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A Global Climatology of Air Mass Characteristics using Traditional and Cluster-based Techniques

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The development of a classification method to characterize the vertical profile of air mass properties is described. The techniques combine elements of traditional air mass analysis with a clustering technique. Objective air mass analysis assumes that the distribution of air mass properties can be represented as a mixture of normal distributions of equivalent potential temperature (θe). Air masses were identified by changes in θe and subsequently defined by a range of θe at a given standard level (85, 70 and 50 kPa). Level-to-level comparisons were made to maintain vertical consistency. The technique was applied to mid and high latitudes. For lower latitudes, the air mass approach was replaced with a clustering technique. A model-based clustering technique (R mclust) was used based on 14 variables. The variables included θe at the surface and 85 kPa, dew point depression at 85 and 70 kPa and other derived parameters such as George's k-index and an inversion parameter. The clustering techniques were also run in the mid and high latitudes and compared with the traditional analyses.

Data consisted of a 10 year data set of upper air radiosonde data (IGRA) comprising approximately 380 stations among the three major oceans and six continental areas. The radiosonde data were supplemented by surface hourly weather data, ICOADS marine observations, and satellite-based sea surface temperatures. The data base is a unique synoptic catalogue of upper air and surface conditions. NCEP reanalysis data were used to supplement the IGRA data in data sparse oceanic regions.

Seasonal air mass scenarios were used to identify air mass source regions. Scenarios that were a combination of air masses were used to identify major storm tracks. In both cases, results were in keeping with basic meteorological principles, but with considerable more detail.

Results of the clustering analysis showed evidence of the annual monsoon cycle in northern Australia and in West Africa. Different clusters could clearly be identified as associated with the various phases of the monsoon circulation. Comparisons of the two techniques were made in the Mediterranean and in the Arctic. In both cases, certain clusters could be identified as being dominated with traditional air mass analyses. Both analyses lend confidence that the cluster analysis is identifying physically important relationships.

The climatology is being used for environmental applications. One such example is propagation studies of microwave and optronic sensor suites. In this case, the evaporation duct height parameter is calculated from the data. The data base is then interrogated to select a particular vertical profile or set of profiles that are characteristic of duct height conditions for a given season and air mass or cluster scenario. Objective criteria are applied based on θe's at the three levels and meteorological parameters that affect duct heights. This approach determines actual cases for subsequent applications with a precise measure of their representativeness. The process is illustrated for Sable Island in the Atlantic Ocean.

Ongoing studies that make use of the combination of traditional and clustering techniques to expand the range of applications are discussed.