ABSTRACT

The application of atmospheric circulation classifications in the interpretation of climate model outputs

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Automated (computer-assisted) classifications of atmospheric circulation patterns (circulation classifications, for short) constitute a tool widely used in synoptic and dynamic climatology to study atmospheric circulation and its link to various atmospheric, environmental, and societal phenomena. The application of circulation classifications to output of dynamical models of the atmosphere has developed considerably since the pioneering studies about three decades ago, reflecting rapid development in statistics, computing technology, and—naturally—climatological research, increasingly more and more dependent on simulations of the atmosphere, facing the paradigm of anthropogenic climate change.

An uncoordinated use of various statistical approaches to analyzing output of global climate models (GCM) or their various ensembles, and an arbitrary selection of circulation variables, spatial and temporal domains, and reference datasets, have contributed to a need for a comparative study, which would shed some light on the sensitivity of studies dealing with an intercomparison of circulation classifications in two datasets to subjective choices. The present thesis responds to this need by its focus on the sensitivity of such studies to the choice of a classification method and—in the case of model validation—to the choice of a reference dataset. Three separate studies were carried out. First, differences between Euro-Atlantic daily mean sea level pressure (SLP) patterns produced by several atmospheric reanalyses were assessed in multiple classifications. Second, the classifications of reanalyses were used to validate the output of an ensemble of GCMs from phase 5 of the Coupled Model Intercomparison Project (CMIP5), and, last, changes in circulation projected by these models over the 21st century under the RCP8.5 representative concentration pathway were assessed.

An intercomparison of five reanalyses (ERA-40, NCEP-1, JRA-55, 20CRv2, and ERA-20C) is based on the frequency of circulation types (CTs) defined by eight algorithms for eight Euro-Atlantic regions for 1961–2000 winters. In general, ERA-40, NCEP-1, and JRA-55 exhibit a fairly small portion of days (under 8%) classified to different CTs if pairs of reanalyses are compared, with the exception of Iceland and the Eastern Mediterranean; over the latter region, ERA-40 and NCEP-1 differ in classification of about 22% days. The 20CRv2, one of two 20th century reanalyses that assimilate only a few surface variables, is significantly different from other reanalyses over all regions and has a clearly suppressed frequency of zonal (westerly) CTs. The differences are considerably sensitive to the choice of a classification method and suggest that each approach reflects specific differences between datasets and only multiple classifications assessed in parallel lead to robust and reliable results.

Utilizing the winter CTs defined in reanalyses, an ensemble of 32 CMIP5 GCMs was validated over four Euro-Atlantic regions. The results show that the ranking of GCMs fundamentally depends on which classification is used and, thus, only a parallel usage of multiple classifications can provide robust rankings of models. Considering all eight classifications, three models (HadGEM2-CC, MIROC4h, and CNRM-CM5) are among the best in simulating the frequency of CTs over all regions. Furthermore, using different reanalyses to validate the model output for the eastern Mediterranean has a marked effect on ranking of some models; in the extreme case, model MRI-CGCM3 ranks 5th against NCEP-1 but only 22nd against ERA-20C. The median error in CT frequency of the best model for each region, relative to the median of reanalyses, is about 10–20%, which is close to the deviation of 20CRv2 from the median. Conversely, the median error of the worst model for each region is at least 50%. The GCM ensemble overestimates the frequency of westerly circulation over all regions (by about 7% over the British Isles, 21% over Central Europe, and almost 70% over the Eastern Mediterranean) and also cyclonic CTs, while easterly and anticyclonic CTs are typically underestimated by 30–40%.

The analysis of model projections is carried out for the British Isles and Central Europe. In future, models show that the zonal flow will become more frequent while the strength of the mean flow is not projected to change. Over the British Isles, the models that better simulate the latitude of zonal flow over the historical period indicate a slight equatorward shift of westerlies in future. Over Central Europe, no robust increase in persistence or frequency of anticyclonic CTs is detected; on the other hand, the easterly flow is robustly projected to become markedly weaker, which we hypothesize might be an important factor contributing to the projected decrease of cold extremes there.

Key words: *atmospheric circulation, classifications, reanalyses, global climate models, validation, projections*