Community Radiative Transfer Model (CRTM) Development and Applications

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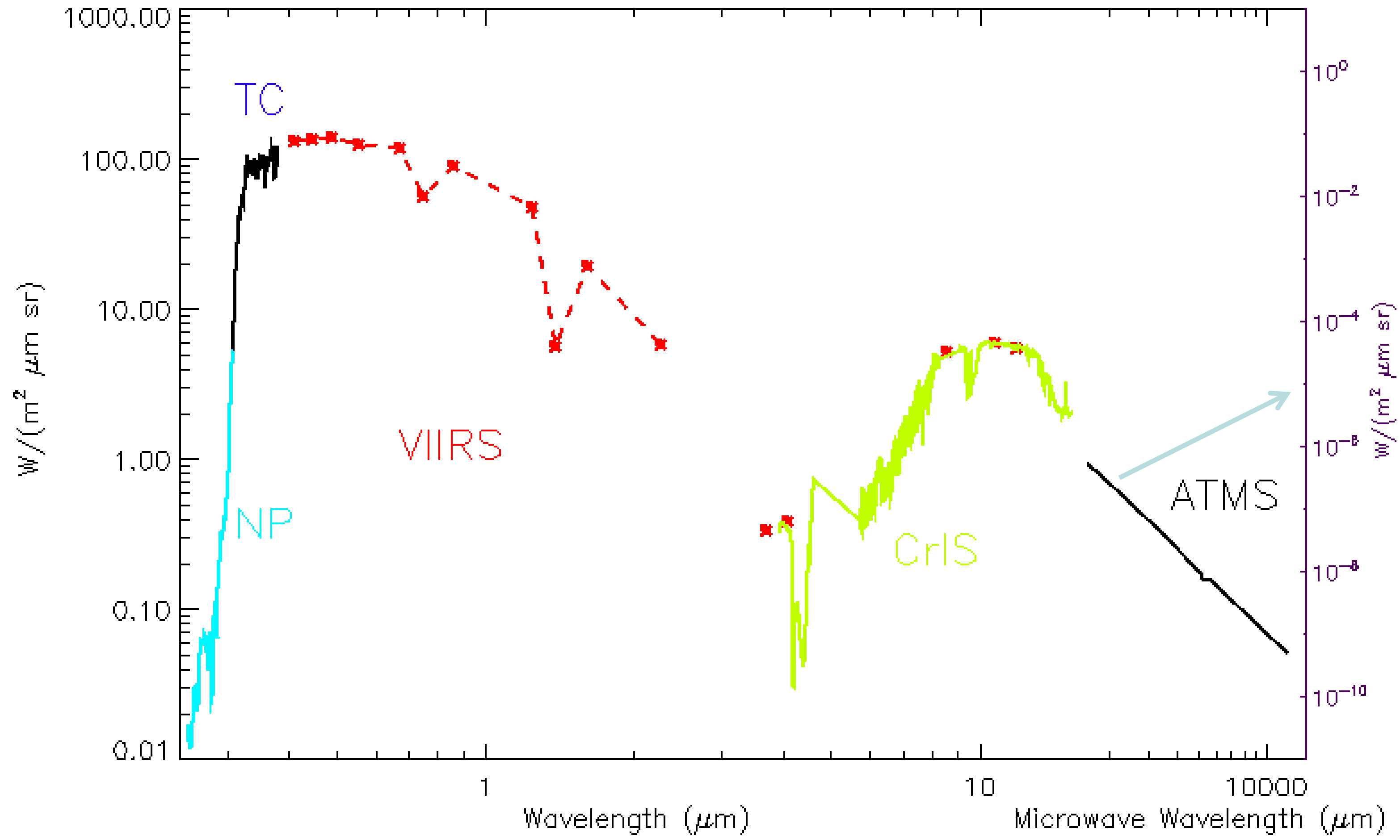
Outline

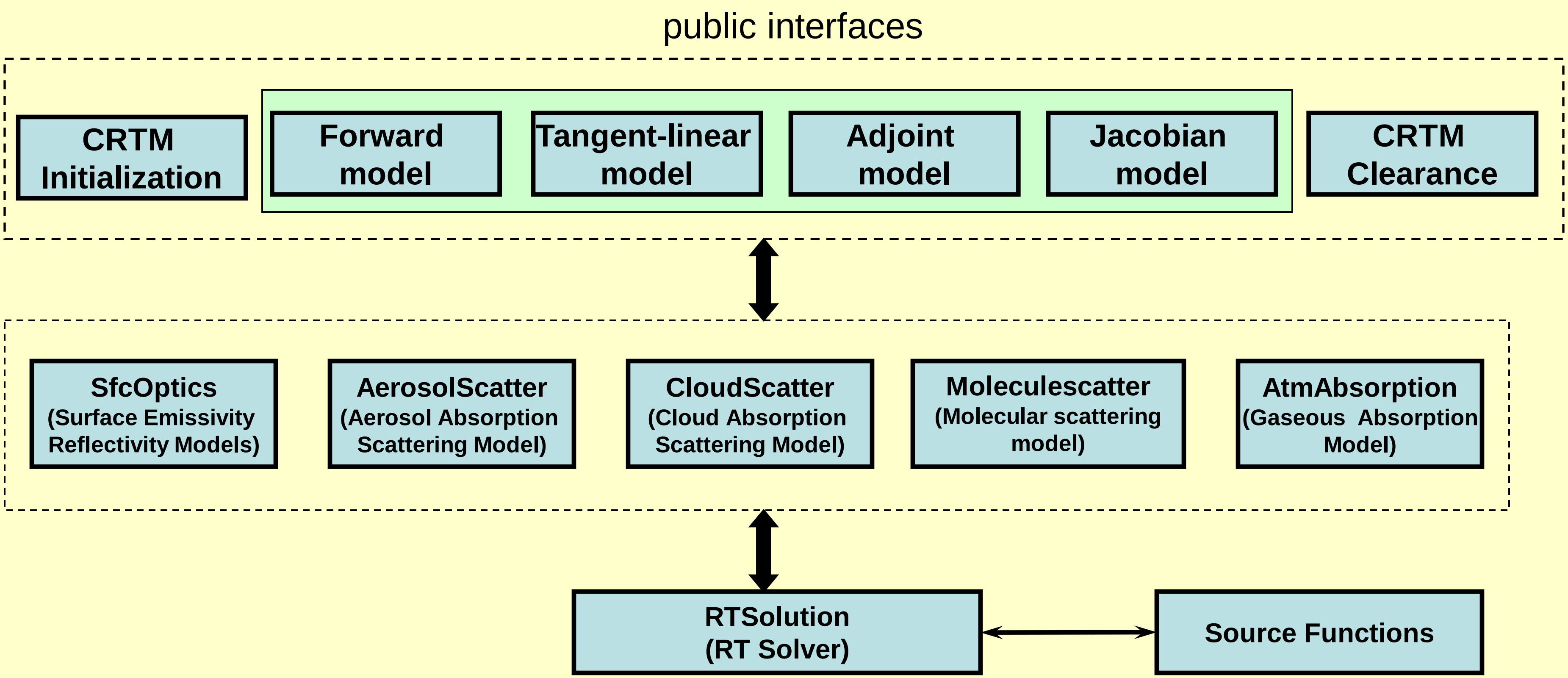
- CRTM Functionalities
- Description of the CRTM Model
- CRTM Applications
- Future Development

CRTM, A Sensor-based Fast RT Model



NPP measured radiance: UV (NP, TC), VIIRS, CrIS, and ATMS.

CRTM Major Modules



CRTM 2.1.3 Release

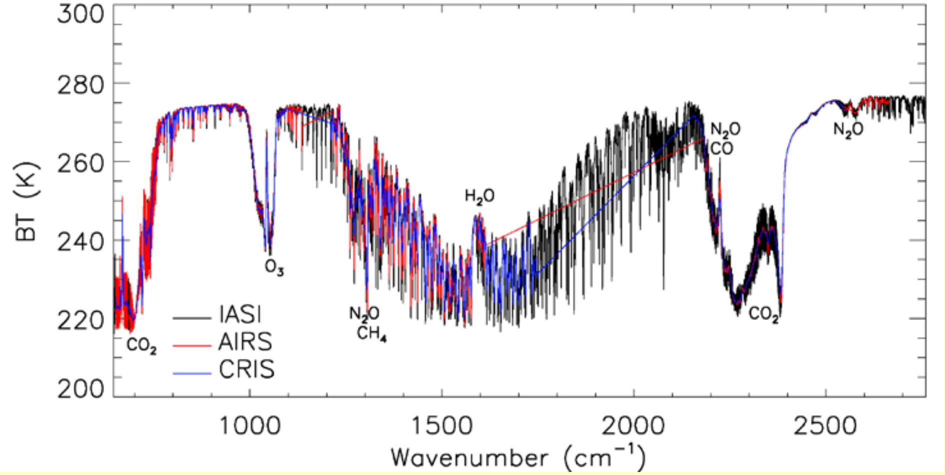
CRTM 2.1.3 was released on Jan. 14, 2014 and can be downloaded from ftp.emc.ncep.noaa.gov .

- ODAS and ODPS transmittance models
- Aerosol optical property functions
- Cloud optical property functions
- Versatile surface emissivity/reflectance models: Fastem5, Wu and Smith IR, Ocean BRDF, empirical and physical models, database, LUT
- ADA and SOI radiative transfer algorithms
- Option structure I/O
- Non-LTE for hyperspectral infrared sensors
- Zeeman-splitting
- Stratosphere Sounder Unit
- Channel subseting
- Number of streams option for scattering atmospheres
- Scattering switch option for clouds and aerosols
- Aircraft instrument capability
- Overcast radiance array

- Contact the CRTM team at ncep.list.emc.jcsda_crtm.support@noaa.gov

Transmittance Models

- Transmittance module
  - ODAS: Optical Depth Absorber Space (O3, H2O, good performance for water vapor absorption)
  - ODPS: Optical Depth Pressure Space (H2O, CO2, O3, N2O, CO, CH4)



CRTM simulated brightness temperature spectra for hyper-spectral infrared sensors IASI (black), AIRS (red) and CrIS (blue).

  - SSU model
  - Fast Zeeman model for SSMIS UAS channels
  - NLTE

Aerosol Models

Global Model, Goddard Chemistry Aerosol Radiation and Transport (GOCART)

Dust
Sea Salt (dry (hydrophobic), wet (hydrophilic))
Organic carbon
Black carbon
Sulfate

Under testing:

Regional Model WRF-NMM, Community Multiscale Air Quality (CMAQ)

Sulfate mass
Ammonium mass
Nitrate mass
Organic mass
Unspecified anthropogenic mass
Elemental carbon mass
Marine mass
Soil derived mass

CRTM Model for GOES-R Applications (preliminary **)**

Continental
Urban
Generic l
Heavy smoke l
Dust

5 Coarse mode aerosol
4 Fine mode aerosol

Aerosols and Air Quality

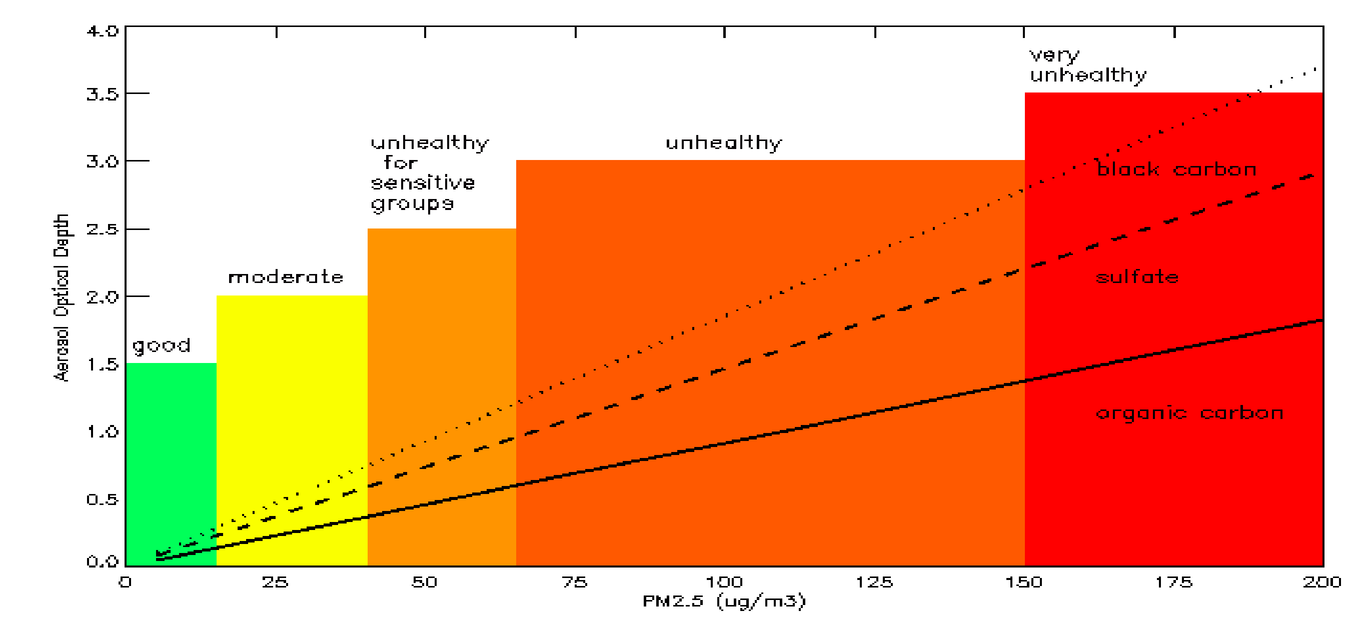
Particulate mass with the size smaller than 2.5 µm (PM2.5) are found in smoke and haze, vehicles and power plants pollution, and burning (Al-Saadi et al., BAMS 2005). U.S. EPA uses PM2.5 as a measure of air quality.

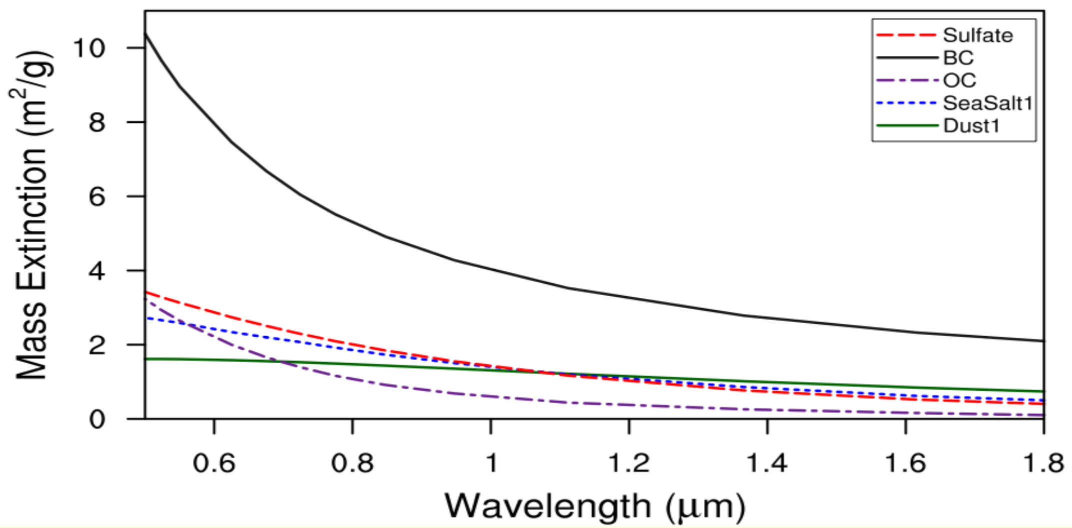
TABLE 1. The U.S. EPA Air Quality Index for Particulate Matter.

Index Values	Category	Cautionary Statements	$PM_{2.5}$ ($\mu g\ m^{-3}$)	PM_{10} ($\mu g\ m^{-3}$)
0–50	Good	None	0–15.4	0–54
51–100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5–40.4	55–154
101–150	Unhealthy for sensitive groups	Sensitive groups should reduce prolonged or heavy exertion	40.5–65.4	155–254
151–200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5–150.4	255–354
201–300	Very unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5–250.4	355–424

Source: US EPA, 1997

Air Quality in term of Aerosol Optical Depth





SSMIS for Stratospheric Temperature

- Zeeman-splitting can have an effect up to 10 K on SSMIS UAS channels.
- The Doppler shift from Earth-rotation can have an effect up to 2 K on SSMIS UAS channels.
- Fast transmittance algorithms are implemented to take both effects into account.

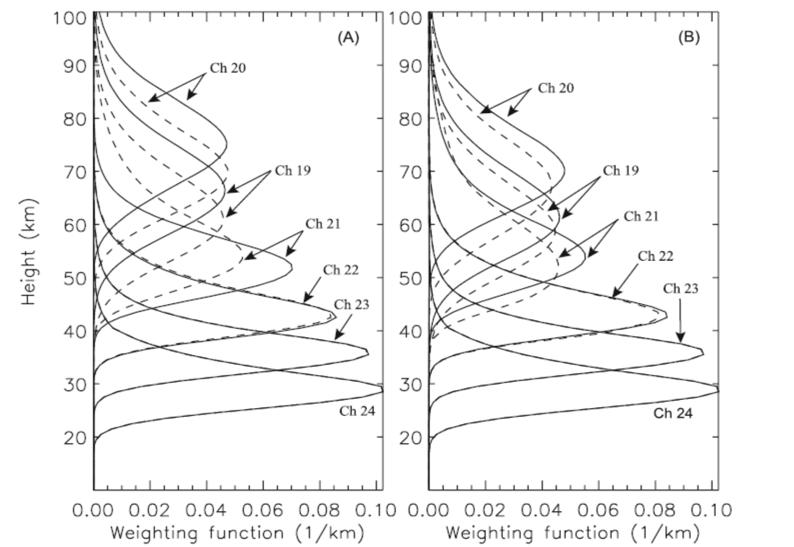
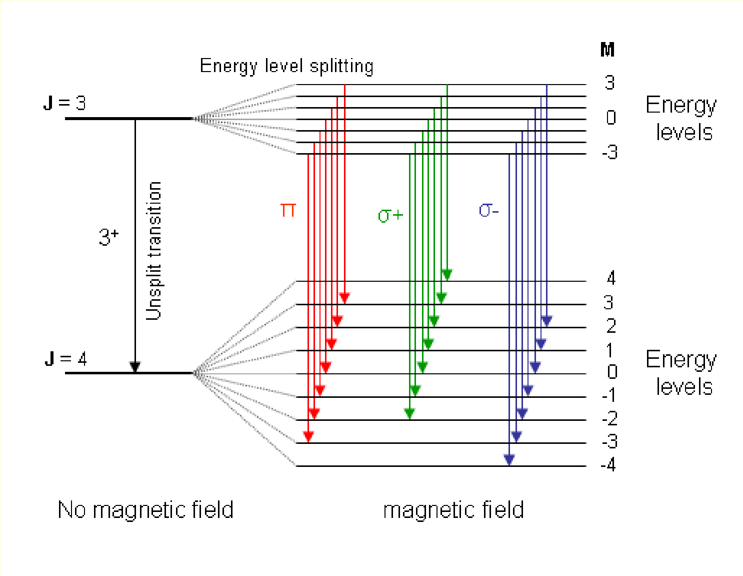
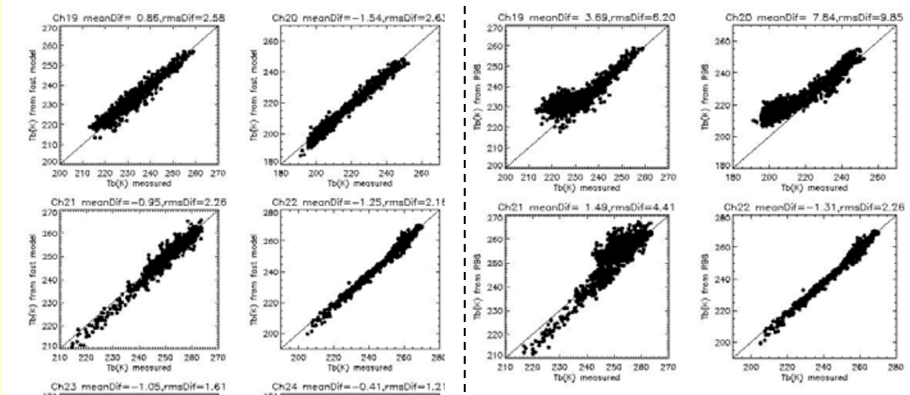


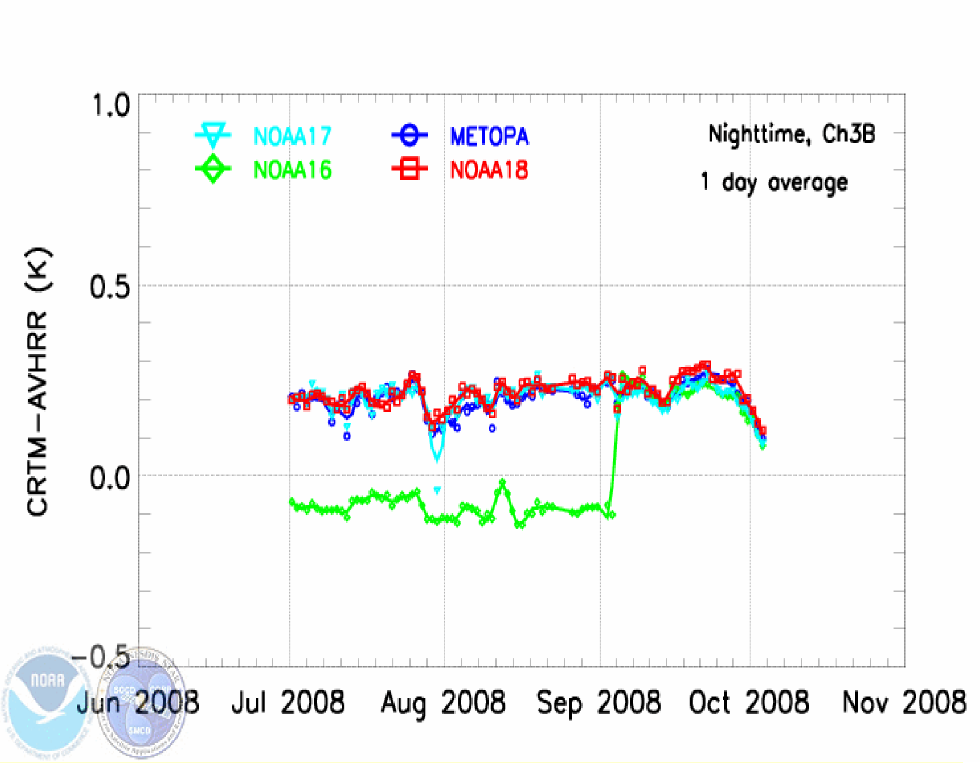
Figure 1. (a) Weighting functions calculated with $B = 23\ \mu T$ (solid lines) and $63\ \mu T$ (dashed lines) at $\cos(\theta_B) = 0.9$ and (b) with $\cos(\theta_B) = 0$ (solid lines) and 1 (dashed lines) at $B = 60\ \mu T$ for the temperature profile of the US-76 standard atmosphere shown in Figure 2.

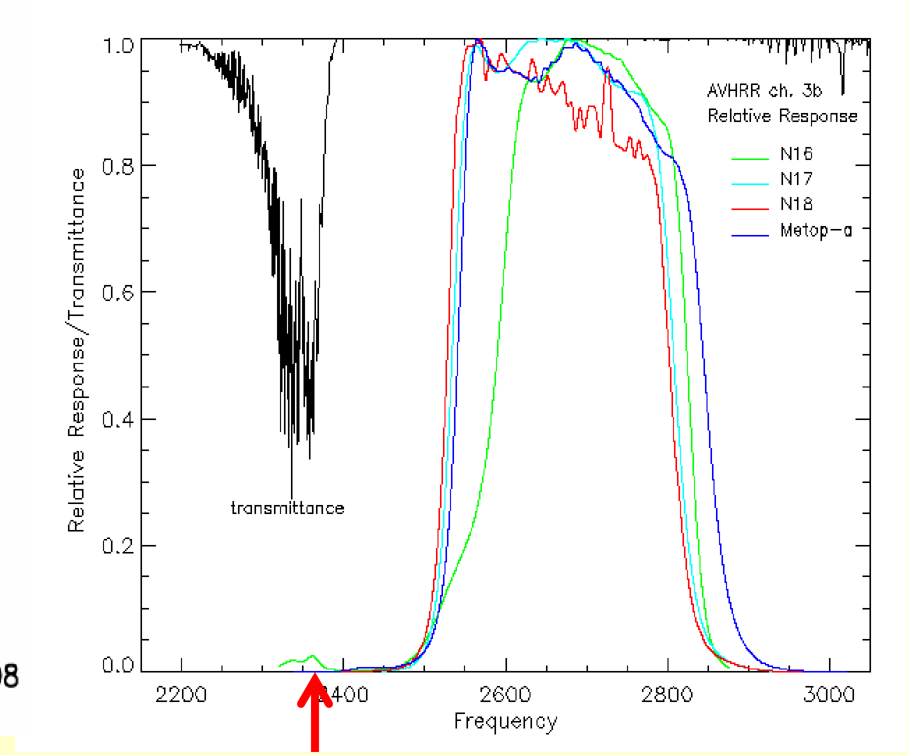




Without considering Zeeman-effect in the RT model

Collaboration: User -- CRTM -- Sensor

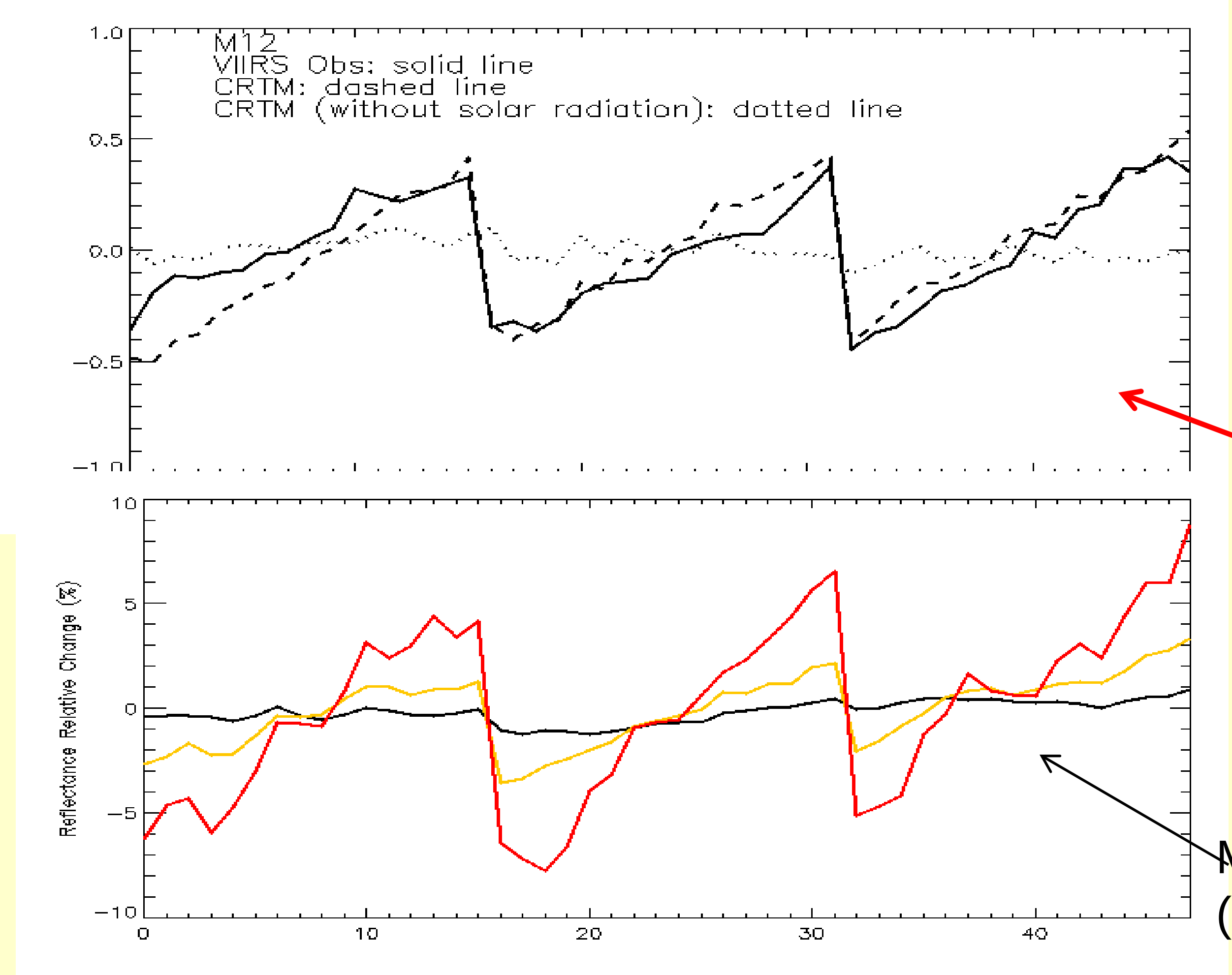


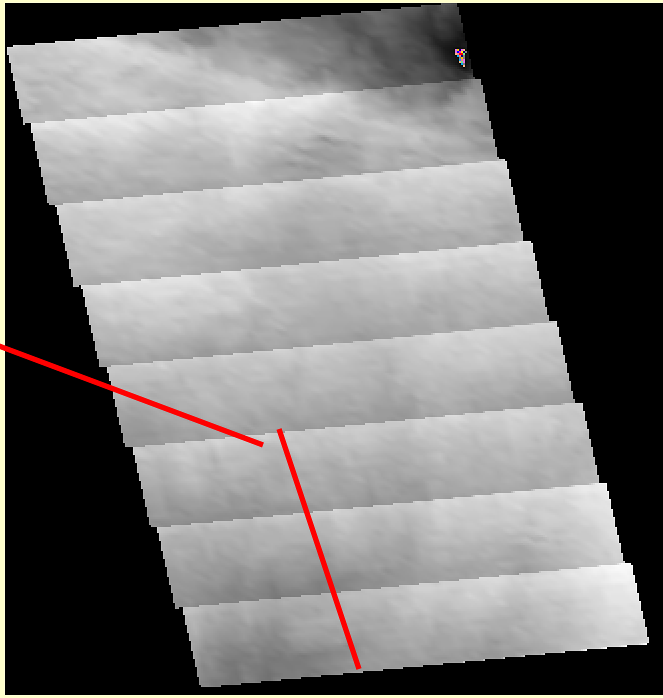


The black line is the transmittance between 0.005 (model top) and 20 hPa.

User reported an unexpected bias (S – O) for NOAA-16 Ch. 3b. CRTM team found that out-of-band was the root cause, and the sensor team confirmed the cause.

VIIRS and CRTM Modeling for M12 Striping Investigation

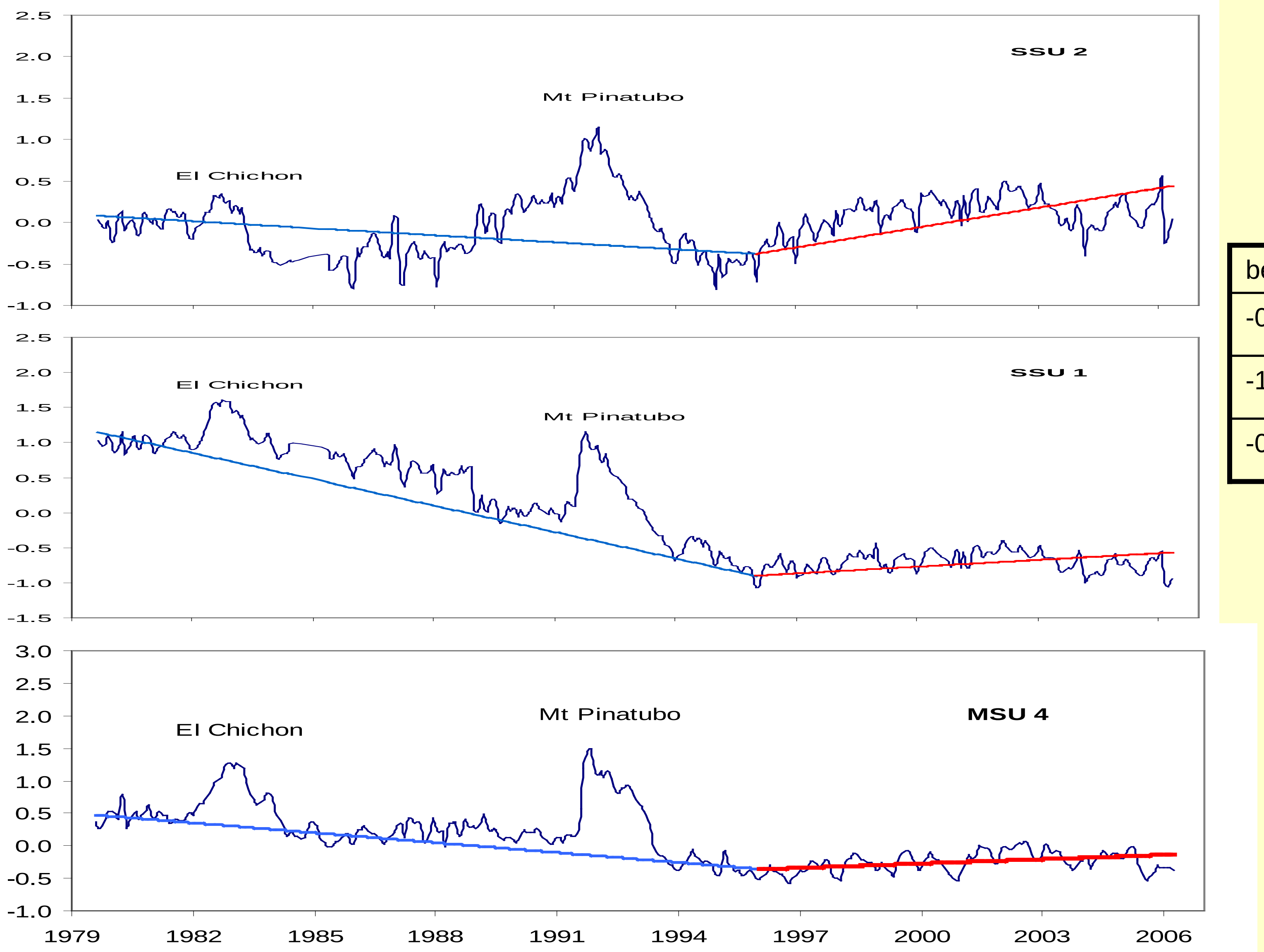




M1, M4, and M11 measured
(R-Rm)/Rm *100

The STAR team applied the CRTM to simulate the VIIRS SDR data.
It is found that the M12 striping reported by the SST EDR team is caused by the difference in VIIRS azimuth angles among detectors.

Time series of brightness temperature at MSU 4, SSU 1, and SSU 2

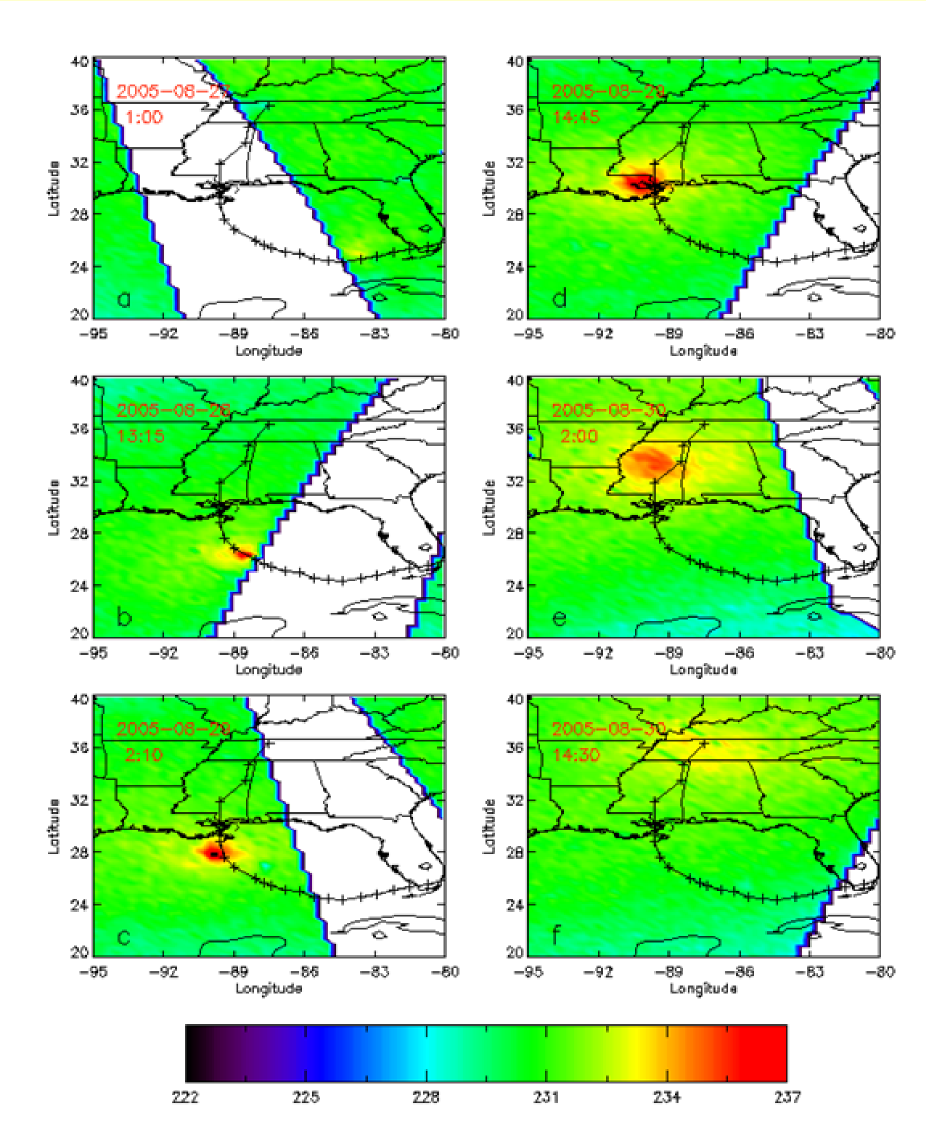


Trendes

k/decade

before	after
-0.51±0.05	0.22±0.14
-1.25±0.04	0.32±0.05
-0.28±0.05	0.78±0.08

Radiances in studying Hurricane (warm core from SSMIS observations at 54.4 GHz)



The SSMIS measures radiances in 24 channels covering a wide range of frequencies (19 – 183 GHz) conical

scan geometry at an earth incidence angle of 53 degrees maintains uniform spatial resolution, across the entire swath of 1700 km.

Katrina forecasting between test-run and control-run

Forecasting time (hour)	Surface minimum pressure (hPa)			Surface maximum wind (m/s)		
	Control	Test	Observation	Control	Test	Observation
00	988.87	983.31	959.00	26.18	31.51	46.20
06	981.55	974.60	950.00	36.36	30.46	48.80
12	970.80	957.90	942.00	39.05	39.33	51.40
18	964.45	945.81	948.00	39.97	48.99	51.40
24	951.71	936.11	941.00	45.19	49.31	51.40
30	935.58	923.40	930.00	49.40	57.20	64.20
36	927.75	913.17	909.00	54.86	58.20	74.50
42	918.92	908.72	902.00	57.94	58.31	77.10
48	916.38	905.25	905.00	54.31	59.67	71.90

Future Development

- Full Stokes RT
- Community Surface Emissivity Model (CSEM)

  + Land bidirectional Reflectance Distribution Function

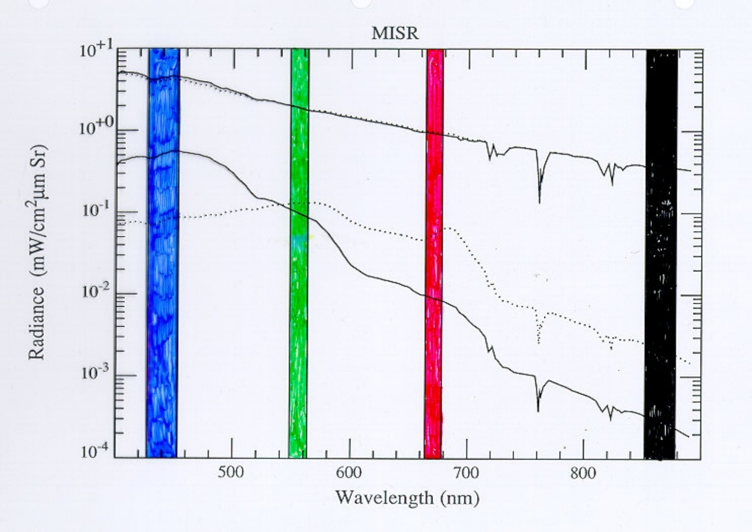
  + Ocean bio-optic model
- Finalize the un-apodized radiance simulation capability
- Multiple Aerosol Optical Models
- Optimize CRTM efficiency
- Active Sensor simulators

Polarization effect on ocean-color product

$$\mathbf{I}_m = \mathbf{M}\,\mathbf{R}(\alpha)\,\mathbf{I}_t$$

$$I_m = I_t + m_{12}(Q_t \cos 2\alpha + U_t \sin 2\alpha) + m_{13}(-Q_t \sin 2\alpha + U_t \cos 2\alpha)$$

$$m_{12} = P_{in} \cos 2\chi_{in}\,, \quad m_{13} = P_{in} \sin 2\chi_{in}$$



Water-leaving radiance for high (dotted) and low (lower solid) chlorophyll. Upper curves are with atmospheric signal. Online downloaded figure.

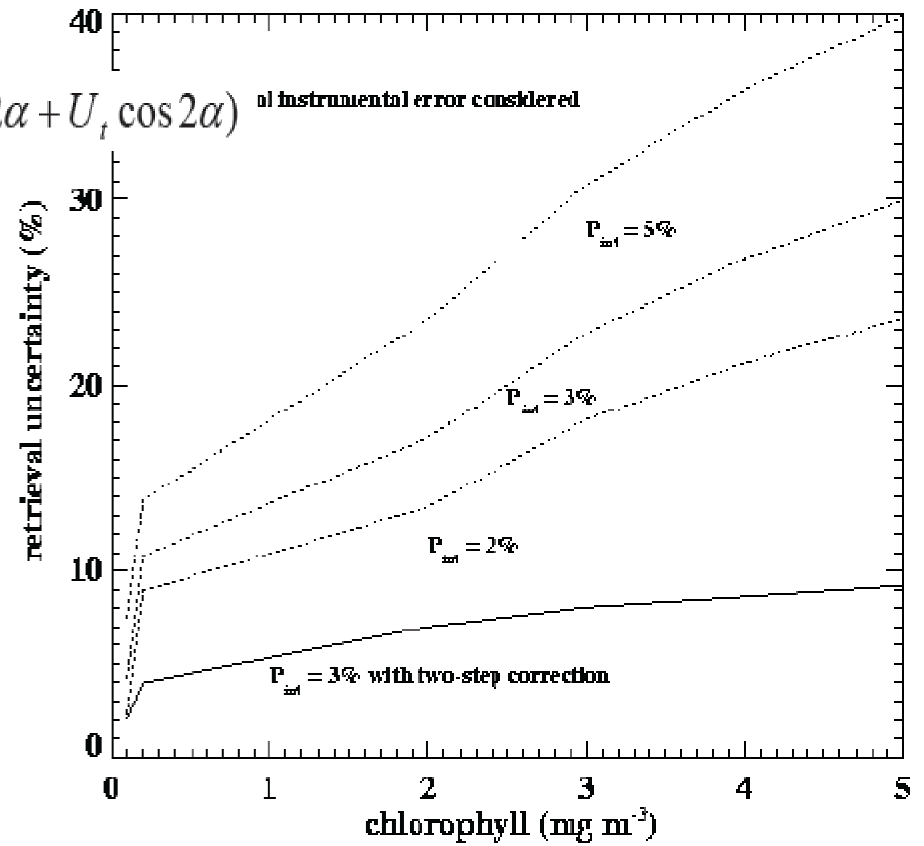


Figure 20. Retrieval uncertainty for various polarization sensitivities. The two-step algorithm yields the best results.