Stratospheric Weather and the Importance of Longwave Radiation

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Disruptions in the stratosphere (the second layer of the Earth's atmosphere as you're going up) can lead to anomalous weather patterns in the troposphere (the lowest level of the atmosphere). Understanding the rate at which the stratosphere cools is important because it allows us to determine how quickly the stratosphere can revert to a more typical circulation pattern following an injection of thermal energy. In the face of climate change and a cooling stratosphere, it is even more important to understand how the stratosphere responds to perturbations that can impact not only surface level weather, but also millions of people.

On January 21, 2006 a large-scale stratospheric weather phenomenon developed over the Arctic leading the temperature of the upper stratosphere to increase up to +50 K above normal in a matter of days. Initiated by upward propagating waves from the troposphere, this form of stratospheric weather, commonly referred to as sudden stratospheric warmings (SSWs), can result in a near breakdown of polar stratospheric circulation. In some cases, this can alter the tropospheric jet stream below, leading to cold-air outbreaks that force bitterly cold Arctic air southward to lower latitudes.

The SSW of 2006 is of particular interest due to both its magnitude and its aftermath: a near complete shut-off of heat supplied by dynamics, the only source of heat in the stratosphere during the winter. The lack of dynamical heating provided the perfect opportunity to measure the radiative relaxation timescale of the stratosphere (the cooling of the stratosphere via the emission of longwave radiation to space). By measuring the longwave cooling rates, we determined that the upper stratosphere cools the fastest with a relaxation time of ~6 days, compared to ~14.5 days in the middle stratosphere. This tell us that the upper stratosphere can more easily remove excess heat and energy; at lower altitudes this process takes longer. Anomalies generally last longer in the lower stratosphere, which can impact tropospheric weather for extended periods of time.

Why is this important?

Disruptions in stratospheric circulation can lead to anomalous weather patterns in the troposphere. Measuring the stratosphere's radiative relaxation timescale reveals how quickly it removes excess energy and revert to a more typical configuration, and lead to better weather predictions.

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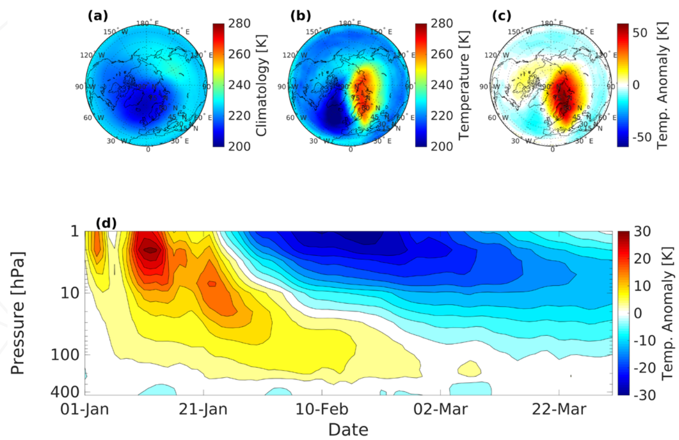

The SSW of 2006 captured at its starting date, shown at the upper stratosphere. (a) the 1979–2016 climatological temperature based on each calendar date, (b) the observed temperature, and (c) the resulting temperature anomaly. (d) The 60°– 90°N averaged temperature anomaly of the stratosphere and upper troposphere during the SSW. (Source: Bloxam & Huang, 2021)