Ideas From Near-Global Process-Oriented Studies of Cirrus Clouds

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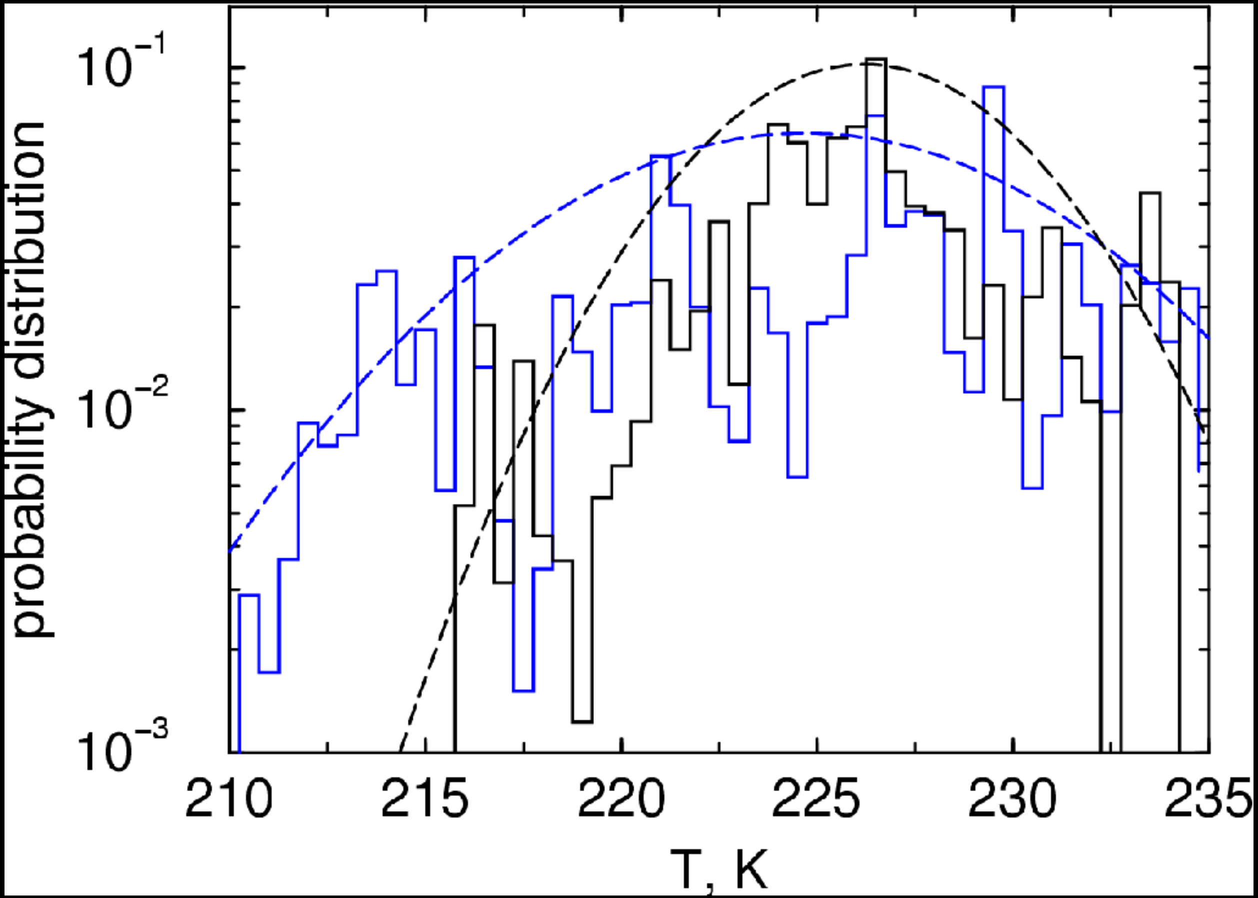
***acknowledging contributions from Werner Haag**

Temperature variability from aircraft observations

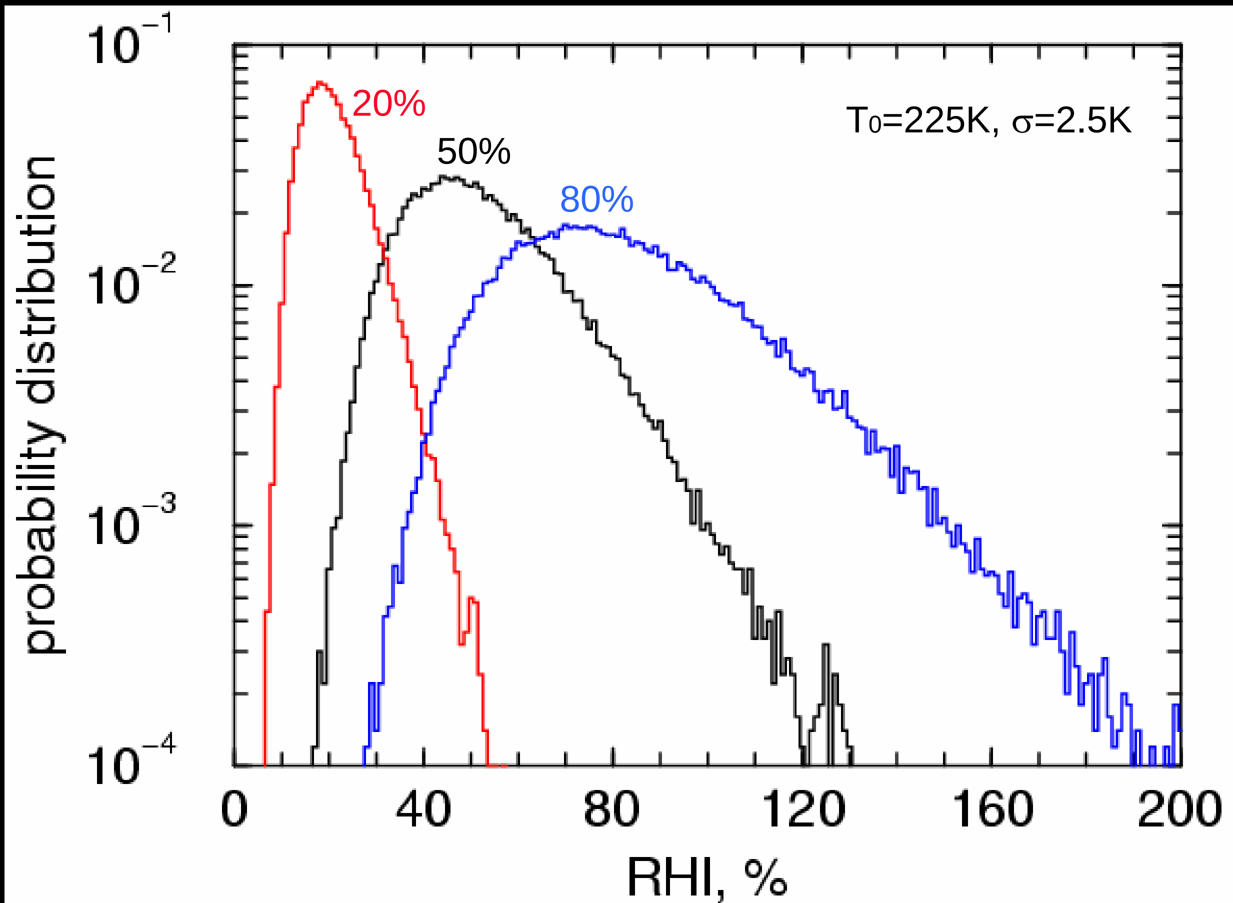
data gathered during INCA campaigns on regional scales (many 100 km)



- distribution of T may be represented by (one, better more) normal modes

- each mode represents a different air mass origin and is associated with a different H_2O mixing ratio distribution

Distributions of RHI from synoptic temperature variability

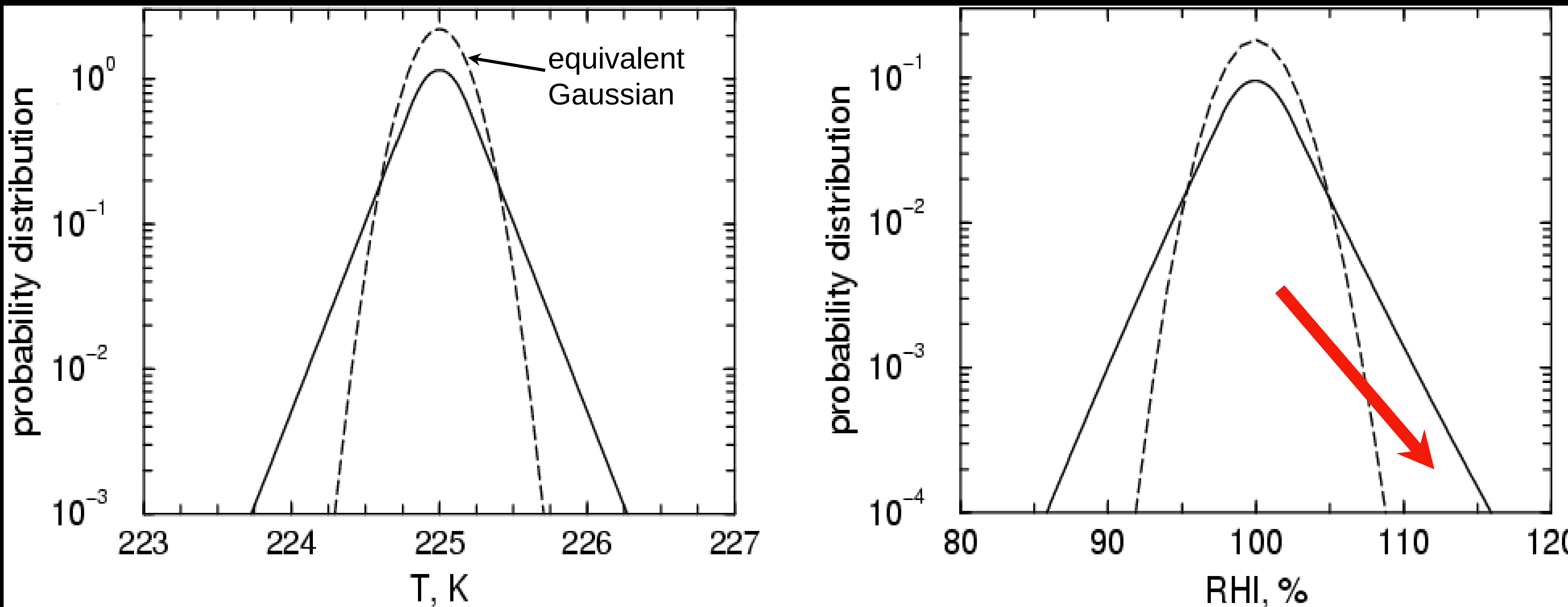


RHI ~ p_w / $p_{sat}(T)$

- letting T vary (here: single Gaussian) yields quasi-exponential tail in RHI distribution
- need to have high mean RHI in order to meet homogeneous freezing conditions

Small-scale temperature fluctuations and inferred RHI variability

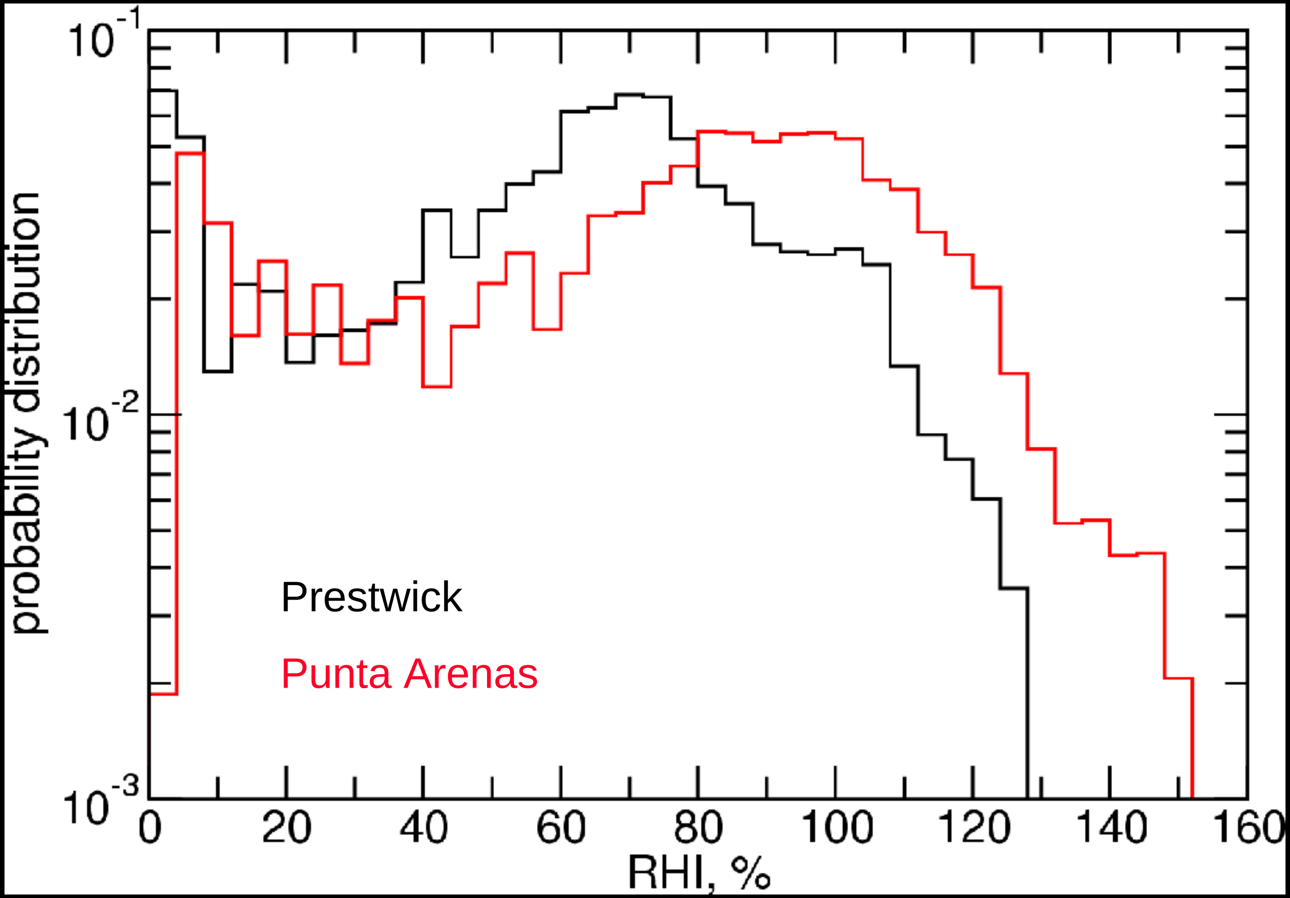
data gathered on the ER-2 on the mesoscale (here: 1-10 km)



- rapid temperature oscillations produced by buoyancy waves
- non-Gaussian wings due to intermittent large-amplitude wave events
- Gaussians provide better overall fits with increasing horizontal length scale

Observed RHI variability

data gathered during INCA campaigns on regional scales (many 100 km)



- dry and humid modes
- quasi-exponential tails

small-scale variability may be hidden in measurement error

Domain-filling trajectory calculations of cirrus properties

- Microphysical simulations based on ECMWF T-511 fields (SON 2000, NH midlatitudes) with superimposed mesoscale temperature fluctuations

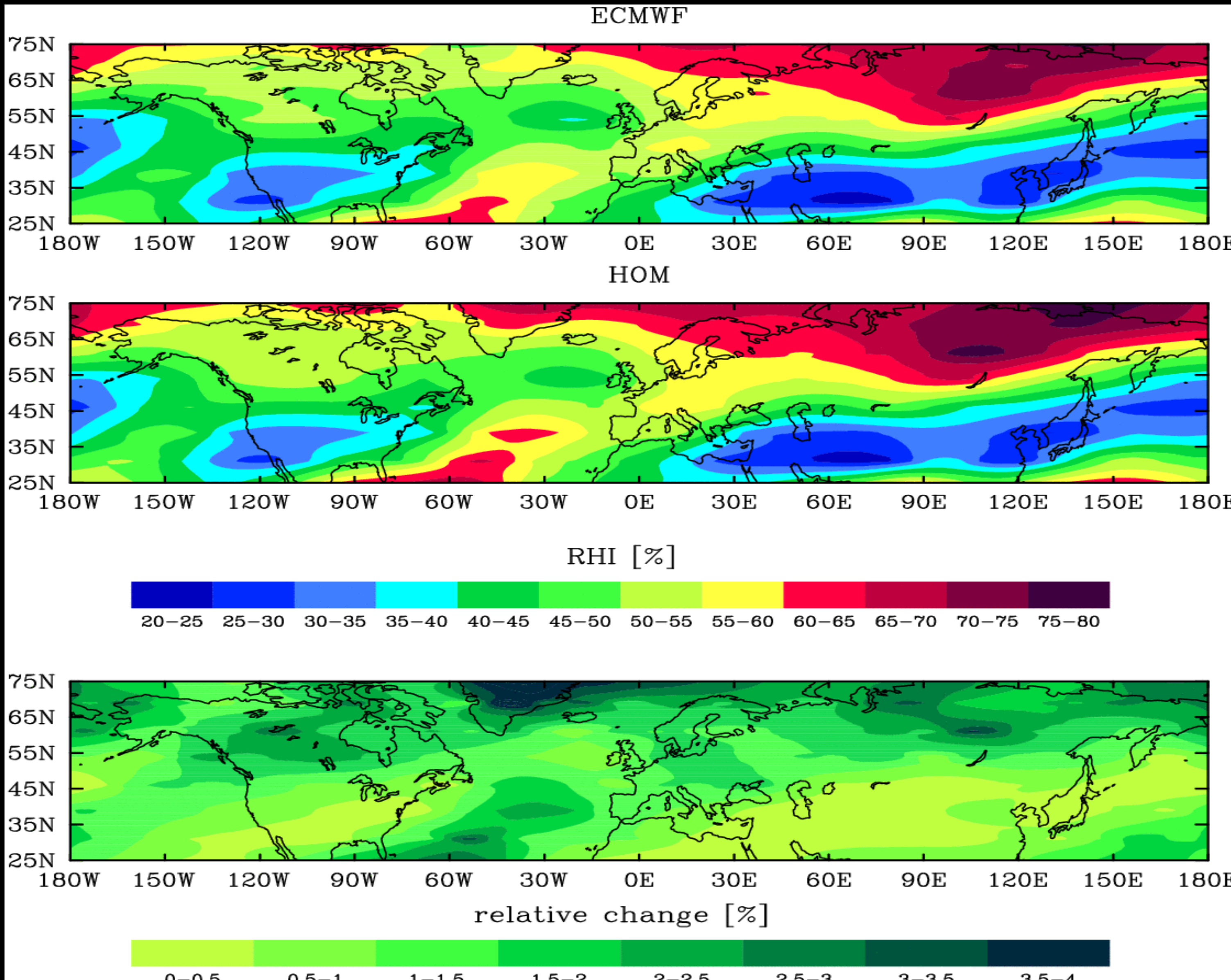
- Statistical analysis of cirrus properties in the UTLS region based on ~10,000 trajectories; here: homogeneous freezing-only scenarios

- Along each trajectory, ECMWF H_2O mixing ratios kept fixed above RHI = 95% to allow ice supersaturation to occur, otherwise reinitialized every 6 hours; parameterized loss of ice water due to ice crystal sedimentation

- Many overall results are broadly consistent with available measurements — distributions of RHI and IWC, total crystal concentrations and sizes

- Such simulations are not possible with current global models — more details in W. Haag and B. Kärcher, JGR 109, D12202, doi:10.1029/2004JD004579, 2004.

Seasonally-averaged fields of RHI

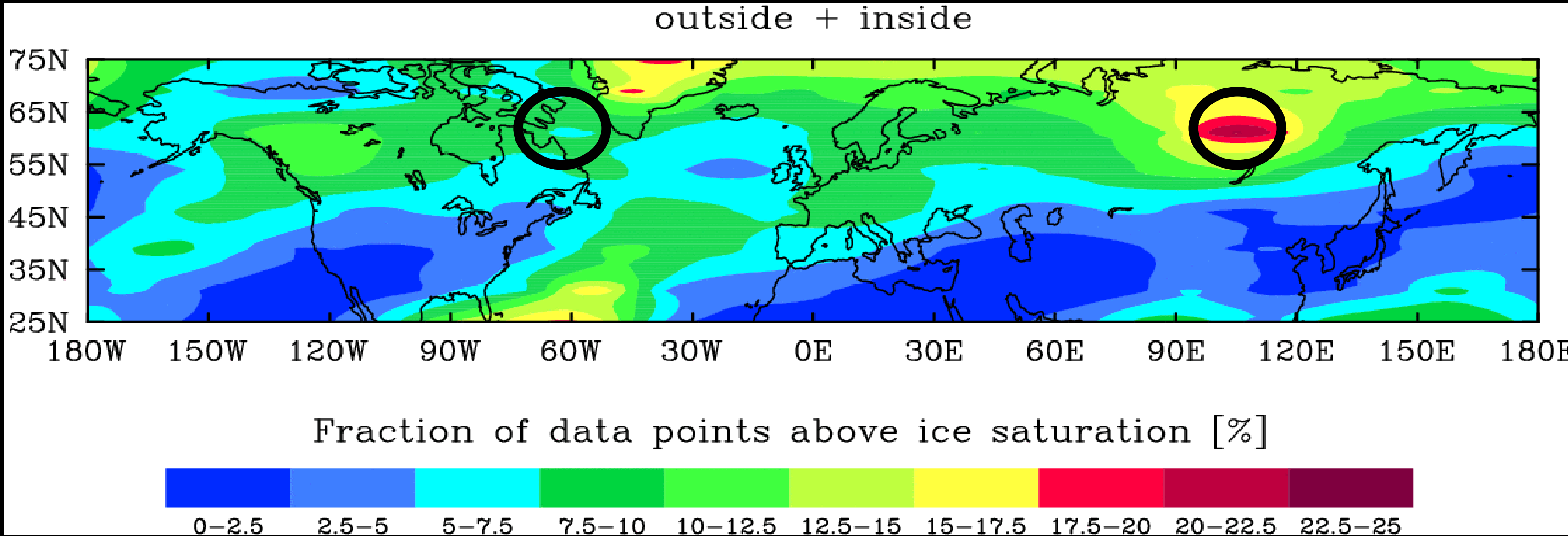


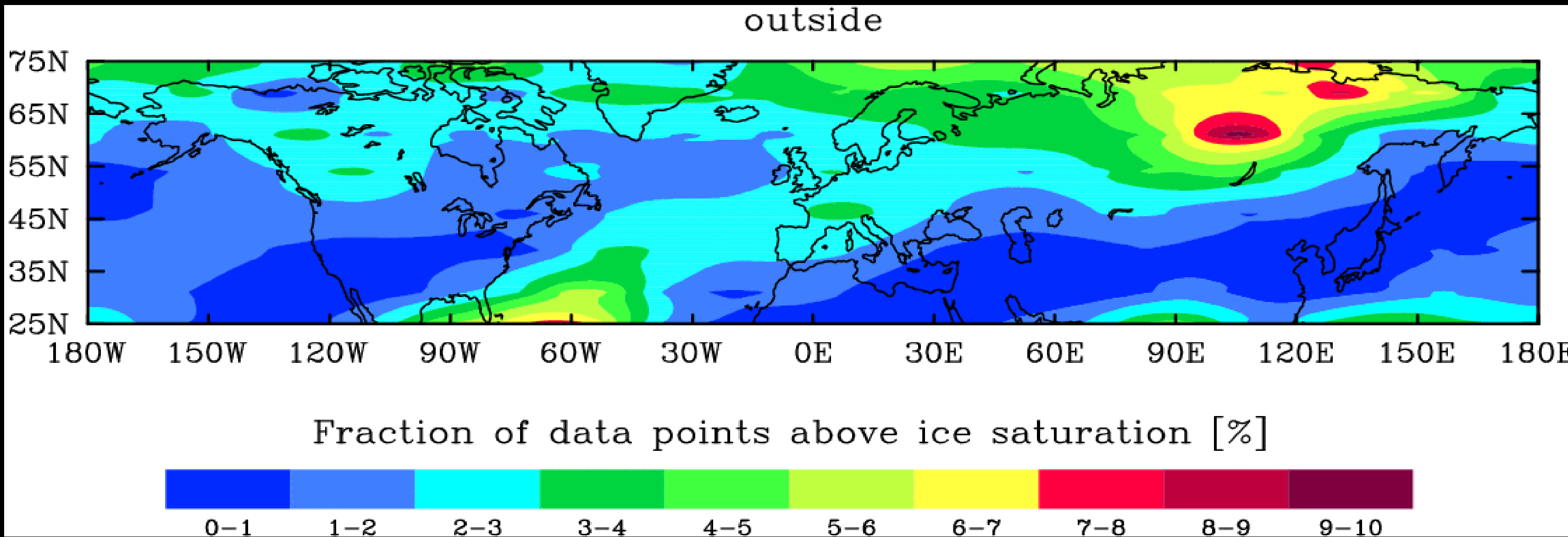
synoptic-scale only

superimposed MTF

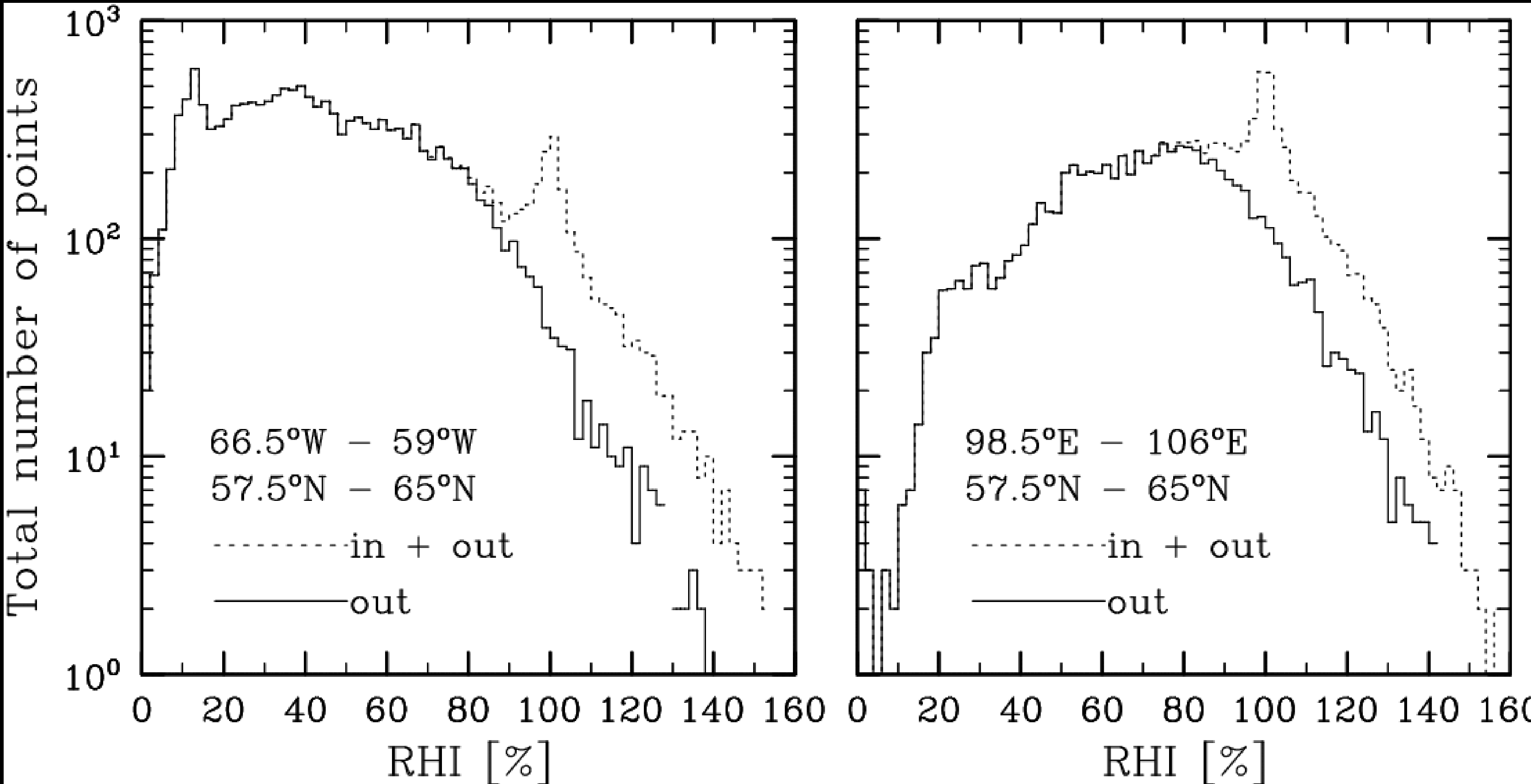
relative change

Frequency of occurrence of ice supersaturation

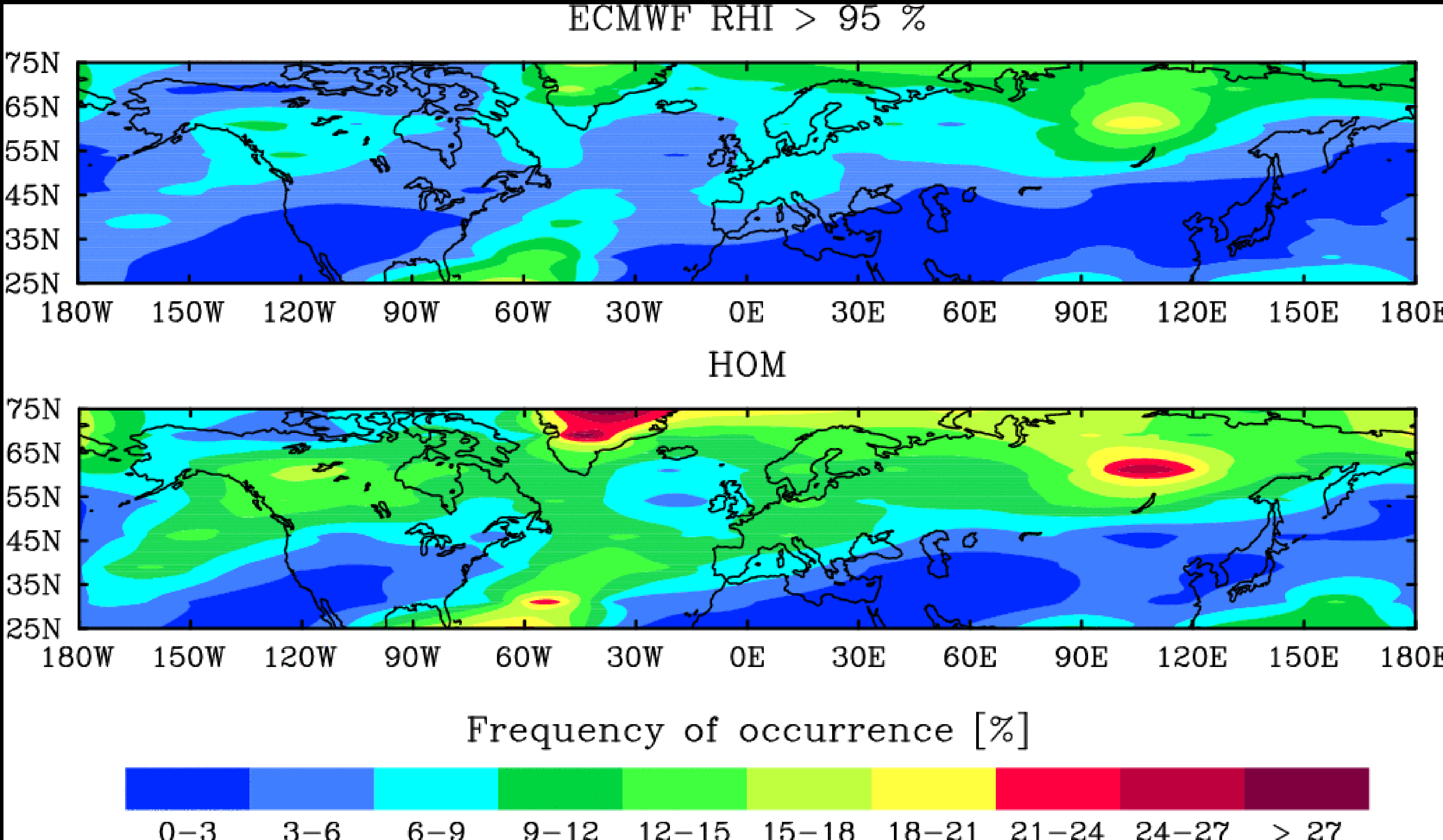




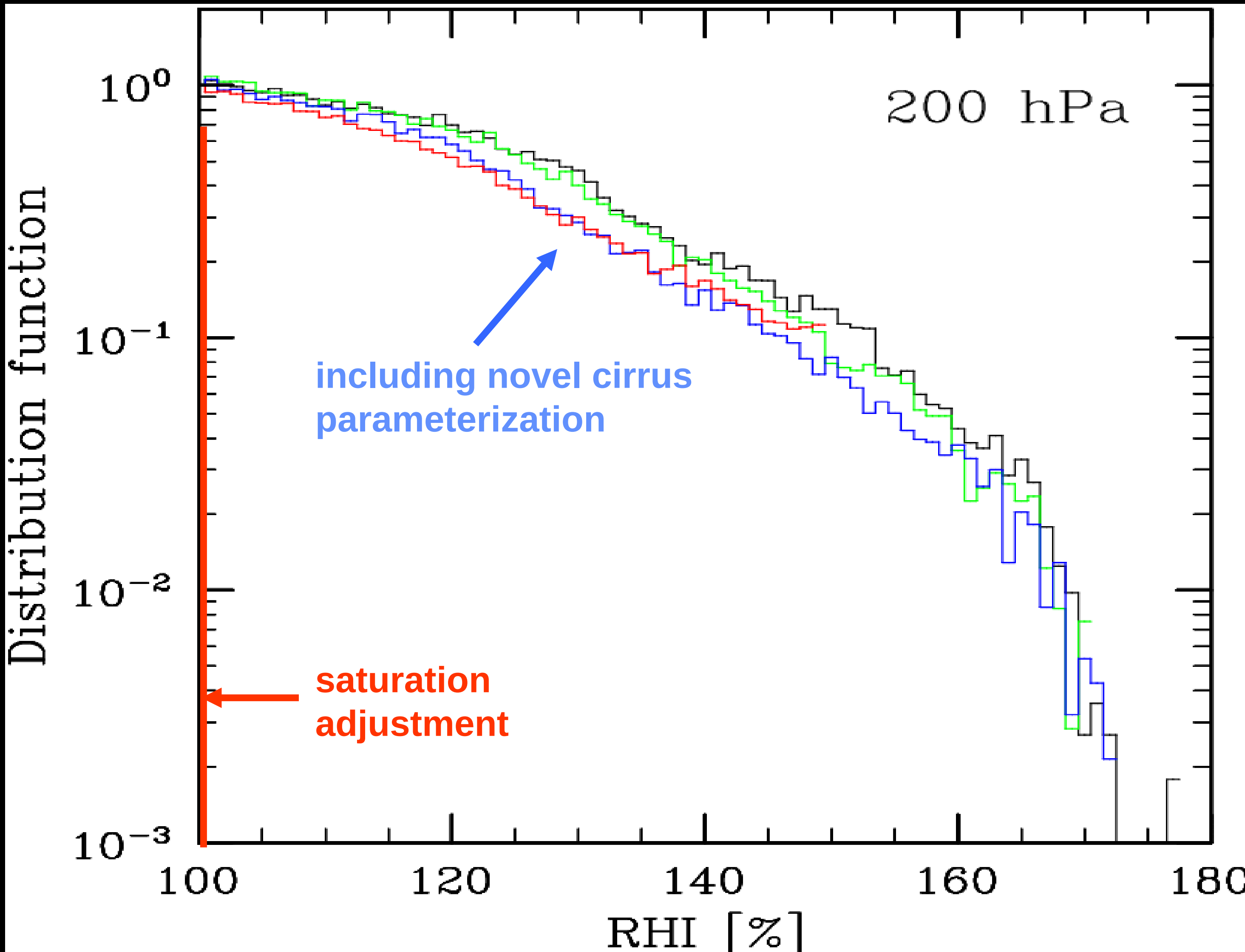
Distributions of RHI in low vs high humidity regions



Seasonally-averaged cirrus cloud cover



Distributions of RHI in the ECHAM-GCM

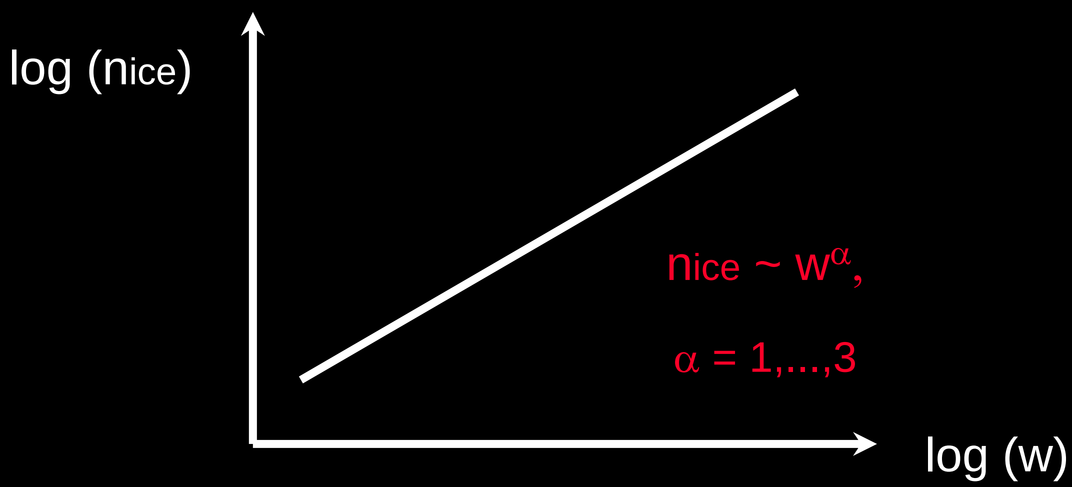


Large-scale models that do not properly account for subgrid-scale variability in vertical velocities .....

..... can simulate ice supersaturation realistically when using a physically-based parameterization scheme for cirrus formation,

but:

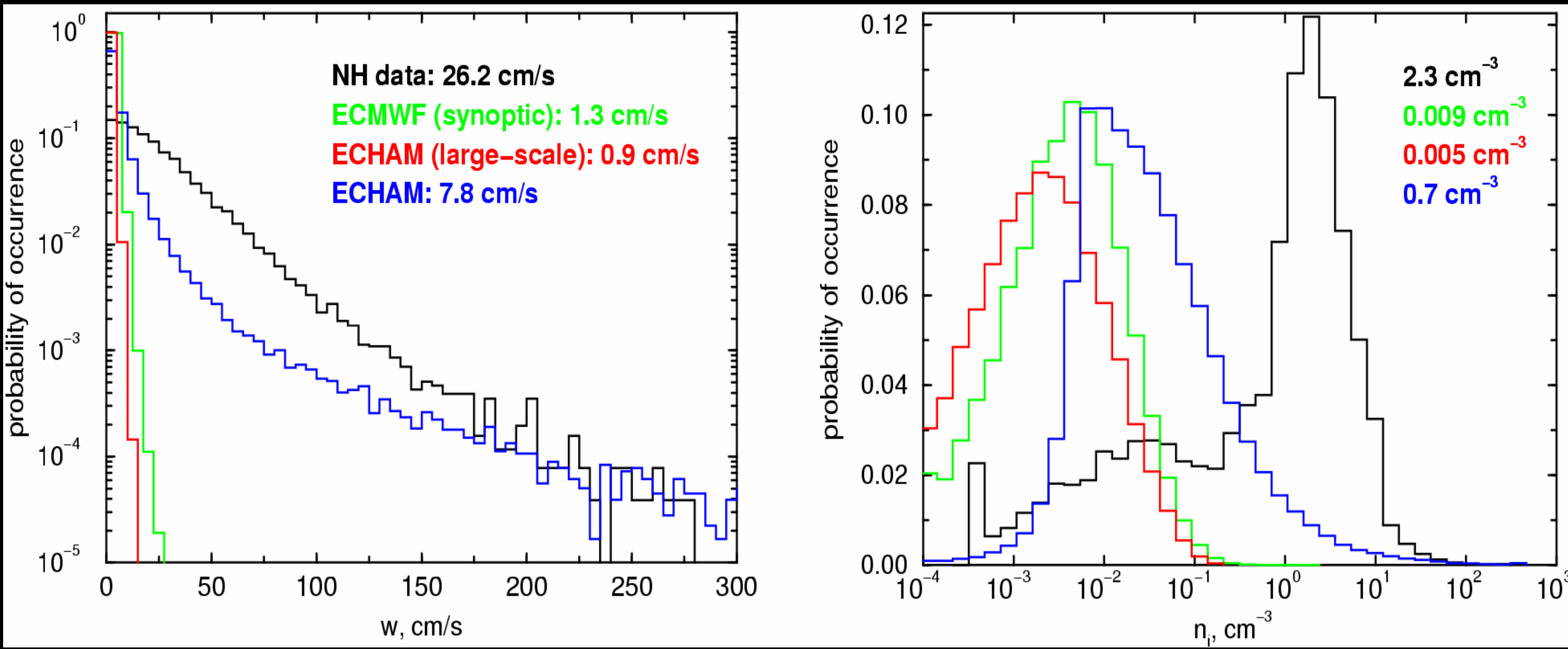
- yield erroneous predictions of the variability of basic cloud properties
- are thus unable to ascribe cause to trends of cirrus cloud properties



$w \sim dT/dt$

Calculated frequency distributions of

updraft speeds vs ice crystal conc´s



Discussion issues

Food for thought based on:

Synoptic cold pools define the overall thermodynamic conditions in which cirrus formation takes place, but cloud properties are determined by mesoscale processes.

Physical processes that determine the frequency of occurrence of cirrus (i.e., cloud cover) and the cloud microphysical properties (i.e., radiative impact) are related.

Changes in upper tropospheric cooling rates or freezing aerosols can lead to changes in global cirrus cover comparable in magnitude to observed decadal trends.

How do we develop accurate parameterization schemes for ice water path, optical depth, and fractional cloud coverage ?

How do we achieve consistency of these schemes with existing schemes for cirrus formation and initial growth ?

How do we bridge the scale gap between clouds (down to 1 m) and GCM grid box (above 100 km) ? What type of statistical information is required that captures subgrid-scale variability ?

Which type of observations and improvements in models are required to make headway ?