Geophysical Research Abstracts
Vol. 21, EGU2019-2039, 2019
EGU General Assembly 2019

Lagrangian Coherent Structures as Sun-Earth Coupling Agents

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The polar vortices play a central role in vertically coupling the Sun-Earth system by facilitating the descent of nitrogen oxides produced by solar energetic particle precipitation (EPP) in the atmosphere. This EPP "Indirect Effect" involves the downward transport of nitrogen oxides (NO_x=N+NO+NO_2) from the mesosphere-lower thermosphere (MLT) to the stratosphere inside the winter polar vortex and is particularly impactful in the wake of prolonged Sudden Stratospheric Warming events. This work is motivated by the fact that all state-of-the-art global climate models severely underestimate this EPP-NO_x transport in the Arctic.

As a step toward understanding the transport pathways by which MLT air enters the top of the polar vortex, here we explore the extent to which Lagrangian Coherent Structures (LCS) impact the geographic distribution of EPP-NO_x near the polar winter mesopause. As a proof-of-concept, we show that an LCS formed atop one of the split polar vortex lobes during the 2009 SSW. We then demonstrate that the LCS acted to confine air with elevated NO_x to high latitudes as the air descended into the top of the polar vortex. These results present a new conceptual model of transport in the polar winter mesosphere whereby regional-scale but long-lived LCS act to sequester elevated NO_x to high latitudes until the air descends to lower altitudes. This work contributes to the ROSMIC science questions, "How is the solar signal transferred from the thermosphere to the troposphere?" and "How does the coupling take place within the terrestrial atmosphere?".