3D CTM Simulation of Arctic Ozone Loss for 2002/3 Winter

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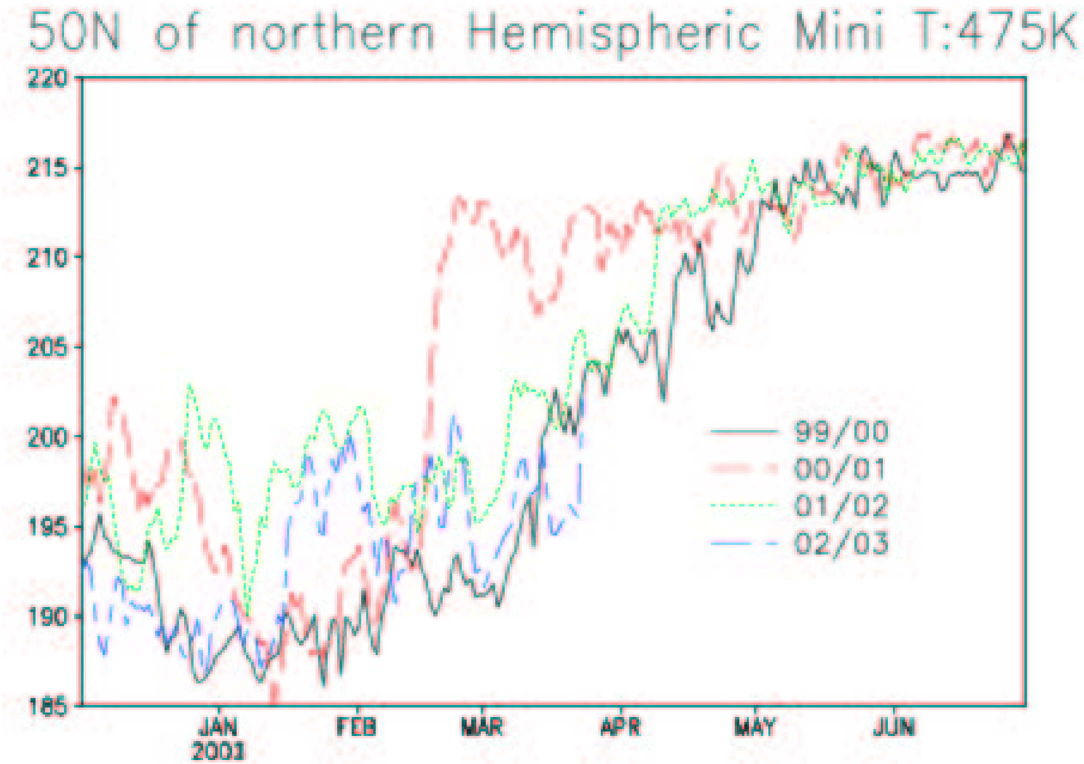
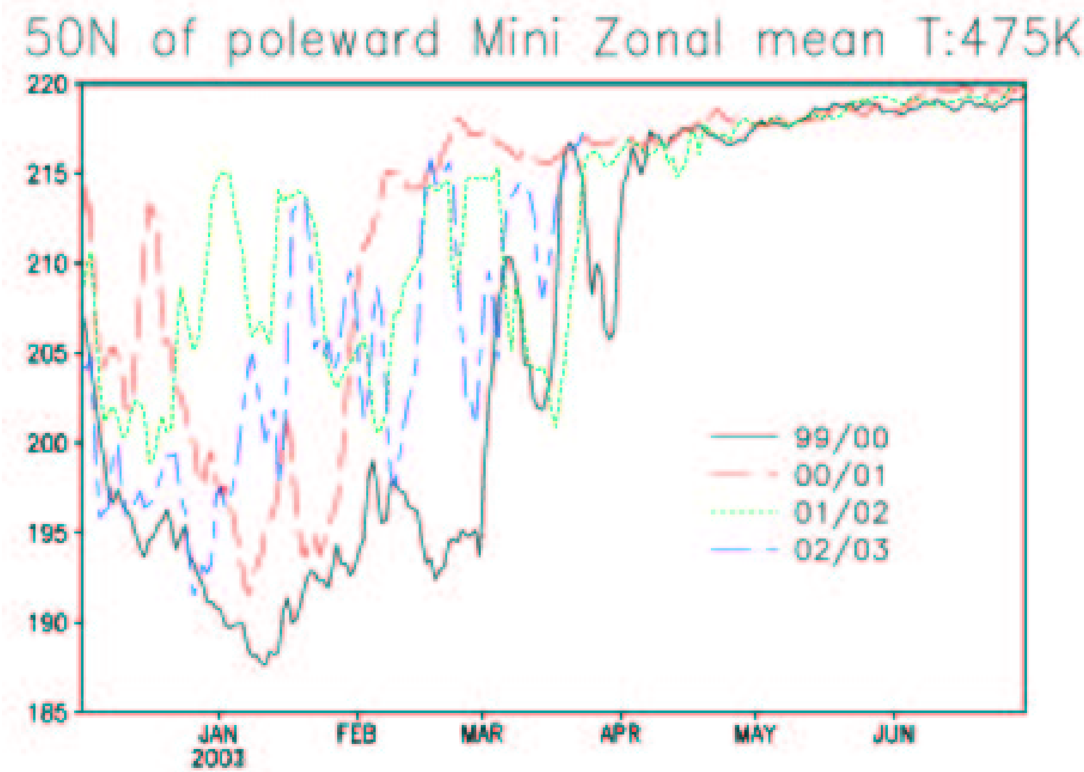
QUILT WP 6200 - Near-real-time SLIMCAT maps available on website: www.env.leeds.ac.uk/slimcat

1. Introduction
2. SLIMCAT NRT Simulation
3. Ozone Budget (Polar region and effect on mid latitudes)
4. Conclusion





- **Cold temperatures in December 2002**

SLIMCAT 3D-CTM

- **3D Off-line Chemical Transport model**
- **Isentropic Vertical coordinate**
- **Tracer Transport**

Horizontal: Prather 2^{nd} order moment scheme

Vertical: MIDRAD radiation Scheme

- **Detailed Chemical Scheme**

41 chemical species;

123 gas phase chemical reactions;

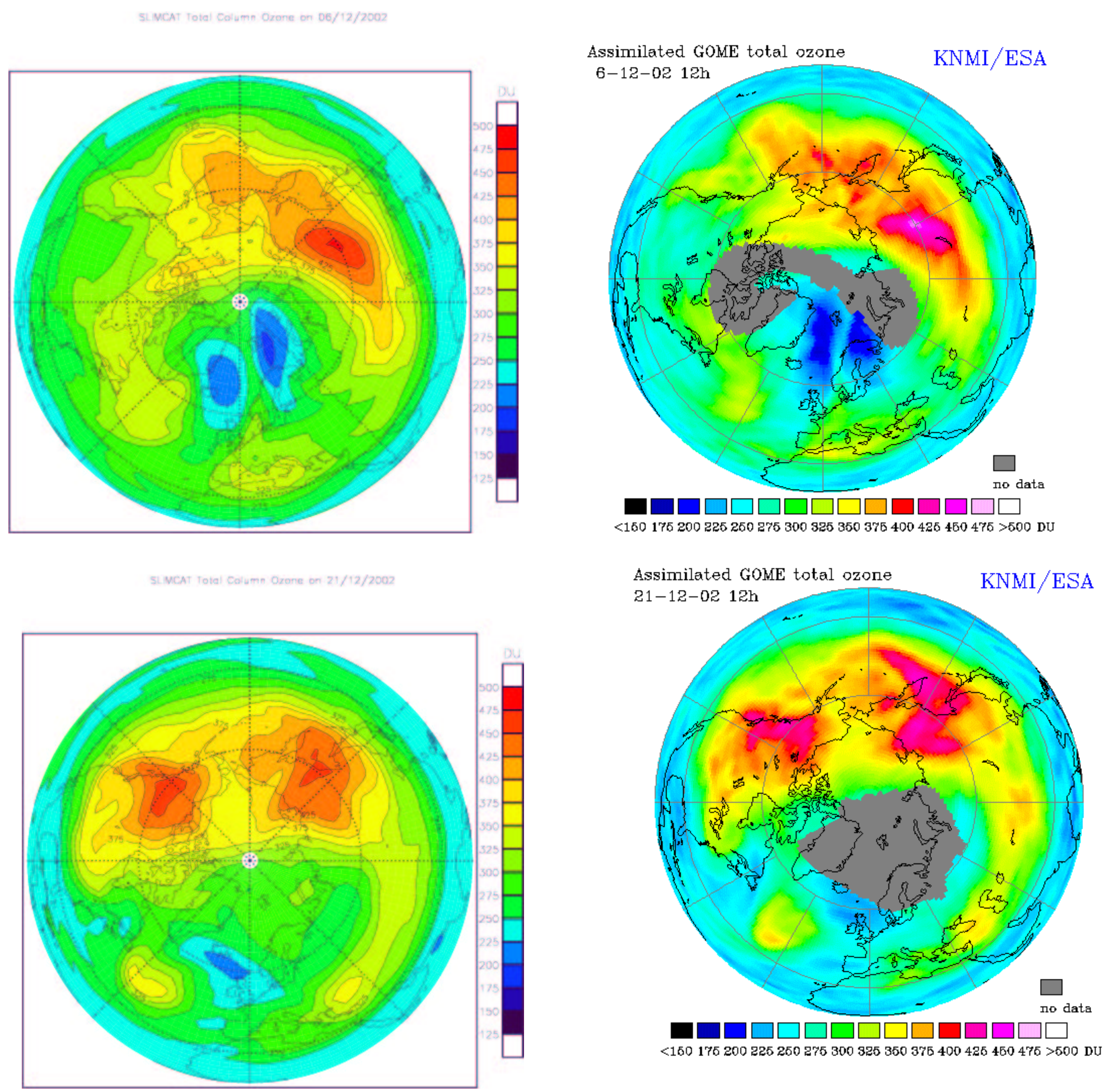
32 photolysis reactions

Heterogeneous reactions (liquid, aerosols, NAT, ice)

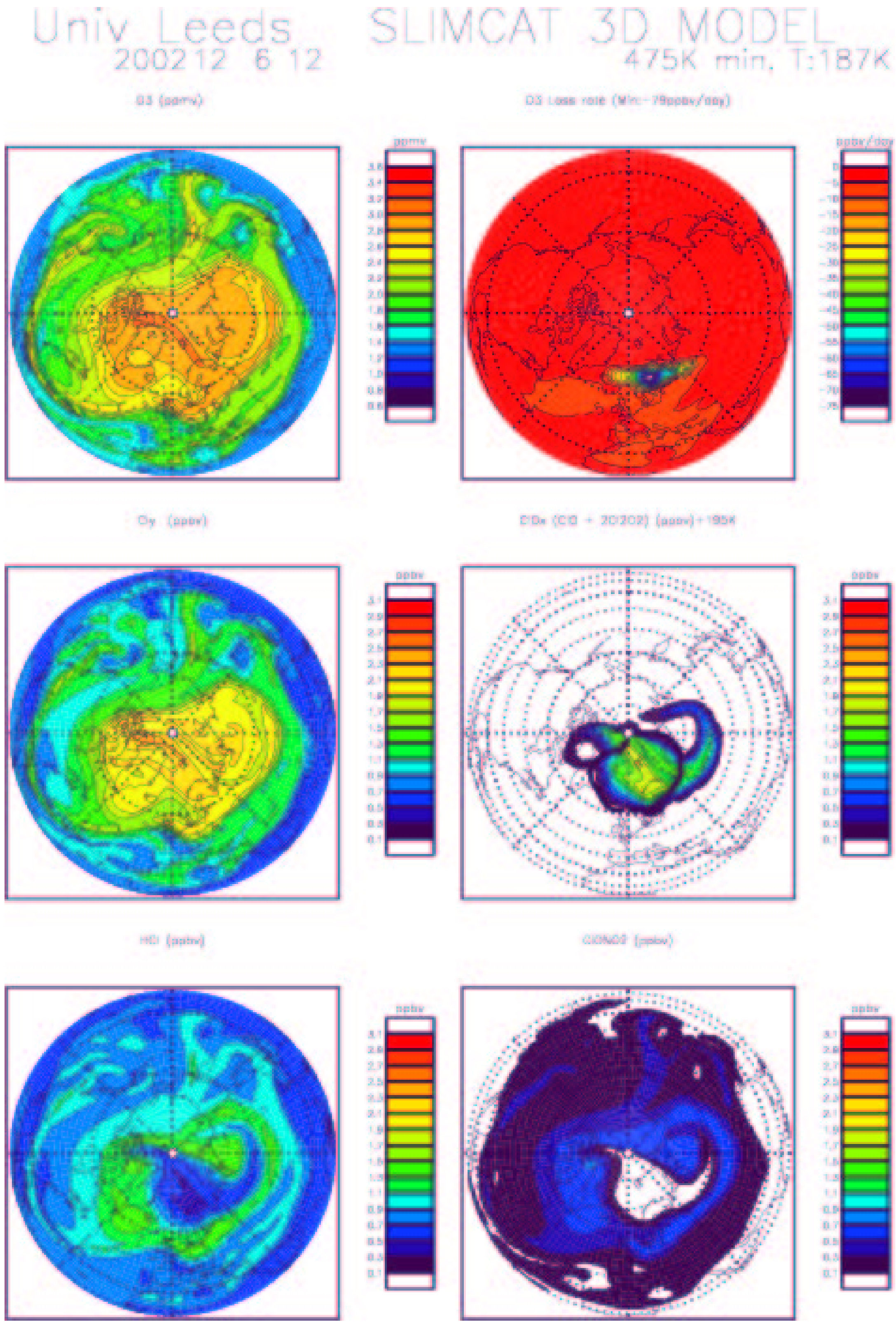
Neal Real Time results forced by ECMWF T42 L60 operational analyses

http://www.env.leeds.ac.uk/slimcat

Arctic Ozone Mini-hole

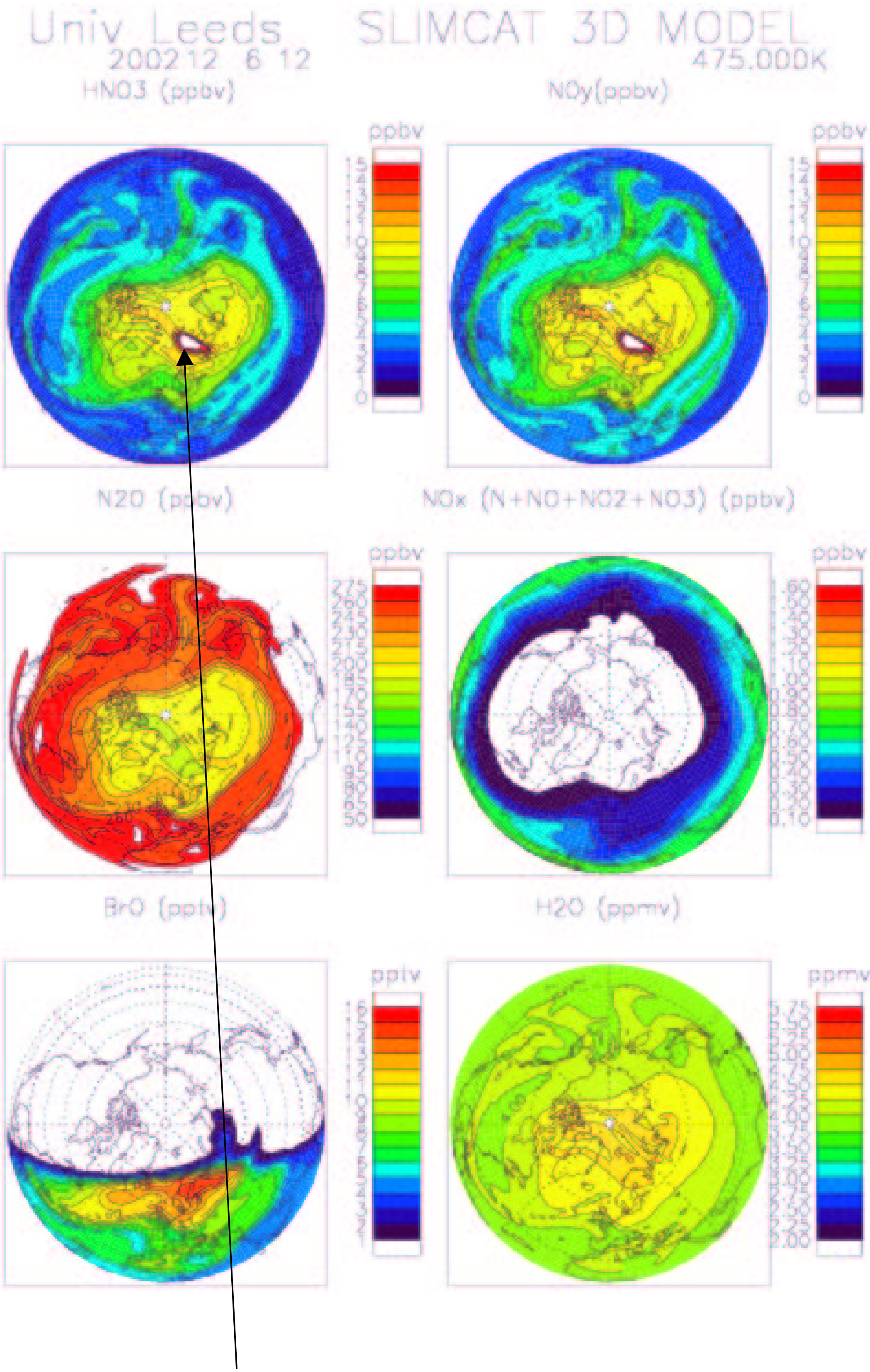


- **SLIMCAT with ECMWF analyses successfully reproduced the December Arctic Ozone Mini-hole**

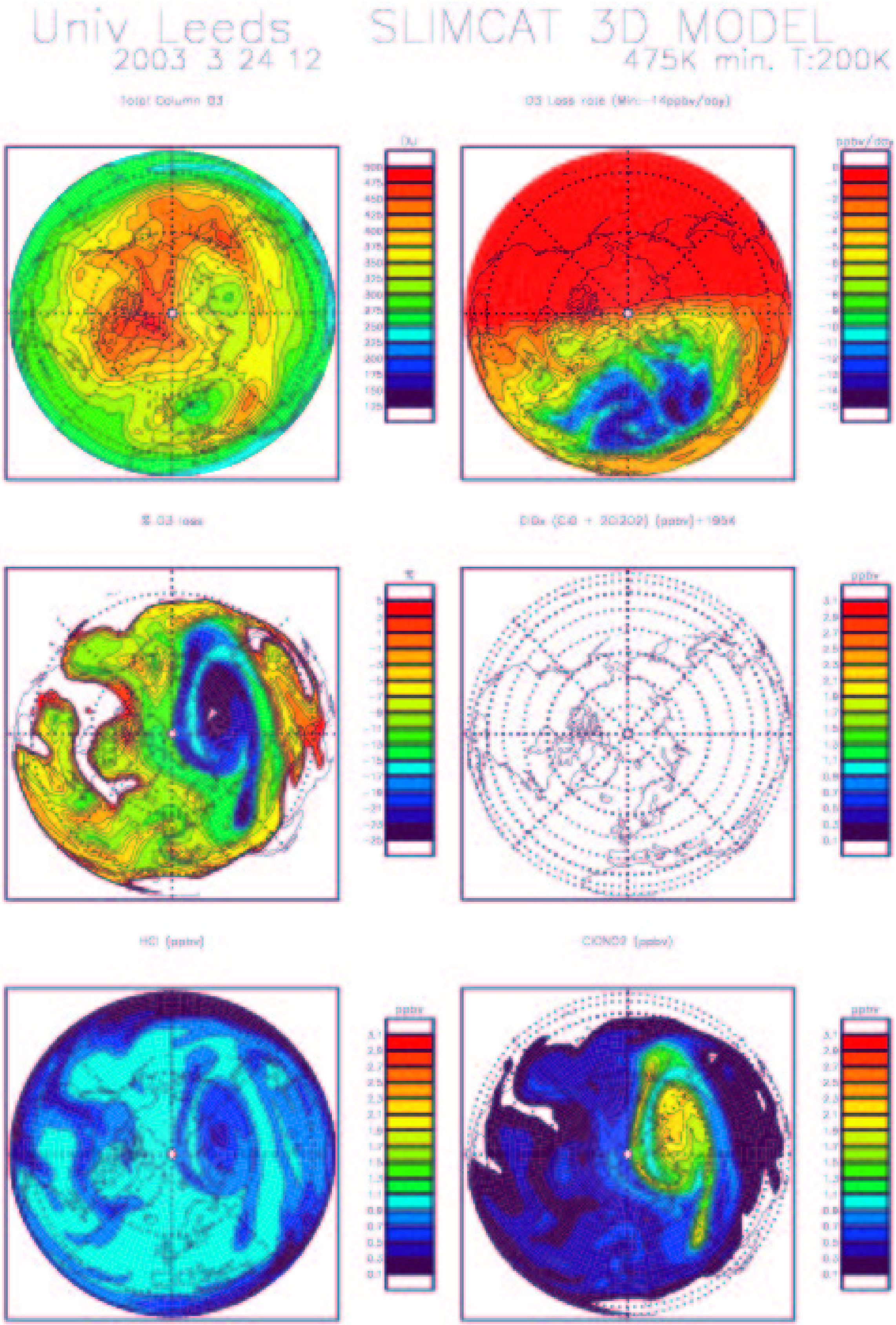


- Fast chemical loss rate (-79ppbv/day)
- Cold Temperature (min T: 187K)
- Chlorine activation on PSCs

Other Chemical species



- Modelled denitrification
- Enhanced BrO



- O_3 loss ~25% since 1/12/2002
- Chlorine De-activation

Continuity Equation

$$\frac{\partial O_3}{\partial t} = P - L - \nabla \bullet \vec{V}_h O_3 - \frac{\partial \dot{\theta} O_3}{\partial \theta}$$

Where

P: Photochemical Production rate of O_3

-L: Chemical loss rate of O_3

$\vec{V}_h$ **: Horizontal Wind**

$\dot{\theta}$ **: Heating rate at the box centre**

$\frac{\partial O_3}{\partial t}$ **: O_3 change**

$-\nabla \bullet \vec{V}_h O_3$ **: Horizontal transport of O_3**

$-\frac{\partial \dot{\theta} O_3}{\partial \theta}$ **: Vertical transport of O_3**

Ozone Budget

1) Overall Chemical Ozone Change

Difference between integrated and passive O_3

2) Horizontal and Vertical Transport of O_3

3) Chemical Loss Rates

Dominated by several key catalytic cycles, e.g.

$$ClO + ClO + M \rightarrow Cl_2O_2 + M$$
$$Cl_2O_2 + h\gamma \xrightarrow{j_1} Cl + ClOO$$
$$ClOO + M \rightarrow Cl + O_2 + M$$
$$2 \times (Cl + O_3 \rightarrow ClO + O_2)$$

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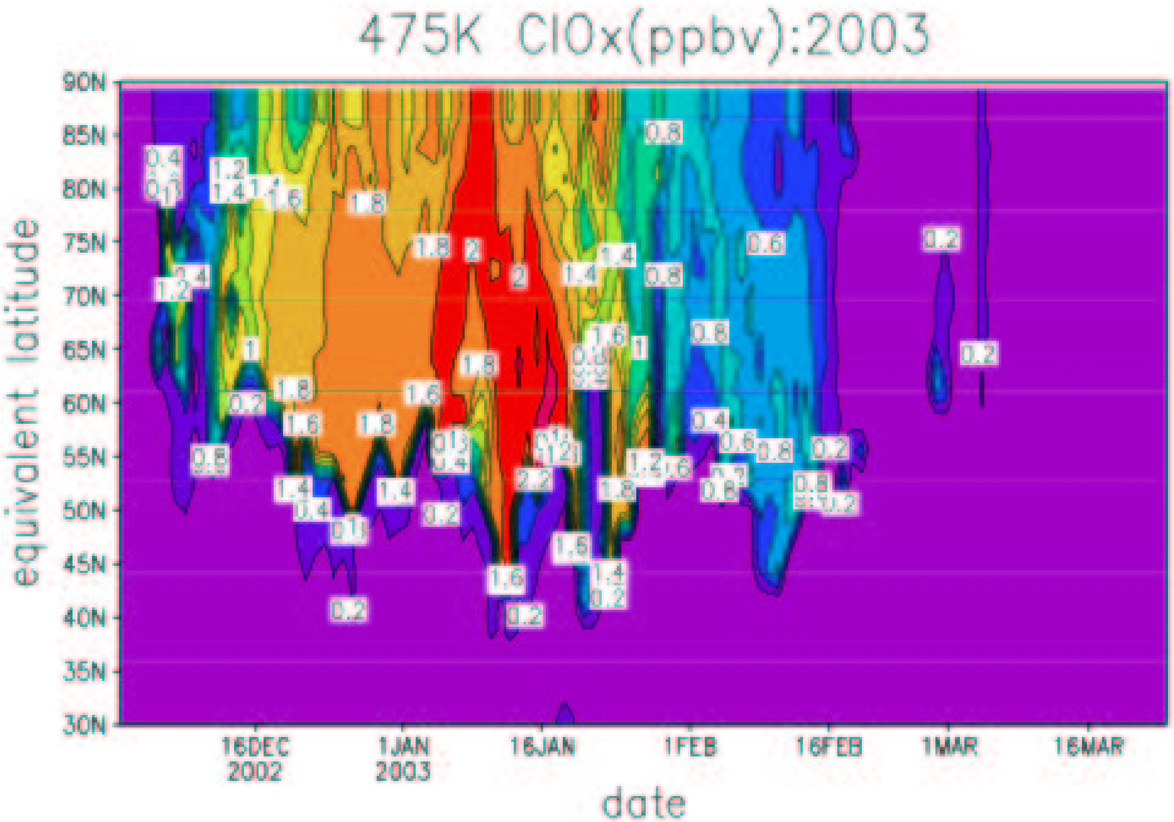
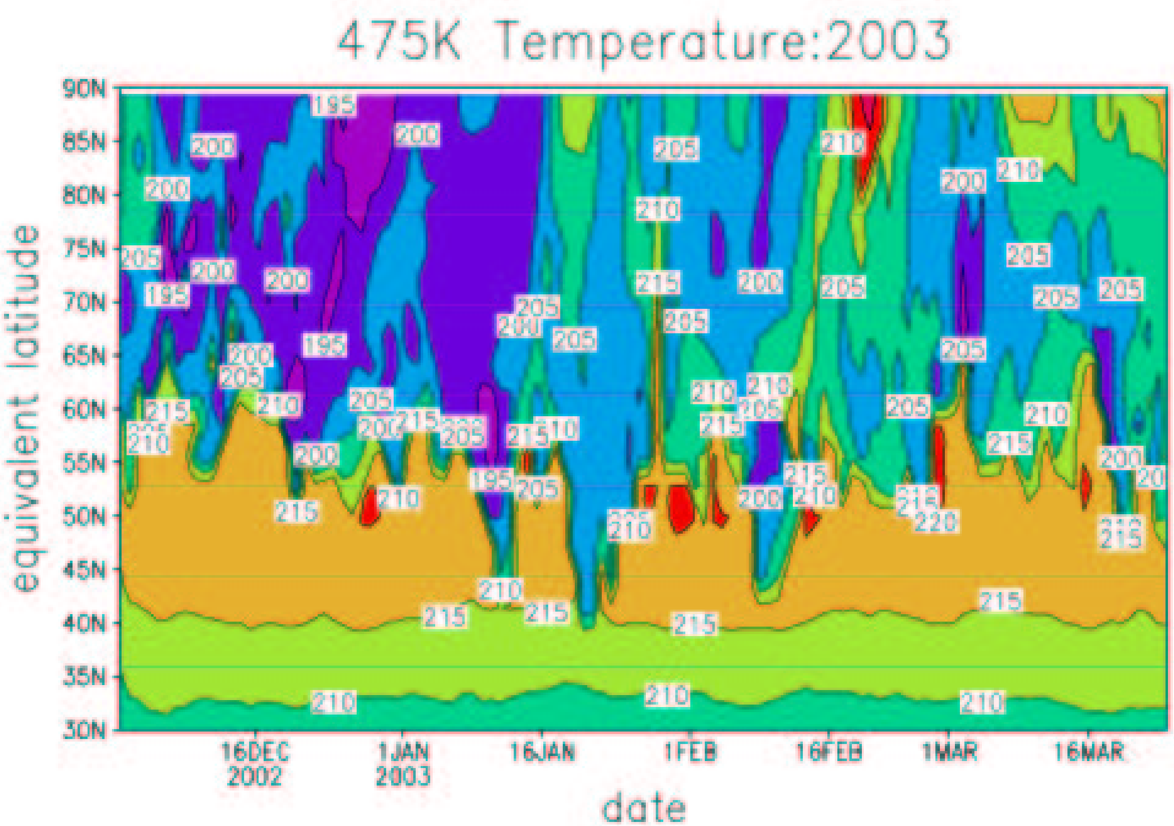
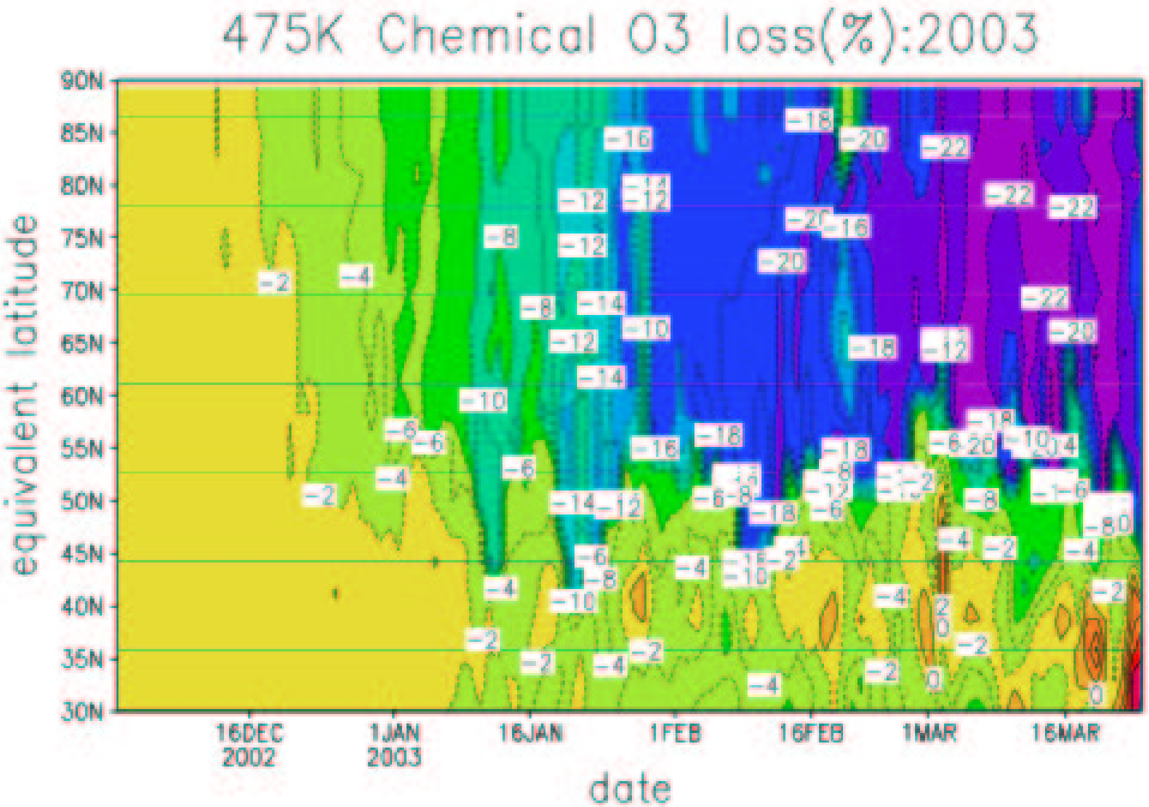
$$net: 2O_3 \rightarrow 3O_2$$

Cycle 1

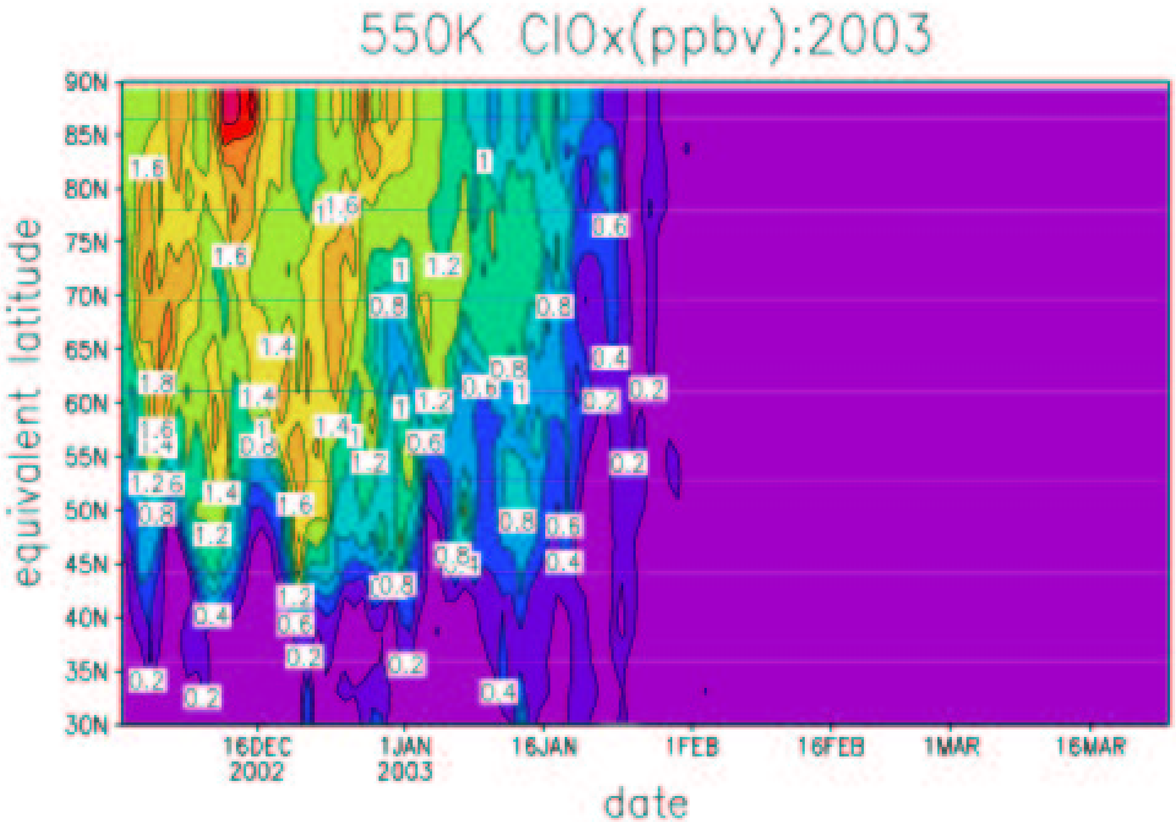


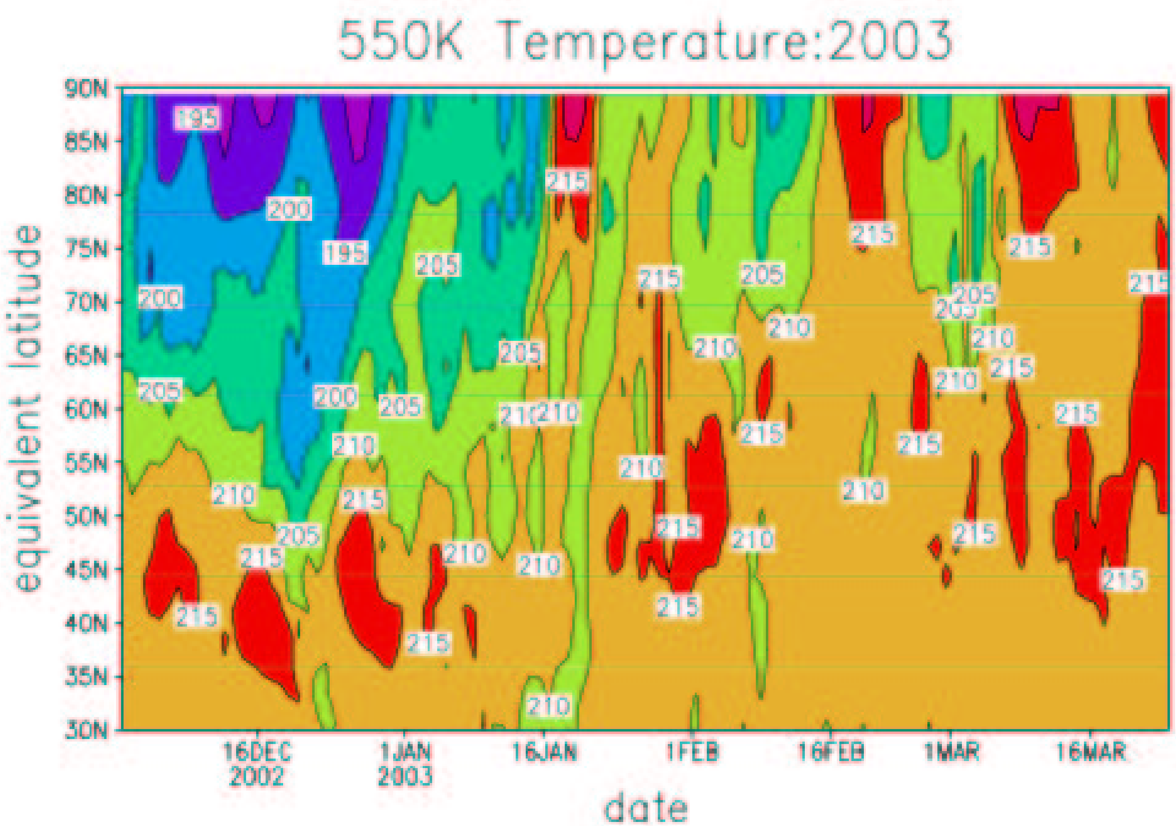


- **Cold temperature leads to high levels of ClO_x inside the polar vortex at 475K/~18km**



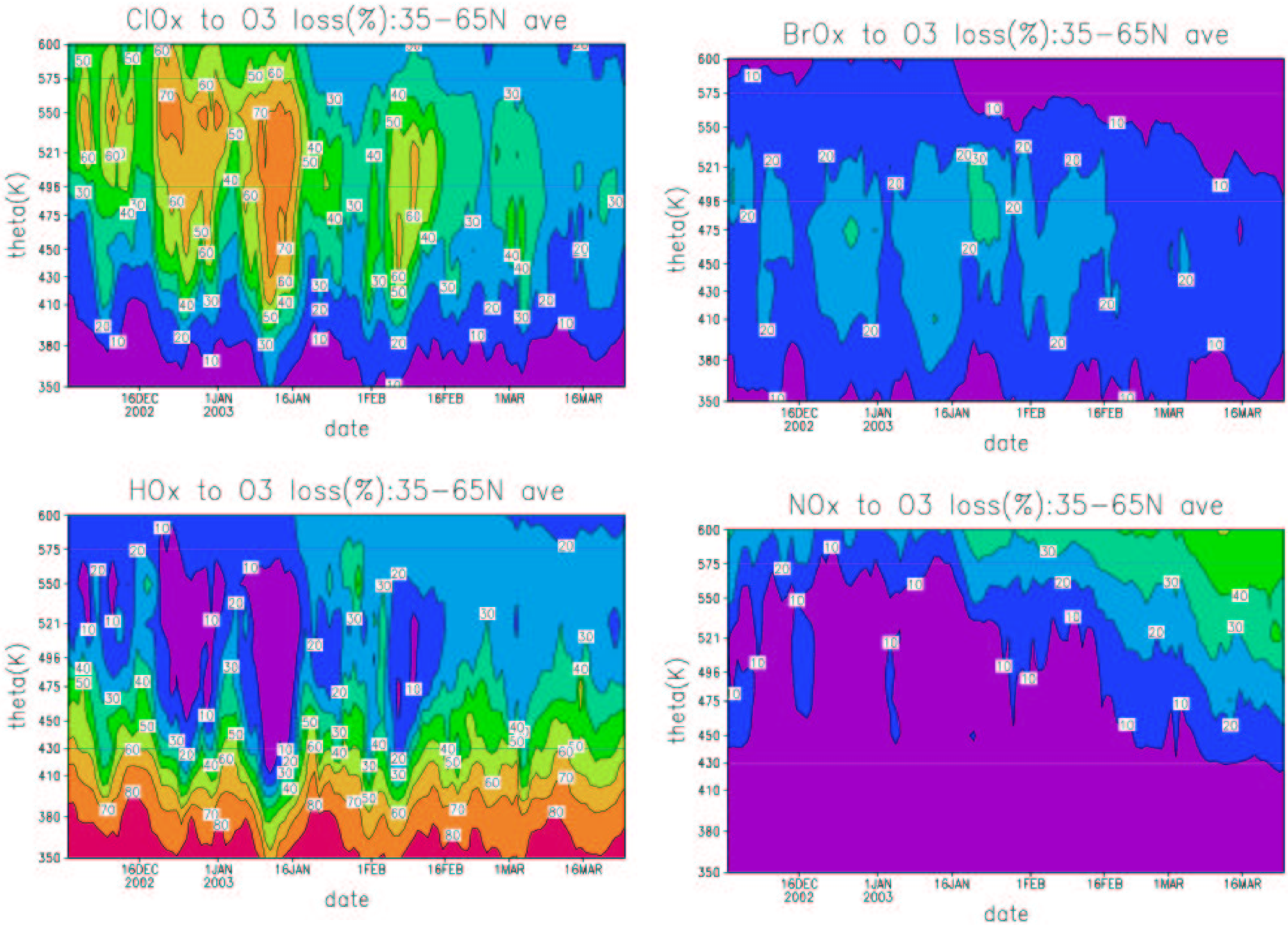
- **Chemical Ozone loss (> 20%)**





- **Cold temperature and high levels of ClO_x at 550K**

Contribution to Mid-lat. O_3 loss



Contributions of the various catalytic reactions cycles with ClO_x, BrO_x, HO_x, , NO_x are responsible averaged 35-65N O_3 loss:

- **ClO_x ~ 70% over 410K**
- **BrO_x ~ 20-30%**
- **HO_x :important below 400K**

Conclusions

- The Arctic 2002/03 winter was cold in December in the lower stratosphere.

- SLIMCAT with ECMWF analyses reproduced the December Arctic O_3 mini-hole.

- Cold temperatures lead to high levels of ClO_x inside the polar vortex.

- 25% chemical loss so far.

- Reactions cycles with ClO_x are responsible for ~70% mid-latitude O_3 loss in the lower stratosphere, while BrO_x are for about 20-30%, and HO_x is most important in the lowermost stratosphere