RTTOV 10
Theory & Exercise

- Overview of RTTOVS Radiative Transfer Model
  - Gases Absorption (water Vapor & other trace gases)
  - Aerosol/Clouds Scattering and Absorption
  - Surface Emissivity/Reflectivity
    - IRSSE & ISEM-6
  - Model Example
- An Exercise in Radiative Transfer Modeling with RTTOV-10 (RTTOV10_Workshopv4.doc; prepared by Dr. Nadia Smith)
  - Running RTTOV-10 using VMware Player
    - RTTOV-10 in IMAPP Virtual Appliance (VA) (prepared by Willem Marais)

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Satellite Direct Broadcast for Real-Time Environmental Applications
ECNU Shanghai, 1-6 June 2011

General Notes

• BTs have been calculated by RTTOV v9.3

• Initial settings: over sea water, no solar radiation

• ISEM is RTTOV's fast surface emissivity ε_s routine for the IR to compute surface emissivity over water

• SST=surface air temperature (last level in model atmosphere profile)

Satellite Platforms supported in RTTOV

Polar Orbiting:
- NOAA
- DMSP
- TRMM
- ERS
- EOS
- METOP
- ENVISAT
- FY-1
- ADEOS
- CORIOLIS

Geostationary:
- Meteosat
- GOES
- GMS
- FY-2
- MSG
- FY-1
- MTSAT

To request a copy of the RTTOV9.1 code go to
http://www.metoffice.gov.uk/research/interproj/nwpsaf/request_forms/index.html

User' s Guide (distributed as part of lecture' s materials): RTTOVS users_guide_92/pdf

RTTOVS – Hyper and Multi –Spectral RTM

Satellite Sensors supported in RTTOV

Infrared/Near IR/Visible:
- HIRS
- AVHRR
- VTPR1 & VTPR2
- AIRS
- MODIS
- ATSR
- IASI
- MVIRI
- SEVIRI
- GOES-Imager & Sounder
- GMS/MTSAT imager
- FY2-VISSR
- FY1-MVISR
- *CriS*
- *VIIRS*

Microwave:
- MSU
- SSU
- AMSU-A
- AMSU-B
- SSMI
- TMI
- SSMIS
- HSB
- MHS
- AMSR
- WINDSAT

Simulation of radiances reaching satellite sensor

The model can simulate both clear sky radiances and cloudy radiances. It uses an approximate form of the atmospheric radiative transfer (RT) equation. If a black opaque cloud is assumed at a single level, the top of the atmosphere upwelling radiance, $L(v,\theta)$ at a frequency v and viewing θ angle from zenith at the surface, neglecting scattering effects, is written as:

$$L(v,\theta) = (1-N)L^{Clr}(v,\theta) + NL^{Cld}(v,\theta)$$

Where $L^{Clr}(v,\theta)$ and $L^{Cld}(v,\theta)$ are the clear sky and fully cloudy top of atmosphere upwelling radiances and *N* is the fractional cloud cover.

Simulation of clear air radiances

If *N,* the cloud cover parameter, is set to zero and the liquid water concentration profile vector is set to zero both the infrared and microwave radiances computed are for clear air with the second right hand term of equation in previous slide (7) being zero. $L^{Clr}(\nu,\theta)$ can be written as:

$$L^{Clr}(\nu,\theta) = \tau_s(\nu,\theta)\varepsilon_s(\nu,\theta)B(\nu,T_s) + \int_{\tau_s}^{1} B(\nu,T)d\tau + (1-\varepsilon_s(\nu,\theta))\tau_s^2(\nu,\theta)\int_{\tau_s}^{1}\frac{B(\nu,T)}{\tau^2}d\tau$$

where τ_s is the surface to space transmittance, ε_s is the surface emissivity and $B(\nu,T)$ is the Planck function for a frequency ν and temperature T.

The transmittances, τ, are computed by means of a linear regression in optical depth based on variables from the input profile vector.

Infrared Surface Emissivity Model (ISEM) (1/2)

calcemiss	RTTOV coeff file version	Input ε	Forward Output ε	Tangent Linear Output ∂ε
			INFRARED CHANNELS	
true	7 or 8 or 9	0	Land=0.98/sea-ice=0.99/ sea= ε_{ISEM}	∂ε about 0.98/0.99/ε_{ISEM}
false	7 or 8 or 9	ε_{user}	ε_{user}	∂ε about ε_{user}

To compute IR ε_s over water there are fast IR surface emissivity routine. This model all compute a surface emissivity for the channel of interest at the given viewing angle. Over the land and sea-ice surfaces only approximate default values are provided for the surface emissivity in the infrared (see Table above). The user also has the option of providing their own estimate of surface emissivity to the model if desired.

ISEM-6:

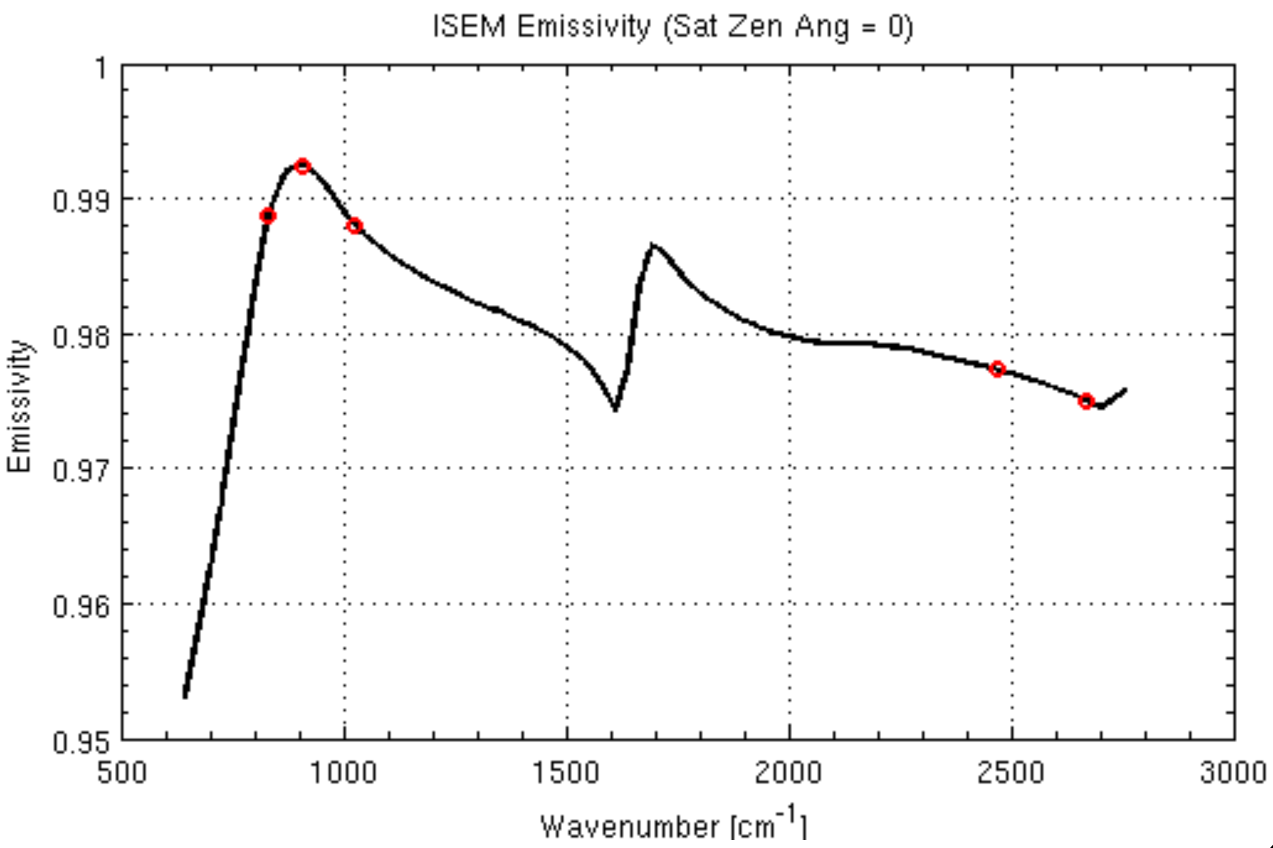
Sherlock, V. 1999 ISEM-6: Infrared Surface Emissivity Model for RTTOV-6. NWP SAF report.
http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/papers/isem6.pdf

Infrared Surface Emissivity Model (ISEM) (2/2)

ISEM-6:

Sherlock, V. 1999 ISEM-6: Infrared Surface Emissivity Model for RTTOV-6. NWP SAF report

μm	Emissivity
12.02	0.988715
11.03	0.992490
9.73	0.987982
4.05	0.977310
3.75	0.975055



InfraRed Sea Surface Emissivity (IRSSE) model (1/2)

The InfraRed Sea Surface Emissivity (IRSSE) model was developed for use in the Global Data Assimilation System (GDAS) at NCEP/EMC. Previously, the GDAS used an IRSSE model based on Masuda *et al* (1988). The Masuda model doesn't account for the effect of enhanced emission due to reflection from the sea surface (only an issue for larger view angles) and the implementation was based on coarse spectral resolution emissivity data making its application to high resolution instruments, such as AIRS, problematic.

The old IRSSE model has been upgraded to use sea surface emissivities derived via the Wu and Smith (1997) methodology as described in Van Delst and Wu (2000). The emissivity spectra are computed assuming the infrared sensors are not polarised and using the data of Hale and Querry (1973) for the refractive index of water, Regenstein (1981) for the extinction coefficient, and Friedman (1969) for the salinitiy/chlorinity corrections. Instrument spectral response functions (SRFs) are used to reduce the emissivity spectra to instrument resolution.

http://www.ssec.wisc.edu/~paulv/Fortran90/Emissivity/Sensor_Emissivity_Model/

InfraRed Sea Surface Emissivity (IRSSE) model (2/2)

Methodology

A starting point was the sea surface infrared emissivity model, SSIREM, described in Sherlock (1999),

$$\varepsilon(\theta,\nu) = c_0(\nu) + c_1(\nu)\hat{\theta}^{c_2(\nu)} + c_3(\nu)\hat{\theta}^{c_4(\nu)}$$

Where $\hat{\theta} = \frac{\theta}{60^\circ}$ is nomarlized view angle and ν is the wind speed in m/s. In generating the model coefficients, for a series of wind speeds 0-15m/s, the coefficients C_i were obtained using Levenberg-Marquardt least-squares minimization. Interpolating coefficients for each C_i as a function of wind speed were then determined. In using the model, the C_i are computed for a given wind speed and these computed coefficients are used in equation above to calculate the view angle dependent emissivity.

Van Delst, P.F.W. and Wu, X. A high resolution infrared sea surface emissivity database for satellite applications. Technical Proceedings of The Eleventh International ATOVS Study Conference, Budapest, Hungary 20-26 September 2000, 407-411

RTTOVS – Hyperspectral RTM
Absorption Gases' Options

	RTTOV-7 Coefficients		RTTOV-8 coefficients		RTTOV-9 coefficients	
Gas	Profile	Coeffs	Profile	Coeffs	Profile	Coeffs
Mixed	Y	Y	Y	Y	Y	Y
H2O	Y	Y	Y	Y	Y	Y
O3	Y	O	O	O	O	O
CO2	N	N	O	O	O	O
N20	N	N	N	N	O	O
CO	N	N	N	N	O	O
CH4	N	N	N	N	O	O

Y=Input mandatory

O=Input optional depending on profile flag and contents of coeff file

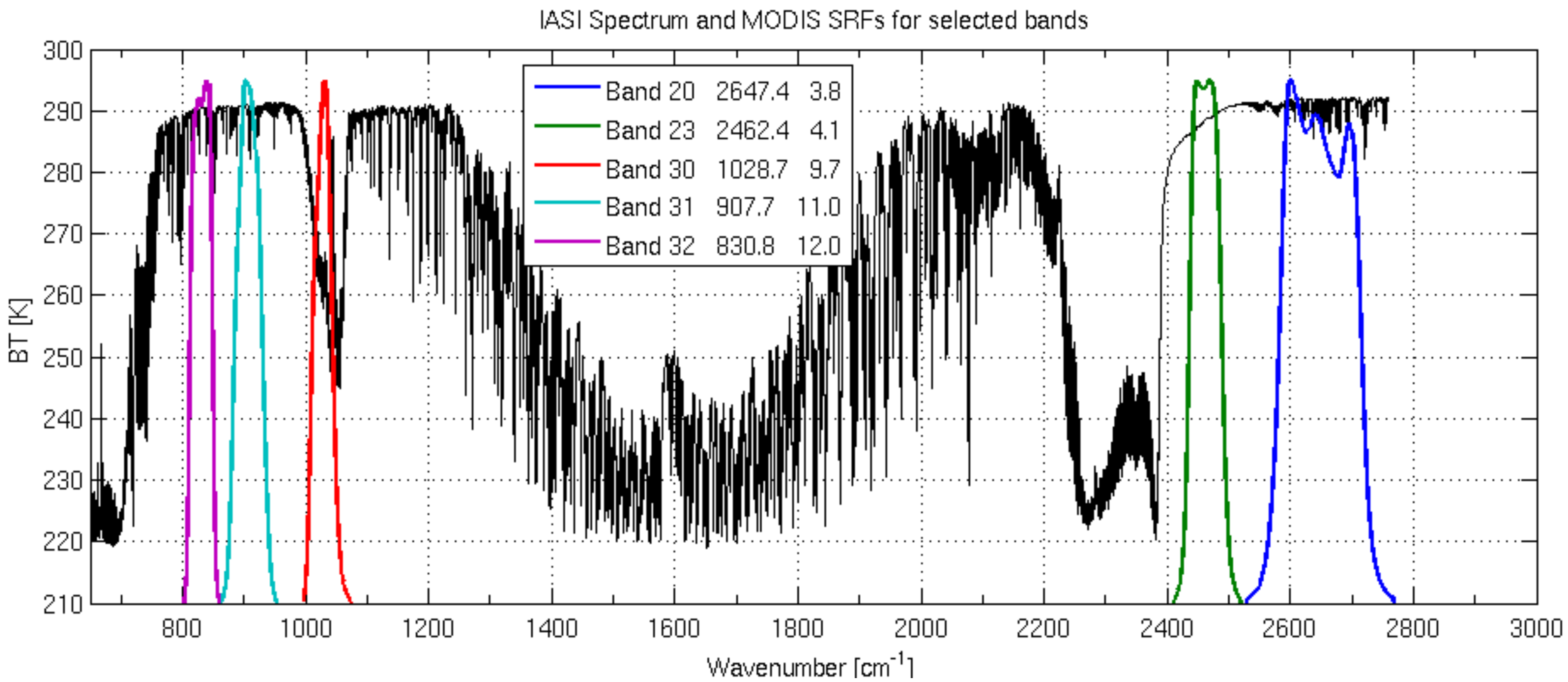
N=No input possible

To effectively simulate effects of gases' absorption in the window channel measurements and their impact on SST retrieval

Options	**Set logical flags and fill profile arrays**	**Define options to convert IWC to effective diameter**	**Define ice crystal shape**
Cloudy simulation	*lclouds=.true.* *Profiles(1)%cld_data=.true.* *Profiles(1)%cloud(i,j)*=layer mean liquid or ice water content in units of g.m^{-3}. *Profiles(1)%cfrac(i,j)=* fractional cloud cover for each layer (0-1) where *i* is the index of the cloud type (see Table 6) and *j* is the level index.	Set *profiles(1)%idg* 1=Ou and Liou (1995) 2=Wyser (1998) 3=Boudala et al (2002) 4=McFarquar et al (2003)	Set *profiles(1)%ish* 1= Hexagonal 2= Aggregates
	Set logical flags and fill profile arrays	**Define climatological profile**	
Aerosol simulation	*laerosl=.true.* *profiles(1)%aer_data=.true.* *profiles(1)%aerosols(i,j)*=layer mean number density in units of cm^{-3} where *i* is the index of the aerosol component (see Table 9) and *j* is the level index.	0=User defined profile Profiles available in file *prof_aerosl_cl.dat* to read into *profiles(1)%aerosols(i,j)* 1=Continental clean 2=Continental average 3=Continental polluted 4=Urban 5=Desert 6=Maritime clean 7=Maritime polluted 8=Maritime tropical 9=Arctic	

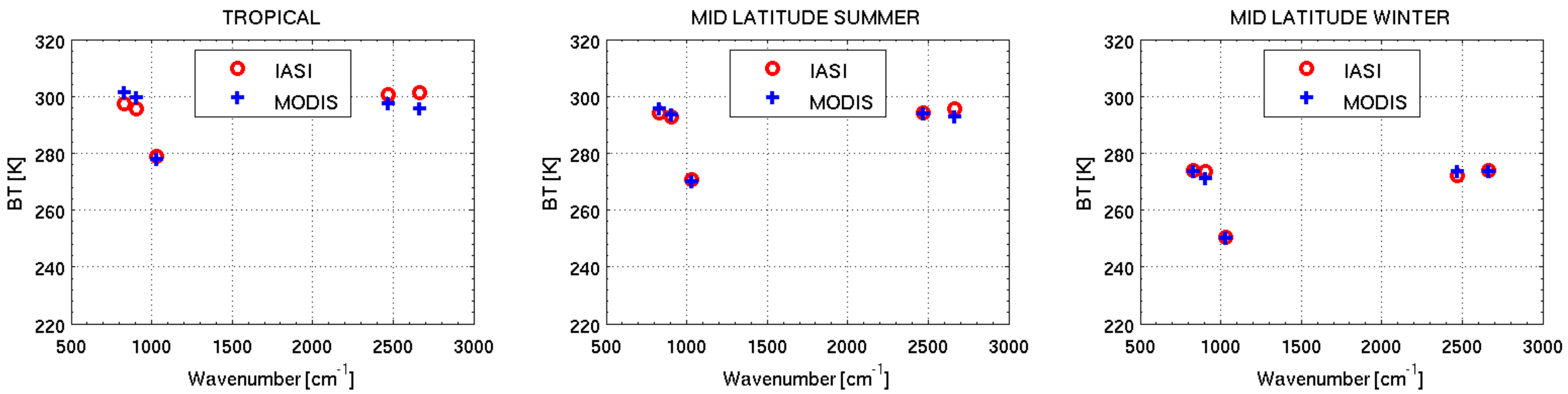
The mixing of the various aerosol components can be defined by the user or climatological profiles with predefined mixing can be supplied. The input profile. To include an aerosol component in the radiative transfer the user must assign the layer mean density (in units of cm-3) for that component.

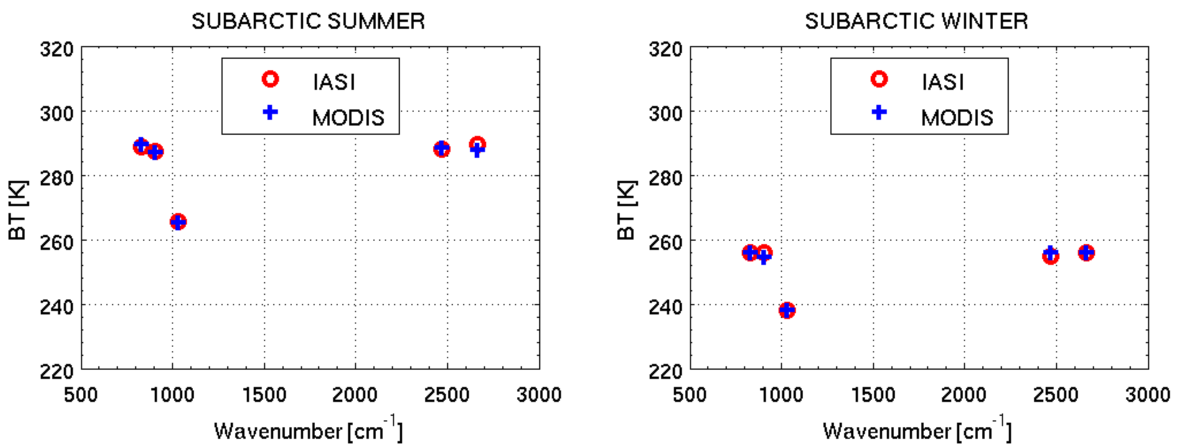
RTTOVS Calculations with ε_s=1 and ε_s from ISEM



RTTOVS Calculations with ε_s=1

IASI and MODIS BTs for 5 atmospheres





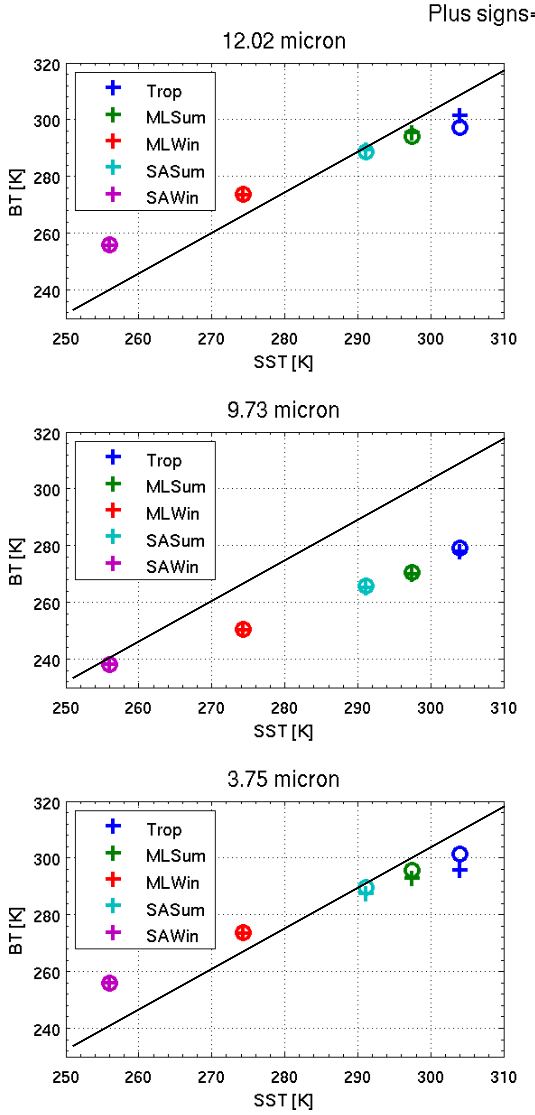
1. Explain why window channels not have the same value?

2. Explain why for some IASI & MODIS ch. have large differences than others?

RTTOVS Calculations with ε_s=1

IASI and MODIS BTs vs. SST for 5 channels

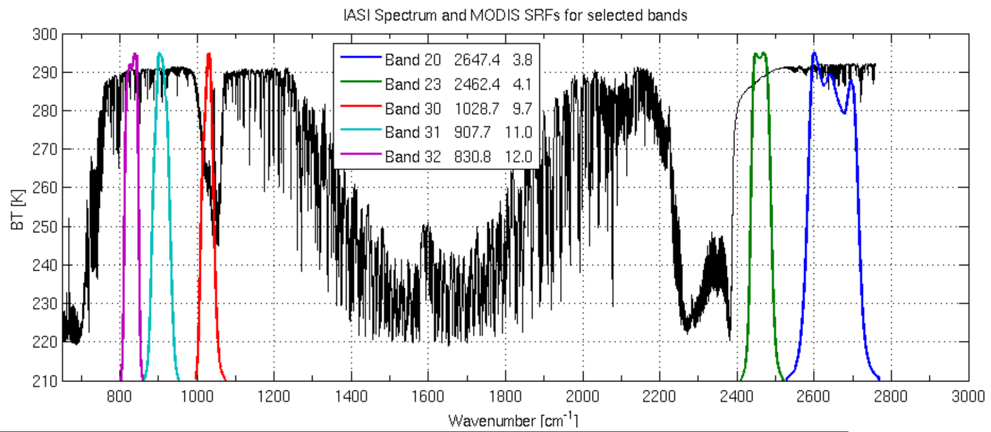
Plus signs=MODIS, Circles=IASI



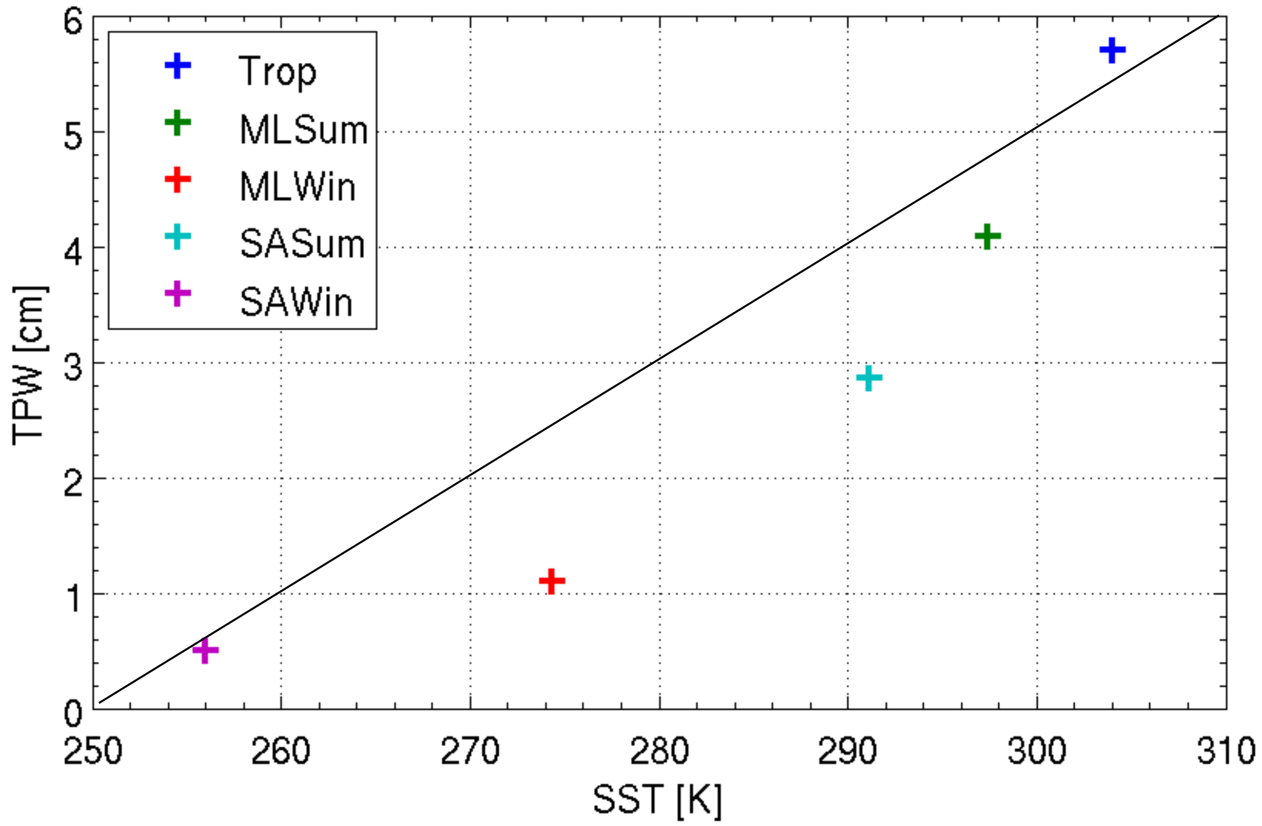
1. Explain why some window Chs have temp. warmr than SST?

2. Explain why some window Chs have temp. warmr than SST?

3. Explain how water vapor play the role in retrieving SST?

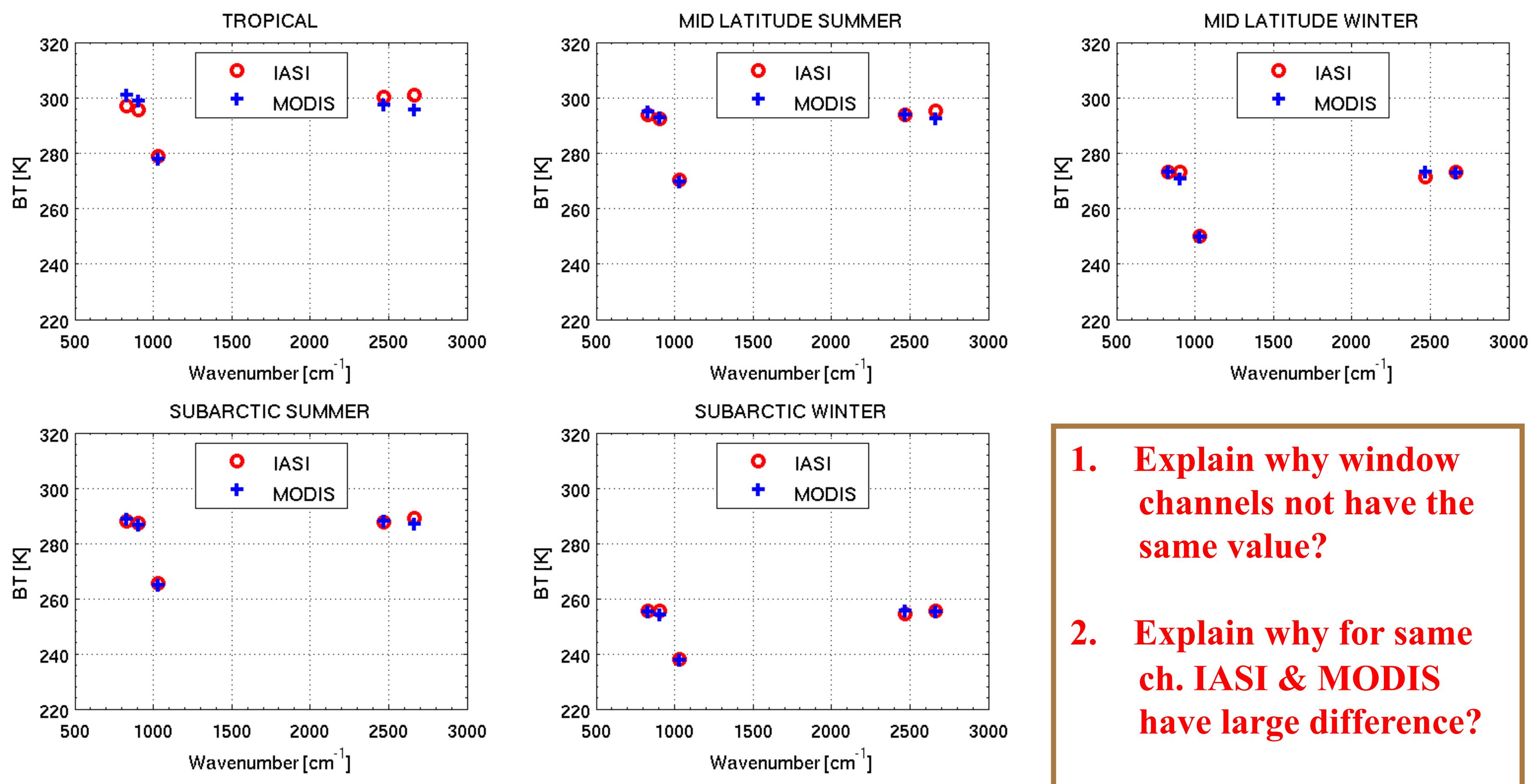


SST vs. TPW for 5 atmospheres, ε_s=1



Discuss any relation between SST and TPW

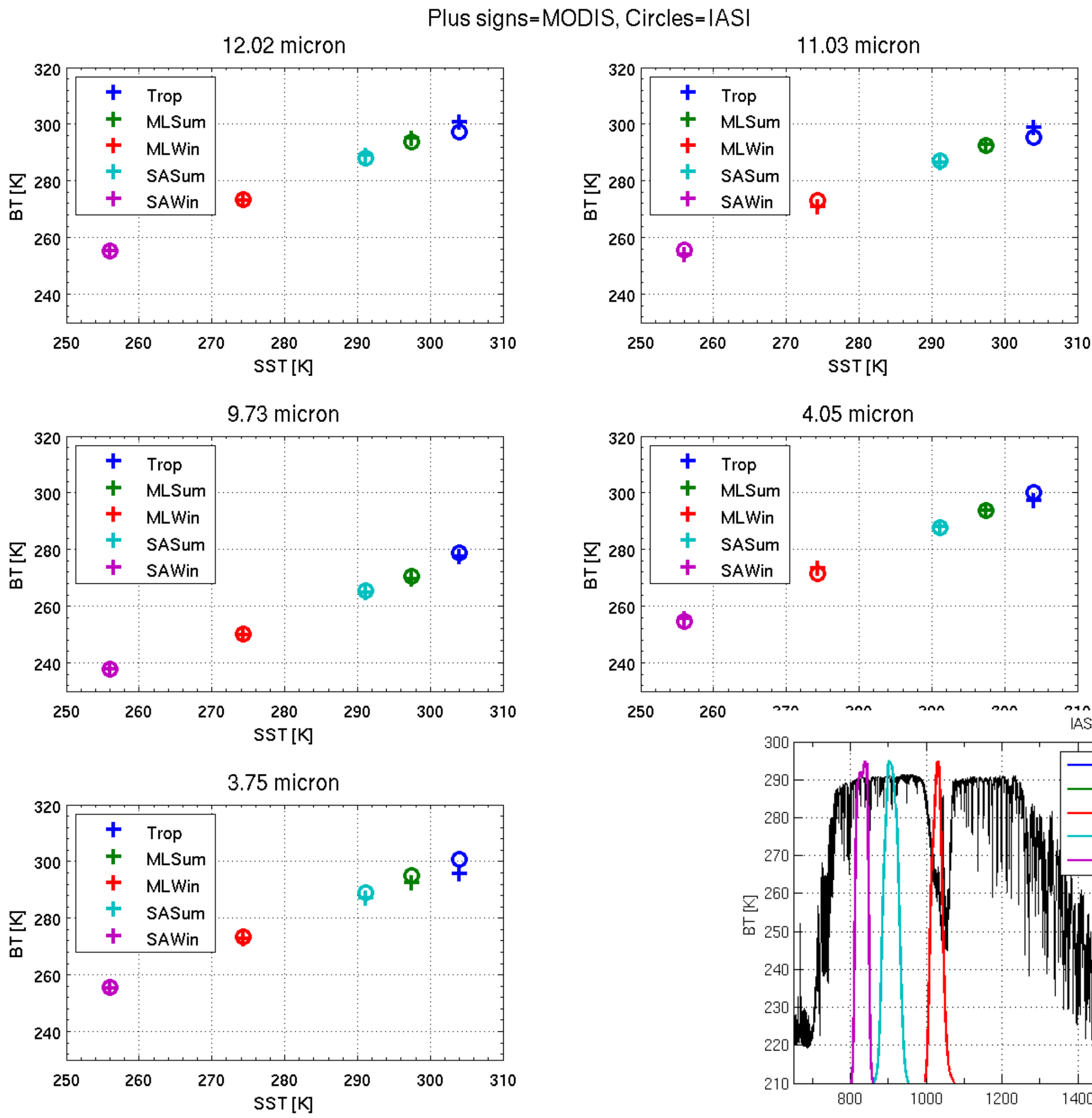
RTTOVS Calculations with ε_s from ISEM
IASI and MODIS BTs for 5 atmospheres



1. Explain why window channels not have the same value?
2. Explain why for same ch. IASI & MODIS have large difference?
3. Are there any difference when compare with ε_s is 1?

RTTOVS Calculations with ε_s from ISEM

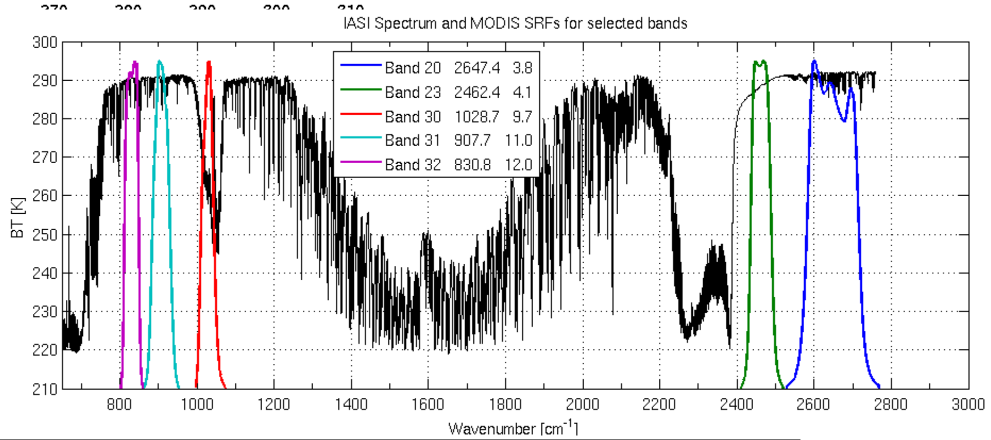
IASI and MODIS BTs vs. SST for 5 channels



1. **Explain why some window Chs have temp. warmr than SST?**

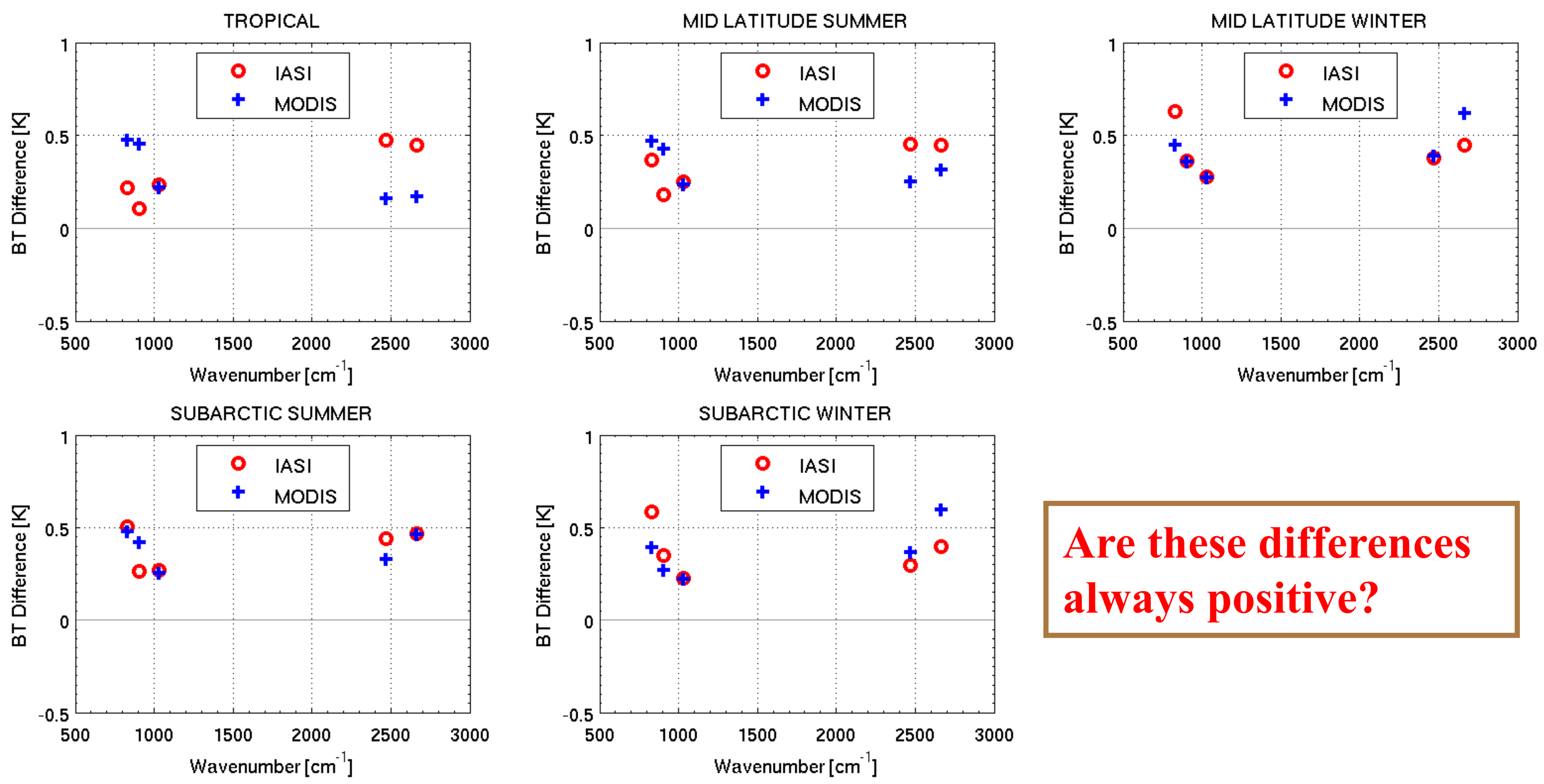
2. **Explain why some window Chs have temp. warmr than SST?**

3. **Explain how water vapor play the role in retrieving SST?**



RTTOVS Calculations with ε_s=1 & ε_s from ISEM

IASI and MODIS BT differences "ε_s=1 minus ε_s from ISEM"

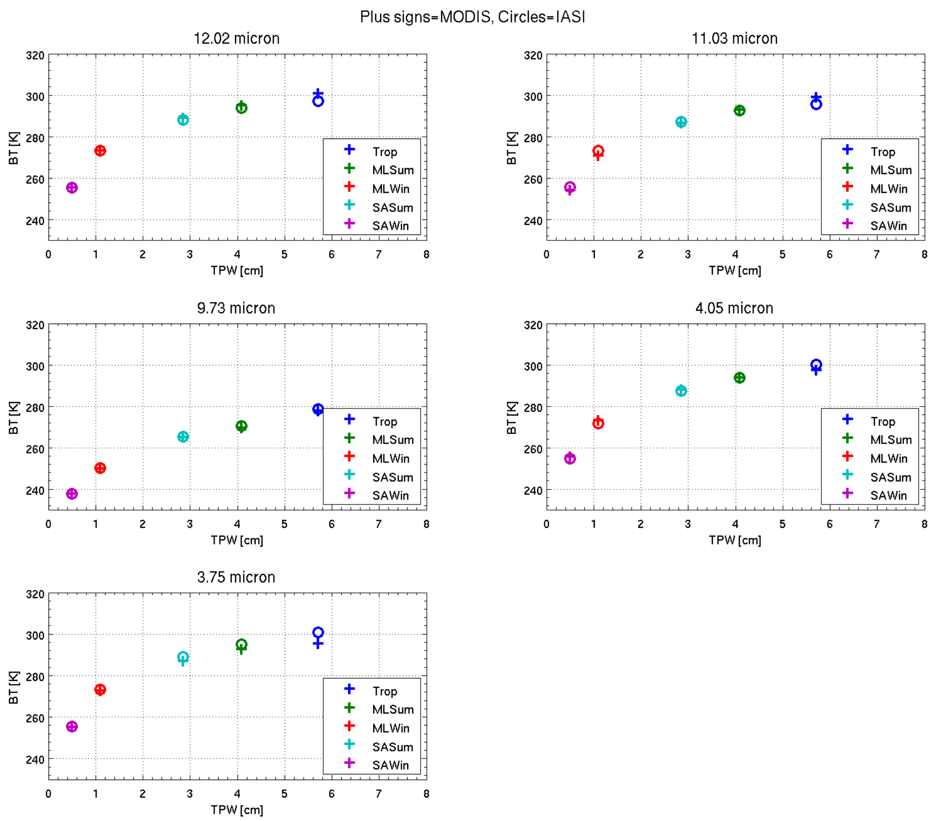


Are these differences always positive?

RTTOVS Calculations with and without H_2O

RTTOVS Calculations with and without H_2O

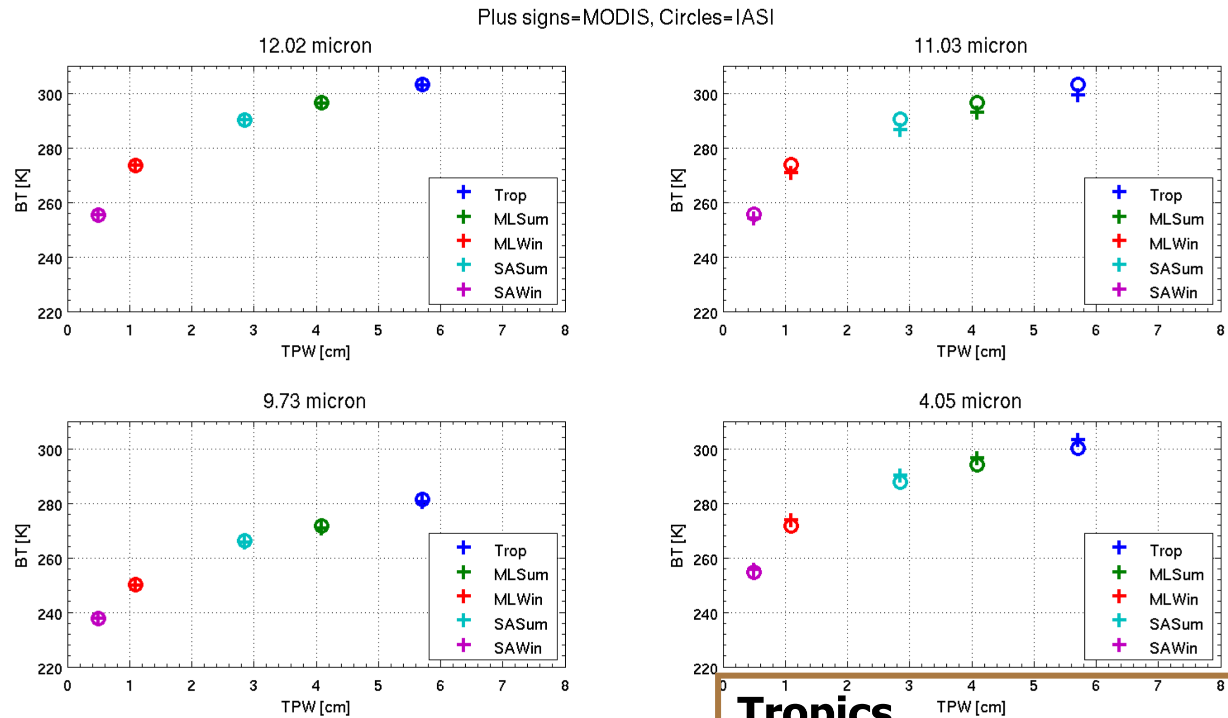
IASI and MODIS BTs vs. TPW for 5 channels, ε_s from ISEM

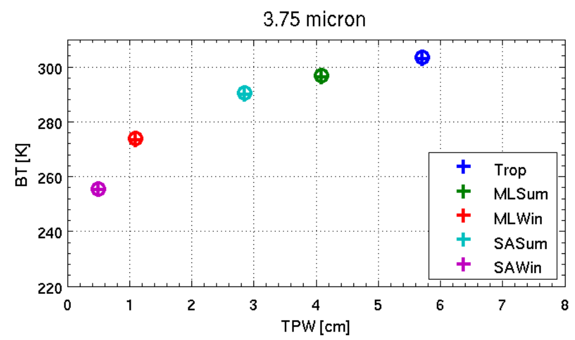


Discuss the relationship between brightness temperatures and TPW!

RTTOVS Calculations without H_2O & ε_s from ISEM

IASI and MODIS BTs vs. TPW for 5 channels





Discuss the relationship between brightness temperatures and TPW! Also discuss the differences of IASI and MODIS of their water vapor impacts

Tropics

SST[K]	TPW[cm]
304.04	5.70

Ch#	WL[μm]	IASI[K]	MODIS[K]	IASI Diff[K]	MODIS Diff[K]
1	12.02	303.09	302.89	-5.89	-2.02
2	11.03	303.14	299.12	-7.66	-0.12
3	9.73	281.37	280.36	-2.61	-2.69
4	4.05	300.23	303.09	-0.14	-5.72
5	3.75	303.39	302.80	-2.57	-7.27

RTTOVS Calculations without H_2O & ε_s from ISEM

IASI and MODIS BTs vs. TPW for 5 channels

MID LATITUDE WINTER

SST[K] TPW[cm]

274.35 1.10

Ch#	WL[μm]	IASI[K]	MODIS[K]	IASI Diff[K]	MODIS Diff[K]
1	12.02	273.59	273.47	-0.34	-0.36
2	11.03	273.69	270.78	-0.55	-0.01
3	9.73	250.22	249.99	-0.13	-0.15
4	4.05	271.58	273.66	-0.00	-0.39
5	3.75	273.83	273.42	-0.49	-0.54

MID LATITUDE SUMMER

SST[K] TPW[cm]

297.39 4.09

Ch#	WL[μm]	IASI[K]	MODIS[K]	IASI Diff[K]	MODIS Diff[K]
1	12.02	296.49	296.31	-2.73	-1.30
2	11.03	296.56	292.97	-4.11	-0.05
3	9.73	271.55	270.85	-1.10	-1.17
4	4.05	293.96	296.52	-0.06	-2.79
5	3.75	296.78	296.23	-1.67	-3.64

Explain why water vapor affects much differently to IASI and MODIS when TPW is high!

RTTOVS Calculations without H_2O & ε_s from ISEM

IASI and MODIS BTs vs. TPW for 5 channels

SUBARCTIC SUMMER

SST[K]	TPW[cm]
291.10	2.85

Ch#	WL[μm]	IASI[K]	MODIS[K]	IASI Diff[K]	MODIS Diff[K]
1	12.02	290.23	290.05	-2.16	-1.13
2	11.03	290.32	286.61	-3.14	-0.04
3	9.73	266.24	265.74	-0.79	-0.85
4	4.05	287.61	290.27	-0.04	-2.16
5	3.75	290.51	289.99	-1.48	-2.92

Explain why water vapor affects much differently to IASI and MODIS when TPW is high!

SUBARCTIC WINTER

SST[K]	TPW[cm]
256.00	0.49

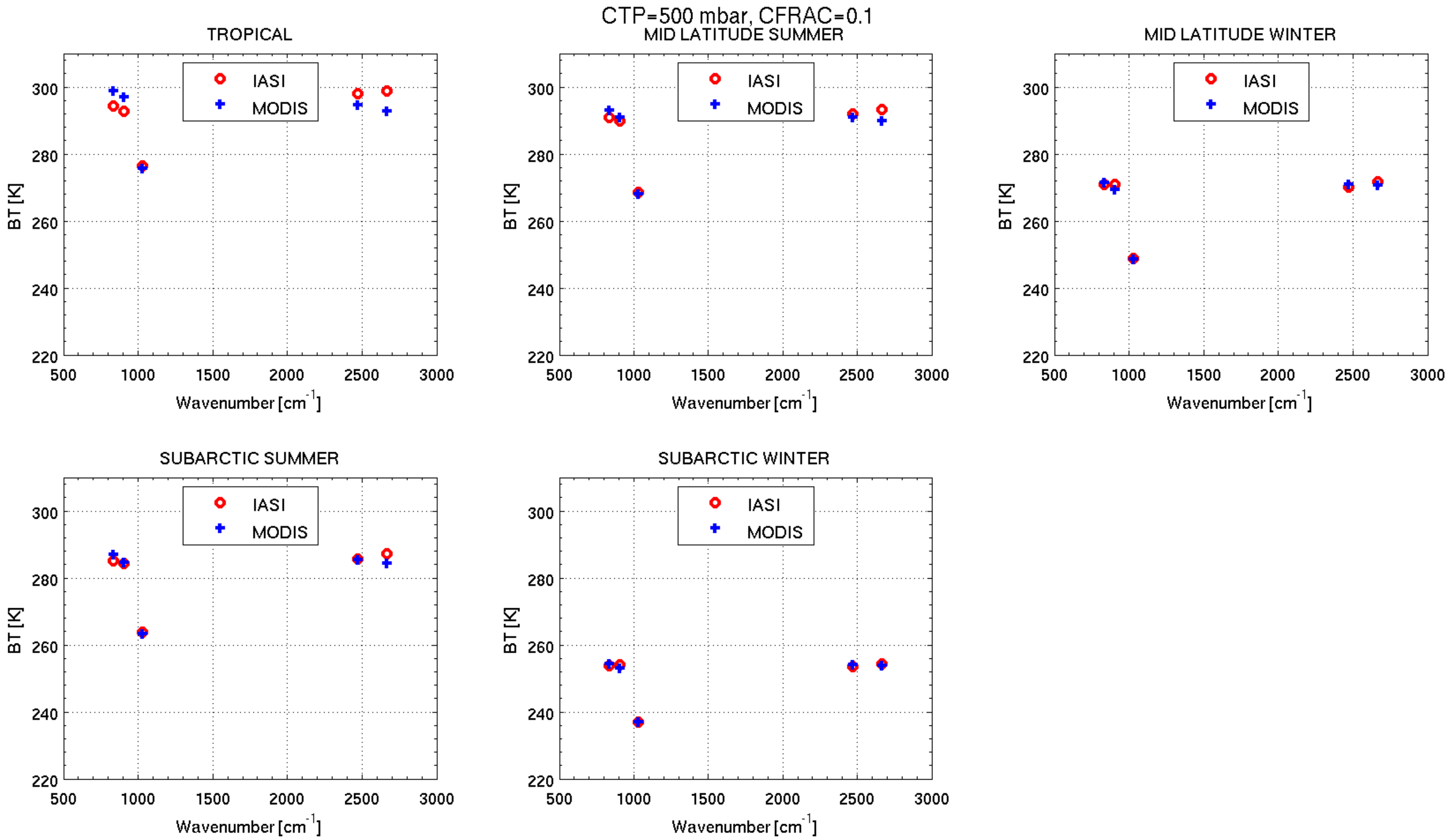
Ch#	WL[μm]	IASI[K]	MODIS[K]	IASI Diff[K]	MODIS Diff[K]
1	12.02	255.36	255.36	0.02	-0.02
2	11.03	255.49	254.11	0.01	0.00
3	9.73	237.87	237.75	0.00	-0.00
4	4.05	254.57	255.48	-0.00	-0.01
5	3.75	255.56	255.25	-0.02	0.01

Simple Cloud calculations

for different cloud top pressures (ctp) and cloud fractions (cfrac)

RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs, CTP=500 mbar, CFRAC=0.1



Exercise 1: Find the relationship between Brightness Temperatures and TPW

 # MID LATITUDE SUMMER

SST[K] TPW[cm]
297.39 4.09

	WL[μm]	IASI BT[K]	MODIS BT[K]
1	12.02	294.13	295.48
2	11.03	292.63	293.34
3	9.73	270.70	269.92
4	4.05	294.35	293.97
5	3.75	295.56	292.90

 # MID LATITUDE WINTER

SST[K] TPW[cm]
274.35 1.10

	WL[μm]	IASI BT[K]	MODIS BT[K]
1	12.02	273.88	273.56
2	11.03	273.49	271.13
3	9.73	250.36	250.11
4	4.05	271.96	273.67
5	3.75	273.79	273.50

 # SUBARCTIC SUMMER

SST[K] TPW[cm]
291.10 2.85

	WL[μm]	IASI BT[K]	MODIS BT[K]
1	12.02	288.58	289.40
2	11.03	287.44	286.99
3	9.73	265.71	265.15
4	4.05	288.01	288.43
5	3.75	289.49	287.53

 # SUBARCTIC WINTER

SST[K] TPW[cm]
256.00 0.49

	WL[μm]	IASI BT[K]	MODIS BT[K]
1	12.02	255.96	255.72
2	11.03	255.85	254.39
3	9.73	238.10	237.97
4	4.05	254.87	255.83
5	3.75	255.94	255.85

Exercise 2: Find the relationship between SST & Brightness Temperatures

MID LATITUDE SUMMER

SST[K] TPW[cm]
297.39 4.09

	WL[µm]	IASI BT[K]	MODIS BT[K]
1	12.02	294.13	295.48
2	11.03	292.63	293.34
3	9.73	270.70	269.92
4	4.05	294.35	293.97
5	3.75	295.56	292.90

MID LATITUDE WINTER

SST[K] TPW[cm]
274.35 1.10

	WL[µm]	IASI BT[K]	MODIS BT[K]
1	12.02	273.88	273.56
2	11.03	273.49	271.13
3	9.73	250.36	250.11
4	4.05	271.96	273.67
5	3.75	273.79	273.50

SUBARCTIC SUMMER

SST[K] TPW[cm]
291.10 2.85

	WL[µm]	IASI BT[K]	MODIS BT[K]
1	12.02	288.58	289.40
2	11.03	287.44	286.99
3	9.73	265.71	265.15
4	4.05	288.01	288.43
5	3.75	289.49	287.53

SUBARCTIC WINTER

SST[K] TPW[cm]
256.00 0.49

	WL[µm]	IASI BT[K]	MODIS BT[K]
1	12.02	255.96	255.72
2	11.03	255.85	254.39
3	9.73	238.10	237.97
4	4.05	254.87	255.83
5	3.75	255.94	255.85

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
240.00	0.026	0.067	27.335	38.889	47.111
240.50	0.027	0.069	27.688	39.332	47.606
241.00	0.028	0.071	28.044	39.779	48.103
241.50	0.028	0.073	28.404	40.230	48.604
242.00	0.029	0.076	28.766	40.683	49.108
242.50	0.030	0.078	29.132	41.140	49.615
243.00	0.031	0.080	29.500	41.600	50.125
243.50	0.032	0.083	29.872	42.063	50.639
244.00	0.033	0.085	30.247	42.530	51.155
244.50	0.035	0.088	30.625	42.999	51.675
245.00	0.036	0.090	31.006	43.472	52.198
245.50	0.037	0.093	31.391	43.948	52.724
246.00	0.038	0.096	31.778	44.428	53.253
246.50	0.039	0.099	32.169	44.911	53.785
247.00	0.041	0.102	32.563	45.397	54.321
247.50	0.042	0.105	32.960	45.886	54.860
248.00	0.043	0.108	33.361	46.379	55.402
248.50	0.045	0.111	33.765	46.875	55.947
249.00	0.046	0.114	34.172	47.374	56.495
249.50	0.047	0.117	34.582	47.877	57.046

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
250.00	0.049	0.121	34.995	48.383	57.601
250.50	0.050	0.124	35.412	48.892	58.159
251.00	0.052	0.128	35.832	49.404	58.720
251.50	0.054	0.131	36.255	49.920	59.284
252.00	0.055	0.135	36.682	50.440	59.852
252.50	0.057	0.139	37.112	50.962	60.422
253.00	0.059	0.143	37.545	51.488	60.996
253.50	0.060	0.147	37.982	52.017	61.573
254.00	0.062	0.151	38.422	52.550	62.153
254.50	0.064	0.155	38.865	53.086	62.737
255.00	0.066	0.160	39.312	53.625	63.323
255.50	0.068	0.164	39.762	54.168	63.913
256.00	0.070	0.169	40.215	54.714	64.506
256.50	0.072	0.173	40.672	55.264	65.103
257.00	0.074	0.178	41.132	55.817	65.702
257.50	0.076	0.183	41.596	56.373	66.305
258.00	0.079	0.188	42.063	56.932	66.911
258.50	0.081	0.193	42.533	57.496	67.520
259.00	0.083	0.198	43.007	58.062	68.132
259.50	0.086	0.203	43.484	58.632	68.748

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
260.00	0.088	0.209	43.965	59.205	69.366
260.50	0.091	0.214	44.449	59.782	69.988
261.00	0.093	0.220	44.937	60.362	70.614
261.50	0.096	0.226	45.428	60.945	71.242
262.00	0.099	0.232	45.923	61.532	71.874
262.50	0.101	0.238	46.421	62.122	72.509
263.00	0.104	0.244	46.922	62.716	73.147
263.50	0.107	0.250	47.428	63.313	73.788
264.00	0.110	0.257	47.936	63.914	74.433
264.50	0.113	0.263	48.448	64.518	75.080
265.00	0.116	0.270	48.964	65.126	75.731
265.50	0.120	0.277	49.483	65.736	76.385
266.00	0.123	0.284	50.006	66.351	77.043
266.50	0.126	0.291	50.532	66.969	77.704
267.00	0.130	0.298	51.062	67.590	78.367
267.50	0.133	0.306	51.596	68.215	79.034
268.00	0.137	0.314	52.133	68.843	79.705
268.50	0.141	0.322	52.673	69.474	80.378
269.00	0.144	0.330	53.218	70.110	81.055
269.50	0.148	0.338	53.765	70.748	81.735

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
270.00	0.152	0.346	54.317	71.390	82.418
270.50	0.156	0.355	54.872	72.036	83.105
271.00	0.160	0.363	55.430	72.685	83.794
271.50	0.165	0.372	55.993	73.337	84.487
272.00	0.169	0.381	56.558	73.993	85.183
272.50	0.173	0.390	57.128	74.652	85.882
273.00	0.178	0.400	57.701	75.315	86.585
273.50	0.183	0.410	58.278	75.981	87.291
274.00	0.187	0.419	58.858	76.651	88.000
274.50	0.192	0.429	59.442	77.325	88.712
275.00	0.197	0.440	60.030	78.001	89.427
275.50	0.202	0.450	60.622	78.682	90.146
276.00	0.207	0.461	61.217	79.365	90.868
276.50	0.213	0.472	61.816	80.053	91.593
277.00	0.218	0.483	62.418	80.743	92.321
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278.50	0.235	0.517	64.248	82.837	94.525
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283.50	0.299	0.648	70.589	90.041	102.080
284.00	0.307	0.662	71.244	90.781	102.853
284.50	0.314	0.677	71.903	91.524	103.629
285.00	0.321	0.692	72.565	92.271	104.409
285.50	0.329	0.707	73.231	93.021	105.191
286.00	0.337	0.722	73.901	93.775	105.977
286.50	0.345	0.738	74.575	94.532	106.766
287.00	0.353	0.754	75.252	95.293	107.559
287.50	0.361	0.771	75.933	96.057	108.354
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288.50	0.379	0.805	77.307	97.597	109.954
289.00	0.387	0.822	78.000	98.371	110.759
289.50	0.396	0.840	78.697	99.150	111.567

Radiance Table for MODIS Window Channels

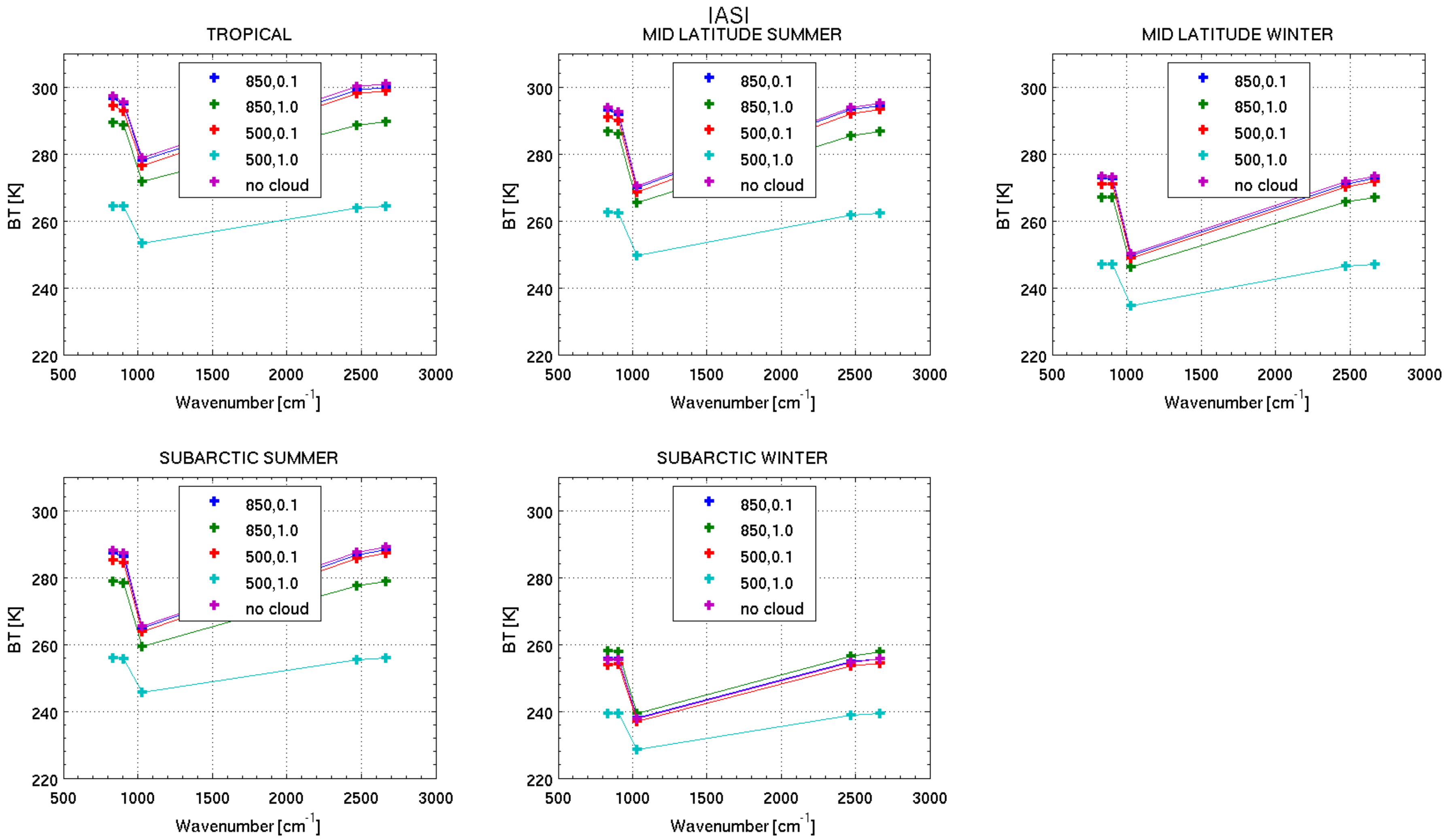
Temp.(K)	3.75	4.05	9.73	11.03	12.02
290.00	0.405	0.858	79.397	99.932	112.379
290.50	0.415	0.876	80.101	100.717	113.193
291.00	0.424	0.894	80.809	101.506	114.011
291.50	0.434	0.913	81.521	102.298	114.832
292.00	0.444	0.933	82.237	103.094	115.656
292.50	0.454	0.952	82.956	103.894	116.483
293.00	0.464	0.972	83.680	104.696	117.313
293.50	0.475	0.992	84.407	105.503	118.146
294.00	0.485	1.013	85.138	106.313	118.983
294.50	0.496	1.034	85.873	107.126	119.823
295.00	0.507	1.055	86.612	107.943	120.666
295.50	0.519	1.077	87.355	108.764	121.512
296.00	0.530	1.099	88.101	109.588	122.361
296.50	0.542	1.122	88.852	110.415	123.213
297.00	0.554	1.145	89.606	111.246	124.069
297.50	0.566	1.168	90.364	112.081	124.928
298.00	0.578	1.191	91.126	112.919	125.789
298.50	0.591	1.215	91.892	113.760	126.654
299.00	0.604	1.240	92.662	114.605	127.522
299.50	0.617	1.265	93.436	115.454	128.394

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
300.00	0.630	1.290	94.214	116.306	129.268
300.50	0.644	1.316	94.995	117.161	130.145
301.00	0.658	1.342	95.781	118.020	131.026
301.50	0.672	1.368	96.570	118.883	131.909
302.00	0.686	1.395	97.363	119.749	132.796
302.50	0.700	1.423	98.160	120.618	133.686
303.00	0.715	1.450	98.962	121.491	134.579
303.50	0.730	1.479	99.767	122.368	135.475
304.00	0.746	1.508	100.575	123.248	136.375
304.50	0.761	1.537	101.388	124.131	137.277
305.00	0.777	1.566	102.205	125.018	138.182
305.50	0.793	1.597	103.026	125.909	139.091
306.00	0.810	1.627	103.850	126.803	140.002
306.50	0.827	1.658	104.679	127.700	140.917
307.00	0.844	1.690	105.511	128.601	141.835
307.50	0.861	1.722	106.348	129.506	142.756
308.00	0.879	1.755	107.188	130.414	143.680
308.50	0.896	1.788	108.032	131.325	144.607
309.00	0.915	1.821	108.881	132.240	145.537
309.50	0.933	1.855	109.733	133.158	146.470
310.00	0.952	1.890	110.589	134.080	147.407

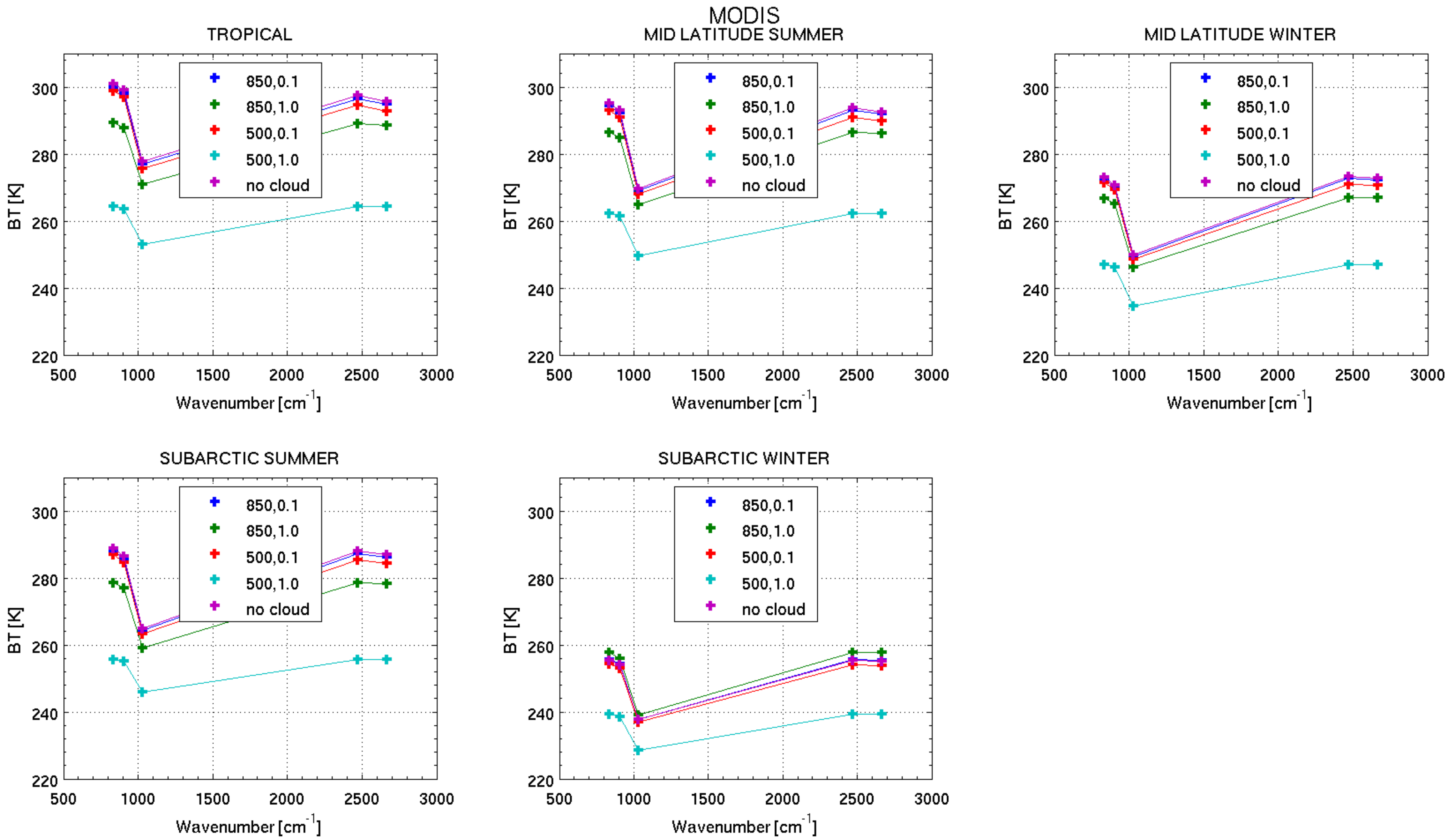
RTTOVS Calculations with ε_s from ISEM

IASI BTs for cloudy cases, various cloud heights & fractions



RTTOVS Calculations with ε_s from ISEM

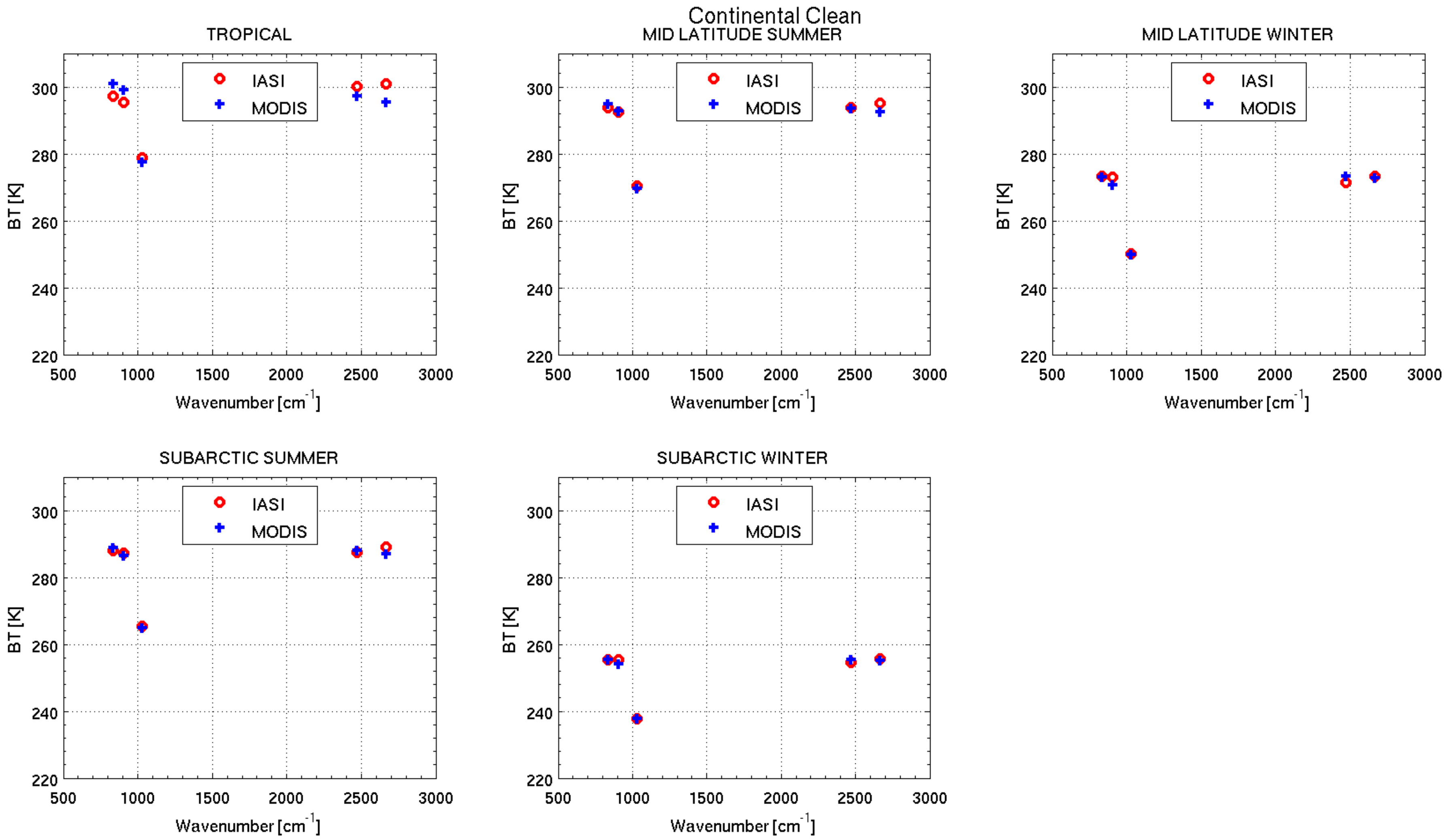
MODIS BTs for cloudy cases, various cloud heights & fractions



Aerosol calculations (using climatological profiles)

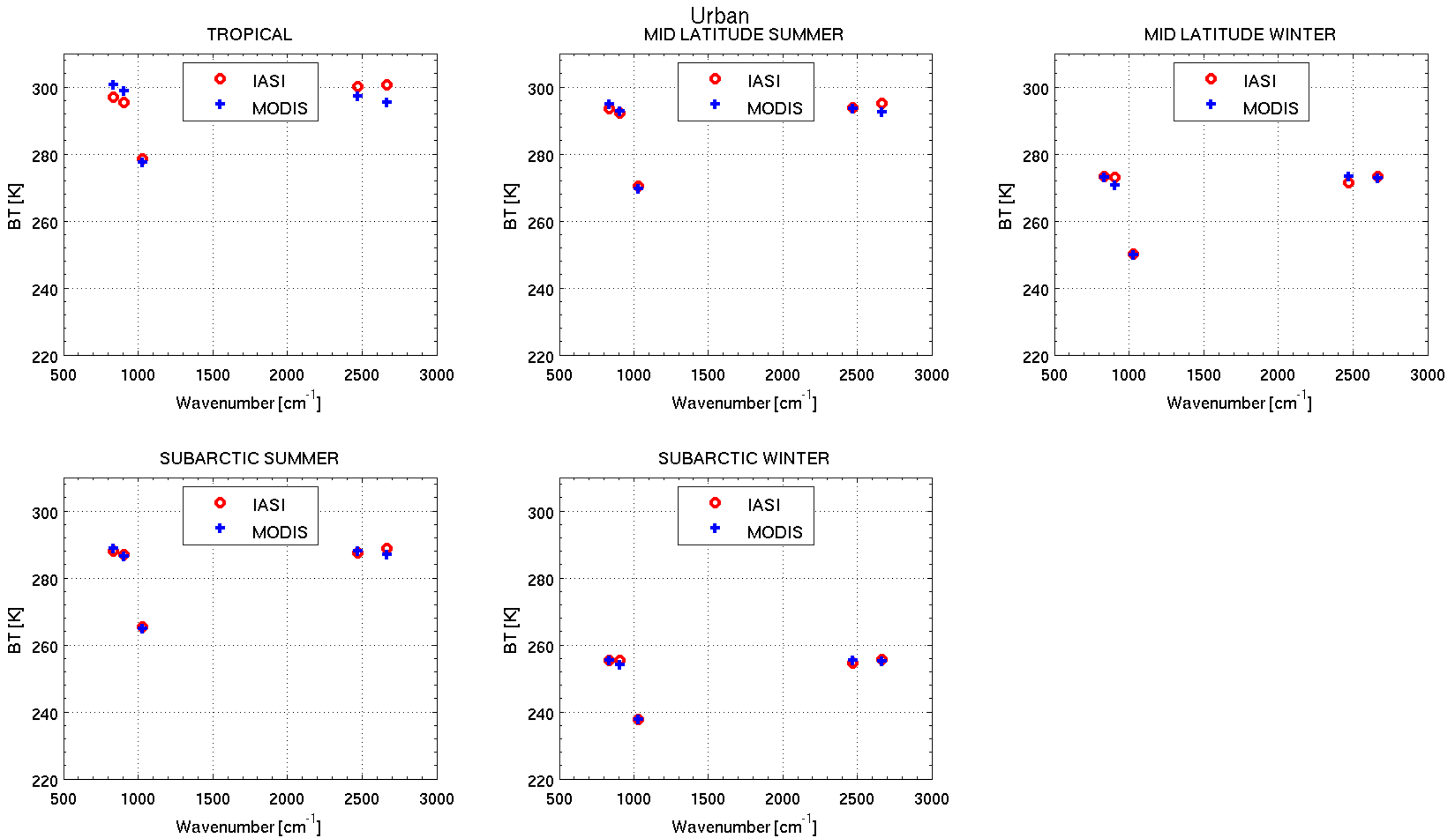
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs, Aerosol climatology: continental clean



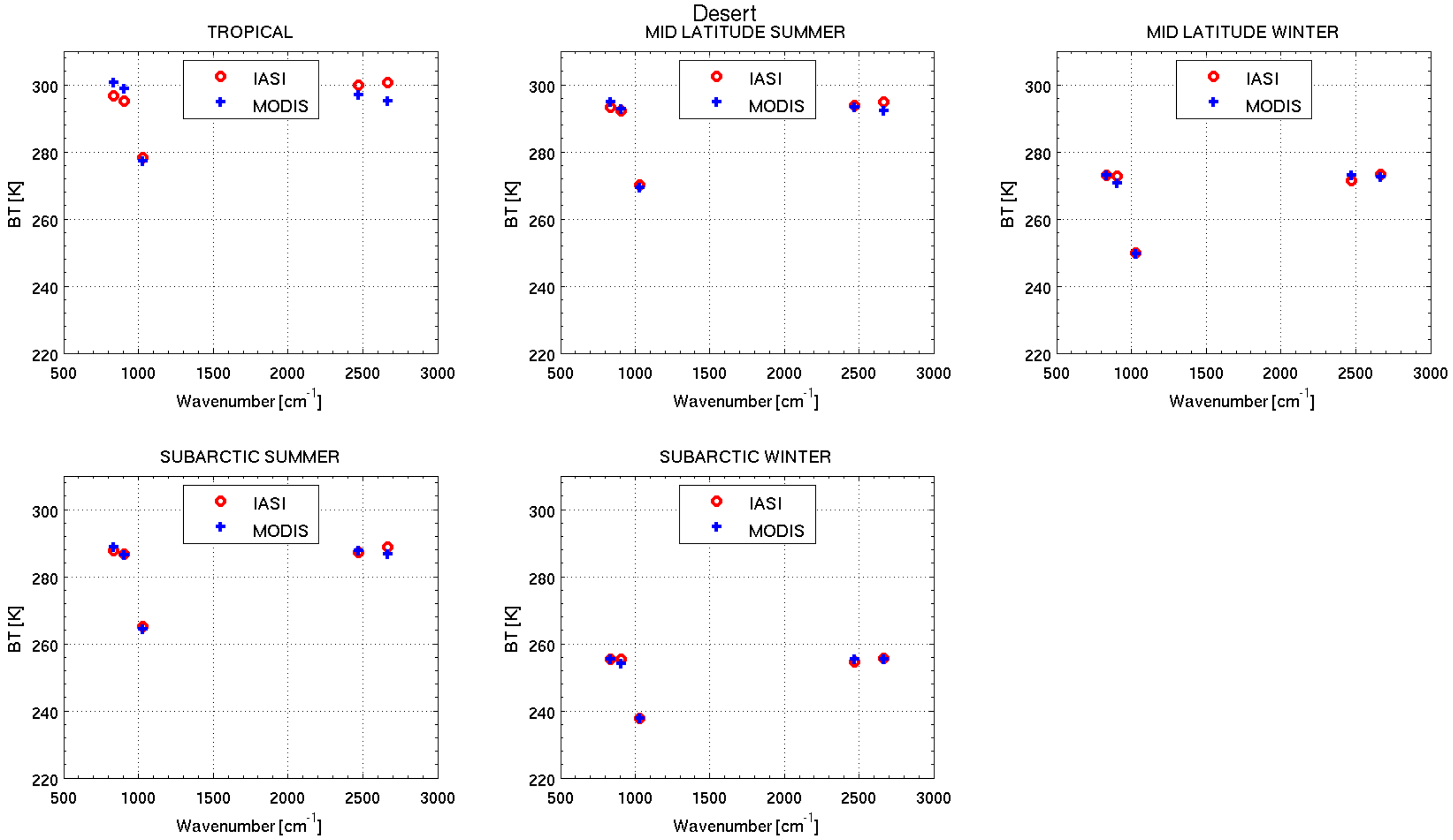
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs, Aerosol climatology: urban



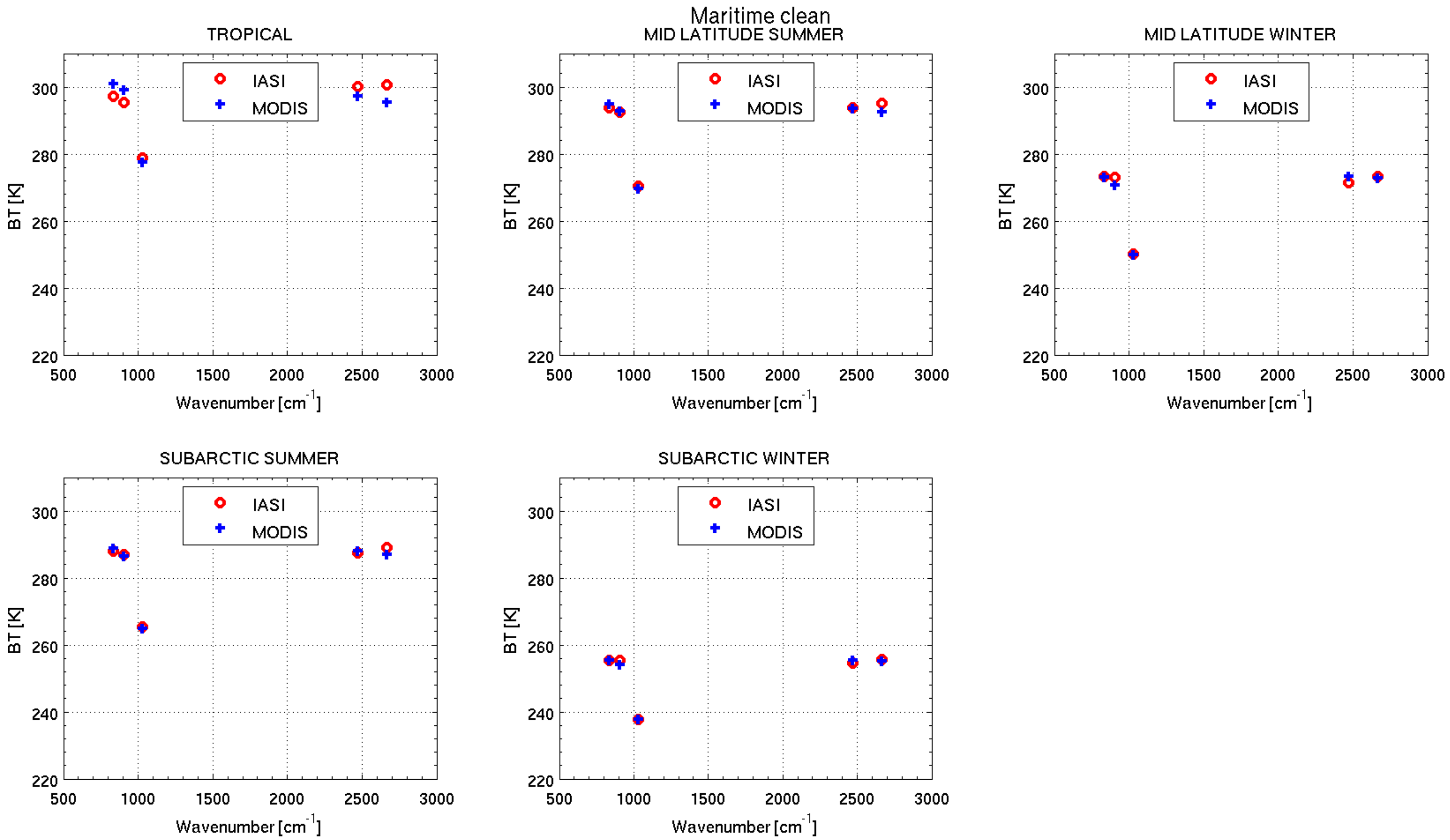
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs, Aerosol climatology: desert



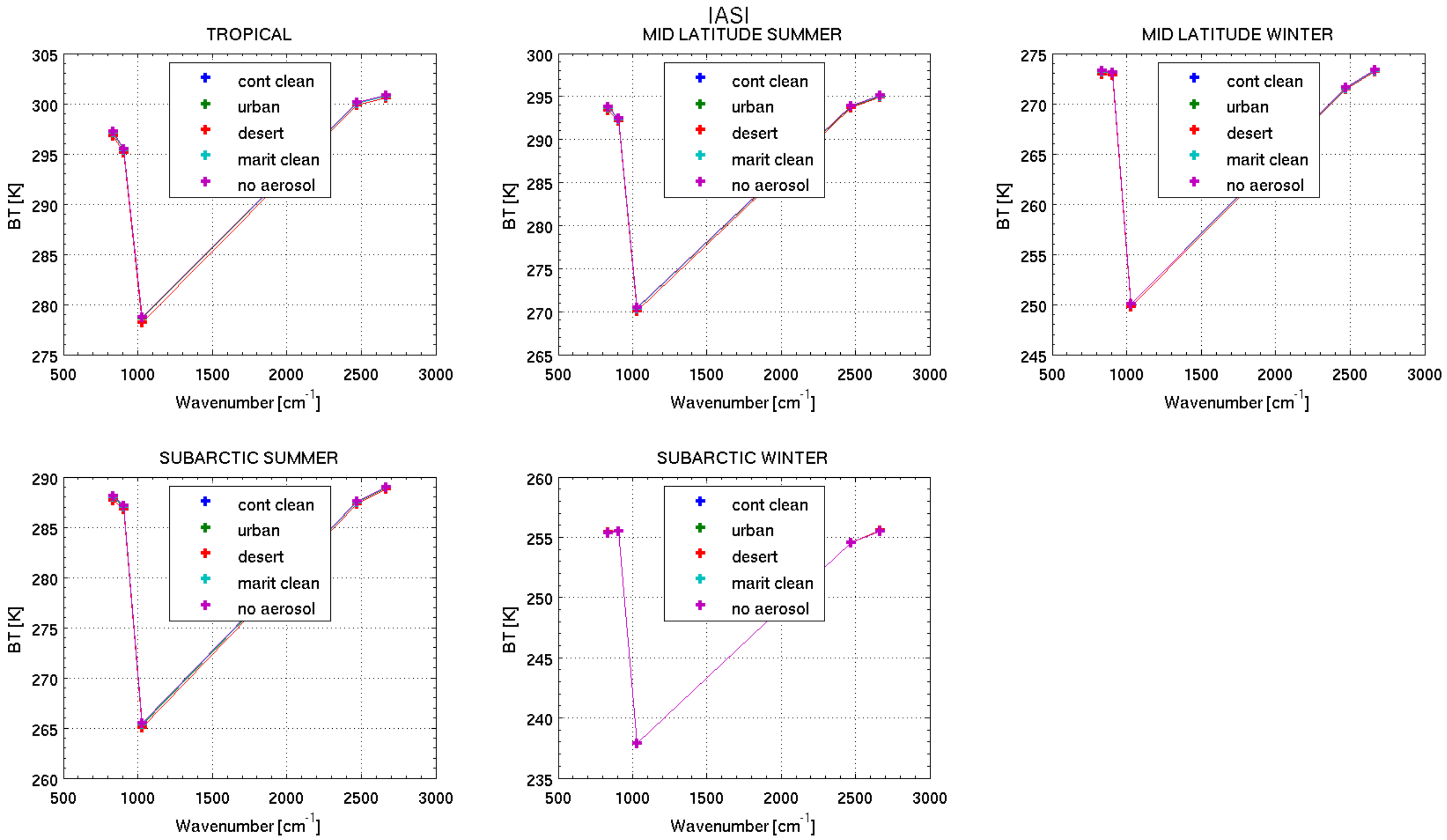
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs, Aerosol climatology: maritime clean



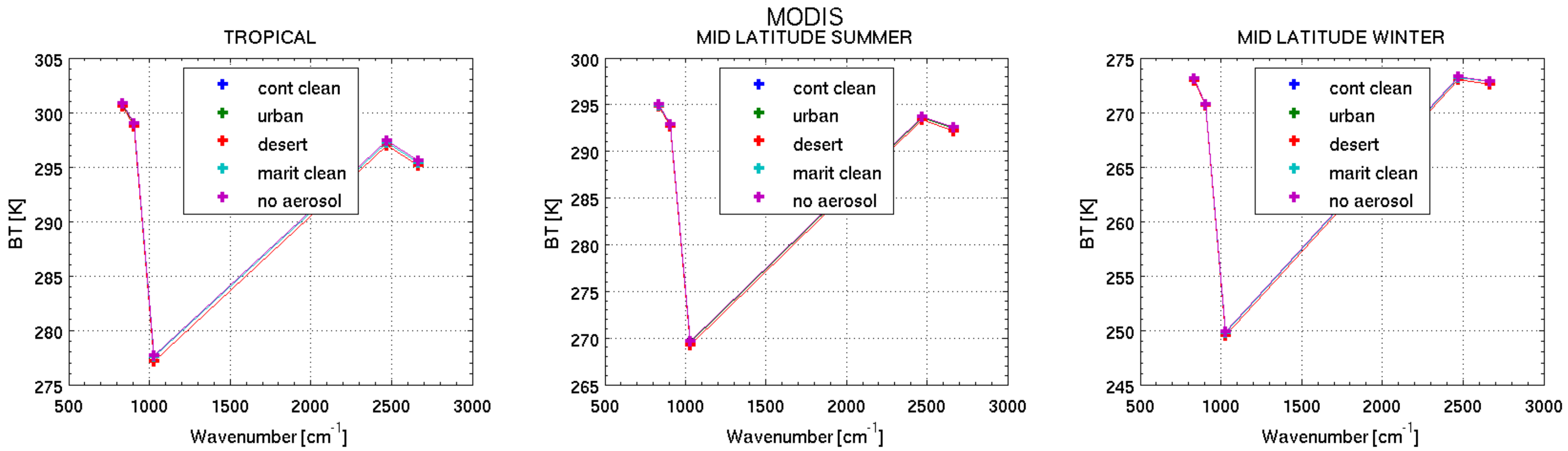
RTTOVS Calculations with ε_s from ISEM

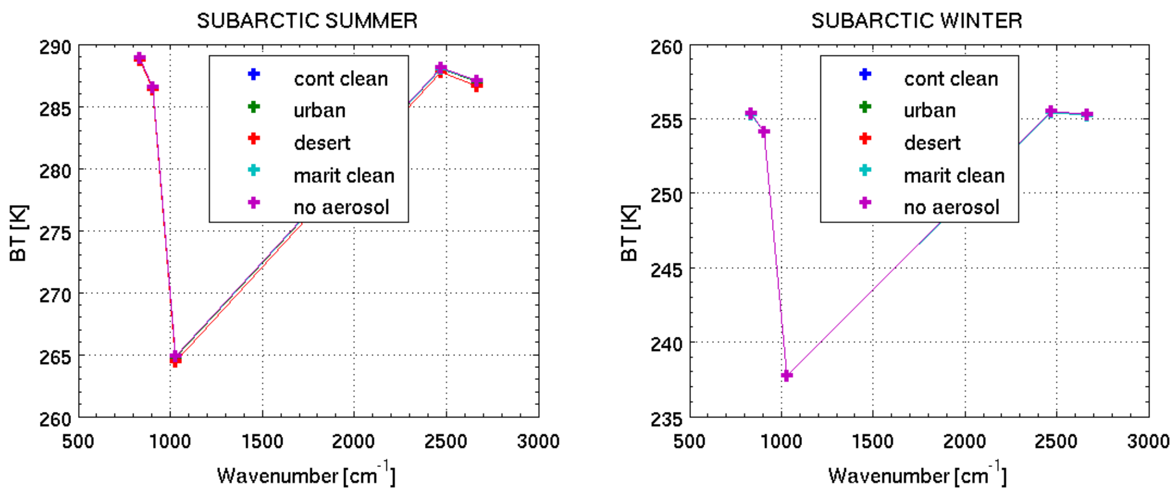
IASI BTs for different aerosol climatologies



RTTOVS Calculations with ε_s from ISEM

MODIS BTs for different aerosol climatologies

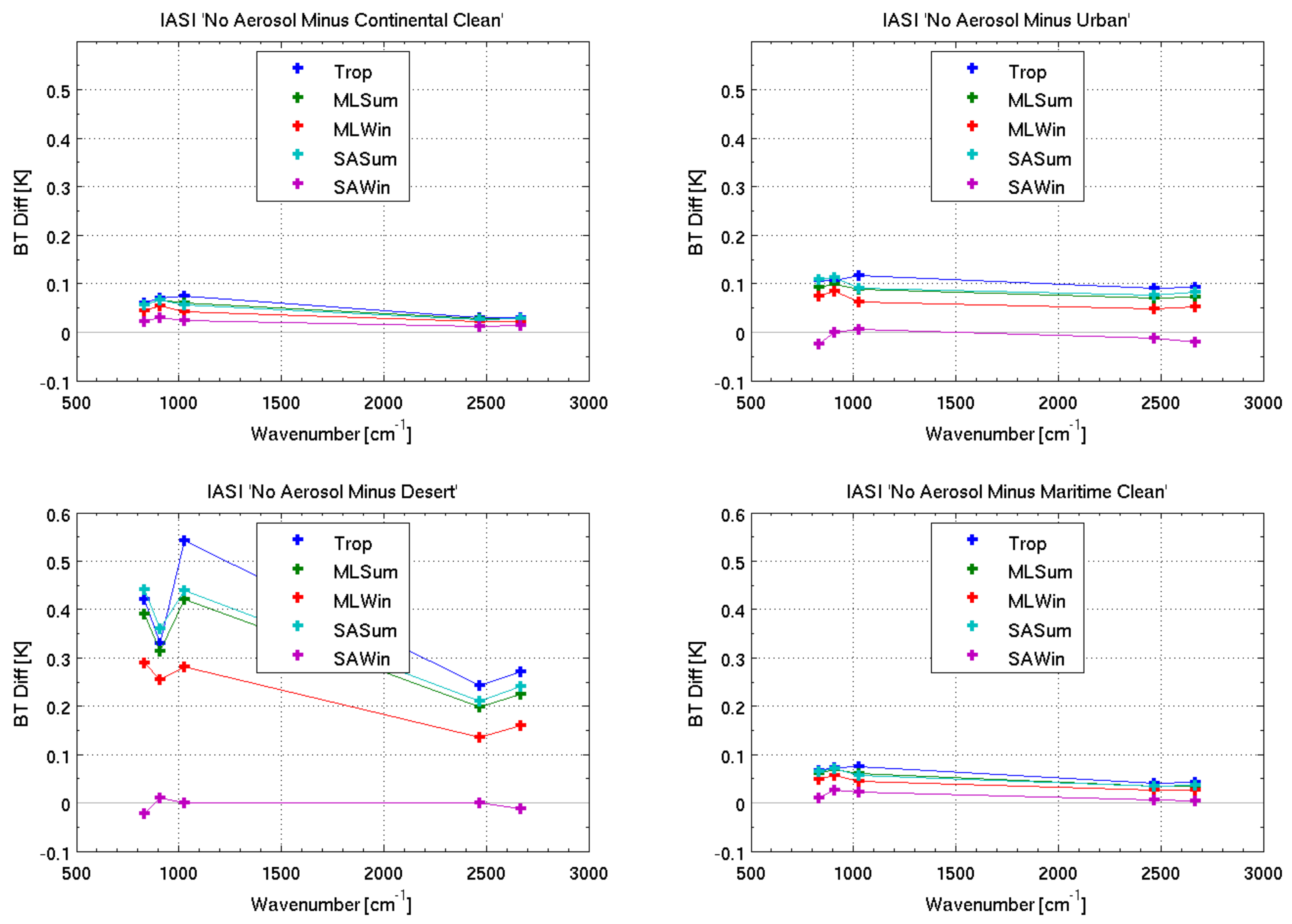




Discuss aerosol impatcs on the brightness temp. Also compare IASI and MODIS to see which measurements suffer more impacts.

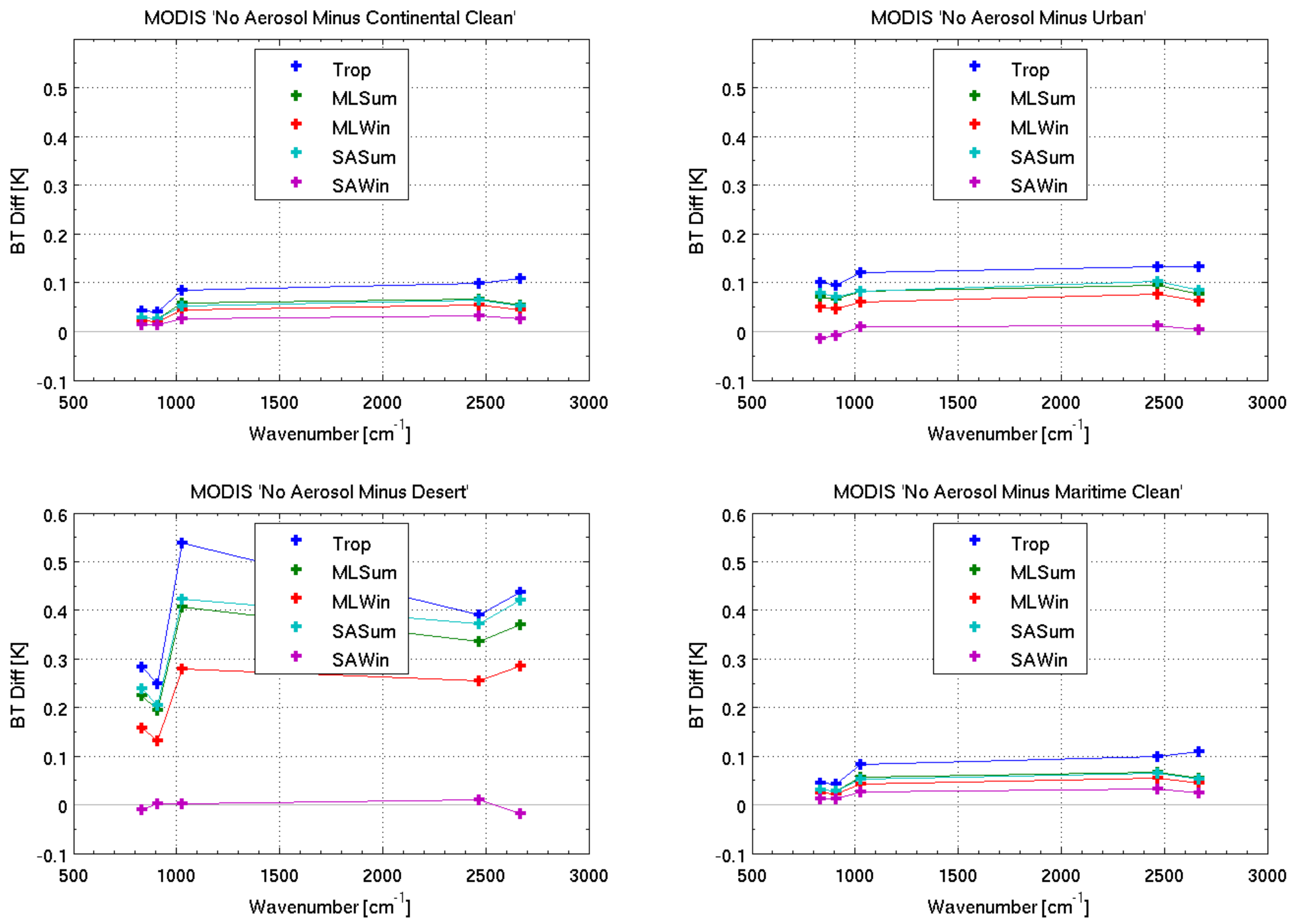
RTTOVS Calculations with ε_s from ISEM

IASI BT differences "No aerosol minus aerosol climatology"



RTTOVS Calculations with ε_s from ISEM

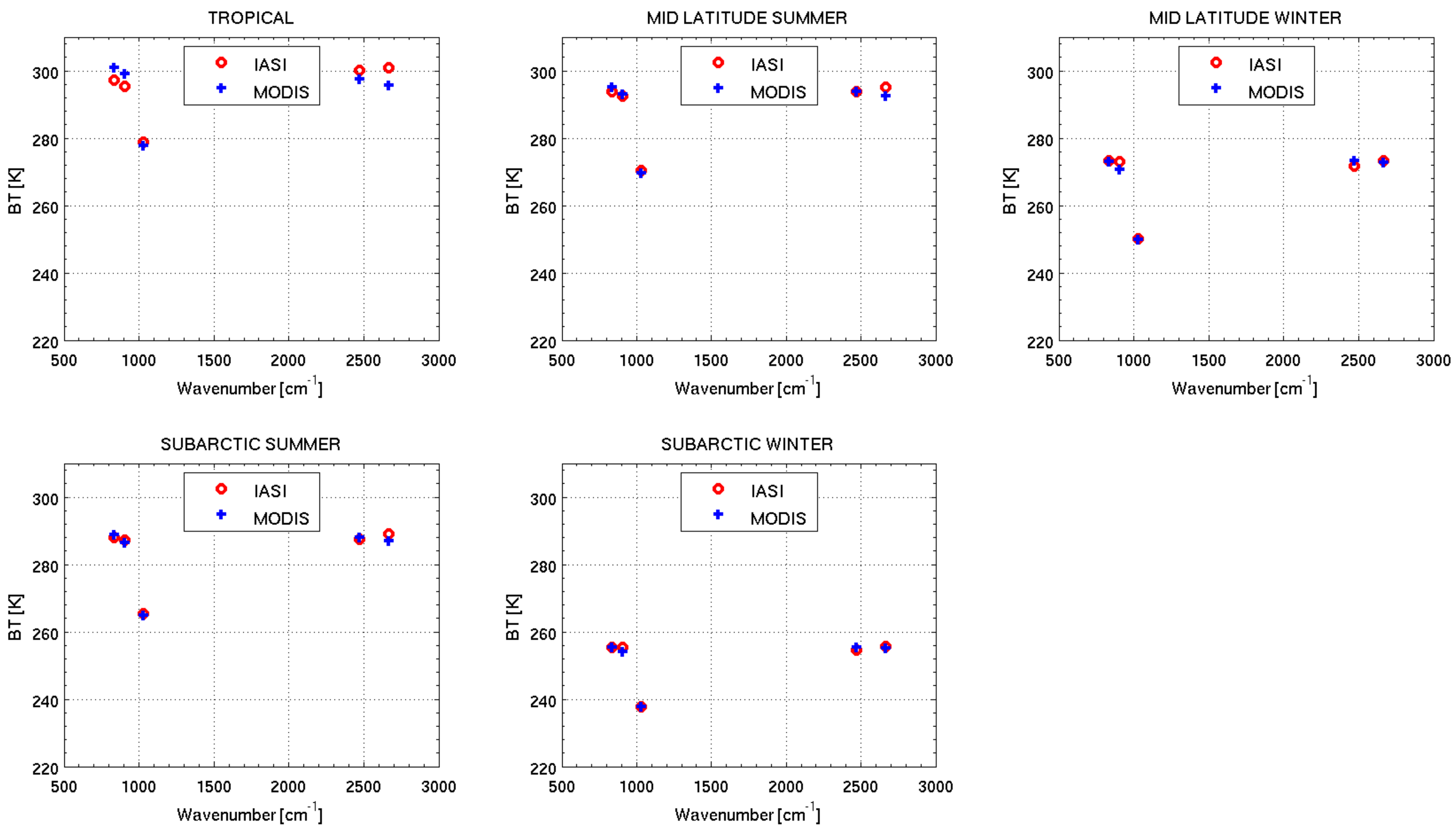
MODIS BT differences "No aerosol minus aerosol climatology"



Double trace gas concentrations (O_3 only)

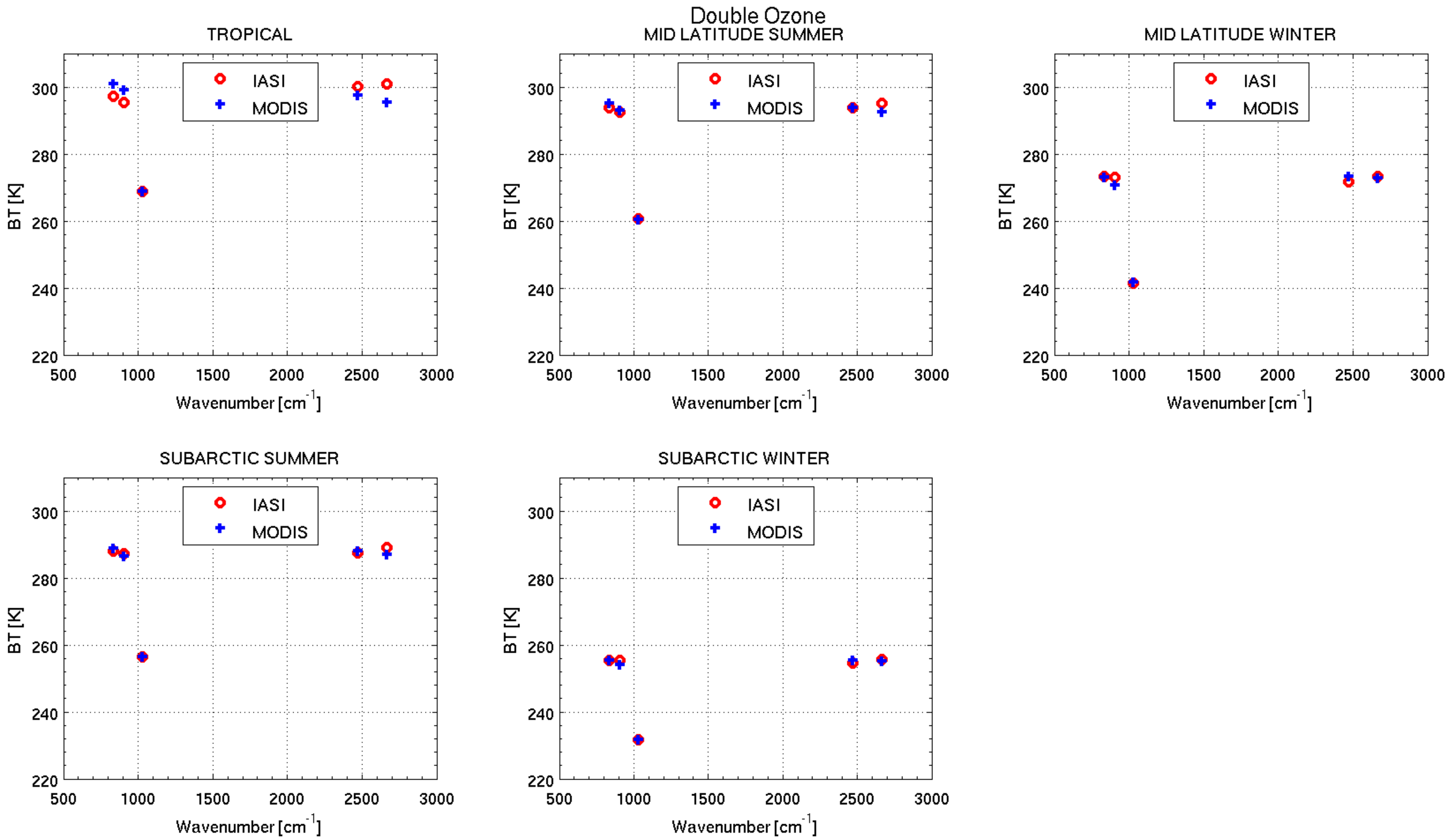
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs with original Ozone



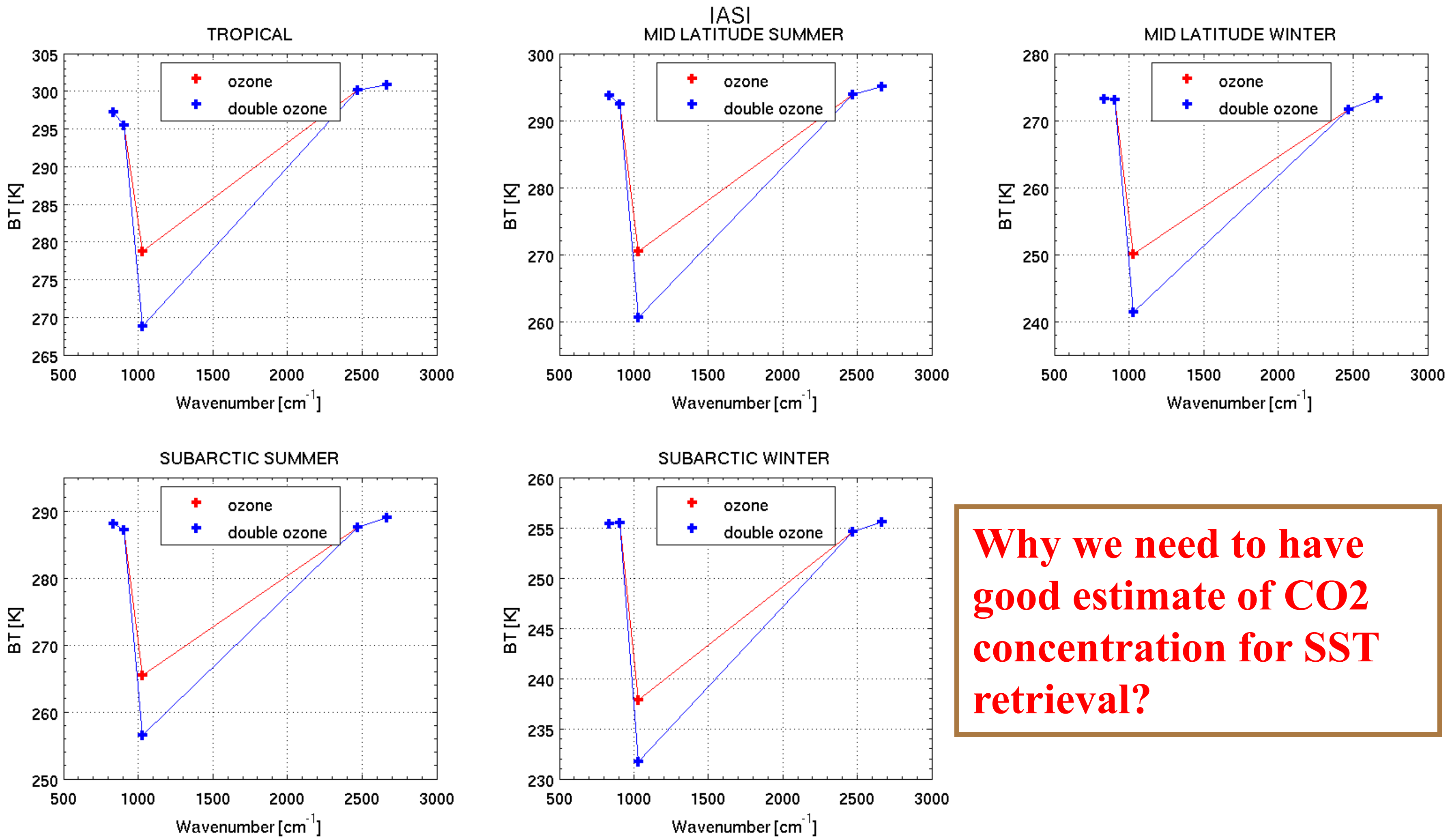
RTTOVS Calculations with ε_s from ISEM

IASI and MODIS BTs for doubled Ozone



RTTOVS Calculations with ε_s from ISEM

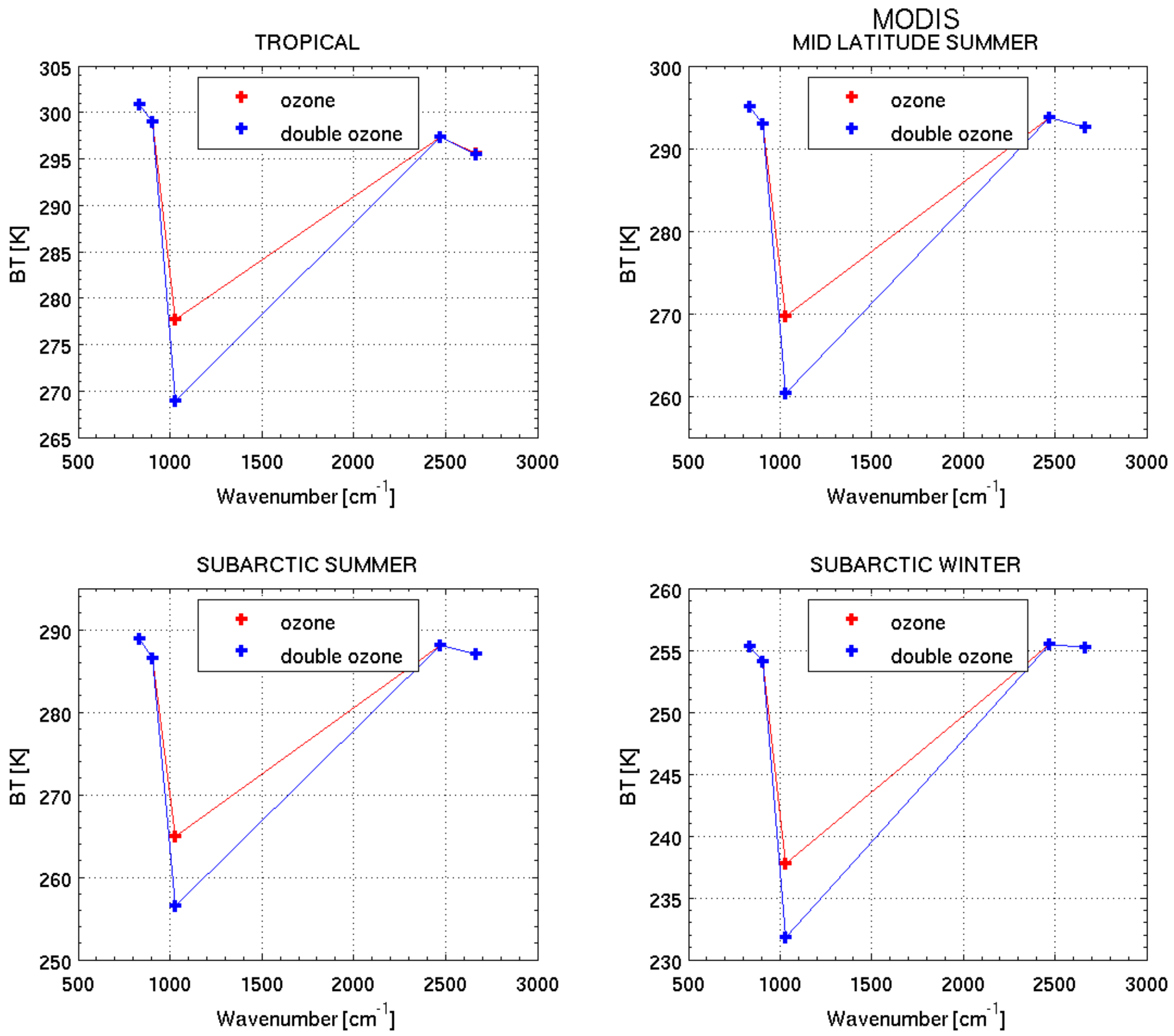
IASI BTs with and without doubled ozone



Why we need to have good estimate of CO2 concentration for SST retrieval?

RTTOVS Calculations with ε_s from ISEM

MODIS BTs with and without doubled ozone

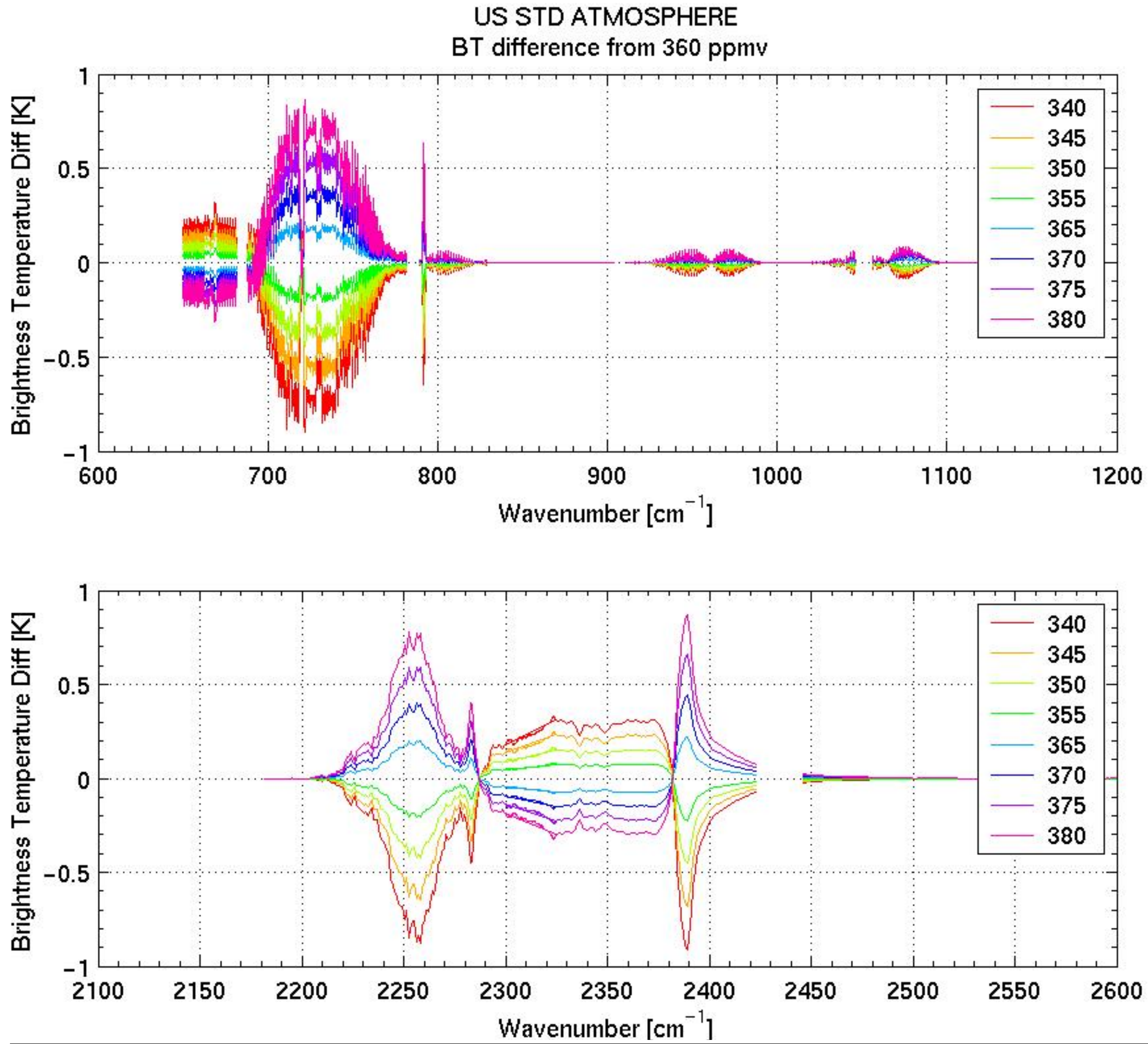


Why we need to have good estimate of CO2 concentration for SST retrieval?

Who suffer more? IASI or MODIS?

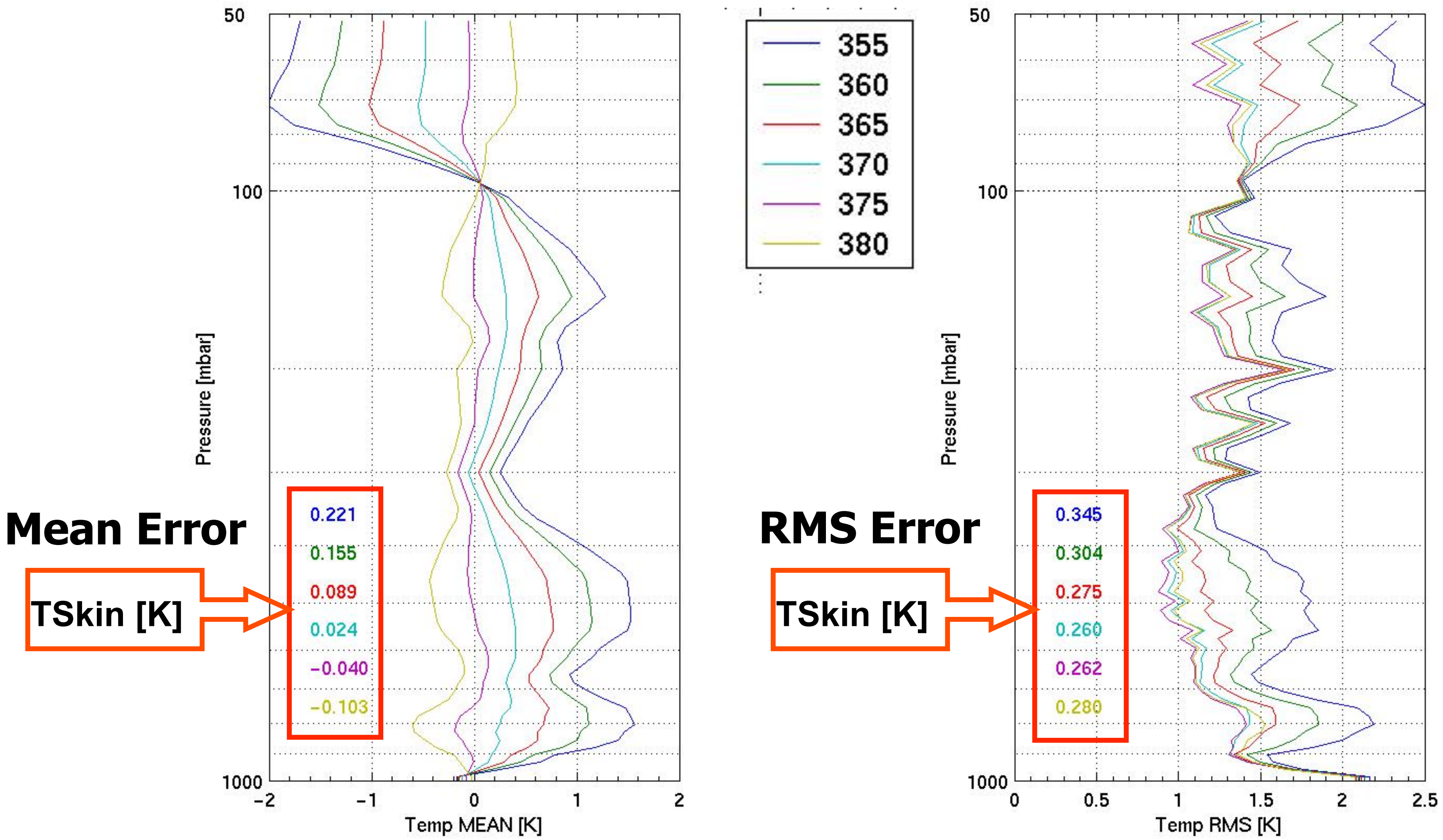
Impact of CO2 Concentration

BT with 360 ppmv minus BT with 340,345,…380 ppmv



Impact of CO2 Concentration

Mean & RMS of [True – RTV@355,360,365,370,375,380 ppmv]



'True' CO2 amount: 375 ppmv

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
240.00	0.026	0.067	27.335	38.889	47.111
240.50	0.027	0.069	27.688	39.332	47.606
241.00	0.028	0.071	28.044	39.779	48.103
241.50	0.028	0.073	28.404	40.230	48.604
242.00	0.029	0.076	28.766	40.683	49.108
242.50	0.030	0.078	29.132	41.140	49.615
243.00	0.031	0.080	29.500	41.600	50.125
243.50	0.032	0.083	29.872	42.063	50.639
244.00	0.033	0.085	30.247	42.530	51.155
244.50	0.035	0.088	30.625	42.999	51.675
245.00	0.036	0.090	31.006	43.472	52.198
245.50	0.037	0.093	31.391	43.948	52.724
246.00	0.038	0.096	31.778	44.428	53.253
246.50	0.039	0.099	32.169	44.911	53.785
247.00	0.041	0.102	32.563	45.397	54.321
247.50	0.042	0.105	32.960	45.886	54.860
248.00	0.043	0.108	33.361	46.379	55.402
248.50	0.045	0.111	33.765	46.875	55.947
249.00	0.046	0.114	34.172	47.374	56.495
249.50	0.047	0.117	34.582	47.877	57.046

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
250.00	0.049	0.121	34.995	48.383	57.601
250.50	0.050	0.124	35.412	48.892	58.159
251.00	0.052	0.128	35.832	49.404	58.720
251.50	0.054	0.131	36.255	49.920	59.284
252.00	0.055	0.135	36.682	50.440	59.852
252.50	0.057	0.139	37.112	50.962	60.422
253.00	0.059	0.143	37.545	51.488	60.996
253.50	0.060	0.147	37.982	52.017	61.573
254.00	0.062	0.151	38.422	52.550	62.153
254.50	0.064	0.155	38.865	53.086	62.737
255.00	0.066	0.160	39.312	53.625	63.323
255.50	0.068	0.164	39.762	54.168	63.913
256.00	0.070	0.169	40.215	54.714	64.506
256.50	0.072	0.173	40.672	55.264	65.103
257.00	0.074	0.178	41.132	55.817	65.702
257.50	0.076	0.183	41.596	56.373	66.305
258.00	0.079	0.188	42.063	56.932	66.911
258.50	0.081	0.193	42.533	57.496	67.520
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272.00	0.169	0.381	56.558	73.993	85.183
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275.00	0.197	0.440	60.030	78.001	89.427
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276.00	0.207	0.461	61.217	79.365	90.868
276.50	0.213	0.472	61.816	80.053	91.593
277.00	0.218	0.483	62.418	80.743	92.321
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279.50	0.247	0.541	65.486	84.249	96.010

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280.50	0.259	0.566	66.739	85.676	97.508
281.00	0.265	0.579	67.372	86.395	98.262
281.50	0.272	0.592	68.008	87.117	99.019
282.00	0.279	0.606	68.647	87.843	99.780
282.50	0.285	0.619	69.291	88.572	100.543
283.00	0.292	0.633	69.938	89.305	101.310
283.50	0.299	0.648	70.589	90.041	102.080
284.00	0.307	0.662	71.244	90.781	102.853
284.50	0.314	0.677	71.903	91.524	103.629
285.00	0.321	0.692	72.565	92.271	104.409
285.50	0.329	0.707	73.231	93.021	105.191
286.00	0.337	0.722	73.901	93.775	105.977
286.50	0.345	0.738	74.575	94.532	106.766
287.00	0.353	0.754	75.252	95.293	107.559
287.50	0.361	0.771	75.933	96.057	108.354
288.00	0.370	0.788	76.619	96.825	109.153
288.50	0.379	0.805	77.307	97.597	109.954
289.00	0.387	0.822	78.000	98.371	110.759
289.50	0.396	0.840	78.697	99.150	111.567

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Temp.(K)	3.75	4.05	9.73	11.03	12.02
290.00	0.405	0.858	79.397	99.932	112.379
290.50	0.415	0.876	80.101	100.717	113.193
291.00	0.424	0.894	80.809	101.506	114.011
291.50	0.434	0.913	81.521	102.298	114.832
292.00	0.444	0.933	82.237	103.094	115.656
292.50	0.454	0.952	82.956	103.894	116.483
293.00	0.464	0.972	83.680	104.696	117.313
293.50	0.475	0.992	84.407	105.503	118.146
294.00	0.485	1.013	85.138	106.313	118.983
294.50	0.496	1.034	85.873	107.126	119.823
295.00	0.507	1.055	86.612	107.943	120.666
295.50	0.519	1.077	87.355	108.764	121.512
296.00	0.530	1.099	88.101	109.588	122.361
296.50	0.542	1.122	88.852	110.415	123.213
297.00	0.554	1.145	89.606	111.246	124.069
297.50	0.566	1.168	90.364	112.081	124.928
298.00	0.578	1.191	91.126	112.919	125.789
298.50	0.591	1.215	91.892	113.760	126.654
299.00	0.604	1.240	92.662	114.605	127.522
299.50	0.617	1.265	93.436	115.454	128.394

Radiance Table for MODIS Window Channels

Temp.(K)	3.75	4.05	9.73	11.03	12.02
300.00	0.630	1.290	94.214	116.306	129.268
300.50	0.644	1.316	94.995	117.161	130.145
301.00	0.658	1.342	95.781	118.020	131.026
301.50	0.672	1.368	96.570	118.883	131.909
302.00	0.686	1.395	97.363	119.749	132.796
302.50	0.700	1.423	98.160	120.618	133.686
303.00	0.715	1.450	98.962	121.491	134.579
303.50	0.730	1.479	99.767	122.368	135.475
304.00	0.746	1.508	100.575	123.248	136.375
304.50	0.761	1.537	101.388	124.131	137.277
305.00	0.777	1.566	102.205	125.018	138.182
305.50	0.793	1.597	103.026	125.909	139.091
306.00	0.810	1.627	103.850	126.803	140.002
306.50	0.827	1.658	104.679	127.700	140.917
307.00	0.844	1.690	105.511	128.601	141.835
307.50	0.861	1.722	106.348	129.506	142.756
308.00	0.879	1.755	107.188	130.414	143.680
308.50	0.896	1.788	108.032	131.325	144.607
309.00	0.915	1.821	108.881	132.240	145.537
309.50	0.933	1.855	109.733	133.158	146.470
310.00	0.952	1.890	110.589	134.080	147.407