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An improved jet-relative coordinate system for the detection of tropopause folds

Louis Rivoire[1], Marianna Linz[1], Jezabel Curbelo[2], and Colleen Golja[3]
[1]Department of Earth and Planetary Science, Harvard University, Cambridge, United States of America
[2]Departament de Matemàtiques, Universitat Politècnica de Catalunya, Barcelona, Spain
[3]John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, United States of America

Tropopause folds are documented to be frequent occurrences in the vicinity of the polar and subtropical jets. The rapidly changing nature of the folds and their complex fine scale structure make quantifying the associated cross-tropopause transport a significant challenge. To date, observational data sets do not provide sufficient coverage or resolution to easily overcome this challenge. In addition, ground-based observations are only representative of local processes or extreme events and do not directly inform global behavior. As a result, cross-tropopause transport estimates have relied on global models and reanalyses. However, observational evidence suggests that such models are prone to errors in both the occurrence frequency of tropopause folds and the amount of transport they generate individually. These limitations serve as the basis for our work, and we focus on a new framework to quantify the occurrence frequency of tropopause folds.

Existing literature provides various methods to quantify the occurrence frequency of tropopause folds, with some using Lagrangian parcel trajectories and others using tracer-like quantities and dynamical proxies for transport. Results vary greatly in distribution and in amplitude. Overall, because tropopause folds are associated with jet streams, a central problem lies in tracking said jet streams. Existing jet tracking algorithms tend to be complex, computationally expensive, and rely on a variety of ad hoc parameters and thresholds that are based on current climatologies (such as a minimum wind speed threshold). Consequently, these algorithms produce outputs that are sensitive to arbitrary choices and that are not well suited for climate studies.

We develop a jet tracking algorithm with two central improvements:

1) it includes temporal information about the evolution of features of interest, by using a time-integrated variable that provides information about parcel transport;

2) it minimizes the use of ad hoc parameters by defining jet features qualitatively, i.e., as spatially and temporally coherent local maxima in parcel transport;

By including temporal information, we are able to track dynamically relevant features, which is a substantial improvement over existing algorithms that use instantaneous meteorological fields. We present a comparison of the jet stream features identified by our algorithm versus existing ones. We also use the output of our algorithm as a jet-relative coordinate system, which allows us to identify tropopause folding events in global data sets, and to quantify their occurrence frequency.