Assessment of cloud properties from Satellite Data: ISCCP,TOVS Path-B, UW HIRS

Claudia Stubenrauch

CNRS/IPSL - Laboratoire de Météorologie Dynamique, France

ISCCP, TOVS Path-B, UW-HIRS cloud climatologies

Evaluation of cloud properties

Average cloud properties

Regional cloud properties + seasonal variations

Diurnal variations

Climate monitoring:

trends and where they can originate from

Global longterm cloud datasets:

1) **Imagers** on geostationary (GEO) and polar (LEO) satellites:

ISCCP *(Rossow et al., BAMS 1999)* **1983-2004**

- 2 radiances during daylight (IR +VIS)
- every 3 hours, 5 km resolution sampled to 30 km, 2.5°
- **CA, T_{cld}, τ_{cld}, p_{cld}, CA per cloud type -> HCA, MCA, LCA**
- **$r_{e,}$ LWP / IWP**

2) **Vertical IR sounders** on polar satellites:

TOVS Path-B *(Stubenrauch et al., J. Clim. 2006)* **…,1987-1995,…**

- cld detection: MSU-HIRS, cld properties: χ^2 - Nε for 5 radiances along CO_2 absorption band
- morning *(NOAA10,12)* + afternoon satellites *(NOAA11)*, 20 km resolution, averaged over 1°
- **CA, T_{cld}, ε_{cld}, p_{cld}, ECA, CA and ECA per cloud type -> HCA, MCA, LCA**
- **D_e, IWP for semi-transparent cirrus**

UW-HIRS *(Wylie et al., J. Clim. 2005)* **1985-2001**

- cld detection: IR window + CO_2 screening, cld properties: CO_2 slicing
- afternoon satellites, nadir ± 18°, correction for satellite drifting, CO_2 correction
- **CA, HCA, MCA, LCA (${T_{cld}}$, p_{cld}, ECA)**

ISCCP

night: 75 hPa p_{cld} bias; uncertainties depend on cloud type:

Stratus clouds, $\tau_{cld}>5$: p_{cld} 25-50 hPa within radiosonde meas., ~ -65 hPa bias; err $T_{cld}<1.5$ K

high clouds (with diffuse top), $\tau_{cld}>5$: 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 double droplet size

TOVS Path-B

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)

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

UW HIRS *(for Wylie and Menzel 1999)*

p_{cld} 70 hPa above top (lidar, North America)

p_{cld} 100 hPa above for transmissive cloud overlying opaque cloud

Average CA

ISCCP (84-04) TOVS-B (87-95)UW-HIRS (85-01)

Cloud type amounts (%)	**global**			**ocean**			**land**		
all	66	73	75	70	74	77	58	69	70
Thick Cirrus	2.8	2.4		2.8	1.9		2.8	3.5	
Cirrus	19.2	27.3		18.2	26.9		21.5	27.8	
High-level	22.1	29.7	33.4	21.1	28.8	34.3	24.3	31.3	33.9
Mid-level	18.0	12.1	11.5	17.9	10.3	10.5	18.1	16.6	11.8
Low-level	25.5	30.9	29.7	29.1	35.1	32.0	16.5	20.5	24.2

diurnal sampling, time period: ~1% effect

~ 70 % (±5%) cloud amount: 5-12% *more over ocean than over land*

25-30% low clouds: 8-15% *more over ocean than over land*

~33% high clouds: *only 3% thick Ci; more over land than over ocean?*

IR vertical sounders ~ 10% more sensitive to Ci

Regional CA

ISCCP (84-04) TOVS-B (87-95)UW-HIRS (85-01)

Cloud type amounts (%)	NH midl			tropics			SH midl		
all	68	73	75	63	71	75	74	79	83
Thick Cirrus	3.4	3.0		3.5	2.5		3.1	2.4	
Cirrus	20.0	24.7		25.5	44.8		16.2	21.8	
High-level	23.4	27.7	32.8	29.0	47.3	44.6	19.3	24.2	33.5
Mid-level	21.1	16.2	12.8	12.7	4.1	5.1	26.7	14.8	15.1
Low-level	25.7	27.1	29.7	19.6	20.6	25.6	36.2	38.7	34.6

IR vertical sounders more sensitive to Ci: 5%-20% (midlat/tropics)

CA: SHm>NHm>trp ISCCP (6%,5%), TOVS-B (6%,2%), UW-HIRS (8%,0%)

HCA: trp>NHm≥SHm ISCCP (10%, 4%), TOVS-B (20%, 4%), UW-HIRS (11%,0%)

LCA: SHm>NHm>trp (10%, 6%), (10%, 6%), (5%, 4%)

UW-HIRS less latitudinal variation than TOVS-B

Average + regional cloud properties

ISCCP (84-04) TOVS-B (87-95)TOVS-A (85-01)

	global			ocean			land		
T_{cld} (K)	**261**	**261**		**265**	**263**		**250**	**255**	
p_{cld} (hPa)	**577**	**604**	**544**	**616**	**628**	**545**	**481**	**543**	**543**
ECA (%)	**55**	**47**	**40**	**59**	**48**	**42**	**46**	**45**	**36**

ISCCP (84-04) TOVS-B (87-95)TOVS-A (85-01)

	NH midl			tropics			SH midl		
T_{cld} (K)	**257**	**259**		**265**	**259**		**259**	**262**	
P_{cld} (hPa)	**552**	**594**	**583**	**544**	**513**	**435**	**624**	**650**	**603**
ECA (%)	**58**	**48**	**45**	**50**	**41**	**32**	**74**	**54**	**54**

T_{cld} within 2K / 5K for ocean /land

clouds lower + thicker over ocean than over land: 135/85/**2** hPa + 13/3/**6** %

P_{cld}, ECA: trp<NHm<SHm: 8/80/150 hPa 70/55/20 hPa + 8/7/13 % 16/6/14 %

TOVS-A much smaller p_{cld} and ECA in tropics than TOVS-B

Subvisible Cirrus ($\tau<0.1$)

Stratospheric Aerosol and Gas Experiment

SAGE II: *1984 – 1991,* **SAGE III:** *since 2002*
Limb occultation sunrise / sunset at 1 μm, 0.5 μm, (7 / 11 λ's)
Path: 200km (x *2.5 km)*

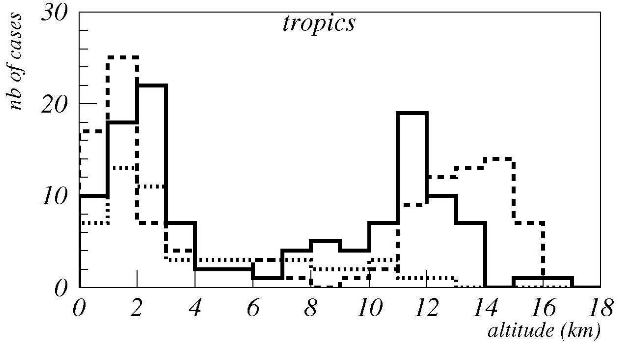
L (km)	High cloud amount (%) *January / July*	Ci (%) *January / July*	Subvisible Ci (%) *January / July*
200	74.6 / 69.0	50.2 / 46.5	24.4 / 22.5
75	32.1 / 29.7	21.6 / 20.4	10.5 / 9.3

(Liao et al. 1995)

ISCCP-SAGE => L=75 km *(Liao et al.1995)*

HIRS-SAGE => L=130 km *(Wylie+Wang 1997)*

1/3 of high clouds: subvisible Ci
(not observed by downlooking radiometers)



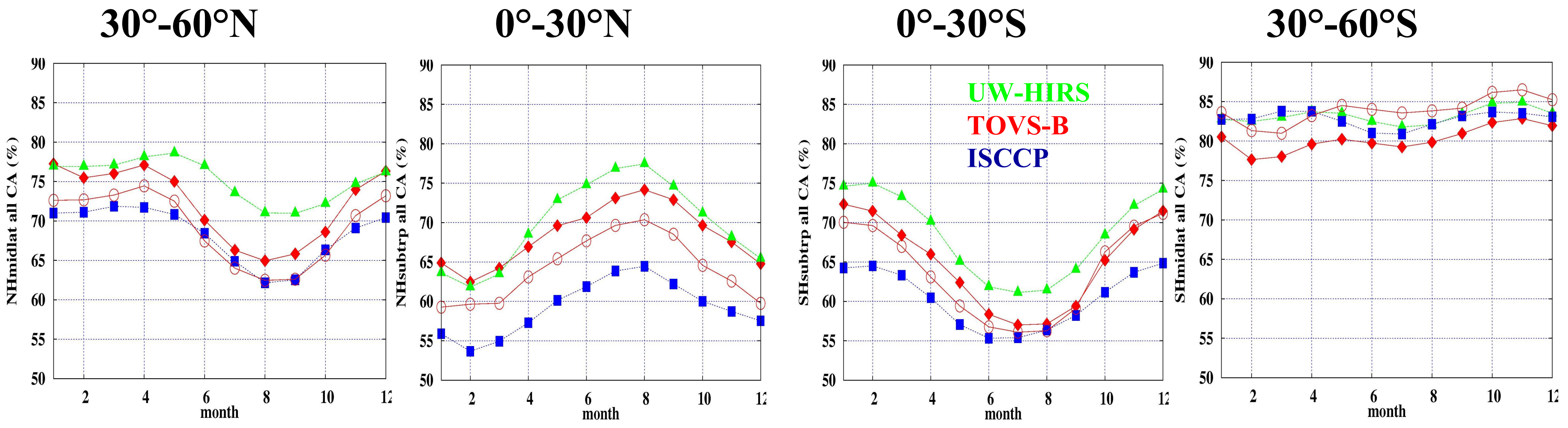
TOVS-B LITE : ***effect of subvisible Ci***

NH midlat.: Δz_{hgh} = **0.3 km**

tropics: Δz_{hgh} = **2 km**

Stubenrauch et al. 2005

CA seasonal cycle in latitude bands



30°-60°N **0°-30°N** **0°-30°S** **30°-60°S**

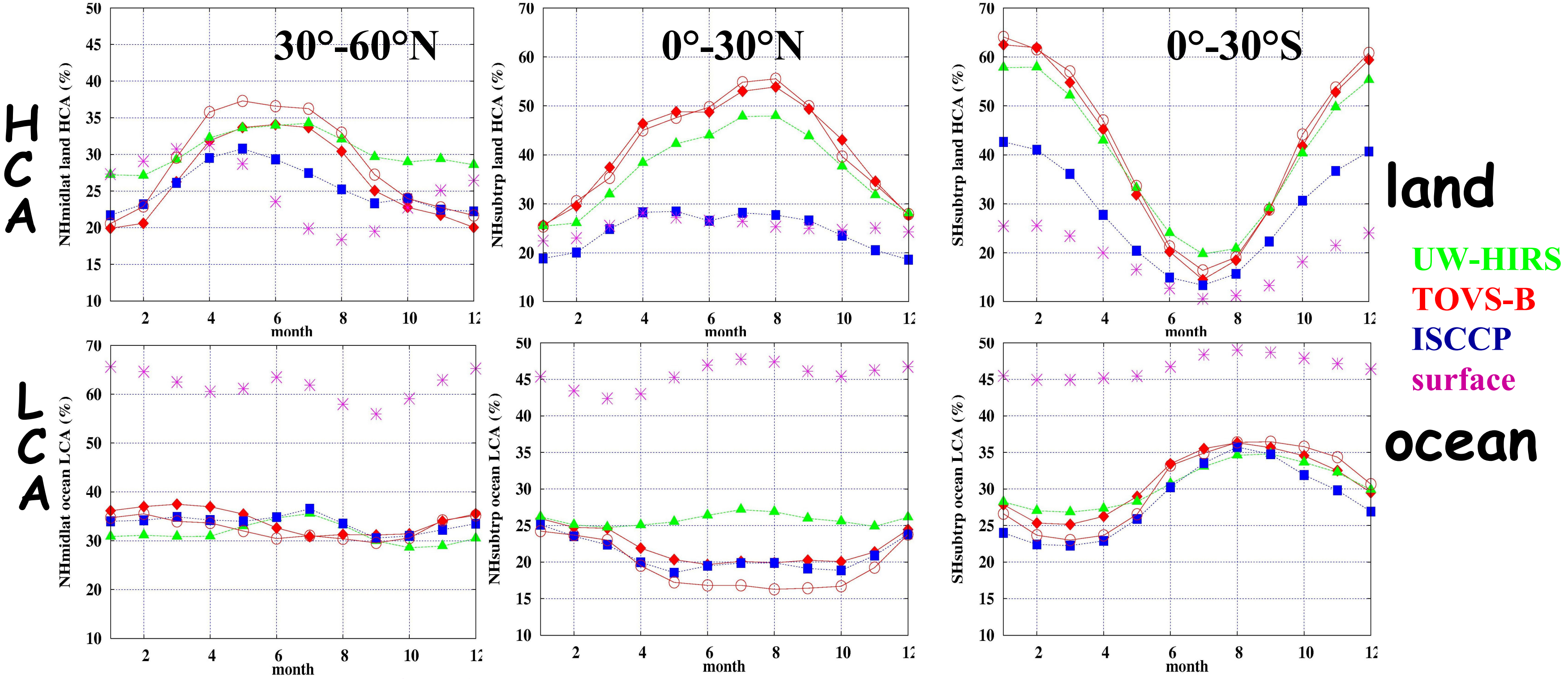
- Seasonal and diurnal cycles stronger over land than over ocean
- Seasonal cycle of CA stronger than the one of ECA (*from TOVS-B*)

TOVS/HIRS absolute values 5-12% larger than ISCCP

Seasonal cycles similar: strongest in subtropics, negligible in SH midl.:

8-10%, 10-15% 10-15% 4%

HCA, LCA seasonal cycles in latitude bands



surface observation averages by Ryan Eastman, Steve Warren

Seasonal cycle HCA: 7-15%, 10-27%, 18-45% over land

Seasonal cycle LCA: 5%, 5-7%, 8-12% over ocean

surface observations: 10-20% more LCA and smaller seas. cycle over ocean than satellite

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

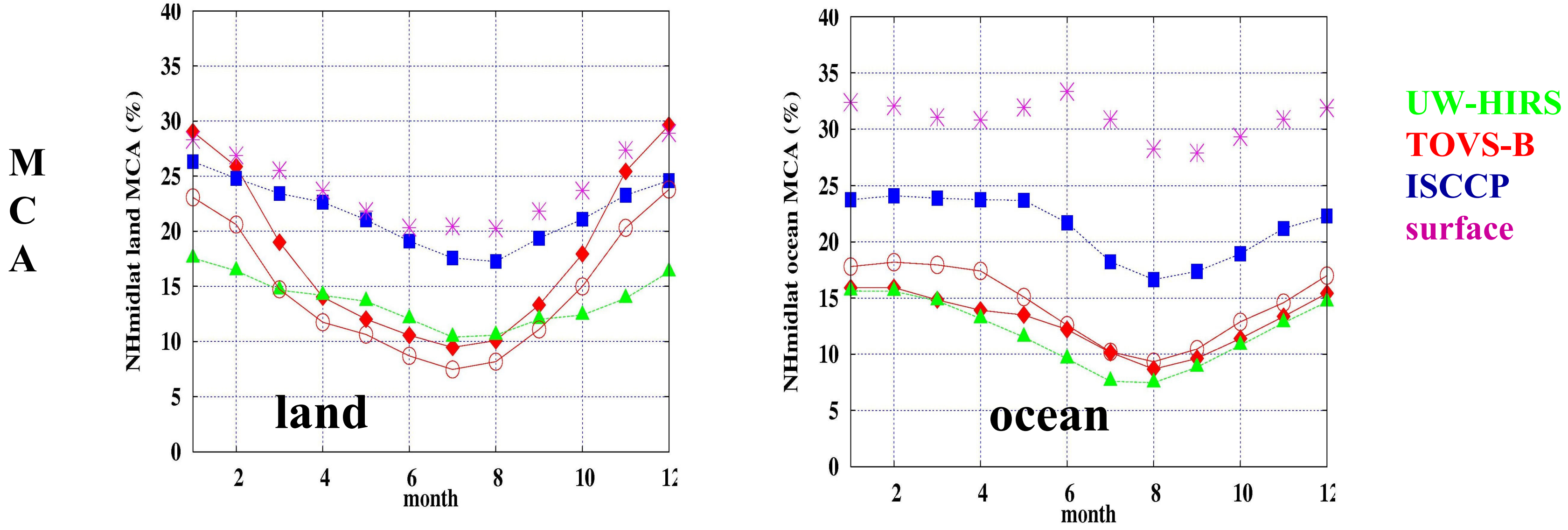
HCA seas. cycle smaller than satellite, modulated by LCA seas. cycle

ISCCP underestimates seasonal cycle of HCA by up to 20%

UW-HIRS slightly smaller seasonal cycle than TOVS-B

MCA seasonal cycle in NH midlatitudes

30°-60°N

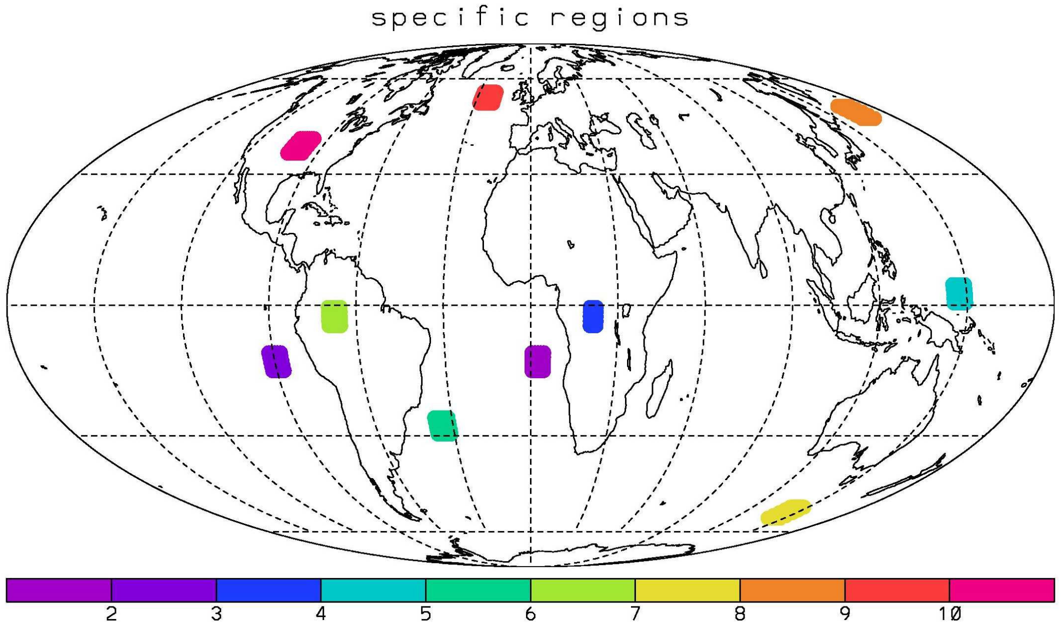


Seasonal cycle MCA: 7-17% over land, 7% over ocean

ISCCP, UW-HIRS smaller seasonal cycle over land than TOVS-B

MCA seas. cycle modulated by HCA seas. cycle: min when HCA largest

CA seasonal cycle over selected regions

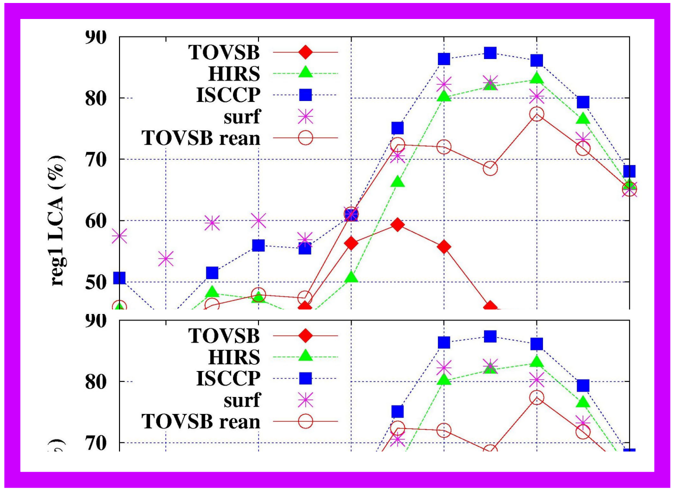


UW-HIRS

TOVS-B

ISCCP

surf

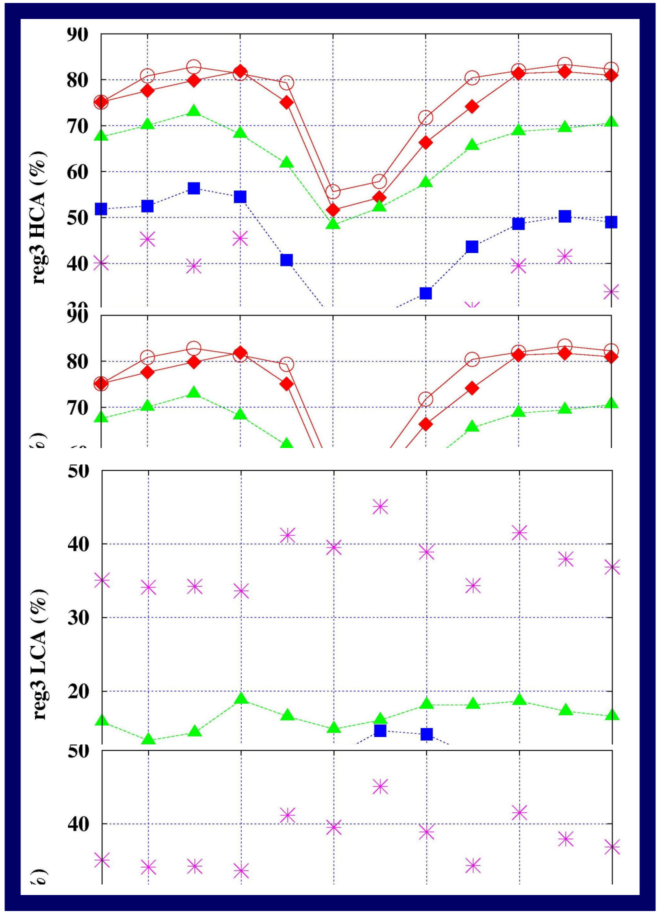


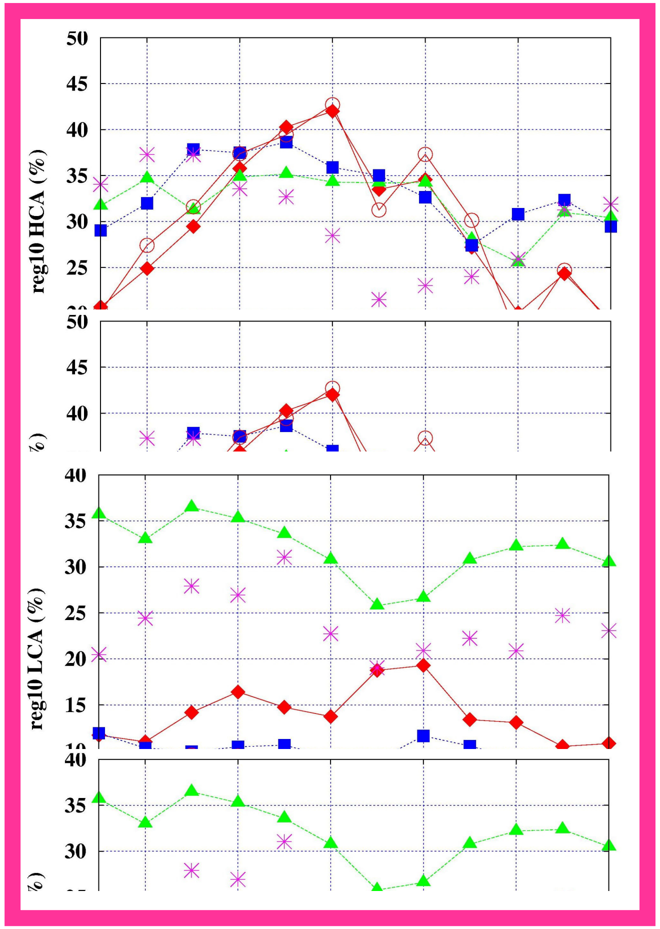
Stratocumulus off West Africa: group A

σCA = 2.8-3.6%, σp_{cld} = 14-28 hPa

TOVS-B did not pick up seas. cycle of low clouds (not detected), re-analysis with improved detection does

Very good agreement with surface observations





UW-HIRS
TOVS-B
ISCCP
surf

convection Africa: group C

σCA=1.5-3.4%, σp_{cld}=19-23 hPa

TOVS-B most high, lessest low clouds

North America: group C

σCA=3.7-3.9%, σp_{cld}=17-26 hPa

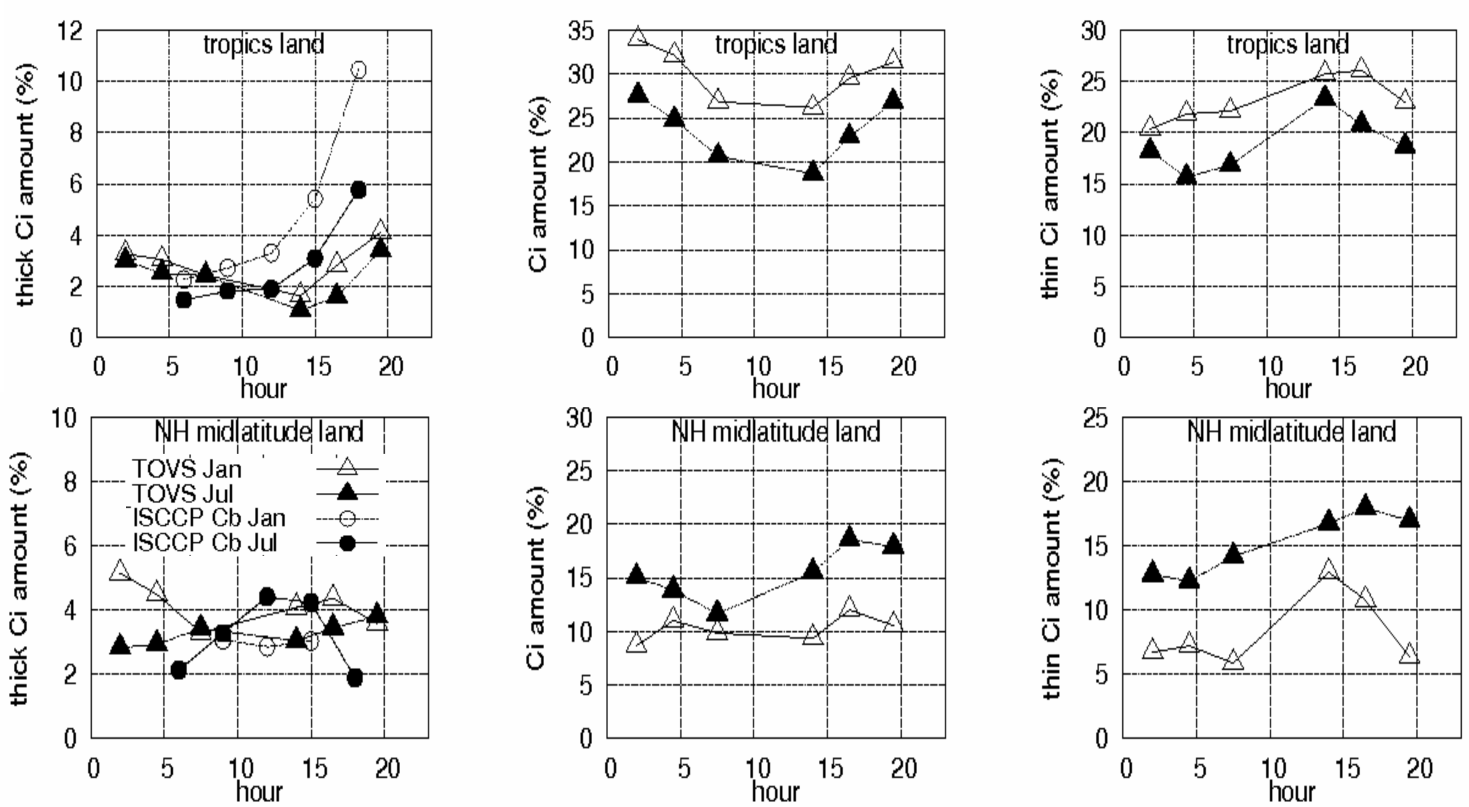
HIRS 15% more low clouds than TOVS-B, ISCCP

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 and in summer

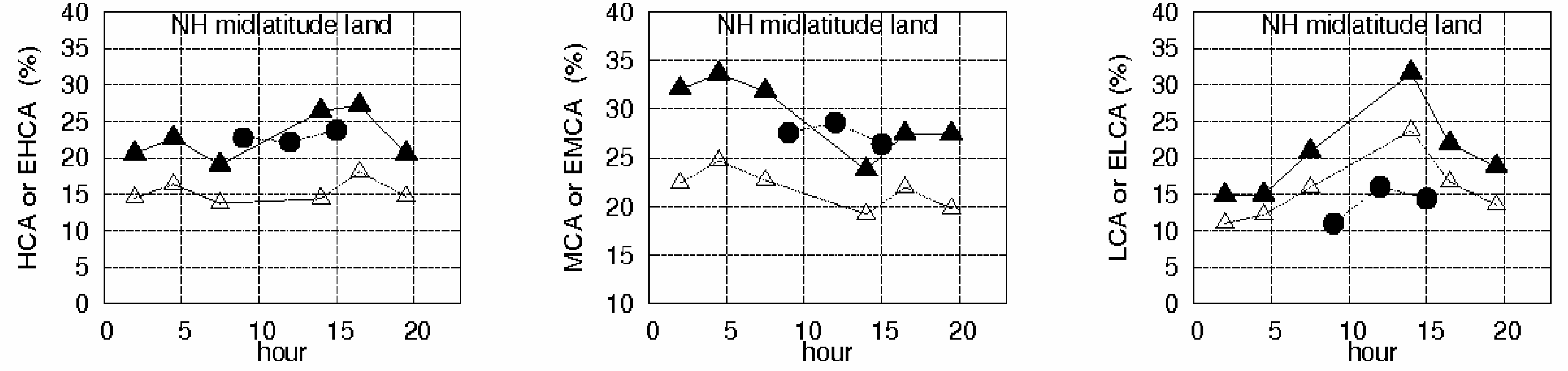


- ➢max. thin cirrus in early afternoon
- ➢max. cirrus and thick cirrus in evening
- ➢cirrus occurrence continues during night and decreases during day

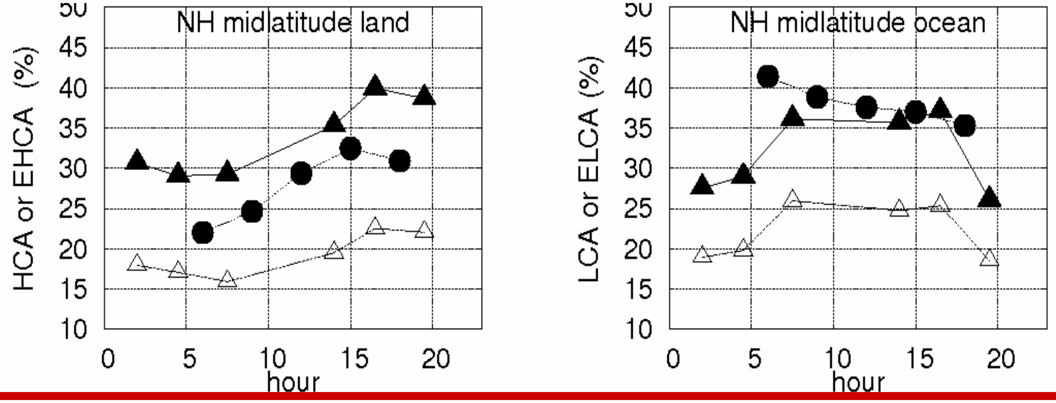
diurnal cycle of clouds in NH midlatitudes

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

diurnal cycles of high and midlevel clouds over ocean negligible



w
i
n
t
e
r



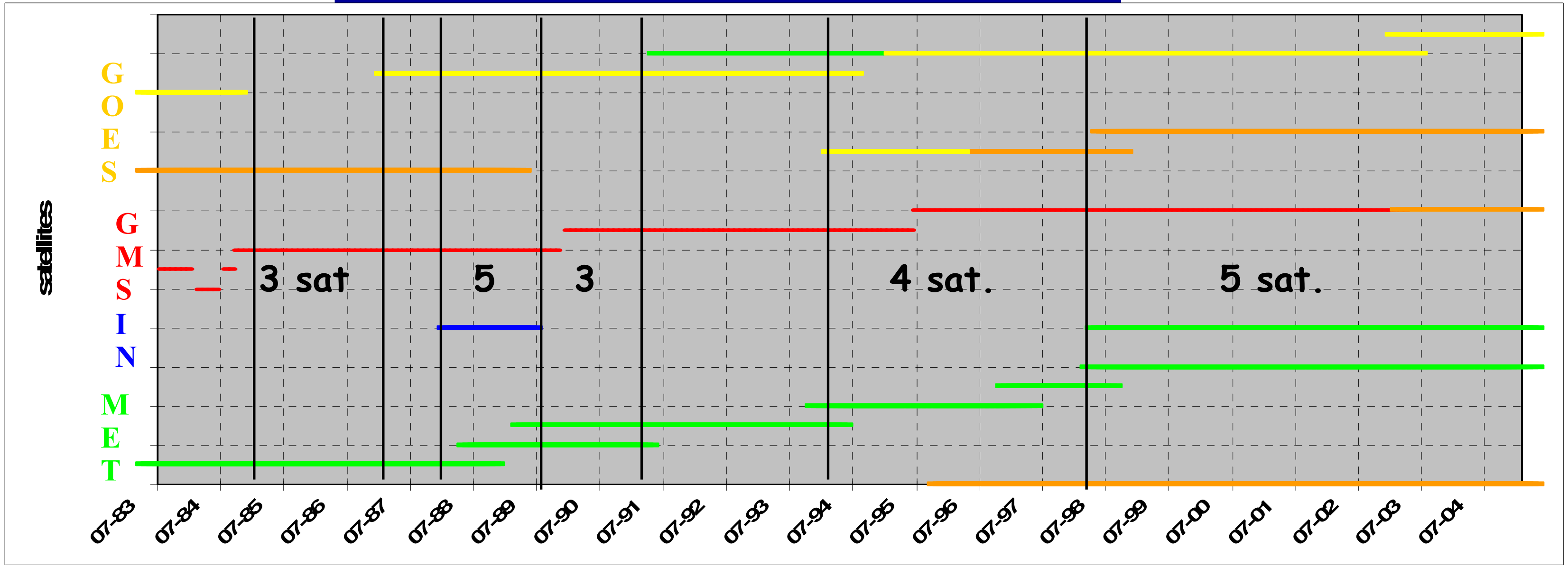
s
u
m
m
e
r

TOVS-B extends ISCCP during night

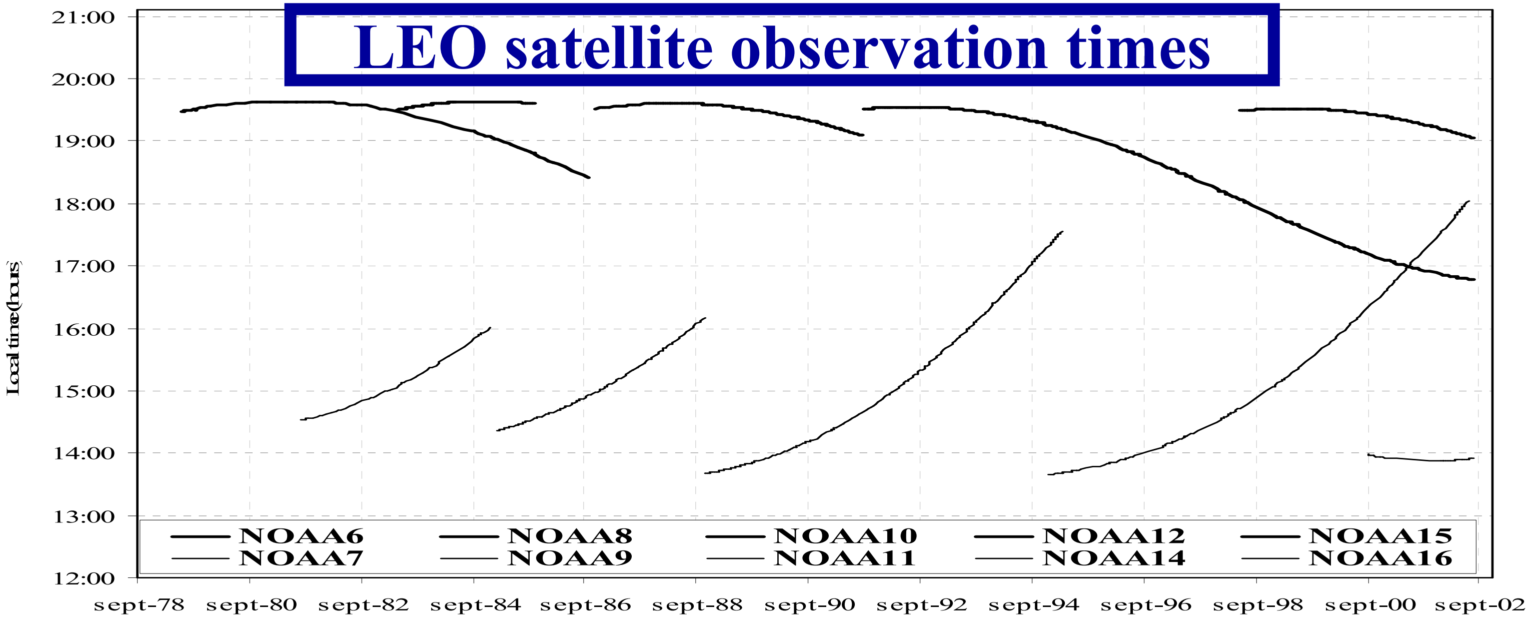
Stubenrauch et al. J. Climate 2006

- ➢land winter: max MCA early morning (10% cycle),
  max thin Ci / LCA in early afternoon (-/15% cycle)
- ➢land summer: max HCA afternoon (10% cycle)
- ➢ocean summer: LCA increase at sunrise, decrease at sunset (10% cycle)

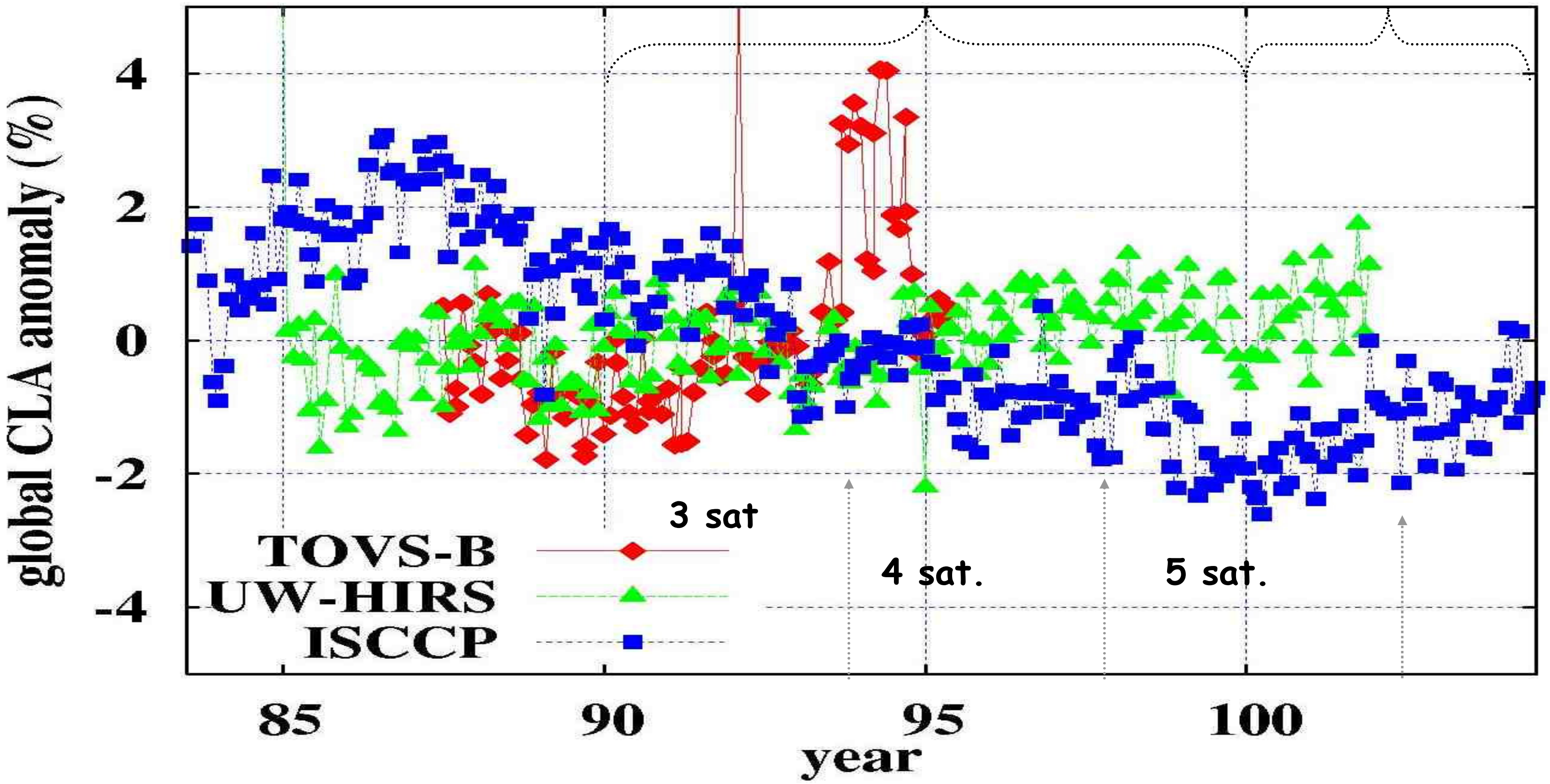
GEO Satellite positions



LEO satellite observation times



Global CA trends: ISCCP, UW-HIRS, TOVS-B



global CLA within ±2.5%

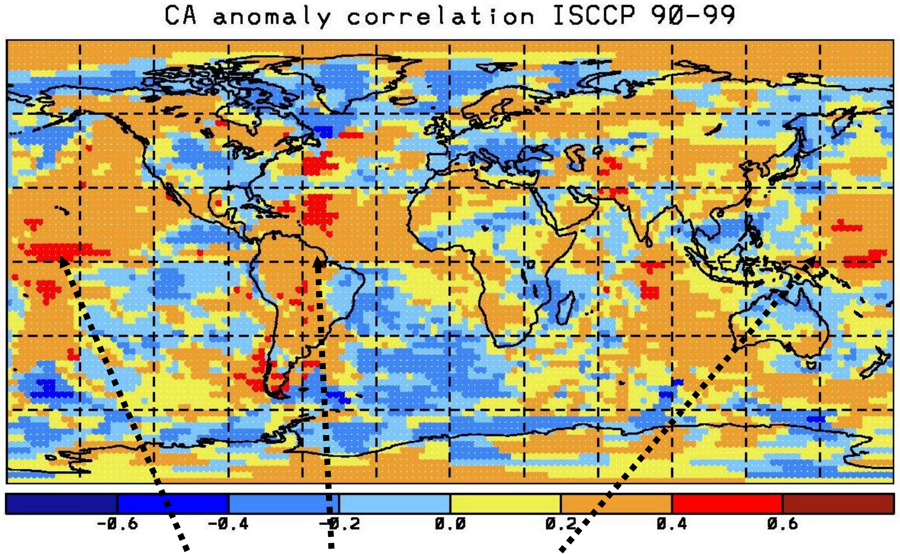
UW-HIRS: more or less stable

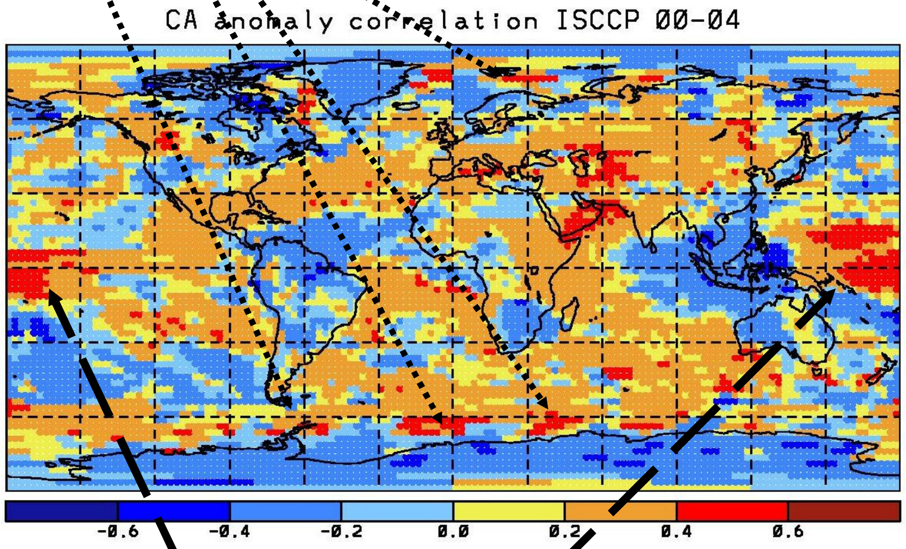
ISCCP: ~5% decrease between 1987 and 2000
related to increasing number of GEO satellites ?

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)*

NOAA14 drift ?

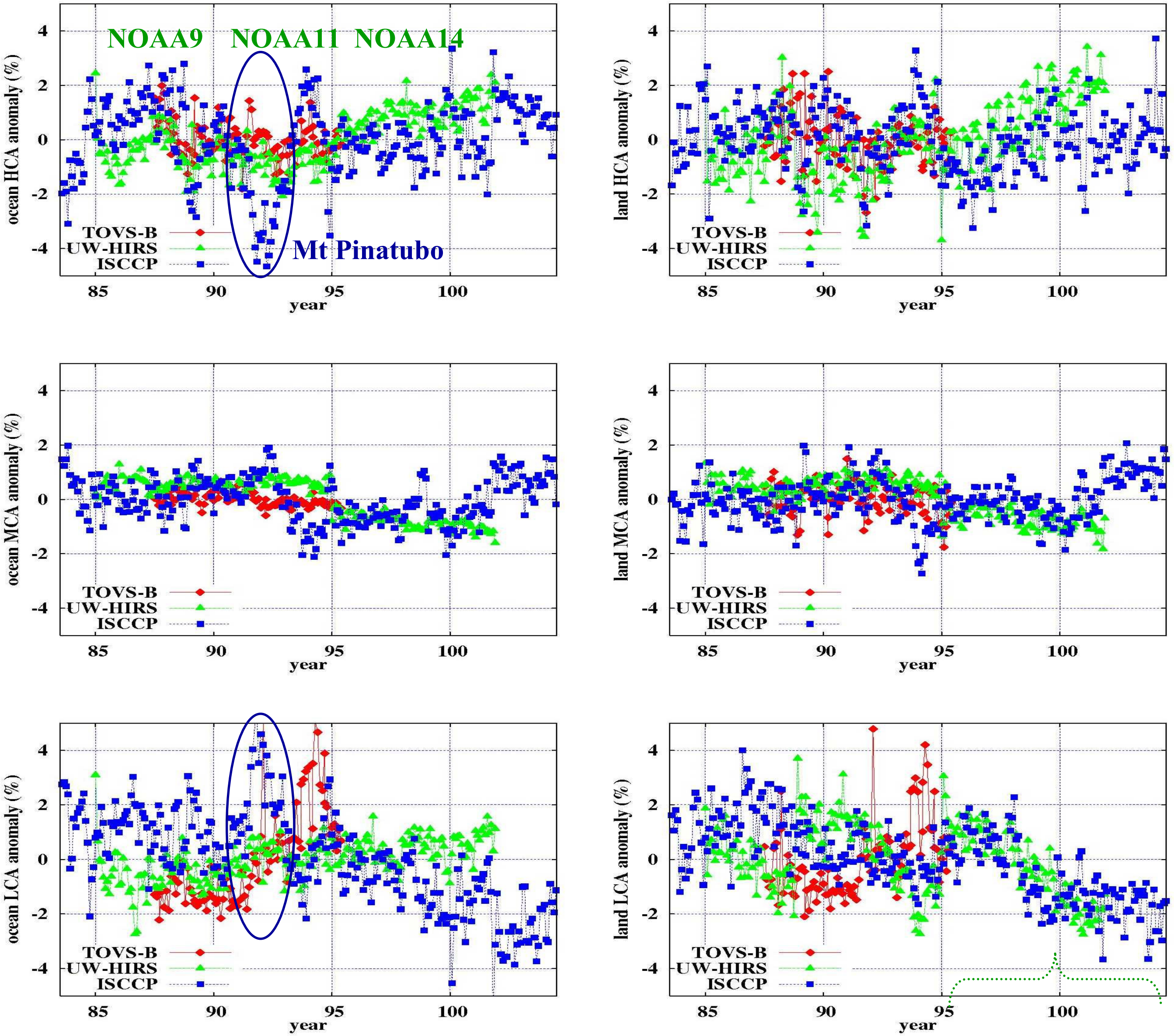




angular effects ?

GMS replaced by GOES in 2003

Trends of cld type amount over ocean and over land



ISCCP:

1991 Mt Pinatubo eruption

4% effect on HCA and LCA

TOVS Path-B:

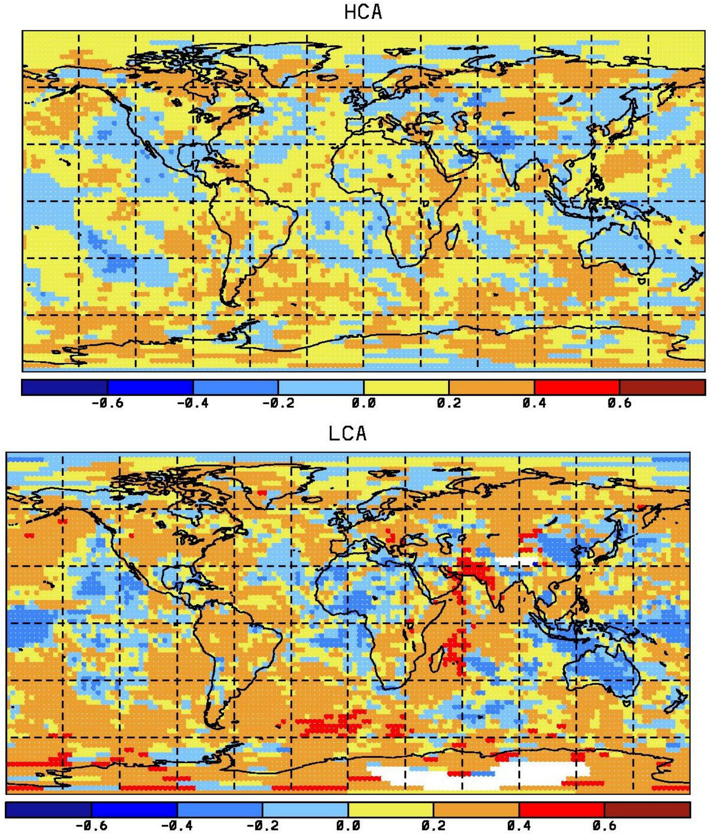
4% LCA increase (in tropics)

UW-HIRS, ISCCP:

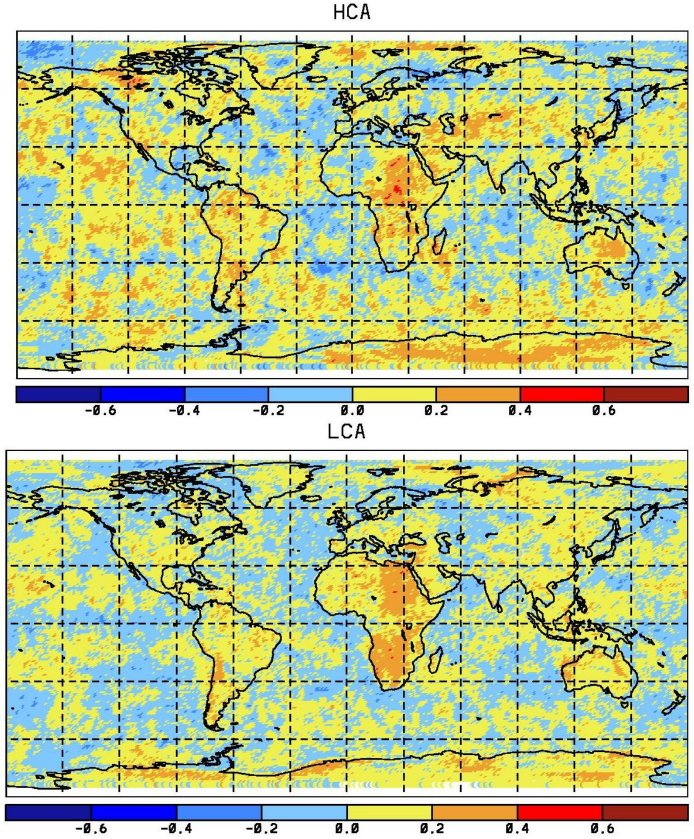
5% LCA decrease over land

linked to NOAA14 4-hour drift?

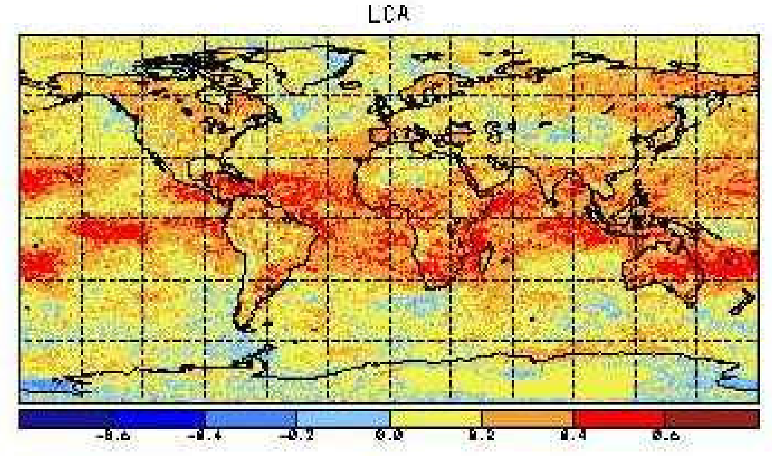
ISCCP 95-04



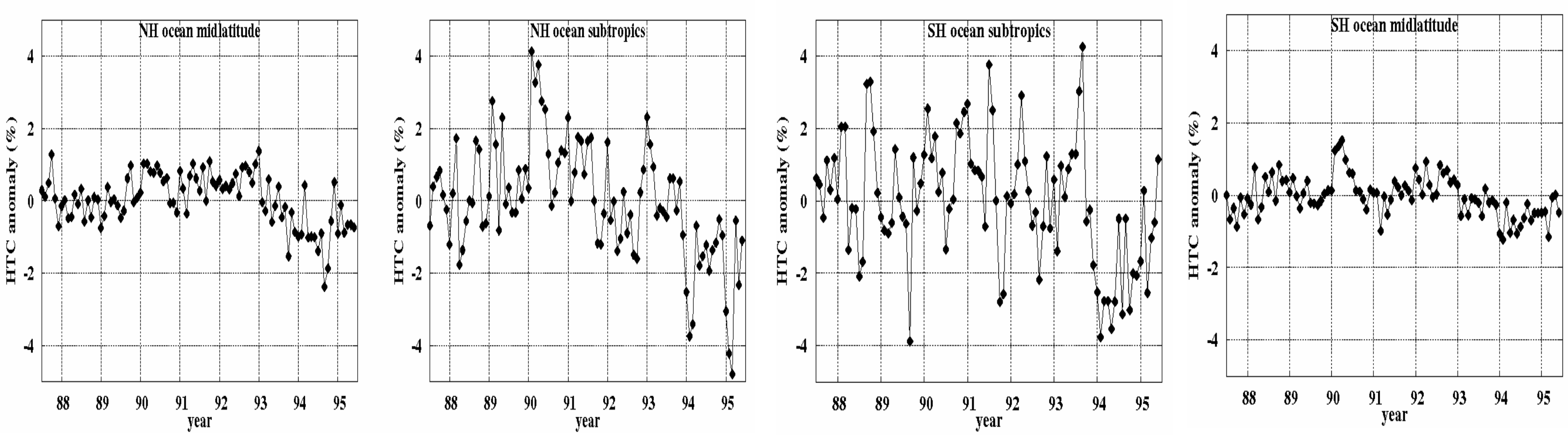
UW-HIRS 95-01



TOVS Path-B 87-95



LCA increase 1993-1994 linked to tropics



HCA stable, but T_{cld} of high clouds decreasing

Satellite observations:

- unique possibility to study cloud properties over long period

Intercomparisons:

- average cloud properties: good agreement

70% (±5%) clouds: 25-30% low clouds,
30% high clouds (+ ~15% subvisible Ci),stable within 2%

- regional variations different (latitudinal, ocean/land)
- IR sounders more sensitive to cirrus: HCA +4% (midlat) - +20 % (trop)
- seasonal cycle: CA good agreement (also surf. obs, except SH midlat, polar)
  - UW-HIRS slightly smaller variation than TOVS-B
  - ISCCP HCA cycle in tropics underestimted
- diurnal cycle: TOVS-B extends ISCCP during night

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