Observation of a tongue pulled out from the Antarctic vortex edge due to barotropic instability

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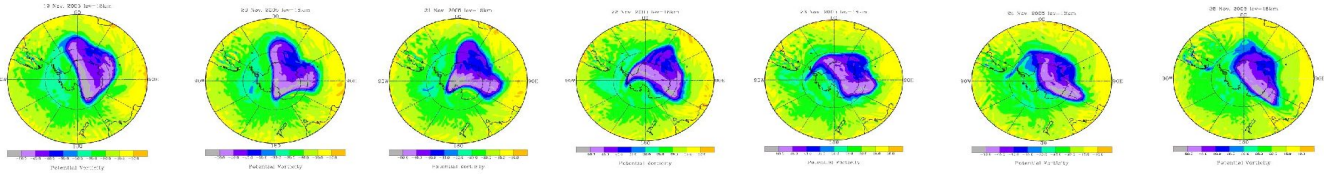
During the VORCORE campaign, 27 superpressure balloons were launched in the southern polar vortex at altitudes of 16-19 km. On November 25, one balloon was advected out of the vortex through a tongue expelled from the edge. Using the ECMWF analysis the evolution of the tongue is studied. It is shown that few days before, the necessary conditions for barotropic instability exist. The role of the barotropic instability in the formation of the tongue is supported by using a two dimensional barotropic model. The model show that a circumpolar vortex perturbed by a localized cyclonic anomaly at its edge, develops a tongue in a region where the necessary conditions for barotropic instability are satisfied.

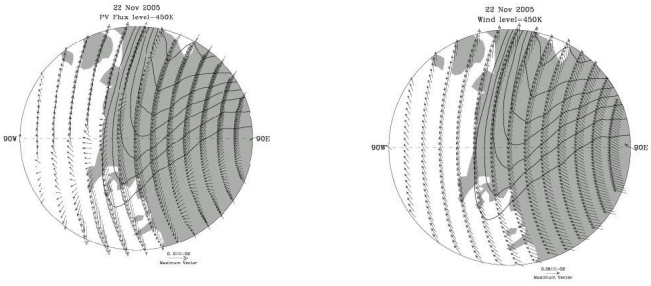
Sequence of the vortex structure at 18 km altitude from 19 to 25 November 2005, obtained from ECMWF analysis



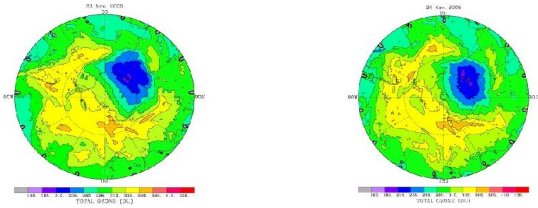
A point which deserve some attention is the flux of potential vorticity on isentropic surfaces, because it can give at a given time the tendency of the deformation of the vortex edge. The Bernoulli function

$$B = c_p T + gz + \left(u^2 + v^2\right)/2$$

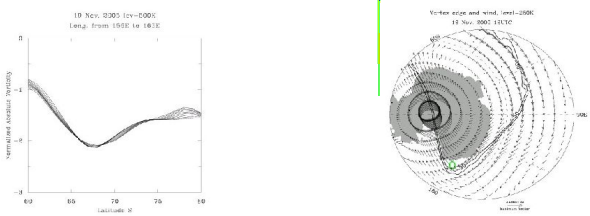
Is the streamfunction of the total flux of potential vorticity on isentropic surfaces, from which we can calculate the flux.



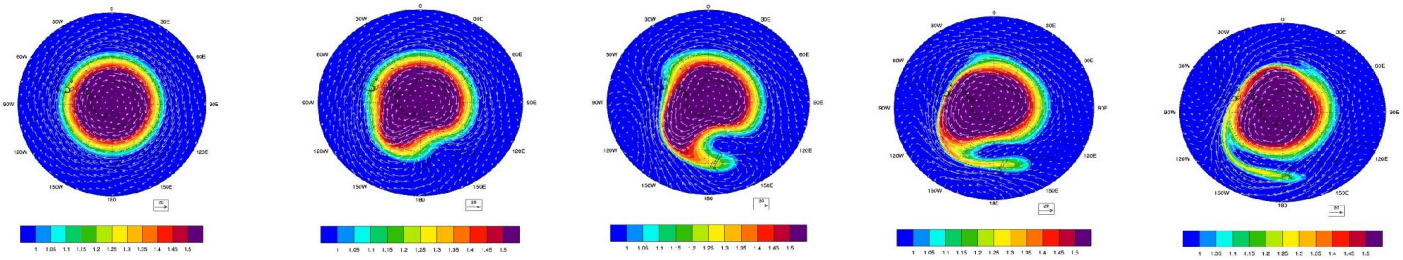
Incidentally we can see from the Total Ozone Mapping Spectrometer that the tongue leads to irreversible mixing of ozone poor air in the surf zone If we take into account that TOMS gives the total columnar ozone, the comparison with the vortex structure looks very good



The necesary conditions for barotropic instability is that the gradient of the absolute vorticity of the mean current must vanishsomewhere in a given region, that is d/dy(f -du/dy) = 0 somewhere. This quantity is merely the latitudinal gradient of the basic state absolute vorticity



The model is based on the non-divergent barotropic vorticity equation in the form , $dQ/dt = \nu\nabla^6\left(Q - Q_0\right)$ where $Q = \Delta\Psi + f + F$,is the PV, Ψ is the stream function and ν is a hyper-diffusion introduced for model stability.



CONCLUSION. The evolution of the vortex edge which start on day 19 with a cyclonic anomaly and the necessary condition for barotropic instability, heighly suggest that this instability is the cause of the tongue formation. Furthermore the 2D model, which after introduction of a cyclonic anomaly develop a tongue, support these hypothesis.