Subvisual cirrus and dehydration in the tropical tropopause layer: Observations from Paramaribo / Suriname

Franz Immler
Alfred Wegener Institute, Bremerhaven, Germany
Outline

• The MARL lidar system
• The STAR pilot study
• Interpretations using trajectory analysis
• Concusions
LIDAR: basic principle

scattering at molecules and particles

P(t) = P(h / 2c)
The MARL container
AWI 002

- Air conditioned container, with automated hatch, rain sensor etc.
- Continuum 9030, Nd:YAG 300 mJ 532,355 nm 30 Hz
- 1.1 m Cassegrain telescope

10 channel detection:
- 532 nm II L
- 355 nm II L
- II far and near field
- 1064 nm
- 387 nm $N_2$ Raman
- 607 nm $N_2$ Raman
- 407 nm $H_2O$ Raman
Lidar Signals

355 nm (elastic backscatter)

387 nm (inelastic (Raman scattering at N₂ molecules))

407 nm (inelastic (Raman scattering at H₂O molecules))
Ground based and ship-borne measurements in the Tropics

- **POLARSTERN**
  - ANTXII/4 May/June 2000
  - ANT XXI/1 Oct/Nov 2003
  - ANT XXIII/1 Oct/Nov 2005
  - Lidar, RS, FTIR, sun photometer

- **STAR pilot study (20.9.-16.11.2004, 19.2.-10.03.2005)**
  - EU project (FP6)
  - Paramaribo/Suriname (5.8° N, 55° W)
  - Lidar, RS80, **Snow white**, FTIR, sun photometer, UV spektral radiometer

![Map of the Tropics](image)
Lidar observations of tropical cirrus clouds
Paramaribo, 28.09.2004
Lidar observations of tropical cirrus clouds
Paramaribo, 30.09.2004
Lidar observations of tropical cirrus clouds
Paramaribo, 06.10.2004
Frequency of occurrence

Snow White RHi versus Lidar depolarization (STAR I)

12km < h < 18km

Relative frequency of relative humidity by SnowWhite (%)

- Volume depol 532 < 0.02
- Volume depol 532 > 0.02

12km < h < 18km
Trajectory analysis of clouds in the TTL

• Trajectories calculated from ECMWF horizontal winds and diabatic heating for the vertical component.

Information on:
• Conditions of Formation/Existence
• Dehydration
• Convective overshooting versus large scale ascent
Visible Clouds on 9. Nov. 2004
optical depth about 0.1
Backward trajectories and Satellite image

Clouds came from deep confection, about 3 day ago
Paramaribo, 02.10.2004

Alfred-Wegener-Institut, Cloud Measurement by MARL
PARAMARIBO 02.10.2004 02:05:22 to 02.10.2004 07:58:49

Cirrus from convective outflow

Cirrus formed in slow updraft

07:00 08:00
02/10 02/10
UTC

RII 532

0.9 1.2 1.6
2.1 2.2 5.2
3.2 9.2
16.6

10 12 14 16 18
-30 -20 -10 0
days

AWI
Thin ice clouds in the TTL

- Cold point tropopause
- Upper tropospheric inversion

Diagram showing alt/km and backscatter ratio against temperature (K).
Water vapor along a trajectory with dehydration
Paramaribo, 16.11.2004

Alfred-Wegener-Institut, Cloud Measurement by MARL
PARAMARIBO, 15.11.2004 19:37 to 16.11.2004 07:50

Radiosonde launches:
16.11.04 06:25
Paramaribo, 16.11.2004

Mean values in TTL:
- RHI SW = 65%
- RHI traj = 68%
Correlation
Relative humidity from Snow White vs trajectory

![Graph showing correlation between measured relative humidity and rel hum ice from trajectories.](image)
Correlation between temperature history of an air parcel and occurrence of clouds:

- Trajectories describe the TTL very well.
- When \( T(t_0) = T_{\text{min}} \), \( (RHI_{\text{Ice traj}} > 100\%) \) → clouds exist
- No information on formation conditions! (Small scale process)
- When the \( RHI_{\text{Ice traj}} < 80\% \) there are in most cases (80%) no clouds observed:
  → air was dehydrated.
Summary: TTL cirrus

• Thin, subvisual cirrus are very abundant in the tropical tropopause region (TTL) above 15 km altitude. Cirrus coverage:
  – 55% in midlatitude
  – 88% in tropics
• Outflow from deep convection creates cirrus at lower altitudes (up to 15 km).
• TTL lower boundary is marked by an inversion (UTI, upper tropospheric inversion, dT/dh > -4 K/km, dh ca 200 m).
• Generally, air inside TTL slowly ascends.
• Where it reaches a minimum in Temperature, clouds are present.
• Clouds efficiently dehydrate air.
• Extremely thin clouds at tropopause are unlikely to be simple ice clouds: NAT?
Transport in the TTL

Corti et al. ACPD 2006
Paramaribo

Alfred-Wegener-Institut, Cloud Measurement by MARL
08.10.2004 00:00 to 15.10.2004 06:00

altitude / km

** Cloud cover (0 - 1)
Paramaribo, 16.11.2004

- Cloud slightly above the tropopause
- All data indicate that air is not saturated with respect to ice
- $r = 5\mu m \rightarrow N = 1 \text{ l}^{-1}$, only about 0.1% of total water is condensed
  $\rightarrow$ no ice cloud!
Outlook

• New campaign in Paramaribo in Oktober/November 2006 funded by the EU project ACCENT (ACLIT) using the new lidar system ComCAL.
• More shipborne measurements aboard 'RV Polarstern' (H2O focus, EUMETSAT).
• Tropical station in Meridá / Venezuela.
The End

Thanks to:

Ingo Beninga      impres
Wilfried Ruhe     impres
Özden Terli       AWI
David Kaiser      AWI
Tom Weinzierl     UB
Paul Fortuin      KNMI
Ge Verver         KNMI
Cor Becker        MDS
The MDS staff     MDS