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 CO_2 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: 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**

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 $2x10^{-4}$ – $2x10^{-2}$ km^{-1}: **subvisible cirrus,** $2x10^{-2}$ 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**

- 0.63µm, 0.86µm, 3.75µm, 10.8µm and 12µm
- 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(*JAJO*04) SAGE(85-99)

Cloud amounts (%)	glo bal					oce an					la nd				
	ISCCP	TOVS-B	UW-HIRS	PATMOS	SAGE	ISCCP	TOVS-B	UW-HIRS	PATMOS	SAGE	ISCCP	TOVS-B	UW-HIRS	PATMOS	SAGE
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 % (±5%) cloud amount: 5-12% *more over ocean than over land*

PATMOS CA low, esp. over land; SAGE CA (clds τ>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(*JAJO*04) SAGE(85-99)

Cloud amounts (%)	NH mi dl					tro pic s					SH 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

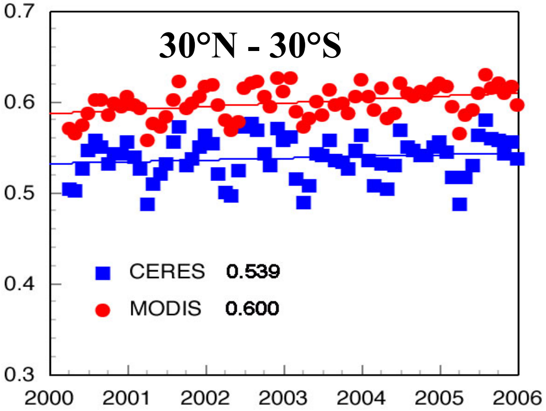
ISCCP (84-04) TOVS-B (87-95)TOVS-A (85-01)

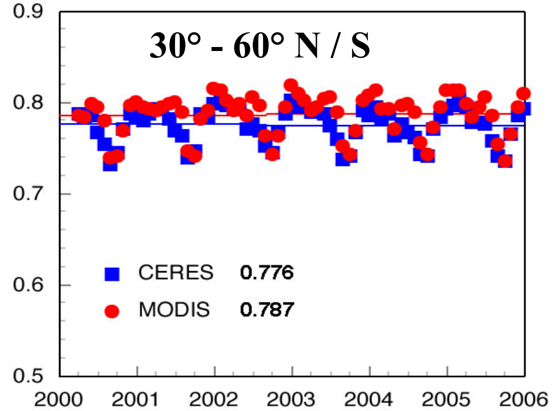
	NH midl			tro pics			SH midl		
T_{cld} (K)	257	259		265	259		259	262	
P_{cld} (hPa)	552	594	583	544	513	435	624	650	603
ECA (%)	58	48	45	50	41	32	74	54	54

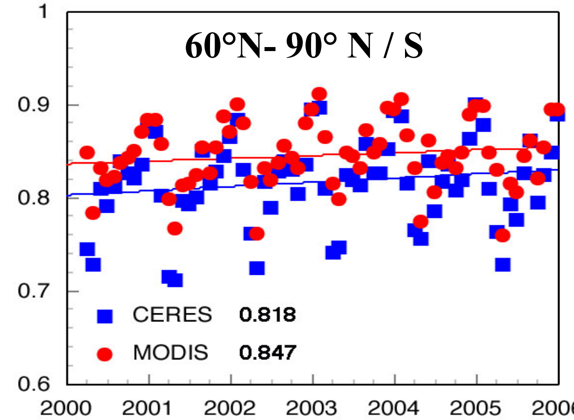
T_{cld} within 2K / 5K for ocean /land
clouds lower + thicker over ocean than over land: 135/85/**2** hPa + 13/3/**6** %
P_{cld}, ECA: trp<NHm<SHm: 8/80/150 hPa 70/55/20 hPa + 8/7/13 % 16/6/14 %
TOVS-A much smaller p_{cld} and ECA in tropics than TOVS-B!

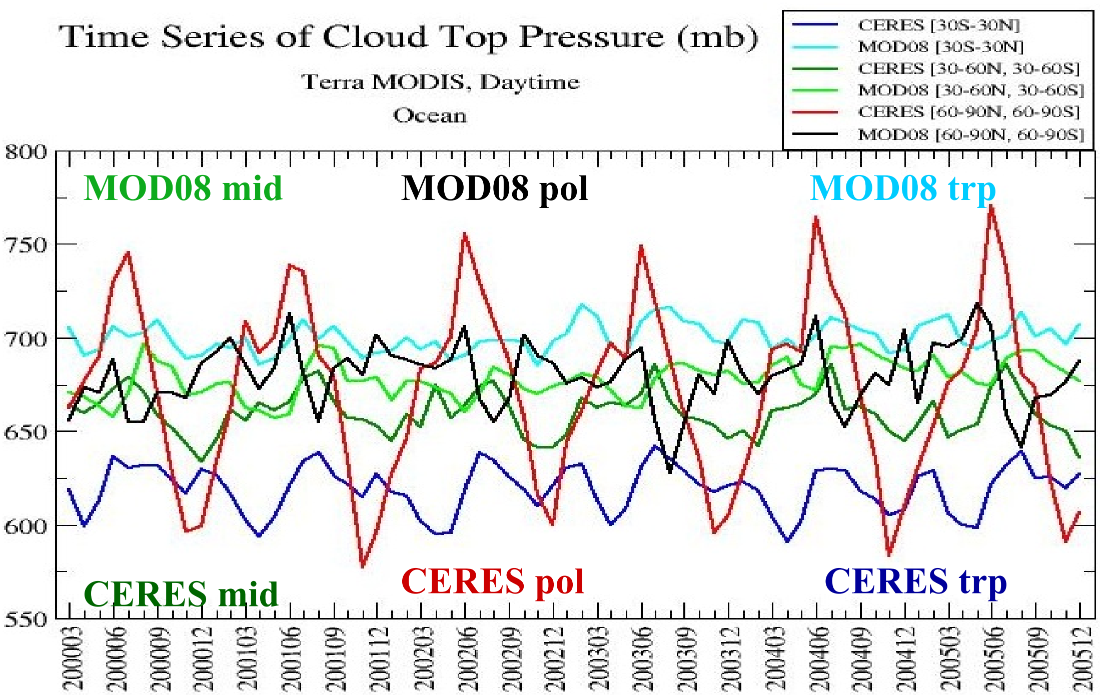
Daytime MODIS CA, p_{cld} : MOD08 *(MODIS Team)* – CERES inversion

P. Minnis









p_{cld} (MOD08) > p_{cld}(CERES)
Tropics: Δ ~ 75 mb

tropics (15°N-15°S)

HCA 27-31% (T-A)

MCA 5%

LCA 22-26%

Analysis by P. Yang

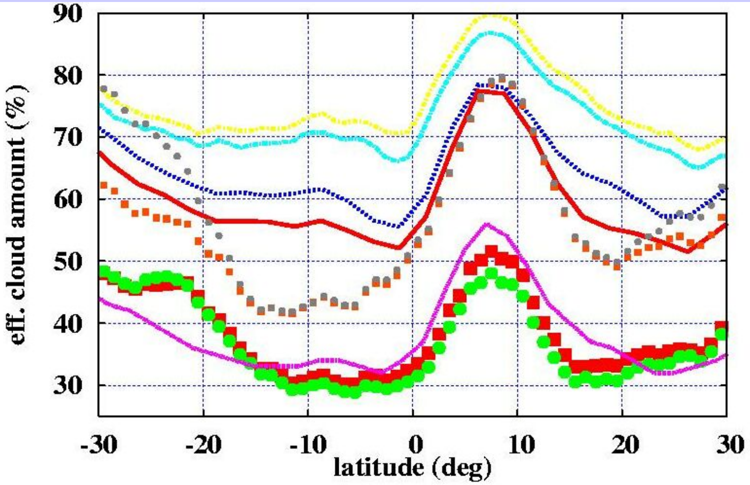
much smaller HCA than TOVS!

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

CA (MOD08) > CA (ISCCP)   ECA (AIRS) ~ECA (TOVS)

CA

ECA



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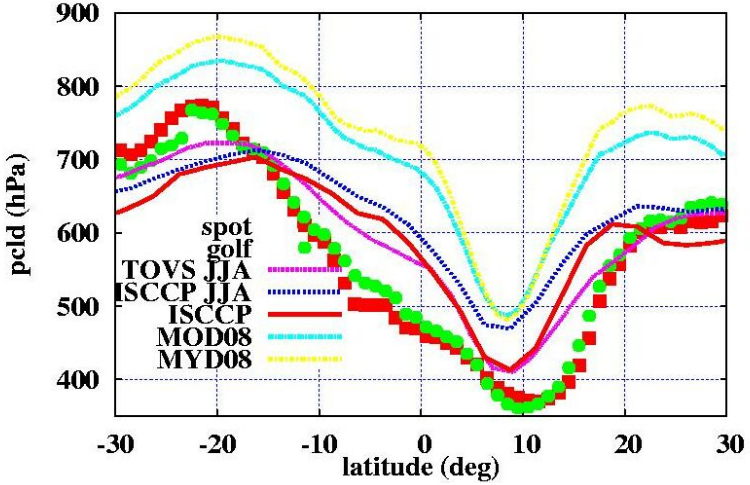
p_{cld} (MOD08) > p_{cld} (ISCCP) >p_{cld} (AIRS) ~ p_{cld} (TOVS)

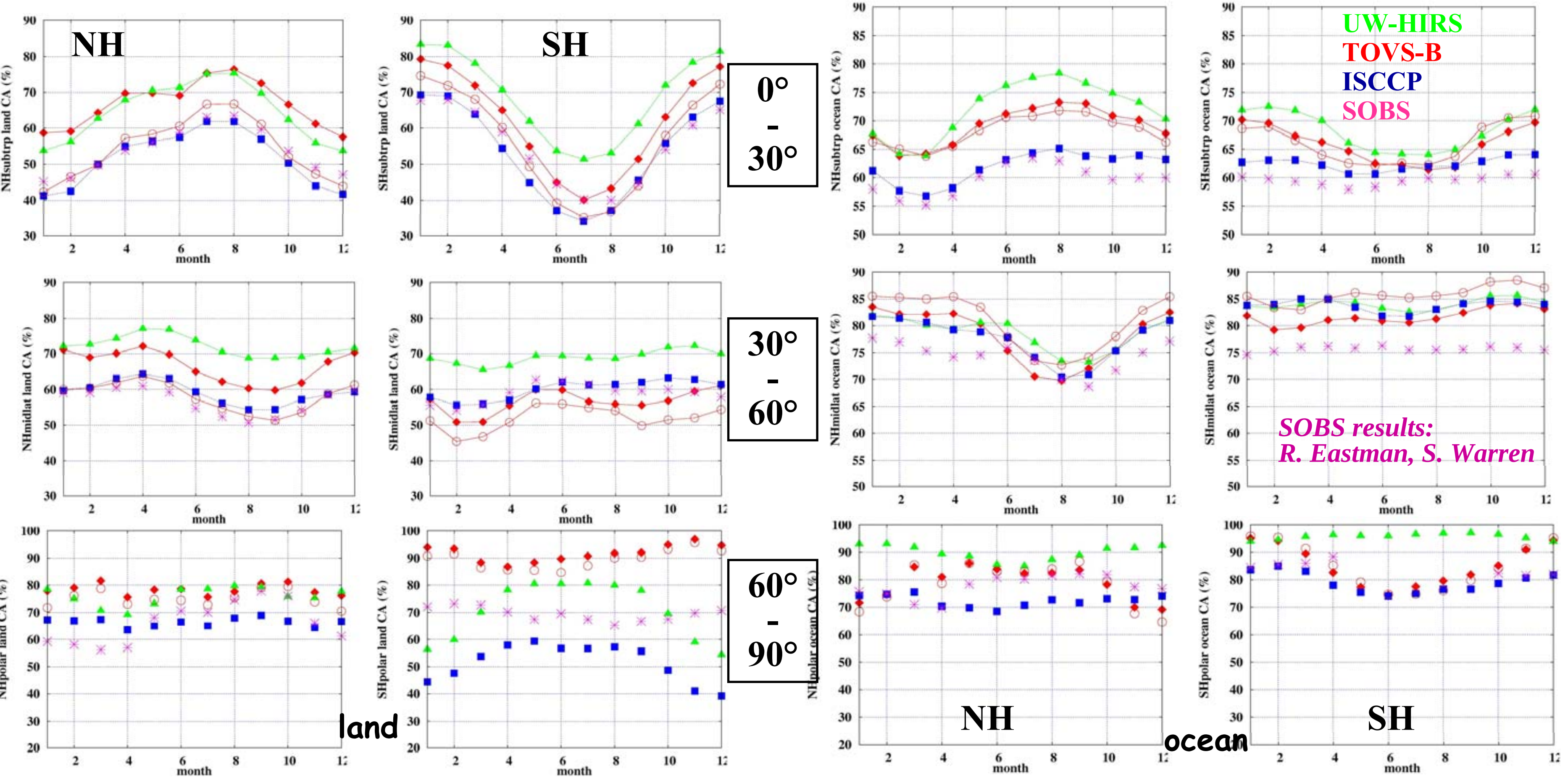
p_{cld}



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

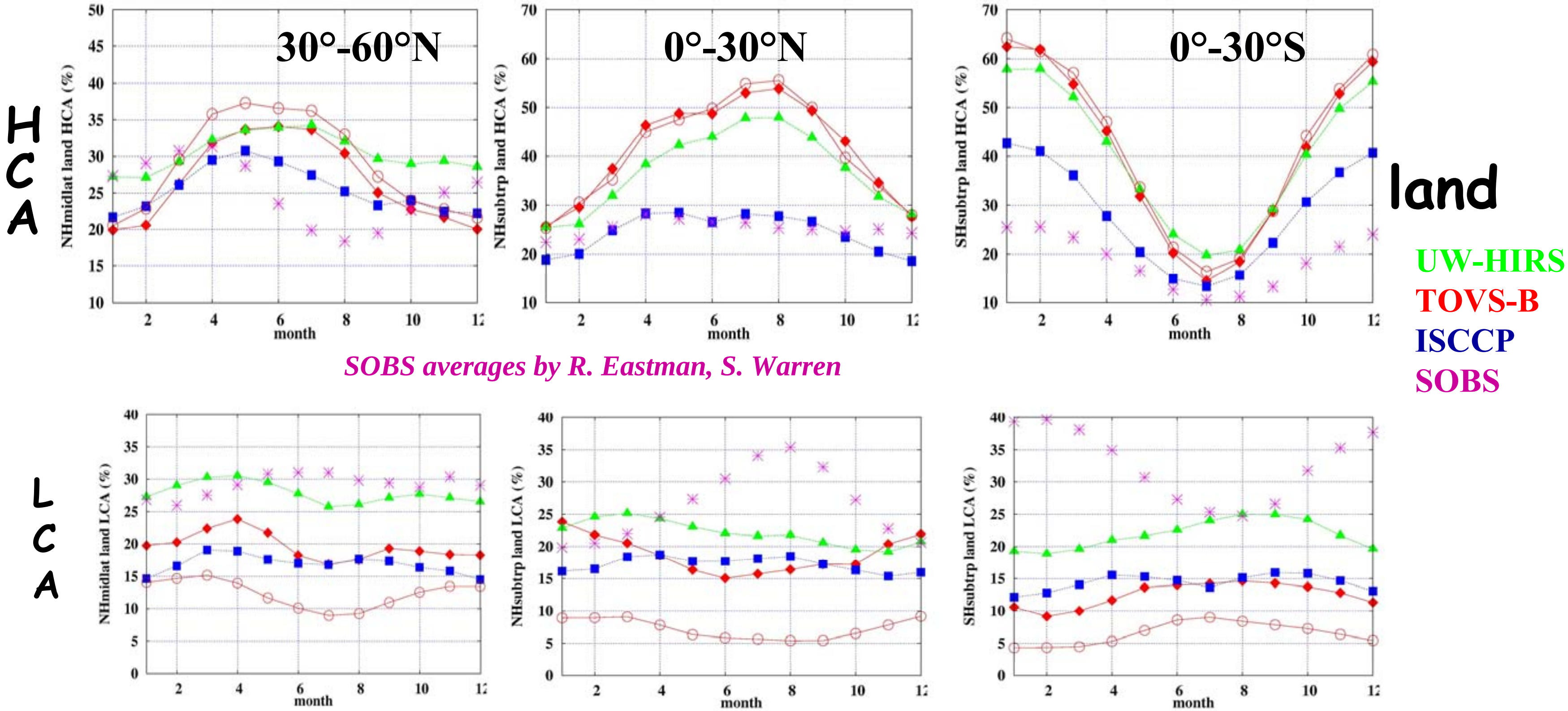
Seasonal cycles similar , exception: SH polar land

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



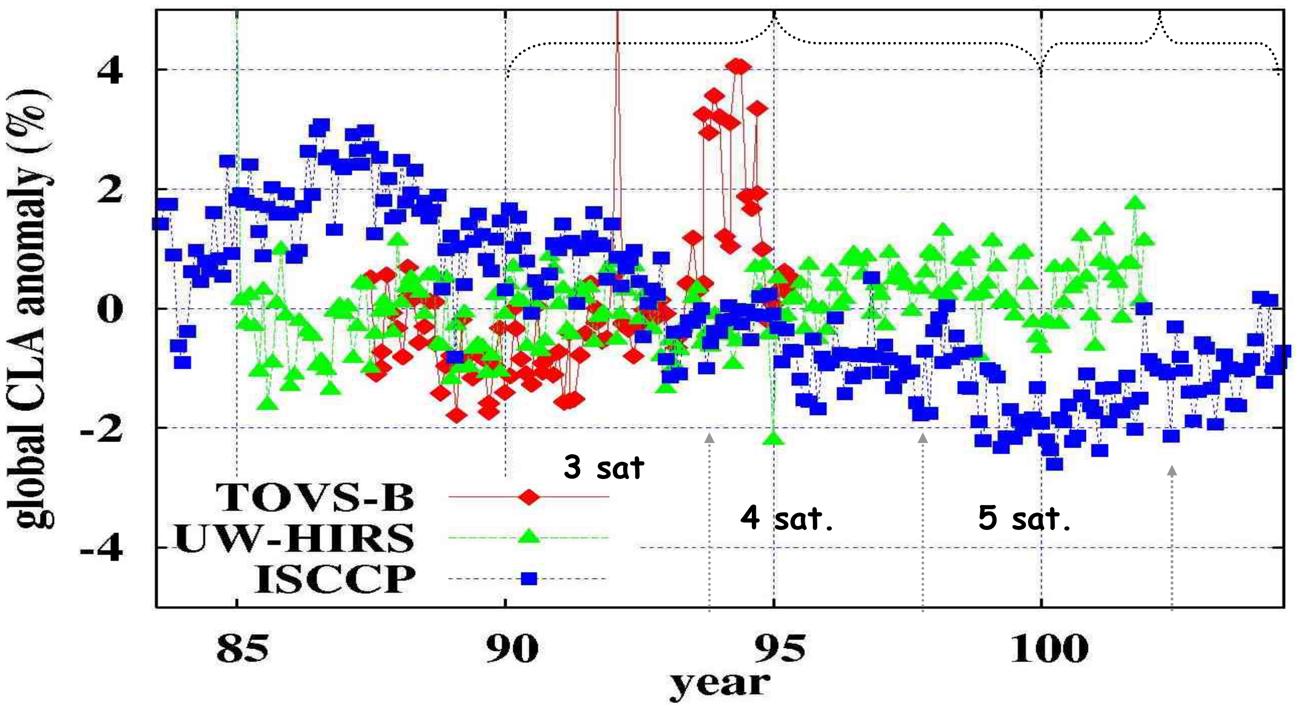
HCA seasonal cycle : 7-15%, 10-27%, 18-45% over land

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

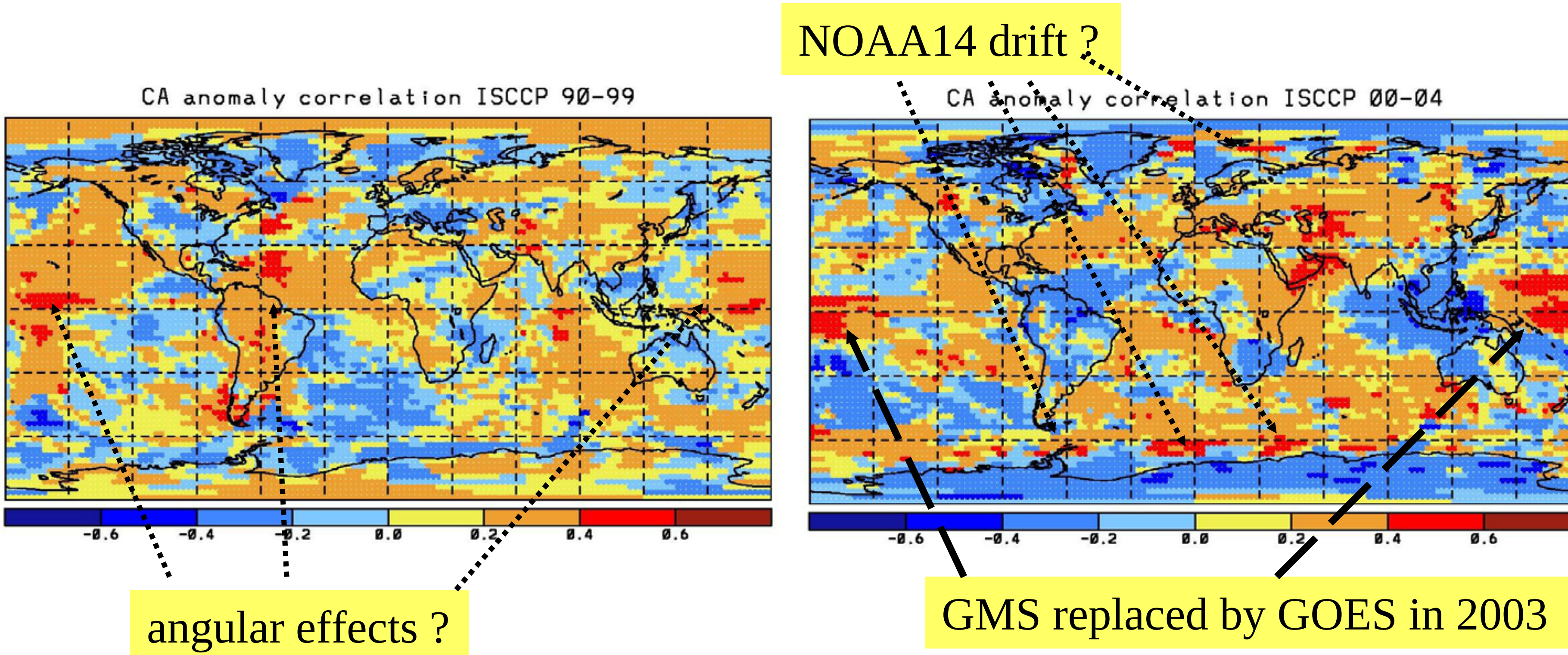


global CLA within ±2.5%
UW-HIRS: more or less stable
ISCCP: ~5% decrease from 1987 to 2000
related to increasing nb of GEO satellites ?

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

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)*

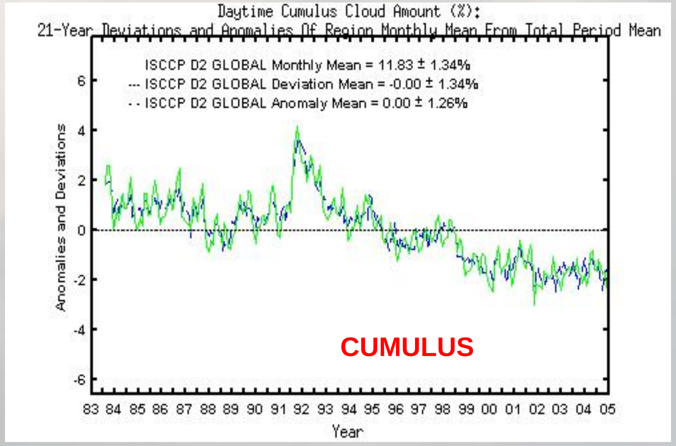


similar results by J. Norris, A. Evans

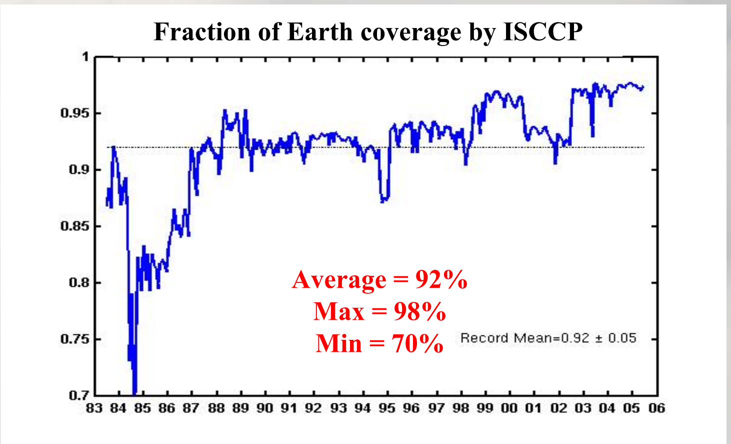
Study on causes for spurious CA changes

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% (±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**

International TOVS Study Conference, 15th, ITSC-15, Maratea,Italy, 4-10 October 2006
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2006.