GEWEX CLOUD PRODUCT ASSESSMENT

PURPOSE: To evaluate the usefulness and reliability of the long-term, global satellite cloud climatology produced by (at least) ISCCP for climate studies

GOALS: To compare the ISCCP products with other available cloud data products and investigate differences/similarities on a "best-effort" basis

MEETING OBJECTIVES: Provide a comprehensive reference data set of cloud properties for climate studies and model evaluation. Investigate results in detail: comparisons to established references, comparisons to similar products by other sensors, sensitivity studies on inputs. Share analysis methods. Report strengths and limitations of each dataset and suitable applications.

SUMMARY OF TESTS COMPLETED

ISCCP CLOUD AMOUNT

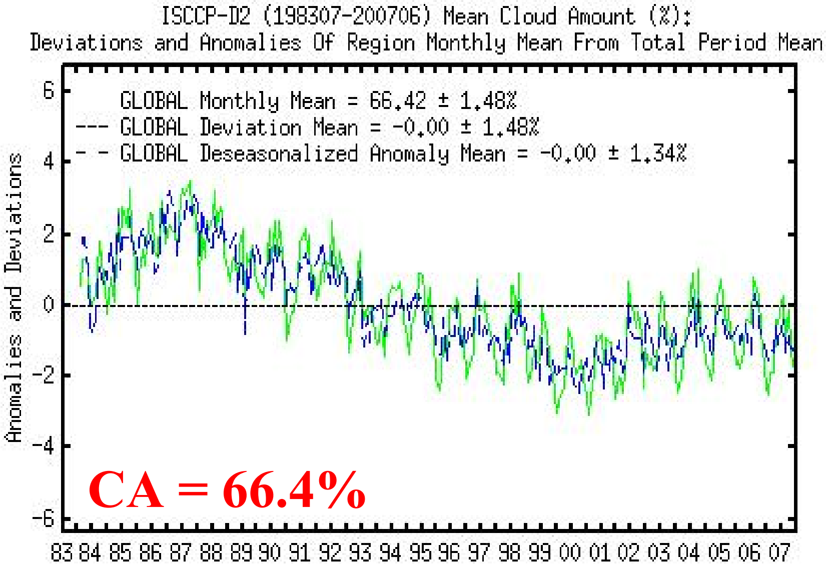
- Space-Time Resolution and Sampling Effects
- Detection Algorithm Comparisons on Same Data
- Evaluation of Clear Sky Radiances & Thresholds

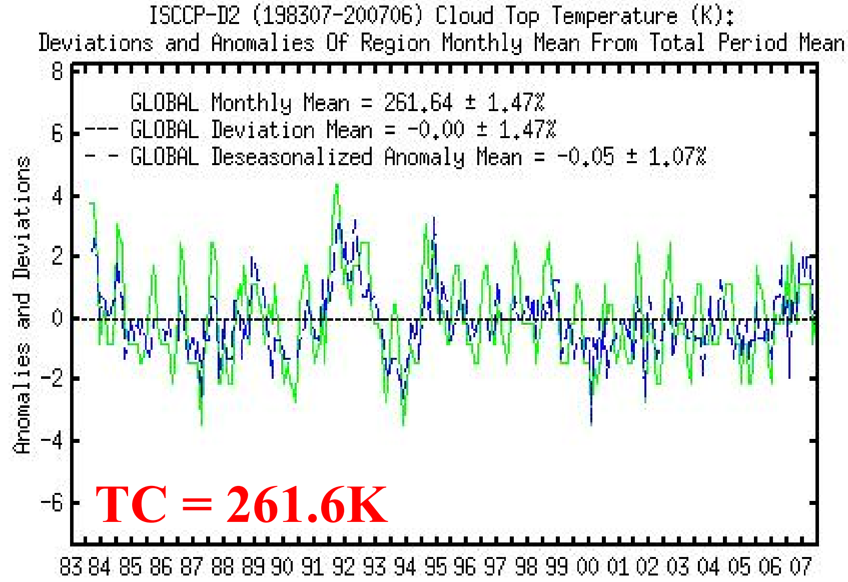
- Comparison with Different Instruments: Surface Observers, SAGE, SSM/I, HIRS, CLOUDSAT, CALIPSO
- Evaluation of Radiative Fluxes (ERBE/CERES, BSRN)

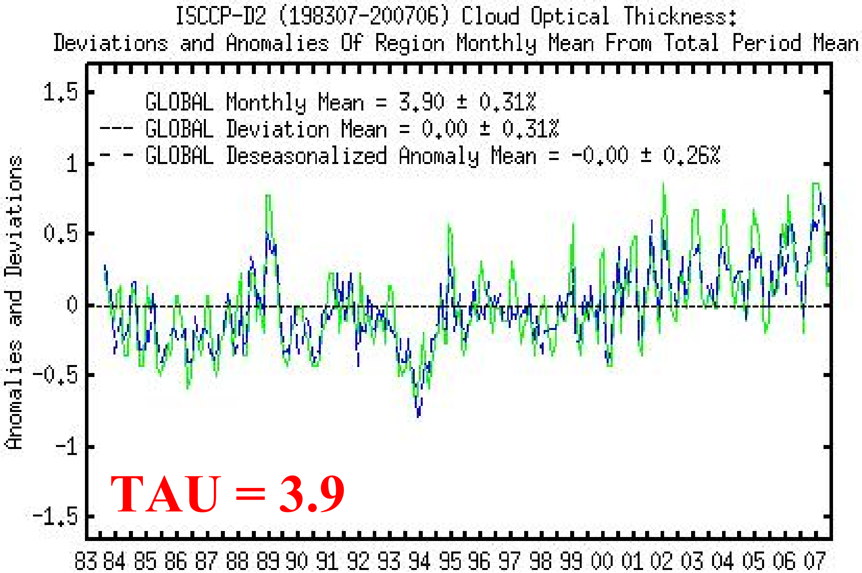
CLOUD AMOUNT (66.4%)

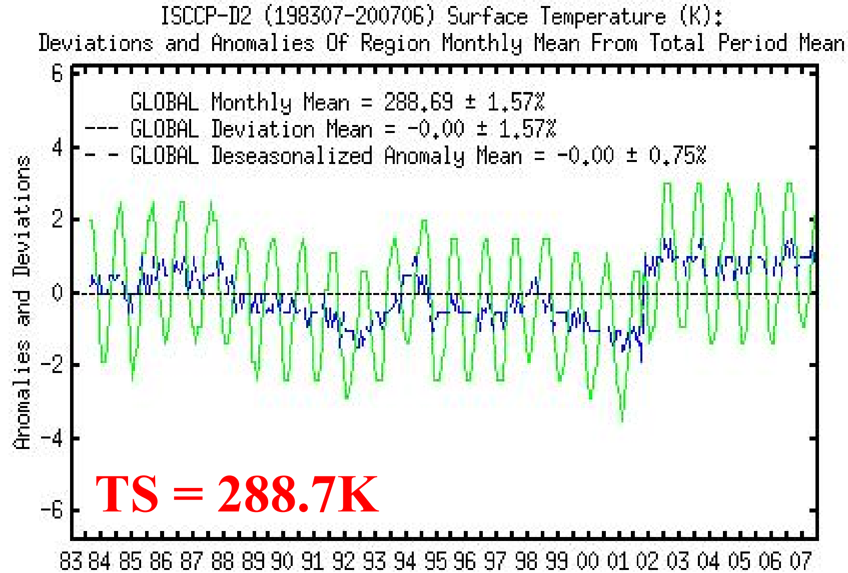
1. **Single-Pixel Cloud Detection:** Combined set of tests of space-time variability to identify clear sky radiances as those that are less variable and tending toward warmer-darker values, followed by regionally-dependent threshold (difference between radiance and clear sky value) tests (additional test on 3.7 micron channel over snow/ice surfaces) = pixel-level cloud fraction is 0 or 1
2. **Area Cloud Fraction:** Determine fraction of all pixels in area 280 km across that are declared cloudy (note that finite threshold offsets small overestimate of cloud fraction)
3. **Total Cloud Amount Evaluation:** 14 Papers – missed thin clouds, underestimate of polar summer and overestimate of polar winter cloud amounts, long-term variation consistent with ERBE/CERES
4. **Precision** ≈5-10% Instantaneous, 1-3% on Average
5. **Accuracy** ≈ 10-15%

UPDATED ISCCP CLIMATOLOGY

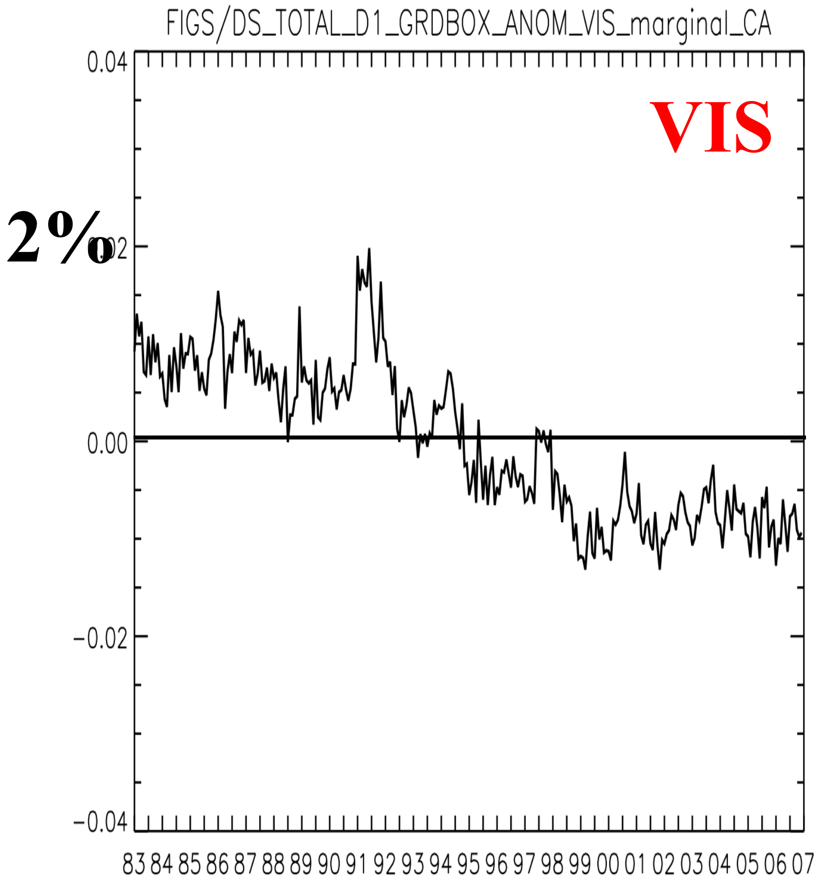


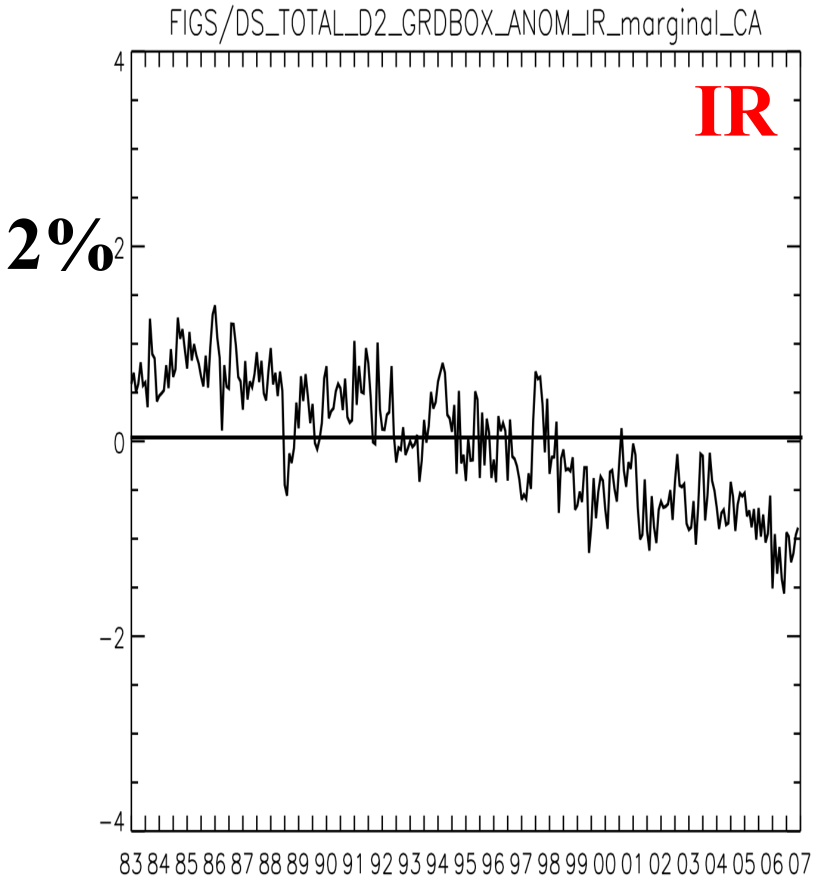




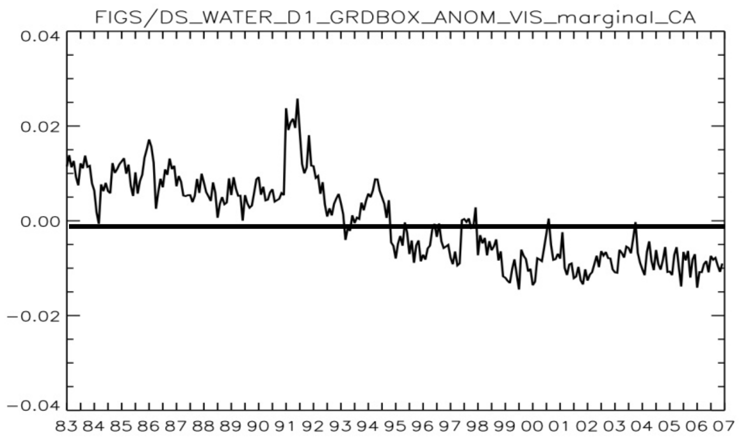


ANOMALY OF "MARGINAL" CLOUD AMOUNT

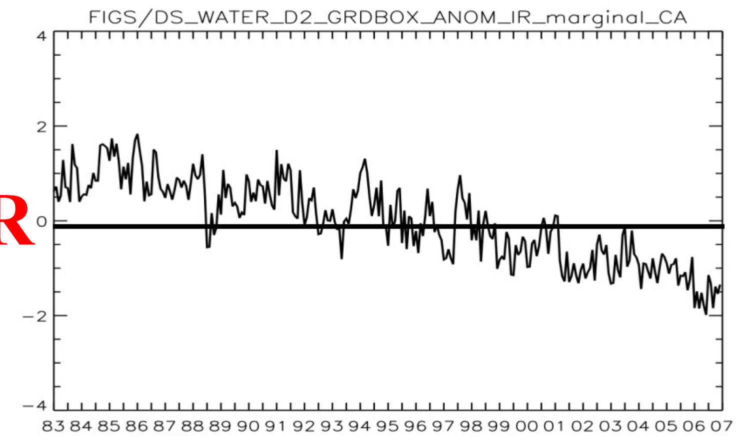




WATER/LAND "MARGINAL" CLOUD AMOUNT ANOMALIES

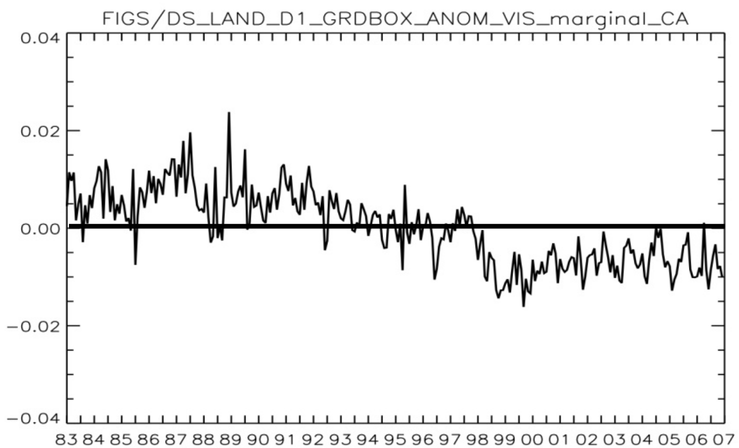


WATER

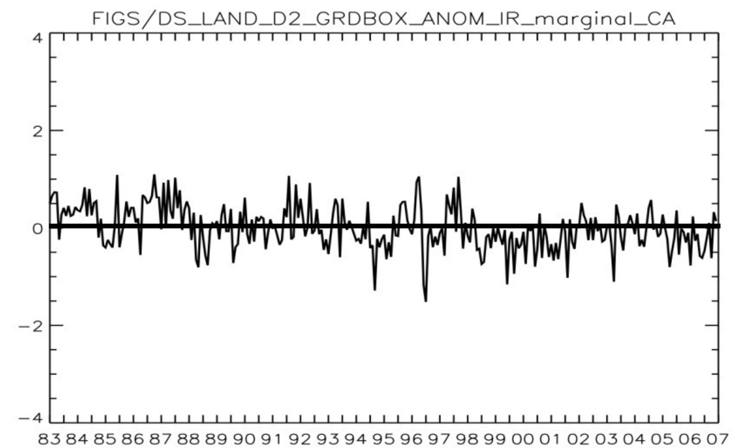


VIS

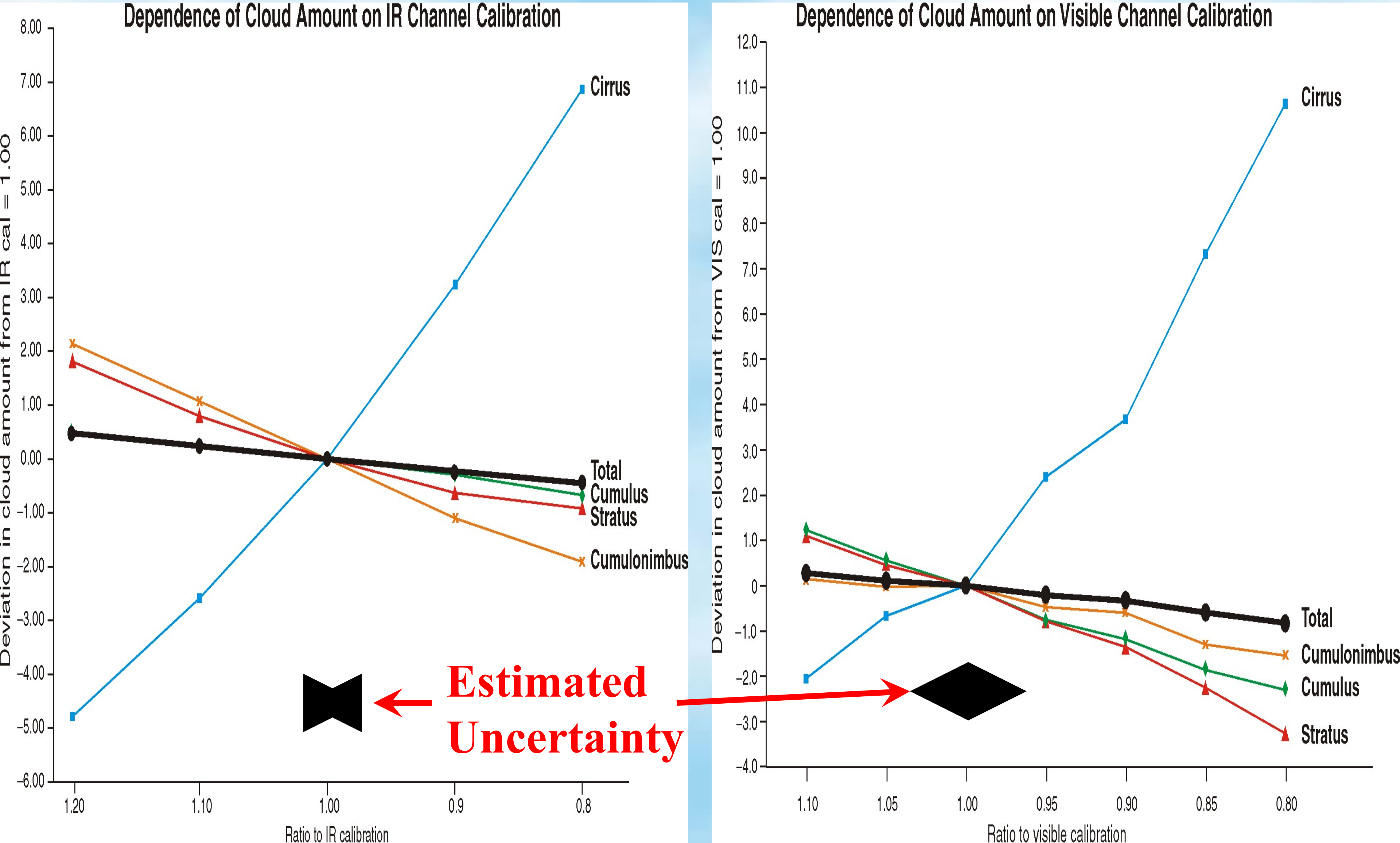
IR



LAND

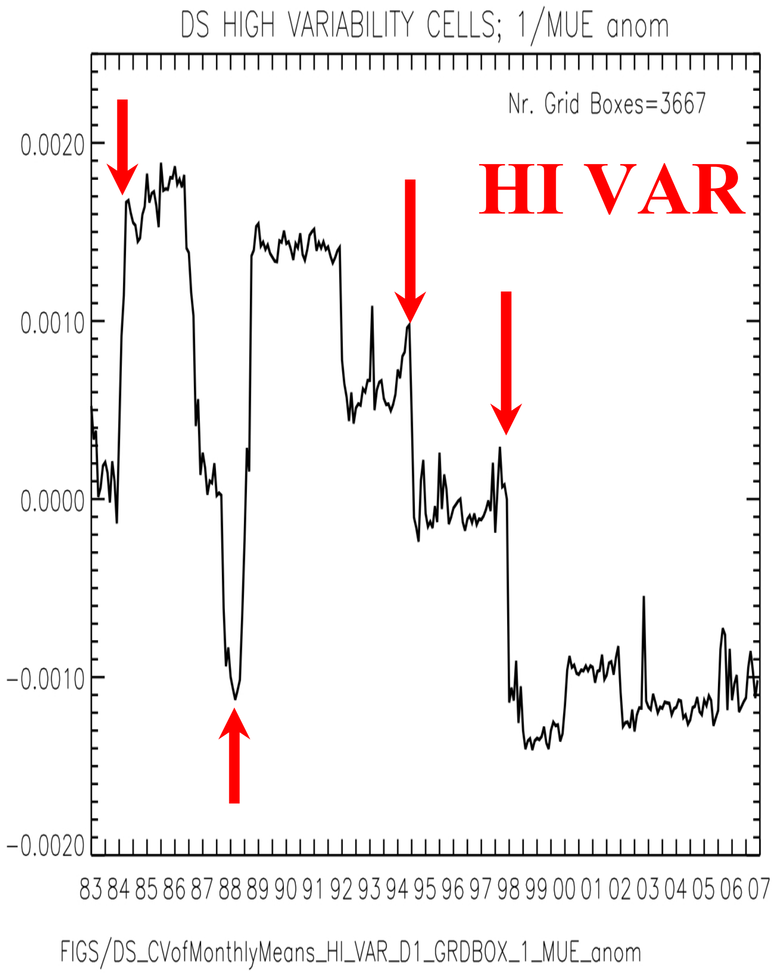


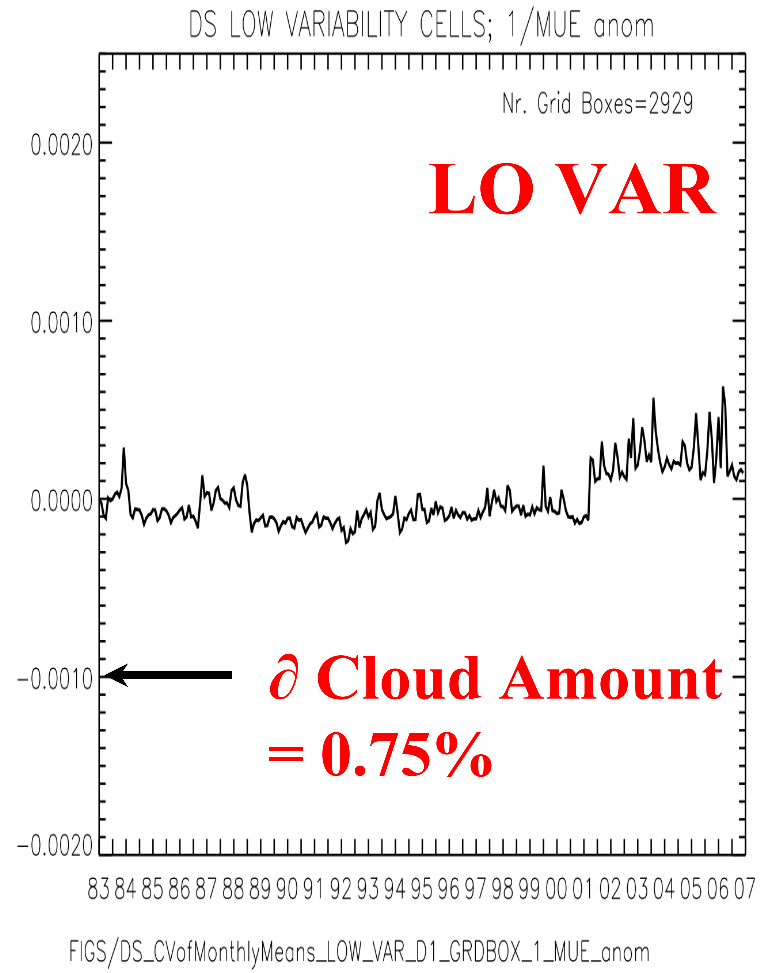
Calibration Effect on Total Cloud Amount



1/MUE ANOMALIES

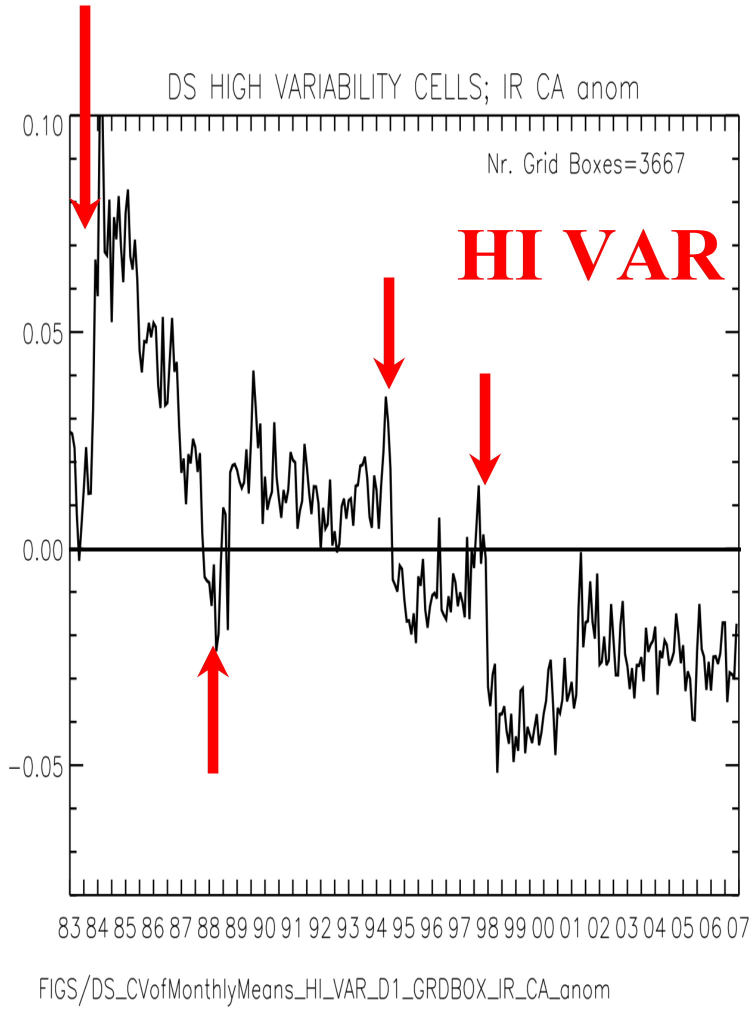
LOOSE THRESHOLD

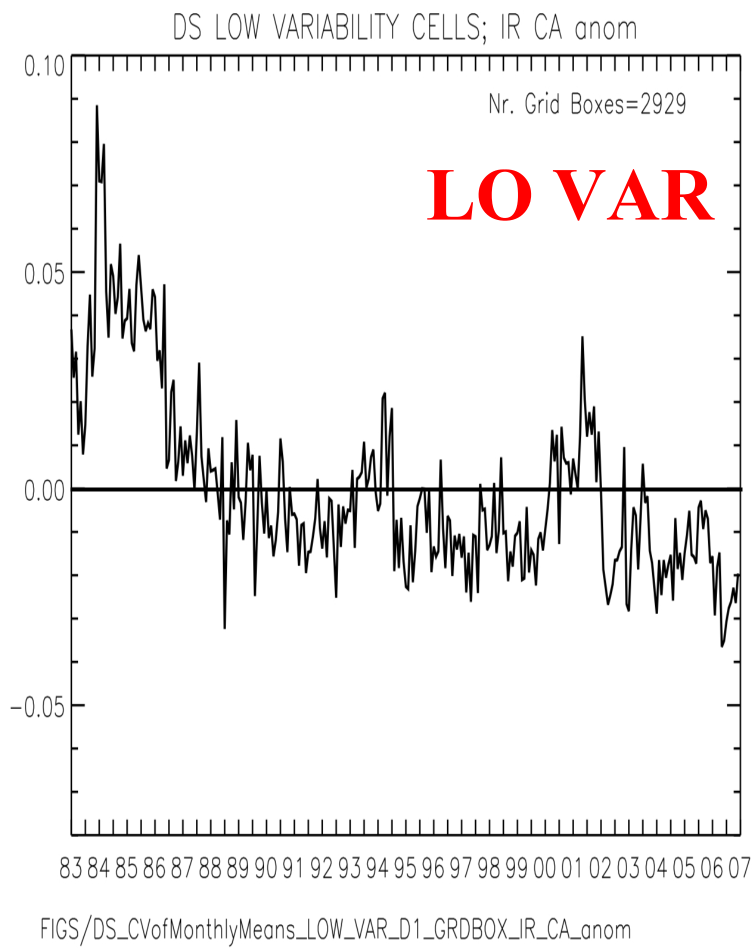




∂ Cloud Amount / ∂ Mue = 25%

SEPARATED CLOUD AMOUNT ANOMALIES

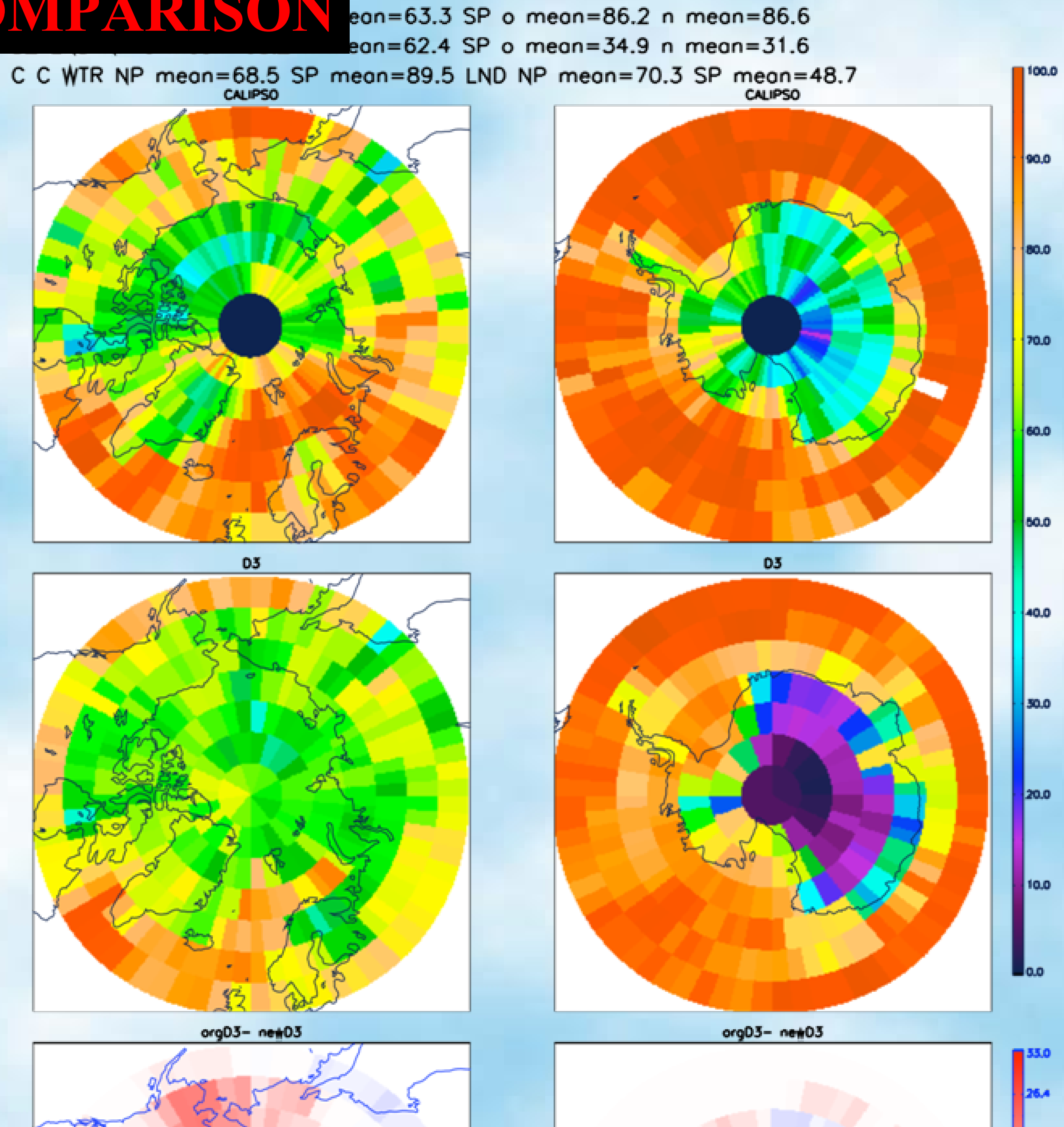




JANUARY COMPARISON

CALIPSO

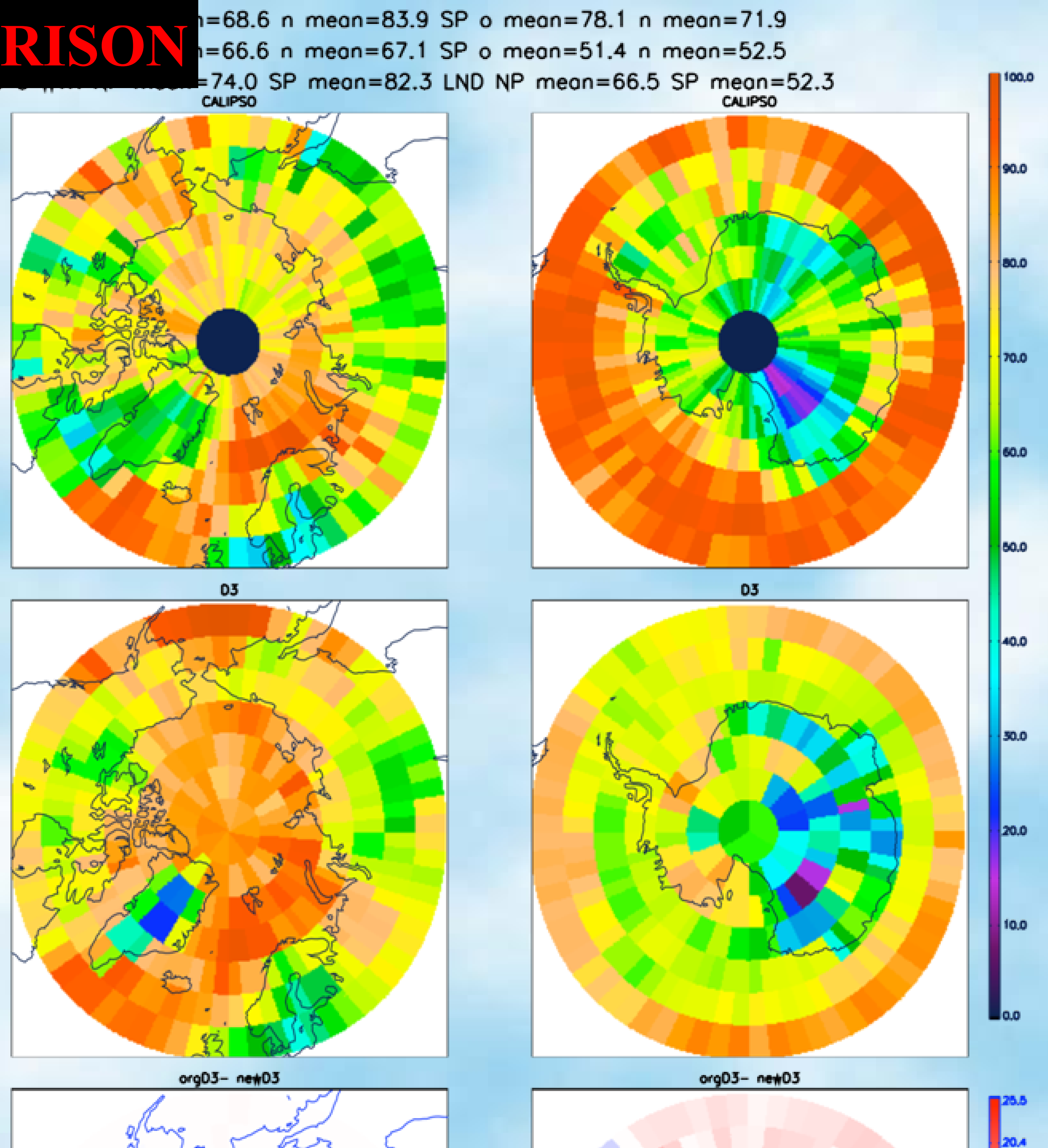
ISCCP

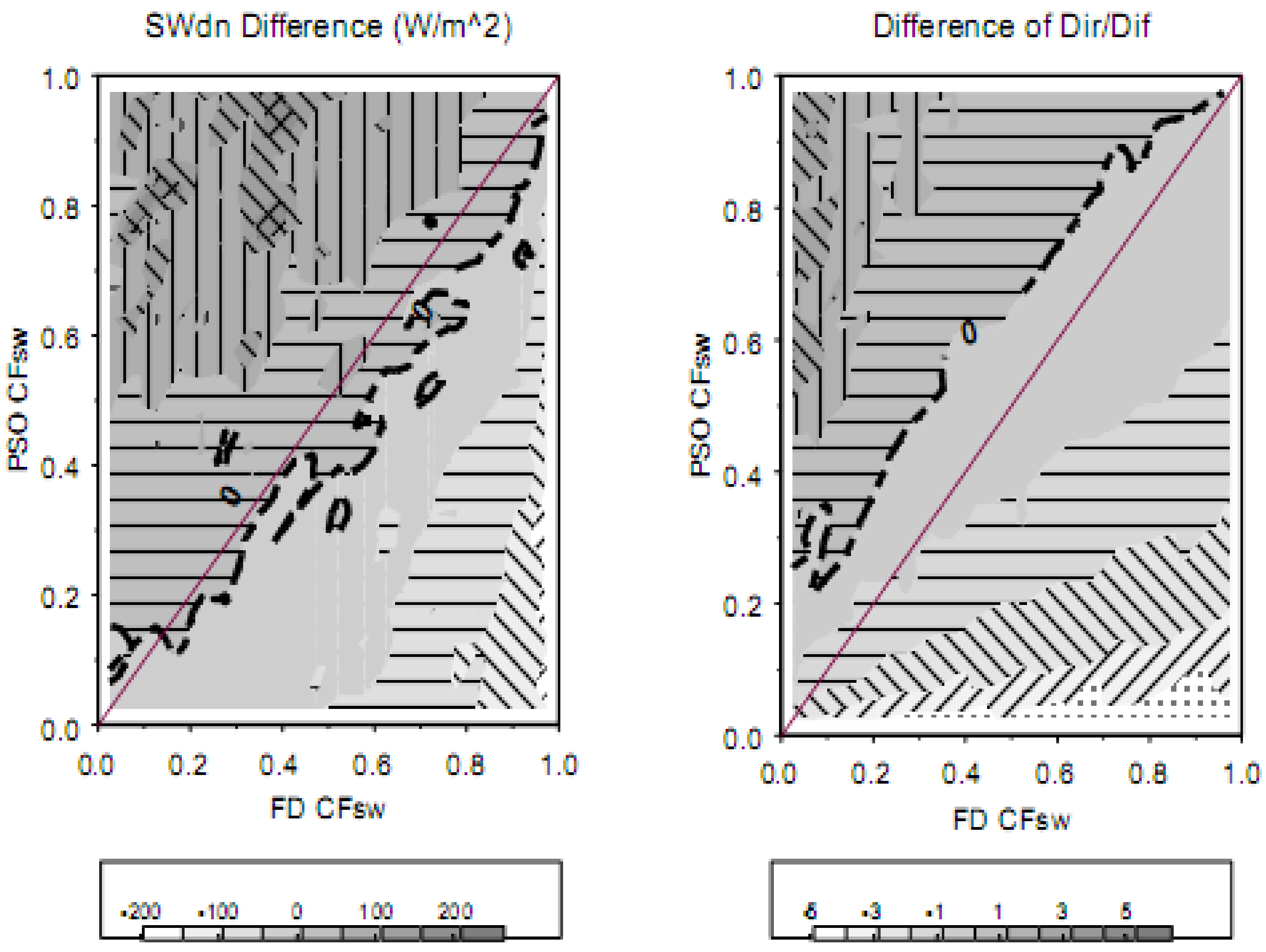


JULY COMPARISON

CALIPSO

ISCCP





SWdn Difference (W/m^2)
Difference of Dir/Dif
PSO CFsw
FD CFsw
0.0
0.2
0.4
0.6
0.8
1.0
-200
-100
0
100
200
-5
-3
-1
1
3
5

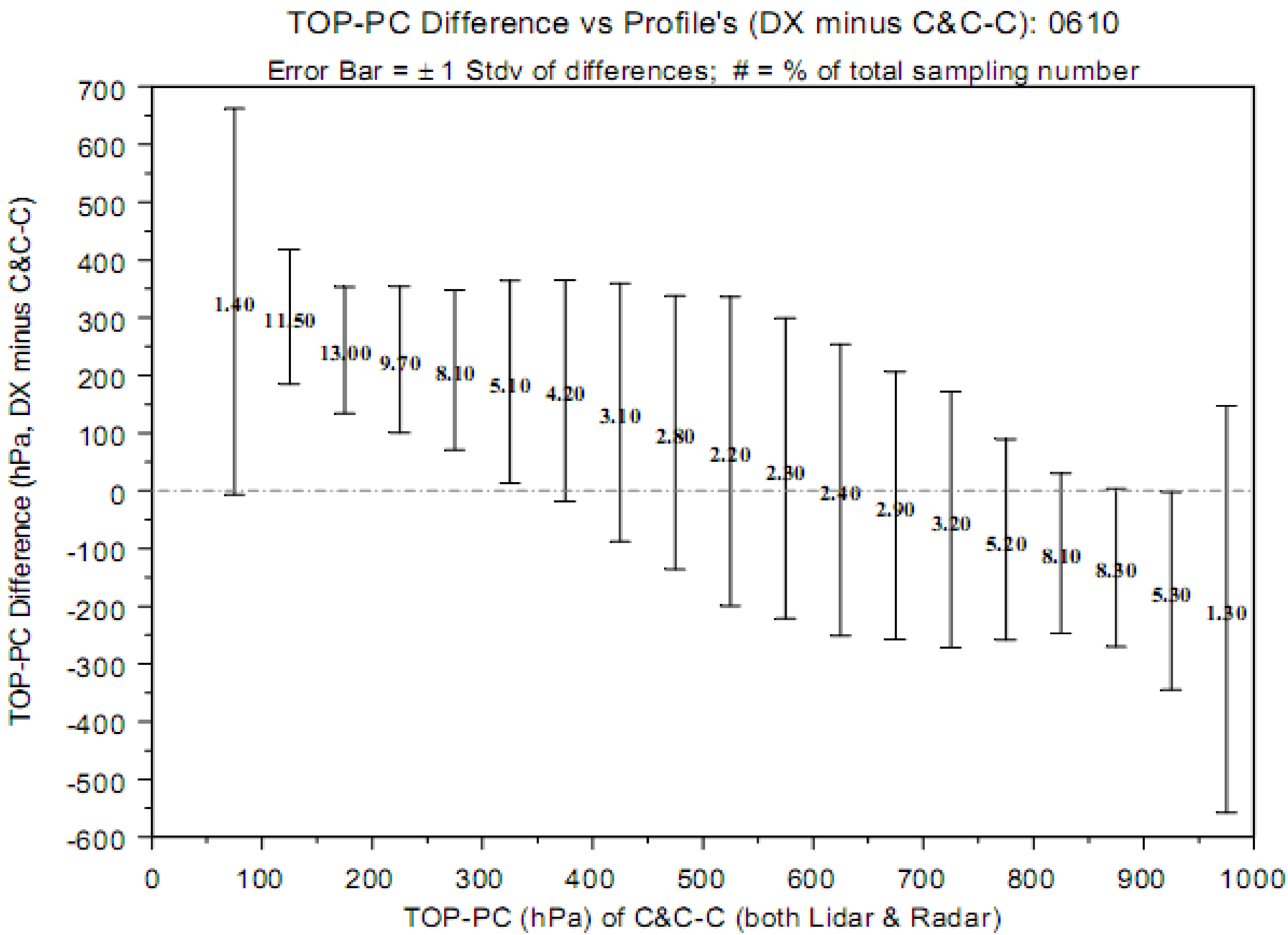
SUMMARY OF TESTS COMPLETED

ISCCP CLOUD TEMPERATURE/PRESSURE

- Space-Time Resolution and Sampling Effects
- Angle Dependence Effects
- Evaluation of Clear Sky Radiances (surface temperatures)
- Evaluation of Input Atmospheric Temperature and Humidity
- Comparison with Different Instruments: SAGE, HIRS, CALIPSO
- Evaluation of Radiative Fluxes

CLOUD TOP TEMPERATURE (261.6K)

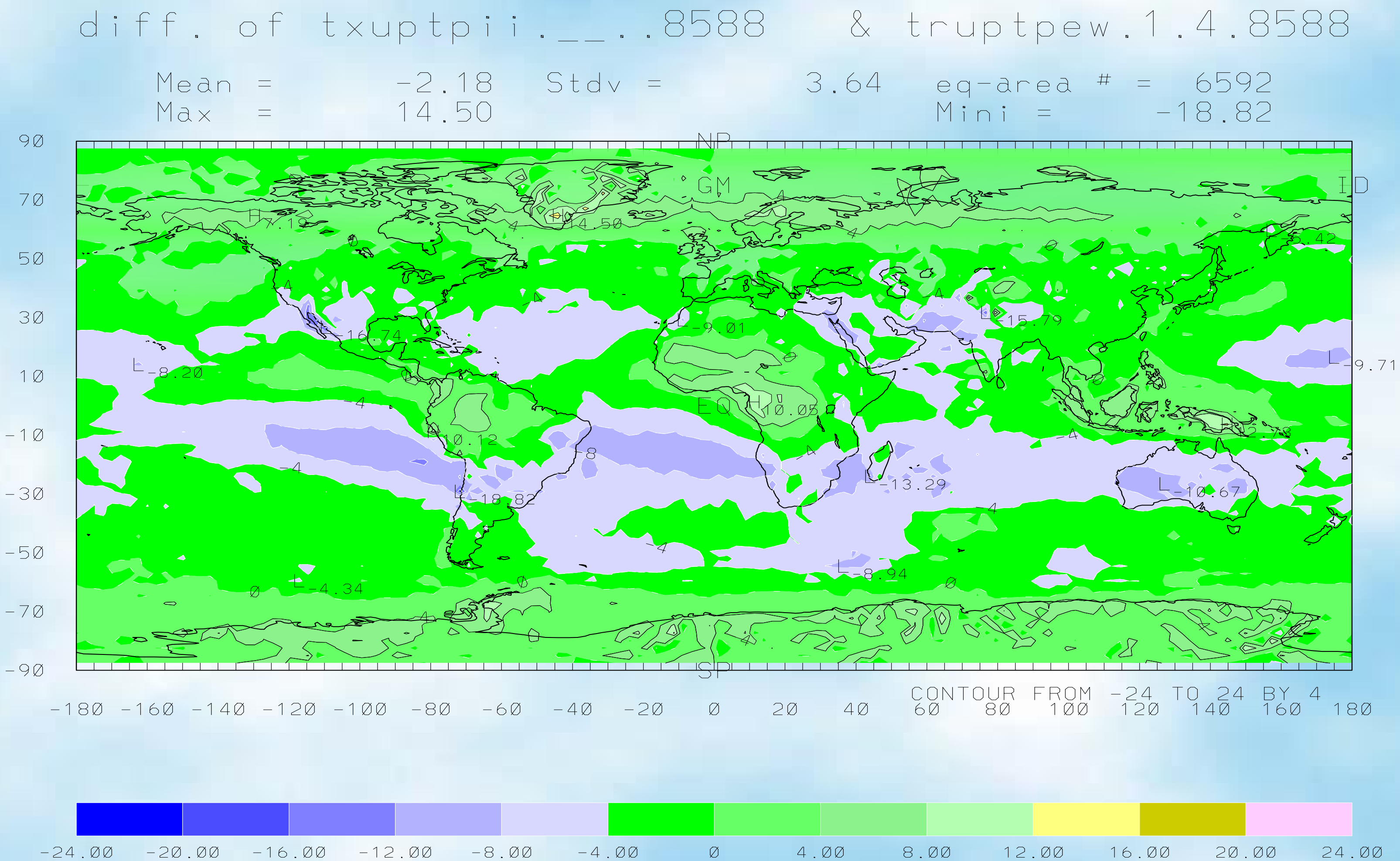
1. **Cloud Top Temperature/Pressure:** Atmospheric temperature/humidity profile, including surface skin temperature obtained from clear sky IR radiance, is converted to brightness temperature (at 10 micron wavelength) profile using plane-parallel radiative transfer code, followed by matching profile to observed cloudy sky brightness, physical temperature of blackbody cloud and pressure from corresponding profile, then values adjusted to account for transmitted radiation using optical thickness converted to emissivity (phase dependent model) – iterated retrieval
2. **Cloud Top Temperature Evaluation:** 9 Papers – very thin cirrus located too high in tropical atmosphere, location of very thin clouds ambiguous
3. **Precision** ≈1-2K Instantaneous for mid/lo clouds, ≈3-6K for hi clouds, similar on Average
4. **Accuracy** ≈ 1-3K



TOP-PC Difference vs Profile's (DX minus C&C-C): 0610
Error Bar = ± 1 Stdv of differences; # = % of total sampling number
TOP-PC Difference (hPa, DX minus C&C-C)
TOP-PC (hPa) of C&C-C (both Lidar & Radar)
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
100
200
300
400
500
600
700
800
900
1000
1.40
11.50
13.00
9.70
8.10
5.10
4.20
3.10
2.80
2.20
2.30
2.40
2.90
3.20
5.20
8.10
8.30
5.30
1.30

Fig. 1

ISCCP-FD Minus ERBE Annual Mean Full-Sky TOA LW↑ (W/m^2) for 85-88



SUMMARY OF TESTS COMPLETED

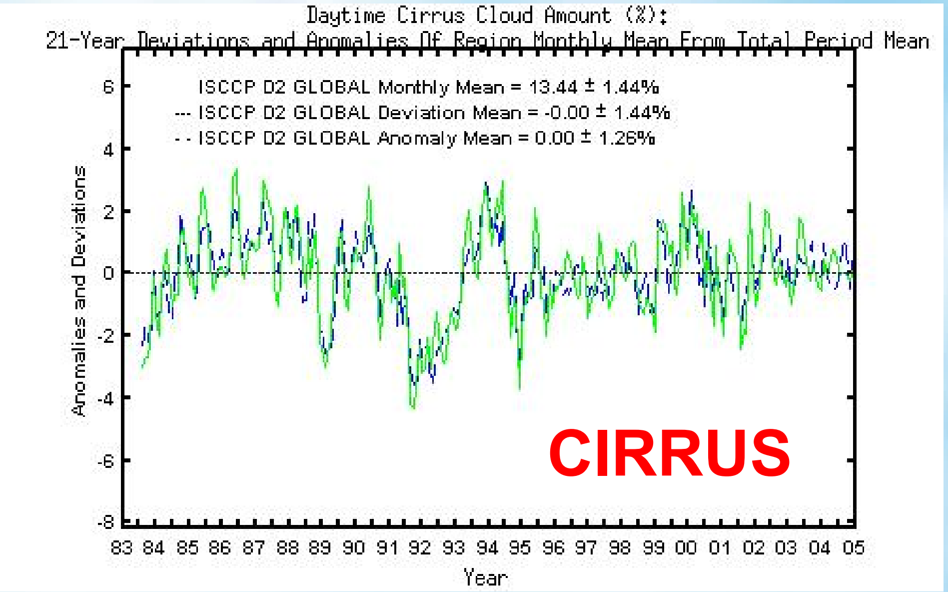
ISCCP LO/MID/HI CLOUD AMOUNTS

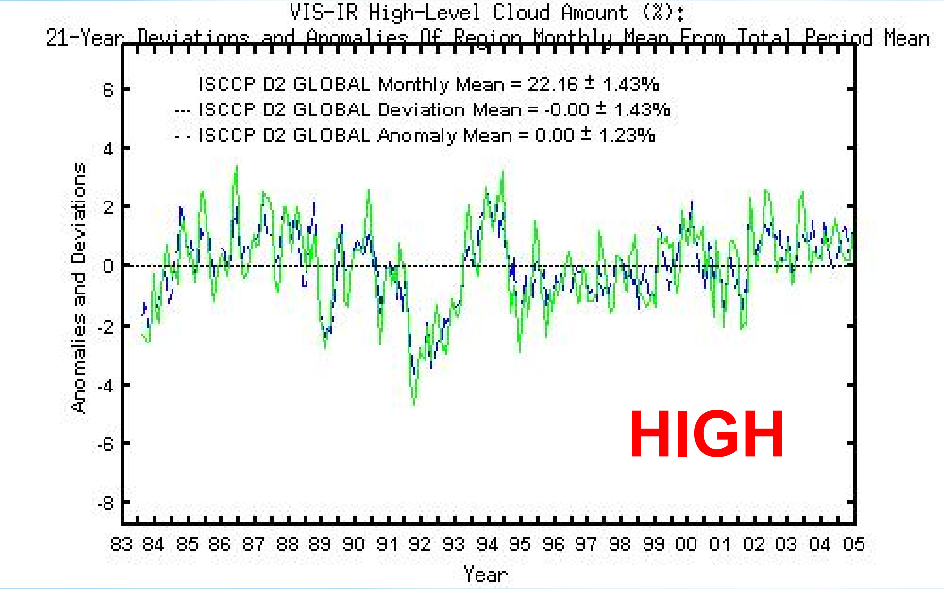
- Space-Time Resolution and Sampling Effects
- Comparison with Different Instruments: SAGE, HIRS, Surface Observers, CLOUDSAT, CALIPSO

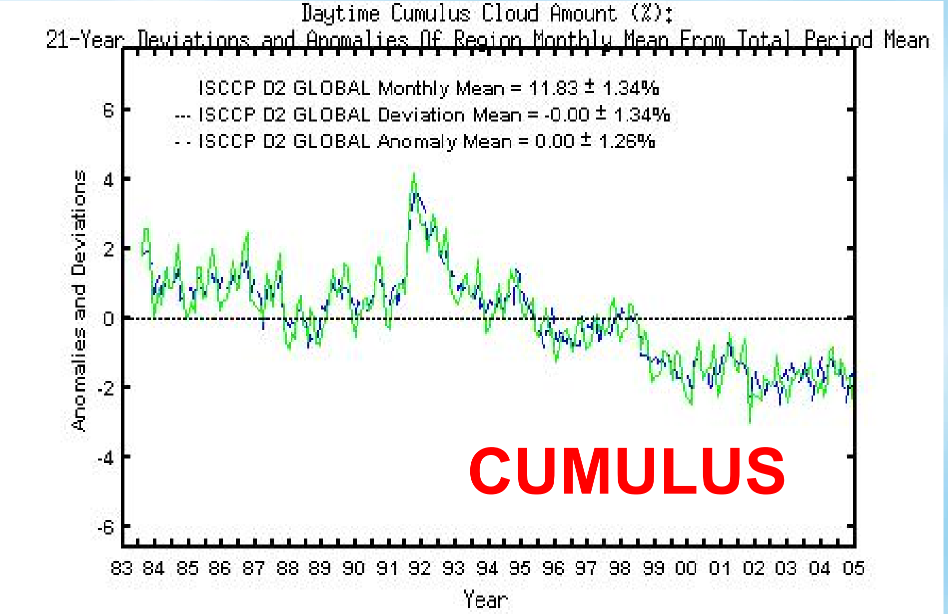
LO/MID/HI CLOUD AMOUNT SUMMARY

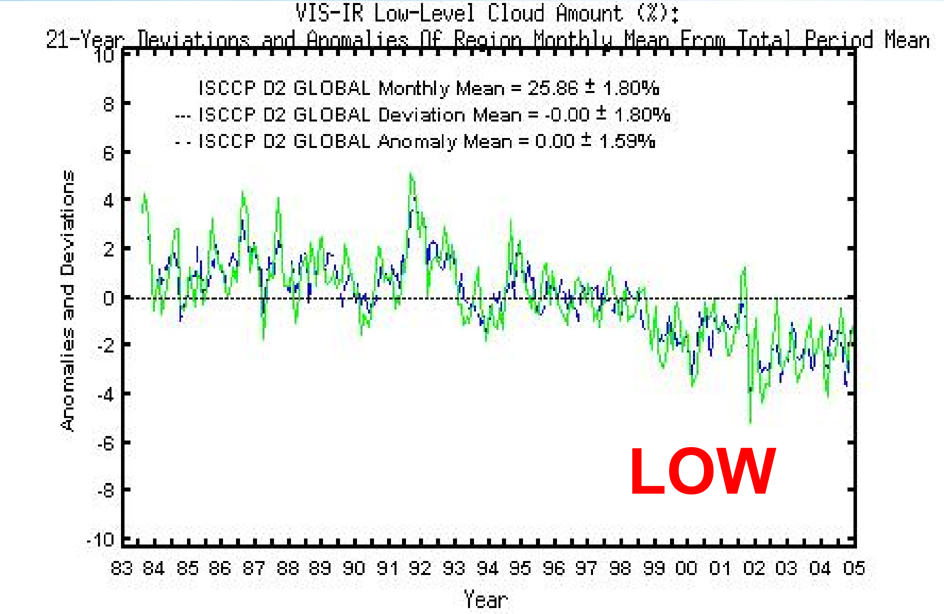
1. **Lo/Mid/Hi Cloud Amounts:** 12 Papers -- about 1/4-1/3 middle-level clouds are thin cirrus over low clouds, cloud location assignment for very thin clouds is very sensitive
2. **Cloud Top Location Evaluation:** 9 Papers – very thin cirrus located too high in tropical atmosphere, location of very thin clouds ambiguous

Cloud Type Variations

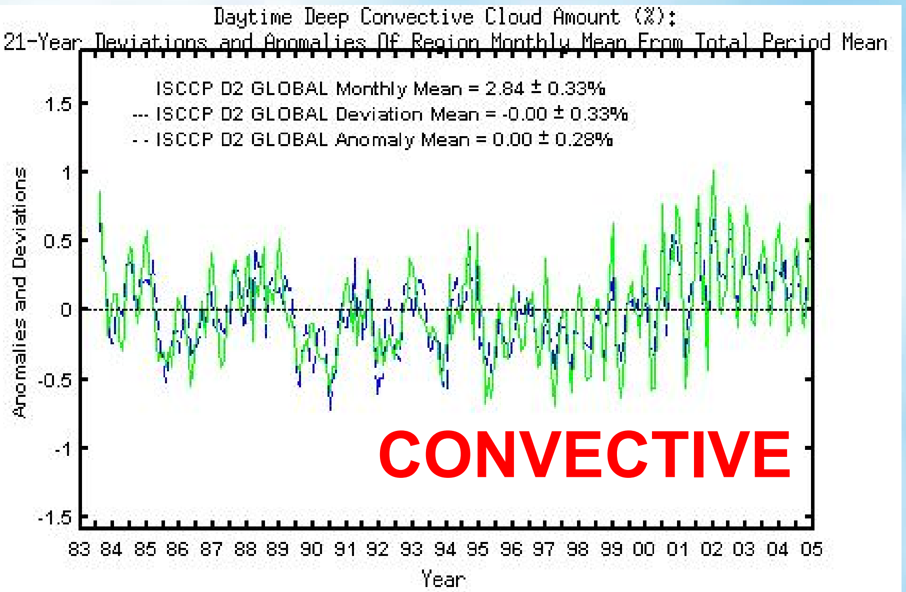


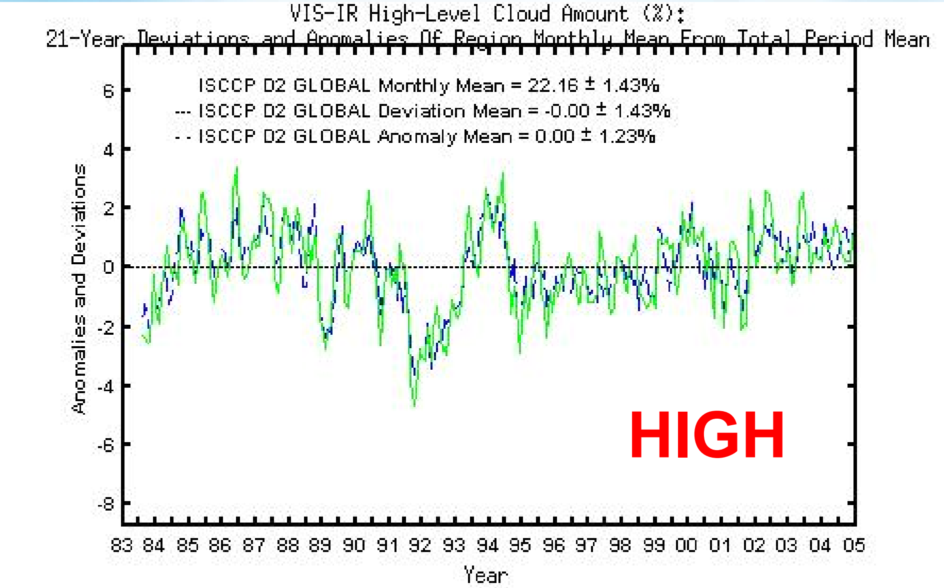


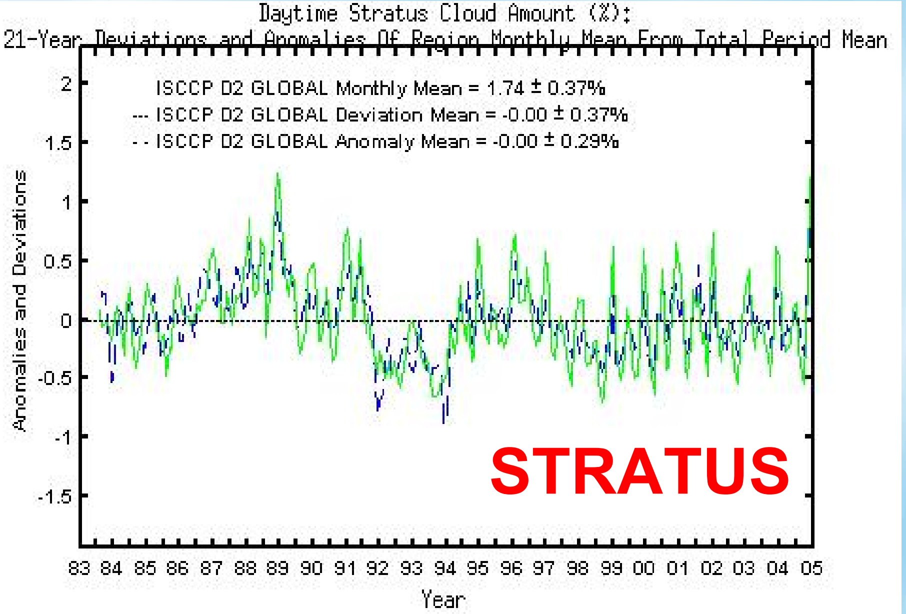


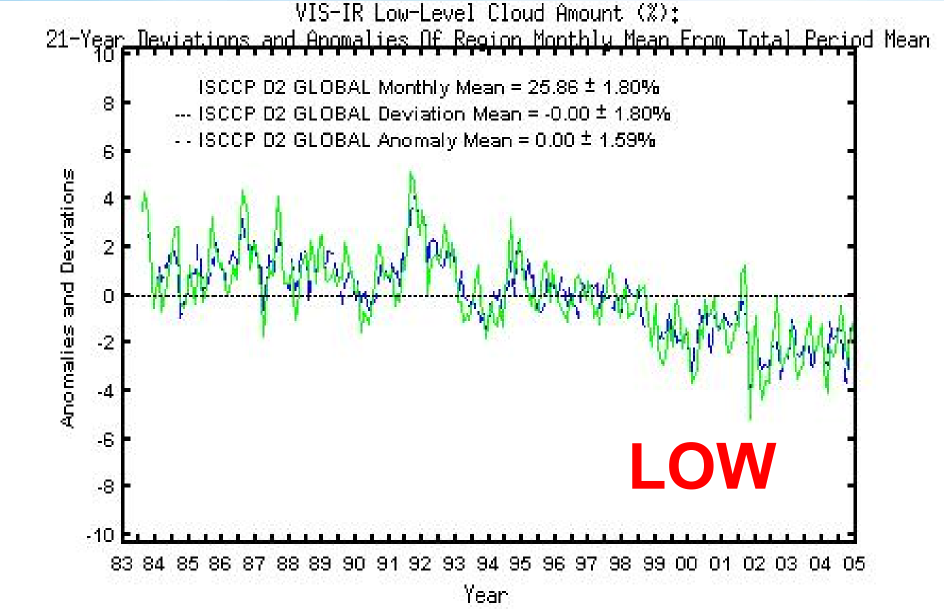


Cloud Type Variations









SUMMARY OF TESTS COMPLETED

ISCCP CLOUD OPTICAL THICKNESS

- Space-Time Resolution and Sampling Effects
- Angle-Dependence Effects
- Evaluation of Clear Sky Radiances (surface reflectances)

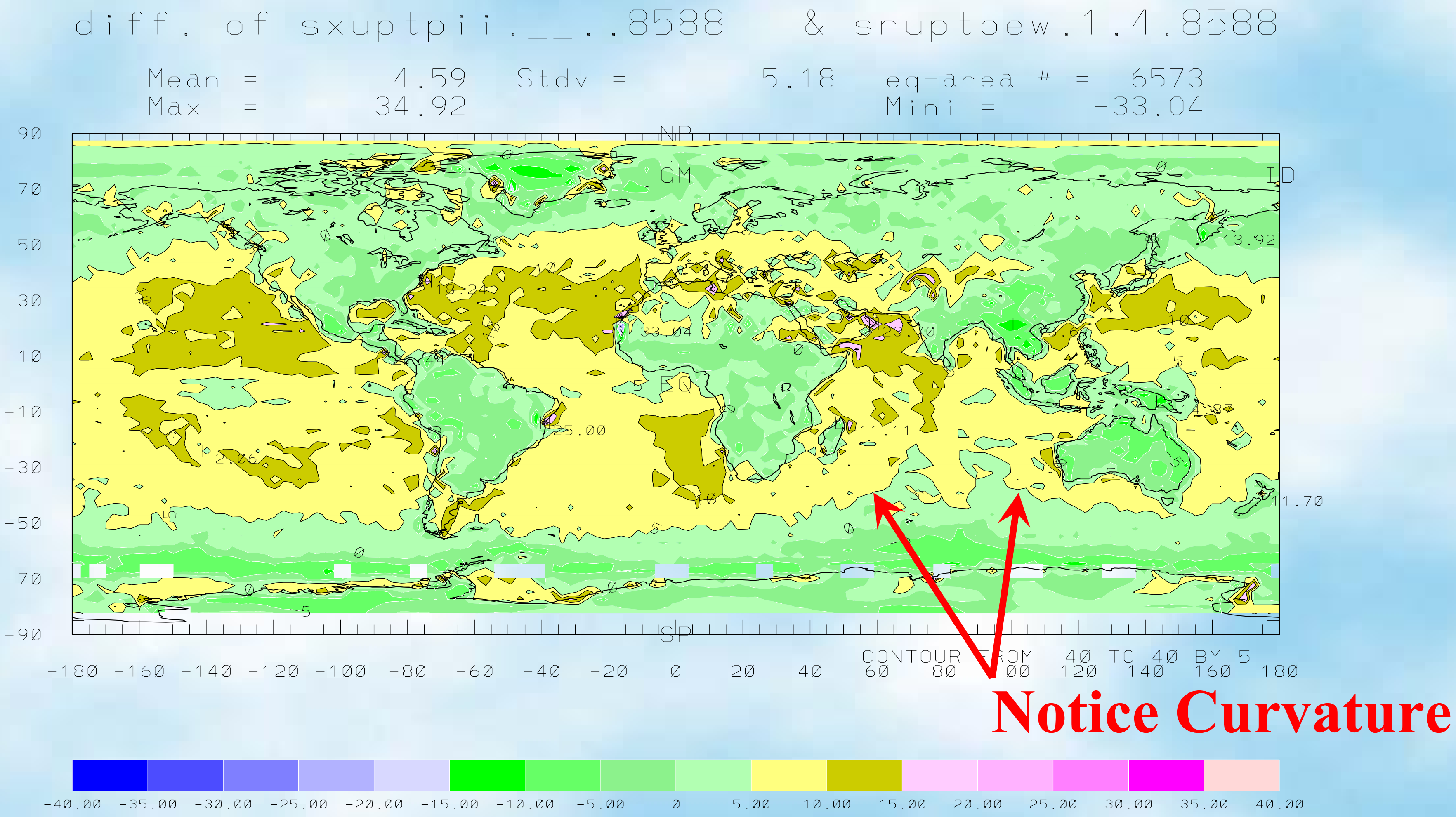
- Comparison with Different Instruments: SSM/I

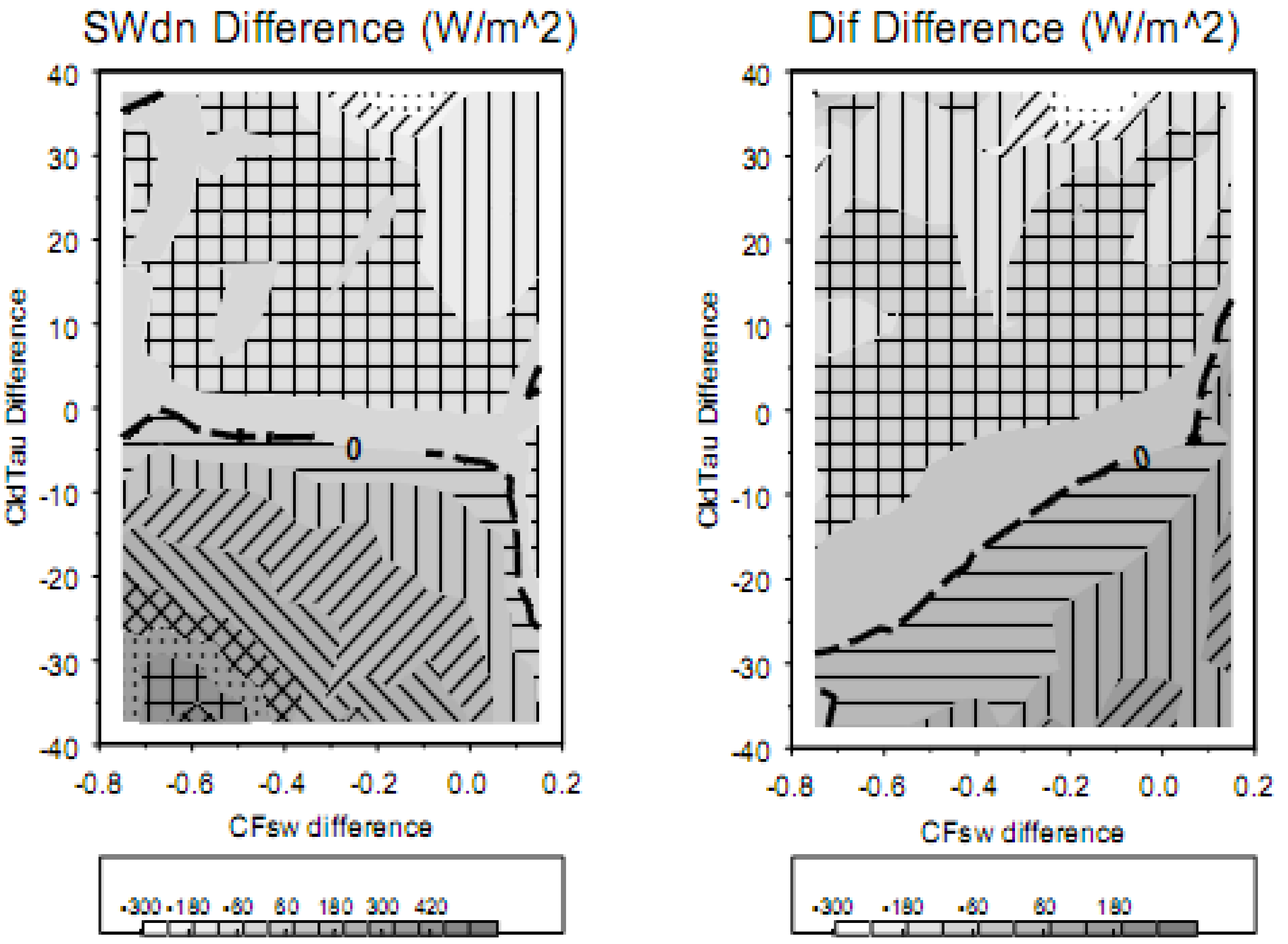
- Evaluation of Radiative Fluxes

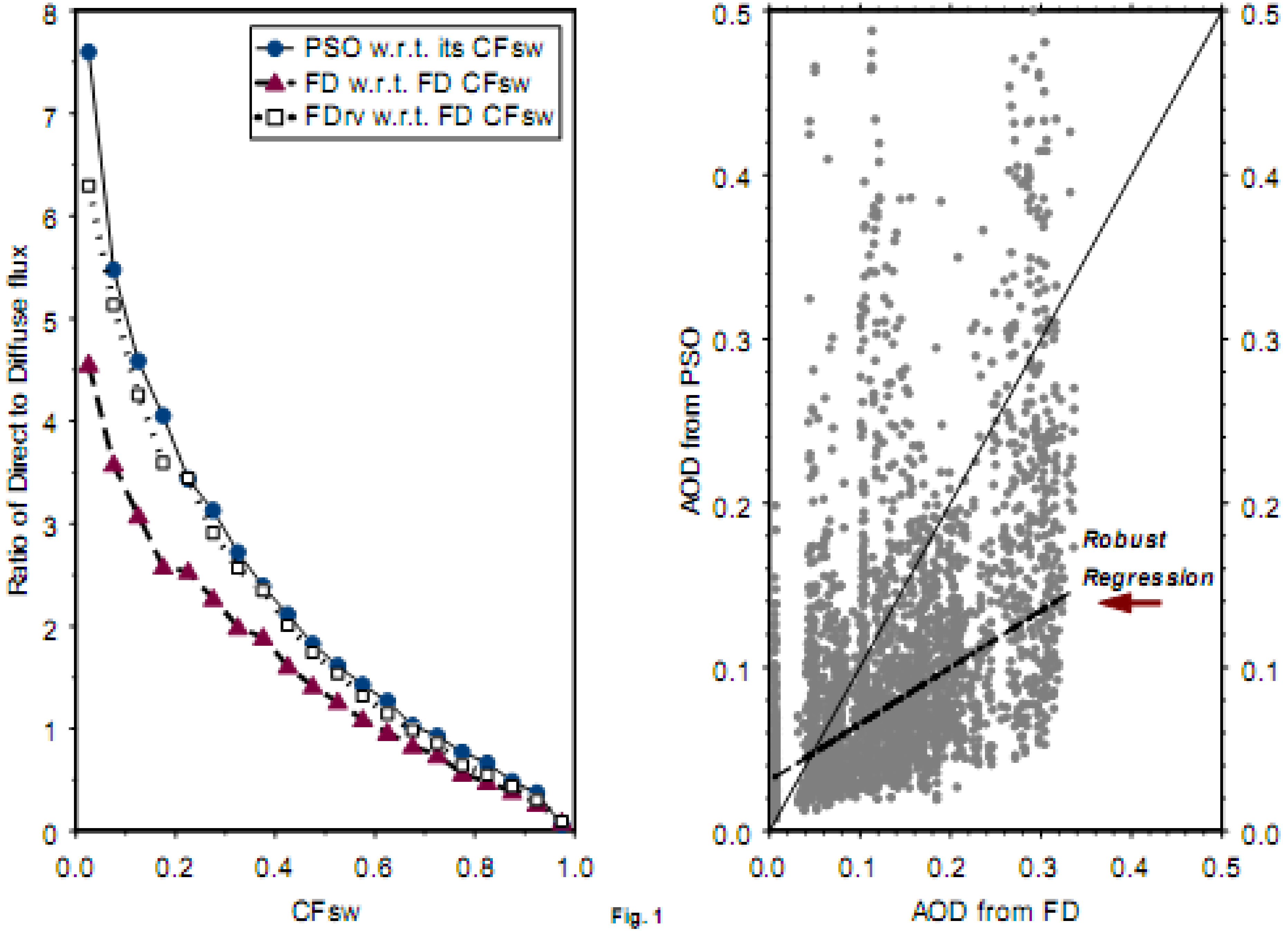
OPTICAL THICKNESS (3.9)

1. **Optical Thickness/Emissivity:** Cloudy visible (0.6 micron wavelength) radiance corrected for ozone absorption and day-of-year sun-Earth distance variations, followed by comparison to pre-calculated cloudy sky radiances as function of viewing/illumination geometry, cloud top pressure and surface reflectance obtained from clear sky VIS radiance – radiative calculation for plane-parallel atmosphere with cloud layer (phase dependent microphysical model determined by cloud top temperature) and gas layer above and below – iterated retrieval – infrared emissivity obtained from visible optical thickness as function of phase-dependent microphysics model
2. **Cloud Optical Thickness/Emissivity:** 11 Papers -- bias caused by assumed particle size for liquid clouds < 3%, sensitivity to assumed particle size/shape for ice clouds suggests bias < 7%, residual plane-parallel effects apparent, evaluation of diurnal variations of Direct/Diffuse ratio shows that optical thickness accurately characterizes atmospheric scattering
3. **Precision** ≈10-15% Instantaneous, < 10% on Average
4. **Accuracy** ≈ 10%

ISCCP-FD Minus ERBE Annual Mean Full-Sky TOA SW↑ (W/m^2) for 85-88




SWdn Difference (W/m^2)
CldTau Difference
CFsw difference
0
-300 -180 -60 60 180 300 420
Dif Difference (W/m^2)
CldTau Difference
CFsw difference
0
-300 -180 -60 60 180



PSO w.r.t. its CFsw
FD w.r.t. FD CFsw
FDrv w.r.t. FD CFsw
Ratio of Direct to Diffuse flux
CFsw
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5
6
7
8
AOD from PSO
AOD from FD
0.0
0.1
0.2
0.3
0.4
0.5
Robust
Regression

Fig. 1

SUMMARY OF TESTS COMPLETED

ISCCP CLOUD PARTICLE SIZES

- Space-Time Resolution and Sampling Effects
- Angle Dependence Effects

- Comparison with Different Instruments: (SSM/I), (MODIS, HIRS)

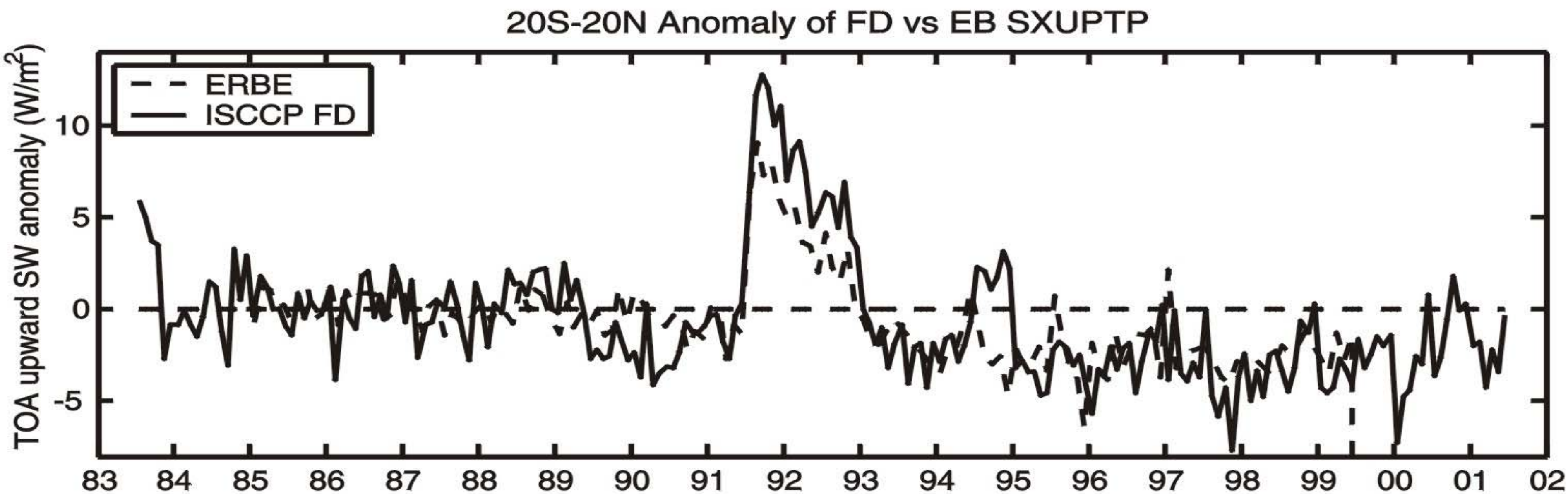
LIQUID – ICE PARTICLE RADIUS (liq ≈ 14 μm ---- ice ≈ 27 μm)

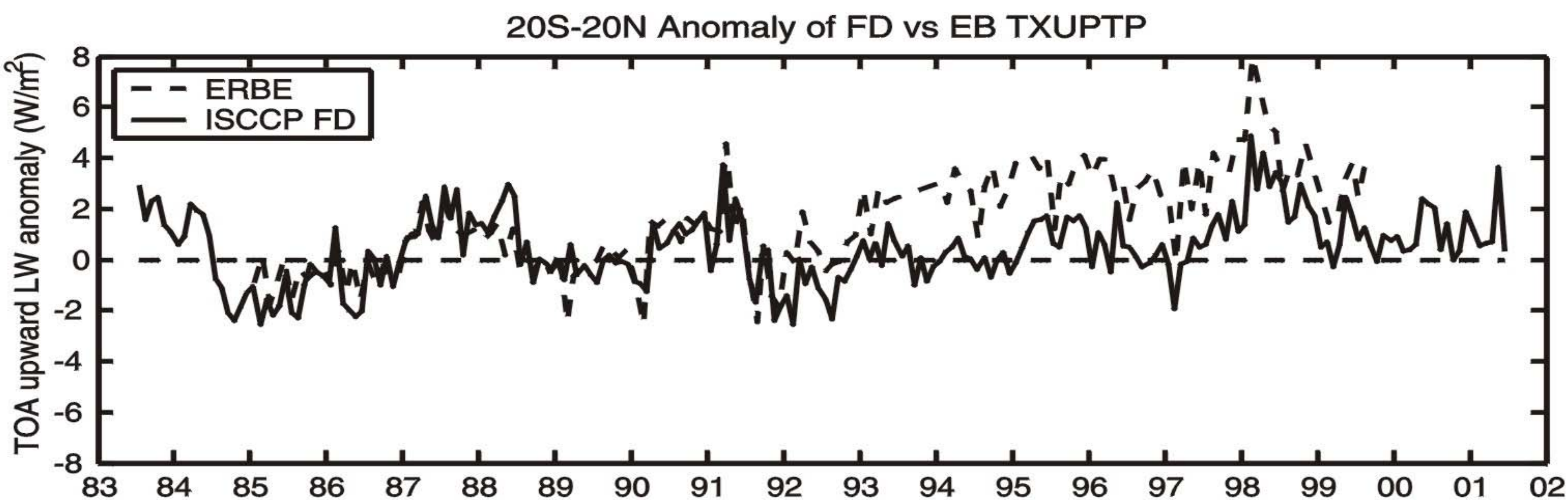
1. **Particle Effective Radius:** Cloudy pixels from AHVRR are reanalyzed using 3.7 micron wavelength radiance, uses standard optical thickness and assumed (phase dependence determined by cloud top temperature) effective radius as first guess in iterative comparison to pre-calculated radiances as function of viewing/illumination geometry, surface reflectance and atmospheric scattering/absorption – optical thickness re-scaled for consistency with effective radius
2. **RE-liquid and RE-ice:** 5 Papers – ice particles most uncertain because of shape effects
3. **Precision** ≈1-2μm Instantaneous Liquid, ≈1μm on Average, ≈3-6μm Instantaneous Ice, ≈2-3μm on Average
4. **Accuracy** ≈1-2μm Liquid, ≈3-7μm Ice

WATER PATH SUMMARY

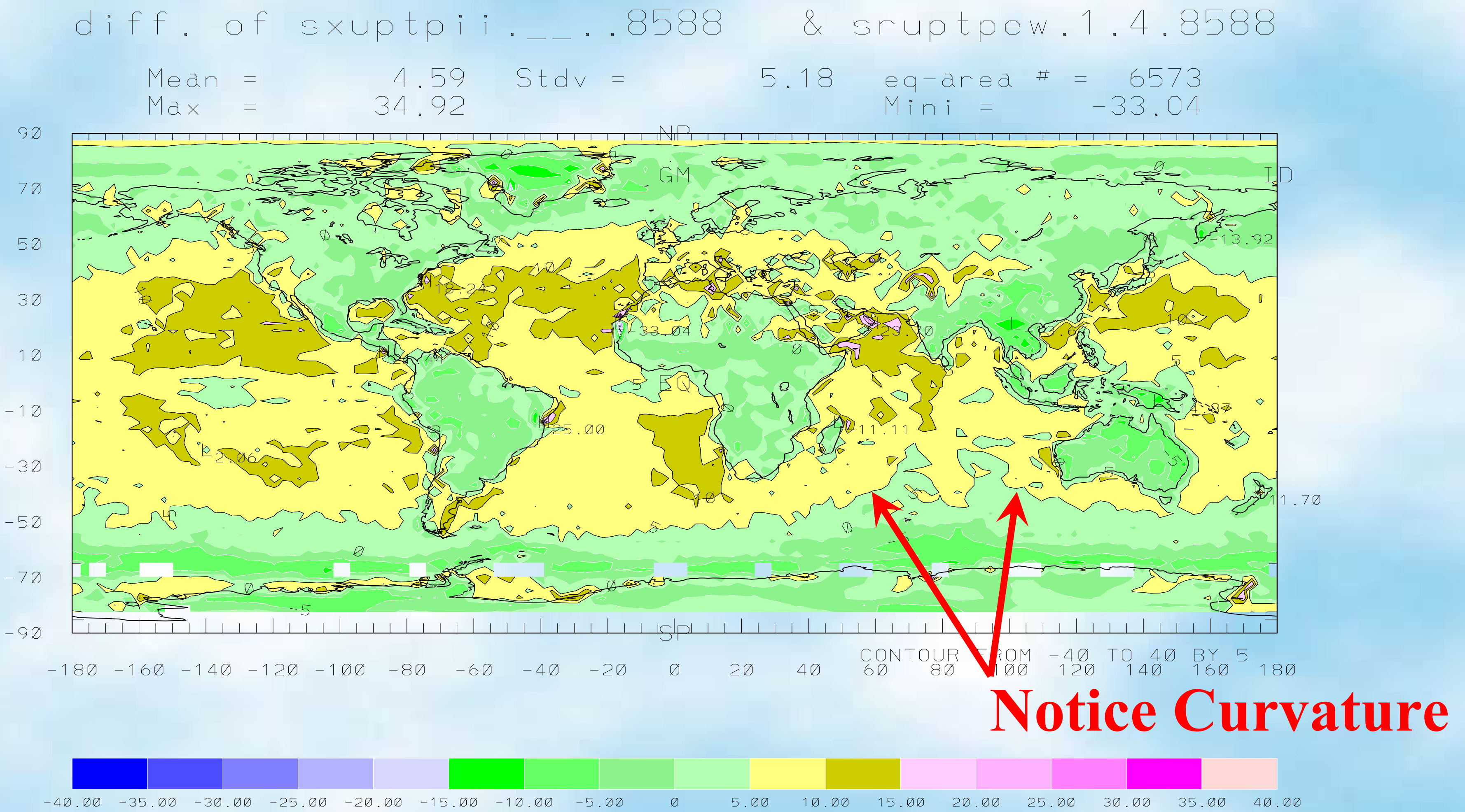
1. **Standard LWP/IWP:** Optical thickness, together with assumed phase-dependent microphysics model, determines water path (phase assumed constant for whole cloud layer)
2. **New LWP/IWP:** New optical thickness and effective radius used to determine water path
3. **LWP/IWP:** 3 Papers – bias associated with vertical variations within cloud layer most significant uncertainty, especially for Ice clouds

ERBE VERSUS ISCCP FD

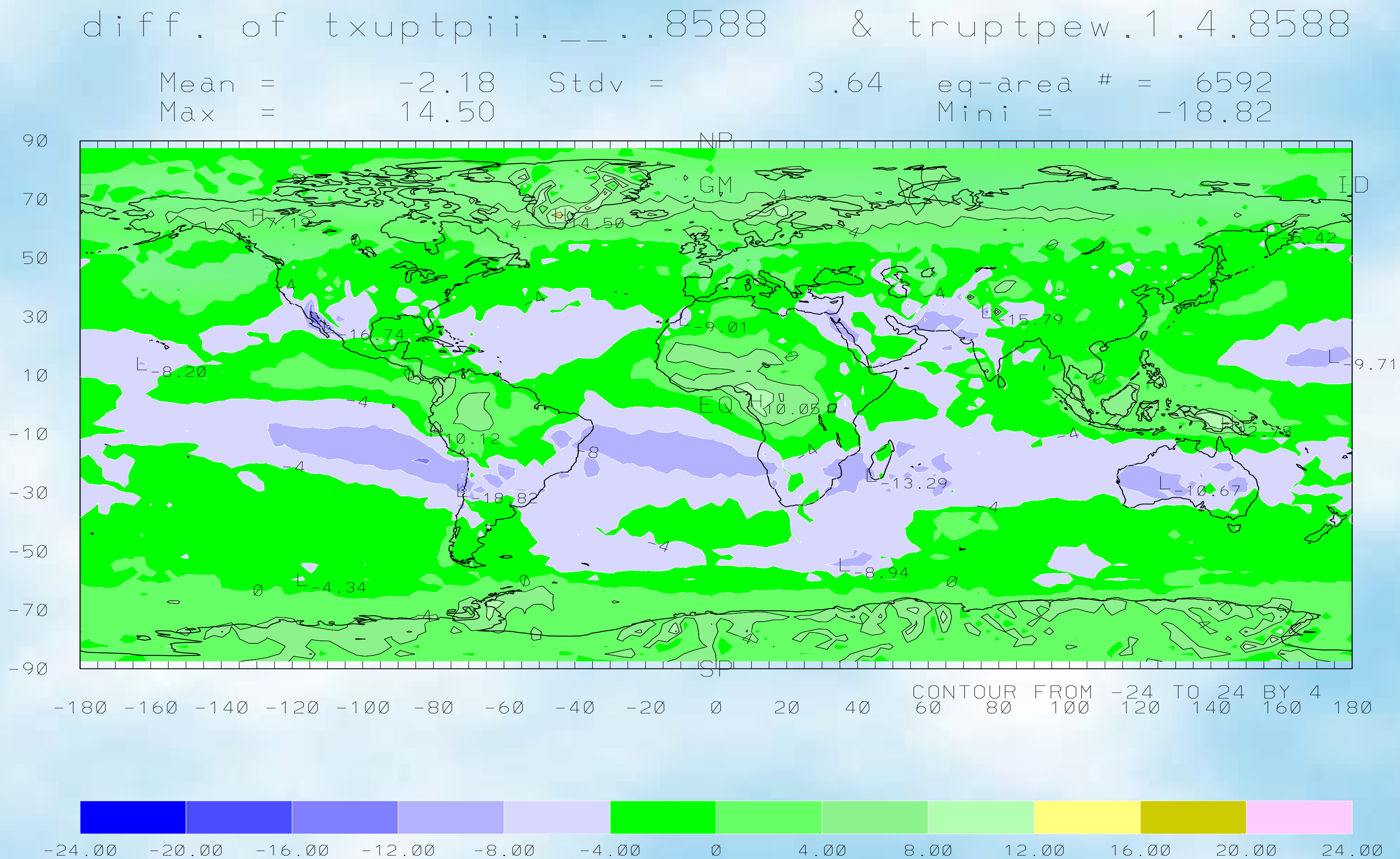




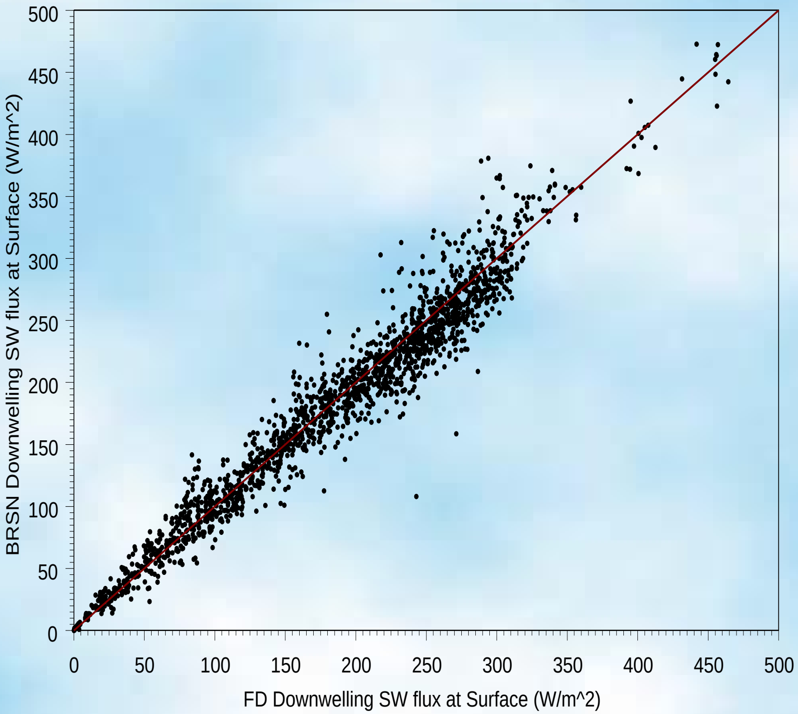
ISCCP-FD Minus ERBE Annual Mean Full-Sky TOA SW↑ (W/m^2) for 85-88

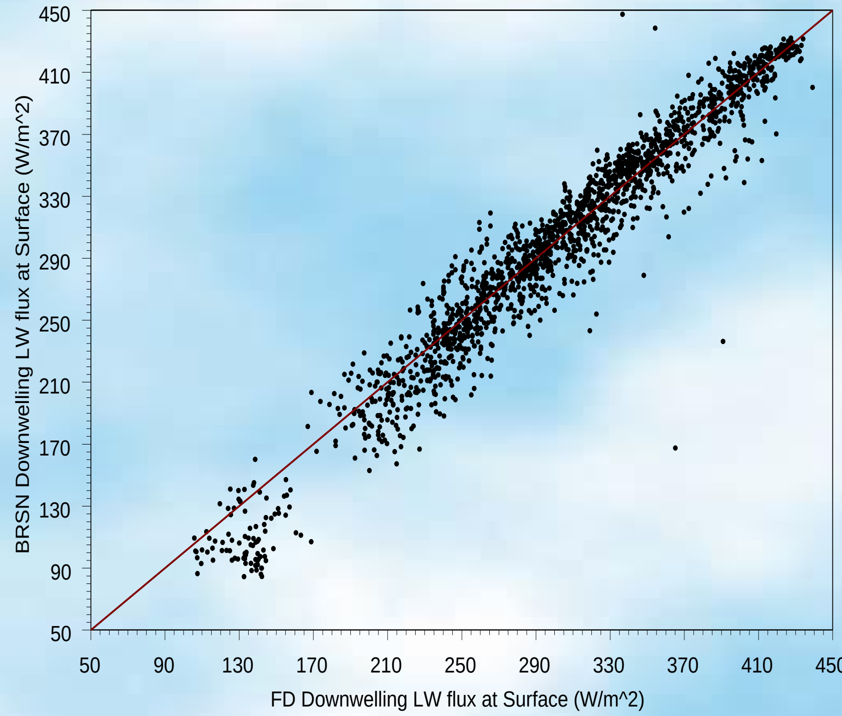


ISCCP-FD Minus ERBE Annual Mean Full-Sky TOA LW↑ (W/m^2) for 85-88



Comparison of Surface SW↓ and LW↓ Fluxes from ISCCP-FD with BSRN





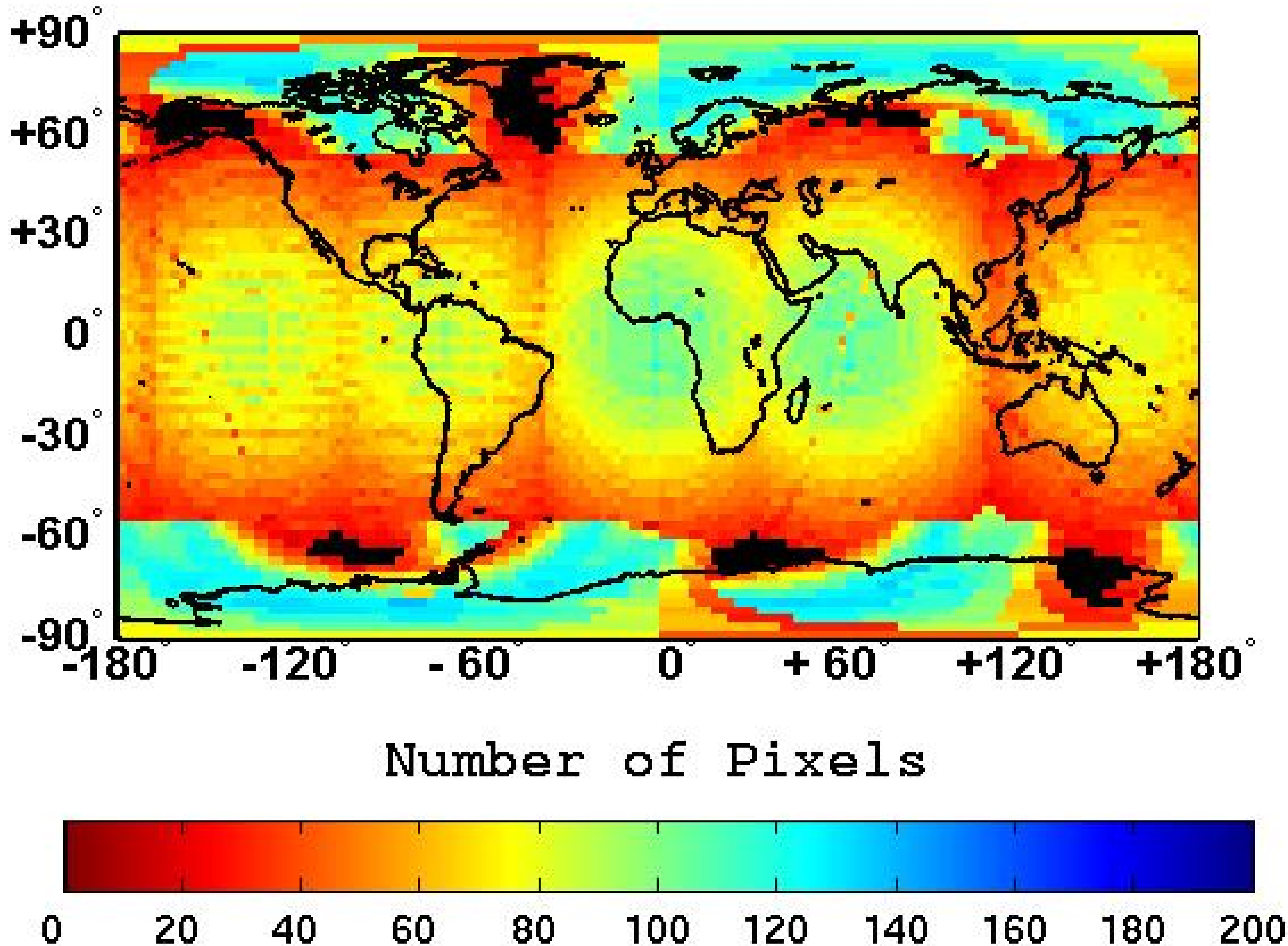
Quantity	FD	BRSN	mean difference	Stdv	corr coefficient	Slope	intercept	Norm dev	sample #
S↓	168.20	166.19	2.017	18.491	0.9825	0.96	3.90	13.07	1970
L↓	302.23	300.01	2.219	19.042	0.9706	1.05	-17.40	12.89	1831

7 PUBLICATIONS

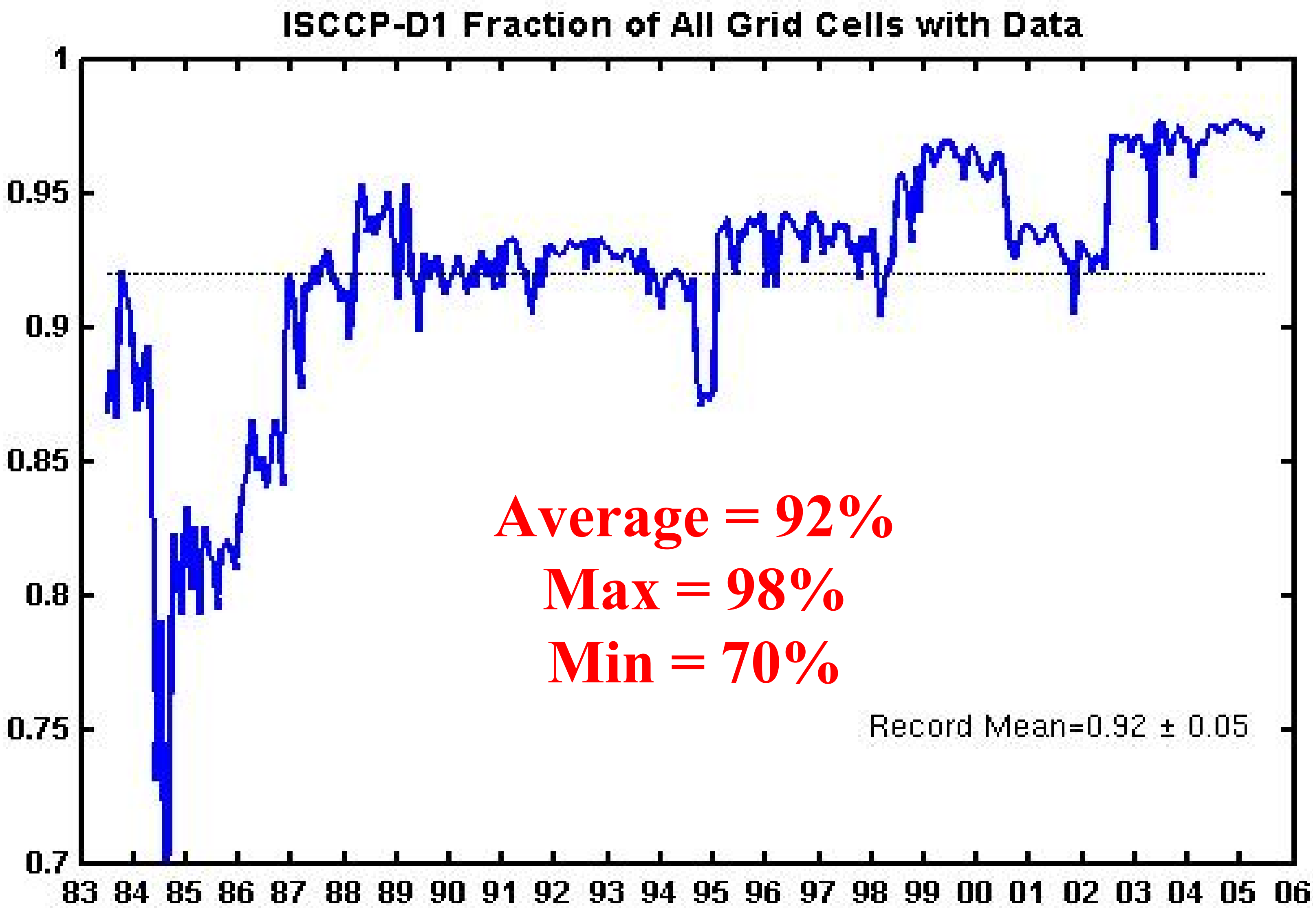
- Rossow, W.B., and A.A. Lacis, 1990: Global, seasonal cloud variations from satellite radiance measurements. Part II: Cloud properties and radiative effects. J. Climate, 3, 1204-1253.
- Zhang, Y-C., W.B. Rossow and A.A. Lacis, 1995: Calculation of surface and top-of-atmosphere radiative fluxes from physical quantities based on ISCCP datasets, Part I: Method and sensitivity to input data uncertainties. J. Geophys. Res., 100, 1149-1165.
- Rossow, W.B., and Y-C. Zhang, 1995: Calculation of surface and top-of-atmosphere radiative fluxes from physical quantities based on ISCCP datasets, Part II: Validation and first results. J. Geophys. Res., 100, 1167-1197.
- Zhang, Y-C., W.B. Rossow, A.A. Lacis, M.I. Mishchenko and V. Oinas, 2004: Calculation of radiative fluxes from the surface to top-of-atmosphere based on ISCCP and other global datasets: Refinements of the radiative transfer model and the input data. J. Geophys. Res., 109, doi 10.1029/2003JD004457 (1-27 + 1-25).
- Zhang, Y., W. B. Rossow, and P. W. Stackhouse, 2006: Comparison of different global information sources used in surface radiative flux calculation: Radiative properties of the near-surface atmosphere. J. Geophys. Res., 111, D13106, doi: 10.1029/2005JD006873, (1-13).
- Zhang, Y-C., W.B. Rossow and P.W. Stackhouse, 2007: Comparison of different global information sources used in surface radiative flux calculation: Radiative properties of the surface. J. Geophys. Res., 112, D01102, doi: 10.1029/2005JD007008, (1-20).
- Zhang, Y-C., W.B. Rossow, C.N. Long and E.G. Dutton, 2010: Exploiting diurnal variations to evaluate the ISCCP-FD flux calculations and Radiative-Flux-Analysis-Processed Surface Observations from BSRN, ARM and SURFRAD. J. Geophys. Res., (in press).

SUMMARY of ISCCP SPACE-TIME SAMPLING and COVERAGE

ISCCP SATELLITE COVERAGE FOR 23 DECEMBER 2004 GMT 0300

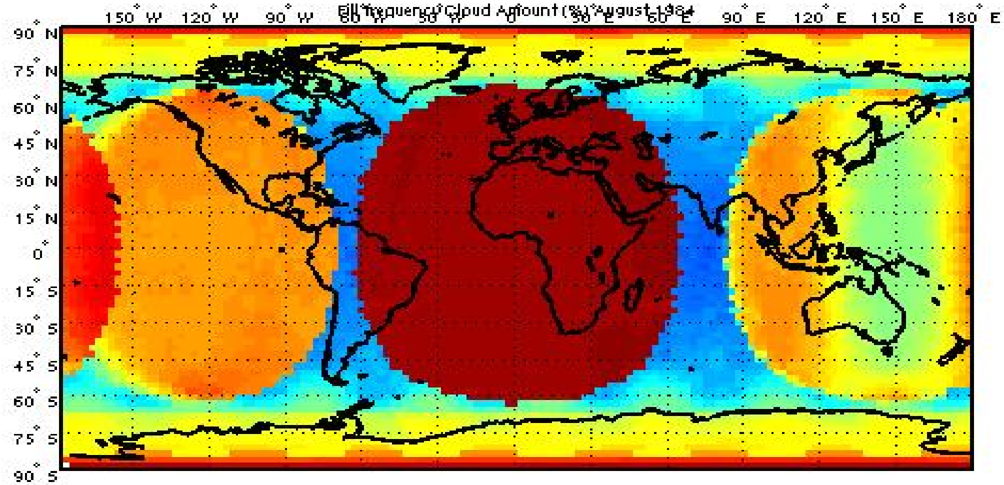


Percentage Coverage of Earth by ISCCP

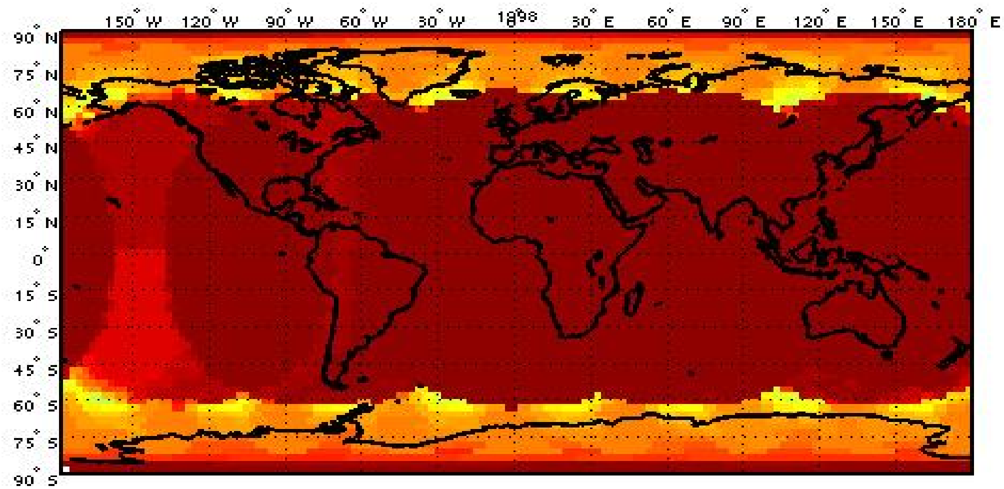


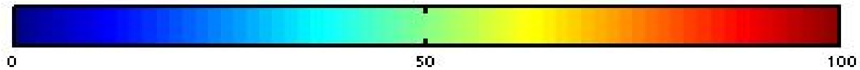
Percentage D1 Sampling for August 1984 and August 1998

August 1984

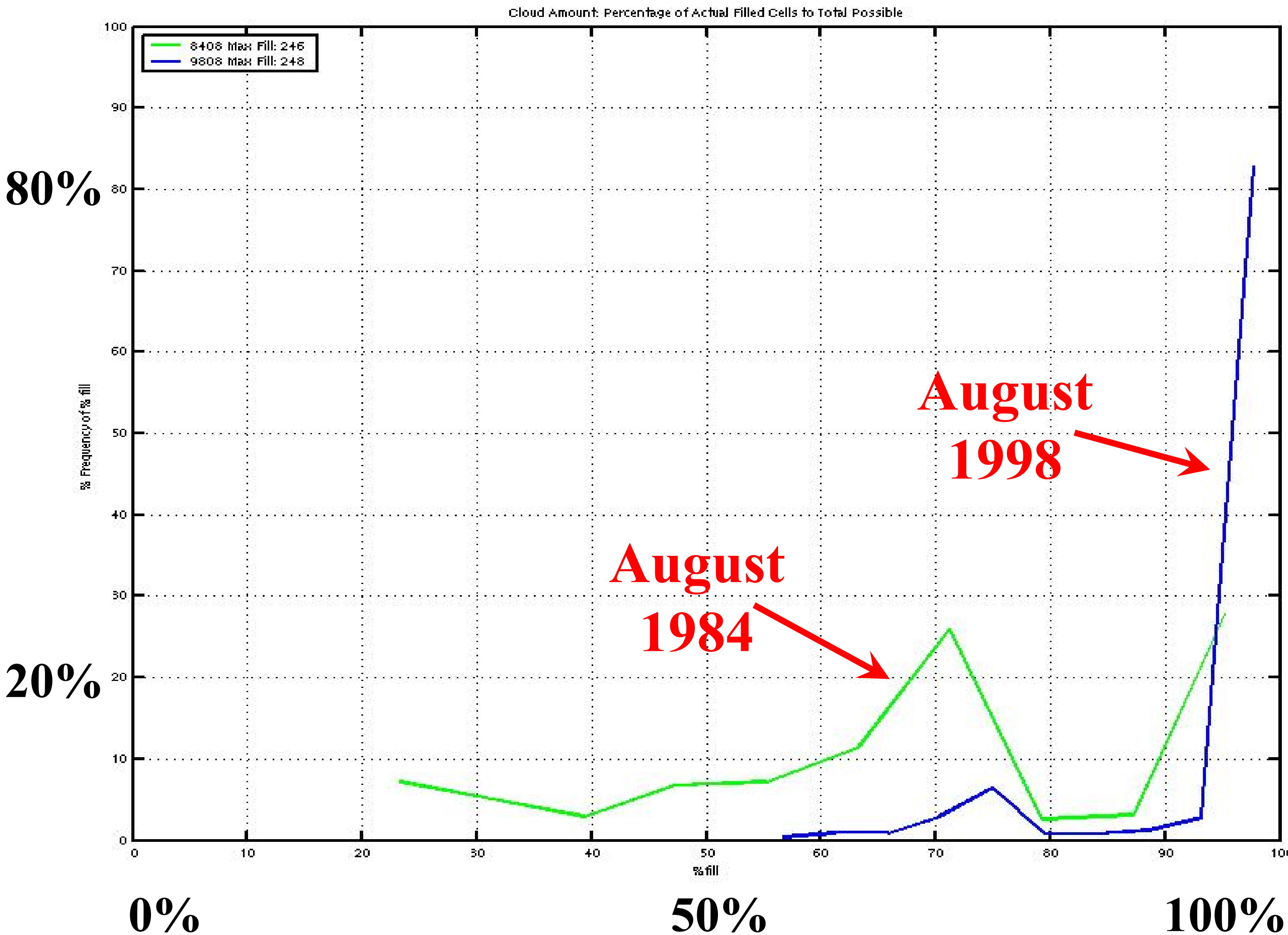


August 1998



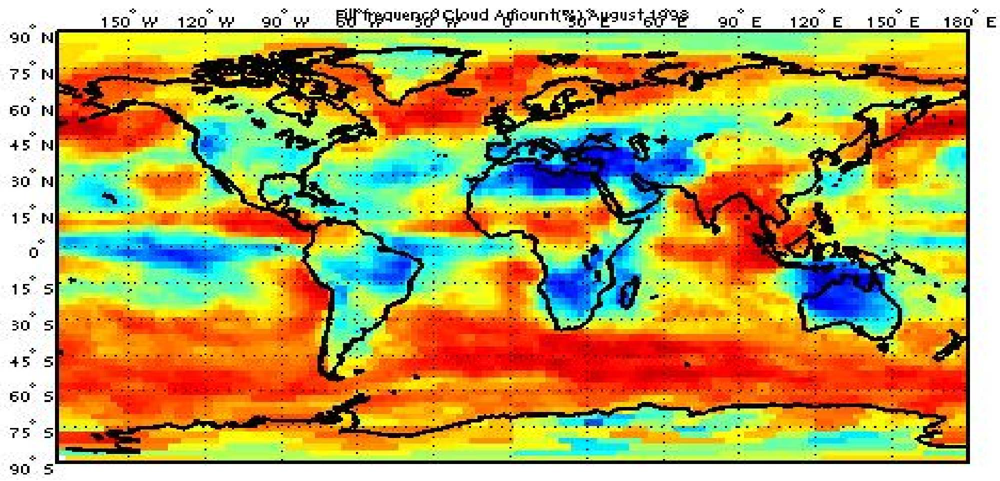
0%  **100%**

Distribution of Percentage Sampling over Globe

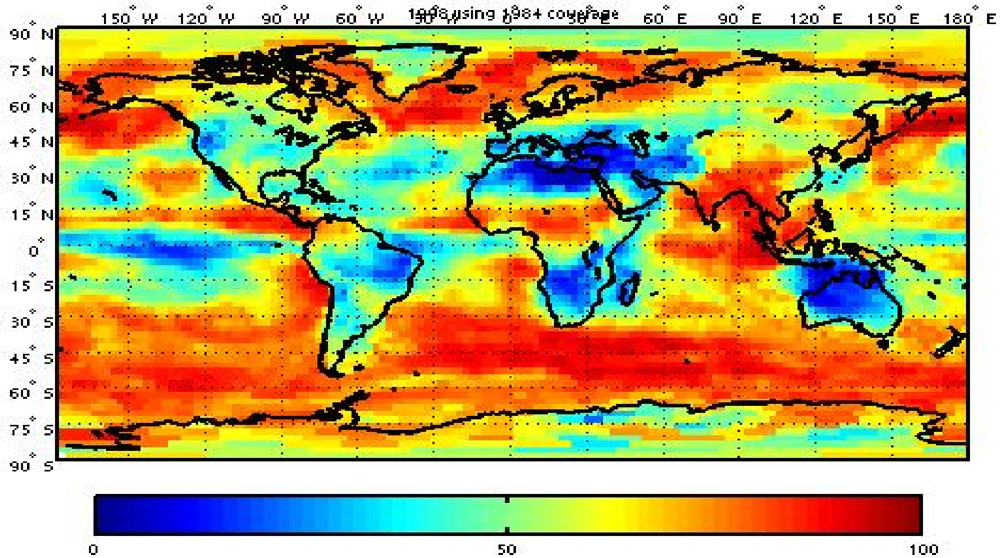


Monthly Mean Cloud Amount for August 1998 Using 1998 and 1984 Sampling

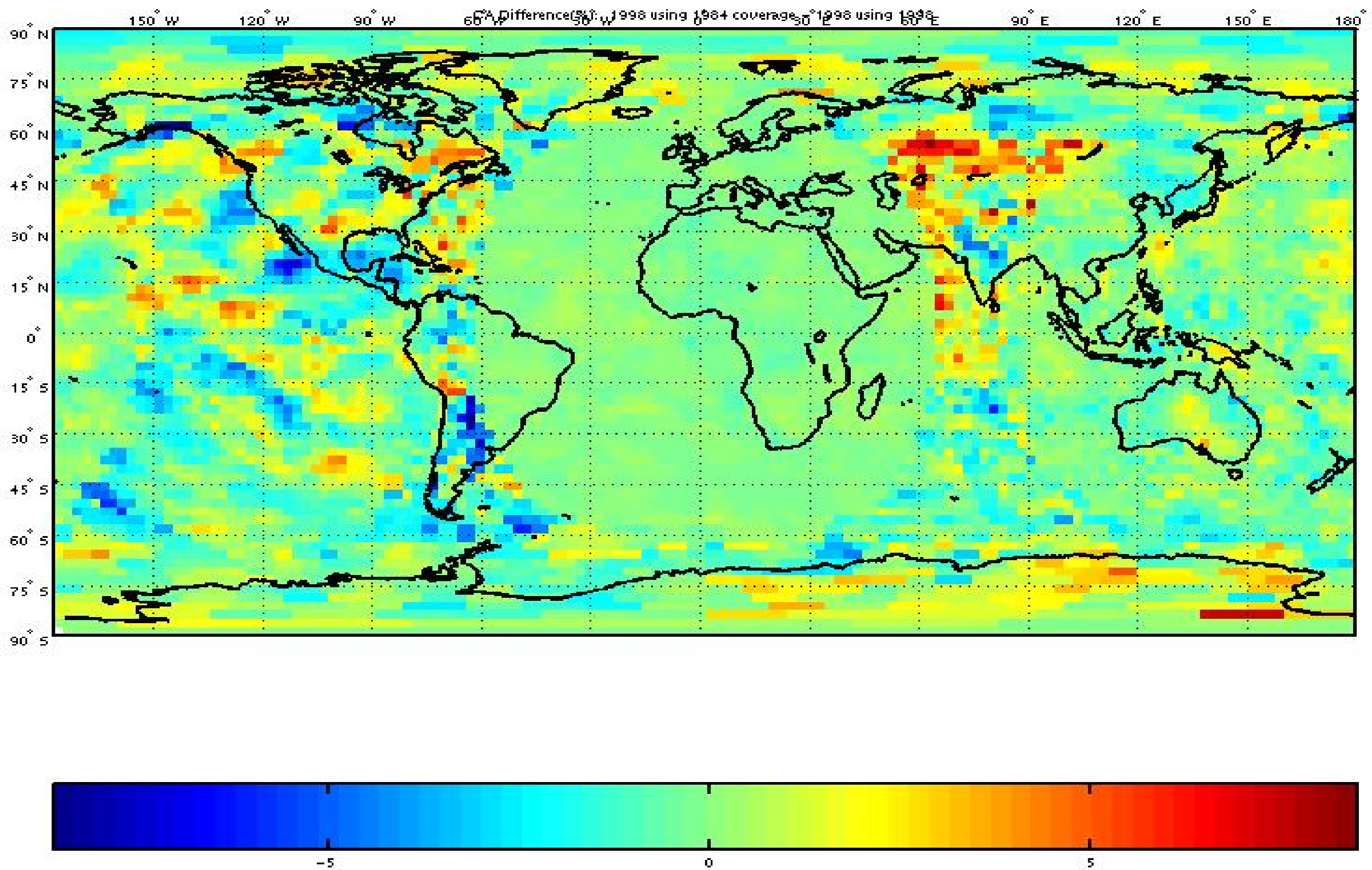
Original



Reduced Coverage



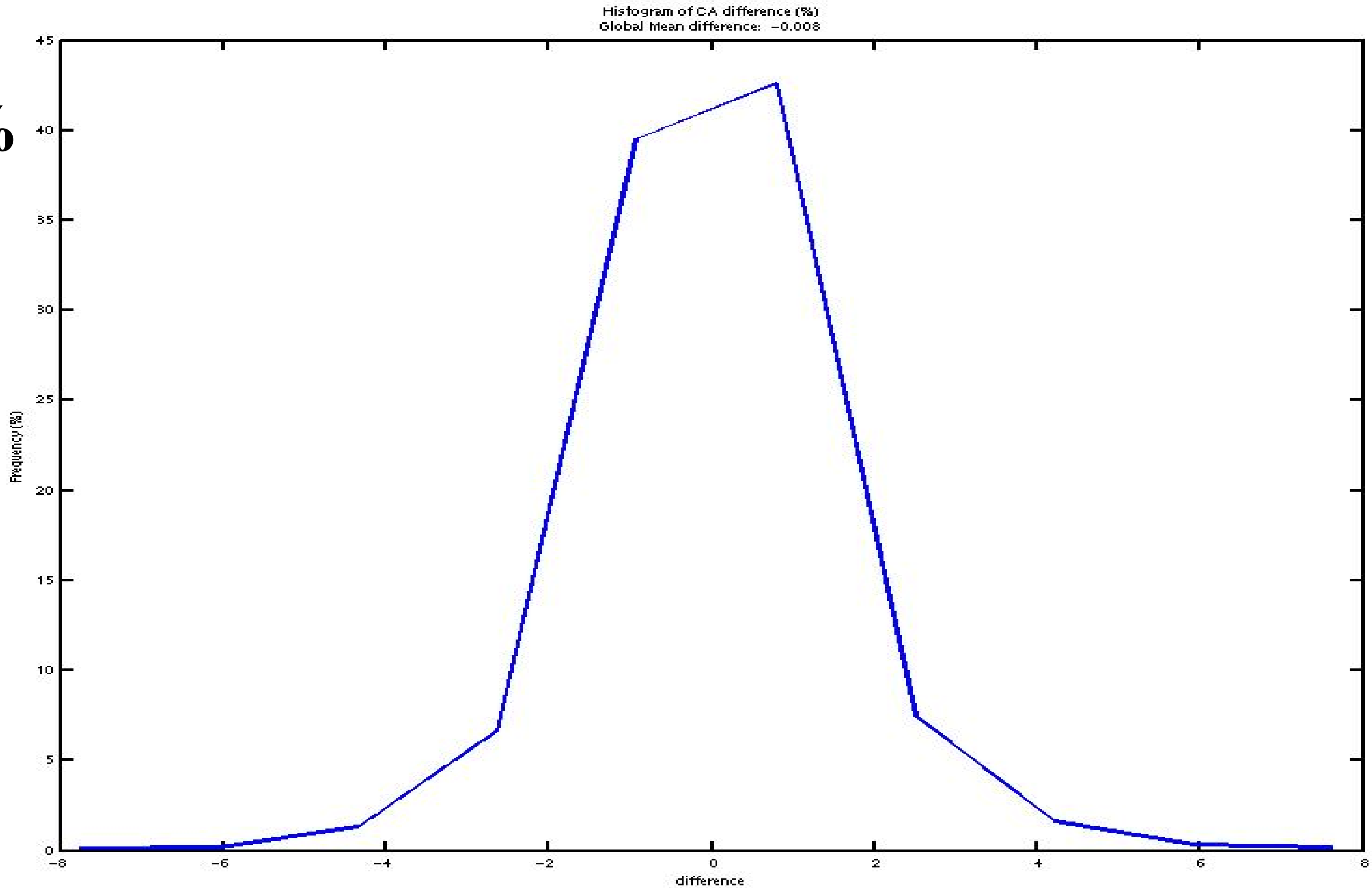
Mean Cloud Amount Difference Produced by Changed Sampling



−5% +5%

Distribution of Mean Cloud Amount Differences (%) Produced by Sampling Change
Global Mean Difference = 0.008%

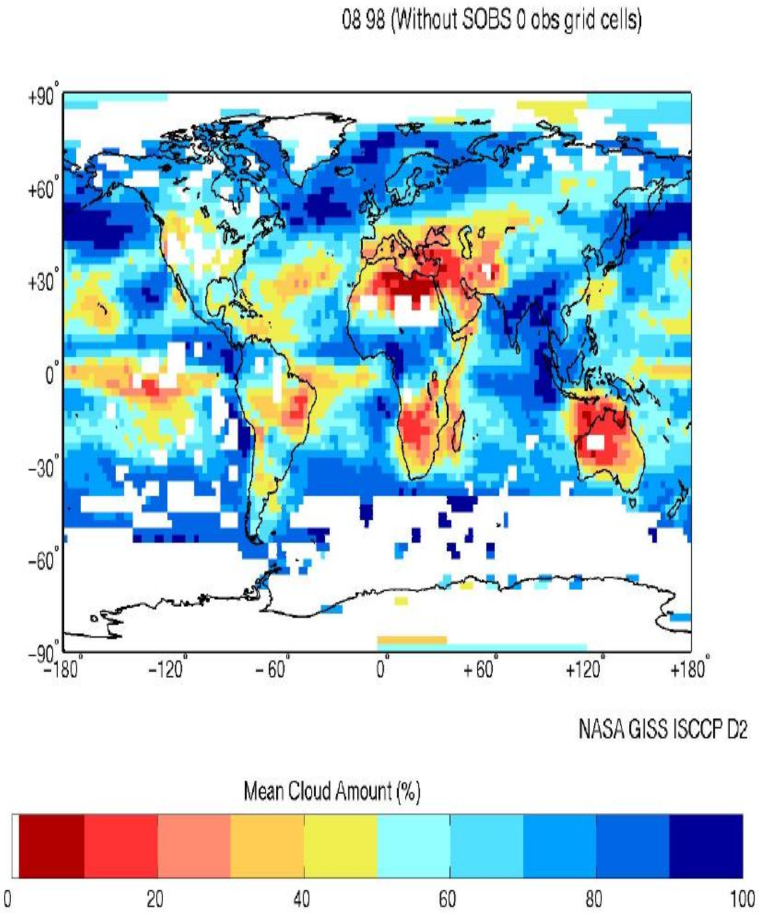
40%



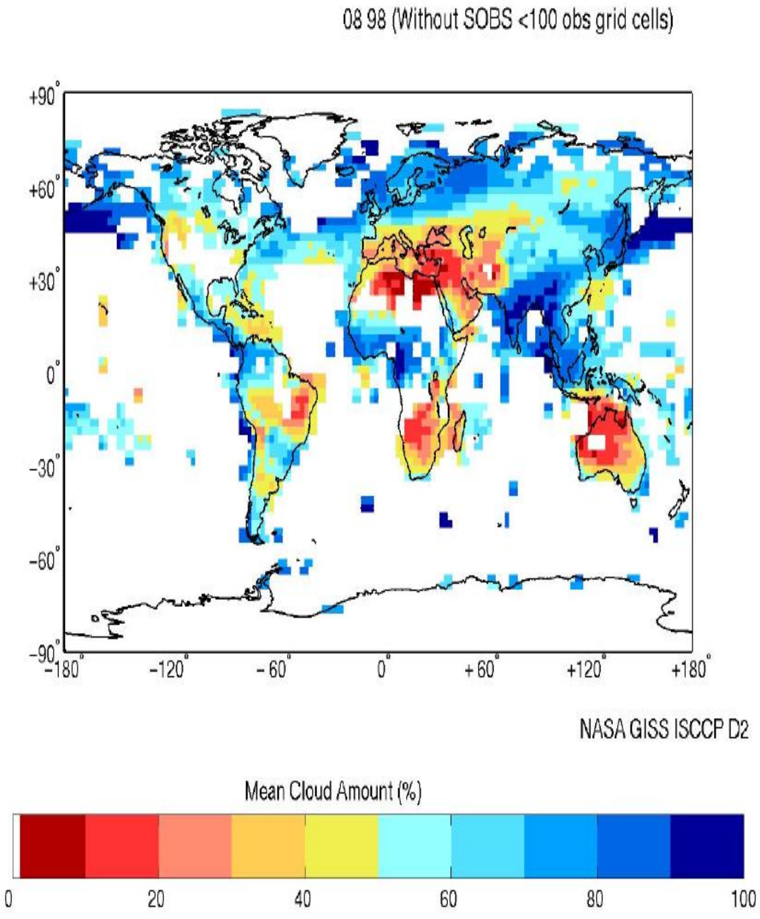
−4% 0% +4%

Global Coverage of Surface Observation Cloud Climatology

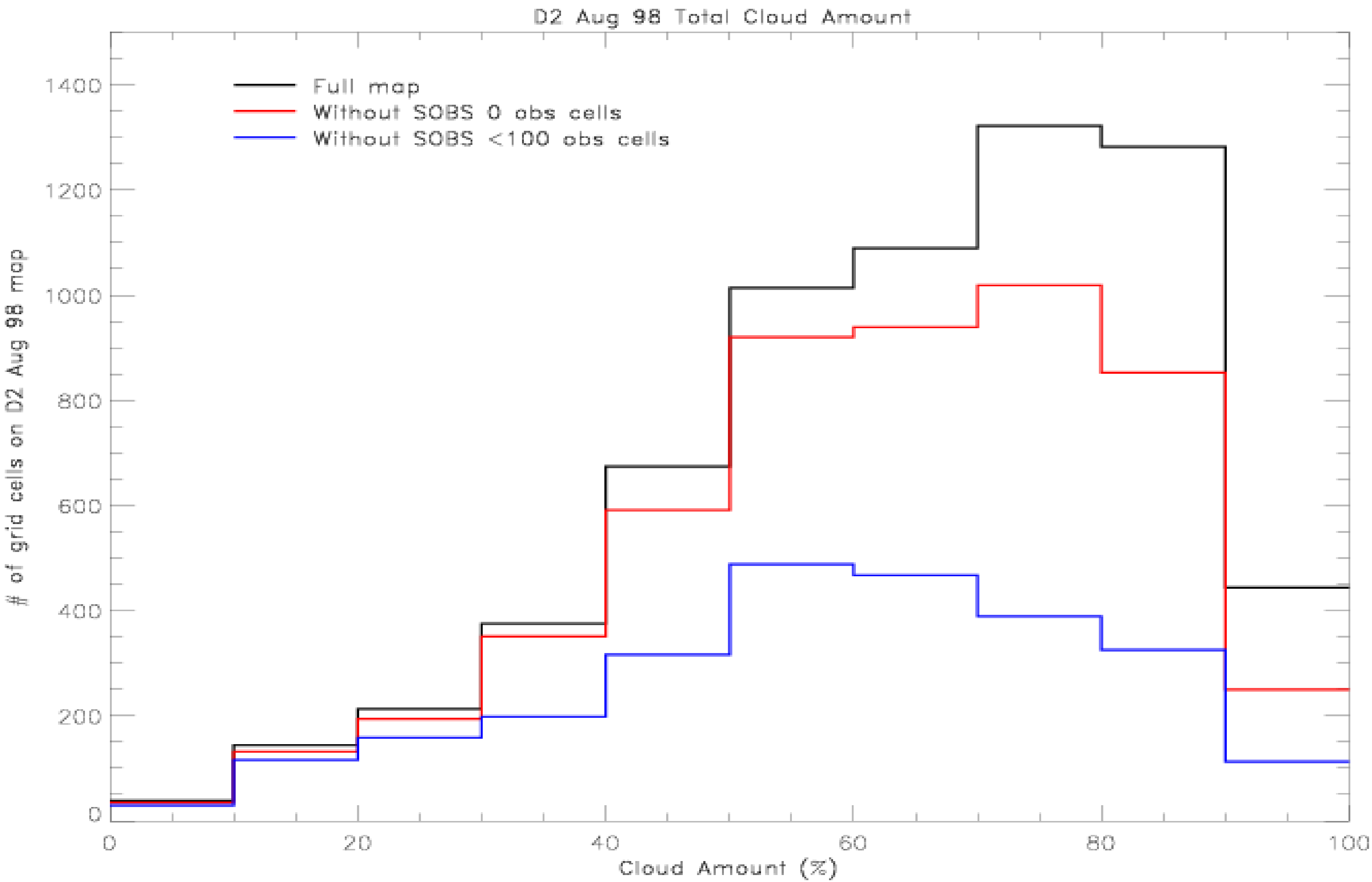
 # OBS > 0



 # OBS > 100

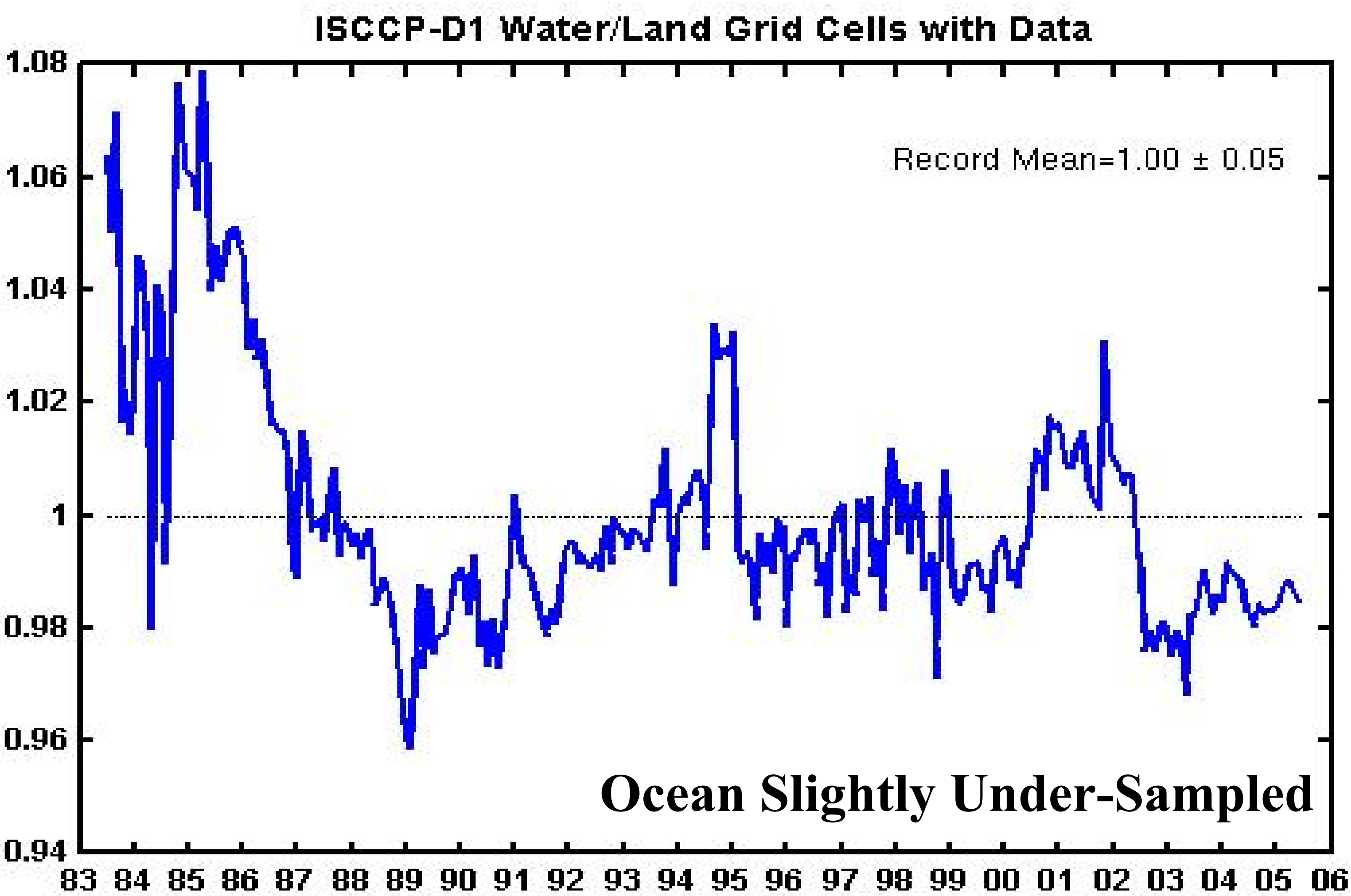


Effect of Coverage on Cloud Amount



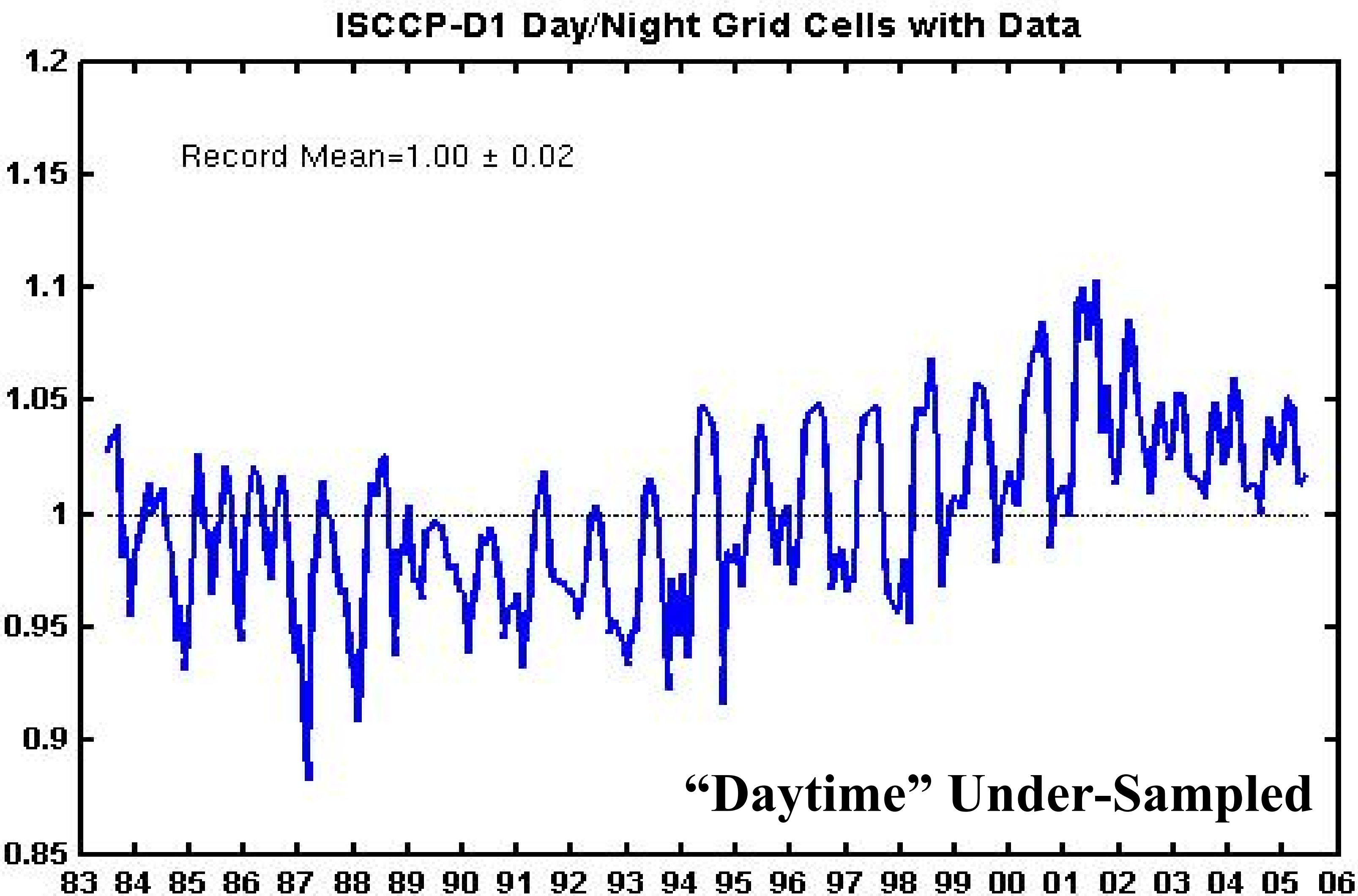
Monthly Anomaly of Water-Land Coverage Ratio

Average = (0.64±0.03)/(0.28±0.02) = 2.29±0.05



Monthly Anomaly of Day-Night Coverage Ratio

Average = (0.36±0.02)/(0.58±0.03) = 0.62±0.02



CONCLUSIONS

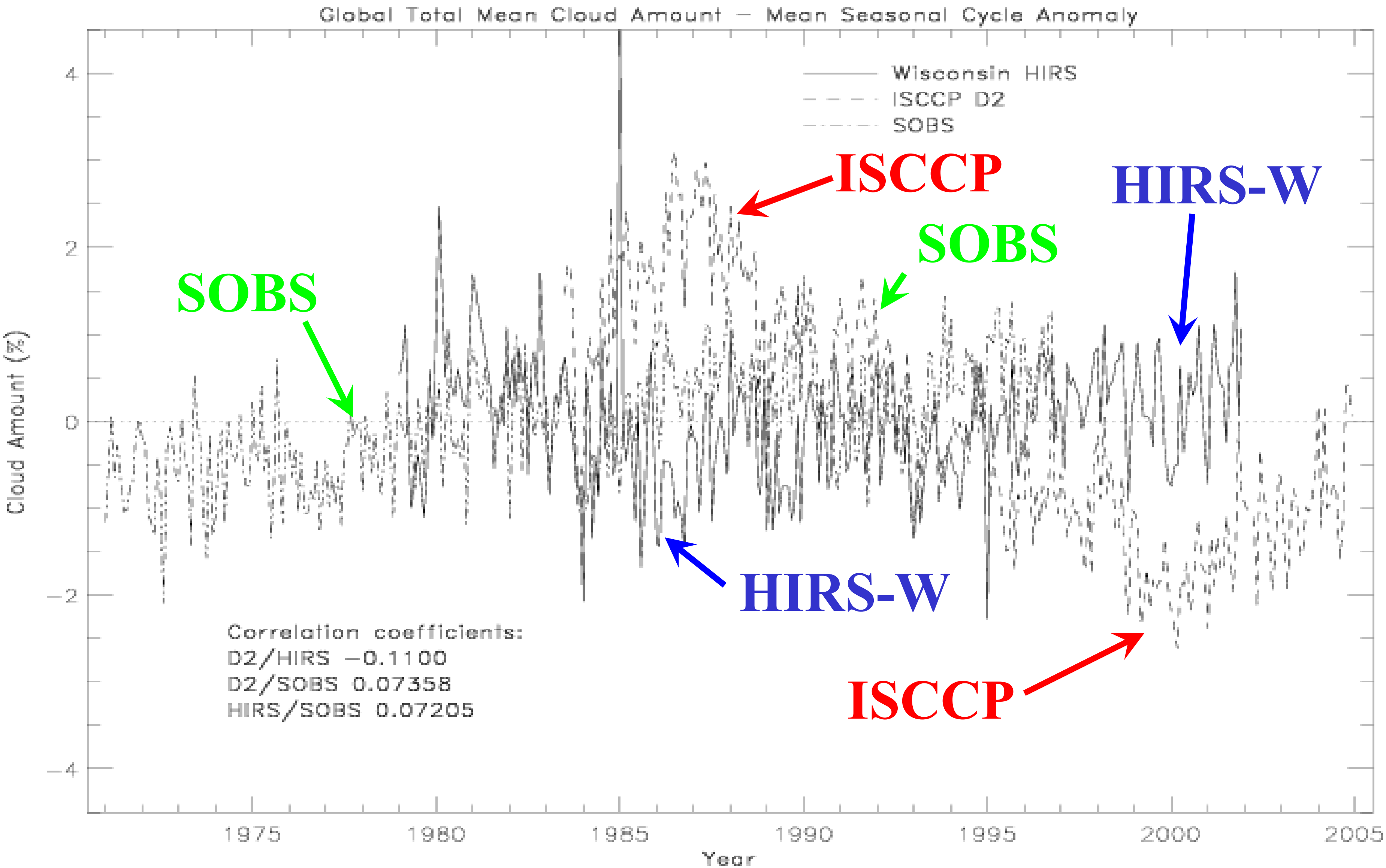
ISCCP is the only dataset that **BOTH** directly resolves the diurnal cycle (except for SOBS over land) and covers the whole globe

Therefore, sampling and diurnal aliasing are NOT problems for ISCCP

Need to Investigate Effects of Trends in Water/Land and Day/Night Coverage Ratios

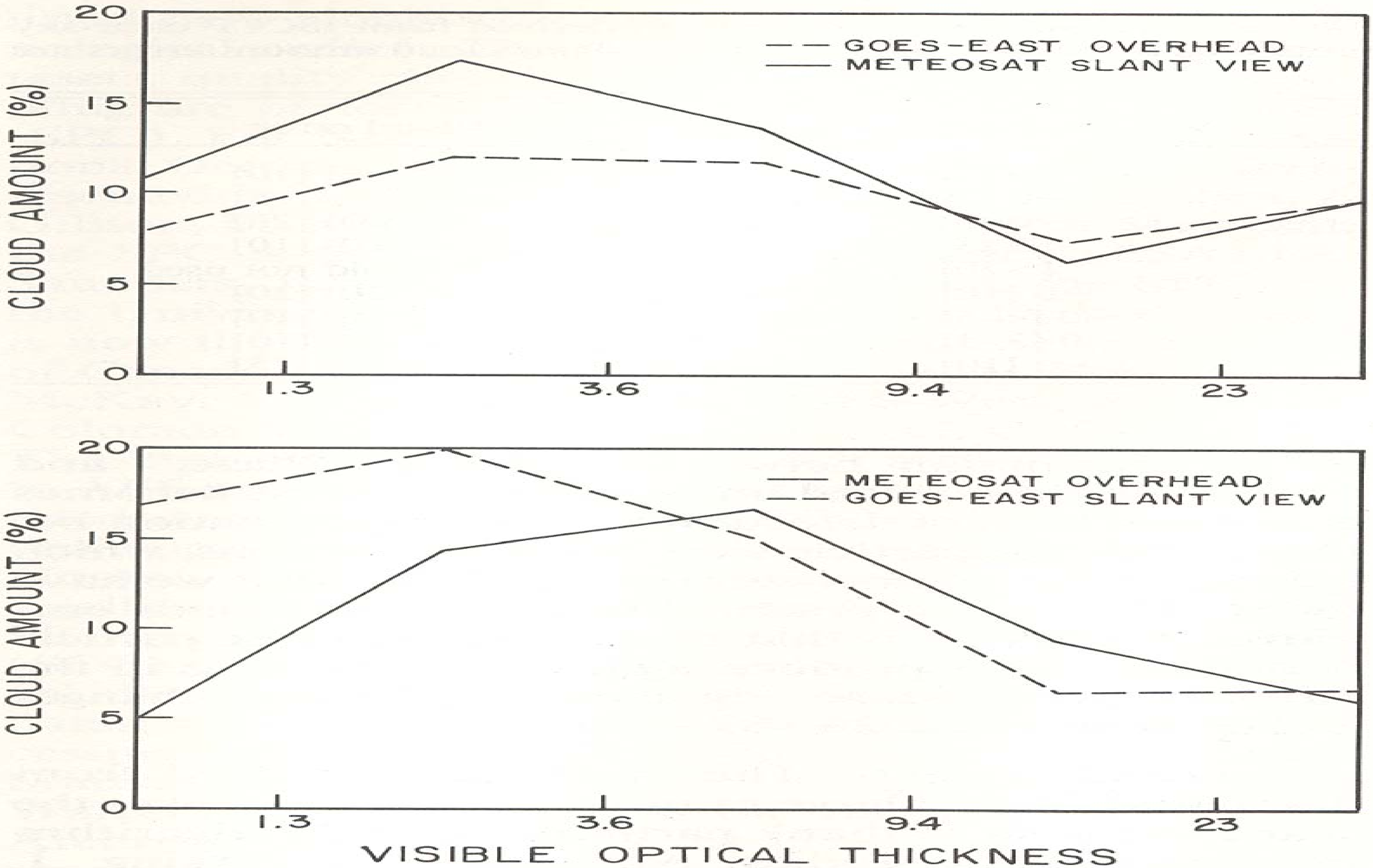
BACKUP SLIDES

Comparison of Three Cloud Climatologies
ISCCP, SOBS, HIRS

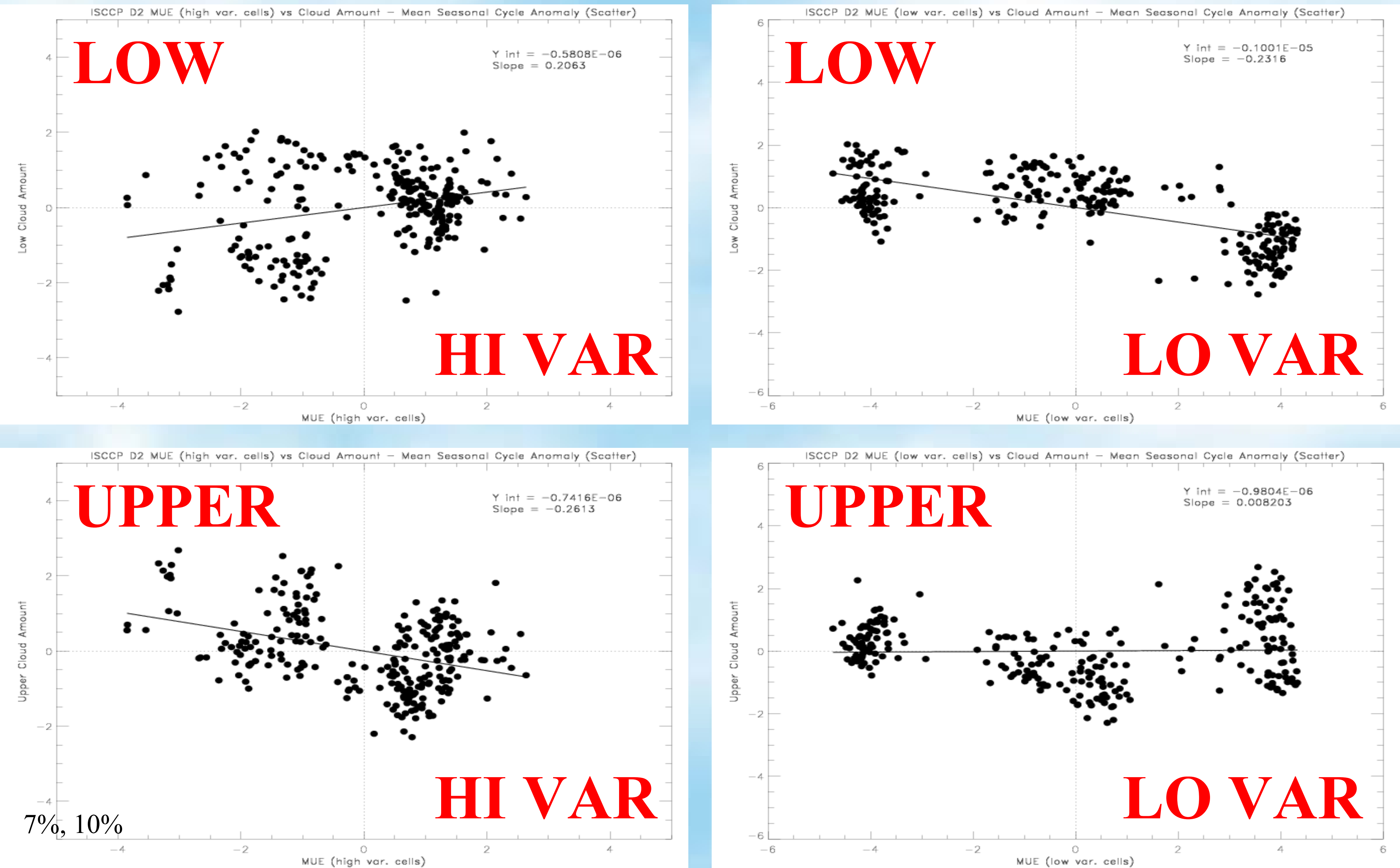


Cloud Detection Variation with View Angle

∂ Cloud Amount / ∂ Mue = 25%

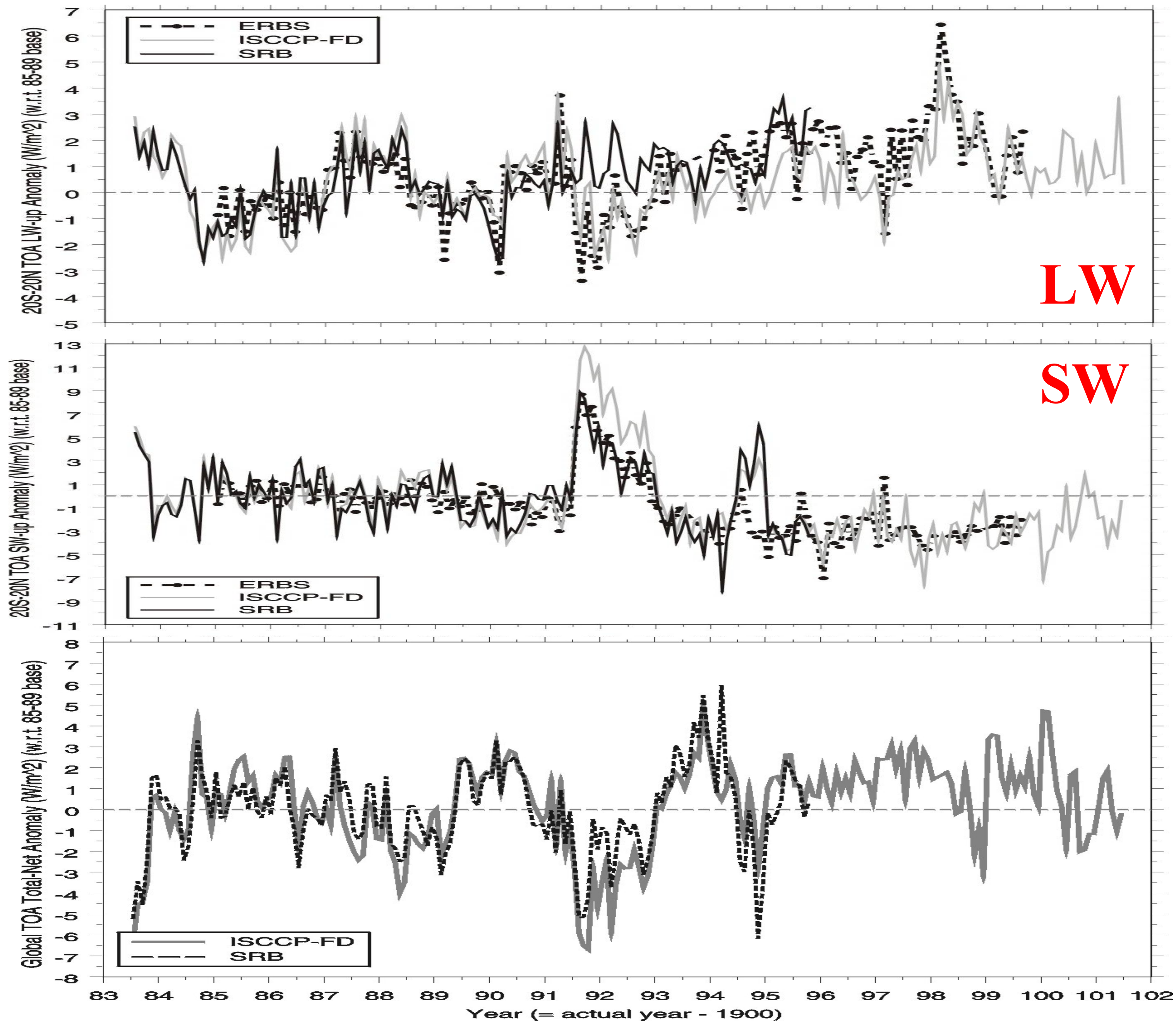


Correlations of Monthly Mean Changes of Low and Upper Cloud Amounts and MUE

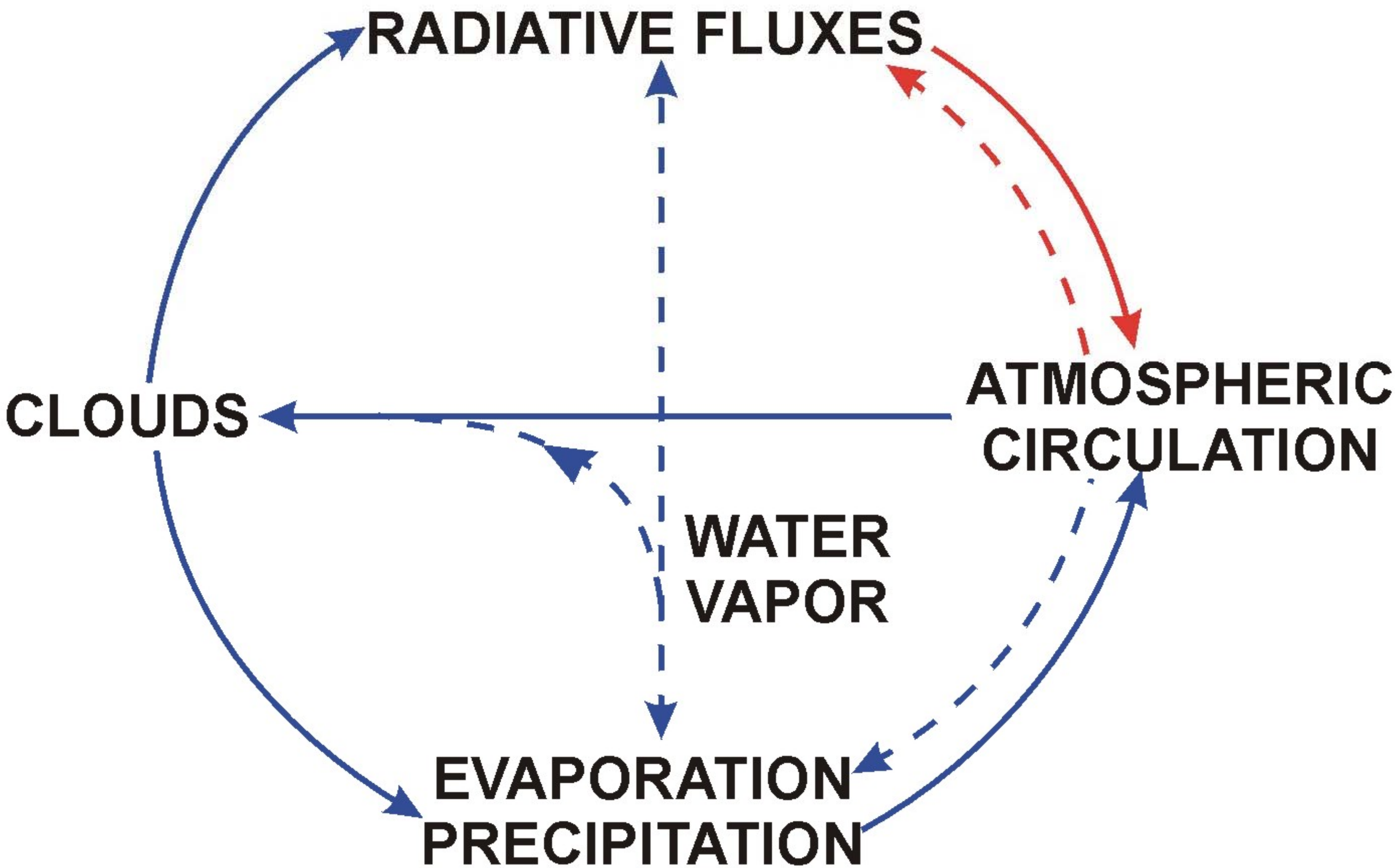


7%, 10%

ERBE VS ISCCP-FD at TOA



ENERGY AND WATER CYCLE OF CLIMATE



OPEN ISSUES

Radiance Calibration – Angle dependent calibration effects and more subtle spectral-angle effects have not been checked as yet for ISCCP, Other Satellite Datasets need to complete calibration studies

Detection Sensitivity – More careful comparisons of ISCCP, SOBS and HIRS are required to explain the "trend" inconsistencies over LONG-TERM

View Angle Effects – Uncertainties can be reduced by improving treatment of angle dependence (Especially in retrieving physical properties)

Sampling – Needs to be checked for some other datasets

Diurnal Aliasing – Problem for polar orbiters but may only cause long-term effects if orbits drift but this is not known for sure

Summary of Retrieval Method

1. **Single-Pixel Cloud Detection:** Combined set of tests of space-time variability to identify clear sky radiances as those that are less variable and tending toward warmer-darker values, followed by regionally-dependent threshold (difference between radiance and clear sky value) tests (additional test on 3.7 micron channel over snow/ice surfaces) = pixel-level cloud fraction is 0 or 1
2. **Area Cloud Fraction:** Determine fraction of all pixels in area 280 km across that are declared cloudy (note that finite threshold offsets small overestimate of cloud fraction)
3. **Cloud Top Temperature/Pressure:** Atmospheric temperature/humidity profile, including surface skin temperature obtained from clear sky IR radiance, is converted to brightness temperature (at 10 micron wavelength) profile using plane-parallel radiative transfer code, followed by matching profile to observed cloudy sky brightness, physical temperature of blackbody cloud and pressure from corresponding profile, then values adjusted to account for transmitted radiation using optical thickness converted to emissivity (phase dependent model) – iterated retrieval
4. **Optical Thickness/Emissivity:** Cloudy visible (0.6 micron wavelength) radiance corrected for ozone absorption and day-of-year sun-Earth distance variations, followed by comparison to pre-calculated cloudy sky radiances as function of viewing/illumination geometry, cloud top pressure and surface reflectance obtained from clear sky VIS radiance – radiative calculation for plane-parallel atmosphere with cloud layer (phase dependent microphysical model determined by cloud top temperature) and gas layer above and below – iterated retrieval – infrared emissivity obtained from visible optical thickness as function of phase-dependent microphysics model
5. **Standard LWP/IWP:** Optical thickness, together with assumed phase-dependent microphysics model, determines water path (phase assumed constant for whole cloud layer)
6. **Particle Effective Radius:** Cloudy pixels from AHVRR are reanalyzed using 3.7 micron wavelength radiance, uses standard optical thickness and assumed (phase dependence determined by cloud top temperature) effective radius as first guess in iterative comparison to pre-calculated radiances as function of viewing/illumination geometry, surface reflectance and atmospheric scattering/absorption – optical thickness re-scaled for consistency with effective radius
7. **New LWP/IWP:** New optical thickness and effective radius used to determine water path

List of Evaluations Completed (37 Papers plus)

1. **Total Cloud Amount:** 1985 – Cloud algorithm comparison, (a) 1989/1990 conclusions, (b) 1991 – Sampling has no systematic effect on cloud amount and effective spatial resolution is pixel size, (c) 1992 – overestimate of cloud fraction with finite sized pixels can be compensated statistically by finite detection threshold, (d) 1993 -- Verification of clear sky retrievals (surface properties) confirms thresholds (IR threshold reduced over land) => all detectable clouds are accounted for, (e) 1993 -- Comparison with individual and average SOBS results shows instantaneous accuracy to within about 10%, (f) 1995 -- Comparison with SAGE shows about 10-15% underestimate of cirrus below detection limit, (g) 1996 -- Comparison with HIRS-Wisc confirms missed cirrus but confirms upper-level cloudiness in polar regions, (h) 1999 -- Comparison with HIRS-3I shows low cloud top pressures underestimated and some high cloud shifted to middle-level, (i) 1996-2008 – Cloud amount underestimated in polar summer by about 10-20% and overestimated in polar winter by about 10%, (j) 2004 – Radiative flux anomalies at top-of-atmosphere shown to be quantitatively consistent with ERBE/CERES, (k) CALIPSO
2. **Cloud Top Temperature:** (a) 1989/1990, (b) 1995-1997 – Comparison with SAGE/HIRS confirms locations (temperatures) of upper troposphere clouds except for very thin cirrus and cirrus overlying low clouds, (c) 1995 – Radiative flux calculations using ISCCP confirm cloud top temperatures overall but discrepancies noted in cirrus-dominated regions, (d) 1999 – Comparison with HIRS and ASTEX data confirms that bias in low cloud top pressures caused by TOVS temperature profile, not retrieved cloud top temperatures, (e) 2002 – Very thin cirrus located too high in tropical atmosphere (but HIRS-SAGE comparison confirms concentration of very thin cirrus near tropical tropopause), (f) Radiative flux calculations using revised ISCCP confirm overall accuracy of cloud top temperatures (improved results in cirrus-dominated regions)
3. **Lo/Mid/Hi Cloud Amounts:** (a) 1989/1990, (b) 1995 – Comparison with SAGE provides estimate of amount of thin cirrus over other clouds, (c) 1995/2000 – ISCCP cloud type associations with midlatitude and tropical storms correspond to classical meteorological classifications, (d) 1997 -- Comparison with HIRS-Wisc indicates that about 1/4-1/3 middle-level clouds are thin cirrus over low clouds, (e) 2000/2005 – Comparison of RAOBS-based cloud layer statistics with ISCCP suggests that layer cloud amounts are statistically in agreement if account is taken of different detection sensitivities and effects of overlap, (f) 2001 – Comparison of cloud types with SOBS shows understandable (and expected) statistical correspondences, (g) 2002 – Sensitivity of ISCCP cloud location assignment for very thin clouds evaluated against HIRS/SAGE, (h) 2005 – Tropical cloud type distributions shown to correspond distinct meteorological situations
4. **Cloud Optical Thickness/Emissivity:** (a) 1989/1990, (b) 1991 – Surface insolation calculations over oceans more accurate using ISCCP cloud amounts and optical thicknesses, (c) 1994 – Cloud particle size for liquid water clouds that is assumed in ISCCP retrieval verified to have a bias < 20%, hence optical thickness bias caused by this assumption < 3%, Similar conclusion obtained by comparison with SSM/I LWP values, (d) 1995 – Top-of-atmosphere shortwave radiative fluxes calculated using ISCCP confirm overall accuracy of optical thickness values but indicate need for better treatment of ice clouds, (e) 1995-1999 – Improved treatment of ice cloud particles and optical thickness retrievals developed, (f) 2002 – Plane-parallel treatment in retrieval and in flux calculations evaluated showing that fluxes determined from two spatial distribution moments are more accurate, (g) 2004 – Radiative flux calculations at top-of-atmosphere and surface using ISCCP cloud optical thicknesses shown to be highly accurate (within 5-10%) confirming improved treatment of ice clouds, (h) 2008 – Evaluation of diurnal variations of Direct/Diffuse ratio shows that ISCCP optical thickness accurately characterize atmospheric scattering
5. **RE-liquid and RE-ice:** (a) 1994 – (a) 1994-1995 – First retrievals for liquid cloud particle sizes compared with field data (FIRE, later ASTEX), liquid clouds over oceans have average particle sizes about 20% larger than assumed in standard ISCCP retrieval and about 15% smaller over land than standard ISCCP retrieval, (b) 1996-1999 – Sensitivity of ice particle size retrieval to shape assumptions investigated, (c) 2008 – New retrieval product being evaluated against available field data
6. **LWP/IWP:** (a) 1994-1995 – Comparisons of retrieval assumptions and with SSM/I products suggest standard ISCCP LWP values are accurate to within about plus-minus 20%, (b) 1999 – Sensivity studies of retrieval assumptions suggest standard ISCCP IWP values are accruate to within about plus-minus 40% except for bias (underestimate) introduced by vertical particle size variations

CLOUD AMOUNT SUMMARY

1. **Single-Pixel Cloud Detection:** Combined set of tests of space-time variability to identify clear sky radiances as those that are less variable and tending toward warmer-darker values, followed by regionally-dependent threshold (difference between radiance and clear sky value) tests (additional test on 3.7 micron channel over snow/ice surfaces) = pixel-level cloud fraction is 0 or 1
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CLOUD TOP TEMPERATURE SUMMARY

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LIQUID – ICE PARTICLE RADIUS SUMMARY

1. **Particle Effective Radius:** Cloudy pixels from AHVRR are reanalyzed using 3.7 micron wavelength radiance, uses standard optical thickness and assumed (phase dependence determined by cloud top temperature) effective radius as first guess in iterative comparison to pre-calculated radiances as function of viewing/illumination geometry, surface reflectance and atmospheric scattering/absorption – optical thickness re-scaled for consistency with effective radius
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WATER PATH SUMMARY

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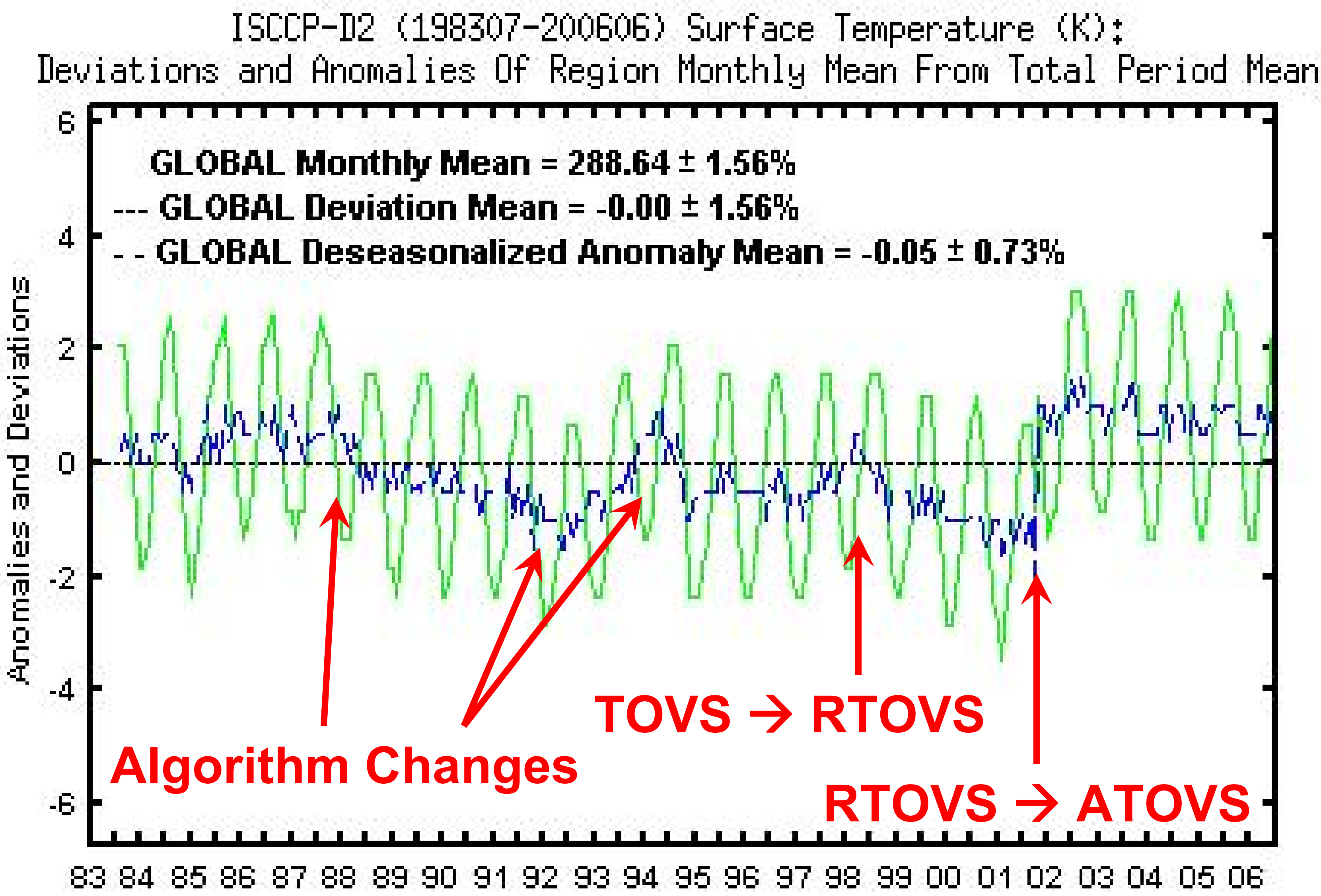
Current Cloud Property Error Estimates

- (Quantity±instantaneous error, mean error, source)

- Cloud Cover ± 12%, 5%, satellite, surface weather obs.
- Cloud Top Temperature ± 3-6K, 2K, satellite
- Cloud Top Height ± 0.5-2 km, 0.3 km, satellite
- Cloud Optical Thickness ± 25%, 10%, satellite
- Cloud Particle Size ± 1 μm (liquid), ± 3 μm (ice), 1 μm (liquid), 10 μm (ice), satellite
- Cloud Water Path ± 10% (liquid), ± 30% (ice), 10% (liquid), 100% (ice), satellite
- Cloud Base Temperature ± 3-6K, 2K, surface obs.
- Cloud Base Height ± 0.5-1 km, 0.3 km, surface obs.

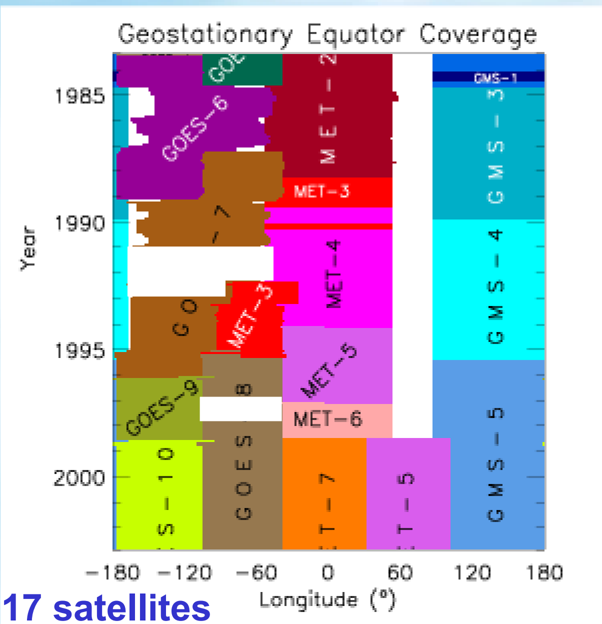
What's Left to Do? → Cloud Vertical Structure!!

Surface Temperature Anomalies



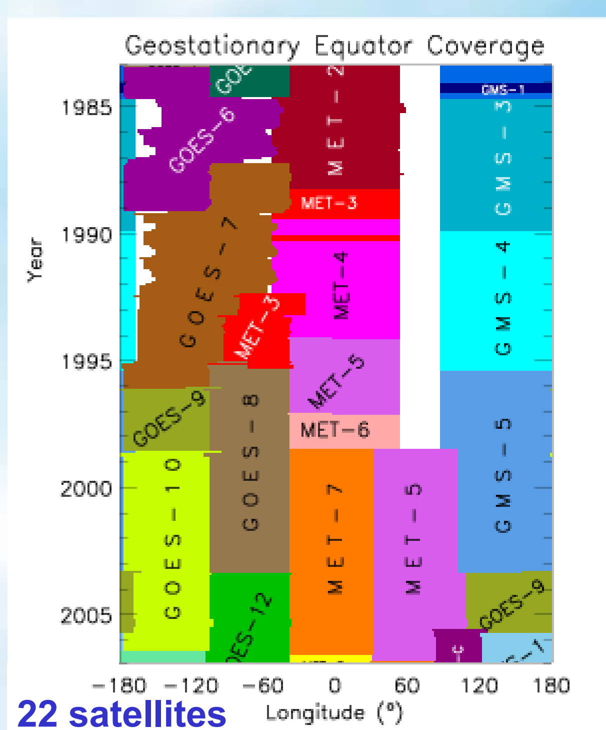
Data Rescue Efforts: Ought Seven

B1 Status - 2003



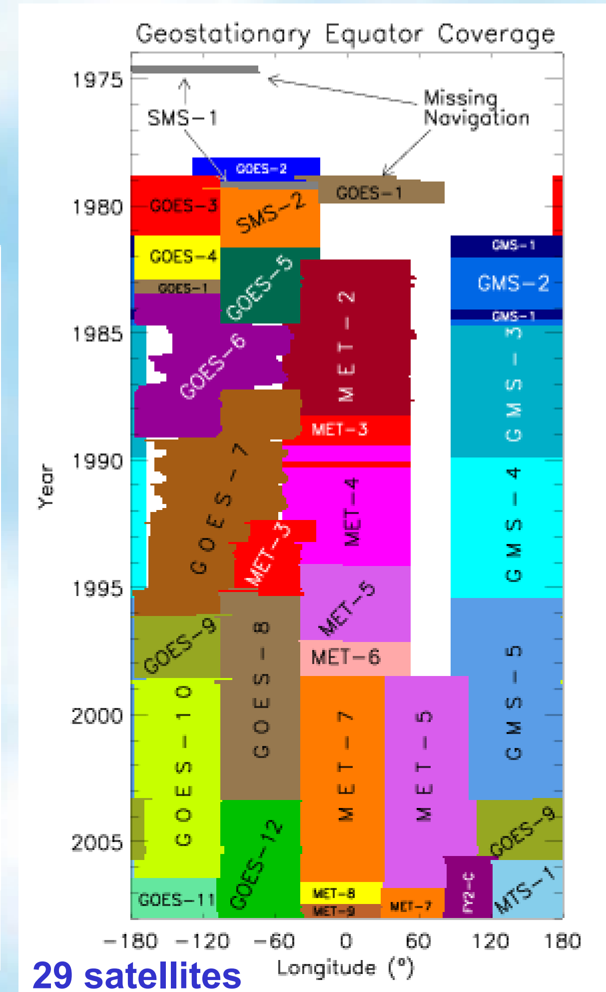
17 satellites

B1 Status - 2006



22 satellites

B1 Status - 2007



29 satellites

Plus 11 Polar Orbiters

KNAPP, NOAA