Cirrus clouds: observations, process modelling, parametrizations

Thomas Peter
With contributions from - Beiping Luo, Stefan Füglistaler, Heini Wernli and Conny Schwierz (The APE-THESEO Team International)

ETH Zurich, Switzerland

Some issues:

• What determines stratospheric humidity – Ci or deep Cb's?

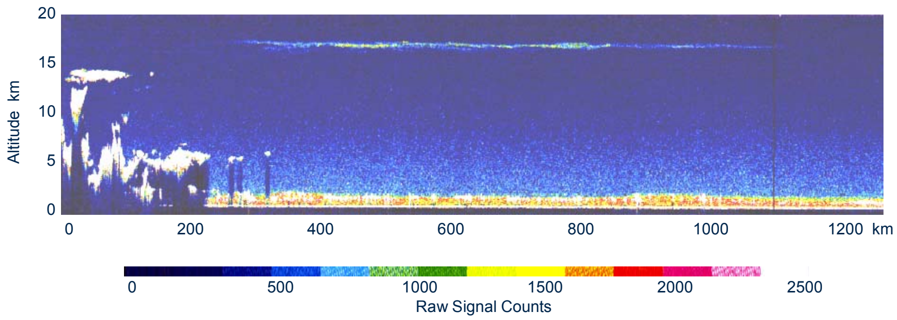
• How do Ci nucleate, how are they maintained?

• How does air undergo TST after the last encounter with the ice phase?

LITE measurements

Lidar In-space Technology Expt (Space Shuttle, Sept 1994)

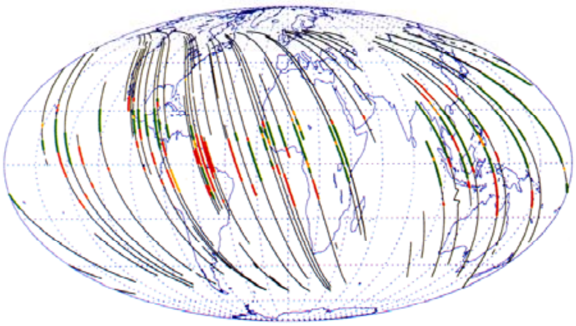
Winker & Trepte, GRL '98:
"Laminar cirrus observed near the tropical tropopause"



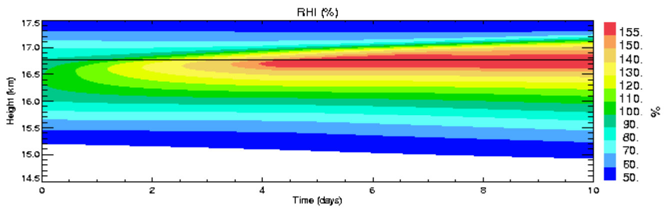
Color-coded backscater at 532 nm over western Pacific Ocean

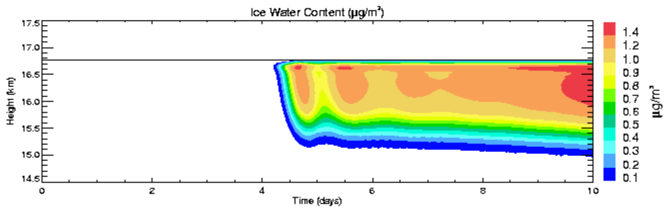
LITE cirrus climatology

Clouds with tops > 15 km:
- thinner 1 km, laminar, in 14 % of all obs.
- deep convection or Ci thicker 1 km
- thinner 1 km above deep convection



Cirrus modeling based on homogeneous nucleation of ice

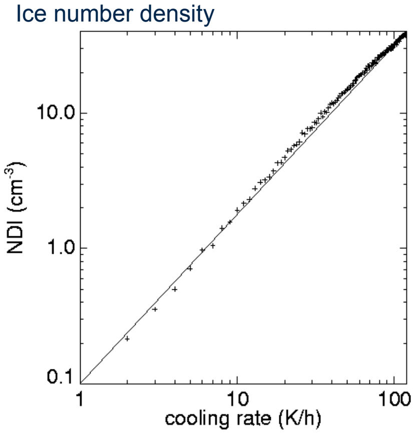




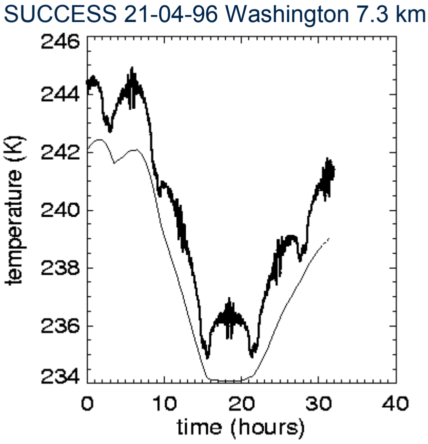
Jensen et al., JGR 2001

Impact of ubiquitous gravity waves on cirrus nucleation

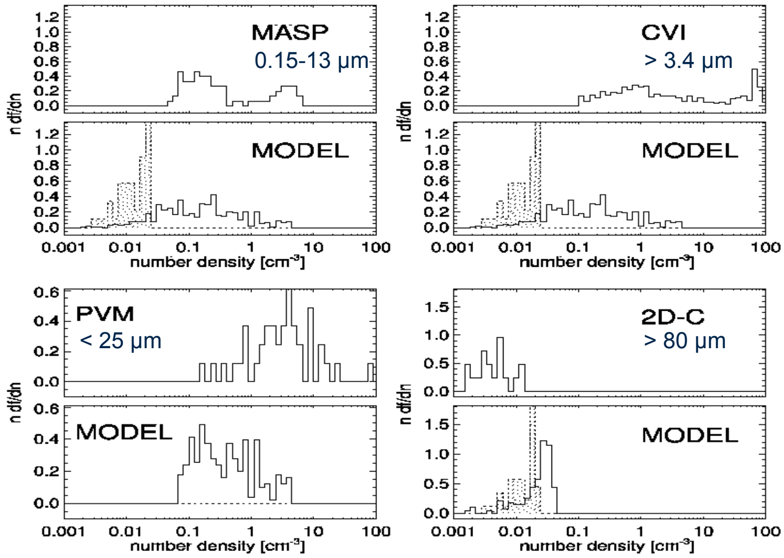
Ice number density



SUCCESS 21-04-96 Washington 7.3 km



Cirrus during SUCCESS 21-04-96, coast of Washington, 7.3 km altitude



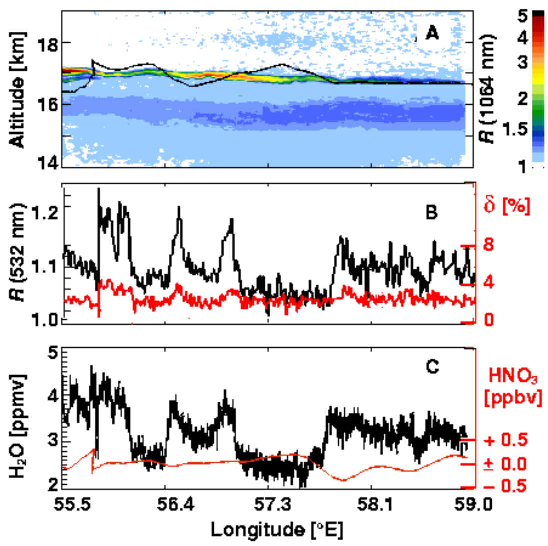
Ubiquitous gravity waves enhance number densities and reduce sizes of ice crystals in cirrus clouds

What makes Ci good dehydrators ?

Particle number density inside Ci
needs to be sufficiently low,
otherwise particles stay too small !

The higher the lower edge of Ci the
more favourable for obtaining the
lowest possible water mixing ratio

Ultrathin Tropical Tropopause Clouds UTTCs



APE-THESEO Mission, Seychelles Feb/March 1999

Zoom of 400 km long detail of flight on 27 Feb 1999

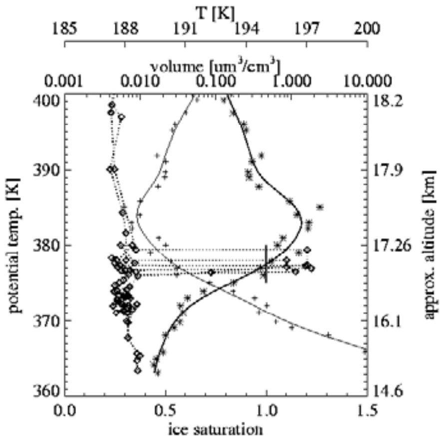
Luo et al., Peter et al, GRL, ACPD, 2003

APE-THESEO measurements of particles and H_2O

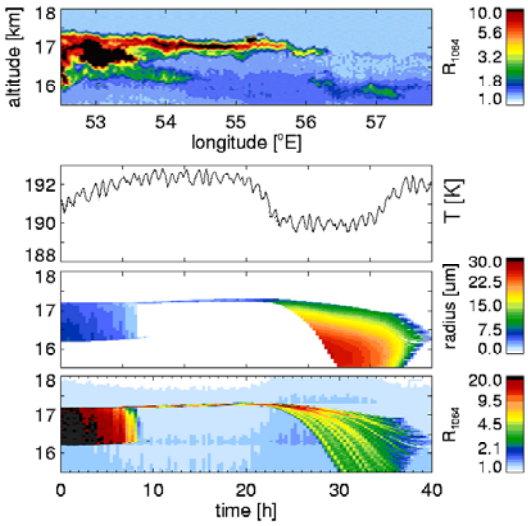
Supersaturation above UTTC, subsaturation below

→ vertical stabilization in a laminar upward wind field

requires ~ 5 mm/s !

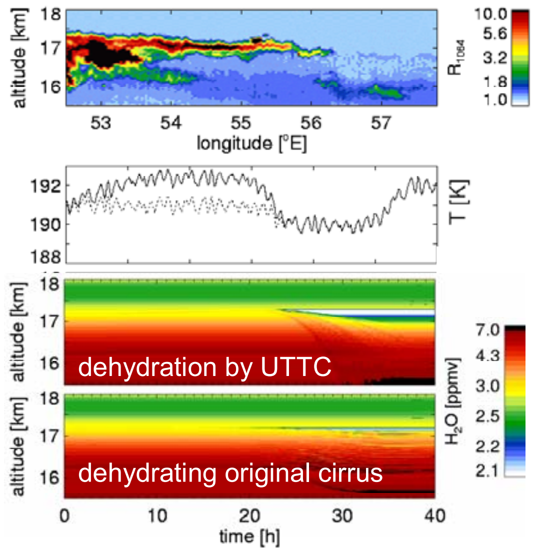


UTTC Modeling



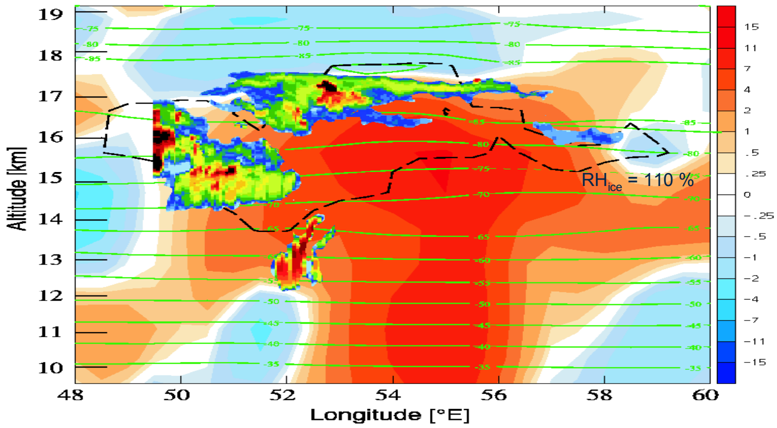
Evolution of a UTTC originating from an evaporating cirrus

UTTC Modeling



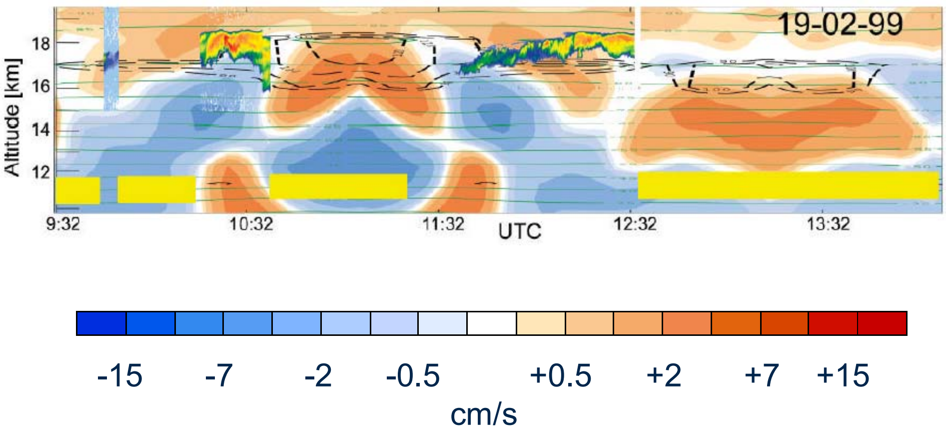
Evolution of a UTTC originating from an evaporating cirrus

ECMWF wind field

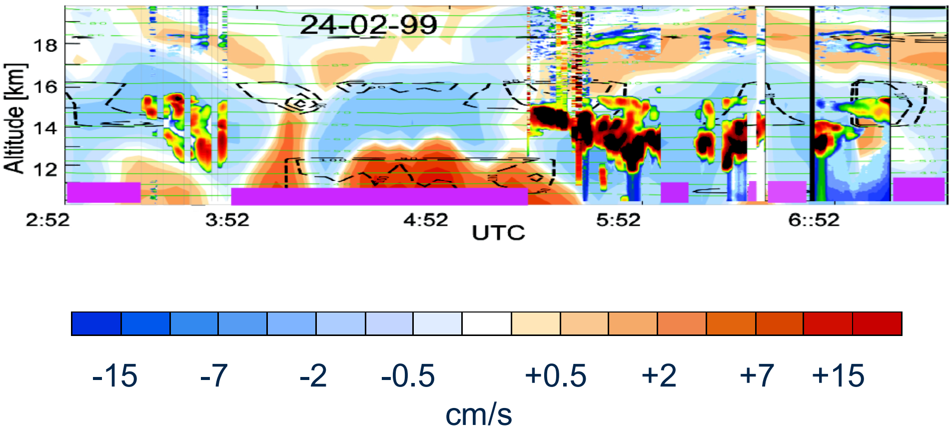


ECMWF operational data 6 UTC 27 Feb 99
→
existence of mesoscale upward motion and high relative humidity just below the cold point tropopause

Upwelling + high RH → UTTCs



Upwelling + high RH → UTTCs



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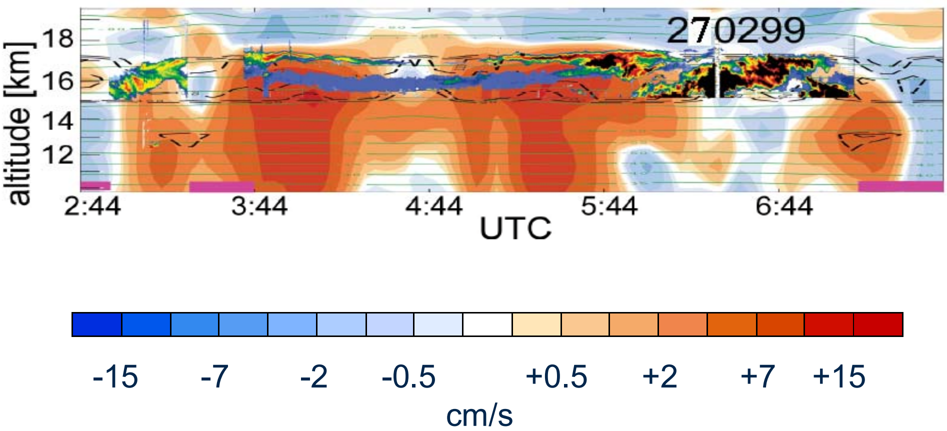

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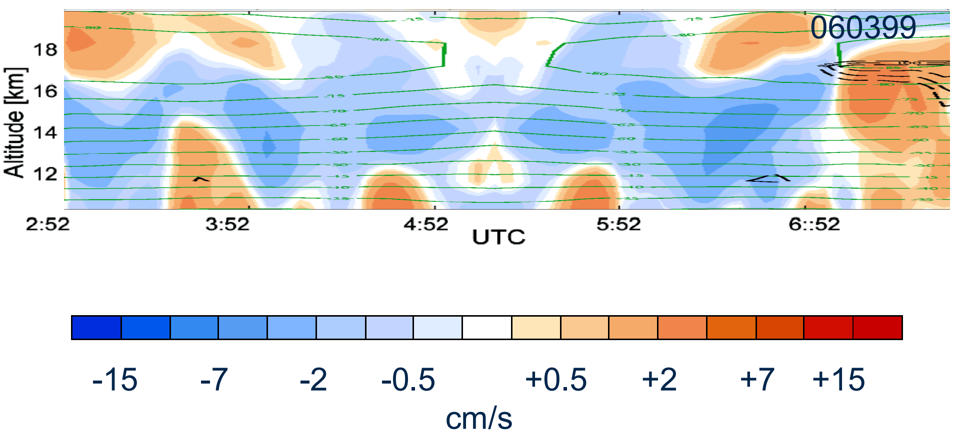

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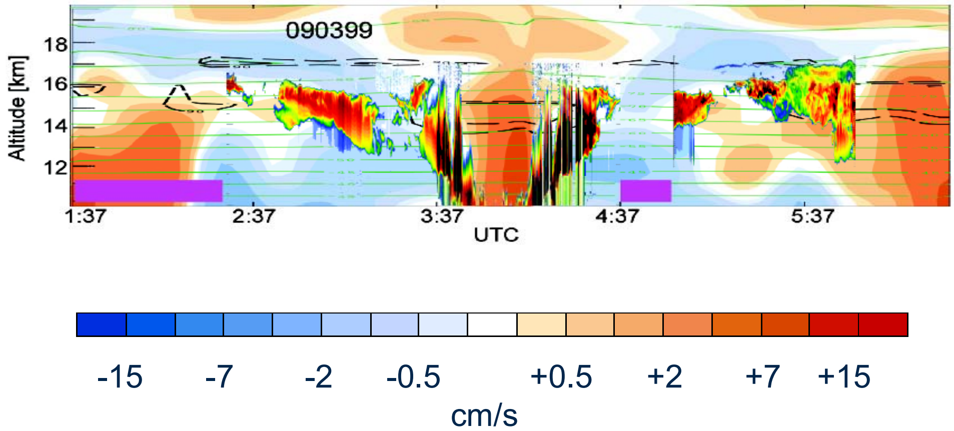

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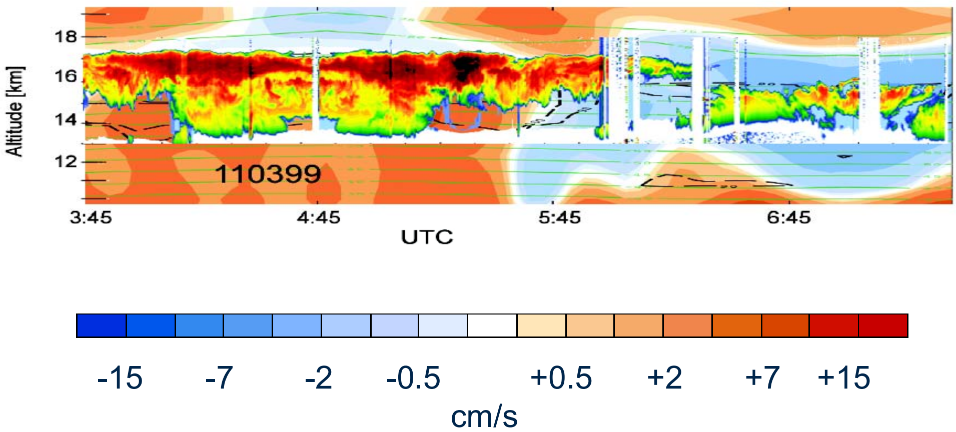

UTTC statistics

19 hours of airborne aerosol lidar observations	Fraction of observations		Correlation with ECMWF vertical wind (> 5 mm/s) and RH_{ice} (>90 %)
Thicker cirrus without UTTCs	40 %		none
Thicker cirrus and UTTCs	19 %	31 %	92 %
Only UTTCs, no thicker cirrus	12 %		
Clear sky	29 %		100 %

Remarkable correlation of UTTC occurrence with *w* and RH_{ice}

Summary

- High tropical Ci need to have low particle number densities in order to develop particles sufficiently large for dehydration
- UTTCs are (often) the last point of contact of the air with the ice phase – they are ideal dehydrators
- UTTCs are ice crystals with $r \sim 5$ µm requiring $w \sim 5$ mm/s, i.e. 10-times higher than expected from zonal average
- ECMWF analysis offers such large upwelling in the regions where UTTCs were observed, but the reason is unclear
- Trajectories based on ECMWF analyses suggest the maritime continent as major source for stratospheric air
- Though in surprising agreement with UTTC observations, quality of vertical wind and heating rates remains questionable