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UNCERTAINTY IN SATELLITE RAINFALL ESTIMATES: TIME SERIES COMPARISON

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ABSTRACT

We examined nine satellite rainfall algorithms and compared the rain fields produced from these algorithms for the period of August 1987 to December 1988. Preliminary results show algorithms which use the same satellite sensor data tend to be similar, suggesting the importance of sampling. Oceanic global mean rainfall ranges from 2.7 to 3.6 mm/d. The variability in zonal mean rain rate is about 1.5-2 mm/d for these algorithms. Published by Elsevier Science Ltd on behalf of COSPAR

INTRODUCTION

There exist a number of operational or semi-operational climate scale satellite rainfall algorithms whose products have been used in diagnostic or comparative studies. To quantify the uncertainty in these algorithms, we compared these rain algorithms at the global and monthly climate scale. Our comparison focused on the time period during which available SSM/I measurements overlap the Atmospheric Modeling Intercomparison Project (AMIP) period, i.e., July 1987 through December 1988. During this period, the algorithms went through at least a seasonal cycle. and hence we can examine the seasonal difference between the algorithms. The responses of the algorithms to the 1986-1987 El Nino Southern Oscillation (ENSO) were evaluated using pattern correlation and paired-t statistics.

ALGORITHMS

The satellite rain algorithms included in this study are:

1. The Goddard Scattering Algorithm by Adler et al. (1993) (denoted Adler),
2. Calibrating GPI IR data with microwave data by Huffman et al. (1993) (Huffman),
3. Monthly oceanic rainfall using SSM/I Tb histogram by Wilheit et al. (1991) (Chang or WCC),
4. Theoretical regression method by Kummerow and Giglio (1993) (Kummerow),
5. Precipitation area dependent technique by Prabhakara et al. (1993) ((Prabhakara),
6. GOES Precipitation Index (GPI) Technique by Arkin and Meisner (1987) (Arkin),
7. Oceanic rainfall from MSU by Spencer (1993) (Spencer),
8. Global precipitation from TOVS by Susskind et al (1984; 1989) (Susskind), and
9. Multi-spectral rainfall algorithm by Wu (1991) (Wu).

The characteristics of these algorithms are summarized in Table 1.

Table 1: Characteristics of rainfall algorithms

Algorithm	Objective	Technique	Input	Spatial Res.	Temporal Res.	Domain
Adler	Instant. Climate scale	MW scattering	SSM/I 19,22, 37 & 85 GHZ	0.5^{o}x0.5^{o}	monthly	global
Huffman	Climate scale	MW calibrated IR threshold	MW and IR	2.5^{o}x2.5^{o}	monthly	+/-40^{o}
Arkin	Climate scale rainfall	IR thresholding	Geostationary and AVHRR	2.5^{o}x2.5^{o}	Pentad	+/-40^{o}
Chang	Climate scale	MW emission, Lognormal pdf constraint	SSM/I 19 and 22 GHz	2.5^{o}x2.5^{o}& 5^{o}x5^{o}	monthly	+/-65^{o} oceans
Kummerow	Instant. rainfall, Profiles	Optimal, piecewise, linear reg.	SSM/I 19, 22, 37 and 85 GHz	pixel	instant.	global
Prabhakara	Instantaneous /Climate scale	Precipitation area	SSM/I 19, 37 and 85 GHz	3^{o}x5^{o}	instant. monthly	+/-50^{o} oceans
Spencer	Climate scale	Reg. using MW threshold	MSU channel 3	2.5^{o}x2.5^{o}	monthly	+/-50^{o} global
Susskind	Instantaneous rainfall	Reg. using retrieved quantities	TOVS sounding products	60 km	twice daily	global
Wu	Mesoscale/ Climate scale	Cloud radiative forcing	TOVS sounding products	4^{o}x5^{o}	10 day, monthly	global

RESULTS AND DISCUSSIONS

Data were available for most algorithms for the period August 1987 to December 1988, except Kummerow and Huffman whose dataset consisted of data till July 1988. SSM/I data for December 1987 is missing. We resampled the data at the lowest resolution of 5° by 5° without area weighting. For example, Prabhakara's data has a resolution of 3 ° latitude by 5 ° longitude and hence latitudinal weights of [3,2], [1,3,1], or [2,3] are used where appropriate. All units are converted to mm/day. We created an ocean mask using the ETOPO5 landmask and computed statistics for oceanic and land areas, respectively. Only oceanic results are presented here.

All algorithms show the major patterns of precipitation in the right locations: the Inter-tropical Convergence Zone (ITCZ), the South Pacific Convergence Zone (SPCZ), and the oceanic dry areas in the western north Atlantic and south Pacific. The intensities at the location of the maximum and minimum are quite varied, however. Table 2 shows the pattern correlation coefficients between algorithms for August 1987. Coefficients greater than 0.85 are bolded. There are high correlation between algorithms of Adler, Chang, Huffman, and Kummerow, who use SSM/I data and those of Susskind and Wu whose algorithms are based on TOVS sounding retrieval products. Huffman's algorithm merges GPI and SSM/I data. Both Arkin and Susskind's algorithm rely on cloud estimates .

Table 2: Pattern Correlation Coefficients for August 1987 between Algorithms

	Huffman	Prabhakara	Chang	Kummerow	Spencer	Arkin	Susskind	Wu
Adler	**0.90**	0.66	**0.88**	**0.92**	0.74	0.82	0.83	0.79
Huffman		0.65	0.83	0.83	0.71	**0.88**	0.82	0.79
Prabhakara			0.70	0.68	0.76	0.60	0.68	0.70
Chang				**0.90**	0.75	0.78	0.79	0.78
Kummerow					0.76	0.79	0.79	0.77
Spencer						0.72	0.81	0.79
Arkin							**0.91**	**0.87**
Susskind								**0.94**

Fig. 1 shows the annual (over the period August 87 - July 88) zonal mean rainfall. All algorithms shows a peak zonal rainfall in the latitude belt 5° - 10°N. The range of rain rate is between 1.5 to 2 mm/d for all latitude belts. Arkin is largest at latitudes 35-40°S and 35-40°N, which is limitation of Arkin's technique (Janowiak, 1992). Prabhakara's zonal means are the highest between 10°N to 25°N and Kummerow's the lowest between 25°S and 40°N.

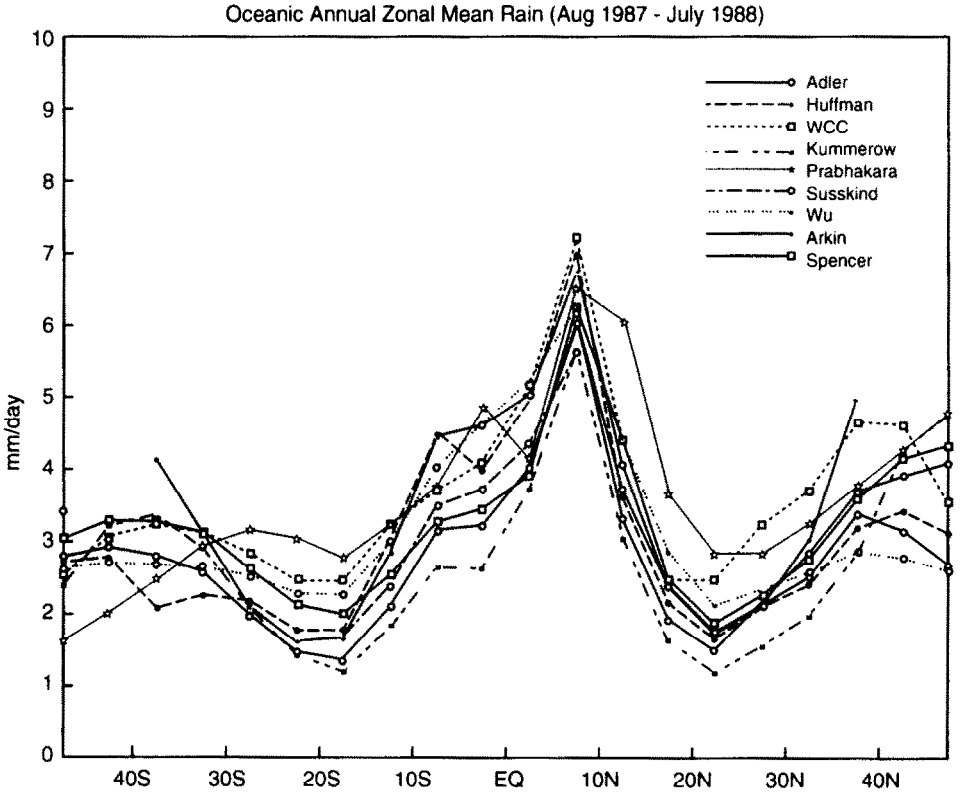

Fig. 1. Zonal Annual (August 1987 - July 1988) Mean Rain Rate for All Algorithms

The global means (50°N - 50°S) range from about 2.7 mm/day (Adler and Kummerow) to 3.6 mm/day (Chang and Prabhakara). These global mean estimates can be compared with the global averages of about 3 mm/day from the heat and water budget consideration (Eagleson 1970).

We examined the responses of the algorithms to the 1986-1987 ENSO event. We defined a paired-t test (Chang et al., 1995) between August 1987 and August 1988 to quantify the algorithm response. Table 3 contains the results of the paired-t tests and pattern correlation coefficients for all the algorithms. None of the algorithms show a paired-t value greater than 1.96, hence the null hypothesis that the two Augusts are different cannot be rejected at the 5% level. Chang's algorithm has the largest paired-t value and Adler's the lowest pattern correlation To better quantify the responses to ENSO events, multi-year data with multi-ENSO events are needed.

Table 3: Paired-t Statistics and Correlation Coefficients between August 87 and August 88

Algorithm	Adler	Prabhakara	Chang	Spencer	Arkin	Susskind	Wu
Mean Aug87 mm/d	2.76	3.18	3.56	3.10	3.48	2.68	3.34
S.D. Aug87 mm/d	3.40	3.09	3.59	2.69	4.38	2.46	2.68
Mean Aug88 mm/d	2.71	2.94	3.29	2.93	3.35	2.60	3.41
S.D..Aug88 mm/d	3.25	2.84	3.41	2.82	4.26	2.49	2.90
paired-t	0.02	0.09	0.09	0.07	0.04	0.05	-0.03
corr. coeff.	0.55	0.58	0.60	0.59	0.70	0.73	0.75

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