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

A. Feofilov, C. Stubenrauch, R. Armante

Laboratoire de Météorologie Dynamique, Ecole Polytecnique, Paris, France

EGU-2014, Vienna, Austria, May 01, 2014

How do clouds affect radiative energy balance?

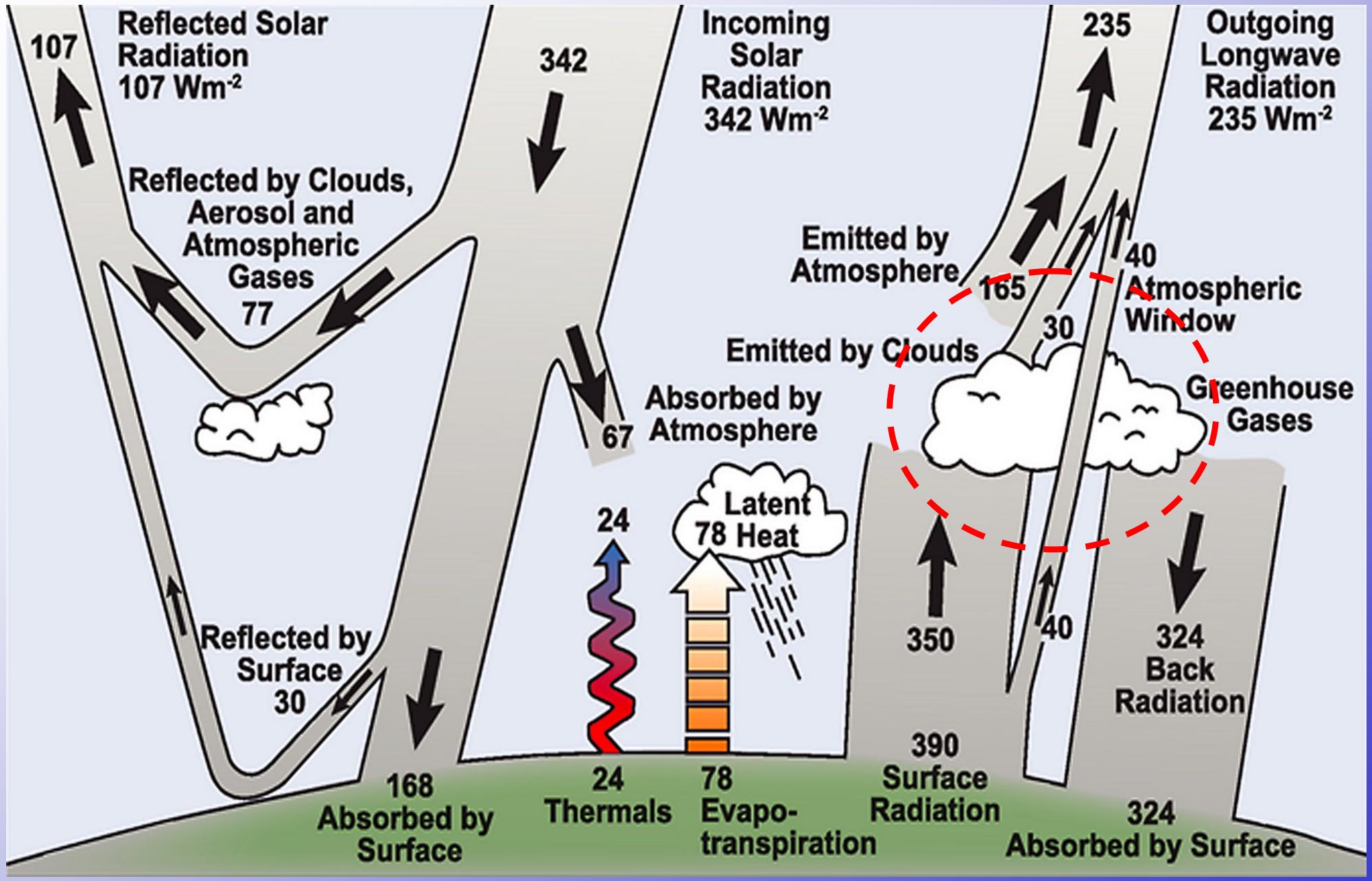


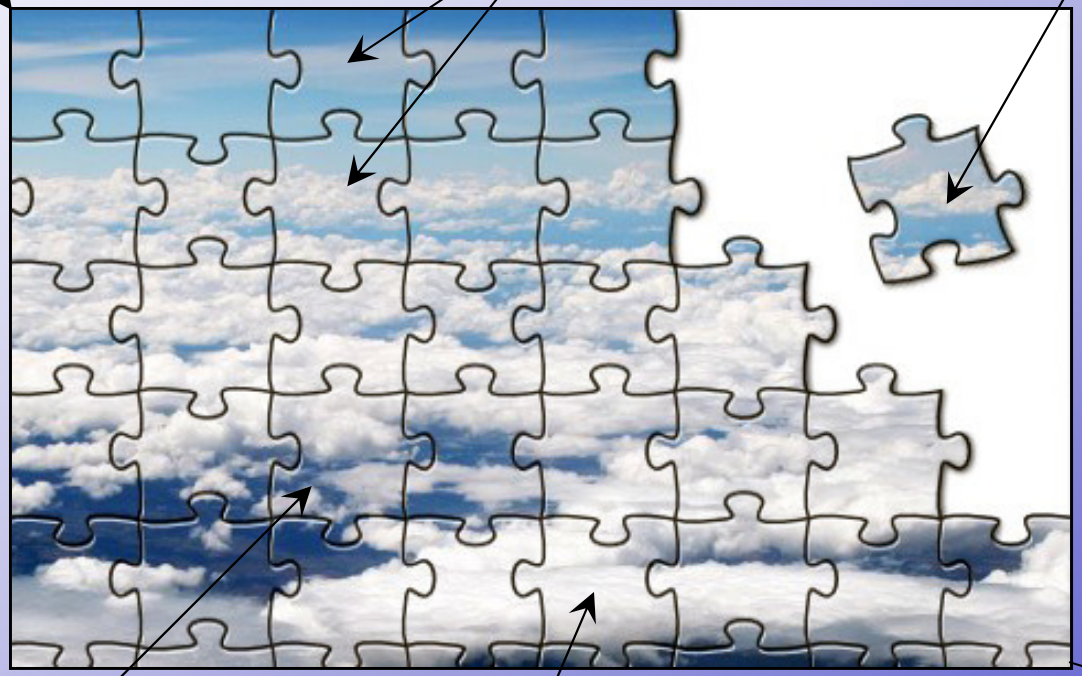
Image credit: IPCC, http://www.ipcc.ch

Understanding the cloud system

Cloud amount

Cloud height

Optical depth



Cloud temperature

Microphysical properties

Energy balance

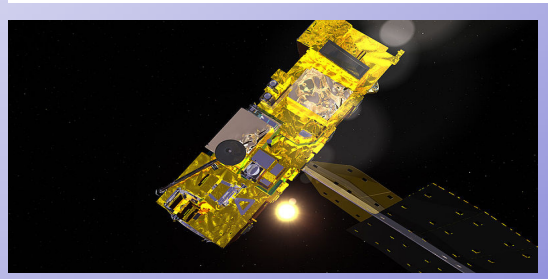
Cloud observations from space and GEWEX CA

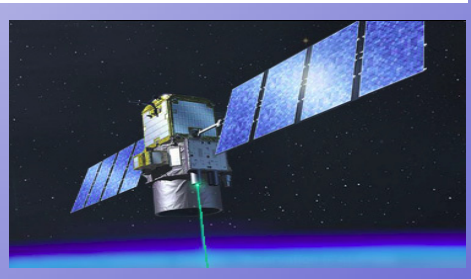
- Multi-spectral imagers: ISCCP, PATMOSX, MODIS-ST, MODIS-CE, ATSR-GRAPE, POLDER, MISR
- Infrared sounders: HIRS-NOAA, TOVSB, AIRS-LMD
- Active sounders: CALIPSO-ST, CALIPSO-GOCCP

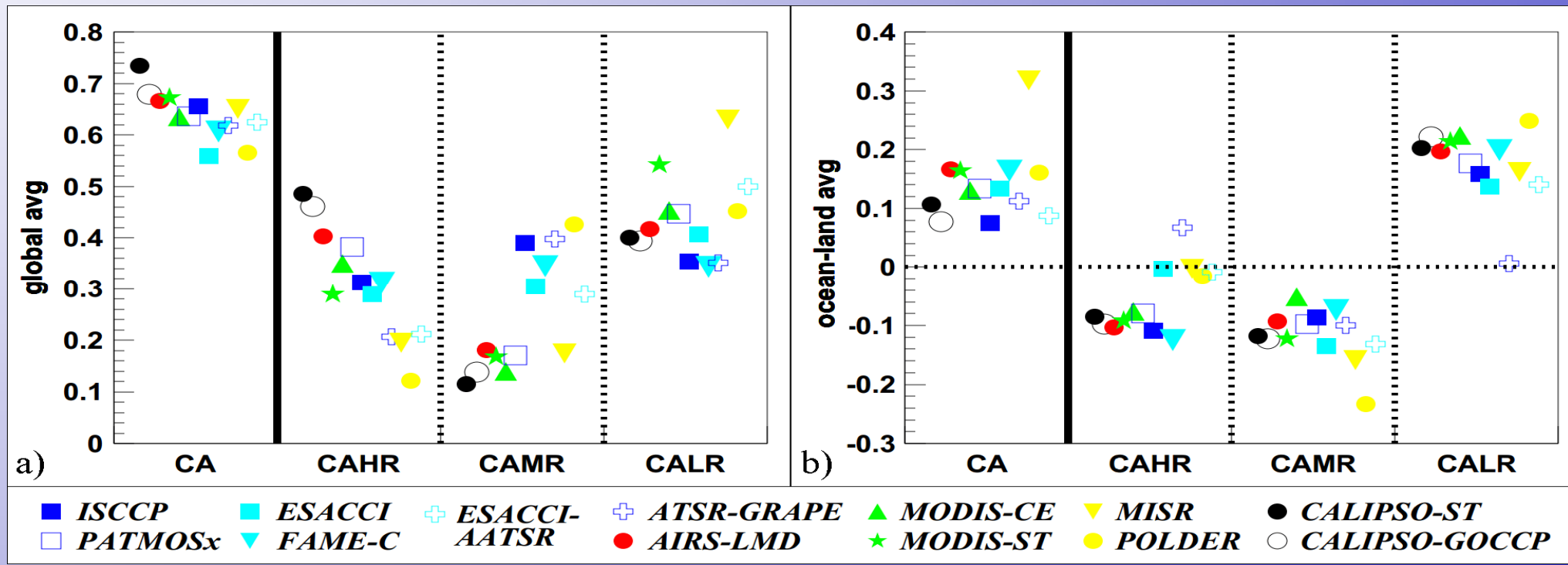
Global Energy and Water Cycle Experiment GEWEX WCRP CLOUD ASSESSMENT

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

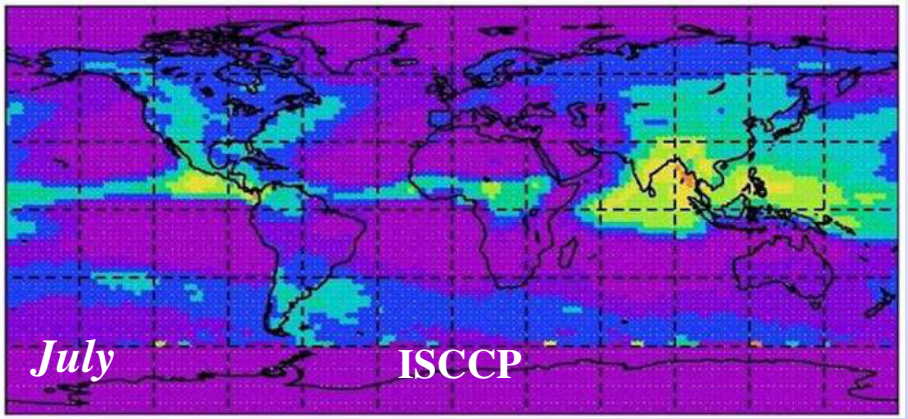
Stubenrauch et al., WCRP report 23/2012;
Stubenrauch et al. BAMS 2013

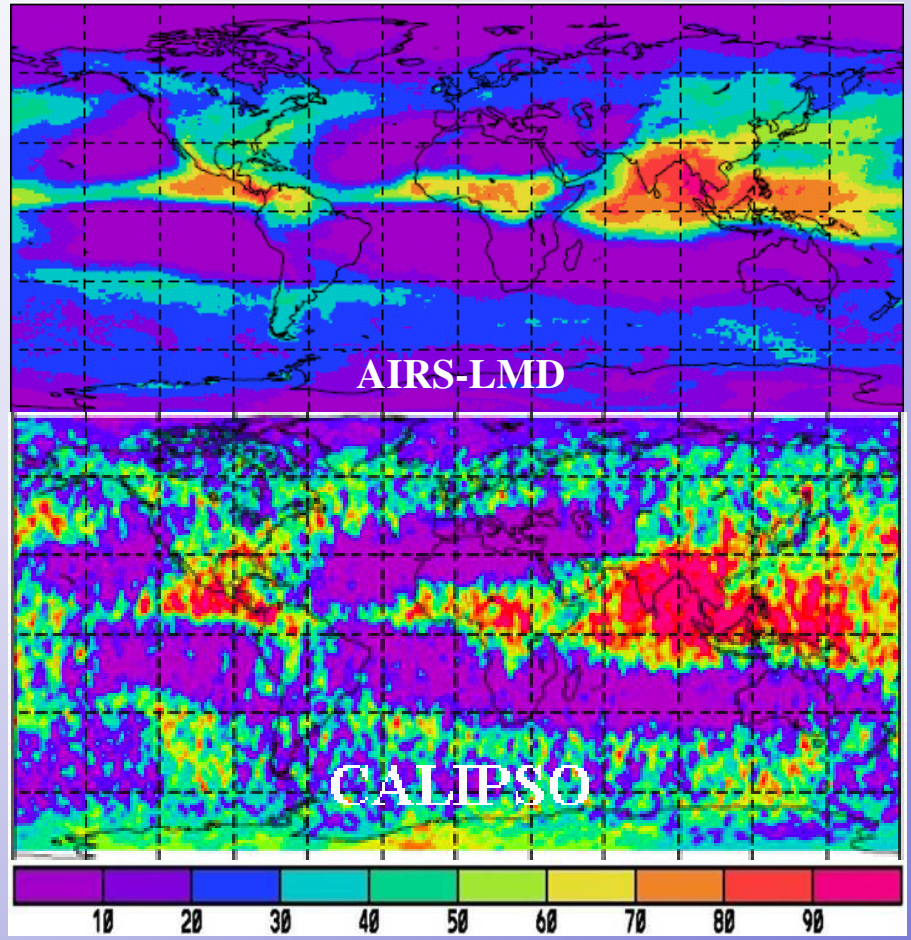






Occurrence of high-level clouds

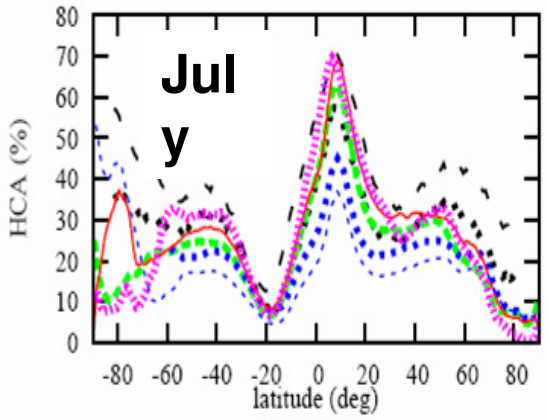




Global Energy and Water Cycle Experiment
GEWEX WCRP
CLOUD ASSESSMENT

http://climserv.ipsl.polytechnique.fr/gewexca
Stubenrauch et al., WCRP report 23/2012;
Stubenrauch et al. BAMS 2013

- 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

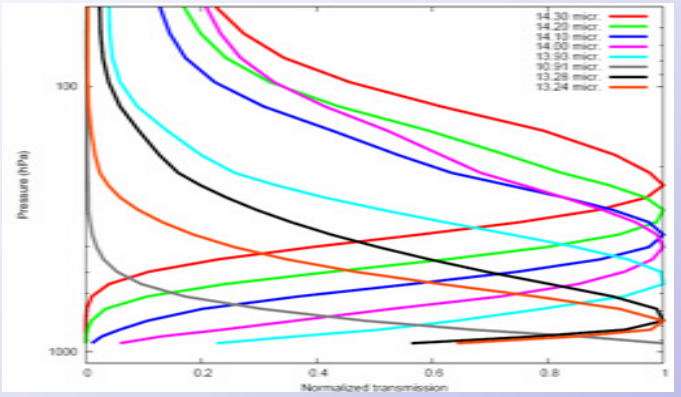
Hilton et al., BAMS 2012

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



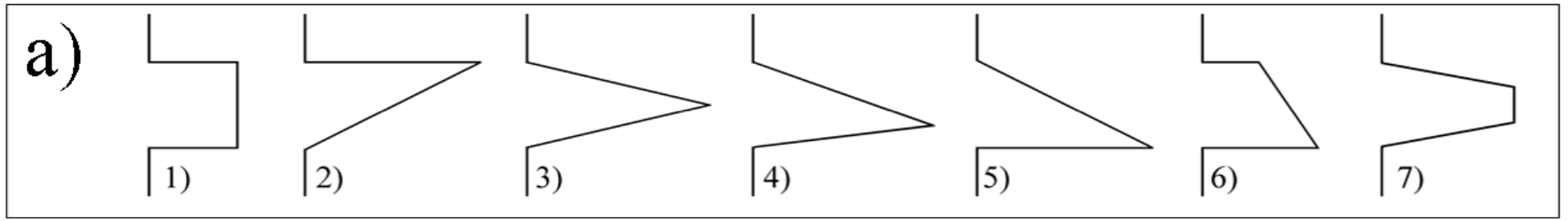
- long time series → climate studies
- increasing spectral resolution → → increased vertical resolution
- retrieval day and night
- RH_{ice}, aerosols and cirrus

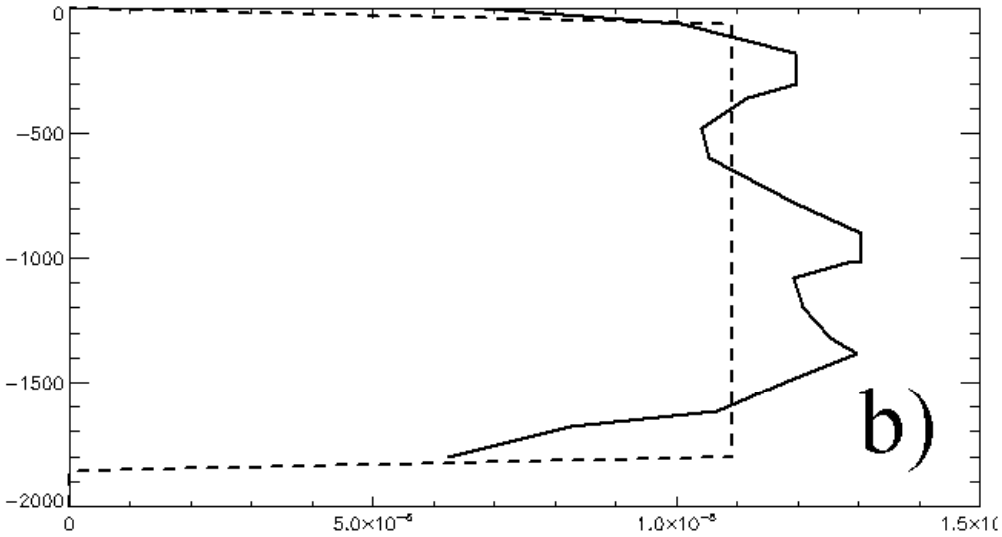
A-Train synergy (AIRS-CALIPSO-CloudSat):
- unique opportunity for global retrieval method validation
- vertical structure of cloud types

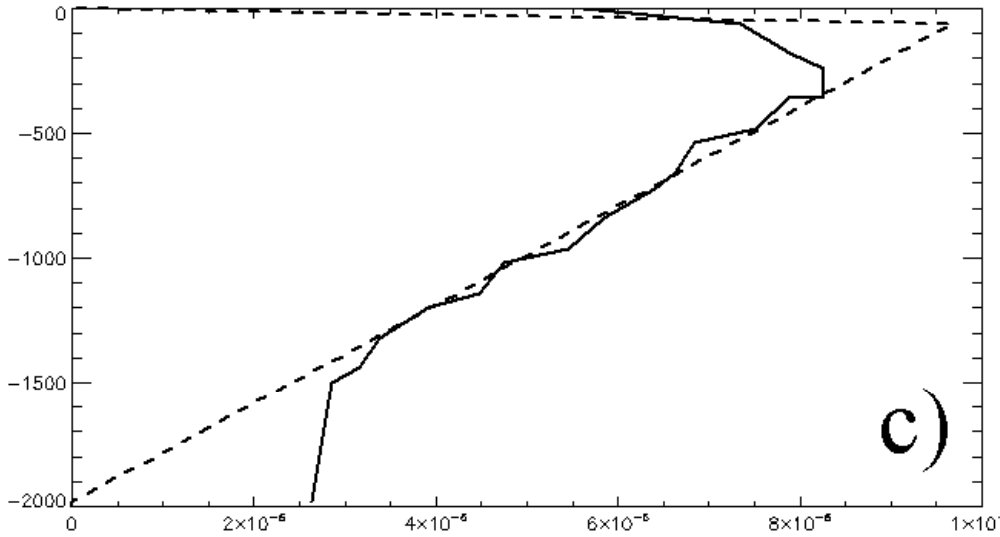
AIRS – IASI synergy : diurnal cycle

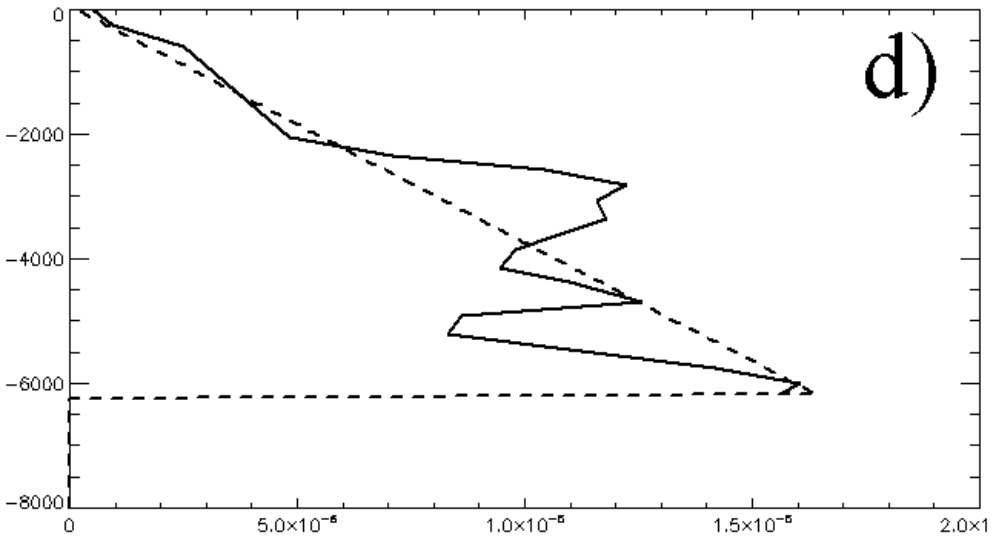
AIRS-LMD L3 cloud data (2003-2009) available at http://ara.abct.lmd.polytechnique.fr/
AIRS-LMD L2 cloud data distributed by ICARE: http://www.icare.univ-lille1.fr/

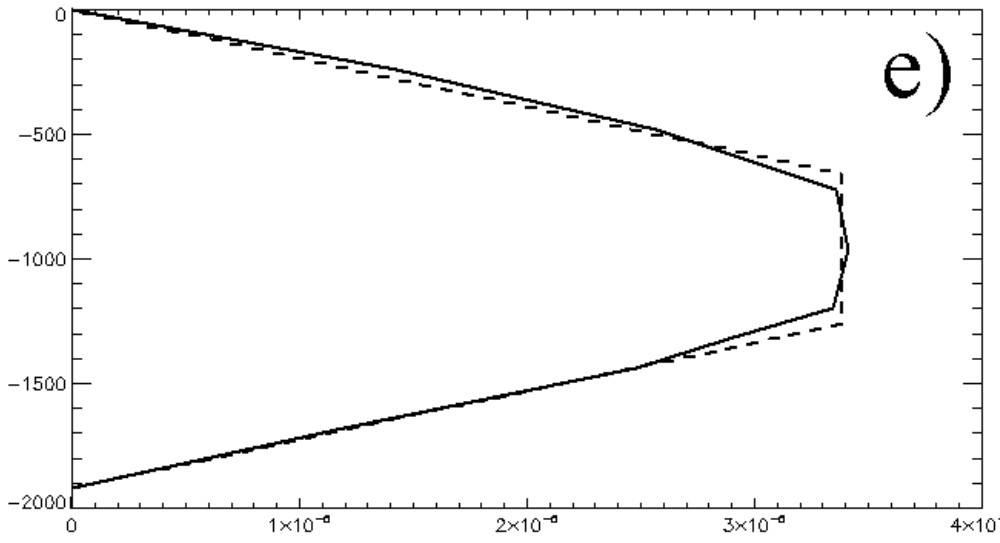
Approximating the IWC(z) with primitive shapes











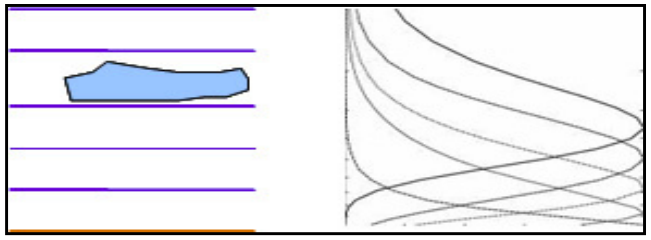
Vertical IWC profile type statistics

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

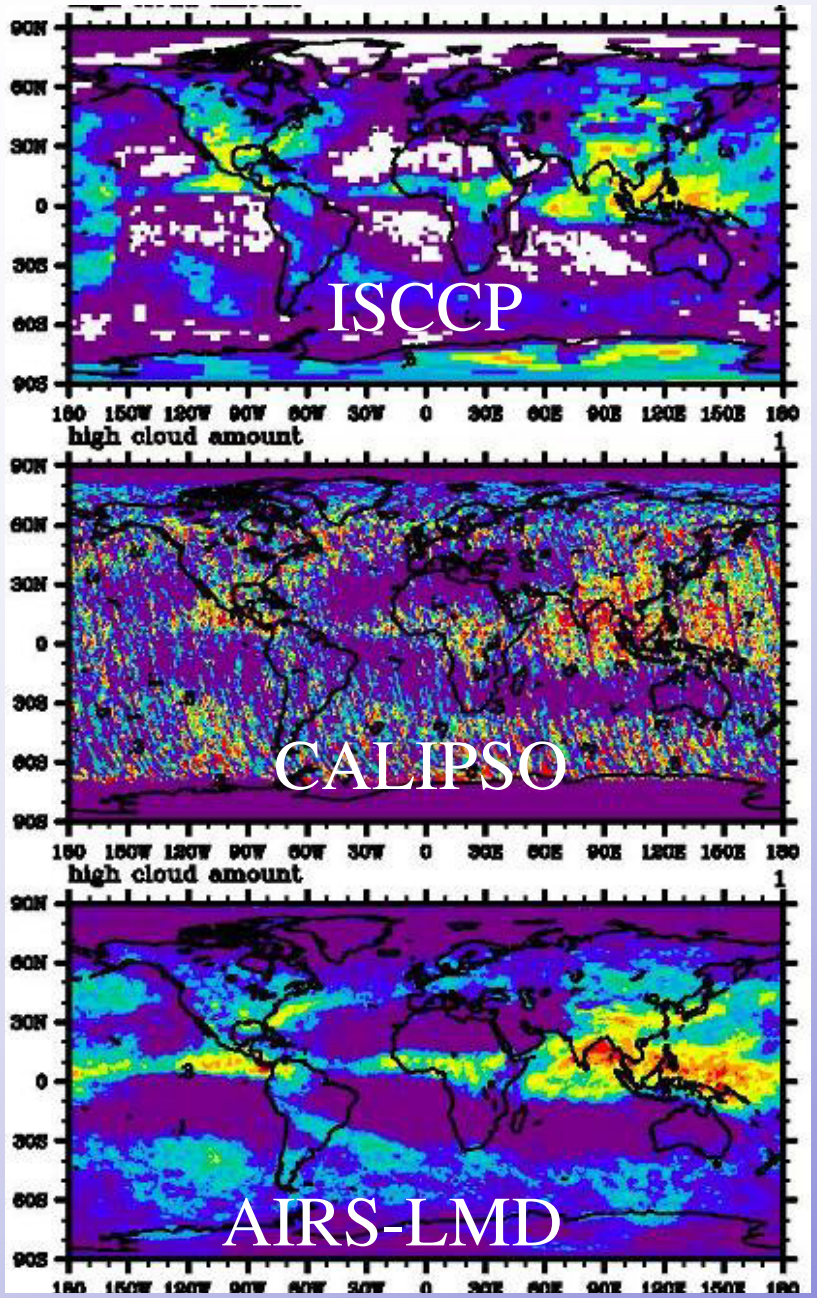


$$\varepsilon(p_k) = \sum_{i=1}^{N} \frac{R_m(\lambda_i) - R_{clr}(\lambda_i)}{R_{cld}(p_k, \lambda_i) - R_{clr}(\lambda_i)}$$

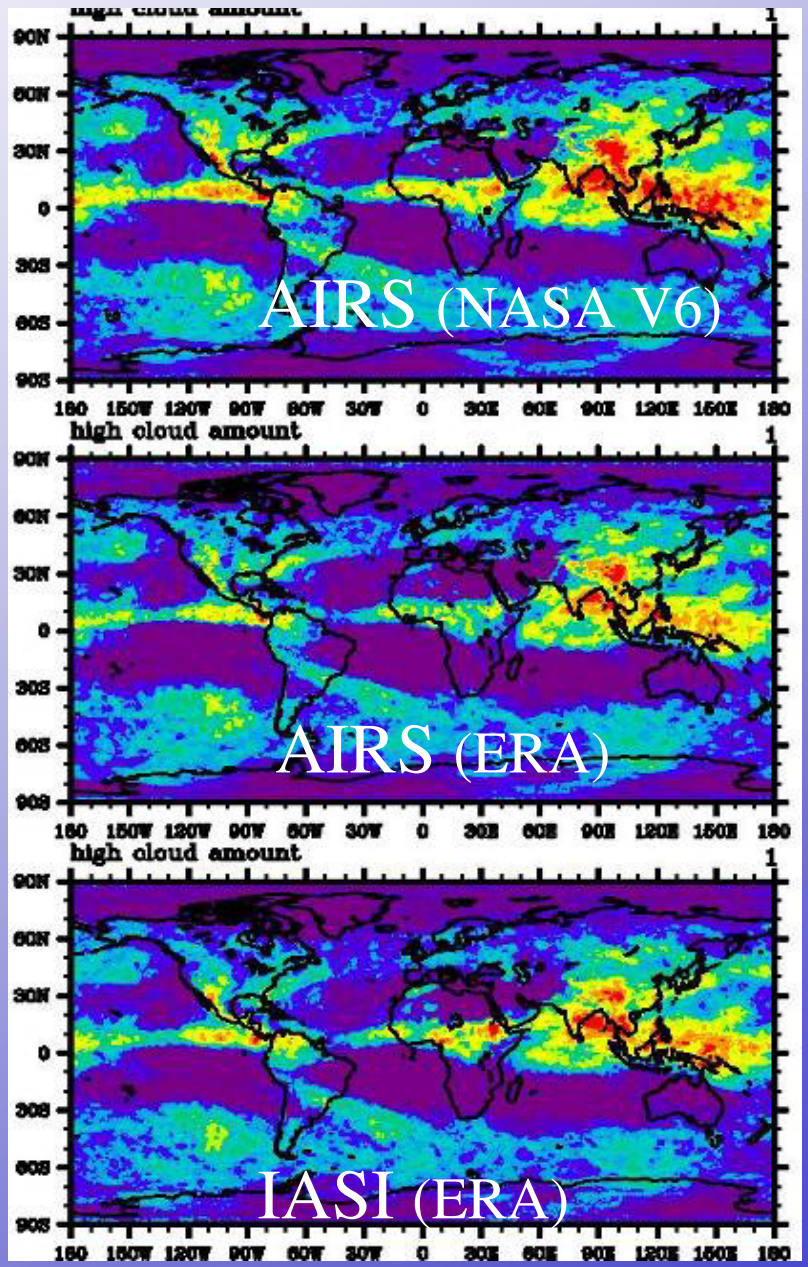
✓ Spectral channel selection
- CO_2 channels closest to AIRS in T_B

✓ 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



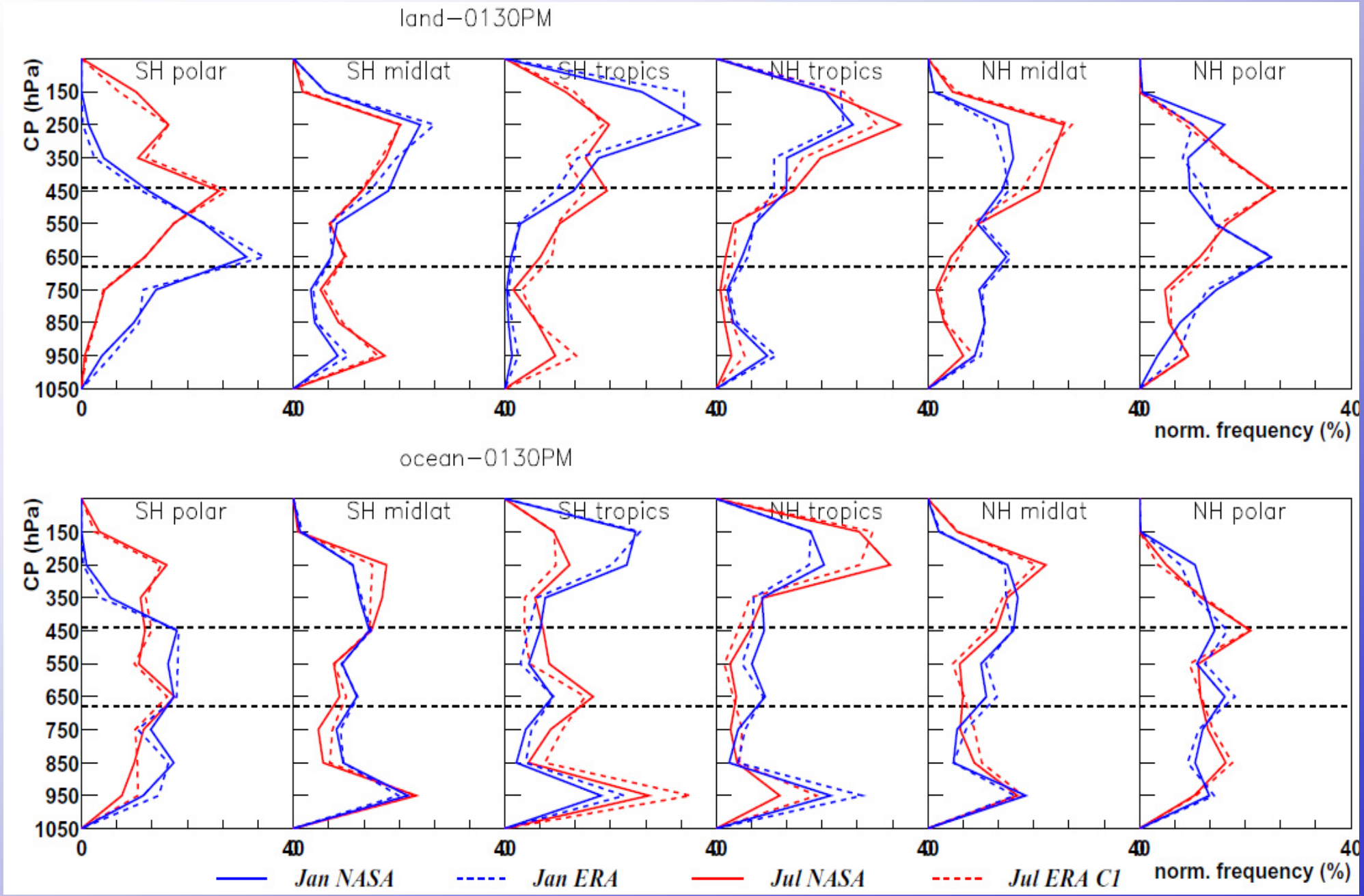
CAH in July (1 year)



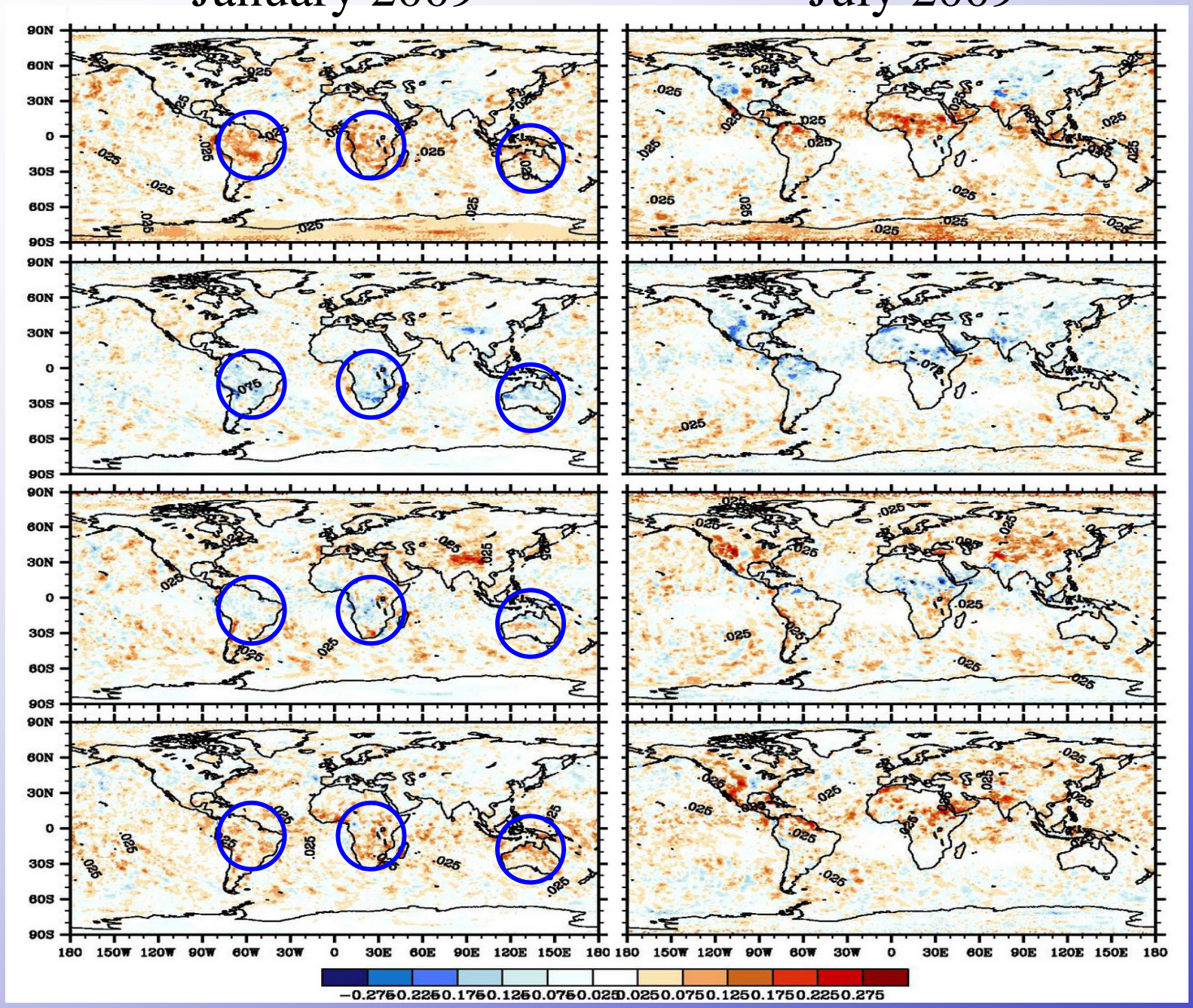
slightly less high clouds in tropics when using ERA Interim atmosph. profiles (too humid)

Influence of L2 atmospheric profiles on CP

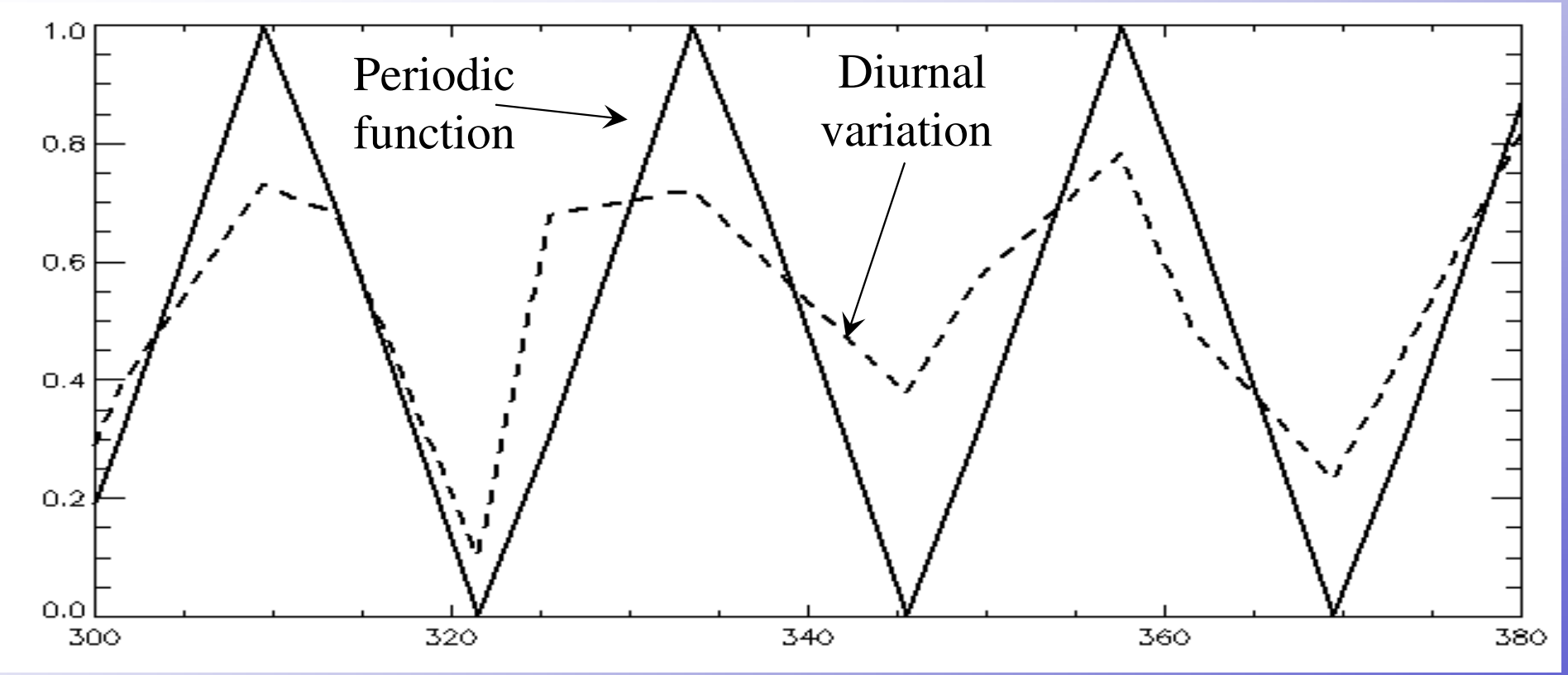
example AIRS-LMD: NASA V6 profiles, ERA Interim



Application to IASI / AIRS_V6 : diurnal variation

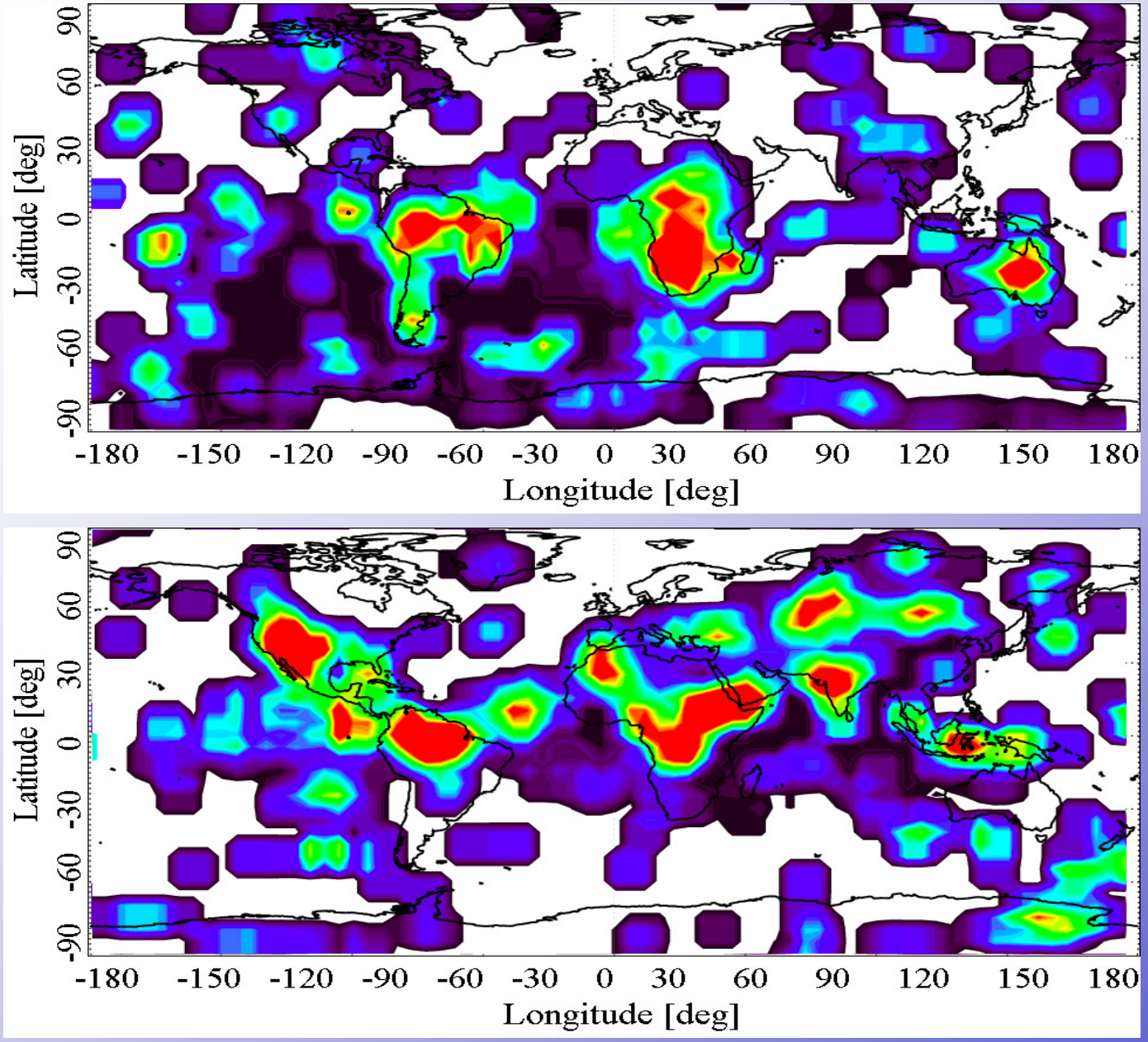


Diurnal variation: analysis approach



- 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

This work was supported by CNRS and ESA Cloud CCI.

We also thank all Science teams as well as the engineers and space agencies for their efforts and cooperation in providing the data !

data processing possible thanks to
Ether, Icare and ClimServ centers