

***Interactive comment on “Abiotic and biogeochemical signals derived from the seasonal cycles of tropospheric nitrous oxide” by C. D. Nevison et al.***

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Received and published: 14 December 2010

Nevison et al. apply correlations of detrended N<sub>2</sub>O seasonal minima and polar winter lower stratosphere temperatures to argue that there is a stratospheric influence in the surface seasonal cycle. They may be correct with their analysis and their conclusion that there is a stratospheric influence on the seasonal cycle, however their argumentation that there is a downward transport of N<sub>2</sub>O-depleted stratospheric air causing the minima in the seasonal cycle is not correct.

Nevison et al. do not take into account the complexity of atmospheric transport,

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especially of stratosphere-troposphere exchange. Diabatic descent is strong in the polar winter hemisphere and indeed transports air with low  $\text{N}_2\text{O}$  to the lower stratosphere. However, the tropopause acts as transport barrier and thus trace gases such as  $\text{N}_2\text{O}$  cannot easily be transported down from the lower stratosphere to the troposphere. Further, air from the stratosphere is not just transported down. On its way downwards it undergoes transformation in form of e.g. mixing (e.g. Appenzeller and Davies, 1992; Cristofanelli et al., 2006). The stratospheric air will quickly mix with tropospheric air and thus lose its stratospheric signal (here e.g.  $\text{N}_2\text{O}$  depleted air). Thus, mixing between tropospheric and stratospheric air will smooth out the gradient in mixing ratio between these air masses.

It has up to now not been possible to evidence an influence of the stratosphere on the lower tropospheric seasonal cycle of  $\text{O}_3$  which has compared to  $\text{N}_2\text{O}$  a major source from the stratosphere (Monks 2000; Liang et al. 2009). The study by Liang et al. (2009) e.g. shows that  $\text{O}_3$  shows a spring maximum throughout the Arctic troposphere and that this maximum is associated with different processes at different altitudes. The spring peak in the upper troposphere is due to stratosphere-troposphere exchange, while the peak in the middle troposphere and lower troposphere is mostly a result of in situ photochemistry. One can expect similar characteristics for  $\text{N}_2\text{O}$ . While in the upper troposphere there may be an influence due to stratosphere-troposphere exchange, in the lower troposphere other processes will affect the seasonal cycle.

### Some specific comments:

P25810, L17-26: *These minima are consistent with a stratospheric signal in which air depleted in both  $\text{N}_2\text{O}$  and CFC-12 descends from the middle and upper stratosphere during winter due to the Brewer-Dobson circulation, undergoes STE, and propagates down to the lower troposphere with a delay of about 3 months (Holton et al, 1995; Nevison et al., 2007; Liang et al. 2008, 2009). While Holton et al., 1995 describe the principal transport processes, nothing which is stated here has been shown by Nevison et al. (2007) or Liang et al. (2008,*

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2009). They solely use this explanation for stating a stratospheric influence on the seasonal cycle. Further, in neither of these studies it is stated what they understand under N<sub>2</sub>O depleted or CFC-12 depleted air. What values of N<sub>2</sub>O and CFC-12 are considered as depleted and how low are these values compared to the tropospheric air?

P25811, L2-5: *Nevison et al. (2007) run a chemical transport model without stratospheric sinks and still obtained late summer minima in N<sub>2</sub>O and CFC-12 at some northern sites, due to seasonal variations in tropospheric transport and circulation. Does that not show that one does not need N<sub>2</sub>O depleted air to get minima in the seasonal cycle? With this simulation no typical stratospheric N<sub>2</sub>O depleted values are present to cause an effect in the seasonal cycle. Thus, the seasonal cycle is maybe mainly influenced by tropospheric transport and circulation.*

P25813, L4-9: *Interannual variation in the strength of the Brewer-Dobson circulation affects the extent to which warm middle and upper stratospheric air, which is depleted in N<sub>2</sub>O and CFCs due to photolysis and oxidation, descends into lower polar stratosphere, causing temperature to covary with N<sub>2</sub>O and CFC minimum anomalies. This sentence is quite long and I would suggest to split it into two. Such a relationship I would expect maybe in the lower stratosphere, but not in the troposphere.*

P25813, L9: *The N<sub>2</sub>O and CFC minima in turn propagate into the troposphere through stratosphere-troposphere exchange. As stated above this does not happen that easily. There is no consistent flow from the stratosphere to the troposphere. One rather needs some specific exchange processes like e.g. tropopause folds or cut-off lows (Holton et al., 1995). These exchange processes occur with a certain frequency of e.g. 20-40 per year on certain locations where the polar or subtropical jet is found (e.g. Cristofanelli et al., 2006). Further, as stated above air of stratospheric character will then quickly lose its stratospheric signal while transported further down in the troposphere (e.g.; Appenzeller and Davies, 1992; Cristofanelli et al., 2006).*

P25813, L10-16: *We interpret correlations between polar winter lower stratospheric temperature and detrended tropospheric N<sub>2</sub>O and CFC seasonal minima as evidence of a stratospheric influence on the tropospheric seasonal cycle. However, we cannot rule out the possibility that these correlations might arise if tropospheric N<sub>2</sub>O and CFC variability is driven by weather anomalies, e.g. convection over continents, that in turn correlate with stratospheric temperatures. For me the possibility that these minima are caused by weather anomalies sounds much more reasonable. Why do you not believe in this possibility and perform further tests on this one? Your major conclusion that there is a stratospheric influence on the seasonal cycle would still hold with this explanation.*

P25817, L22-23: *Since STE of N<sub>2</sub>O depleted air takes place mainly at midlatitudes (Ishijima et al., 2010), the South Pole site is more poorly situated than the other sites to detect the stratospheric signal. That STE occurs mainly in midlatitudes is well known (e.g. Holton et al., 1995), however, Ishijima et al. (2010) have definitely not shown this relationship in their study. Furthermore, one should consider here, that no descent is found at midlatitudes and that thus the gradient of N<sub>2</sub>O across the tropopause is much lower than at the pole (e.g. see N<sub>2</sub>O Profiles for midlatitudes and tropics in Engel et al., 2006 and Warneck, 1988). Thus, there is no strongly, but only slightly N<sub>2</sub>O depleted air that can be transported from the stratosphere to the troposphere in the midlatitudes.*

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