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Implementation of Optimal Spectral Sampling (OSS) Method in CRTM

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Outline

I. **Brief Introduction of OSS Model**
II. **OSS Structure and Implementation to CRTM Rel-2.2.0**
III. **OSS Forward Model Testing and Comparison**
IV. **OSS TL, KM, and FFD Jacobians Testing**
V. **Summary and Future Work**

I. Introduction of OSS Model

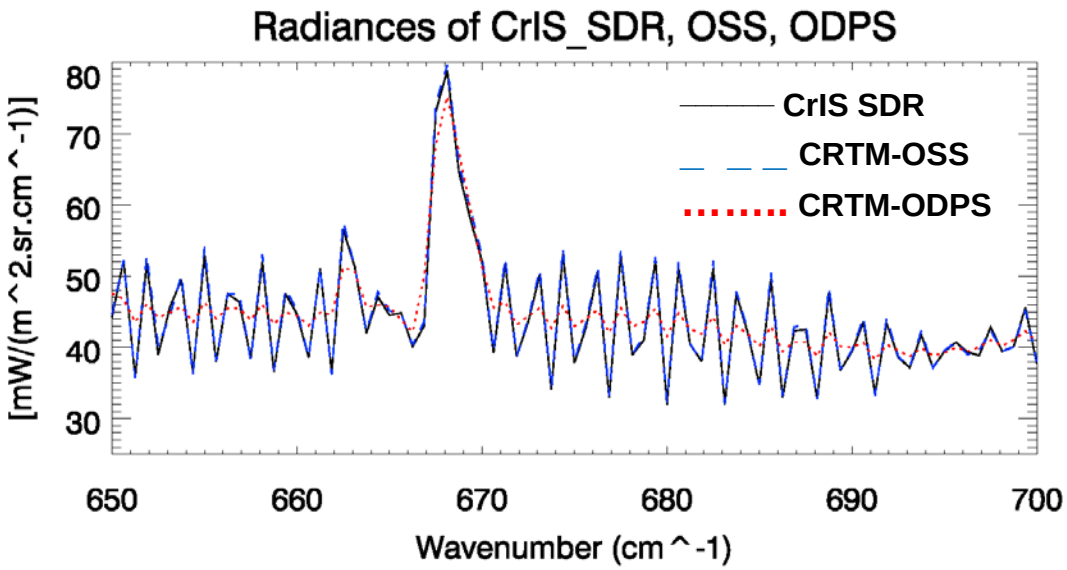
- Current CRTM transmittance methods: ODPS, ODAS.
- The OSS method, developed at AER, is a approach for extending the k-distribution or the sum fitting of transmittance techniques:

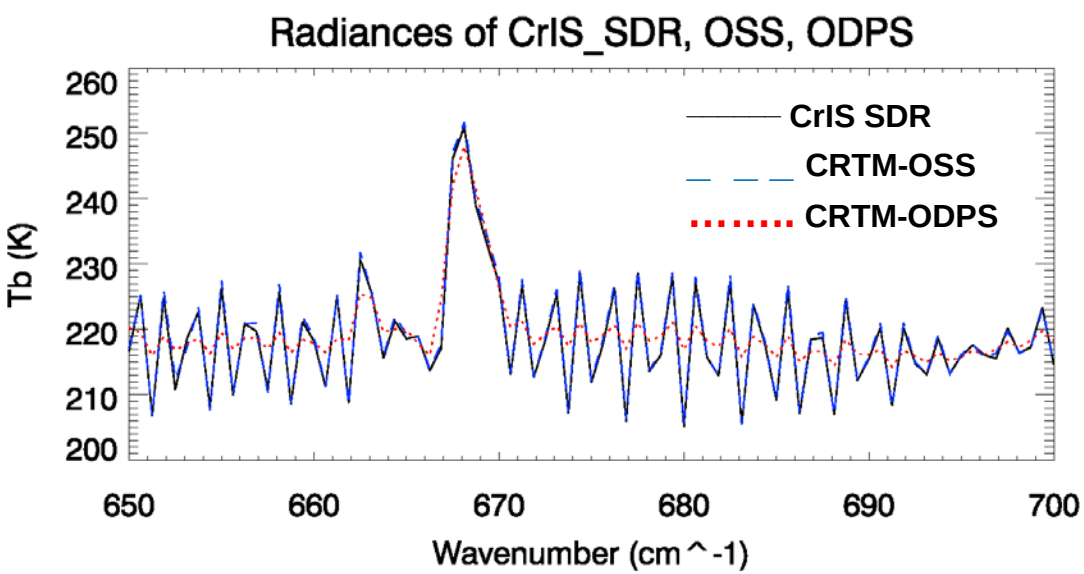
$$\overline{R} = \int_{\Delta\nu} \phi(\nu) R(\nu) d\nu \cong \sum_{i=1}^{N} w_i R(\nu_i);$$

- Where Wavenumber ν_i (nodes) and weights w_i are determined by fitting the LBL model calculations (training set)

- Jean-Luc Moncet, Gennady Uymin, Alan E. Lipton, and Hilary E. Snell, 2008: Infrared Radiance Modeling by Optimal Spectral Sampling. *J. Atmos. Sci.*, **65**, 3917–3934.
- Jean-Luc Moncet, Thomas Nehrkorn, Gennady Uymin, Eli Mlawer and Matthew Alvarado: Radiative transfer modeling support to the JCSDA. *Final Report*, June 30, 2014.

OSS Advantages





- **Advantages of OSS method include:**
  - Unapodized radiances assimilation
  - Accuracy and fidelity with respect to the reference line-by-line model
  - Flexibility in the handling of trace species
  - Speed advantage for hyper spectral IR sensors, like CrIS, AIRS, IASI

OSS coefficients

OSS coefficients	Channel numbers	Training nodes
AIRS-B12-glob-clear-6V-L12.0. OSSLUT.bin	1864	395
AIRS-B12-glob-clear-6V-L12.0. OSSSel.bin	1864	395
AIRS-B123-loc-clear-6V-L12.0. OSSLUT.bin	2378	3479
AIRS-B123-loc-clear-6V-L12.0. OSSSel.bin	2378	3479
CRIS-B12-glob-clear-6V-L12.0. OSSLUT.bin	1146	638
CRIS-B12-glob-clear-6V-L12.0. OSSSel.bin	1146	638
CRIS-B123-loc-clear-6V-L12.0. OSSLUT.bin	1305	7665
CRIS-B123-loc-clear-6V-L12.0. OSSSel.bin	1305	7665
CRIS-hires-B12-glob-clear-6V-L12.0. OSSLUT.bin	1578	539
CRIS-hires-B12-glob-clear-6V-L12.0. OSSSel.bin	1578	539
CRIS-hires-B123-loc-clear-6V-L12.0. OSSLUT.bin	2211	5522
CRIS-hires-B123-loc-clear-6V-L12.0. OSSSel.bin	2211	5522
IASI-B12-glob-clear-6V-L12.0. OSSLUT.bin	5420	404
IASI-B12-glob-clear-6V-L12.0. OSSSel.bin	5420	404
IASI-B123-loc-clear-6V-L12.0. OSSLUT.bin	8461	3680
IASI-B123-loc-clear-6V-L12.0. OSSSel.bin	8461	3680
IASI-B1-loc-clear-6V-L12.0. OSSLUT.bin	2260	1012
IASI-B1-loc-clear-6V-L12.0. OSSSel.bin	2260	1012

OSS and ODPS Speed Test

Simulation time (second) for 2 gases, clear sky

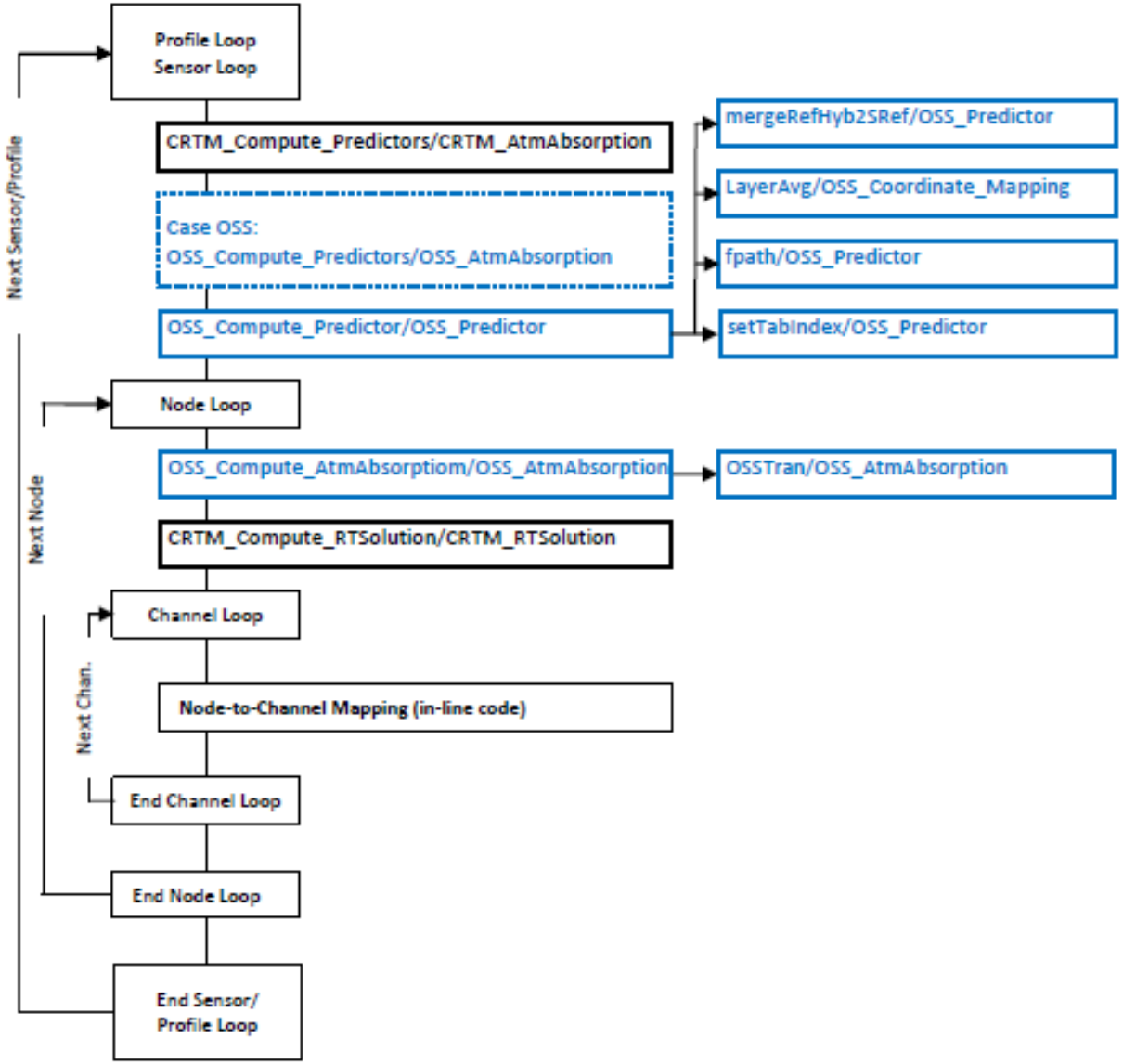
Sensors	OSS	ODPS	Speed ratio: (ODPS/OSS)
IASI_B1_metop-a_L (2260 bands)	Nd1998 - 5.312	5.730	1.08
	Nd1012 - 2.712		2.11
IASI_8461_metop-a_L (8461 bands, Nd-3680)	8.662	22.006	2.54
CrIS_npp_G (1146 B1+B2, Nd-638)	1.686	3.303	1.96
CrIS_npp_L (1305 bands, Nd-7665)	17.643	3.719	0.21

II. OSS Model Structure and Implementation

- OSS Model Structure
- Implementation of CRTM-OSS-2.0.5 to CRTM Rel-2.2.0
  - In 2013, AER delivered an OSS package which was built with an offline CRTM REL-2.0.5, so was not commit back to CRTM repository.

Current CRTM RT calculation flowchart

CRTM-OSS RT calculation flowchart



Implement CRTM OSS Model

OSS merge into CRTM 2.2.0 sub-directories
(No change |With changes|New|Merge Completed)

Root/ FD, TL, KM	Atmosphere	GeometryInfo	RTSolution	Test_Utility
Ancillary	AtmScatter	InstrumentInfo	SensorInfo	Utility
AntennaCorrection	ChannelInfo	Interpolation	SfcOptics	Zeeman
AtmAbsorption	Coefficients	NLTE	Source_Functions	
AtmOptics	CRTM_Utility	Options	Surface	

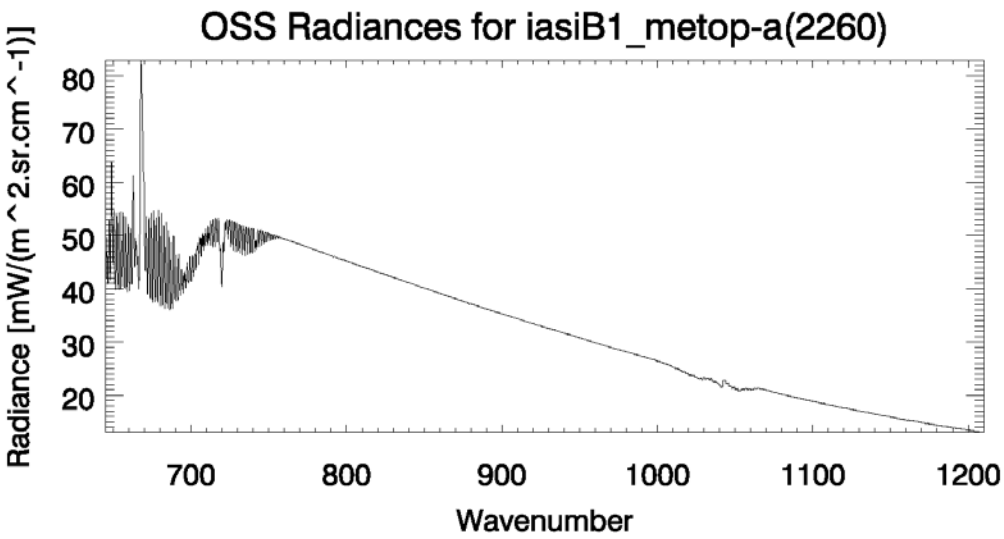
Differences in AtmAbsorption module

Files	CRTM-2.0.5	CRTM-2.2.0
CRTM-2.0.5 version: •CRTM_AtmAbsorption.f90 **CRTM-2.2.0 version:** •CRTM_AtmAbsorption.f90 •CRTM_AtmAbsorption_Define.f90 •CRTM_Predictor_Define.f90 •CRTM_Predictor.f90	CRTM_Predictor_type CRTM_AAVariables_type CRTM_APVariables_type	USE ODPS_AtmAbsorption, ONLY: ODPS_AAVar_type => iVar_type USE ODPS_Predictor, ONLY: ODPS_APVar_type => iVar_type
	CRTM_Allocate_APV CRTM_Destroy_APV CRTM_Allocate_Predictor CRTM_Destroy_Predictor	CRTM_Predictor_Associated CRTM_Predictor_Destroy CRTM_Predictor_Create CRTM_Predictor_Inspect
	CRTM_Allocate_AAV CRTM_Destroy_AAV	CRTM_Associated_AtmAbsorption CRTM_Destroy_AtmAbsorption CRTM_Allocate_AtmAbsorption CRTM_Assign_AtmAbsorption
	CRTM_Compute_AtmAbsorption/_TL_AD CRTM_Compute_Predictors/_TL_AD CRTM_Apply_Ps_AD_matrix	CRTM_Compute_AtmAbsorption/_TL_AD CRTM_Compute_Predictors/_TL_AD

III. OSS Forward Model Testing and Comparison

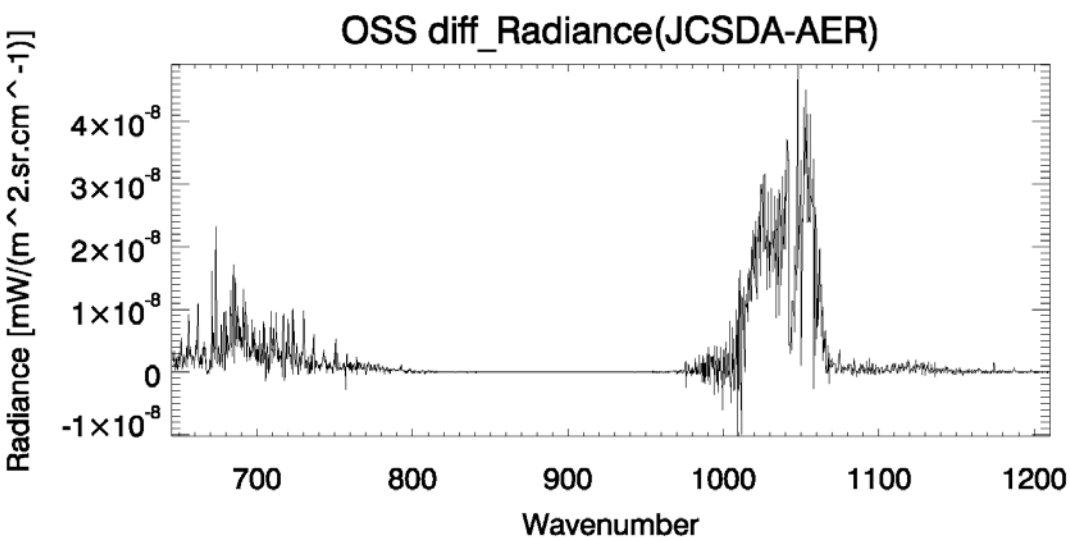
- Comparison between OSS-2.0.5 runs at AER and JCSDA
- Comparison between OSS-2.0.5 and OSS-2.2.0
- Comparison between OSS-2.2.0 and ODPS

OSS run at AER vs JCSDA



* Two gases: WV, O3
* One layer ice-cloud

* OSS AER result
* Same code run at JCSDA

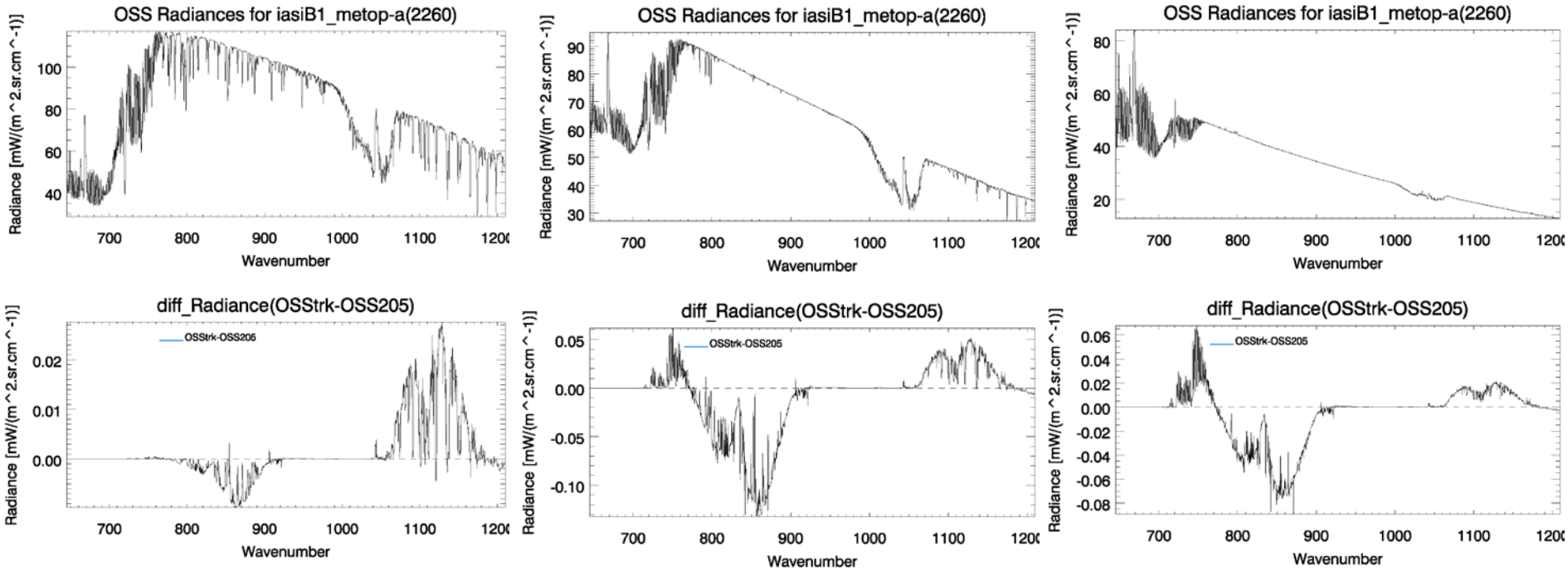


OSS-2.0.5 vs OSS-2.2.0 IASI-B1 for 3profiles

Profile: Warm
Tskin=302.56 K

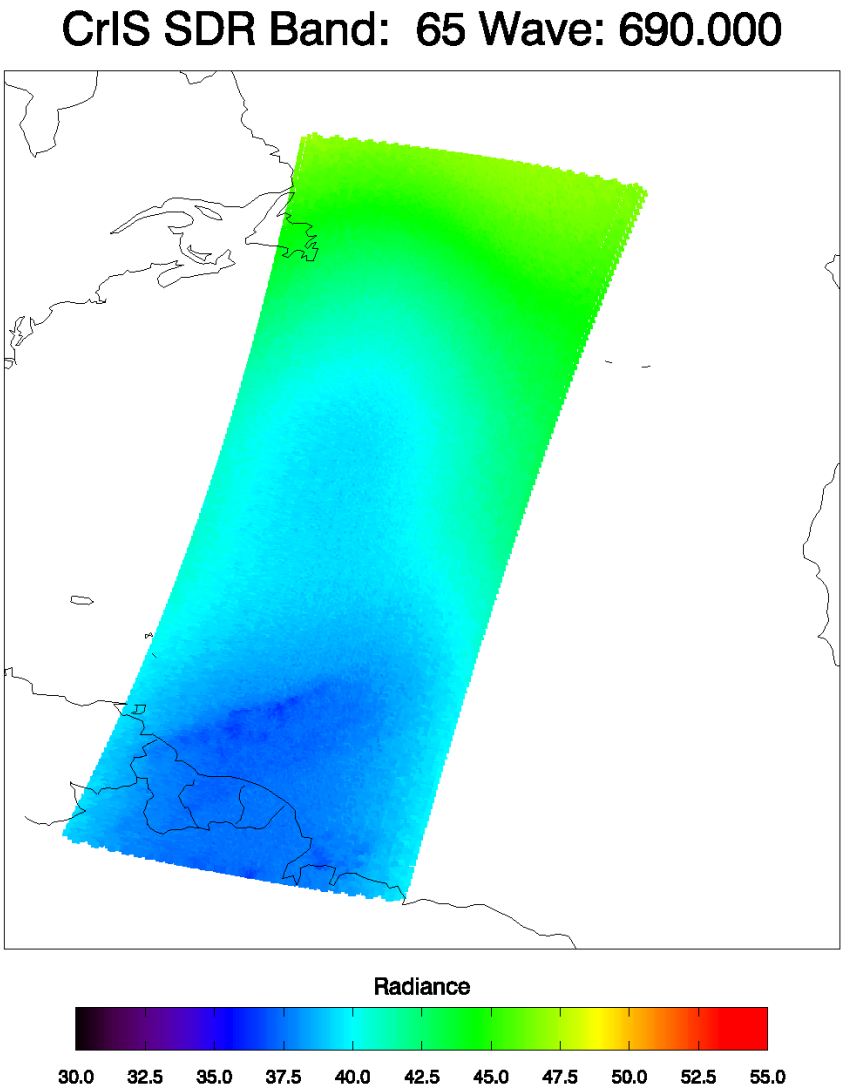
Profile: Moderate
Tskin=272.99 K

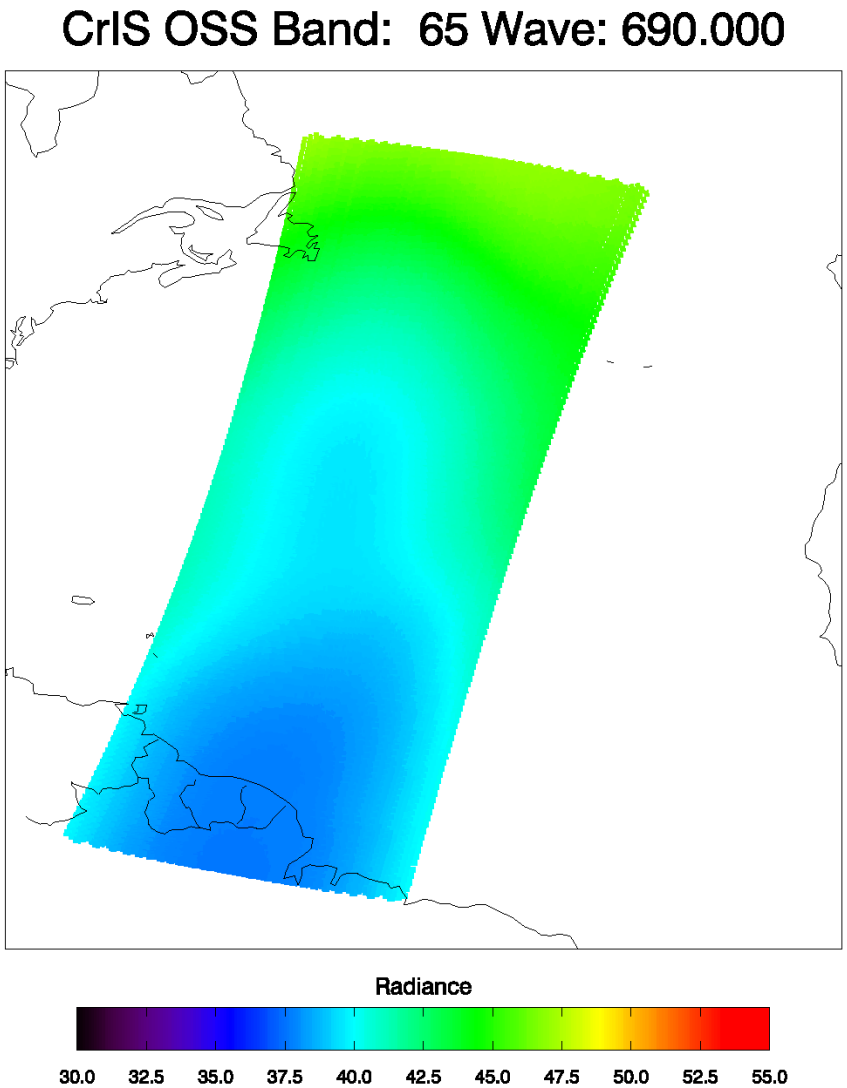
Profile: Cold
Tskin=236.07 K



With 2 absorbers (WV,O3), and clear sky condition.

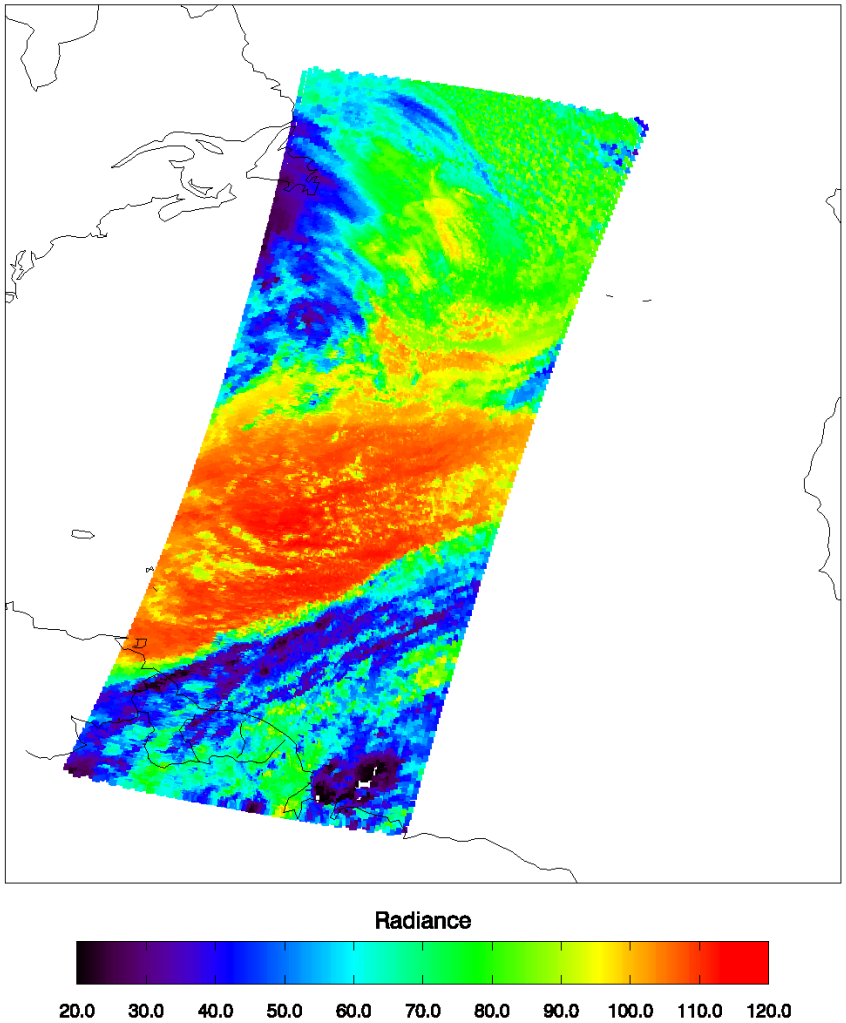
CrIS-SDR vs. CRTM-OSS



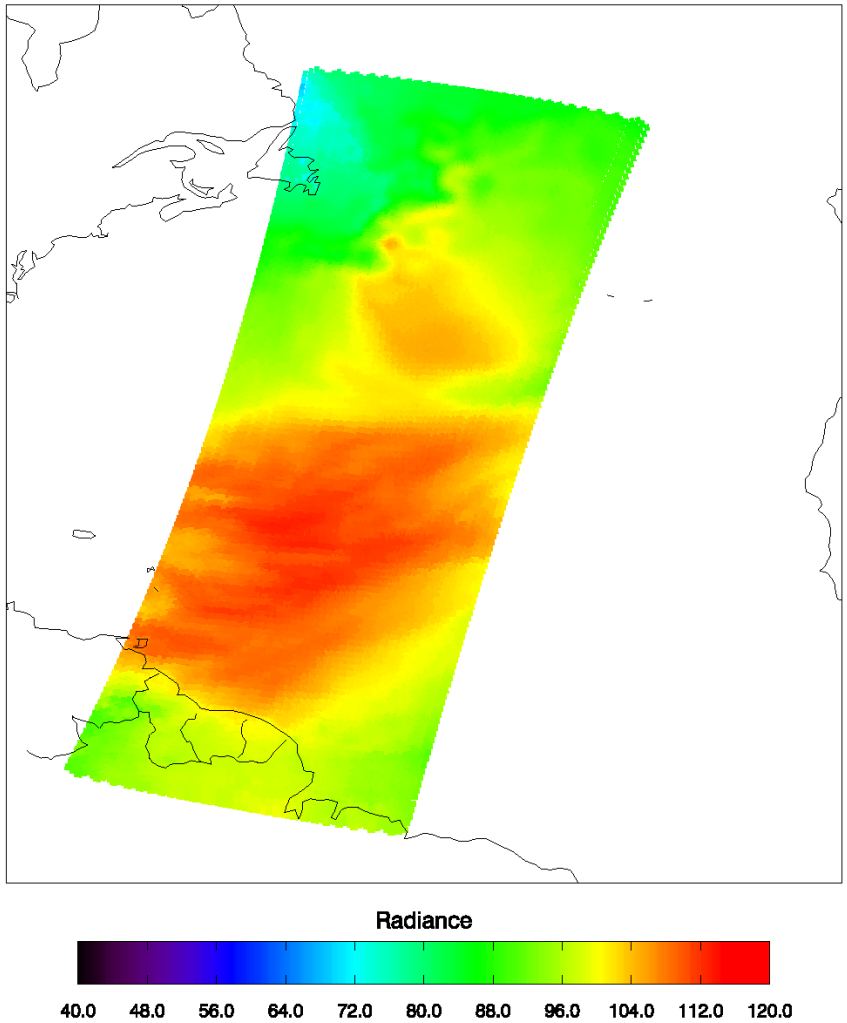


CrIS-SDR vs. CRTM-OSS

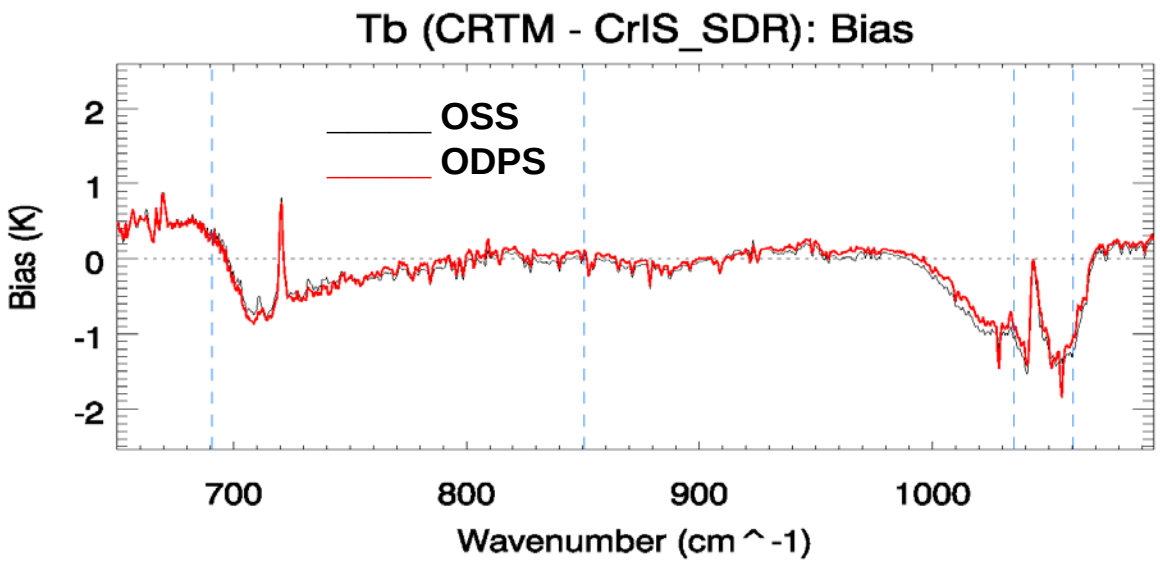
CrIS SDR Band: 321 Wave: 850.000



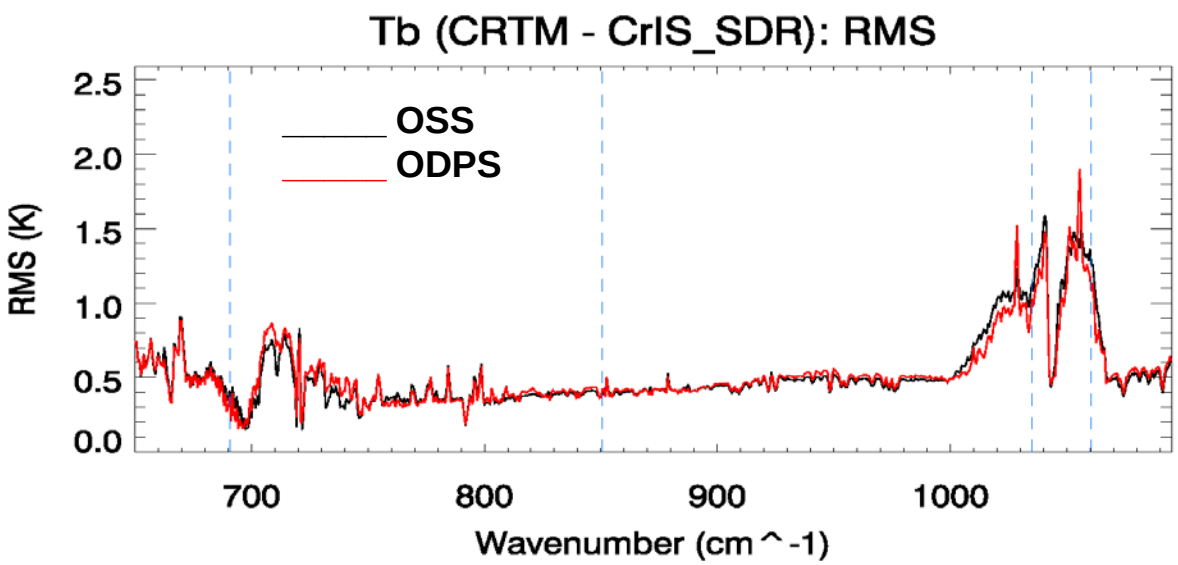
CrIS OSS Band: 321 Wave: 850.000



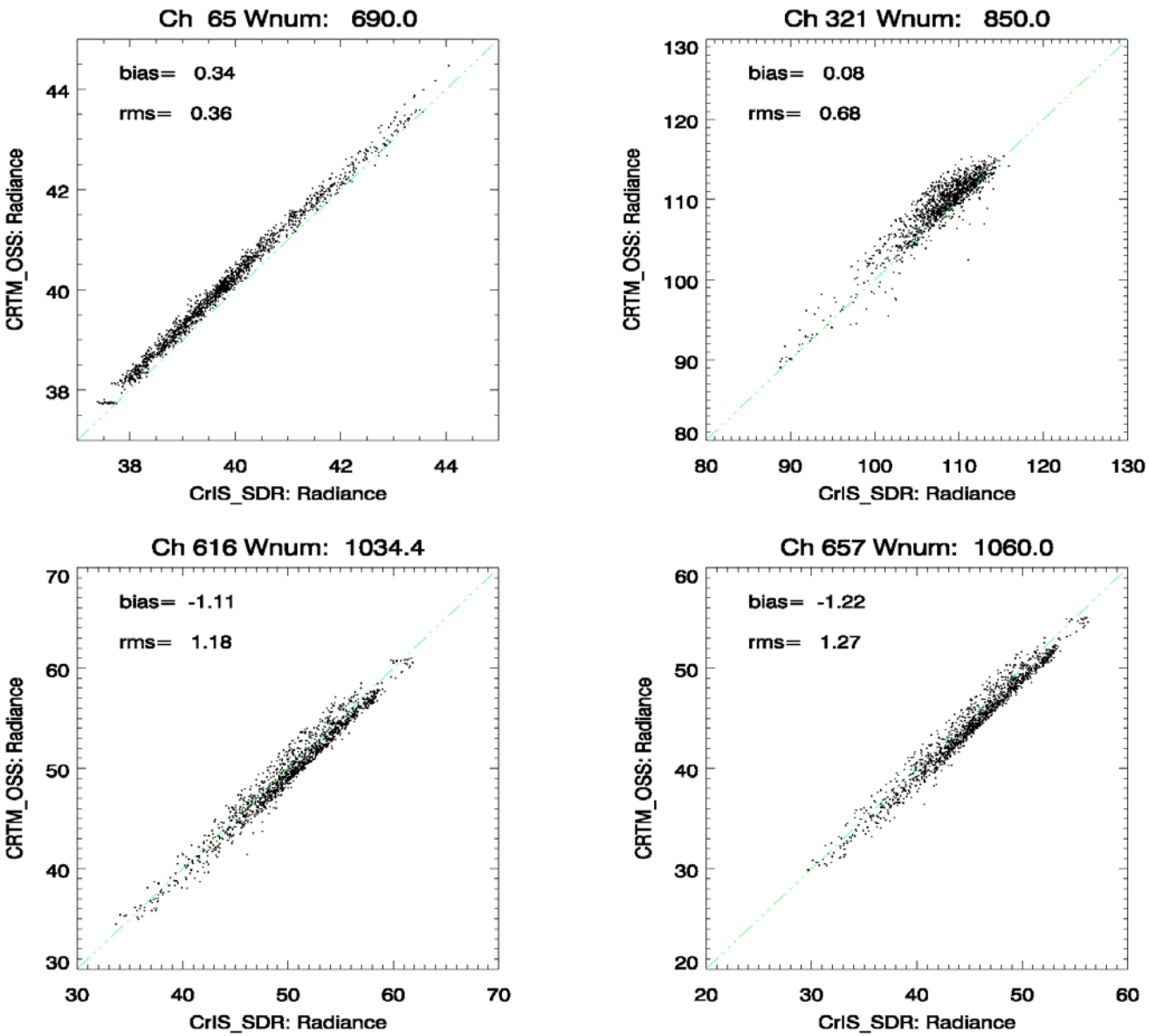
CrIS obs vs. OSS/ODPS



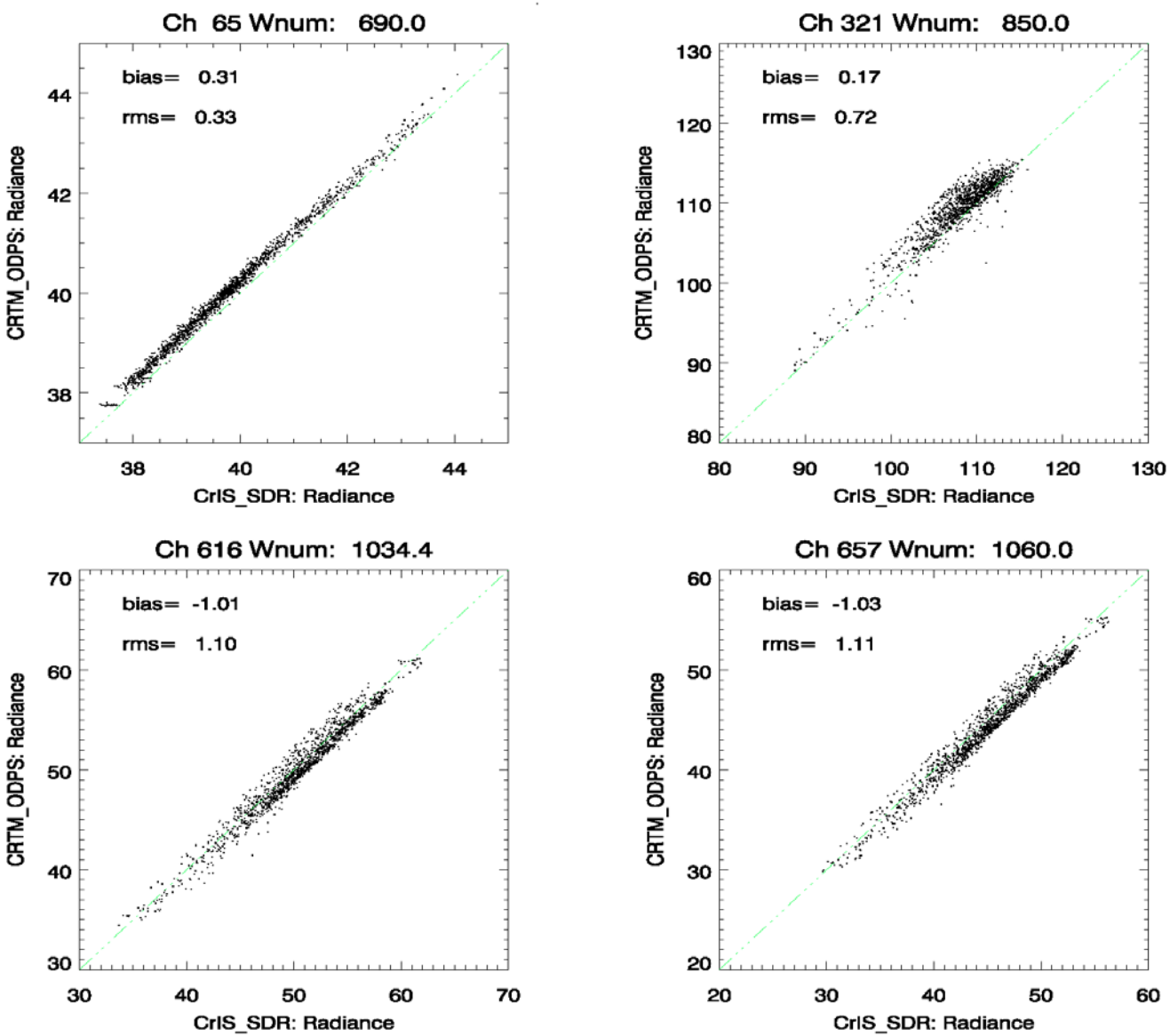
- Clear-Sky simulation
- Two gases: WV, O3



CrIS observation vs. OSS simulation



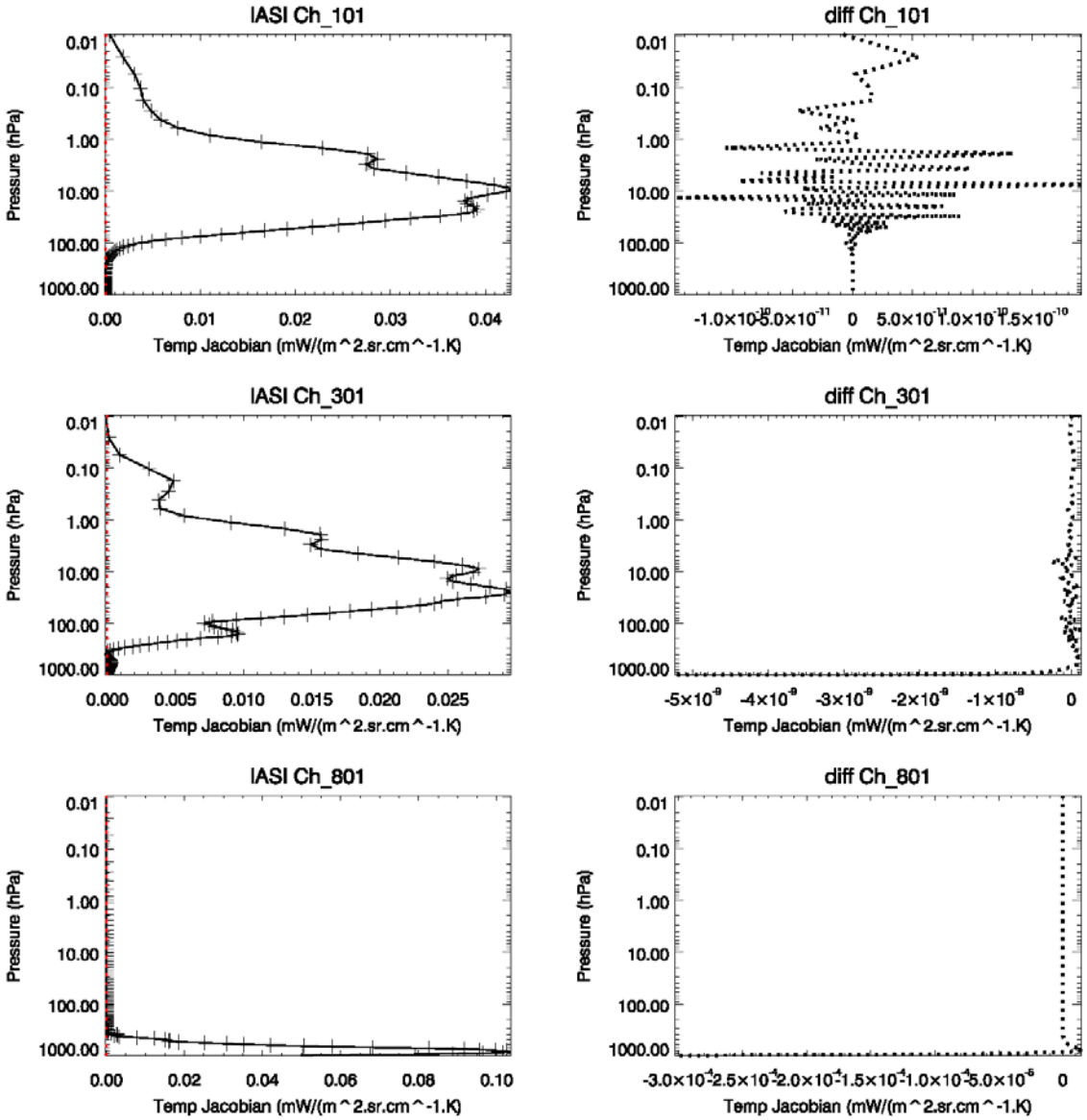
CrIS observation vs. ODPS simulation



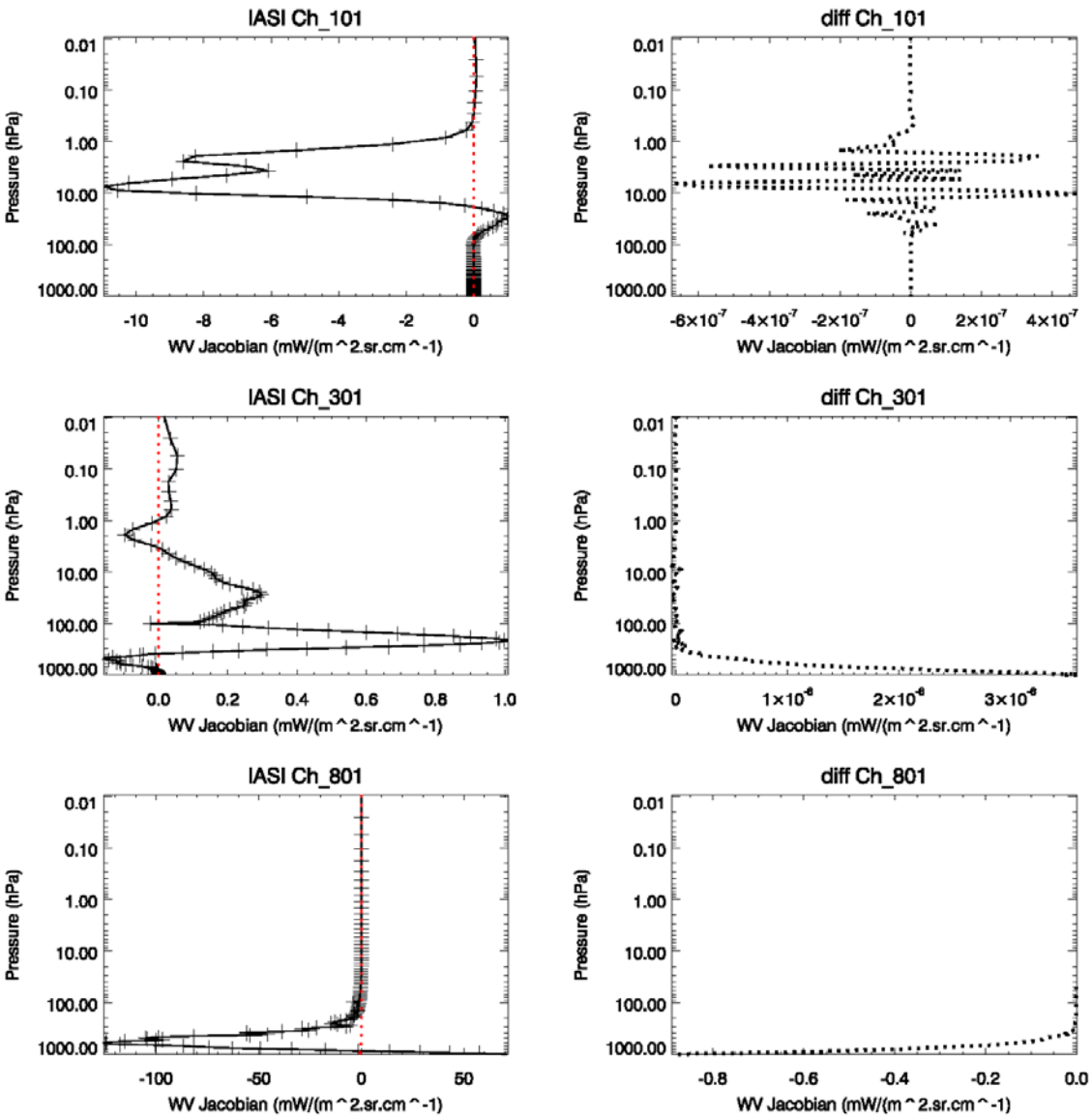
IV. OSS Jacobians Testing

- Tangent_Linear and K-Matrix testing
- K-Matrix and Finite FWD testing

Comparison of KM and TL Temp Jacobians

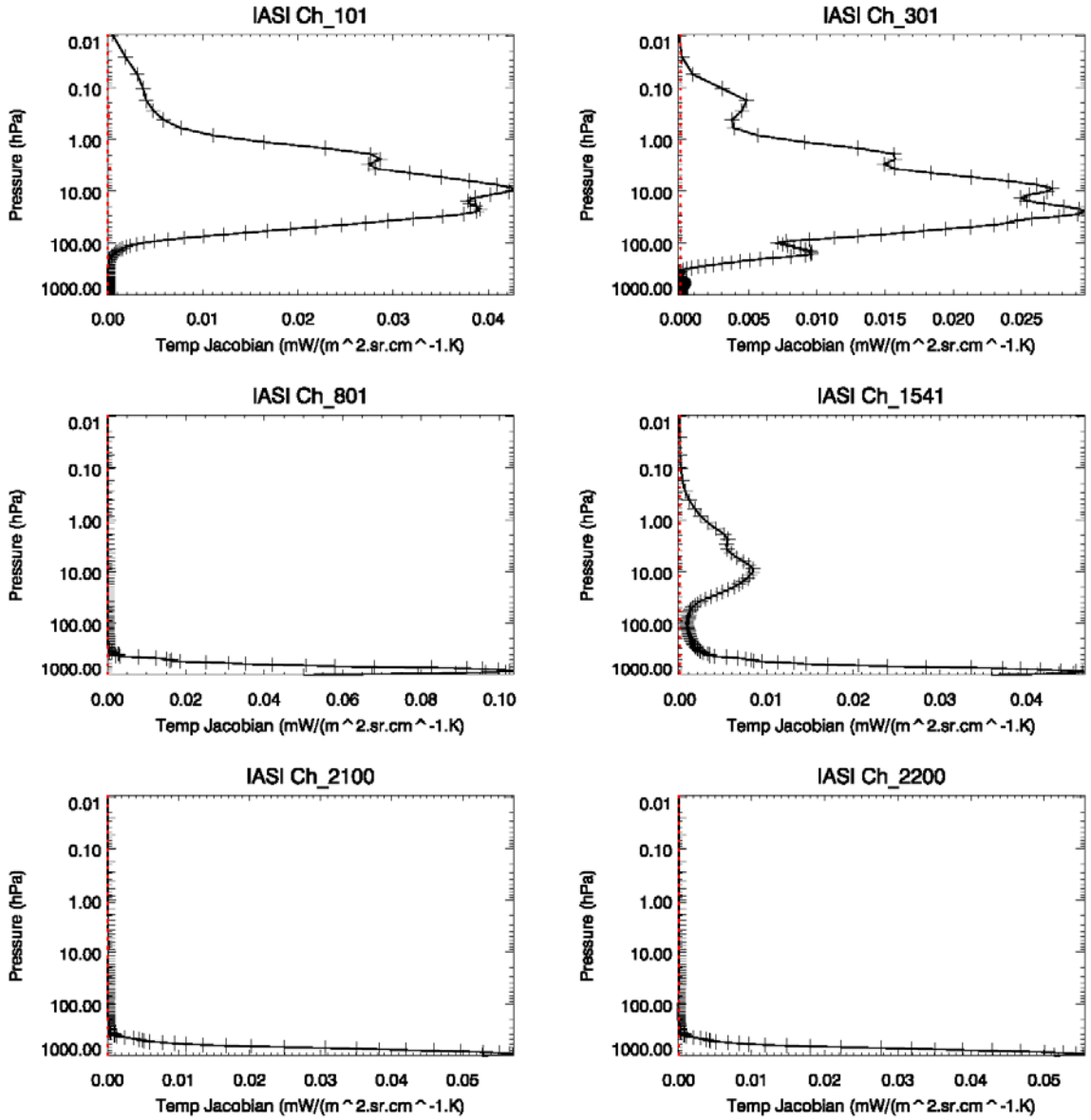


Comparison of KM and TL WV Jacobians



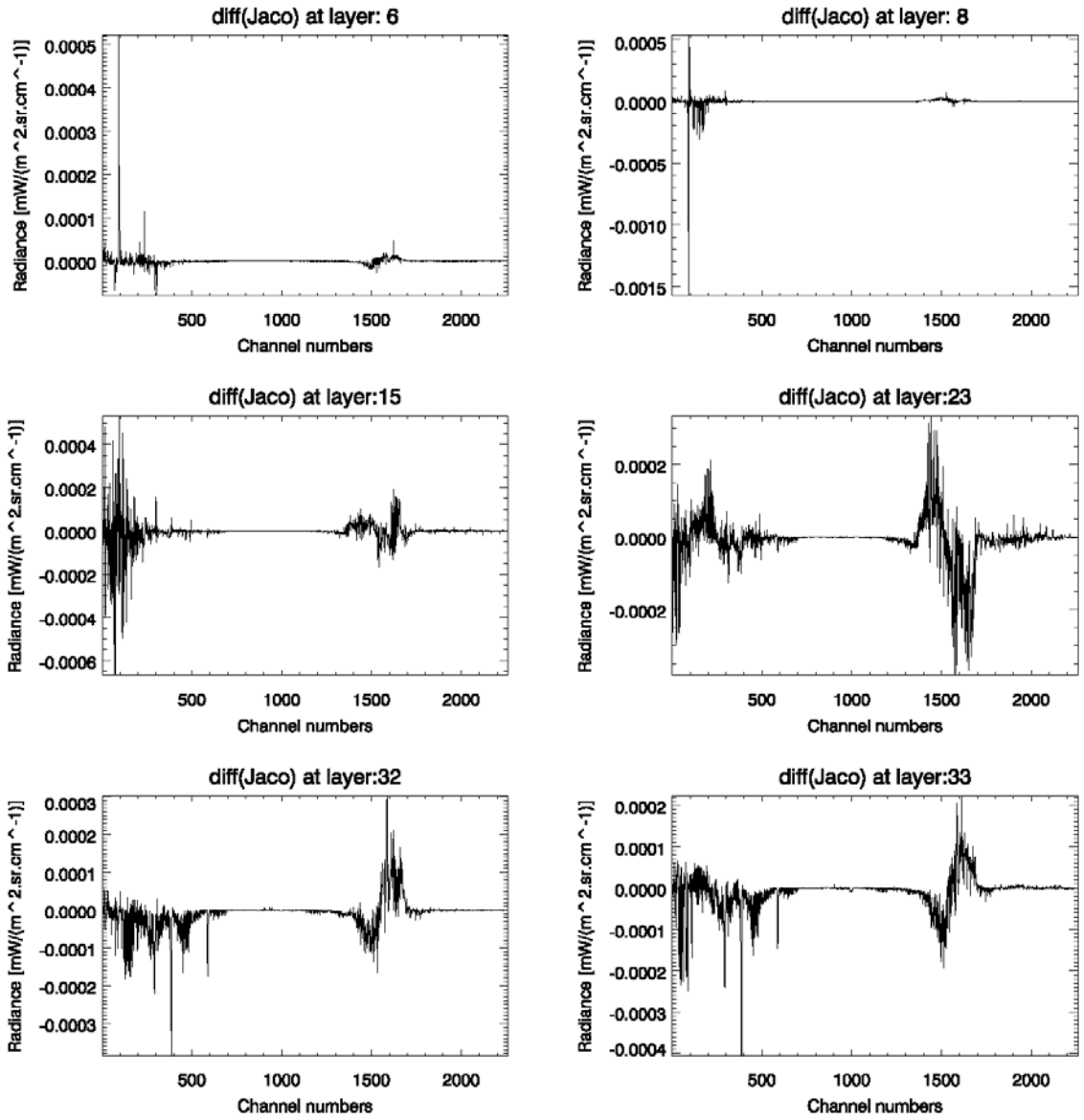
Temp Jacobians of K-Matrix and FD finite difference

Profile# 1



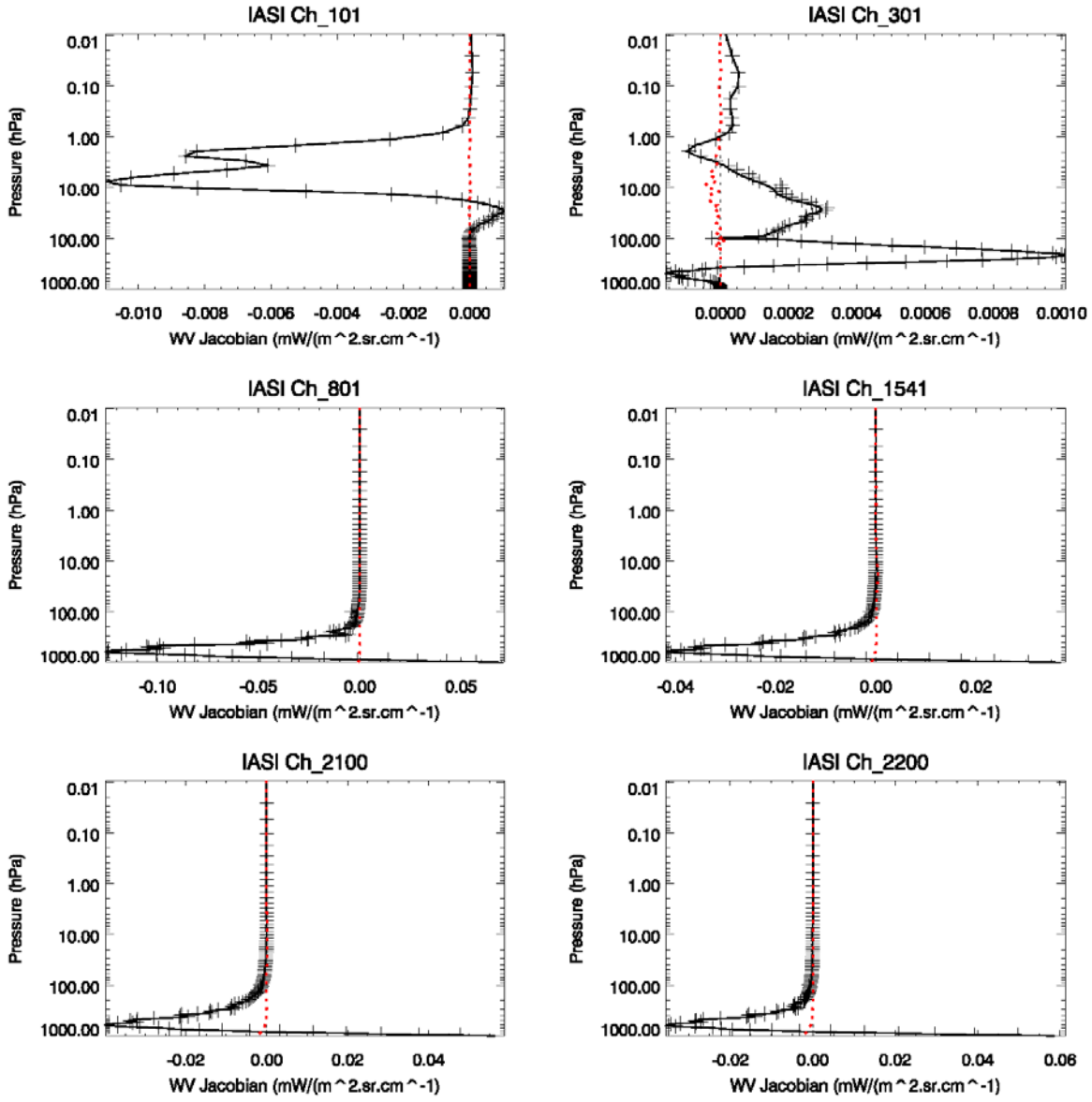
Temp Jacobians of K-Matrix and FD finite difference

Profile# 1

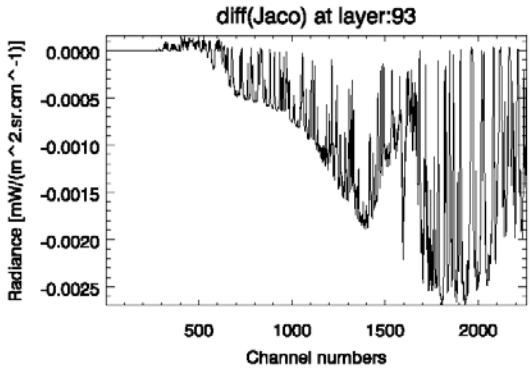


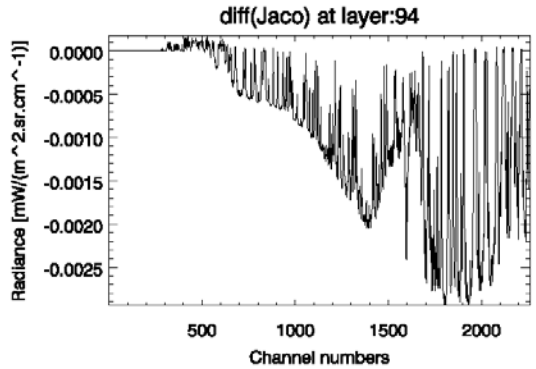
WV Jacobians of K-Matrix and FD finite difference

Profile# 1

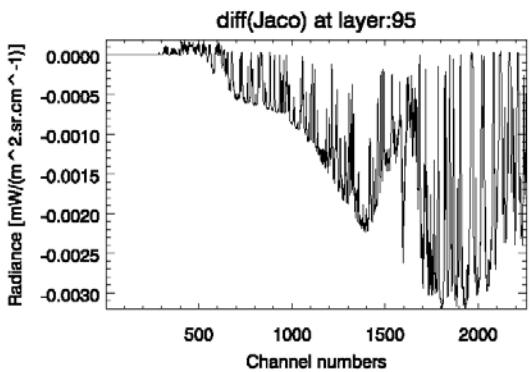


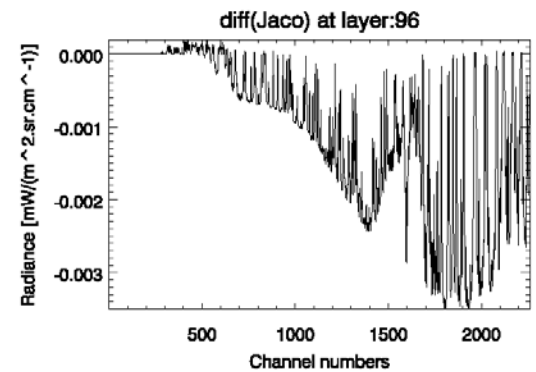
IASI-B1 (2260 channels) KM and FD WV Jacobian differences at 5 layers with bigger differences

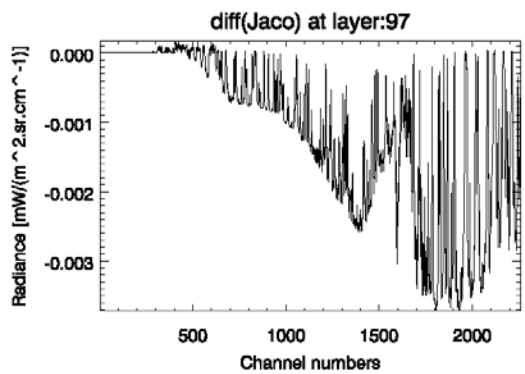




Profile# 1







- There are total 97 layers, counting from top to bottom.
- note that all bigger differences are near surface.

Summary and Future Work

- Implemented OSS to CRTM Rel.2.2.0 and committed the codes to a branch of CRTM repository
- Finished most TL, KM, and FFD testing, need to fix WV jacobian calculation bug
- Will perform comparison between CRTM-OSS-2.2.0 with LBLRTM
- Will perform speed testing for OSS-2.2.0 FWD, K-Matrix runs
- Assist AER to work on the new OSS project under CRTM subversion control
- AER is working on the implement NLTE correction into OSS

Preparing for CRTM new release: REL-2.3.0

CRTM Rel-2.3.0

- CRTM for cloudy fraction capability
- Turned on the transmittance calculation for all-sky conditions
- Correction of the FASTEM-X surface reflection under scattering condition
- Updated coefficients for SSMI/S
- Bug fix for 3.9 µm band simulation, by changing VIS_flag to Solar_flag
- Bug fix for multi-stream calculations in FASTEM-X, saving an internal variable for all angles
- Bug fix in CRTM_SfcOptics.f90 (AD calculation) for mixed surface coverage for IR sensors

CRTM Ongoing/Future Development

- Add TL, AD and KM codes for Aircraft measurement assimilation
- CRTM-OSS for unapodized radiance assimilation
- Implementation of CSEM emissivity model
- Active Sensors capability
- Expand CRTM capability to CMAQ aerosols
- Support new sensors: CERES, MicroMAS-2, CIRAS, EPIC-DISCOVR, JPSS-1 sensors