Assessment of Global Cloud Climatologies

project of GEWEX Radiation Panel / WCRP

cloud properties & their variation

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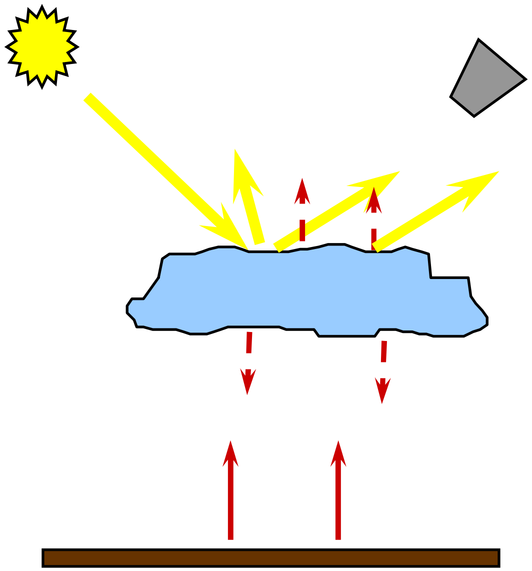
GEWEX cloud assessment group

Satellite radiometers measure:



emitted, reflected, scattered
radiation

INVERSION

cloud detection
inverse radiative transfer

cloud properties

GEO (3hrs) *+polar* | *polar satellites* (12/6 hrs)

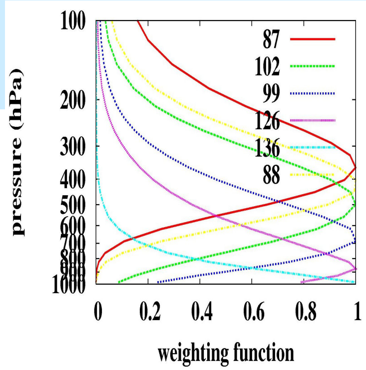
ISCCP — *IR, VIS*

PATMOS-x — *IR, NIR, VIS*

HIRS-NOAA, TOVS Path-B — *IR Vertical Sounder: CO_2-band*

MODIS

AIRS



Longterm cloud climatologies:

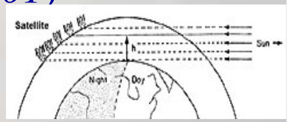
ISCCP *GEWEX cloud dataset* ***1983-2006*** *(Rossow et al. 1999)*

PATMOS-x ***AVHRR*** ***1981-2006*** *(NESDIS/ORA; Heidinger et al.)*

HIRS-NOAA ***13h30/1h30*** ***1985-2001*** *(Wylie et al. 2005)*

TOVS Path-B ***7h30/19h30*** ***1987-1995*** *(Stubenrauch et al. 2006)*

SAGE ***limb solar occultation*** ***1984-1991,1993-2005*** *(Wang et al. 1996, 2001)*



SOBS (Surface Observations): ***1952-1996(sea), 1971-1996(land)*** *(Hahn & Warren 1999; 2003)*

EOS cloud climatologies *(since 2000, 2002)*:

MODIS-ST *(Ackerman et al.)* **MODIS-CE** *(Minnis et al.)*

AIRS-LMD *(Stubenrauch et al. 2008)*

+ A-Train *(since 2006)*:

CALIPSO L2 data (V2) *(Winker et al. 2007)* ***active lidar***

CloudSat *(Mace)* **POLDER** *(Riedi)* **MISR** *(DiGirolamo* **ATSR2** *(Poulsen)*

Global Energy and Water Cycle Experiment GEWEX WCRP

Cloud Assessment

co-chairs:
C. Stubenrauch, S. Kinne

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

ISCCP *(Rossow & Schiffer BAMS, 1999)*

Evaluation

night: +75 hPa p_{cld} bias *(Stubenrauch et al. 1999)*

uncertainties depend on cloud type:

- ***Stratus (τ_{cld}>5):*** p_{cld} 25-50 hPa within radiosonde meas., ~ -65 hPa bias; err T_{cld}<1.5 K
- ***high clouds (τ_{cld}>5, with diffuse top):*** p_{cld} 150 hPa (trp)/ 50 hPa (midl) above top
- ***isolated thin Cirrus:*** difficult to detect
- ***thin Cirrus above low clouds:*** often identified as midlevel or lowlevel cloud
- 15% τ_{cld} decrease for doubling droplet size

TOVS Path-B *(Stubenrauch et al. J. Clim. 2006)*

p_{cld} uncertainty 25 hPa over ocean, 40 hPa over land (2nd χ^2 solution)

p_{cld} = mid-cloud p_{cld}: 600m/ 2 km below cloud-top (low/high clouds) (LITE, *Stubenrauch et al. 2005*)

Sensitivity study for D_e of Ci *(Rädel et al. 2003)*

HIRS-NOAA *(Wylie & Menzel J. Clim. 1999, Wylie et al. J. Clim. 2005)*

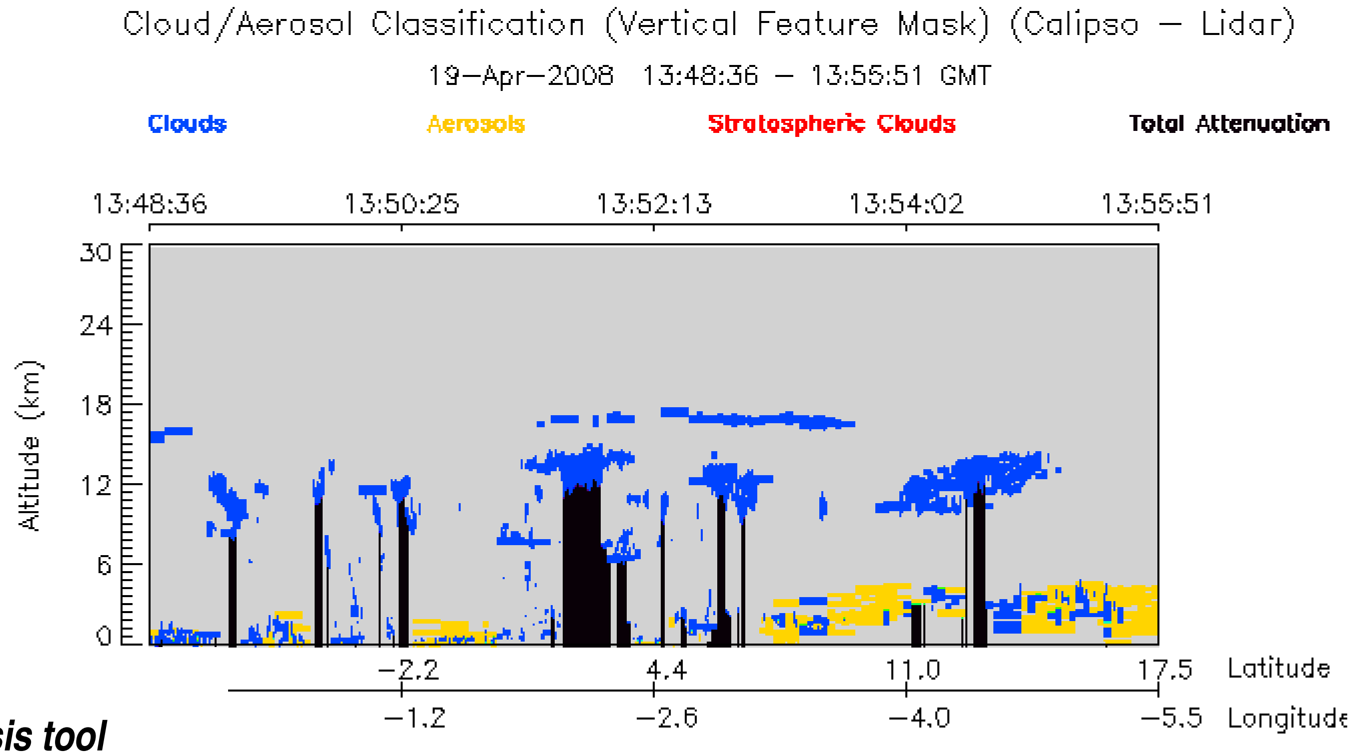
p_{cld} 70 hPa above top (lidar, *Wylie & Menzel 1989*)

100 hPa above for transmissive cloud overlying opaque cloud *(Menzel et al. 1992)*

z 0.4 – 4km lower than top (GLAS, Wylie et al. 2007)

A-Train: synergy of passive and active instruments

active instruments -> vertical structure of clouds
lidar sensitive to very thin cirrus



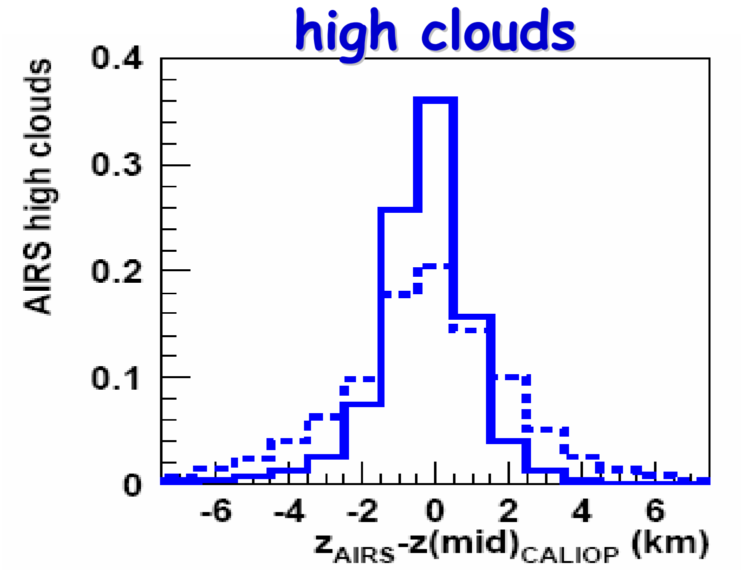
NASA Giovanni:
online data visualization & analysis tool

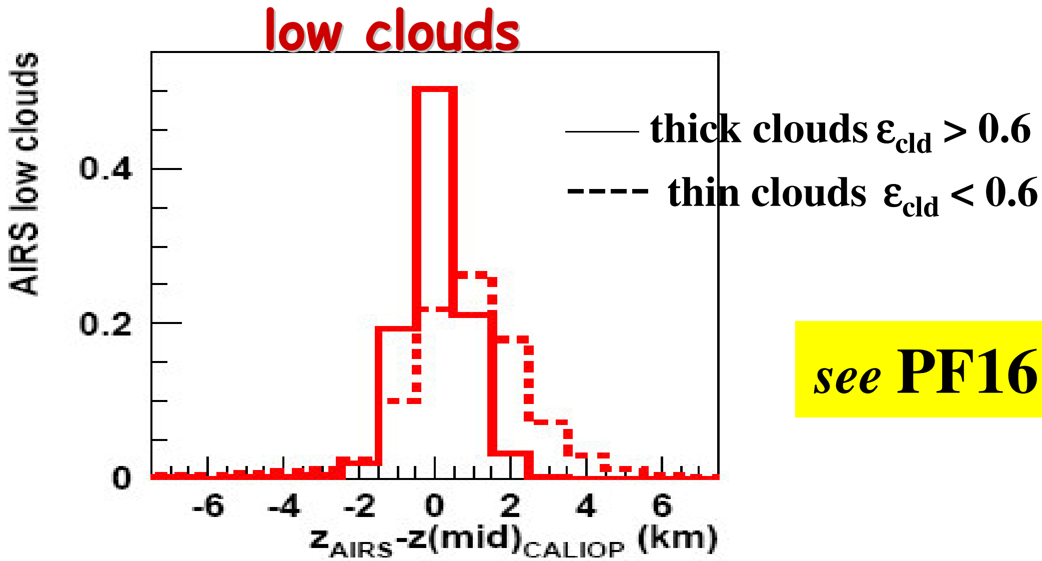
http://disc.sci.gsfc.nasa.gov/techlab/giovanni

Evaluation of AIRS-LMD cloud height with 1 year collocated CALIPSO data

retrieval based on weighted χ^2 method as in TOVS-B

Stubenrauch et al., JGR 2008





***see* PF16**

good agreement with CALIPSO midlevel of cloud *(highest with τ>0.1)*
slightly broader distributions for optically thinner clouds, but no bias
sampling: *(5 km x 0.07 km) in (13.5 km x 13.5 km)*

Δz_{mid}(AIRS-CALIPSO) ± 1.5 km:

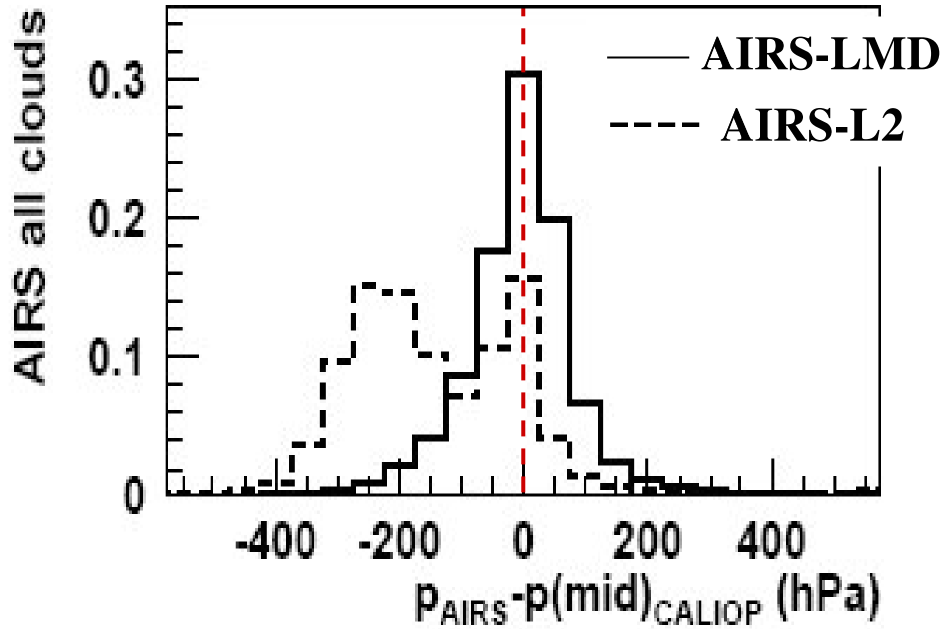
High:	**51%**	**55%**	**66%**
Low:	**70%**	**74%**	**80%**
	hghst	*/ hghst w τ>0.1*	*/ closest layer*

Δp_{mid}(AIRS-CALIPSO) ± 75 hPa:

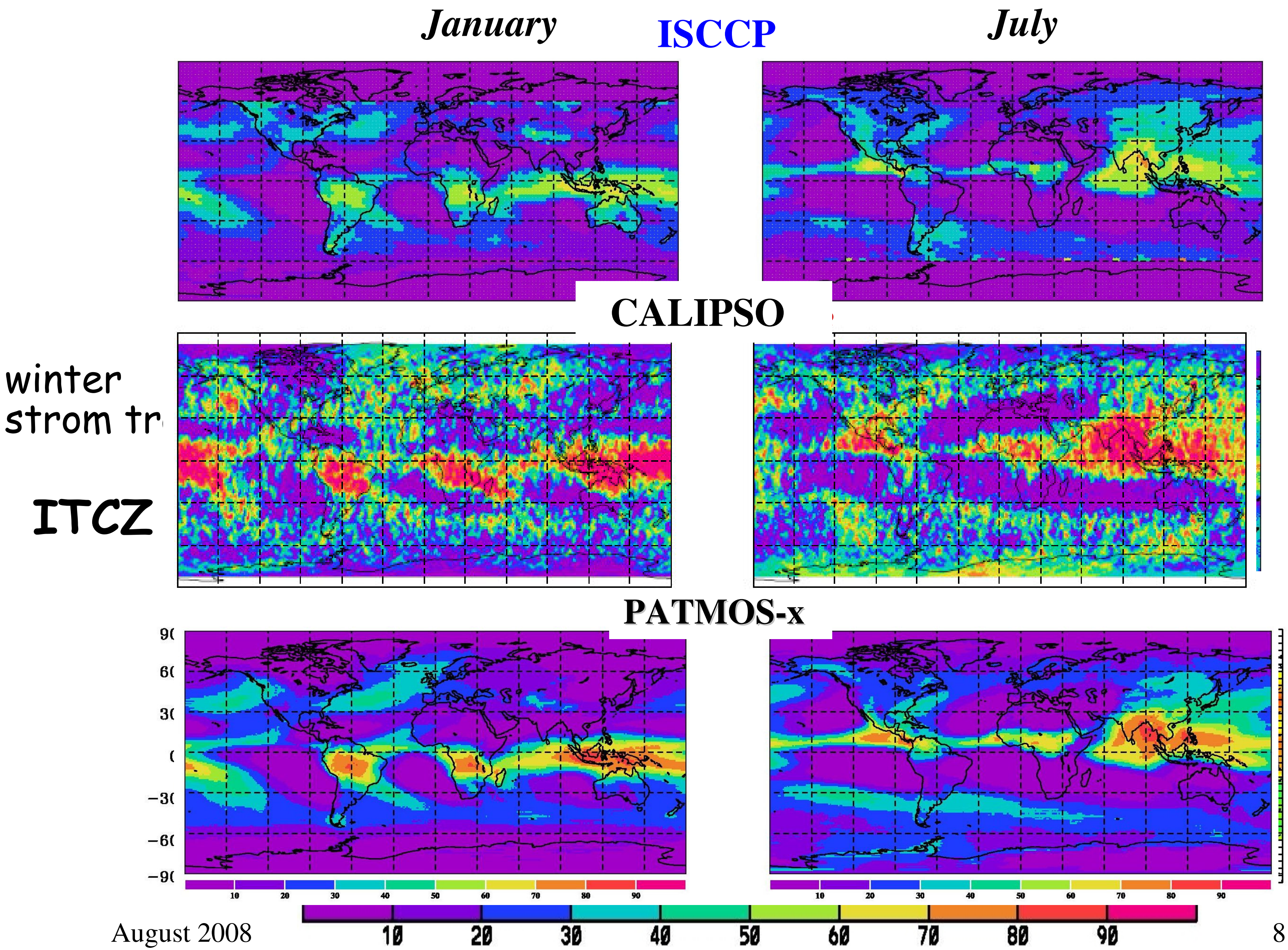
High:	**72%**	**81% (thick); 63% (thin)**
Low:	**59%**	**69% ; 38%**

Cloud properties depend also on retrieval method!

single layer AIRS-L2 clouds



HCA geographical distributions



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***

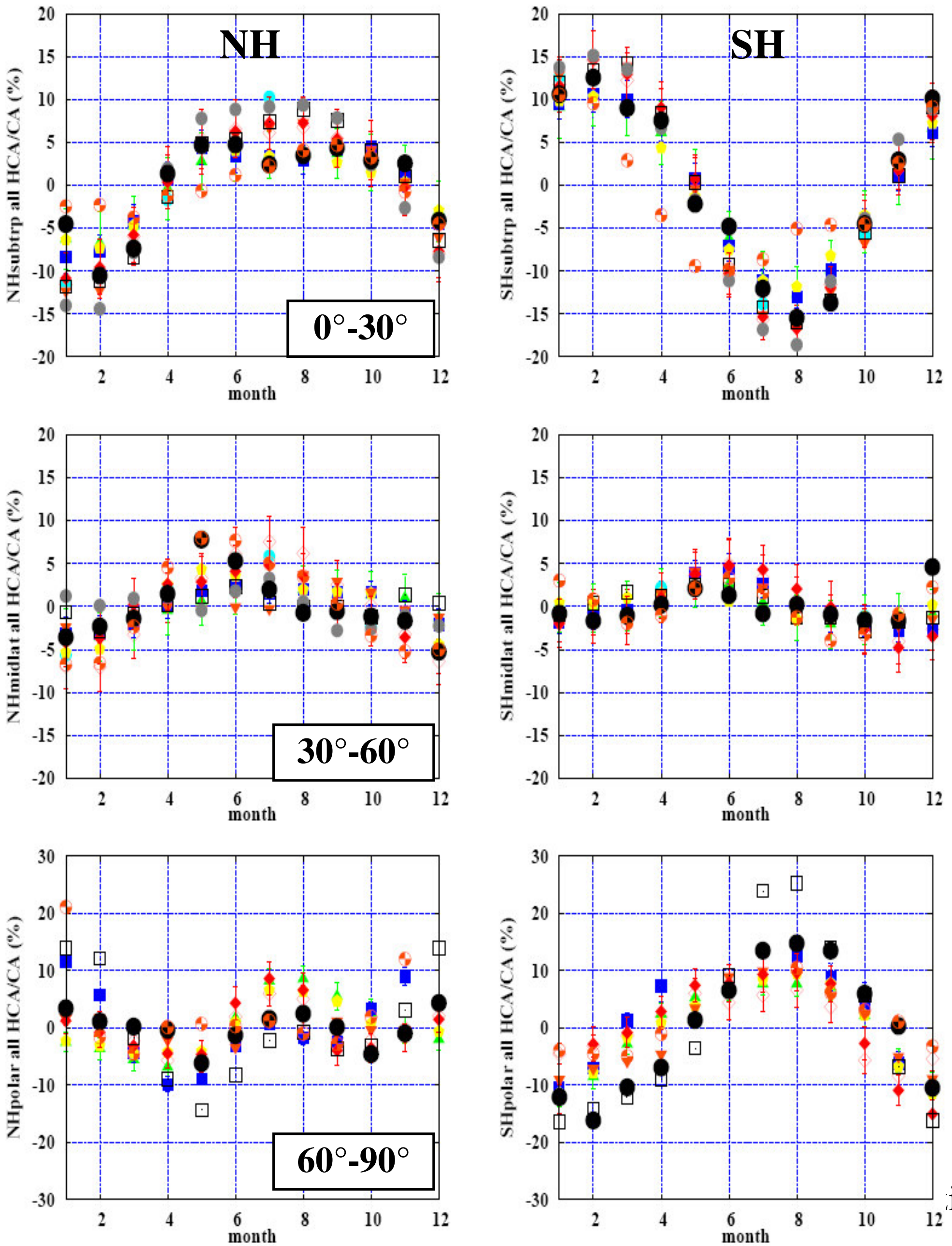
40% high clouds: ***only 3% thick Ci; more over land than over ocean***

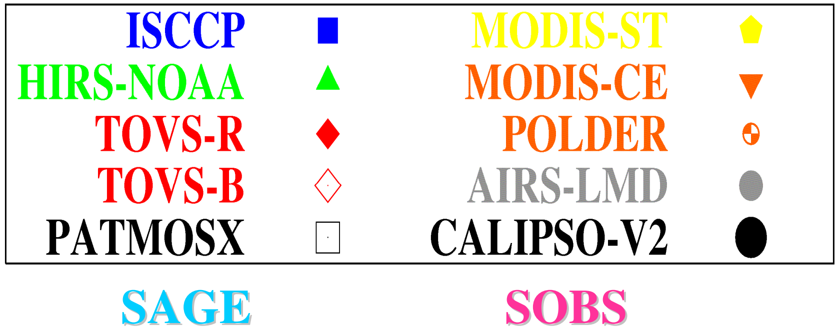
IR sounders ~ 10% more sensitive to Ci than ISCCP (15% in trps)

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/CA seasonal cycle

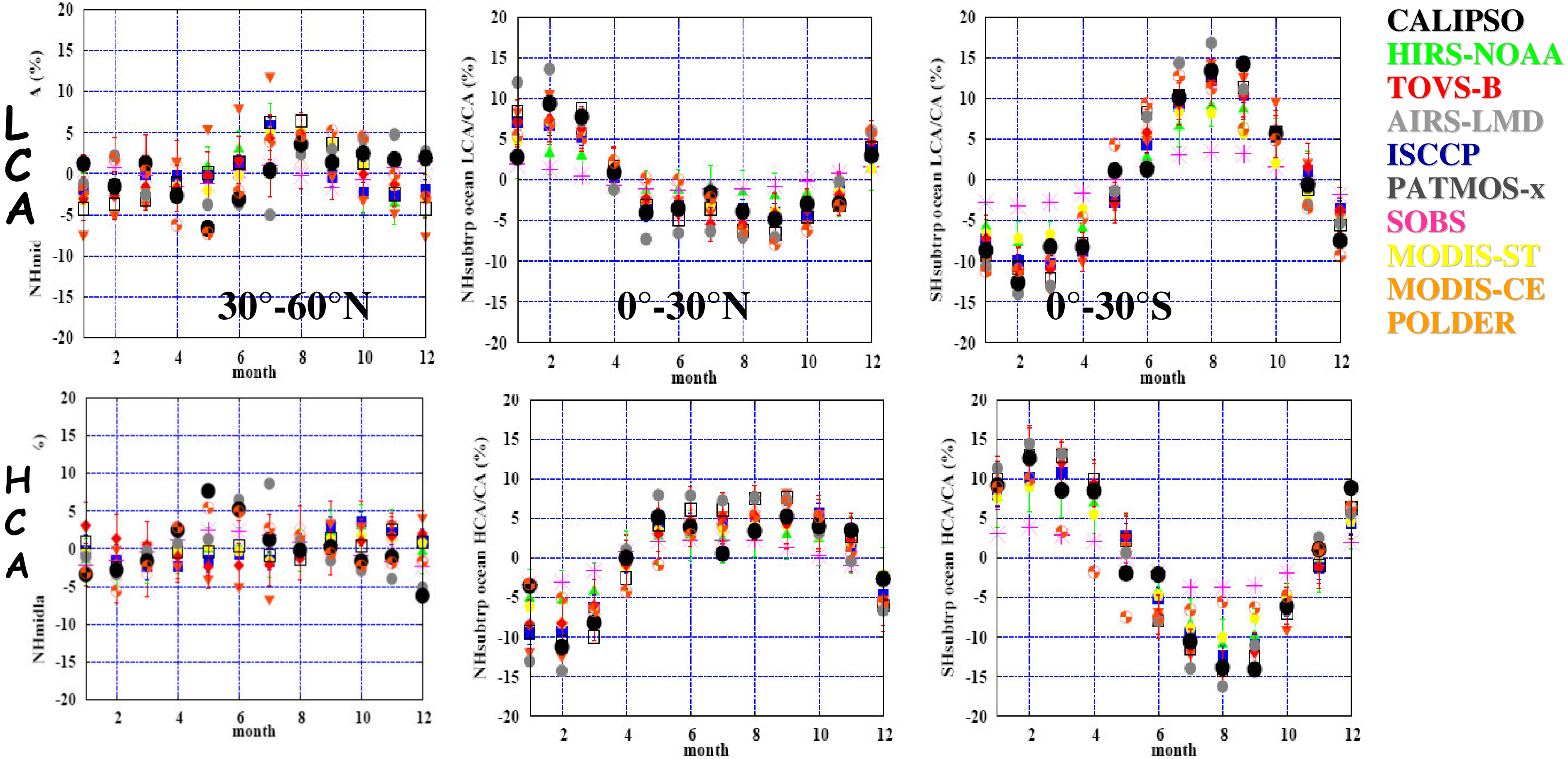




Seasonal cycles similar:

25% in SH tropics to 5% in SH midlatitudes

LCA/CA seasonal cycle over ocean



small seasonal cycle; exception: SH subtropics stratocumulus regions (20%)

SOBS: 18% more LCA and smaller seas. cycle over ocean

=> LCA seas. cycle from satellite modulated by HCA & MCA seas. cycle

near noon

early evening

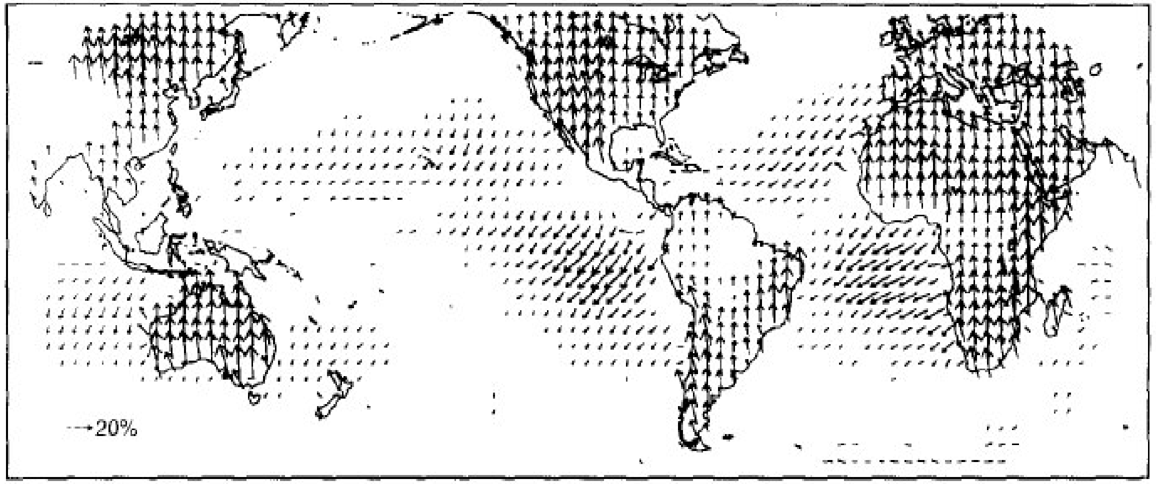
diurnal cycle of clouds

Cairns, Atm. Res. 1995

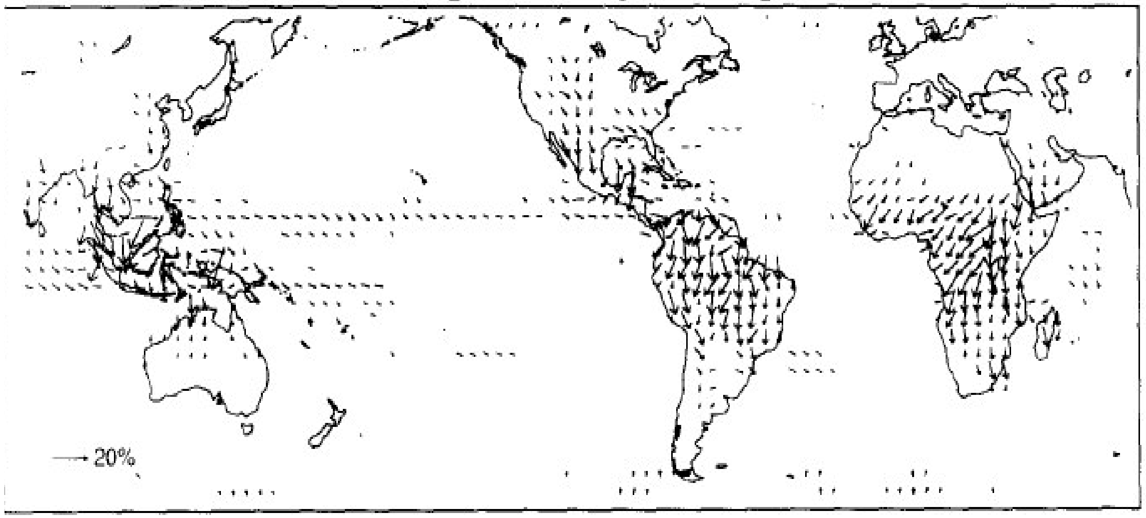
ISCCP C2, Complex Empirical Orthogonal Functions,

project. on distorted diurnal harmonics

Annual Average Diurnal Cycle for Low Cloud



Annual Average Diurnal Cycle for High Cloud



- **Low clouds over land:**
  significant diurnal cycle,
  max early afternoon

- **Low clouds over ocean:**
  max in early morning

- **High clouds:**
  max in evening

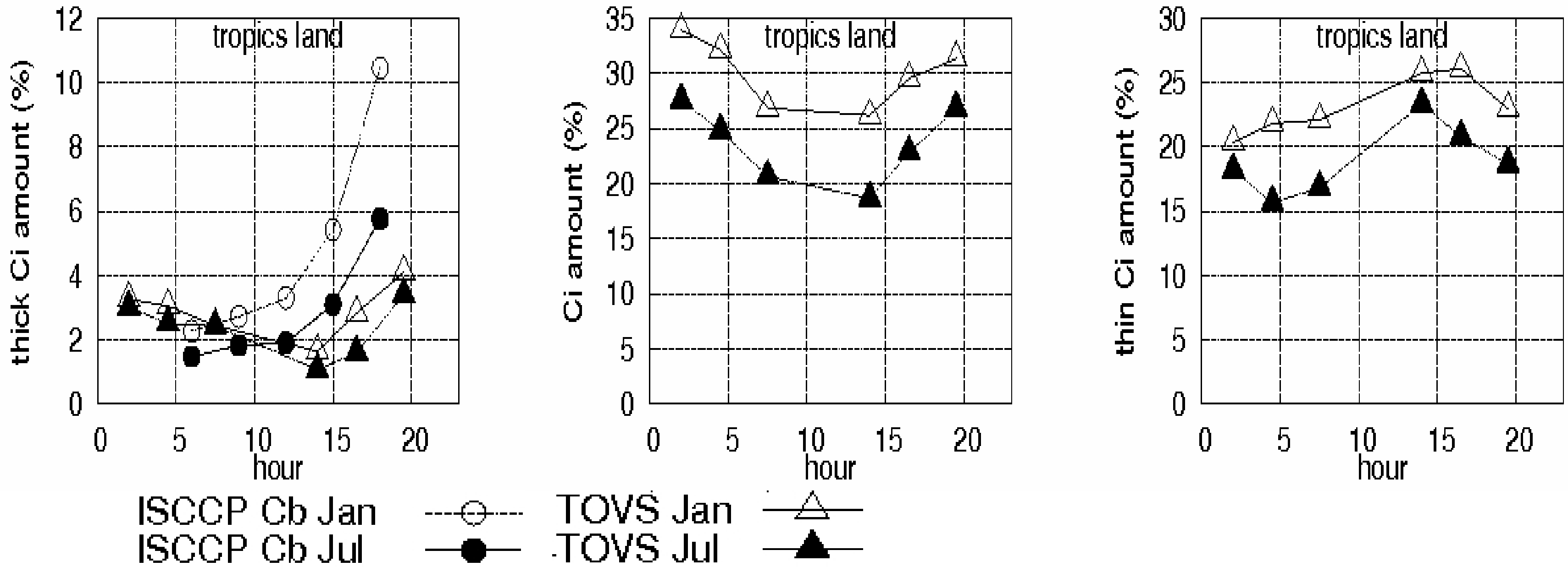
- **Mid clouds:**
  max in early morning
  or late at night
  (cirrus -> TOVS)

TOVS-B diurnal cycle of high clouds

Stubenrauch et al. J. Climate 2006

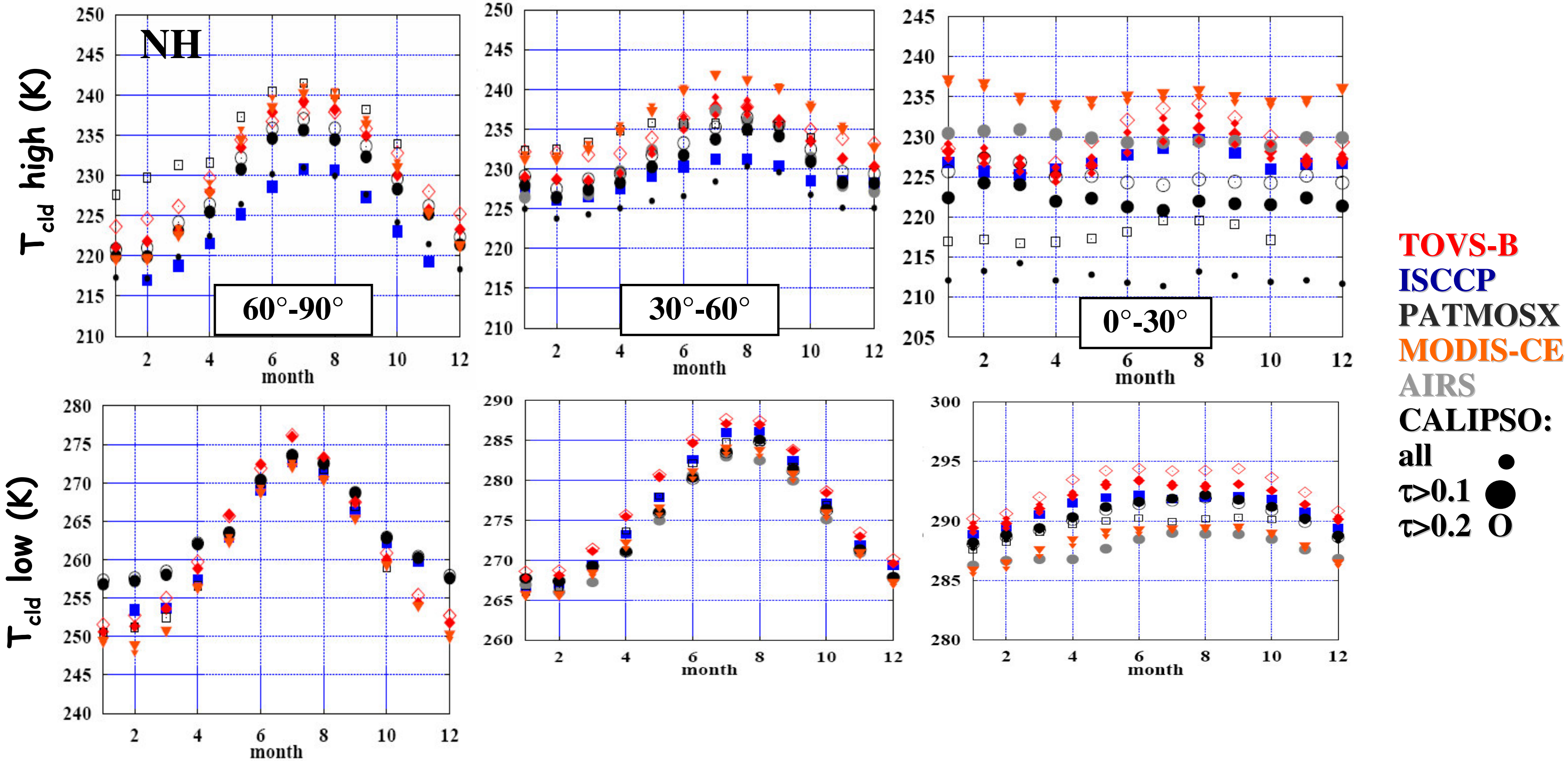
NOAA10/12 7h30 AM&PM, NOAA11 2h00 AM&PM(1989-90) NOAA11 4h30 AM&PM(1994-95)

strongest diurnal cycles over land, in tropics (& in midlat summer)



- max Cb (ISCCP) in early evening
- max. thick (large-scale) cirrus & cirrus in evening
- cirrus occurrence continues during night & decreases during day
- max. thin cirrus in early afternoon

cloud temperature of high and low clouds



Seasonal cycle of high T_{cld} decreases from polar (15°), midlat (10°) to tropics (5°)
low T_{cld} (20°) (20°) (5°)

CALIPSO: thin high clouds colder than thicker high clouds (τ>0.1), esp. in tropics

differences : largest for high clouds in tropics, very good agreement for low clouds

uncertainties in cloud height determination (esp. thin cirrus), T profiles

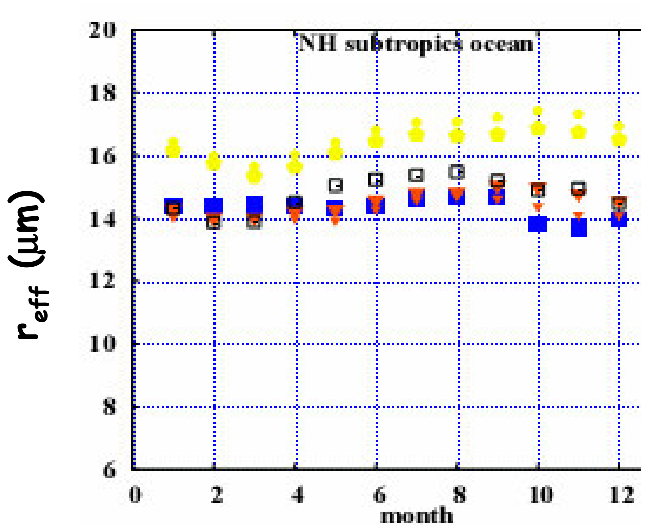
water cloud effective droplet radius

ISCCP: AVHRR NIR-VIS

Han, Rossow & Lacis J. Clim. 1994, Han et al. 1998

cloud properties	global	ocean	land
r_e [μm]	11.4	11.8	8.5
τ	7.0	6.9	8.1
LWP [gm^{-2}]	87.1	87.4	85.4

r_e slightly larger over ocean than over land



ISCCP
PATMOSX
MODIS-CE
MODIS-ST

preliminary

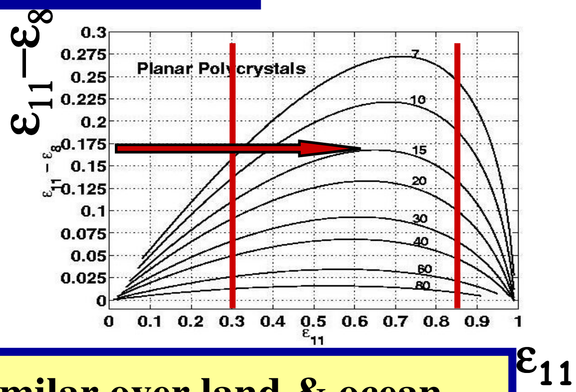
good agreement between ISCCP, PATMOSX, MODIS-CE

MODIS-ST:
2.1 μm instead of 3.7 μm

effective ice crystal diameter

semi-transparent cirrus **TOVS Path-B, 87-91** *(Rädel et al. JGR 2003)*

cloud properties	60N-60S	ocean	land
D_e [µm]	55.3	54.7	56.8
ε	0.59	0.58	0.60
IWP [gm^{-2}]	30	30	31

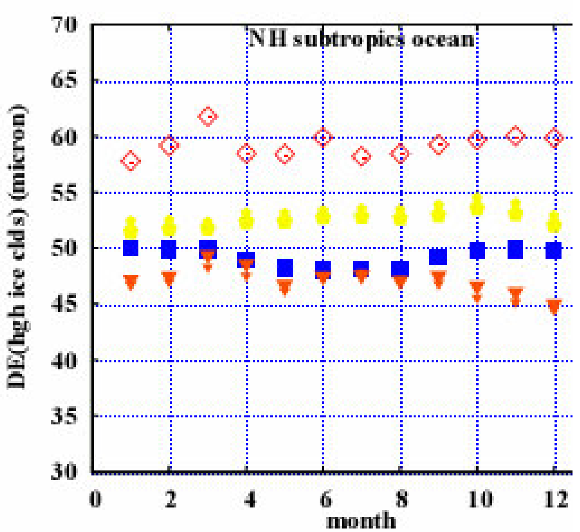


D_e similar over land & ocean

high clouds **MODIS-ST, 02-05** *(Hong et al. J. Appl. Met. 2007)*

cloud properties	30N-30S	ocean	land
D_e [µm]	53.0	55.6	47.0
ε	0.69	0.70	0.66

D_e slightly larger over ocean



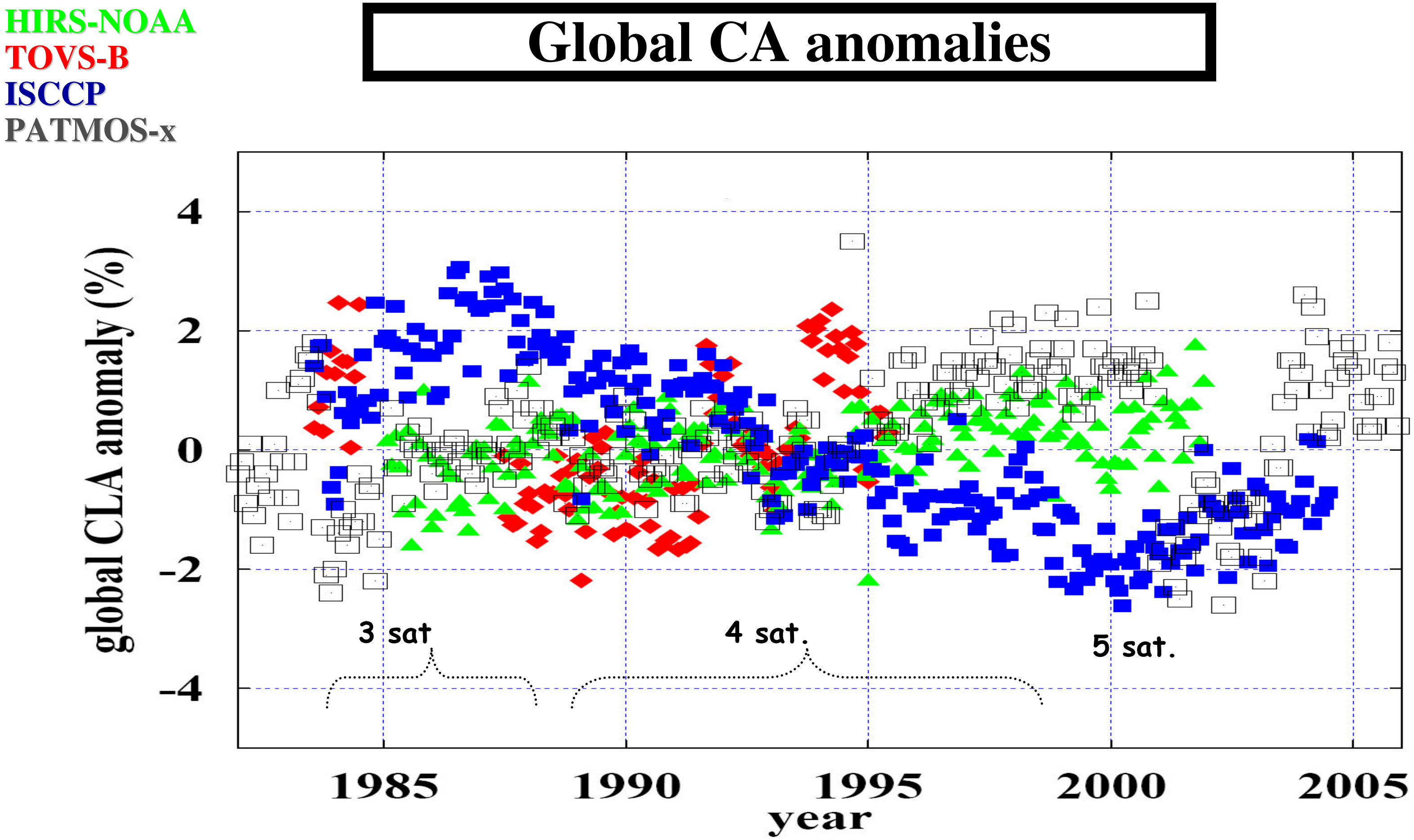
ISCCP
TOVS-B
MODIS-CE
MODIS-ST

preliminary

NIR-VIS:
D_e near cloud top

IR:
D_e averaged over cloud depth

Global CA anomalies



global CLA within ±2.5%

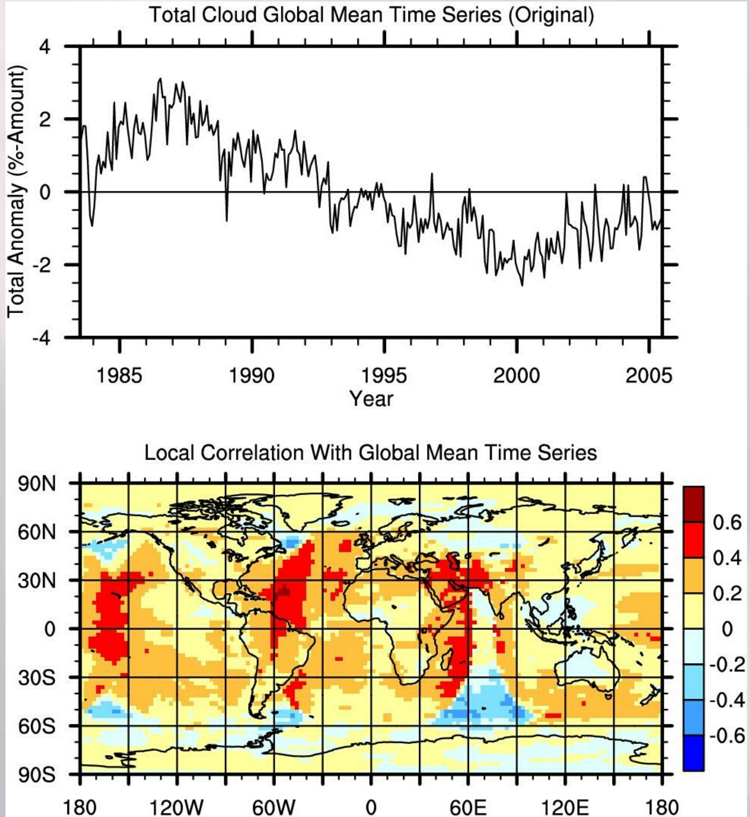
CA change : cluster analysis correcting for artefacts

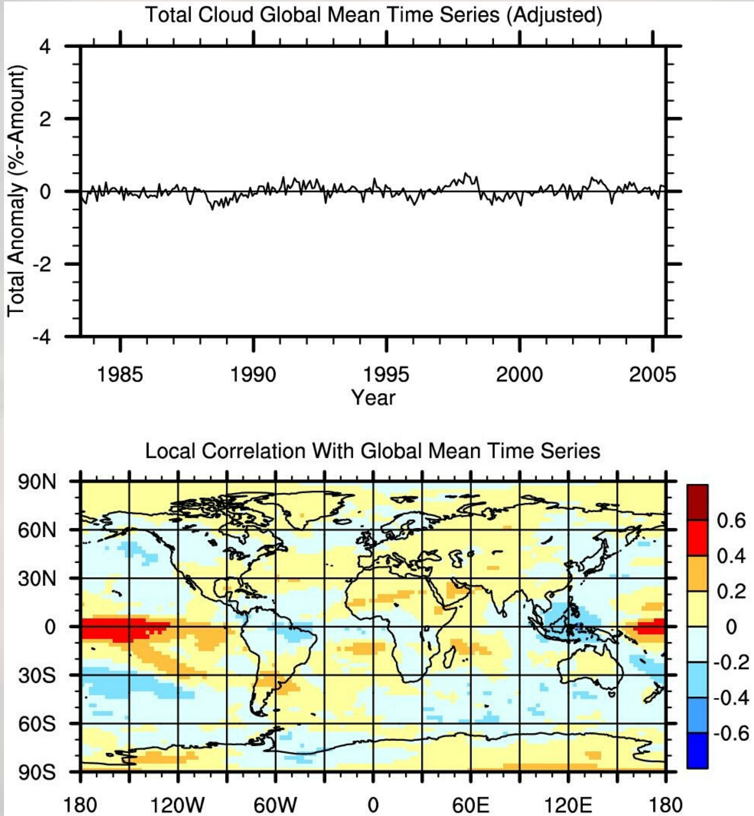
J. Norris

http://meteora.ucsd.edu/~jnorris/isccp_artifacts.html

6 clusters out of 7 related to artificial satellite features:
sea-ice: Oct-Dec 2004, high lat land: > Oct 2001(NOAA16)
nb of GEOs - view angle, GEO view area

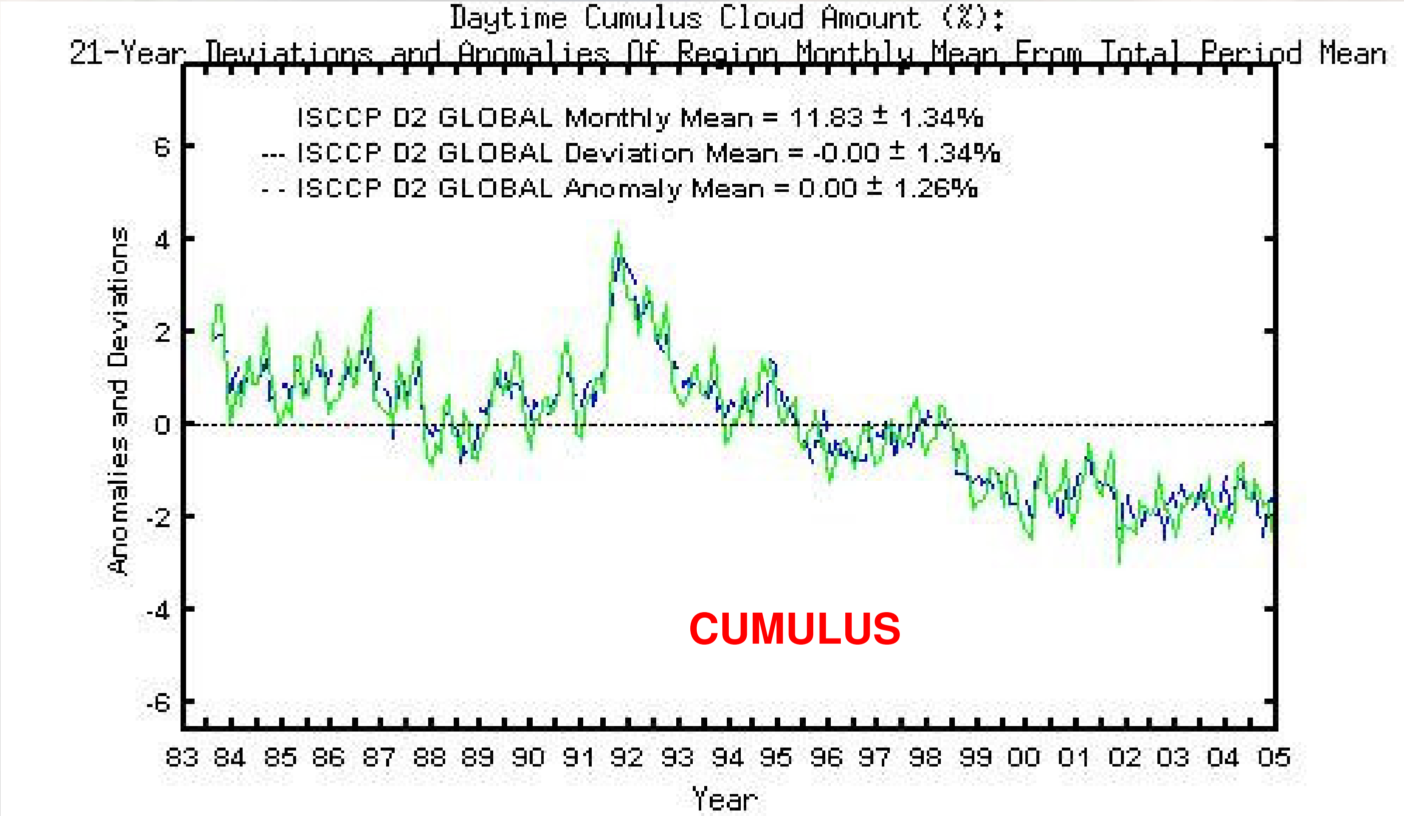
also
(Evan et al. GRL 2007)





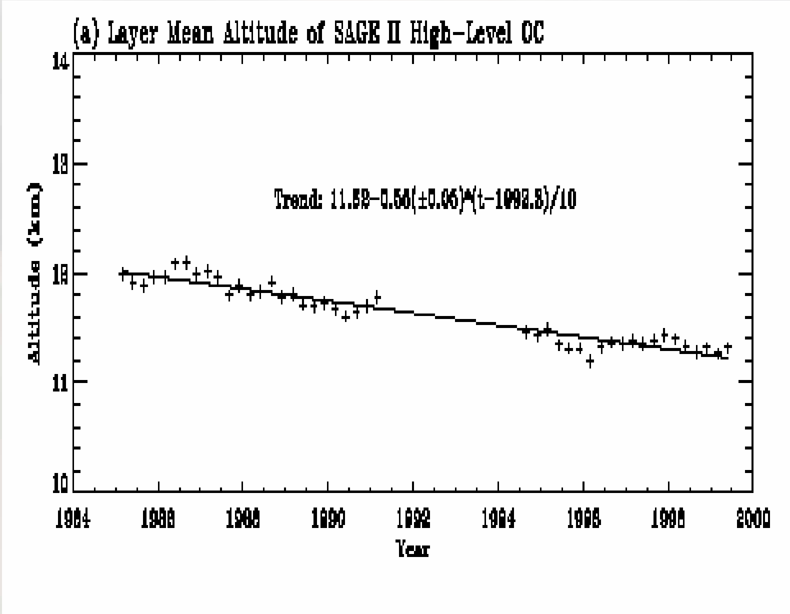
Anomaly per cloud type

W. B. Rossow



Changes in Cloud Property Distribution : decreasing τ of low clouds -> below detection (*Tselioudis et al. 1992*: τ decreases with T)

Trend analysis of high clouds: synergy of different variables



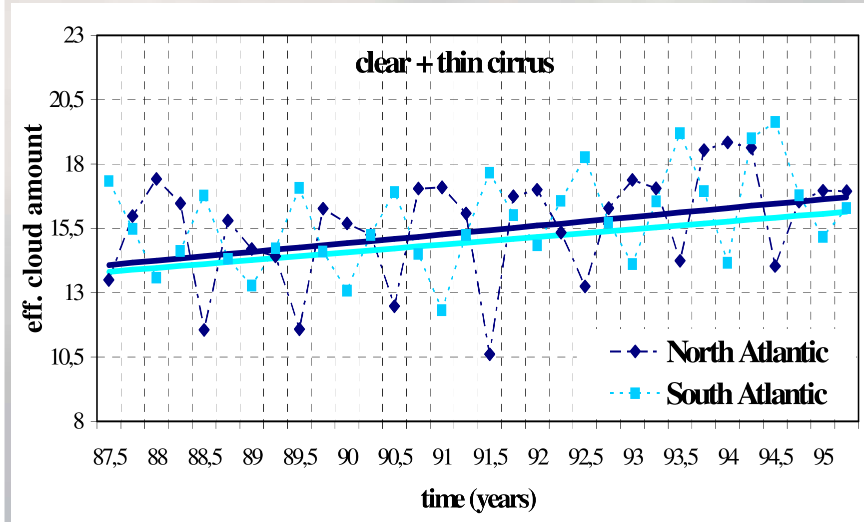
Tropics *(Wang et al., J. Clim., 2007, in rev.)*:

- **decreasing NCEP humidity suggests decrease in HCA**

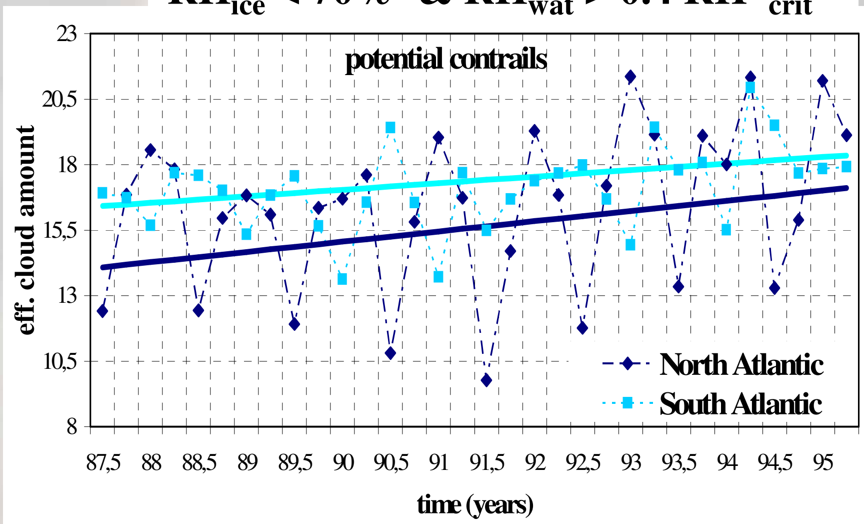
SAGE: thinner & lower high clouds in tropics rather than simple HCA decrease

- **cause of UTH drop? Is it real?**

Midlatitudes *(Stubenrauch & Schumann, GRL 2005)*:



RH_{ice} < 70% & RH_{wat} > 0.4 RH^*_{crit}



increase of thin Ci in <u>both</u> hemispheres

stronger increase related to contrails in NH

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)

PATMOS, MODIS still in validation process, but will miss more thin Ci than TOVS/HIRS, AIRS, IASI

❖CALIPSO-CLOUDSAT to determine vertical structure of clouds & help to evaluate other cloud properties

❖ droplet size smaller over land than over ocean

❖ ice crystal size slightly larger from IR than from NIR-VIS

❖ synergy of different variables & datasets important

❖ evaluation continues & WMO report in preparation

❖ monthly mean values of different datasets will be available at:

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