COST 723 Data Exploitation and Modeling for the Upper Troposphere and Lower Stratosphere

COST 723 Workshop on

Cirrus Clouds and their Supersaturated Environment

Overview, Examples, and Problems

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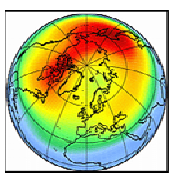
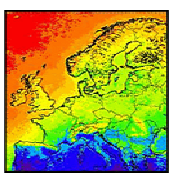
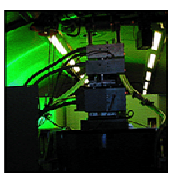




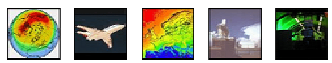


Cirrus and climate — a problematic relationship

1. Cirrus clouds may heat or cool the Earth-Atmosphere System depending on
   - ➔ micro-/macrophysical properties
   - ➔ temperature (altitude)
   - ➔ generation mechanism (incl. synoptic situation, geogr. location)

2. Complex ice crystal shapes (*inter alia* T- and S_i- dependent) render calculation of radiative transfer a tough problem

3. Various modes of ice crystal formation
   - ➔ homogeneous freezing of aqueous solution droplets
   - ➔ heterogeneous modes:
     - ⇨ deposition freezing
     - ⇨ immersion and condensation freezing
     - ⇨ contact nucleation



Cirrus and climate — a problematic relationship

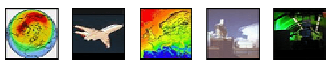
4. Cirrus clouds have only a loose relation to ice saturation, viz.
   - ➔ they do not form at saturation
   - ➔ once formed, they are not very strongly attracted by the equilibrium state

Consequently:

there is plenty of ice supersaturated, yet clear air in the UT
(sometimes marked by persistent contrails)

Cirrus clouds are embedded in supersaturated airmasses

RHi pdfs within cirrus have long tails into the supersaturated regime



Cirrus and climate change — an unsolved problem

Freezing/nucleation thresholds are high above saturation

$\Rightarrow$ extremal states in the RHi field

Extremal states react much more sensitive to changes of background conditions than do averages.

Hence it is difficult to estimate, how the probability will change in a changing climate that in the RHi field the nucleation thresholds will be surpassed.

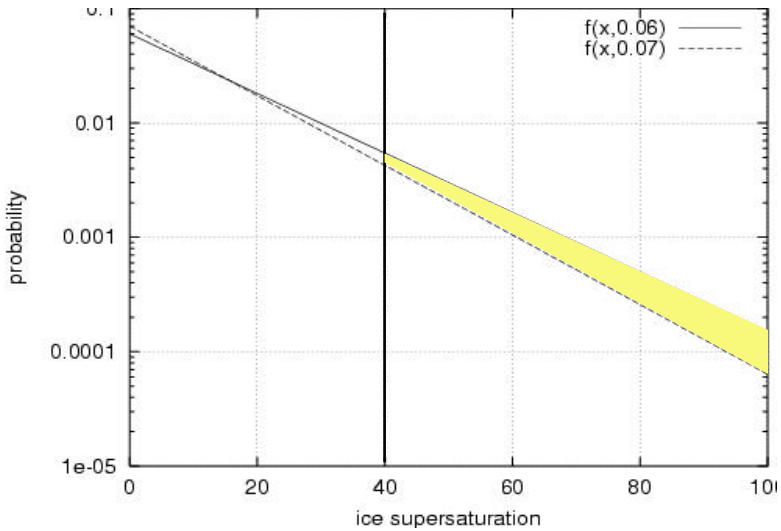
Example:

mean S_i increases from 6 to 7%

but probability to surpass 40%

decreases by about 1/3

wrt to the earlier pdf



Cirrus and climate — what we can do

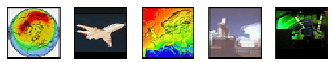
We must represent ice-supersaturation in the models when we want to make reliable predictions of cirrus cloudiness and climate change

(Working Group 2)

and

we must have a good representation of the relation between cirrus clouds and their supersaturated environment

(Working Group 1)



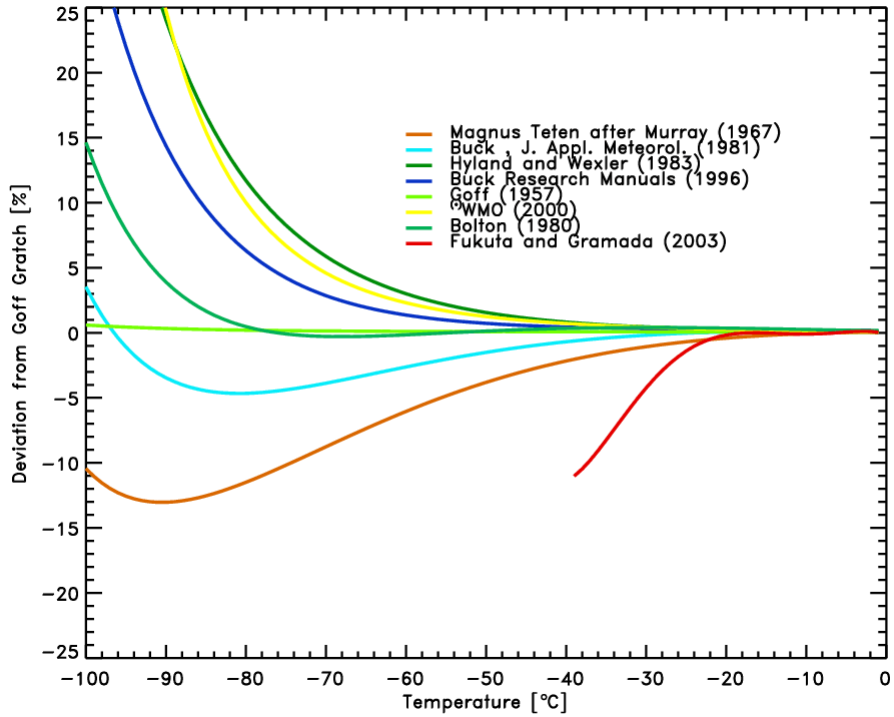
Cirrus and climate — what others can do

A saturation curve with respect to liquid water at T<-40°C does merely exist as a couple of mathematical extrapolations without physical reality. Various formulations differ widely (>10%).

Therefore, WMO should abandon the practice to report relative humidities wrt liquid water. Below -40°C relative humidities should be reported wrt ice.

and

Producers of satellite data products (UTH_i) should cease to constrain their data products to values below saturation.

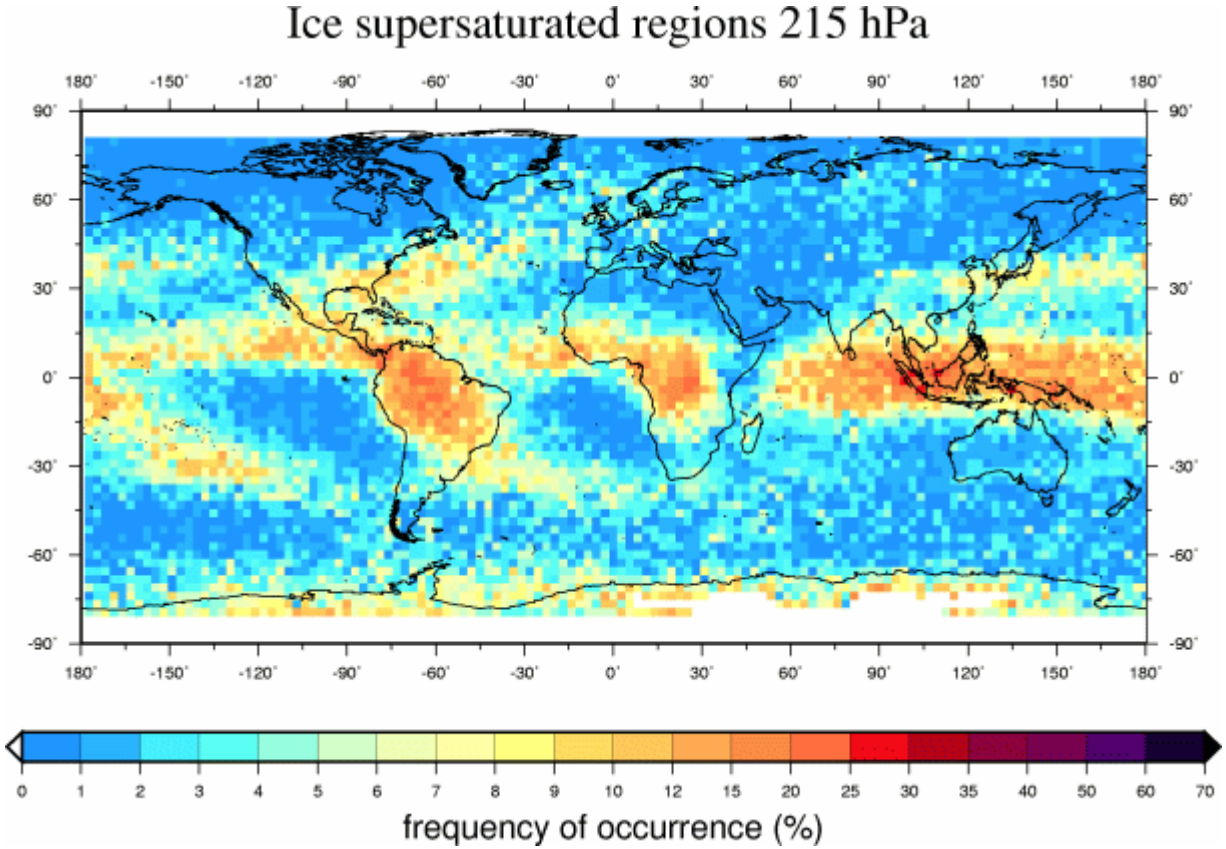


courtesy of Holger Vömel, U Colorado

http://cires.colorado.edu/~voemel/vp.html

Cirrus and their supersaturated environment: Examples and problems

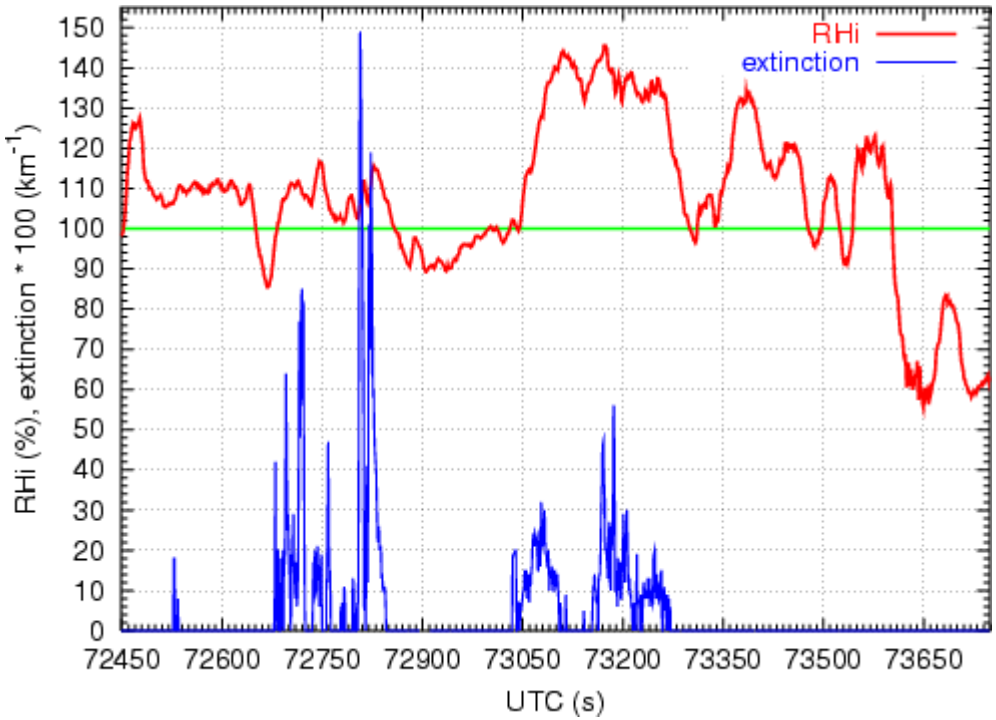
Global distributions of cirrus and ISSRs are quite similar



Spichtinger et al., 2003

Cirrus and their supersaturated environment: Examples and problems

Cirrus clouds embedded in supersaturated airmasses
(INCA measurements, Punta Arenas,
frostpoint hygrometer and polar nephelometer)



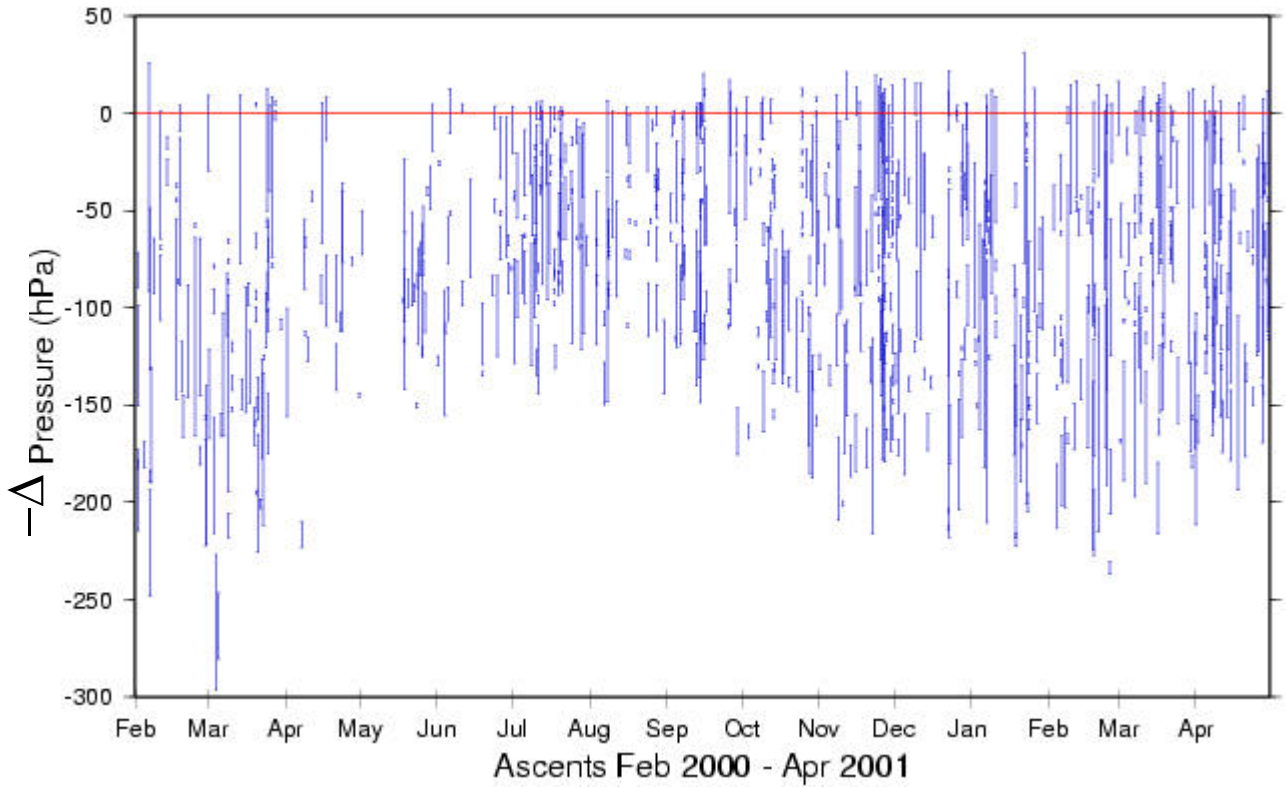
Spichtinger et al., 2004

Cirrus and clear air coexist in ISSRs. Whether Ci forms or not depends probably on the local vertical velocity.

A climatology of w is missing, although this is one of the most important parameters for Cirrus

Cirrus and their supersaturated environment: Examples and problems

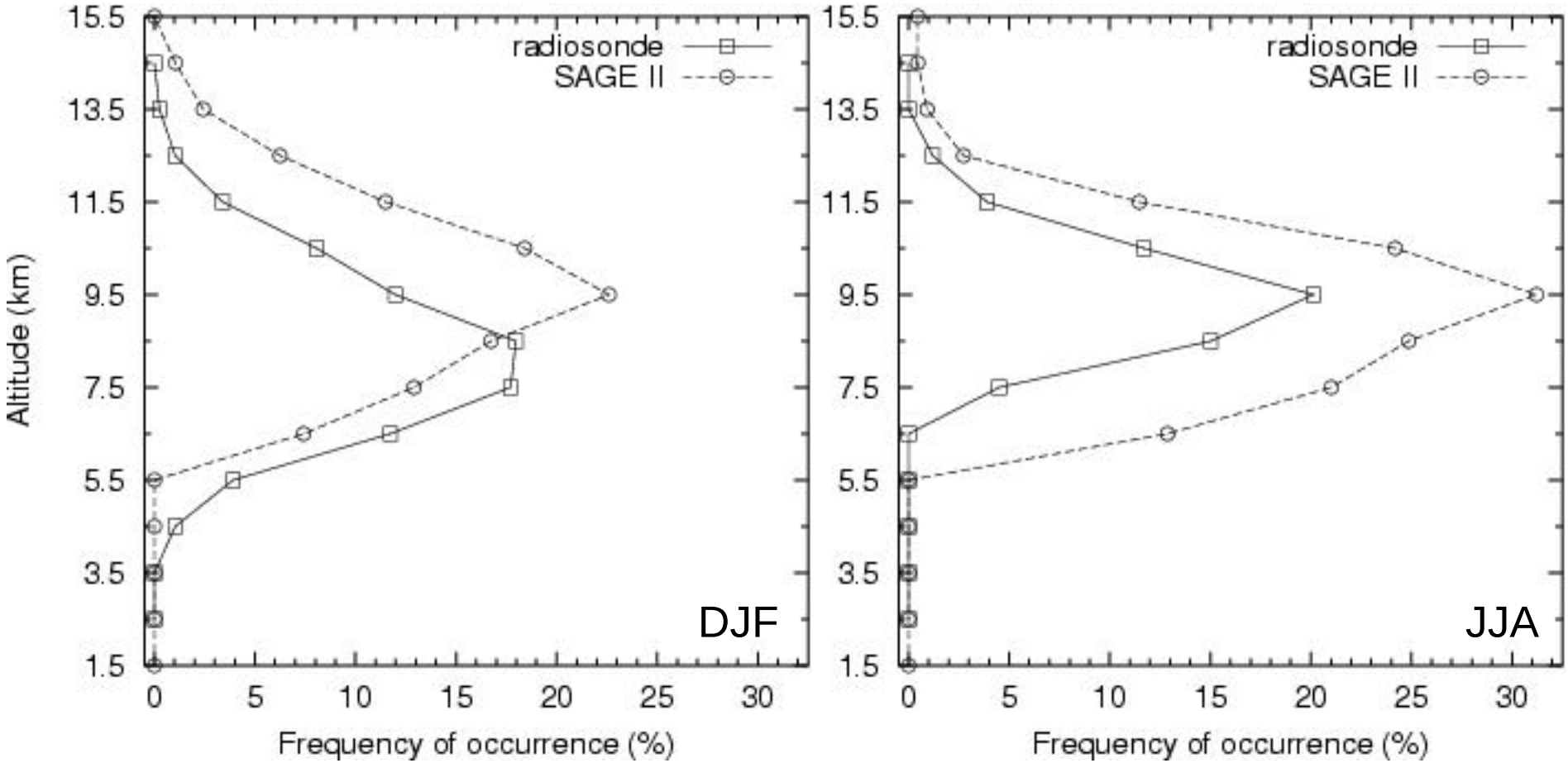
Altitudes of ISSRs wrt local tropopause (Lindenberg radiosonde)



Spichtinger et al., 2003

Cirrus and their supersaturated environment: Examples and problems

Similar altitude distribution of ISSRs and SVC (SAGE II) over Lindenberg

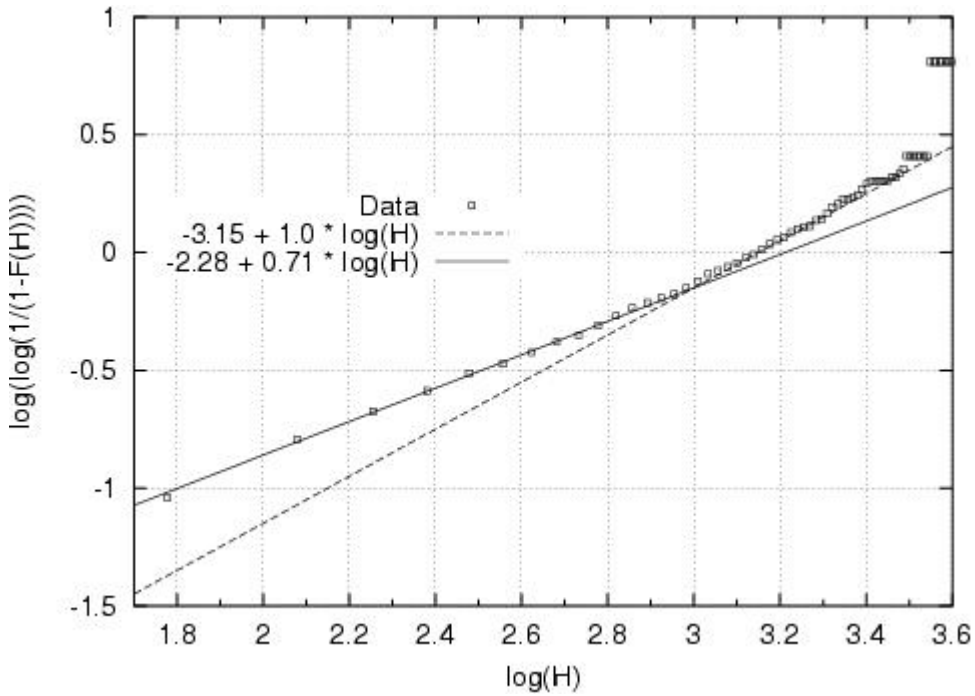


Spichtinger et al., 2003

Cirrus and their supersaturated environment: Examples and problems

Vertical extension of ice supersaturation layers is 500 m on the average, (Radiosonde data from Lindenberg, Germany), similar to SVC, but

cirrus cloud layers are typically more than 1 km thick (e.g. Sassen‘s Lidar data)



Spichtinger et al., 2003

Cirrus and their supersaturated environment: Examples and problems

Exponential pdf of supersaturation implies low probality (<10%) to reach threshold for homogeneous nucleation ($S_{i,nuc}$>40%).

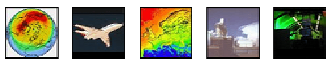
Average supersaturation is generally far below $S_{i,nuc}$.

How is it then possible to have Ci-coverage of perhaps 30%?

Furthermore:

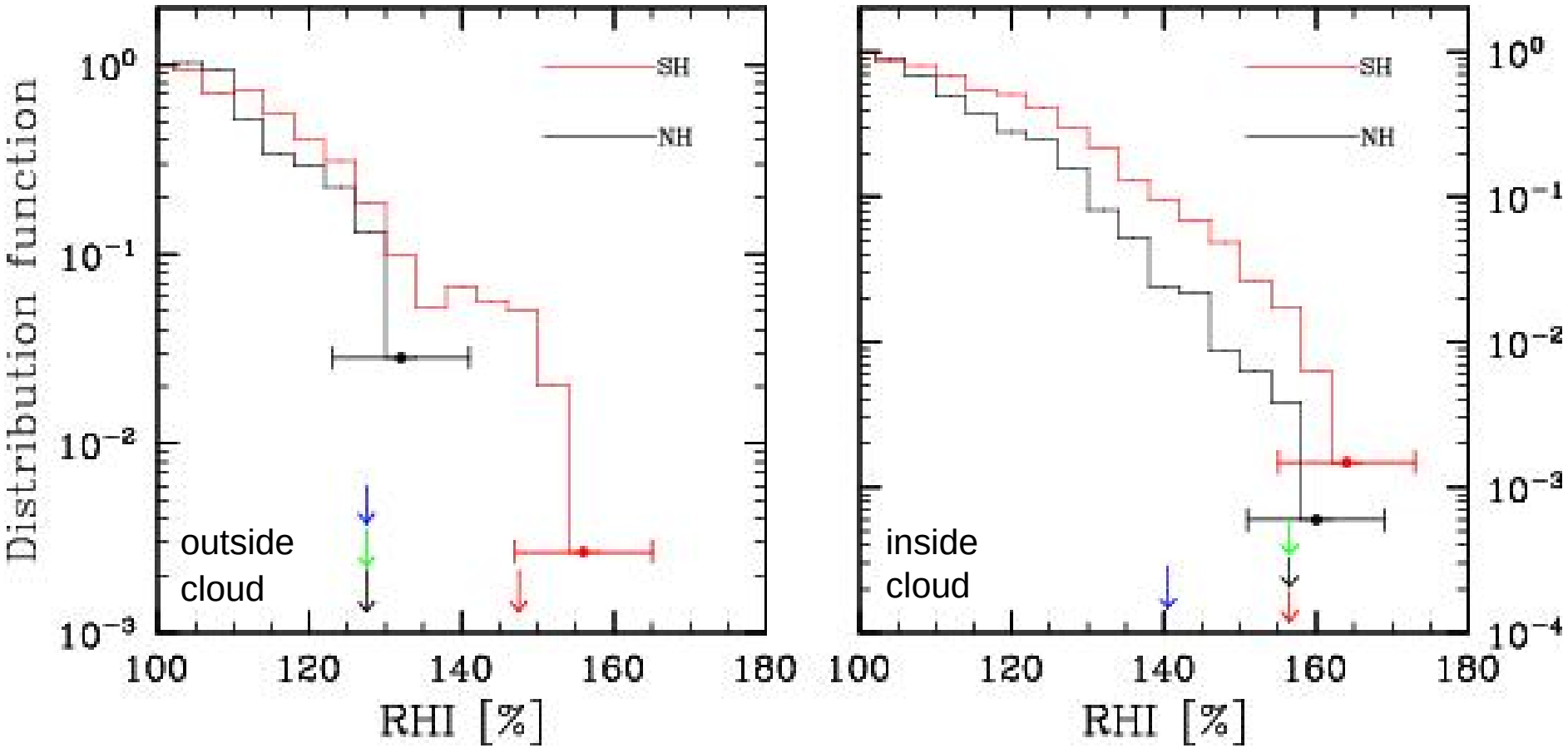
All available data sources show the fractional coverage of ISSR to be less than that of cirrus.

Not all cirrus forms within ISSRs, but we have to explain an enhancement factor of perhaps 10.



Cirrus and their supersaturated environment: Examples and problems

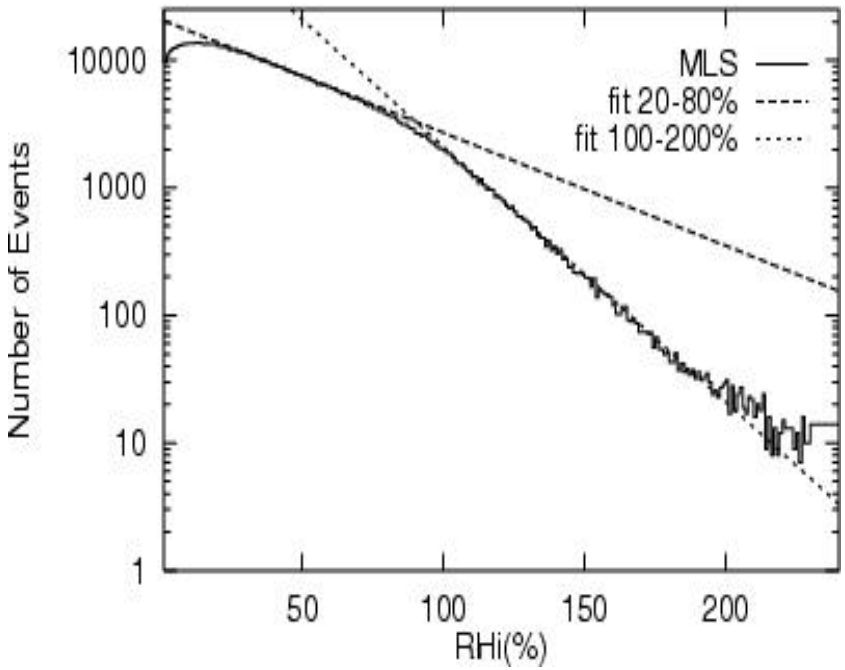
Nucleation thresholds and their effect on humidity statistics



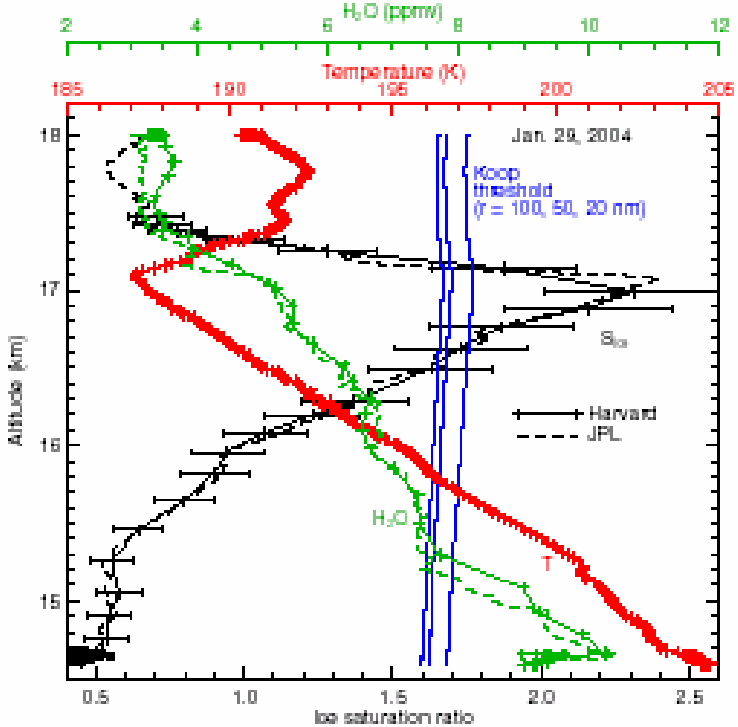
Haag et al., 2003

Cirrus and their supersaturated environment: Examples and problems

Nucleation thresholds do not show up in very large data sets (MLS, MOZAIC), perhaps because they are not always good defined



Spichtinger et al., 2002

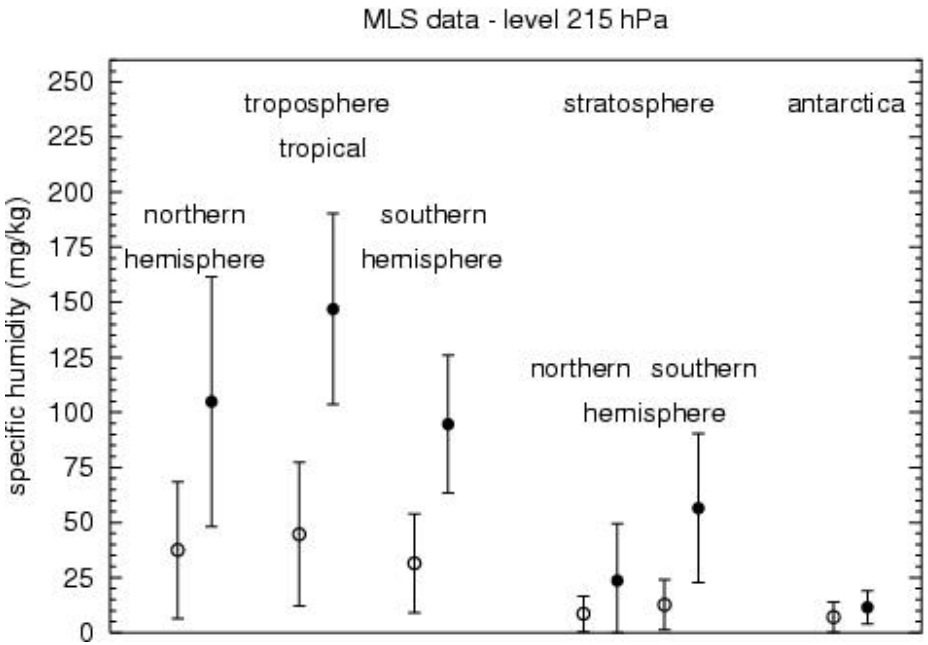


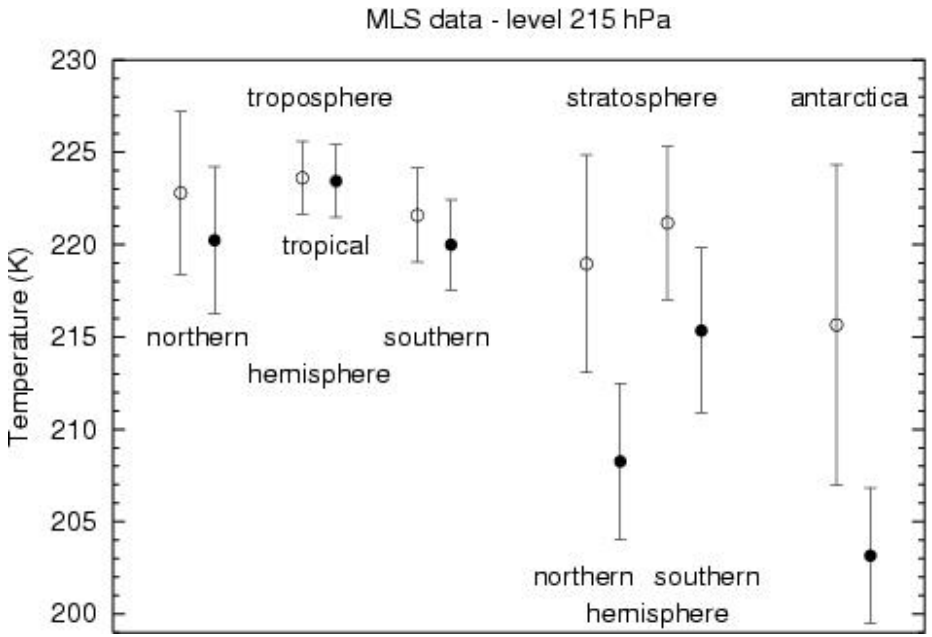
$IWC \ll 1$ ppmv (little or no ice)

Jensen et al., pre-AVE data

Cirrus and their supersaturated environment: Examples and problems

Supersaturated and subsaturated regions differ in terms of q and T, depending on prevalent processes leading to supersaturation

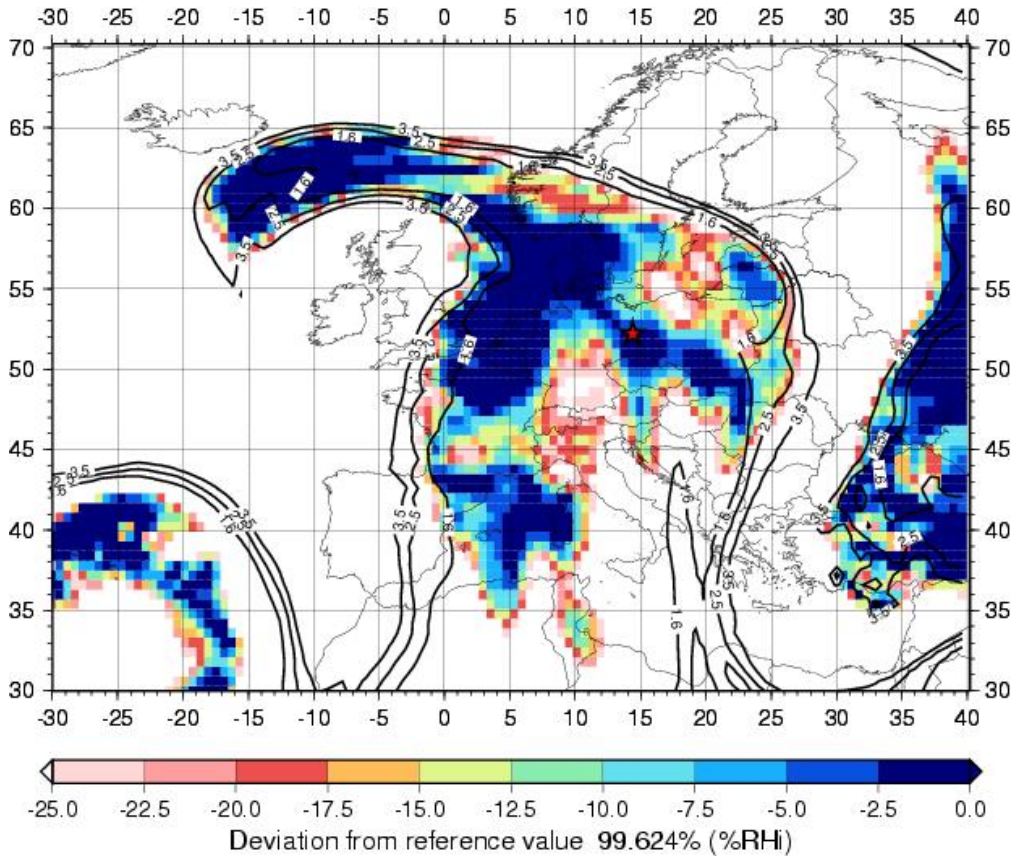




How are the corresponding contrasts for in/out-of clouds ?

Cirrus and their supersaturated environment: Examples and problems

Ice supersaturated regions could show up in meteorological analyses if the model‘s humidity fields were not constrained to RHi <100%



ECMWF analysis

p=229 hPa

Spichtinger et al., 2004

Summary and program for discussions

1.) We need representation of ice supersaturation in models

2.) We need better knowledge about the relation between Ci and ISSR

3.) We need better knowledge of vertical velocity in the UTLS

4.) We need better knowledge of nucleation and nucl. impedance mechanisms

5.) WMO should report relative humidities at T<-40°C as RHi

6.) Satellite data products like UTHi should not be constrained to values <100%

7.) .....