Trajectory analysis on Bear Island (Bjørnøya) from 1998- 2005

Background

In a report from Norwegian Polar Institute and Norwegian Institute for Nature Research (Verrault et al., 2006) the changes in organic chlorine contaminants in glaucous gulls from Svalbard during the last 10 years are presented. Monitoring of persistent organic pollutants (POPs), particularly the organochlorine (OC) compounds, in glaucous gulls (*Larus hyperboreus*) has been given high priority in Svalbard. Special attention on the glaucous gull is the consequence of its widespread distribution and key role as top predator-scavenger in the Svalbard marine food web. Thus far among circumpolar seabird species and populations, Svalbard glaucous gulls are reported to accumulate some of the highest concentrations of OCs.

Surveys of OCs in blood of adult (i.e., > 5 years of age) glaucous gulls were carried out between 1995 and 2004, with the exception of 1999 and 2003. During this approximately ten-year period, 468 individuals (221 males and 247 females) were sampled from May through July in major breeding colonies in Svalbard (Ny-Ålesund and Bjørnøya). The main contaminants from Bjørnøya are plotted in figure 1 to figure 4.

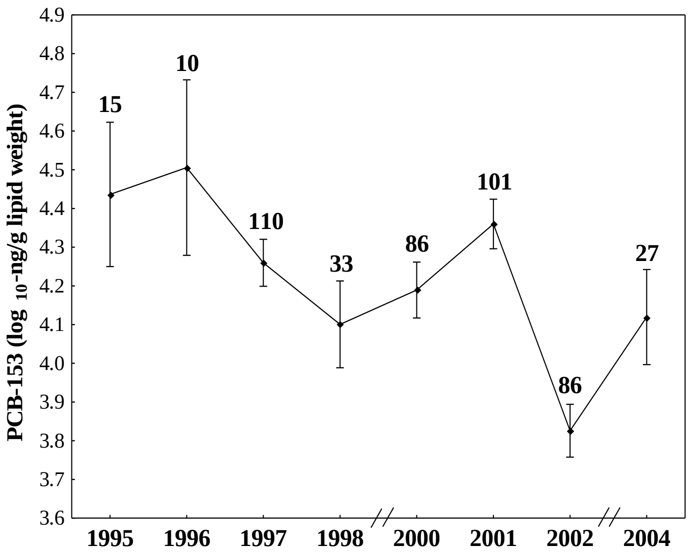

Fig. 1: Temporal trend (1995-2004) of PCB-153 concentrations (ng/g lipid weight concentrations transformed using $\log_{10}$) in blood of glaucous gulls from Svalbard. The PCB-153 concentration means are shown with ±95% confidence intervals as vertical bars, and are adjusted statistically for the effect of sex and catch day (i.e., the number of days elapsed after May 1st). The sample size for each year is indicated above the means.

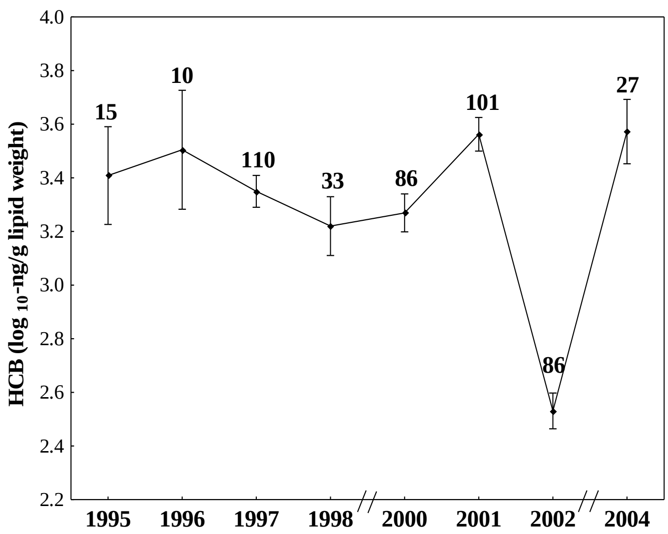

Fig. 2: Temporal trend (1995-2004) of HCB concentrations (ng/g lipid weight concentrations transformed using $\log_{10}$) in blood of glaucous gulls from Svalbard. The HCB concentration means are shown with ±95% confidence intervals as vertical bars, and are adjusted statistically for the effect of sex and catch day (i.e., the number of days elapsed after May 1st). The sample size for each year is indicated above the means.

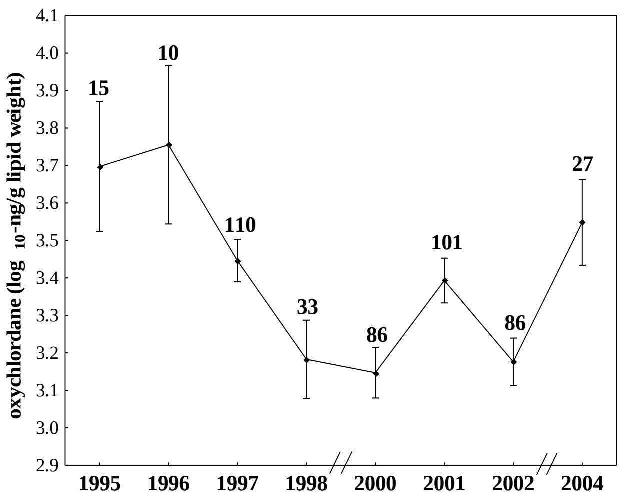

Fig. 3: Temporal trend (1995-2004) of oxychlordane concentrations (ng/g lipid weight concentrations transformed using $\log_{10}$) in blood of glaucous gulls from Svalbard. The oxychlordane concentration means are shown with ±95% confidence intervals as vertical bars, and are adjusted statistically for the effect of sex and catch day (i.e., the number of days elapsed after May 1st). The sample size for each year is indicated above the means.

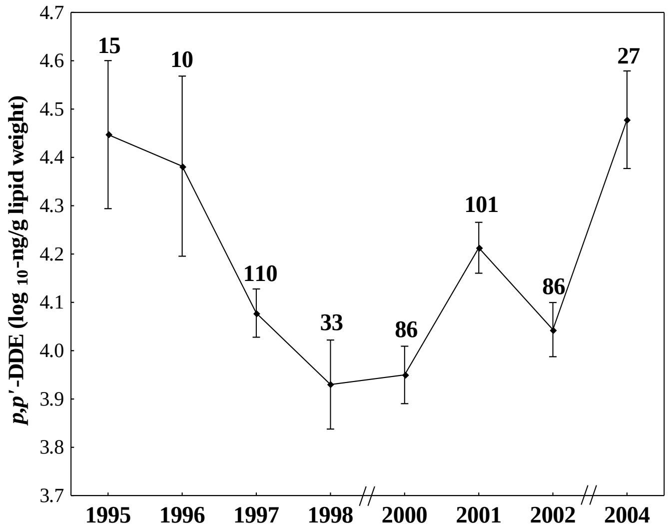

Fig. 4: Temporal trend (1995-2004) of *p,p*'-DDE concentrations (ng/g lipid weight concentrations transformed using $\log_{10}$) in blood of glaucous gulls from Svalbard. The *p,p*'-DDE concentration means are shown with ±95% confidence intervals as vertical bars, and are adjusted statistically for the effect of sex and catch day (i.e., the number of days elapsed after May 1st). The sample size for each year is indicated above the means.

Data from 1999 and 2003 are absent, but the years 2001 and 2002 are conspicuous. For all the contaminants, the values in 2001 are higher than 2000 and 2002, and the values in 2002 are lower than in 2001 and 2004. The concentrations of the PCB-153 and HCB are exceptionally low in 2002 compared to the other years. The main sources of these contaminants are found over land, near populated areas (anthropogenic). This gave the idea to look closer to the air transport to Bjørnøya during these years.

Method

A short climatology for Bjørnøya was done for the years 1998-2005. Air mass trajectories are calculated using the FLEXTRA trajectory model (Stohl et. al., 1995; Stohl and Seibert, 1998) and using meteorological data provided from ECMWF (European Centre for Medium Range Weather Forcasts). The meteorological data used are analyses with a spatial resolution of 1.25 degree and a temporal resolution of 6 hours. Trajectories arriving at height level 1500 m and twice a day (00 UTC and 12 UTC) were picked out for this study (www.nilu.no\trajectories).

The total number of trajectories for the whole period is 5782. They are classified into transport patterns through the use of cluster analysis. Cluster analysis is a variety of multivariate statistical analysis techniques designed to explore structure within a dataset and divide the dataset into groups or "clusters" of similar cases. The idea is to maximize the similarity of individual group members while keeping separate groups as distinct as possible. In this study, the Ward minimum variance technique (Romesburg, 1984) is used to find the best clustering result. The cluster procedure is applied to all trajectories arriving at 1500 m at Bjørnøya for the whole 8-year period to investigate year-to-year and month-to-month variability. A cluster group of 5 patterns are shown in figure 5 as cluster 1 to 5, representing 5 different areas from where the trajectories arrive. Different coloured stars are used to denote the starting point of the trajectory (7 days before arrival) and the path is a black dotted line. Cluster 1 (purple) is trajectories arriving from the Atlantic Ocean (and Greenland), cluster 2 (turquoise) is trajectories arriving from Alaska/Canada, cluster 3 (green) is trajectories arriving from Siberia, cluster 4 (pink) is trajectories arriving from the Arctic Ocean and cluster 5 (blue) is trajectories arriving from North Europe.

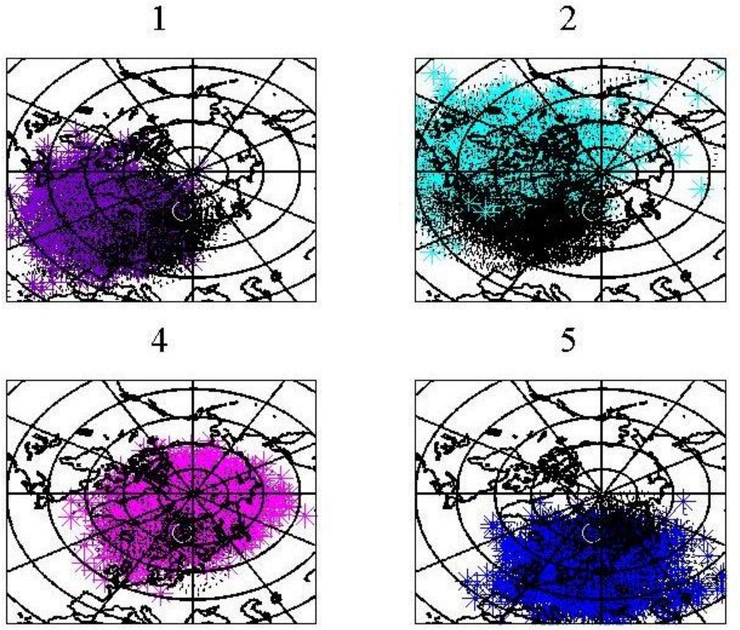

Fig. 5:Trajectories arriving at Bjørnøya, 00 UTC and 12 UTC, divided into clusters obtained from the cluster analysis. Cluster 1 (purple) the Atlantic Ocean (and Greenland), cluster 2 (turquoise) Alaska/Canada, cluster 3 (green) Siberia, cluster 4 (pink) the Arctic Ocean and cluster 5 (blue) North Europe.

Results

The distribution of the trajectories in the different clusters has a year-to-year variability and this can be seen in figure 6. In this study the focus is on the years 2001 and 2002 because these are the years that differ from the others when it comes to the concentration of contaminants in the blood of glaucous gulls. The three months before sampling are shown in figure 7. The transport pattern these months are believed to have largest influence on the concentration of contaminants on Bjørnøya. Thus this would influence the food the gulls are eating during spring before laying their eggs. Figure 8 shows the distribution of the trajectories in the different months throughout the year. In this way it is possible to see which cluster is most common during winter and which is dominant during summer.

Cluster 1 (Atlantic Ocean) is the cluster with lowest number of trajectories in the year 1998, 1999, 2000, 2001 and 2004 and has an increase in number of trajectories from 2001 to 2002 (figure 6). When looking at the three months, March, April and May, there is also a large increase of number of trajectories from 2001 to 2002 (figure 7). There seem to be a “shift” from the years before 2001 with few numbers of to the years after 2001 with high numbers of trajectories. The cluster is a typical summer cluster occurring most frequent in summertime (figure 8). The area where the air comes from is mainly over ocean and there are few anthropogenic sources here.

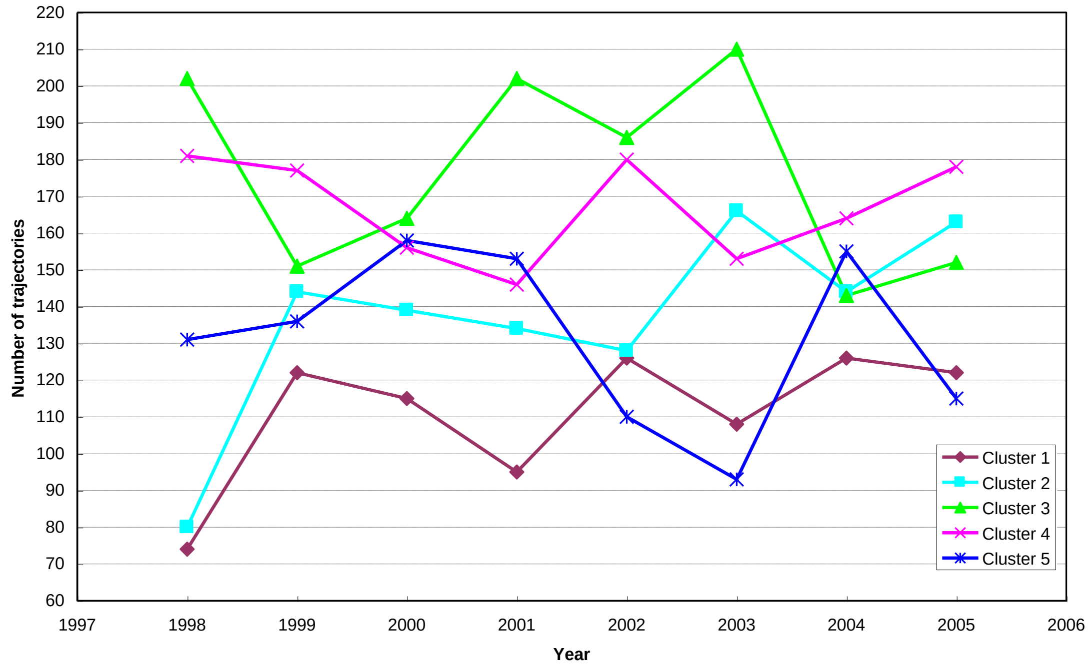

Fig. 6: Number of trajectories in each cluster for the years 1998-2005 arriving at Bjørnøya.

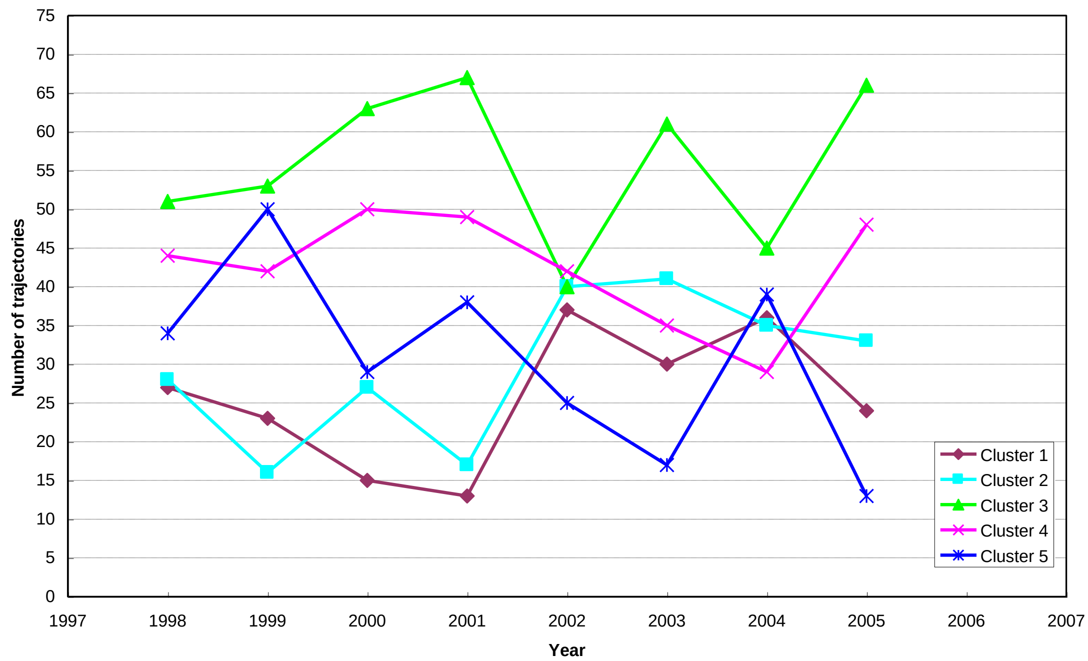

Fig. 7: Number of trajectories in each cluster for the years 1998-2005 during the months March, April and May arriving at Bjørnøya.

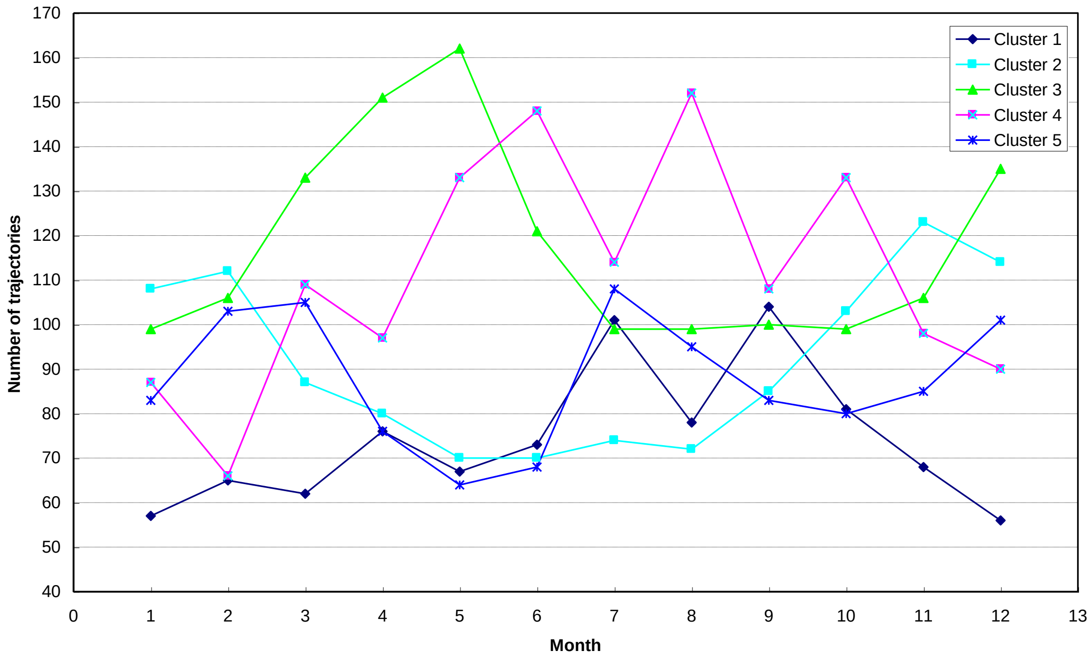

Fig. 8: Number of trajectories in each cluster for each month from 1998-2005 arriving at Bjørnøya.

Cluster 2 (Alaska/Canada) vary little from 1999 to 2002, but have lowest number of trajectories in 1998 and highest number of trajectories in 2003. But looking only at the three-month period (March, April and May) there is an increase in number of trajectories from 2001 to 2002. Like in cluster 1, there seem to be a shift in 2001 from few numbers of trajectories before 2001 and higher numbers of trajectories after 2001. This is a winter cluster, occurring most frequent in wintertime. There are some anthropogenic sources in Alaska/Canada, but they are not large on the relevant components.

Cluster 3 (Siberia) varies much from year to year, but have a highest number of trajectories in 2003. Looking at the three-month period (March, April and May) the number of trajectories increases from 1998 to 2001, but then there is a large decrease from 2001 to 2002 followed by an increase again in 2003. The cluster is a winter cluster, but occurs most frequently in spring. There are many anthropogenic sources in the area represented by the cluster, especially of the components oxychlordane (figure 3) and p,p’-DDE (figure 4).

Cluster 4 (Arctic Ocean) have a small year-to-year variability, but has an increase in number of trajectories from 2001 to 2002. In the three-month period (March, April and May) there is a small decrease from 2001 to 2002 of number of trajectories in this cluster, and the lowest number of trajectories is in 2004. This cluster is a typical summer cluster and occurs when there are few lows and weak wind conditions, resulting in short trajectories mainly inside the Arctic basin. In this area there are few anthropogenic sources.

Cluster 5 (North Europe) have an increase of number trajectories from 1998 to 2000, and then a decrease in number of trajectories from 2000 to 2003. In 2004, the number of trajectories is just about the same as the years from 1998 to 2000, but then there is a decrease in the number of trajectories again in 2005. So this cluster has a large year-to-year variability, like cluster 3, and is also a winter cluster (though it appears sometime also in the summertime). In the three-month period, the number of trajectories varies a lot, but there is a decrease from 2001 to 2003, and an increase to 2004. The area where the trajectories comes from has strong anthropogenic sources of various contaminants, especially the components PCB-153 (figure 1) and HCB (figure 2).

Not only the air mass transport (trajectories) have influence on the concentration of contaminants on Bjørnøya. Among other components is temperature and precipitation, and the mean of March, April and May for the years 2000-2005 is plotted in figure 9 (from www.met.no). The temperature is varying from year to year, with a minimum in 2001 and a maximum in 2004. The precipitation is not vary just as much, but has a minimum in 2003 and a maximum in 2000.

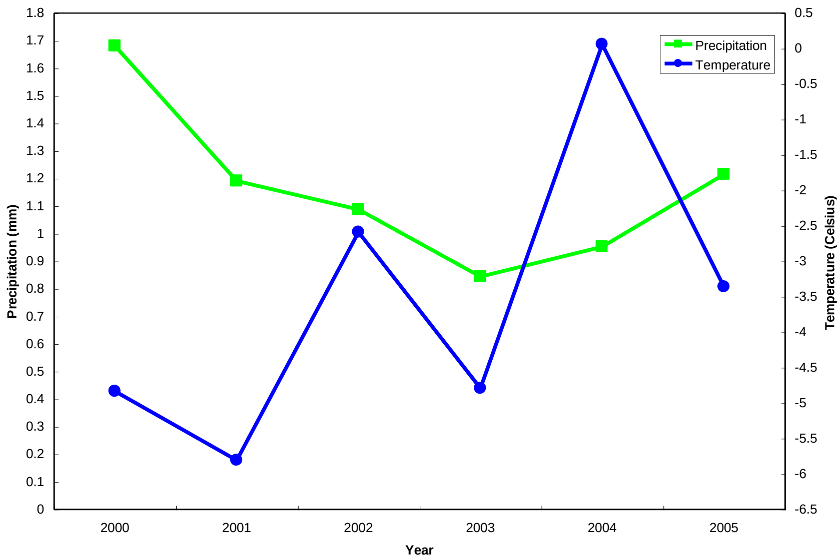

Fig. 9: Mean temperature and precipitation for March, April and May from 2000-2005 at Bjørnøya.

Conclusion

A cluster analysis was done on 7-days backtrack trajectories arriving at 00 UTC and 12 UTC on Bjørnøya from 1998 to 2005. This resulted in 5 different clusters representing 5 main areas, with the starting point and path of the trajectories. These areas are the Atlantic Ocean (cluster 1), Alaska/Canada (cluster 2), Siberia (cluster 3), Arctic Ocean (cluster 4) and North Europe (cluster 5). The distribution of the trajectories in these clusters during the three month period, March, April and May, is compared to the measured concentration of different contaminants in blood of glaucous gulls on Bjørnøya; the PCB-153, HCB, oxychlordane and the *p*,*p*'-DDE.

The main sources of these components are anthropogenic, thus the amount of trajectories within cluster 3 and cluster 5 should be of most important for the concentration. The concentration of the contaminants in glaucous gulls increases from 2000 to 2001, and the number of trajectories in cluster 3 and cluster 5 also increases from 2000 to 2001. This means more air is coming to Bjørnøya from the Siberia and North Europe region in 2001, than in 2000. At the same time the number of trajectories in cluster 1 and cluster 2, which is from areas with few anthropogenic sources, decreases. Thus there is less transport of “clean” air masses to Bjørnøya in 2001 than in 2000. Then there is a shift in the transport pattern again from 2001 to 2002. The number of trajectories in cluster 3 and cluster 5 decreases and the number of trajectories in cluster 1 and cluster 2 increases. This means that there is more transport of “clean” air masses to Bjørnøya, which could be one of the explanations for the low concentration of the contaminants in glaucous gulls in 2002. Taking into account the mean temperature for 2002, the mean for March, April and May for this year is higher than for 2001 and 2003, which also leads to less deposition of contaminants and could be an additional explanation for the low concentration of contaminants.

The data for glaucous gulls in 2003 is unfortunately missing, but there are some data in 2004 (though low sample number). The concentration has increased again for all contaminants, but not as much for the PCB-153 and HCB as for the oxychlordane and the *p,p*'-DDE. The number of trajectories in cluster 3 is lower this year than in 2003, but in cluster 5 there are more trajectories than in 2001. In cluster 1 and cluster 2 the change from 2002 until 2004 is not large, but the number of trajectories in cluster 4 (Arctic Ocean) has a minimum in 2004. This could be an explanation for the high concentration of contaminants this year. The temperature mean is high in 2004, but it is not easy to know how large effect this have on the deposition of components.

The use of trajectories through cluster analysis is useful way of trying to explain some of the changes in the concentration of contaminants in glaucous gulls on Bjørnøya.

Reference

Romesburg, H.C.: Cluster analysis for Researchers. Lifetime Learning Publications, Belmont, California, 129-135, 1984

Stohl, A., G. Wotawa, P. Seibert, and H. Kromp-Kolb (1995): Interpolation errors in wind fields as a function of spatial and temporal resolution and their impact on different types of kinematic trajectories. J. Appl. Meteor. 34, 2149-2165.

Stohl, A., and P. Seibert (1998): Accuracy of trajectories as determined from the conservation of meteorological tracers. Q. J. Roy. Met. Soc. 124, 1465-1484.

Verrault, J., Bustnes, J. O. and Gabrielsen, G. W. (2006). Organochlorine Contaminants in glaucous gulls from Svalbard- Temporal changes during the last 10 years.