GLOBAL PERSISTENCY DISTRIBUTIONS OF CAPE AND CIN

K. Riemann-Campe[1,2], R. Blender[2], N. Dotzek[3], K. Fraedrich[2], F. Lunkeit[2]

[1]*International Max Planck Research School on Earth System Modelling (IMPRS-ESM), Bundesstraße 53, 21046 Hamburg, Germany, kathrin.riemann@zmaw.de*

[2]*Meteorologisches Institut der Universität Hamburg, Grindelberg 5, 20144 Hamburg, Germany*

[3]*Deutsches Zentrum für Luft und Raumfahrt (DLR) - Institut Physik der Atmosphäre, Oberpfaffenhofen, Münchner Straße 20, 82234 Wessling, Germany*

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I. INTRODUCTION

Convective available potential energy (CAPE) is used to categorise and forecast convective storms. Convection might be inhibited by positive values of convective inhibition (CIN) which defines the energy needed to reach the CAPE layer. Therefore, CIN indicates the probability of convection occurring, while CAPE determines the intensity of convection (Colby, 1984).

The basis of predictability is the knowledge of persistency (also known as memory). Global distributions of persistency in CAPE (100 hPa mixed layer, pseudo-adiabatically) and CIN in a present-day climate are analysed in daily observations (ECMWF reanalysis, ERA-40, 1979-2001, T106 resolution) and simulations (ECHAM5/MPIOM, scenario 20C, 1900-2001, T63 resolution). Yano et al. (2001) are the first to analyse CAPE with respect to persistency reporting 1/f scaling up to months over the tropical west Pacific. In general, analyses of inter-annual and inter-decadal persistency are widely applied on temperature and moisture variables revealing persistency patterns over oceans and continents on almost all latitudes (e.g. Fraedrich and Blender, 2003). CAPE and CIN are variables dependent on temperature and moisture and are therefore expected to show signals of persistency, too.

II. DATA & METHODOLOGY

Daily values of the reanalysis data of the European Centre for Medium-Range Weather Forecast ECMWF (ERA-40) is used in the spectral truncation T106 (horizontal resolution ~ 1.125°) during 1979-2001. The ERA-40 data is compared with a 20th century ensemble simulation (20C) with the coupled atmosphere-ocean model ECHAM5/MPIOM, which is a part of the IPCC contributions. The 20C simulations incorporate anthropogenic forcings such as CO2, CH4, N2O, CFCs, O3 and sulphate. The three ensemble members are simulated with T63 spectral truncation (~ 1.875° resolution) during 1900-2001. For a direct comparison of the simulated data with ERA-40, 20C is analysed in the same time period, 1979-2001. Since the persistency properties during 1900-2001 are similar to those in the short period (1979-2001), the long period is used for further analysis, for example for an analysis of ENSO, which is expected to influence the memory of CAPE in the tropics.

On inter-annual time scales many climatological time series reveal long term memory (LTM) which is related to increasing variance for decreasing frequency. The detrended fluctuation analysis (DFA, Peng et al., (1995)) provides a method to detect LTM in time series. The memory is expressed by Hurst exponents exceeding 0.5. The

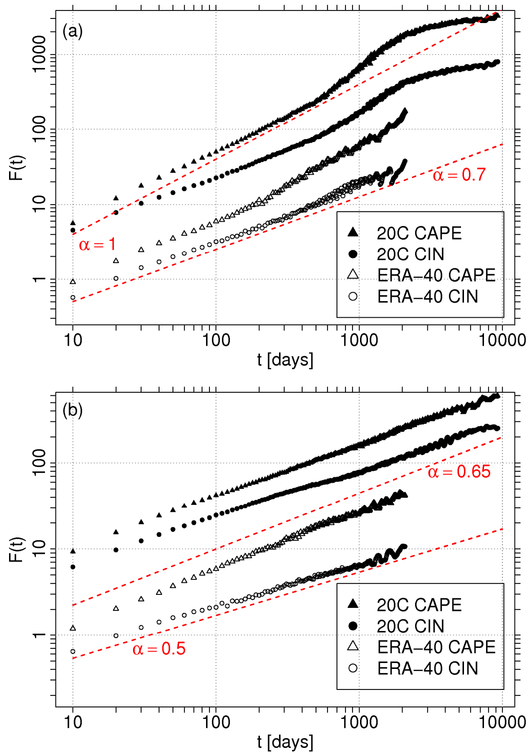

FIG. 1: Fluctuation functions (DFA2) of CAPE (triangles) and CIN (circles) at the western equatorial Pacific (a), and south-east of Greenland (b) computed from ERA-40 (open symbols) and 20C (filled symbols). Dashed lines indicate Hurst exponent α. Fluctuation functions are shifted to avoid overlap.

DFA is applied to global distributions of CAPE and CIN in the frequency range 400 days to 5 years focusing on inter-annual time-scales. DFA is also applied to regional CAPE and CIN in the frequency range 10 days to 9,000 days (~ 25 years). A first focus is on the western equatorial Pacific (at ~ 160° East, 0.5° North). Yano et al. (2001) report 1/f scaling (Hurst exponent α = 1) in CAPE in this region. A second region is chosen in the North Atlantic south-east of Greenland (at ~ 40° West, 56.6° North) where LTM in sea surface temperature is found (Fraedrich and Blender, 2003).

III. RESULTS AND CONCLUSIONS

The Hurst exponent α of CAPE and CIN in the western equatorial Pacific reveals a superimposed cycle between 1000 and 2000 days in 20C (FIG. 1a). It is not clear whether the enhanced slope around 2000 days in CAPE indicates a cycle in ERA-40. Prior to the occurrence of the cycle the slope α equals approximately one for CAPE and α ~ 0.7 for CIN in both datasets. This confirms the findings of Yano et al. (2001) who report α = 1 in 4 months of observational data. As the cycle is indicated by a 'saddle point', the slope increases and decreases respectively within the cycle and thus changes the value of α within the considered frequency range. The period of the cycle between 1000 and 2000 days as well as its location suggest ENSO (El Niño Southern Oscillation Index) to be the physical mechanism.

The Hurst exponents south-east of Greenland reveal persistency up to 9,000 days. CAPE (in ERA-40 and 20C) and CIN (in 20C only) reveal a uniform slope of α ~ 0.65 (FIG. 1b). In contrast, ERA-40 CIN does not reveal any persistency. Thus, the question arises why CIN differs in ERA-40 and 20C above the North Atlantic but not above the equatorial Pacific.

The global pattern of the inter-annual persistency distribution shows highest values of α ≥ 1 over the equatorial Pacific which decreases towards the poles; with 0.55 < α < 0.8 over almost all continents and ocean basins (FIG. 2). The persistency pattern in CIN is less pronounced than in CAPE with regards to spatial extent and magnitude of α. The Hurst exponent reaches up to α = 1.4 over central and western parts of the Pacific. Such high values are caused by ENSO. The ENSO cycle which superimposes the memory enlarges the Hurst exponent in the periodicities affected (between 1000 and 2000 days). In 20C the regions with α > 1 show a larger spatial extent. According to van Oldenborgh et al. (2005) the ENSO cycle is represented realistically regarding its strength and location within 20C. Therefore, the weaker Hurst exponent indicates an underestimation of ENSO in ERA-40 which is probably related to the shorter length of the data set.

The comparisons of ERA-40 data with the 20C ensemble simulations reveal a good agreement of the global memory patterns. 20C findings show generally smoother patterns which are partly due to the lower resolution of the model, partly due to the fact that the mean of three ensemble member is presented, and partly due to the longer time series analysed.

Although α is relatively weak, the persistency in CAPE lasts up to 9,000 days south-east of Greenland. Research on polar low occurrence yields explanations on probable mechanisms of the persistency. Claud et al. (2007) report associations between large-scale atmospheric circulations and polar low development over the North Atlantic including SST distribution, sea ice extent and the NAO (North Atlantic Oscillation). Carleton and Carpenter (1990) report similar relations for the Southern Hemisphere. According to their studies polar low occurrences and thus CAPE are related to sea ice extent and ENSO. A correlation of monthly means between CAPE and ENSO, and NAO respectively reveals global teleconnections including the PNA (Pacific North America pattern) (not shown). ENSO is identified to influence strongly the variability in CAPE and CIN in the tropical Pacific and in the mid-latitudes via correlations to NAO and PNA. However, the correlation between CAPE and ENSO do not confirm the relation between Southern Hemispheric polar lows and ENSO.

The memory analysis of related parameters such as vertical mean temperature and specific humidity in the lowest 100 hPa and above reveal that their influence on the persistency in CAPE and CIN differs with location. In the tropics the spatial pattern of vertical mean specific humidity resembles that of CAPE suggesting to play the dominant

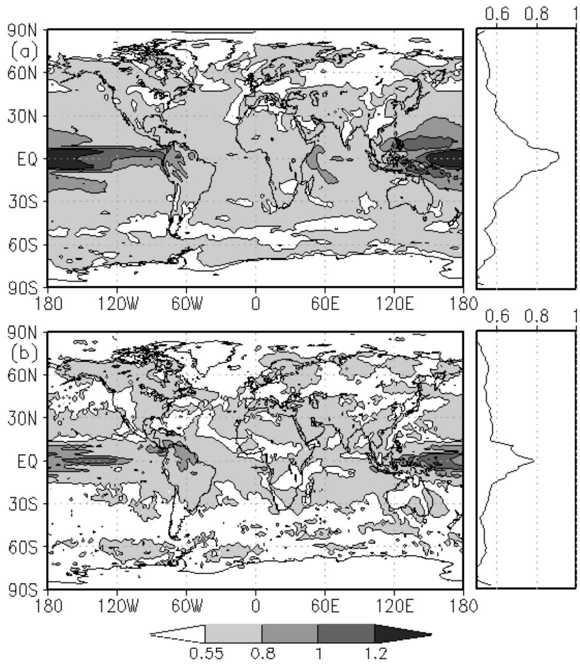

FIG. 2: Hurst exponent of CAPE (a) and CIN (b) computed from 20C. Global distribution and zonal mean in 400 days to 5 years. Hurst exponents exceeding 0.5 indicate memory.

role in CAPE persistency. However, in the extra-tropics temperature and specific humidity in the lowest 100 hPa have a stronger influence on the persistency of CAPE, when comparing their spatial memory pattern.

IV. AKNOWLEDGMENTS

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