POWER LAW BEHAVIOR OF ATMOSPHERIC VORTICES

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I. INTRODUCTION

Atmospheric vortices exist on different scales e.g. there are tornadoes on the convective scale, hurricanes on the meso-scale, and extra-tropical cyclones on the synoptic scale. These vortices are rotating pressure anomalies that are capable of producing high wind speeds which can cause serious damages.

Atmospheric vortices are characterized by their intensity which is often expressed with help of the minimum core pressure or maximum wind speed or with help of related parameters. On the other hand, vortices are characterized by their geometric properties such as area or path length. Cyclone climatologies often consider either intensities or the other properties, but a combination of both characteristics is rarely used.

In this point of view, the study of single properties of vortices seems to give an incomplete picture of low pressure systems. In this work, we will introduce a parameter that combines local-state intensity and geometric properties of vortices. This work concentrates on the analysis of probability density distributions of synoptic-scale cyclones. The results will be compared to earlier results of tornado distributions (see Schielicke and Névir, 2011).

II. ATMOSPHERIC MOMENT OF VORTICES AND ITS CONNECTION TO THE SEISMIC MOMENT OF EARTHQUAKES

This section gives a short overview over the parameter used for the analysis of the synoptic scale low pressure systems in this work.

Based on the horizontal Eulerian equation of motion, Schielicke and Névir (2009) defined a mass-specific energy of displacement as the radial integral over the accelerations that balance the mass-specific pressure-gradient force. This energy of displacement has been identified as mass-specific work that was necessary for the generation of the system when taken at the moment of maximum intensity. The explicit expression of the energy of displacement depends on the scale of the system and on the prevailing balance of forces. For example, the energy of displacement expression of tornadoes is given by the mass-specific kinetic energy.

Schielicke and Névir (2011) multiplied the energy of displacement expression with the total during lifetime affected mass and obtained an atmospheric moment definition:

$$M_a := (C^{LE} / C^{HV}) L A \Delta P$$

The components of the atmospheric moment are: L: track length, A: area, ΔP: pressure deficit between environmental and core pressure, C^{LE}: a constant relating Eulerian density field and Lagrangian density of the system, C^{HV}: a constant relating horizontal and vertical dimension of the vortex (for more details see Schielicke and Névir, 2011).

The atmospheric moment definition is comparable to the seismic moment of earthquakes. The seismic moment is a measure for the size of an earthquake. It is proportional to the energy released during the rupture process. The seismic moment can be used as parameter in earthquake statistics. The empirical Gutenberg–Richter law of earthquakes is one of the most famous statistical laws in earth sciences. It describes the relation between magnitude and cumulative frequency of earthquakes.

If magnitude is expressed with the help of seismic moments the cumulative distribution function becomes a power law with an exponent of about -2/3 and -5/3 for the probability density function, respectively (e.g. Ben-Zion, 2003).

III. METHODOLOGY AND DATA

Cyclones are tracked and analysed using the ERA-interim data set which covers a period of more than 20 years (1989-2010). A shorter period will be used for the analysis. The ERA-interim data is given 4-times daily in a resolution of about 1.5°.

The identification and tracking algorithm follows the algorithm of Blender et al. (1997) who defined a cyclone as a local minimum of geopotential in the 1000 hPa-plane and who used a nearest-neighbour search method for the tracking algorithm. Local minima are detected when the 8 surrounding points have higher values of geopotential. The area is estimated with help of the contour algorithm of gnuplot. The outermost surrounding closed contour is searched and defined as edge of the system. Then the area is calculated.

IV. EXPECTED RESULTS

So far, no results have been produced, but power law behaviour is expected for the probability density distributions (PDFs) of cyclones concerning their atmospheric moment mostly due to the large variability of vortex volumes (areas, track length, as well as lifetimes).

The PDFs will be compared to the PDFs of tornadoes and earthquakes which are also characterized by power laws (Schielicke and Névir, 2011). Methodology and theory will be presented in the talk.

V. REFERENCES

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