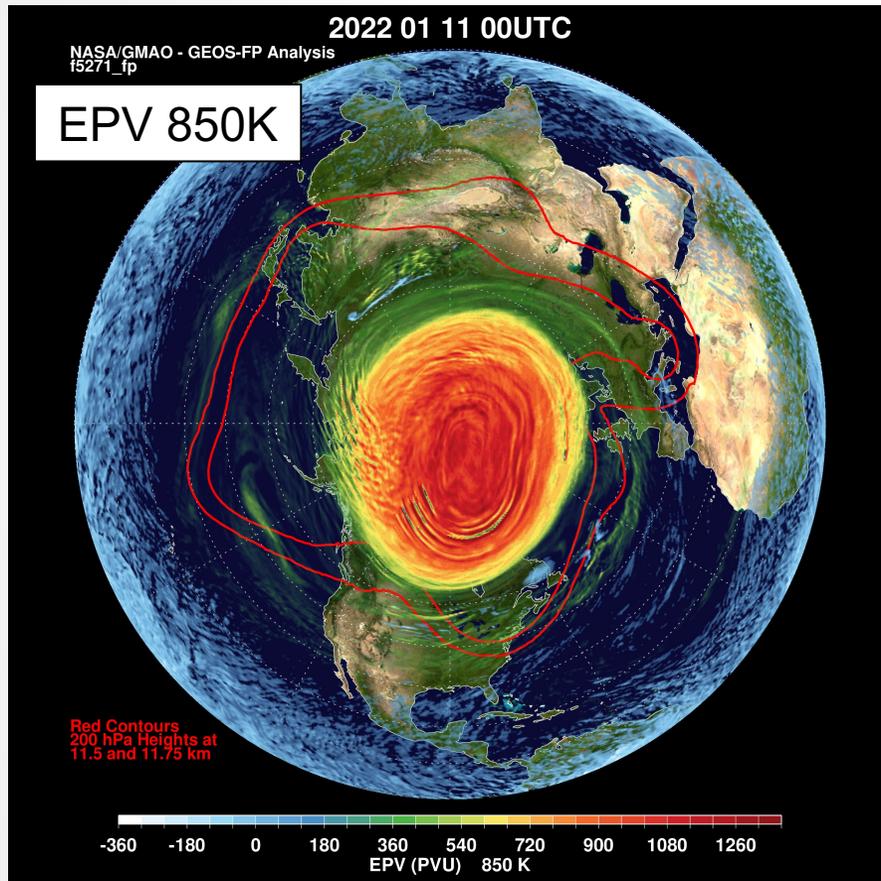


The generation of mixing across the stratospheric polar vortex edge by breaking gravity waves



11 January 2022

The Northern Hemisphere winter of 2021-2022 stayed relatively peaceful, without a major stratospheric sudden warming event.

Lawrence Coy

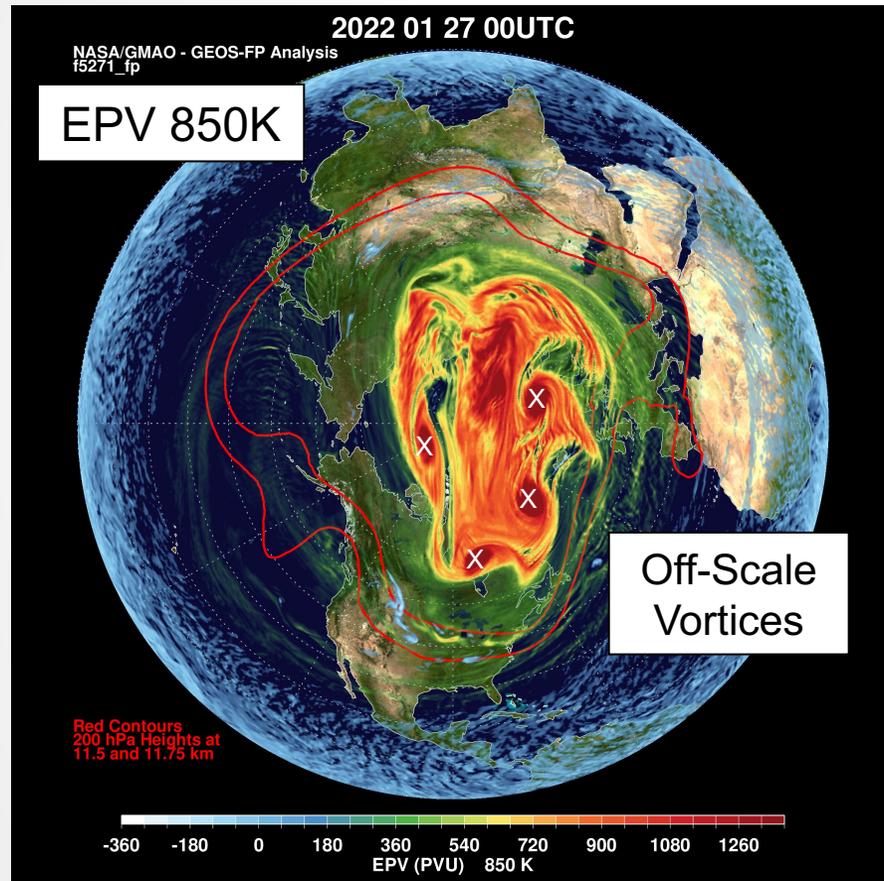
Paul Newman

Steven Pawson

NASA Goddard Space
Flight Center

December 17, 2022

The generation of mixing across the stratospheric polar vortex edge by breaking gravity waves



27 January 2022

Yet by the end of January, the vortex was highly disturbed.

How did this happen?

Lawrence Coy

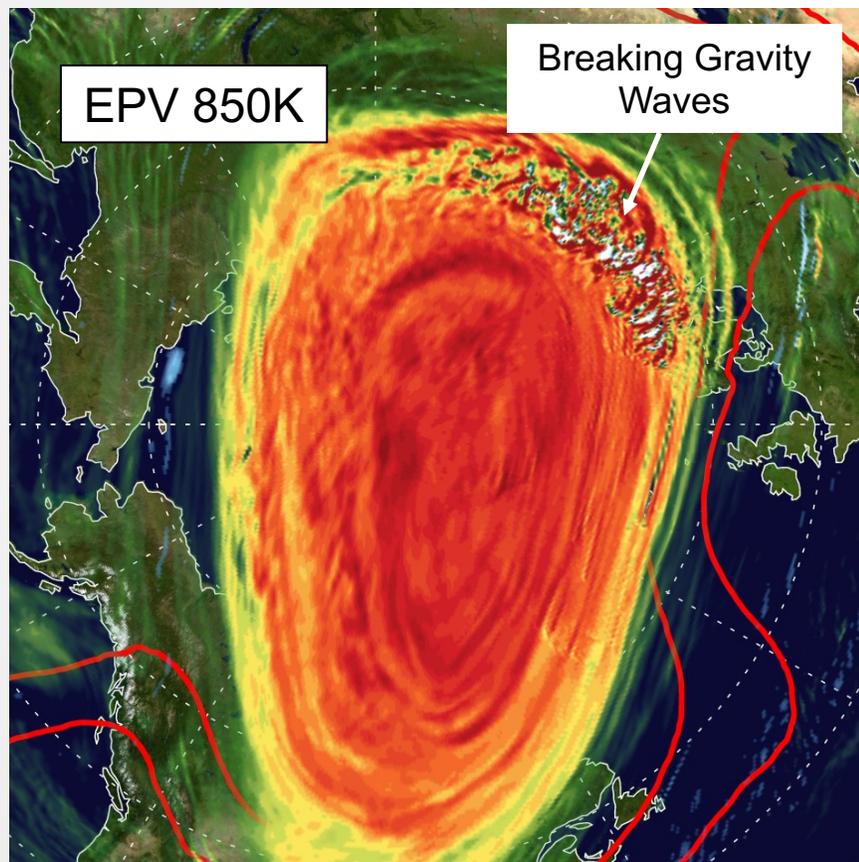
Paul Newman

Steven Pawson

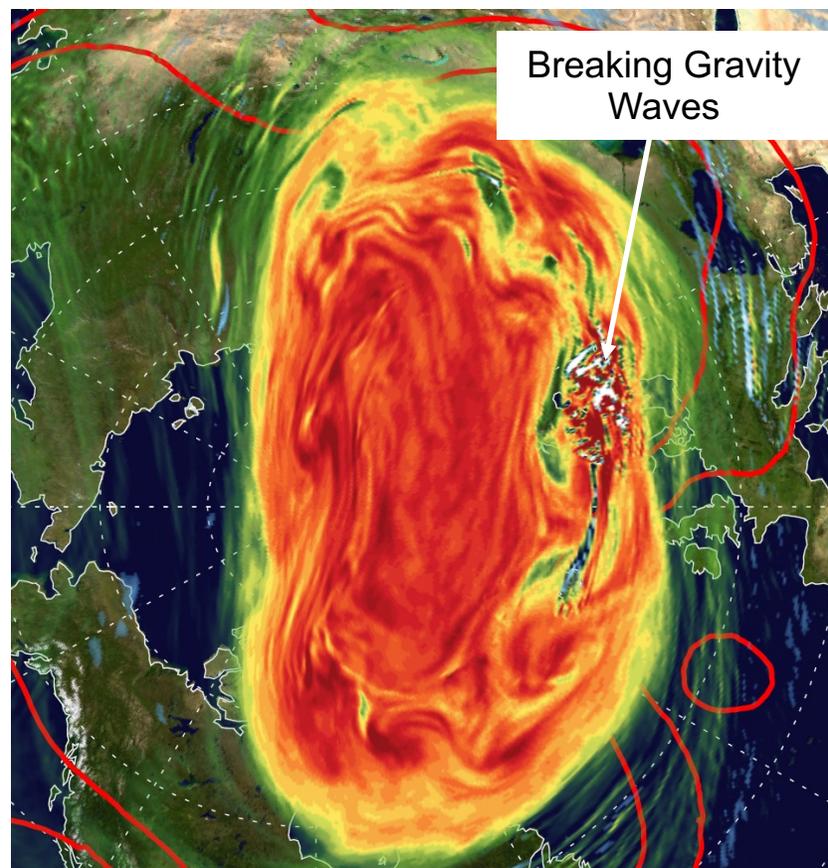
NASA Goddard Space
Flight Center

December 17, 2022

Gravity waves over Northern Europe disturbed the stratospheric polar vortex



14 January 2022

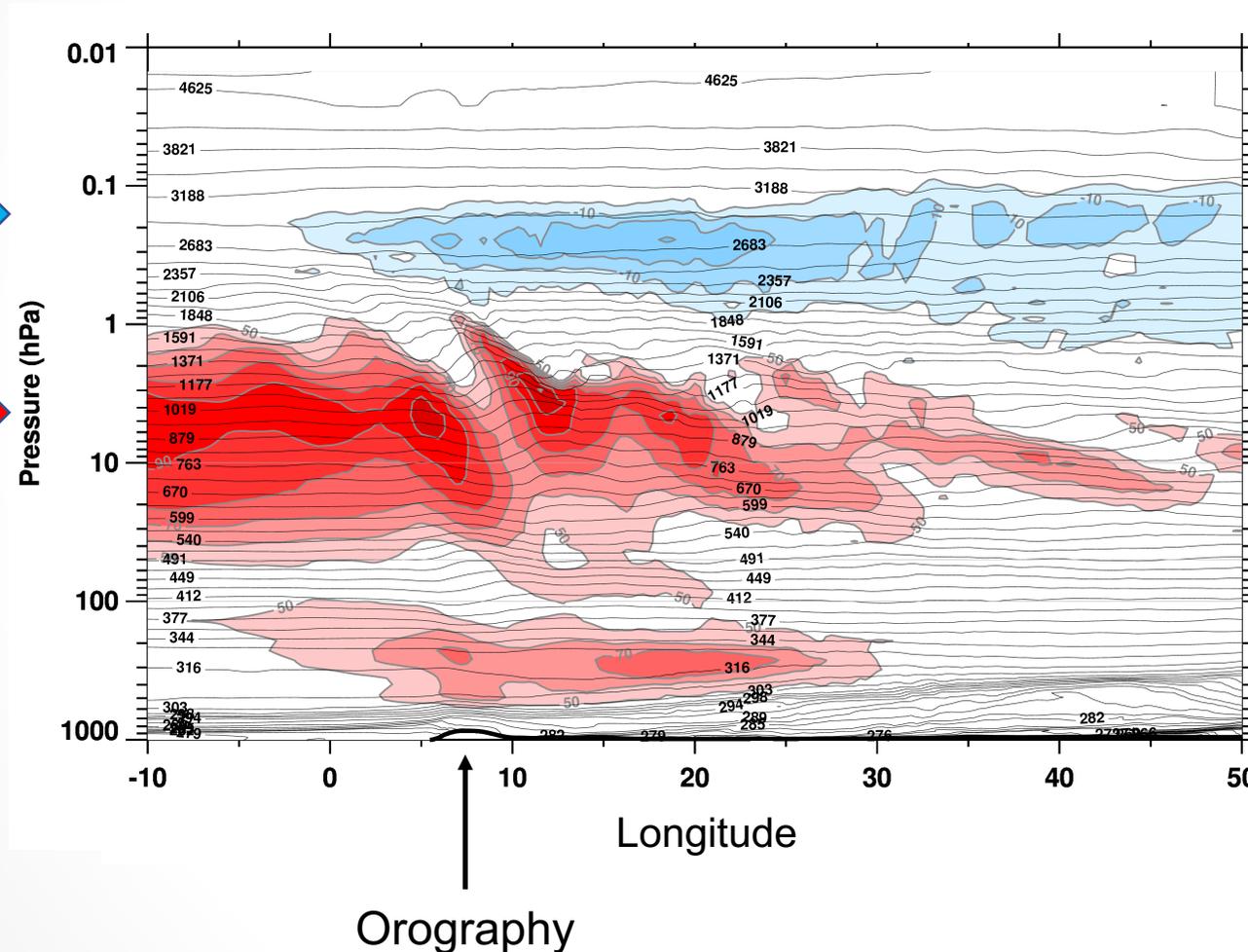


17 January 2022

Breaking gravity waves over Northern Europe slowed the upper stratospheric zonal wind

Zonal Wind
-20-0 m/s

Zonal Wind
50-100 m/s



14 Jan 2022
60°N, 10°W-50°E

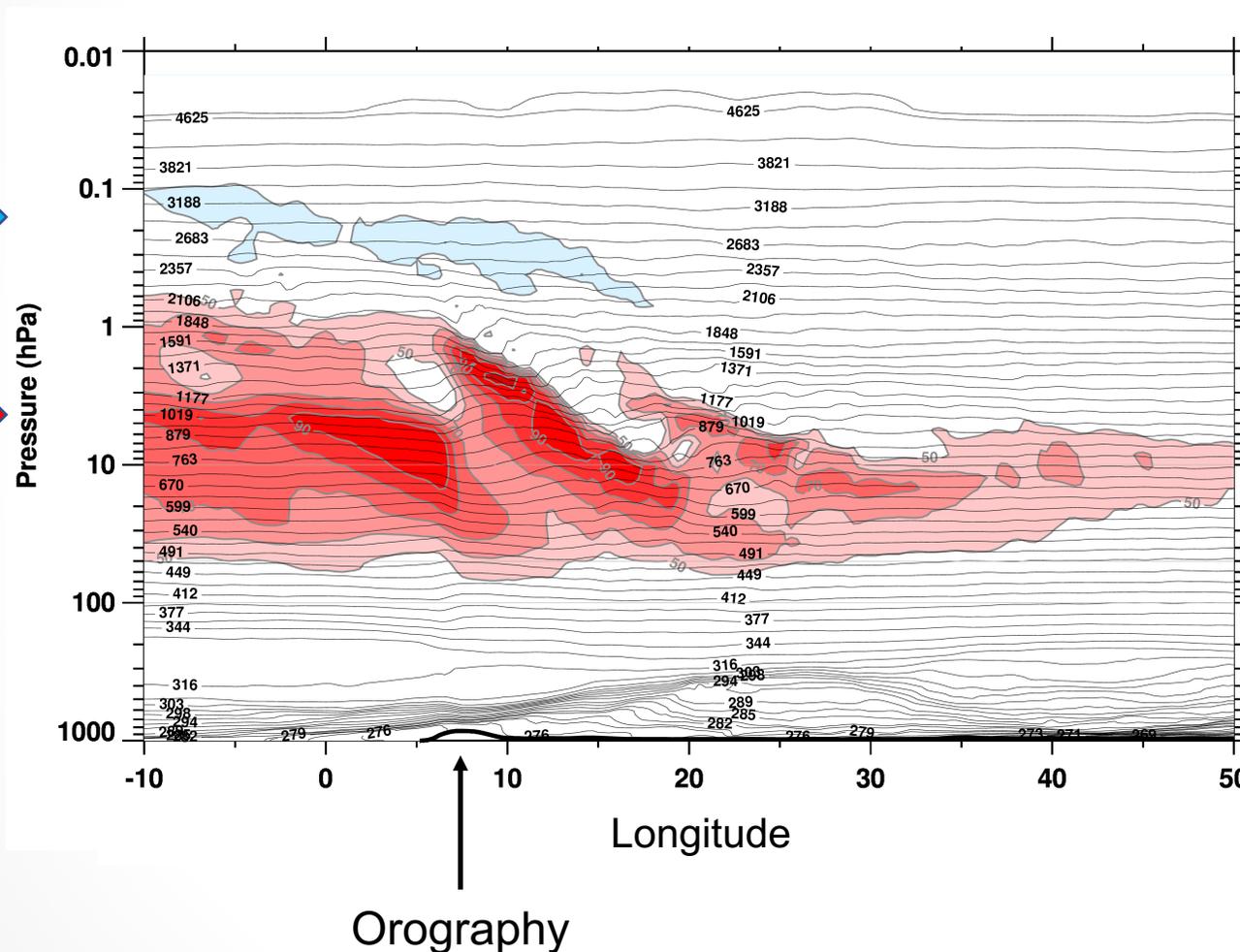
} Upper Stratosphere

Breaking gravity waves over Northern Europe slowed the upper stratospheric zonal wind

Zonal Wind
0 m/s



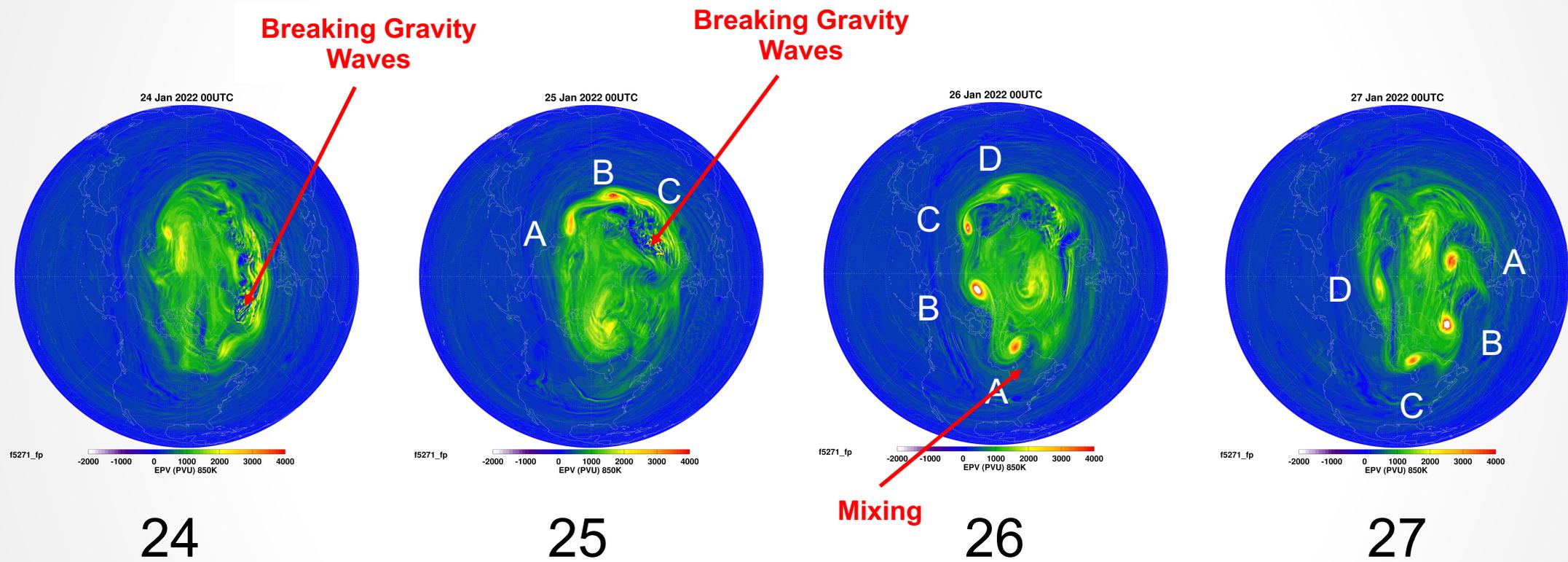
Zonal Wind
50-90 m/s



17 Jan 2022
60°N, 10°W-50°E

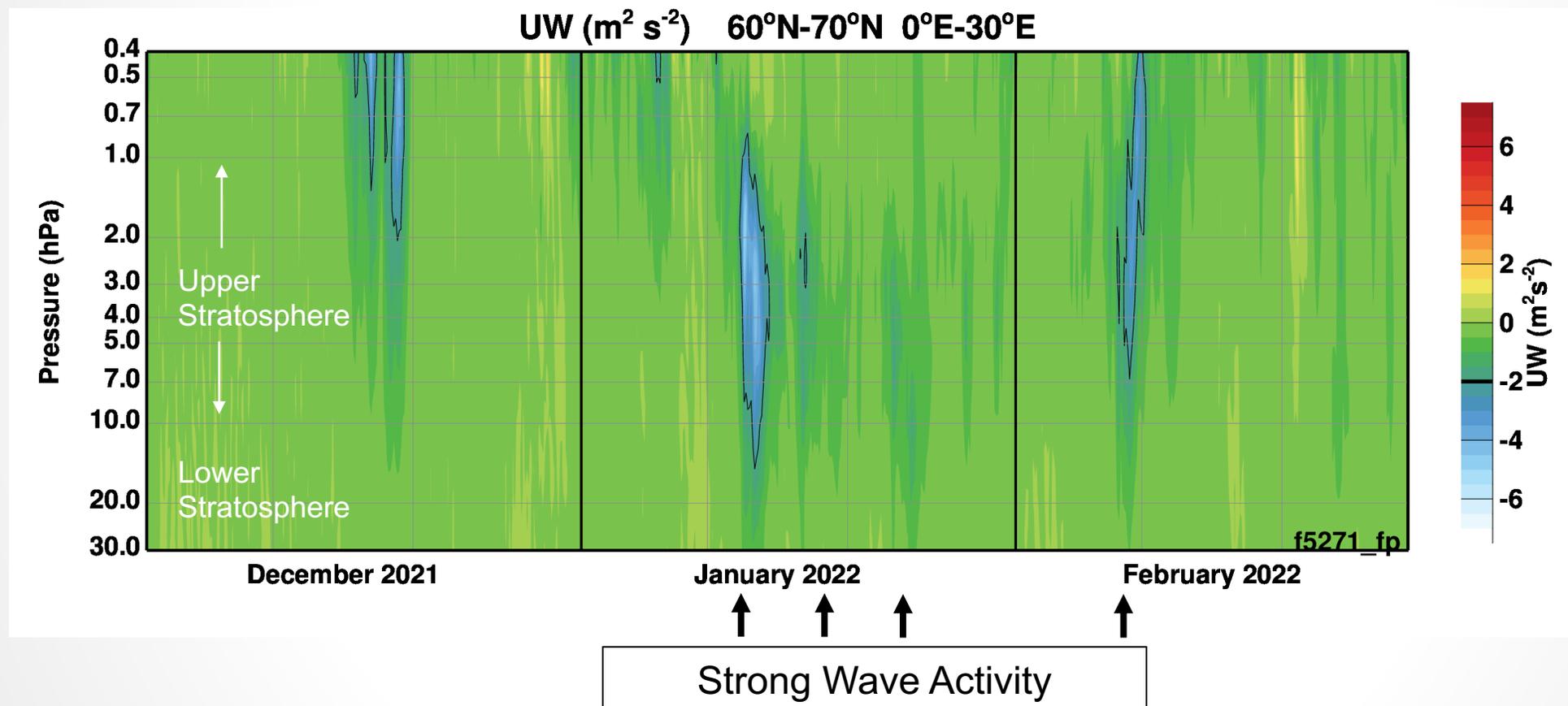
} Upper Stratosphere

These breaking gravity waves created unstable flow around the vortex that led to well defined high EPV eddies



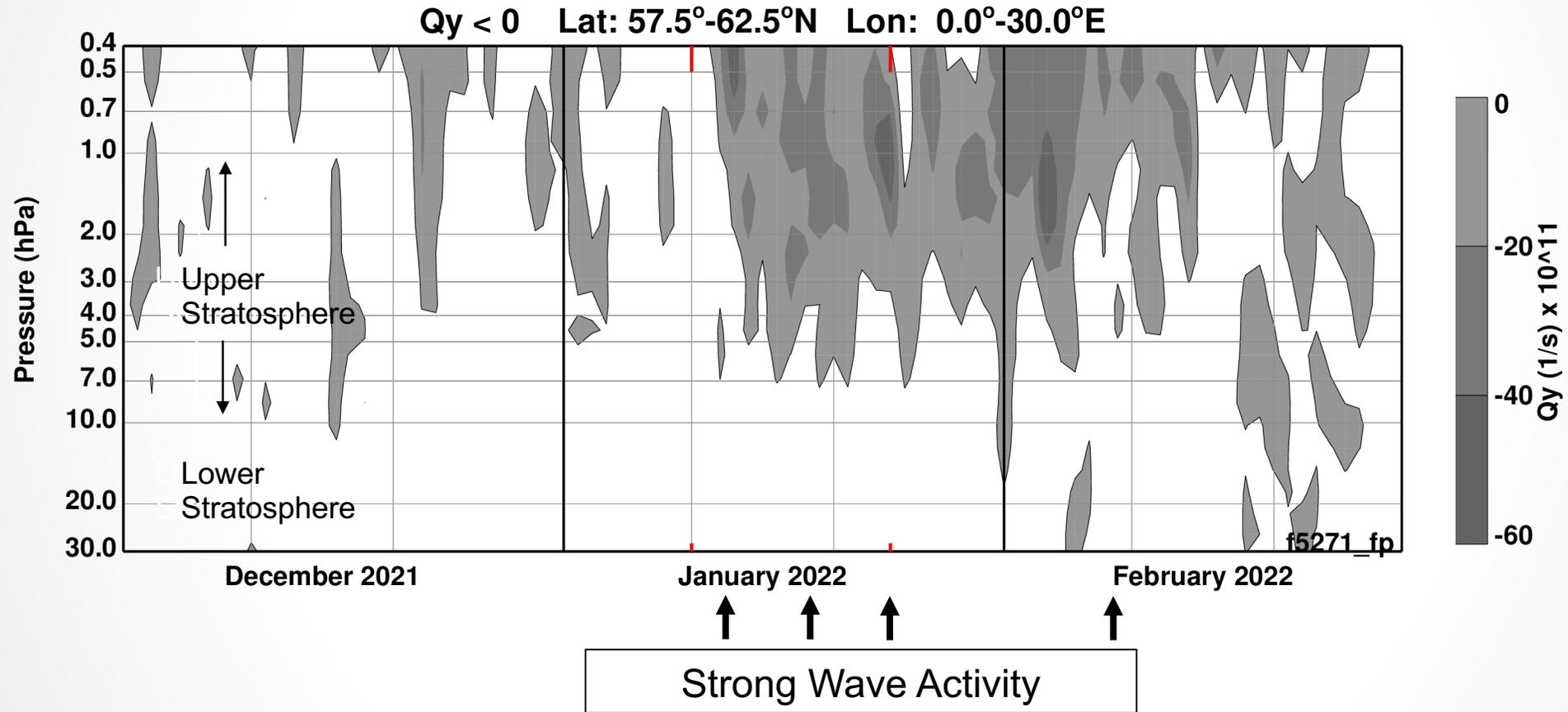
January 2022

Strong gravity wave momentum fluxes appeared in January 2022 over the wave breaking region

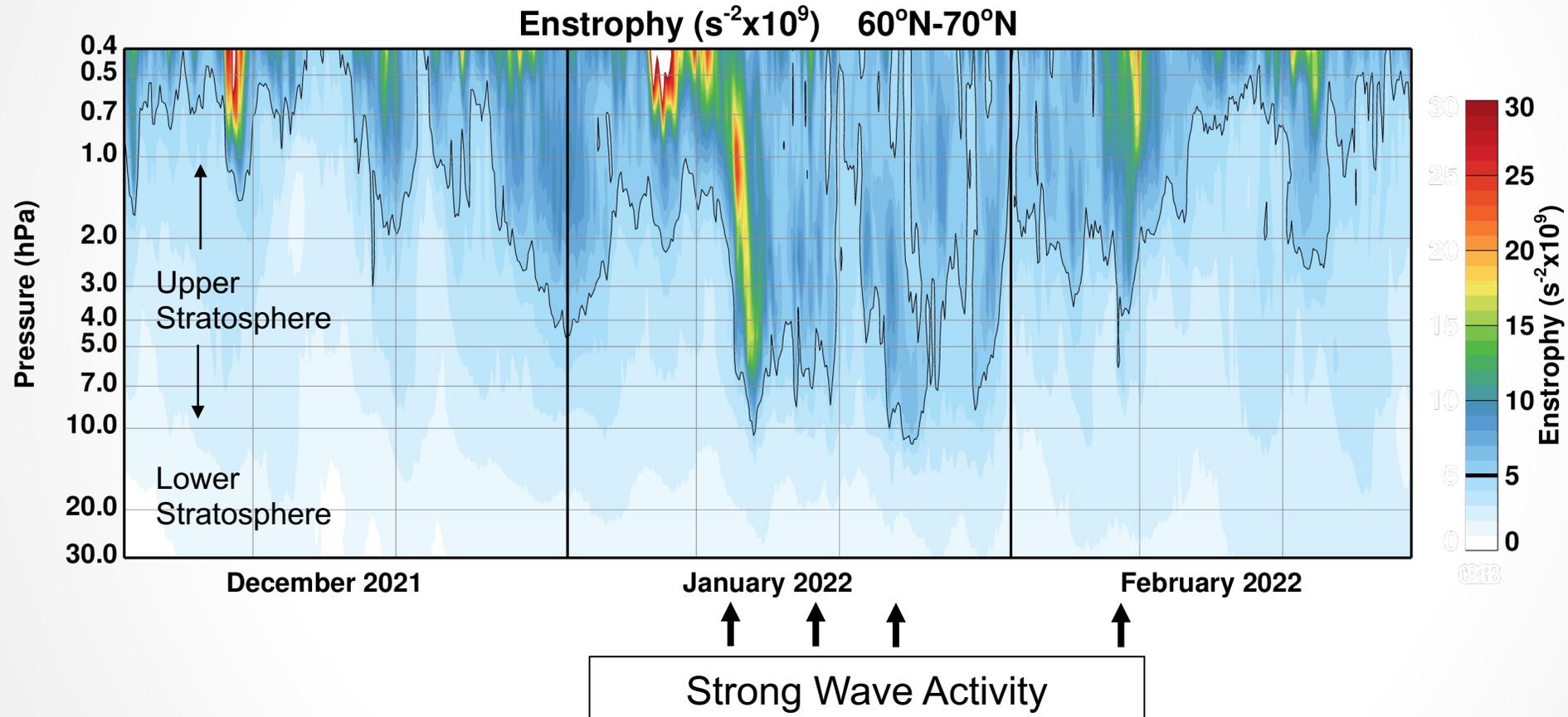




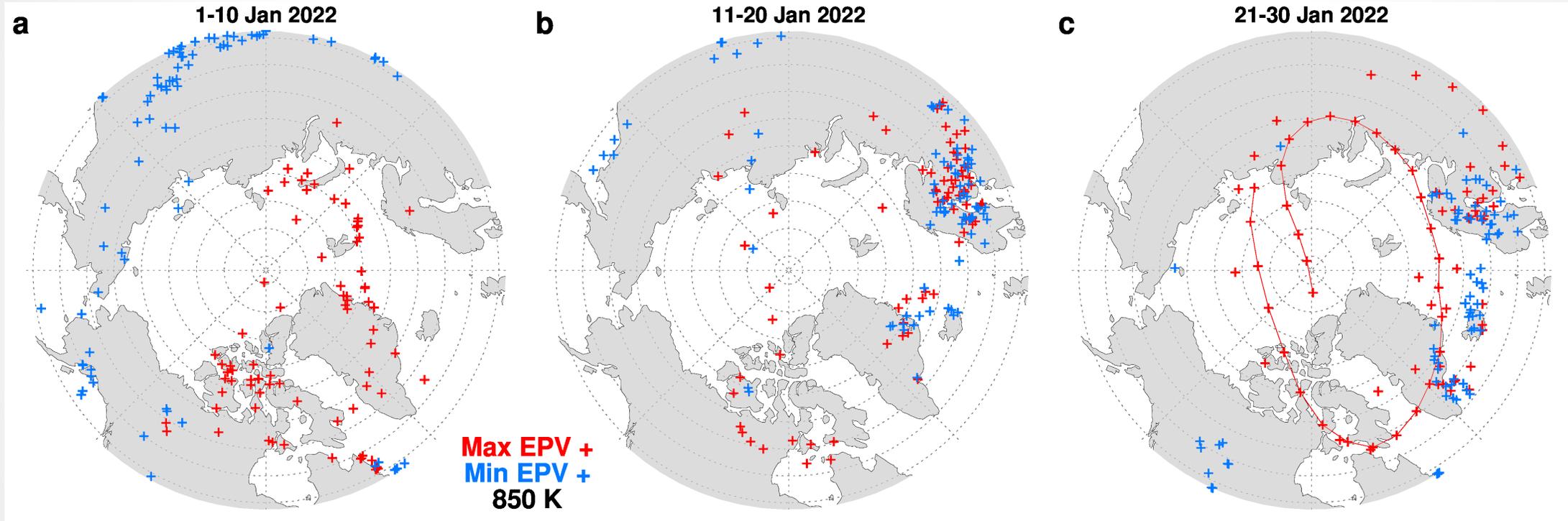
This gravity wave activity developed a persistent region conducive to jet instability (negative Q_y)



The breaking gravity waves and subsequent eddies increased the enstrophy (square of the vorticity) in the polar region



The character of the EPV field changed in response to the breaking gravity waves



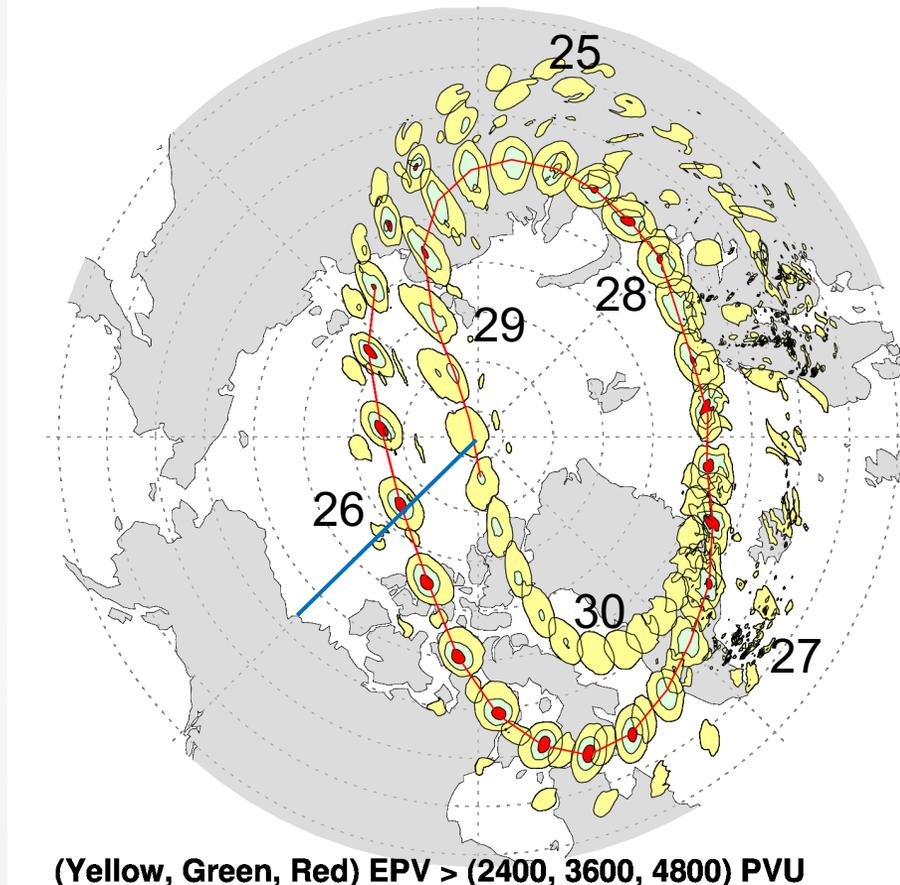
Little GW Activity
Highs near pole
Lows south

Strong GW Activity
Highs and Lows near
Orography

Still Strong GW Activity
Strong Eddy Tracked

High EPV eddy, originating in the breaking gravity wave region, is tracked twice around the vortex

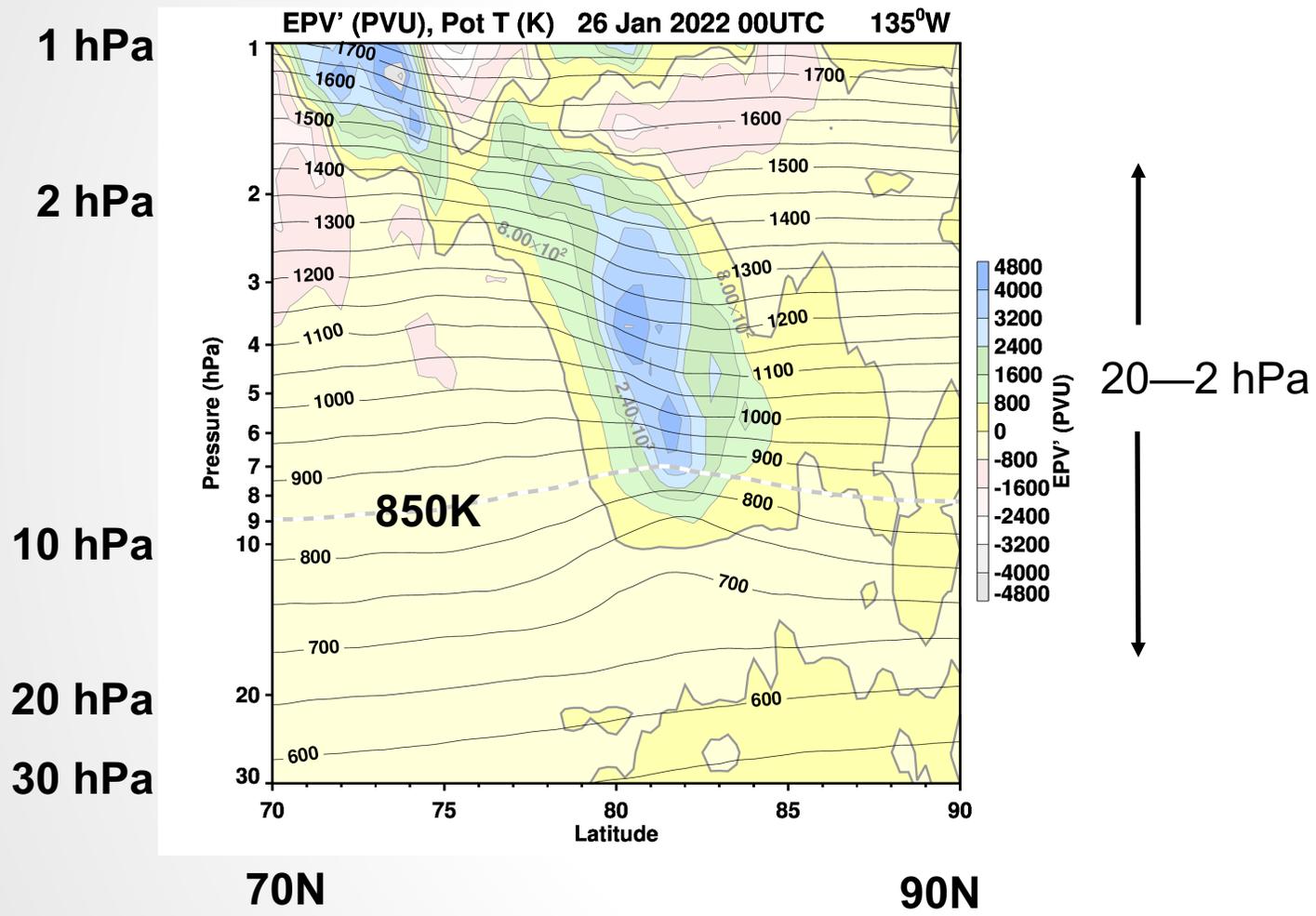
EPV 850K 24-31 Jan 2022



EPV plotted every three hours

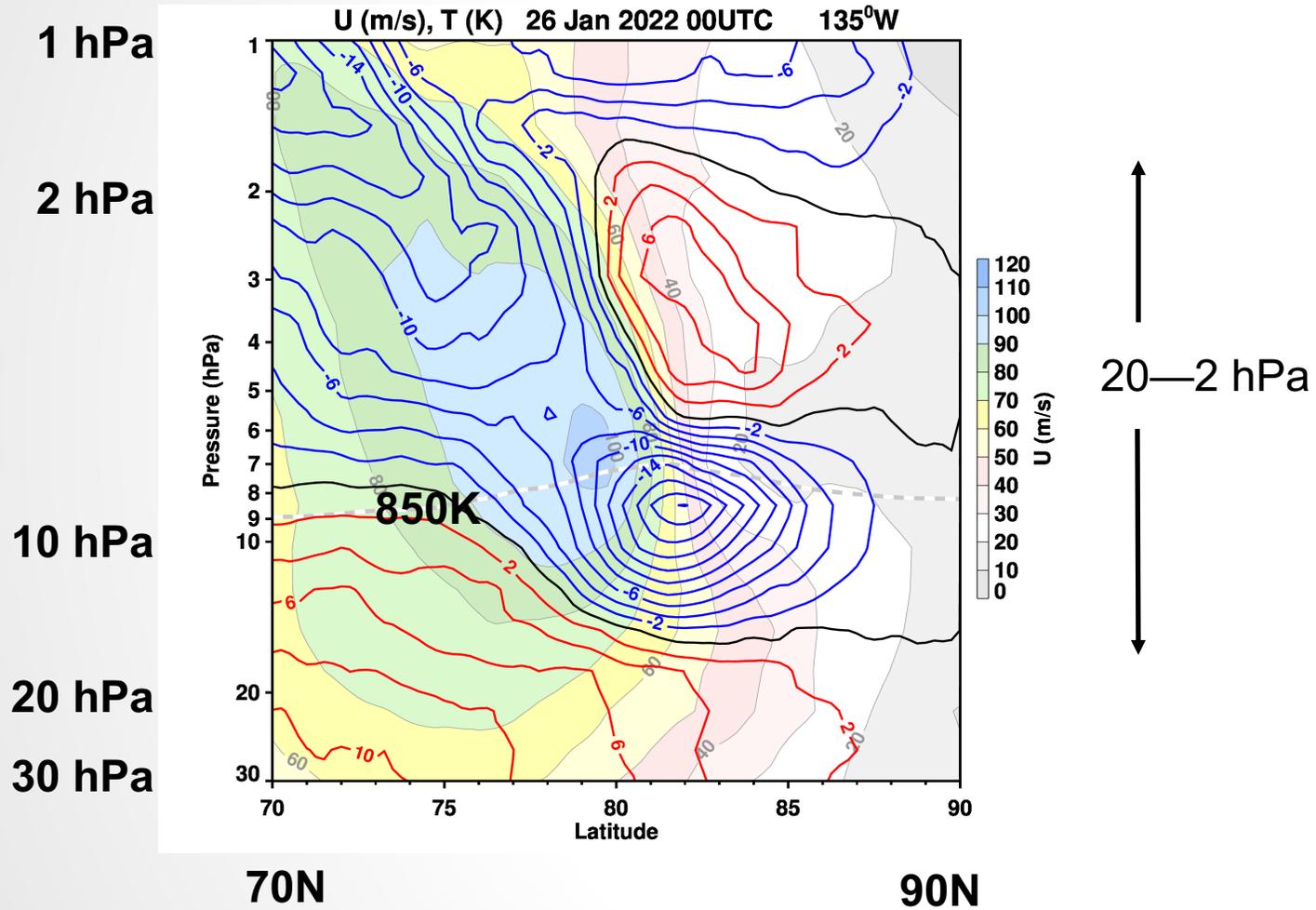


Eddy structure extends from about 20 to 2 hPa



EPV deviation from the zonal mean
Potential temperature cross section

The zonal wind gradient is strong at the center of the PV eddy.

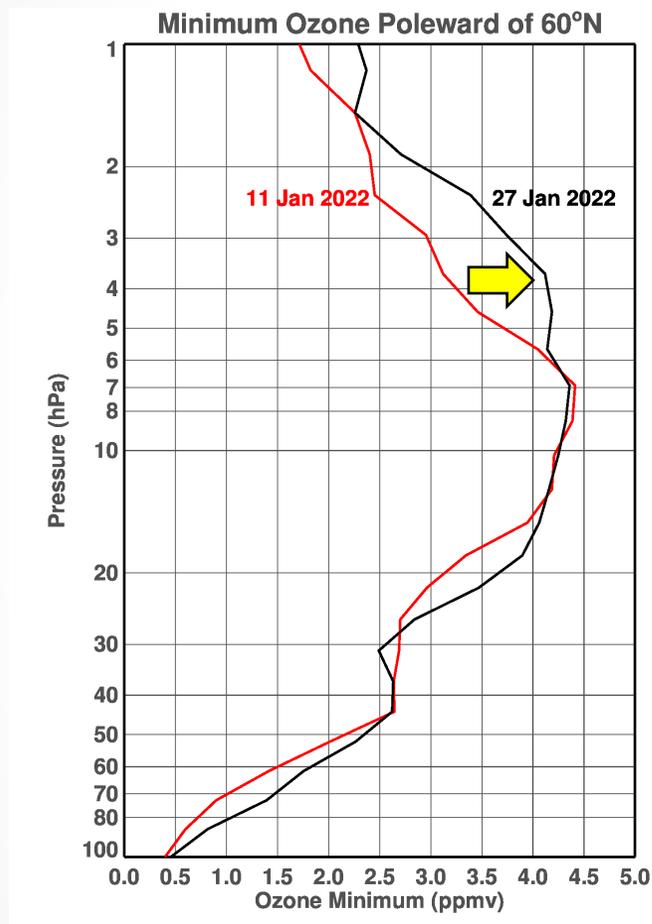


Zonal wind deviation from the zonal mean

Temperature deviation from zonal mean

20—2 hPa

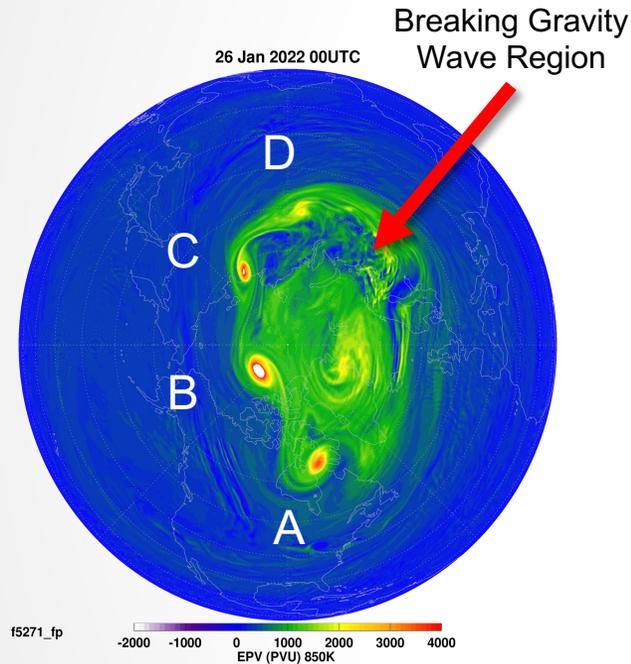
Mixing may have increased polar ozone in the upper stratosphere



11 to 27 January 2022

Minimum Value of Ozone Increases in
the NH Polar Region

In summary, breaking gravity waves can significantly disturb the polar vortex in the upper stratosphere



Gravity Waves breaking in the middle stratosphere (~10 hPa) can disturb the polar vortex edge, creating high and low EPV values.



If widespread the GW breaking can create significant **EPV disturbances** along the vortex edge.



If **unstable**, the perturbed EPV can lead to the formation of **small vortices** along the edge of the polar vortex.



These vortices can potentially lead to **increased mixing** of trace gases into the polar vortex.