Application of FY3 in Data Assimilation

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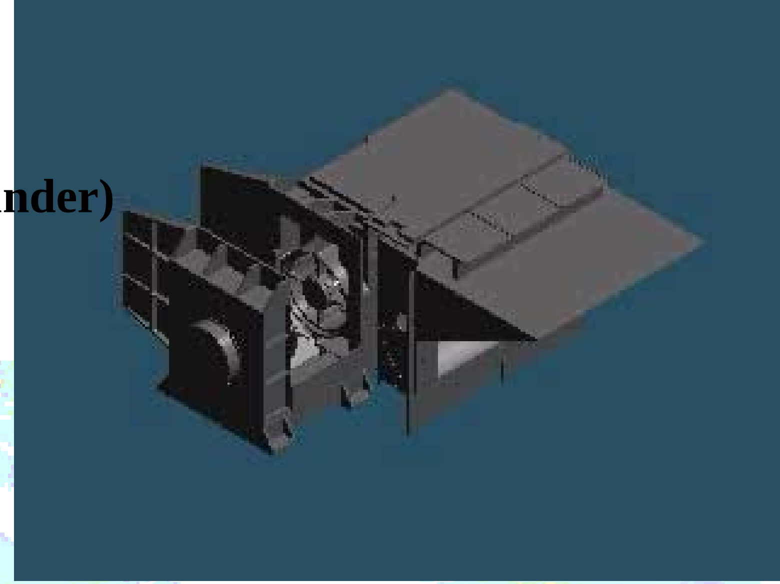
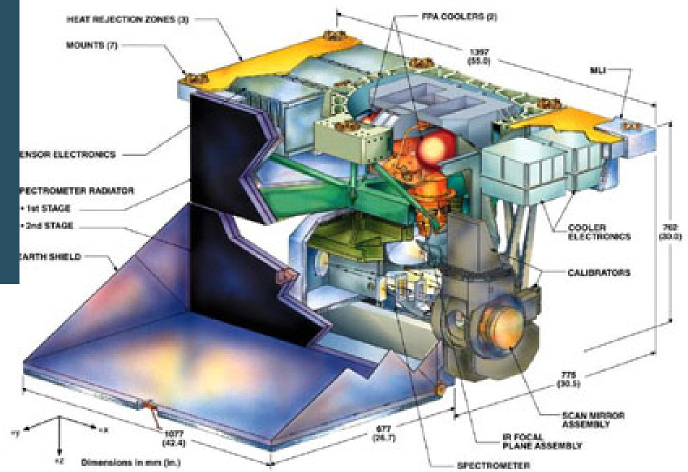
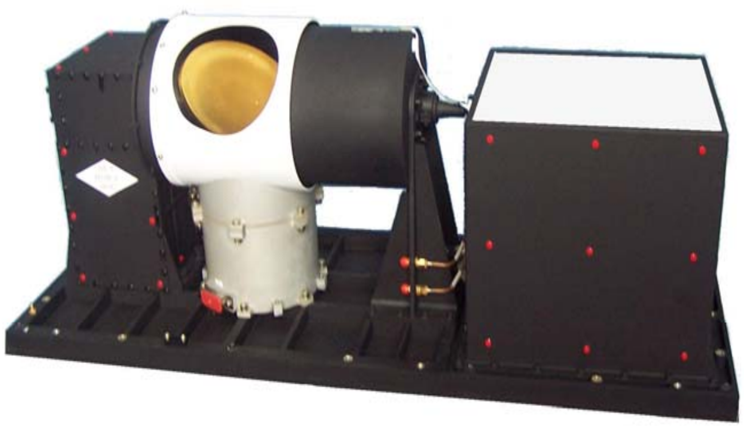
IRAS(InfRared Atmosphere sounder)





AIRS



MWTS(MicroWwave Temperature Sounder)

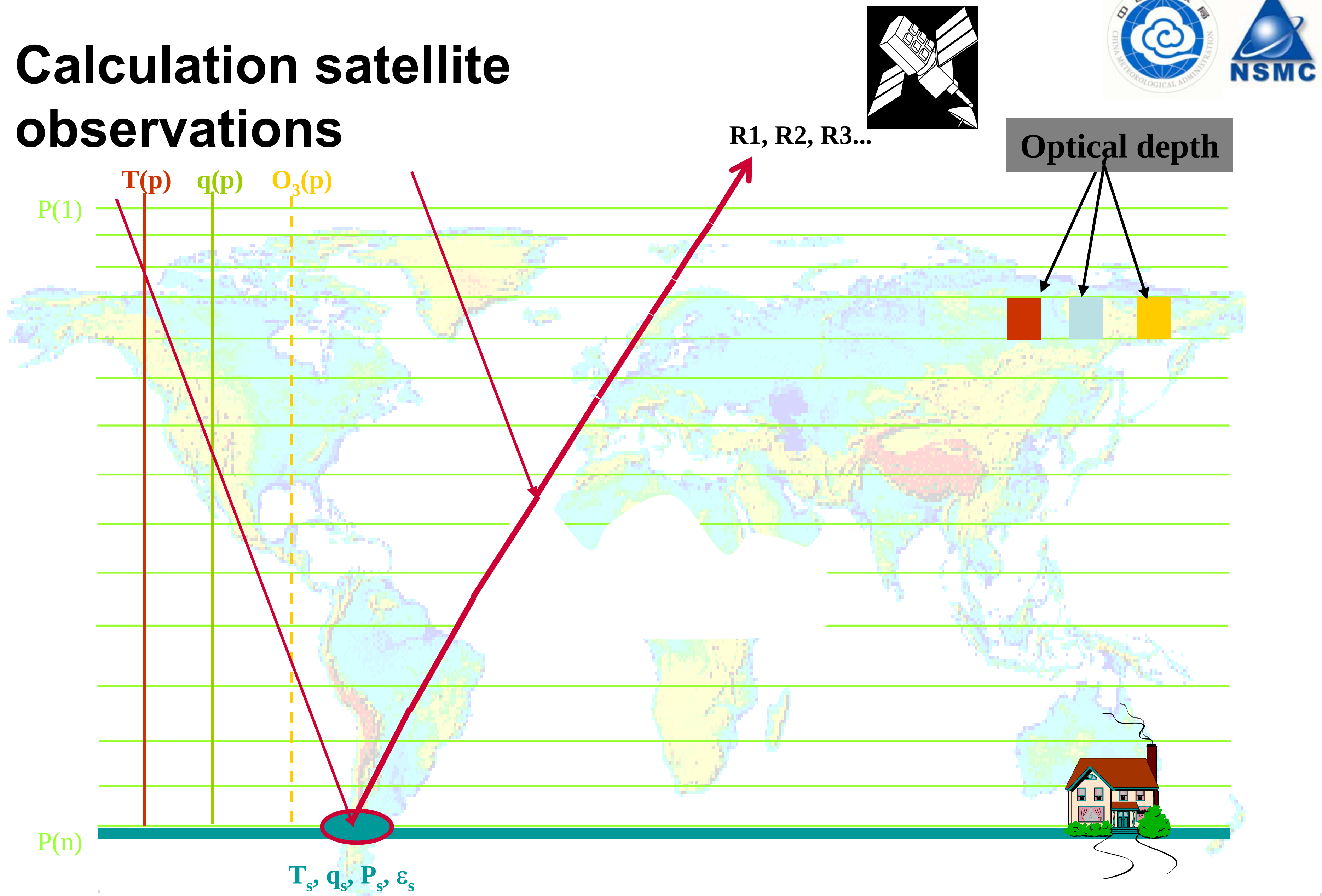
MWHS(MicroWave Humidity Sounder)

- Introduce FY3 data into assimilation is one of the most important in the development of NWP in CMA
- Sounding data of satellite are the primary data in NWP data assimilation now
- Application radiance data from satellite in NWP data assimilation depend on a linear fast forward model

- Question:
- Impact of matching data from NWP model grid to satellite pixel?
- Bias generate from defination of predictor in fast radiative transfer model?

Analysis to predictors in fast forward model

Calculation satellite observations



Radiative transfer equation

$$R_\nu \cong \varepsilon_\nu B_\nu(\Theta_s)T_{s,\nu} + \int_{p_s}^{0} B_\nu(\Theta(p))\frac{\partial T_\nu(p,\theta_u)}{\partial p}dp$$
$$+(1-\varepsilon_\nu)T_{s,\nu}\int_{0}^{p_s} B_\nu(\Theta(p))\frac{\partial T_\nu^*(p,\theta_d)}{\partial p}dp + \rho_\nu T_{s,\nu}T_\nu(p_s,\theta_{sun})F_{0,\nu}\cos\theta_{sun}$$

- **Radiance from surface**
- **Upwelling radiance from atmosphere**
- **Downwelling radiance reflected by surface**
- **Short-wave radiance from sun**

Main input for the fast forward model

Position in vector/element	Profile Array Contents	Units
1 to NLEV/1	Temperature profile	Deg/K
1 to NLEV/2	Water vapour profile	Kg/Kg
1 to NLEV/3	Ozone profile	Kg/Kg
1 to NLEV/4	Liqud water concentration profile(not used)	
Position in vector	Surface Array Contents	***Units***
1	Surface 2m temperature	Deg/K
2	Surface 2m water vapour	Kg/Kg
3	Surface pressure	hPa
4	2m vector wind speed u	$m.s^{-1}$
5	2m vector wind speed v	$m.s^{-1}$
Position in vector	Surface Skin Array Contents	***Units***
1	Radiative skin temperature	Deg/K
Position in vector	Cloud Array Contents	***Units***
1	Cloud top pressure	hPa
2	Cloud fractional cover	0-1
Position in vector	Surface Emissivity Array Contents	***Units***
1 to NCHAN	Surface emissivity	

Predicted channel optical depth for each layer

- Impact from mixed gas, water vapor and O3 are taken into considered while Channel transmittance is computed

$$\tau_{i,j} = e^{-d_{i,j}^{c}}$$

- The predictor $a_{i,j,k}$□are regressed from a LBL transmittance database which is generated from TIGR43 and GENLN2

$$d_{i,j} = d_{i,j-1} + \sum_{k=1}^{K} a_{i,j,k} X_{k,j}$$

$$X_{j,k} = X_{j,k} - X_{j,k}^{ref}$$

Defination of predictors are same to RTTOV

Predictor	Fixed gases	Water vapour	Ozone
$X_{j,1}$	$sec(\theta)$	$sec^2(\theta)\,W_r^2(j)$	$sec(\theta)\,O_r(j)$
$X_{j,2}$	$sec^2(\theta)$	$(sec(\theta)\,W_w(j))^2$	$\sqrt{sec(\theta)\,O_r(j)}$
$X_{j,3}$	$sec(\theta)\,T_r(j)$	$(sec(\theta)\,W_w(j))^4$	$sec(\theta)\,O_r(j)\,\delta T(j)$
$X_{j,4}$	$sec(\theta)\,T_r^2(j)$	$sec(\theta)\,W_r(j)\,\delta T(j)$	$(sec(\theta)\,O_r(j))^2$
$X_{j,5}$	$T_r(j)$	$\sqrt{sec(\theta)\,W_r(j)}$	$\sqrt{sec(\theta)\,O_r(j)}\ \delta T(j)$
$X_{j,6}$	$T_r^2(j)$	$\sqrt[4]{sec(\theta)\,W_r(j)}$	$sec(\theta)\,O_r(j)^2\,O_w(j)$
$X_{j,7}$	$sec(\theta)\,T_w(j)$	$sec(\theta)\,W_r(j)$	$\frac{O_r(j)}{O_w(j)}\sqrt{sec(\theta)\,O_r(j)}$
$X_{j,8}$	$sec(\theta)\,\frac{T_w(j)}{T_r(j)}$	$(sec(\theta)\,W_r(j))^3$	$sec(\theta)\,O_r(j)\,O_w(j)$
$X_{j,9}$	$\sqrt{sec(\theta)}$	$(sec(\theta)\,W_r(j))^4$	$O_r(j)\,sec(\theta)\,\sqrt{(O_w(j)\,sec(\theta)}$
$X_{j,10}$	$\sqrt{sec(\theta)}\ \sqrt[4]{T_w(j)}$	$sec(\theta)\,W_r(j)\,\delta T(j)\,\lvert\delta T(j)\rvert$	$sec(\theta)\,O_w(j)$
$X_{j,11}$	0	$(\sqrt{sec(\theta)\,W_r(j)}\,)\,\delta T(j)$	$(sec(\theta)\,O_w(j))^2$
$X_{j,12}$	0	$\frac{(sec(\theta)\,W_r(j))^2}{W_w}$	0
$X_{j,13}$	0	$\frac{\sqrt{(sec(\theta)\,W_r(j)\,W_r(j)}}{W_w(j)}$	0
$X_{j,14}$	0	$sec(\theta)\,\frac{W_r^2(j)}{T_r(j)}$	0
$X_{j,15}$	0	$sec(\theta)\,\frac{W_r^2(j)}{T_r^4(j)}$	0

$$T(j)=[T^{profile}(j)+T^{profile}(j-1)]/2 \qquad T^*(j)=[T^{reference}(j)+T^{reference}(j-1)]/2$$

$$W(j)=[W^{profile}(j)+W^{profile}(j-1)]/2 \qquad W^*(j)=[W^{reference}(j)+W^{reference}(j-1)]/2$$

$$O(j)=[O^{profile}(j)+O^{profile}(j-1)]/2 \qquad O^*(j)=[O^{reference}(j)+O^{reference}(j-1)]/2$$

$$T_r(j)=T(j)/T^*(j) \qquad \delta T(j)=T(j)-T^*(j) \qquad W_r(j)=W(j)/W^*(j)$$

$$O_r(j)=O(j)/O^*(j)$$

$$T_w(j)=\sum_{l=2}^{j}P(l)[P(l)-P(l-1)]T_r(l-1)$$

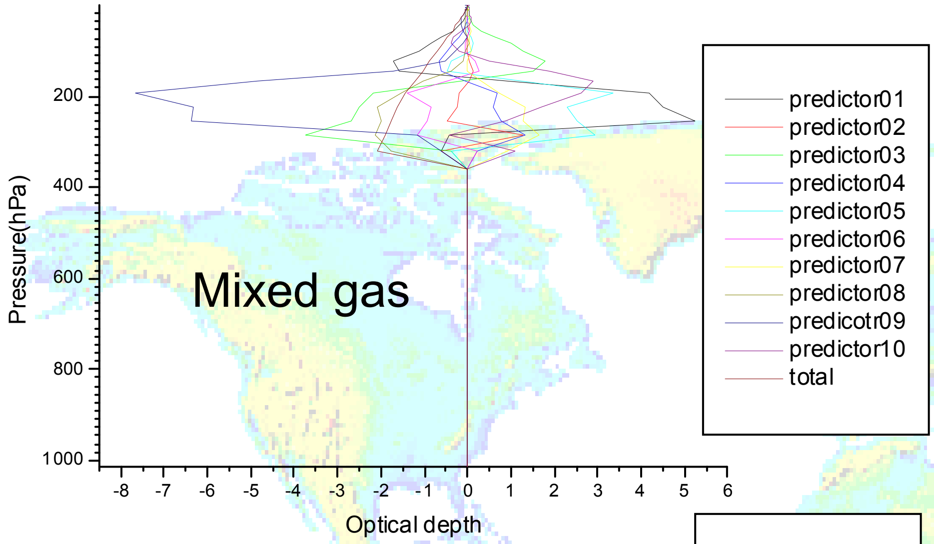
$$W_w(j)=\left\{\sum_{l=1}^{j}P(l)[P(l)-P(l-1)]W(l)\right\}/\left\{\sum_{l=1}^{j}P(l)[P(l)-P(l-1)]W^*(l)\right\}$$

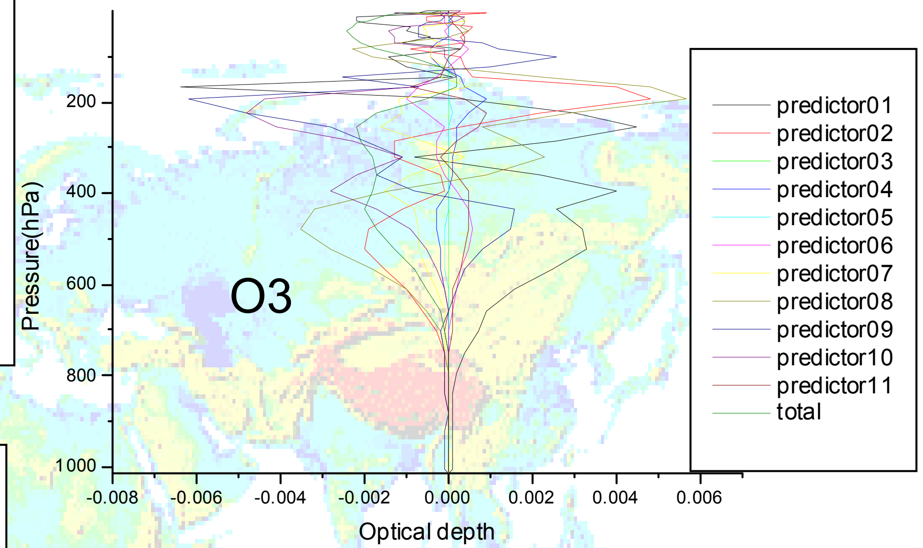
$$O_w(j)=\left\{\sum_{l=1}^{j}P(l)[P(l)-P(l-1)]O(l)\right\}/\left\{\sum_{l=1}^{j}P(l)[P(l)-P(l-1)]O^*(l)\right\}$$

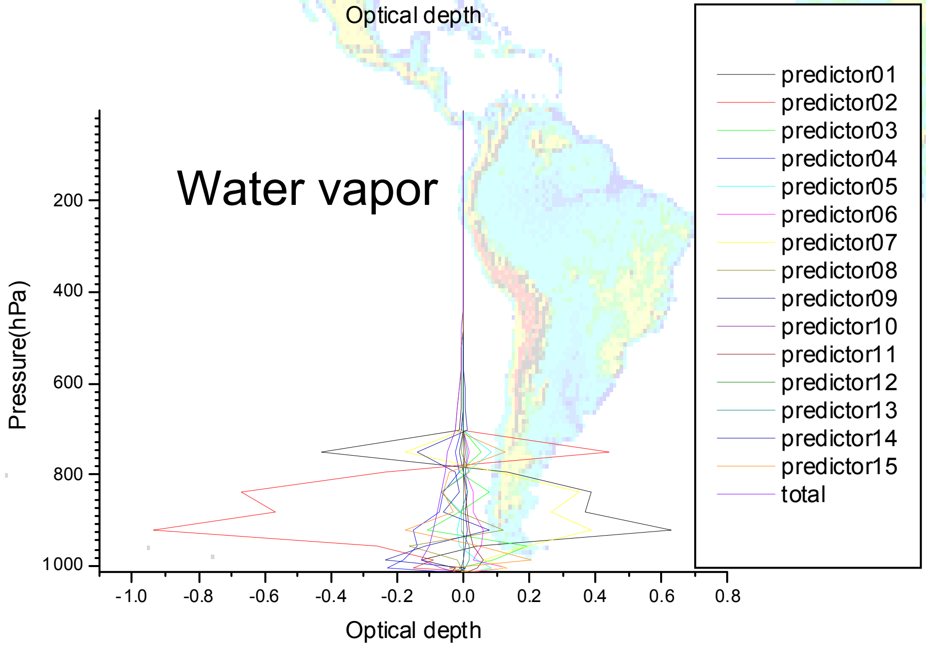
Parameters of IRAS

Channel number	Central wavenumber(cm^{-1})	Central wave lenth (μm)	Half power width (cm^{-1})	Main absorbers	Maximum observing temperature (K)	NEΔN (mW/m^2-sr-cm^{-1})	The most contribution layer (hPa)
1	669	14.95	3	CO_2	280	4.00	30
2	680	14.71	10	CO_2	265	0.80	60
3	690	14.49	12	CO_2	250	0.60	100
4	703	14.22	16	CO_2	260	0.35	400
5	716	13.97	16	CO_2	275	0.32	600
6	733	13.84	16	CO_2/H_2O	290	0.36	800
7	749	13.35	16	CO_2/H_2O	300	0.30	900
8	802	12.47	30	window	330	0.20	surface
9	900	11.11	35	window	330	0.15	surface
10	1030	9.71	25	O_3	280	0.20	25
11	1345	7.43	50	H_2O	330	0.23	800
12	1365	7.33	40	H_2O	285	0.30	700
13	1533	6.52	55	H_2O	275	0.30	500
14	2188	4.57	23	N_2O	310	0.009^*	1000
15	2210	4.52	23	N_2O	290	0.004^*	950
16	2235	4.47	23	CO_2/N_2O	280	0.006^*	700
17	2245	4.45	23	CO_2/N_2O	266	0.006^*	400
18	2388	4.19	25	CO_2	320	0.003^*	atmosphere
19	2515	3.98	35	window	340	0.003^*	surface
20	2660	3.76	100	window	340	0.002	surface
21	14500	0.69	1000	window	100%A	0.10%A	cloud
22	11299	0.885	385	window	100%A	0.10%A	surface
23	10638	0.94	550	H_2O	100%A	0.10%A	surface
24	10638	0.94	200	H_2O	100%A	0.10%A	surface
25	8065	1.24	650	H_2O	100%A	0.10%A	surface
26	6098	1.64	450	H_2O	100%A	0.10%A	surface

Analysis to the predicted optical depth for each predictor on every layer(1) – for AIRS



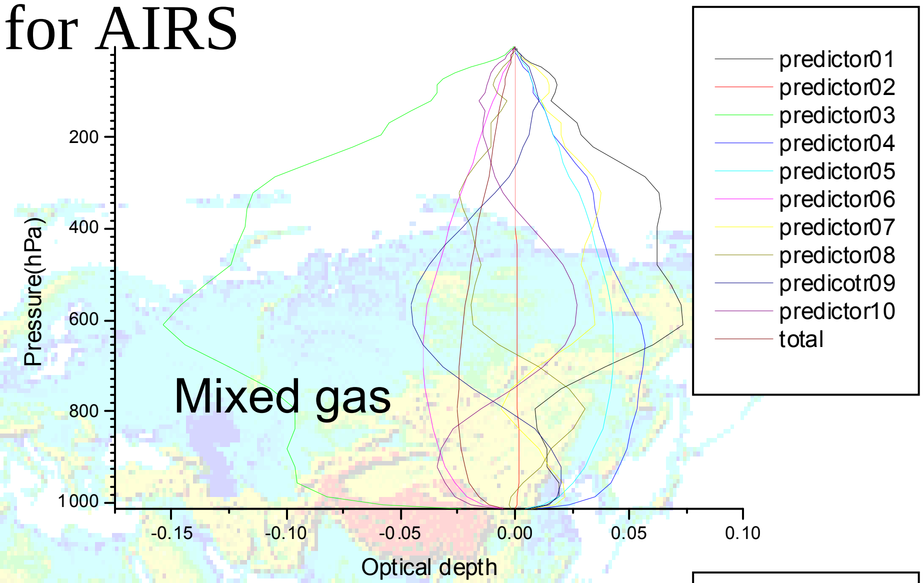


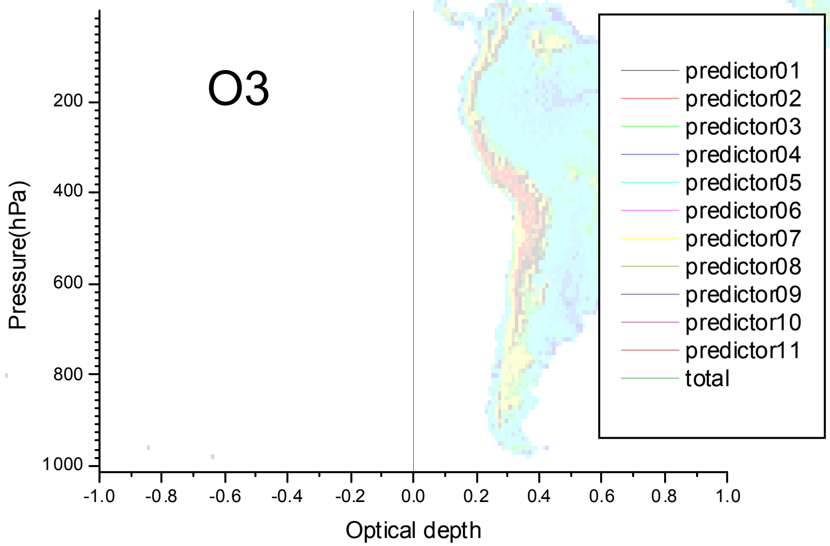


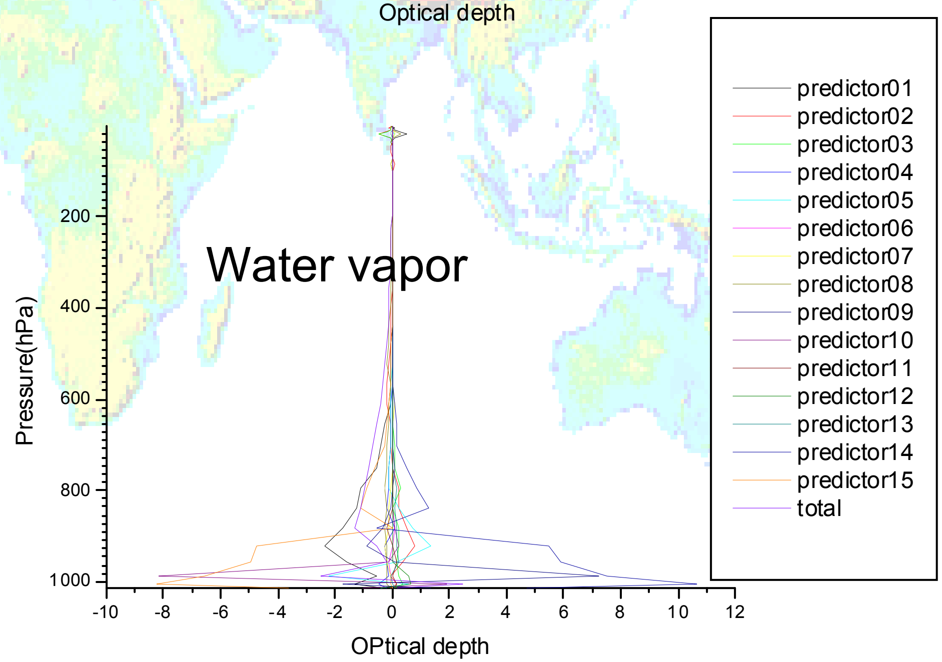
- **Upper channel at CO_2 15µm □ch25□central wavenumber 655.32cm-1□**

Analysis to the predicted optical depth for each predictor on every layer(2) – for AIRS

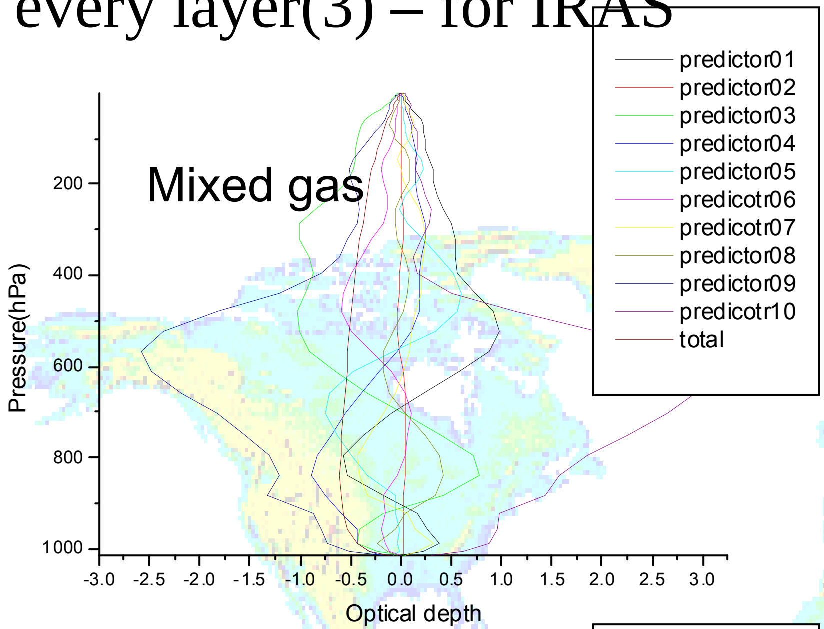
Middle channel at H2O 6.7µm (ch1520, central wavenumber 1367.64cm-1)

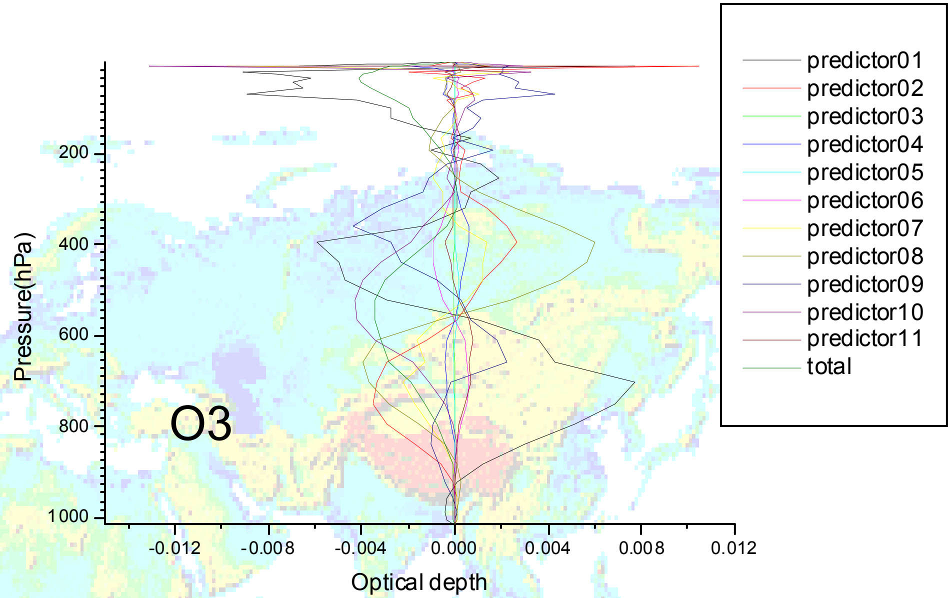


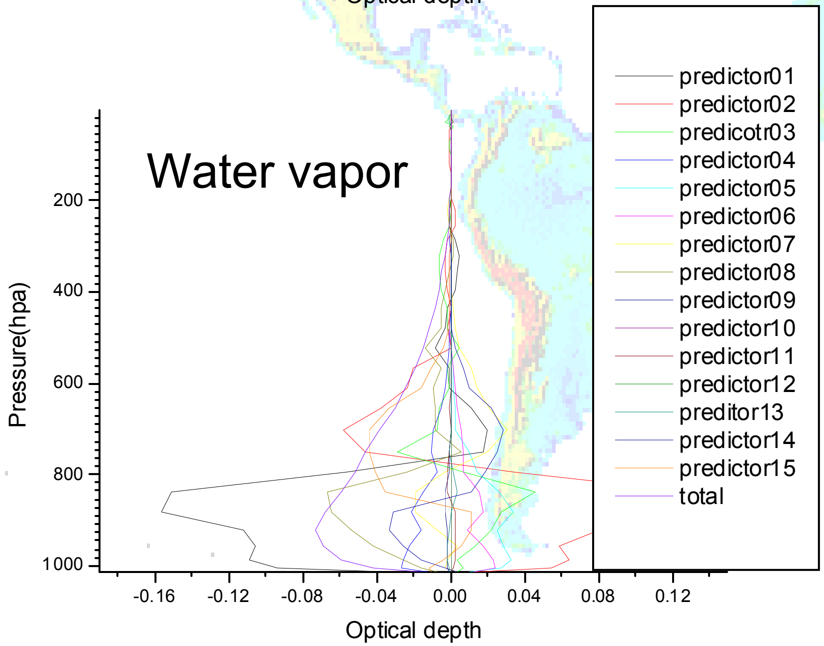




Analysis to the predicted optical depth for each predictor on every layer(3) – for IRAS



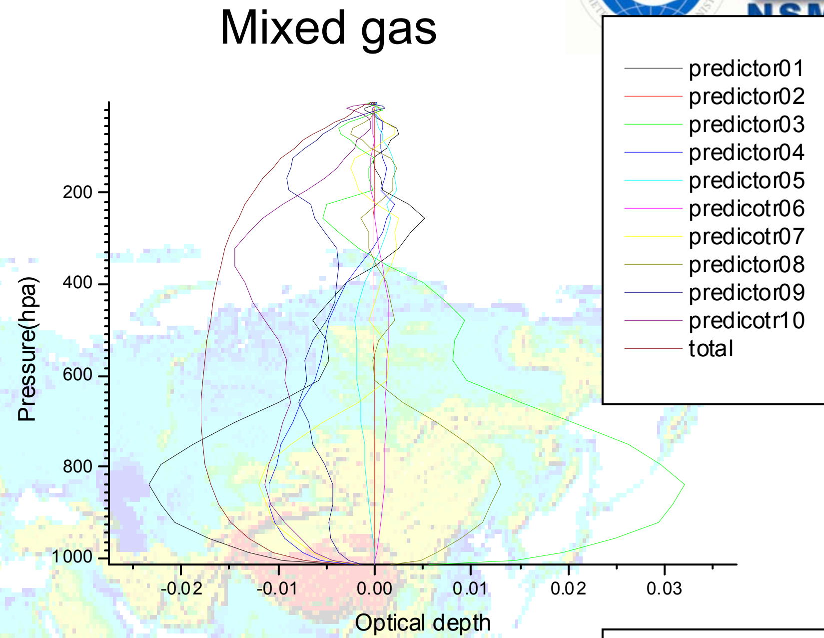


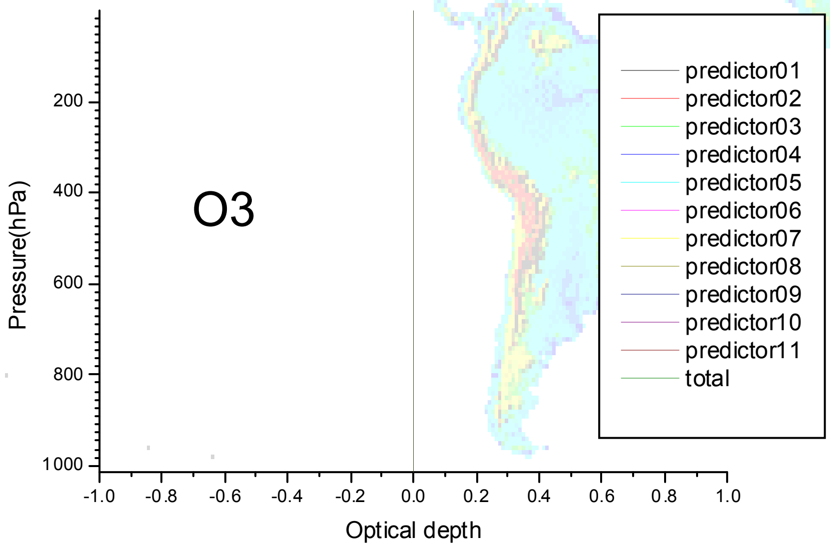


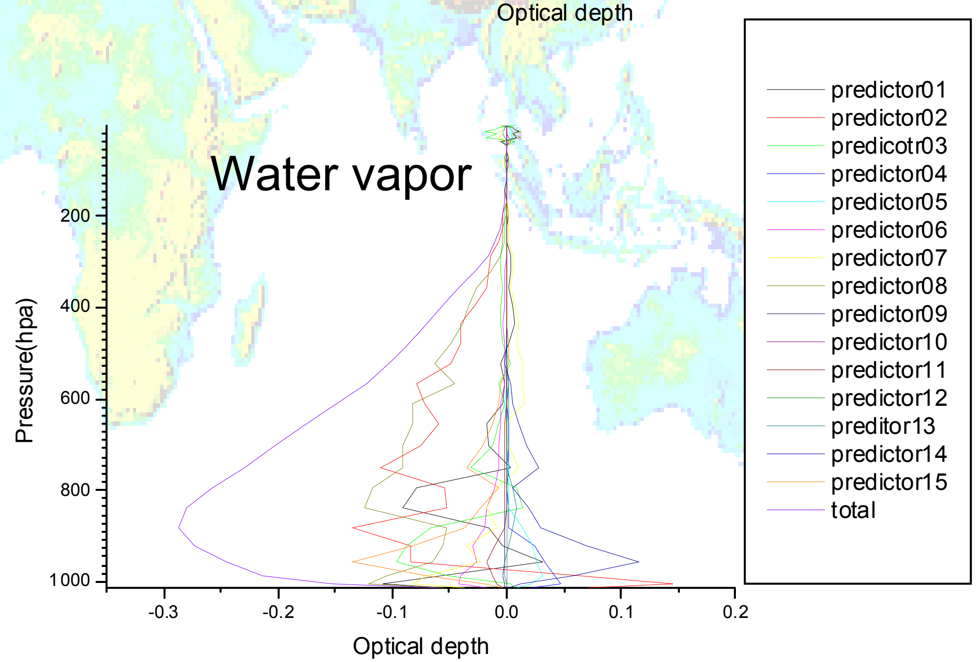
Middle channel at CO2 15μm□ch3□ central wavenumber 691.09cm-1□

Analysis to the predicted optical depth for each predictor on every layer(4) – for IRAS

Middle channel at H_2O 6.7μm □ch11□central wavenumber 1340.45cm-1□







Parameters for MWTS

Channel number	Central frequency (GHz)	Main absorbers	Band width (MHz)	NEΔT (k)	Eddicency for antenna band(%)	Observing field (K)	Calibration precision ** (K)
1	50.30	□□	180	0.5*	□90	3-340	1.2
2	53.596±0.115	O_2	2×170	0.4	□90	3-340	1.2
3	54.94	O_2	400	0.4	□90	3-340	1.2
4	57.290	O_2	330	0.4	□90	3-340	1.2

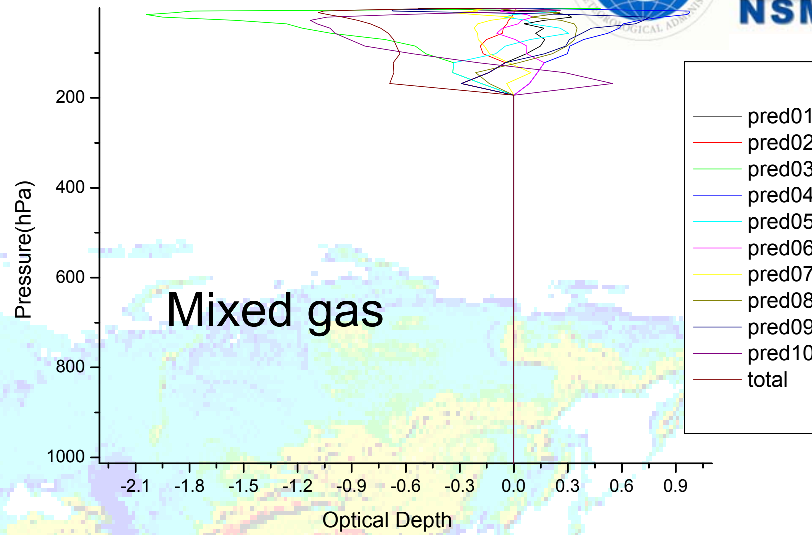
* The final target is 0.55K

** not include NEΔT

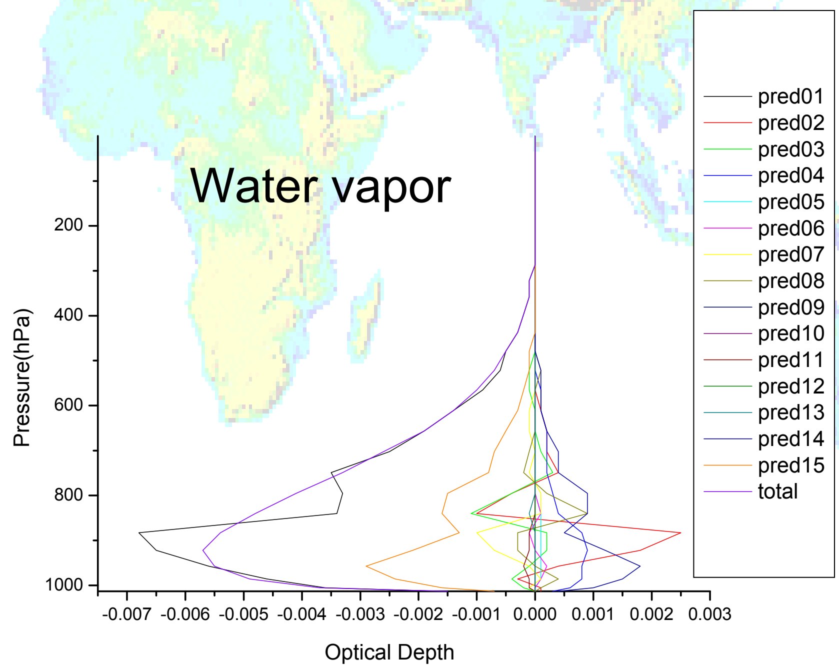
Parameters for MWHS

□□ □□	□□□□ (GHz)	□□□□□□ □	□□ □□ (MHz)	NEΔT* (k)	Frequency stability (MHz)	Eddicency for antenna band	Receiver mode	Obsewrving field(K)
1	150(V)	□□	1000	0.9	50	≥95%**	□□□	3-340
2	150(H)	□□	1000	0.9	50	≥95%**	□□□	3-340
3	183.31±1	H_2O	500	1.1	30	≥95%	□□□	3-340
4	183.31±3	H_2O	1000	0.9	30	≥95%	□□□	3-340
5	183.31±7	H_2O	2000	0.9	30	≥95%	□□□	3-340

Analysis to the predicted optical depth for each predictor on every layer(5) – for MWTS

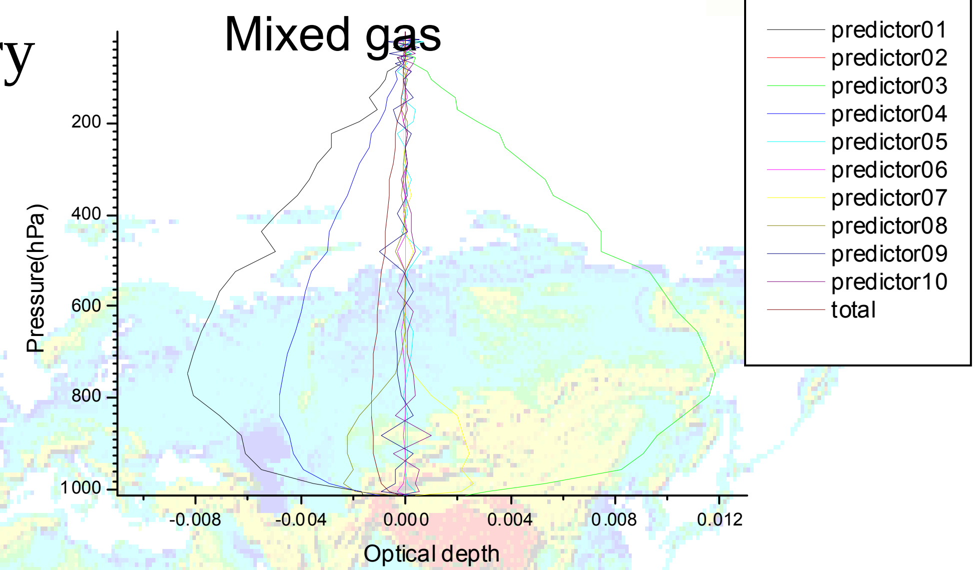


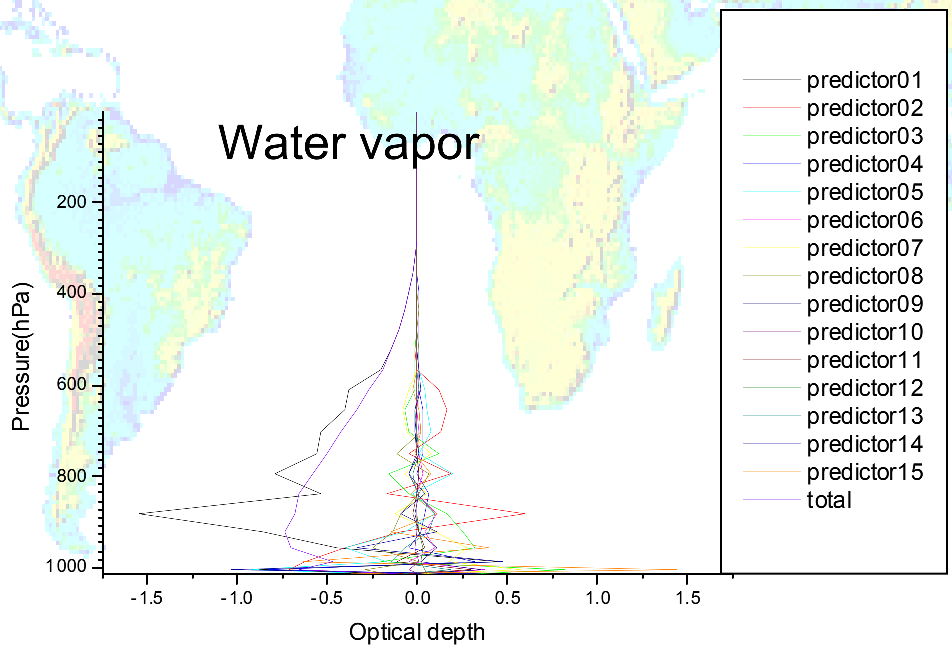
Upper channel at O2 58GHz □ch14□central frequency 57.29GHz□



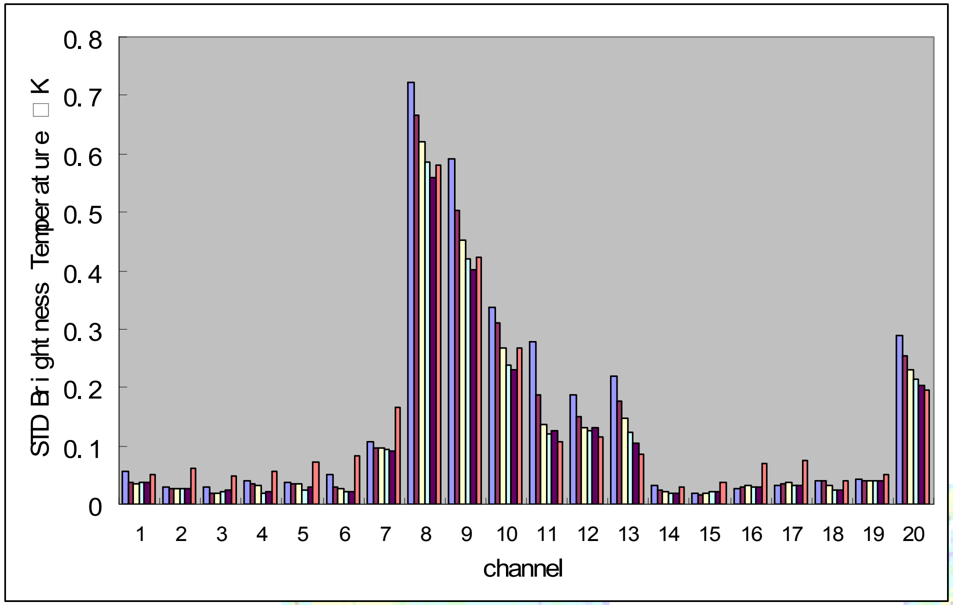
Analysis to the predicted optical depth for each predictor on every layer(6) – for MWHS

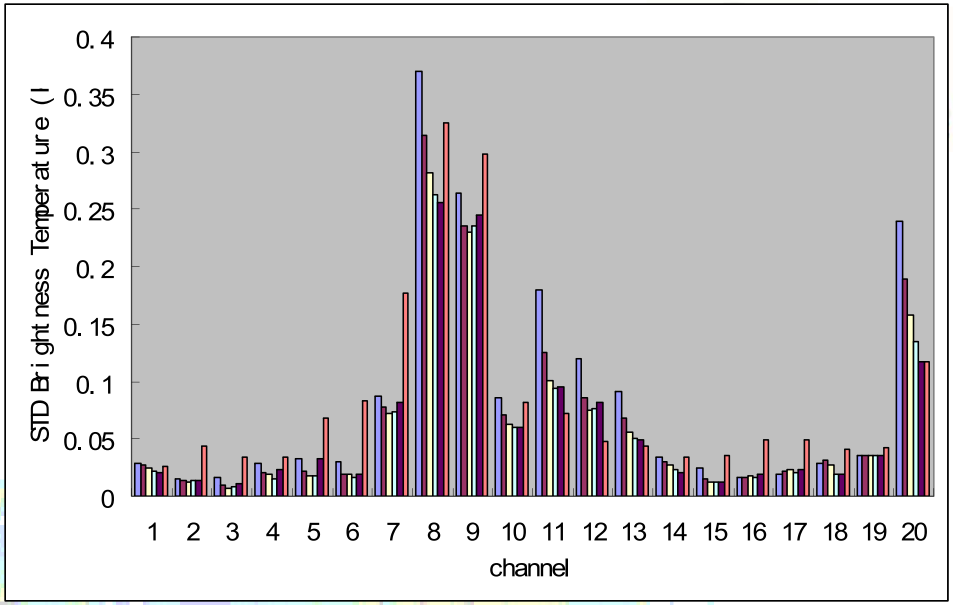
Middle channel at H_2O 183GHz
□ch4□central frequency 183.31±3GHz □





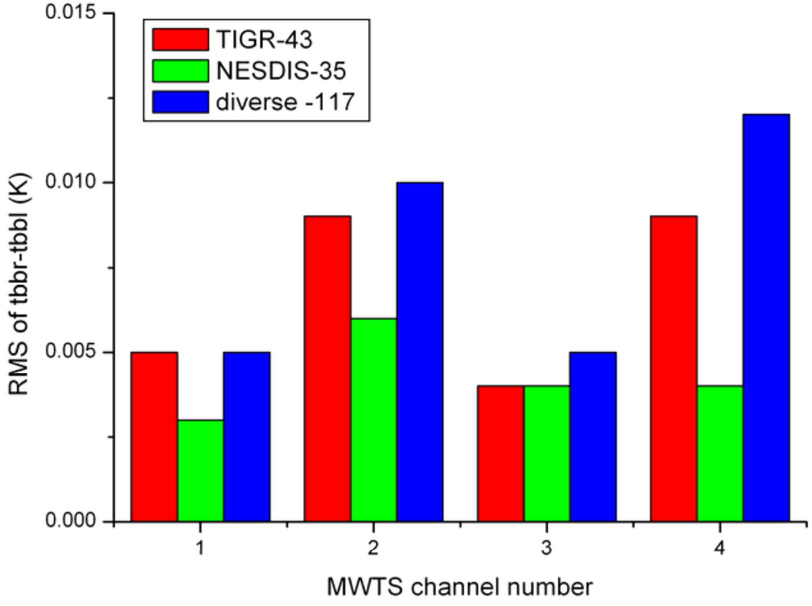
Precision to the fast forward model

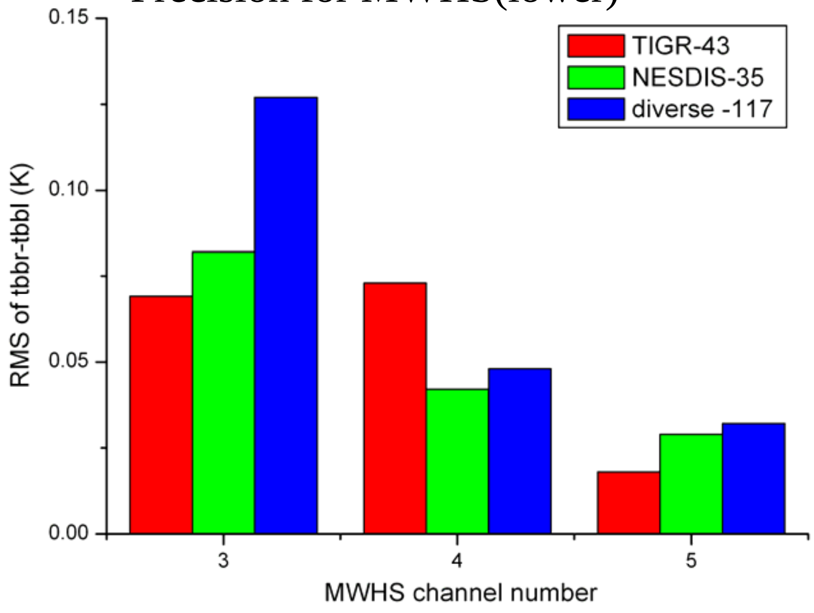




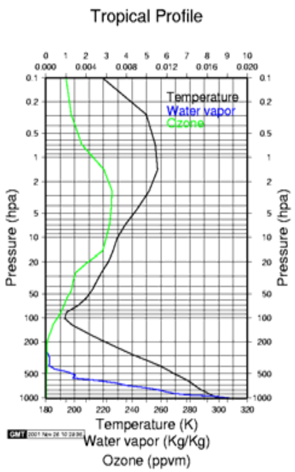
Precision for IRAS from fast model to GENLN2 with TIGR43(upper)
Pescision for MWTS(lower)

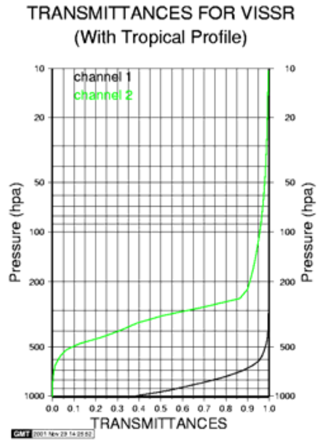
Precision for IRAS from fast model to GENLN2 with Neidis35(upper)
Precision for MWHS(lower)

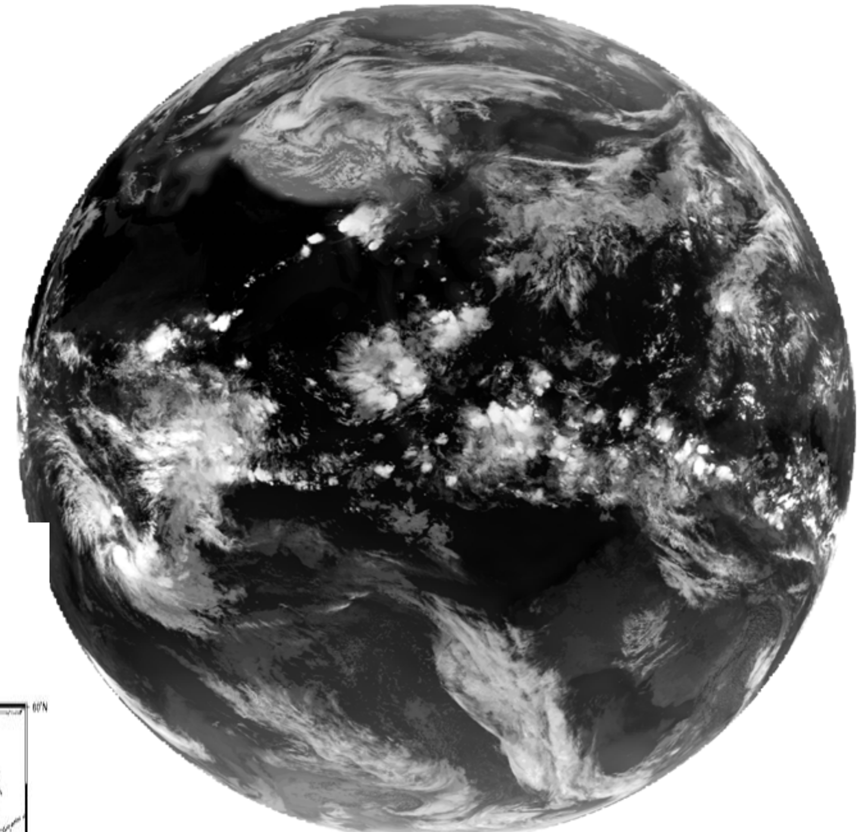


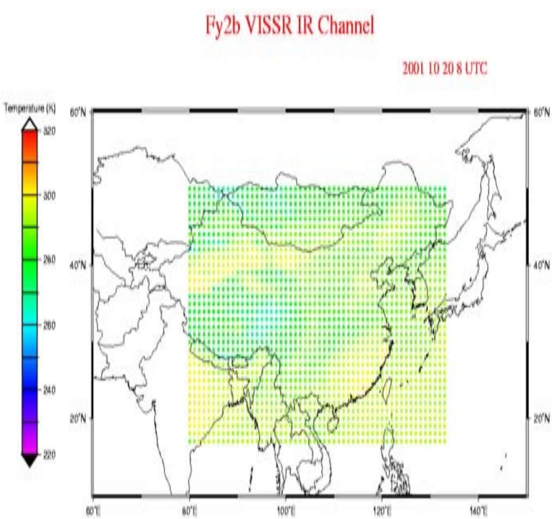


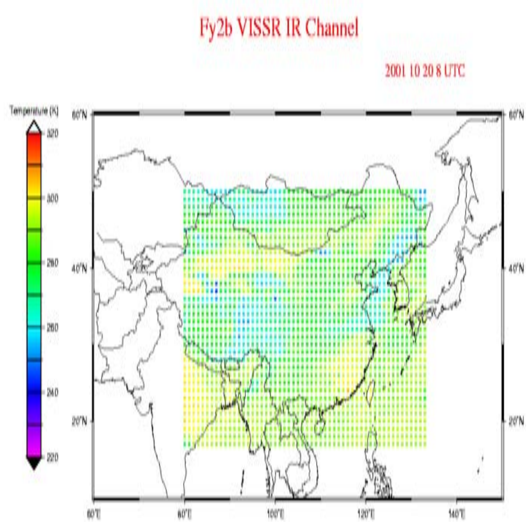
□□□□□□□□FY2B/C□□□□□□□□□


Tropical Profile
Temperature
Water vapor
Ozone
Pressure (hpa)
Temperature (K)
Water vapor (Kg/Kg)
Ozone (ppvm)


TRANSMITTANCES FOR VISSR
(With Tropical Profile)
channel 1
channel 2
Pressure (hpa)
TRANSMITTANCES

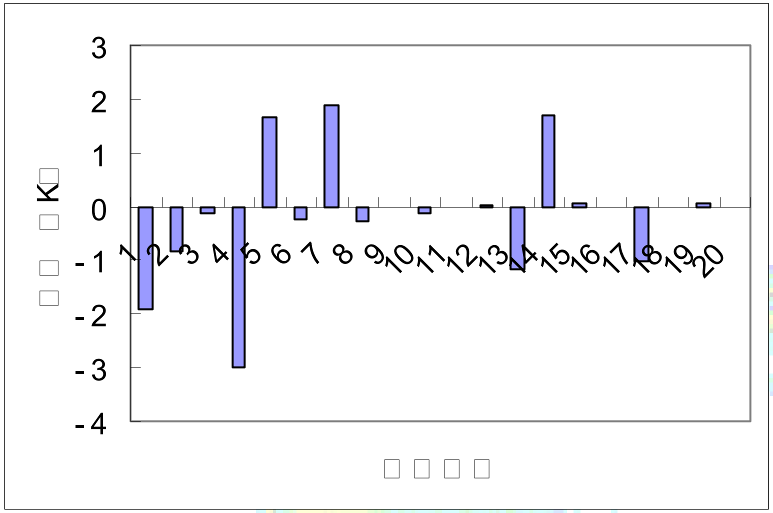


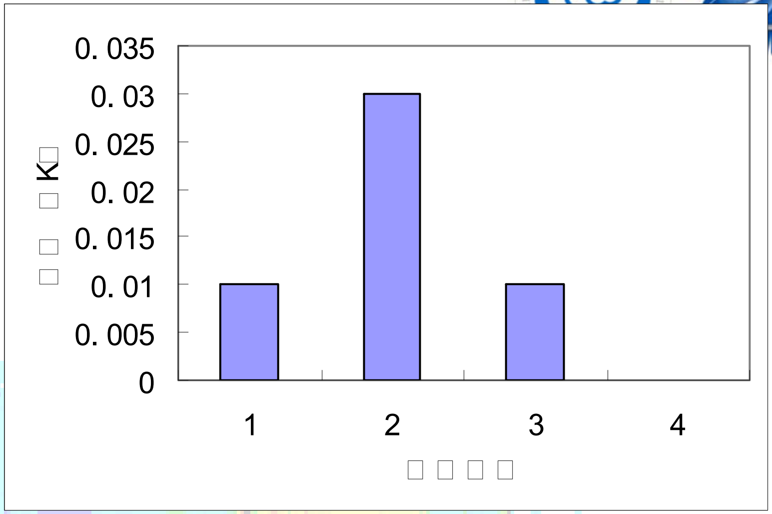

Fy2b VISSR IR Channel
2001 10 20 8 UTC
Temperature (K)

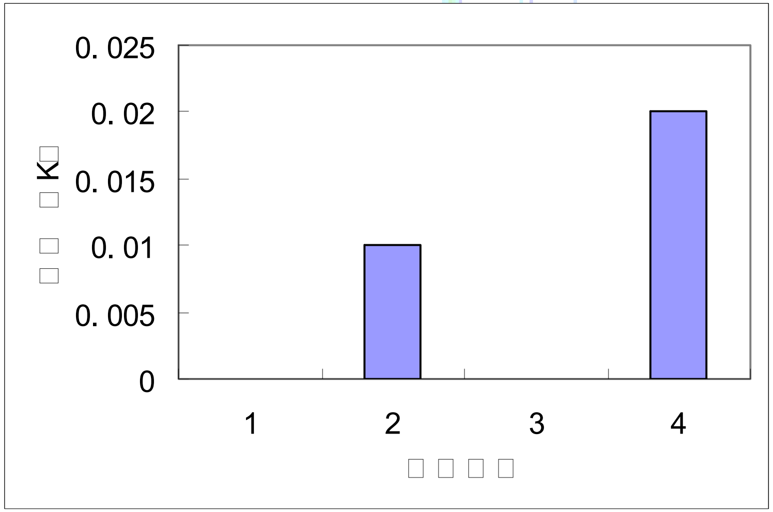

Fy2b VISSR IR Channel
2001 10 20 8 UTC
Temperature (K)

FY2C□□□□□□□□□

Set up observations of FY3



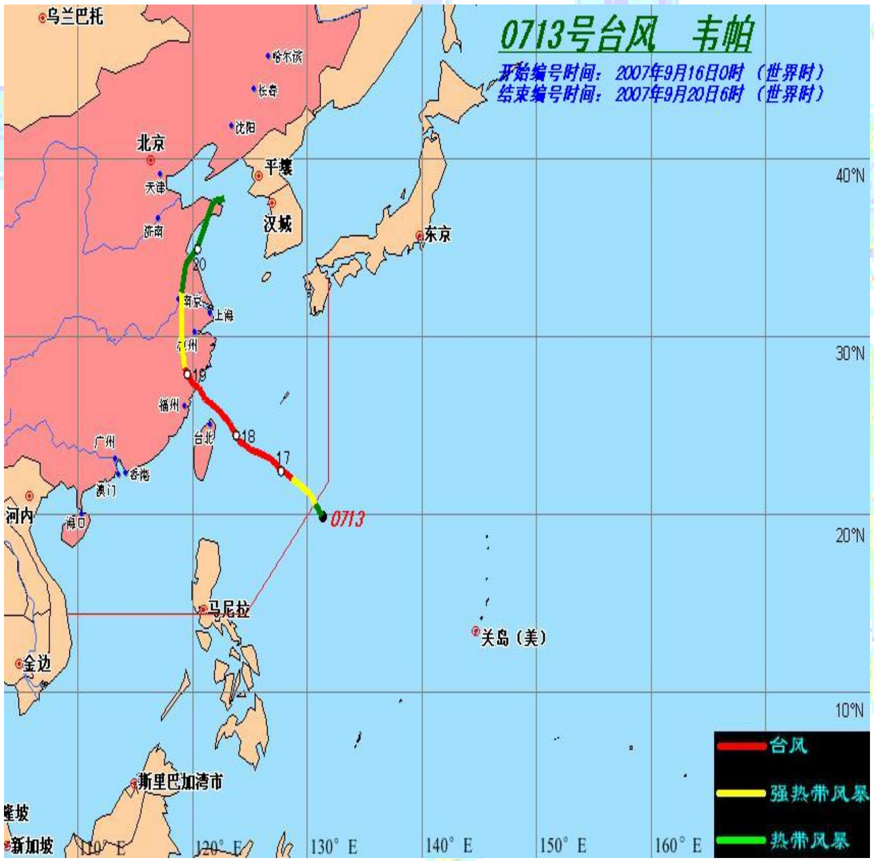




Biases for the simulated brightness temperature from FY3 VASS (IRAS, MWTS and MWHS) to NOAA16 ATOVS

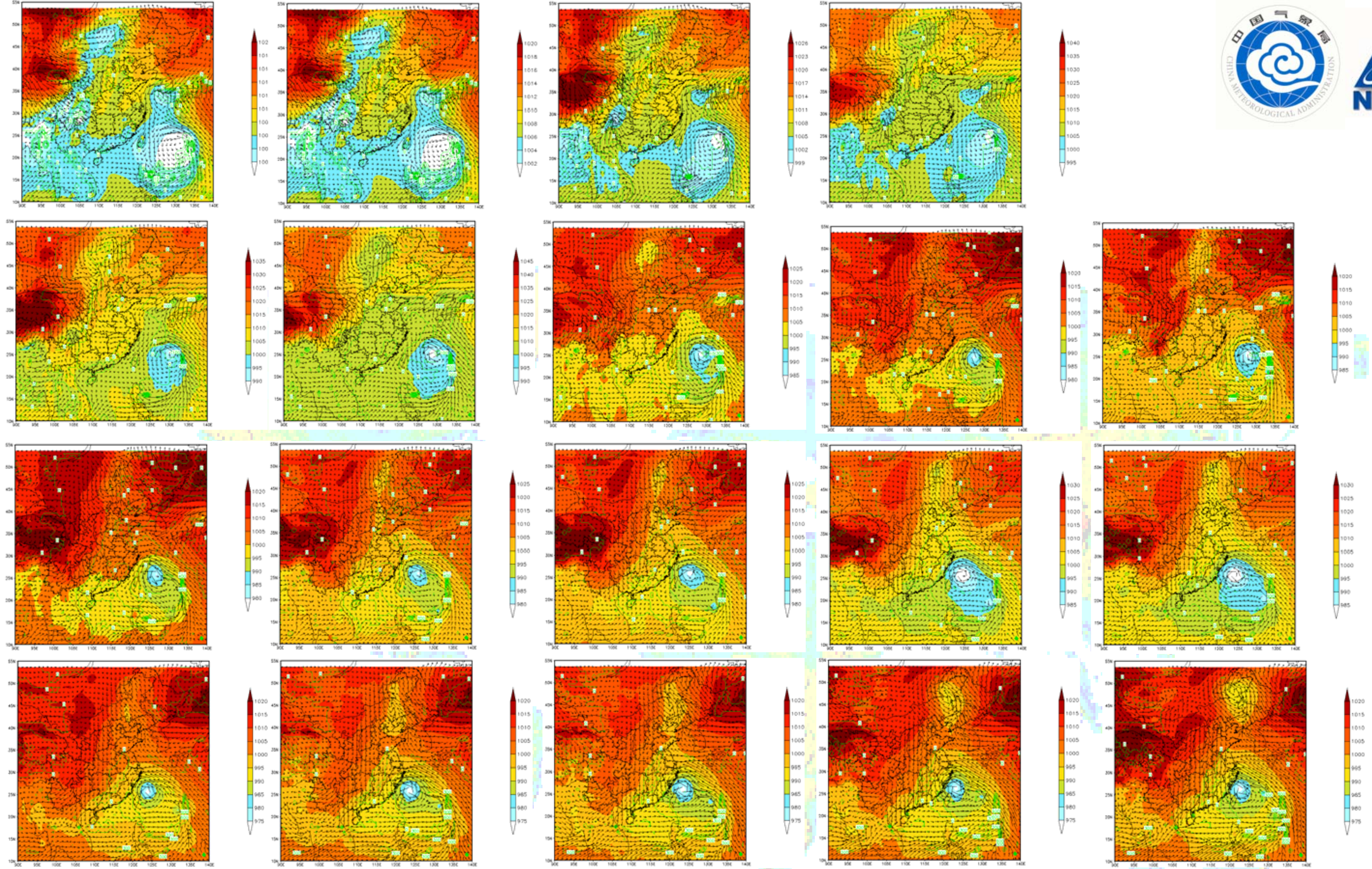
Assmilation/prediction test with the simulated FY3 observations for a typhoon case

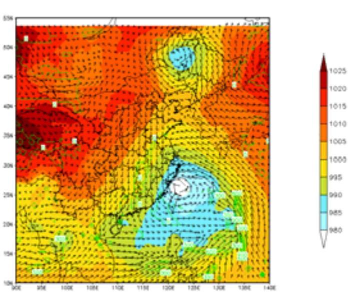
Image for the 0713th typhoon’track



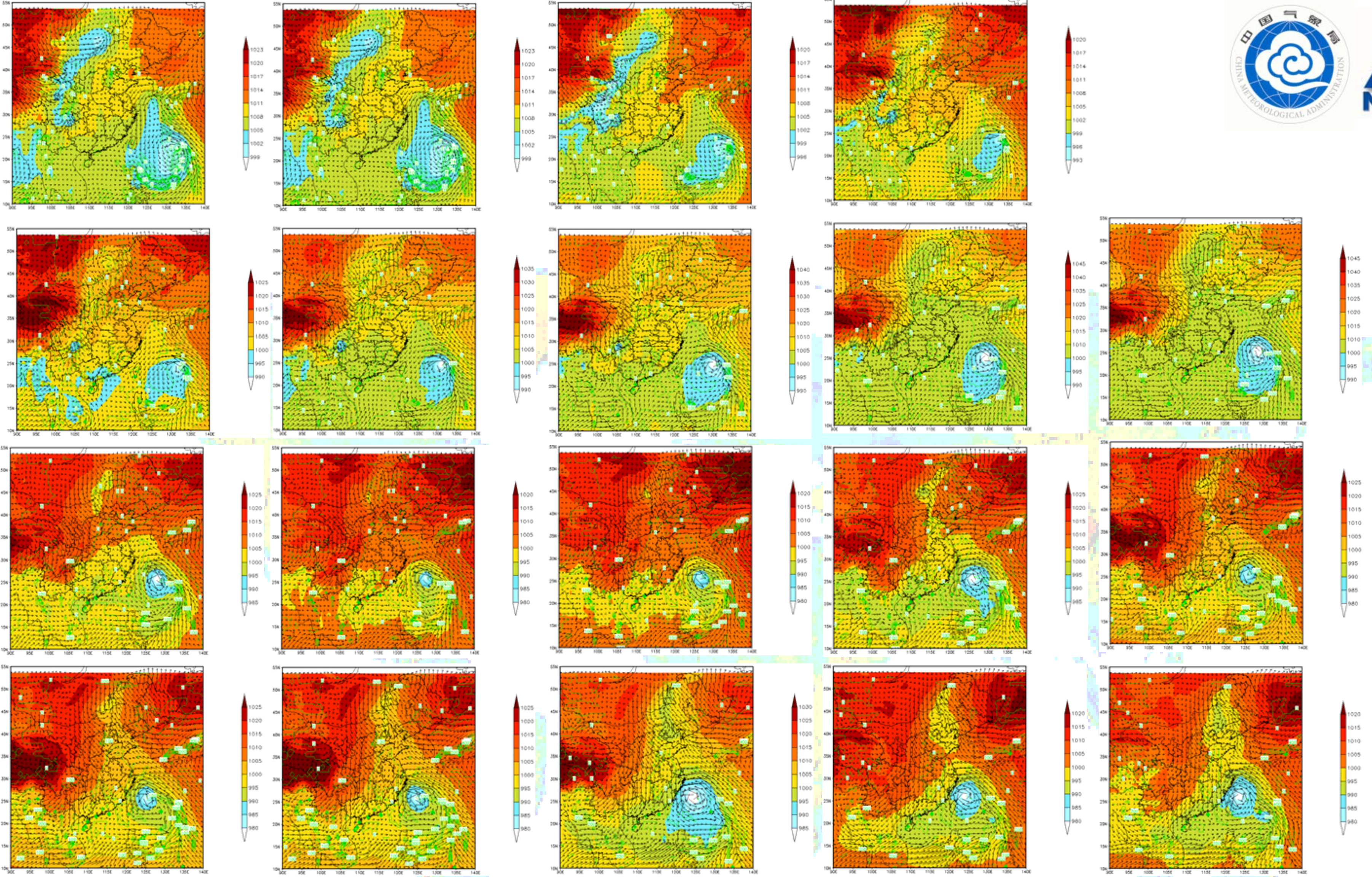
Parameters for grapes model

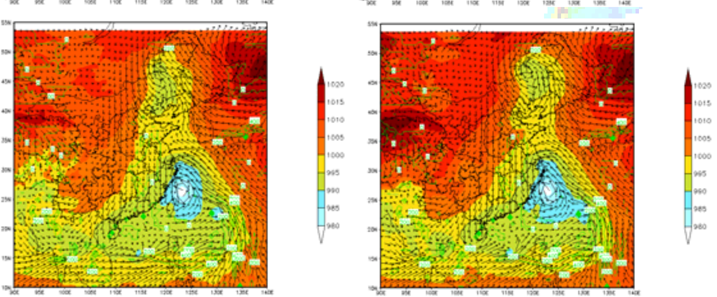
- Grids: 119*89*23
- resolution□0.5625°*0.5625°
- Assmilation window□ 20070901606±3 hr
- prediction□66□□





prediction without assimilation of FY3 radiances (every 3 hours)





prediction with assimilation of FY3 radiances (every 3 hours)

Main conclusion

- Predicted optical depth for mixed gas is consistent to channel’s weighting function both for infrared and for microwave

- Predicted optical depth for water vapor only contributes in lower atmosphere

- By using a profiles database and infrared and microwave LBL model, fast coefficients for IRAS, MWTS and MWHS have been generated

- Validation to the fast coefficients of IRAS, MWTS and MWHS shows a good precision while brightness temperature sfor the instruments from LBL model are compared

- Validation indicates that brightness temperature of NOAA ATOVS are quite consistent to the values of FY3 VASS

- Assimilation of FY3 radiance in grapes model shows a weak impact to the prediction of typhoon’s path

Plan in the future

- **Set up a new LBL transmittances database with the nearest profiles database from ECMWF**

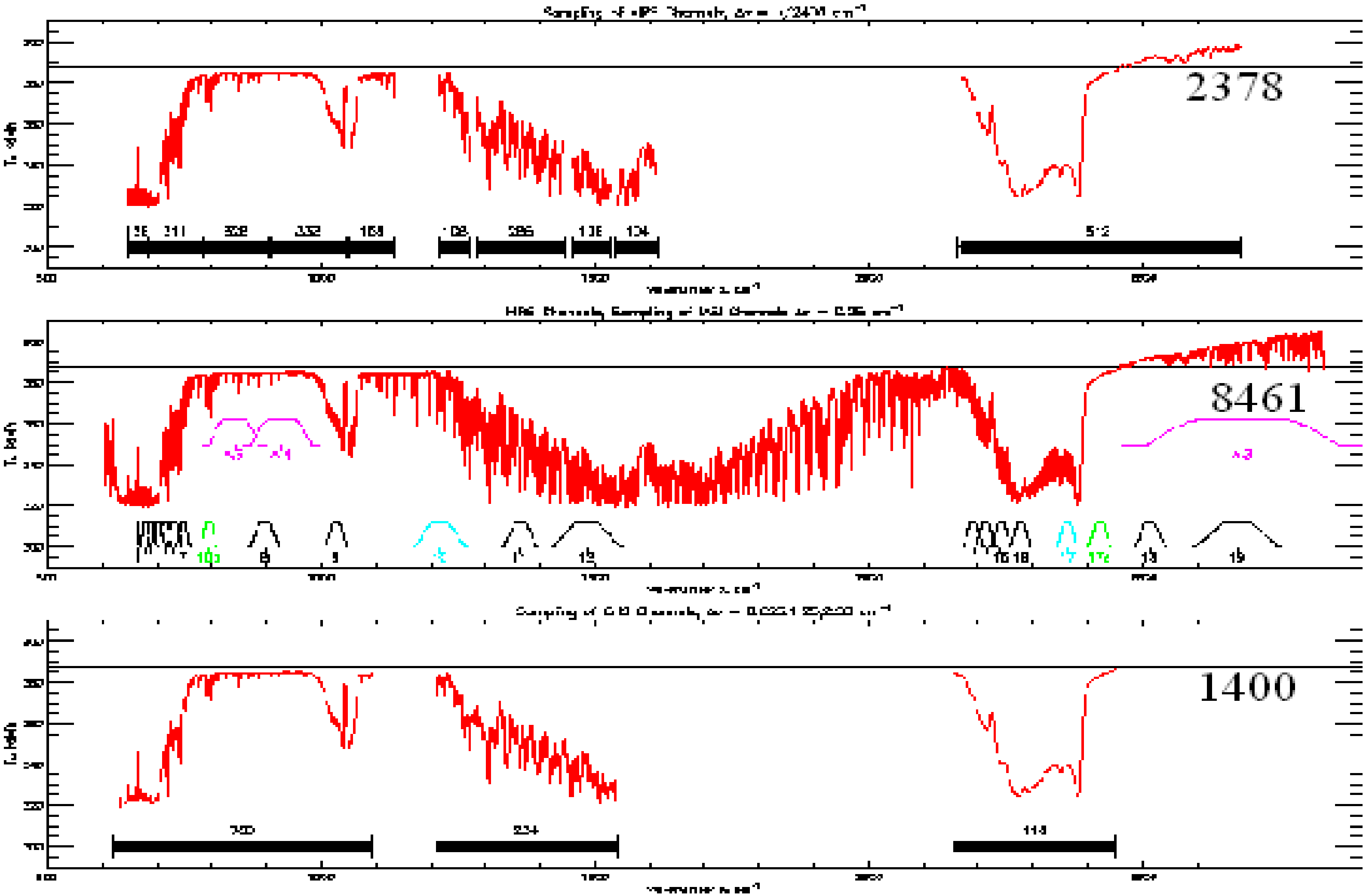
- **Analysis the contribution from predictors with other profile**

- **Introduce quality control and bias correction for assimilation of FY3 VASS radiance**

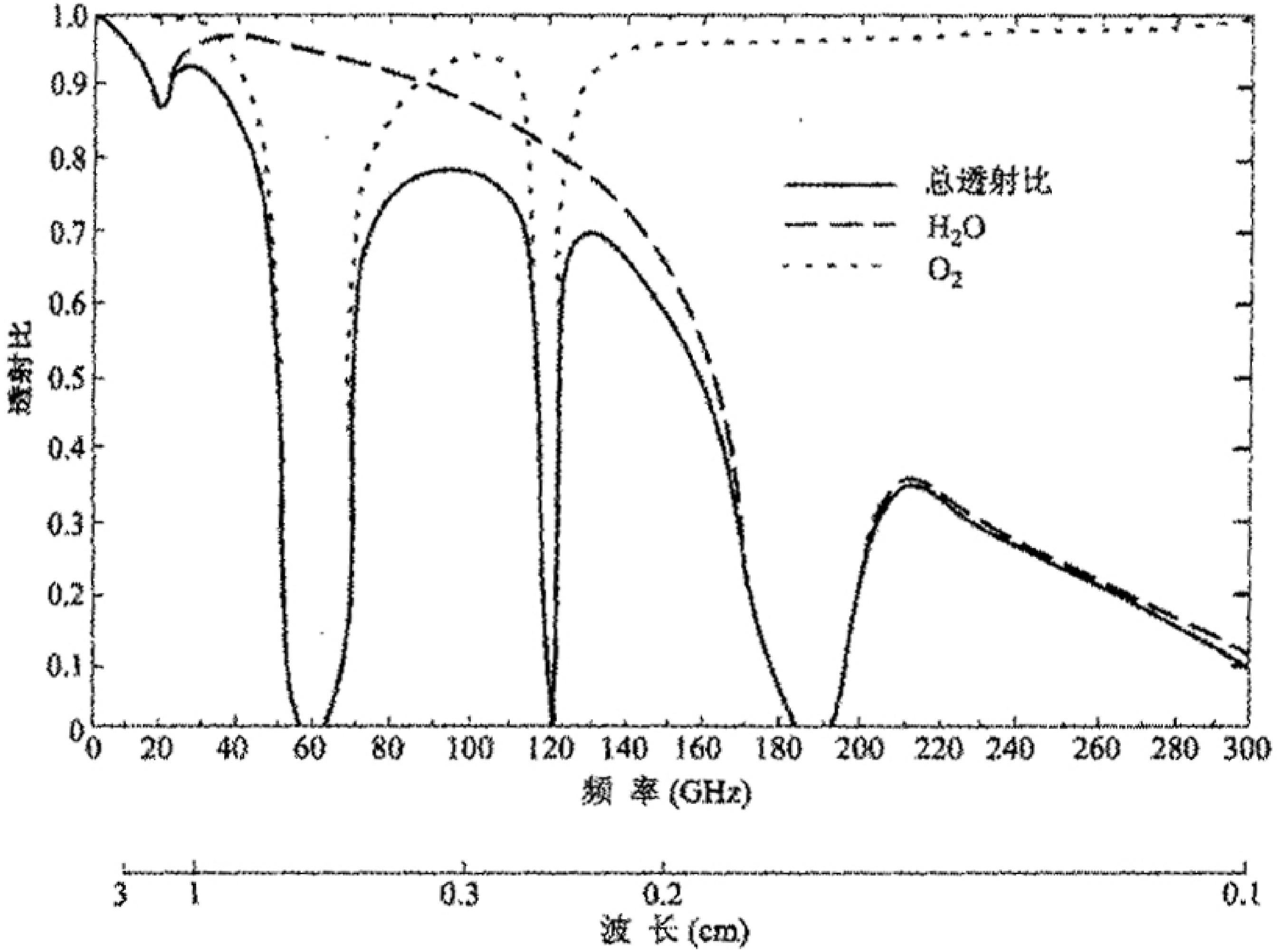
- **Further test to confirm the possible impact from assimilation of FY3 radiance**

Thank you!

AIRS□IASI□HIRS□CRIS

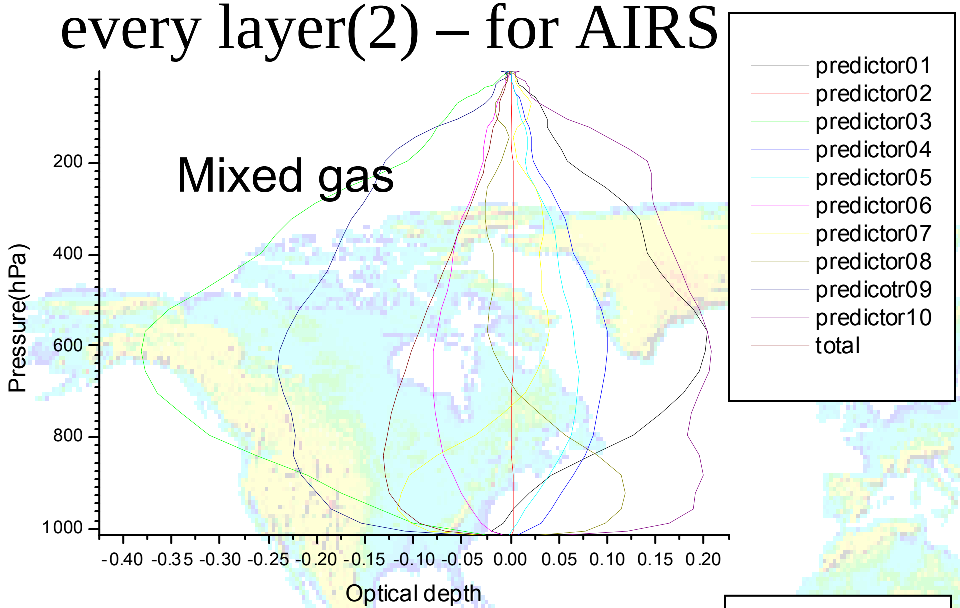


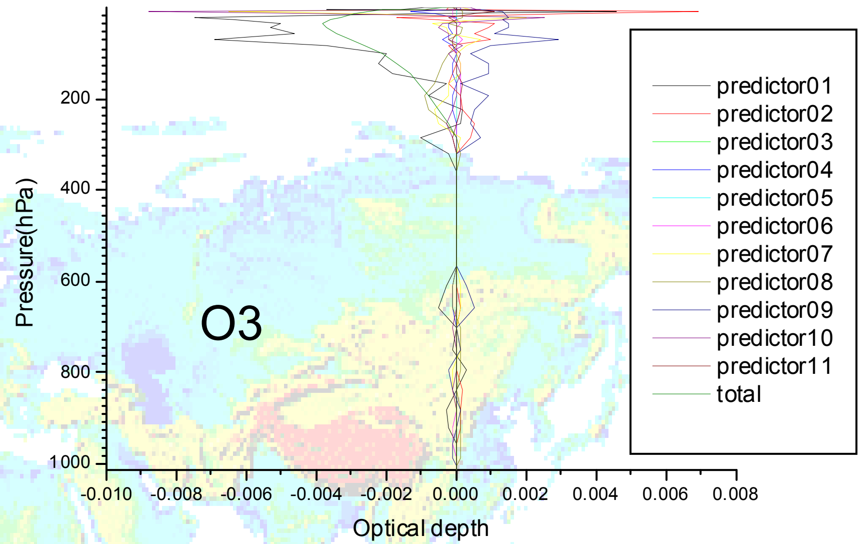
L M

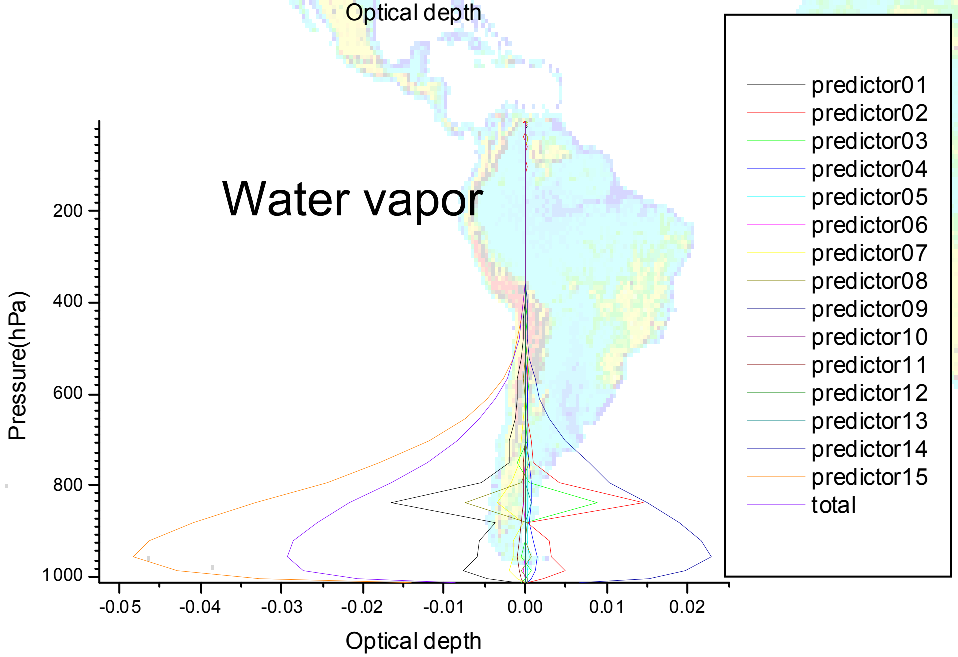


Atmospheric transmittance for microwave

Analysis to the predicted optical depth for each predictor on every layer(2) – for AIRS

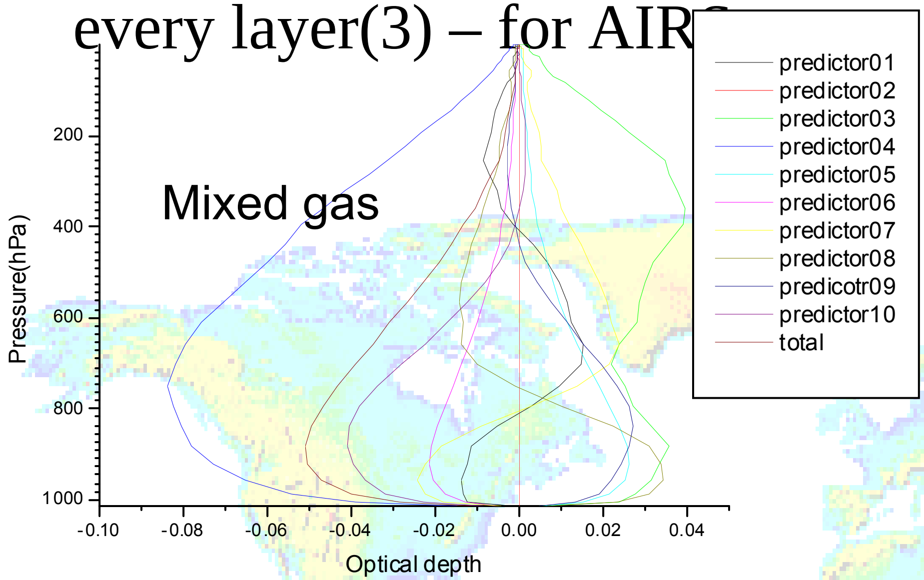


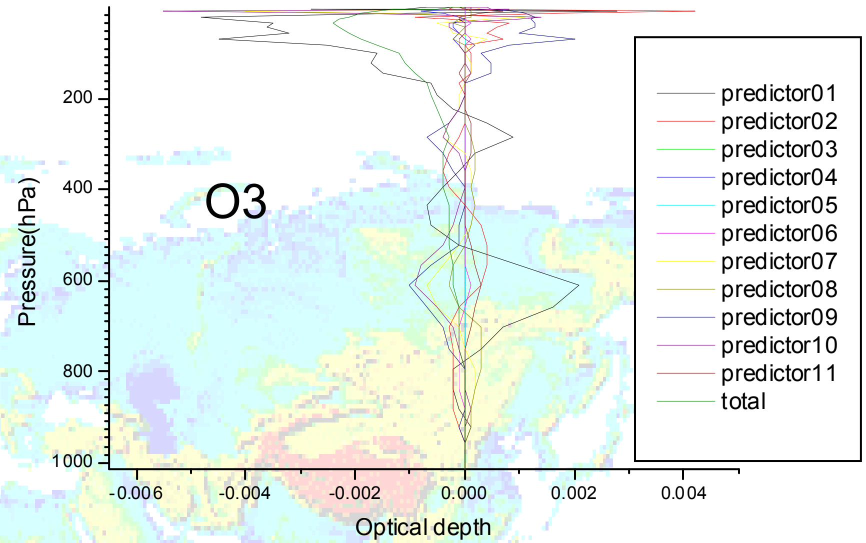


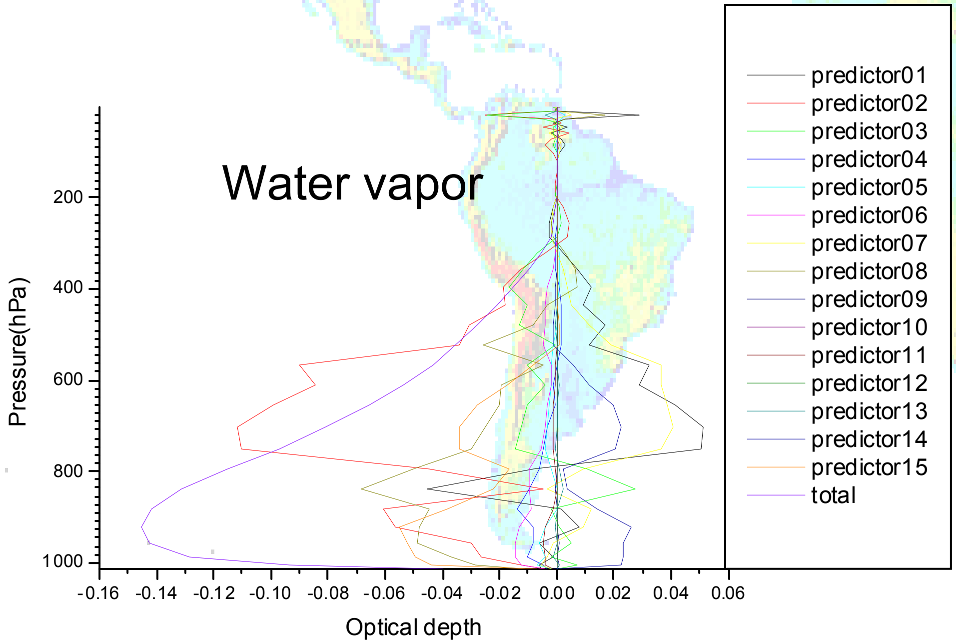


Middle channel at CO_2 15μm □ch296□central wavenumber 734.38cm-1□

Analysis to the predicted optical depth for each predictor on every layer(3) – for AIRS



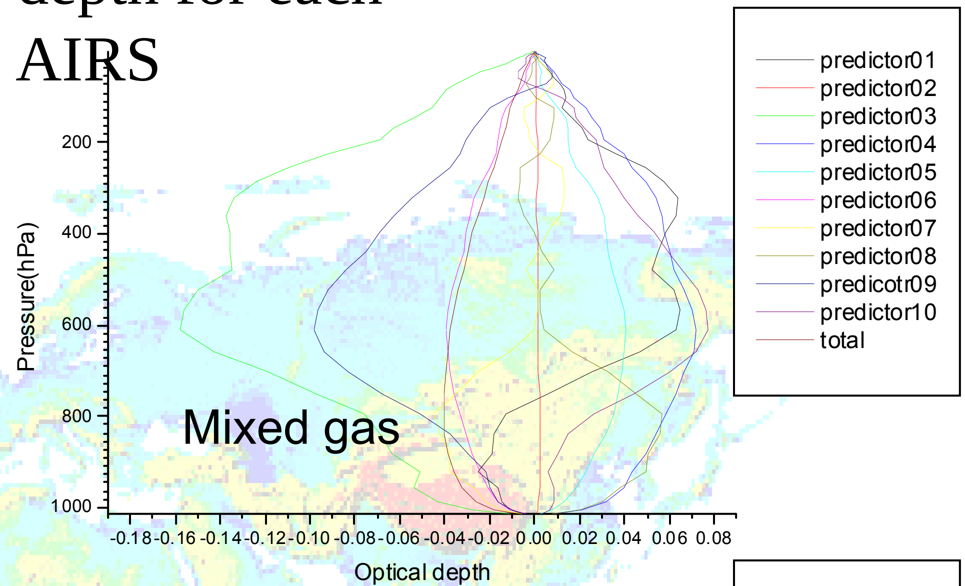


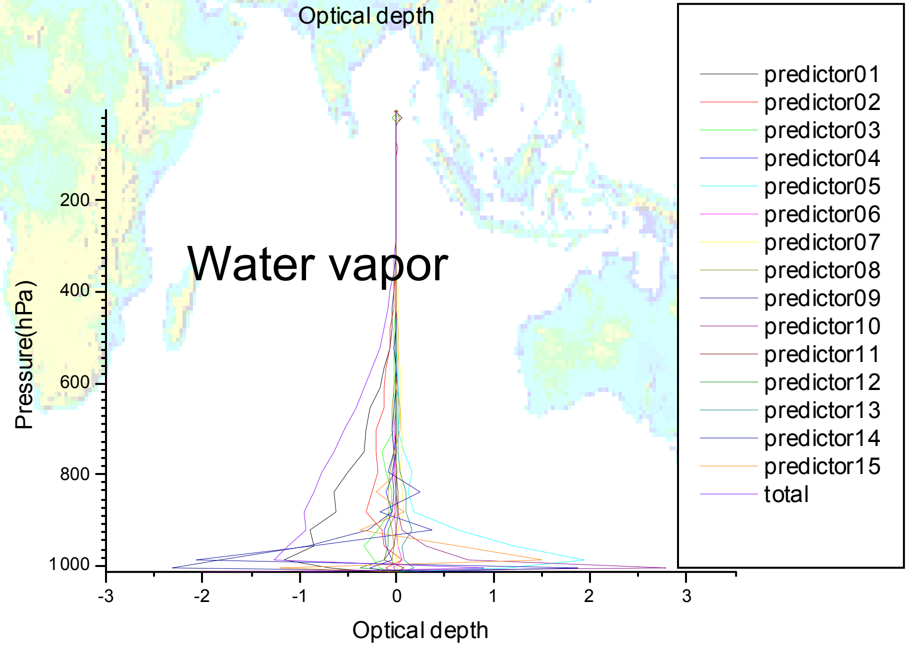


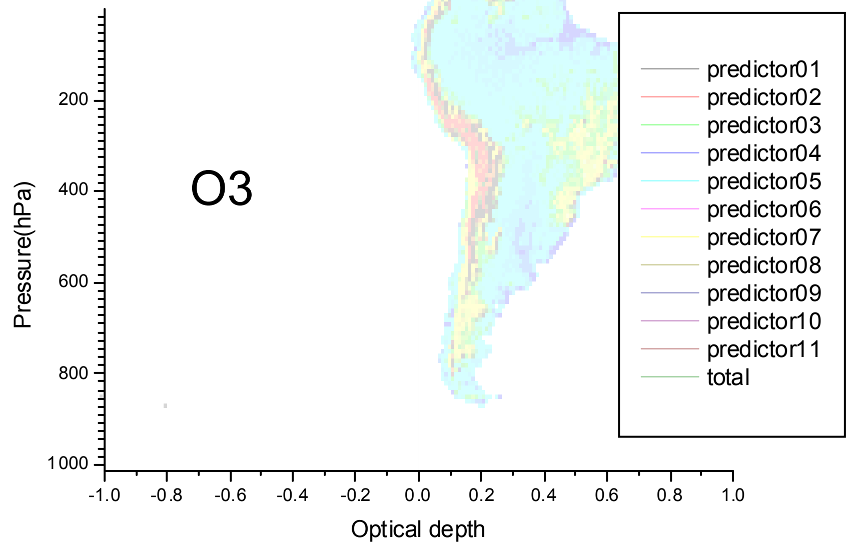
Lower channel at CO_2 15μm（ch329）central wavenumber 744.66cm-1）

Analysis to the predicted optical depth for each predictor on every layer(4) – for AIRS

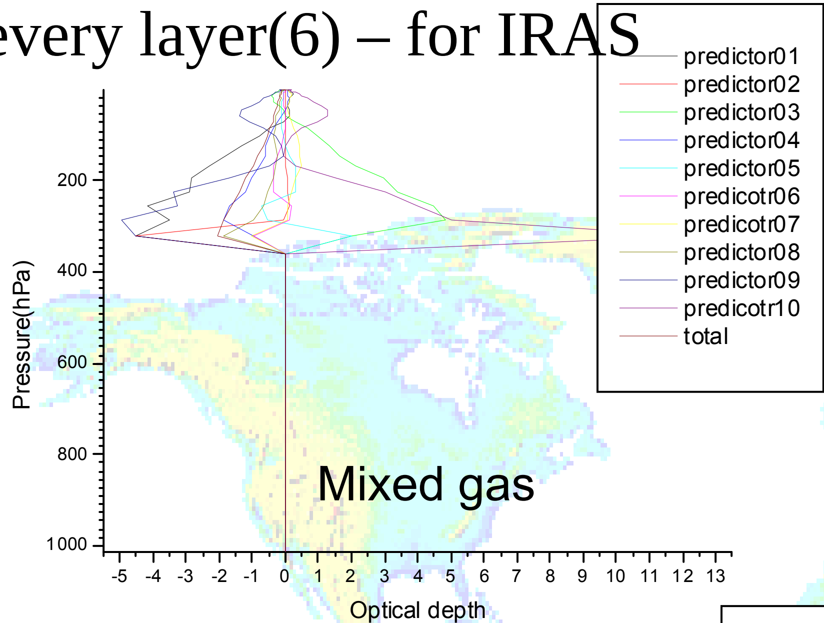
Upper channel at H2O 6.7μm □ch1506□central wavenumber 1360.24cm-1□

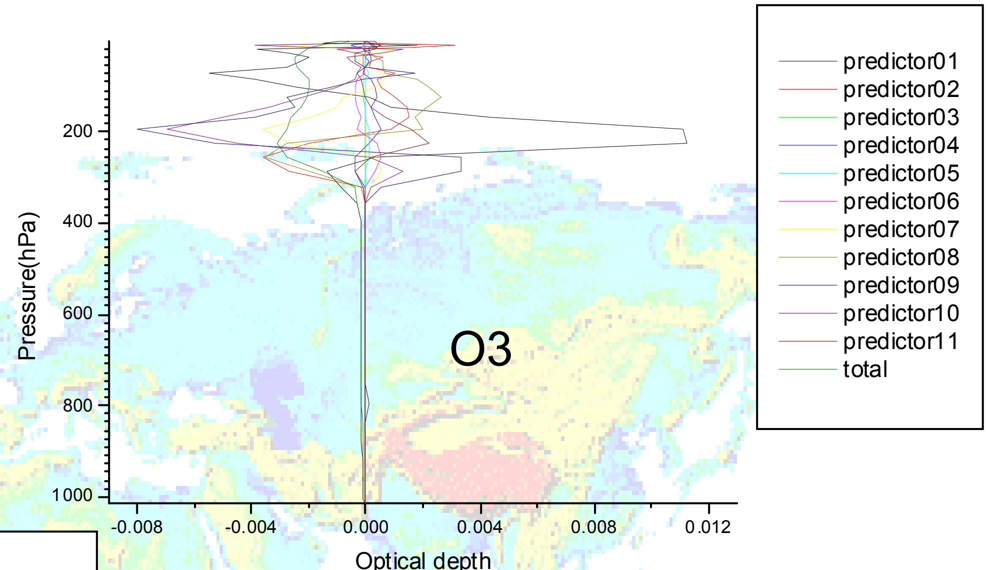


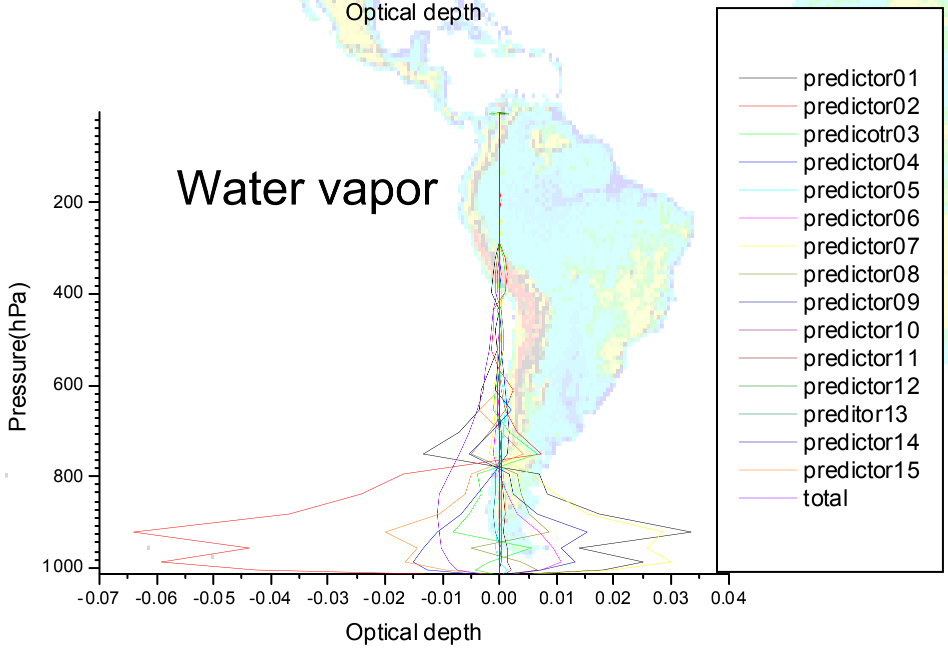




Analysis to the predicted optical depth for each predictor on every layer(6) – for IRAS

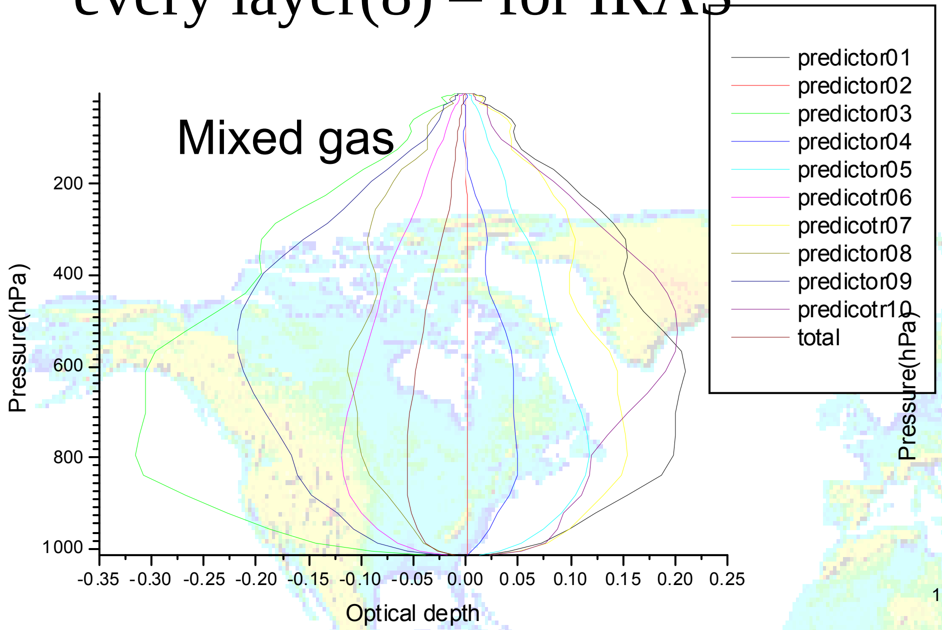


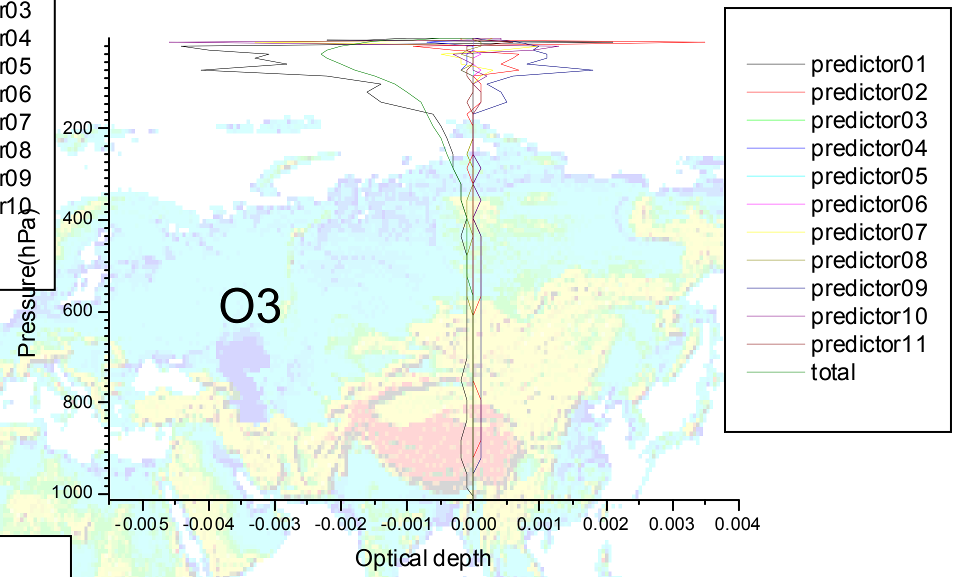


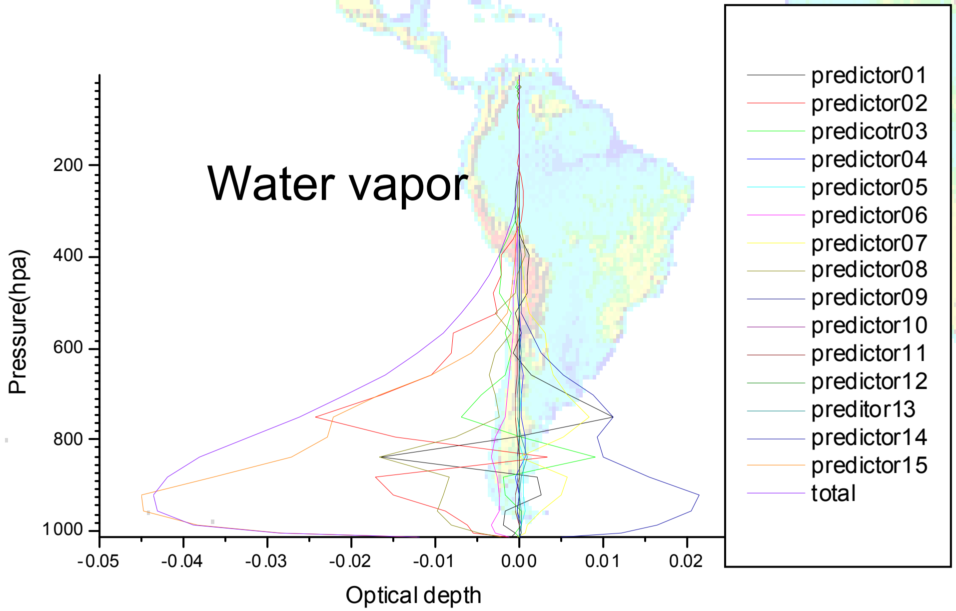


- **Upper channel at CO_2 15µm □ch1□central wavenumber 669.29cm-1□**

Analysis to the predicted optical depth for each predictor on every layer(8) – for IRAS



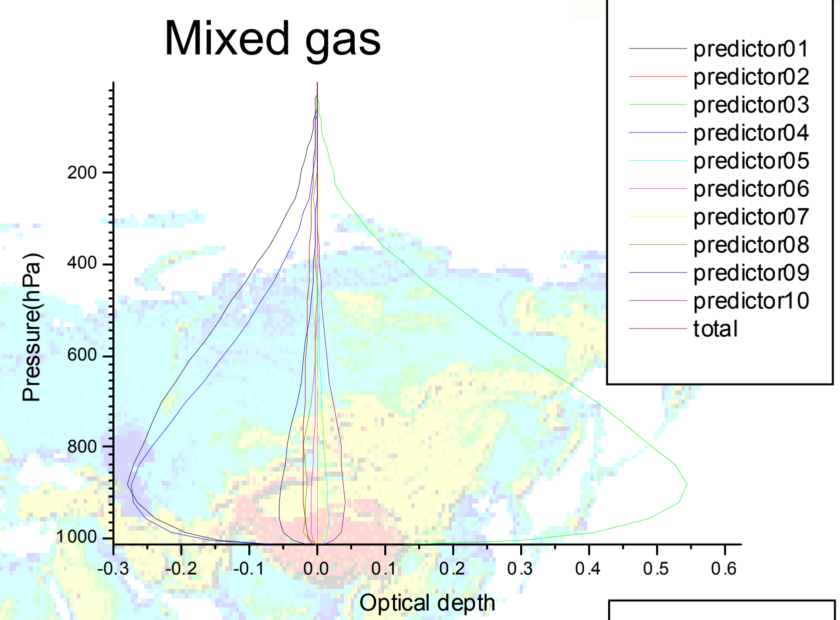


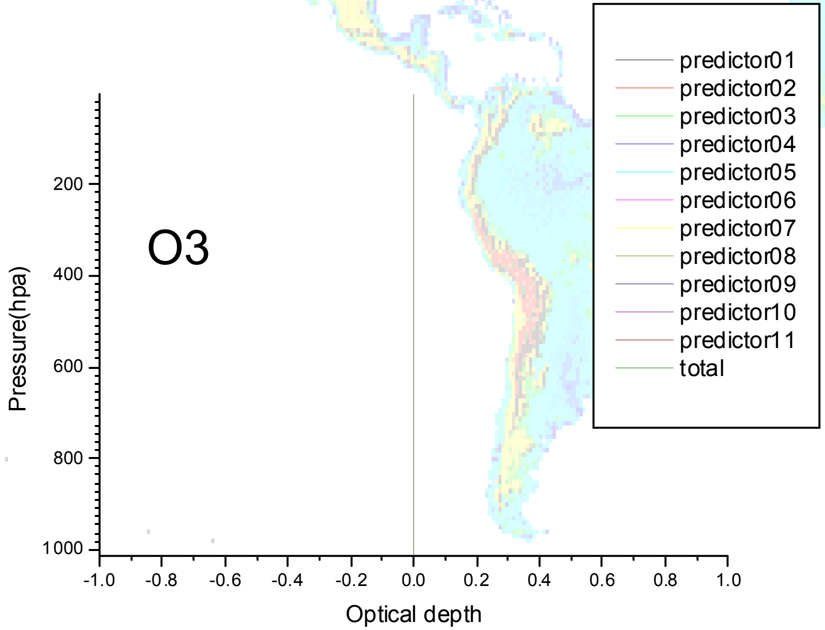


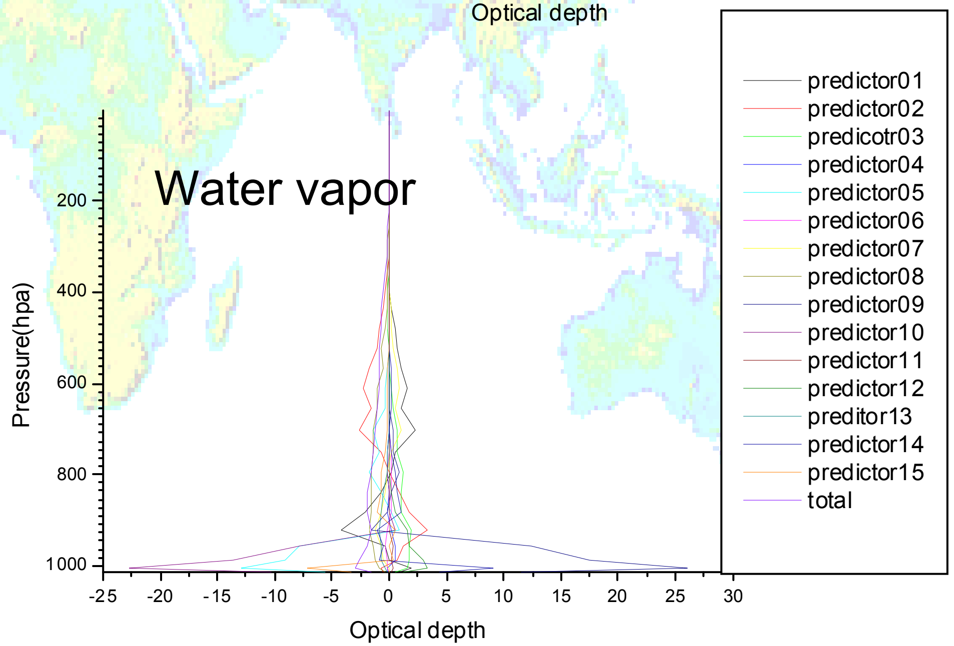
Lower channel at CO2 15μm□ch7□ central wavenumber 747.98cm-1□

Analysis to the predicted optical depth for each predictor on every layer(9) – for IRAS

Upper channel at H2O 6.7µm （ch13，central wavenumber 1532.4cm-1）

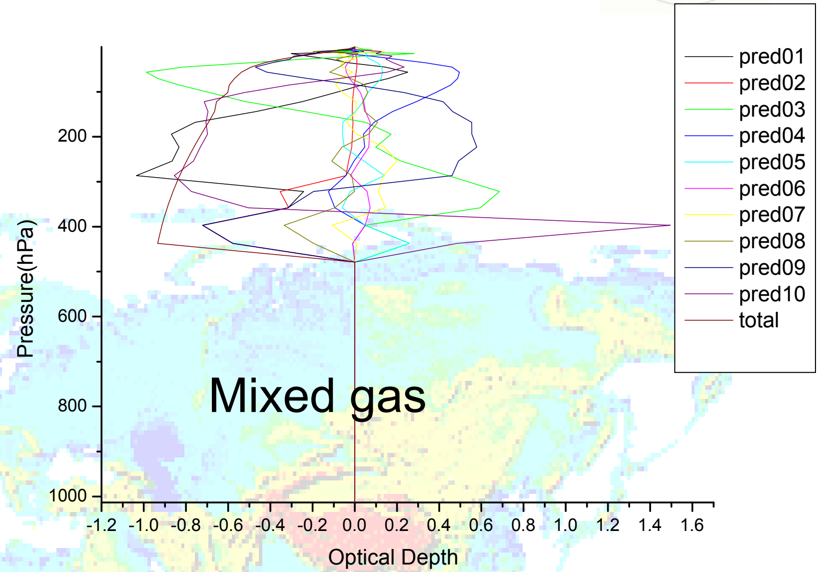


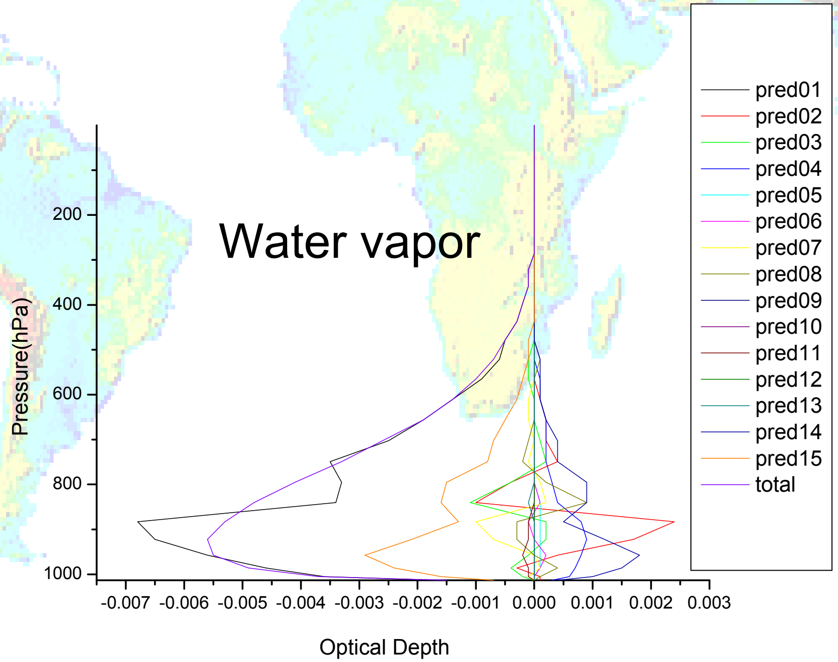




Analysis to the predicted optical depth for each predictor on every layer(12) – for MWTS

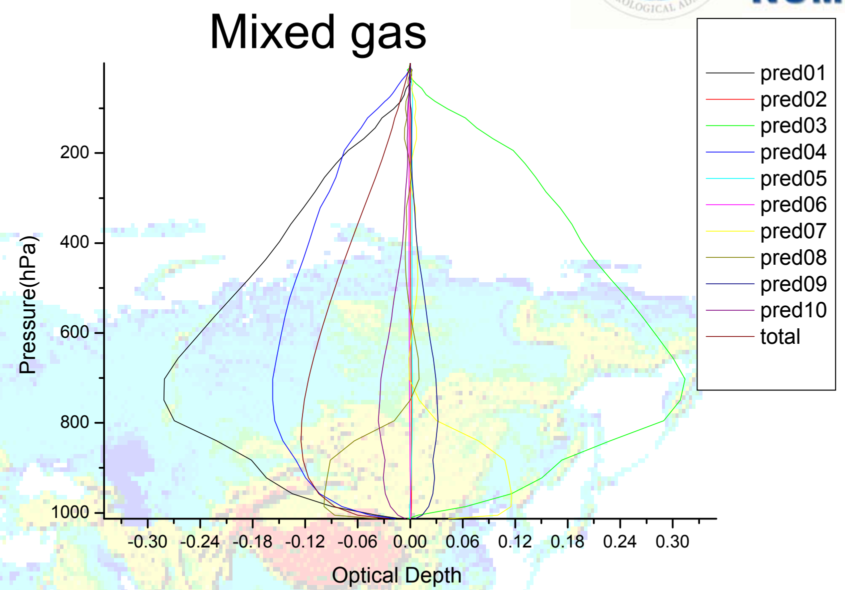
Middle channel at O2 58GHz
□ch10□central frequency 57.29+/–0.217 GHz□

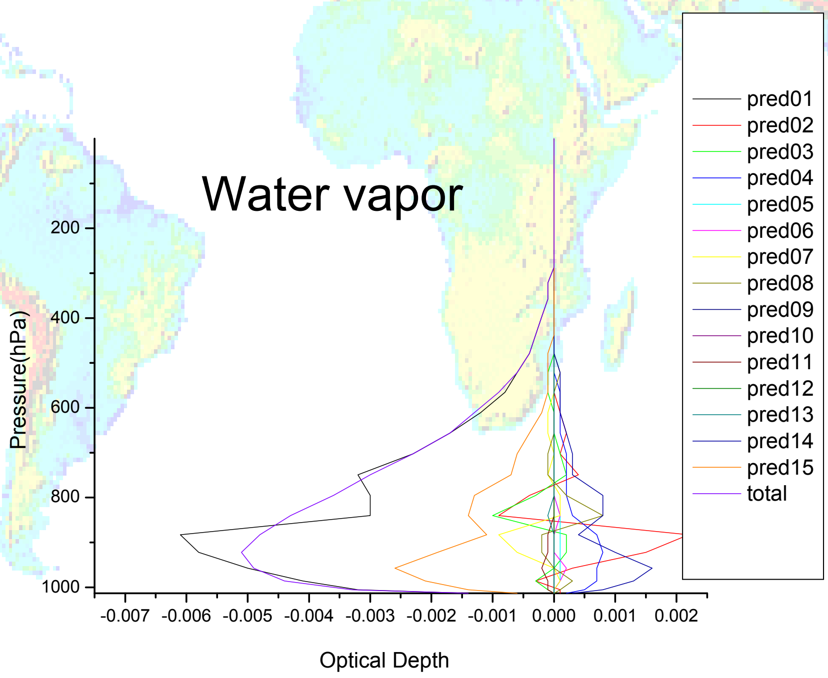




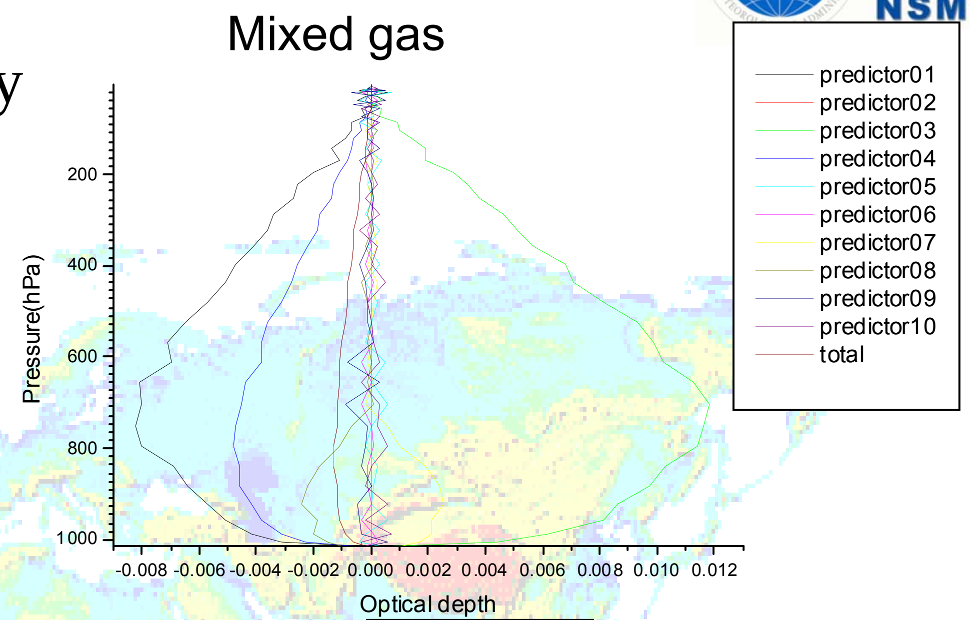
Analysis to the predicted optical depth for each predictor on every layer(13) – for MWTS

Lower channel at O2 58GHz
ch5central frequency 53.596+/–0.115 GHz





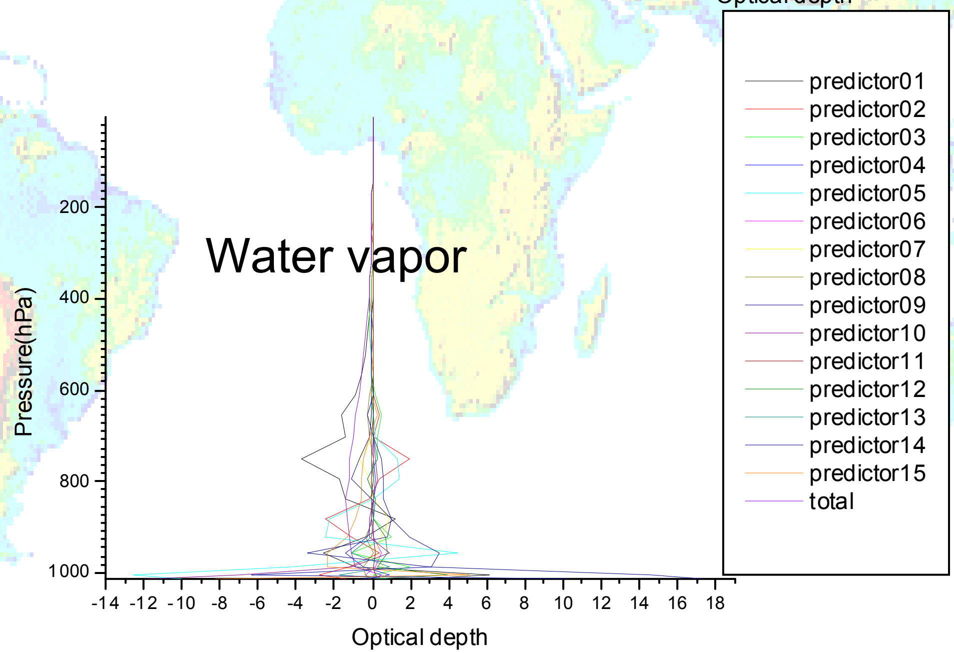
Analysis to the predicted optical depth for each predictor on every layer(14) – for MWHS



Upper channel at H_2O 183GHz

□ch3□central frequency

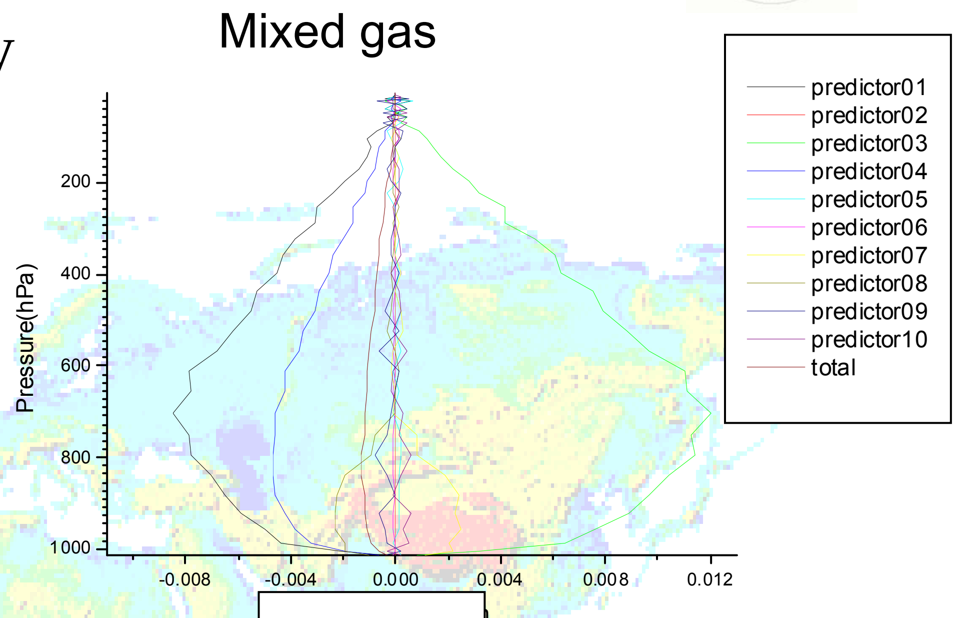
183.31±1GHz □

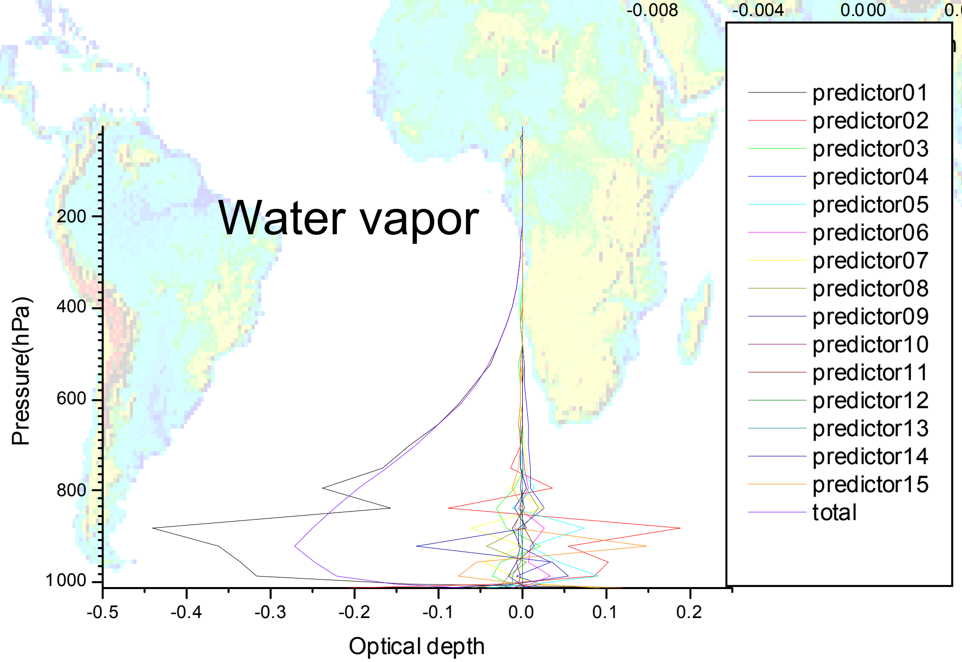


Analysis to the predicted optical depth for each predictor on every layer(16) – for MWHS

Lower channel at H2O 183GHz

□ch5□central wavenumber 183.31±7GHz □





Channel number	Central wavenumber (cm^{-1})	Central wavelenth (μm)	Half power band width (cm^{-1})	□NEΔN□ mW/(m^2-sr-cm^{-1})
1	669	14.95	3	3.00
2	680	14.71	10	0.67
3	690	14.49	12	0.50
4	703	14.22	16	0.31
5	716	13.97	16	0.21
6	733	13.64	16	0.24
7	749	13.35	16	0.20
8	900	11.11	35	0.10
9	1030	9.71	25	0.15
10	802	12.47	16	0.15
11	1365	7.33	40	0.20
12	1533	6.52	55	0.20
13	2188	4.57	23	0.006
14	2210	4.52	23	0.003
15	2235	4.47	23	0.004
16	2245	4.45	23	0.004
17	2420	4.13	28	0.002
18	2515	4.00	35	0.002
19	2660	3.76	100	0.001
20	14500	0.69	1000	0.10%albedo

Spectral parameters: HIRS/3 s IRAS

Channel number	Central wavenumber (cm^{-1})	Central wavelenth (μm)	Half power band width (cm^{-1})	Main absorbers	The highest observing temperature (K)	NEΔN (mW/m^2-sr-cm^{-1})	The most contribution layer (hPa)
1	669	14.95	3	CO_2	280	4.00	30
2	680	14.71	10	CO_2	265	0.80	60
3	690	14.49	12	CO_2	250	0.60	100
4	703	14.22	16	CO_2	260	0.35	400
5	716	13.97	16	CO_2	275	0.32	600
6	733	13.84	16	CO_2/H_2O	290	0.36	800
7	749	13.35	16	CO_2/H_2O	300	0.30	900
8	802	12.47	30	window	330	0.20	surface
9	900	11.11	35	window	330	0.15	surface
10	1030	9.71	25	O_3	280	0.20	25
11	1345	7.43	50	H_2O	330	0.23	800
12	1365	7.33	40	H_2O	285	0.30	700
13	1533	6.52	55	H_2O	275	0.30	500
14	2188	4.57	23	N_2O	310	0.009	1000
15	2210	4.52	23	N_2O	290	0.004	950
16	2235	4.47	23	CO_2/N_2O	280	0.006	700
17	2245	4.45	23	CO_2/N_2O	266	0.006	400
18	2388	4.19	25	CO_2	320	0.003	atmosphere
19	2515	3.98	35	window	340	0.003	surface
20	2660	3.76	100	window	340	0.002	surface
21	14500	0.69	1000	window	100%A	0.10%A	cloud
22	11299	0.885	385	window	100%A	0.10%A	surface
23	10638	0.94	550	H_2O	100%A	0.10%A	Water vapor
24	10638	0.94	200	H_2O	100%A	0.10%A	Water vapor
25	8065	1.24	650	window	100%A	0.10%A	surface
26	6098	1.64	450	window	100%A	0.10%A	surface

Channel number	Central frequency (MHz)	Channel width(MHz)*	Main absorbers	The most contribution layer	□NEΔN□ mW/(m2-sr-cm-1)
1	23,800	251.02	□□	□□	0.3
2	31,400	161.20	□□	□□	0.3
3	50,300	161.14	□□	□□	0.4
4	52,800	380.52	O_2	1000 hPa	0.25
5	53,596+/–115	168.20	O_2	700 hPa	0.25
6	54,400	380.54	O_2	400 hPa	0.25
7	54,940	380.56	O_2	270 hPa	0.25
8	55,500	310.34	O_2	180 hPa	0.25
9	f_0=57,290.344	310.42	O_2	90 hPa	0.25
10	f_0+/–217	76.58	O_2	50 hPa	0.4
11	f_0+/–322.2 +/–48	35.11	O_2	25 hPa	0.4
12	f_0+/–322.2 +/–22	15.29	O_2	12 hPa	0.6
13	f_0+/–322.2 +/–10	7.93	O_2	5 hPa	0.8
14	f_0+/–322.2 +/–4.5	2.94	O_2	2 hPa	1.2
15	89,000	1998.98	□□	□□	0.5

Spectral parameters: AMSU-a s MWTS

Table 3.4.1-1. AMSU-B Channel Characteristics (based on actual instrument build and measured NEΔT from thermal vacuum data).

Channel number	Center freq. of channel (GHz)	No. of pass bands	Bandwidth per passband (MHz)	NEΔT[1] (K)	Polarization angle[2]
16	89.0±0.9	2	1000	0.37	90-
17	150.0±0.9	2	1000	0.84	90-
18	183.31±1.00	2	500	1.06	90-
19	183.31±3.00	2	1000	0.70	90-
20	183.31±7.00	2	2000	0.60	90-

[1] Values from first flight model.
[2] The polarization angle is defined as the angle from horizontal polarization (i.e., electric field vector parallel to satellite track) where is the scan angle from nadir. In this table, the polarization angle is horizontal when the angle indicated is and vertical when 90- .

Channel number	Central frequency (MHz)	Channel width(MHz)	Main absorbers	The most contribution layer	□NEΔN□ mW/(m2-sr-cm-1)
1	50,310	180	□□	□□	0.5
2	53,596±115	170	O_2	700 hPa	0.4
3	54,940	400	O_2	300 hPa	0.4
4	57,290	330	O_2	90 hPa	0.4

Spectral parameters: AMSU-b s MWHS

Channel number	Central frequency (MHz)	Channel width(MHz)	Main absorbers	The most contribution layer	□NEΔN□ mW/(m2-sr-cm-1)
1	150(V)	500×2	□□	□□	1.1
2	150(H)	500×2	□□	□□	0.9
3	183.3±1	250×2	H_2O	400hpa	0.9
4	183.3±3	500×2	H_2O	600 hPa	0.9
5	183.3±7	1000×2	H_2O	800 hPa	0.9

Problem during the generation of FY3 sounding data

- Channel 12 of IRAS hasn’t a corresponding channel in HIRS
- 15 pixels for each MWTS scanline are quite different from 30 pixels for AMSU-a
- 98 pixels for each MWHS scanline are quite different from 90 pixels for AMSU-b
- Other differences for NEΔN