CLOUD PROPERTIES RETRIEVED FROM INFRARED SOUNDERS AND THEIR ANALYSIS IN SYNERGY WITH ACTIVE REMOTE SENSING

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How do clouds affect radiative energy balance?

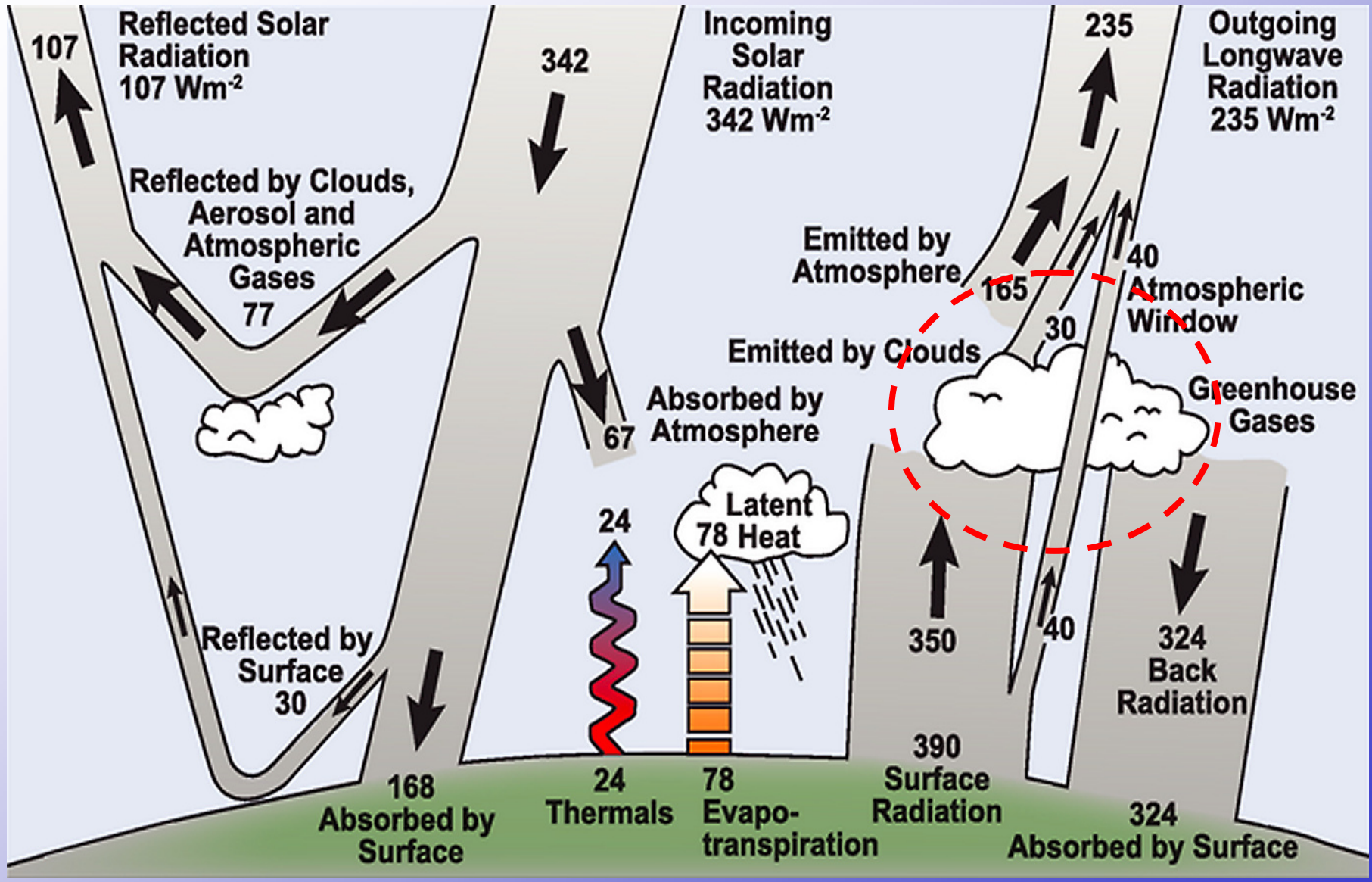


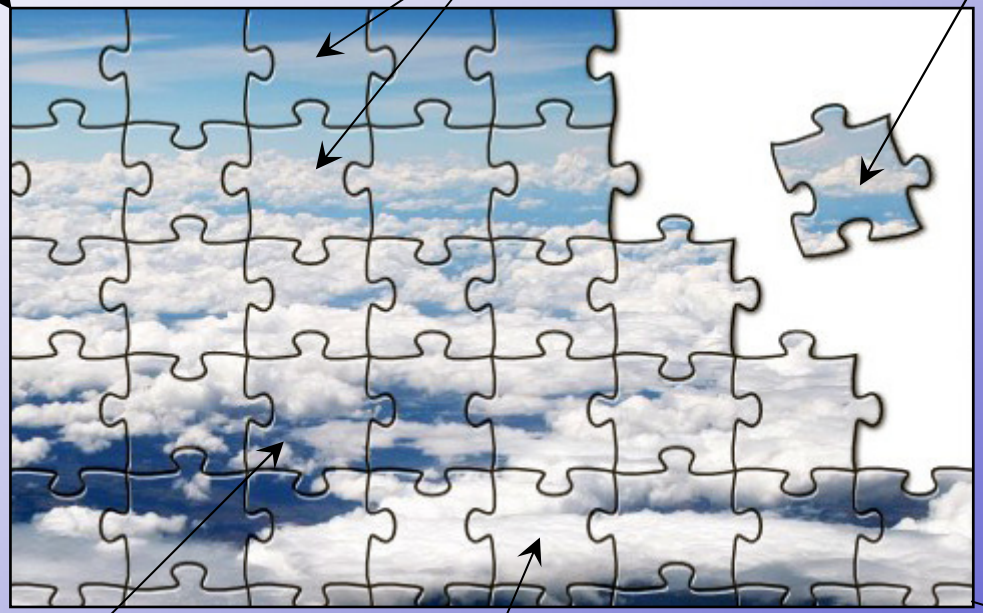
Image credit: IPCC, http://www.ipcc.ch

Understanding the cloud system

Cloud amount

Cloud height

Optical depth



Cloud temperature

Microphysical properties

Energy balance

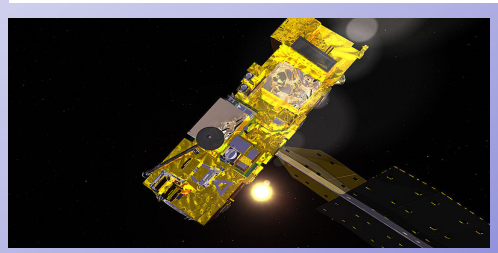
Cloud observations from space and GEWEX CA

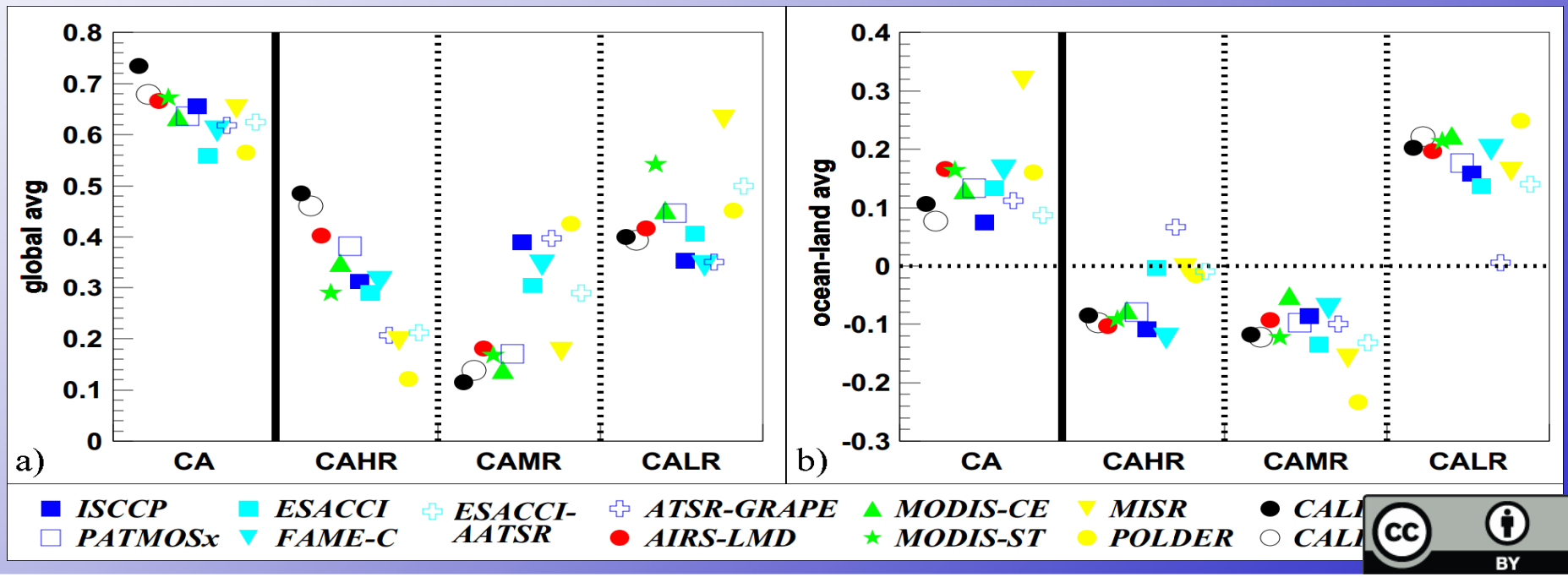
- Multi-spectral imagers: ISCCP, PATMOSX, MODIS-ST, MODIS-CE, ATSR-GRAPE, POLDER, MISR
- Infrared sounders: HIRS-NOAA, TOVSB, AIRS-LMD
- Active sounders: CALIPSO-ST, CALIPSO-GOCCP

Global Energy and Water Cycle Experiment GEWEX WCRP CLOUD ASSESSMENT

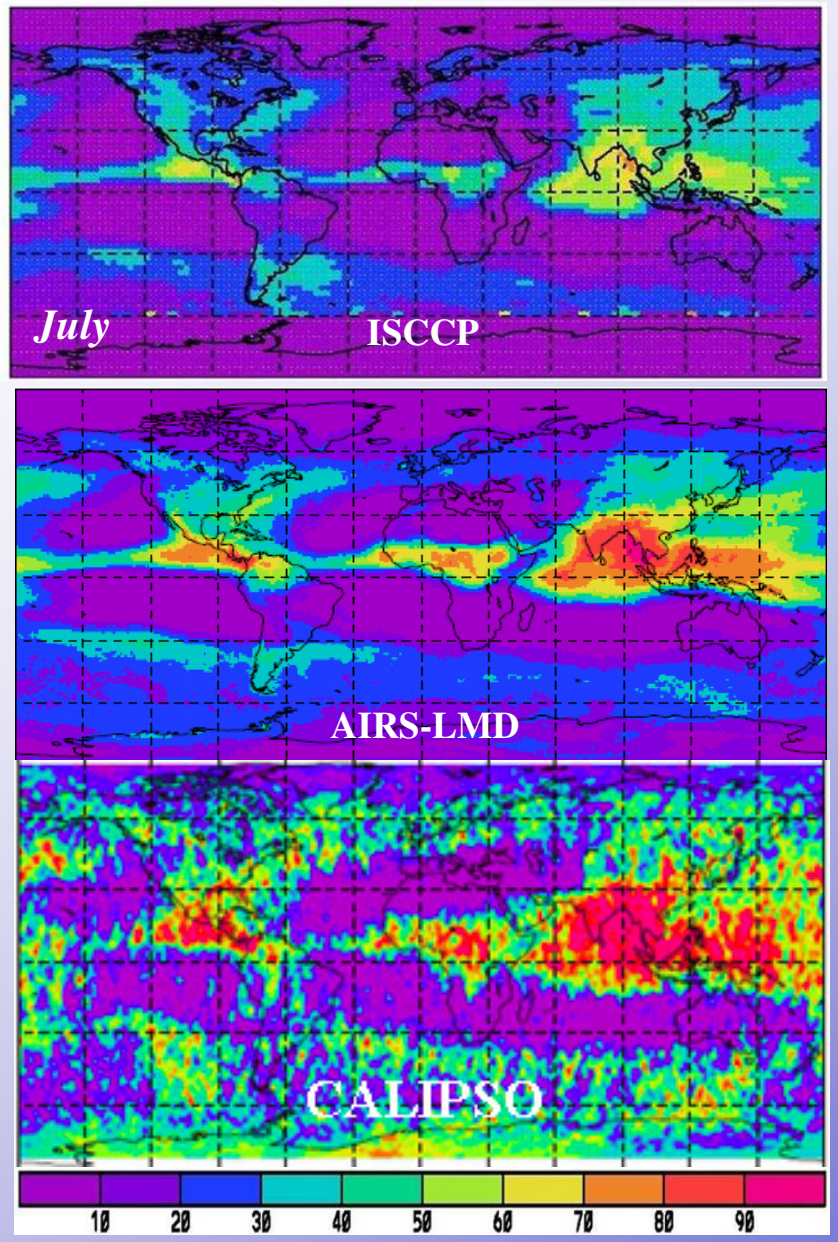
http://climserv.ipsl.polytechnique.fr/gewexca

Stubenrauch et al., WCRP report 23/2012; Stubenrauch et al. BAMS 2013





Occurrence of high-level clouds



Global Energy and Water Cycle Experiment GEWEX WCRP CLOUD ASSESSMENT

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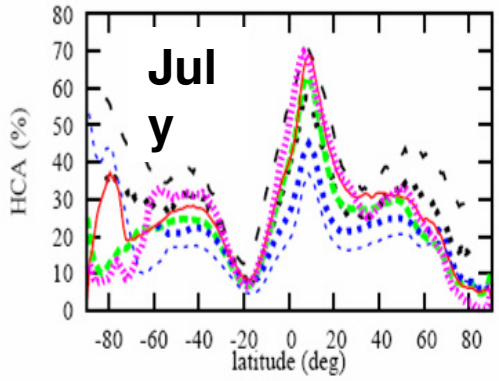
- 40-45% (50%) of all clouds are high (+ subvisible)
- Retrieved HCA depends on sensitivity to thin cirrus: CALIPSO > IR sounders > ISCCP
- similar geographical / seasonal distributions
- land – ocean : +10%



CALIPS incl subvis Ci
excl subvis Ci
ISCCP day
day + night
TOVS-B
AIRS-LMD
IASI-LMD

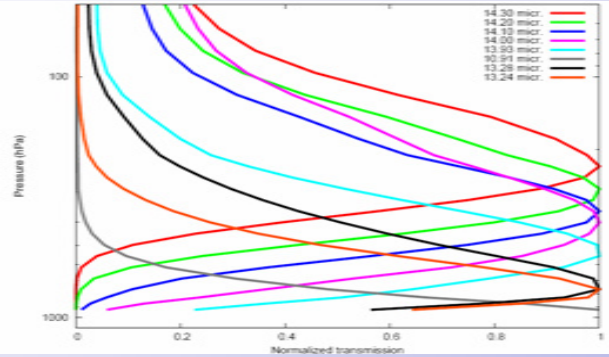
Hilton et al., BAMS 2012

Climate monitoring with IR Sounders

Sounders: TOVS, ATOVS, AIRS, IASI (1,2,3), IASI-NG

>1980 / 1995 NOAA, ≥2002 NASA, ≥2006 CNES-EUMETSAT

onboard polar orbiting satellites, with local observation time at:
7:30 AM/PM, 1:30 AM/PM, 9:30 AM/PM



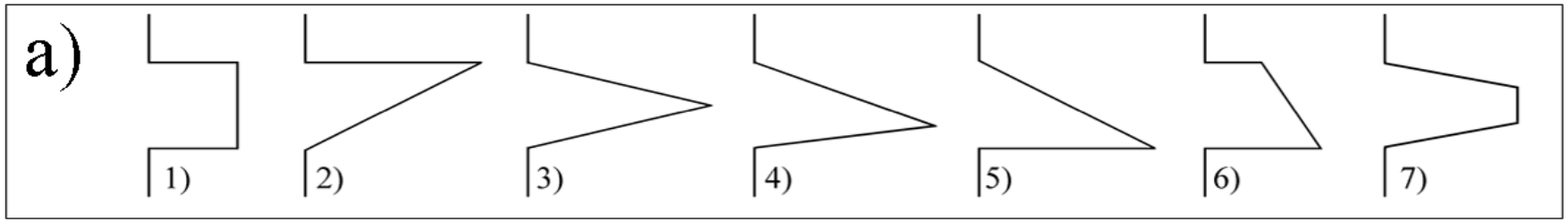
- long time series → climate studies
- increasing spectral resolution → → increased vertical resolution
- retrieval day and night
- RH_{ice}, aerosols and cirrus

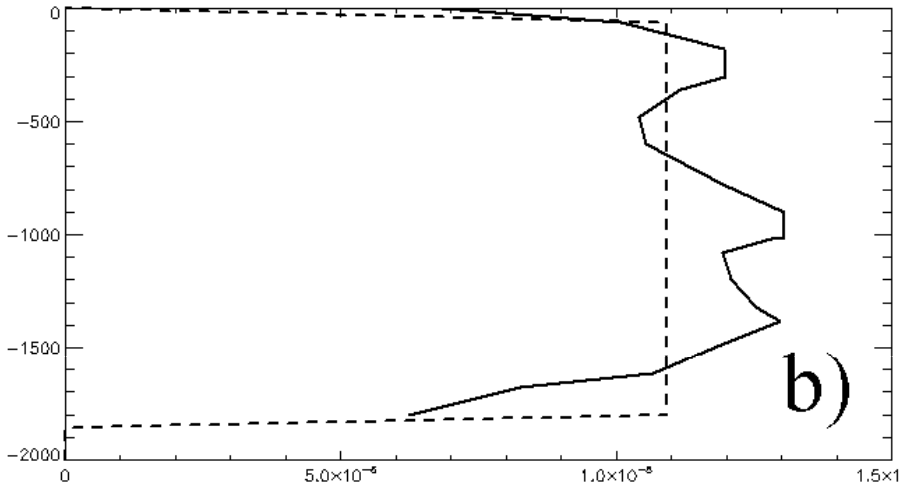
A-Train synergy (AIRS-CALIPSO-CloudSat):
- unique opportunity for global retrieval method validation
- vertical structure of cloud types

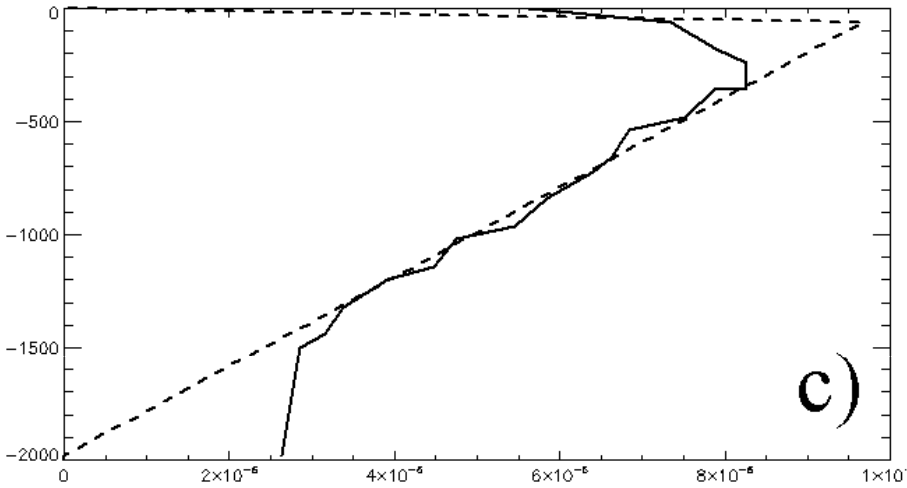
AIRS – IASI synergy : diurnal cycle

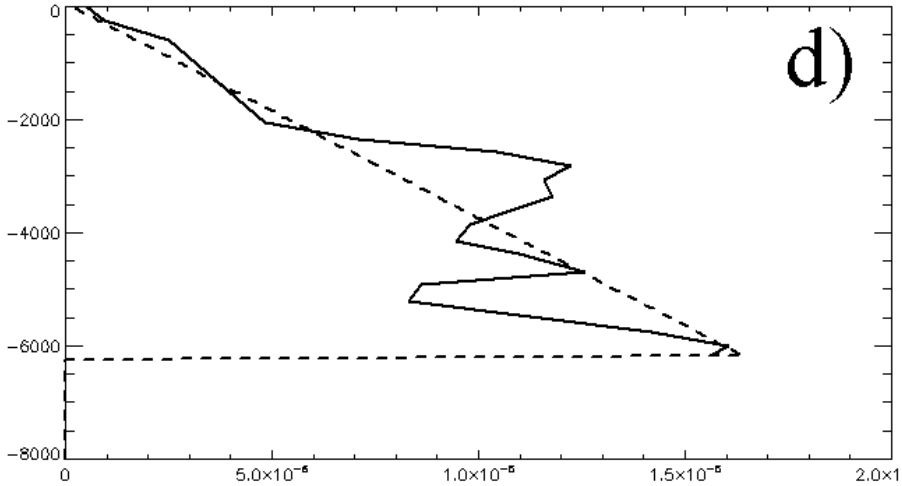
AIRS-LMD L3 cloud data (2003-2009) available at http://ara.abct.lmd.polytechnique.fr/
AIRS-LMD L2 cloud data distributed by ICARE: http://www.icare.univ-lille1.fr/

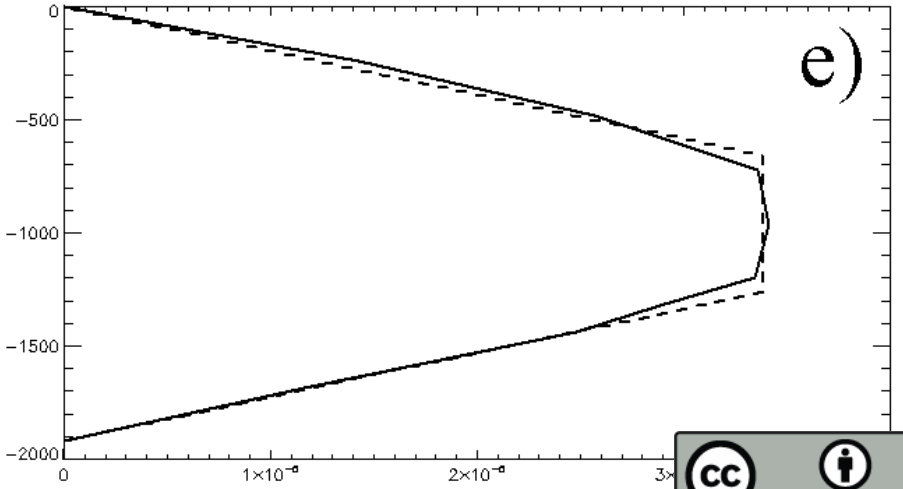
Approximating the IWC(z) with primitive shapes











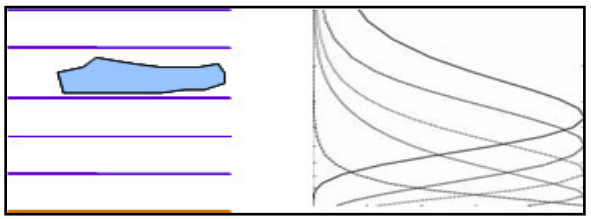
Vertical IWC profile type statistics

IWP (g/m2)	boxcar	trapezoid	lower triangle	upper triangle	Histogram value
0-10	**54%**	**20%**	**10%**	**16%**	**51%**
10-30	**31%**	**48%**	**13%**	**8%**	**29%**
30-100	**28%**	**56%**	**14%**	**3%**	**17%**
100-300	**26%**	**51%**	**21%**	**2%**	**3%**
300-1000	**38%**	**35%**	**26%**	**1%**	**<1%**

- Boxcar and trapezoid correspond to 80% of the profiles
- Lower triangles increase with IWP from 10 to 26%
- Upper triangles only for IWP < 30 g/m2
- Only strong vertical wind affects upper/lower triangles
- ~2W/m2 extra cooling for real profiles vs boxcar

New code for P_{cld} / T_{cld} / ε_{cld} retrieval (IR Sounders)

✓ Main features of the **CloudRet** research/operational code developed at LMD
- χ^2 minimization of cloud emissivity from $\{\varepsilon_i\}$, λ_i, i=1…N *(Stubenrauch et al. 1999)*
- allows using various instruments, spectral channels, auxiliary data
- improved calculation of radiative transfer for layers close to ground
- improved calculation of clear sky radiances

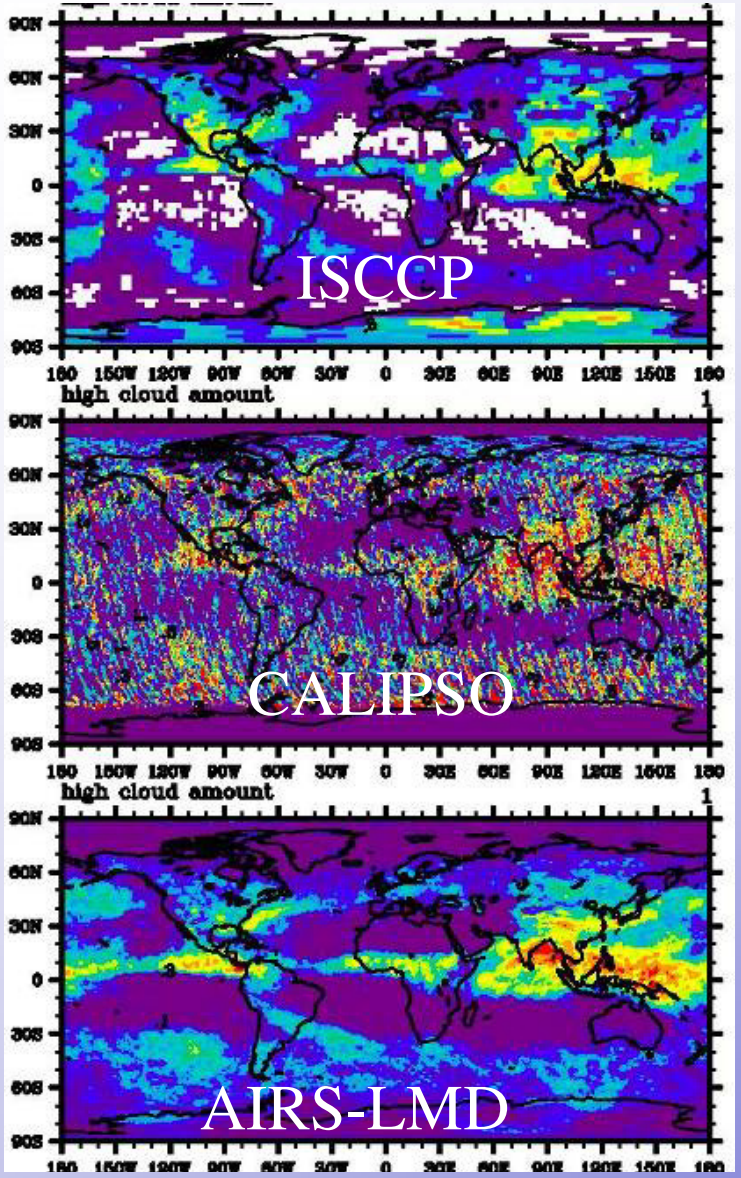


$$\varepsilon(p_k) = \sum_{i=1}^{N} \frac{R_m(\lambda_i) - R_{clr}(\lambda_i)}{R_{cld}(p_k, \lambda_i) - R_{clr}(\lambda_i)}$$

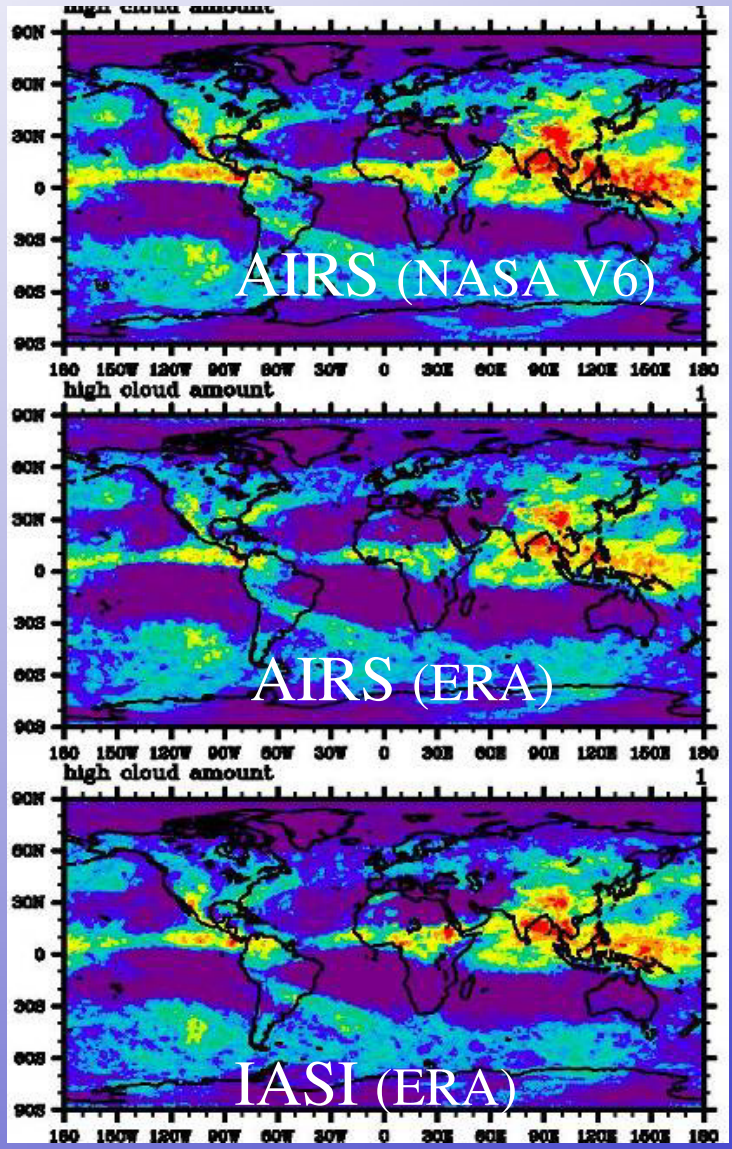
✓ Spectral channel selection
- CO_2 channels closest to AIRS in T_B

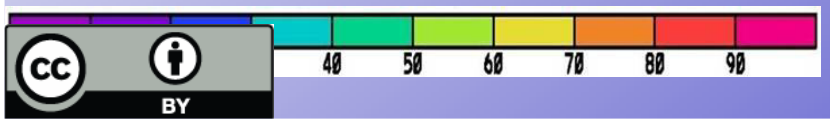
✓ Using auxiliary data:
- atmospheric T/H_2O profiles, T_{surf}, $T_{surfair}$, P_{surf}, ice/snow: L2 instantaneous for good quality profiles; averages for other cases or ERA-Interim
- tropopause determined from L2 atmospheric profiles *(Reichler et al. 2003)*
- spectral weights, spectral transmissivities pre-computed for TIGR profiles and used for radiative transfer
- spectral surface emissivities (monthly climatologies): 30N-30S AIRS-LMD, IASI-LMD, 90S-30S, 30N-90N MODIS. Option: 90S-90N IASI-LERMA

New code: application to AIRS / IASI retrievals



CAH in July (1 year)

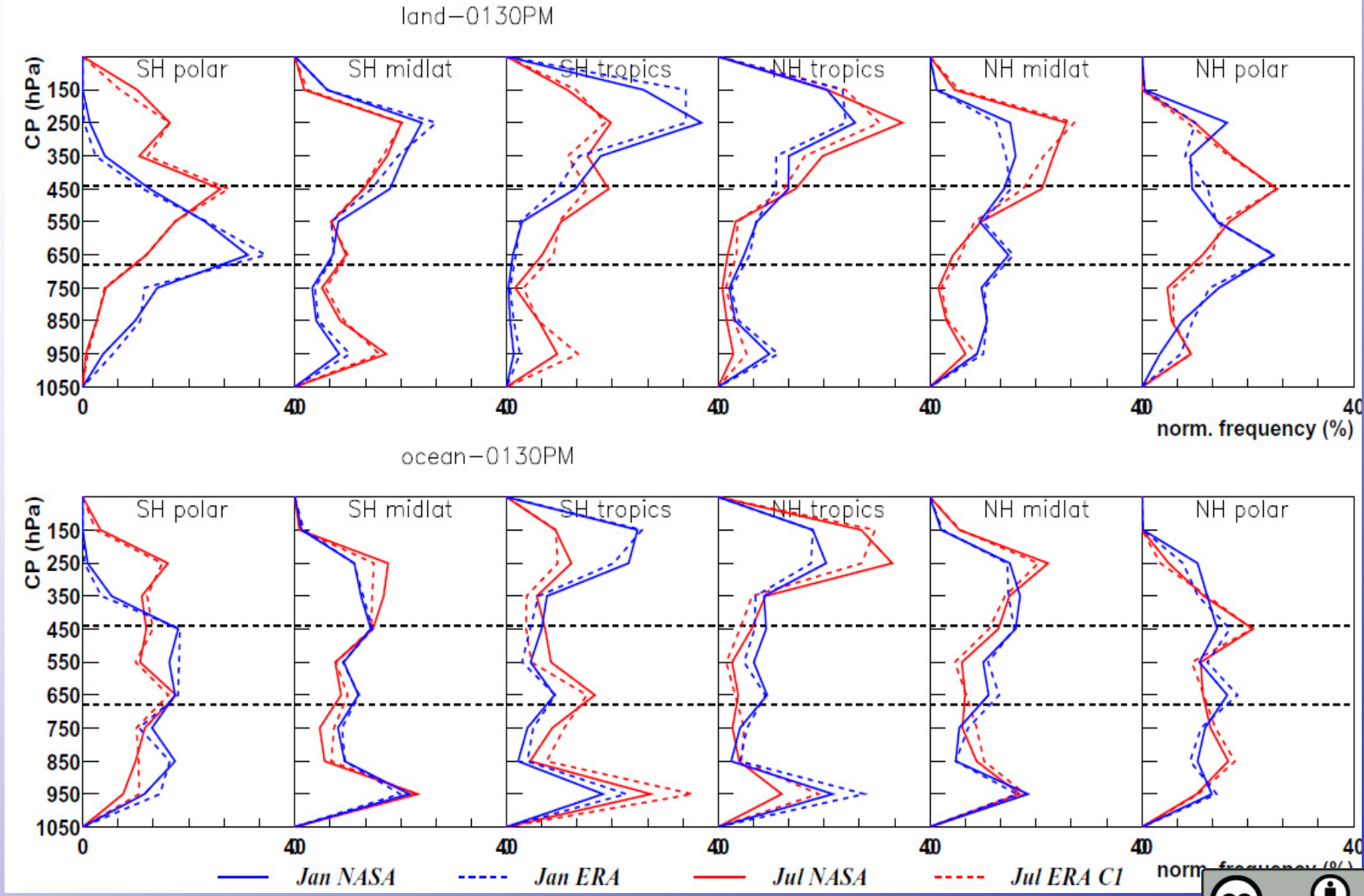




slightly less high clouds in tropics when using ERA Interim atmosph. profiles (too humid)

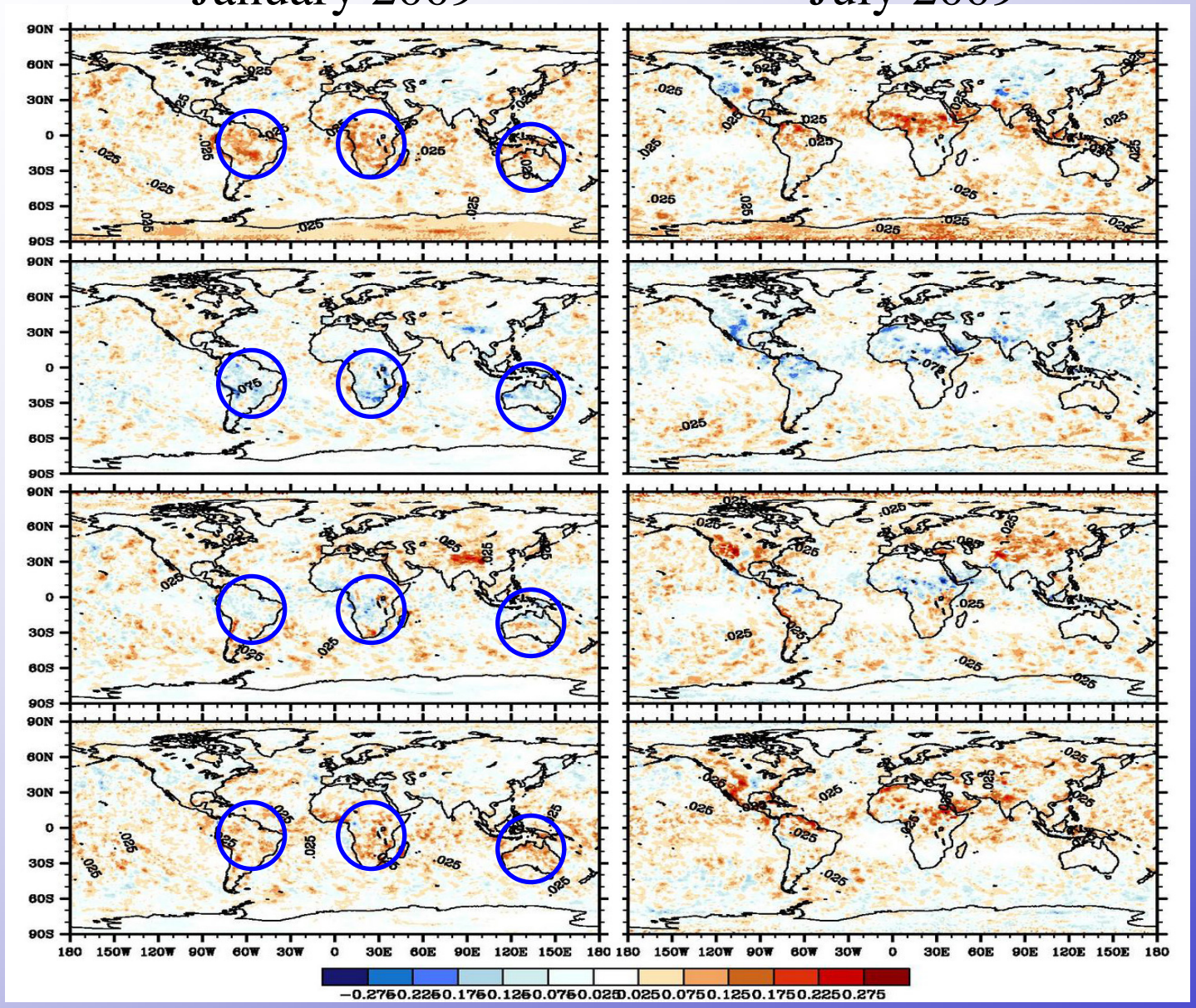
Influence of L2 atmospheric profiles on CP

example AIRS-LMD: NASA V6 profiles, ERA Interim



Application to IASI / AIRS_V6 : diurnal variation

January 2009 July 2009



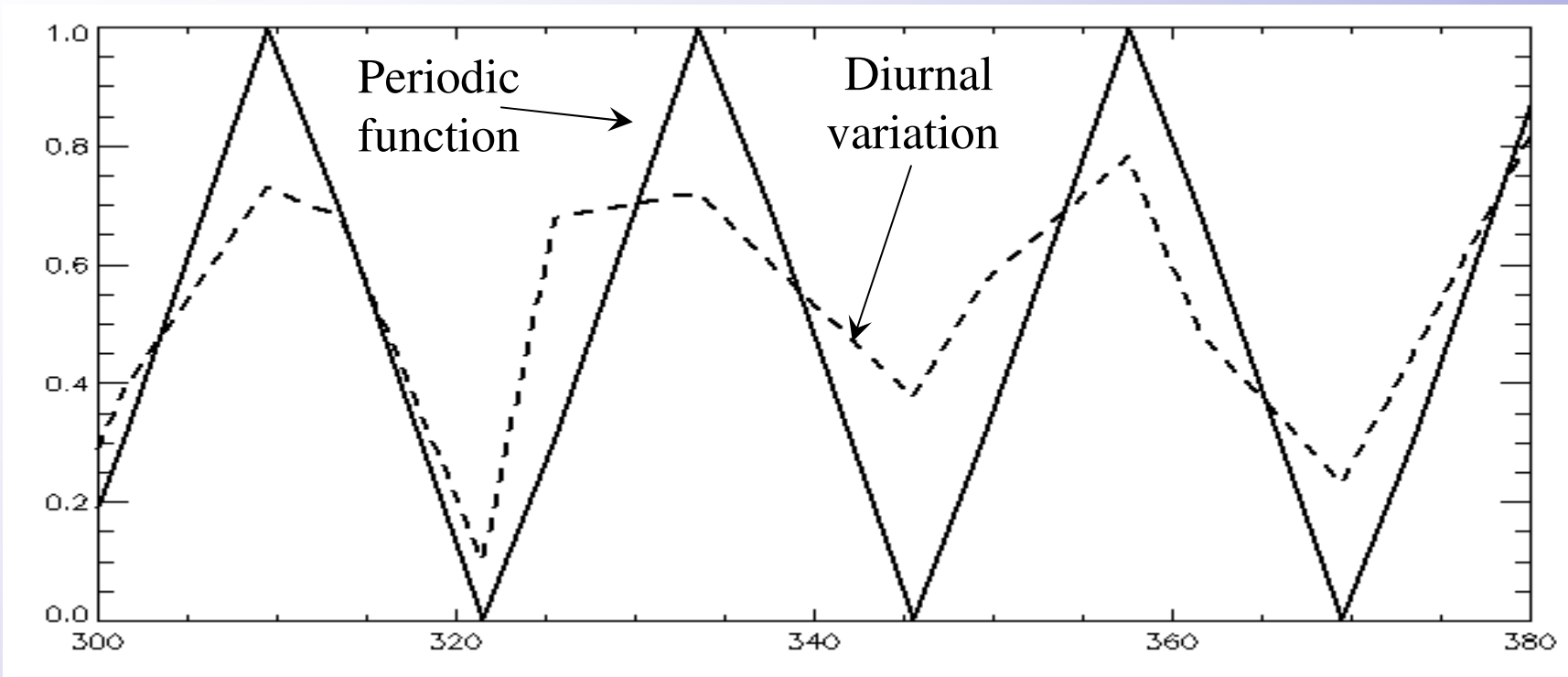
AIRS, 01:30

IASI, 09:30

AIRS, 13:30

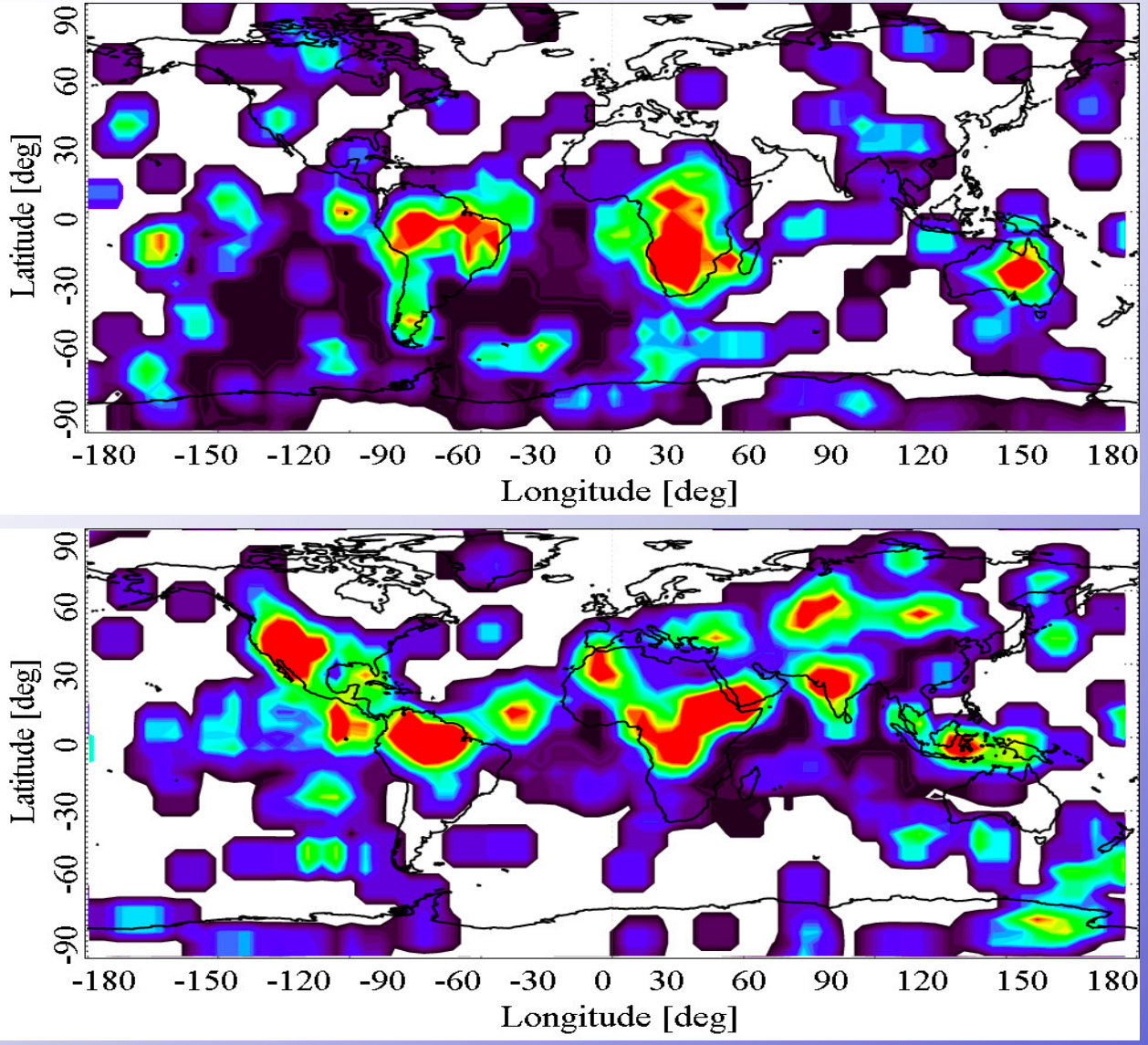
IASI, 21:30

Diurnal variation: analysis approach



- Cloud retrieval with the same auxiliary dataset (ERA-Interim) is performed to exclude possible L2 biases effects
- Binning of the cloud data is made (5 x 5 deg)
- Time series for each lat/lon bin is built
- Correlation with periodic function is searched
- Only bins with $k_{corr} > 0.3$ are taken
- r.m.s. of the diurnal variation is built

Diurnal variation in high cloud amount (r.m.s.)



- Main variability over land
- The r.m.s. values are consistent with [Tian et al., 2003]

Conclusions and outlook

- Cloud properties from multiple satellite instruments provide coherent picture, the differences are understood (GEWEX CA)
- IR sounders are sensitive to cirrus, day and night
- The effects of different vertical types of profiles on radiative energy balance are estimated and explained
- A new research/operational cloud retrieval code CloudRet has been developed and applied to AIRS_V6 and IASI
- The retrievals are sensitive to L2 biases at the lowermost layer
- Retrieving the diurnal cycle from two different satellite instruments requires using a single source of L2 auxiliary data
- The r.m.s. of the diurnal cycle for HCA is up to ~0.2 over land
- Processing of NOAA HIRS/MetOp data planned with DWD

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