Assessment of Global Cloud Properties

Co-chairs:

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+ input from participants of GEWEX cloud assessment

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

2^{nd} Cloud Climatology Assessment Workshop

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

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

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**

ISCCP *(Rossow & Schiffer 1999)*

night: +75 hPa p_{cld} bias

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

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 1999)*

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

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

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				
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 op. 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)

	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** %

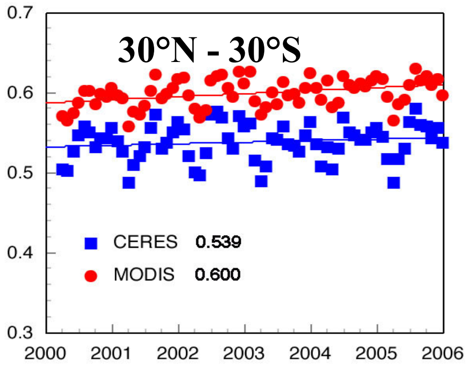
P_{cld}, ECA: trp<NHm<SHm: 8/80/150 hPa 70/55/20 hPa + 8/7/13 % 16/6/14 %

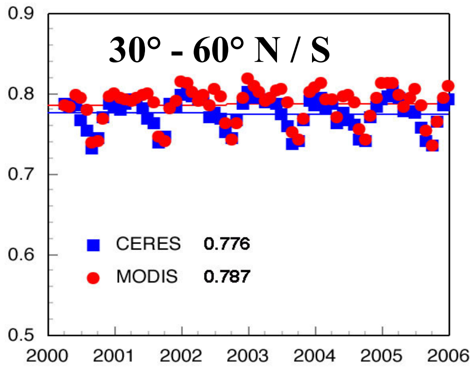
TOVS-A much smaller p_{cld} and ECA in tropics than TOVS-B!

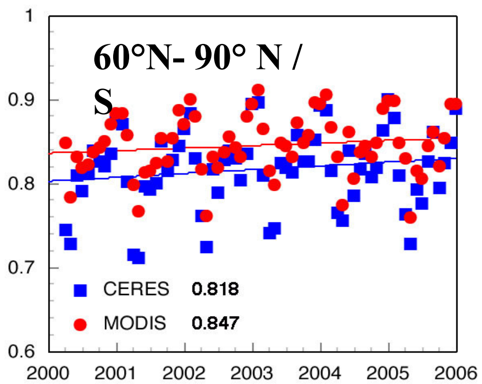
EOS Dataset Comparisons:

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

P. Minnis







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

<u>tropics (15°N-15°S)</u>

HCA 27-31% (T-A)

MCA 5%

LCA 22-26%

Analysis by P. Yang

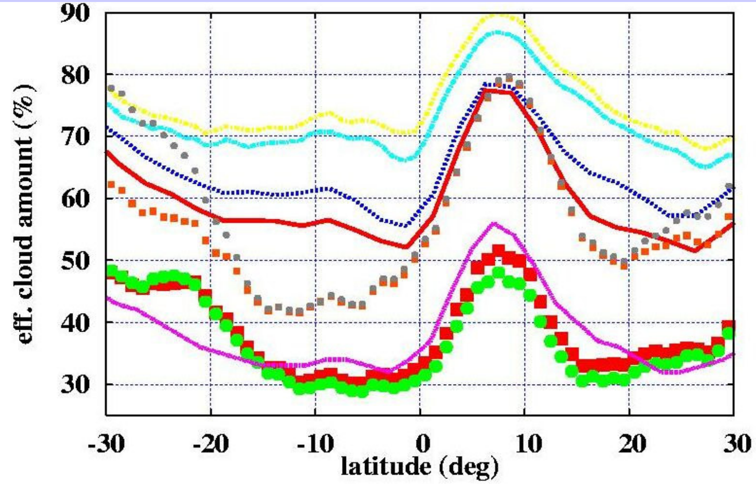
much smaller HCA than TOVS!

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

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

CA

ECA



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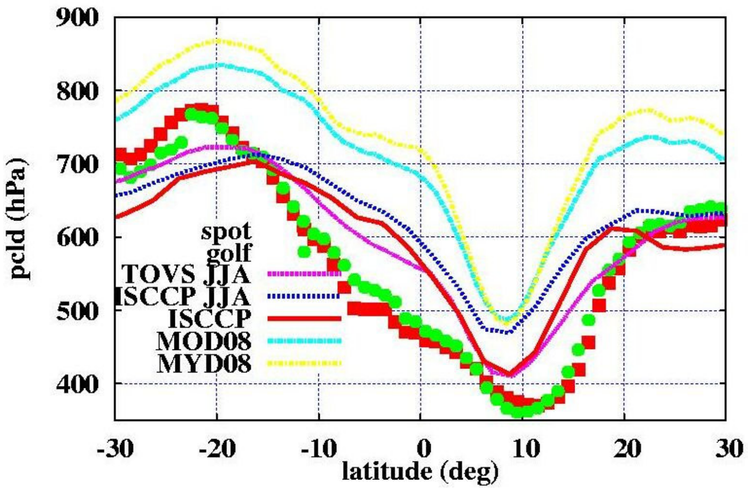
p_{cld} (MOD08) > p_{cld} (ISCCP) >p_{cld} (AIRS) ~ p_{cld} (TOVS)

p_{cld}

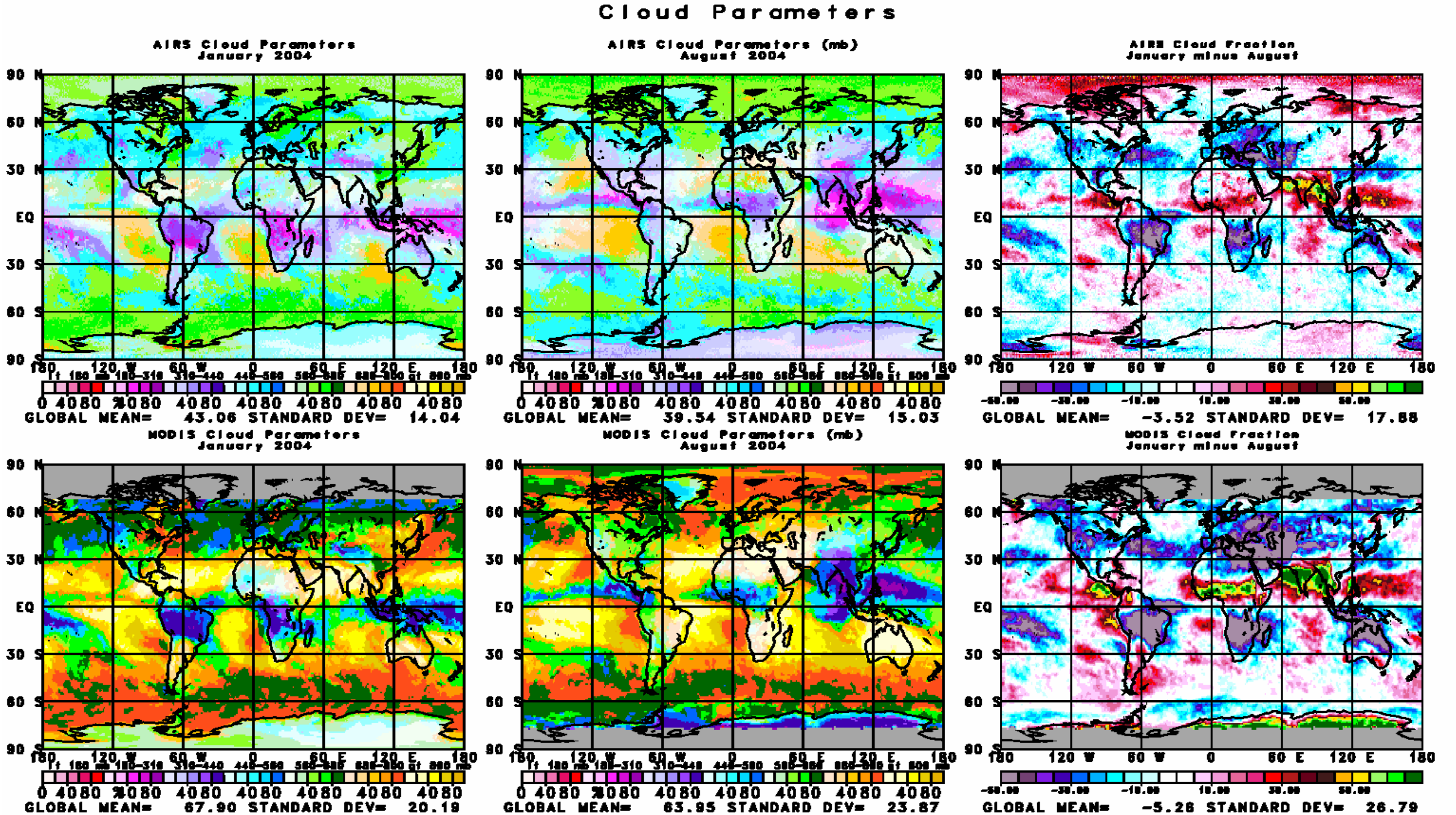


AIRS cloud retrieval preliminary

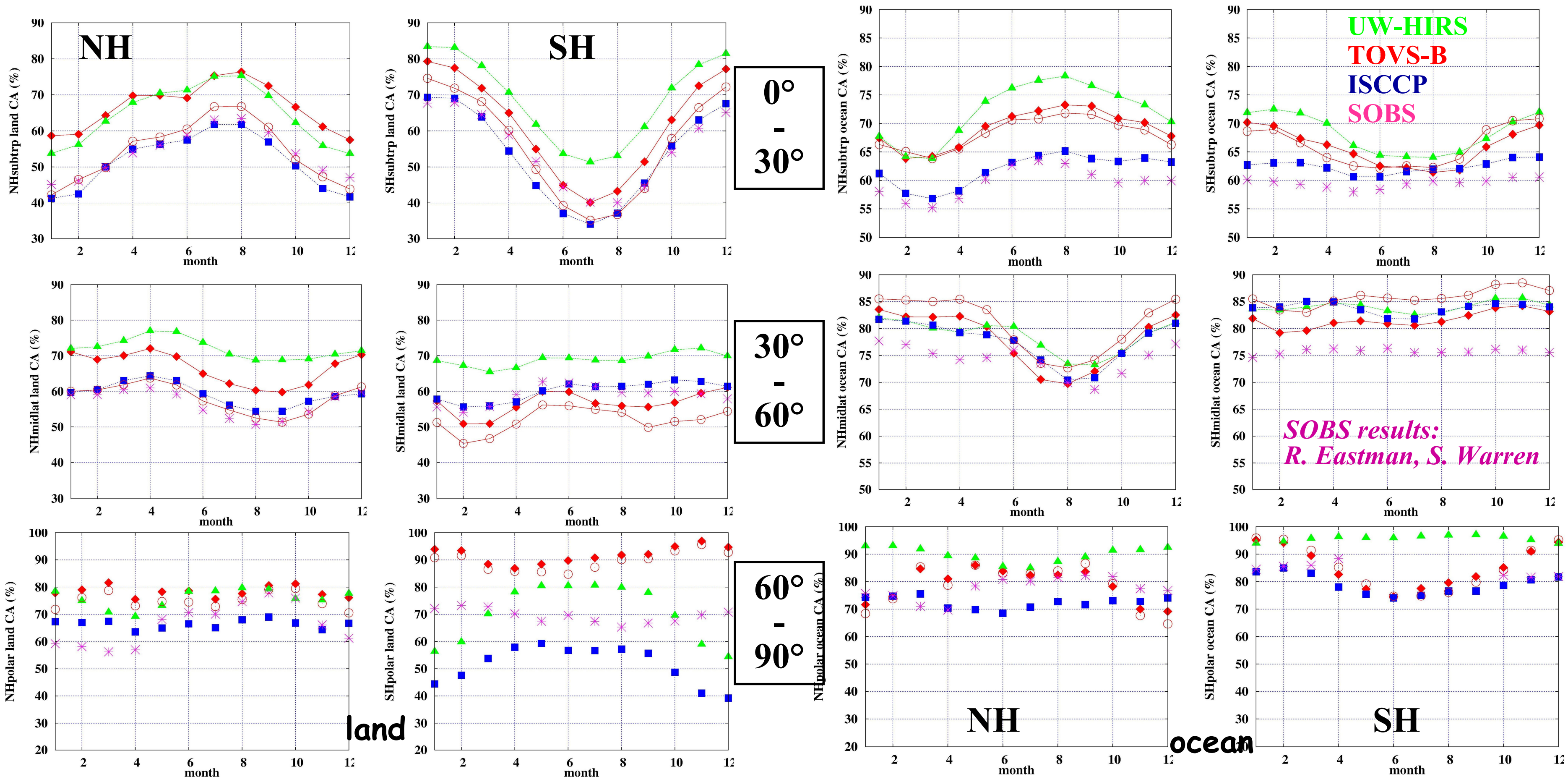
CA, p_{cld}: MOD08 – AIRS (AIRS team)

G. Molnar, J. Susskind

p_{cld} (MOD08) > >p_{cld} (AIRS),
but intra-seasonal variations similar (corr. coef. 0.84)



CA seasonal cycle: *NH –SH subtropics, midlatitudes, polar regions*



Seasonal (and diurnal cycles) stronger over land than over ocean, strongest in subtropics

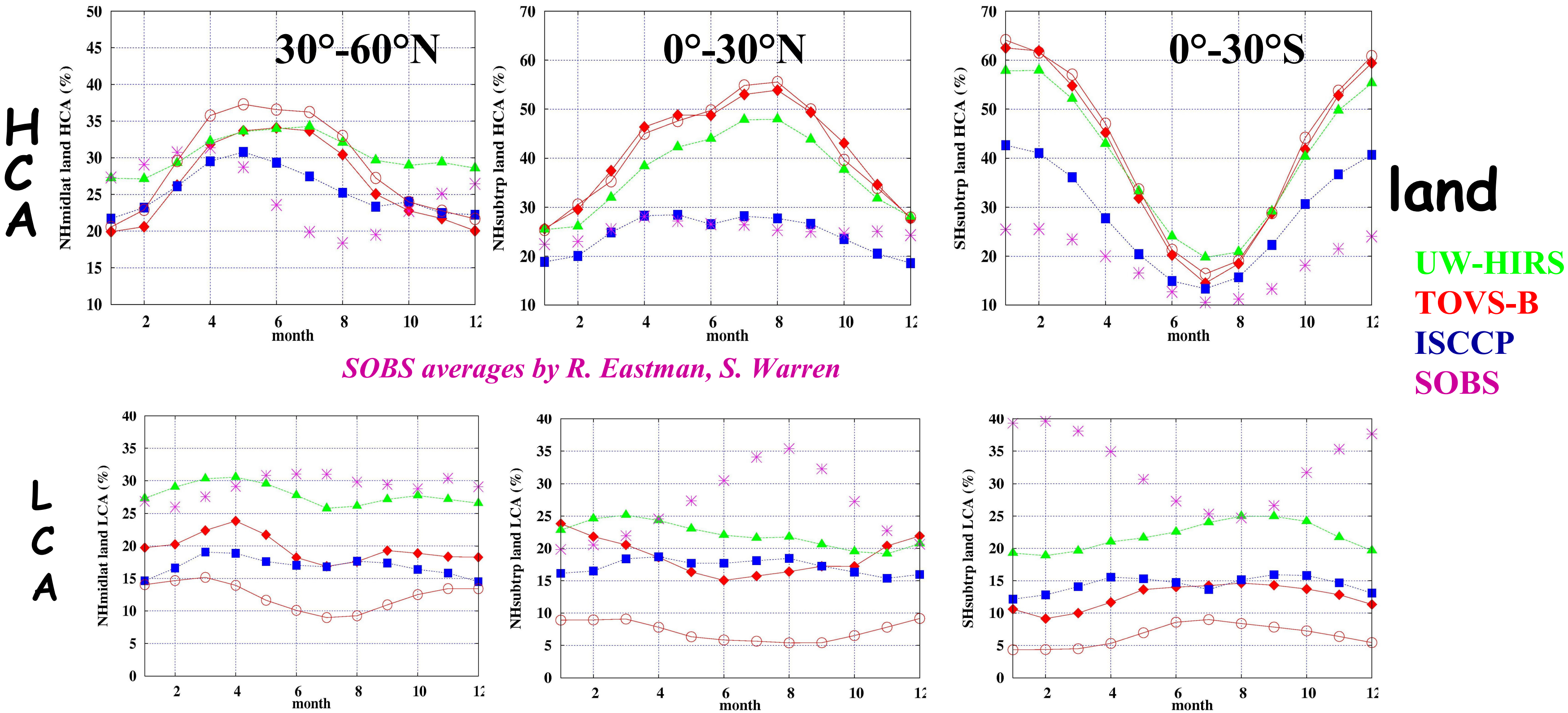
Seasonal cycles similar , exception: SH polar land

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



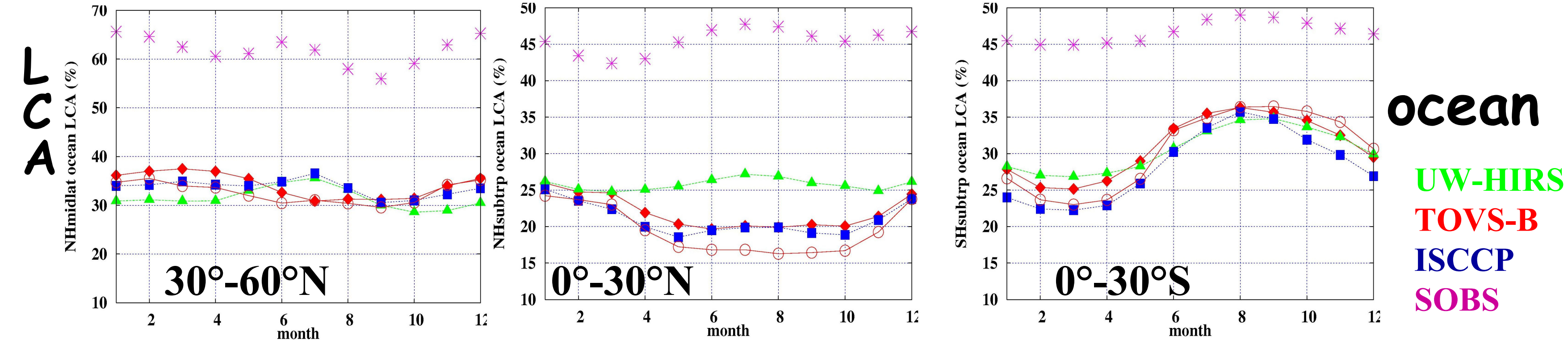
HCA seasonal cycle : 7-15%, 10-27%, 18-45% over land

ISCCP underestimates seasonal cycle of HCA by up to 20%

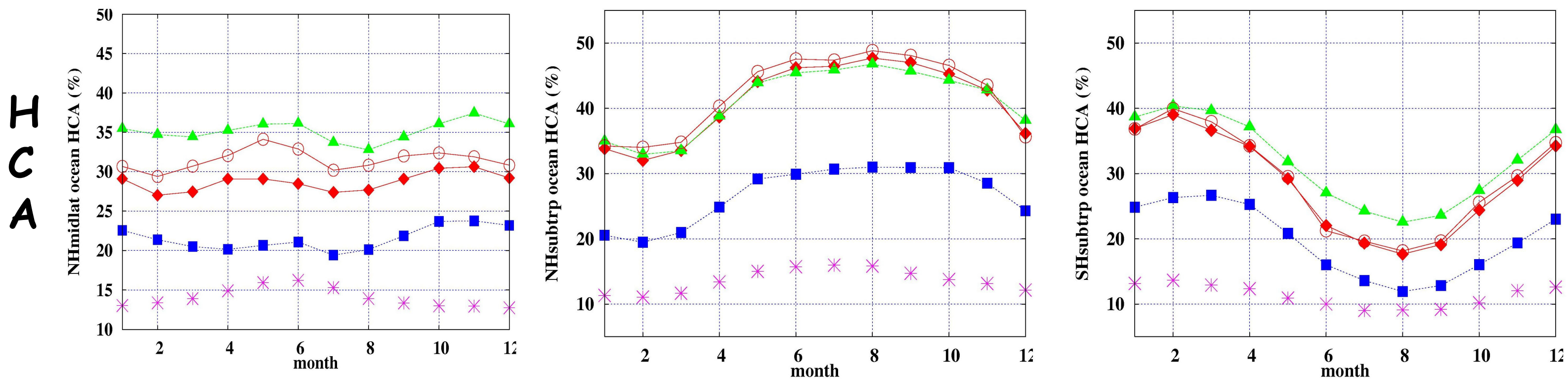
UW-HIRS slightly smaller seasonal cycle than TOVS-B

SOBS HCA seasonal cycle modulated by clouds underneath: HCA min in NH midlat. when LCA max

LCA seasonal cycles in latitude bands



SOBS averages by R. Eastman, S. Warren



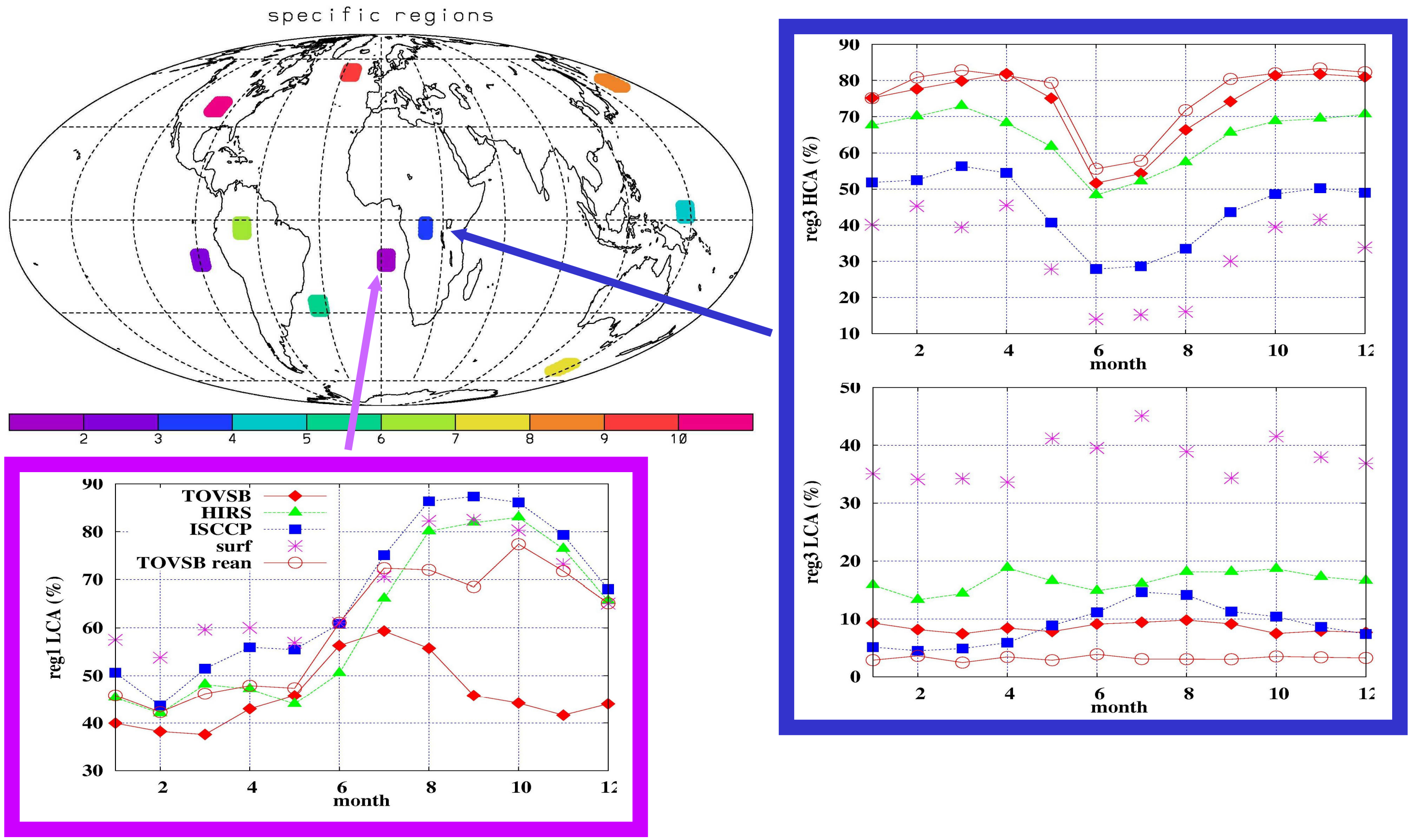
Seasonal cycle LCA: 5%, 5-7%, 8-12% over ocean

UW-HIRS slightly smaller seasonal cycle

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

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

CA seasonal cycle over selected regions



UW-HIRS
TOVS-B
ISCCP
SOBS

SOBS averages by

R. Eastman, S. Warren

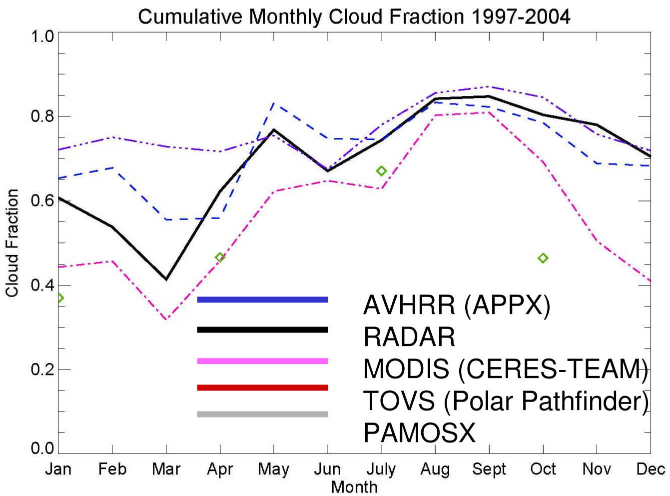
TOVS-B did not pick up seas. cycle of low clouds (not detected), improved detection does

Very good agreement with SOBS

regional differences can be larger

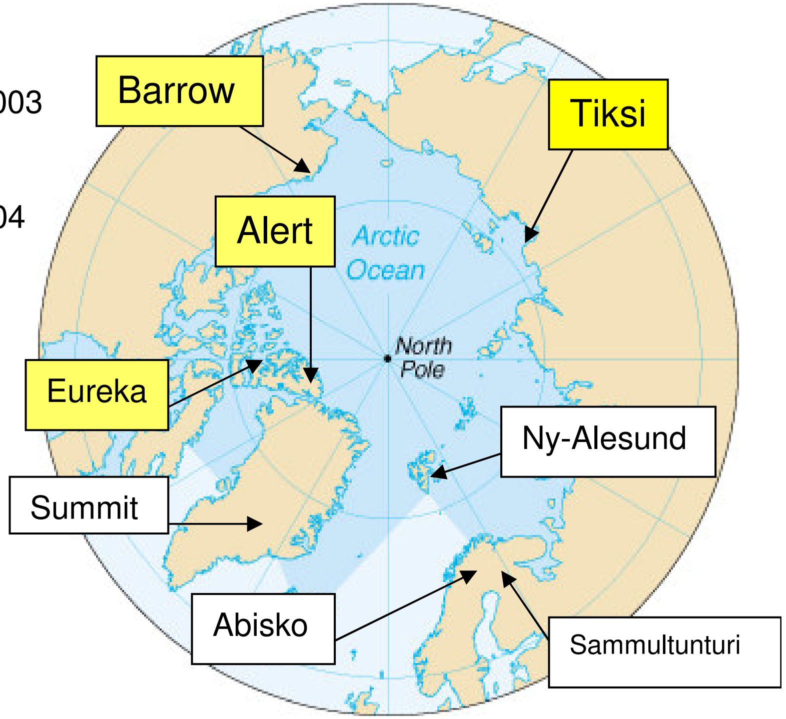
reasons have still to be explored

Polar Datasets: ***Taneil Uttal, Xuanji Wang, Jeff Key, Axel Schweiger***

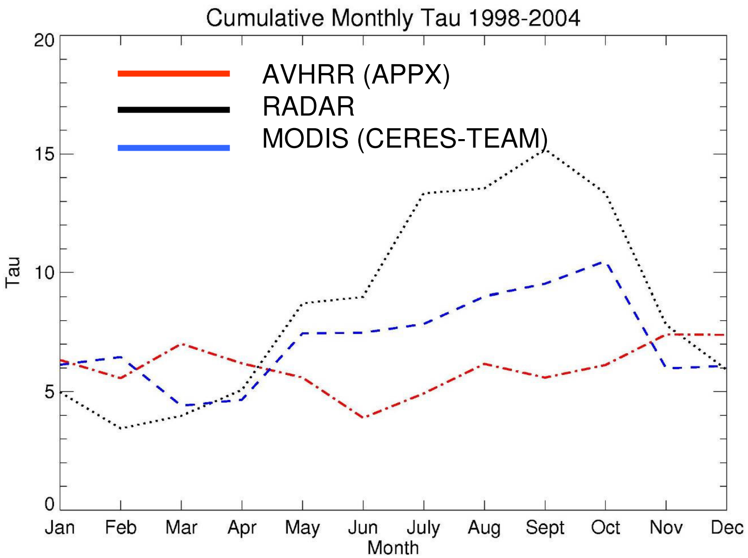


APPX 1998-2000
CERES TEAM 2000-2003
Radar data 1998-2004
TOVS data 1997-2006
PATMOSX 1998 to 2004

Barrow



cloud optical depth more important than CA in defining radiative impact of clouds on the surface



subregions with significant differences in cloud properties

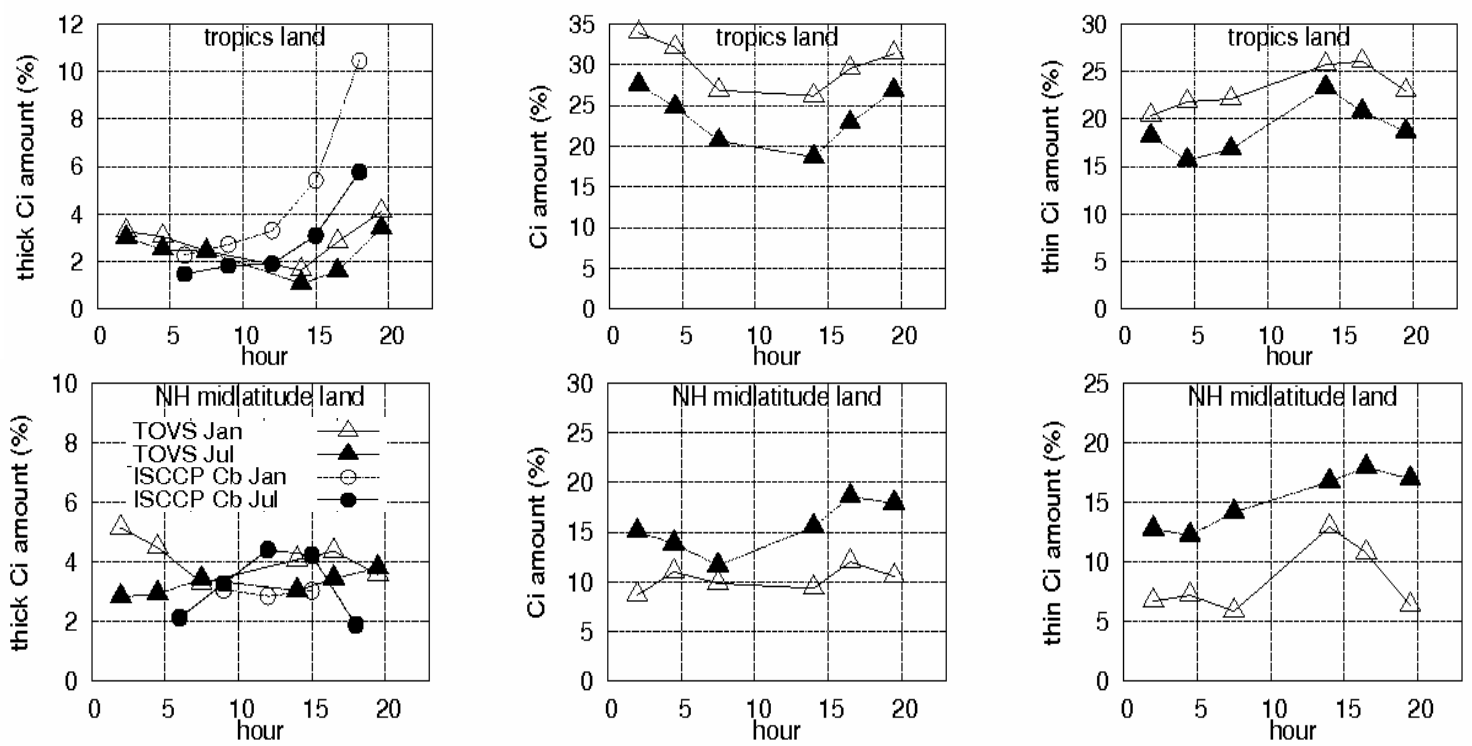
=> no latitudinal averaging

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)

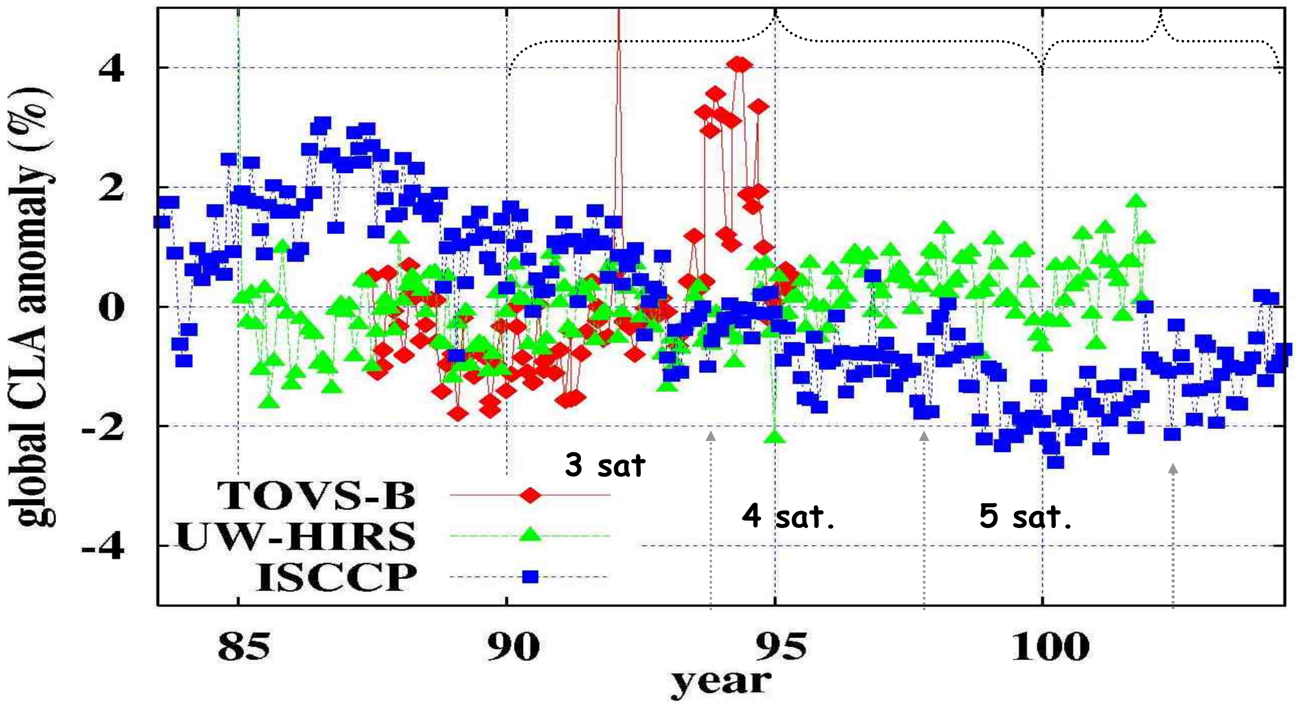
strongest diurnal cycles over land, in tropics and in summer



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

TOVS-B extends ISCCP during night

Global CA anomalies

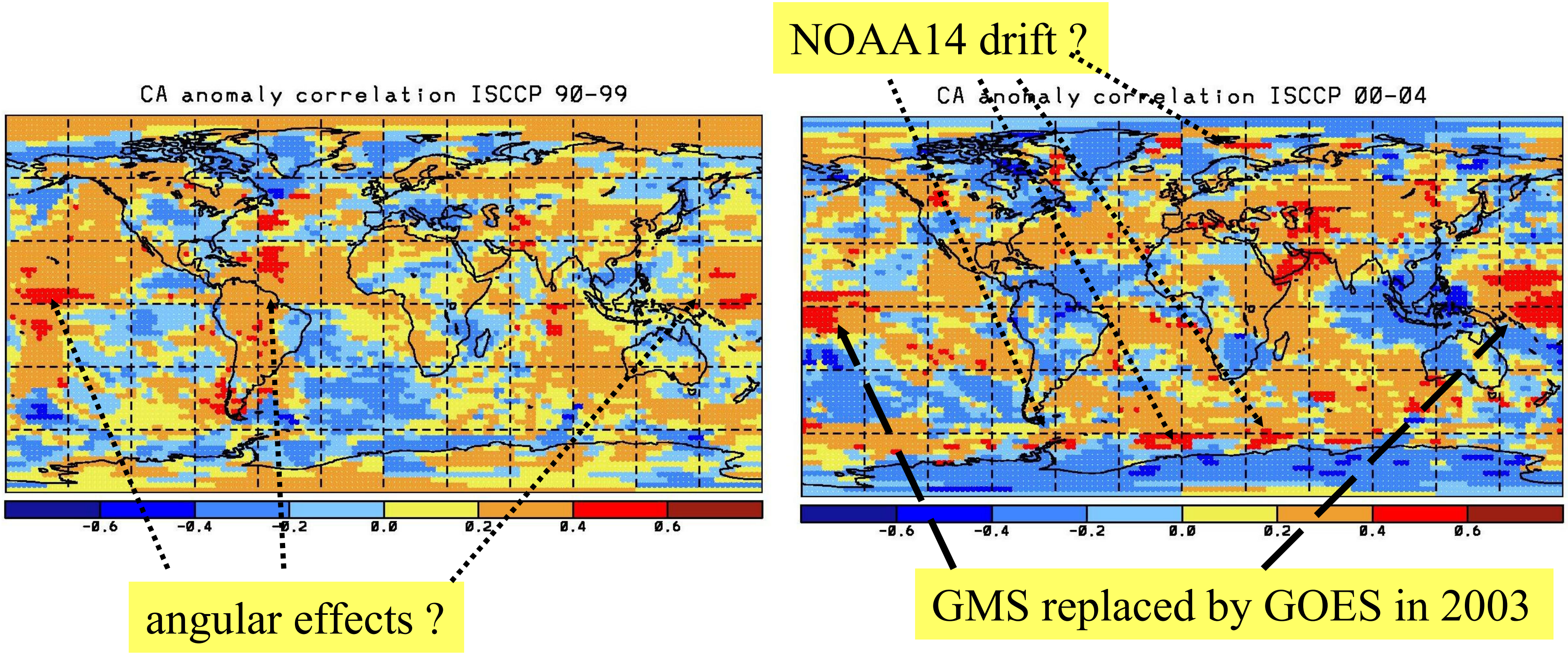


global CLA within ±2.5%
UW-HIRS: more or less stable
ISCCP: ~5% decrease from 1987 to 2000
related to increasing nb of GEO satellites ?

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: $r(i,j)$

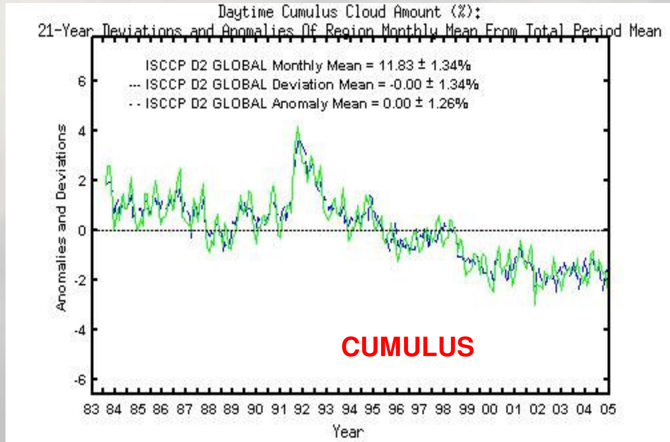


similar results by J. Norris, A. Evan

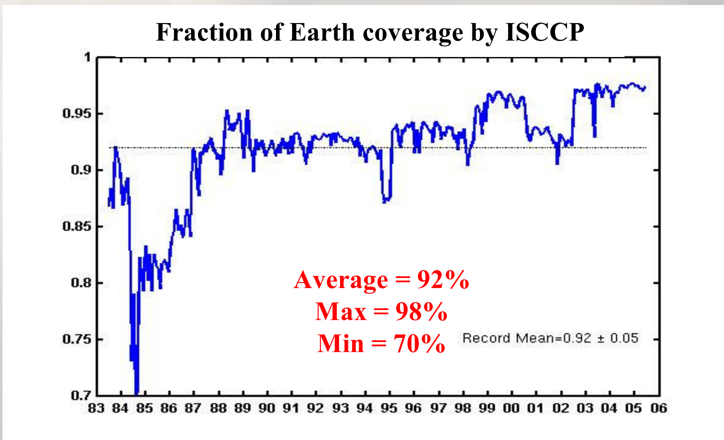
Study on causes for spurious CA changes

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)

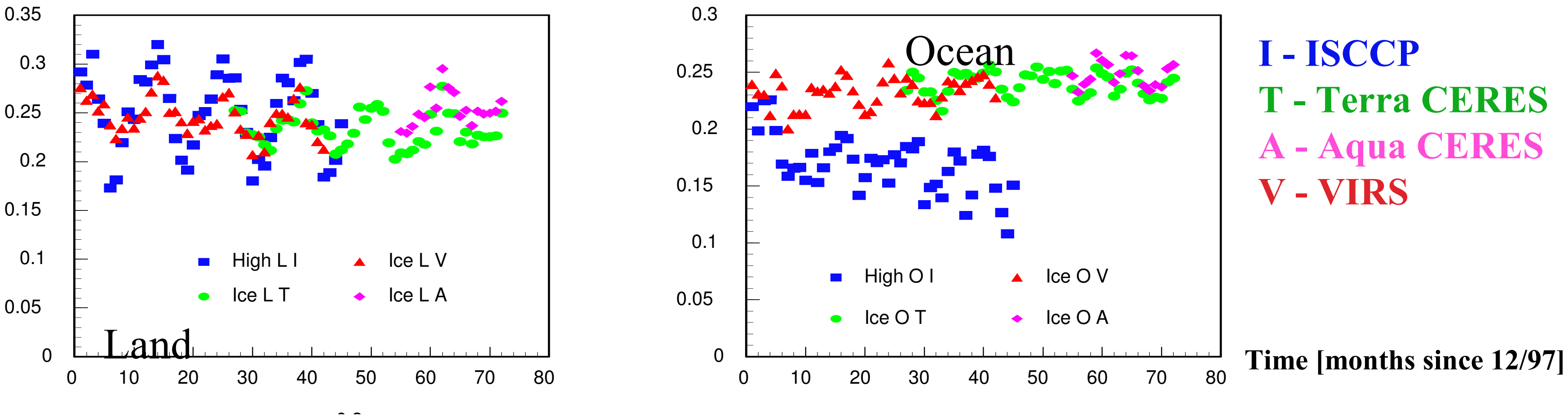


- Changes in Sampling Distribution & Coverage:
  check for other datasets



HCA Comparison with EOS Climatologies (37°N-37°S) 1998-2003

P. Minnis



land: ISCCP HCA trend consistent with recent dataset

decent correlation with humidity

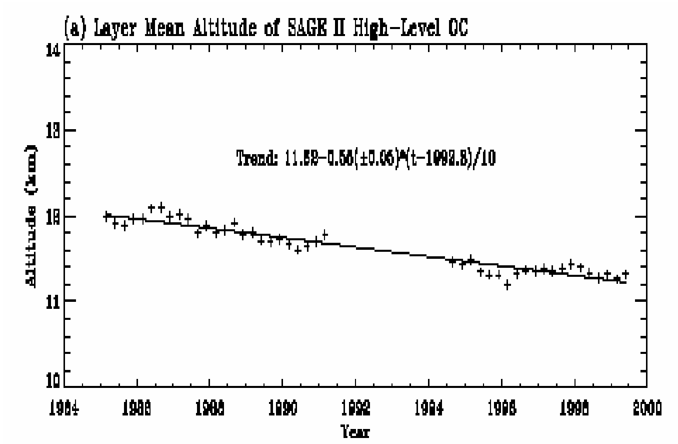
ocean: ISCCP HCA trend different

only weak correlation with NCEP RH

• decreasing humidity suggests decrease in HCA

SAGE analysis: response includes thinner clouds in tropics & drop in mean height rather than simple HCA decrease

• cause of UTH drop? Is it real?



Wang et al., J. Clim., submitted

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

❖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. polar) **& WMO report in preparation**