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

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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)

Datasets & Teams

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

ISCCP	***GEWEX cloud dataset***	***1984-2007***	*(Rossow and Schiffer 1999)*
MODIS-ScienceTeam		***2001-2009***	*(Menzel et al.2008; Platnick et al. 2003)*
MODIS-CERES		***2001-2009***	*(Minnis et al. 2011)*
TOVS Path-B		***1987-1994***	*(Stubenrauch et al. 1999, 2006; Rädel et al. 2003)*
AIRS-LMD		***2003-2009***	*(Stubenrauch et al. 2010; Guignard et al. 2012)*
HIRS-NOAA		***1982-2008***	*(Wylie et al. 2005)*

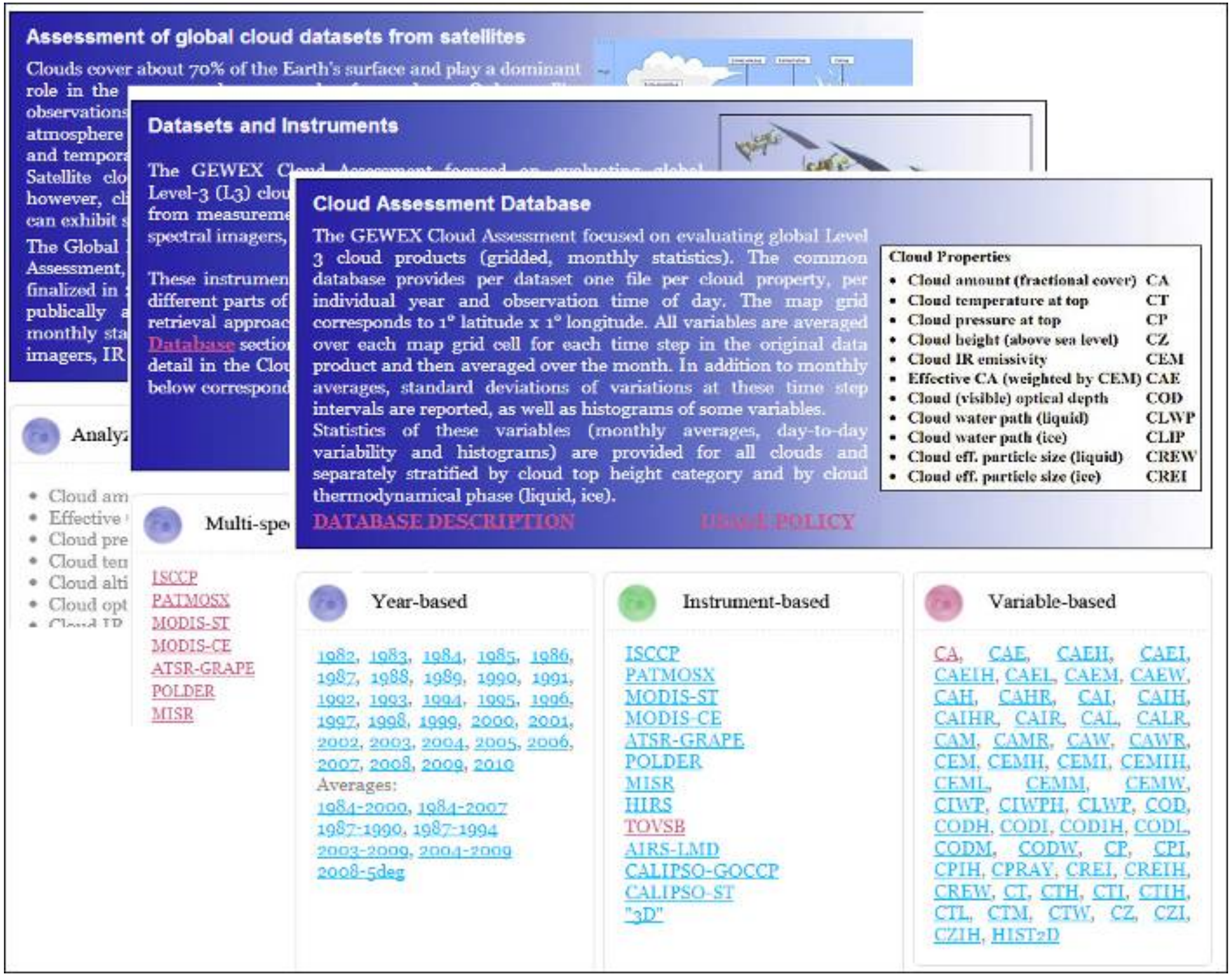
relatively new retrieval versions:

PATMOS-x	***(AVHRR)***	***1982-2009***	*(Heidinger et al. 2012, Walther et al. 2012)*
ATSR-GRAPE		***2003-2009***	*(Sayer et al. 2011)*

complementary cloud information:

CALIPSO-ScienceTeam	***2007-2008***	*(Winker et al. 2009)*
CALIPSO-GOCCP	***2007-2008***	*(Chepfer et al. 2010)*
MISR	***2001-2009***	*(DiGirolamo et al. 2010)*
POLDER	***2006-2008***	*(Parol et al. 2004; Ferlay et al. 2010)*

GEWEX Cloud Assessment Web-site



- **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?

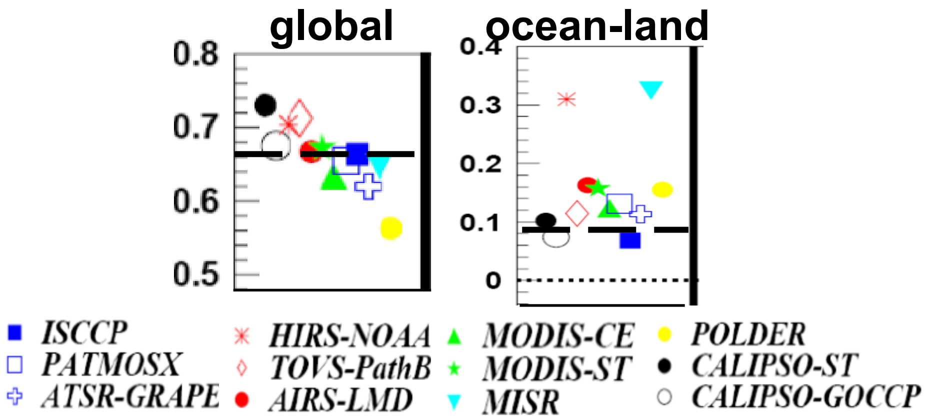
Cloud Amount : 0.68 ± 0.03

for clouds with COD>0.1

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

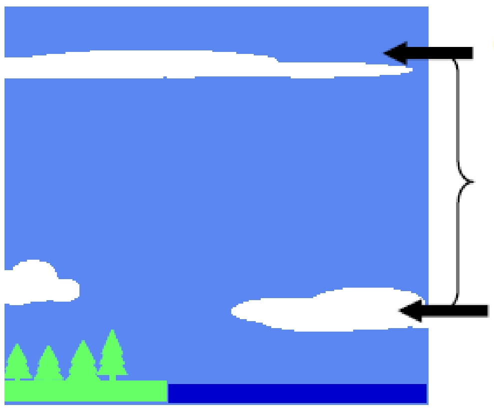
synoptic (day-to-day) variability : 0.25-0.30
inter-annual variability : 0.025

0.10-0.15 larger over ocean than over land



Ci over low clouds : Interpretation of Cloud height

20% of all cloud scenes *according to CALIPSO*



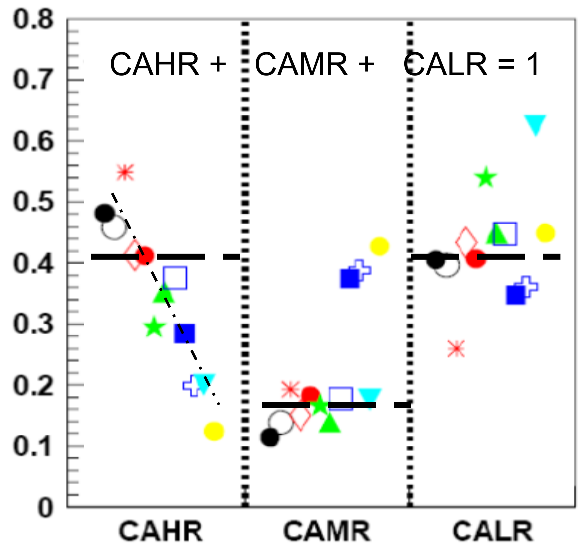
CALIPSO, HIRS,TOVS,AIRS, MODIS

ISCCP, PATMOSx, ATSR-GRAPE

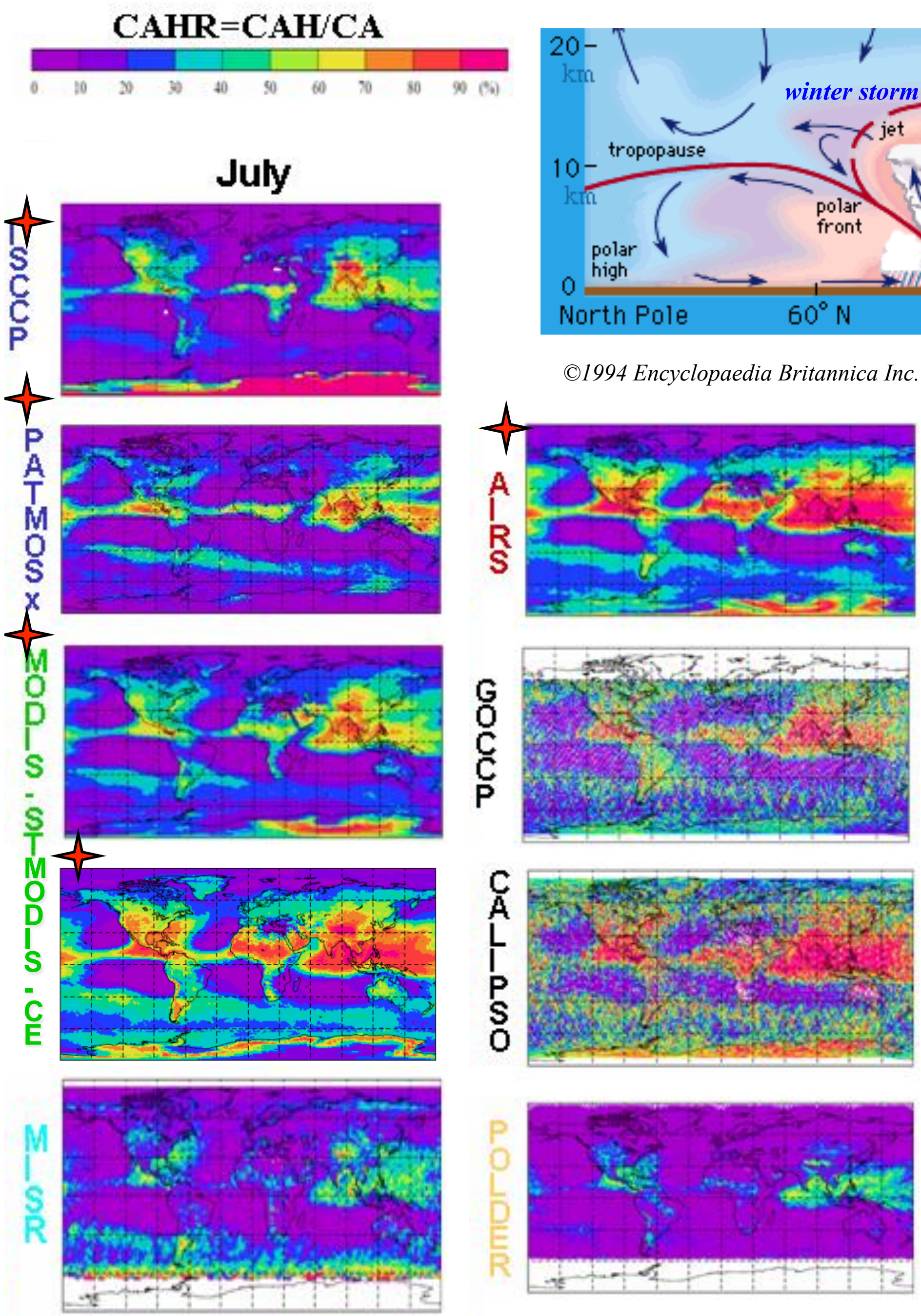
MISR, POLDER

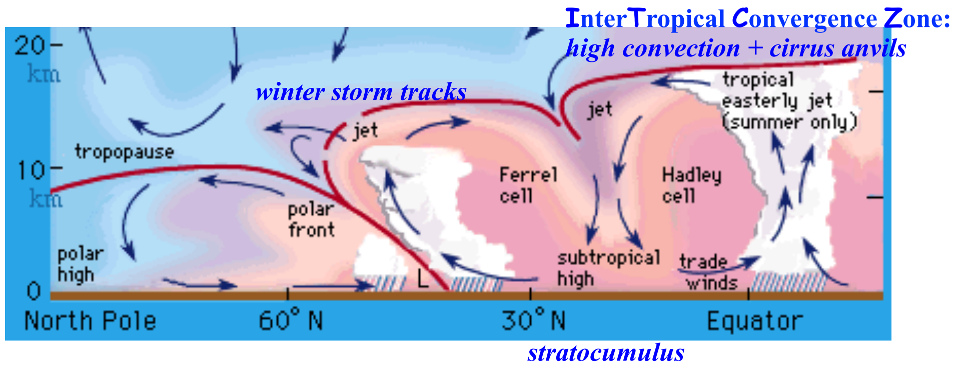
Total Cloud Amount consists of 42% high clouds and 42% single layer low clouds

Global height-stratified CA



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





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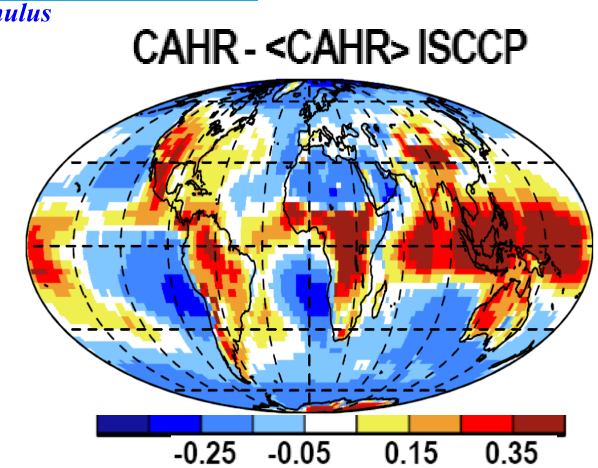
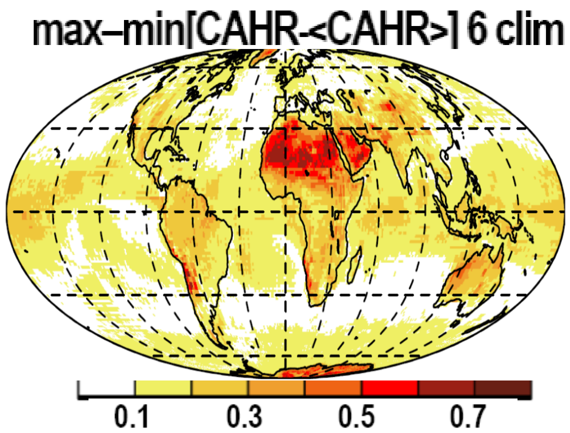


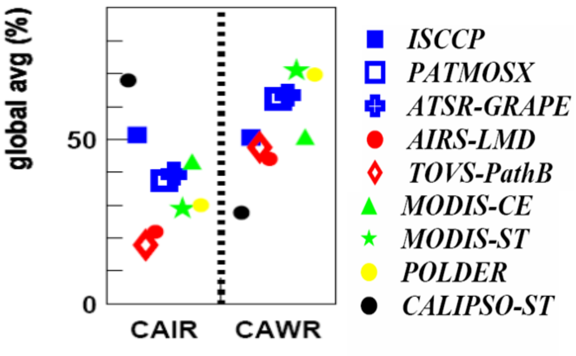
uncertainty on regional variability:

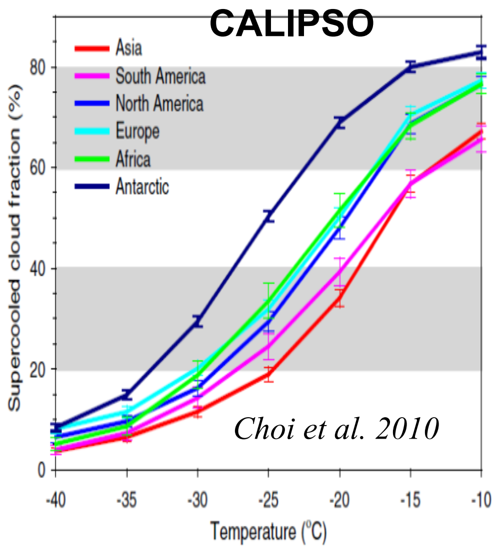


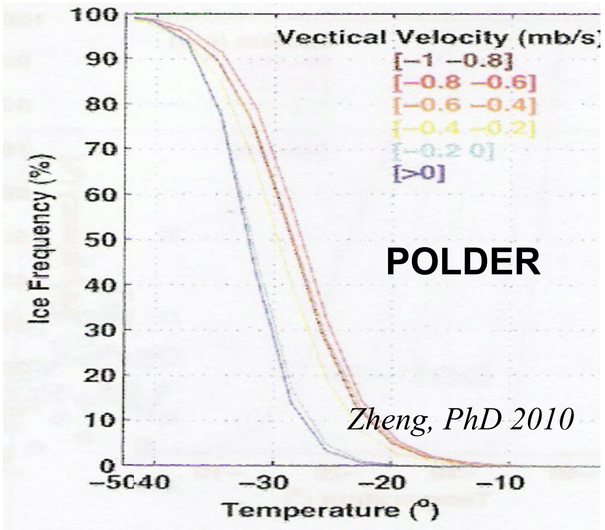
Thermodynamic phase & retrieval of optical / microphysical properties

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} -> COD

R_{VIS} & R_{SWIR} -> COD & CRE (smaller particles reflect more)

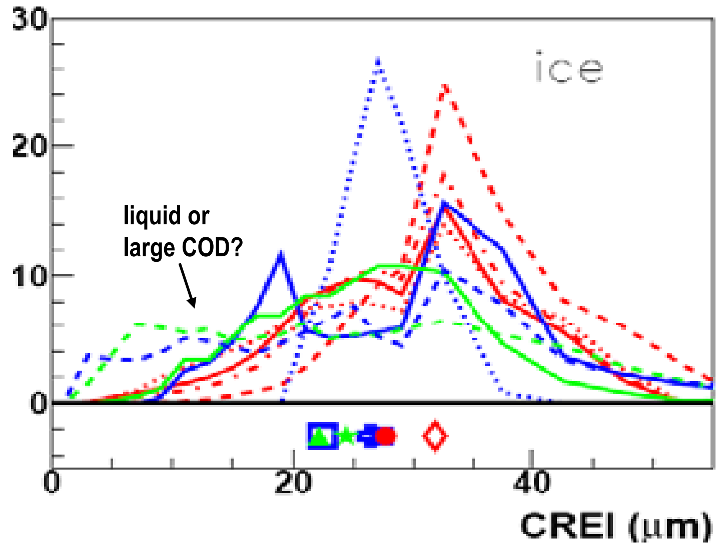
assumptions in radiative transfer: particle habit, size distribution, phase

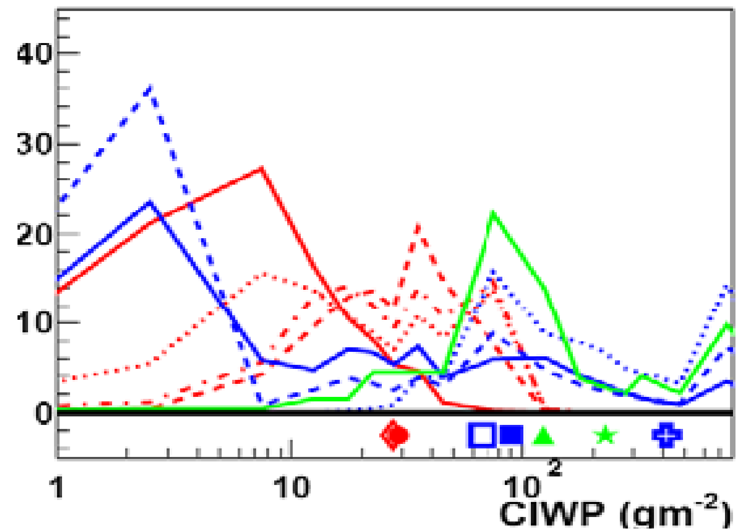
WP = 2/3 x COD x ρ x CRE (vertically hom.)

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

Ice bulk microphysical properties: Re & IWP

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

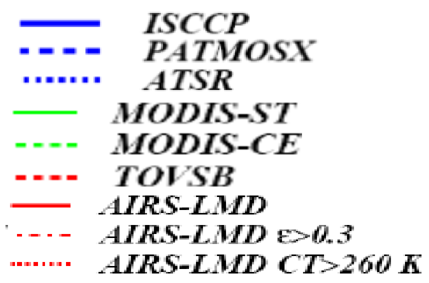




Effective Particle radius: 25 ± 2 μm
differences linked to retrieval filtering
of optically thicker clouds
& less to different channels (3.7 / 2.1 / 1.6 μm)
-> only retrieved near cloud top

Cloud Water Path: 25 – 300 gm^{-2}

averages & distributions strongly depend on
retrieval filtering & partly cloudy fields
(MODIS-ST, ATSR retrieval filtering COD > 1, AIRS COD < 4)



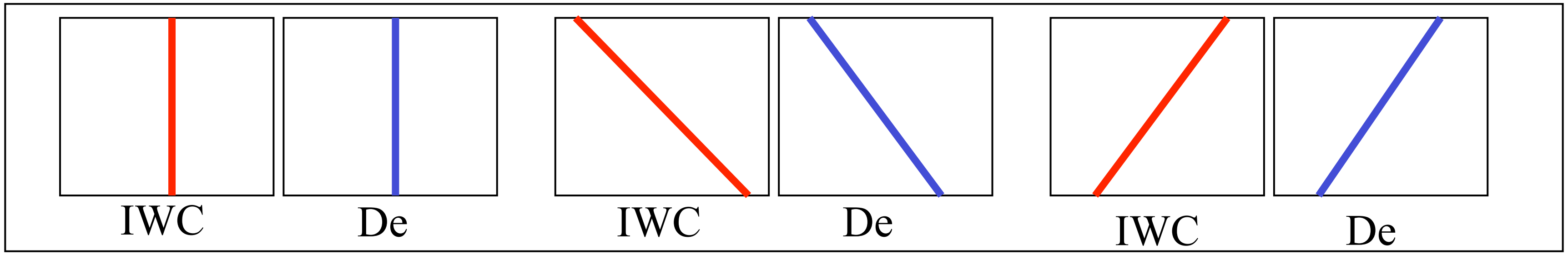
Retrieval filtering essential to be taken into account when comparing to models!

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?



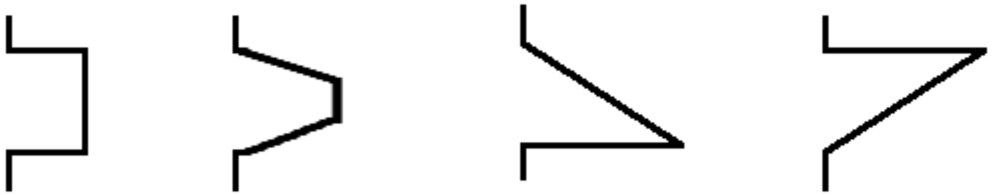
increasing IWC compared to const. IWC leads to stronger cooling of atmosphere

-> analysis using AIRS - lidar-radar GEOPROF - liDARraDAR data

(Mace et al. 2009) *(Delanoë & Hogan 2010)*

IWC profile classes & dependency on IWP

Feofilov et al. , EGU 2013, paper in preparation



constant trapecia lower triangle upper triangle

IWP (g/m2) (occurrence)	**constant**	**trapecia**	**low trian**	**upp trian**
0-10 (51%)	**54%**	**20%**	**10%**	**16%**
10-30 (29%)	**31%**	**48%**	**13%**	**8%**
30-100 (17%)	**28%**	**56%**	**14%**	**3%**
100-300 (3%)	**26%**	**51%**	**21%**	**2%**
300-1000 (<1%)	**38%**	**35%**	**26%**	**1%**

using const. instead of increasing IWC profile might underestimate radiative cooling of atmosphere by 1 – 2 Wm^{-2}

const & trapecia correspond to 80% of the profiles

lower triangle increases with IWP from 10 to 25%

upper triangle only for IWP < 30 g/m2

strong vertical wind might affect occ of low / upp triangles

nearly independent of location / season !

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