

Global Energy and Water Cycle Experiment



Cloud Assessment

## a review

Claudia Stubenrauch\*

+

S. Kinne, W. B. Rossow, C. Pearl, A. Heidinger, A. Walther, A. Guignard, S. Ackerman, S. Platnick, B. Maddux, P. Minnis, S. Sun-Mack, L. DiGirolamo, A. Menzies, P. Menzel, E. Olsen, J. Riedi, S. Zeng, D. Winker, B. Getzewich, H. Chepfer, G. Cesana, C. Poulsen, A. Sayer

presented by Anthony Guignard\*

\*Laboratoire de Météorologie Dynamique, IPSL/CNRS  
Ecole Polytechnique, France



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



initiated in 2005 by GEWEX Radiation panel (GRP)

2005-2010: 4 workshops (*Madison, New York, Berlin*)

2009-2011: Preparation of common data base (*monthly statistics in netCDF format*)

2011: WCRP report, BAMS article & opening of data base to public

Assessments essential for climate studies & model evaluation

## Heritage of GEWEX cloud assessment

- cooperation of 12 cloud teams
- statistical analysis of cloud properties
- global evaluation of retrieval methods
- insight of how clouds are perceived by different instruments
- combination of different instruments leads to additional information

# participating cloud climate records:

## *most complete data sets:*

<b>ISCCP</b> <i>GEWEX cloud dataset</i>	<i>1984-2007</i>	<i>(Rossow et al. 1983, 1999)</i>
<b>TOVS Path-B</b>	<i>1987-1994</i>	<i>(Stubenrauch et al. 1999, 2006)</i>
<b>AIRS-LMD</b>	<i>2003-2009</i>	<i>(Stubenrauch et al. 2008, 2010)</i>
<b>MODIS-ST</b>	<i>2001/3-2009</i>	<i>(Ackerman et al.; Platnick et al.)</i>
<b>MODIS-CE</b>	<i>2001/3-2006</i>	<i>(Minnis et al.)</i>

## *relatively new retrieval versions:*

<b>PATMOS-x (AVHRR)</b>	<i>1982-2009 (histos 96-09)</i>	<i>(Heidinger et al.)</i>
<b>ATSR-GRAPE</b> <i>ERS, 1999-2002 / ENV, 2003-2009</i>		<i>(Poulsen et al.)</i>
<b>POLDER (O<sub>2</sub> &amp; Rayleigh)</b>	<i>2006-2008</i>	<i>(Riedi et al.)</i>

## *only CA or CAE & CT:*

<b>HIRS-NOAA</b> <i>only av</i>	<i>1982-2008</i>	<i>(Wylie et al. 2005)</i>
<b>CALIPSO-ST</b> <i>av &amp; histos</i>	<i>2007-2008</i>	<i>(Winker et al. 2007, 2009)</i>
<b>CALIPSO-GOCCP</b>	<i>2007-2008</i>	<i>(Chepfer et al. 2009)</i>

## *only averages of CA's:*

<b>MISR</b>	<i>2001-2007</i>	<i>(DiGirolamo et al.)</i>
-------------	------------------	----------------------------

# GEWEX Cloud Assessment Common Data base

Monthly statistics per year & obs time,  $1^\circ \times 1^\circ$

• average, • monthly variability, • histograms

*properties:*

- cloud amount **CA**
- rel. cloud amount **CAR**
- Pressure/ height **CP/CZ** (tot)
- temperature **CT**
- IR emissivity **CEM** (tot, H, M, L, W, I)
- eff cloud amount **CAE** (tot, H, M, L, W, I)
- VIS optical depth **COD** (tot, H, M, L, W, I)
- Water path **CLWP/CIWP**
- $r_{\text{eff}}$  **CRE**

*separate statistics:*

(tot, High, Midlevel, Low, Water, Ice)

CP < 440 hPa, CP > 680 hPa

(tot, H, M, L, W, I)

(W, I, IH)

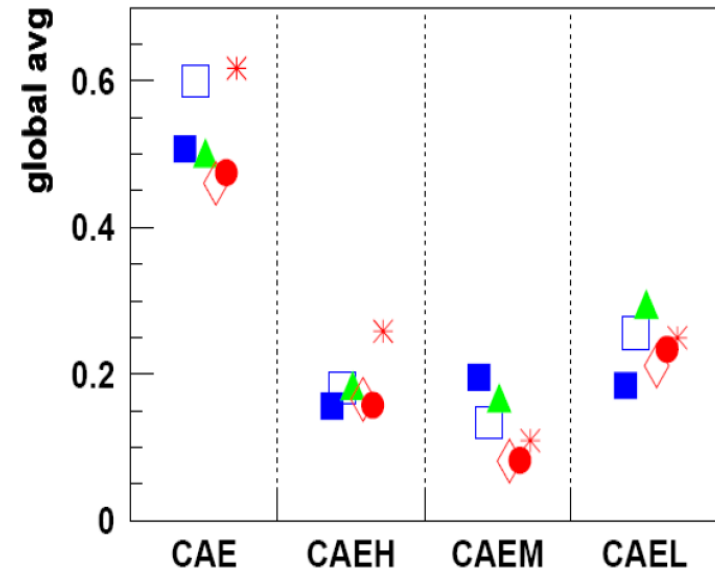
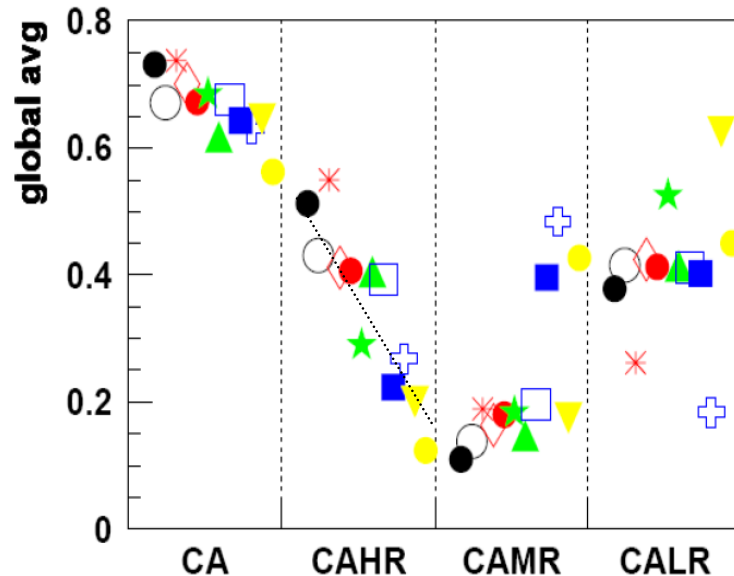
(W, I, IH)

CT > 260K, CT < 260 / 230K

*joint histograms*

- **COD – CP, CEM – CP, COD – CRE**

# Interpretation of cloud properties from satellite observations



**CALIPSO only considers uppermost layers to better compare with the other data sets**

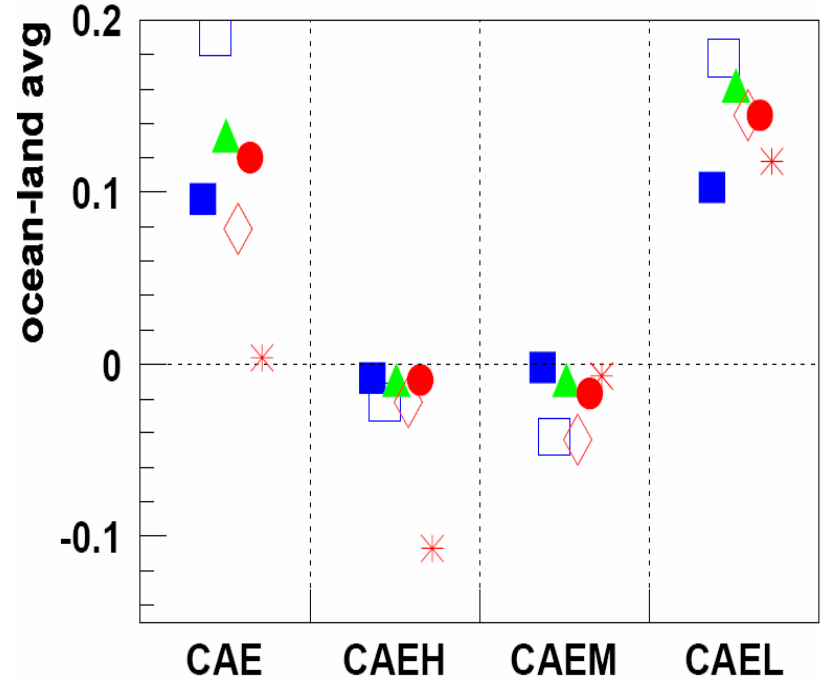
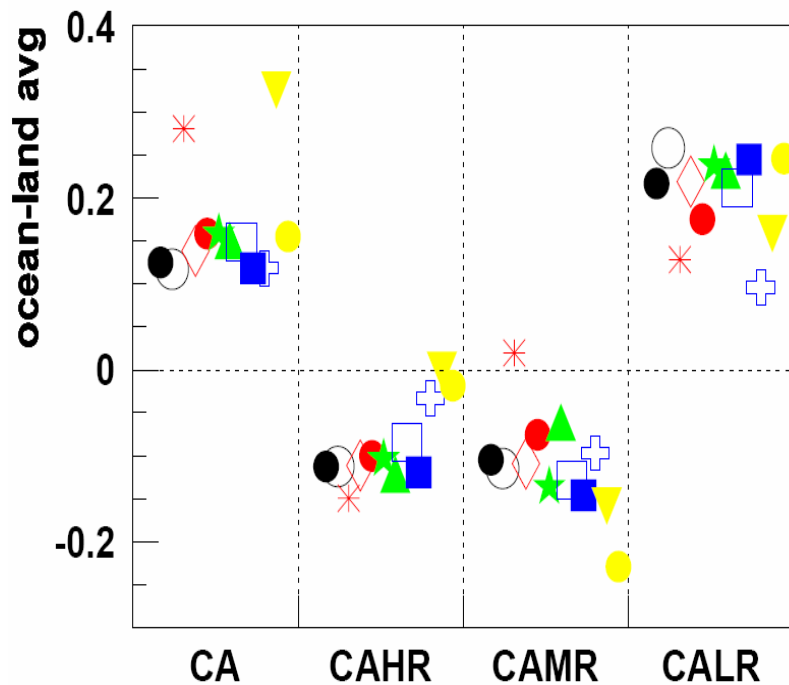
global CA 60-70% (+ 5% subvisible Ci) : 40% high , 40% single layer low

CAHR (hgh clds out of all clds) depends on sensitivity to thin Ci  
(misidentified as midlevel clouds by ISCCP, ATSR, POLDER)

CAE (effective CA=CA weighted by cld emissivity) agrees better

global monthly variability of CA: 20%-30% of CAE: 0.25-0.30

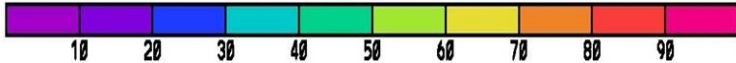
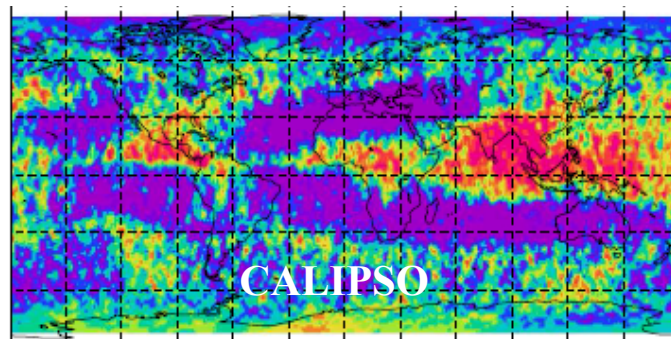
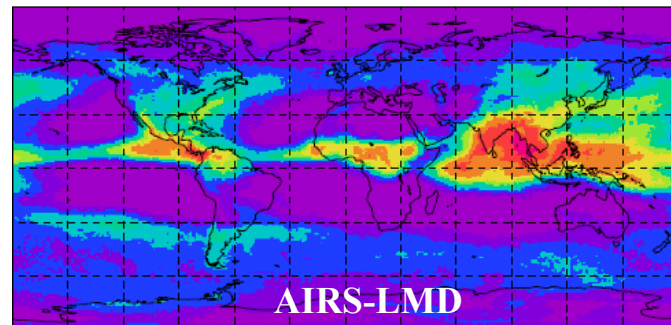
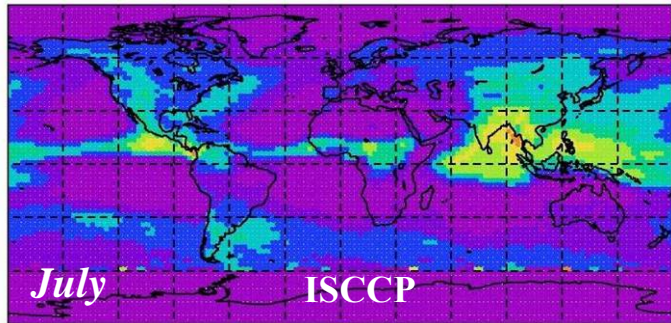
# Differences ocean - land



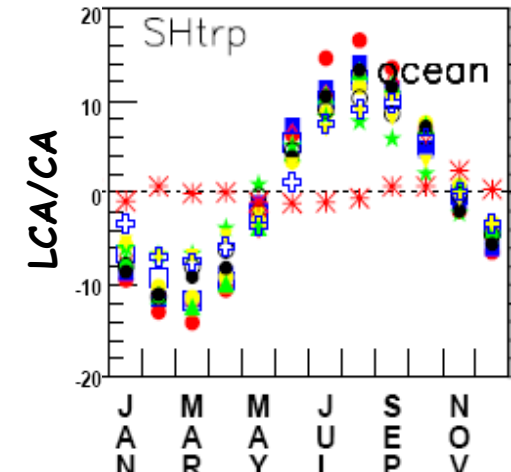
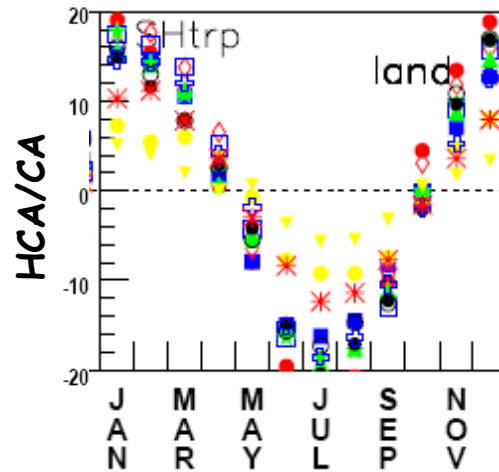
15% more clouds over ocean than over land (low clouds),  
whereas over land there are more high and midlevel clouds

The latter are optically thinner over land, so that effective cloud amount of those is similar

# Amount of uppermost cloud layers



Stubenrauch et al. 2009, GEWEX news



- AIRS-LMD ▲ MODIS-CE ▼ MISR
- ◇ TOVS ★ MODIS-ST ● POLDER
- GOCCP ■ ISCCP + ATSR
- CALIPSO □ PATMOSX \* HIRS

➤ Geographical distributions,  
latitudinal & seasonal variations similar

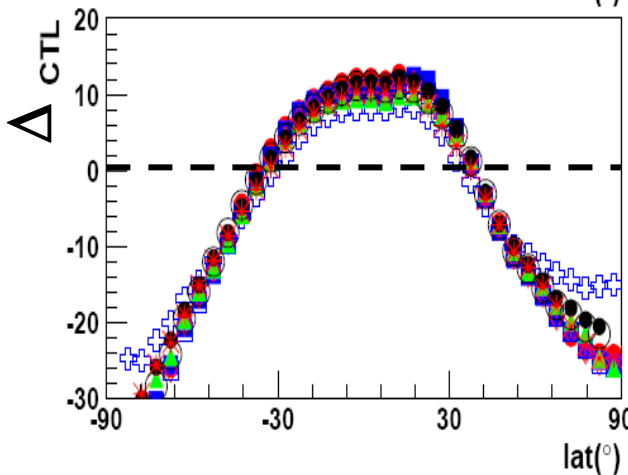
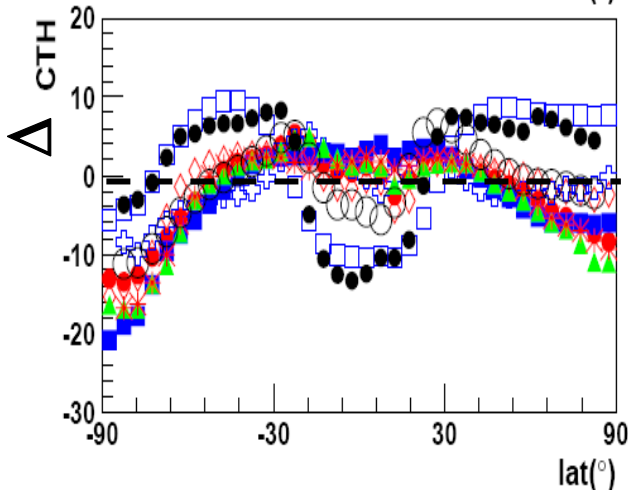
HCA depends on sensitivity to thin cirrus  
CALIPSO > TOVS/AIRS > MODIS/PATMOS  
> ISCCP > POLDER/MISR

# Cloud temperature:

latitudinal variation

&

distributions



CALIPSO:

including subvis Ci, T(cld top)

passive remote sensing:

T(rad. cld height)

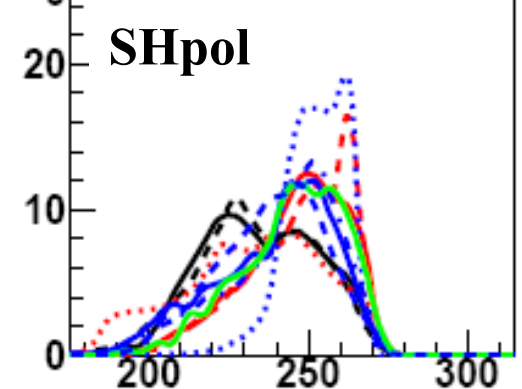
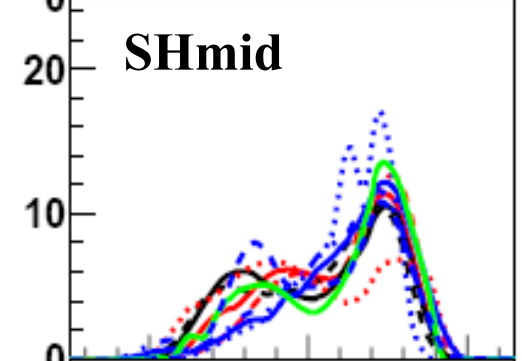
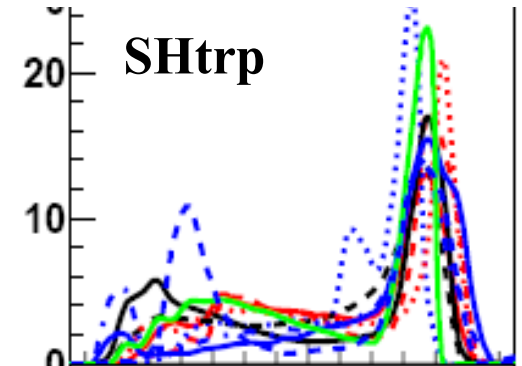
=> CTH(CALIPSO) should be lowest

& nearest to tropopause,

largest latitudinal variability

(PATMOSX should not be like CALIPSO for high clouds)

CT distributions reflect decrease of vertical extent of troposphere from tropics to poles



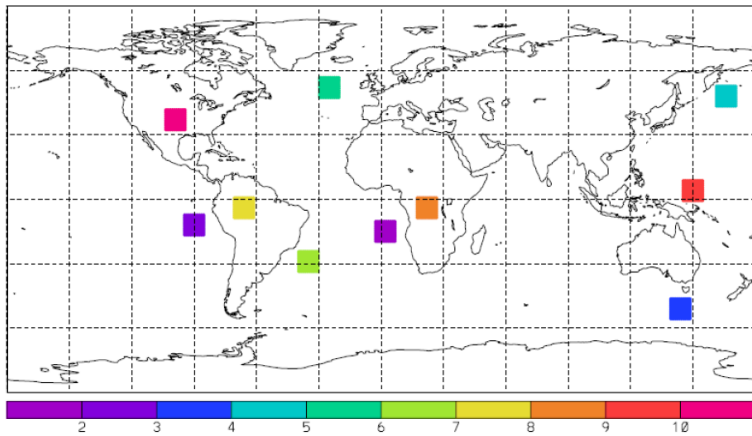
- ◇ TOVS
- ★ MODIS-ST
- POLDER
- GOCCP
- ISCCP
- ⊕ ATSR
- CALIPSO
- PATMOSX
- ✱ HIRS

- AIRS-LMD
- - - TOVSB
- ⋯ HIRS
- ⋯ ATSR
- MODIS-ST
- POLDER
- ISCCP
- ⋯ ISCCP 3PM
- - - PATMOSX
- CALIPSO-ST
- - - CALIPSO-GO
- - - MISR

# Specific regions, compared to globe

Rossow et al. J. Clim. 2002

10° x 10° regions of typical climate regimes  
with increasing small scale variations:  
(1 - <math>\langle \text{COD}(\text{rad}) \rangle / \langle \text{COD}(\text{lin}) \rangle</math>)



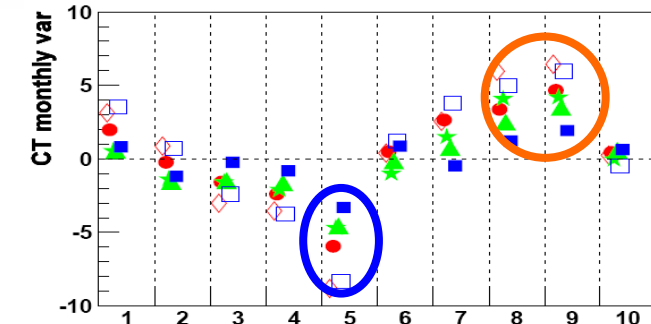
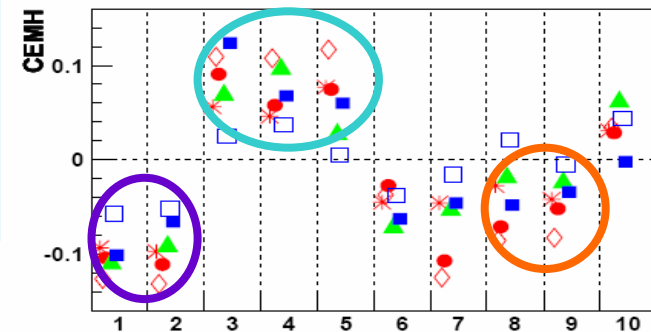
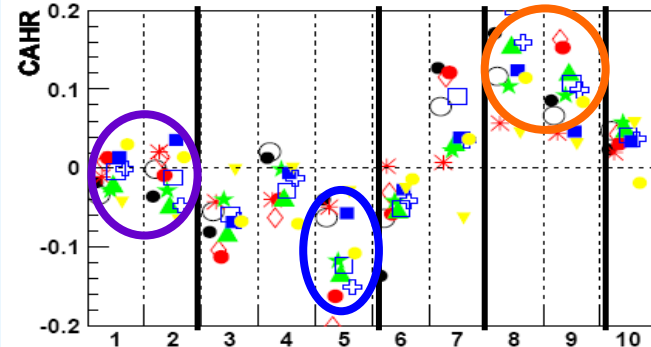
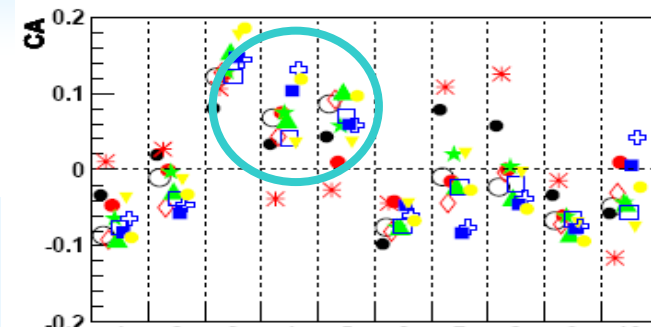
- 1: SH Str Africa
- 2: SH Str America
- 3: SH midlat
- 4: NH EPacific
- 5: NAtlantic storms
- 6: SH Ci off America
- 7: SH Ci Amazon
- 8: SH Cb Africa
- 9: NH Cb Indonesia
- 10: ARM Southern Great Plain

Strcum regions (1,2):  
average CAHR, but  
optically thin

Storm regions (3,4,5):  
largest CA  
NAtlantic (5): smaller  
CAHR & monthly CT  
variability

ITCZ (8,9):  
largest CAHR (small  
CEMH, linked to Ci) &  
largest monthly CT  
variability

- CALIPSO-ST
  - CALIPSO-GOCCP
  - ▲ MODIS-CE
  - ★ MODIS-ST
  - ▼ MISR
  - POLDER
  - ◆ TOVS
- EGU 2011

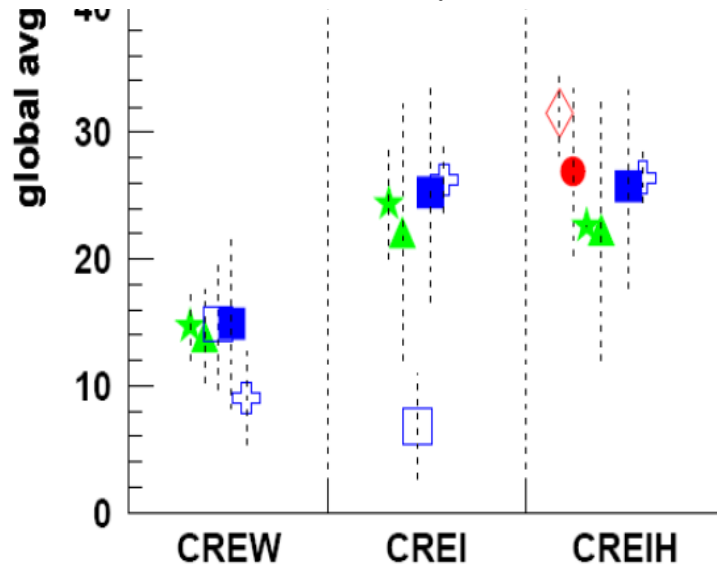


April 2011

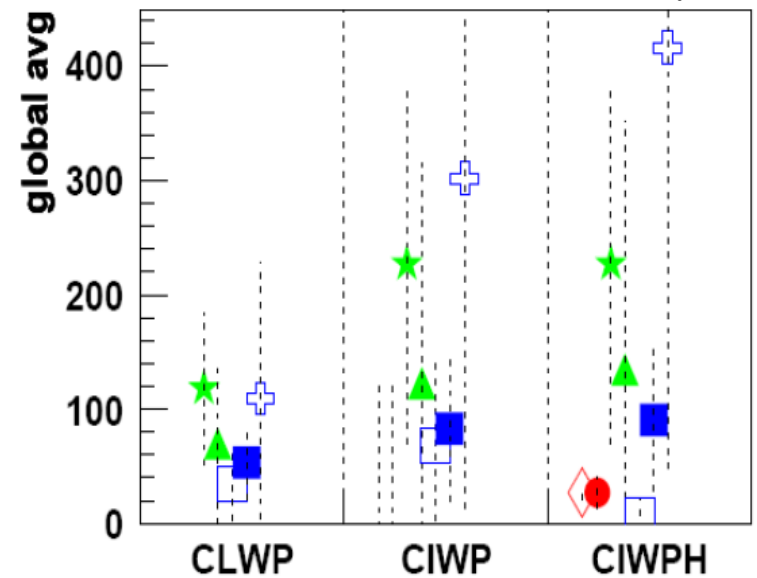
- ISCCP
- PATMOSX
- ⊕ ATSR
- ✱ HIRS
- AIRS-LMD
- ◆ TOVS

# Bulk microphysical properties:

eff. liquid / ice particle radius



& liquid / ice water path



■ ISCCP    + ATSR    ● AIRS-LMD    ▲ MODIS-CE  
 PATMOSX    ✱ HIRS    ◇ TOVS    ★ MODIS-ST    ----- monthly mean variability

Whereas CA, CEM, CT, CP of the data base are well understood, differences in CRE and CWP have still to be further explored

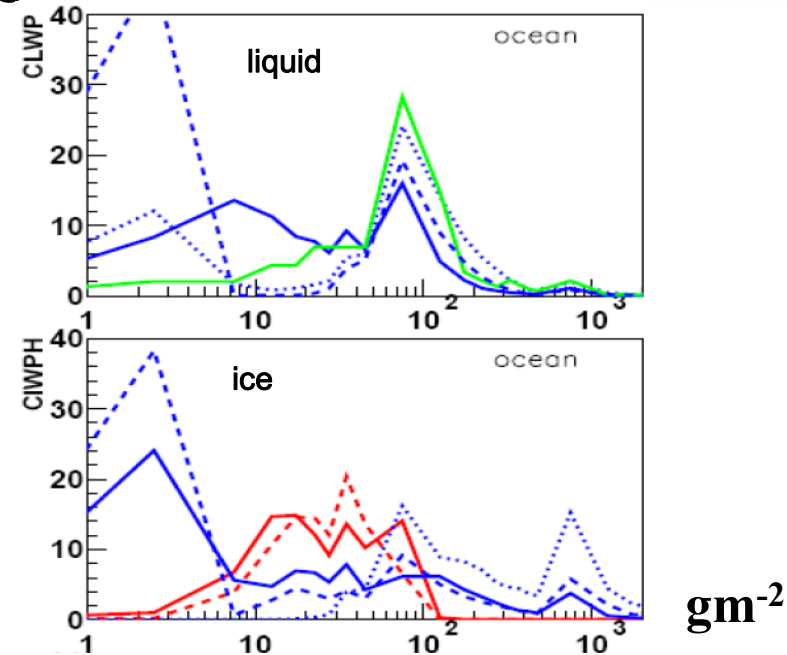
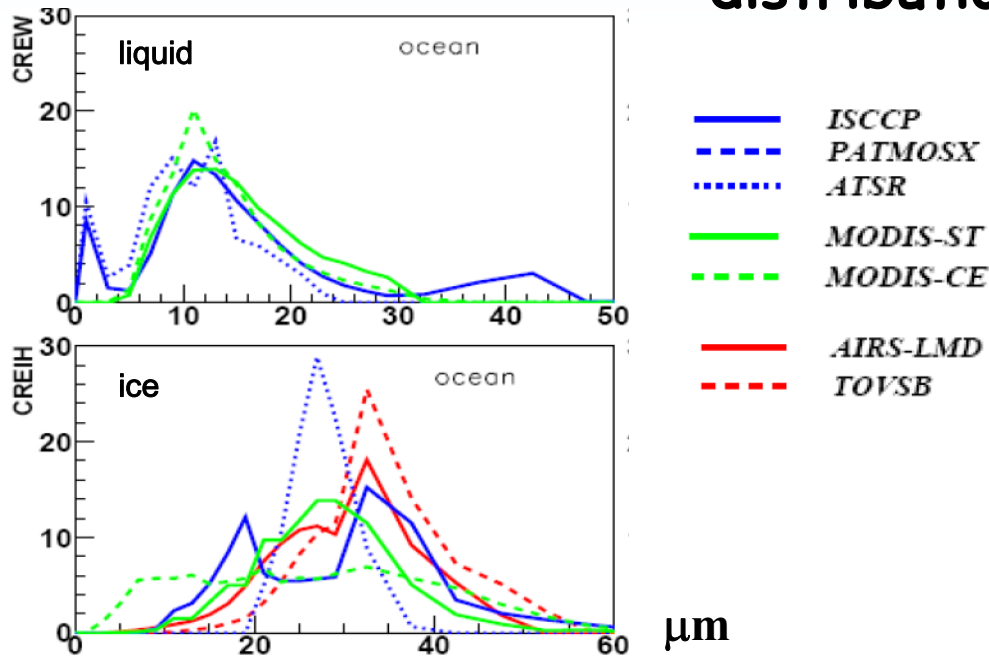
Global averages of CREW / CREI(H) agree quite well with  $15\mu\text{m}$  /  $25\mu\text{m}$

IR sounders determine CREIH, CIWPH only for a subsample: semi-transparent ice clouds  
 $\Rightarrow$  CIWPH is much smaller ( $25\text{ gm}^{-2}$ ) than averaged over all ice clouds ( $\sim 100\text{ gm}^{-2}$ )

VIS-IR methods: MODIS-ST / ATSR-GRAPES much larger values than ISCCP / MODIS-CE / PATMOSX

distributions are not Gaussian ....

# eff. particle radius & water path distributions

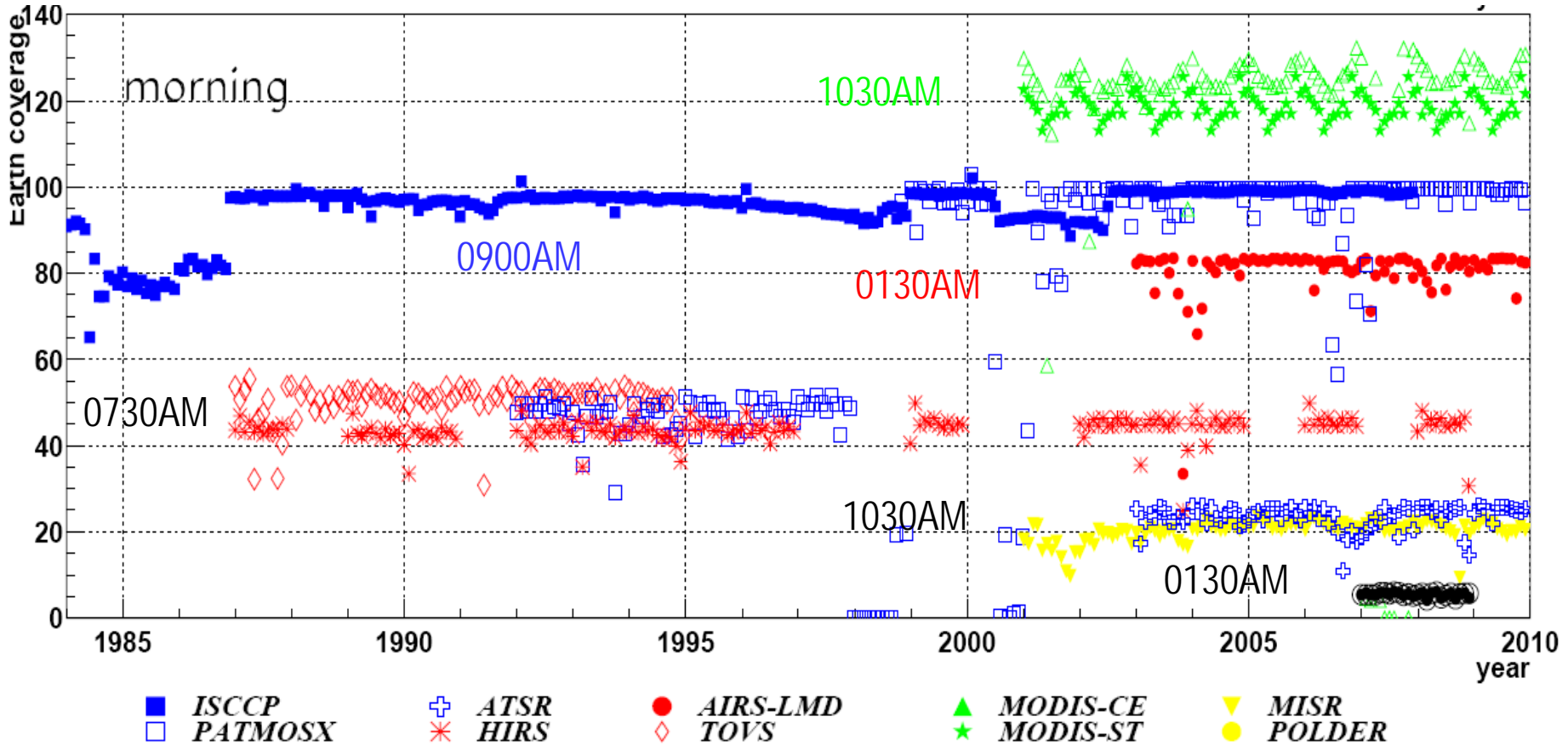


CREW distributions agree quite well,  
 with a large peak around  $11\mu\text{m}$ ,  
 small peak at  $42\mu\text{m}$  from ISCCP  
 (perhaps water cloud misidentification)  
 CREIH: IR sounders, ISCCP: large peak at  $32\mu\text{m}$ ,  
 second peak of ISCCP at  $18\mu\text{m}$  (at top for opt  
 thick clouds)  
 peaks of MODIS-ST and ATSR-GRAPe at  $27\mu\text{m}$

CLWP: large peak at  $80\text{ gm}^{-2}$   
 CIWPH: AIRS, TOVS compact distribution  
 between  $5$  &  $100\text{ gm}^{-2}$ ;  
 ISCCP, PATMOSX large peak at  $4\text{ gm}^{-2}$   
 (regions with low clouds clouds?)

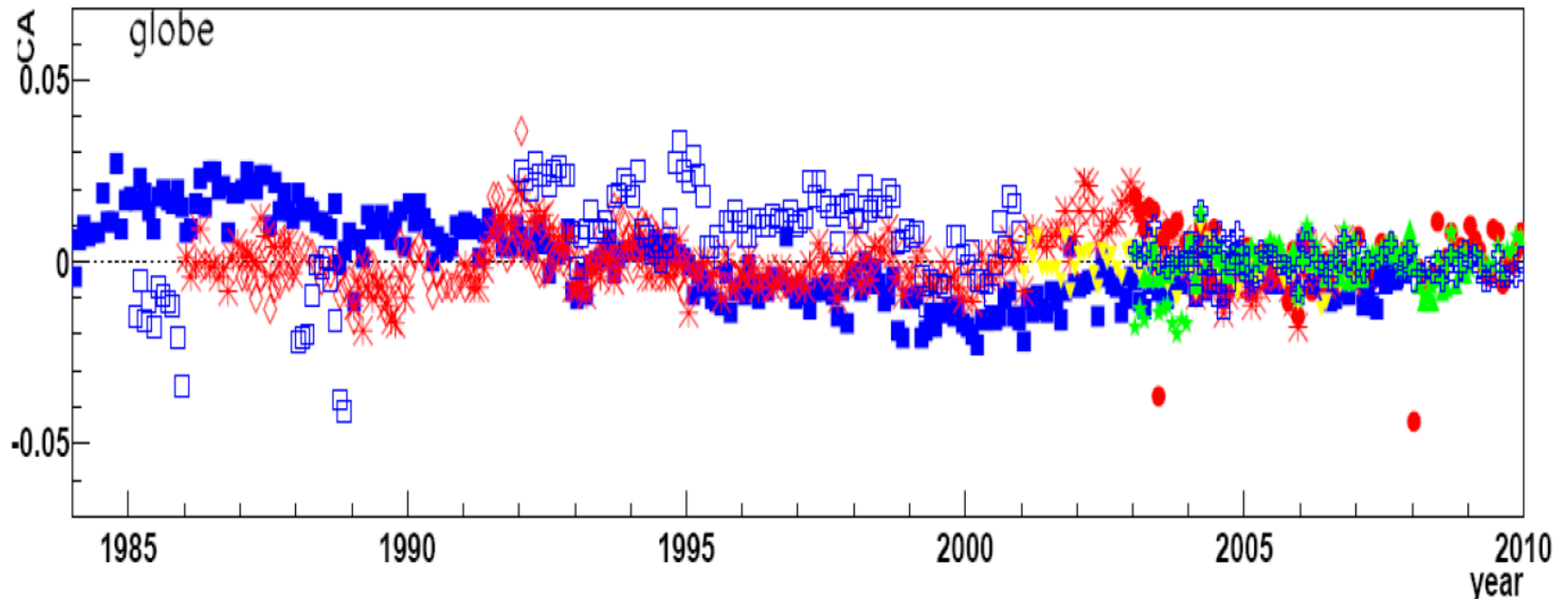
further investigations necessary!  
 (see also poster 6346 in Session AS3.3)

# Monitoring of Earth coverage



**climate change studies: be aware of temporal changes in coverage!**  
 MODIS at high latitudes more orbit passages, all others have kept only one passage  
 ISCCP nearly 100% coverage, CALIPSO 5%

# Global CA anomalies



global CA within  $\pm 2.5\%$  ( $\sim$  interannual & monthly mean variability)

possible origins of variability:

- changing average view angle (decreasing with nb of covering geo sat for ISCCP)
- satellite drift (for NOAA polar afternoon satellites (HIRS))
- change in Earth coverage, .....

# Conclusions

- To produce a common data base is challenging  
(*GEWEX Cloud Assessment activity not funded*)

However, once the data base is reliable,  
it provides a wealth of information for climate studies & model evaluation

So far statistical analyses:

- ❖ geographical distributions, latitudinal & seasonal variations agree quite well
  - ❖ differences can be mostly understood by different sensitivities to cirrus,  
(problems in retrieval methods, misidentification water-ice clouds)
  - ❖ monitoring of cloud properties very difficult (*need synergy of different variables*)
- Phase II of assessment (*next 3 months*): review knowledge of stratocumulus, storms, cirrus  
to contribute please contact: [stubenrauch@lmd.polytechnique.fr](mailto:stubenrauch@lmd.polytechnique.fr), [kinne@zmaw.de](mailto:kinne@zmaw.de)
  - ESA Cloud\_CCI project (Climate Change Initiative) includes assessment activities  
& another cloud assessment workshop is foreseen at the end of the project (2013)