Usage of differential absorption method in the thermal IR: a case study of quick estimate of clear-sky column water vapor

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Outline

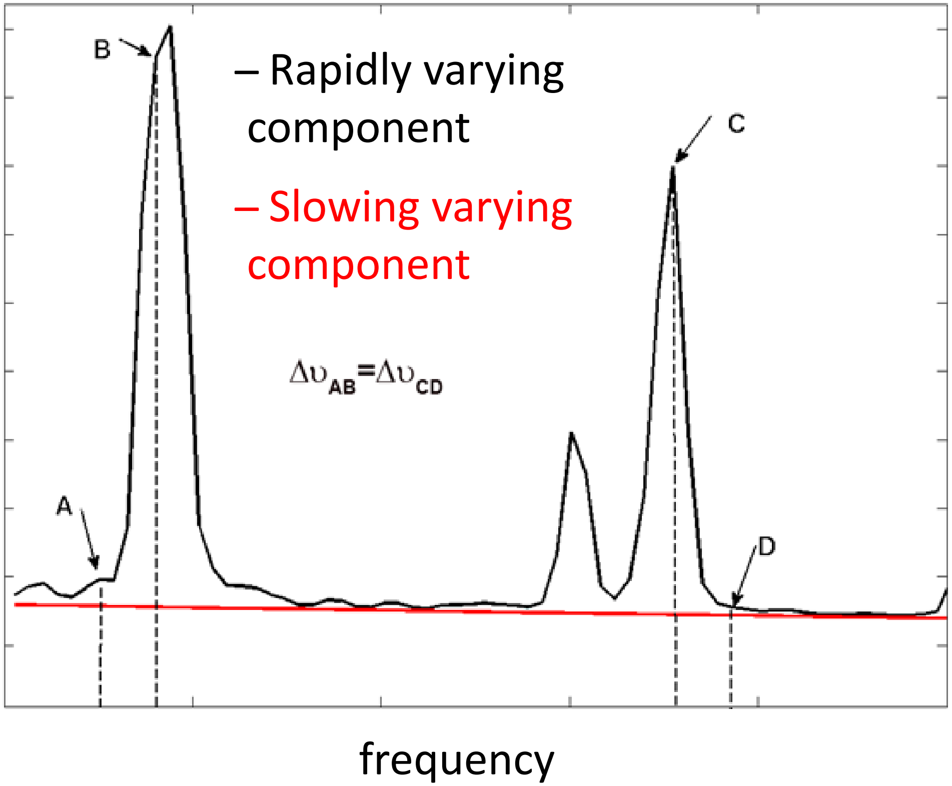
- Motivation: *the differential absorption method*
  - – UV and Visible
  - – Thermal-IR?
- Algorithm
- Validations
- Conclusions

Motivation: the differential absorption method

Example 1: The Differential Optical Absorption Spectroscopy (DOAS) instrumentation, **visible and UV**

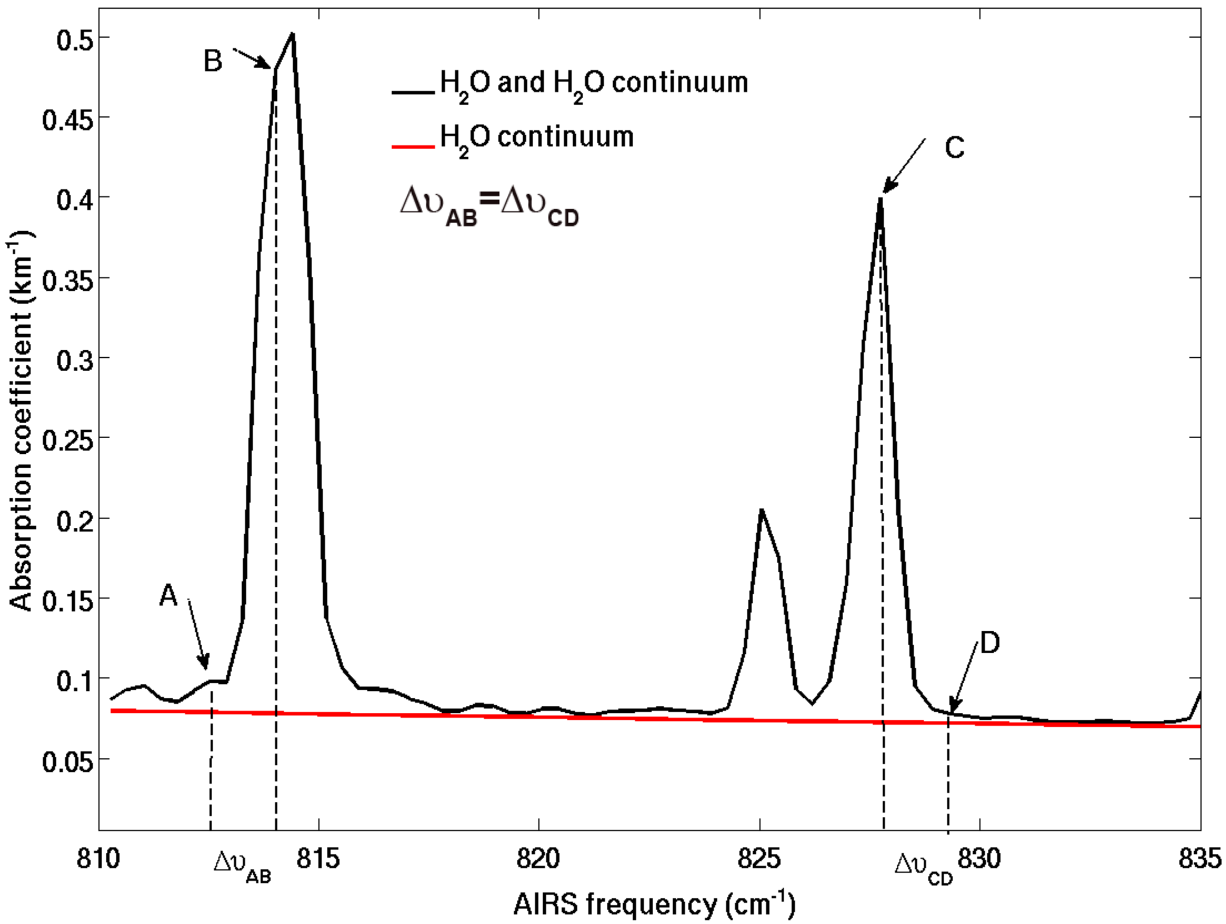
Example 2: Dobson spectrophotometer for ozone concentration, **UV**

Main point: double pairs of wavelengths are used to remove slowing varying component while retaining rapidly varying component



Motivation: the differential absorption method

Can we apply the concept to **thermal IR**?
A case study: clear-sky total column water vapor (CWV) retrieval from AIRS radiance



Algorithm

Flowchart for clear-sky CWV retrieval from AIRS radiance

AIRS radiance

Double difference

$$DDR = (R_D - R_C) - (R_B - R_A)$$

H_2O continuum is nearly canceled

H_2O line absorption contrast is highlighted

Ts effect (BT_E)

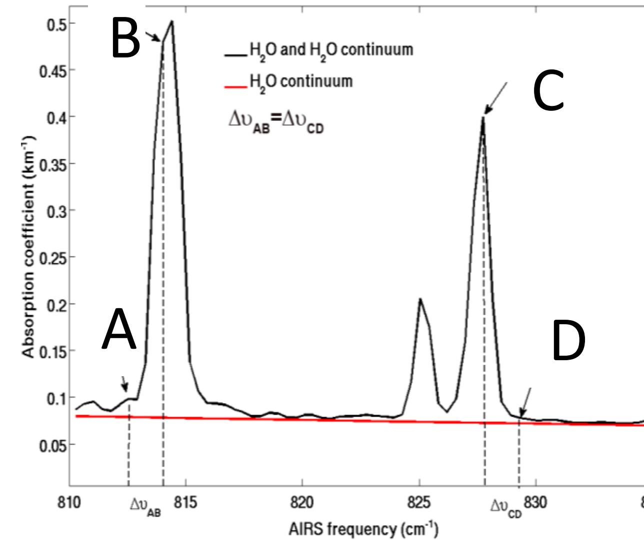
Take emission into account

Lapse rate effect ($BT_E - BT_F$)

Look-up-table

Land or ocean?

CWV



Algorithm

Datasets and model for training

- 6-hourly ECMWF ERA-Interim reanalysis
  Four months (Jan., Apr., Jul., Oct.) in 2005
- PCRTM (principal-component based radiative transfer model, Liu et al., 2006)

Datasets for validations

- 6-hourly ECMWF ERA-Interim reanalysis (diff. from the training data set)
  Four months (Jan., Apr., Jul., Oct.) in 2008
- Thermodynamic Initial Guess Retrieval (TIGR2000 v1.2)
  measured by real raidosondes, 1968-1989
- AIRS L2 cloud-cleared radiance in year of 2004
- AIRS L2 H_2O retrievals : accuracy ±10% , RMS 20-35%

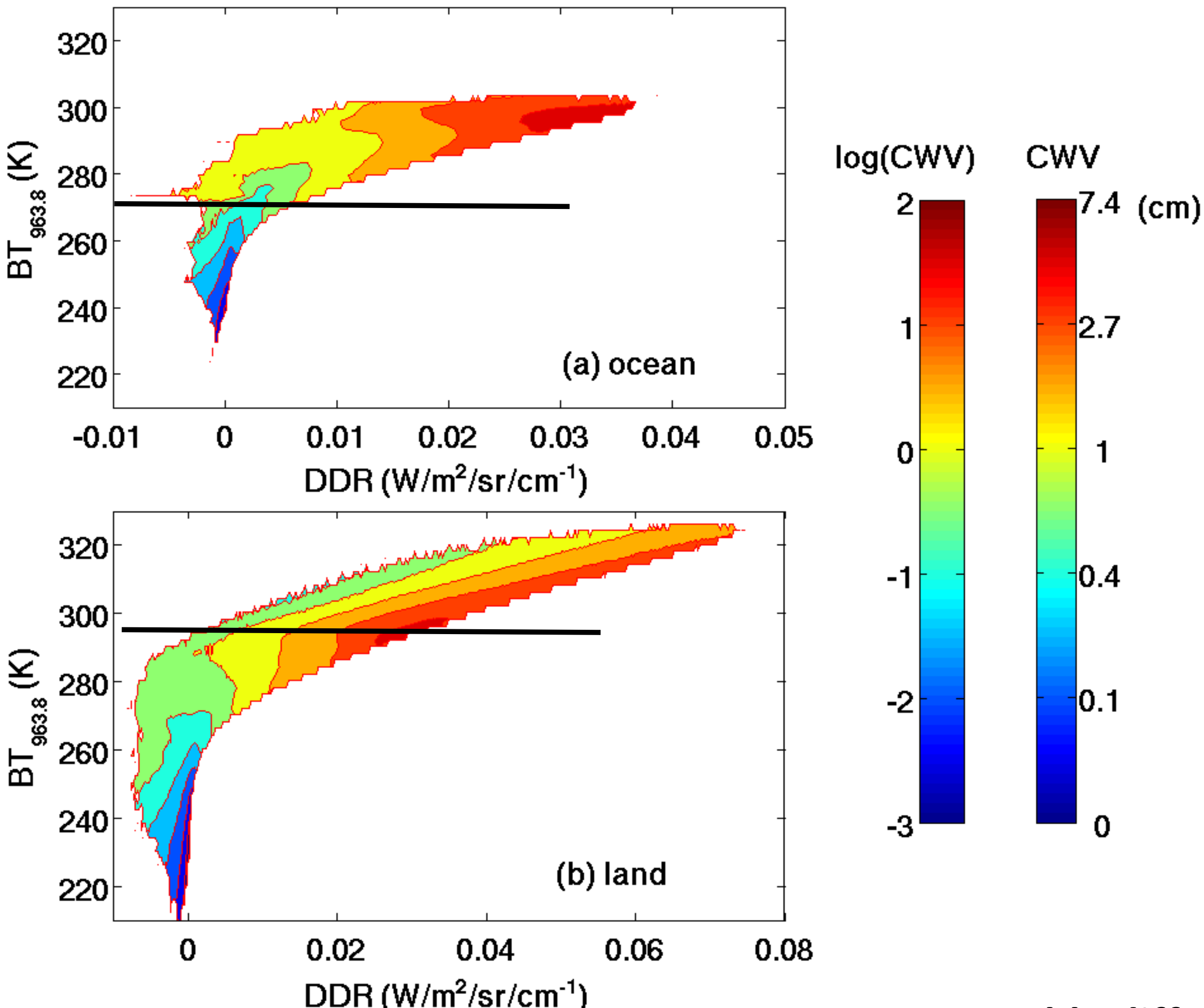
Algorithm

Information on the selected AIRS channels

ID	Channels (cm^{-1})	Peak of weighting function	Major absorption features	Surrogates	
A	812.531	surface	H_2O continuum	DDR	
B	814.029	80hPa above surface	H_2O weak line and continuum		
C	827.747	80hPa above surface	H_2O weak line and continuum		
D	829.299	surface	H_2O continuum		
E	963.836	surface	H_2O continuum	$BT_{963.8}$ for T_s	$\Delta BT_{963.8\text{-}748.6}$ for lapse rate
F	748.6	753.6 hPa	CO_2		

Algorithm

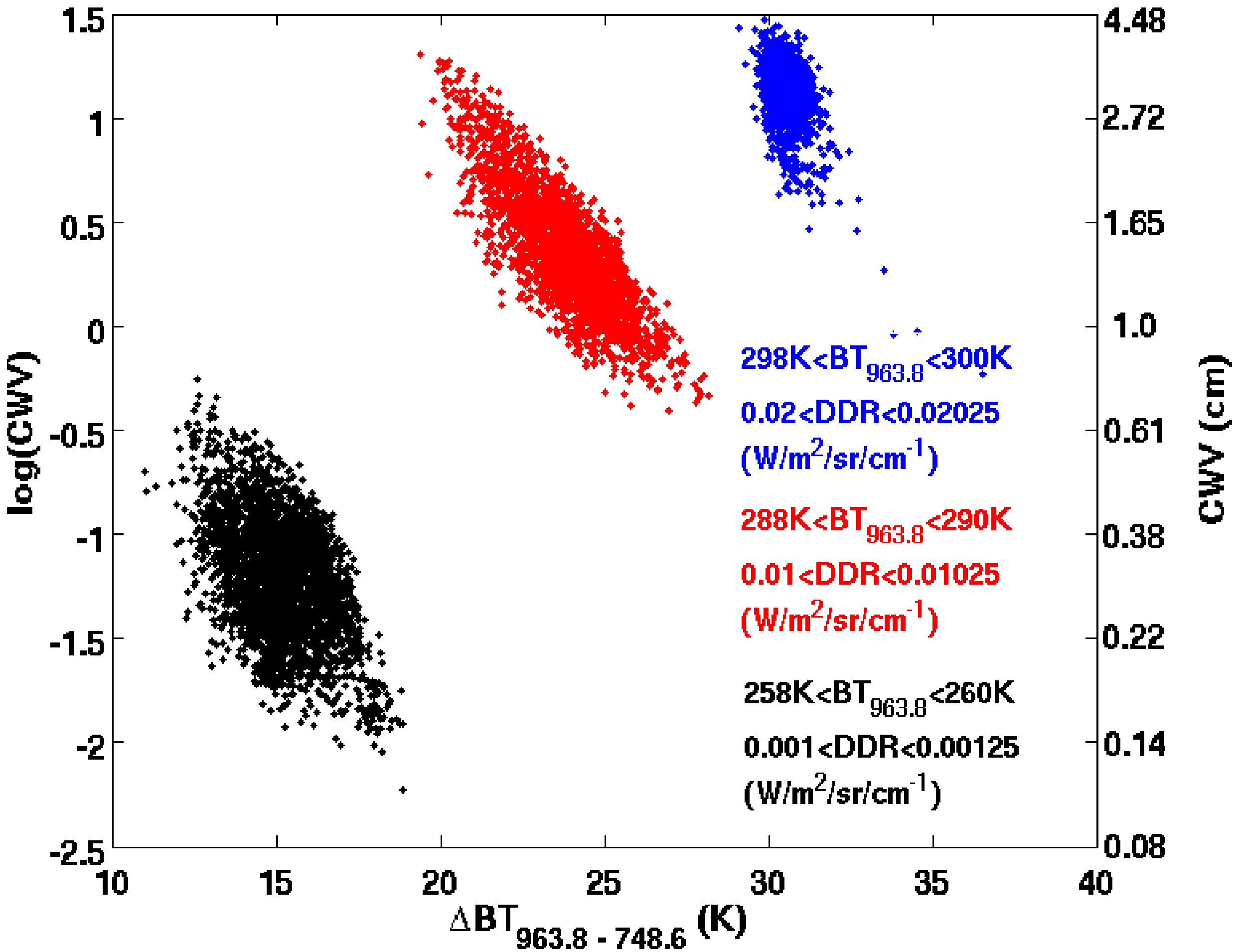
Composites of log(CWV) as functions of DDR and $BT_{963.8}$ (proxy of T_s)



DDR = Double difference radiance

Algorithm

Scatter plot of log(CWV) w.r.t. $\Delta BT_{963.8\text{-}748.6}$ (proxy of lapse rate)

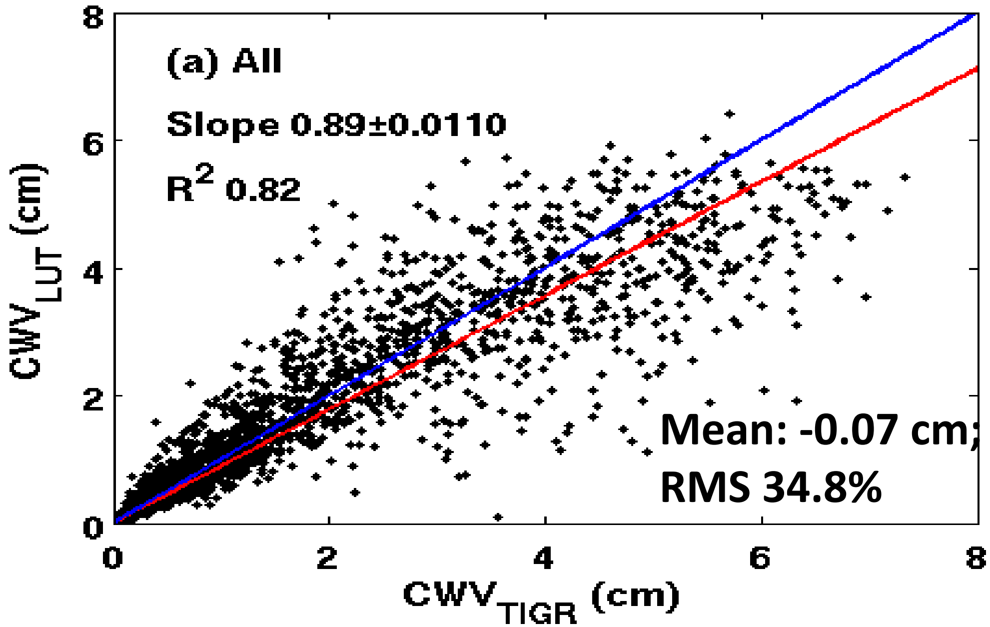


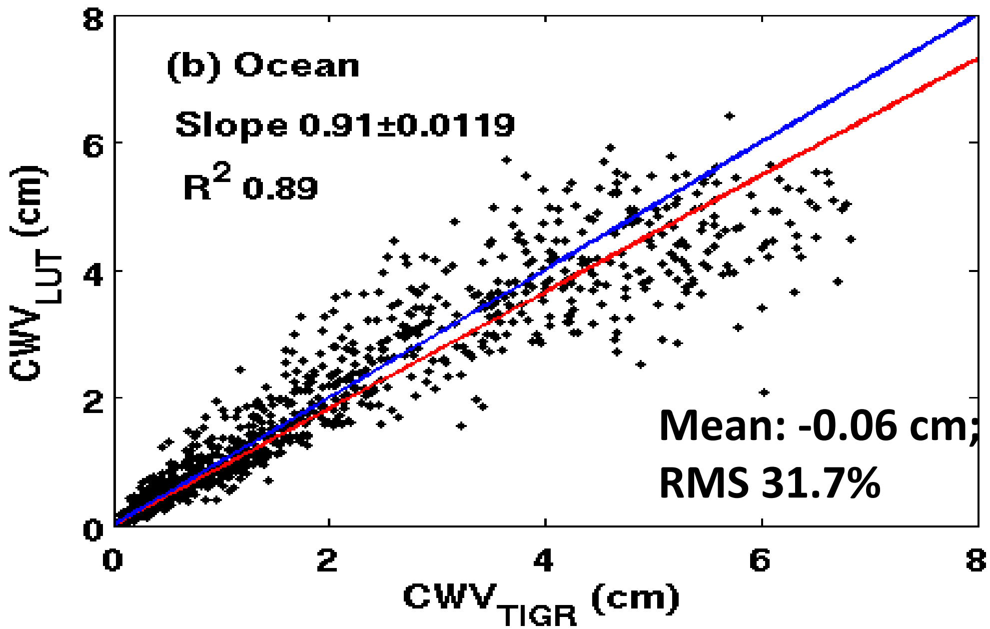
Algorithm

Look-up-table

- Composites of CWV w.r.t. DDR, $BT_{963.8}$, $\Delta BT_{963.8-748.6}$
- Ocean and land respectively
- Denoted as CWV_{LUT} in following plots/validations

Validation I





Validation I:
CWV_{LUT} (y axis)
VS.
CWV_{TIGR} (x axis)

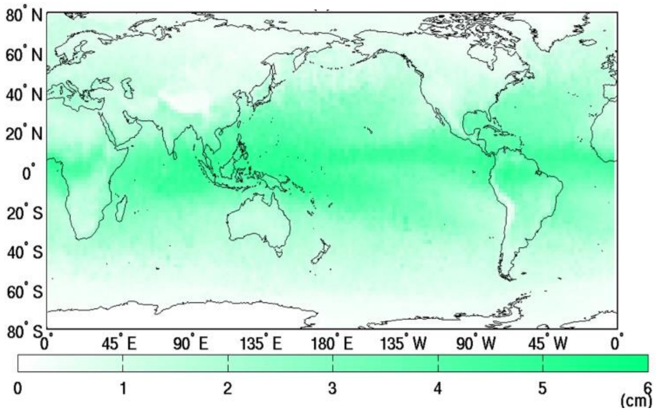
Regression slope

1:1 line

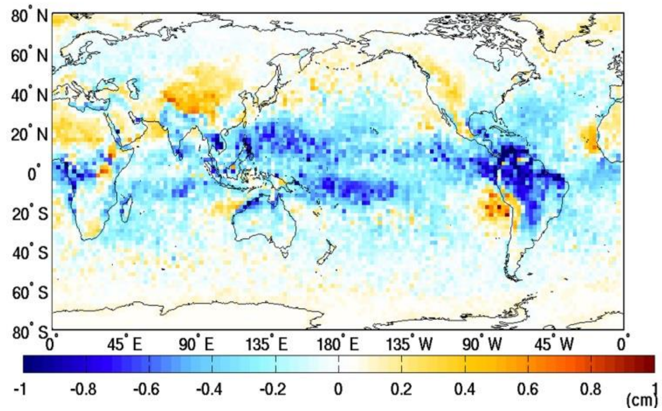
Validation II

Validation II:
CWV_{LUT} from real AIRSL2 cloud-cleared radiances **VS.** CWV_{AIRS}

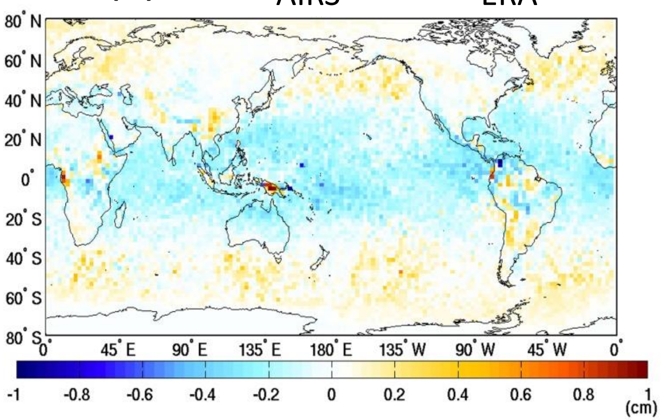
(a) CWV_{AIRS}



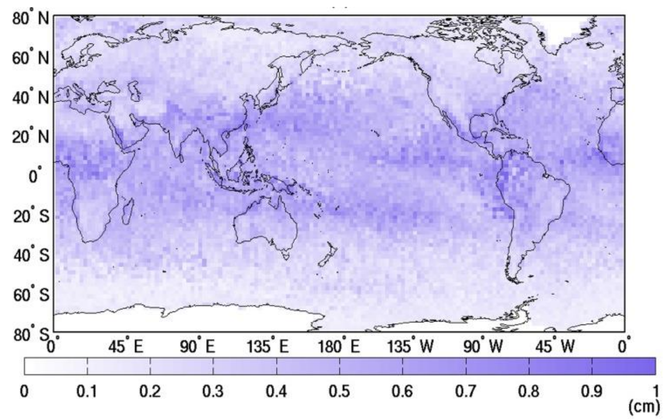
(b) CWV_{LUT} - CWV_{AIRS}



(c) CWV_{AIRS} – CWV_{ERA}



(d) STD of (CWV_{LUT} – CWV_{AIRS})



Mean is -0.05 cm
RMS is 33.8%.

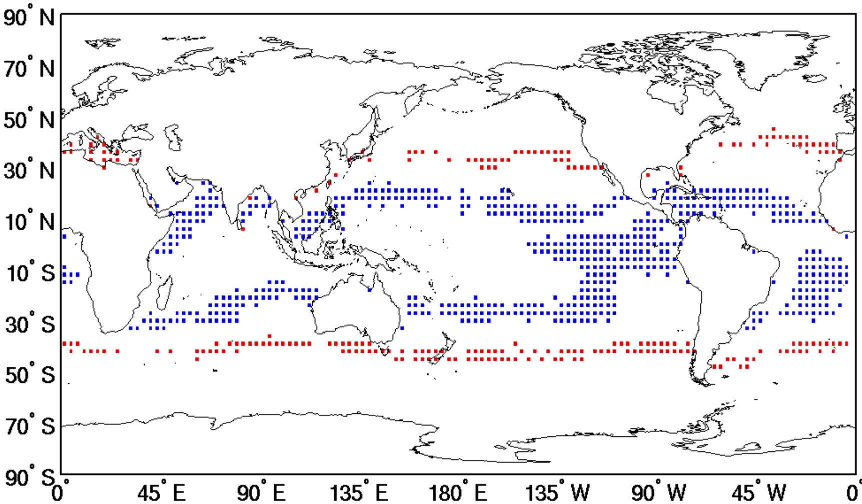
Conclusions

- Differential absorption method is extended to the thermal-IR.
- CWV can be quickly estimated from look-up tables.
- The method is tested using multiple data sets. The mean bias is within ±0.07cm and the RMS fractional error is ~33%.
- It could be used as a first guess for other more sophisticated retrieval algorithms for CWV, or quick estimation of CWV for scene type classifications.

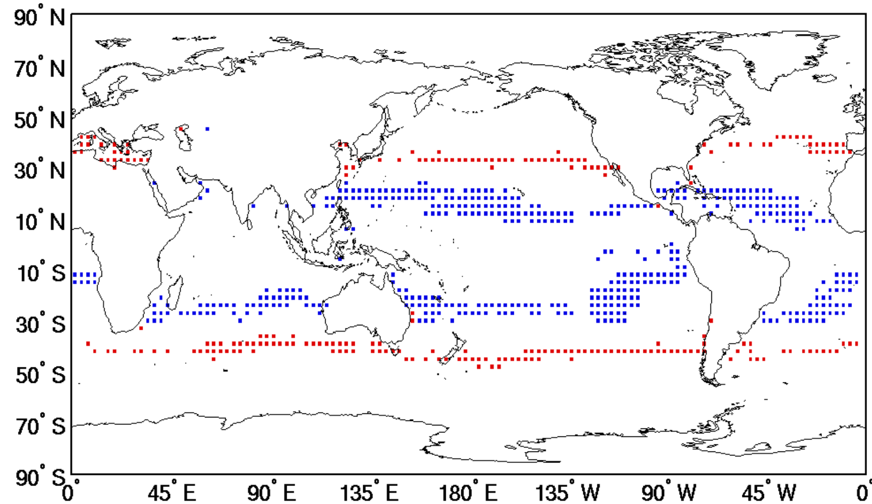
X. H. Chen and X. L. Huang. Usage of differential absorption method in the thermal IR: a case study of quick estimate of clear-sky column water vapor. JQSRT, 140,99-106, 2014.

Thank you for attention !

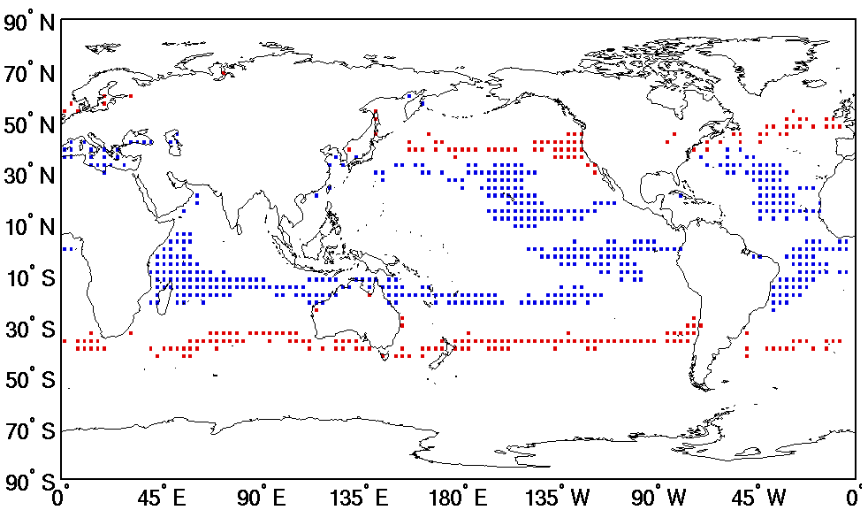
Jan 2005



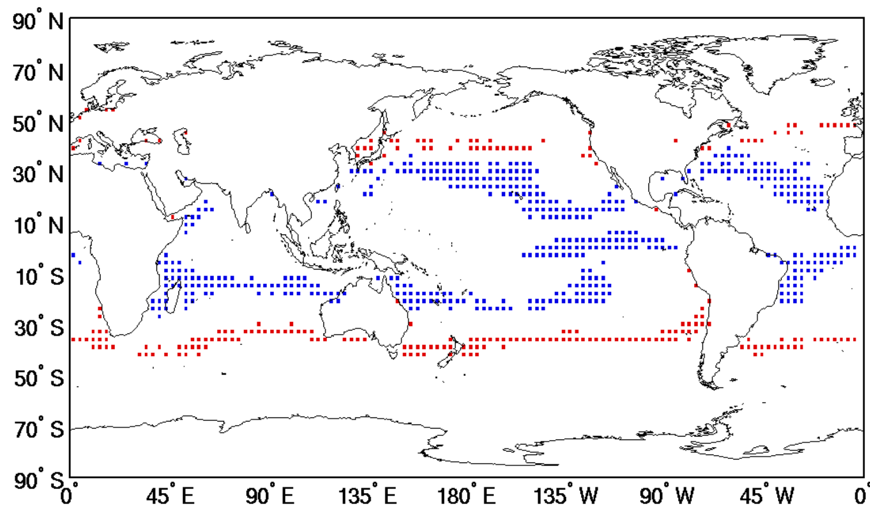
Apr 2005



Jul 2005



Oct 2005



Blue dots

298K<BT<300K

0.02<DDR<0.02025 $Wm^{-2}/sr/cm^{-1}$

Red dots

288K<BT<290K

0.01<DDR<0.01025 $Wm^{-2}/sr/cm^{-1}$