SHORT CONTRIBUTION

Global model-based monthly mean rainfall climatology

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RESUMEN

El pronóstico inmediato de la precipitación diaria usando la inicialización física, suministra una estructura dinámica y termodinámica congruente respecto de la precipitación "observada" impuesta. Este procedimiento suministra una habilidad muy alta para la lluvia modelada en comparación con los totales de lluvia observados. Este mismo procedimiento se extiende por periodos de meses para ilustrar la muy alta habilidad en la recuperación de la lluvia "observada" a partir del modelo, utilizando la inicialización física dentro de una asimilación de datos con una longitud de un mes. Este procedimiento también suministra detalles de la temperatura, viento, humedad y el campo de presión superficial, que son congruentes con el campo de lluvia media mensual. Tales conjuntos de datos son útiles para la validación de modelos climáticos globales.

En esta nota, presentamos el impacto de la inicialización física sobre la climatología pluvial. Comparamos la climatología de la precipitación de la Universidad Estatal de Florida (FSU) con el pronóstico del tiempo del Centro Europeo a Mediano Plazo (ECMWF) y el reanálisis del Centro Nacional Para la Predicción Ambiental (NCEP).

ABSTRACT

Nowcasting of daily rainfall using physical initialization provides a dynamical and thermodynamical structure consistent with respect to the imposed 'observed' rainfall. This procedure provides a very high skill for the modeled rain as compared to the observed rainfall totals. This same procedure is extended over periods of months to illustrate the very high skill for recovering the 'observed rain' from the model by using physical initialization within a month long data assimilation. This procedure also provides details of the temperature, wind, humidity and surface pressure field that are consistent with the month mean rainfall field. Such data sets are useful for the validation of global climate models.

In this note, we present the impact of physical initialization on rainfall climatology. We compare the Florida State University (FSU) rainfall climatology with the European Centre for Medium Range Weather Forecast (ECMWF) and the National Center for Environmental Prediction (NCEP) reanalysis.

1. Introduction

In recent years several satellite products have provided rainfall estimates that have been extremely useful in improving our knowledge of precipitation climatology. Outgoing long-wave radiation and satellite borne radiometric data sets have been used to infer rainfall rates. More recently in 1998 we have also seen the first radar on board a satellite, the Tropical Rainfall Measurement Mission (TRMM), providing estimates of rainrates and the vertical distribution of hydrometeors. These types of data sets have provided a unique opportunity to improve the forecast model's ability to improve their rainfall climatology.

This note is intended to illustrate some current advancements in precipitation data assimilation methods that enable us to have forecast models at high resolution incorporate such data sets and thus to improve the reanalysis-based monthly mean model-based climatology.

2. High resolution data assimilation

The procedure we use has been described in some detail in several recent papers, Krishnamurti *et al.* (1991, 1998) and Treadon (1996, 1997). Physical initialization is invoked within a data assimilation phase of model forecast. This entails the restructuring of the vertical distribution of humidity, using several reverse algorithms, for a given estimate of the observed rainfall rates.

Reverse Cumulus parameterization algorithm: Given the 'observed' rain, the reverse algorithm restructures the vertical distribution of specific humidity such that the use of the forward algorithm now produces almost the same rain from the use of a forward cumulus parameterization algorithm as was supplied to it. A reverse surface similarity theory restructures the specific humidity in the surface (the constant flux layer) such that the surface evaporation and the prescribed precipitation are in close balance, within the assimilation. This component provides a balance among the vertically integrated evaporation, precipitation and the substantial derivative of the specific humidity following Yanai *et al.* (1973) definition of the apparent moisture sink. In addition to these, a restructuring of the specific humidity of the upper troposphere based on a matching of a global forecast model based outgoing long wave radiation with that seen from satellite based estimates is also carried out within the physical initialization. This makes use of a simple successive correction procedure. All of the aforementioned components of physical initialization are contained within the model's data assimilation. This is based on a Newtonian relaxation procedure, also called nudging.

3. Rainfall climatology skill

The results, shown here, are based on a multi-level FSU global spectral model which is described in Krishnamurti *et al.* (1991). When this is all done, what do we accomplish? We have noted that the correlations between the 'observed' and the model based daily rainfall totals over the global tropical belt are of the order of 0.9 for (October, 1991) almost every day of the month, Krishnamurti *et al.* (1994). A typical such comparison is presented in Figure 1a, b. By placing the reverse and the forward cumulus algorithms adjacently in the assimilation and having already tested the near reversibility of the numerical algorithms, the assimilation provides a very high skill. Figure 2a, b, c, d, e, f illustrates an example of a comparison of the monthly mean rainfall (October, 1991) based on satellite/raingauge (panel a) observation and those based on model's initialization (panel b); these results are over the global tropical belt. Panel b is based on physical initialization using the FSU global model, Krishnamurti *et al.* (1991). Panels c, d, e, and f show respectively the results over South America. Panel c shows
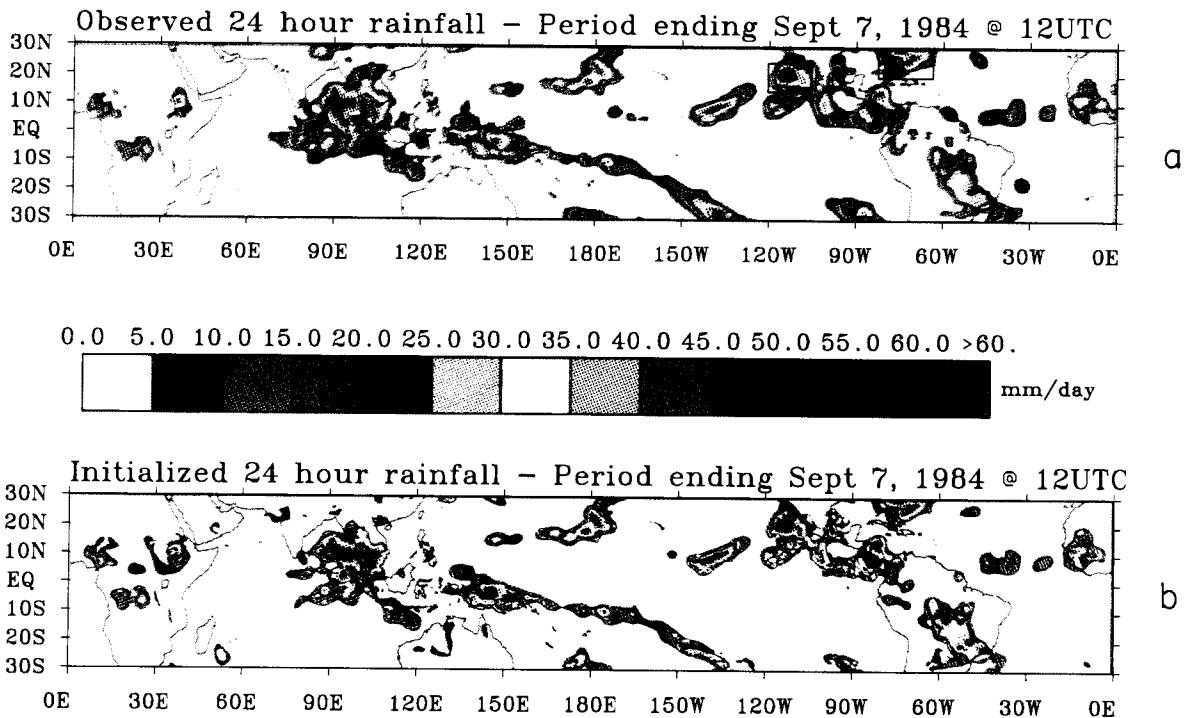
Fig. 1. 24 hours precipitation ending September 7, 1984 at 12 UTC. (a) Observed over global tropics. (b) Model-based FSU reanalysis over global tropics. Units: mm/day.

the satellite/raingauge based monthly rainfall; panel d shows the results based on FSU model and physical initialization; panels e and f show the model rains from the ECMWF and NCEP based on their respective Global Data Assimilation Systems (GDAS). These were all obtained from daily values and averaged over one month, i.e. for October 1991. The correlations of the FSU model's rain with the 'observed' satellite based rain over the global tropical belt (panels a and b) is 0.92. Over the South American domain shown in panels c, d, e, and f the correlations of the model rain with respect to the 'observed' satellite/raingauge rain are: FSU (panel d) 0.91, ECMWF (panel e) 0.62, NCEP (panel f) 0.34. These correlations are based on daily global assimilation and forecasts carried through an entire month, in this instance the month of october 1991. The models compared here, follow different procedure for initialization. They also use somewhat different initial data sets. Furthermore there are inherent differences among the models resolution, physics and dynamics algorithms. It appears that by improving the daily nowcasting skill of rain using physical initialization, the monthly totals (based on the summation of the daily initial rain) is also vastly improved. An outcome of this procedure is that we are able to develop a global climatological data base for the winds, temperature, vorticity, divergence, pressure and humidity that are in an equilibrium with the observed (or the physically initialized) rain.

Monthly mean observed precip (mm/day) Oct 1991
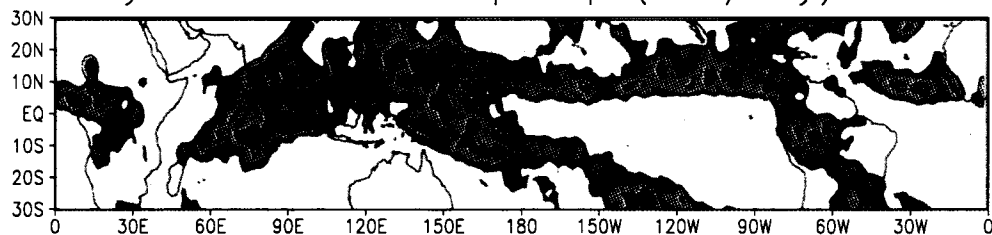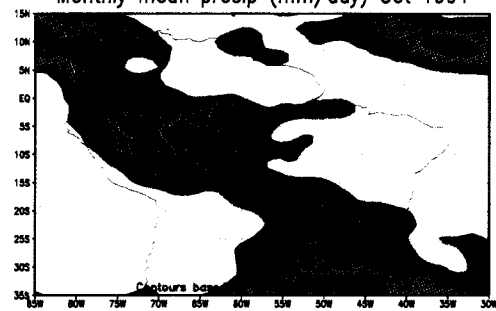

a

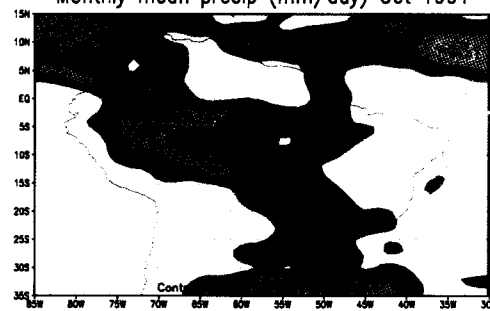## Monthly mean phy. Init. precip (mm/day) Oct 1991
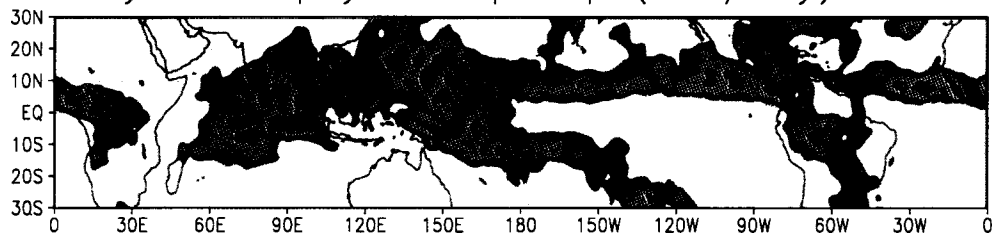
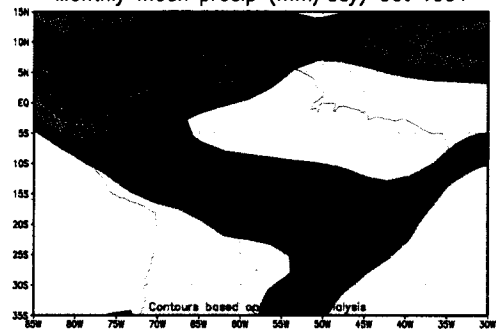b

Monthly mean precip (mm/day) Oct 1991

c

Monthly mean precip (mm/day) Oct 1991

d

Monthly mean precip (mm/day) Oct 1991

e

Monthly mean precip (mm/day) Oct 1991

f

Fig. 2. Monthly mean precipitation for Oct., 1991. (a) Observed over global tropics. (b) Model-based FSU reanalysis over global tropics. (c) Observed over South America domain. (d) FSU reanalysis over South American domain. (e) ECMWF analysis over South American domain. (f) NCEP analysis over South American domain. Units: mm/day

4. Conclusion

Physical initialization appears to be a powerful tool for the rainfall climatology. This procedure includes additional information over the data void region. This data is the observed precipitation measurements obtained from the raingauges and satellite-based indirect estimates of rainrates from Outgoing Long-wave Radiation (OLR) and microwave radiometer. This tool enhances the definition of divergence, vorticity, vertical motion, convective heating and surface pressure tendencies.

One of the main purposes for the initialization of model rain to a high degree of accuracy with respect to observed estimates is that one can thus obtain a dynamical and a thermodynamic state of the atmosphere consistent with the rainfall. This paper shows that the monthly mean climatology (and daily estimates as well) of the rainfall totals can be captured via physical initialization to a very high degree of accuracy. The correlation of the model based and the 'observed' estimates is of the order of 0.9. This accuracy comes from the use of reverse algorithms for cumulus parameterization within our data assimilation. The assimilation includes three reverse algorithms, i.e. the reverse surface similarity, the reverse cumulus parameterization and the OLR matching. The reverse cumulus parameterization algorithm modifies the vertical profile of humidity such that the rain produced by the forward algorithm is nearly the same as that provided to the reverse algorithm. The high degree of accuracy is obtained by placing the reverse algorithm adjacent to the forward algorithm. This assures a high skill for each time step for the rainfall retrieval by the model. Accumulation of the registers over an entire month (for each transform grid point) assures the near matching of the modeled versus the 'observed' rainfall totals.

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