Precipitation Correction in the ERA-40 Reanalysis,

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1 Introduction

The ECMWF 40-year reanalysis project ('ERA-40') has recently reached its completion. These reanalyses of the state of the atmosphere from September 1957 to August 2002 provide a very high quality reference atmospheric state for quite a long period and adds a competitor to the hitherto available NCEP/NCAR 50-year and ECMWF ('ERA-15') 15-year reanalyses.

Evaluation of the precipitation over tropical oceans show excessive amounts when compared to independent estimates (GPCP, http://precip.gsfc.nasa.gov and Huffman *et al.*, 1997) during the latter parts of ERA-40. This has been found to be due to a fundamental problem in the variational analysis of humidity over tropical oceans in areas of high density observations, such as satellite radiances. The increased precipitation with time might also be part of the climate signal, but our estimates indicate that the first order effect is indeed due to the humidity analysis deficiency. We will therefore assume that the real average precipitation during the 45 years does not vary significantly.

Precipitation is an essential component of the fields used to force ocean models. Since in the European Project ENACT (Enhanced Ocean Data Assimilation and Climate Prediction) the choice was made to use the ERA-40 fields to force the various ocean models taking part in the project, a solution to the excessive precipitation issue had to be sought. This paper presents the solution adopted in the context of ENACT but which might have wider applications. The procedure, its assumptions and its results are presented in section 2. A brief summary is given in section 3.

2 The precipitation correction

The production phase of the ERA-40 reanalysis consisted of five consecutive periods or streams: 1956-1963, 1964-1972, 1973-1978, 1979-1988 and 1989-2001. Three main assumptions (or constraints) are adopted in order to calculate the magnitude of the precipitation correction, which will be different for each stream: 1) The ERA-40 precipitation field for the reference stream should conform to (be consistent with) the observed precipitation field. A pseudo-climatological precipitation is the product of this evaluation; 2) The water budget, precipitation minus evaporation, has to be zero in a global sense for each stream; 3) The evaporation field is treated as error-free.

In particular, the second assumption may be applied in two ways: a) by calculating the precipitation minus evaporation (PmE) for the entire globe (i.e., land plus ocean) or b) by calculating the same budget but for the ocean area only. In the latter case, the river runoff contribution has to be considered too, i.e., (P+R-E) should balance out. Since the original objective of this investigation was to use precipitation as an ocean model forcing, the second approach was taken. It has been tested, however, that the two approaches, a) and b), are equivalent.

Note that, because the largest differences in precipitation appear only in the oceanic tropical band, the correction is evaluated only for the latitudinal range between 30°S and 30°N over the ocean. No attempt is made to refine the correction to be longitude-dependent.

The minimisation procedure only involves a single coefficient, α:

$$\alpha = \frac{\left(\overline{P} + \overline{R} - \overline{E}\right)}{\left(\overline{P} - \overline{P_O}\right)} \tag{1}$$

where $\overline{P}$ is the mean original ERA-40 precipitation, $\overline{P_O}$ is either the observed or the pseudo-climatological precipitation. Note that P_O coincides with the original ERA-40 precipitation outside the $\pm 30^\circ$ band. $\overline{E}$ is the mean evaporation and $\overline{R}$ is the mean river runoff ($\overline{R}$ is assumed to be about 10% of $\overline{E}$). The means of these variables are weighted according to the latitudinal length of the grid.

The reference stream was chosen to be that for 1964-1972 because, for this period, there are enough observations to constrain the model fields but, at the same time, not too many humidity observations to disrupt the precipitation field. Next, the pseudo-climatological precipitation is derived by combining the 1964-1972 stream with the 1979-2001 GPCP climatology, by solving (1). As the ERA-40 precipitation field has consistently larger values than GPCP in the tropical band, the value of α is positive and equal to about 0.25 (see last column in table 1).

OCEAN MEAN VALUES (mm day^{-1})							
Stream	$\overline{P}$	$\overline{E}$	$\overline{PmE}$	$\overline{P_C}$	$\overline{P_C mE}$	$(\overline{P_C}+\overline{R}-\overline{E})$	α
1956-1963	3.20	3.33	-0.30	3.16	-0.34	-0.004	0.39
1964-1972	3.24	3.27	-0.20	3.12	-0.32	0.005	0.25
1973-1978	3.40	3.16	0.07	3.10	-0.23	0.09	1.40
1979-1988	3.43	3.29	-0.04	3.14	-0.33	0.003	0.95
1989-2001	3.72	3.27	0.29	3.10	-0.34	-0.008	1.02
GPCP (1979-2001)	2.82						

Table 1: Mean values for precipitation, Evaporation, PmE, corrected precipitation ($\overline{P_C}$), corrected PmE ($\overline{P_C mE}$) and ($\overline{P_C}+\overline{R}-\overline{E}$). The last column shows the values for the alpha coefficients calculated by using equation (1).

The same procedure is then applied to the remaining four streams but, in this case, the derived pseudo-climatology precipitation is used in place of the GPCP climatology. The results are again shown in Table 1. With the applied precipitation corrections, the water balance, ($\overline{P_C}+\overline{R}-\overline{E}$), turns out to be well closed, that is its value is less than 1% of the precipitation and evaporation values (the dominant terms in the balance). The sole exception is the 1973-1978 stream which, however, is affected by both errors in the precipitation at latitudes poleward of $\pm 30^\circ$ and in the evaporation field.

3 Summary

A method to correct the excessive tropical precipitation over the oceans in the ERA-40 reanalysis has been presented. The basic idea of this method is the closure of the water budget. To this end, the assumption was made that the evaporation field is only affected by second order errors, hence for our purposes the evaporation is error-free.

The precipitation correction is only applied as a function of latitude and is different for each of the five periods in which the ERA-40 production phase was performed. The calculated correction coefficients are available from the authors.

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