Polar Stratospheric Clouds and Heterogeneous Chemistry

The link between chlorofluorocarbons and the ozone hole which occurs over Antarctica each spring is well known. However, some aspects of Polar Stratospheric Cloud (PSC) formation and their part in Chlorine Activation, the conversion of inert chlorine reservoirs (ClONO₂, HCl) into active forms which ultimately destroy atmospheric ozone, remain poorly quantified.

One of the key heterogeneous reactions on the surface of the PSCs which involves the two main chlorine reservoirs is indicated below:

\[
\text{ClONO}_2 + \text{H}_2 \text{O} \rightarrow \text{HCl} + \text{HOCl}
\]

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HCl Depletion and PSC Areal Coverages

Figure 5. HCl depletion areas over APV in 2005 at 20 km (left) and 23 km (right) for different HCl uptake phase thresholds (see Figure 4) and corresponding with PSC areas (red 23 km, PSC area calculations are derived from temperatures below 195 K from NCEP/NCAR reanalysis and EOS MLS satellite-based data using the algorithm described in Figure 1).

Table 1. Correlation coefficients and differences between HCl depleted area based on three thresholds versus the PSC area. Values derived at four stratospheric altitudes from 2005 to 2009. Yellow text (first row in each altitude) are correlation coefficients, area differences are white text for full year and 01 June to 01 August, HCl variables are derived via Homen and Mosenow (1988) formulation derived from H₂O measured daily by EOS MLS data and MLS HNO₃ as the nitrogen source to every pixel. The mean Tᵥ, Cl uptake phase, Cl threshold 1 area values were derived to be 193.9 K, 194.5 K, 195.6 K and 192.2 K over the period of time 2005-2009 at 17 km, 20 km, 23 km and 26 km respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>Altitude</th>
<th>Tᵥ (K)</th>
<th>HCl Depletion Area threshold 1</th>
<th>HCl Depletion Area threshold 2</th>
<th>HCl Depletion Area threshold 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>17 km</td>
<td>193.9 K</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>2006</td>
<td>20 km</td>
<td>194.5 K</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>2007</td>
<td>23 km</td>
<td>195.6 K</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>2008</td>
<td>26 km</td>
<td>192.2 K</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
</tr>
</tbody>
</table>

CONCLUSION

Results shown indicate that HCl depletion areas are generally larger than PSC area derived from different Tᵥ, Cl thresholds, especially during the HCl uptake phase during the Antarctic winter at lower stratospheric altitudes (17 and 20 km). This lack of correspondence maybe due to air mass processing by PSC and is an area for further work.

References:

- Andolsa, A. J., and McDonnell, A. (2009). Heterogeneous reactions on the surface of the PSCs which involves the two main chlorine reservoirs (ClONO₂, HCl) into active forms which ultimately destroy atmospheric ozone, remain poorly quantified.
- Andolsa, A. J., and McDonnell, A. (2009). Heterogeneous reactions on the surface of the PSCs which involves the two main chlorine reservoirs (ClONO₂, HCl) into active forms which ultimately destroy atmospheric ozone, remain poorly quantified.
- Andolsa, A. J., and McDonnell, A. (2009). Heterogeneous reactions on the surface of the PSCs which involves the two main chlorine reservoirs (ClONO₂, HCl) into active forms which ultimately destroy atmospheric ozone, remain poorly quantified.

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Figure 6. Scheme of the ice evolution

- HCl threshold 1 is determined as the mean HCl concentrations over a two month period before the uptake phase takes place minus 2σ of this mean value HCl threshold 2 rather utilizing key criteria and HCl threshold 3 gives 2σ.

- HCl production phase

- Breaking up of ClHCl uptake phase and beginning of production phase.