What determines the potential vorticity in the polar stratosphere?

Universiteit Utrecht

Yvonne Hinssen and Aarnout van Delden
(y.b.l.hinssen@uu.nl)

IMAU
Institute for Marine and Atmospheric research Utrecht

The potential vorticity (PV) distribution in the lower stratosphere is of importance for the circulation in the troposphere. A change in the lower stratospheric PV over the pole can lead to a change in surface winds at midlatitudes. Therefore, we would like to know how the PV distribution in the stratosphere is formed and how a change in atmospheric composition affects the PV distribution.

The PV distribution is affected by processes related to, for example, radiation, friction, mixing (wave-breaking) and latent heat release. The focus of this study is on radiation processes. The seasonal cycle of the PV distribution over the poles is examined for the ECMWF ERA-40 dataset for the years 1979-2001. This is compared to model results of the PV.

The model used is a primitive equations model, in 2D, with σ-coordinates, 200 layers and 3 degree latitude bands. Further it includes a radiation scheme:
Shortwave radiation: Divided into 2 channels. One channel (1%) corresponds to the Harley band (200-300 nm) and is absorbed in the stratosphere. The rest reaches the Earth's surface unattenuated. Earth's albedo = 0.3
Longwave radiation: Homogeneously distributed greenhouse gases absorb a certain fraction ε of the thermal radiation emitted by the Earth's surface, and their emittance is also proportional to ε.

(For more details about the radiation scheme see poster 00134 by Van Delden.)

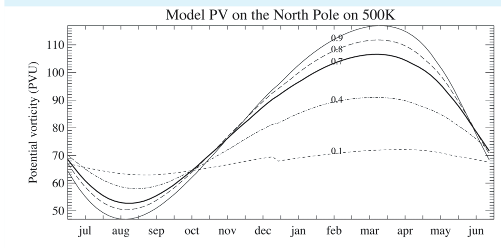

Figure 2: PV on the North Pole on 500K throughout the year for different greenhouse gas concentrations as indicated by the values of ε.

What is the influence of varying the longwave emissivity?

Increasing the amount of greenhouse gases (increasing ε), increases the amplitude of the seasonal cycle in PV on 500K (fig. 2). On the pole the PV evolution in time is determined by the diabatic advection term (fig. 3a), the stretching term (fig. 3b) and friction. More greenhouse gases will emit more radiation to space in winter, leading to a cooling of the lower stratosphere and more diabatic advection. In summer more greenhouse gases will absorb more radiation, and the opposite occurs.

For very small greenhouse gas concentrations (ε=0.1), there is hardly a seasonal cycle, since there is very little absorption of thermal radiation, and also the emittance of radiation to space is not efficient.

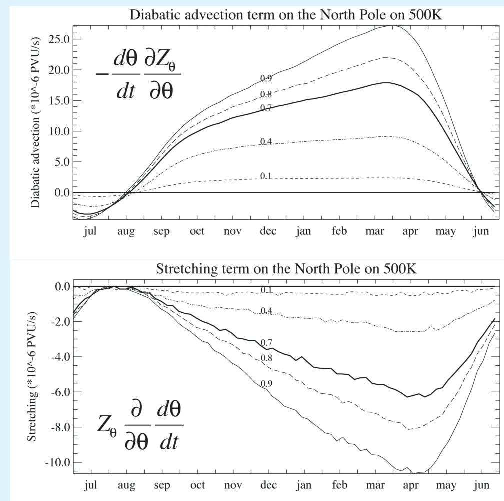

Figure 3: Terms that determine the evolution of PV at the pole: diabatic advection term (top) and stretching term (bottom) on the North Pole on 500K throughout the year, for different values of ε.

How well does the model reproduce the seasonal cycle of the PV in the lower stratosphere?

- vortex formation is simulated better than vortex breakdown (fig. 1)
- in winter the SH modeled PV is close to the mean ERA40 PV
- NH modeled PV is higher than mean ERA40 PV → mixing of PV by breaking waves is important
- problem: modeled PV in spring and summer

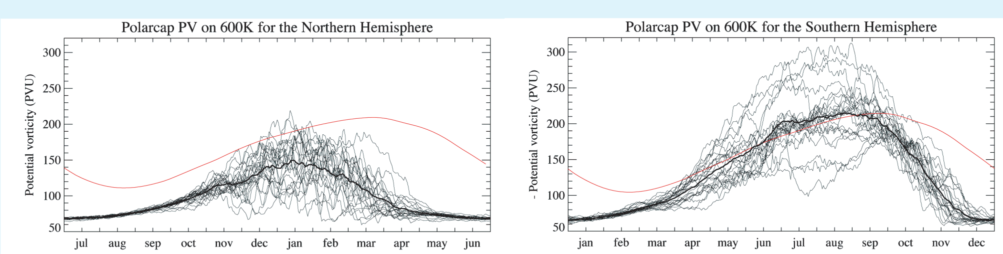

Figure 1: Polarcap PV (area weighted average PV poleward of 70 degrees, 1 PVU = 10^{-6} K m^2 kg^{-1} s^{-1}) throughout the year on 600K for the ERA40 data (thin lines: individual years, thick line: mean) and for the model (red line), for the Northern Hemisphere (left, ERA40 data from 1 jul 1979 - 30 jun 2002) and the Southern Hemisphere (right, ERA40 data from 1 jan 1979 - 31 dec 2001).

Conclusions

- Our simplified 2D model reproduces the PV in winter quite well, but gives too high values in summer.
- With increasing greenhouse gas concentrations the lower stratospheric PV over the pole increases in winter and decreases in summer in the model.
- This is related to the diabatic heating caused by absorption and emission of radiation.

Future research:

- Try to improve the PV over the summer pole.
- Look at the diabatic heating and its effect on PV in more detail.
- Examine the effect of the hydrological cycle on the PV in the lower stratosphere.