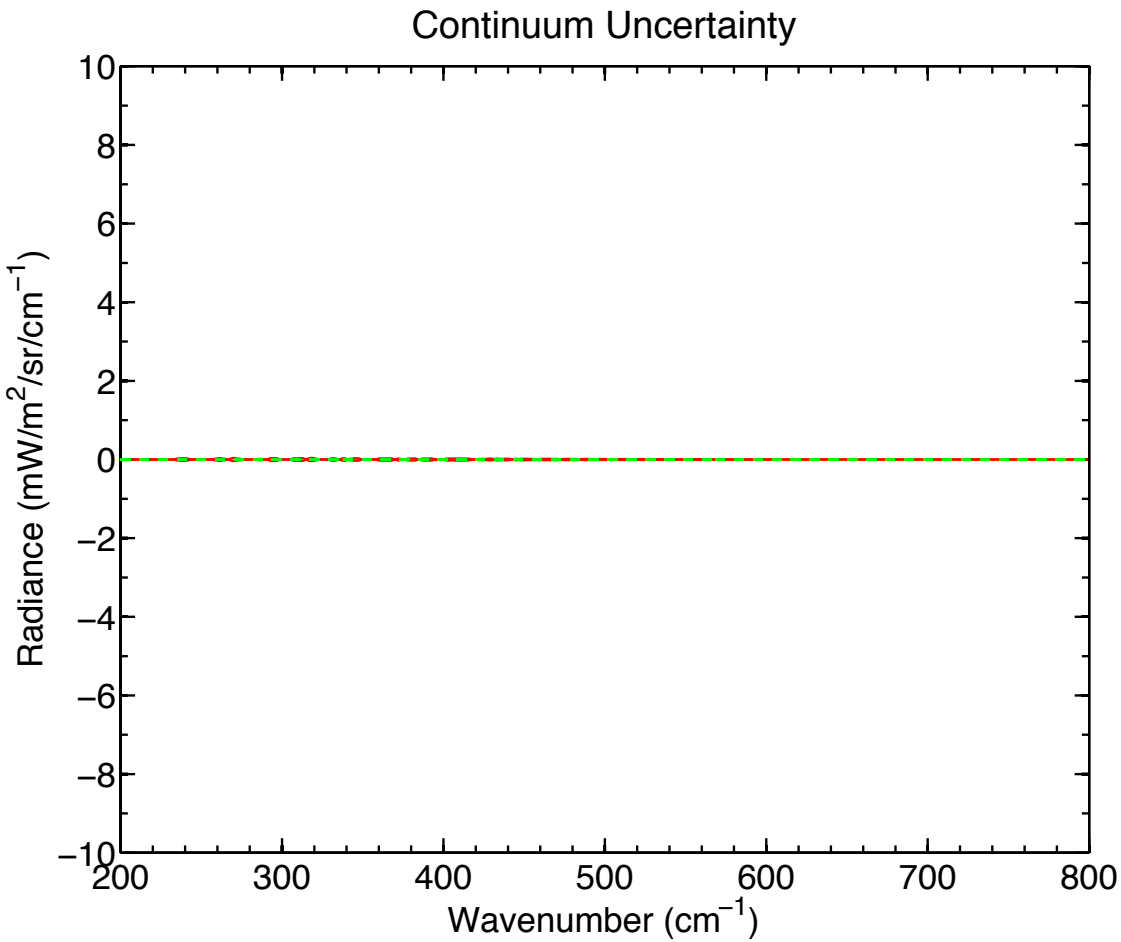
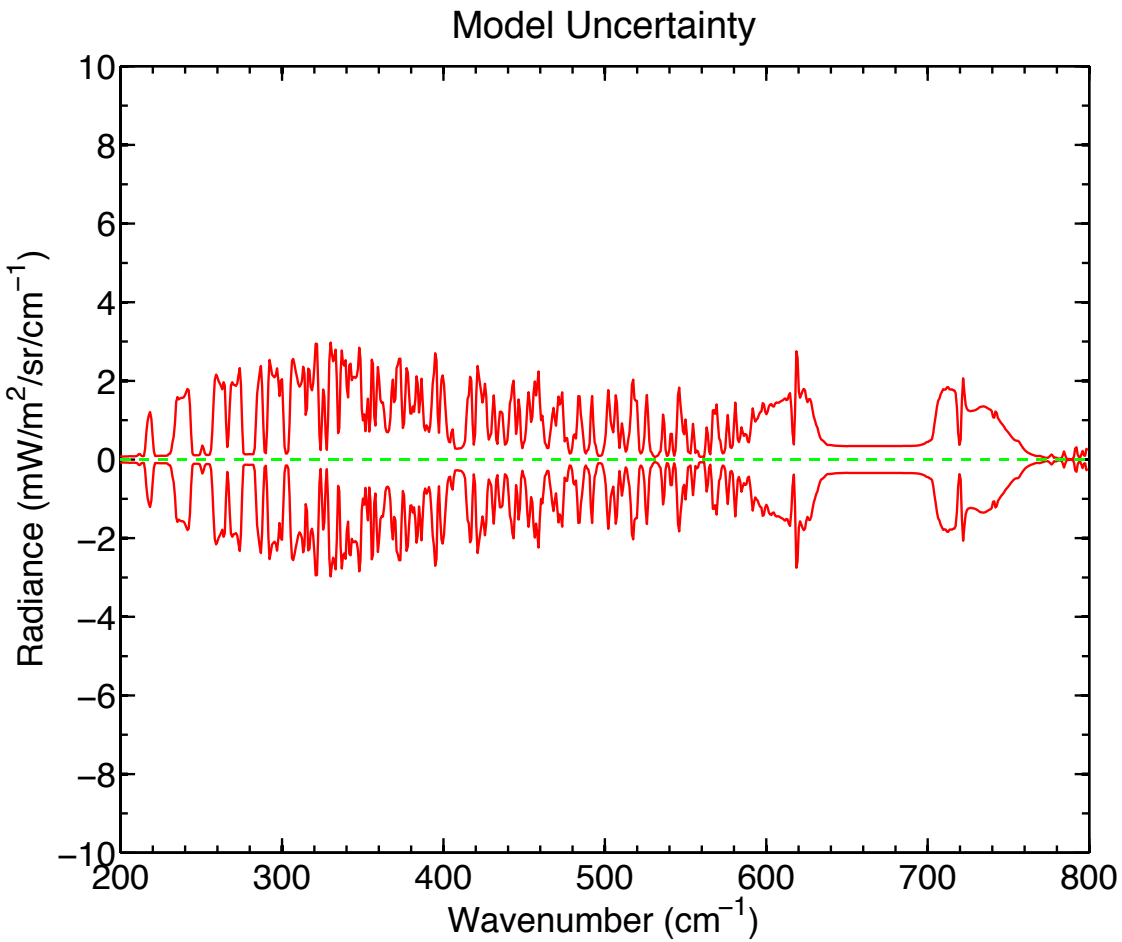


Uncertainties in LBLRTM Line Parameter Inputs, 9/23 cont.





Water vapor continuum uncertainty, 9/13 cont.



RSS of Model Uncertainties, 9/13 cont.