

# Ice clouds observed by passive remote sensing : What did we learn from the GEWEX Cloud Assessment ?



**Claudia Stubenrauch**  
Laboratoire de Météorologie Dynamique, IPSL/CNRS, France



# Clouds are extended objects of many very small liquid / ice particles

*Cirrus (high ice clouds)*



**satellite radiometers**



**bulk quantities**

**at spatial & temporal scales  
to resolve  
weather & climate variability**

*Cloud structures over Amazonia*



*Cumulonimbus (vertically extended)*



*Cumulus (low fair weather clouds)*



global gridded L3 data (1° lat x 1° long) : monthly averages, variability, Probability Density Functions

<b>ISCCP</b> <i>GEWEX cloud dataset</i>	<i>1984-2007</i>	<i>(Rossow and Schiffer 1999)</i>
<b>MODIS-ScienceTeam</b>	<i>2001-2009</i>	<i>(Menzel et al.2008; Platnick et al. 2003)</i>
<b>MODIS-CERES</b>	<i>2001-2009</i>	<i>(Minnis et al. 2011)</i>
<b>TOVS Path-B</b>	<i>1987-1994</i>	<i>(Stubenrauch et al. 1999, 2006; Rädel et al. 2003)</i>
<b>AIRS-LMD</b>	<i>2003-2009</i>	<i>(Stubenrauch et al. 2010; Guignard et al. 2012)</i>
<b>HIRS-NOAA</b>	<i>1982-2008</i>	<i>(Wylie et al. 2005)</i>
<i>relatively new retrieval versions:</i>		
<b>PATMOS-x (AVHRR)</b>	<i>1982-2009</i>	<i>(Heidinger et al. 2012, Walther et al. 2012)</i>
<b>ATSR-GRAPE</b>	<i>2003-2009</i>	<i>(Sayer et al. 2011)</i>
<i>complementary cloud information:</i>		
<b>CALIPSO-ScienceTeam</b>	<i>2007-2008</i>	<i>(Winker et al. 2009)</i>
<b>CALIPSO-GOCCP</b>	<i>2007-2008</i>	<i>(Chepfer et al. 2010)</i>
<b>MISR</b>	<i>2001-2009</i>	<i>(DiGirolamo et al. 2010)</i>
<b>POLDER</b>	<i>2006-2008</i>	<i>(Parol et al. 2004; Ferlay et al. 2010)</i>

# GEWEX Cloud Assessment Web-site

**Assessment of global cloud datasets from satellites**

Clouds cover about 70% of the Earth's surface and play a dominant role in the observations atmosphere and temporal Satellite cloud however, clouds can exhibit s The Global Assessment, finalized in monthly sta imagers, IR

**Datasets and Instruments**

The GEWEX Cloud Assessment focused on evaluating global Level-3 (L3) cloud from measurements spectral imagers, These instruments different parts of retrieval approach Database section detail in the Cloud below correspond

**Cloud Assessment Database**

The GEWEX Cloud Assessment focused on evaluating global Level 3 cloud products (gridded, monthly statistics). The common database provides per dataset one file per cloud property, per individual year and observation time of day. The map grid corresponds to 1° latitude x 1° longitude. All variables are averaged over each map grid cell for each time step in the original data product and then averaged over the month. In addition to monthly averages, standard deviations of variations at these time step intervals are reported, as well as histograms of some variables. Statistics of these variables (monthly averages, day-to-day variability and histograms) are provided for all clouds and separately stratified by cloud top height category and by cloud thermodynamical phase (liquid, ice).

**Cloud Properties**

- Cloud amount (fractional cover) CA
- Cloud temperature at top CT
- Cloud pressure at top CP
- Cloud height (above sea level) CZ
- Cloud IR emissivity CEM
- Effective CA (weighted by CEM) CAE
- Cloud (visible) optical depth COD
- Cloud water path (liquid) CLWP
- Cloud water path (ice) CLIP
- Cloud eff. particle size (liquid) CREW
- Cloud eff. particle size (ice) CREI

**Multi-spectral**

- Cloud am
- Effective
- Cloud pre
- Cloud ten
- Cloud alti
- Cloud opt
- Cloud ID

**Database Description**

**Year-based**

[1982](#), [1983](#), [1984](#), [1985](#), [1986](#), [1987](#), [1988](#), [1989](#), [1990](#), [1991](#), [1992](#), [1993](#), [1994](#), [1995](#), [1996](#), [1997](#), [1998](#), [1999](#), [2000](#), [2001](#), [2002](#), [2003](#), [2004](#), [2005](#), [2006](#), [2007](#), [2008](#), [2009](#), [2010](#)

Averages:  
[1984-2000](#), [1984-2007](#)  
[1987-1990](#), [1987-1994](#)  
[2003-2009](#), [2004-2009](#)  
[2008-5deg](#)

**Instrument-based**

[ISCCP](#)  
[PATMOSX](#)  
[MODIS-ST](#)  
[MODIS-CE](#)  
[ATSR-GRAPE](#)  
[POLDER](#)  
[MISR](#)  
[HIRS](#)  
[TOVSE](#)  
[AIRS-LMD](#)  
[CALIPSO-GOCCP](#)  
[CALIPSO-ST](#)  
["3D"](#)

**Variable-based**

[CA](#), [CAE](#), [CAEH](#), [CAEI](#), [CAEIH](#), [CAEL](#), [CAEM](#), [CAEW](#), [CAH](#), [CAHE](#), [CAI](#), [CAIH](#), [CAIHR](#), [CAIR](#), [CAL](#), [CALR](#), [CAM](#), [CAMR](#), [CAW](#), [CAWR](#), [CEM](#), [CEMH](#), [CEMI](#), [CEMIH](#), [CEML](#), [CEMM](#), [CEMW](#), [CIWP](#), [CIWPH](#), [CLWP](#), [COD](#), [CODH](#), [CODI](#), [CODIH](#), [CODL](#), [CODM](#), [CODW](#), [CP](#), [CPI](#), [CPIH](#), [CPRAY](#), [CREI](#), [CREIH](#), [CREW](#), [CT](#), [CTH](#), [CTI](#), [CTIH](#), [CTL](#), [CTM](#), [CTW](#), [CZ](#), [CZI](#), [CZIH](#), [HIST2D](#)

• General sections: description, meetings, publications, etc

• “Datasets” : provides individual descriptions

• “Database” : contains links to zipped netCDF files, grouped per variable, instrument and year, ftp-accessed.

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

# GEWEX Cloud Assessment key results

IR-NIR-VIS Radiometers, IR Sounders, multi-angle VIS-SWIR Radiometers  
exploiting different parts of EM spectrum

*How does this affect climatic averages & distributions?*

**Cloud Amount :  $0.68 \pm 0.03$**

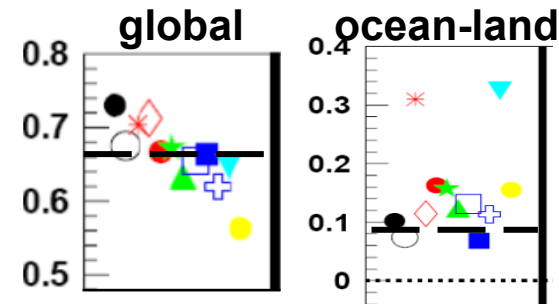
for clouds with COD > 0.1

+ 0.05 subvisible Ci, -> 0.56 (clds with COD > 2)

synoptic (day-to-day) variability : 0.25-0.30

inter-annual variability : 0.025

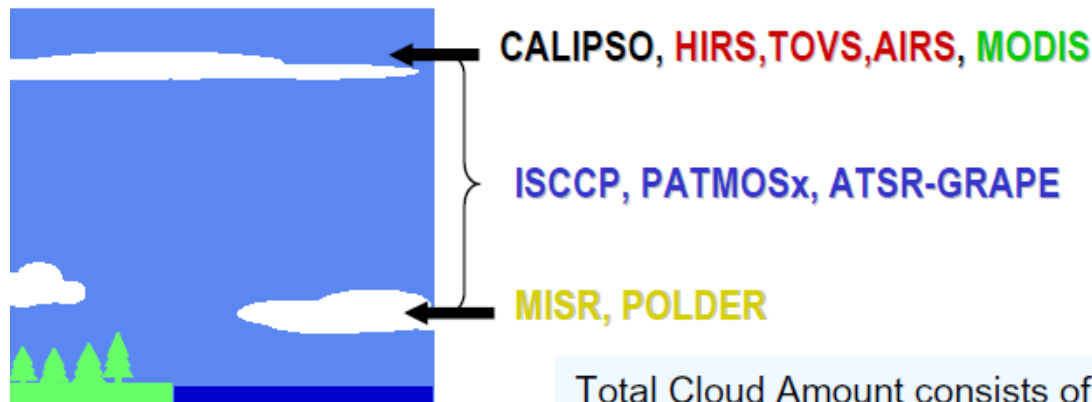
**0.10-0.15 larger over ocean than over land**



- ISCCP
- \* HIRS-NOAA
- ▲ MODIS-CE
- POLDER
- PATMOSX
- ◇ TOVS-PathB
- ★ MODIS-ST
- CALIPSO-ST
- ⊕ ATSR-GRAPE
- AIRS-LMD
- ▼ MISR
- CALIPSO-GOCCP

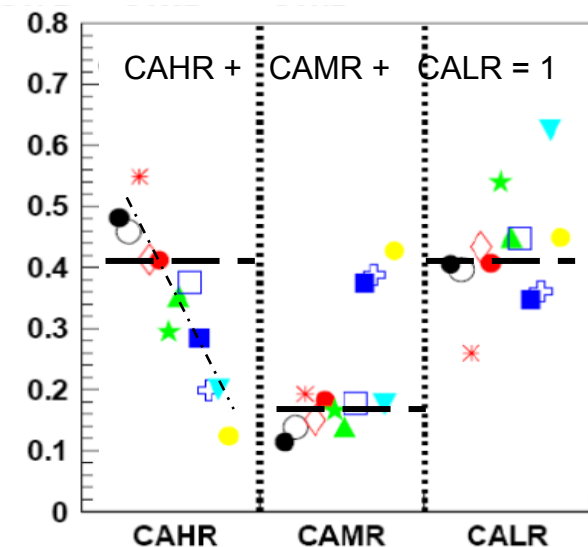
## Ci over low clouds : Interpretation of Cloud height

20% of all cloud scenes according to CALIPSO

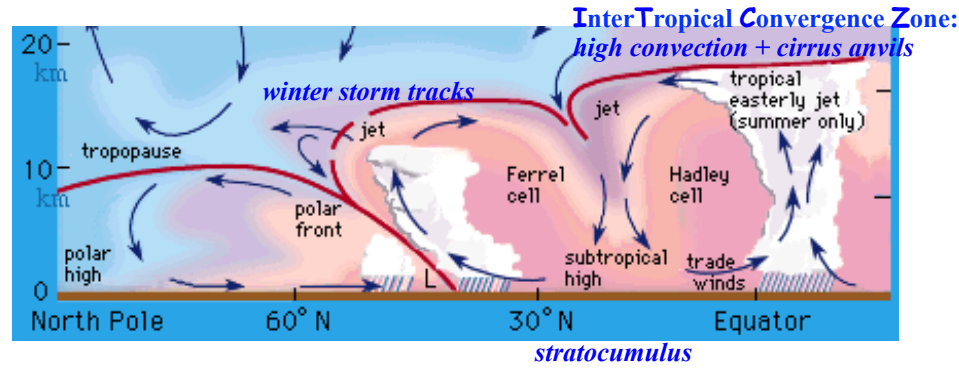
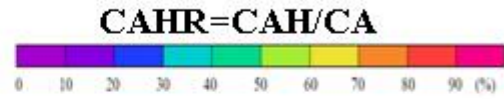


Total Cloud Amount consists of 42% high clouds and 42% single layer low clouds

## Global height-stratified CA

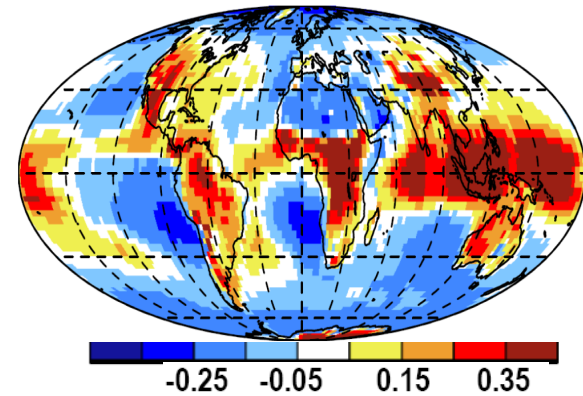


# Even if absolute values depend on Ci sensitivity, geographical cloud distributions agree!



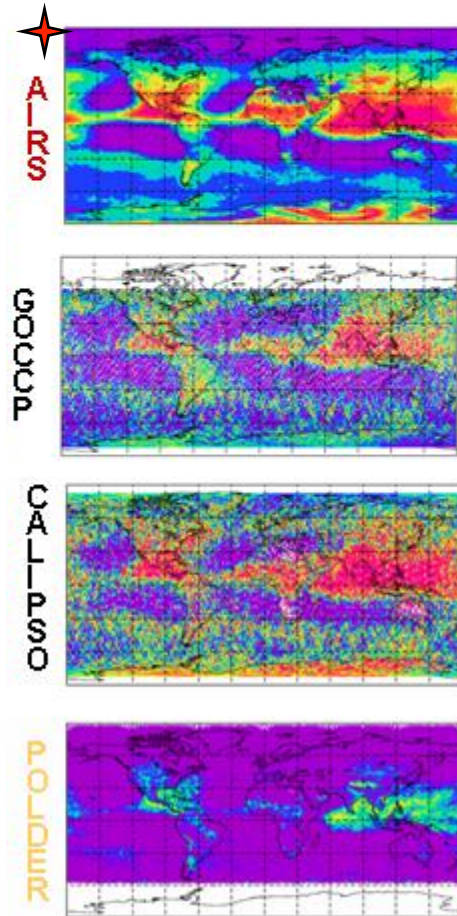
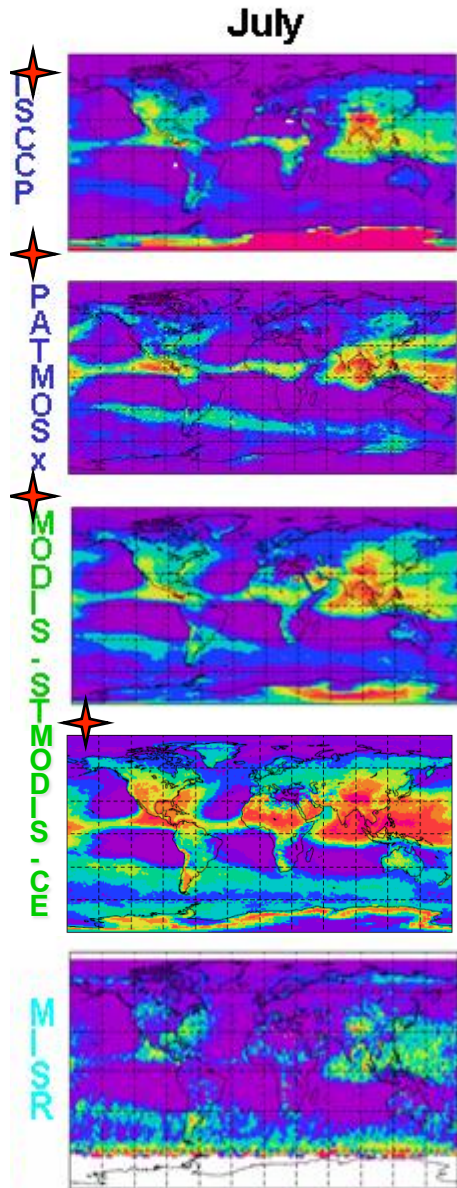
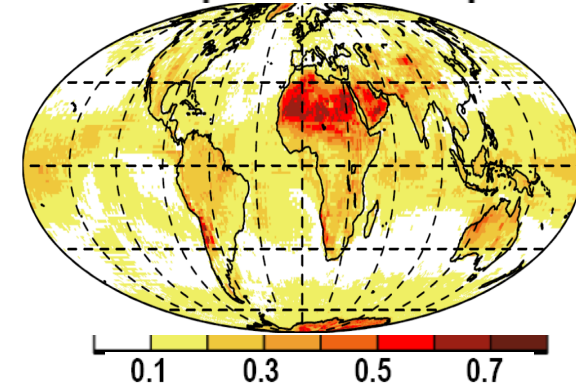
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CAHR - <CAHR> ISCCP



uncertainty on regional variability:

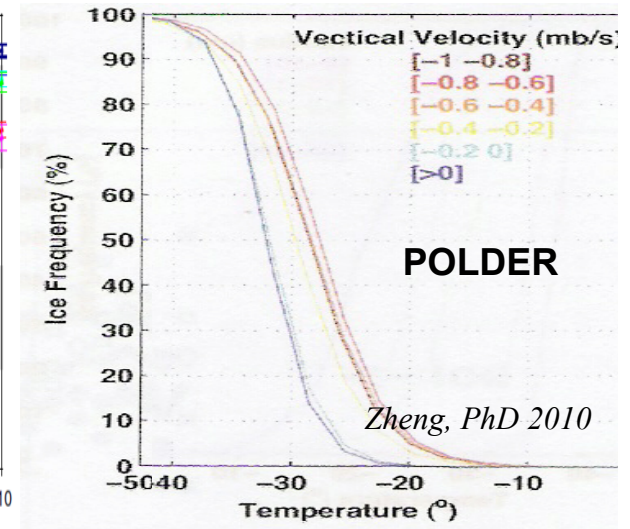
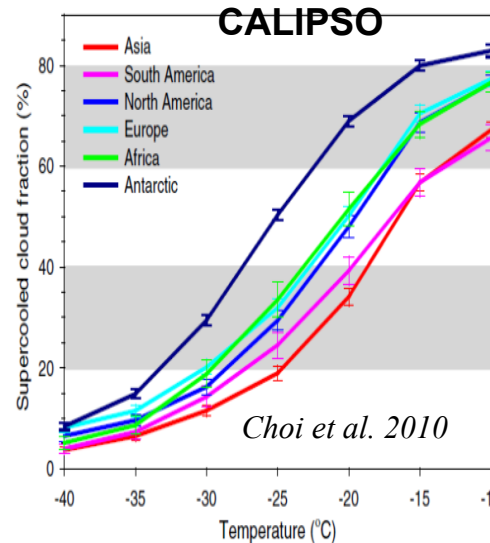
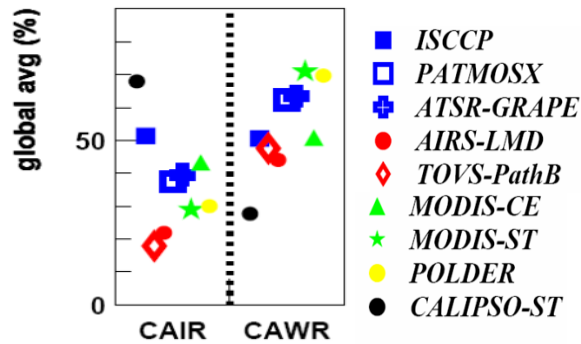
max-min[CAHR-<CAHR>] 6 clim



# Thermodynamic phase & retrieval of optical / microphysical properties

Retrieval of optical / bulk microphysical properties needs thermodynamic phase distinction:

- polarization (POLDER, CALIPSO)
- multi-spectral (PATMOS-x, MODIS, ATSR)
- temperature (ISCCP, AIRS, TOVS)



$R_{VIS} \rightarrow COD$

$R_{VIS} \ \& \ R_{SWIR} \rightarrow COD \ \& \ CRE$  (smaller particles reflect more)

assumptions in radiative transfer: particle habit, size distribution, phase

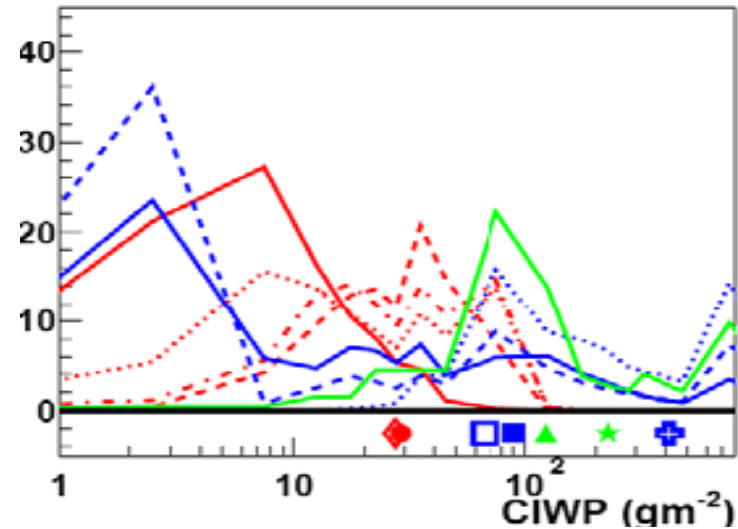
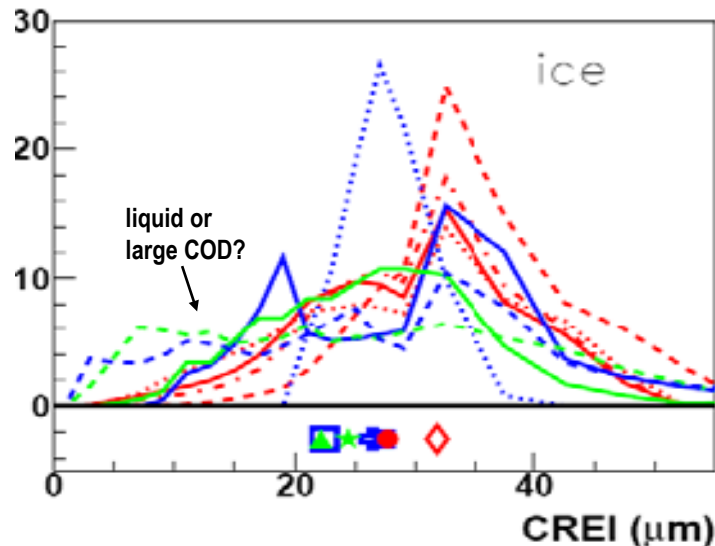
$WP = 2/3 \times COD \times \rho \times CRE$  (vertically hom.)

IR: small ice crystals in semi-transparent Ci lead to slope of CEM' s between 8 & 12

$\mu m$

# Ice bulk microphysical properties: Re & IWP

Single scattering properties in radiative transfer depend on phase / particle shape



**Effective Particle radius:**  $25 \pm 2 \mu\text{m}$   
 differences linked to **retrieval filtering**  
 of **optically thicker clouds**  
 & less to different channels (3.7 / 2.1 / 1.6  $\mu\text{m}$ )  
 -> only retrieved near cloud top

**Cloud Water Path:**  $25 - 300 \text{ gm}^{-2}$   
 averages & distributions strongly depend on  
**retrieval filtering & partly cloudy fields**  
 (MODIS-ST, ATSR retrieval filtering COD > 1, AIRS COD < 4)

- ISCCP
- - - PATMOSX
- ..... ATSR
- MODIS-ST
- - - MODIS-CE
- - - TOVSB
- AIRS-LMD
- - - AIRS-LMD  $\varepsilon > 0.3$
- ..... AIRS-LMD CT > 260 K

**Retrieval filtering essential to be taken into account when comparing to models!**

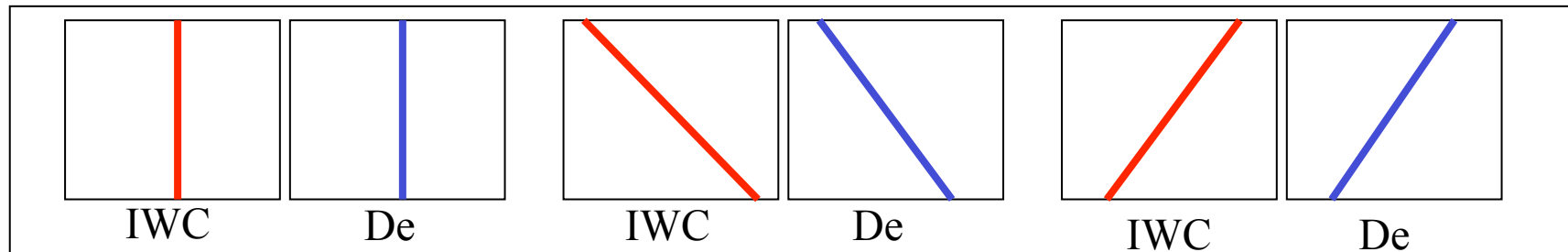


# A-Train Synergy: Classification of IWC profiles

*A. Feofilov, LMD*

Clouds with same IWP may have different IWC and De profiles  
-> influence on radiation ?

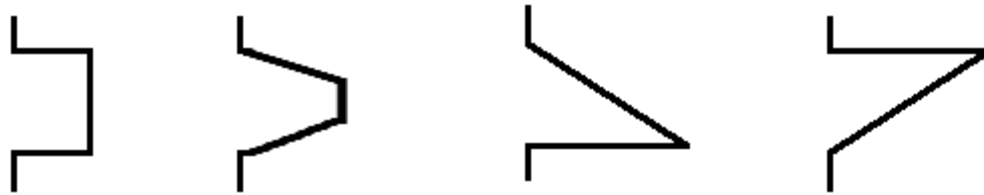
Is it possible to give a shape probability in dependence of cloud properties or atmospheric properties?



***increasing IWC compared to const. IWC leads to stronger cooling of atmosphere***

-> analysis using **AIRS** - **lidar-radar GEOPROF** - **liDARraDAR data**  
(Mace et al. 2009) (Delanoë & Hogan<sup>9</sup> 2010)

# IWC profile classes & dependency on IWP



constant    trapecia    lower triangle    upper triangle

*Feofilov et al. , EGU 2013,  
paper in preparation*

IWP (g/m <sup>2</sup> ) (occurrence)	constant	trapecia	low trian	upp trian
0-10 (51%)	<b>54%</b>	<b>20%</b>	<b>10%</b>	<b>16%</b>
10-30 (29%)	<b>31%</b>	<b>48%</b>	<b>13%</b>	<b>8%</b>
30-100 (17%)	<b>28%</b>	<b>56%</b>	<b>14%</b>	<b>3%</b>
100-300 (3%)	<b>26%</b>	<b>51%</b>	<b>21%</b>	<b>2%</b>
300-1000 (<1%)	<b>38%</b>	<b>35%</b>	<b>26%</b>	<b>1%</b>

**const & trapecia  
correspond to 80% of  
the profiles**

**lower triangle increases  
with IWP from 10 to  
25%**

**upper triangle only for  
IWP < 30 g/m<sup>2</sup>**

**strong vertical wind  
might affect occ of  
low / upp trianges**

**nearly independent  
of location / season !**

using const. instead of increasing IWC profile might underestimate radiative cooling of atmosphere by 1 – 2 Wm<sup>-2</sup>

# Conclusions

- **Satellite instruments:** unique possibility to study cloud properties over long period
- **GEWEX Cloud Assessment:**
  - first coordinated intercomparison of L3 cloud products of 12 global ‘state of the art’ datasets
  - common database facilitates further assessments, climate studies & model evaluation
- **ISCCP:** only dataset that directly resolves diurnal cycle (3-hourly) & covers whole globe
- geographical distributions, latitudinal & seasonal variations agree well
- accuracy is scene & instrument dependent (interpretation of cloud height):  
differences can be mostly understood by different performance to identify Ci  
(problems in some retrieval methods, misidentification water-ice clouds)
- histograms are important (esp. for optical and microphysical properties)
- cloud products adequate for model evaluation & monitoring regional variability
- longterm datasets -> robust statistics & explore rare events
- global monitoring of cloud properties very difficult
  
- even if instantaneous cloud properties are not very accurate,  
synergy of different variables provides invaluable potential for improving understanding of clouds