

Assessment of Global Cloud Climatologies from Satellite Observations

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input from participants of GEWEX Cloud Assessment

2nd GEWEX Cloud Climatology Assessment Workshop

6-7 July 2006 in Madison, USA: 20 presentations, 50 participants

Co-chairs: Bryan Baum (SSEC, Univ. Wisconsin), Claudia Stubenrauch

Longterm cloud climatologies:

ISCCP

TOVS Path-A, TOVS Path-B, UW-HIRS

Surface observations

SAGE

PATMOS-X

EOS cloud climatologies:

MODIS

AIRS

MISR

Polar cloud datasets

Summary and evaluation of cloud properties:

average cloud properties, regional, interannual, seasonal, diurnal variations

Climate monitoring: trends and where they can originate from

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

Longterm cloud datasets:

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

ISCCP (*Rossow et al., BAMS 1999*)

1983-2005

- 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 (TOVS) on polar satellites:

TOVS Path-A (*Susskind et al., BAMS 1997*)

reanalysis: **1985-2001**

- cld clearing, cld properties: from 5 radiances along CO₂ absorption band & 2 FOVs
- **ECA, p_{cld} weighted by ECA**

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

...,1987-1995,...

- cld detection: MSU-HIRS, cld properties: $\chi^2 - N\epsilon$ for 5 radiances along CO₂ 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 + CO₂ screening, cld properties: CO₂ slicing
- afternoon satellites, nadir $\pm 18^\circ$, correction for satellite drifting, CO₂ correction
- **CA, HCA, MCA, LCA**

3) Analysis using surface weather reports:

SOBS ocean (Hahn & Warren 1999) 1952-1996 SOBS land (Hahn & Warren 2003) 1971-1996

- every 6 to 3 hours, 5°
- CA, LCA; MCA, HCA (random overlap assumed), cloud base

4) Cloud occurrence from solar occultation :

SAGE (Wang et al. 1996, 2001) 1984-1991, 1993-2005

- at sun rise and sun set: 2.5 x 200 km hor. & 1 km vert. resolution
- extinction $2 \times 10^{-4} - 2 \times 10^{-2} \text{ km}^{-1}$: **subvisible cirrus**, $2 \times 10^{-2} \text{ km}^{-1}$: **opaque cloud**
- Occurrence per 1km layer, T_{cld} , P_{cld}

5) Radiometers (AVHRR) on polar satellites:

PATMOS-X (NESDIS/ORA; Heidinger) Jan, Apr, Jul, Oct 1984-2004

- 0.63 μm , 0.86 μm , 3.75 μm , 10.8 μm and 12 μm
- afternoon satellites + morning satellites (1995-2004), 4 km resolution, averaged over 0.5°
- CA, T_{cld} , ϵ_{cld} , P_{cld} , **cloud type**, HCA, MCA, LCA

Average CA

PATMOS averages by A. Heidinger
SAGE averages by P.-H. Wang, preliminary

ISCCP (84-04) TOVS-B (87-95) UW-HIRS (85-01) PATMOS(JAJO04) SAGE(85-99)

Cloud amounts (%)	glo bal					oce an					la nd				
all	66	73	75	62	92	70	74	77	67	91	58	69	70	46	93
Thick Cirrus	3	2	2			3	2	1			3	4	5		
Cirrus	19	27	31			18	27	33			21	27	29		
High-level / CA	33	41	44	37	43	30	39	44	34	44	41	45	49	48	45
Mid-level / CA	27	16	16	18	20	26	14	14	14	19	31	25	17	24	25
Low-level / CA	39	42	37	45	36	41	47	42	42	37	29	30	34	28	30

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 % ($\pm 5\%$) cloud amount: 5-12% more over ocean than over land
PATMOS CA low, esp. over land; SAGE CA (clds $\tau > 0.03$) 1/3 higher (200 km path)
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 sounders ~ 10% more sensitive to Ci than ISCCP&PATMOS
SAGE cloud vertical structure in good agreement with IR sounders

Regional CA

PATMOS averages by A. Heidinger
SAGE averages by P.-H. Wang, preliminary

ISCCP (84-04) TOVS-B (87-95) UW-HIRS (85-01) PATMOS(JAJO04) SAGE(85-99)

Cloud amounts (%)	NH					tro pic s					SH						
	mi	dl										mi	dl				
all	68	73	75	63	91	63	71	75	65	95	74	79	83	76	88		
Thick Cirrus	3	3				4	3				3	2					
Cirrus	20	25				26	45				16	22					
High-level / CA	34	38	44	35	45	46	66	60	54	56	26	30	41	29	42		
Mid-level / CA	31	22	17	22	29	21	6	7	11	13	36	19	18	20	25		
Low-level / CA	38	37	40	43	26	32	30	35	35	32	49	49	42	51	34		

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

CA: SHm>NHm>trp 8-11% difference *exception : SAGE (sampling?)*

HCA: trp>NHm≥SHm 14-36% difference

LCA: SHm>NHm>trp 2-19% difference

UW-HIRS, SAGE less latitudinal variation than TOVS-B:

NCEP - retrieved atmos. profiles

Average + regional cloud properties

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

	glo bal		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		tro pics			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

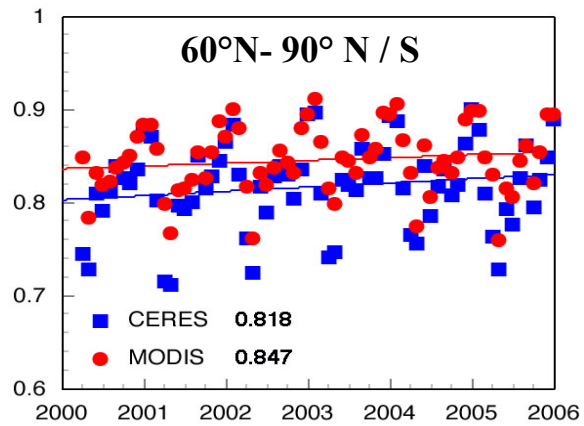
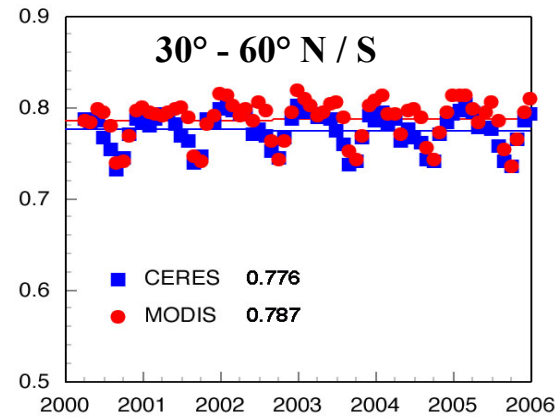
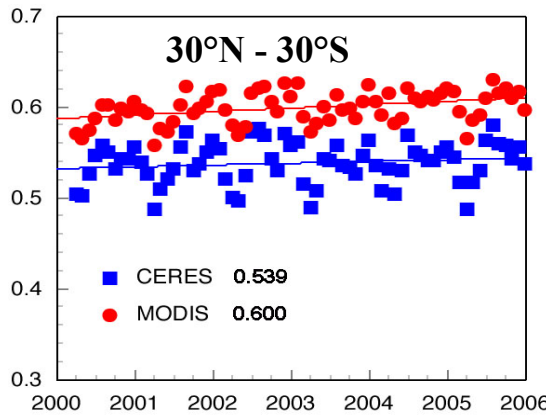
clouds lower + thicker over ocean than over land: 135/85/2 hPa + 13/3/6 %

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!

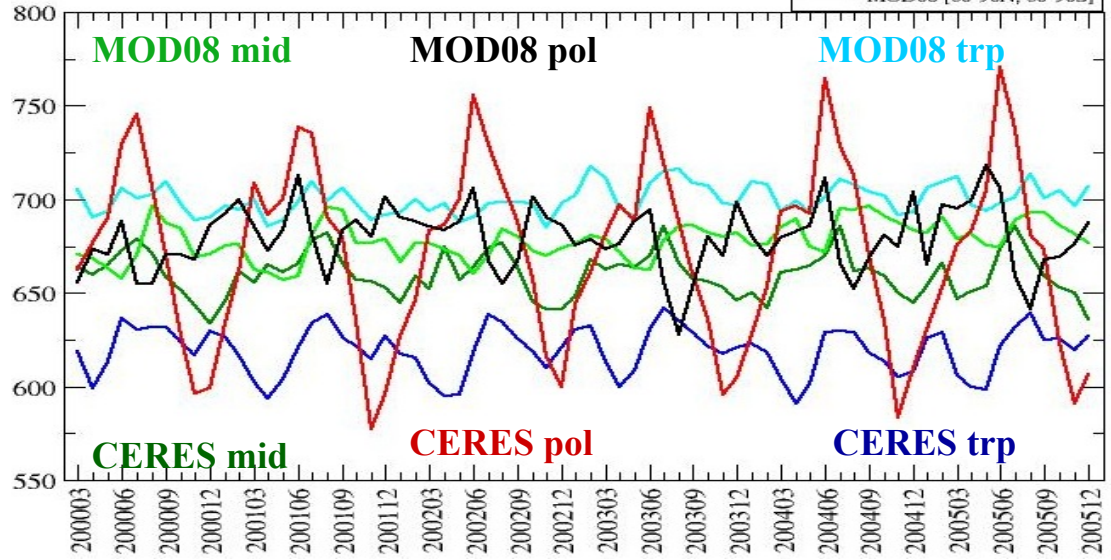
Daytime MODIS CA, p_{cld} : MOD08 (MODIS Team) – CERES inversion

P. Minnis



Time Series of Cloud Top Pressure (mb)

Terra MODIS, Daytime
Ocean



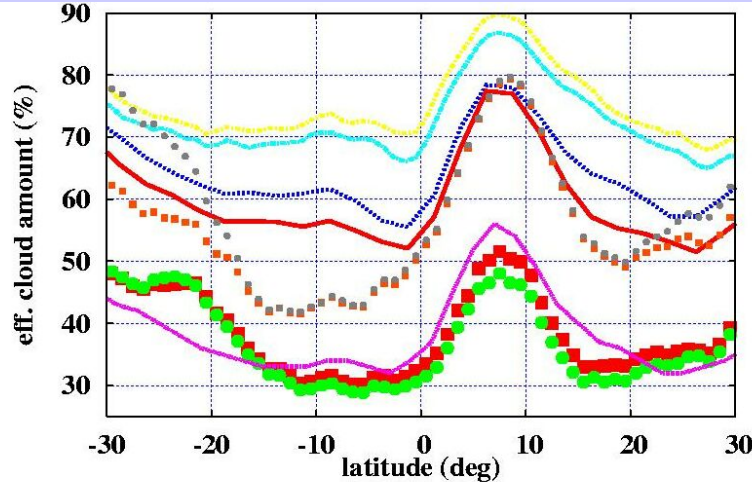
$p_{\text{cld}}(\text{MOD08}) > p_{\text{cld}}(\text{CERES})$
Tropics: $\Delta \sim 75 \text{ mb}$

tropics (15°N-15°S)
HCA 27-31% (T-A)
MCA 5%
LCA 22-26%
Analysis by P. Yang
much smaller HCA than TOVS!

MOD08–AIRS (LMD retrieval) – ISCCP – TOVS B

$CA (MOD08) > CA (ISCCP)$ $ECA (AIRS) \sim ECA (TOVS)$

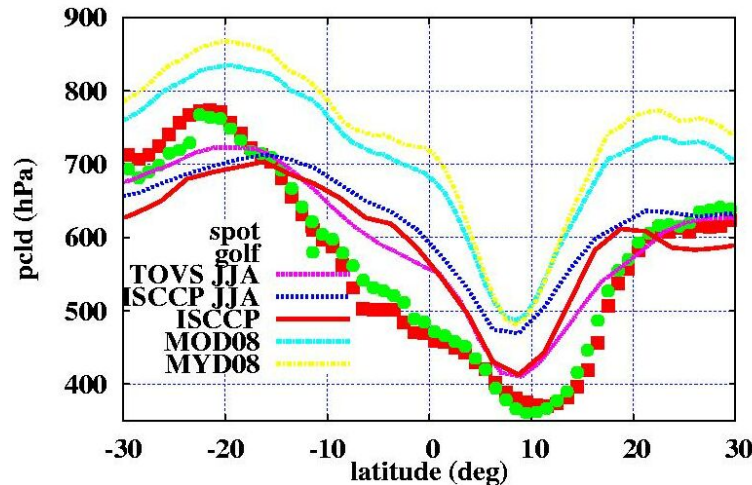
CA
ECA



0703

$p_{cld} (MOD08) > p_{cld} (ISCCP) > p_{cld} (AIRS) \sim p_{cld} (TOVS)$

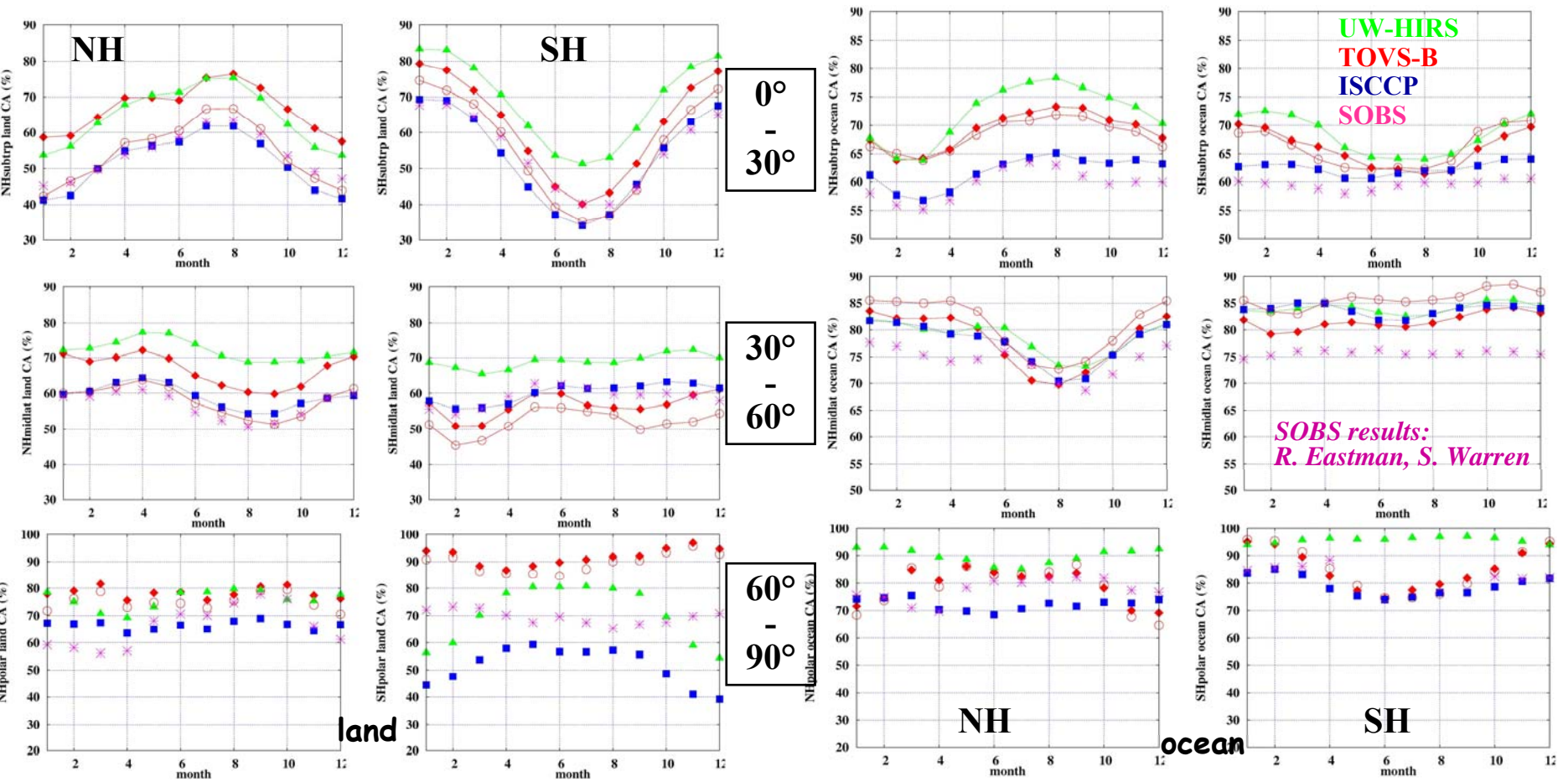
P_{cld}



See poster tomorrow

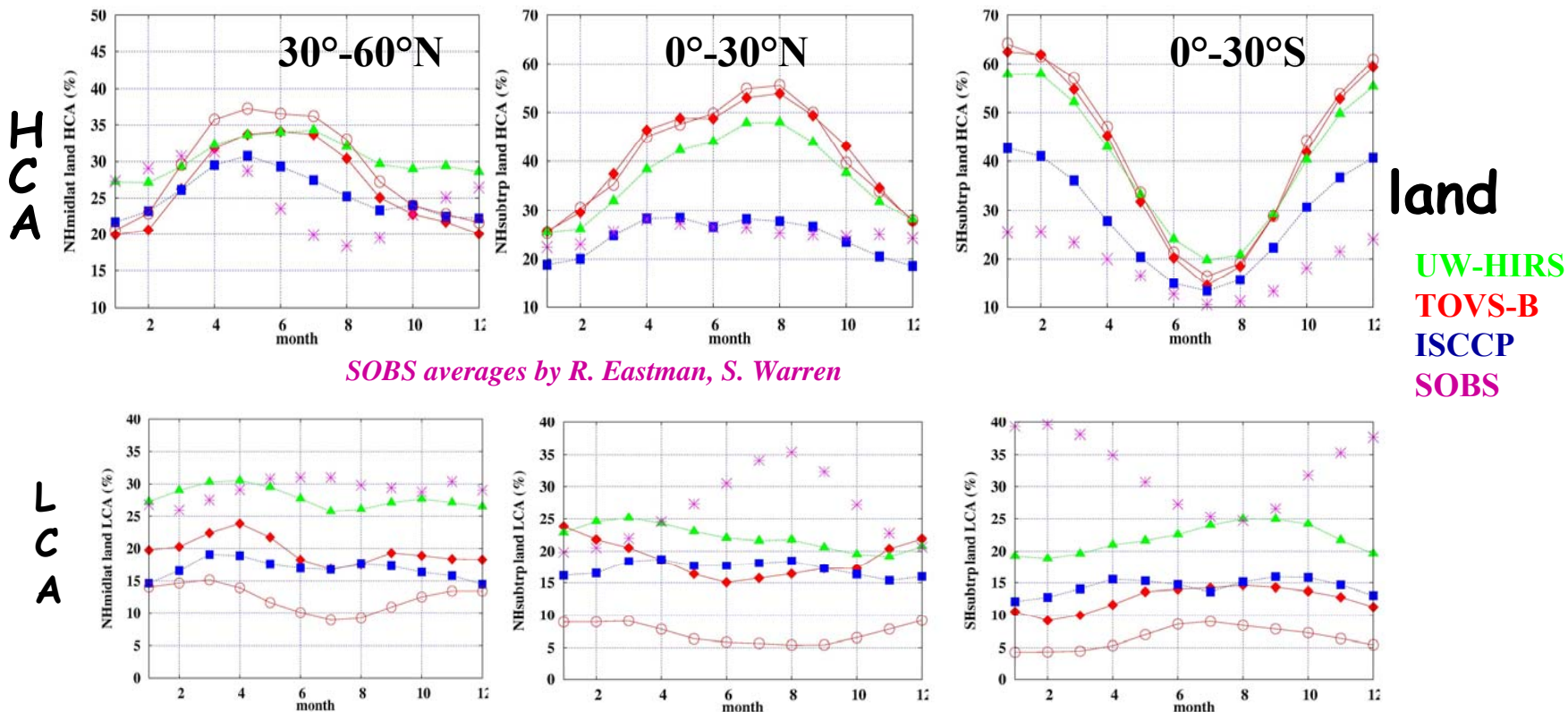
AIRS cloud retrieval preliminary

CA seasonal cycle: NH-SH subtropics, midlatitudes, polar regions



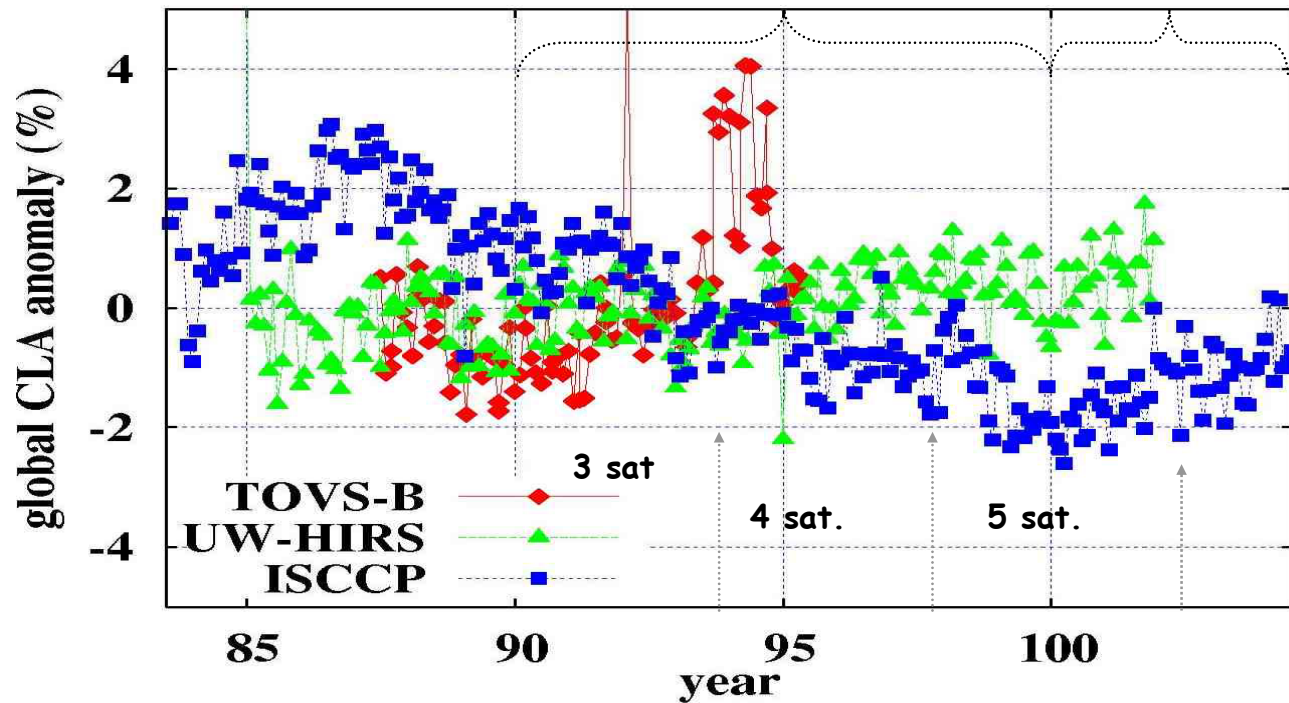
Seasonal (and diurnal cycles) stronger over land than over ocean, strongest in subtropics
Seasonal cycles similar , exception: SH polar land
 N 5% 10% 20% 35% 5-10% 5-15% S N 5-10% 5-15% 10% 5-8% 5% 3-8% S
TOVS/HIRS absolute values 5-12% larger than ISCCP
SOBS close to ISCCP, better agreement over land than over ocean (prob. statistics)

HCA seasonal cycles in latitude bands



HCA seasonal cycle : 7-15%, 10-27%, 18-45% over land
 ISCCP underestimates seasonal cycle of HCA by up to 20%
 UW-HIRS slightly smaller seasonal cycle than TOVS-B
 SOBS HCA seasonal cycle modulated by clouds underneath: HCA min in NH midlat. when LCA max

Global CA trends



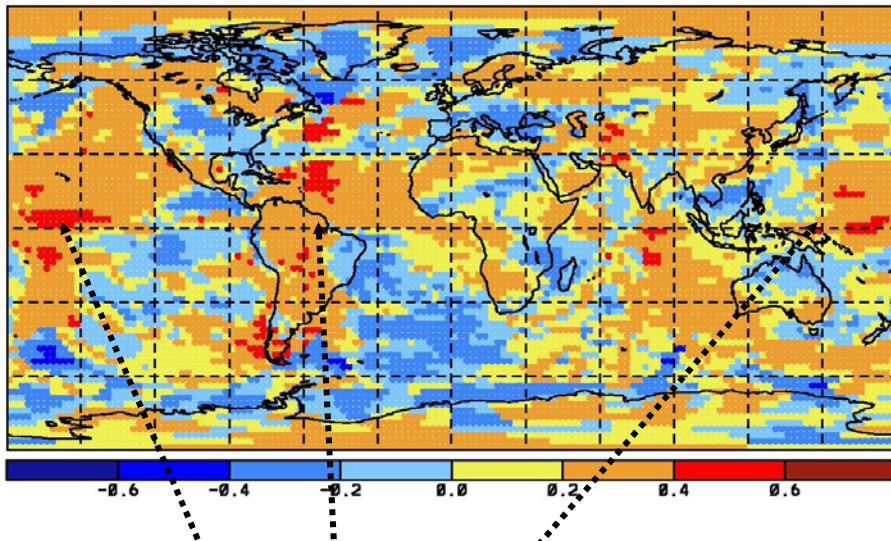
global CLA within $\pm 2.5\%$
UW-HIRS: more or less stable
ISCCP: $\sim 5\%$ decrease from 1987 to 2000
related to increasing nb of GEO satellites ?

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

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: $r(i,j)$

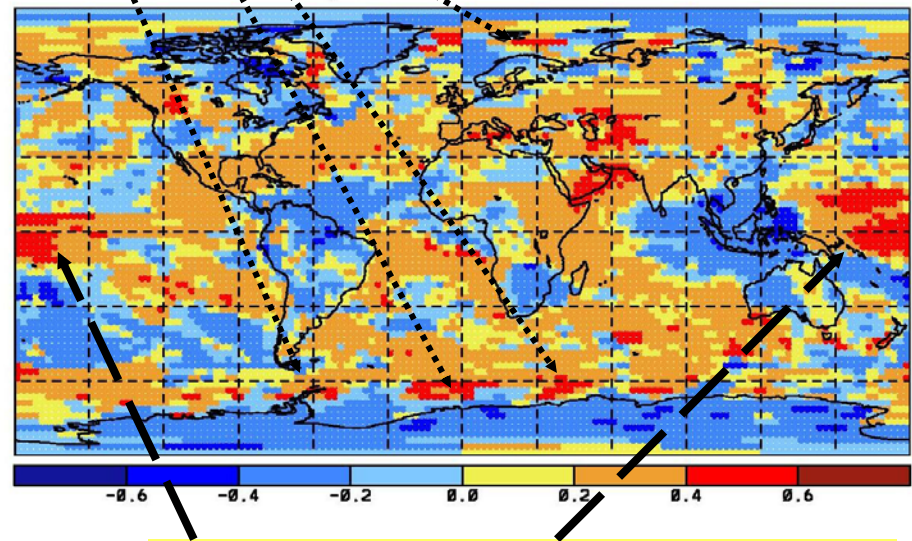
CA anomaly correlation ISCCP 90-99



angular effects ?

NOAA14 drift ?

CA anomaly correlation ISCCP 00-04



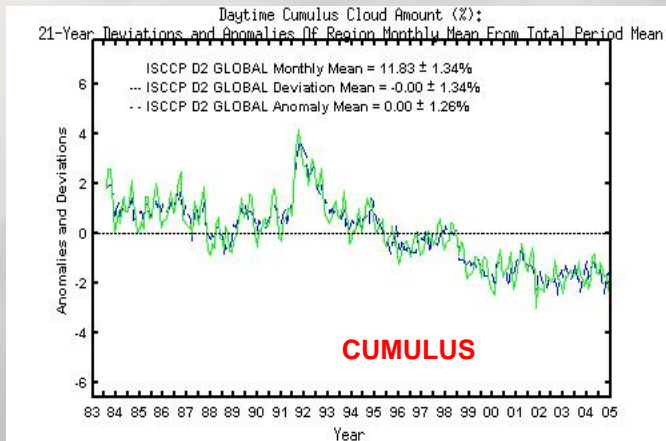
GMS replaced by GOES in 2003

similar results by J. Norris, A. Evans

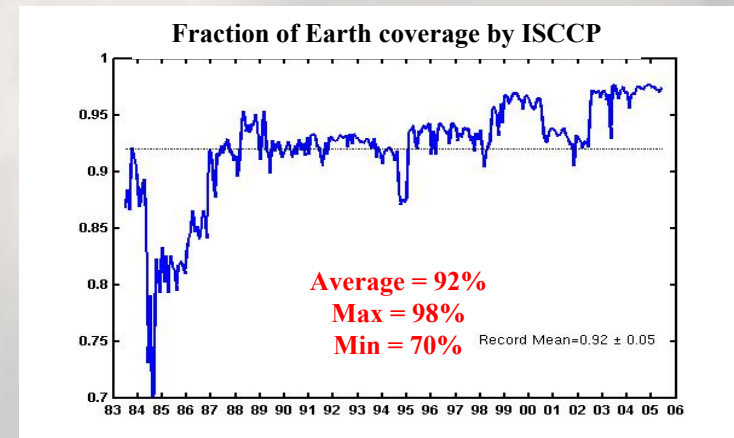
Study on causes for spurious CA changes

W. B. Rossow

- Radiance Calibration effects: <0.5% on ISCCP CA; <1% on CA per type
- Satellite Viewing Geometry effect: 1%
BUT: pattern of θ_v variations does not match CA changes
- Changes in Cloud Property Distribution : decreasing τ of low clouds -> below detection
(*Tselioudis et al. 1992: τ decreases with T*)



- Changes in Sampling Distribution & Coverage:
check for other datasets



Satellite observations:

- ❖ unique possibility to study cloud properties over long period

Intercomparisons:

- ❖ **average cloud properties:** in general good agreement

70% ($\pm 5\%$) clouds: 25-30% low clouds,

30% high clouds (+ ~15% subvisible Ci), stable within 2%

- ❖ **seasonal cycle:** CA good agreement (except SH polar land)

- ❖ ISCCP HCA cycle in tropics underestimated

- ❖ SOBS LCA cycle over ocean smaller; absolute value 18% larger

- ❖ **regional differences** (latitudinal, ocean/land):

linked to cirrus sensitivity: IR sounders & SAGE : HCA +4% (midl) to +20 % (trp)

atmos. profiles: TOVS B less HCA in SH compared to SAGE & HIRS

- ❖ **diurnal cycle:** TOVS-B extends ISCCP during night (see ITSC 14)

- ❖ EOS datasets still in validation process

- ❖ **Trend analysis:** careful of satellite drifts, calibration etc.

many processes important

synergy of different variables important !

- ❖ **Intercomparison continues** (esp. on trends) & **WMO report in preparation**