Atmos. Chem. Phys. Discuss., 3, S1322–S1327, 2003
www.atmos-chem-phys.org/acpd/3/S1322/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The North Atlantic Oscillation controls air pollution transport to the Arctic" *by* S. Eckhardt et al.

Anonymous Referee #2

Received and published: 18 August 2003

"The North Atlantic Oscillation controls air pollution transport to the Arctic"

By S. Eckhardt et al.

The authors are addressing an important aspect of the atmospheric pollution in the Northern Hemisphere. They argue convincingly - based on model experiments - that the atmosphere is more effective in transporting pollution into the Arctic region when the large scale flow pattern can be categorized as being in the positive phase of the North Atlantic Oscillation, here referred to as NAO+.

There are not enough observations to yield a numerical analysis of the spatial distribution of pollutants in the Arctic area. Therefore a numerical, atmospheric model is the appropriate mean. Model results are compared to a few existing observed data sets. The authors make use of data from satellite measurements and a few surface stations.

Although both North American and European pollution sources contribute to the pollution of the Arctic atmosphere the European emission is shown to be the most important, mostly because the emitted pollution is being picked up by a dominating westerly flow - especially strong when the atmosphere is in NAO+-status - and via the downstream large scale wave formation is brought to higher latitudes on time scales shorter or the same as the life time of the pollutants. And of course also because the European sources are strong.

All in all, a nice solid work adding to a consistent picture of atmospheric variability and related effects that is now evolving in relation to the NAO. Many different aspects are supporting each other and as the authors are saying the results of this study is maybe not so surprising taking into account what is already known -and what can be inferred via a classical meteorological analysis of weather situations. However, their basic scientific idea is clear and the paper is providing the quantitative documentation for the situation.

In their discussion the authors make an attempt to relate their findings to the observed trends in surface temperature for the Northern Hemisphere over the last decades. It is also argued qualitatively that there may exist a positive feedback between the atmosphere and its flow pattern and the air pollution transported into the high latitudes. However, there is a no quantitative documentation and the arguments seem a bit confusing. Therefore, it is suggested that the section is changed, see below.

A general comment: The paper is not always clear in defining and illustrating general concepts. It would aid the reading of the paper if some explanations and specifications are inserted. Examples:

1) NAO index values, NAO+ and NAO- months I suppose that the authors refer to Dec.-February as winter months. I also understand that this gives 3*15 = 45 months that are considered more or less as being independent. I would welcome a list of these values. The selected 20 % NAO+/NAO- winter months should also be shown.

ACPD

3, S1322–S1327, 2003

Interactive Comment

Are there substantial fluctuations among the months in these ensembles? Or do they behave in the same manner?

2) The concept "slope" Again as mentioned by the other referee it could improve the paper if more details about the mathematics behind it was provided. It is used in line 16, page 3227, without any introduction. Table 1 helps the reader in clarifying the situation somewhat, but more explanation would be welcome.

Here follows a more detailed discussion of specific points:

Page 3224 Line 5: Sulfate and cadmium are substances in contrast to scattering which is a property of aerosols. The sentence should be rephrased.

Line 9: It is said : "..., the most prominent and recurrent pattern of atmospheric variability is the North Atlantic oscillation (NAO)". This is in a way true, but it really depends on the time scales studied. The high frequency atmospheric variability associated with the travelling extratropical lows is prominent and recurrent too. The aggregated effect of this variability constitutes the findings of this paper on a larger time scale.

Line 21: I agree with the other referee's comments about the word "signal".

Line 26: It is suggested that the word "climatology" is replaced by "pollution climatology" to make it consistent with the next sentence and distinct from the climatology of the ECMWF 15 year meteorological data set.

Page 3225 Lines 12 to line 11, page 3226: The approach used in this study is rather complex with several concepts involved: travel time, life time, a binning of tagged plume values into 12 age classes, application of monthly averages and composites. I have no simple solution of how to present all this in a easy-to-capture way, but I find figures 2 and 3 both appropriate to substantiate the discussion.

Page 3226 Line 7: As mentioned above data on the NAO would be relevant here.

Page 3227 Line 13: I am sorry, but again I agree with the other referee. It is not easy

ACPD

3, S1322–S1327, 2003

Interactive Comment

to read from figure 4 that the NAO dependence decreases with the e-folding lifetime. And what is the physics behind this property of the flow?

Line 22: Figures 4 and 5d show much less contribution from Asian sources to the pollution at high latitudes. But it does show the same bi-polar pattern over South-East Asia as observed in both the European and North American cases. I wonder if this feature has a specific physical explanation also in Asian case or if it can be attributed to the regression analysis solely?

Page 3228 Line 4: Again, it is suggested that the NAO-values of these particular years are presented in the paper. As also pointed out by the authors these years are not overlapping with the simulated 15-year period. There are only 7 winters (1996 - 2002) available for this verification. Does that mean that only 3-4 months can be categorized as NAO+/NAO-?

Line 9: It is not clear what is meant by ... NAO+ and NAO- conditions revealed no correspondence to the identified spatial structures ... Surely, the tropopause height in the European region must depend on the NAO phase. So with this not being the point what is the point then?

Page 3229 Line 1: The word "however" seems not to be the appropriate word in this context.

Line 3: I suppose you mean: the analysis shows that NAO explains about ...

Line 4 to 10: This section is a nice demonstration of the good correspondence between model results and simple meteorological reasoning.

Line 11 to 14: There are also for the used time period rather few winter cases available for the analysis. How can one get such highly significant correlations in this case?

Line 13: Reference to "Figs. 1-4" must be Figs. 2-4?

Line 21: It is true that NAO explains an European-Atlantic phenomenon and therefore

ACPD

3, S1322–S1327, 2003

one would expect it to capture the effects of the transport of European emission better, but in your case you are looking for a more hemispheric phenomenon (although the result is that Europe is dominating). One should think AO then was more appropriate. At least, AO was constructed in order to describe the pressure distribution on a hemispheric scale. How much better were the results using NAO compared to AO?

Page 3230 Line 3: ... correlation with the NAO index was strongest ... Which correlations are referred to here?

Lines 10 to 18: This paragraph puts forward the hypothesis that there is a physical relationship between the surface temperature at high latitudes and the pollution transported into the region. More pollution should lead to an enhanced warming of the surface. However, I have some doubt about the arguments.

Although it is true that certain aerosols over white surfaces lead to a net heating of the surface/lower atmospheric layers through absorption its role in the discussion is not at all clear. It is said that anthropogenic aerosols reduce cloud droplet sizes which globally leads to a negative radiative forcing due to an increase in cloud reflectivity, but under Arctic conditions the aerosols warm the surface by downward longwave emission.

In this sentence a secondary property of aerosols in the climate system is confronted with a primary property of an aerosol layer. This is a bit confusing and it is also not clear how a general property of aerosols can lead to the large scale wave-like temperature change pattern that is observed at high latitudes (warming is strongest over central parts of the Northen Hemisphere continents).

It is an interesting idea, but I suggest a rewriting of the whole paragraph. I would also like to see some data demonstrating how the cooling in the Arctic takes place in these years.

Lines 22 to 25: It is also an interesting idea that there could be a feedback mechanism between the transport of pollutants to the Arctic region modulated by the NAO and the

ACPD

3, S1322–S1327, 2003

Interactive Comment

flow pattern itself. However, it seems a bit speculative and needs much more research before any firm statement can be put forward.

Line 23: What is meant by ...short-lived greenhouse gases?

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 3223, 2003.