Literature review

Different fields of atmospheric convection exhibit varying degrees of organization, even for fixed large-scale velocities or precipitation amounts. Some indices have already been developed to quantify the degree of this organization or aggregation. Hovmoeller diagrams have long been used as a means of qualitatively identifying patterns in atmospheric fields [3, 6].

Tobin et al. developed the simple convective aggregation index (SCAI) on the basis of convective cluster number and separation [8]. Cluster counting is straightforward, and cluster separation is quantified with the geometric and arithmetic means over all distances from the center of mass of one cluster to that of another. SCAI is then the product of normalized cluster number and distance. Stein et al. find that for a fixed large-scale vertical velocity and precipitation amount in a given domain, the amount of low cloud and clear sky increase dramatically as SCAI-defined aggregation increases [7]. They find that outside of deep convective regions the mid- and upper troposphere are drier in fields with higher SCAI. Because low- and mid-level cloud amounts are also reduced, the outgoing longwave radiation increases dramatically.

[10] used column relative humidity, or the column precipitable water normalized by saturation water, to study aggregation in simulations of radiative-convective equilibrium. [2], on the other hand, used bimodal distributions of column water vapor. In their study on the effects of resolution and mixing parameterization on convective organization, Tompkins and Semie define another organization metric I_{org}, calculated by defining clusters of grid cells at the 730 hPa level whose updrafts are greater than 1 m s^{-1} [9]. The probability distribution of centroid-to-centroid distances between these clusters is also calculated and compared to a Weibull distribution, the theoretical"nearest-neighbor" probability density if convection can be described by a Poisson process. The area under this distance probability distribution is integrated to generate I_{org}. More recently, [1] created a "convection organization potential" using a combination of model output and satellite measured outgoing longwave radiation and a connected components labeling algorithm to identify convective elements. Thereafter, interaction potentials between elements and for the full scene are calculated and the impact of model resolution and convective parameterization on these potentials is assessed.

But, as [1] note, the column relative humidity and water vapor are mostly useful for simulation output, as moisture values with both regular horizontal and vertical coverage are needed and little physical insight is given to the organizational mechanism. A characteristic feature scale and a maximum number of features must be assumed for normalization of SCAI values. But given the importance of the absolute feature size and inter-feature distance, for example via cold pool interactions or variability in radiative heating and cooling rates [4, 5]

Information entropy has already been used to quantify turbulence in geophysical flows. For example, three stages of turbulent development - magnification of instability, establishment of large-scale structures, and fluctuations of steady-state conditions - have been identified.

Algorithm

Here we instead use the information entropy to quantify the organization of a given cloud field. A window of certain dimension d is defined for a cloud field of dimensions m x m. The algorithm iterates through every grid cell in the cloud field and creates a subdomain of d grid cells above, below, to the right, and to the left of the central grid cell, assuming periodic boundary conditions. Then within this "window subdomain", a probability of values being the same as the central one is calculated. For a binary field as in Figure 1, if both the central and subdomain value are either ones or zeros, then a one is added to the numerator, and if the two values are different, a zero

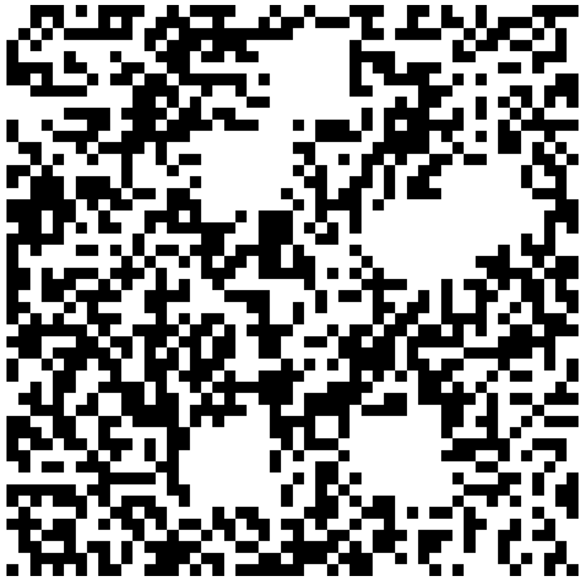

Figure 1: Sample binary field with clusters of 1's or cloud cover

is added, and this sum is normalized by the total number of grid cells in the window subdomain. Once probabilities have been calculated at all grid cells, the information entropy of these values is calculated as

$$H = \sum_{i=0}^{i=m^2} p_i \log_2(p_i). \tag{1}$$

The information entropy is normalized by the number of grid cells in the field, and the lower its value, the more ordered the field. With this normalization, H tends to 0.5 in the limit of randomly-distributed field and tends to 0 in the limit of a perfectly-uniform field.

References

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