Correction Note on "Linear Prediction of Indian Monsoon Rainfall"

Timothy DelSole[1] and J. Shukla

Center for Ocean-Land-Atmosphere Studies, Calverton, MD and George Mason University, Fairfax, VA

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[1]Corresponding author address: Timothy DelSole, Center for Ocean-Land-Atmosphere Studies, 4041 Powder Mill Rd., Suite 302, Calverton, MD 20705-3106. Email to delsole@cola.iges.org

An error has been found in the paper by DelSole and Shukla (2002; hereafter DS). The error concerns the predictor called *TE*, which measured the December-January-February (DJF) average surface temperature in northern Europe. Specifically, DS erroneously used the value of *TE* corresponding to the winter *after* the Indian summer monsoon, rather than the winter value *before* the Indian summer monsoon, as would be available in a ordinary forecast situation. This error is of some interest because, as noted in DS, the predictor *TE* appeared to be the single most useful predictor of Indian monsoon rainfall out of all predictors examined. A second, independent reason for revisiting DS is that the Indian monsoon rainfall data set from the Indian Institute of Tropical Meteorology, Pune, India was updated in December 2002, after publication of DS. The updated data set differs from that used in DS only after 1993. The purpose of this paper is to discuss the result of using the (more appropriate) value of *TE* corresponding to the winter *before* the Indian summer monsoon, and using the updated rainfall data. The essential result is that prior winter value of *TE* is not an important predictor for Indian summer monsoon, at least compared to Darwin tendency and location of the 500hPa ridge, and that the skill of the best prediction models with the correct *TE* are reduced relative to DS. These results are discussed in more detail below. Another purpose of this paper is to draw attention to the fact that this error is interesting in its own right, because it suggests that while *TE* is not a useful predictor of Indian monsoon rainfall, Indian monsoon rainfall may be a useful predictor of *TE*.

The main result of this paper are tables 1a, b, c. These tables summarize the skill of forecasts of total, June-September Indian monsoon rainfall for each year in the period 1967-2000, as given by the updated data, based on linear regression models derived strictly from the 25 years preceding each forecast year. The predictors used in the regression models were selected according to five different criteria, indicated in the rows of tables 1a, b, c (see DS for an explanation for these criteria). There are two distinct pools of predictors. The first pool consists of "Data set II" in DS, which includes the value of *TE after* the monsoon season. The second pool is exactly the same as the first, except that the predictor *TE after* the monsoon is replaced by the value of *TE before* the monsoon. The table shows that the skill of the predictions based on the value of *TE* before the monsoon, as would be ordinarily available, are not as skillful as those based on *TE* after the monsoon. For instance, the correlation skill of the best prediction model drops from 0.51 to 0.44, and the explained variance drops from 21% to 10%.

The prediction models selected by the F-test from the predictor pool that includes *TE* before the monsoon are shown in table 2. We see that *TE* is selected only once, namely in 1992. This contrasts with the fact that the predictor *TE* after the monsoon was chosen 12 times (namely, in the years 1984-1995), as shown in DS. These results strongly suggest that the value of *TE* preceding the monsoon is not a useful predictor of Indian monsoon rainfall.

The above difference suggests the intriguing possibility that the index *TE* contains information about the preceding Indian monsoon. If so, then monsoon rainfall might serve as a useful predictor for European surface temperatures. The idea that Indian monsoon rainfall may be a useful predictor of other climate variables goes back at least as far back as Normand (1953). More recently, Kirtman and Shukla (2000) and Wu and Kirtman (2003) have used coupled ocean-atmosphere models to investigate how the Indian summer monsoon affects subsequent ENSO variability. Hoskins and collaborators also have suggested a connection between Indian summer monsoon and subsequent rainfall anomalies in Europe (personal communication).

To explore the above possibility, we compute the correlation between DJF surface temperature and monsoon rainfall. The surface temperature data set was obtained from the Climatic Research Unit, University of East Anglia, and covers the years 1856-2002. This data set contains substantial gaps in space and time, but was considered the best available data set for our purpose. We consider only those grid points for which at least 80 years in the monsoon record (1871-2002) were available. The correlation between total Indian monsoon rainfall and the DJF surface temperature before and after the monsoon at each grid point is shown in fig. 1. Unshaded grid boxes indicate regions which had less than 80 years of data. As a point of reference, the 1% significance level correlation is 0.20 for 132 independent samples, and 0.25 for 80 samples. We see that the correlations between antecedent winter surface temperature and Indian summer monsoon are fairly weak over most of the globe for which data is available, indicating that surface temperature is not a useful predictor of Indian monsoon rainfall. In contrast, the correlations between monsoon rainfall and the DJF surface temperature *after* the monsoon reveal significant correlations over parts of the globe, especially in the Indian ocean. As expected, positive correlations can be seen in northern Europe. To test whether the above results were influenced by the global warming trend, the correlations were re-computed for the period 1871-1970, in which the warming trend is weak. Nearly the same large scale features were produced in this case. These results strongly suggest that Indian monsoon rainfall may be a useful predictor of surface temperature in certain parts of the globe.

References

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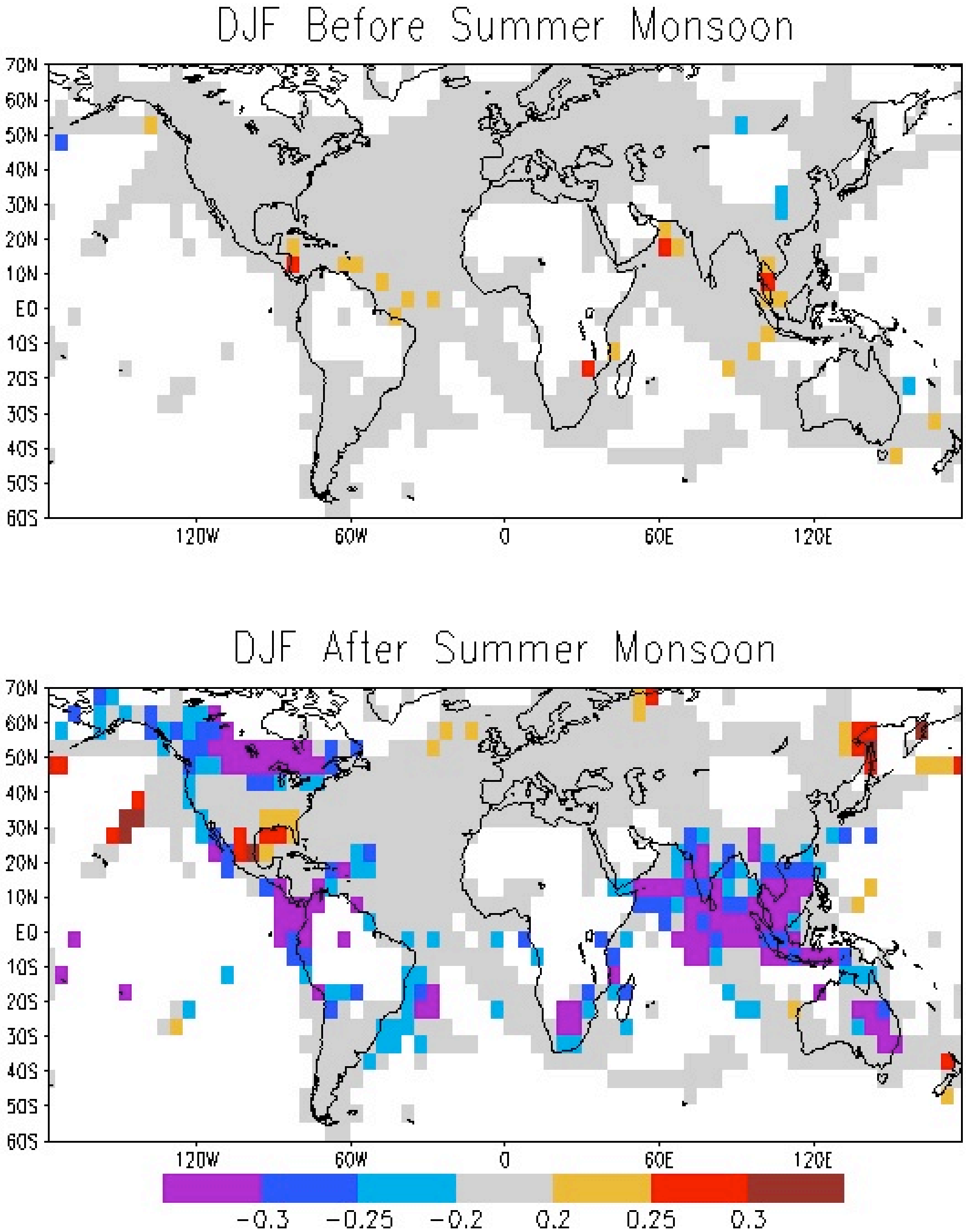

Figure 1: Correlation between Indian summer monsoon rainfall, and the DJF surface temperature before (top) and after (bottom) the summer monsoon, during the period 1871-2002. Unshaded grid boxes represent regions with too little data (less than 80 years) for computing correlations.

A Selection Criteria	Predictors including TE after Monsoon ACC	Predictors including TE before Monsoon ACC
F-test(2%)	0.51	0.44
Mallow's Cp	0.43	0.38
Max Si	0.33	0.35
All Predictors	0.39	0.38
Climatology	-0.11	-0.11

B Selection Criteria	Predictors including TE after Monsoon Normalized Error Var.	Predictors including TE before Monsoon Normalized Error Var.
F-test(2%)	0.79	0.90
Mallow's Cp	0.93	1.00
Max Si	1.18	1.13
All Predictors	1.06	1.06
Climatology	1.08	1.08

C Selection Criteria	Predictors including TE after Monsoon RMSE	Predictors including TE before Monsoon RMSE
F-test(2%)	7.13	7.59
Mallow's Cp	7.72	8.00
Max Si	8.72	8.51
All Predictors	8.25	8.26
Climatology	8.35	8.35

Table 1: The skill of regression models chosen with different selection criteria for the period 1967-2000. Skill is measured by the correlation coefficient (A), error variance normalized by the 1967-2000 variance (B), and the root mean square error (C) in cm. The forecast models were derived strictly from the 25 years preceding each forecast year. The two columns of numbers correspond to two different data sets. The first data set ("*TE* after Monsoon") has exactly the same predictors as used in DelSole and Shukla (2002) in their "Data set II" experiments, and employs an updated JJAS monsoon rainfall record. The second data set ("*TE* before Monsoon") is exactly the same as the first, except the value of *TE* after the monsoon is replaced by its value before the monsoon.

year	error	prediction	truth	Dtend	Nino3	NAOJF	NAOAM	TE(premonsoon)	ridgeapr
1967	1.7	87.8	86.0						
1968	11.9	87.4	75.5						
1969	3.8	86.9	83.1						
1970	-4.0	90.0	94.0	-4.1					
1971	-3.5	85.2	88.7	-4.3					
1972	10.9	76.2	65.3	-4.8					
1973	6.4	97.8	91.4	-5.7					
1974	6.4	81.2	74.8	-5.3					
1975	-4.2	92.1	96.3						3.4
1976	5.2	90.9	85.7						3.5
1977	-10.2	78.2	88.3	-3.4					2.6
1978	-10.2	80.8	91.0						3.3
1979	7.8	78.6	70.8	-3.6					2.2
1980	-3.4	84.9	88.3	-3.5					2.5
1981	-0.3	84.9	85.2	-3.5					2.5
1982	1.1	74.7	73.6	-3.5					2.3
1983	-6.6	88.9	95.6	-3.3					2.4
1984	-0.1	83.6	83.7	-3.8					2.4
1985	11.5	87.5	76.0	-3.8					2.4
1986	7.6	81.9	74.3	-3.4					2.6
1987	7.7	77.5	69.7	-3.8					2.5
1988	-11.0	85.2	96.2	-4.0					2.5
1989	2.8	89.5	86.7	-4.3					2.5
1990	2.4	93.3	90.9	-4.6					2.6
1991	0.2	78.7	78.5	-4.3					2.6
1992	4.2	82.7	78.5	-1.4	-5.3	1.0	-1.4	0.3	2.4
1993	-16.1	73.6	89.7	-4.2					2.6
1994	-14.1	79.8	93.8		-6.5	1.9			2.5
1995	12.8	91.9	79.1		-6.8	2.0			2.0
1996	0.8	86.1	85.3				-5.7		
1997	0.7	87.8	87.1				-5.9		
1998	0.9	86.0	85.1				-5.0		
1999	-3.7	78.1	81.9				-4.9		
2000	12.8	90.1	77.3				-5.2		

Table 2: Regression coefficients (in the six rightmost columns), predictions, and errors of the regression models selected by the F-test criterion of DelSole and Shukla (2002; DS), with α = 2%. Each regression model was derived strictly from the 25 year time series preceding the forecast year. The data differs from that in DS in that the value of *TE* before the monsoon is used, and the monsoon rainfall data set has been updated in the years 1994-2000. An empty table entry indicates that the selection criteria did not chose that particular predictor for that year.