TMS CRTM Observation Operator

and Coefficient Generation

Version Log

Version	Date	Updating Author	Description
1.0	3/30/23	R. Honeyager	

Introduction

The Tomorrow Microwave Sounder (TMS) is a passive radiometer onboard Tomorrow.io's polar-orbiting S1-S18 satellites that will launch starting around winter 2023 to spring 2024. The Defense Innovation Unit (DIU) has funded Tomorrow.io to simulate this instrument and conduct algorithm development and experiments throughout 2023. In the March 2023 deliverable, Tomorrow.io 1) provides 40 days of data for this instrument in two possible orbits, 2) a reference copy of the internal observation operator that we use with our nature run to provide these simulated observations, and 3) a public domain observation operator for use in data assimilation applications with forward, tangent-linear, and adjoint capabilities, along with appropriate instrument coefficients.

DIU have indicated that they aim to use this simulated data within a JEDI-MPAS-based data assimilation system. JEDI is the Joint Effort for Data assimilation-Integration project, and is a product of the Joint Center for Satellite Data Assimilation (JCSDA). At the present time, JEDI provides bindings for the Community Radiative Transfer Model (CRTM), a public domain code that provides full forward, tangent-linear, and adjoint capabilities for microwave sounders. CRTM is fully supported and tested extensively within JEDI, and on this basis Tomorrow.io will provide CRTM coefficients and instructions for running TMS simulations using CRTM.

Due to manufacturing variability, each TMS instrument will have a different spectral response. As such, the CRTM coefficient implementation described in this document is a first guess for research applications.

CRTM Scattering Coefficients

Channel Assumptions

The table below summarizes the draft channel layout of the Tomorrow Microwave Sounder (TMS) instrument. TROPICS channels are added for comparison.[1] Channels 2 and 3 are single sideband (lower sideband only).

Channel	TMS Center Freq. (GHz)	TMS Bandwidth (GHz)	TMS NEDT (K)	TROPICS Center Freq. (GHz)	TROPICS Bandwidth (GHz)	TROPICS NEDT (K)
1	91.65	2	0.27	91.65 +/- 1.4	1	0.66
2	118.75±3.5	1	0.39	114.5	1	0.96
3	118.75±2.625	0.75	0.45	115.95	0.8	0.82
4	118.75±1.875	0.75	0.45	116.65	0.6	0.86
5	118.75±1.25	0.5	0.55	117.25	0.6	0.79
6	118.75±0.75	0.5	0.55	117.8	0.5	0.81
7	118.75±0.375	0.25	0.78	118.24	0.38	0.9
8	118.75±0.125	0.25	0.78	118.58	0.3	1.03
9	184.41	2	0.45	184.41	2	0.58

[1] Note: The TROPICS Millimeter-wave Sounder is also abbreviated TMS. We refer to it as TROPICS in the table to avoid confusion.

10	186.51	2	0.45	186.51	2	0.55
11	190.31	2	0.45	190.31	2	0.53
12	204.8	2	0.45	204.8	2	0.52

Table 1 - Channel data for TMS

Spectral Response Function (SRF) Assumptions

Since the instrument is in the planning stage and no precise SRF measurements are yet available, the SRF data for the CRTM instrument coefficients was estimated as a collection of boxcar SRFs based on the channel center frequencies and bandwidths listed above. The SRFs for all channels are shown in Figures 1 and 2 below. These figures are split to avoid crowding on the plots, as seven channels are near 118 GHz.

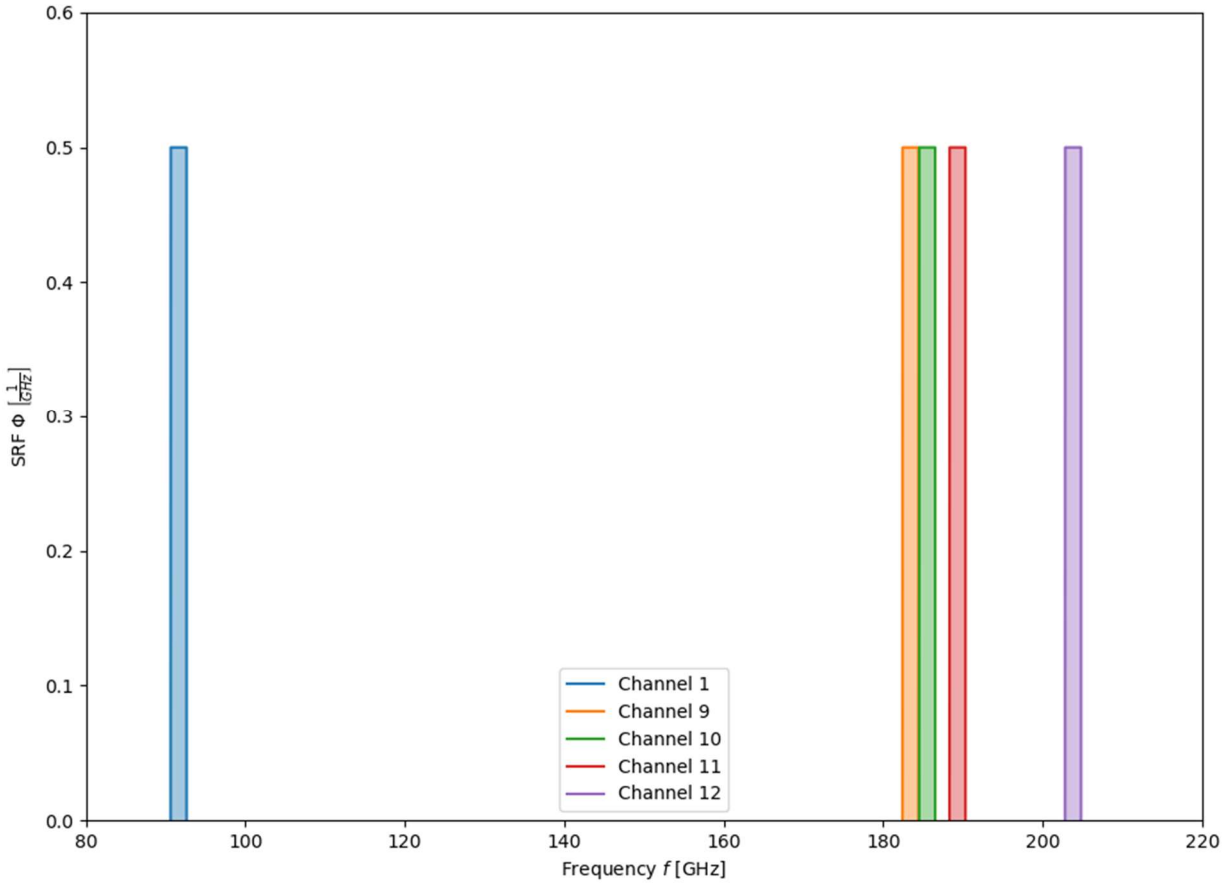

Figure 2 - Normalized boxcar spectral response functions for channels 1, 9-12.

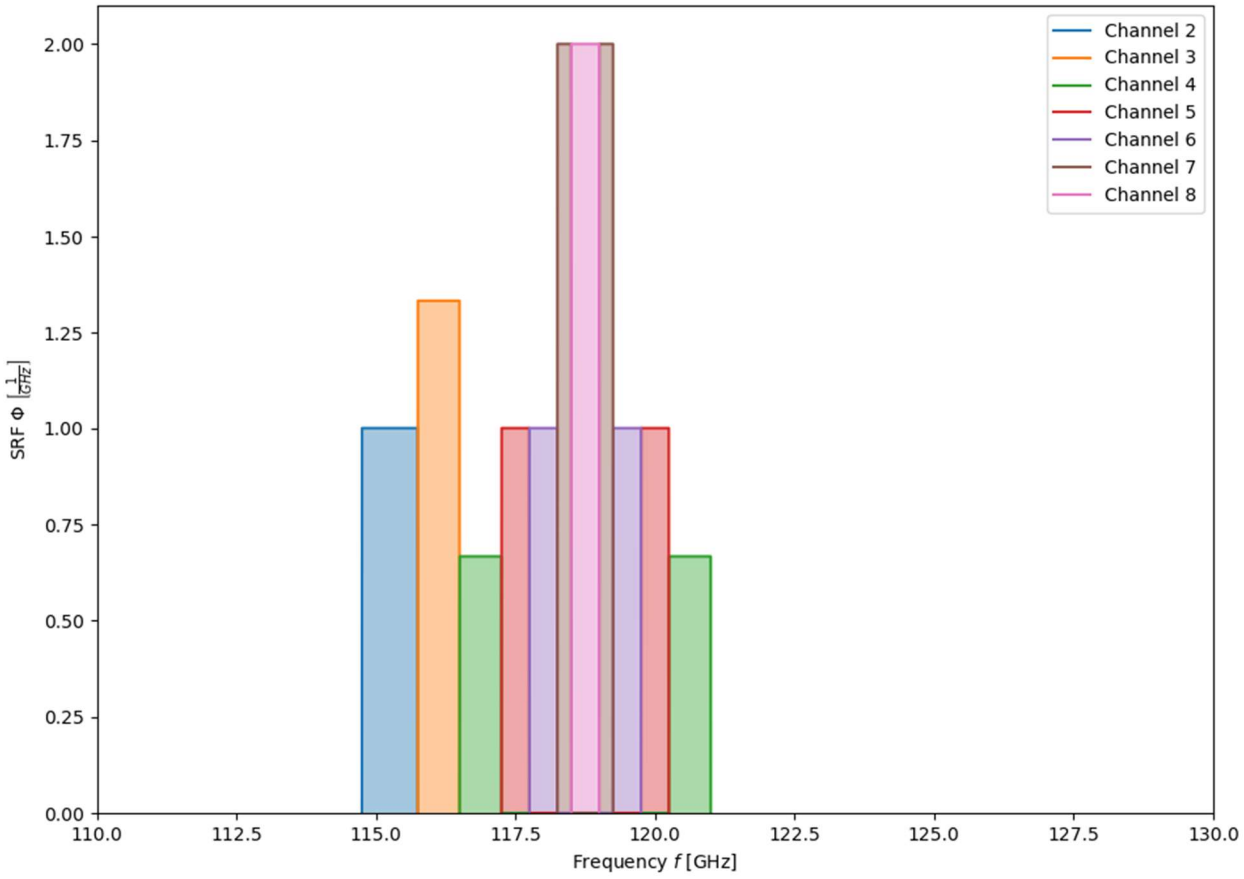

Figure 3 - Normalized boxcar spectral response functions for channels 2-8. Channels are adjacent and do not overlap.

Coefficient Calculations

We generated coefficients that match the most recent publicly-released version of CRTM, v2.4-jedi.2 (December 19, 2022). The CRTM source code is enclosed in the coefficient delivery, but are also available via GitHub at https://github.com/JCSDA/crtm/releases/tag/v2.4-jedi.2. The CRTM team have recently enhanced CRTM's handling of polarization for Tropics-like satellites, and we anticipate that these improvements should be available in the next public CRTM v2.4 release (expected early April 2023).

The microwave line-by-line calculations for the CRTM coefficients were performed using the CRTM-internal Rosenkranz 2003 model at a resolution of 1 MHz, and for the coefficient regression the Optical Depth in Pressure Space (ODPS) scheme was used.

The generated coefficients are expressed in two binary files: tms_v1.SpcCoeff.bin and tms_v1.TauCoeff.bin. When running CRTM using JEDI, these files must be placed in a common folder, and this folder needs to be referenced in

the CRTM observation operator configuration. This folder also needs to contain AerosolCoeff.bin, CloudCoeff.bin, and FASTEM6.MWwater.EmisCoeff.bin, which may be copied over from the regular CRTM coefficients bundle, which is provided as part of the standard CRTM release and is available in the standard JEDI bundles. Alternatively, it may be obtained at https://bin.ssec.wisc.edu/pub/s4/CRTM/fix_REL-2.4.1_latest.tgz. The figure below shows an example configuration and highlights the settings needed to use these coefficients.

```
observations:
  get values:
    variable change:
      variable change name: Model2GeoVaLs
  observers:
  - obs space:
      name: TMS-pathfinder
      obsdatain:
        engine:
          type: H5File
          obsfile: /backup/GEOS/NR/processed/2020-02-01/jedi_L1B/jedi_TMS_S3.BRTT.L1B.Granule00409.V03-05.ST20200201-003300.ET20200201-012658.CT202
84813.nc
      obsdataout:
        engine:
          type: H5File
          obsfile: /home/diu/data/jedi_hofx/hofx_jedi_TMS_S3.BRTT.L1B.Granule00409.V03-05.ST20200201-003300.ET20200201-012658.CT20230314-184813.nc
      simulated variables: [brightnessTemperature]
      channels: 1-12
    obs operator:
      name: CRTM
      Absorbers: [H2O]
      obs options:
        Sensor_ID: tms_v1
        EndianType: little_endian
        CoefficientPath: /home/diu/share/CRTM_coefficients/tmsv1
```

Figure 4 - Example JEDI YAML configuration file segment highlighting CRTM configuration settings

