Systematic Differences Between Satellite-Based Precipitation Climatologies Over the Tropical Oceans

Franklin R. Robertson
NASA Marshall Space Flight Center
Global Hydrology and Climate Center
Huntsville, AL 35806

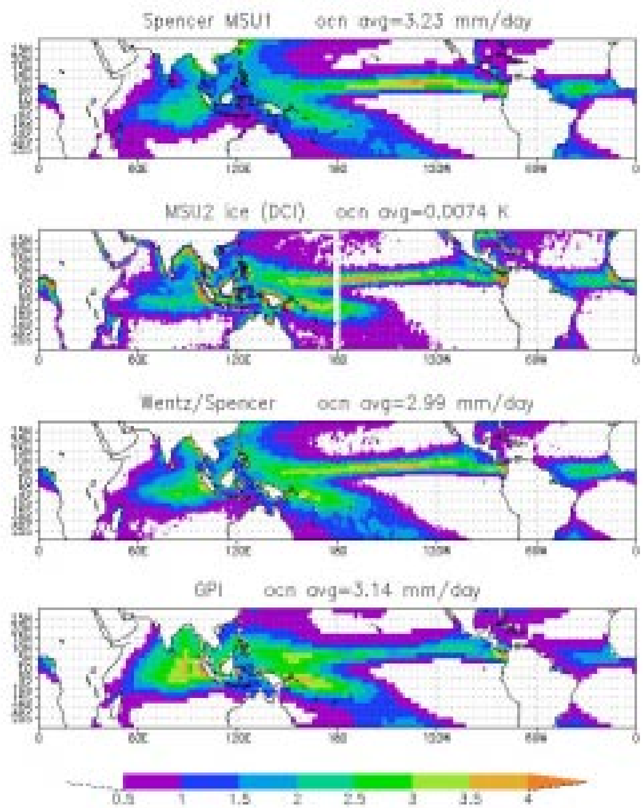
email: pete.robertson@msfc.nasa.gov
ph: 256 922 5836

Why do existing satellite based climatologies exhibit systematic differences? What are the prospects for reconciling these differences in moving toward a better observational data base?

- Current satellite based climatologies have notable differences in their spatial details and in their temporal variability.

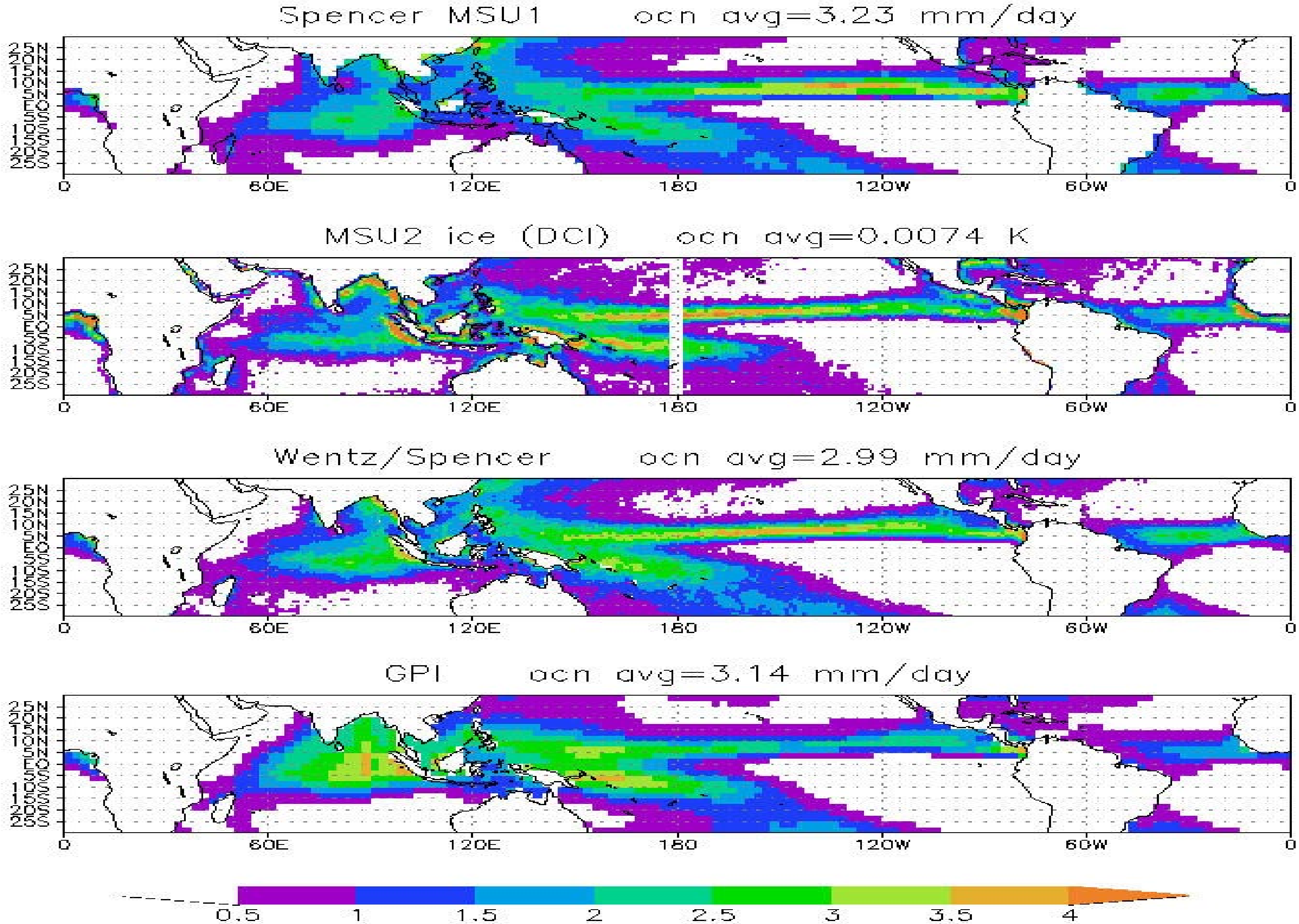
- Climate models and 4-DDA systems have advanced to the state that “observational uncertainty” is a serious issue.

- Can we turn the diverse physics of the satellite algorithms to our advantage in determining why each portrays rainfall somewhat differently?



Roadmap

- **Review and comparison of satellite climatologies (ocean only)**
- **A new convective ice climatology from MSU2**
- **Cloud water and precipitation: implications for MSU1**
- **GPI and TOVS cold cloud tops:**
  What does cloud top morphology tell us?
- **Tropical oceanic time series.**
  Interannual precipitation anomalies and relationship to SST variations
- **Synthesis with tropical dynamics**



Tropical oceanic precipitation climatologies July1987 through1997. Data have been normalized by the areal mean to facilitate comparison of spatial distributions.

Key Aspects of Relevant Precipitation Algorithms

MSU1 Precipitation Spencer (1993 J Clim)

Ocean only, 1979 to present, daily 2.5 deg, ~4 samples / day

Top 15% frequency distribution of emission from liquid water at 50.3 GHz after atmospheric temperature corrections from MSU2,3.

Calibrated to island / coastal rain gauges

Limited dynamic response to raindrops at rain rates above few mm/h

Wentz-Spencer SSM/I Wentz (1995 JGR; 1997 JAS)

Currently applied to SSM/I data at daily, 0.25 deg resolution (2.5 deg, monthly used here)

Physical retrieval for rainfall, ocean surface wind speed, and column-integrated water vapor, liquid water

Beamfilling correction, ice/ precipitation scattering effects included

GPI Arkin (1979 MWR), Arkin et al., (1994 Rem Sen Rev), Joyce and Arkin (1997 JTECH) 1985 to present, 2.5 degree 40 deg N/S, pentads

Frequency of IR cold cloud tops (Tb < 235K) from 3h geostationary sampling scaled by 3.0 mm/h effective rain rate.

Some supplementary OLR from polar orbiters in Indian Ocean.

MSU1 Deep Convective Ice (DCI) Index

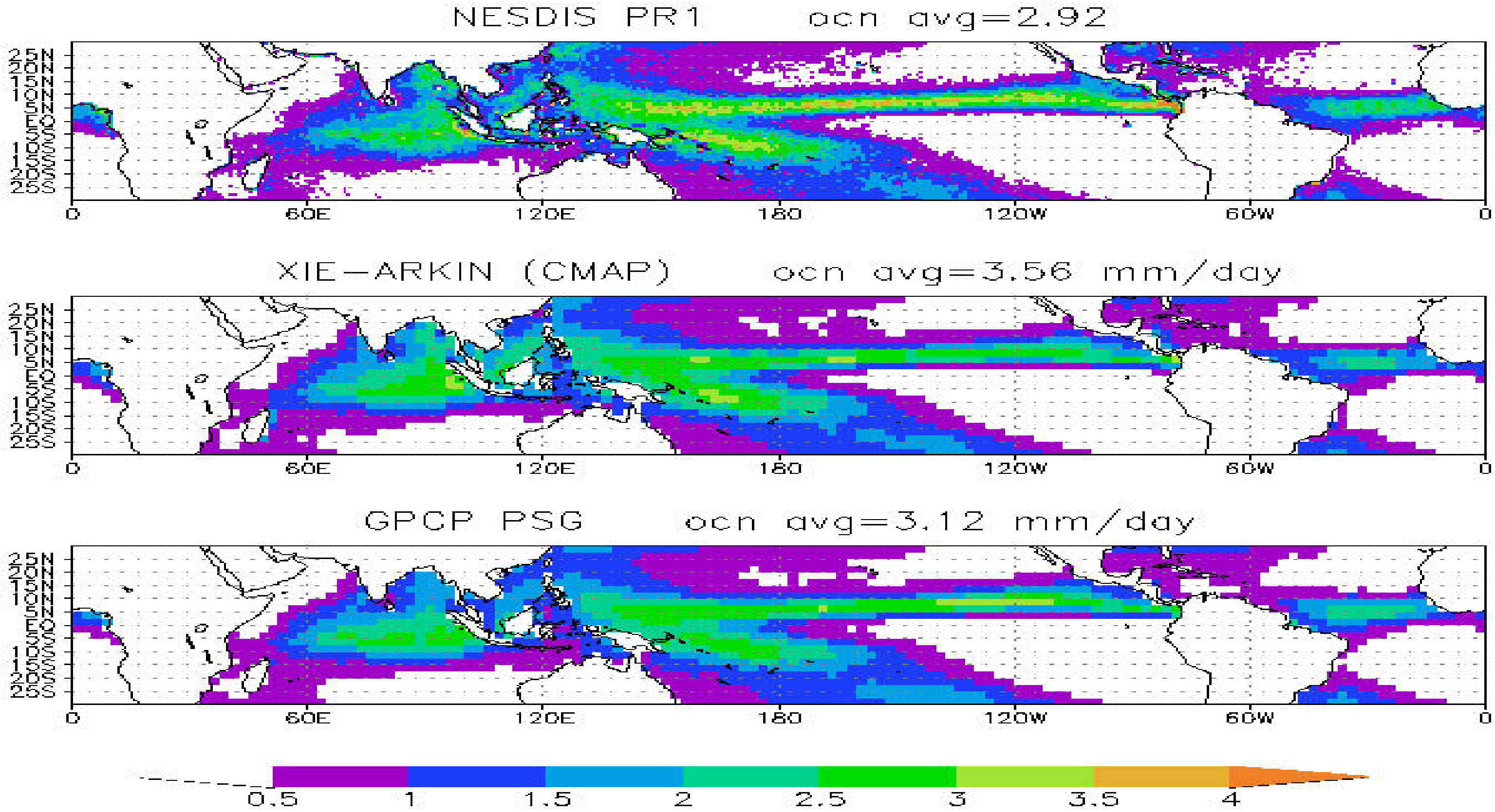
- Upwelling radiation from surface and lower troposphere at 53.7 GHz is attenuated by scattering from large ice particles (snow, graupel, hail).

- Due to large MSU footprint size (110 to >200 km), scattering signals in gridded, limb-corrected data range are typically a few Kelvins.
  Largest instantaneous values ~10K

- A 5 x 5 degree high-pass spatial filter applied to 1.0 degree gridded ascending and descending passes is used to isolate convective ice scattering

- Instantaneous comparisons to SSM/I 85 GHz PCT show cor ~ .80 when SSM/I retrievals are spatially smoothed to MSU resolution.

- Over land and coastal areas surface elevation and consequent T_{SFC} gradients induce noise and bias. Work in progress to extend algorithm to land.



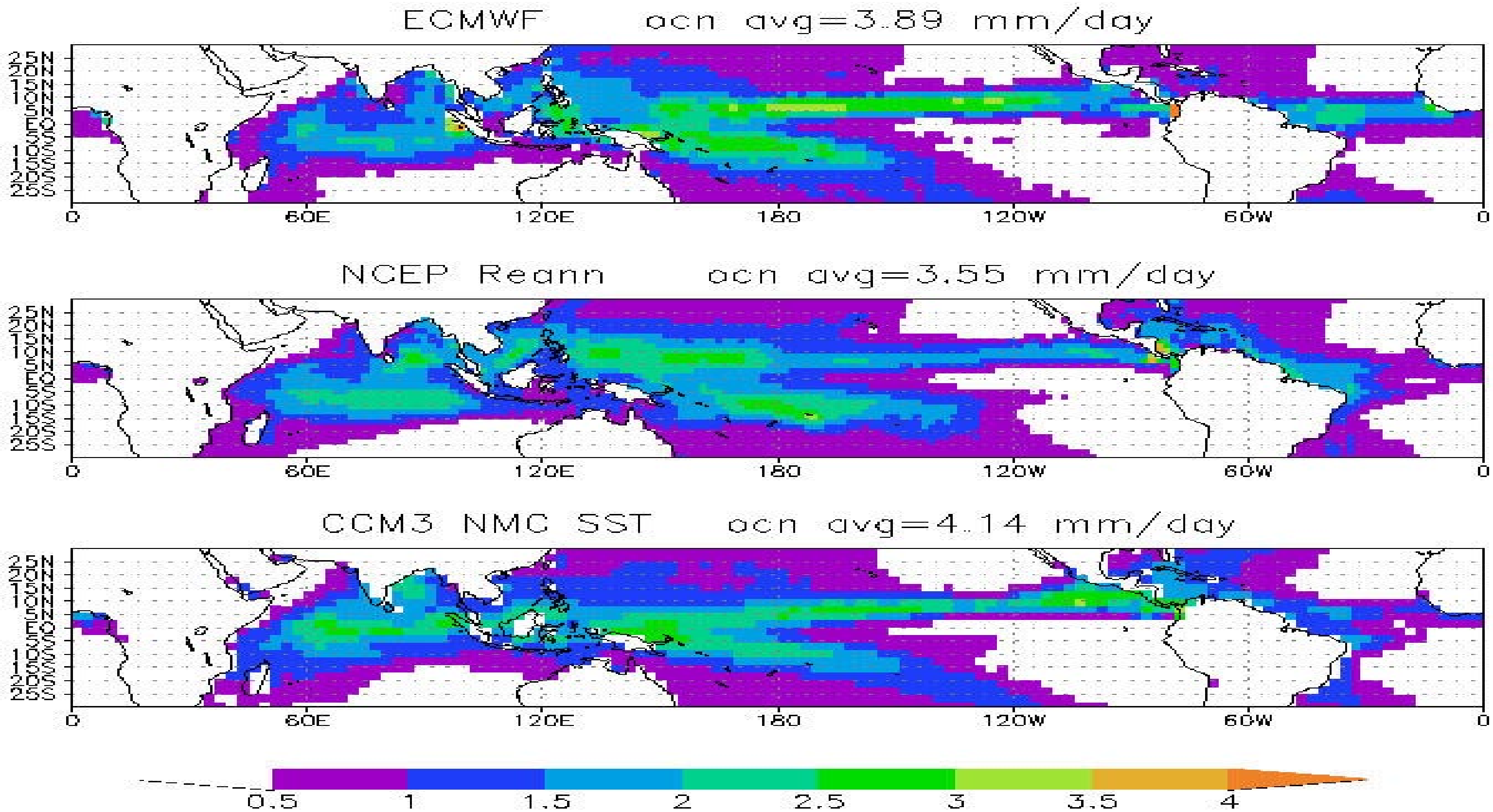
Tropical oceanic precipitation climatologies July1987 through1997 (Xie-Arkin through Dec 1996). Data have been normalized by the areal mean to facilitate comparison.

Key Aspects of Relevant Precipitation Algorithms

NESDIS PR1 Ferraro et al. (1996 BAMS)
Jul 1987 to present, 1.0 and 2.5 deg grids, monthly
Precipitation algorithm is scattering-based using 85 GHz (Grody, 1991 JGR)
supplemented by emission algorithm (Weng et al., 1994, JGR) over ocean.
LWP and mean cloud fraction are also retrieved

GPCP psg Huffman et al., (1995 J Clim) Huffman and Coauthors, 1996 BAMS
Jul 1987 to present, 2.5 deg, monthly
Oceanic precipitation is a blend of Wilheit-Chang (1991 JTECH) and
AGPI (Adler et al., 1994 Rem Sens Rev) adjusted by rain gauge.

Xie-Arkin (CMAP) Xie and Arkin (1996 J Clim; 1997 BAMS)
1979 to 1995, 2.5 degree, monthly, global
Max Likelihood Estimation and subsequent bias adjustment using rain gauge
data are used to combine satellite, rain gauge, and reanalysis (optional) estimates
GPI, OPI, Wilheit-Chang, NESDIS, MSU1 (modified) are satellite algorithms



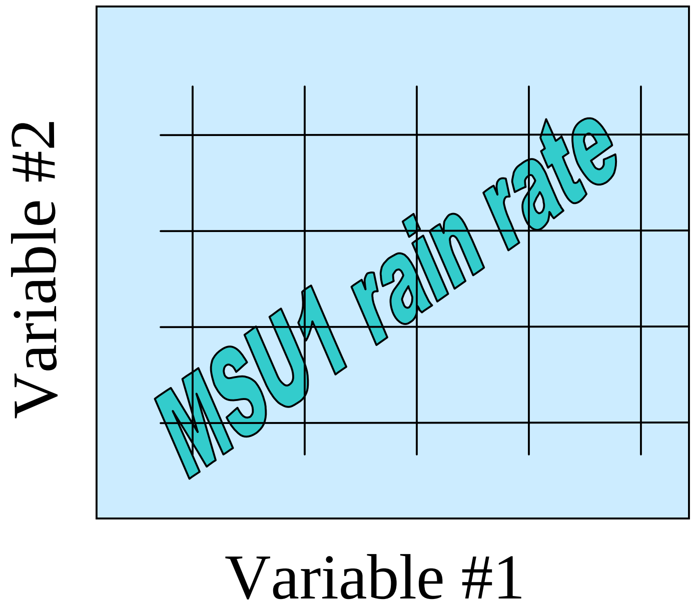
Tropical oceanic precipitation climatologies. ECMWF reanalysis (July '87/Dec'90). NCEP Reanalysis (July '87/'97). CCM3 forced with NCEP SSTs (July '87 / Dec'94). Data have been normalized by the areal mean to facilitate comparison.

Using SSM/I Cloud Liquid Water, Precipitation and Ice retrievals to Understand MSU1 Precipitation Patterns

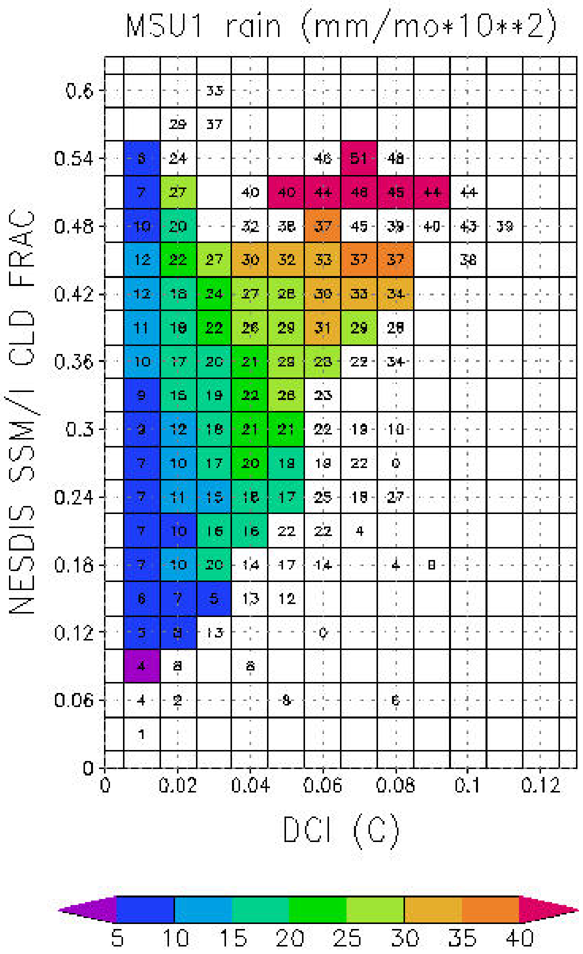
- MSU1 Tb is sensitive to liquid water and large consecutively-produced ice
- SSM/I retrievals that explicitly isolate cloudwater, liquid precipitation, and MSU2 retrievals of precipitating ice can be used to better understand spatial distributions seen in MSU1

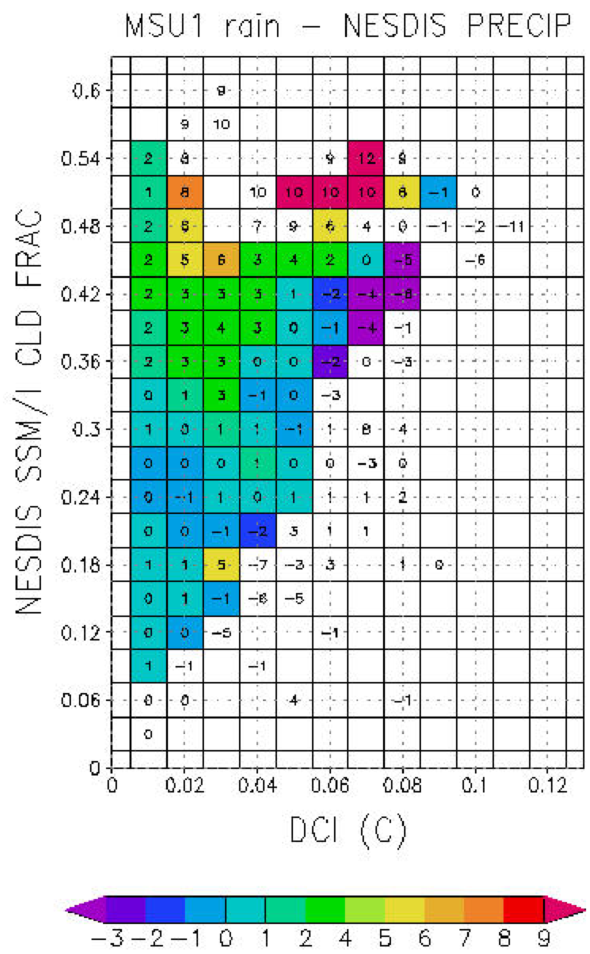
Four years (1990-1993) of monthly, 2.5 deg gridded date are used.

Data are binned in a two-parameter analysis to isolate response of MSU1 rain rate to a given variable while another remains fixed.

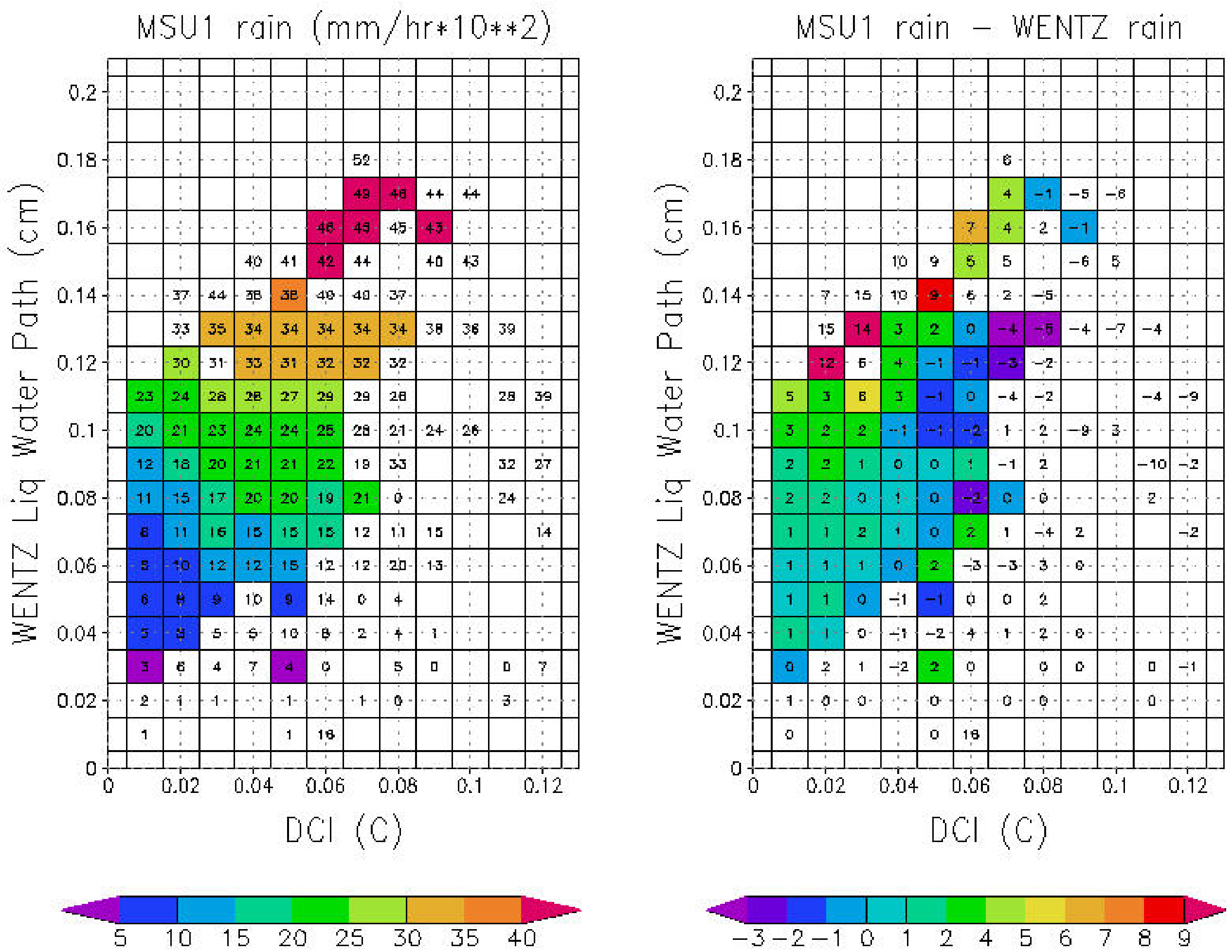


Relative Sensitivity of MSU1 and NESDIS Rain to Cloud Fraction And the Presence of Precipitating Ice

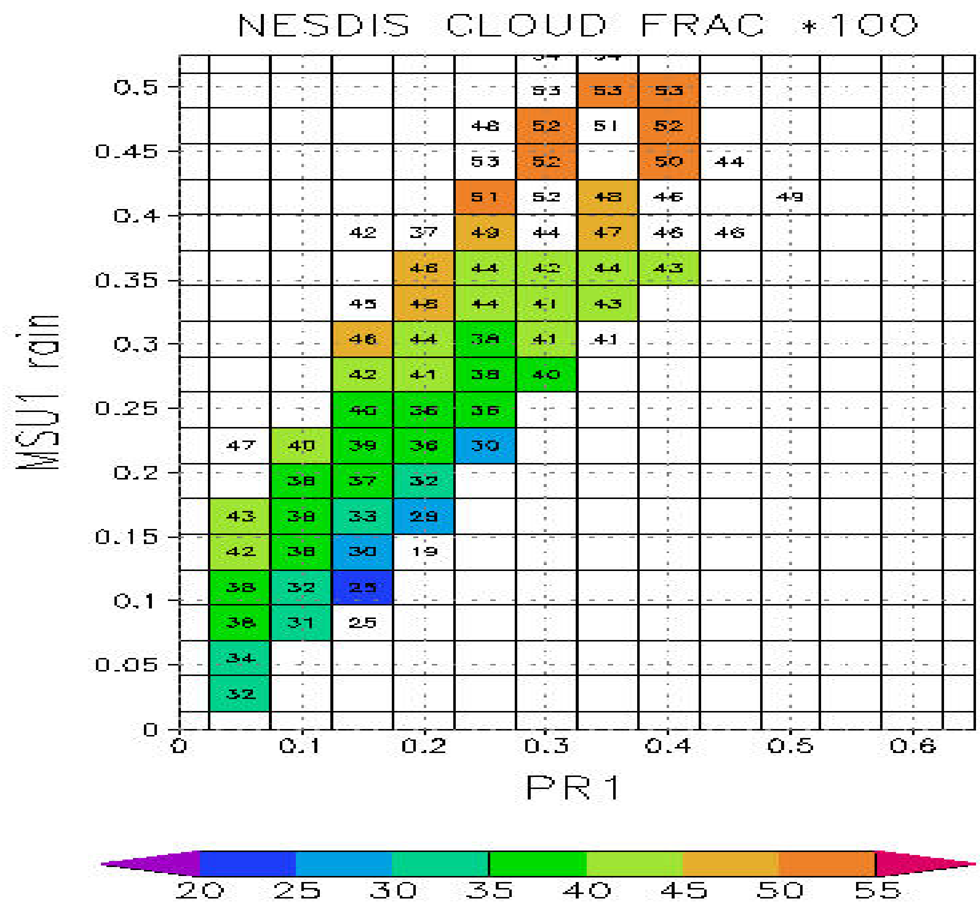




Relative Sensitivity of MSU1 and NESDIS Rain to Cloud Liquid Water Path And the Presence of Precipitating Ice



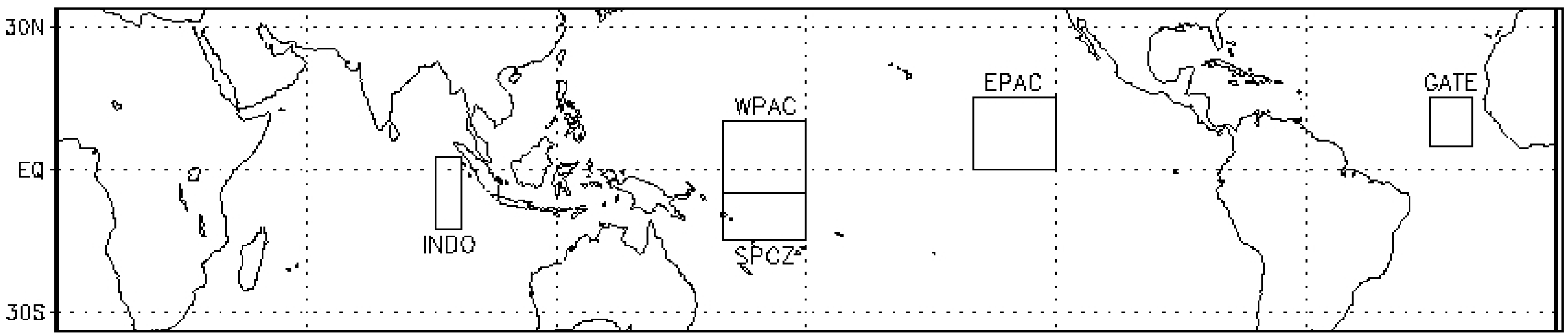
Cloud Fractional Area As a Function of MSU1 and NESDIS Rainrates



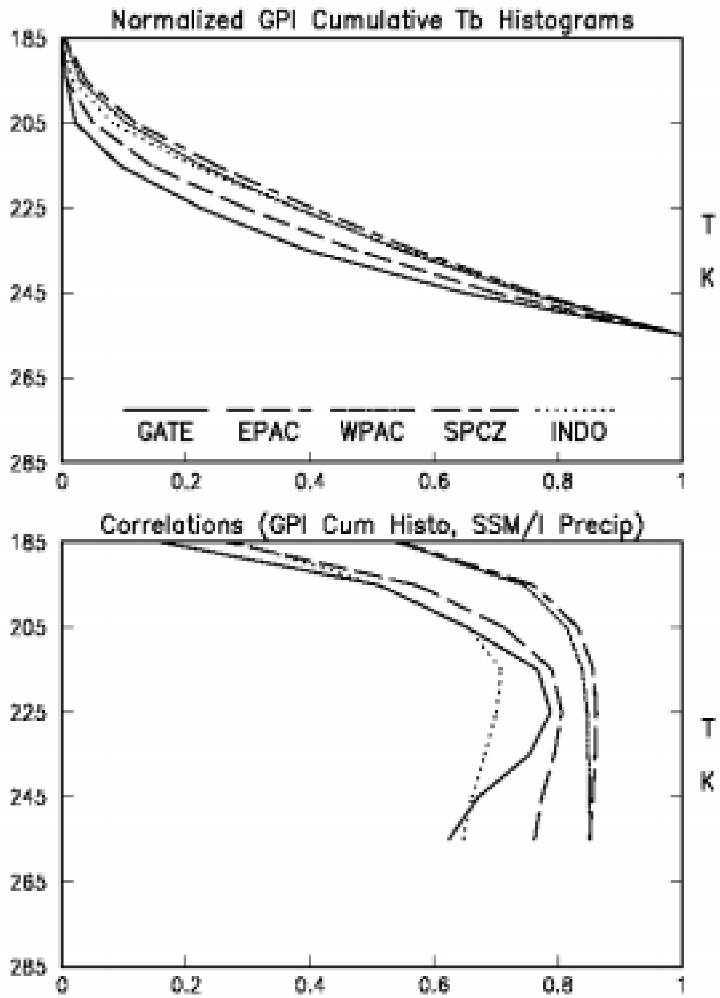
How Does GPI Cold Cloudiness Relate to SSM/I rainfall?

- Four years of monthly-mean GPI Tb histogram data and Wentz/Spencer SSM/I rainfall were analyzed.
- Correlations using GPI / SSMI pairs at 2.5 deg res within five study areas were examined.
- Results were repeated with TOVS layer-mean cloud fractions in lieu of GPI to understand thin (non-black) cirrus effects.

GPI Study Areas



GPI Statistics from Five Oceanic Climatic Regions



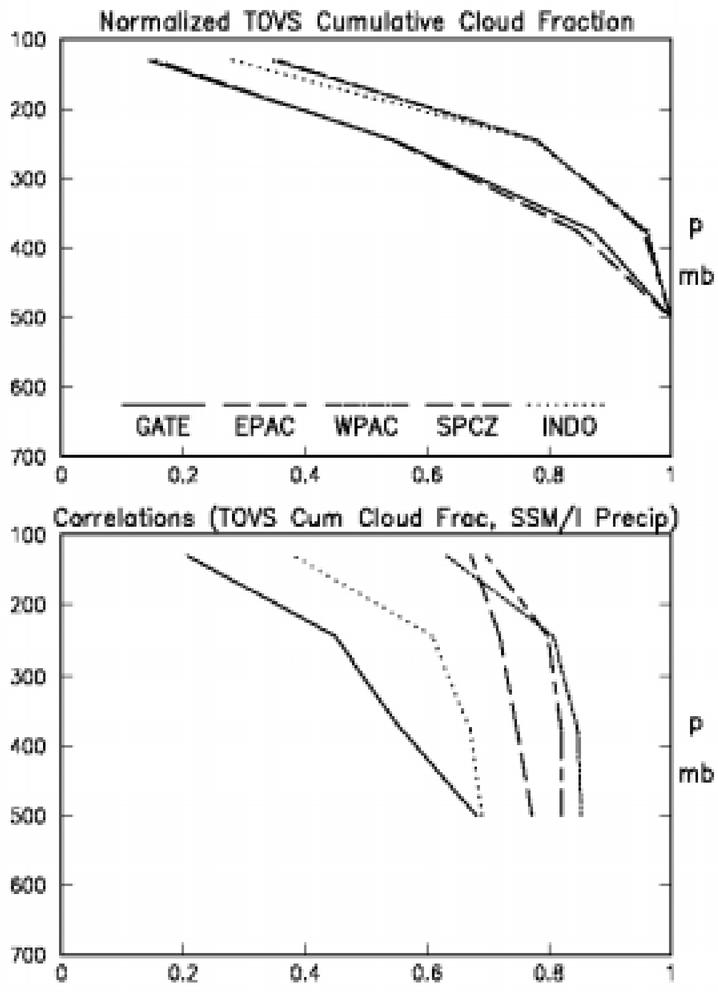
Cumulative fractional Tb coverage below specified Tb thresholds is normalized by the value at 255K.

GATE and EPAC show substantially fewer clouds penetrating colder than 215K and pro-portionately more clouds warmer than 235K

Correlations between cumulative Tb cover and rainfall tend to maximize near 225K. (For individual levels correlations maximize at 205 to 215K.)

Weakened correlations at Tb>235 in GATE and EPAC are due to seasonal effects of non-convective cirrus.

TOVS Statistics from Five Oceanic Climatic Regions



Cumulative cloud fractions are normalized by value of layer centered at 500 mb.

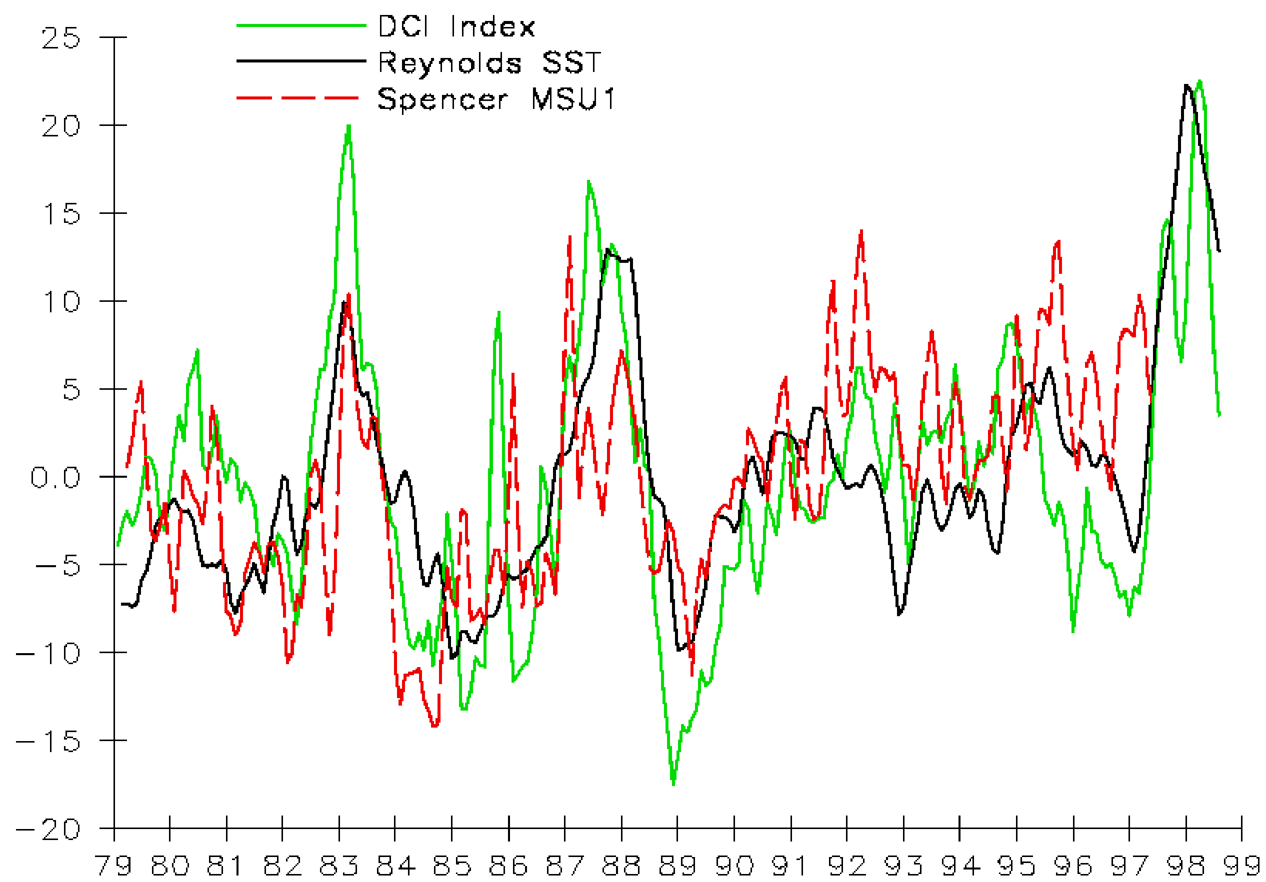
Since TOVS retrieves cloud cover and includes thin clouds as well as convective anvils the fractional cloud and Tb histogram data look different:

More of the total cloud cover occurs above 400 mb.

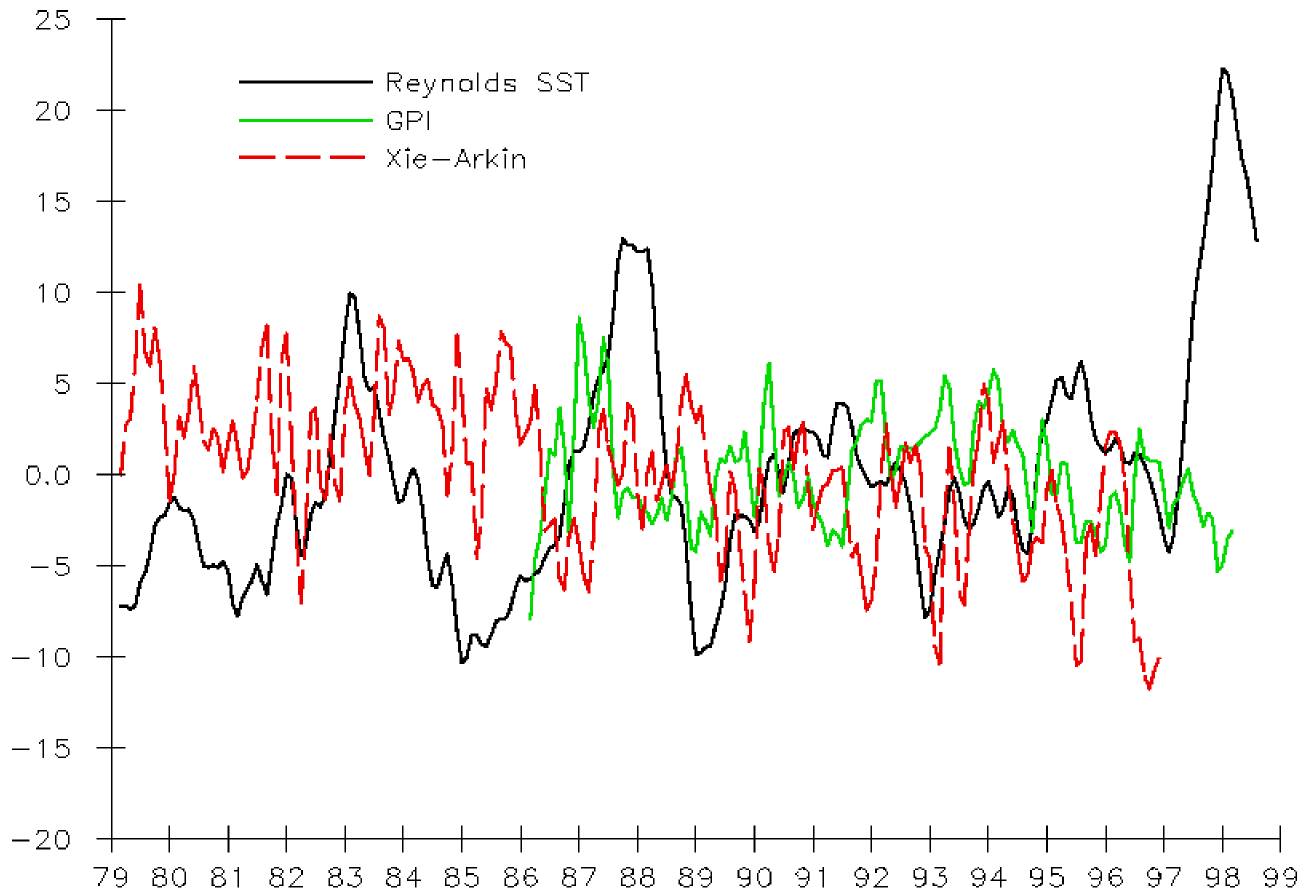
Correlations of cumulative cloud fraction and rainfall are smaller at highest levels (due to non-precipitating cirrus) and increase downward.

	DCI	MSU1	Xie-Arkin	GPI	GPCP-psg	Wentz / Spencer
Cor with DCI	**1.00**	**0.36**	**0.06**	**-0.23**	**0.29**	**0.57**
Cor with SST	**0.69 (0.61)**	**0.47 (0.41)**	**-0.24**	**-0.22**	**0.21**	**0.47**

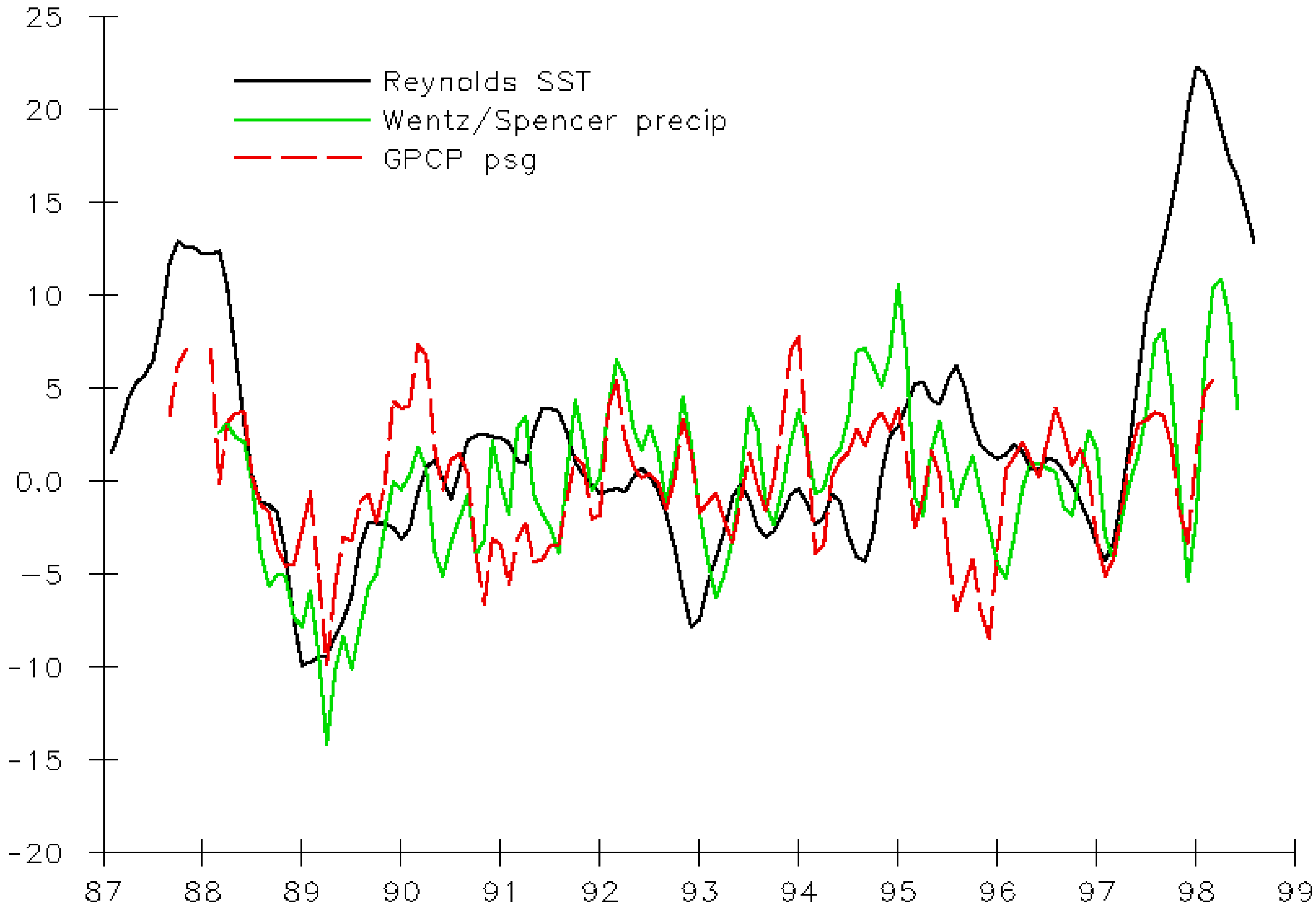
Correlations between monthly-mean, tropical-average 30° N/S, ocean only) satellite estimates of precipitation with DCI (top row) and SST (bottom row). Correlations involving GPCP psg and Wentz/Spencer algorithms pertain to the period 1988 through 1997 due to length of SSM/I data set. DCI and MSU1 numbers in parentheses correspond to that period. GPI spans 1985 through 1997. All other results extend from 1979 to 1997.



Time series of monthly anomalies of SST (K x 40), DCI, and MSU1 precipitation averaged over the tropical oceans (30^o N/S). DCI and MSU1 units are nondimensional (% departure from climatological mean).



Time series of monthly anomalies of SST (K x 40), GPI, and Xie-Arkin precipitation averaged over the tropical oceans (30^{o} N/S). GPI and Xie-Arkin units are nondimensional (% departure from climatological mean).



Time series of monthly anomalies of SST (K x 40), Wentz/Spencer, and GPCP-psg precipitation averaged over the tropical oceans (30° N/S). Wentz/Spencer and GPCP psg units are nondimensional (% departure from climatological mean).