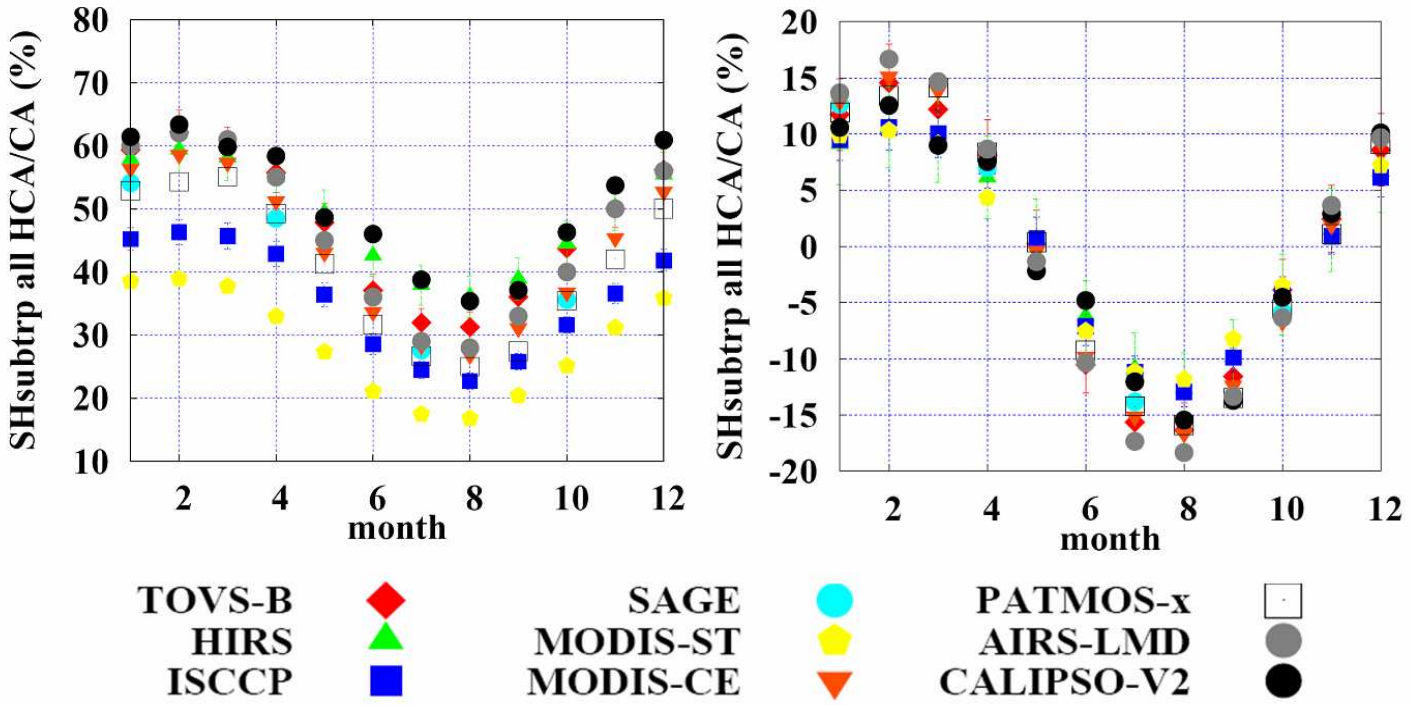
Goal: **comprehensive reference data base of cloud properties for climate studies & model evaluation**

data base issues

Stefan Kinne, NY 2008

- the user wants *(e.g. global modeling)*
  - ONE (and not many) global cloud climatology (-ies)
  - UNCERTAINTIES (-maps) for cloud climatologies
- clouds are defined beyond cloud cover
  - by MICRO-physics (particle conc, size and phase)
  - by MACRO-physics (altitude [T], structure, overlap)
- definitions are often unclear
  - sampling issues
  - the 'art' of temporal and spatial averages
- influence of ancillary data and assumptions

GEWEX news article, Feb 2009



Key results:

- 70% (±5%) clouds: ~ 40% high clouds & ~40% single-layer low clouds
- geographical cloud structures & seasonal cycles agree quite well
- absolute values depend on instrument sensitivity (& retrieval method)
- detection thresholds also affect average cloud opt. depth & T
- trend analysis difficult, synergy of data sets & variables important

netCDF data : a s h (e)

only averages

* most complete variables

Longterm cloud climatologies:

*ISCCP *GEWEX cloud dataset*	*1984-2007*	AMPM
PATMOS-x *AVHRR*	*1982-2007*	AMPM
*TOVS Path-B	*1987-1995*	7:30AM, 7:30 PM, AMPM
HIRS-NOAA	*1982-2008*	2:00AMPM, 8:00AMPM
SAGE *limb solar occultation*	*1984-2005*	*sunrise, sunset*
SOBS *Surface OBServations*	*1952-1996*	

EOS cloud climatologies:

MODIS-ST	*2001/3-2009*	10:30AM,10:30 PM, 1:30AM,1:30PM
MODIS-CE	*2001/3-2006*	10:30AM,10:30 PM, 1:30AM,1:30PM
*AIRS-LMD	*2003-2009*	1:30AM,1:30PM
MISR	*2001-2007*	10:30AM,10:30 PM

+ A-Train:

POLDER	*2006-2008*	1:30PM
CALIPSO / GOCCP	*2007-2008*	1:30AMPM

*ATSR-GRAPE	*ERS, 1997-2002 / ENV, 2003-2009*	10:30, 10:00 AMPM

3 kinds of measurements: Imagers, multi-spectral radiometers, IR sounders

complementary: MISR, POLDER, CALIPSO/GOCCP

Outliers?

For each data set:

- **state strength & limitations & suitable applications**

intercomparison :

- **make clear statements on the different cloud properties**

global averages : tables or figures?

latitudinal variability, histograms

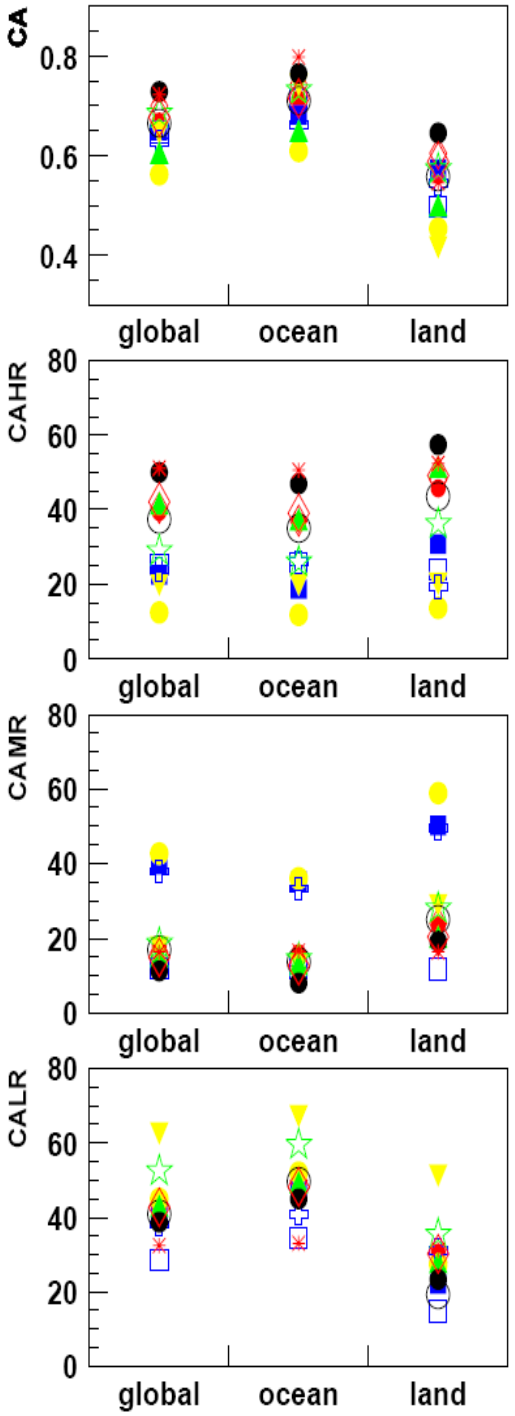
regional comparisons ***(cloud type transitions, dynamical regimes, polar regions)***

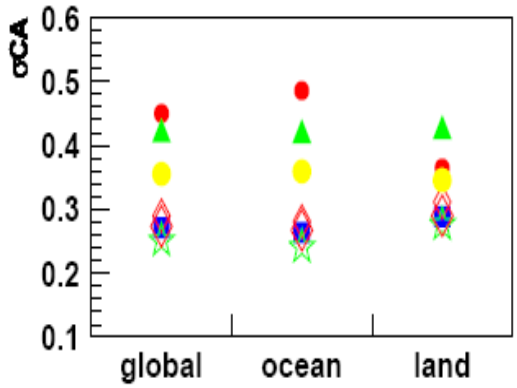
seasonal cycles

diurnal cycle

interannual variations

longterm anomalies





Average CA & monthly variability

retrieved cloud amount depends on:

sensitivity to thin cirrus & partially covered footprints

max CA : 75%, 5-15% ***more over ocean than over land***
(min CA: 57% POLDER, 60% MODIS-CE)

CAH, CAM & CAL scaled by CA: more useful for comparisons

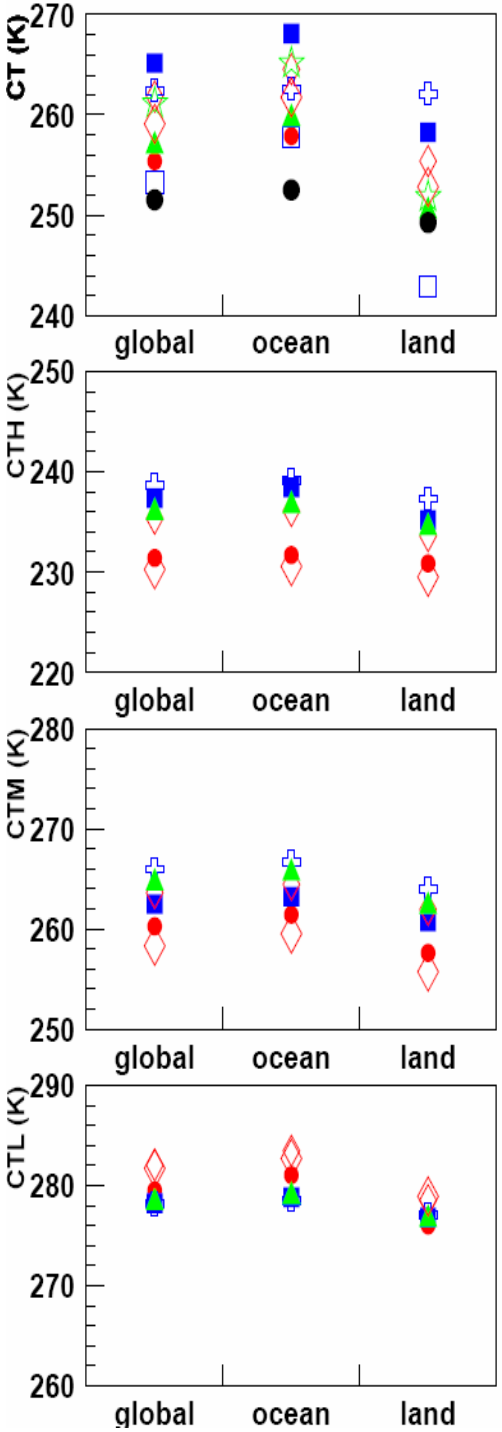
distribution of uppermost cloud layers:

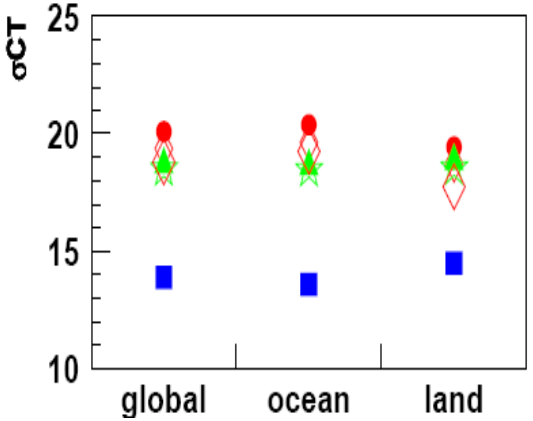
50% / 10% / 40% high / midlevel / lowlevel	**CALIPSO**
42.5% / 15% / 42.5%	**IR sounders, MODIS-CE**
30% / 15% / 55%	**MODIS-ST**
25% / 40% / 35%	**ISCCP, ATSR**

POLDER O_2 band cloud height << radiative cloud height

more high clouds over land / more low clouds over ocean

Average CT & monthly variability





T variability may indicate sensitivity:

TOVS/AIRS & MODIS similar, ISCCP lower

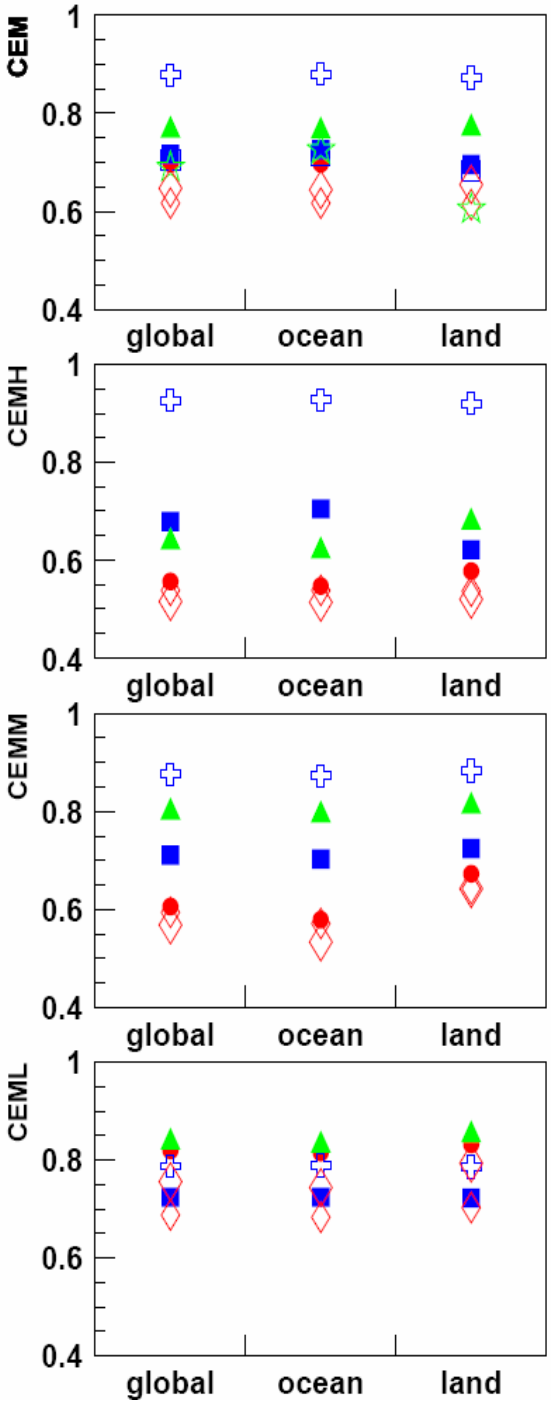
CALIPSO most sensitive to thin Ci => coldest T

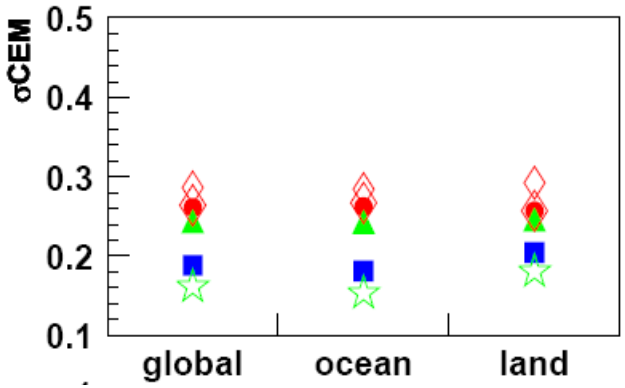
$$T_{CALIPSO} - T_{ISCCP} \cong 13\ K$$

larger spread for high clds than for low clds

(due to thin Ci sensitivity)

Average CEM & monthly variability





~0.7

monthly variability and average CEMH indicate again sensitivity to thin Ci

ATSR much too large!!

Average CA

ISCCPday(84-04) TOVS-B, TOVS rean(87-95) HIRS-NOAA(85-01) SAGE(85-99) CALIPSO(06-07) PATMOS-x(81-06) MODIS-CE(03-05) MODIS-ST(02-06) ISCCP-IR(84-04) SOBS(84-04)

CA (%)	glo bal											oce an												la nd										
all	66	73	70	75	95	76	66	61	67	61	64	70	74	74	77	95	84	72	66	73	65	69		58	69	61	70	97	63	50	50	59	51	54
Thick Ci	3	2	1	2								3	2	1	1									3	4	2	5							
Cirrus	19	27	31	31								18	27	31	33									21	27	30	29							
HCA/ CA	33	41	45	44	44	50	38	42	30	21	23	30	39	42	44	44	46	35	37	27	18	17		41	45	53	49	45	61	47	56	37	29	43
MCA / CA	27	16	14	16	20	14	19	16	19	33	44	26	14	12	14	18	12	17	14	15	29	42		31	25	20	17	25	20	25	20	29	43	48
LCA / CA	39	42	37	37	36	35	44	44	52	46	72	41	47	42	42	38	42	49	51	59	52	80		29	30	23	34	29	19	29	26	34	27	48

diurnal sampling, time period for ISCCP / TOVS-B: 1% effect; low-level over land: 2% (Stubenrauch et al. 2006)

~ 70 % (±5%) cloud amount: 5-15% *more over ocean than over land*

PATMOS, MODIS-CE low (land), SAGE CA (200km, clds τ>0.03) **1/3 higher**

40% single-layer low clouds: *more over ocean than over land; SOBS*

40% high clouds: *only 3% thick Ci; more over land than over ocean*

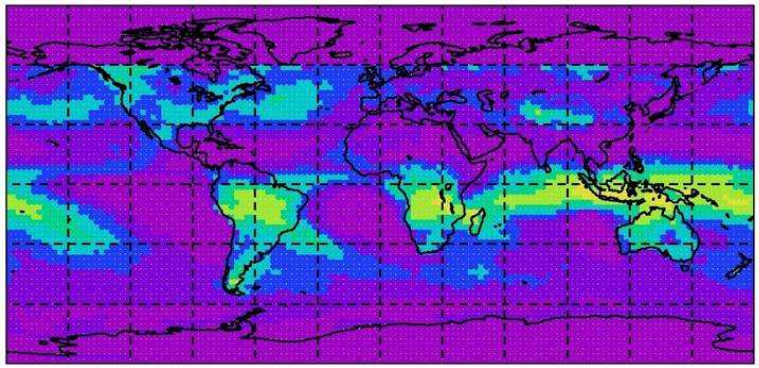
IR sounders ~ 10% more sensitive to Ci than ISCCP (15% in trps)

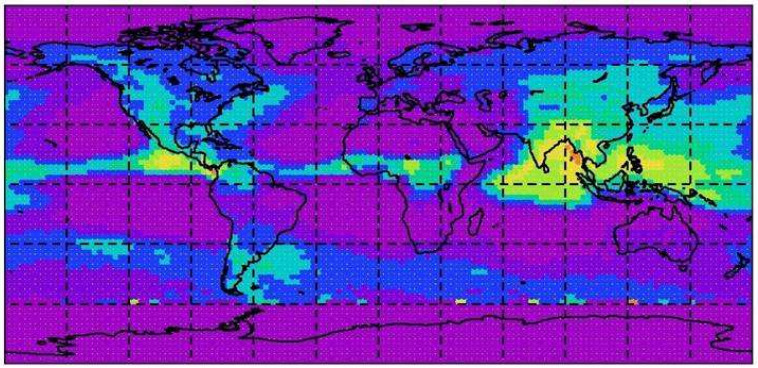
SAGE cloud vertical structure in good agreement with IR sounders

HCA/CA: CALIPSO>SAGE,TOVS/HIRS > MODIS-CE > PATMOS > ISCCP$_{day}$ > MODIS > ISCCP$_{IR}$

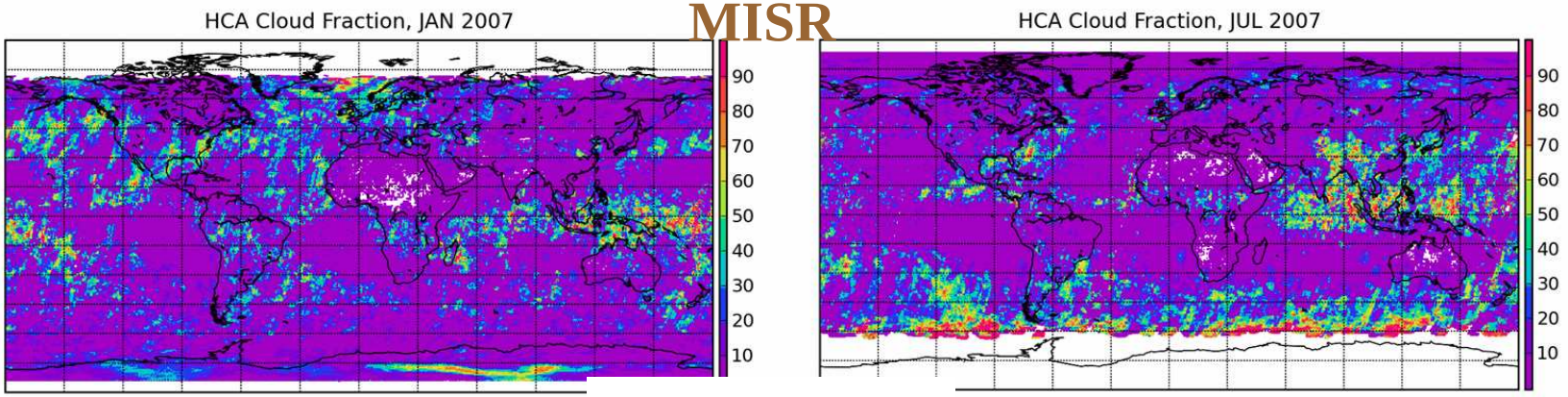
HCA geographical distributions

January **ISCCP** *July*





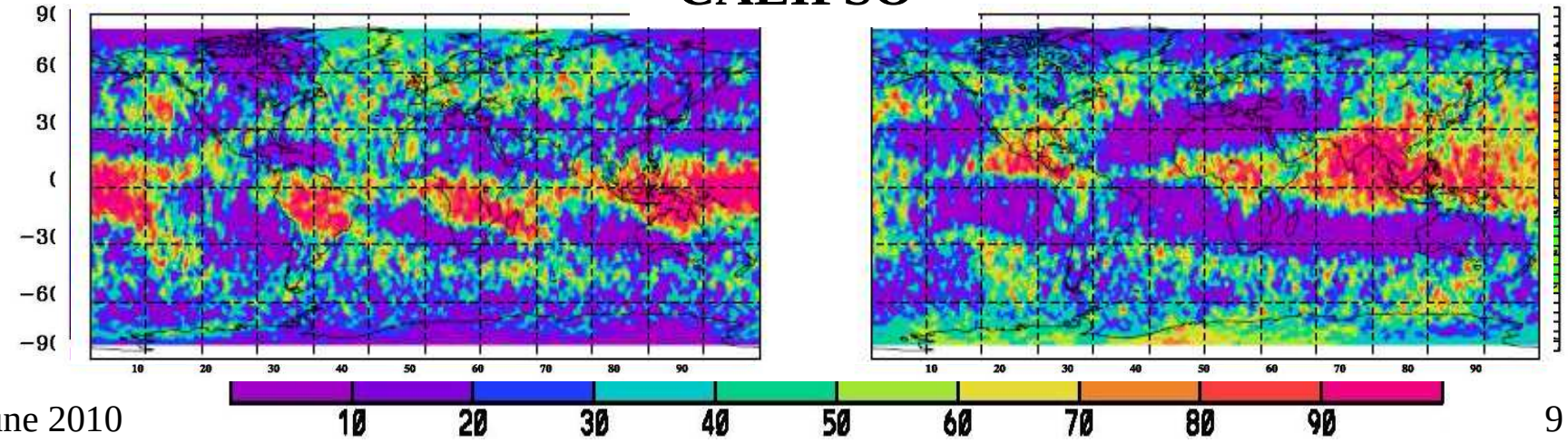
MISR



winter
strom tr

ITCZ

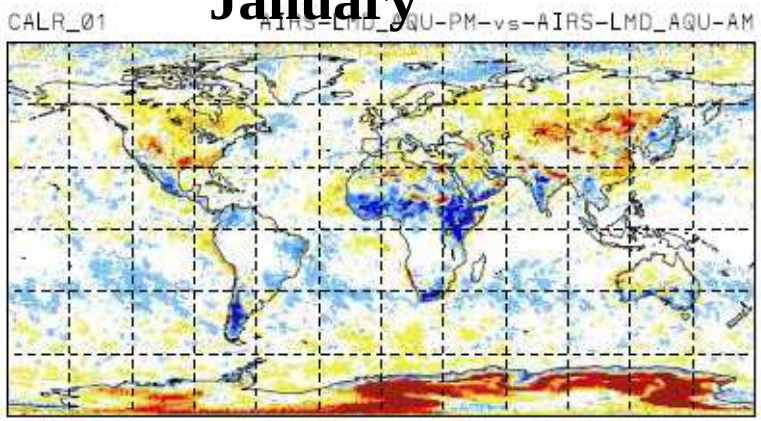
CALIPSO

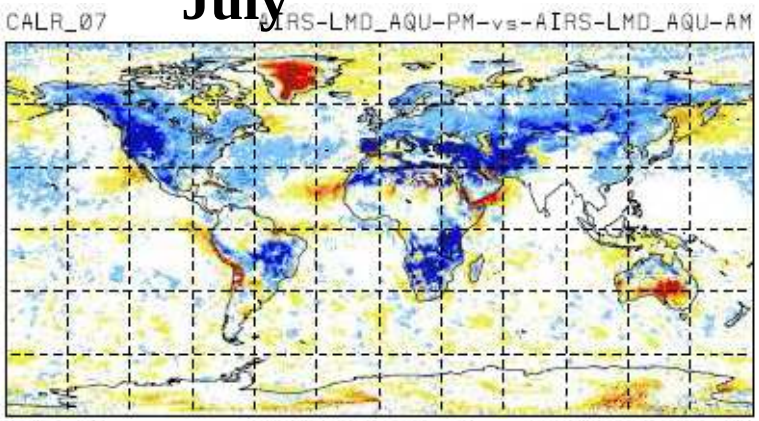


Difference in low clouds between 1h30PM and 1h30AM

January

July

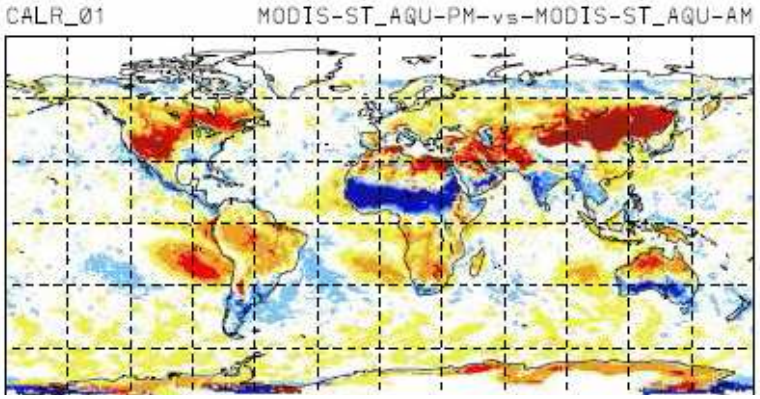


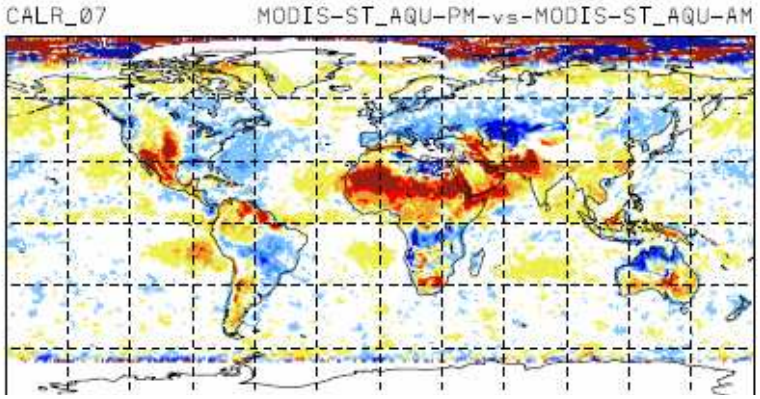


AIRS-LMD

max over land in early afternoon

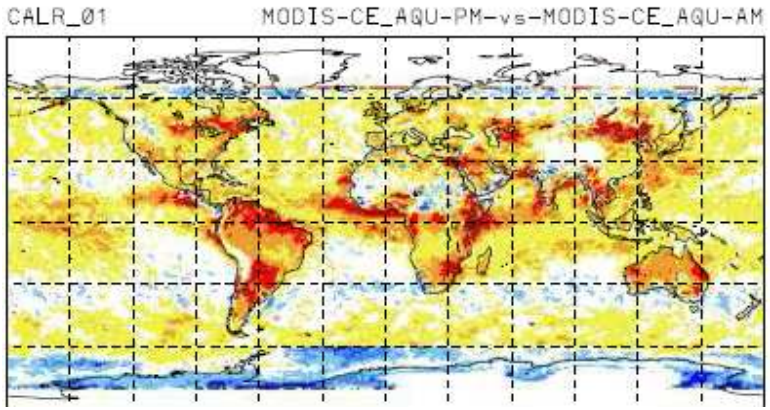
only in winter !

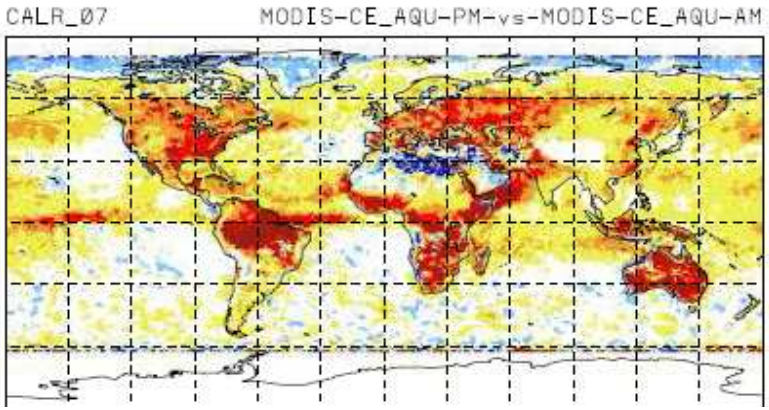




MODIS-ST

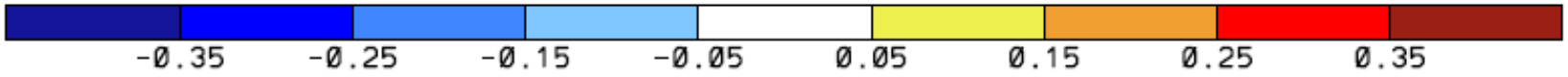
similar to AIRS over land



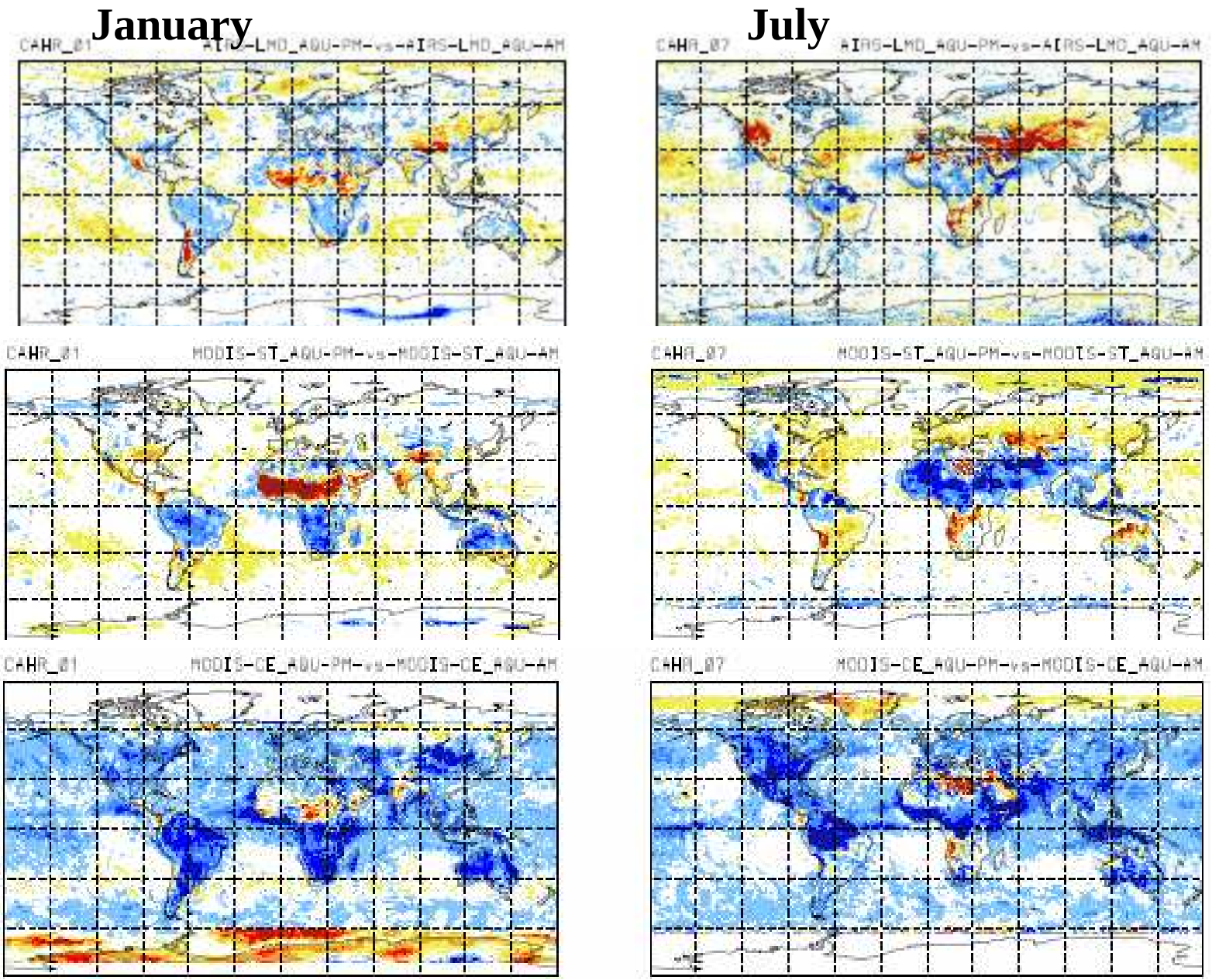


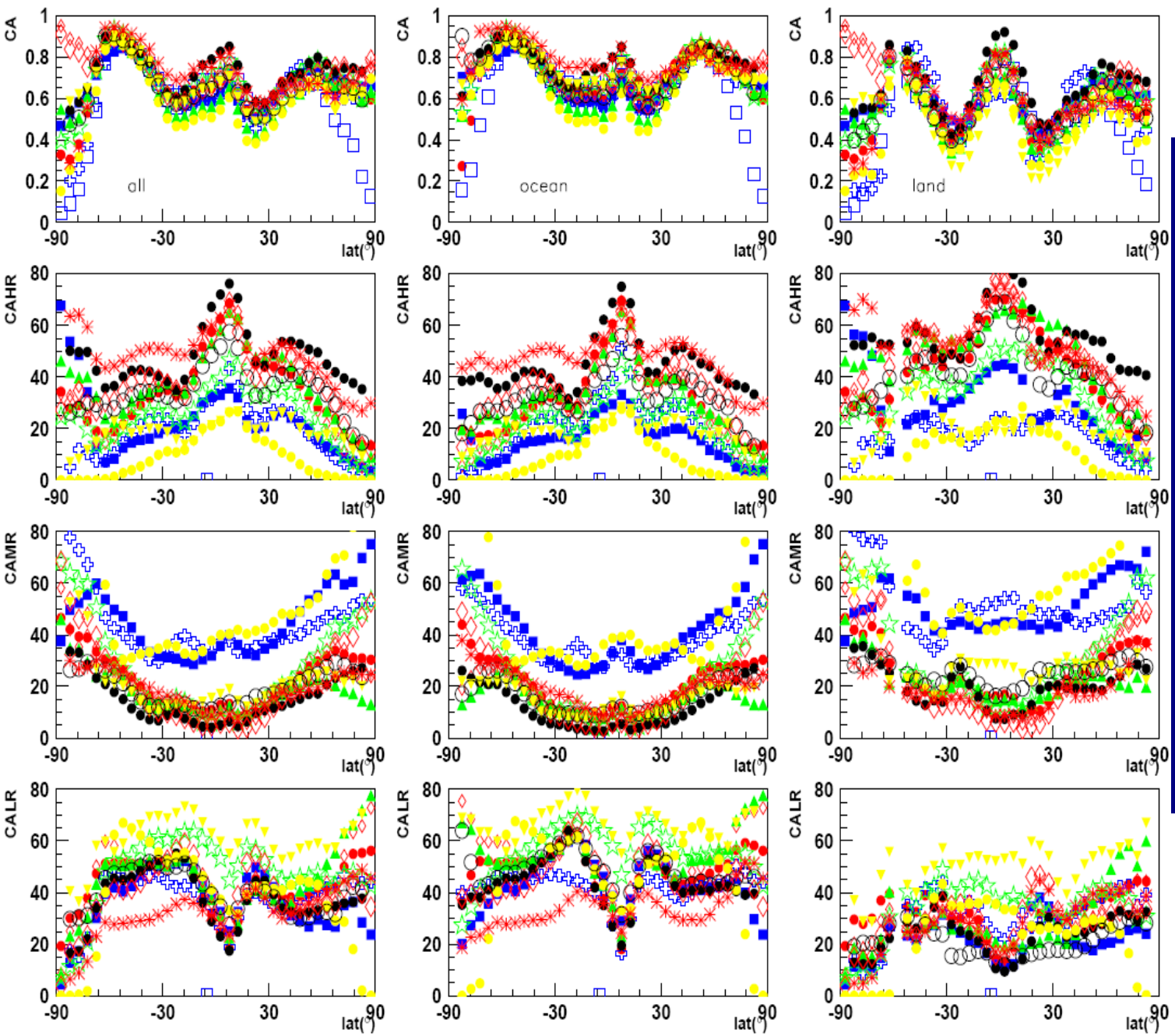
MODIS-CE

difference probably linked to VIS channel during day (PM)



Difference in high clouds between 1h30PM and 1h30AM





latitudinal structure similar
(except SH polar)

- **peak of high clds in tropics**
- **more high clds in NH**
- **more low clds in SH**
- **min of midlevel clds in tropics**
- **peak of low clds in subsidence over ocean**

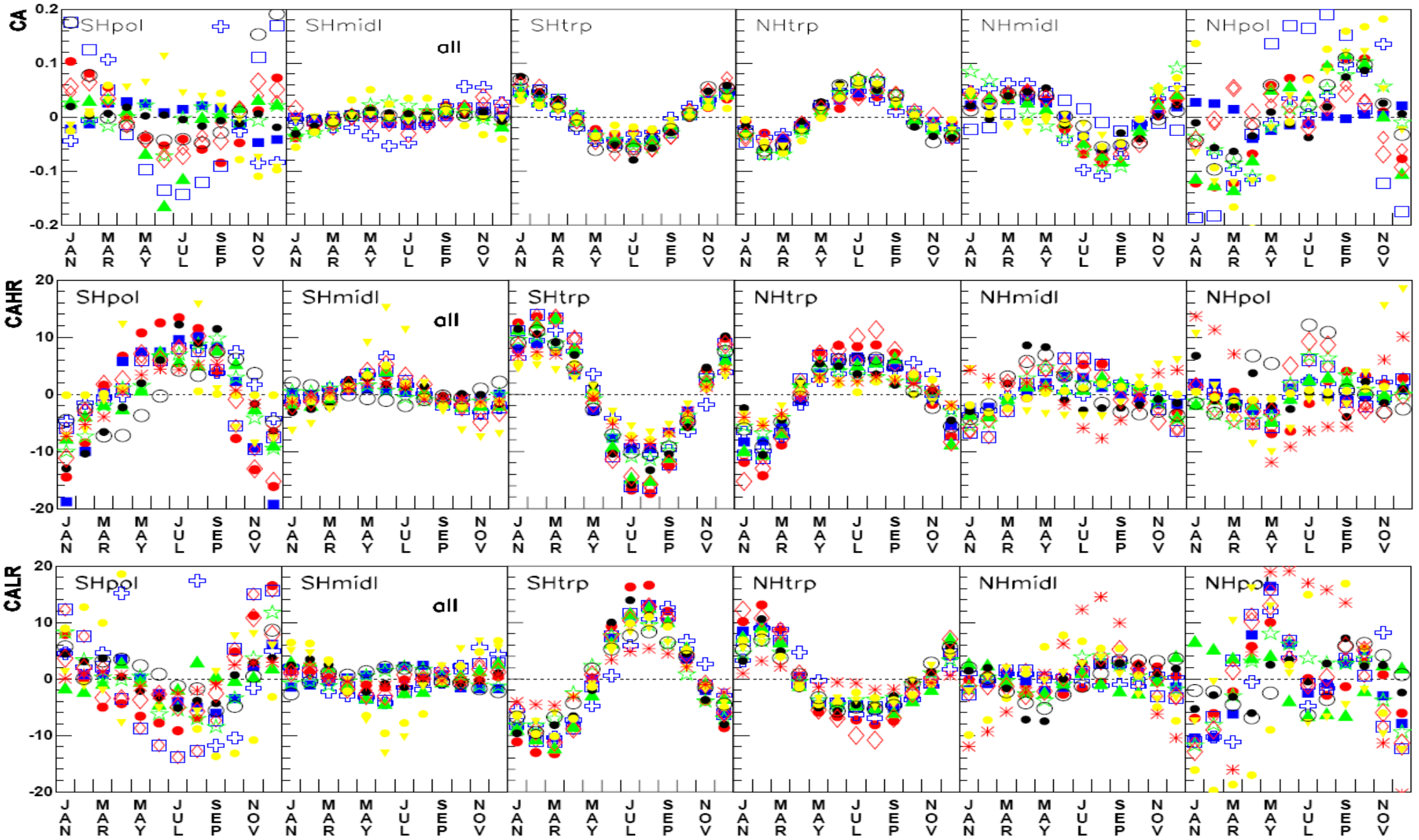
IR sounder close to CALIPSO

HIRS pb over ocean

ISCCP, ATSR: thin cirrus misidentified as midlevel clds

MODIS-ST: thin cirrus misidentified as low clds

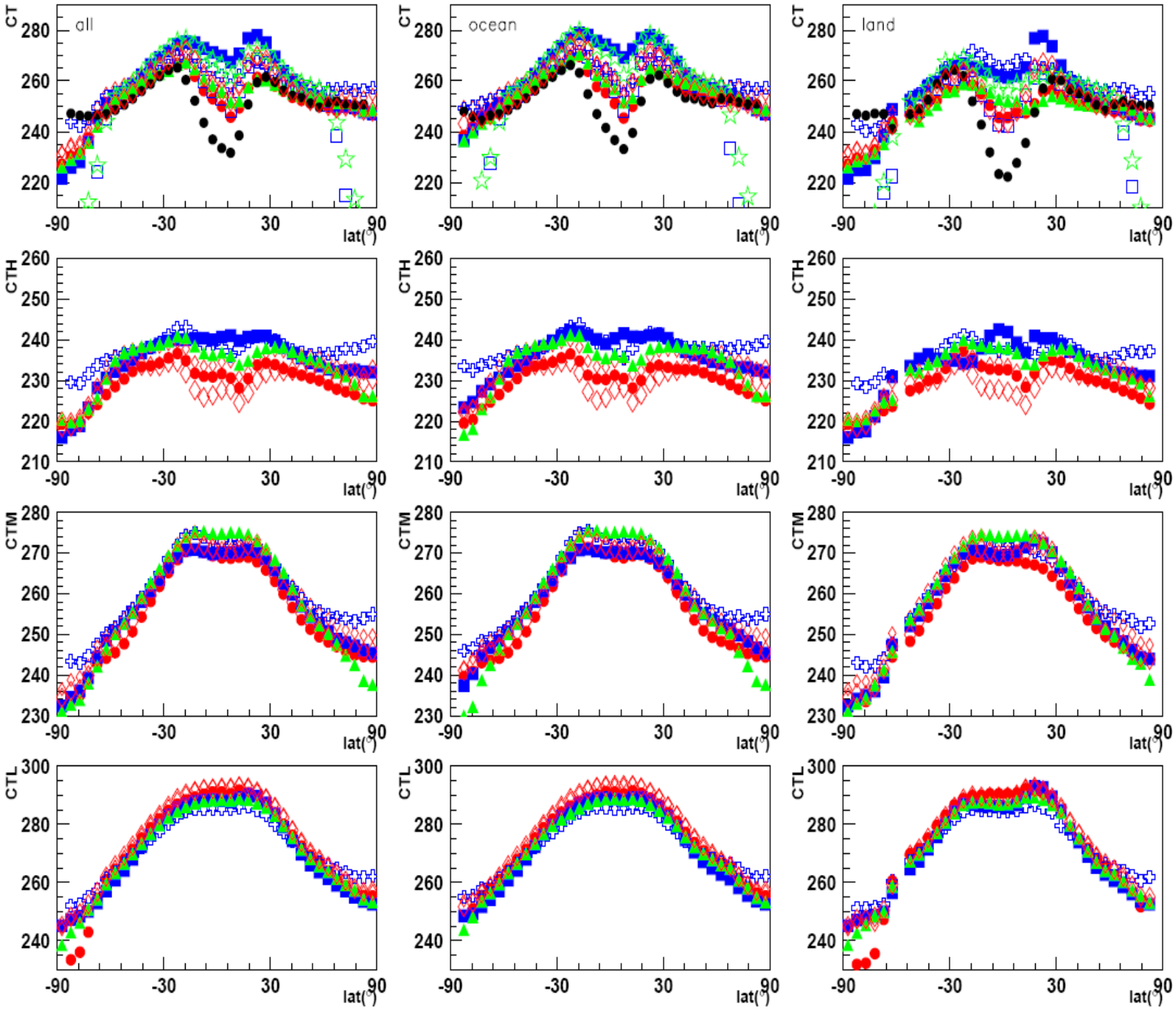
Seasonal cycle of *CA*



seasonal cycles agree quite well (*except polar latitudes & NH land*): largest in 0-30S, smallest in 30S-60S

AIRS-LMD *MODIS-CE* *MISR* *TOVS* *MODIS-ST* *POLDER* *GOCCP* *ISCCP* *ATSR* *CALIPSO* *PATMOSX* *HIRS*

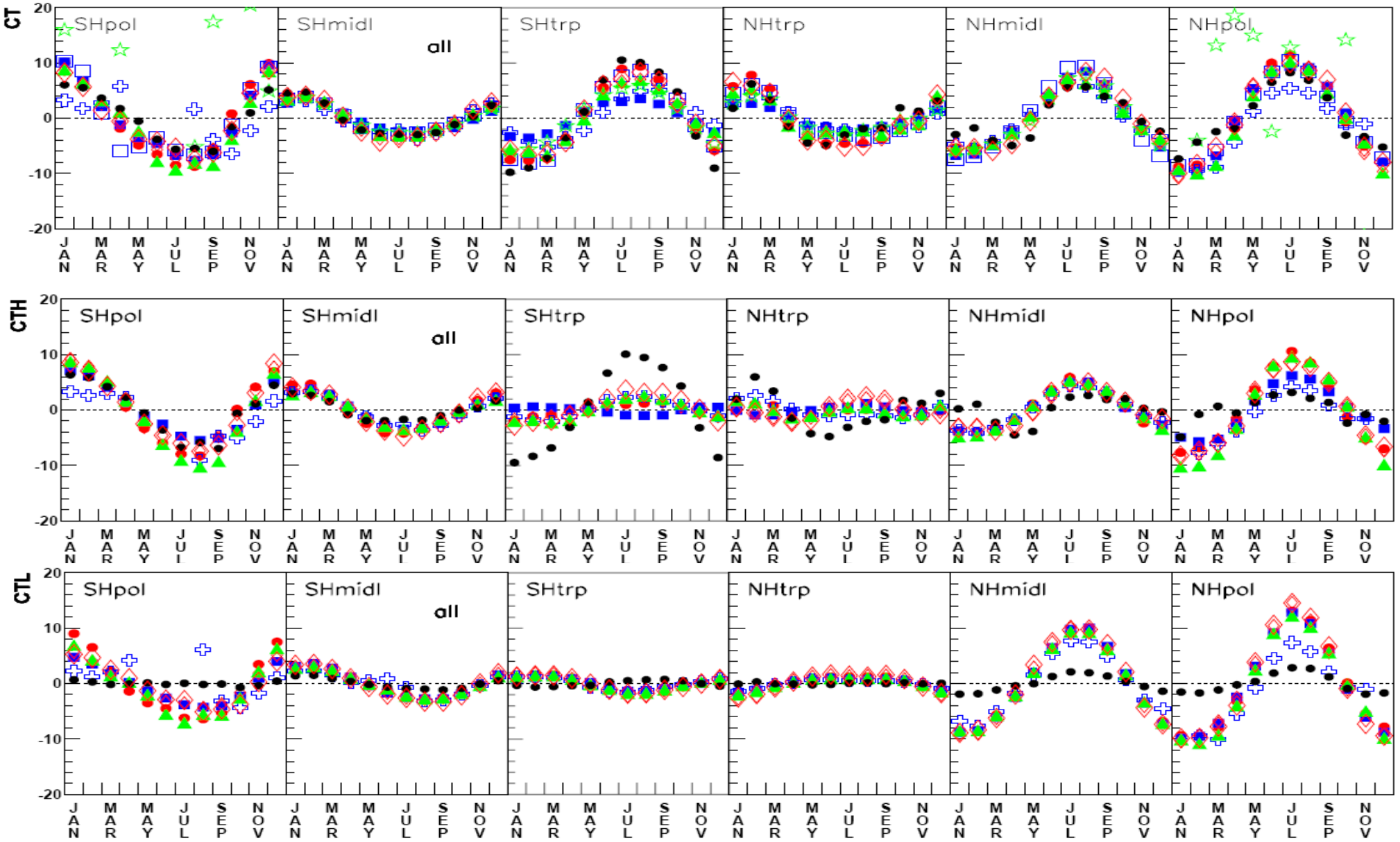
Latitudinal behaviour of CT



latitudinal structure similar
(except SH polar)

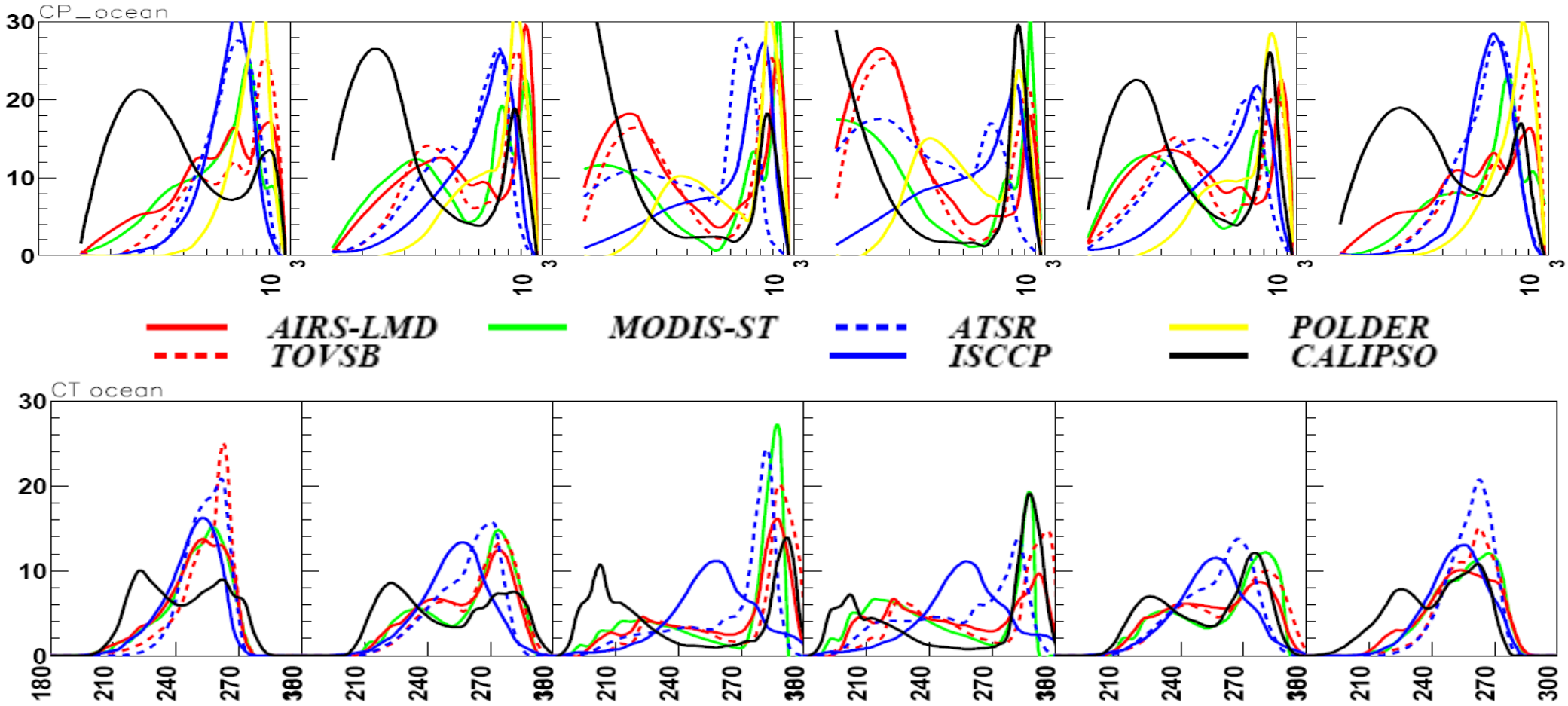
- **largest difference in tropics**
  (linked to thin Ci)
- **stronger latitudinal dependence for low clouds than for high clouds**
- **spread larger for high clouds than for low clouds**
  (high clouds more diffuse)

Seasonal cycle of CT



CT seasonal amplitude 20K; CTH/CTL seasonal cycle increases from tropics towards poles; ***pb CALIPSO?***

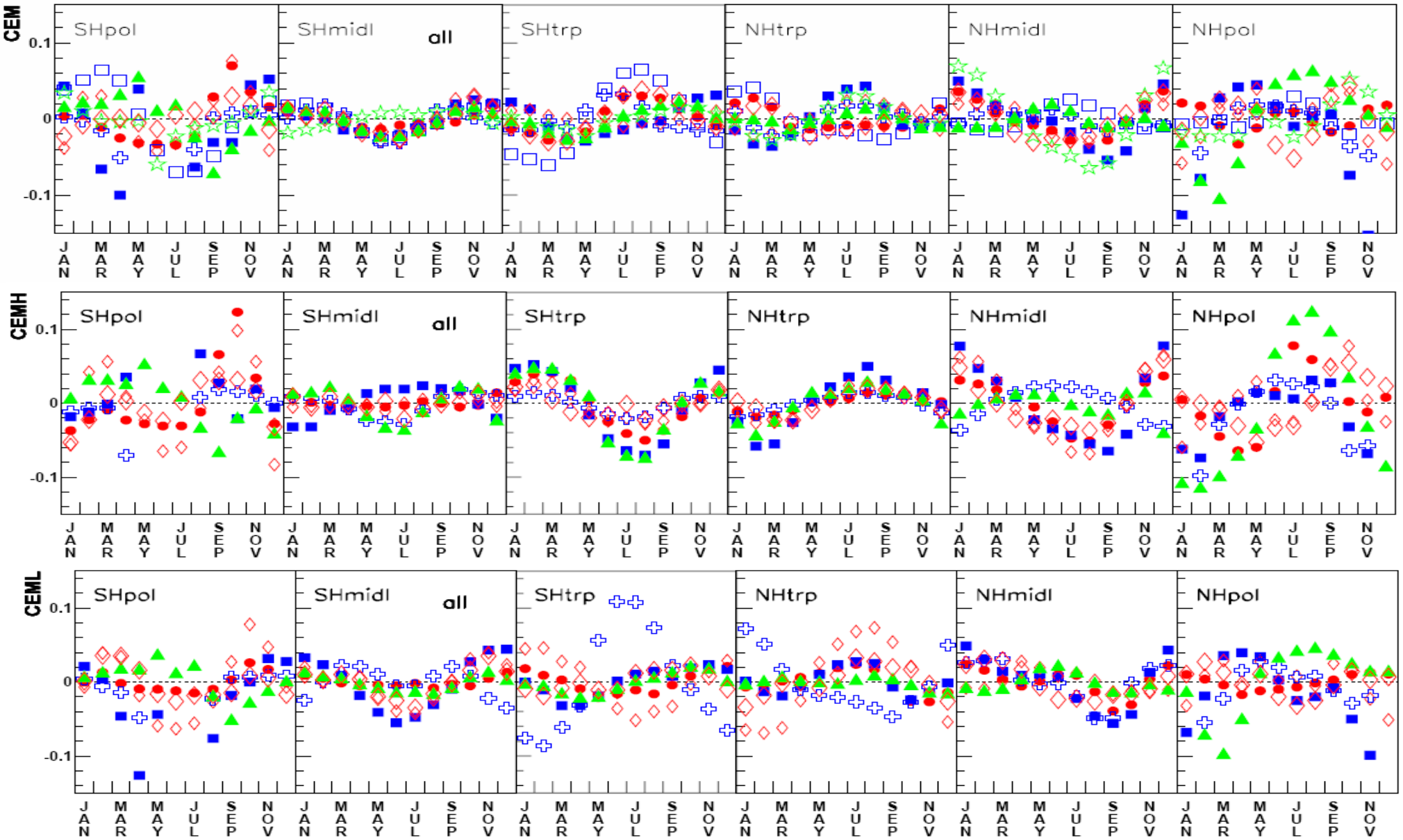
Distributions of CP & CT in latitude bands



CALIPSO: highest cloud layer (no subvisible clouds, det. 5km)

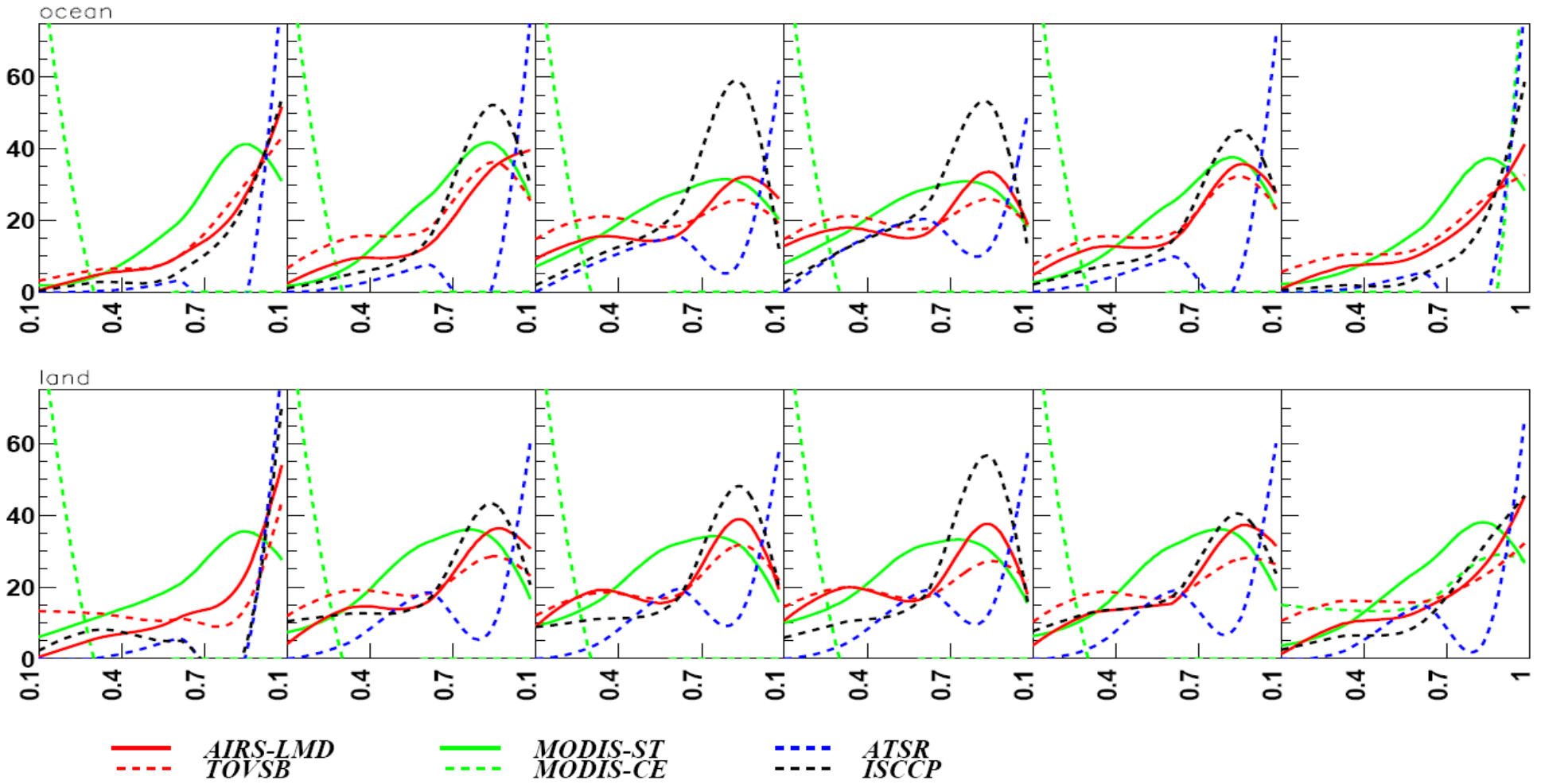
largest CT spread in tropics, spread largest with CALIPSO, ISCCP misplaces thin Ci at midlevel

Seasonal cycle of CEM



Small seasonal cycle; AIRS & ISCCP seasonal cycle in NH midlatitudes agree well! MODIS-CE, ATSR diff. no agreement in polar latitudes

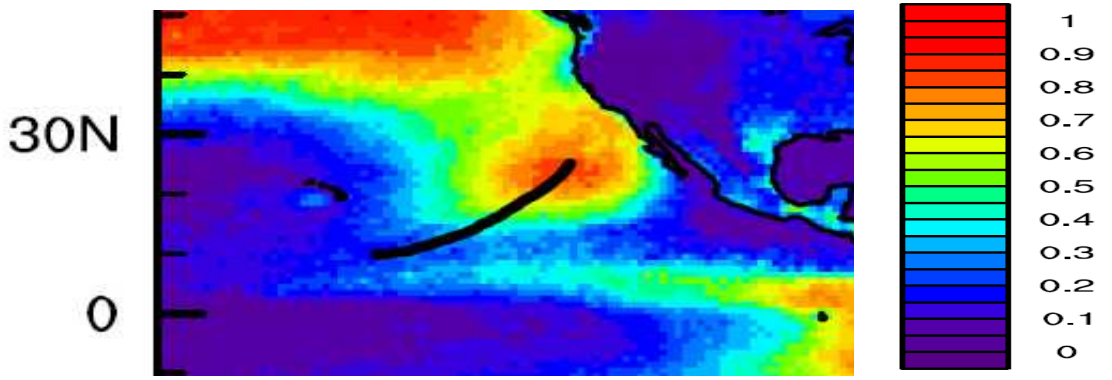
Distributions of CEM in latitude bands



Pacific Cross-section Intercomparison of GEWEX Cloud System Study
stratocumulus-> shallow cumulus

Analysis by Irina Sandu, MPI-M

MODIS CALW

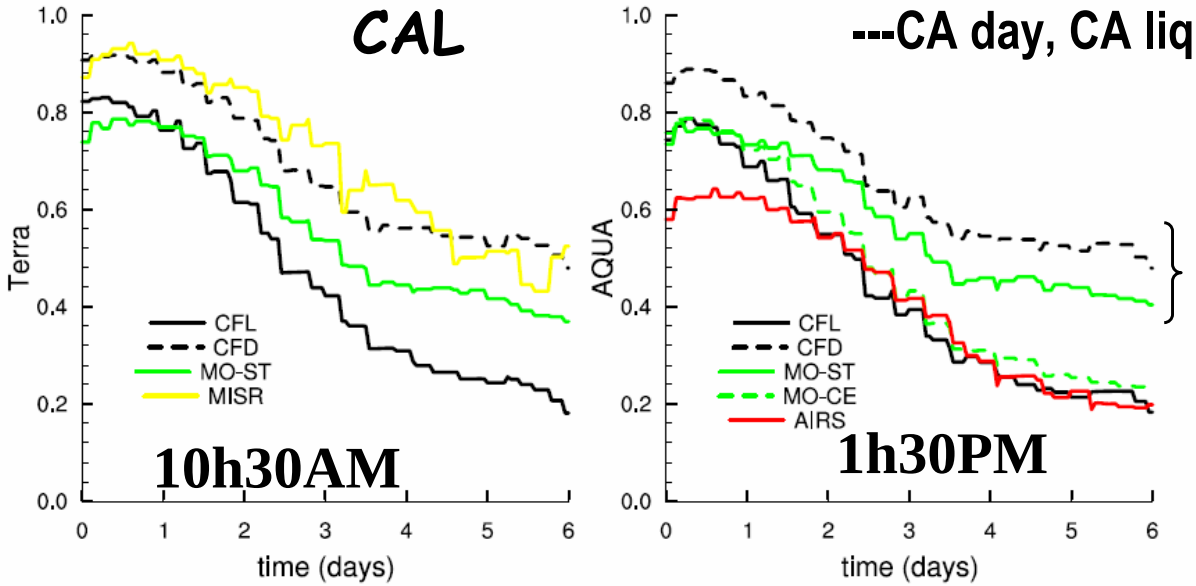


Trajectory analysis JJA 2006

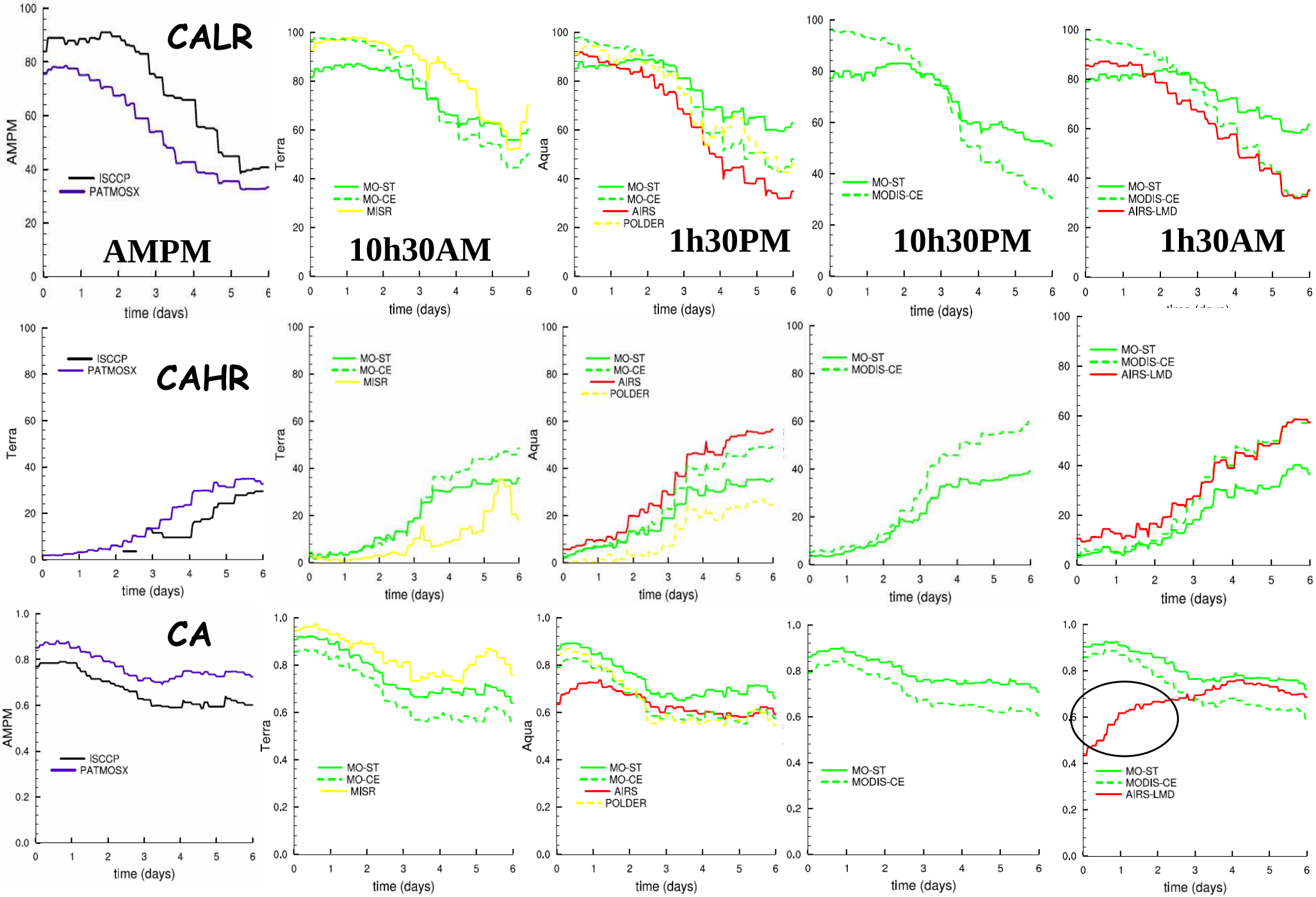
method decribed in (*Sandu et al. ACP 2009)*

MODIS-ST:

---CA day, CA liquid, GEWEX netcdf



should be identical !!!


CALR
AMPM
10h30AM
1h30PM
10h30PM
1h30AM
CAHR
CA
AMPM
Terra
Aqua
time (days)
ISCCP
PATMOSX
MO-ST
MO-CE
MISR
AIRS
POLDER
MODIS-CE
AIRS-LMD

Satellite observations:

❖ unique possibility to study cloud properties over long period
-> climatological values of CA, HCA, MCA & LCA
(also variabilities, T_{cld}, ε, τ, D_{eff}, WP) to help evaluate climate models

❖70% (±5%) clouds: ~ 40% high clouds & ~40% single-layer low clouds

❖**in general geographical cloud structures agree quite well:**
max of high clouds in ITCZ (up to 60%),
few single-layer midlevel clouds in tropics (5%), most in NH midlat winter (15%)
low clouds over ocean: seasonal cycle in Stratocum regions in good agreement

❖Seasonal cycle of LCA from SOBS smaller and abs value 20% higher
-> multilevel clouds

❖**CALIPSO L2 analysis confirms:**
IR sounders are the passive instruments most sensitive to cirrus
They only miss 10%/5% subvisible cirrus in tropics/midlat
(These are caught by limbsounding SAGE & active CALIPSO)

ISCCP miss 15%/10% in tropics/midlat compared to IR sounder, (included in MCA)

❖ **diurnal cycle**: well determined by ISCCP (midlevel clds –cirrus -> TOVS)

Be careful of systematic biases in diurnal differences

monthly mean values depend mainly on sensitivities distributions

Uncertainties: only provided by TOVSB, AIRS-LMD

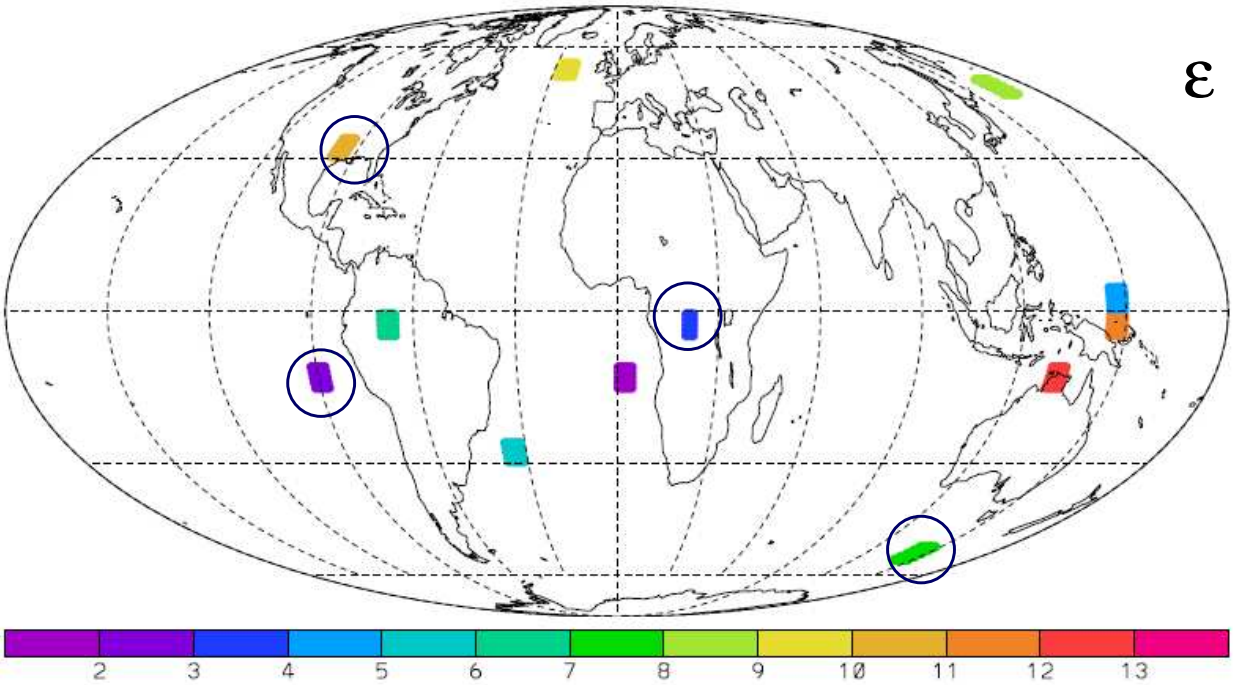
Histograms should be provided by all participating data sets

what to do with outliers?

specific regions

Rossow et al. J. Clim. 2002

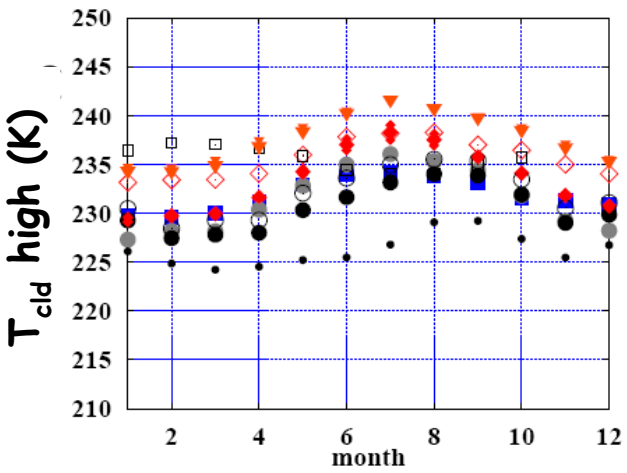
$\varepsilon = 1 - \langle\tau(\text{rad})\rangle / \langle\tau(\text{lin})\rangle$

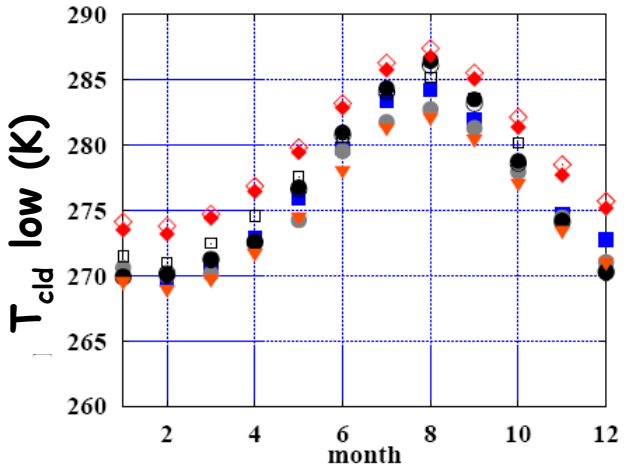


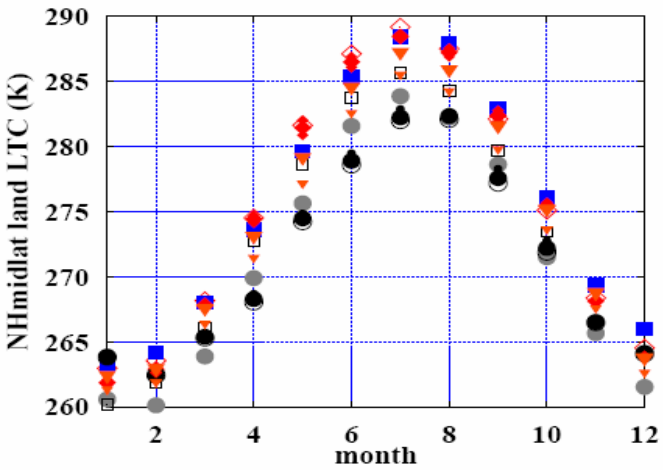
Cloudy regions grouped by magnitude of small-scale variations

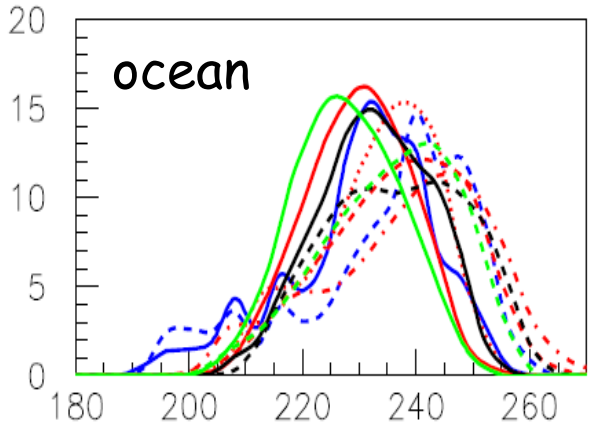
marine boundary layer:	(1,2)	**A**	peak(ε)= 0.05
ocean storm tracks:	(7,8,9)	**B**	peak(ε)= 0.10
tropical cirrus:	(5,6)	**B,C**	
active trop. convection:	(3,4)	**C**	peak(ε)= 0.25
midlatitude land:	(10)	**C**	peak(ε)= 0.25

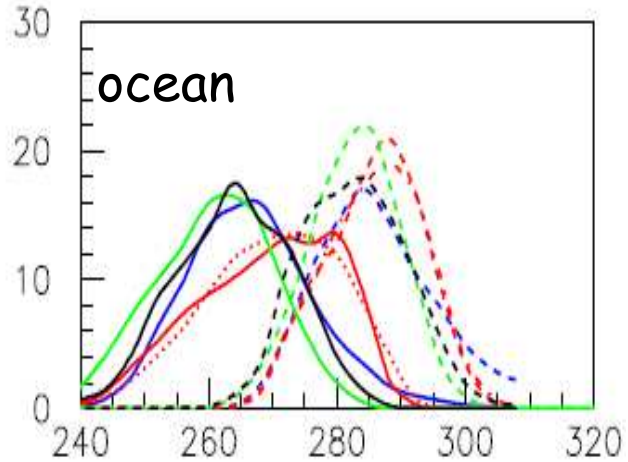
T_{cld} in NH midlatitudes

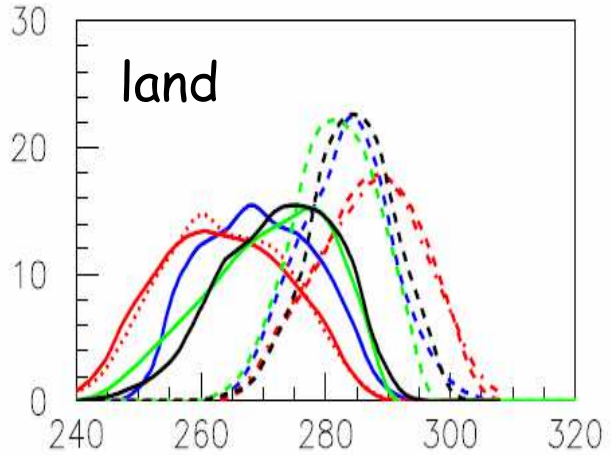












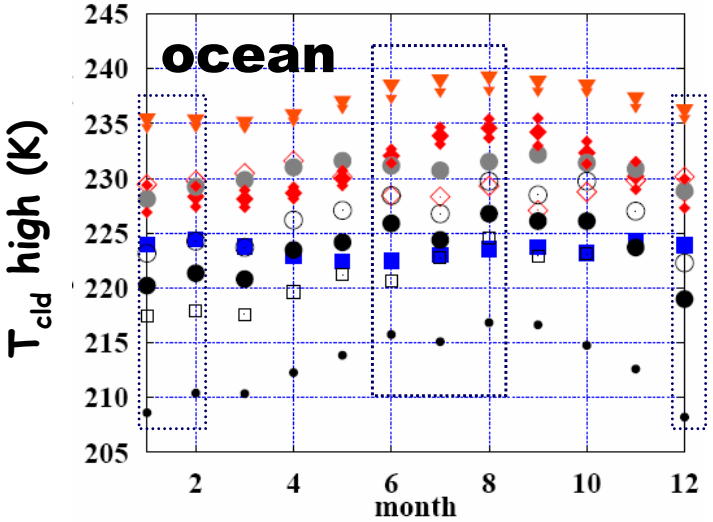
ISCCP CALIPSO TOVS AIRS —— **winter** - - - - **summer**

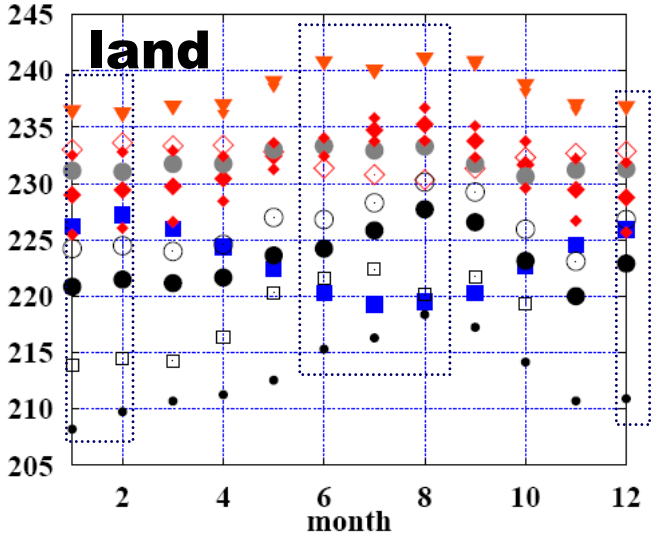
high clouds over ocean: agreement within 5 K
low clouds: seasonal cycle larger over land than over ocean, narrowest distribution in sum over land

Tropical high clouds: T_{cld} distributions

SH

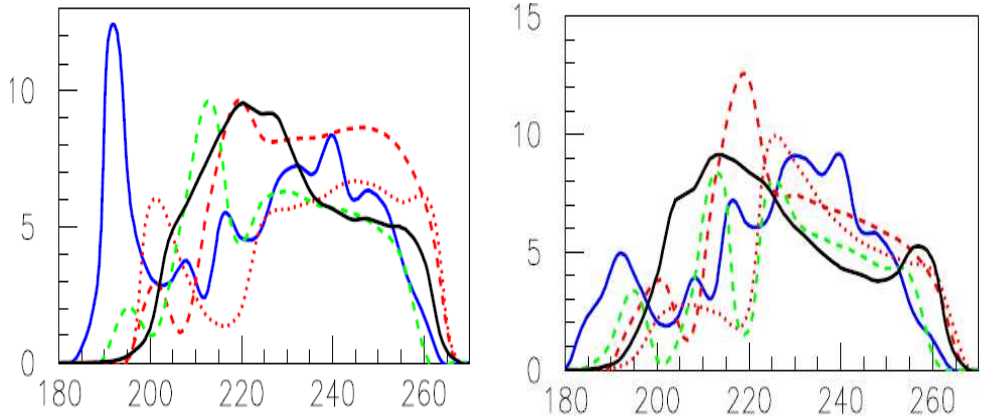
0°-30°





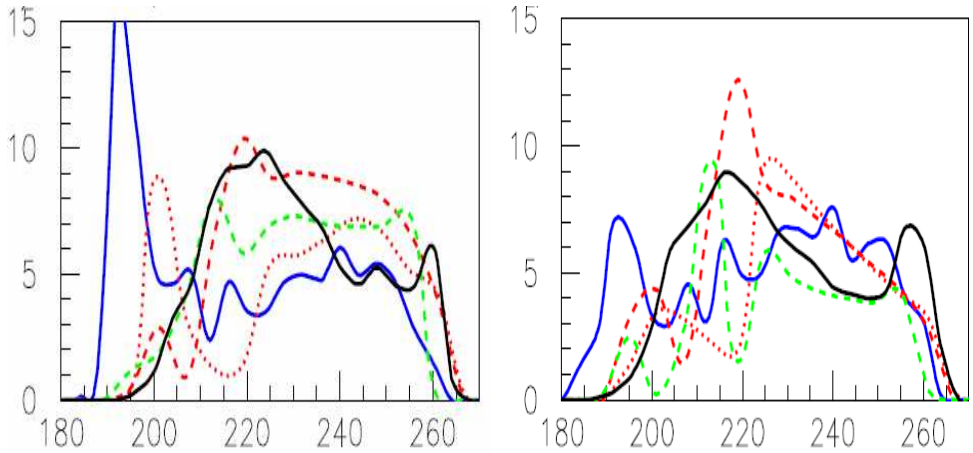
TOVS-B
ISCCP
PATMOSX
MODIS-CE
AIRS
CALIPSO:
all
τ>0.1
τ>0.2

ISCCP CALIPSO TOVS AIRS



boreal summer

boreal winter



T_{cld} distribution shape differences