Intercomparison of RTTOV and CRTM: Simulated radiances of AMSU-A and microwave scattering solver

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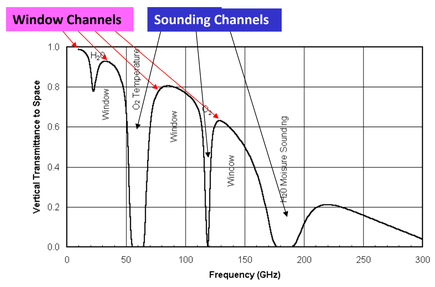
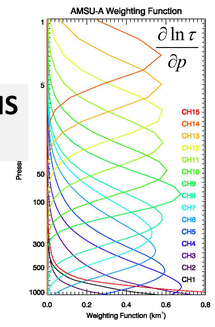
1. Introduction



Passive microwave sensors

- **Sounder** : AMSU-A/B, FY-3, SSMIS, ATMS
- **Imager** : SSMIS, TMI, AMSR-2, GMI

AMSU-A has 15 channels, 12 temperature sounding channels around the O2 absorption band (50~60 GHz) and 3 image channels at 23.8, 31.4, and 89 GHz. It is cross-track scanning radiometer, which has an instantaneous field of view (IFOV) of 50 km at nadir and the swath width of 2300 km.



2. RTTOV and CRTM

	Clear RTTOV (v10.2)	Cloudy RTTOV_SCATT (microwave)	Clear+Cloudy CRTM (common interface) v2.1.1
Input variables	▪ Layer : p,q,t ▪ 2m : t,p,q,u,v ▪ Skin : t, salinity, sfc type, elevation ▪ Geometry : satellite zenith angle, sun zenith angle, latitude	▪ Level : p ▪ Layer : Mixing ratio (clw, ciw, rain, snow), cloud cover	▪ Layer : p, q, t, water content and hail effective radius of hydrometeors (clw, ciw, rw, snow, graupel, hail) ▪ Level : p ▪ 10m : wind ▪ Skin : t, salinity, sfc type, elevation ▪ Geometry : satellite zenith angle, sun zenith angle, viewing angle
	$TB_{allsky} = TB_{cloud} \times cldfrac + TB_{clr} \times (1 - cldfrac)$		
Scattering solver	**Two-stream Eddington approximation model** (Bauer et al. 2006)		**Advanced doubling-adding (ADA) method** (Liu and Weng 2006)

3. Results for surface emissivity

✓ One day's observations from NOAA-15, 18, 19 and MetOp-A are used.

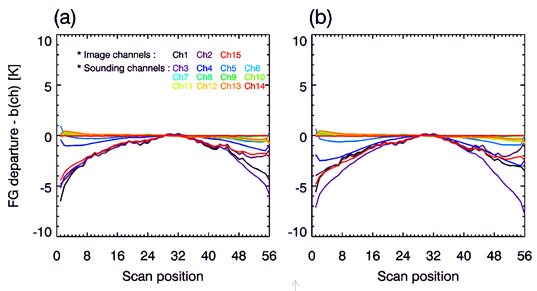
For Ocean

1) Comparing OmB for FASTEM

CH	RTTOV				CRTM			
	Mean(O-B)		STD(O-B)		Mean(O-B)		STD(O-B)	
	V 4	V 5	V 4	V 5	V 4	V 5	V 4	V 5
1	6.0	5.5	13.22	13.22	7.8	7.7	12.99	12.98
2	9.4	8.6	14.10	14.14	9.9	9.4	14.1	14.13
3	5.5	4.5	6.05	5.96	7.0	6.3	6.3	6.14
4	0.5	0.3	1.38	1.38	1.0	0.9	1.67	1.58
5	-0.1	-0.1	0.57	0.58	0.0	0.0	0.62	0.61
6	-0.8	-0.8	0.38	0.38	-0.7	-0.7	0.37	0.37
7	-0.6	-0.6	0.53	0.53	-0.6	-0.6	0.51	0.51
8	-0.6	-0.6	0.49	0.49	-0.5	-0.5	0.47	0.47
9	-1.0	-1.0	0.52	0.52	-1.0	-1.0	0.49	0.49
10	-1.1	-1.1	0.46	0.46	-1.0	-1.0	0.45	0.45
11	-1.3	-1.3	0.50	0.50	-1.3	-1.3	0.50	0.50
12	-1.2	-1.2	0.54	0.54	-1.2	-1.2	0.55	0.55
13	-0.9	-0.9	0.81	0.81	-1.0	-1.0	0.88	0.88
14	-0.4	-0.4	1.92	1.92	-0.5	-0.5	2.11	2.11
15	8.3	6.4	8.96	8.71	9.1	7.4	9.29	8.94

- For FASTEM version, there are no differences in OmB of channel 6 to 14 in both models.
- Differences are relatively large on channel 2, 3, and 15.
- On channel 1-5 and 15, OmBs from RTTOV is smaller than those from CRTM.

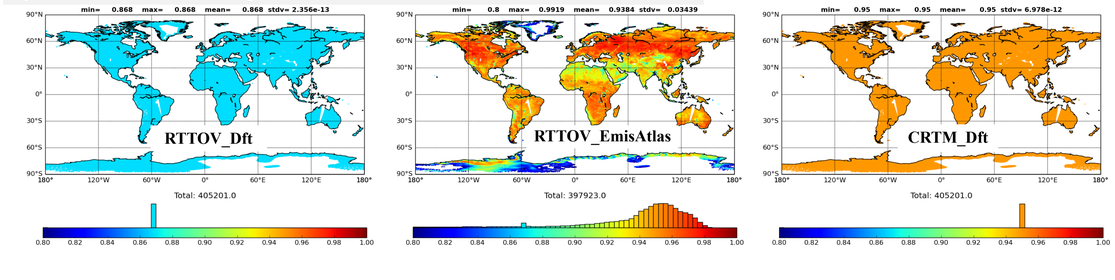
2) Comparing OmB for scan positions



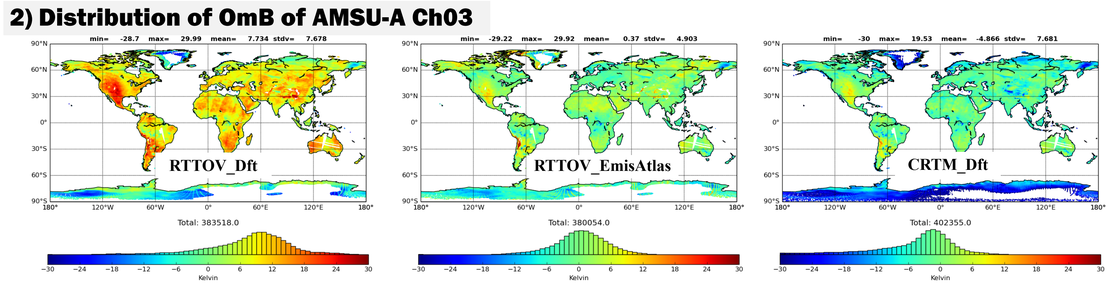
- The correction of FG departures according to the scan position is done by removing the values (b_{ch}) between observed and simulated TBs of mid-point of beam positions on each channel.

For Land

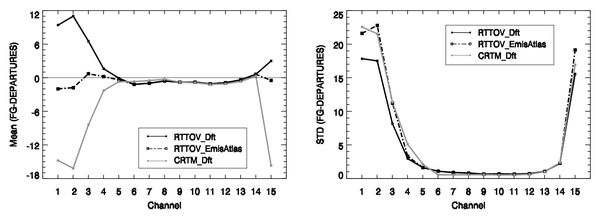
1) Surface emissivity of AMSU-A Ch02 (Satellite zenith angle = 15°)



2) Distribution of OmB of AMSU-A Ch03



3) Mean and STD of OmB for 15 channels



- Additional inputs for EmisAtlas in RTTOV are informations for that month, latitude, and longitude. How about CRTM?

```
! Compute the surface optical parameters
IF ( SC(SensorIndex)%Frequency(ChannelIndex) < FREQUENCY_CUTOFF ) THEN
  ! Frequency is low enough for the model
  DO i = 1, SfcOptics%n_Angles
    CALL NESDIS_LandEM(SfcOptics%Angle(i),                  & ! Input, Degree
                       SC(SensorIndex)%Frequency(ChannelIndex),   & ! Input, GHz
                       SurfaceInfo%Soil_Moisture_Content, & ! Input, g.cm^-3
                       SurfaceInfo%Vegetation_Fraction,   & ! Input
                       SurfaceInfo%Soil_Temperature,      & ! Input, K
                       SurfaceInfo%Land_Temperature,      & ! Input, K
                       SurfaceInfo%Lai,                   & ! Input, Leaf Area Index
                       SurfaceInfo%Soil_Type,             & ! Input, Soil Type (1 - 9)
                       SurfaceInfo%Vegetation_Type,       & ! Input, Vegetation Type (1 - 13)
                       ZERO,                              & ! Input, Snow depth, mm
                       SfcOptics%Emissivity(i,2),         & ! Output, H component
                       SfcOptics%Emissivity(i,1)          ) ! Output, V component
    ! Assume specular surface
    SfcOptics%Reflectivity(i,1,i,1) = ONE-SfcOptics%Emissivity(i,1)
    SfcOptics%Reflectivity(i,2,i,2) = ONE-SfcOptics%Emissivity(i,2)
  END DO
ELSE
  ! Frequency is too high for model. Use default.
  DO i = 1, SfcOptics%n_Angles
    SfcOptics%Emissivity(i,1:2)          = DEFAULT_EMISSIVITY
    SfcOptics%Reflectivity(i,1:2,i,1:2) = ONE-DEFAULT_EMISSIVITY
  END DO
END IF

END FUNCTION Compute_MW_Land_SfcOptics
```

- Are those detailed informations about surface are used in real DA?
- Please, comment me for your application for Land surface emissivity of CRTM.

For Sea-ice

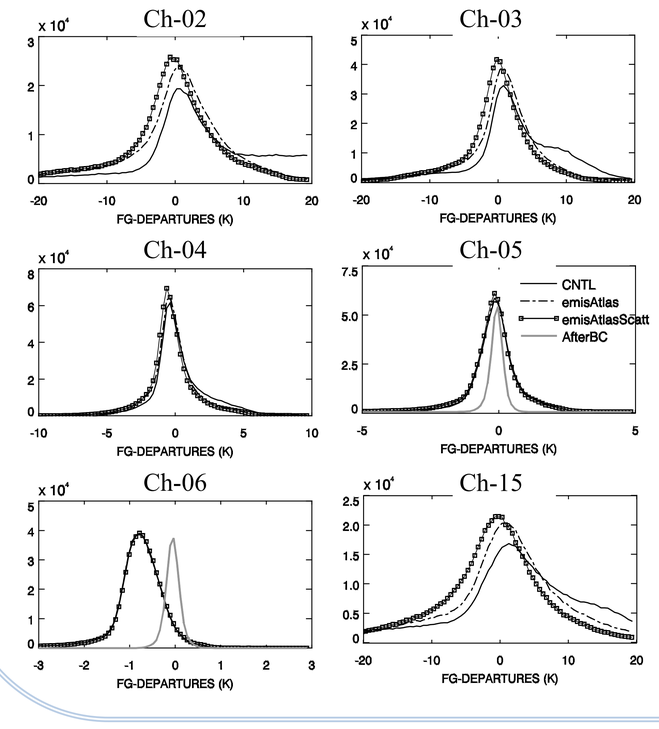
	RTTOV	CRTM

Surface emissivity	`if (rttov_prof % skin % surftype .eq. 0.) then ! Land`
	`rttov_profIskinFastem(1) = 3.`
	`rttov_profIskinFastem(2) = 5.`
	`rttov_profIskinFastem(3) = 15.`
	`rttov_profIskinFastem(4) = 0.1` ~ 0.87
	`rttov_profIskinFastem(5) = 0.3`
	`else if (rttov_prof % skin % surftype .eq. 2.) then ! Sea-ice`
	`rttov_profIskinFastem(1) = 2.2`
	`rttov_profIskinFastem(2) = 3.7`
	`rttov_profIskinFastem(3) = 122.0`
	`rttov_profIskinFastem(4) = 0.0` ~ 0.96
	`rttov_profIskinFastem(5) = 0.15`
	`endif`
		DEFAULT_EMISSIVITY = 0.92_fp

- Please, comment me for your application for Sea-ice surface emissivity of RTTOV and CRTM.

Current status of RTTOV in KOPS (microwave)

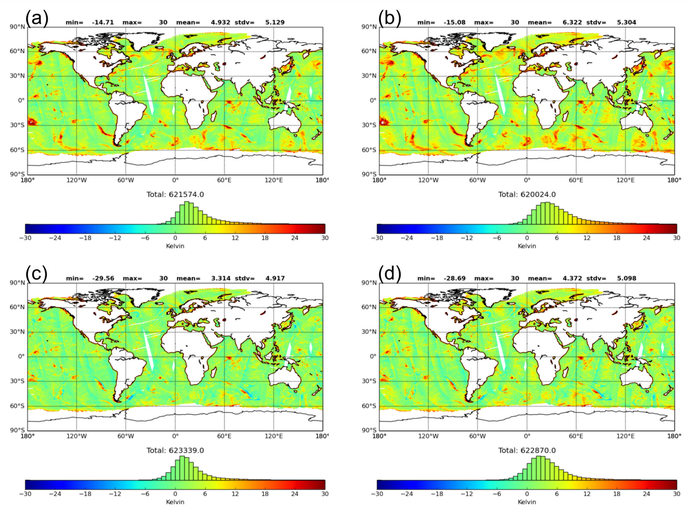
Histograms of FG-departures for AMSU-A



- **RTTOV-DIRECT driver** has been installed. (January 2013)
- **RTTOV-SCATT driver** has been installed. (July 2013)
- **CRTM driver** has been installed for comparison. (September 2013)
- **RTTOV-K driver** has been installed. (January 2014)
- **RTTOV TELSEM_EmisAtlas** has been used. (February 2014)

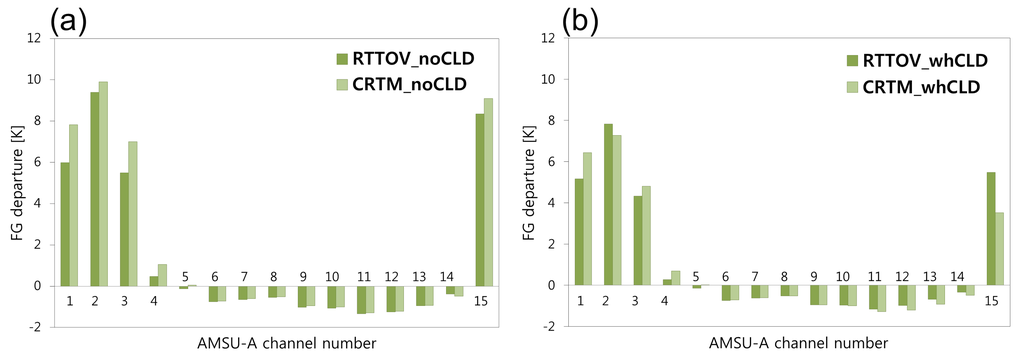
- When TELSEM EmisAtlas is used and cloud scattering informations are ingested, distributions for OmB histogram for surface channels are getting closer to Gaussian. For temperature sounding channels, our bias correction module works well.
- This RTTOV driver will be upgraded by RTTOV version 11.

4. Results for considering cloud informations



AMSU-A channel 3 FG departures for RTTOV and CRTM at 0000 UTC on 7 November 2012 over ocean: (a) RTTOV without cloud condition, (b) CRTM without cloud condition, (c) RTTOV with cloud condition, and (d) CRTM with cloud condition.

- The UM provides three cloud parameters for each atmospheric layer, which are cloud fraction, cloud liquid water, and cloud ice.
- When clouds are added, FG departures are reduced. If all hydrometeors (rain water and solid precipitations) are included, positive biases will be reduced more.



AMSU-A FG departures using RTTOV and CRTM (a) without and (b) with cloud conditions for observations on 7 November 2012 over ocean.

- When cloud particles are considered, FG departures of image channels and low tropospheric sounding channels are reduced in both models. Especially for channel 2 (31.4 GHz) and 15 (89.0 GHz), statistics of bias and standard deviation of CRTM are getting much lower than those of RTTOV.
- Another thing to note is that FG departures from RTTOV in mid- and upper-tropospheric sounding channels are slightly decreased when cloud fields are included since the final TBs in RTTOV are combined radiances of both clear and cloud sky.

5. Plans

- RTTOV version 11 with updated Mie table will be implemented and optimal cloud and precipitation particles will be ingested.
- Pre-processing system for MHS will be developed.

Reference

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