1 ER-2 Flights

The following figures show measurements of chemical species along the flight paths of the ER-2 aircraft on 16 flights between 6 January and 16 March 2000. Flights between 20 January and 12 March started from Kiruna (Sweden) and probed the stratospheric polar vortex and surf zone, while the other flights were transfer and test flights.

Additionally, the flight path and several parameters along the flight paths that are helpful for interpretation of the measurements are shown, including pressure, temperature and solar zenith angle.

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Figure 1: Flight paths of the ER-2 for all campaign flights. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight (either at 00 UTC or 12 UTC).
Figure 1: Flight paths of the ER-2 for all campaign flights. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight (either at 00 h UTC or 12 h UTC).
Figure 2: Pressure as a function of flight time (UTC). The blue line shows the pressure along the actual flight path (from ER-2 measurements) and the red line shows the pressure on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis, either at 00 h UTC or 12 h UTC).
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Figure 22: Cl\textsubscript{y} as a function of flight time (UTC) from the sum of all modeled inorganic Cl species (black line).
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Figure 28: HO$_2$ as a function of flight time (UTC) from measurements of the Harvard HO$_x$ instrument (blue dots) compared to modeled values (black lines). Cyan lines show 2$\sigma$ uncertainties.
The next figures show measurements of the Mark IV and the SLS instrument on the OMS remote balloon flights of 3 December 1999 (also used for initialization) and 15 March 2000. Note that the Mark IV and SLS instruments have different viewing geometries and measurement times. The first set of figures is interpolated to the Mark IV instrument, but shows additionally the SLS measurements, if available. The second set is interpolated to the SLS instrument, but shows additionally the Mark IV instrument.
Figure 29: Flight parameters for the Mark IV instrument on 3 December 1999. From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude.
Figure 29: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 3 December 1999 (blue and red lines with error bars) compared to modeled values interpolated to the Mark IV viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values or passive ozone. Species are (from upper left to lower right): CFC-11, CFC-12, CFC-113, CH$_3$Cl, CCl$_4$, HCFC-22, H$_2$O, CH$_4$, N$_2$O, CO, O$_3$, CH$_2$O.
Figure 29: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 3 December 1999 (blue and red lines with error bars) compared to modeled values interpolated to the Mark IV viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values. Species are (from upper left to lower right): ClONO$_2$, HCl, ClO, HOCl, NO, NO$_2$, HNO$_3$, N$_2$O$_5$, H$_2$O$_2$. 
Figure 30: Flight parameters for the SLS instrument on 3 December 1999. From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude.
Figure 30: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 3 December 1999 (blue and red lines with error bars) compared to modeled values interpolated to the SLS viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values or passive ozone. Species are (from upper left to lower right): O$_3$, N$_2$O, HNO$_3$, HCl, ClO
Figure 31: Flight parameters for the Mark IV instrument on 15 March 2000. From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude.
Figure 31: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 15 March 2000 (blue and red lines with error bars) compared to modeled values interpolated to the Mark IV viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values or passive ozone. Species are (from upper left to lower right): CFC-11, CFC-12, CFC-113, CH$_3$Cl, CCl$_4$, HCFC-22, H$_2$O, CH$_4$, N$_2$O, CO, O$_3$, CH$_2$O.
Figure 31: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 15 March 2000 (blue and red lines with error bars) compared to modeled values interpolated to the Mark IV viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values. Species are (from upper left to lower right): ClONO$_2$, HCl, ClO, HOCl, NO, NO$_2$, HNO$_3$, N$_2$O$_5$, H$_2$O$_2$. 
Figure 32: Flight parameters for the SLS instrument on 15 March 2000. From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude.
Figure 32: Several species as a function of pressure altitude for measurements of the Mark IV instrument and the SLS instrument on 15 March 2000 (blue and red lines with error bars) compared to modeled values interpolated to the SLS viewing geometry (black lines). Grey lines show total (solid and gas phase) modeled values or passive ozone. Species are (from upper left to lower right): O$_3$, N$_2$O, HNO$_3$, HCl, ClO.
3 OMS in situ balloon flight

The next figures show measurements of the LACE instrument on the OMS in situ balloon flight of 5 March 2000.
Figure 33: From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude.
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4 Ozone sondes

The next figures show measurements of ozone sondes from the stations Ny-Alesund (polar), Hohenpeissenberg (mid-latitudes), Samoa and Paramaribo (tropical) between December 1999 and March 2000. The legend of all figures is the same and only given here:

From upper left to lower right: (1) Flight path of the balloon. The blue line shows the actual flight path and the red line is the position of the probed air parcels at the last model time step before the flight. (2) Temperature as a function of pressure altitude. The blue line shows the measured temperature and the red line shows the temperature on the position of the probed air parcels at the last model time step before the flight (from the ERA Interim reanalysis). The thin black and green lines show the NAT and ice formation temperatures. (3) Solar zenith angle as a function of pressure altitude. (4) Equivalent latitude as a function of pressure altitude. (5) Measured ozone profile (blue dots) as a function of pressure altitude compared to modeled values (black line). The grey line is the passive ozone profile.
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Figure 38: Hohenpeissenberg 6 January 2000
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Figure 40: Hohenpeissenberg 9 January 2000
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Figure 42: Ny-Alesund 20 January 2000
Figure 43: Ny-Alesund 31 January 2000

Figure 44: Hohenpeissenberg 31 January 2000
Figure 45: Samoa 3 February 2000

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Figure 48: Ny-Alesund 26 February 2000
Figure 49: Paramaribo 1 March 2000

Figure 50: Ny-Alesund 11 March 2000
Figure 51: Ny-Alesund 15 March 2000

Figure 52: Hohenpeissenberg 15 March 2000
5 Vortex means

The next figures show vortex means averaged over all air parcels inside the inner vortex boundary according to the Nash criterion and over several hybrid coordinate (i.e. potential temperature) intervals equivalent to the mixing depth of the model. From upper left to lower right: Ozone, ozone loss as difference between chemically active ozone and the passive ozone tracer, denitrification as difference between NO$_y$ and the passive NO$_y$ tracer, ClO and NO$_x$. 
Figure 53: Vortex means of ozone, ozone loss, denitrification, ClO and NO\textsubscript{x} inside the inner vortex boundary according to Nash.
6 HALOE zonal means

The next figures show zonal and monthly mean mixing ratios for HCl, O₃, CH₄, H₂O and NOₓ as a function of pressure altitude and equivalent latitude for February 2000. Left: HALOE measurements, right: modeled values.
Figure 54: Zonal and monthly mean mixing ratios of HCl, O₃ and CH₄ as a function of pressure altitude and equivalent latitude for February 2000. Left: HALOE measurements, right: modeled values.
Figure 54: Zonal and monthly mean mixing ratios of H₂O and NOx as a function of pressure altitude and equivalent latitude for February 2000. Left: HALOE measurements, right: modeled values.