THE ARTIFICIAL INTELLIGENCE MODEL
OUTPUT ANALYZER

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1. INTRODUCTION

The Ocean Large Eddy Model (OLEM) (Denbo and Skillingstad, 1992) is an oceanographic, non-hydrostatic, large-eddy simulation model designed to resolve small-scale, turbulent, non-hydrostatic processes. It has recently been used in the study of thermobaric convection and the associated convective plumes. These plumes are created when small, vertical perturbations in the bottom of the shallow mixed layer become unstable due to the thermobaric instability. This instability occurs because water has different compressibility at different temperatures and salinities. Convective plumes are an important component of the global meridional ocean circulation, affecting oceanic transportation and storage of heat and carbon dioxide, which in turn affect the global climate.

Research on plumes is important for better understanding of the effect of this deep, penetrative convection on meridional circulation. General statistics about plumes will be used to assess the quality of the representation of processes in large ocean models. However, such statistics on plumes are difficult to calculate, due primarily to difficulty in determining exactly what is or is not a plume. This difficulty led to the creation of the "artificial intelligence model output analyzer."

Plumes are primarily identified as areas of water with high downward velocity (w) surrounded by areas with moderate upward velocity (Figure 1). These areas also have relatively low temperature (t), and relatively high subgrid turbulent kinetic energy (tke) values. All three of these factors as well as the proximity to other areas with similar and different characteristics must be taken into account to identify a plume. With the large amounts of data being analyzed, manual identification becomes unrealistic.

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Figure 1. The temperature and vertical velocity of water in and around a plume. The darker colors indicate cooler temperatures. The velocity vectors indicate only direction, not magnitude.

2. THE MODEL OUTPUT ANALYZER

The model output analyzer takes as input a netCDF (Raw and Davis, 1990) file in the format of OLEM output files. The files, containing a time history of the three-dimensional velocity, tke and temperature fields, as well as the data for several other variables, often exceed 1.5 gigabytes in size.

2.1 *The Confidence Array*

There are several steps involved in identifying plumes in these data. The first is to go through the model output array and determine a value that expresses the program's confidence that each point is in a plume. The program looks at the relevant fields and modifies the confidence value according to the values in these fields.

Figure 2. The temperature, vertical velocity and tke fields compared to the confidence array. The dark areas indicate low temperature, high downward velocity and low tke. The shaded areas in the confidence array indicate areas with confidence of 25% or more.

The program first looks at the vertical velocity, the most important element of a plume. The program goes through the velocity array at a given time-step and finds the average vertical velocity and the highest downward velocity. It then goes through the array, assigning a value to each point according to its velocity in relationship to these values. Any point whose velocity is upward gets a confidence value of 0. Points with a downward velocity higher than the average get a confidence value dependant on the difference from the average and a user-specified weighting factor. This factor determines the percentage of confidence influenced by

each of the important elements (t, w, tke, and neighboring points).

The process is repeated for the temperature and tke of each of the points, except those points with a confidence value of 0. These points keep their 0 confidence, since points cannot be in a plume without downward vertical velocity.

The last test looks at the neighboring points. Each confidence value greater than 0 is increased by the confidence of the points around it, adjusted by a user specified weighting factor. This strengthens the confidence of groups of points, emphasizing plumes over anomalies.

The confidence array gives consistent results compared to manual methods. Although it gives confidence values greater than 0 for plumes, surface waves, and internal waves, when the user looks only at confidences above 25%, the results identify only plumes and the remainders of plumes.

Figure 2 illustrates a sample of the confidence array. There is a high correlation between the high downward velocity and the confidence array when at least one of the other fields also has the correct characteristics. However, figure 2 also demonstrates how the confidence array distinguishes between plumes and anomalies. Areas with only one of the fields as an indicator (i.e. the region of low temperature in figure 2) does not show up as a plume in the confidence array.

2.2 *Plume Identification*

The next step is identifying which points band together to make up a plume. The user first inputs the confidence level required to be considered part of a plume. Each point with a high enough confidence level is considered. The program looks at the point to the left of each point. If it is in a plume, the new point is added to that plume. If not, the program looks at the previous row to see whether the point next to it in that row is part of a plume. If so, the new point is added to that plume. If both of the tests are true, it checks to make sure that all three points are in the same plume. If neither test is true, a new plume is started.

Once a depth level has been classified into plumes versus non-plumes, it is compared with the next depth lower to combine the plumes that exist in both layers. A plume with two or more plumes below it is considered a merged plume. A separate account of merged plumes is kept in order to use these statistics once their dynamic significance is understood. The program does not attempt to follow plumes between time-steps, due to the significant movement of the plumes during the period between time steps.

2.3 *Find Plume Centers*

The next step involved in identifying plumes for statistics is to identify the "center" of a plume. This center consists of a line going through the middle of the plume with a single point at every depth. There are many ways this center can be calculated, and six methods are available for the user to try. These methods are the following: 1) the highest confidence at each depth, 2) the physical center of the plume, 3) a weighted physical center which includes confidences as well as locations in the calculation, 4) the highest downward velocity, 5) the highest temperature, and 6) the highest tide.

2.4 *Statistics*

Once the plumes and centers are identified, it is possible to calculate many statistics. Currently, the statistics included are the average number of plumes at a given time and the total water volume in plumes, in merged plumes, and in neither. These volumes can be calculated by time, depth, average or overall. Many more statistics are planned, including the average size of plume, the average velocity and other statistics at points certain distances from the center of a plume, the average bottom depth and many others. This program is designed to be used as a toolkit of functions that users can call from their own programs and use interactively.

3. CONCLUSION

With the creation of the artificial intelligence model output analyzer, the evaluation of large numbers of plumes in large data sets has become realistic. It allows the user to adjust factors and confidence limits until there is confidence that the plumes found by the analyzer are in agreement with the plumes found manually. These values can then be used to compute otherwise difficult statistics on large numbers of data sets and plumes. These statistics will assist researchers in improving large scale ocean models.

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