Comparisons of cirrus cloud microphysical properties between polluted and pristine air

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Introduction

- Radiative properties of cirrus depend on particle sizes and concentrations.
- If anthropogenic emissions influence cirrus in a significant manner, then one should expect a systematic difference in cirrus properties between pristine (clean) air and polluted air (Ström et al., 2000).
- Pollution contrast between the Southern (SH) and Northern Hemispheres (NH) should cause also interhemispheric differences in cirrus properties.
- This study studies in-situ observations from two global flight campaigns: HIPPO and INCA.

HIAPER Pole-to-Pole Observations (HIPPO)

- The HIPPO global campaign (2009-2011) performed observations over the North America continent and the central Pacific Ocean from 87°N to 67°S.
- Ice crystals are measured by a Fast-2DC probe, and the analyses are restricted to particles >87.5 µm to minimize shattering effects and optical uncertainties.
- A previous data analysis found that the evolution of microphysical parameters (ice crystal size and concentration) are similar between the NH and SH (Diao et al., GRL 2014).
- The same was found for the relative timescale of the life cycle of ice supersaturated regions (ISSRs) and ice crystal regions (ICRs) (as defined in Diao et al., GRL, 2013).

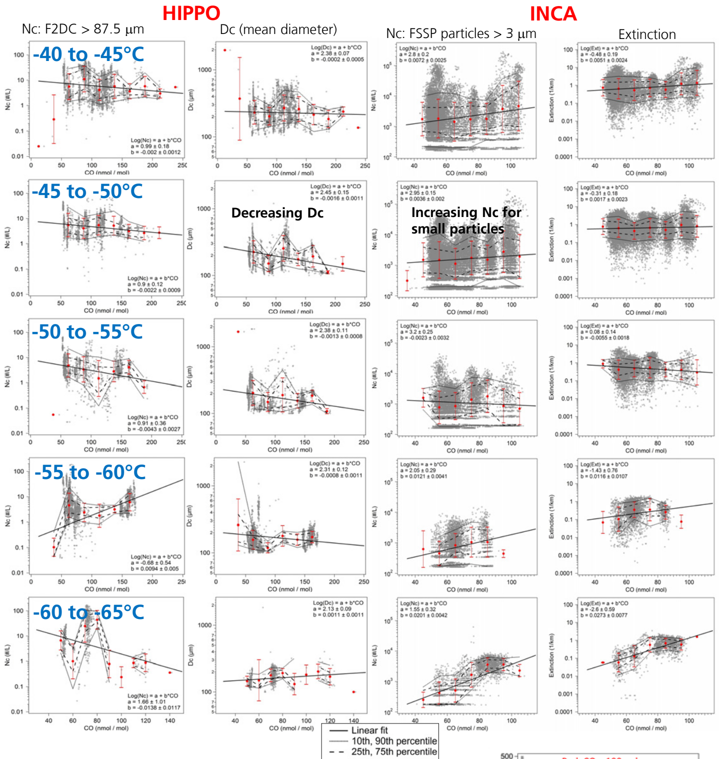
Interhemispheric Differences In Cirrus Properties from Anthropogenic Emissions campaign (INCA)

- The INCA campaign (2000) investigated cirrus properties at midlatitudes (near 50°S and N), over the Pacific west of Punta Arenas and over the North Atlantic west of Great Britain using the DLR Falcon.
- Cirrus clouds were sampled with optical particle counters in the size range of ~1 to 800 µm.
- Simultaneous measurements of trace gases (CO, NOx and O_3) and a suite of aerosols properties show that the measurements in the SH occurred in air masses which were far cleaner than those measured in the NH (Baehr et al., GRL, 2003; Minikin et al., GRL, 2003).
- Previous INCA data analysis revealed differences between SH and NH cirrus: a lower ice number concentration N_c, a larger effective diameter D_{eff}, and a larger extinction in the cirrus in the SH compared to the NH (Gayet et al., JGR, 2004).
- Here, we assume that any shattering effect, that may be present, is independent of CO mixing ratio.

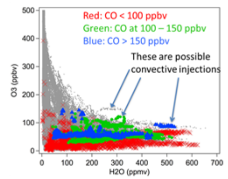
HIPPO & INCA: Correlations between cirrus properties and carbon monoxide (CO) – as pollution indicator

Correlations between cirrus microphysical properties: HIPPO (number concentrations Nc by Fast-2DC > 87.5 µm; Dc: number weighted mean diameter); INCA (FSSP > 3 µm and extinction). All analyses are restricted to T≤ -40°C.

Summary of findings	HIPPO_Nc	HIPPO_Dc	INCA_Nc	INCA_Ext
Measurement range	Fast 2DC > 87.5 µm	Fast 2DC > 87.5 µm	FSSP > 3 µm; or 2DC > 100 µm	FSSP > 3 µm
Higher CO concentration correlates with:	Lower Nc for larger ice particles	Smaller Dc	Higher Nc for small ice particles; Lower Nc for larger particles	No strong trend at T > -55°C, but increasing Ext at T < -55°C

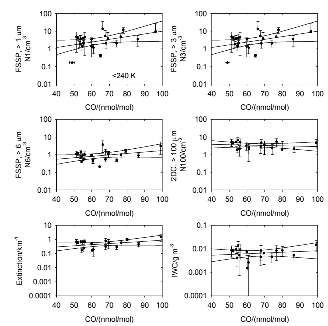


Discussion:
1. Higher CO correlates with decreasing size of ice crystals (as shown by HIPPO data), which is consistent with the increasing Nc for smaller particles observed from INCA.
2. The O_3-H_2O tracer correlation plot shows that only a small amount of data were under influence of deep convection injection.



INCA: Correlations between cirrus properties and carbon monoxide (CO)

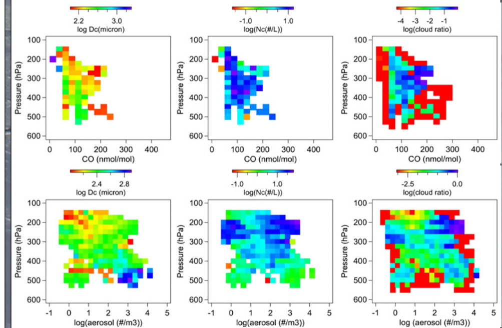
- Ice crystal concentrations increase with CO for small cut-off sizes (1, 3 and 6 µm) and decrease for large particles. Here for T<240 K (similar for lower temperature limits). r^2 within a range of 0.2 to 0.6.
- Weak trend for extinction, no trend for IWC.
- Circles and error bars: mean values and standard deviations for data from individual flights.
- Lines: linear regressions and 95% confidence intervals.



- Further results: Higher ice supersaturation in air masses with low CO concentration.
- Correlations of w^2 and T with CO are sufficiently weak to assume that dynamic effects were reasonably similar.

HIPPO: Analysis of ice crystal distributions – CO and total aerosols

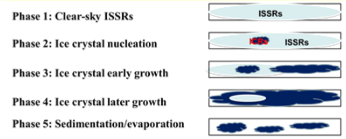
- The occurrence frequency of in-cloud conditions increases with CO and total aerosol concentrations.
- Ice crystal sizes decrease with higher CO concentrations and increase with total aerosol concentrations.

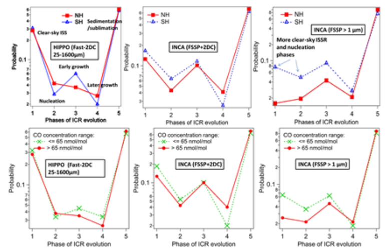


Discussion: Cirrus evolution phases

- Diao et al. (GRL, 2013) suggested a method to identify the occurrence frequencies of five different phases of ice crystal evolution.
- The HIPPO (Fast-2DC) and INCA (FSSP+2DC) data show similar frequencies for these evolution phases in the NH and SH.
- For small ice, the INCA FSSP data (> 1 µm) show more "clear-sky ice supersaturated region" and "nucleation" events to occur in the SH than in the NH.
- The probability of each evolution phase for lower and higher CO concentrations is similar.

•Five phases of ice crystal region evolution





Conclusions

- When comparing pristine and polluted regions (with high and low CO), we found higher small ice particle concentrations (shown by INCA data) and smaller ice crystal sizes (shown by HIPPO and INCA data).
- For large ice particles (from HIPPO and INCA), the evolution phases of cirrus clouds occur at similar frequency in clean and polluted air masses.
- For small ice particles (so far INCA data only), clear-sky ice supersaturated regions and cirrus in the nucleation phase occur more frequently in clean/SH data than in polluted/NH data.
- The results are consistent with and extend earlier findings (Gayet et al., 2014).

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- The INCA data base (http://www.pa.op.dlr.de/inca/) was recently renewed with help of instruments PIs.