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Validation of forecast cloud parameters from multispectral AIRS radiances

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Data Assimilation and Satellite Meteorology Research Section

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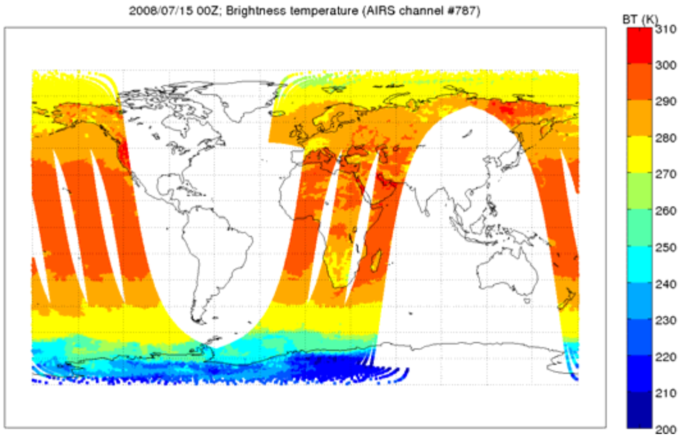
Motivation

- Provide to modelers a reliable methodology to validate cloud height and amount distributions in forecasts
- Improve cloud parameter retrievals, with applications to model validation, data assimilation and climate studies
- Use hyperspectral sounders to do this in a general framework (applicability to AIRS, IASI, Cris…)



Typical 6-h AIRS coverage

Basic idea

Assumption: Comparing directly model output cloud parameters with retrievals subject to ambiguous results due to limitations of the retrieval technique

Therefore:

- Retrieve effective cloud height and amount from CO_2 - slicing technique using observed AIRS radiances
- Retrieve same parameters from calculated AIRS radiances using forecast output at real observation locations

⇨ Eliminates ambiguity of definition between retrieved and model values of cloud parameters: comparing apples with apples. This also allows to understand and minimize limitations of the retrieval technique.

Data, RTM

INPUT:

Collected data: AIRS 281-channel set reduced to center pixel in 3X3 "golf ball" (in assimilation warmest, but this is not suitable for climatology of cloud parameters)

Forecast model: EC global model, 600 X 800 grid (~35 km), interpolated at the location of observation, 6 h forecast (valid interval 3-9h) and 12h forecast (valid interval 9-15h) at 45 min intervals. Entire month of July 2008 used (31 days times 4 forecasts/day).

Radiative transfer model: modified RTTOV 8.7 version

Cloud optical properties: cloud overlap scheme [*Räisänen, 1998*], fixed liquid particle size (10 μm radius over land and 13 μm radius over ocean), ice particle size parameterization [*McFarquhar et al. 2003*]

Revision/adaptation of CO_2-slicing technique

following this study

- 13 radiance pairs used, all in narrow range 13.2-14.1 μm
- Median value of height retained with corresponding effective amount

before

- Original implementation for AIRS in 2004 used 12 pairs with channel 528 (12.2 μm) used in all pairs. Mean was retained.

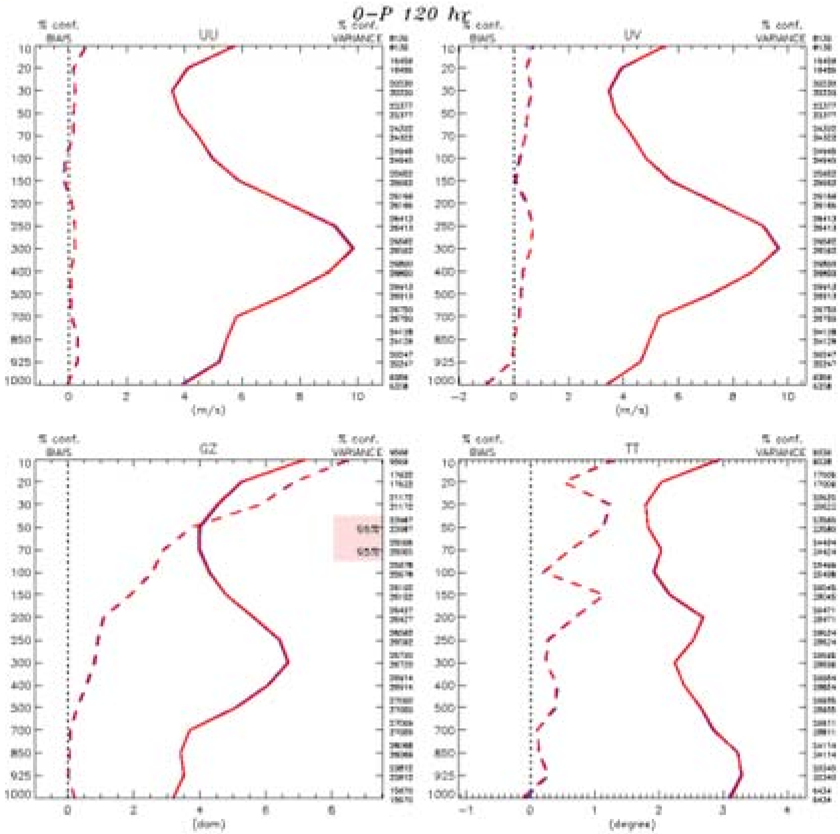
CO_2-slicing technique: new selection

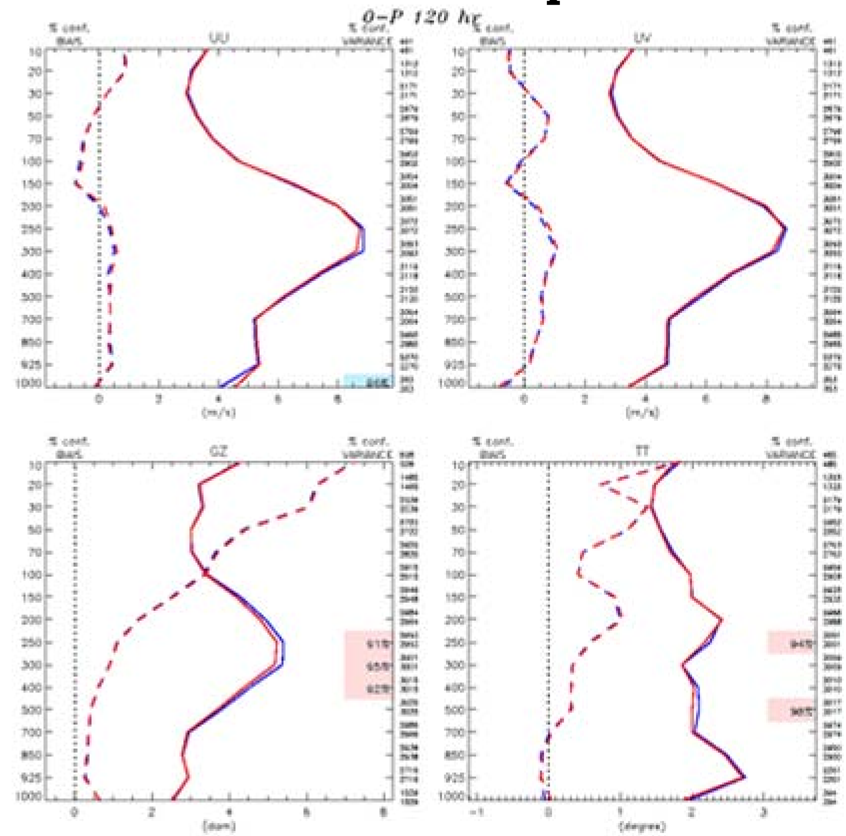
Initial configuration: 12 channels coupled with a reference channel	
Channel #	Wavenumber
204	707.770
221	712.661
232	715.862
252	721.758
262	724.742
272	727.752
299	735.298
305	737.152
310	738.704
355	752.970
362	755.237
475	801.001
Reference channel	
528	820.731

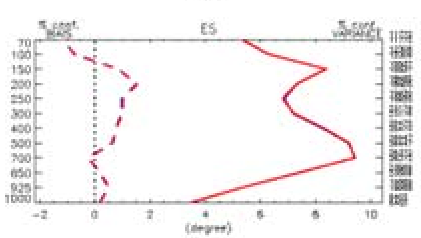
Chosen configuration: 13 pairs of coupled channels In narrow limited range				
	Channel A		Channel B	
Pair #	#	cm^{-1}	#	cm^{-1}
1	**204**	707.770	**252**	721.758
2	**221**	712.661	**262**	724.742
3	**232**	715.862	**272**	727.752
4	**252**	721.758	**299**	735.298
5	**262**	724.742	**305**	737.152
6	**272**	727.752	**310**	738.704
7	**299**	735.298	**355**	752.970
8	**305**	737.152	**362**	755.237
9	**310**	738.704	**375**	759.485
10	**355**	752.970	**375**	759.485
11	**362**	755.237	**262**	724.742
12	**375**	759.485	**252**	721.758
13	**375**	759.485	**204**	707.770

Assimilation impact test on CO2-slicing channel selection: 120 h forecast vs observations

Global **Southern Hemisphere**



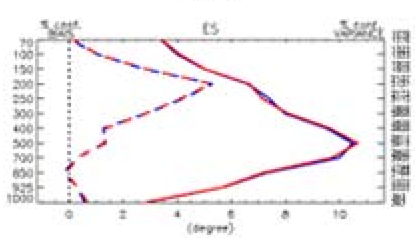




Ref channel AIRS-528 (820 cm^{-1}), mean of 13 pairs

All pairs in range 797-760 cm^{-1}, median of 13 pairs

Positive impact in Southern hemisphere



Definition of model cloud parameters

Based on cloud transmittance τ_{cloud} *(I, TOA)* in a window channel, considering cloud emissivity and overlap assumptions

CTH = effective Cloud Top Height = *level* I where $\tau_{cloud} = 0.9$

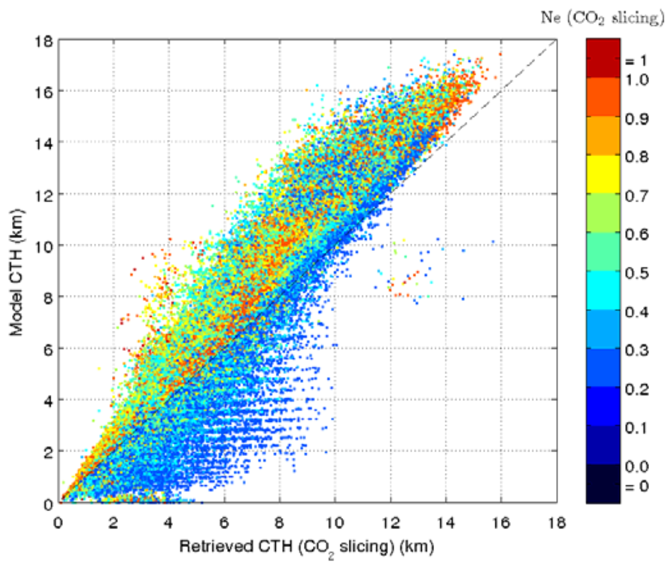
Ne = effective cloud fraction = 1 - τ_{cloud}

N = cloud fraction, same definition, but assuming cloud emissivity of unity: cloud mask

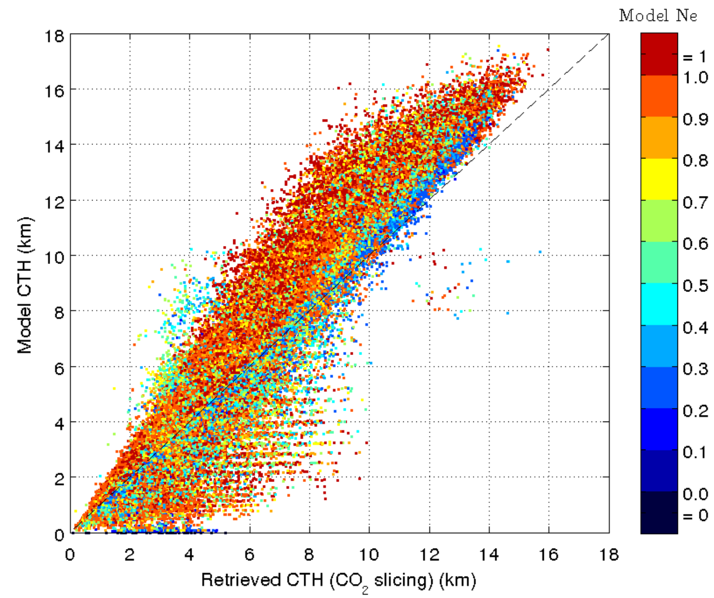
Understanding CO_2-slicing

Direct model output CTH vs retrieved CTH

Color Ne retrieved



Color Ne model output



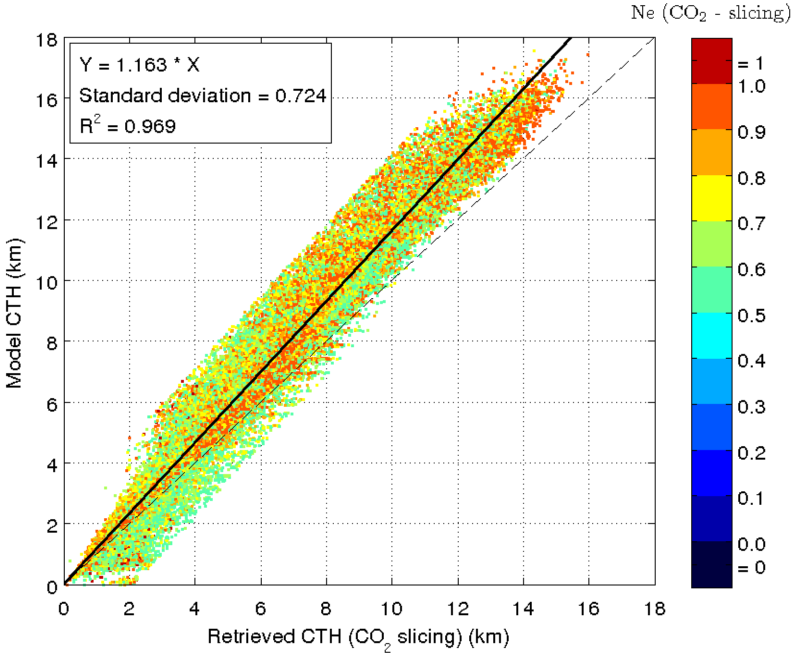
- Bias increases with height except for low Ne
- Underestimation of retrieved overcast cases

Validation results: cloud top height bias

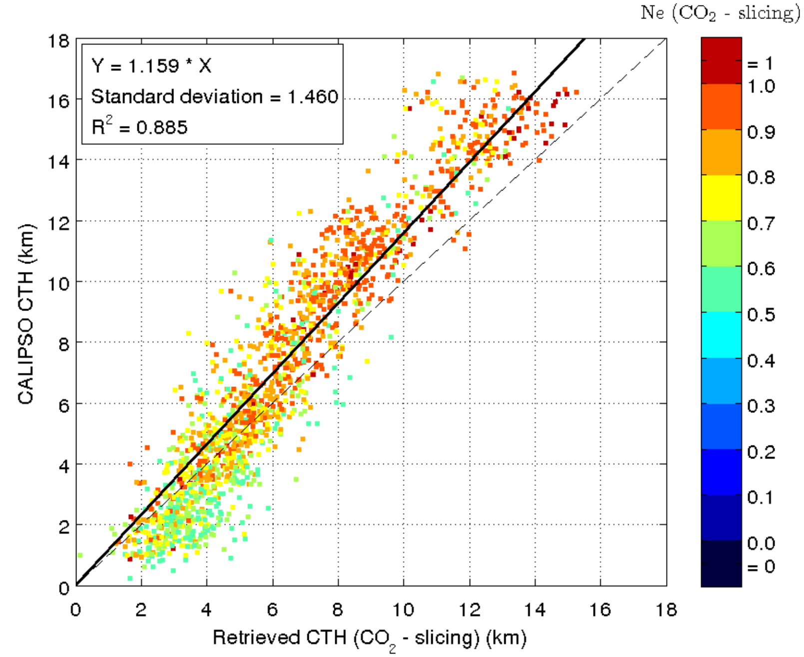
Model CTH vs retrieved CTH from simulated AIRS radiances

Global data

Model CTH vs retrieved CTH from simulated AIRS radiances



CALIPSO CTH vs retrieved CTH from real AIRS radiances



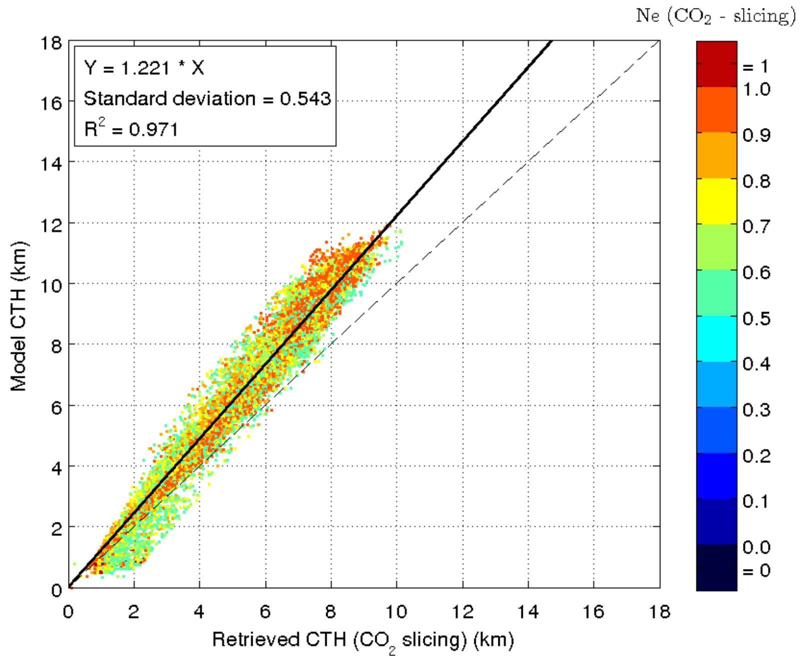
Remarkable similitude in dynamic range and bias attributed to CO_2 slicing technique. Implies definition of model height OK.

Validation results: cloud top height bias

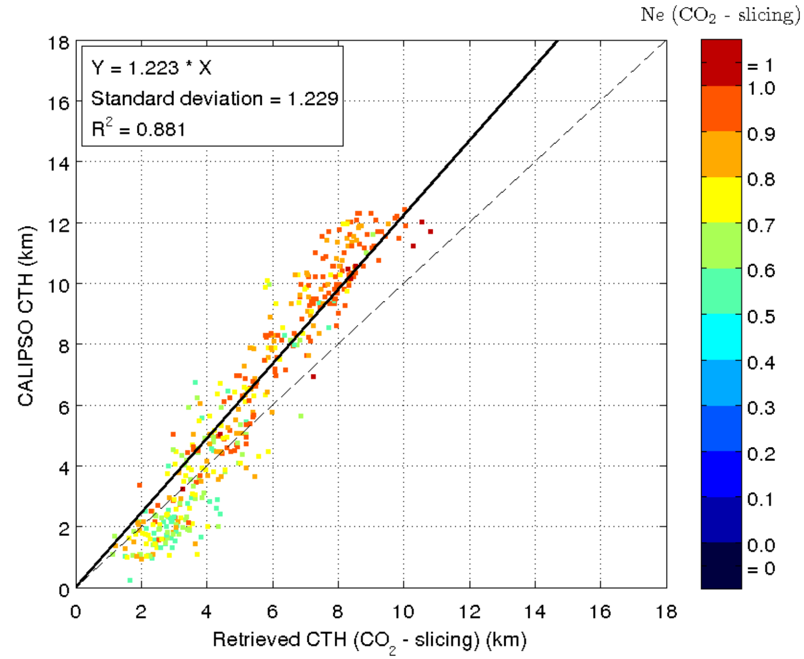
Model CTH vs retrieved CTH from simulated AIRS radiances

65˚S – 40˚S

Model CTH vs retrieved CTH
from simulated AIRS radiances



CALIPSO CTH vs retrieved CTH
from real AIRS radiances

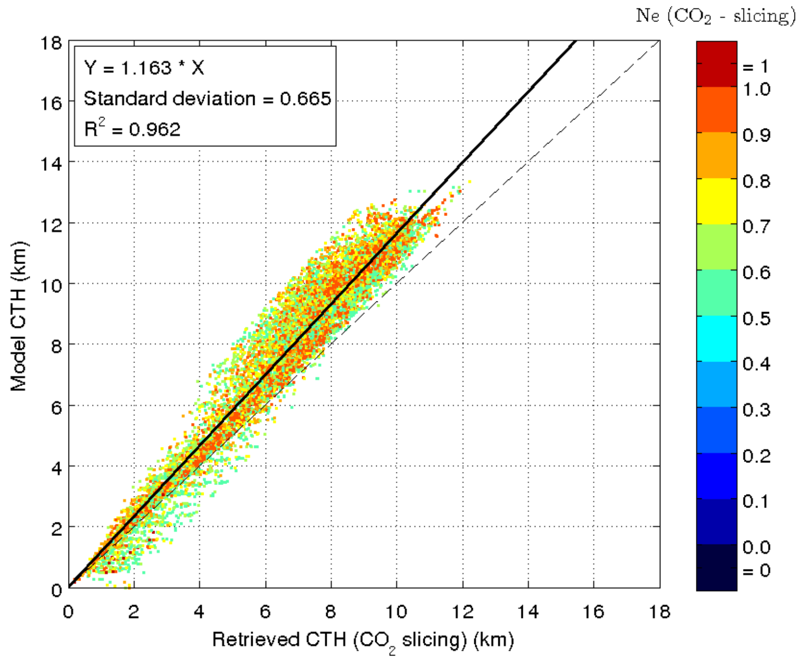


Validation results: cloud top height bias

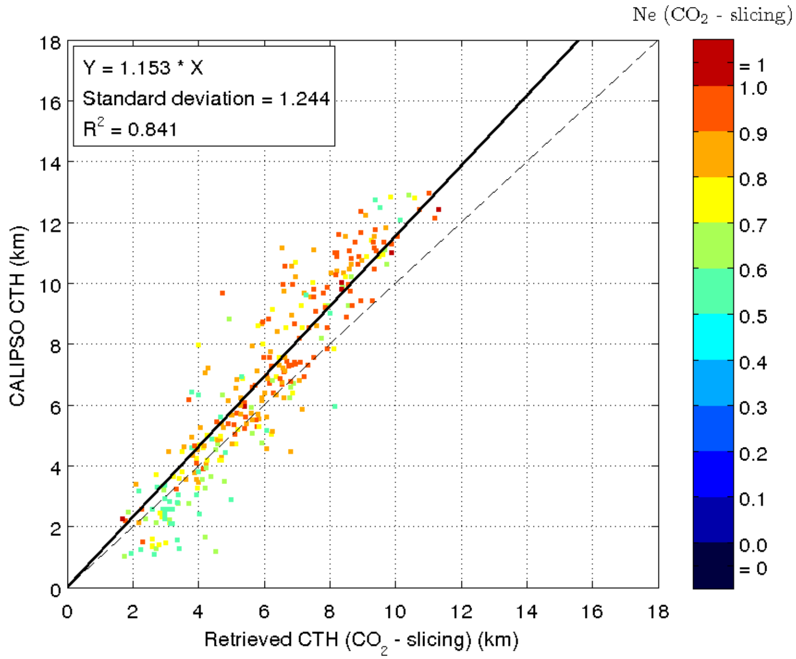
Model CTH vs retrieved CTH from simulated AIRS radiances

40˚N – 65˚N

Model CTH vs retrieved CTH
from simulated AIRS radiances



CALIPSO CTH vs retrieved CTH
from real AIRS radiances

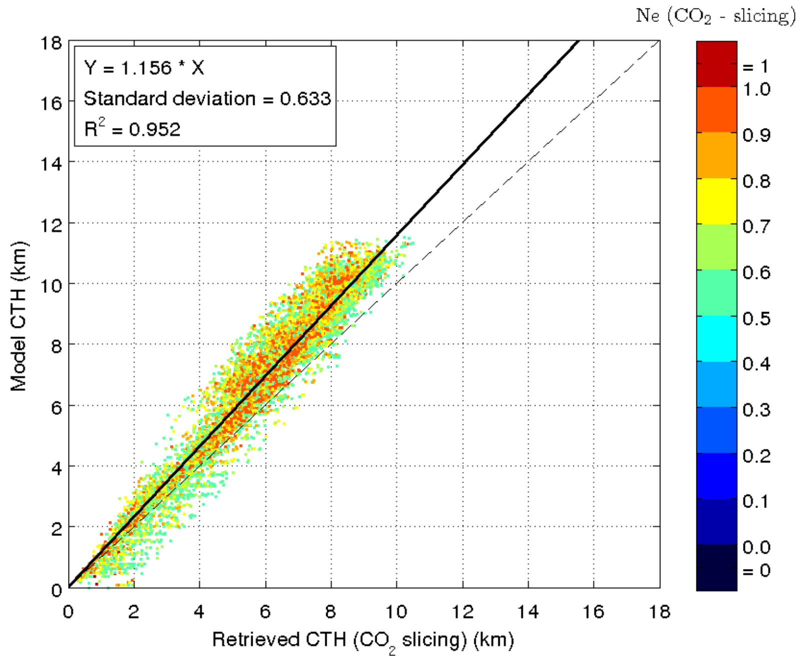


Validation results: cloud top height bias

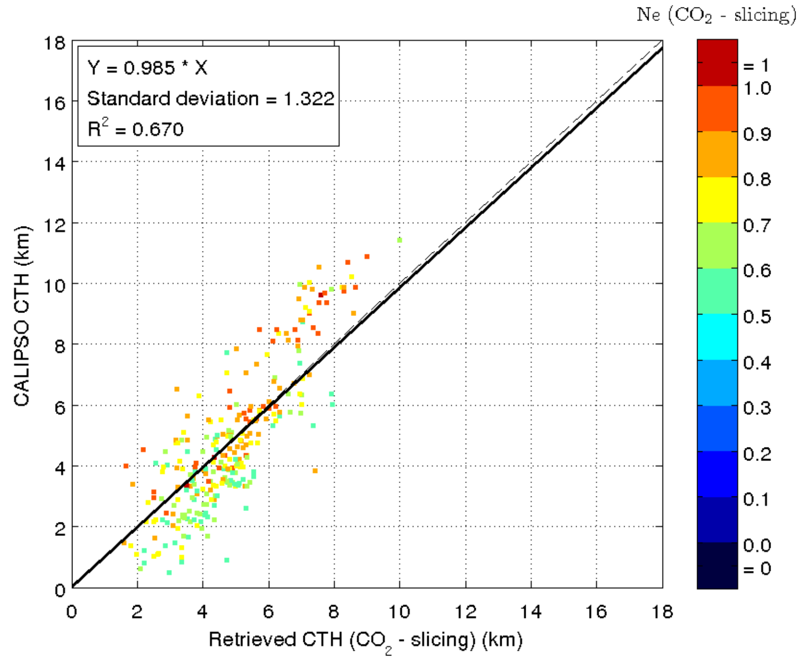
Model CTH vs retrieved CTH from simulated AIRS radiances

Arctic: 65˚N – 90˚N

Model CTH vs retrieved CTH from simulated AIRS radiances



CALIPSO CTH vs retrieved CTH from real AIRS radiances

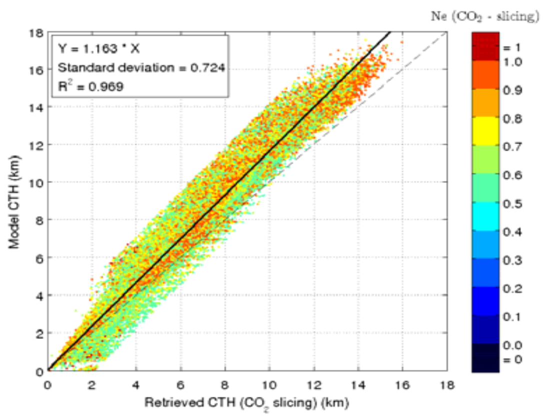


Validation results: cloud top height bias

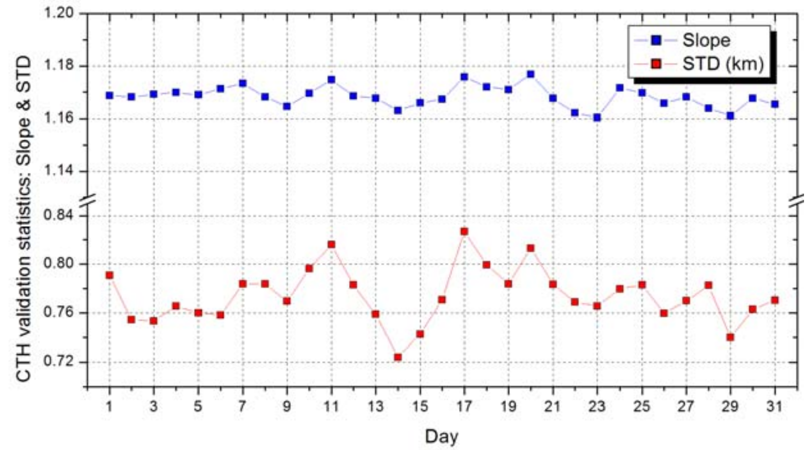
The bias model vs retrieved is quite stable. Only cloud amounts superior to 0.5 were considered.

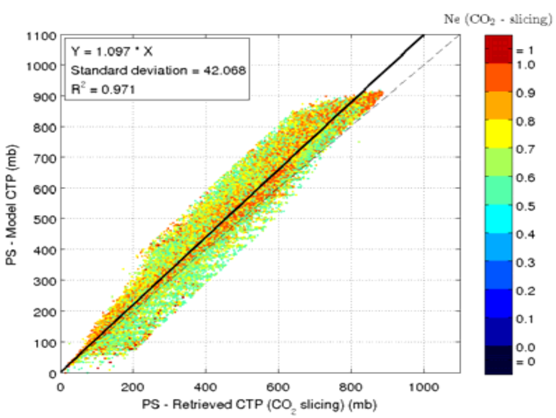
2008/07/14

Daily values for July 2008

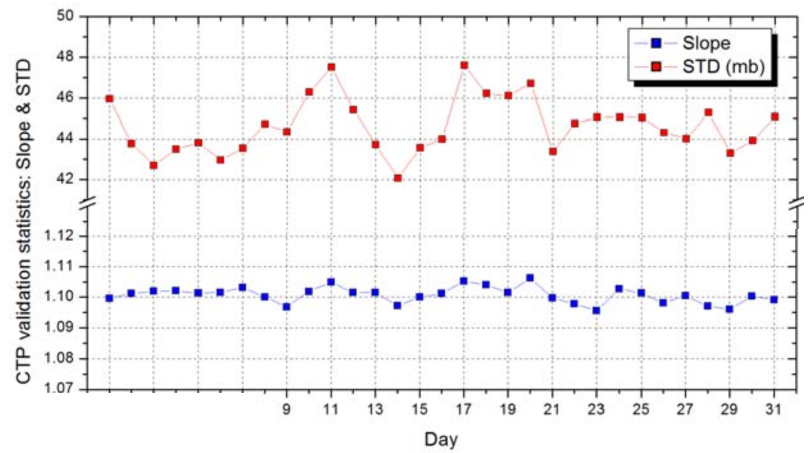


CTH bias





CTP bias



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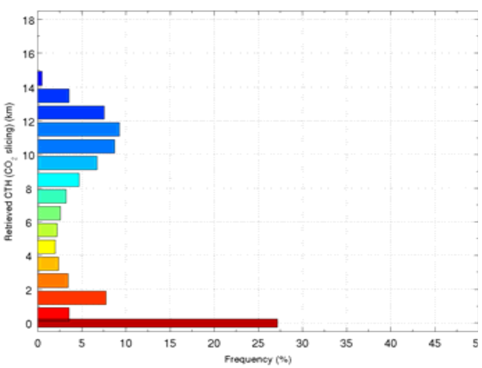
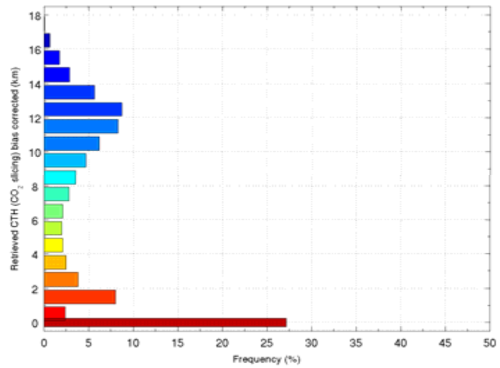
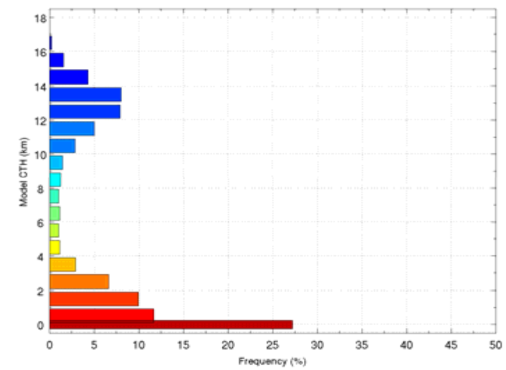
Importance of CTH bias correction

CO_2 slicing from simulated BTs
Raw Unbiased

CTH directly from
Model output



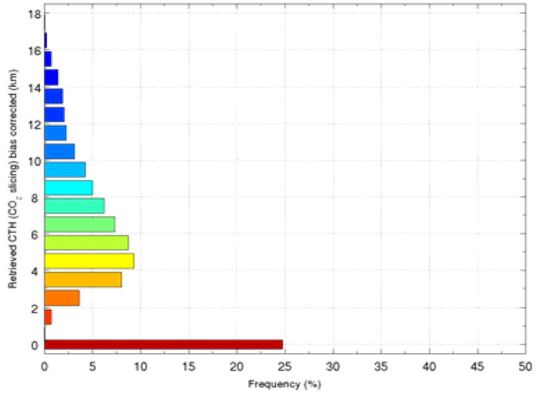




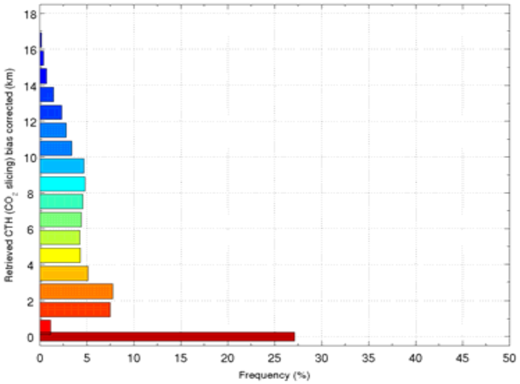
15-S to 15 S CTH distribution

Tool to the modeler: cloud height distributions. Here global for 15 june 2008

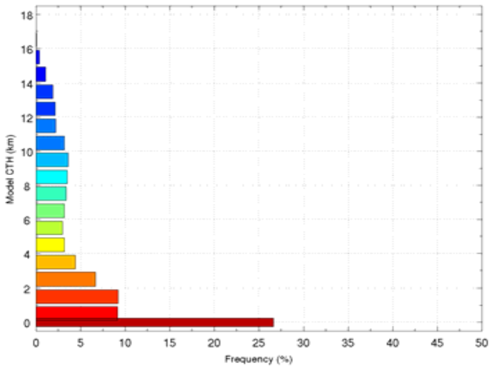
Real data Co2-slicing



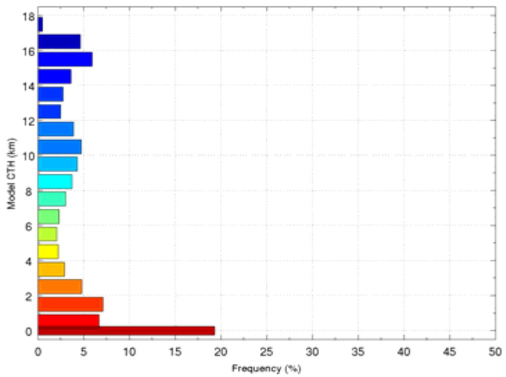
Simulated data CO2-slicing



Direct model output (e<=1)

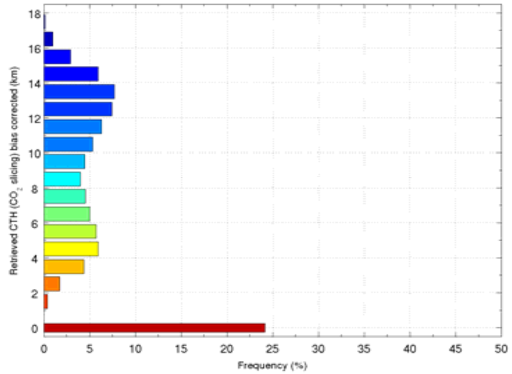


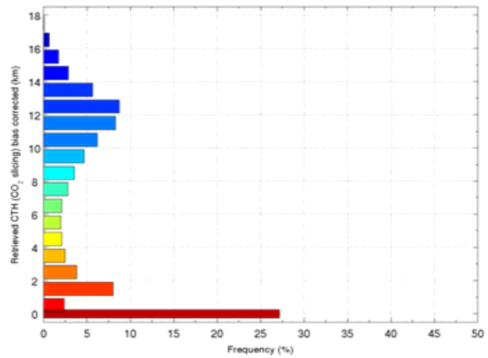
Direct model output (e=1)



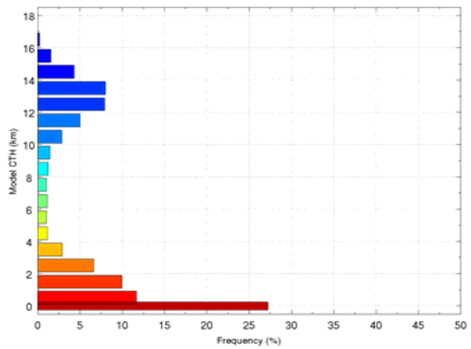
CTH distributions 15S=15N

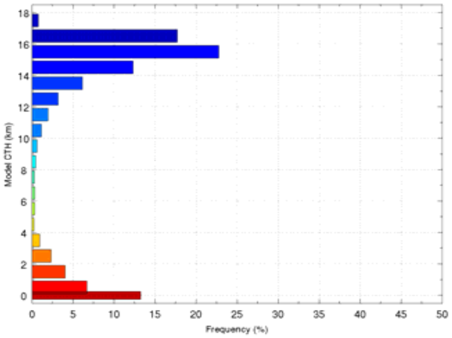
Real data Co2-slicing	Simulated data CO2-slicing





Direct model output (e<=1)	Direct model output (e=1)

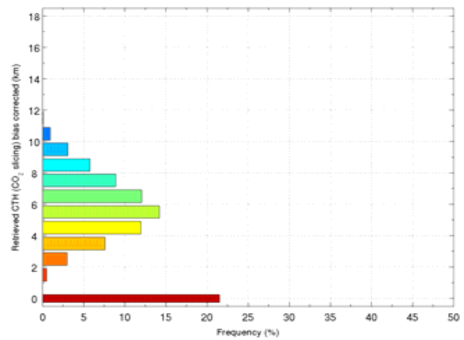


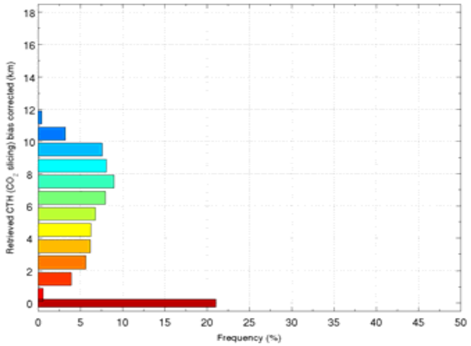


CTH distributions 65-90 N

Real data Co2-slicing

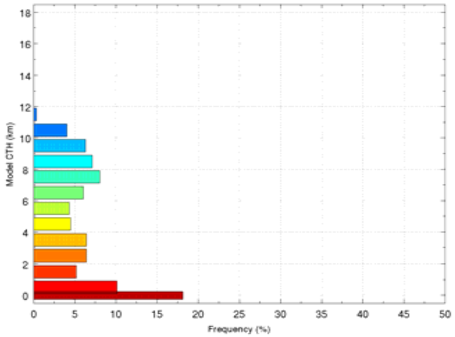
Simulated data CO2-slicing

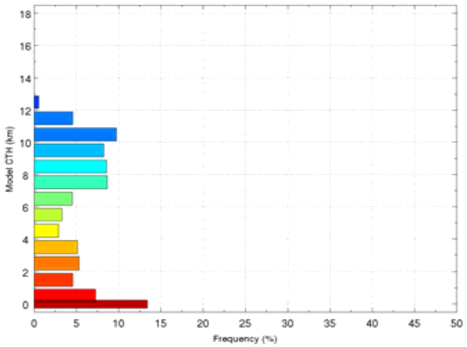




Direct model output (e<=1)

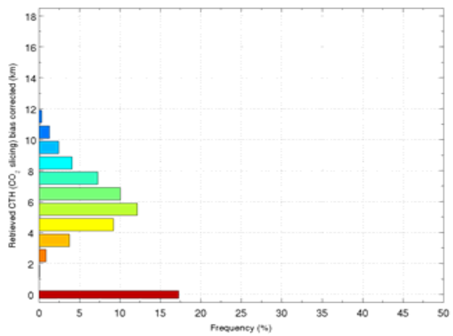
Direct model output (e=1)

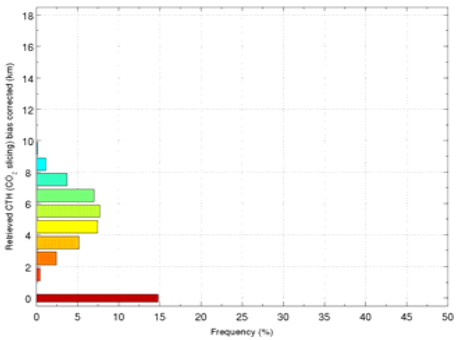




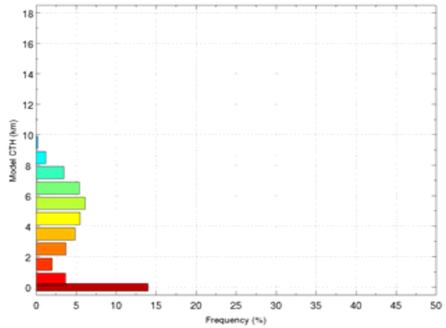
CTH distributions 65-90 S

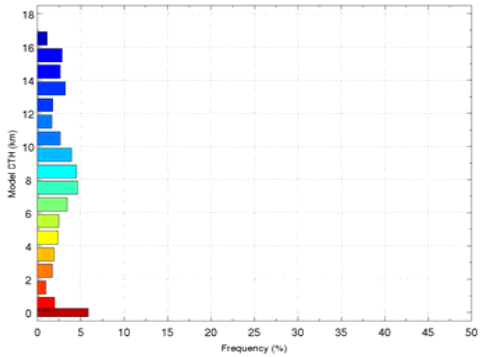
Real data Co2-slicing	Simulated data CO2-slicing



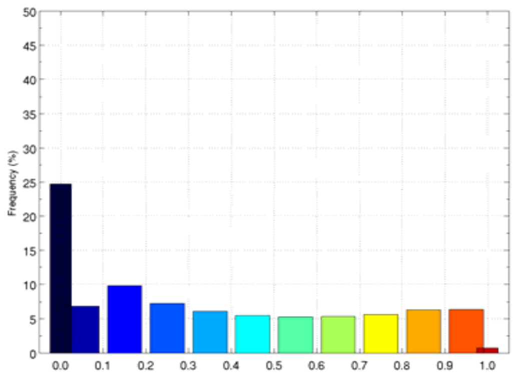


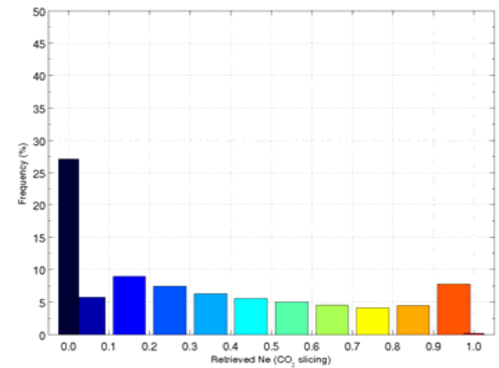
Direct model output (e<=1)	Direct model output (e=1)





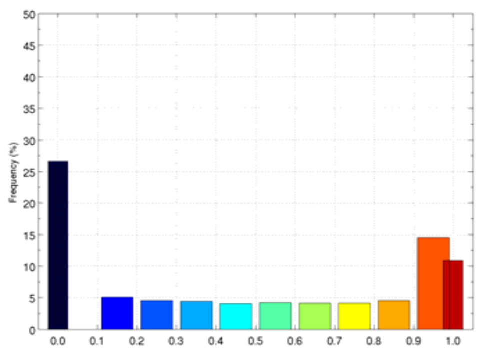
Ne global distributions

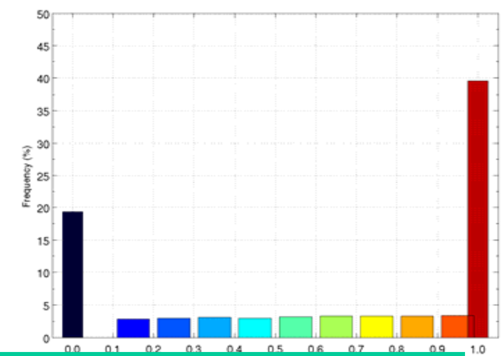




real retrievals

simulated retrievals

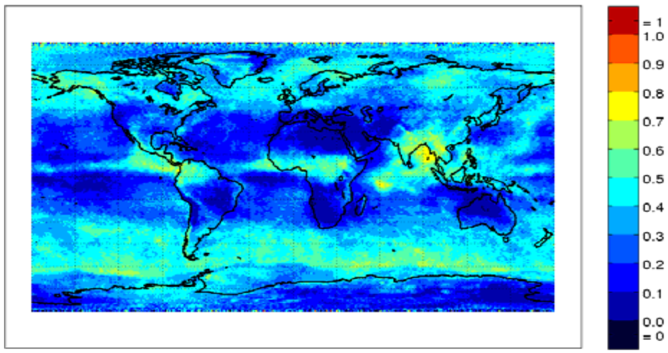




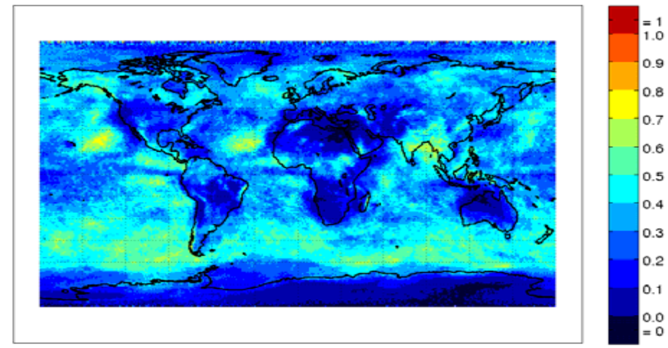
Direct output e<=1

direct output e=1

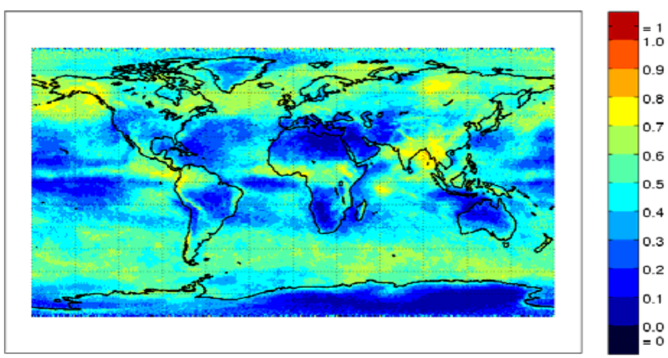
Effective cloud amount Ne monthly results



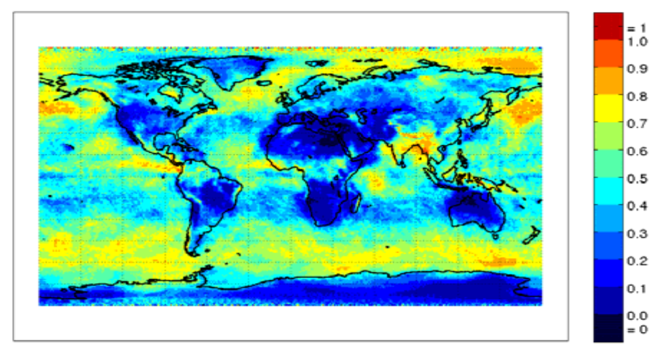
Observed Ne AIRS-CMC



Model 3-9-h Ne simulated BTs



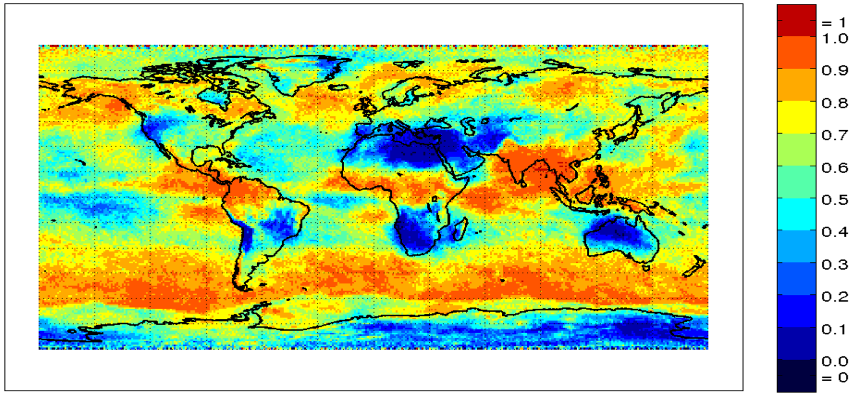
Observed Ne AIRS-JPL



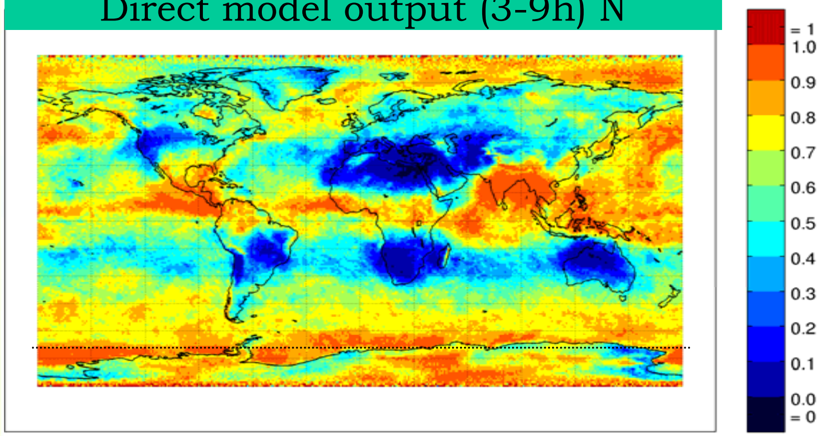
Ne from direct 3-9h model output

Cloud fraction (N) comparisons

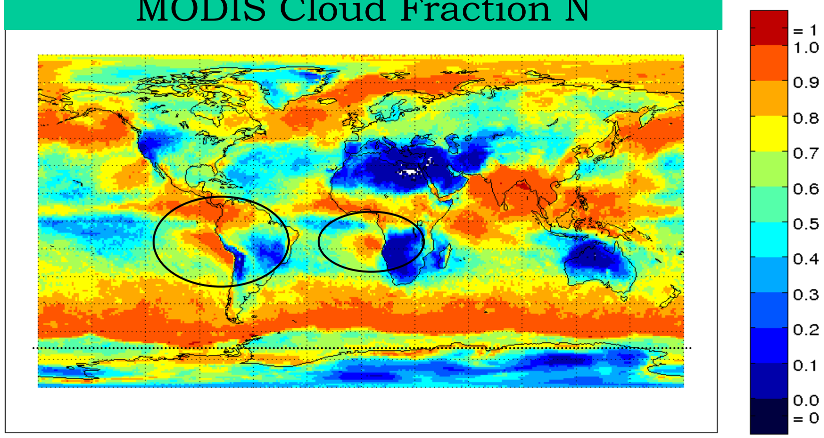
AIRS-CMC cloud fraction



Direct model output (3-9h) N



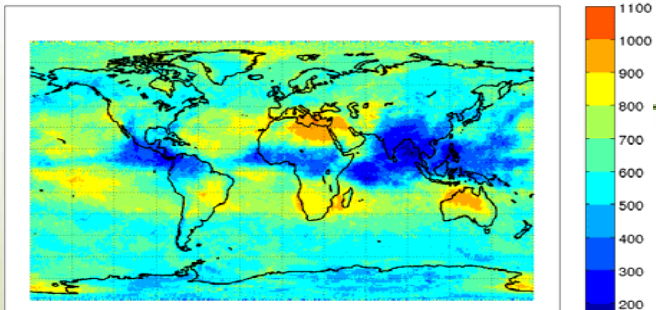
MODIS Cloud Fraction N



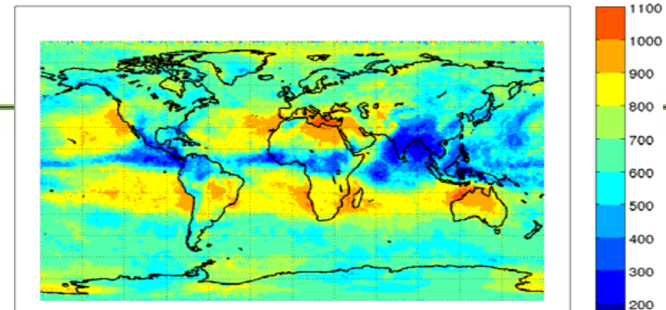
Source: MODIS science team

Excellent agreement between AIRS-CMC and MODIS Model has maximum Cloudiness next to Antartic coast, not supported by observations.

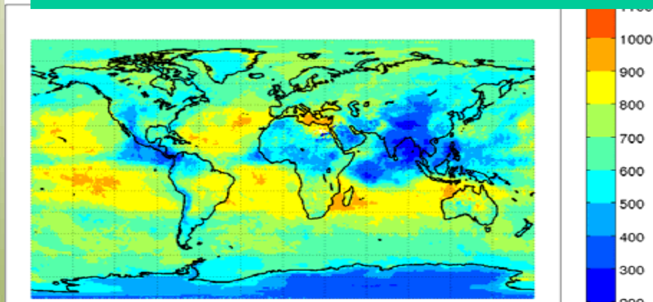
Monthly cloud height results



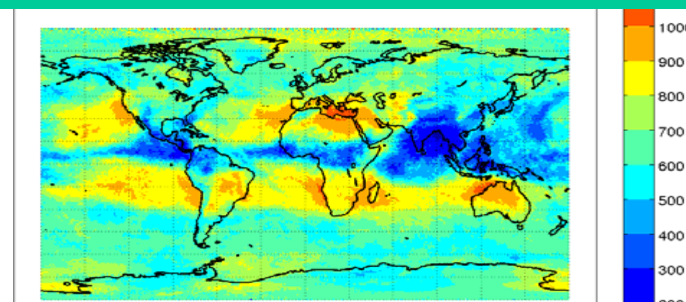
Observed AIRS-CMC



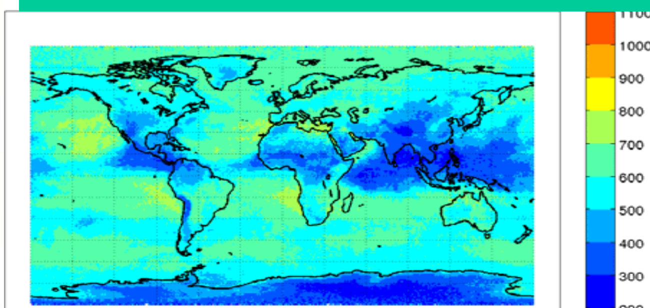
Model 3-9h forecasts CO2-slicing



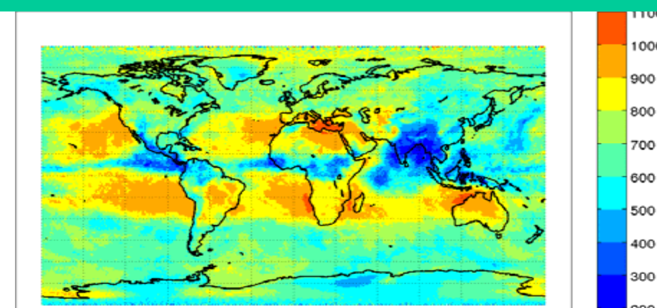
Observed Modis



Model 9-15h forecasts CO2-slicing



Observed AIRS-JPL



Direct model output 3-9h forecasts

Conclusions

- A model validation methodology for basic cloud parameters was presented based on the following principle: Apply the same retrieval technique to real and simulated radiances
- Robust definitions of model effective height and amount are proposed
- The method is designed for hyperspectral sounders and relies on well established Co2-slicing method
- CO_2-slicing technique was revised. It is suggested to use ~13 independent pairs in range 13.2-14.1 mm range. Retain median CTH and corresponding Ne.
- A simple CTH bias correction is proposed based on simulated retrievals with remarkable similarity to real retrievals compared to CALIPSO heights
- Vertical distributions of CTH is the main output to the modeler to adjust cloud and radiation parameterizations.
- Monthly products compare well with independent sources such as AIRS-JPL and MODIS. Differences are attributed to different retrieval methodology.