Assessment of Global Cloud Climatologies

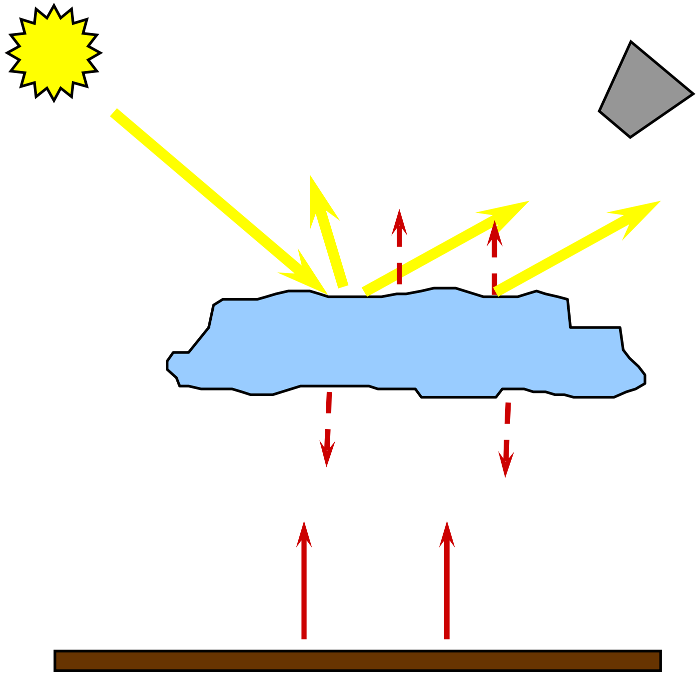
project of GEWEX Radiation Panel / WCRP

Claudia Stubenrauch
+
GEWEX cloud assessment group
**(S. Ackerman, R. Eastman, A. Evan, A. Heidinger, N. Lamquin, B. Maddux, P. Minnis,
J. Norris, W. B. Rossow, S. Sun-Mack, P.-H. Wang, S. Warren, D. Winker, D. Wylie…)**

http://cimss.ssec.wisc.edu/cloud_climatology/2006

Co-chairs: B. Baum, *SSEC, University of Wisconsin, USA*
C. Stubenrauch, *CNRS/IPSL - Laboratoire de MétéorologieDynamique, France*

Satellite radiometers measure:



emitted, reflected, scattered

radiation

INVERSION

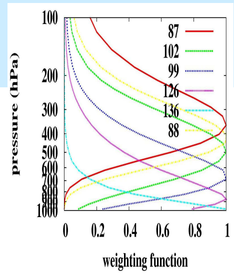
cloud detection
inverse radiative transfer

cloud properties

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

ISCCP	**PATMOS-x**	**HIRS-NOAA**, **TOVS Path-B**
IR, VIS	*IR, NIR, VIS*	*IR Vertical Sounder: CO_2-band*

MODIS **AIRS**



http://cimss.ssec.wisc.edu/cloud_climatology/2006
http://ara.lmd.polytechnique.fr

Longterm cloud climatologies:

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

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

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 *(Stubenrauch et al.) very preliminary*

Evaluation & analysis of cloud properties:

CALIPSO L2 data *(Winker et al.)* ***8/2006-4/2007*** ***active lidar (A-Train)***
prelim. analysis of highest cloud layers: N. Lamquin

average, regional, seasonal & interannual variations

Climate monitoring: **trends and where they can originate from**

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)*

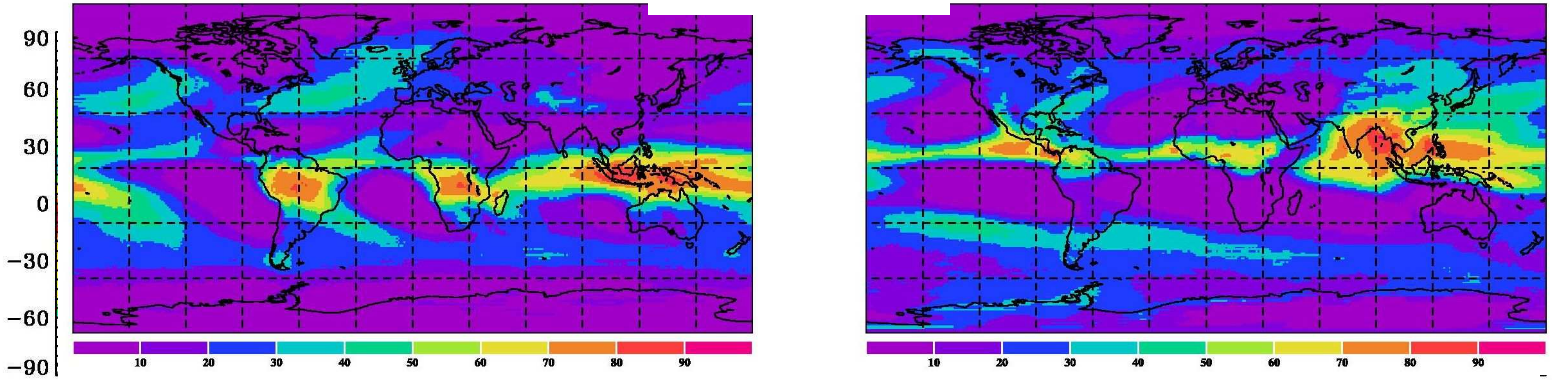
UW HIRS *(for Wylie & Menzel J. Clim. 1999, not yet for Wylie et al. J. Clim. 2005)*

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

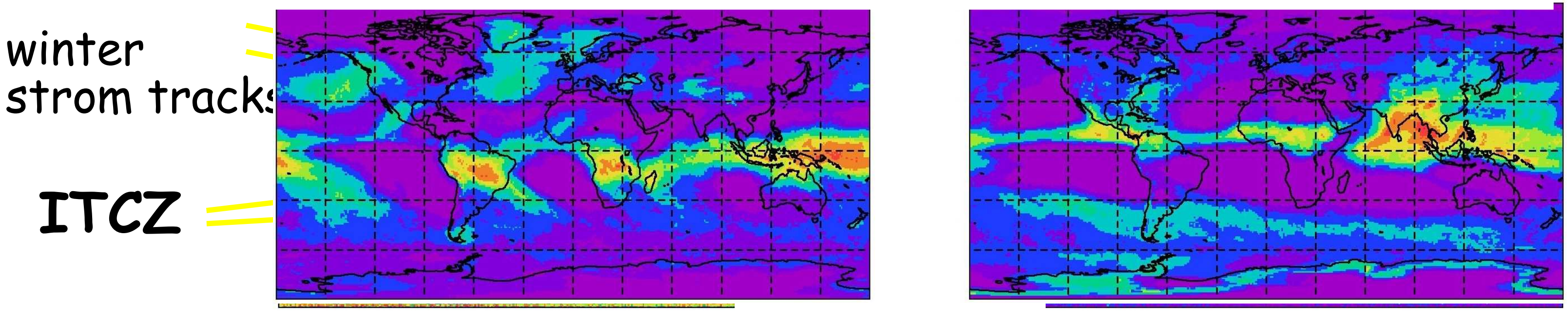
100 hPa above for transmissive cloud overlying opaque cloud *(Menzel et al. 1992)*

HCA geographical distributions

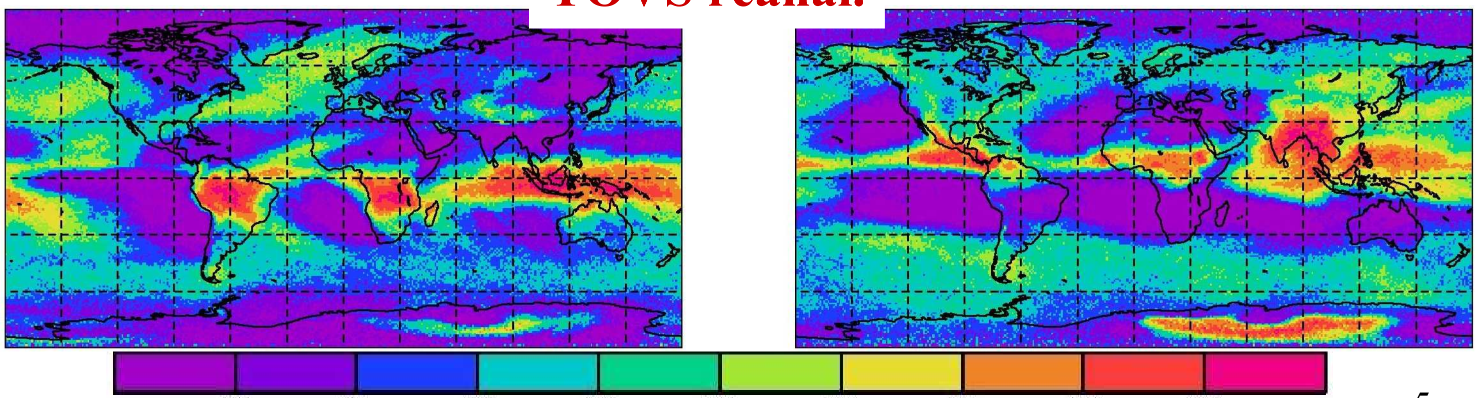
PATMOS-x



MODIS-CE



TOVS reanal.



Average CA

ISCCP(84-04) day/night TOVS-B(87-95) UW-HIRS(85-01) SAGE(85-99) PATMOS-x(81-06) MODIS-CE(03-05) MODIS-ST(02-06) SOBS(84-04)

CA (%)	glo bal										oce an										la nd								
all	66	73	70	75	95	66	61	67	61	64	70	74	74	77	95	72	66	73	65	69	58	69	61	70	97	50	50	59	51
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	38	42	25	21	23	30	39	42	44	44	35	37	21	18	17	41	45	53	49	45	47	56	34	29
MCA / CA	27	16	14	16	20	19	16	32	33	44	26	14	12	14	18	17	14	28	29	42	31	25	20	17	25	25	20	39	43
LCA / CA	39	42	37	37	36	44	44	46	46	72	41	47	42	42	38	49	51	50	52	80	29	30	23	34	29	29	26	27	27

diurnal sampling, time period for ISCCP / TOVS-B: 1% effect; low-level over land: 2%
can be more important if using afternoon satellites *(D. Wylie, A. Evan)*

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

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

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

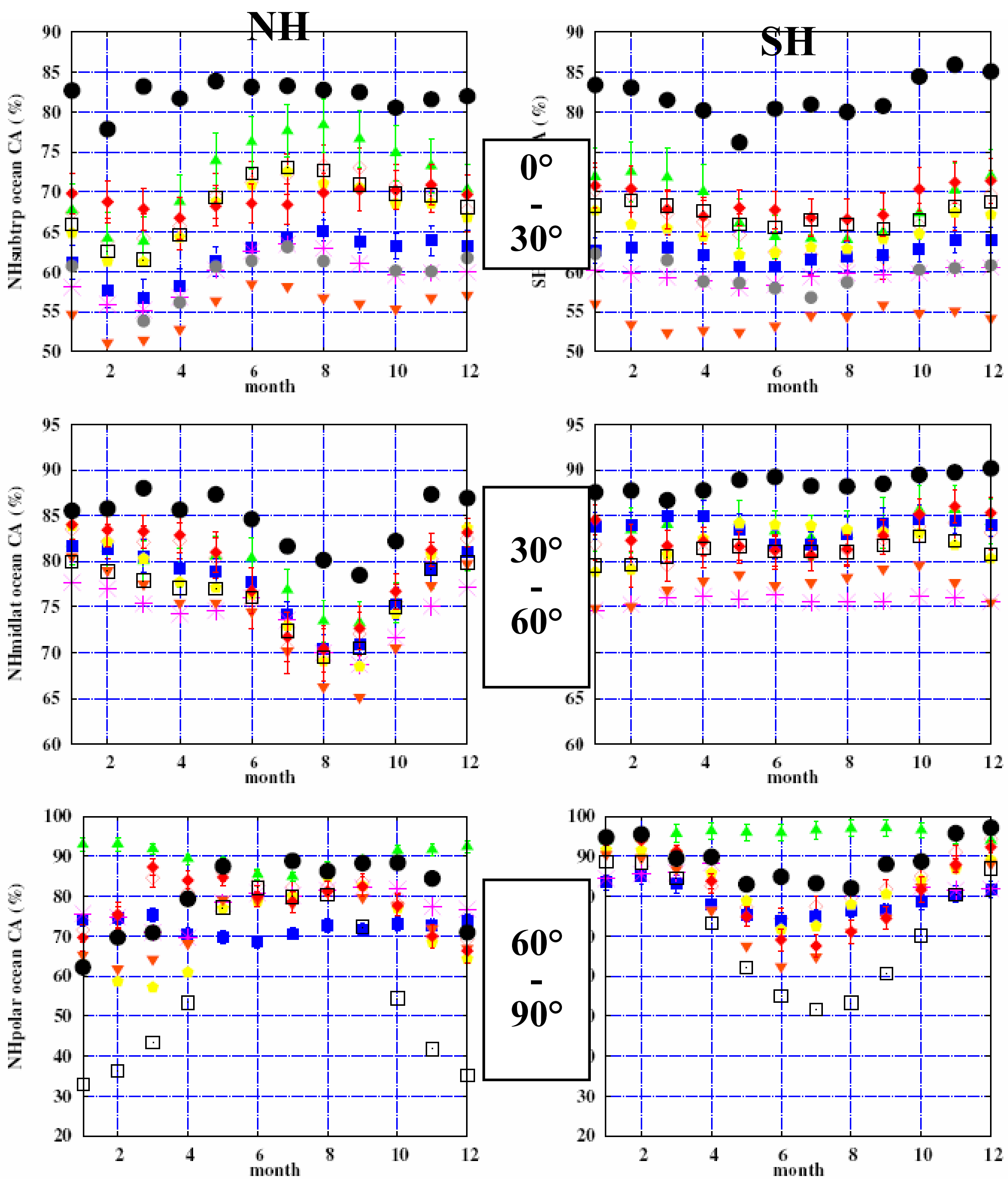
40% high clouds: ***only 3% thick Ci; more over land than over ocean***

IR sounders ~ 10% more sensitive to Ci than ISCCP

SAGE cloud vertical structure in good agreement with IR sounders

HCA/CA: SAGE,TOVS/HIRS > MODIS-CE > PATMOS > ISCCPday > MODIS > ISCCPnght

CA seasonal cycle over ocean



CALIPSO
AIRS
HIRS-NOAA
TOVS-B
ISCCP
PATMOS-x
SOBS
MODIS-ST
MODIS-CE

Seasonal cycles:

- **stronger in NH than SH**

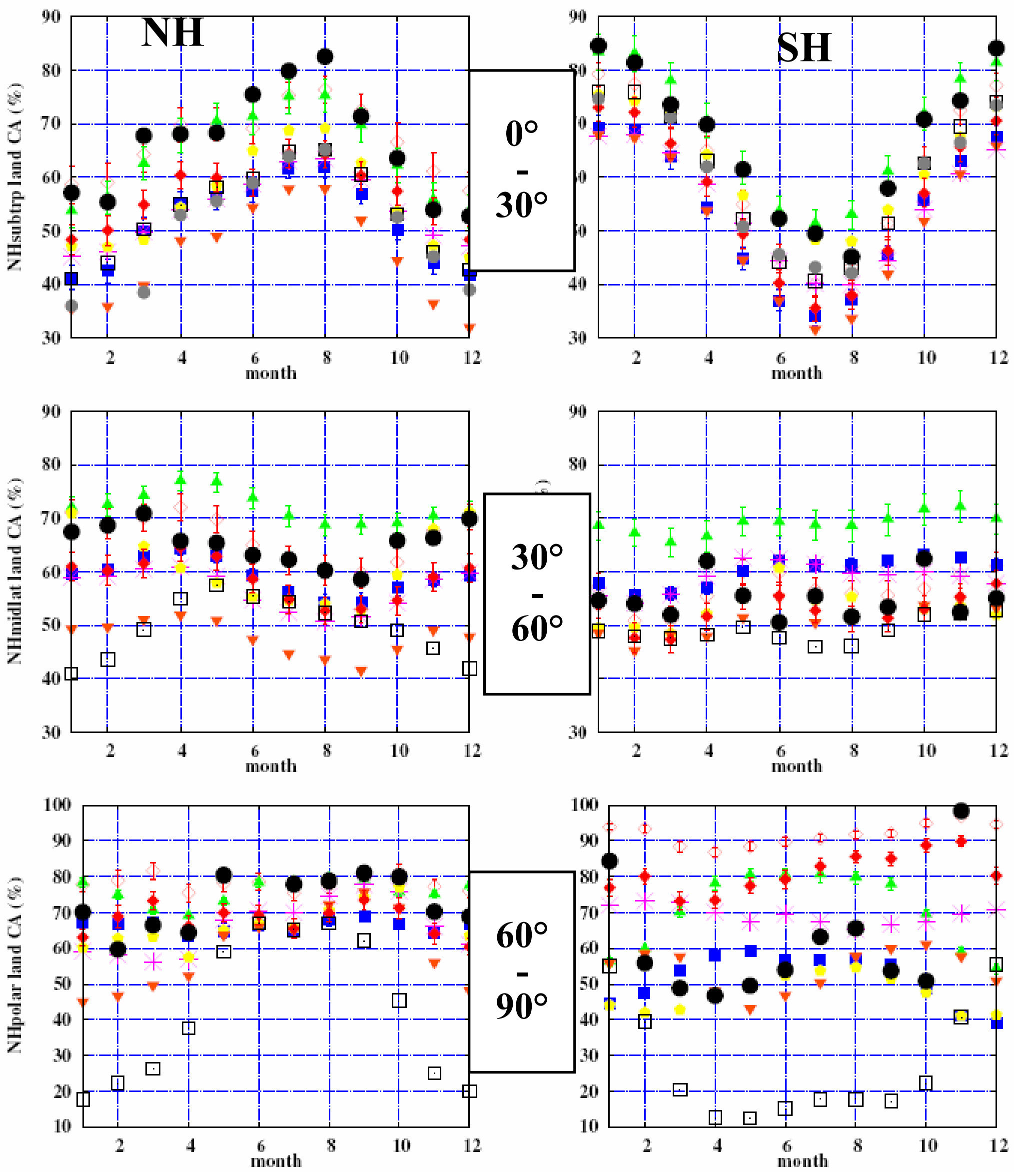
Seasonal cycles similar

exception: *HIRS/PATMOS at polar lat.*

CALIPSO CA: 10-15% higher in tropics
5% higher in midlat
than TOVS/HIRS CA
linked to laminar cirrus ?

MODIS-CE < MODIS-ST
AIRS a postiori cloud detection
conservative (for cloud property retrieval)

CA seasonal cycle over land



CALIPSO
AIRS
HIRS-NOAA
TOVS-B
ISCCP
PATMOS-x
SOBS
MODIS-ST
MODIS-CE

Seasonal (& diurnal) cycles:
- **stronger over land than over ocean**
- **strongest in subtropics**

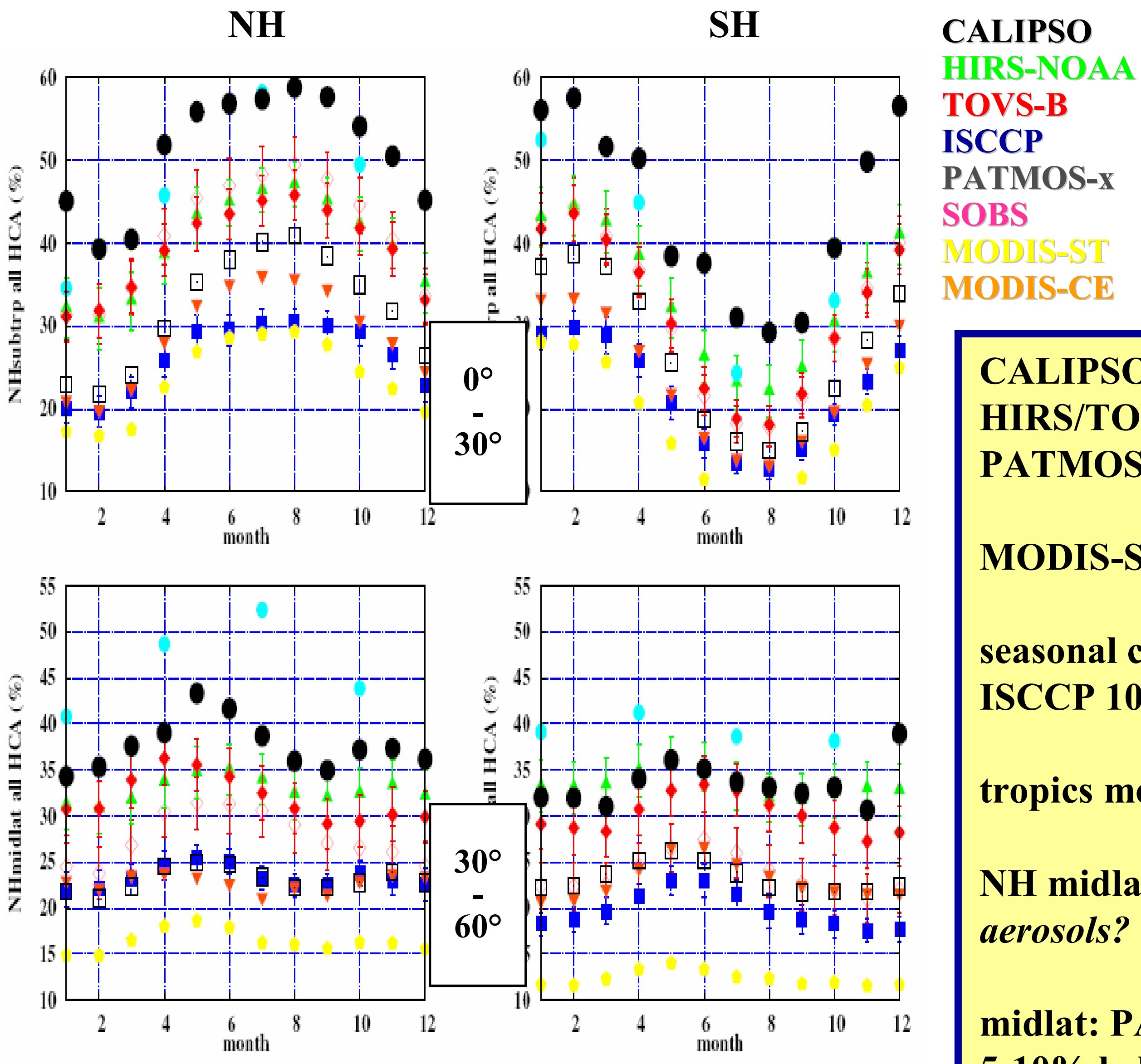
Seasonal cycles similar
<u>exception</u>: *SH polar land and PATMOS, MODIS-CE in NH midlat*

TOVS/HIRS CA 5-12% larger than ISCCP & PATMOS

CALIPSO close to TOVS/HIRS

SOBS close to ISCCP

HCA seasonal cycle



CALIPSO/SAGE most sensitive to cirrus
HIRS/TOVS
PATMOS/MODIS-CE, ISCCP

MODIS-ST too low!

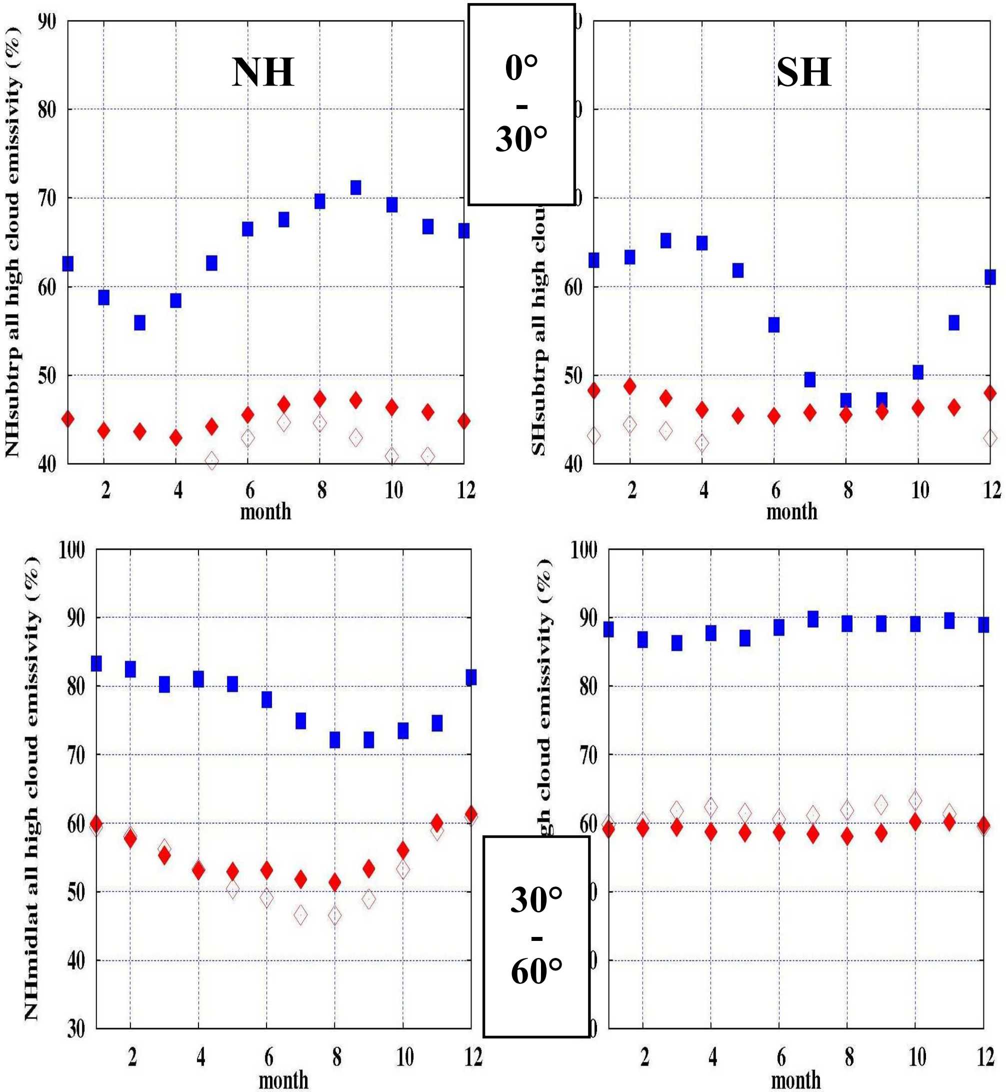
seasonal cycles similar, but
ISCCP 10-15% smaller HCA

tropics more laminar cirrus than midlat

NH midlat: SAGE too many cirrus
aerosols?

midlat: PATMOS/MODIS-CE, ISCCP
5-10% below HIRS/TOVS

High cloud emissivity



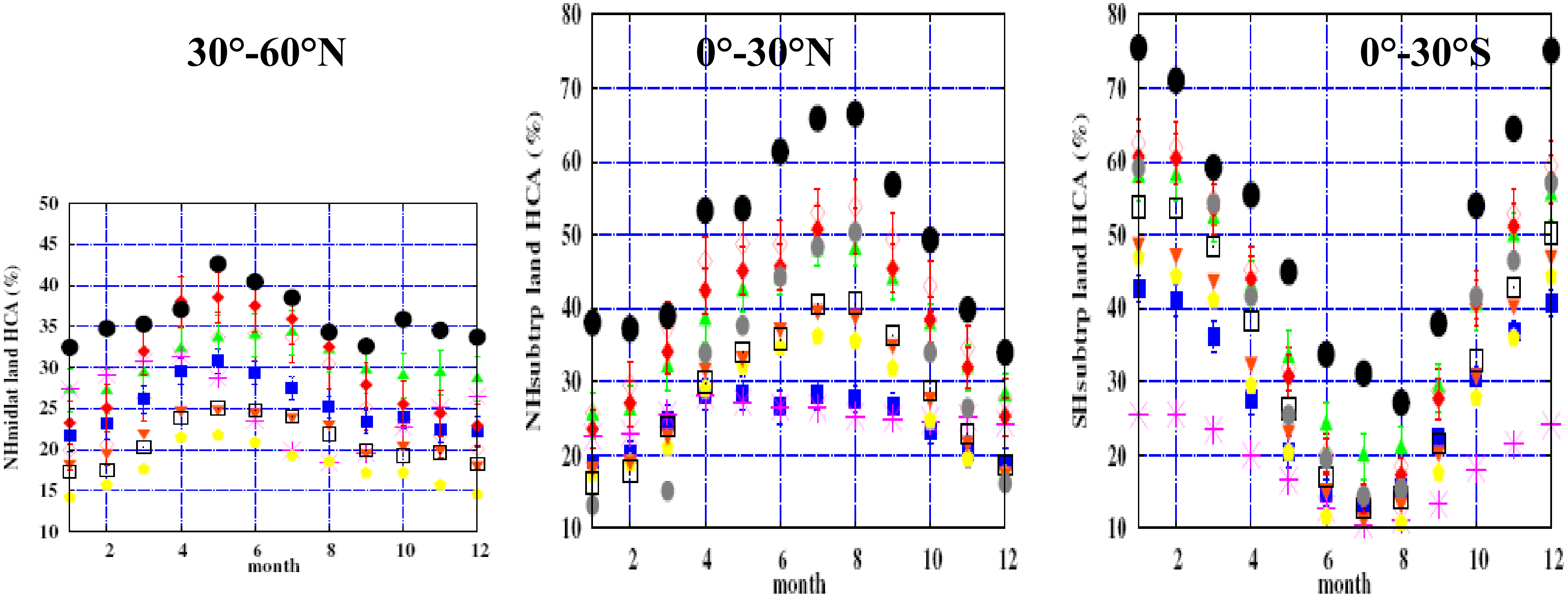
TOVS-B
ISCCP

TOVS larger HCA, but smaller ε

ISCCP ε seasonal cycle follows HCA seasonal cycle: underestimated HCA = overestimated ε

$$\varepsilon_{IR} = 1 - \exp(-\tau_{VIS}/2)$$

HCA seasonal cycle over land



CALIPSO AIRS HIRS-NOAA TOVS-B ISCCP PATMOS-x MODIS-ST MODIS-CE SOBS

HCA seasonal cycle : 7-15%, 10-30%, 20-50%

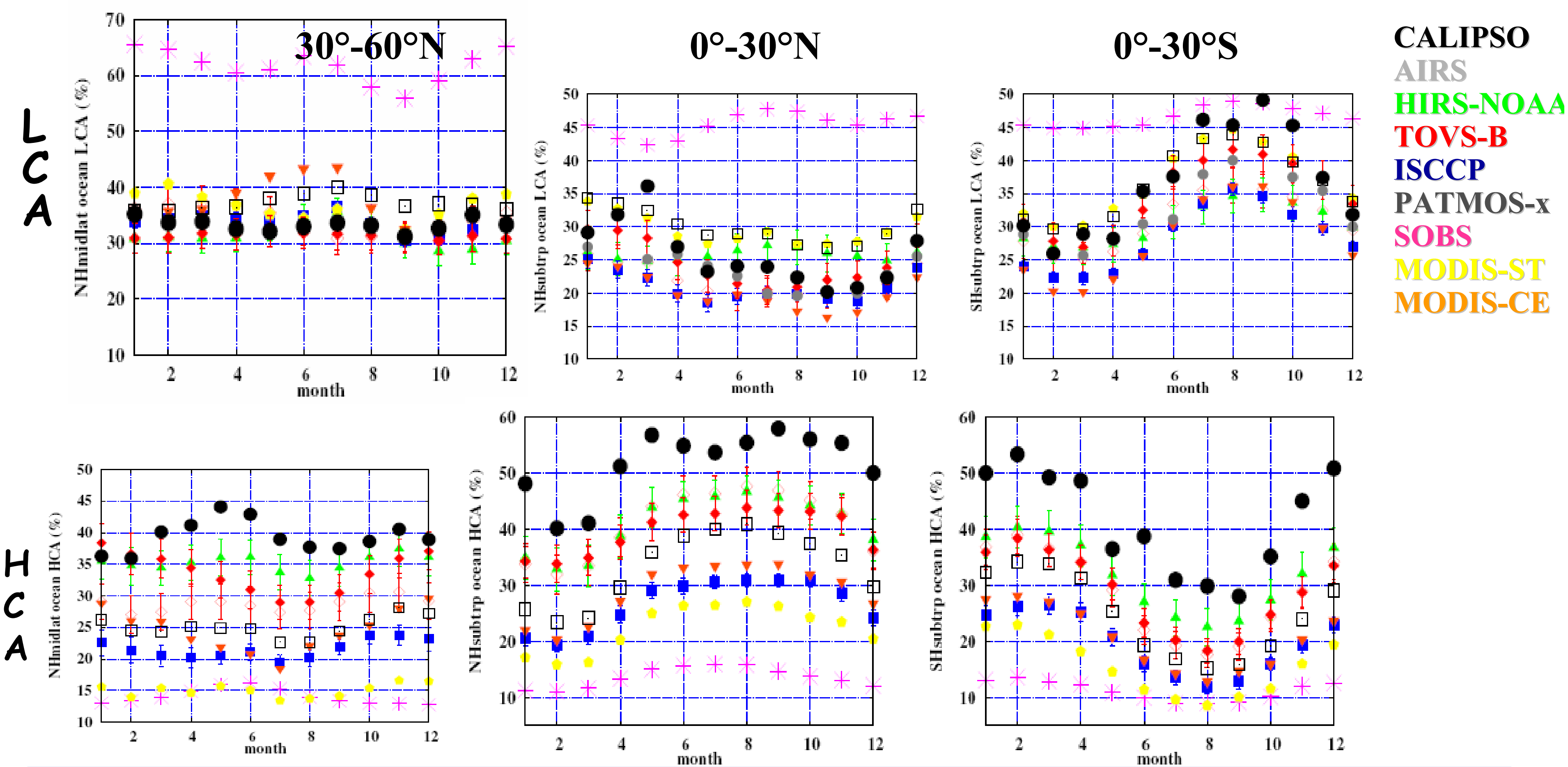
ISCCP underestimates seasonal cycle of HCA by up to 20%

CALIPSO 10-15% higher than HIRS/TOVS-B/AIRS

PATMOS & MODIS HCA too low in NH midlatitudes

SOBS HCA seasonal cycle modulated by clouds underneath

LCA seasonal cycle over ocean

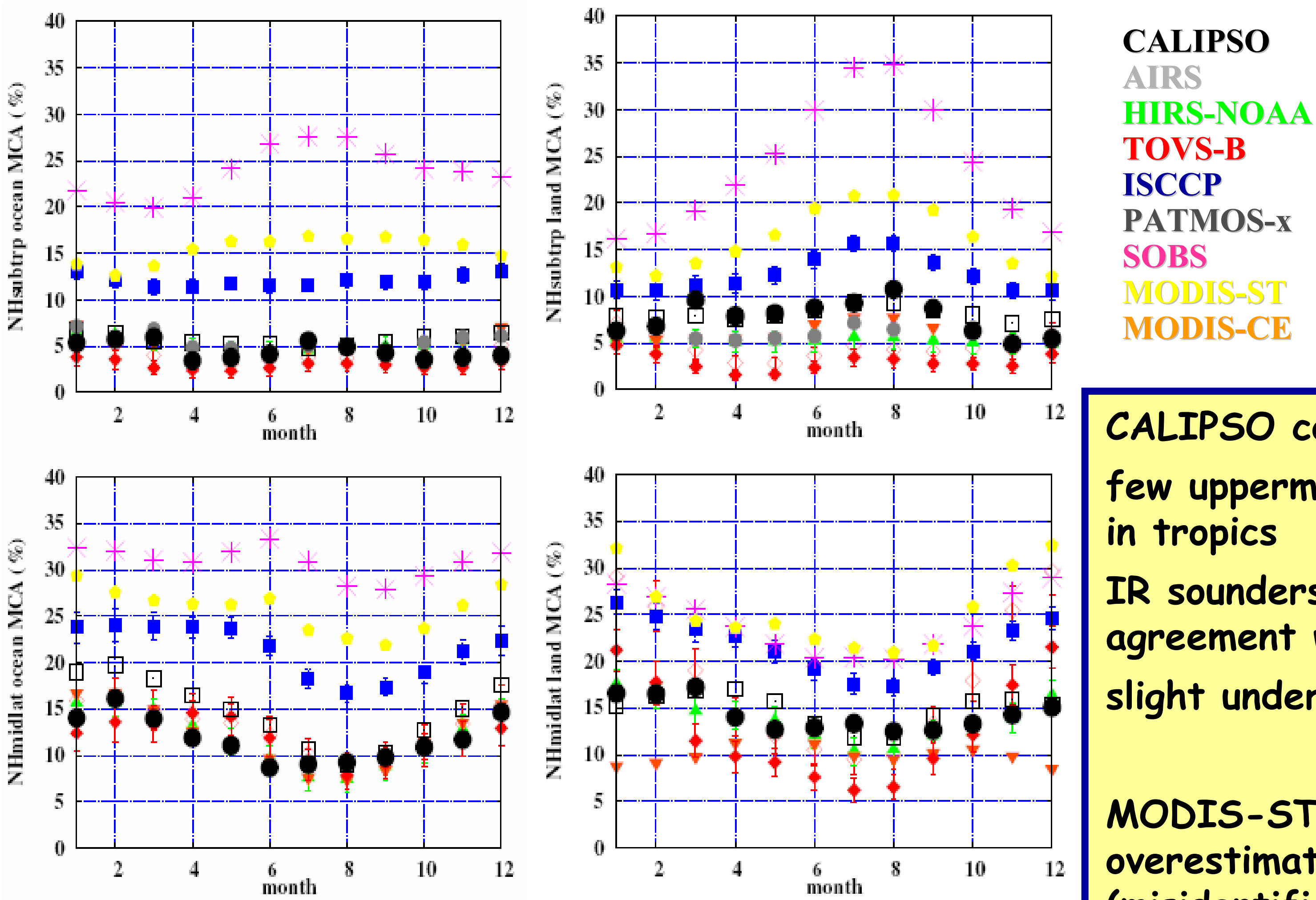


small seasonal cycle; exception: SH subtropics stratocumulus regions (12%)

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

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

MCA over NH ocean & land



CALIPSO confirms:

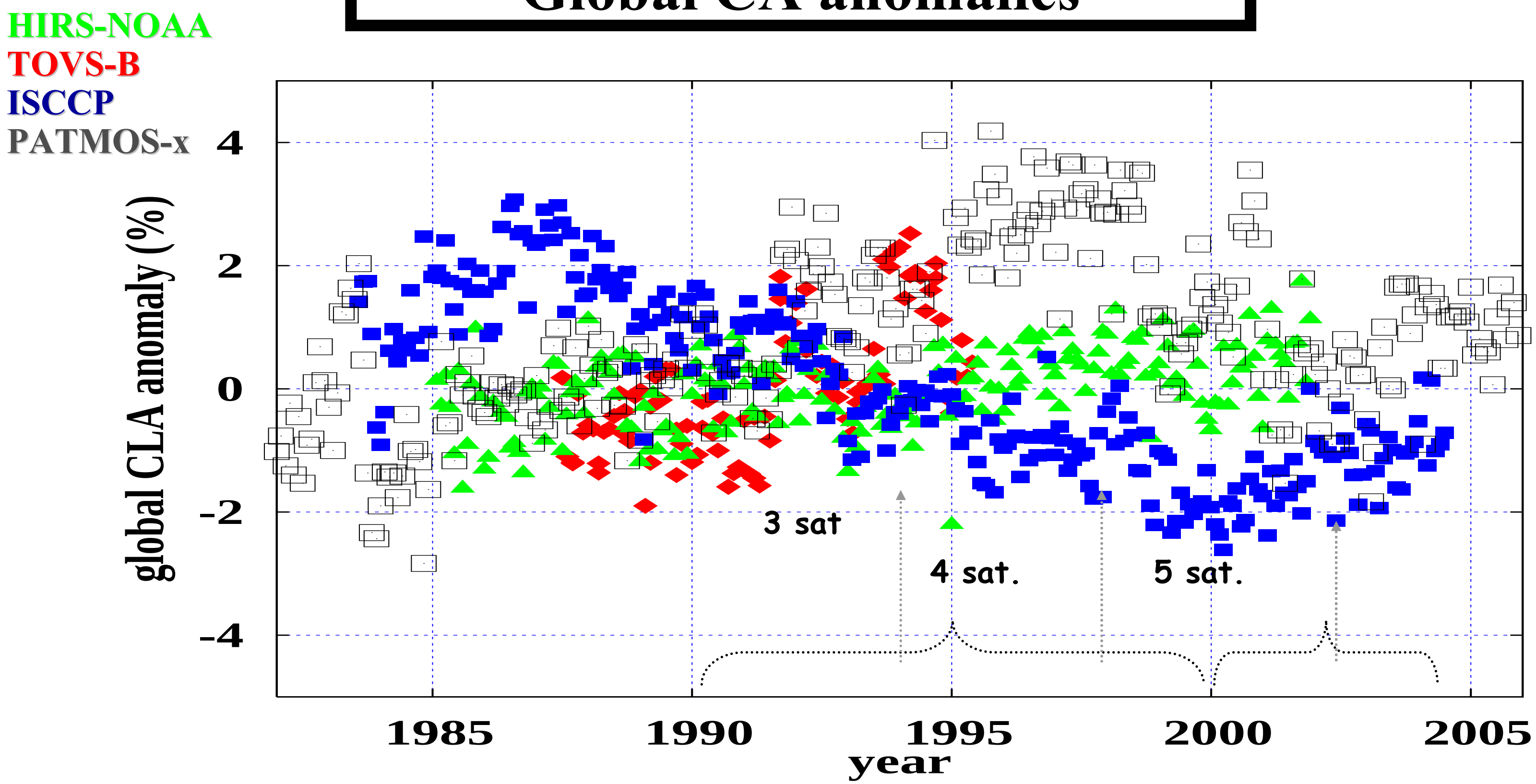
few uppermost midlevel clouds in tropics

IR sounders in good agreement with CALIPSO

slight underest. over trp land

MODIS-ST, ISCCP: overestimation (misidentification Cirrus)

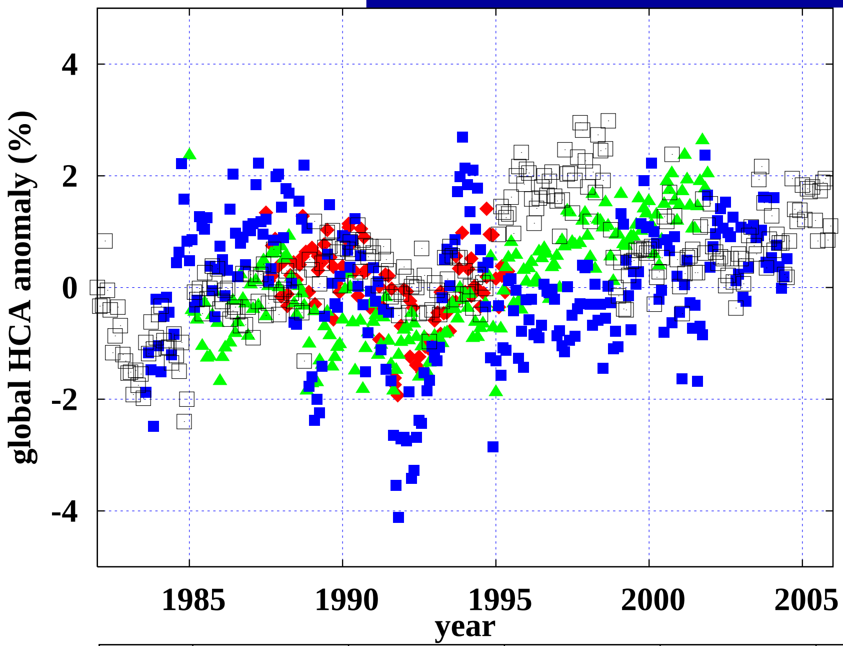
Global CA anomalies

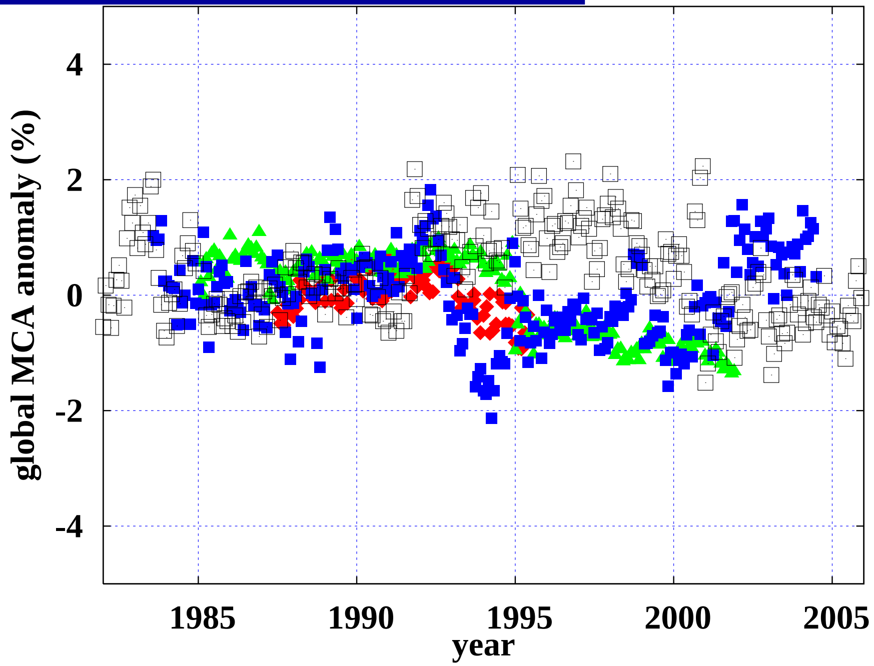


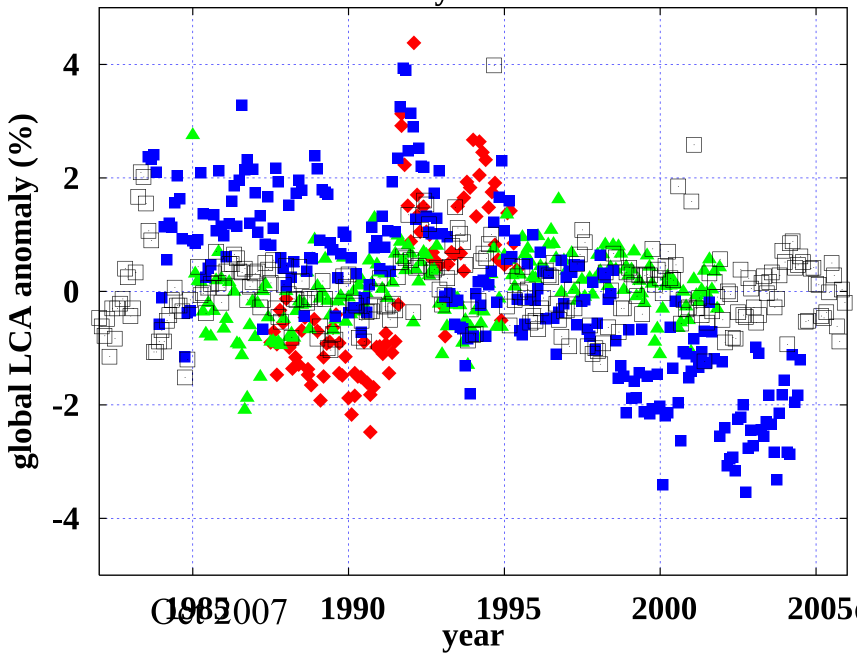
global CLA within ±2.5%
HIRS-NOAA: more or less stable
ISCCP: ~5% decrease from 1987 to 2000
related to increasing nb of GEO satellites ?

SOBS: increasing over ocean, stable over land >1985 *(Warren et al. J. Clim. 2006)*

Trends of cld type amount







ISCCP:

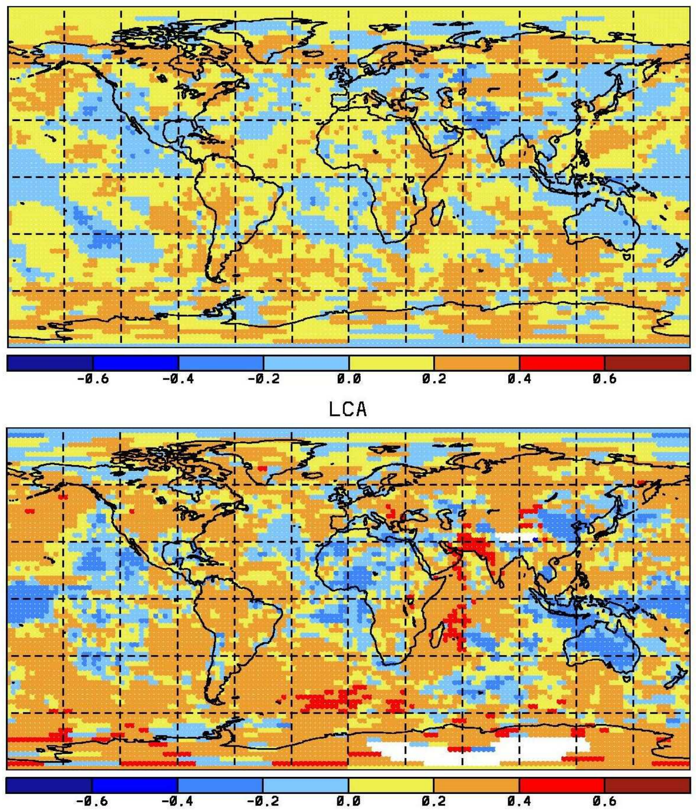
1991 Mt Pinatubo eruption

4% effect on HCA and LCA

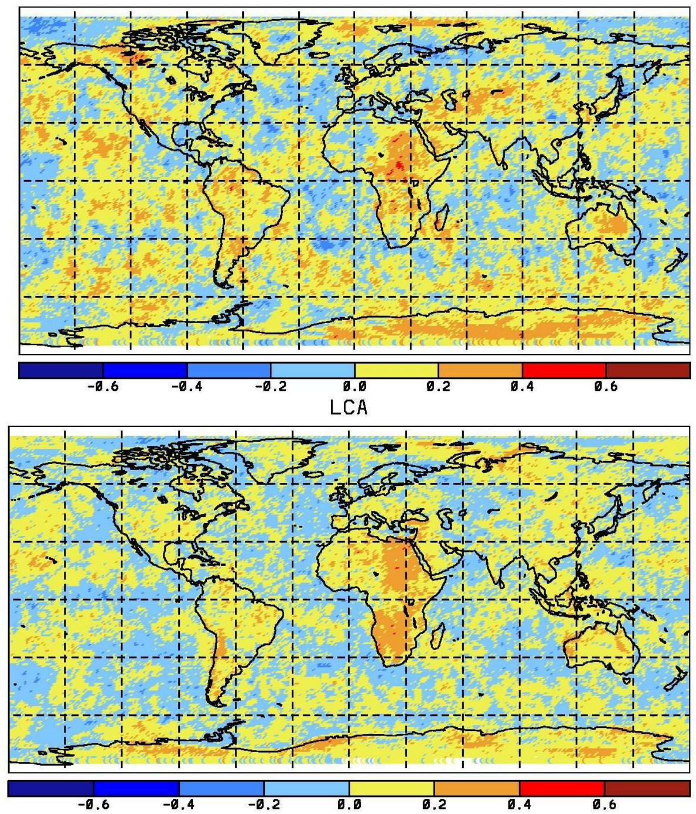
Correlation between global and regional anomaly:

1. calculate anomaly maps per month and per year: *A(i,j,m,y)*
2. calculate global anomaly per month and per year: *AG(m,y)*
3. determine map of (linear) correlation coefficients: *r(i,j)*

HCA **ISCCP 95-04**



HCA **HIRS-NOAA 95-01**



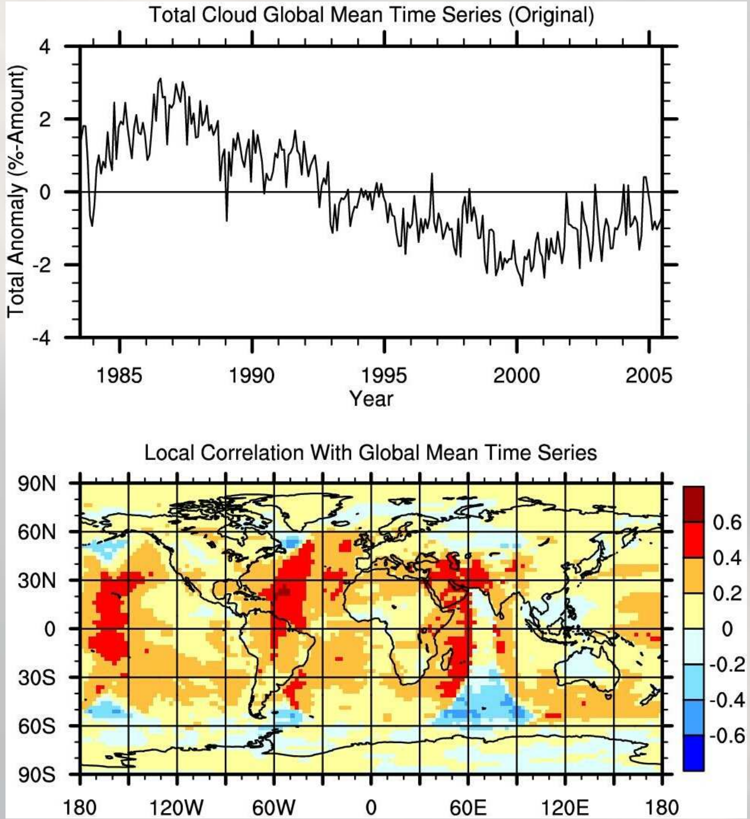
CA change : cluster analysis correcting for artefacts

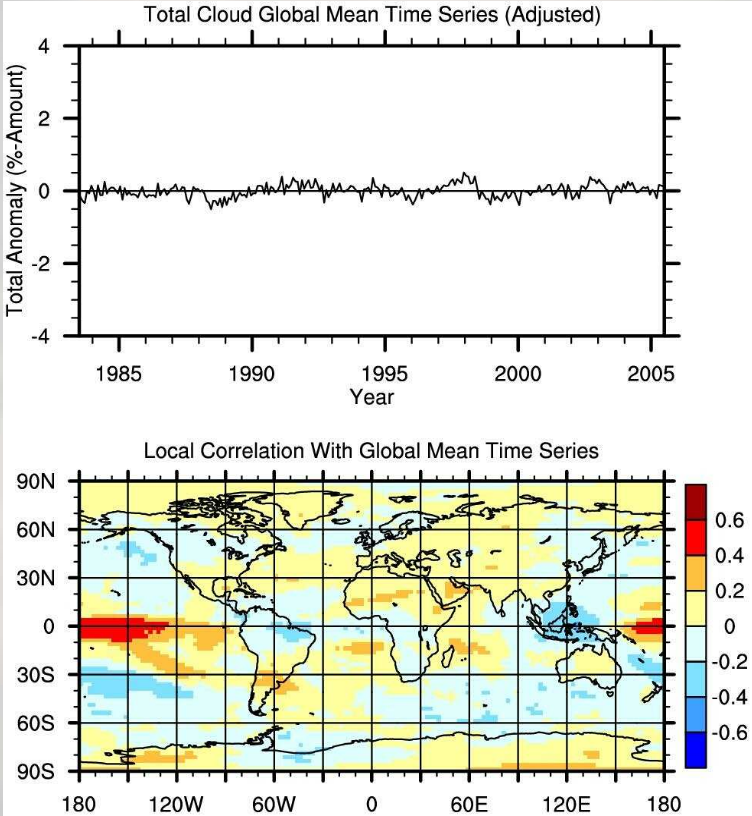
J. Norris

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)





Satellite observations:

❖ unique possibility to study cloud properties over long period

-> climatological values of CA, HCA, MCA and LCA (also ε, τ) 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

❖**preliminary 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 and active CALIPSO)

ISCCP underestimates HCA by 25%/10% in tropics/midlat, overestimates MCA

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

❖ **investigate effect of CALIPSO coverage**

❖ **diurnal cycle**: TOVS-B (using sat drift) extends ISCCP during night

❖ **Trend analysis:** careful of satellite drifts, calibration etc.
synergy of different variables important !

❖**finish WMO report (spring 2008) & prepare publication**

❖**Climatological values of CA, HCA, MCA, LCA maps per month are made available for HIRS-NOAA, PATMOS, MODIS-CE, ISCCP (also Hτ, Mτ, Lτ), TOVSB (also Hε, Mε, Lε):**

-> flux computations by *Stefan Kinne*

❖ **next meeting probably in late spring 2008**