Recent Results using the DLR Airborne 2µm-Wind and Water Vapour Lidars

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Recent Airborne Measurement Campaigns

- **2µm Wind Lidar**
  - **NA_TReC 2003** Iceland — Wind Measurements over the North Atlantic
- **Water Vapour DIAL**
  - **IHOP 2002** Oklahoma — Boundary Layer, Free Troposphere
  - **MIPAS-Validation 2002** Italy — Lower Stratosphere (Mid-Lat)
  - **TROCCINOX 2003** Brazil — Upper Troposphere (Tropics) Free Troposphere

The Falcon 20 D-CMET

Overall length	17.2 m
Wingspan	16.3 m
Maximum takeoff weight (MTOW)	13.2 t
Engines	Garret TFE 731-5BR-2C
Maximum Altitude	45000 ft (13.7km)
Maximum Range	3700 km (2000 nm)
Maximum Endurance	5:30 h
Maximum Payload (with max fuel)	1.1 t
Maximum Speed (TAS)	917 km/h (0.865 Mach)

National Atlantic Regional THORPEX Campaign (NA-TReC)

November/December 2003 - Iceland

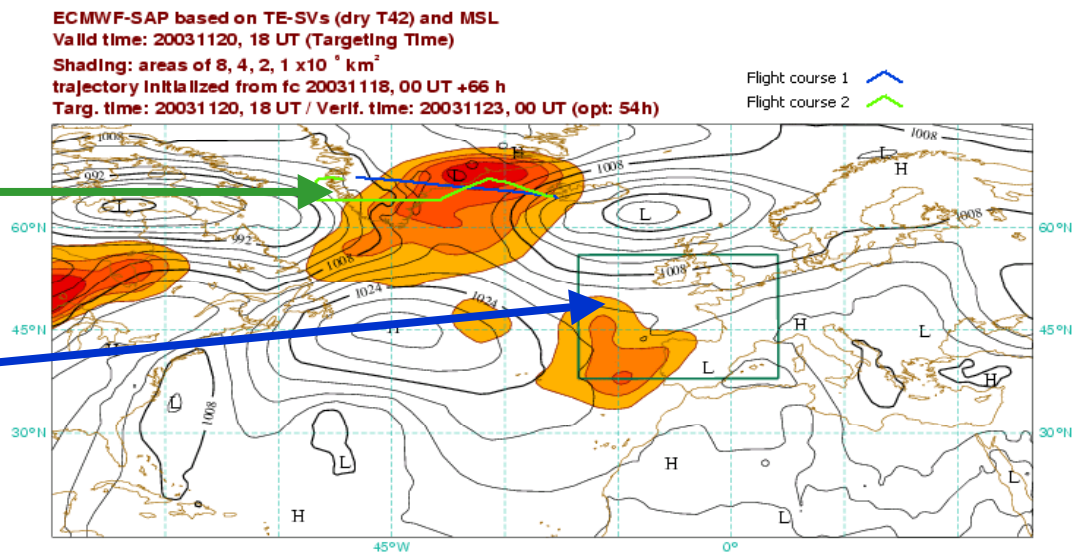
Goals:

Improve Numerical Weather Forecast by Targeted Observations

Wind Lidar Measurements over the North Atlantic

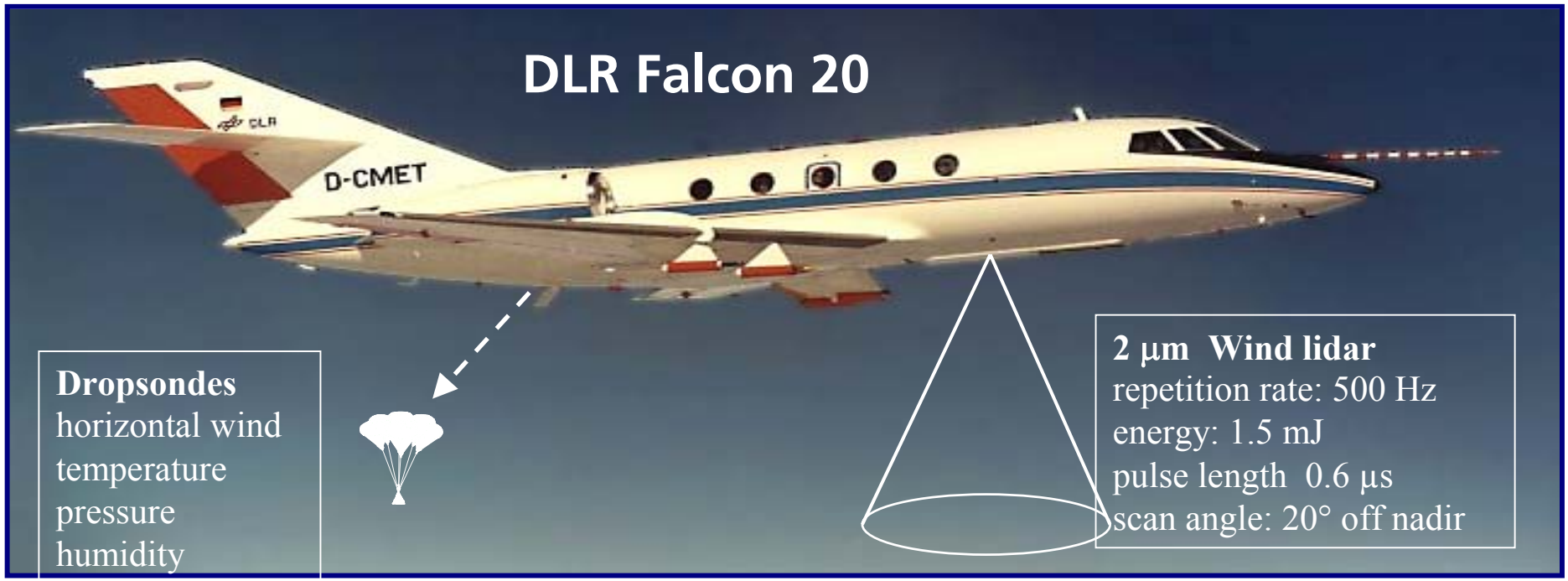
Target Area

Observation Area



National Atlantic Regional THORPEX Campaign (NA-TReC)

November/December 2003

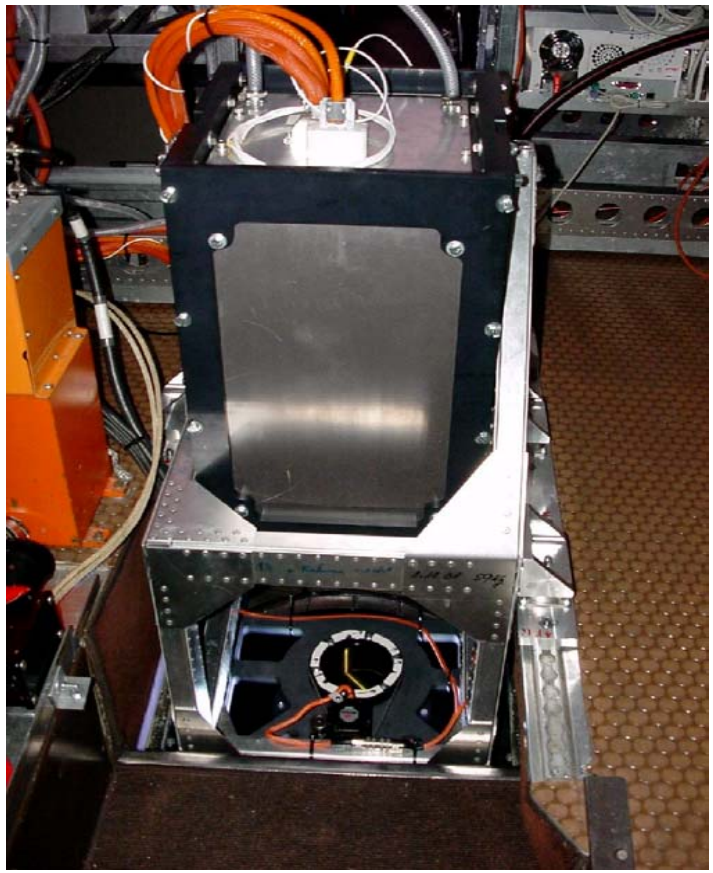


- 8 flights: 5 TReC cases + 2 transfer flights + ENVISAT SAR validation
- 30 flight hours
- 1594 Wind profiles, 40115 good values (~25 values per profile)
- Comparison with 35 dropsondes

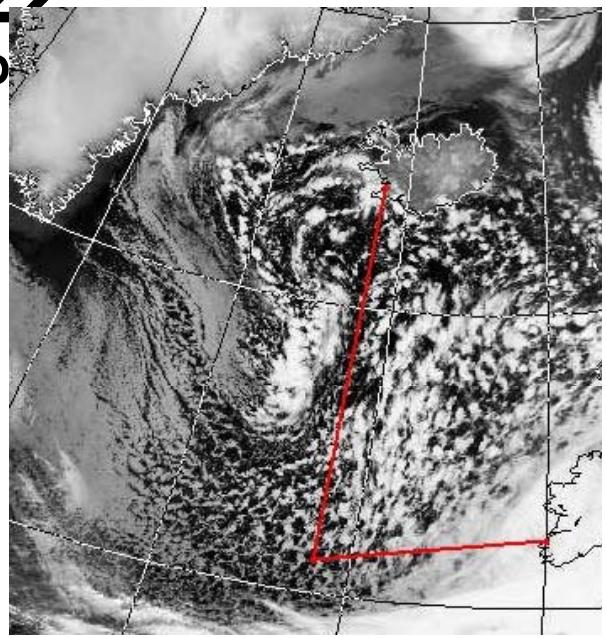
http://www.pa.op.dlr.de/na-trec/

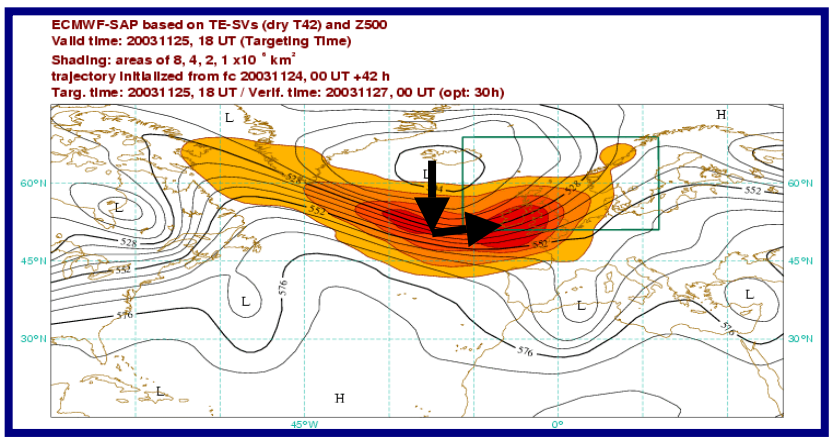
Coherent Airborne Doppler Lidar at 2µm

2 µm lidar

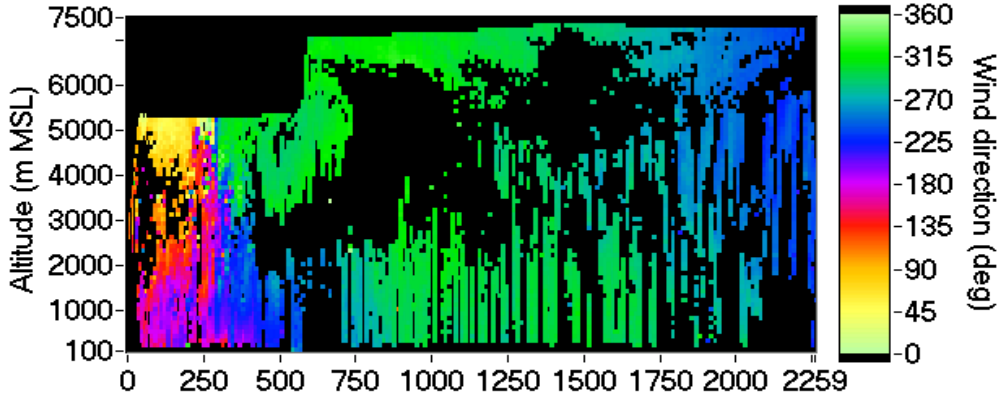


	2 µm lidar
development	DLR, CLR Photonics
transmitter	Tm:LuAG solid-state laser
wavelength	2.02254 µm
energy	1.5 mJ
repetition rate	500 Hz
pulse length	600 ns FWHM
vert. resolution	100 m
telescope ∅	10 cm
scan	conical with 20° step and stare
power•aperture	6 $mW \bullet m^2$
horizontal wind speed accuracy	0.3 – 1.3 ms^{-1}

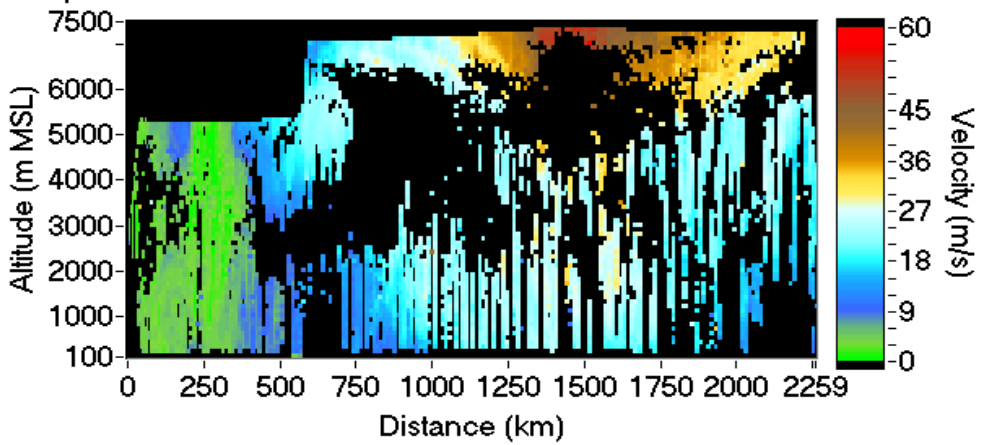




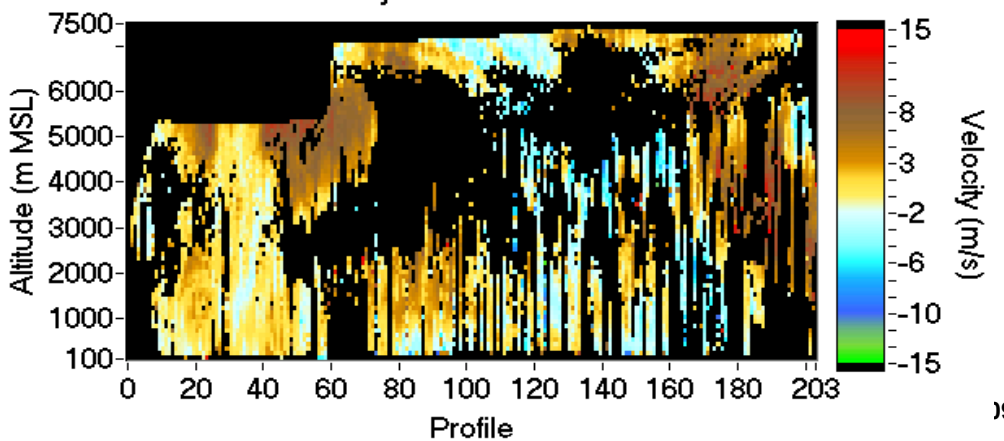
Wind direction



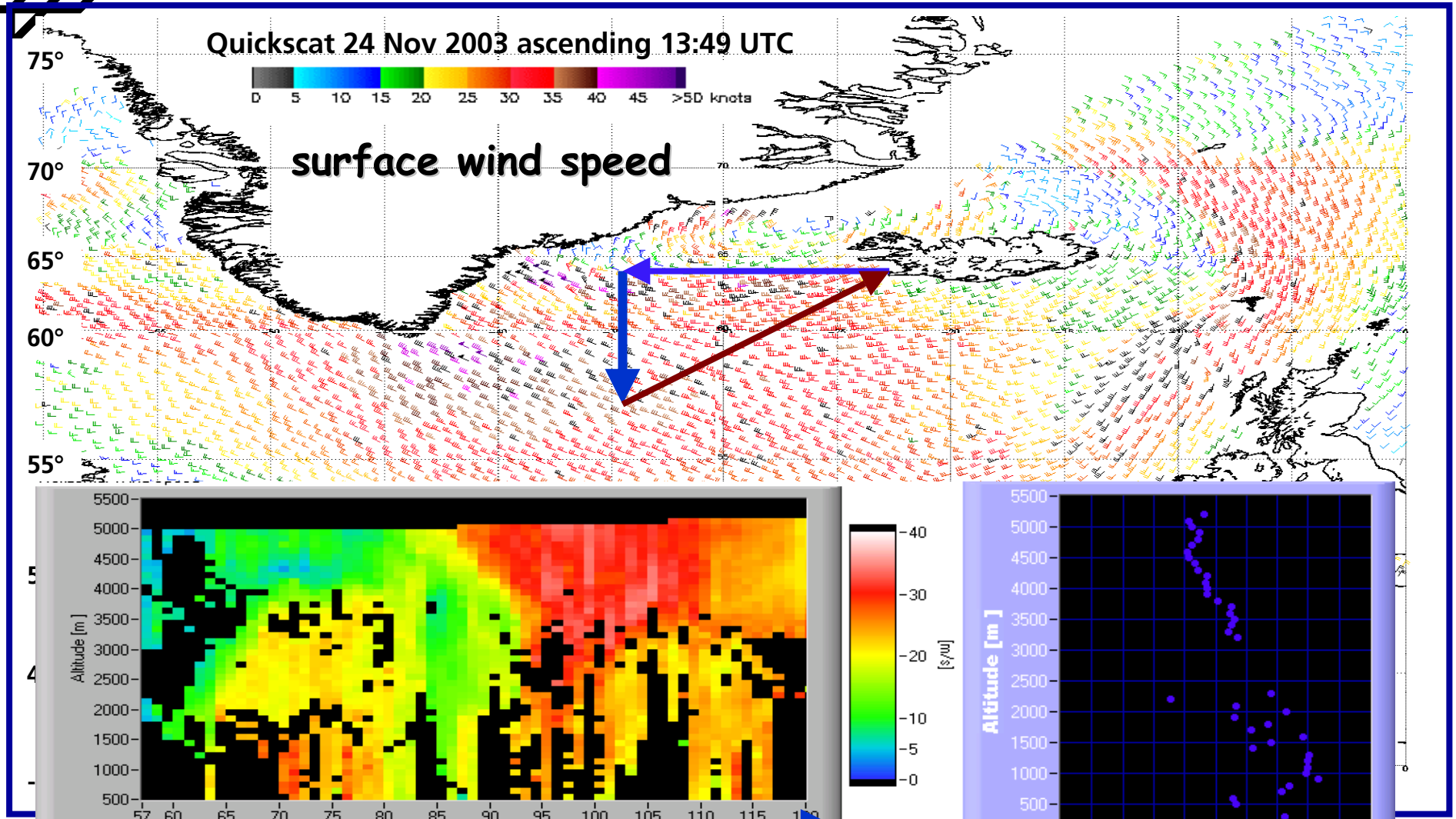
Wind speed



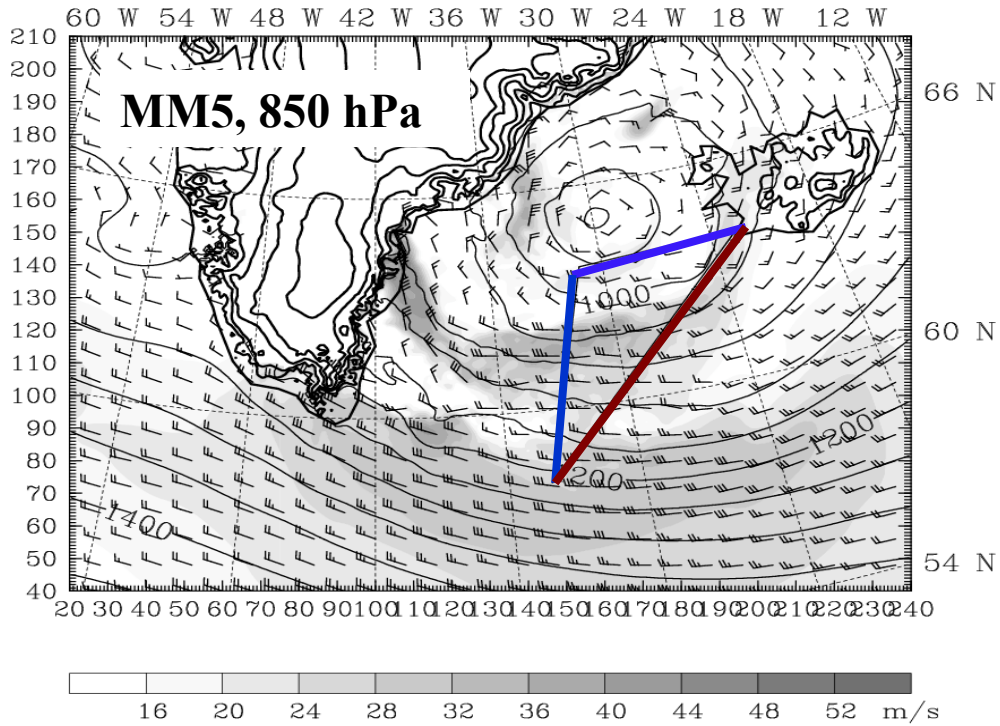
Difference Lidar-ECMWF Analysis



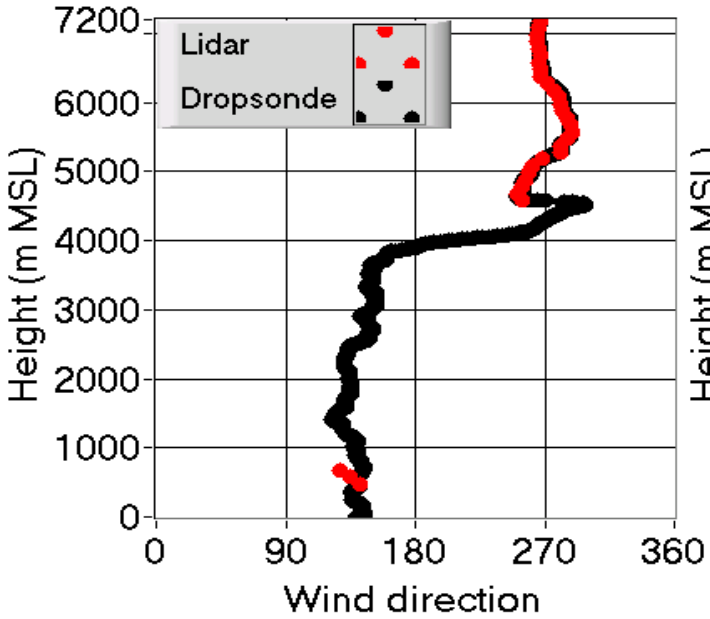
25 November 2003

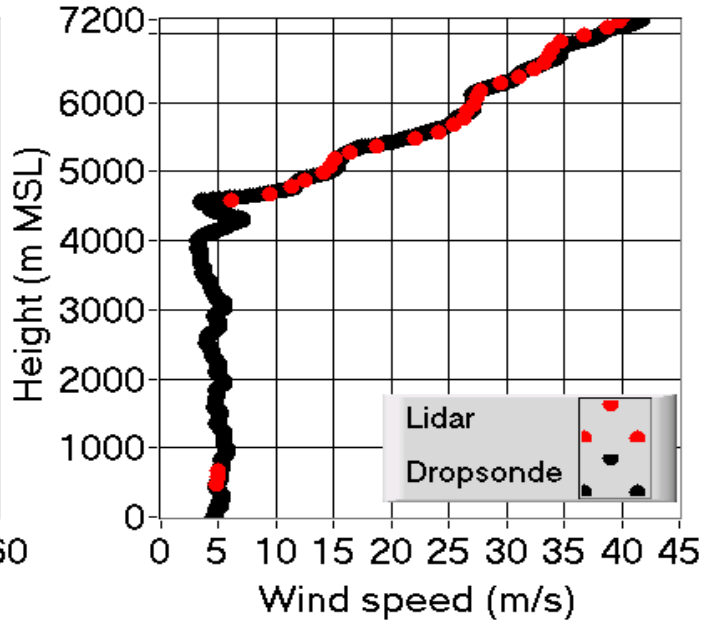


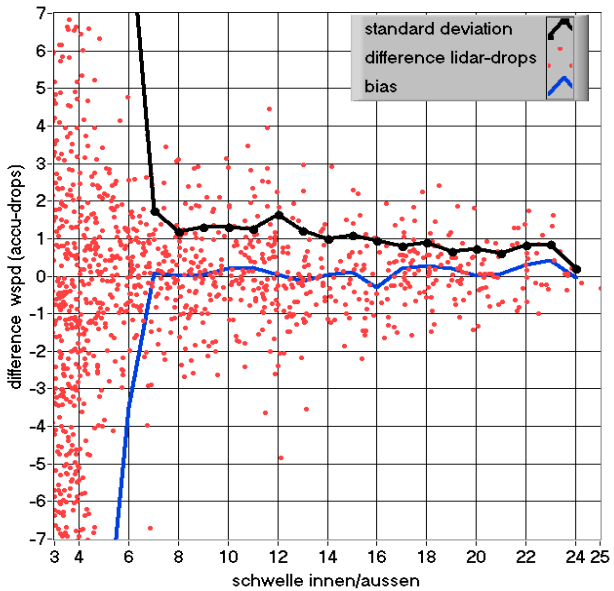
Lidar wind speed (1230-1330 UTC)


MM5, 850 hPa
60 W 54 W 48 W 42 W 36 W 30 W 24 W 18 W 12 W
66 N
60 N
54 N
1000
1200
1400
16 20 24 28 32 36 40 44 48 52 m/s

Comparison with 35 Dropsondes







Standard deviation **0.7 - 1.8 m/s**

Unknown bias **< 0.2 m/s**

Relative error **5 - 10%**

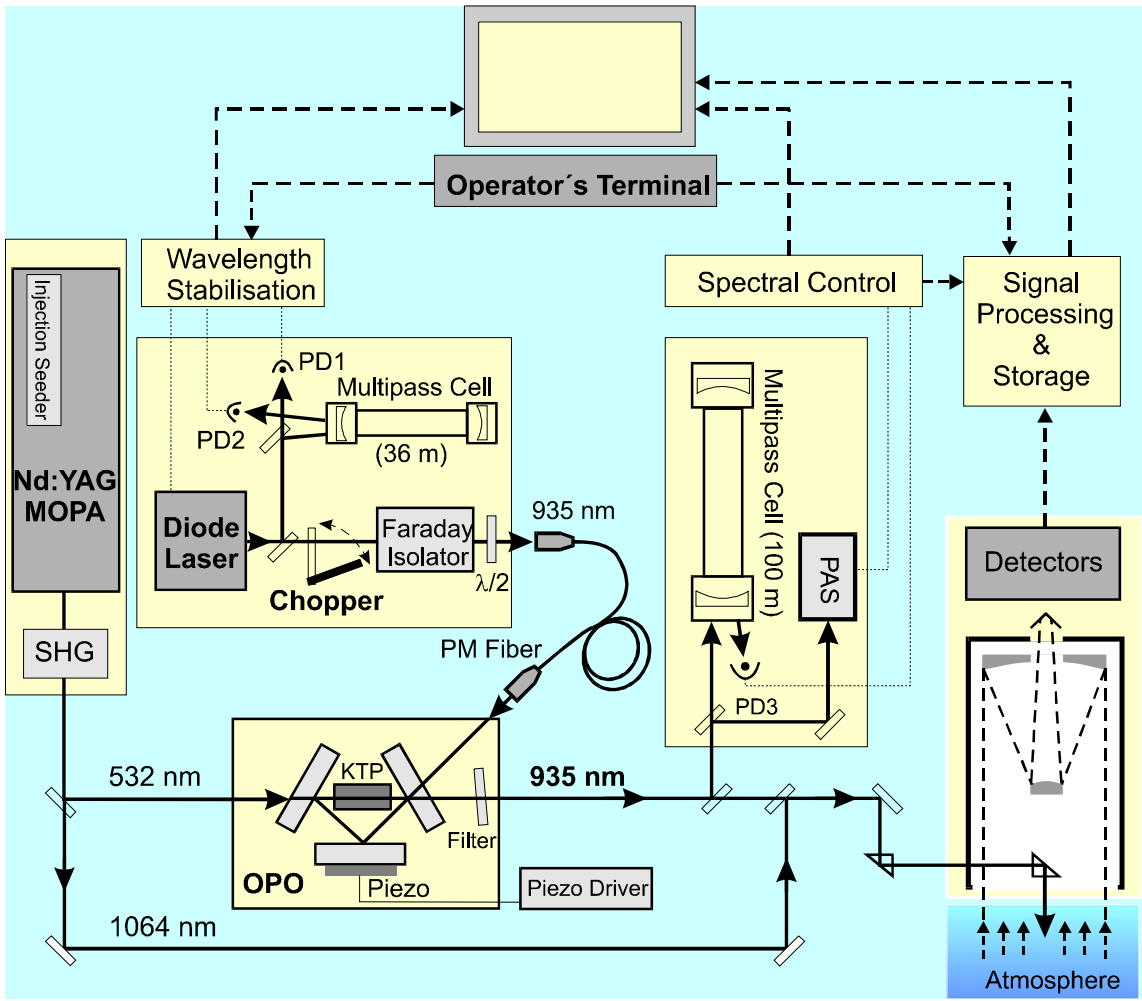
Individual estimate of standard dev.

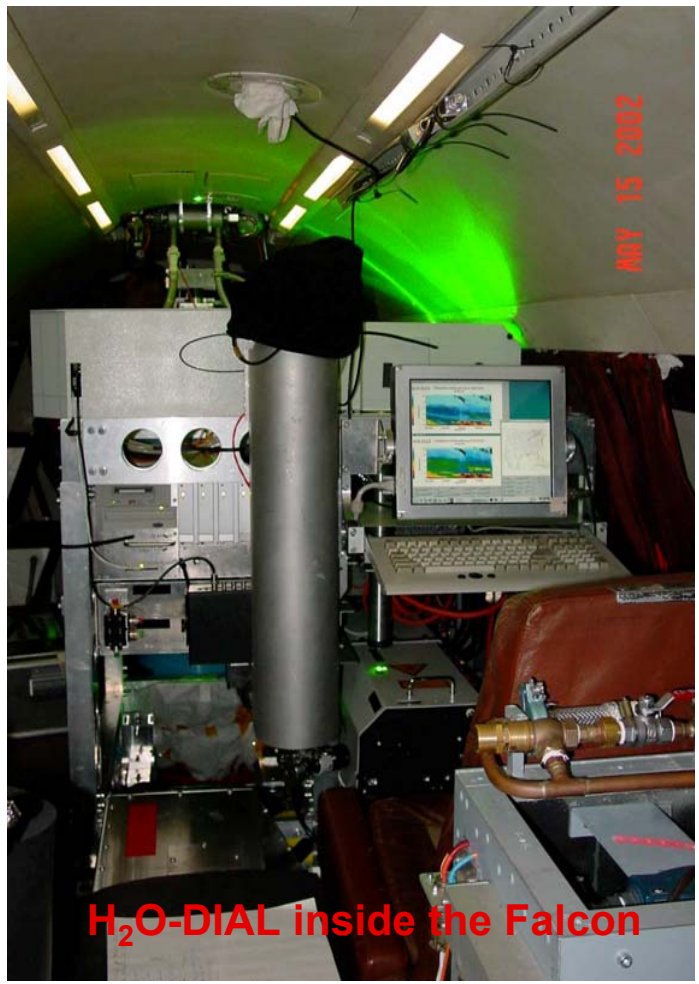
Recent Water Vapour DIAL Measurements

Campaign	Location	Target	Viewing Direction
IHOP 2002 (WALEX I)	Oklahoma	Boundary Layer, Free Troposphere	↓
MIPAS-Validation 2002	Italy	Lower Stratosphere	↑
TROCCINOX 2003 (WALEX 2)	Brazil	Upper Troposphere (Tropics) Free Troposphere	↑ ↓

H_2O-DIAL: Experimental Set-up

Key Features: λ ~920-945nm, 100Hz, 2W

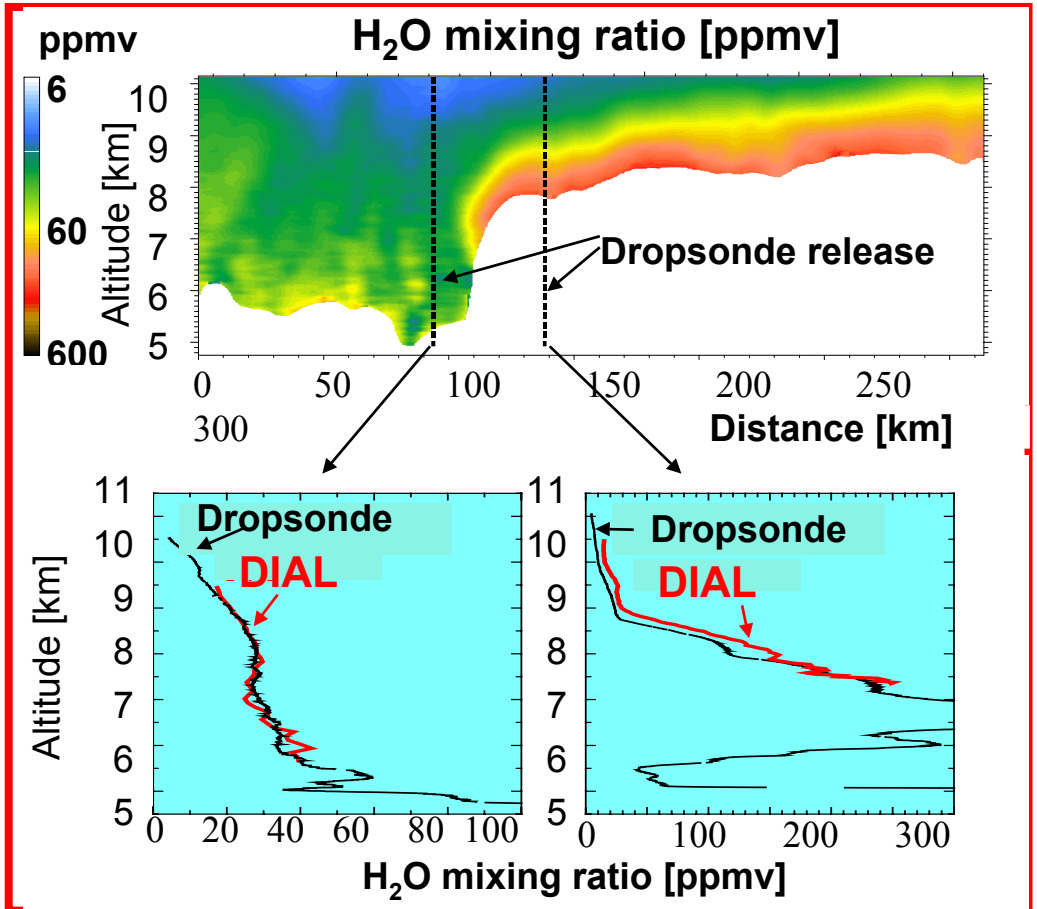




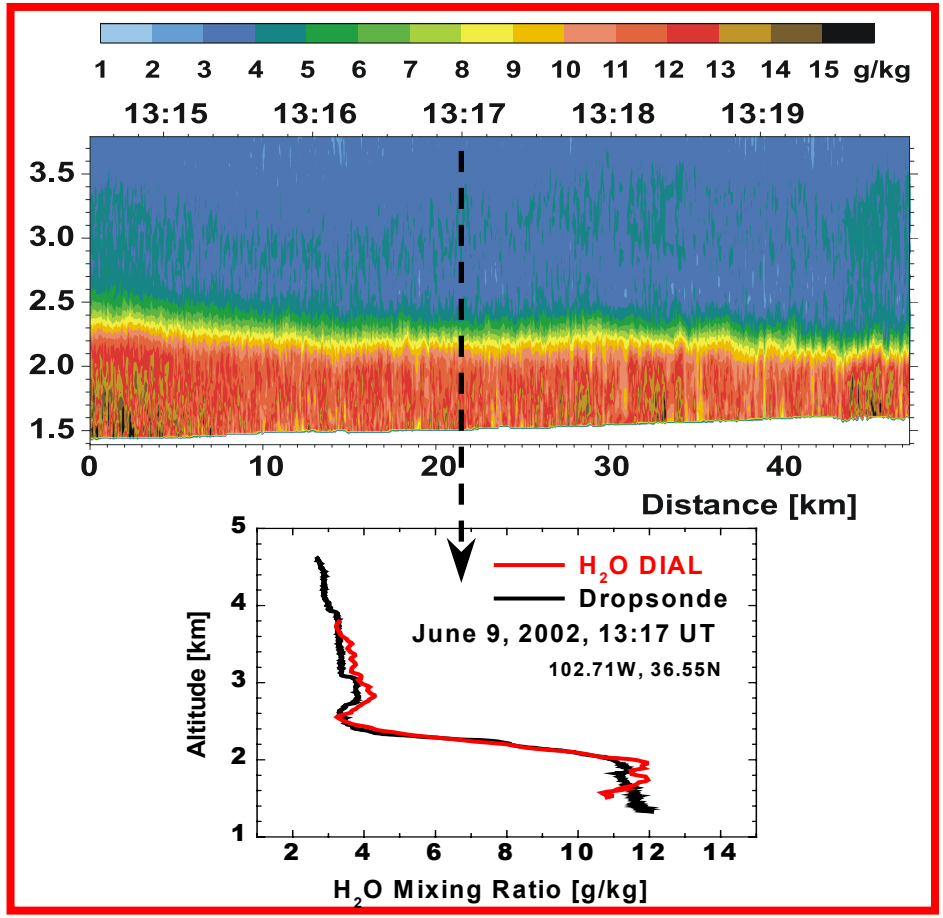
H_2O-DIAL inside the Falcon

H_2O-DIAL: Comparison to Dropsondes

UT/LS:



Boundary Layer:



November 15, 1999

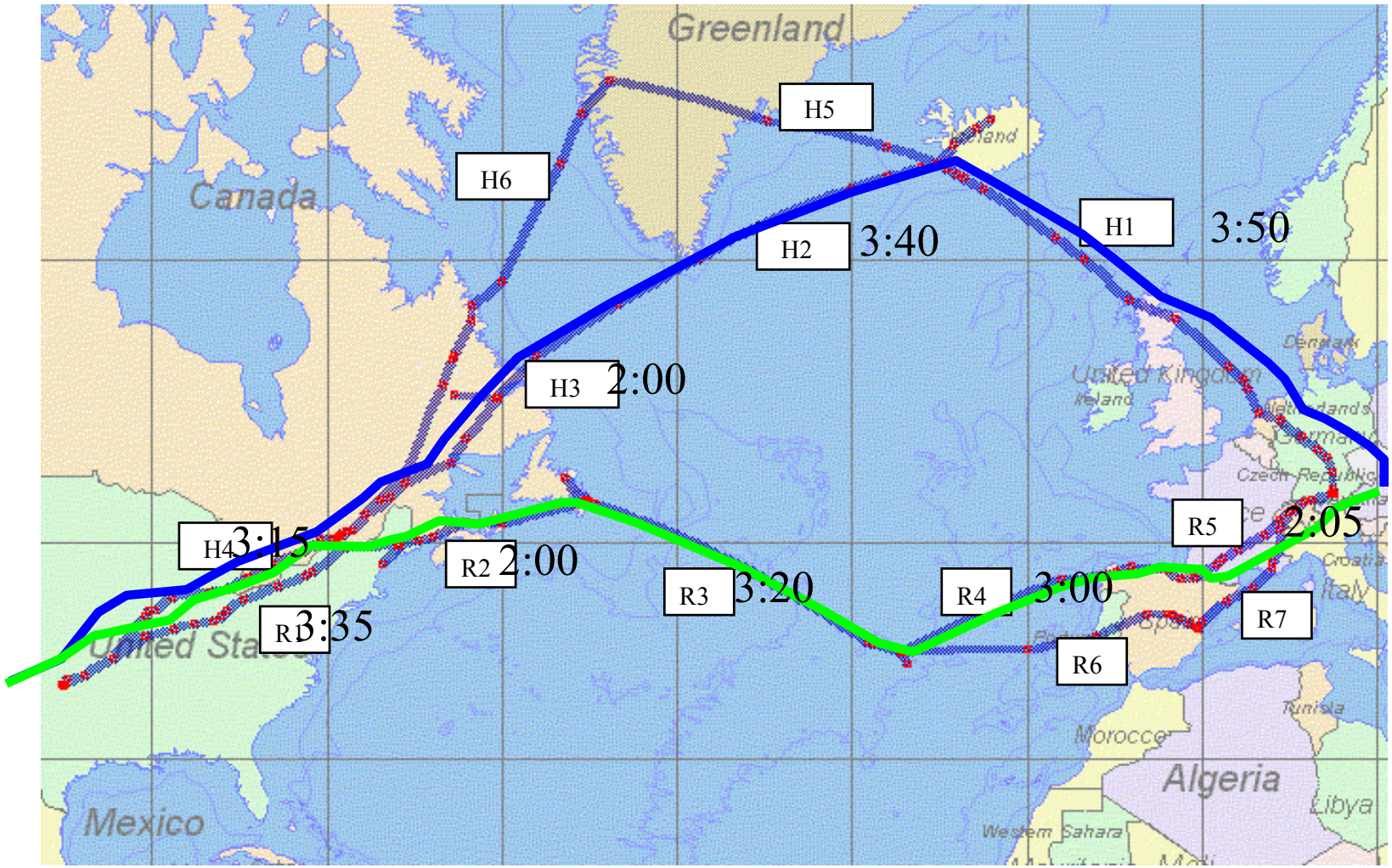
June 9, 2002

EXTENDED-RANGE WATER VAPOUR CROSS SECTIONS OVER THE NORTH ATLANTIC REGION

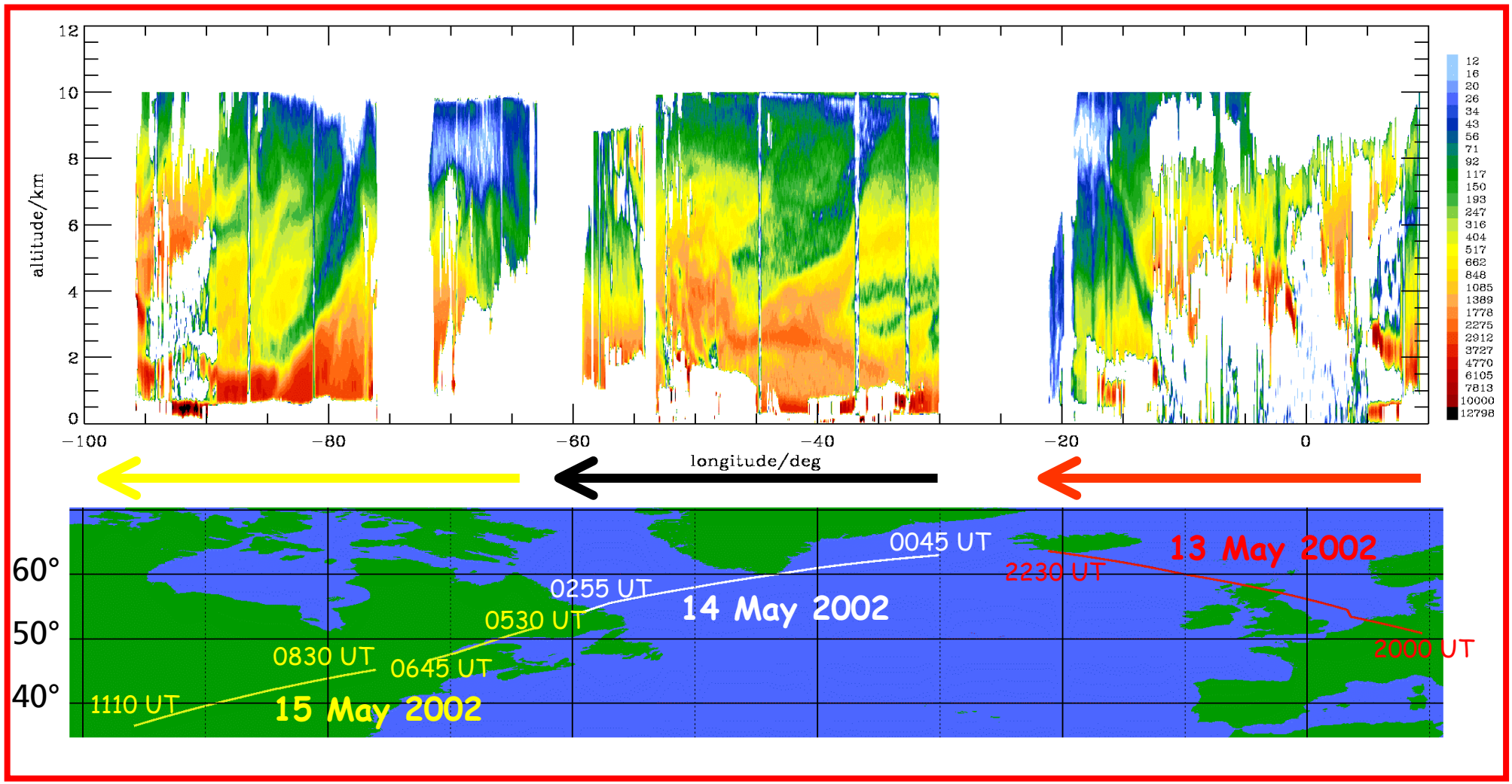
Selected case studies of the Trans-Atlantic Flights to Oklahoma

Goal: Provide a Water Vapour Reference Data Set for the WALES Mission

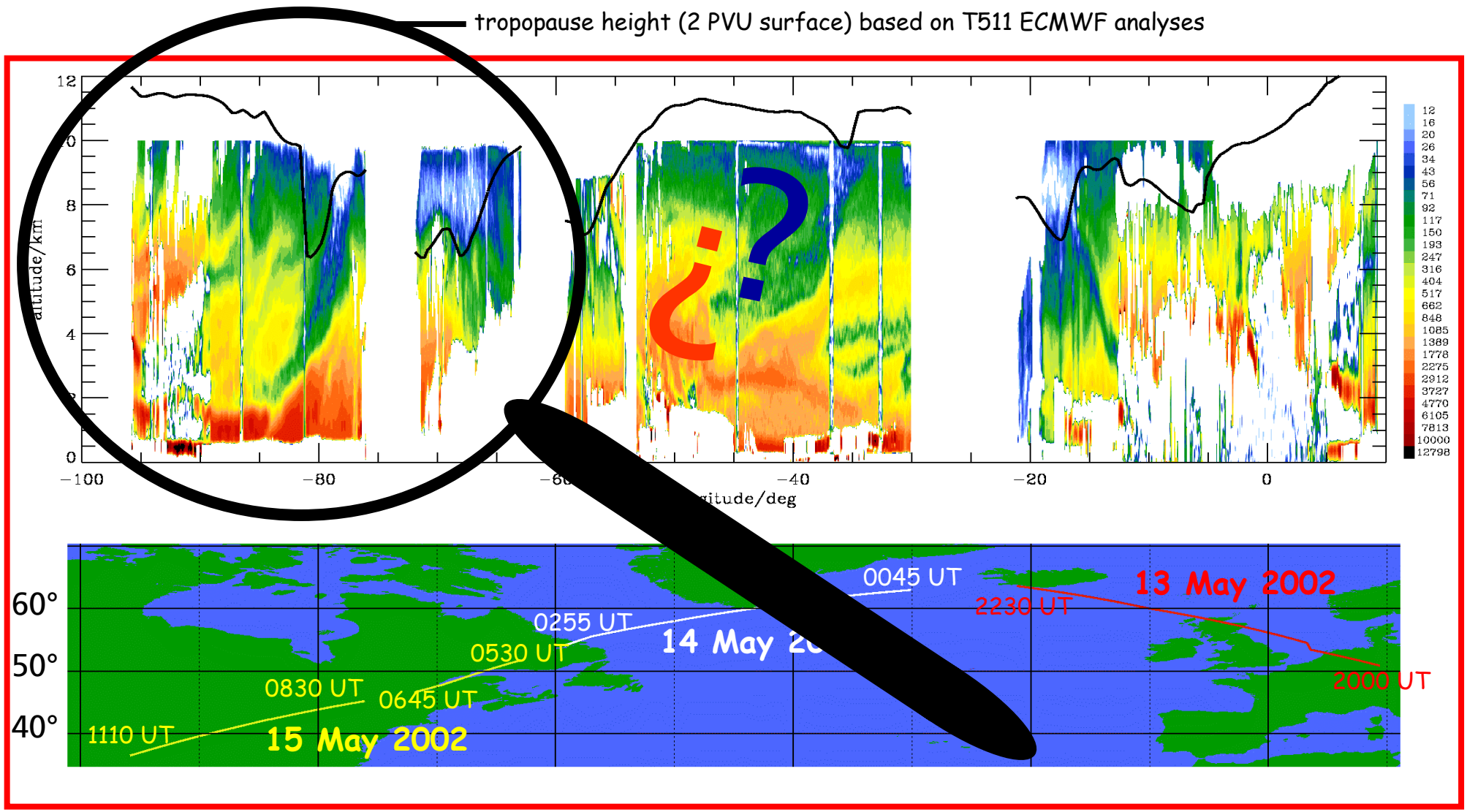
IHOP Transfer Flights
13.-15.05.2002 and 16.-18.06.2002



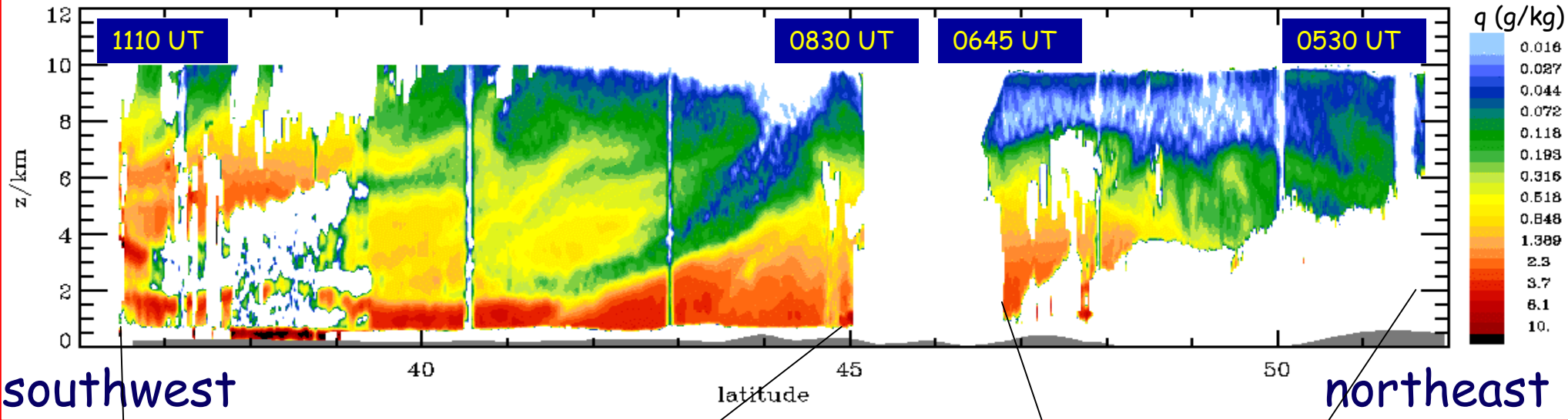
DIAL: Water vapor mixing ratio (mg/kg)

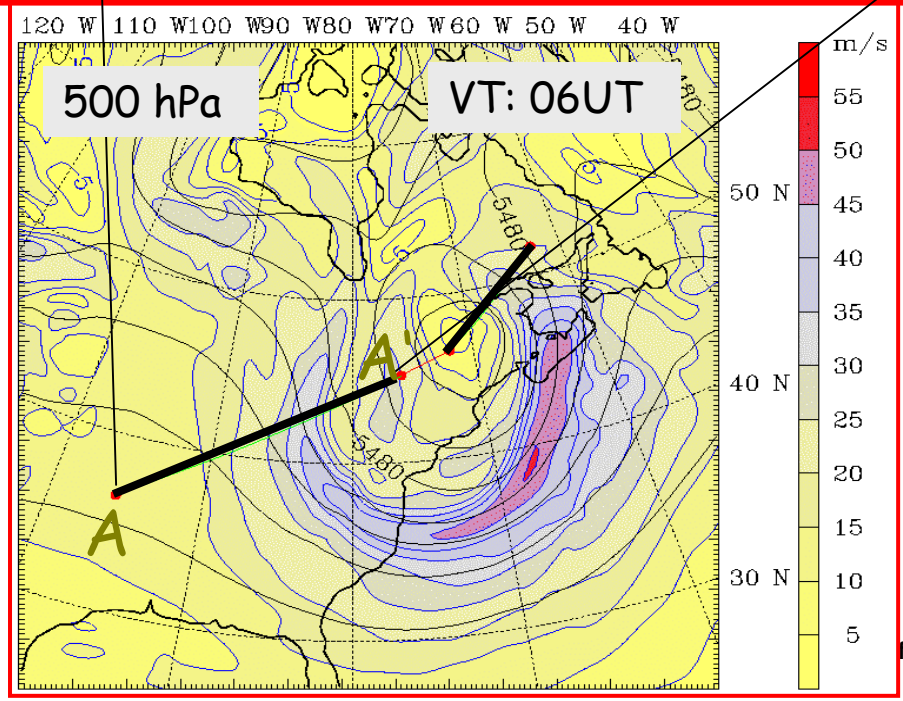


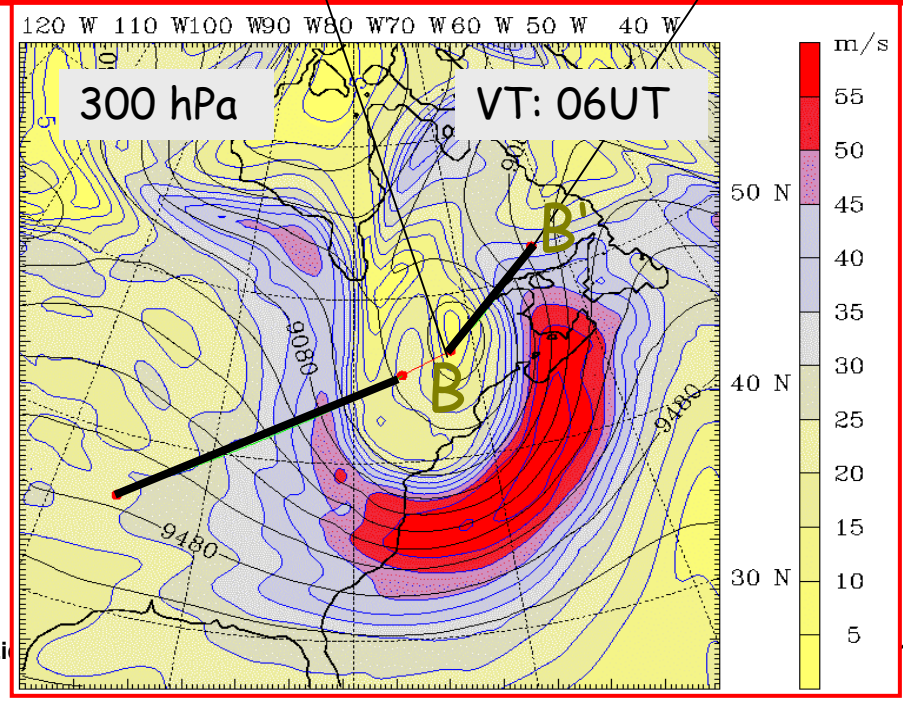
DIAL: Water vapor mixing ratio (10-3g/kg)



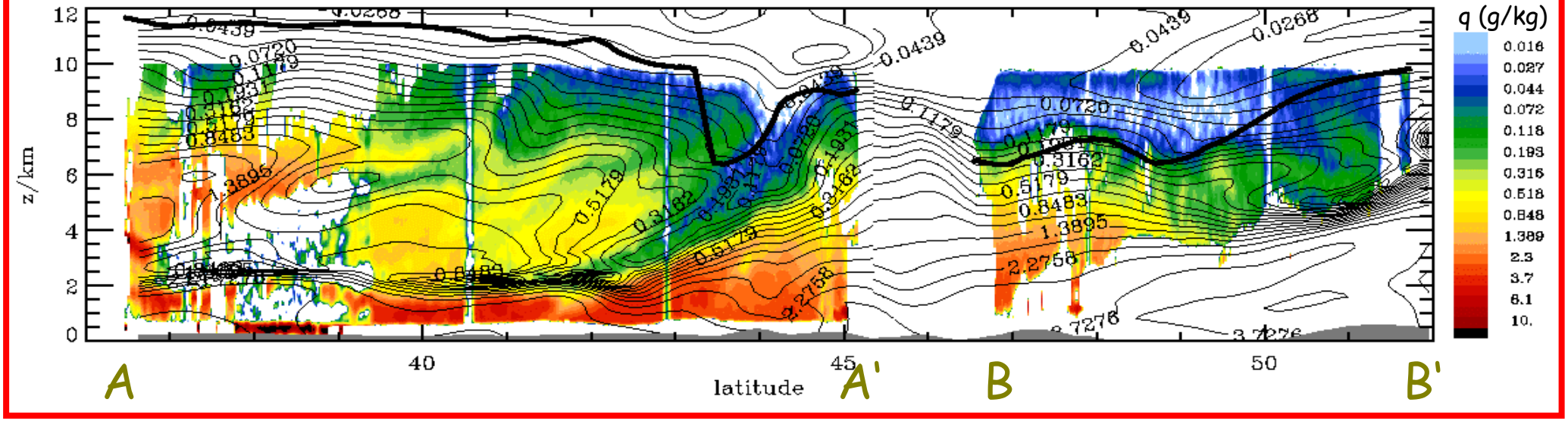
15 May 2002 6-11 UT - ´through´ a cyclone

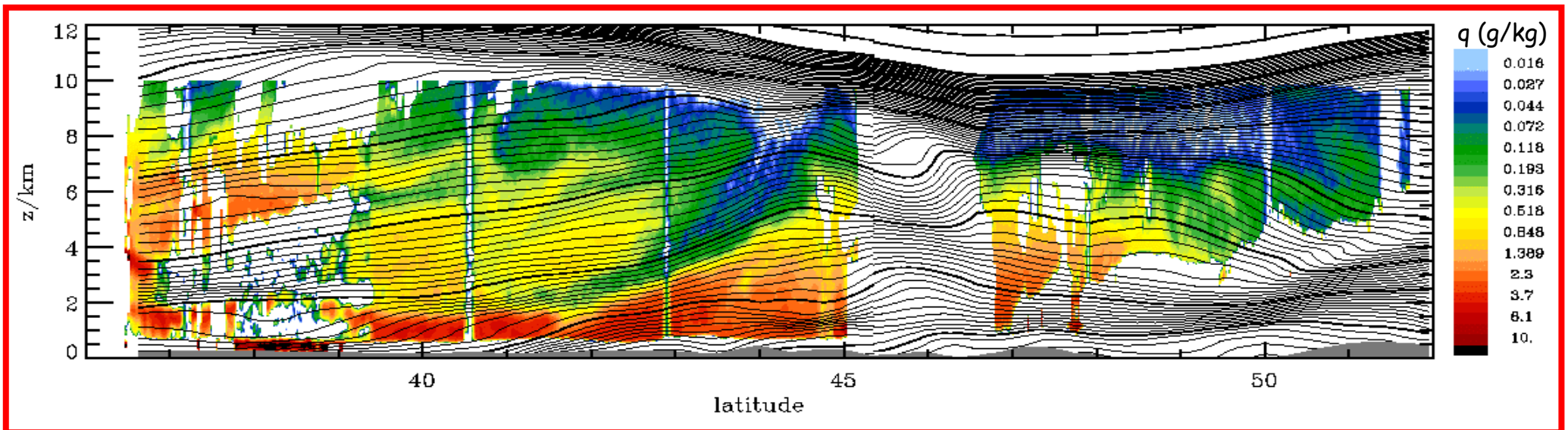






Comparison with MM5 simulation (Δx=36 km)





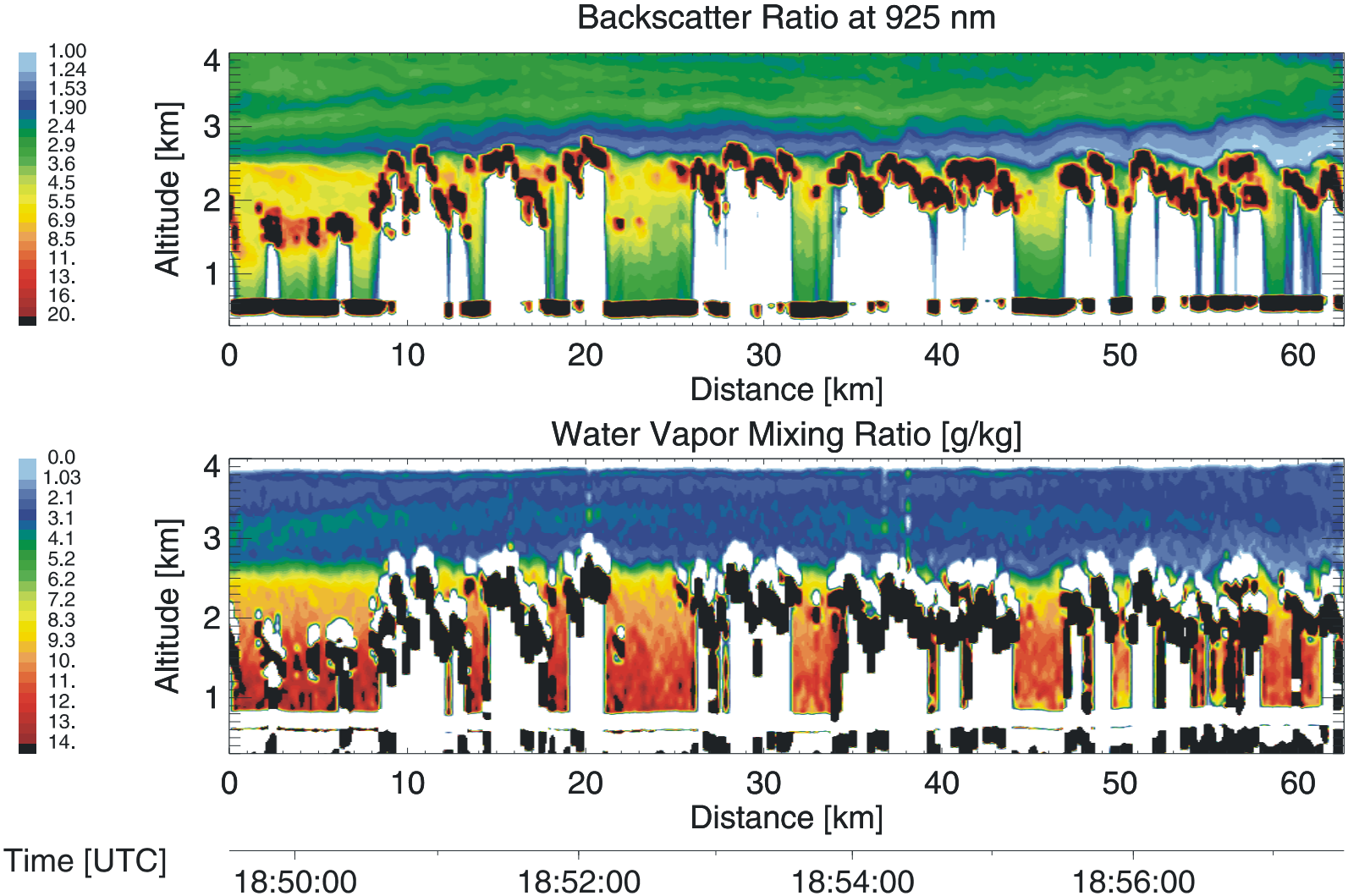
A VT: 15 May 2002 08 UT A' VT: 15 May 2002 06 UT B'

WALEX I: Summary

- 15 hours (≈11000 km) of lidar data from long Atlantic cross sections
- Valuable for evaluating the potential, impact, and observational requirements of WALES
- Water vapour measurements are possible below thin clouds
- Small and meso-scale structures in aerosol and water vapour can be resolved
- Dry filaments in water vapour due to frontal shear
- Intrusions of dry lower stratospheric air is no rare phenomenon
- H_2O-DIAL (together with mesoscale modelling and, potentially, other tracers) is a valuable tool to understand dynamical processes

Water Vapour in the Convective Boundary Layer during IHOP_2002

DIAL



MIPAS-H2O Validation with the DLR Falcon

- Part of the ESABC activities

- Validation of MIPAS water vapour and aerosol profiles using the airborne Water Vapour Differential Absorption Lidar (H_2O-DIAL) onboard the Falcon

- Joint campaign with the GEOPHYSIKA mid-latitude validation activities (Forli', Italy (October 2002))

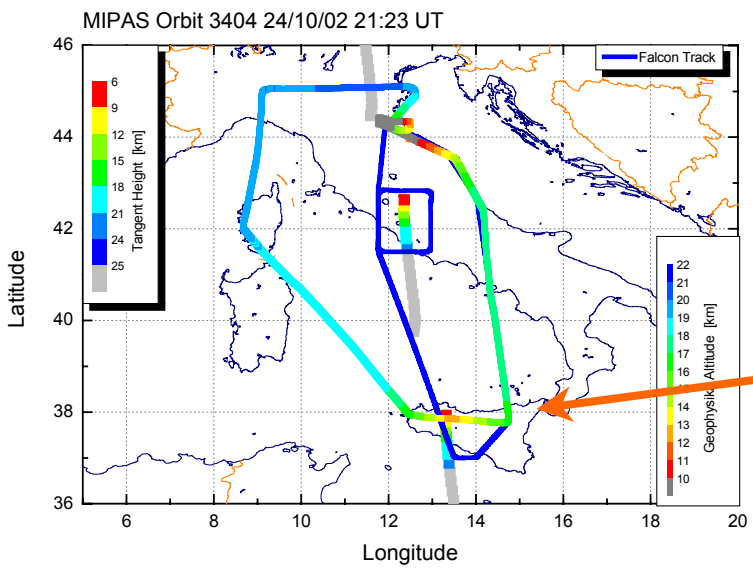
Summary of MIPAS overpasses during the Forli' 2002 campaign (14-28/10/02)

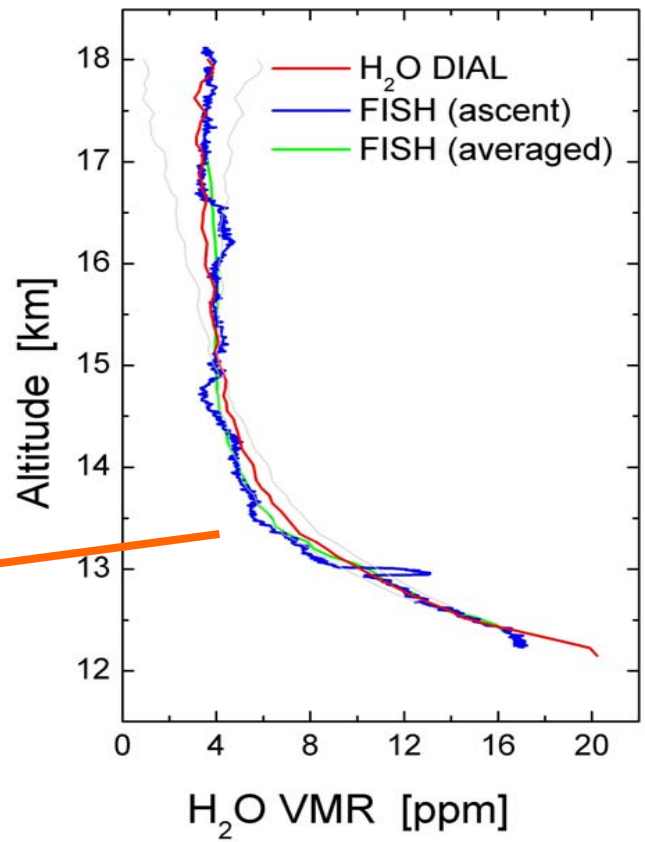
8 Falcon Flights total (25.5 h)
4 Flights co-ordinated with GEOPHYSIKA)*
4 flights at daylight
4 flights at night-time

Date	Orbit No.	Crossed Scan Index	Departure [UTC]	Arrival [UTC]	MIPAS Data	
					ESA v. 4.61	FZK
14/10/02	3261	7, 8	18:50	21:15		
17/10/02	)*		08:45	12:10		
18/10/02	3318	6, 7	18:45	21:45	x	x
22/10/02	3368)*	26, 27	07:10	10:50		x
23/10/02	3390	7	18:45	21:50		
24/10/02	3404)*	6, 7	18:50	22:10	x	
25/10/02	3411	25, 26	09:05	11:45	x	x
28/10/02	3454)*	26, 27	07:10	10:45		x

Quality Check: H_2O-DIAL vs. Geophysika FISH

24/10/02, Orbit 3404





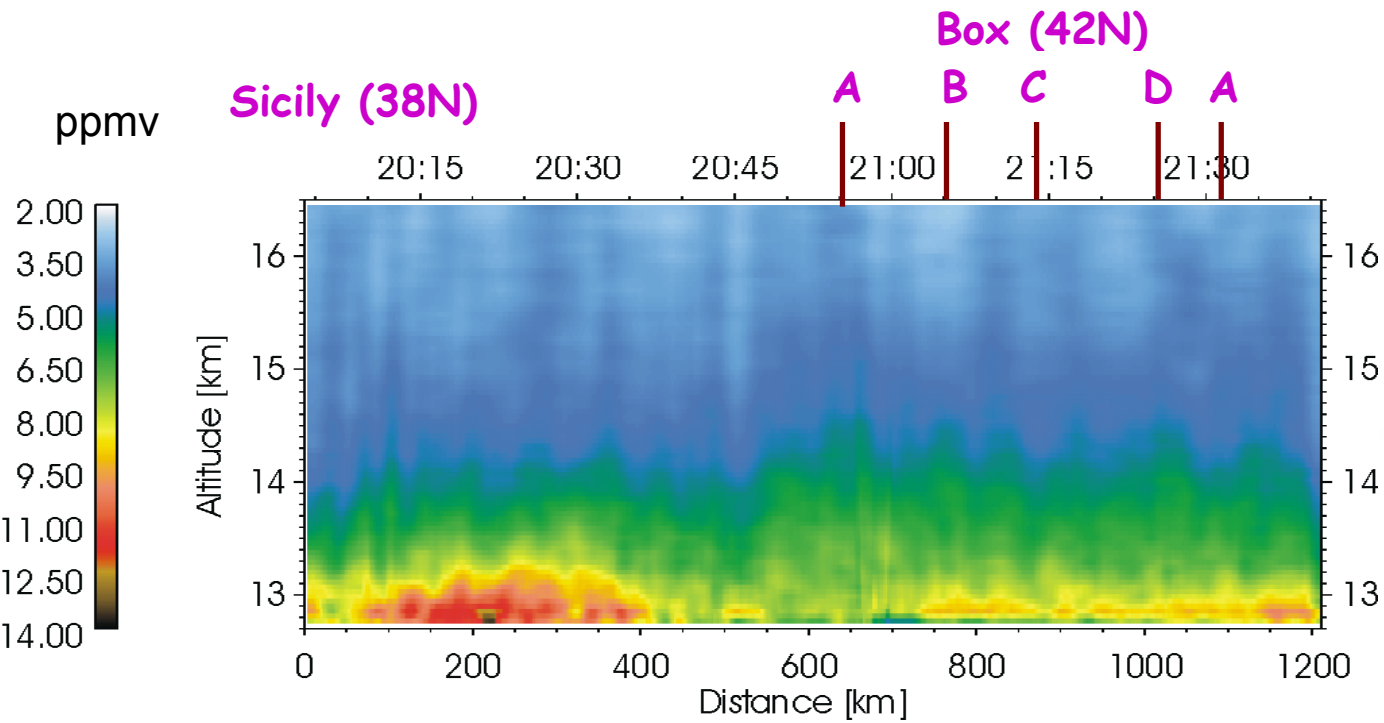
FISH: C. Schiller, M. Bläsner FZ Jülich

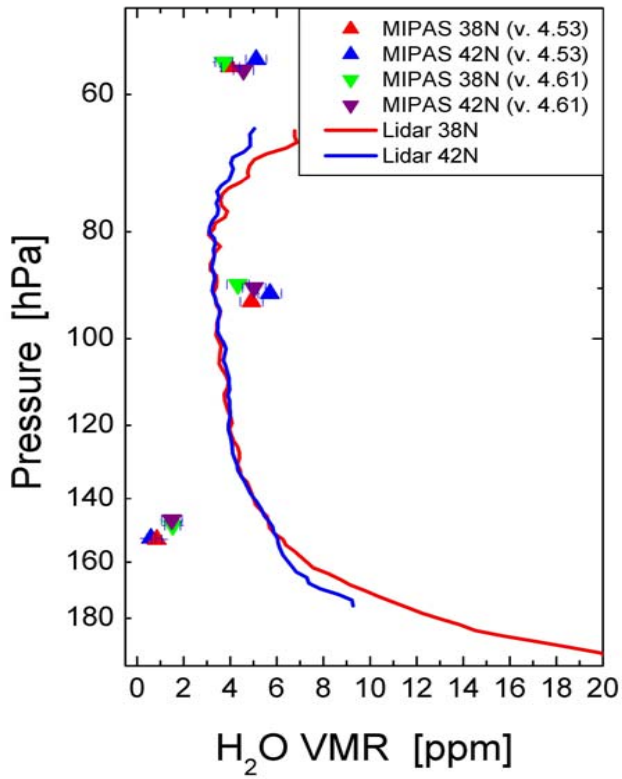
H20-DIAL Error:

up to 15.5km: <10%
up to 16.3km: <20%
up to 17.0km: <40%

H_2O-DIAL: Comparison to MIPAS 24/10/02, Orbit 3404

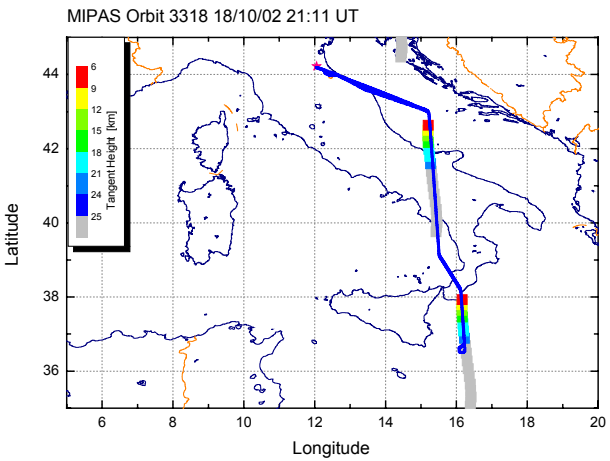
H_2O vert. Resolution:
- 75m (Near Field)
- 975m (Far Field)



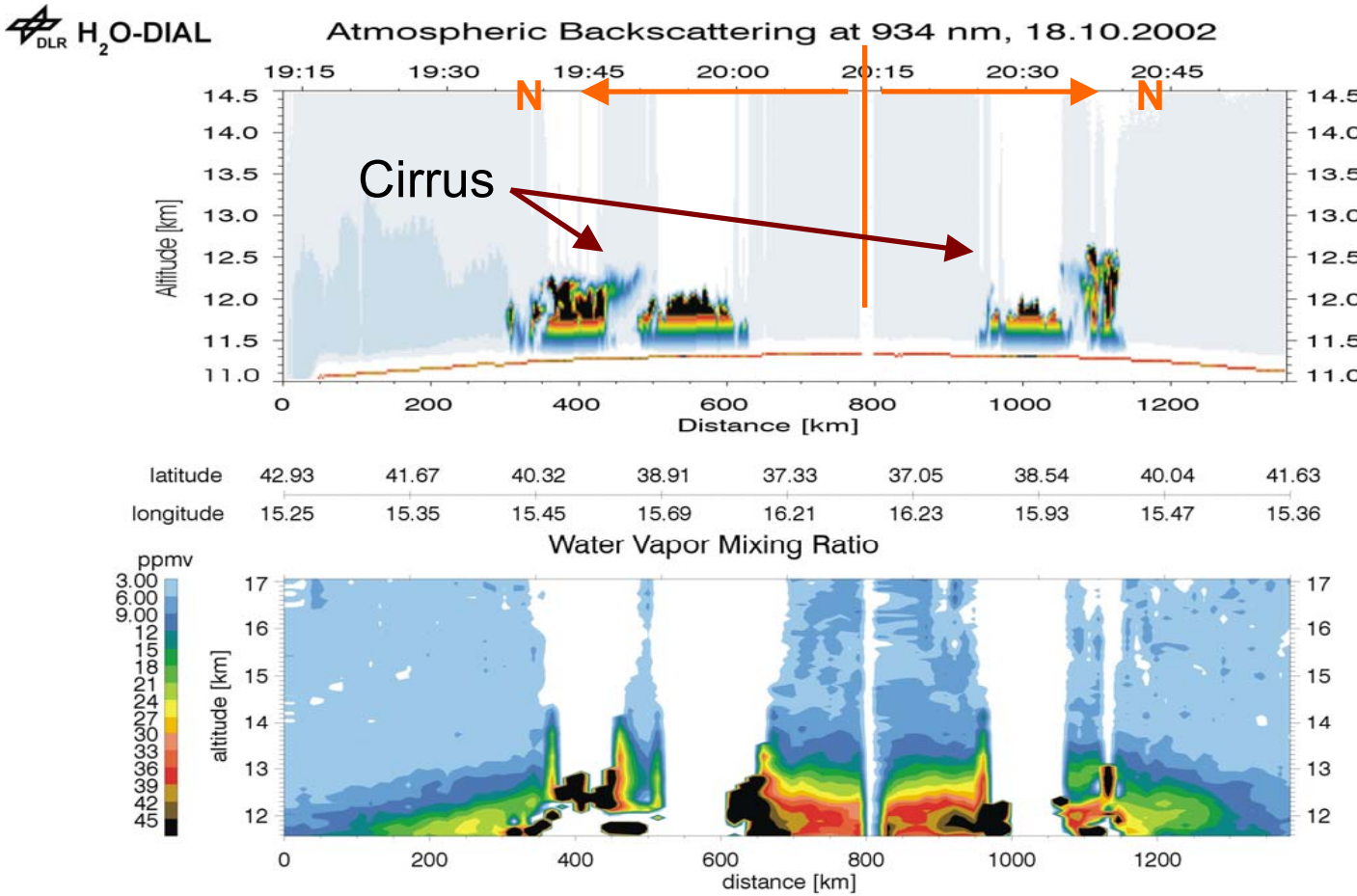


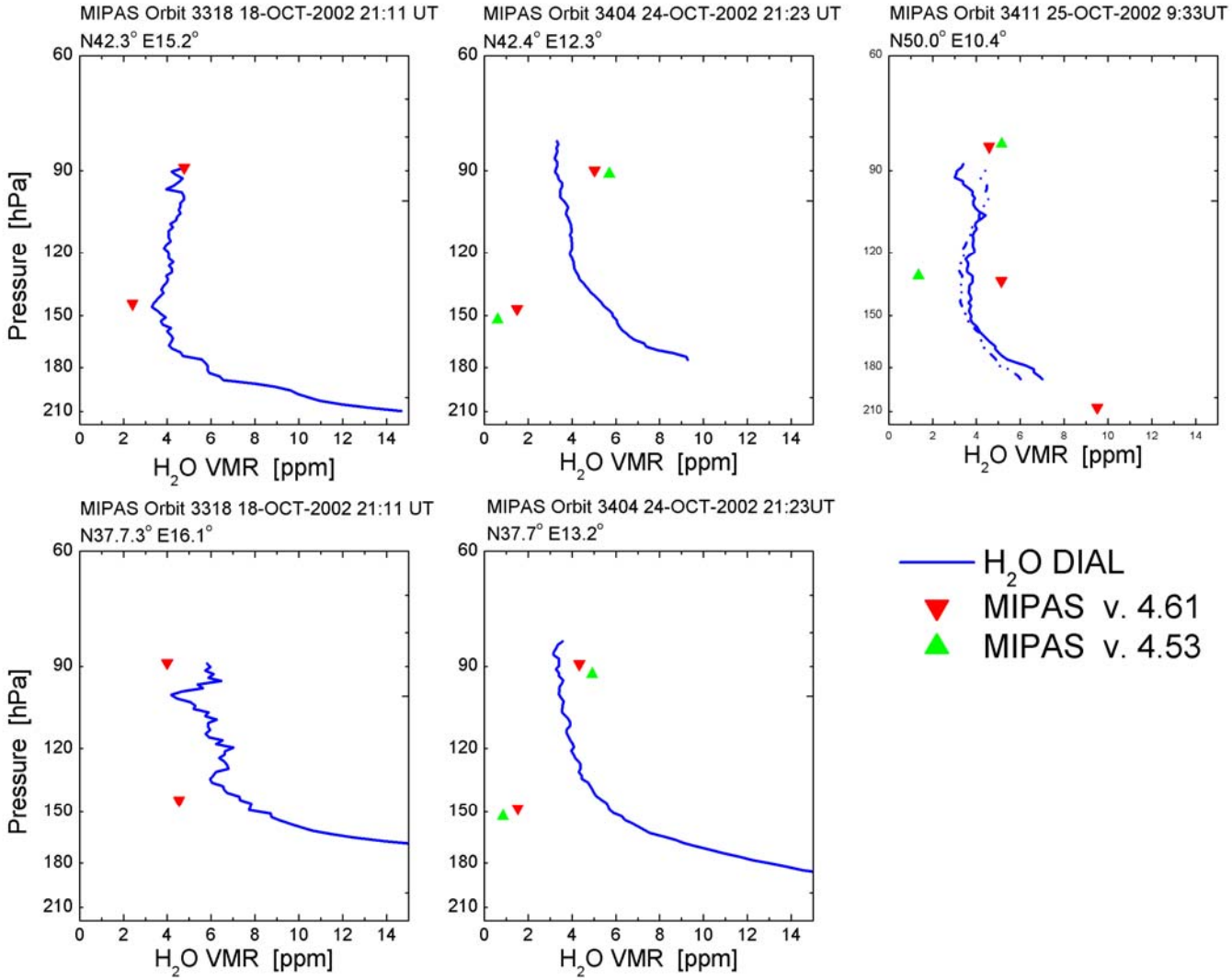
Typical Result: H_2O-DIAL 2-dim cross sections

18/10/02; Orbit 3318



H_2O vert. Resolution:
- 75m (Near Field)
- 975m (Far Field)




MIPAS Orbit 3318 18-OCT-2002 21:11 UT
N42.3° E15.2°
MIPAS Orbit 3404 24-OCT-2002 21:23 UT
N42.4° E12.3°
MIPAS Orbit 3411 25-OCT-2002 9:33UT
N50.0° E10.4°
MIPAS Orbit 3318 18-OCT-2002 21:11 UT
N37.7.3° E16.1°
MIPAS Orbit 3404 24-OCT-2002 21:23UT
N37.7° E13.2°
Pressure [hPa]
H2O VMR [ppm]
H2O DIAL
MIPAS v. 4.61
MIPAS v. 4.53

MIPAS Validation: Conclusion

- Successful Campaign performed in Oct. 2003
- Joint Measurements with the M55 - Geophysika
- Currently 5 MIPAS v. 4.61 profiles for comparison
- The 2-3 lowest tangent heights (i.e. UT/LS region) can be compared

DLR Falcon is a very flexible platform for satellite validation

Results from the TROCCINOX campaign in Brazil (02-03/2003)

- Measurements of Upper Tropospheric Humidity in the Tropics
- Transfer Flights from the Tropics to the Mid-Latitudes

TROCCINOX Science Goals:

- What is the impact of tropical deep convection on the balance and distribution of ***NO_x*** and other trace gases?
- How do troposphere-stratosphere exchange processes contribute to the amount of ***water vapour*** entering the stratosphere?
- What is the effect of tropical deep convection on the formation and distribution of ***aerosol particles***?
- What are the origins of ***cirrus clouds*** in the tropics and how do cirrus clouds affect air composition?
- What is the role of the main transport processes in the tropical UT/LS in determining **trace gas budgets**?


Microsoft MapPoint
AMAZONAS
PARÁ
MARANHÃO
Teresina
Natal
Araguaína
Campina Grande
Recife
Maceió
Porto Velho
BRAZIL
Palmas
ACRE
RONDÔNIA
BAHIA
Aracaju
MATO GROSSO
Salvador
GOIÁS
Rio Araguaia
PERU
Cuiabá
Brasília
Goiânia
BOLIVIA
MINAS GERAIS
La Paz
Santa Cruz
Belo Horizonte
Sucre
Arica
Campo Grande
Rio Grande
Vitória
Gavião Peixoto
SÃO PAULO
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General Pico
PACIFIC OCEAN
©2004 Microsoft Corp.
65°
60°
55°
50°
45°
40°
35°
30°
25°
10°
15°
20°
25°
30°
35°
km 0 1000 2000
mi 0 500 1000
Large - 65

Data coverage I: Transfer

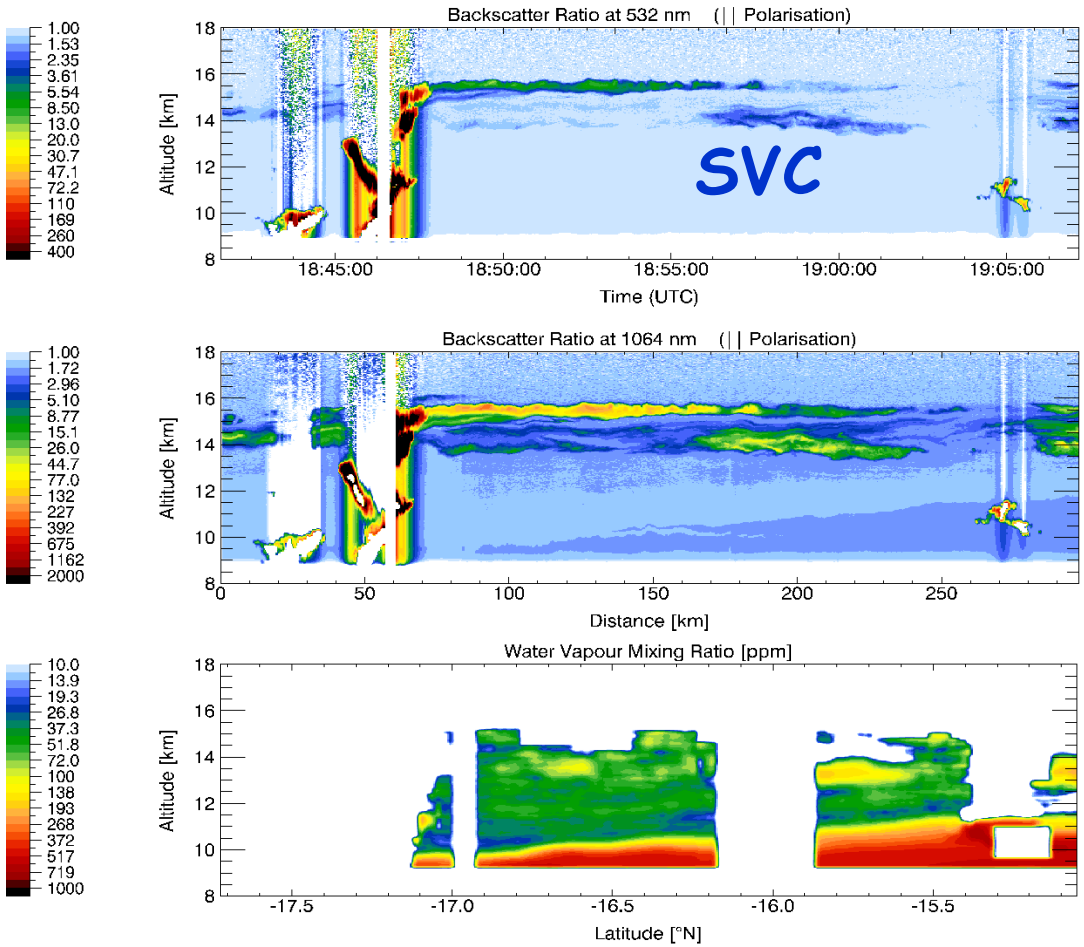
Flight section	Data acquisition	Data	Special features
OP - Sevilla	9:18-10:31; 10:47-11:02	Aerosol (up)	Ci
Sevilla - Sal	11:49-12:09; 12:17-12:44 12:48-14:23	Aerosol (up)	Junge Layer
Sal – Fernando	16:46-17:41; 17:48-18:37 18:42-19:36	Aerosol, 15 min H_2O (up)	Junge Layer
Fernando -Recife	no measurement	-	-
Recife - Gav. P.	no measurement	-	-
Gav. P. - Recife	no measurement	-	-
Recife - Sal	10:52-14:10	H_2O, Aerosol	scattered Cb, sloping humid layer
Sal - Sevilla	16:26-19:22	H_2O, Aerosol	stratospheric intrusion
Sevilla - OP	14:18-15:31; 15:34-15:51 15:56-16:22	Aerosol	aerosol transport
Total	**11:59 (transfers)**		

Data coverage II: TROCCINOX

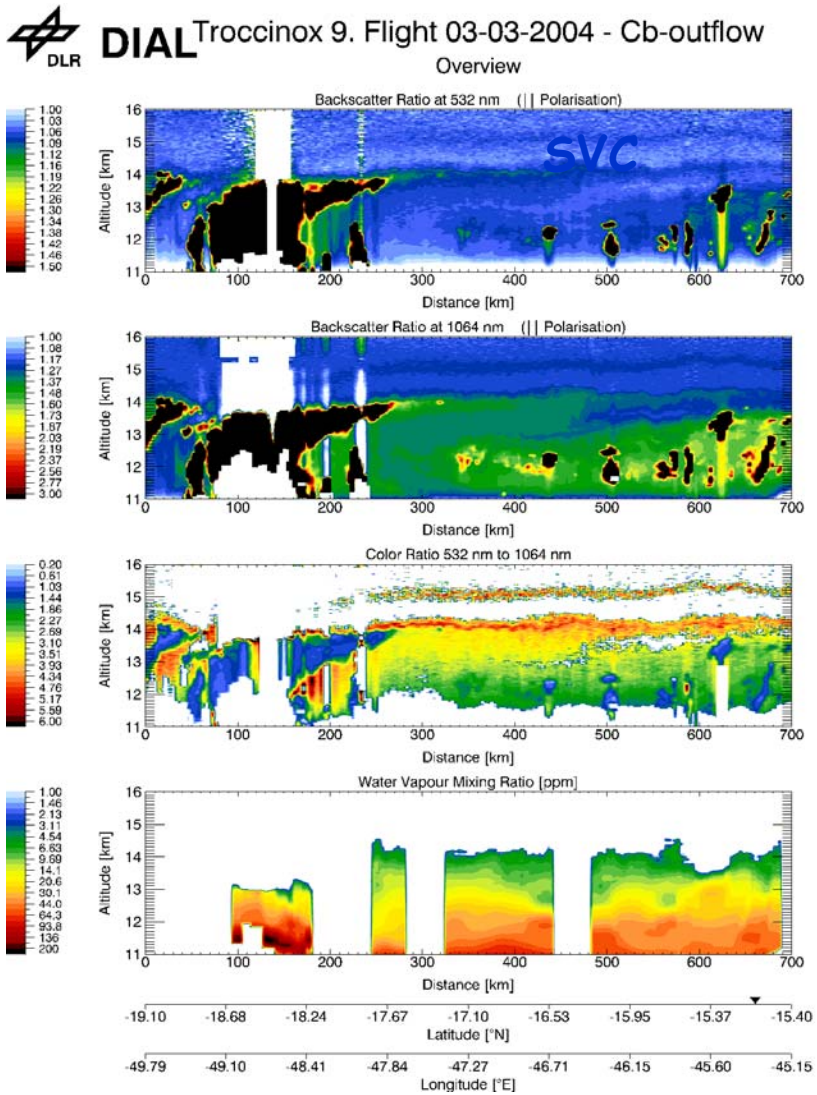
Flight date	Mission	Data	Special features
13.02.	GP ↔ 14°S, 44°W	aerosol, 14-21°S	Cb; Ci in 14-15 km
16.02.	Intercomp. – regional flight	H_2O (↑ 16 km) & aerosol; ≈ 1h	clear; dry layers @ 7,8,9 km
17.02.	22°S ↔ 10°S	H_2O(↑ 15-17km) & aerosol,15-21°S	Cb-outflow; hygropause
19.02.	GP ↔ 16°S, 38°W	H_2O intermitt. (↑ 15 km) & aerosol	Ci
20.02.	Triangle, GP – 16°S, 52°W – 25°S, 52°W – GP	H_2O intermitt. (↑ 16-18 km) & aerosol	Ci; hygropause
27.02.	GP ↔ 53°W	H_2O (↑ 15-16 km) & aerosol	clear; hygropause
28.02.	SAOZ comparison – regional flight	H_2O (↑ 15-17 km) & aerosol	clear, few Cb
03.03.	Triangle, GP – 24°S, 44°W – 15°S, 45°W – 20°S, 51°W - GP	H_2O intermitt. (↑ 14-16 km) & aerosol	Cb outflow (SVC?); hygropause
03.03.	regional flight - NO_x	sparse data due to Cb; H_2O (↑ 15 km) & aerosol	Cb
04.03	regional flight – aged plume	H_2O intermitt. (↑ 15 km) & aerosol	Ci; high humidity
05.03	47°W ↔ 51°W	H_2O intermitt. (↑ 15-17 km) & aerosol	clear; hygropause
07.03	GP - 19°S ↔ 28°S - GP	H_2O (↑ 15-17 km) & aerosol	horizontal H_2O gradients; aerosol layers, SVC?
10.03	GP ↔ 28°S, 46°W (NADIR-looking!)	H_2O (↓ 4 km) & aerosol	marine PBL; humid layer above 8 km, SVC?

TROCCINOX

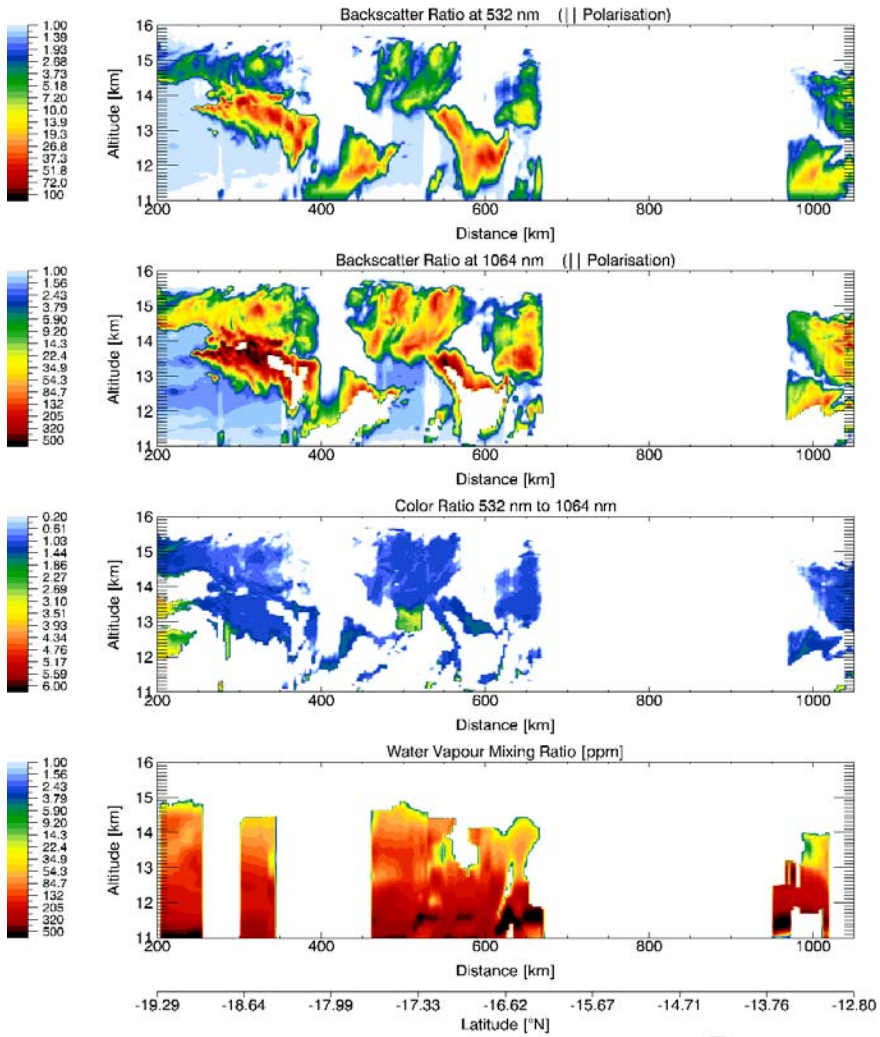
Cb outflow on 17.02



Cb outflow on 03.03



TROCCINOX

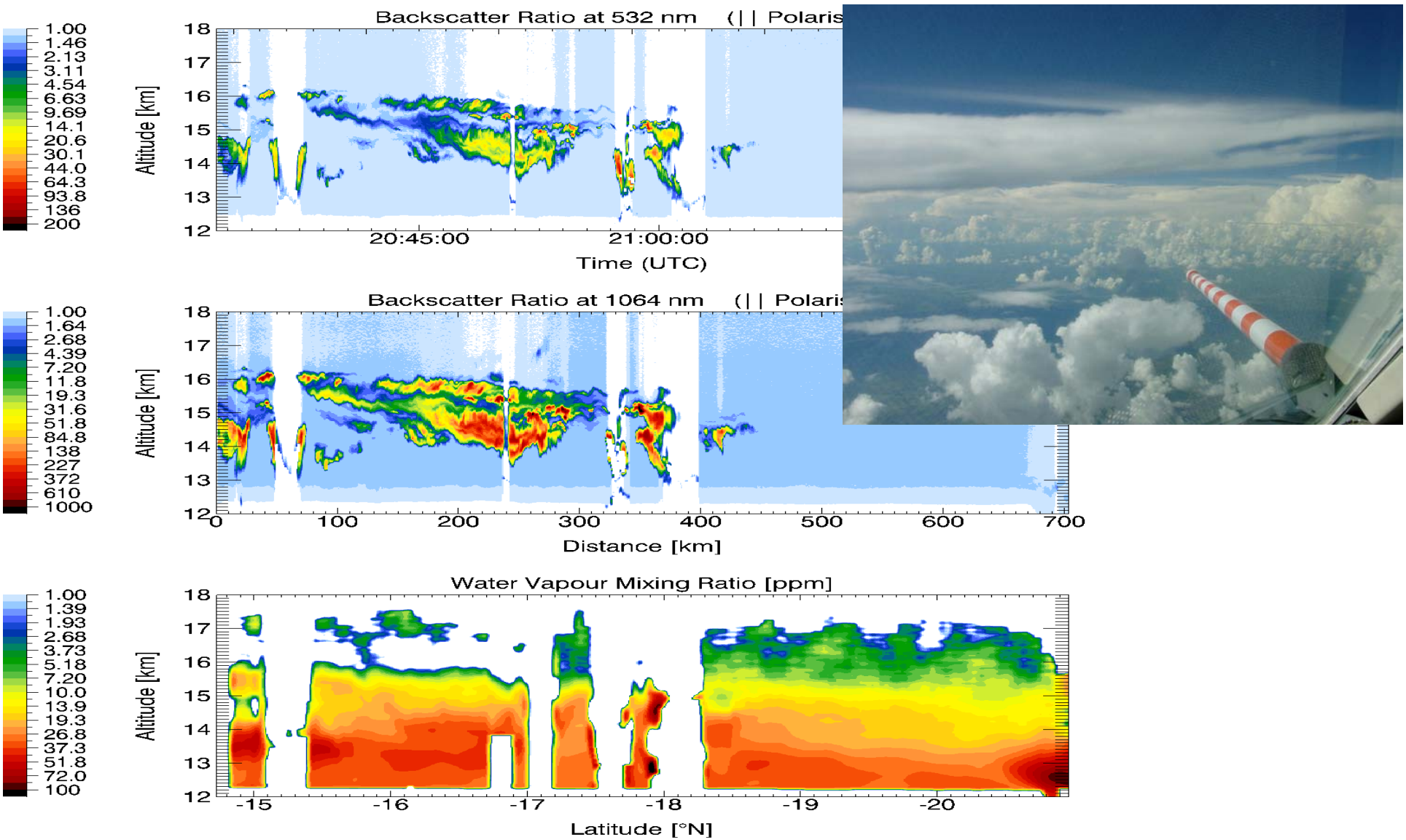


Humid upper troposphere on 04.03.2004:

30 ppm H_2O in 14-15 km

DIAL

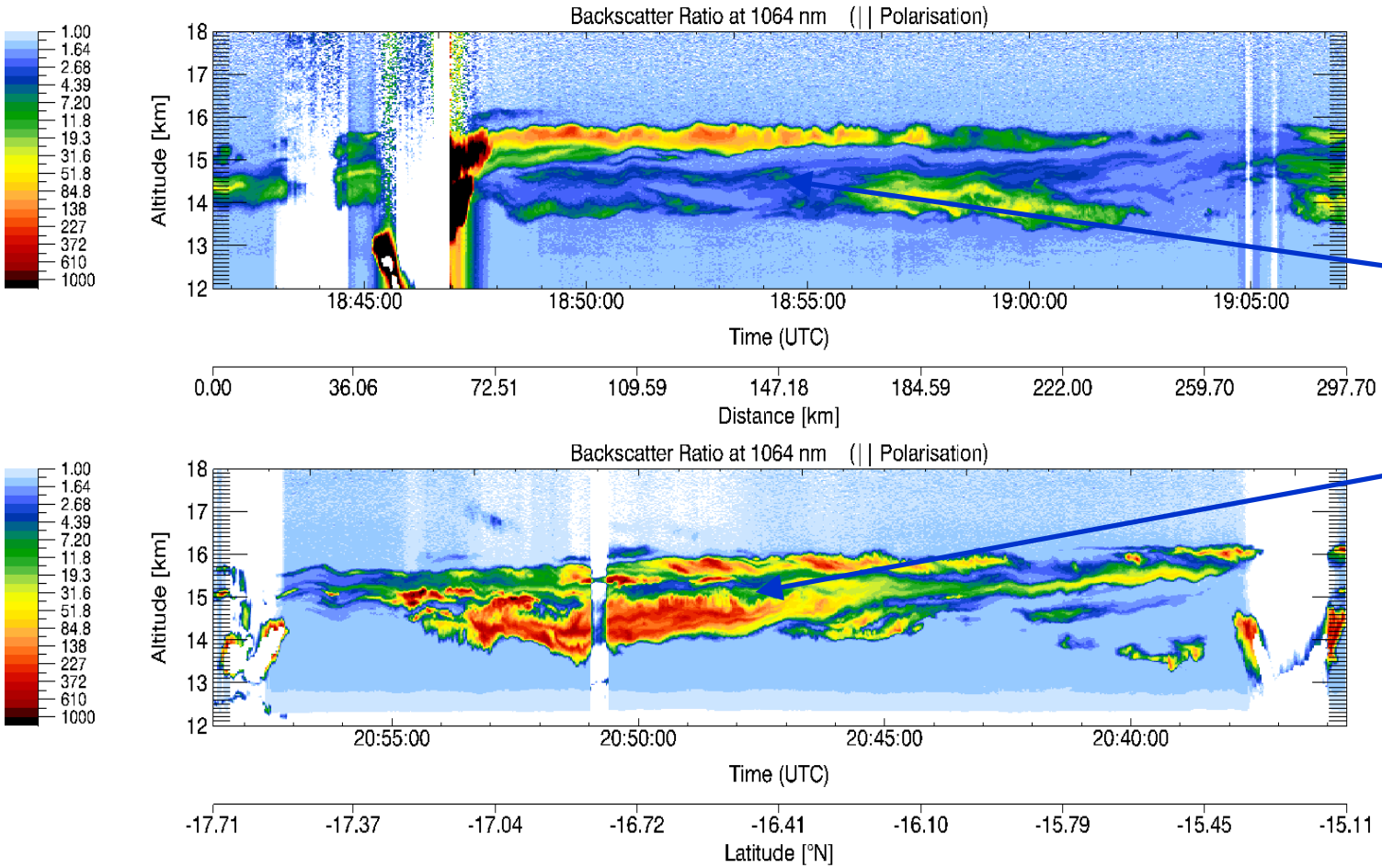
Troccinox 4. Flight 17-02-2004 Part 3



Life cycle of CB outflow

DIAL

Troccinox 4. Flight 17-02-2004

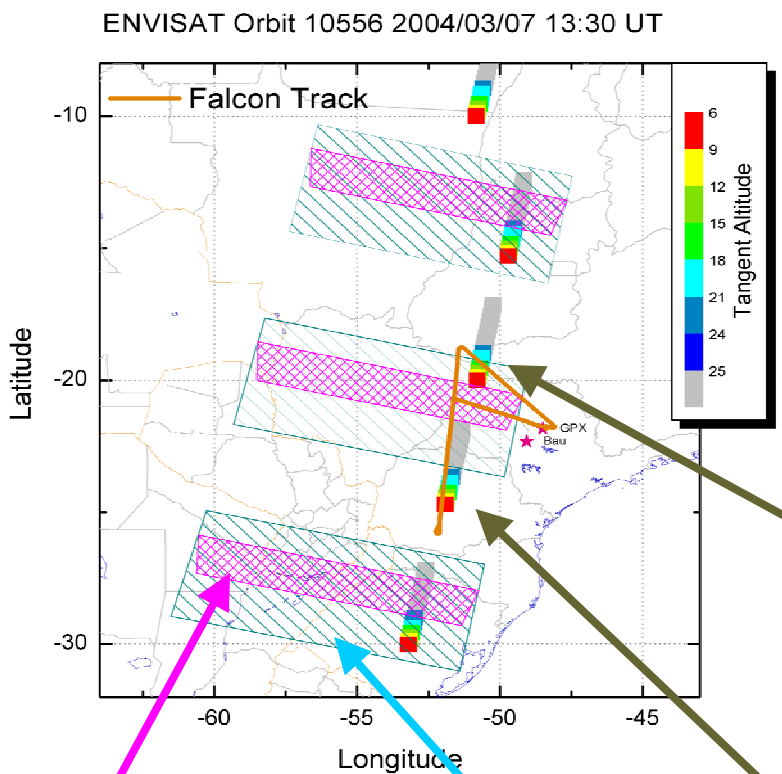


CB outflow

2 hours later

ENVISAT Validation Flight (07/03/04)

Flight Pattern:



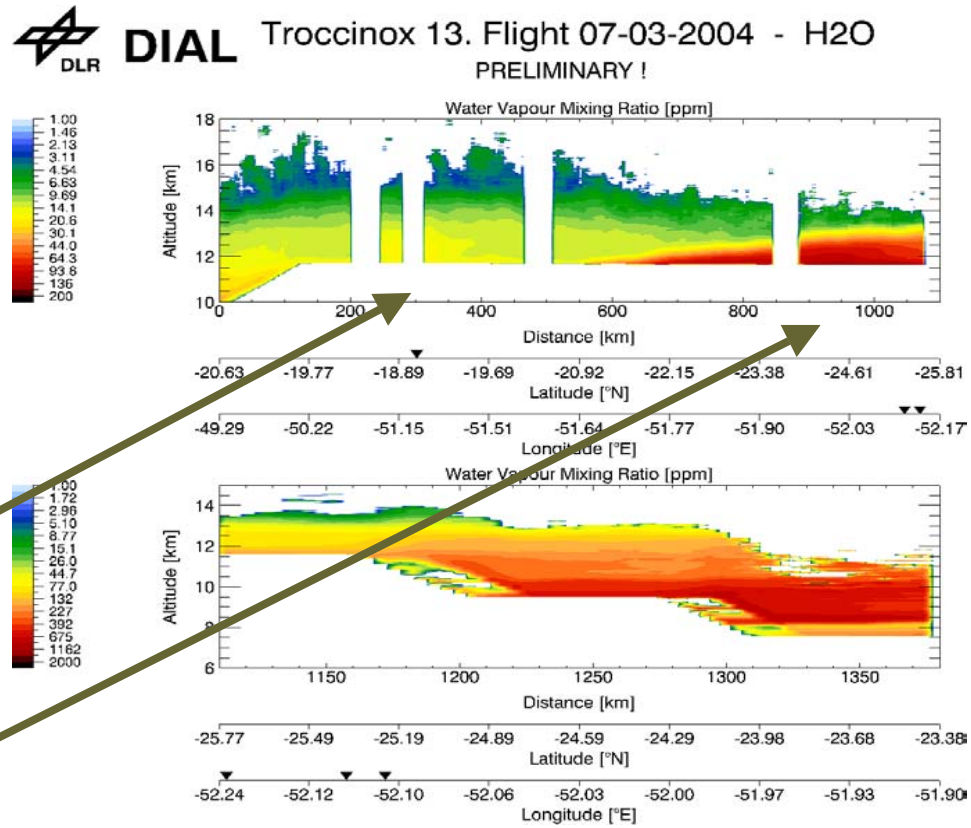
SCIAMACHY Limb Scan

SCIAMACHY Nadir Scan

MIPAS Scan 39

MIPAS Scan 40

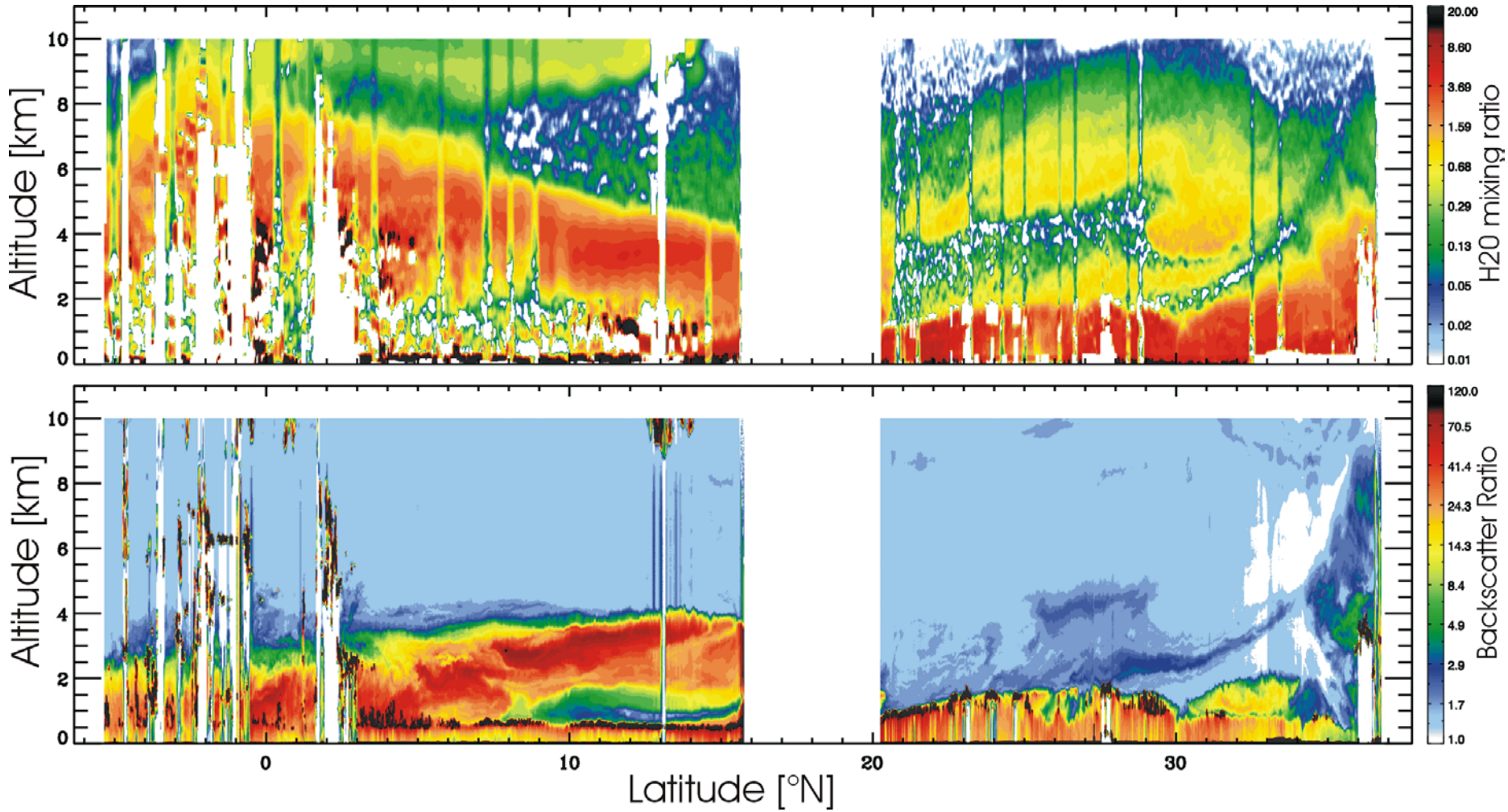
Results from H_2O DIAL:



Large Water Vapour Gradient !


TROCCINOX
D-CMET
FERRY BACK
OP
Sevilla
Sal
Recife
GPX
CANADA
UNITED STATES
GERMANY
FRANCE
UKRAINE
RUSSIA
ROMANIA
ITALY
GREECE
TURKEY
MOROCCO
ALGERIA
LIBYA
EGYPT
WESTERN SAHARA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
ETHIOPIA
SOMALIA
KENYA
VENEZUELA
COLOMBIA
PERU
BRAZIL
BOLIVIA
CHILE
PARAGUAY
ARGENTINA
CONGO
DEMOCRATIC
REPUBLIC
OF CONGO
TANZANIA
ANGOLA
ZAMBIA
MOZAMBIQUE
MADAGASCAR
BOTSWANA
NAMIBIA
SOUTH AFRICA
0
500
1000
1500
2000
NAUTICAL MILES

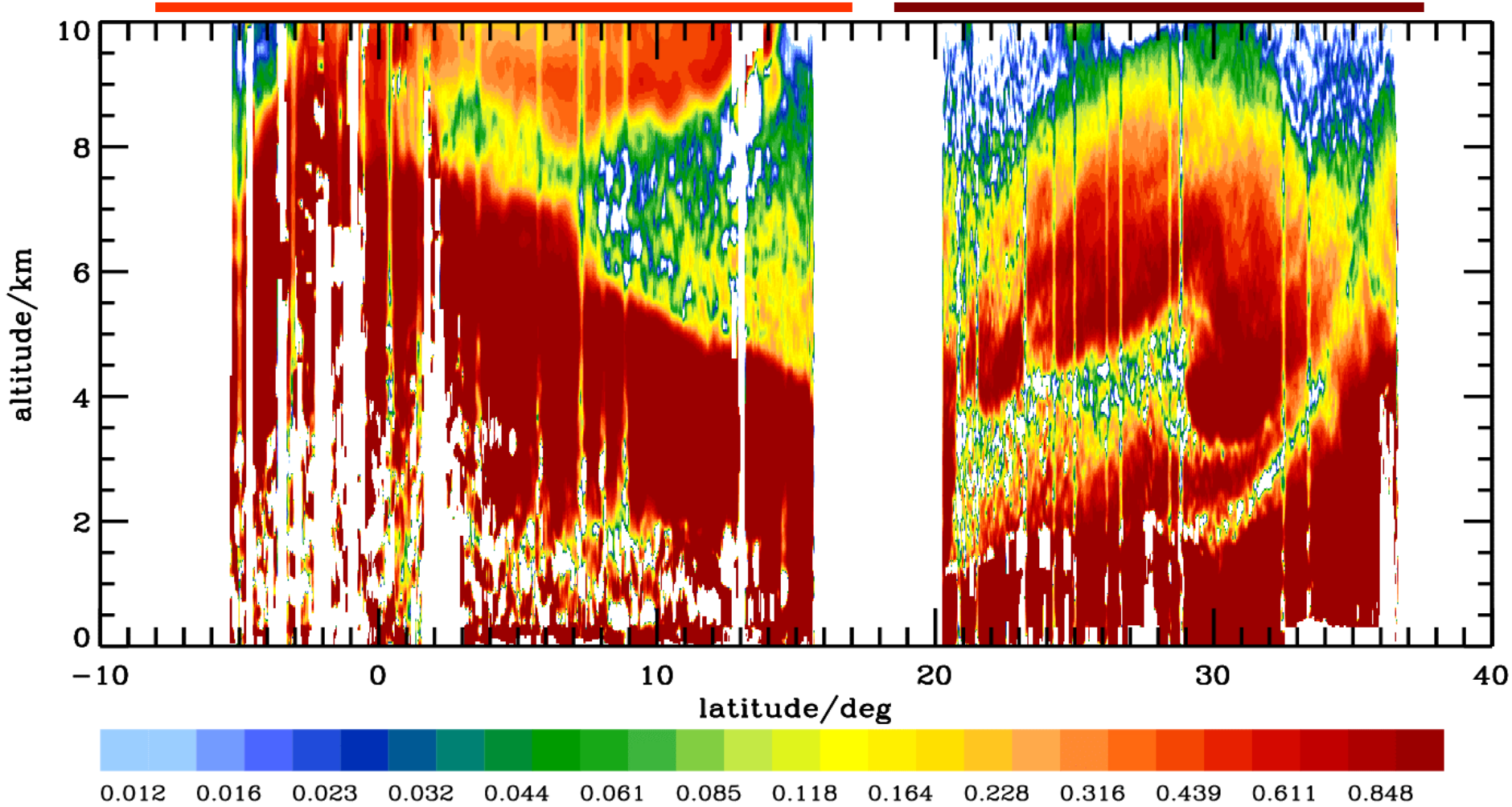
Transfer GPX → OP: 14 March 2004



H_2O Mixing Ratio (g/kg) on March 14

1000 and 1400 UTC

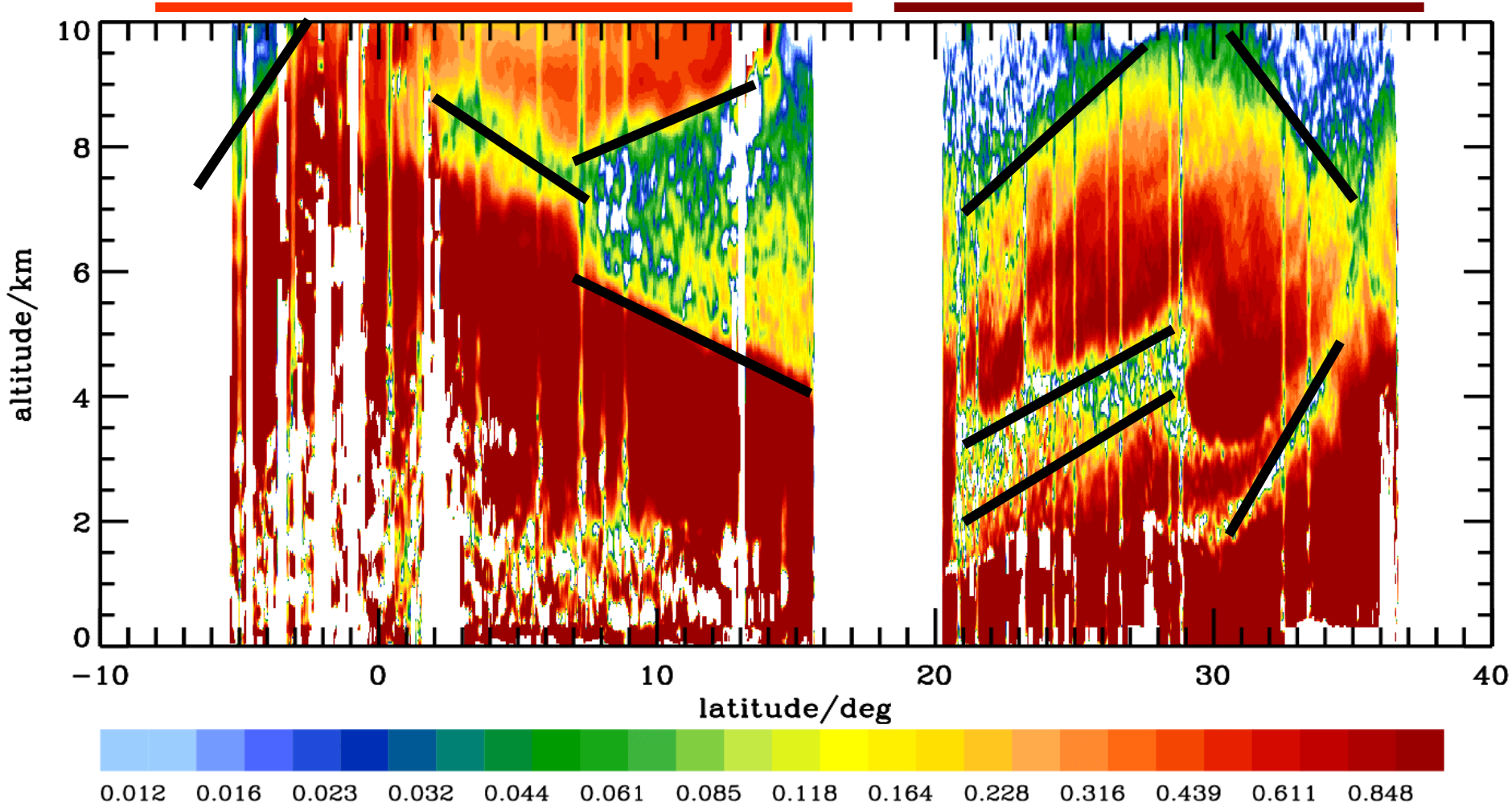
1500 and 1900 UTC



H_2O Mixing Ratio (g/kg) on March 14

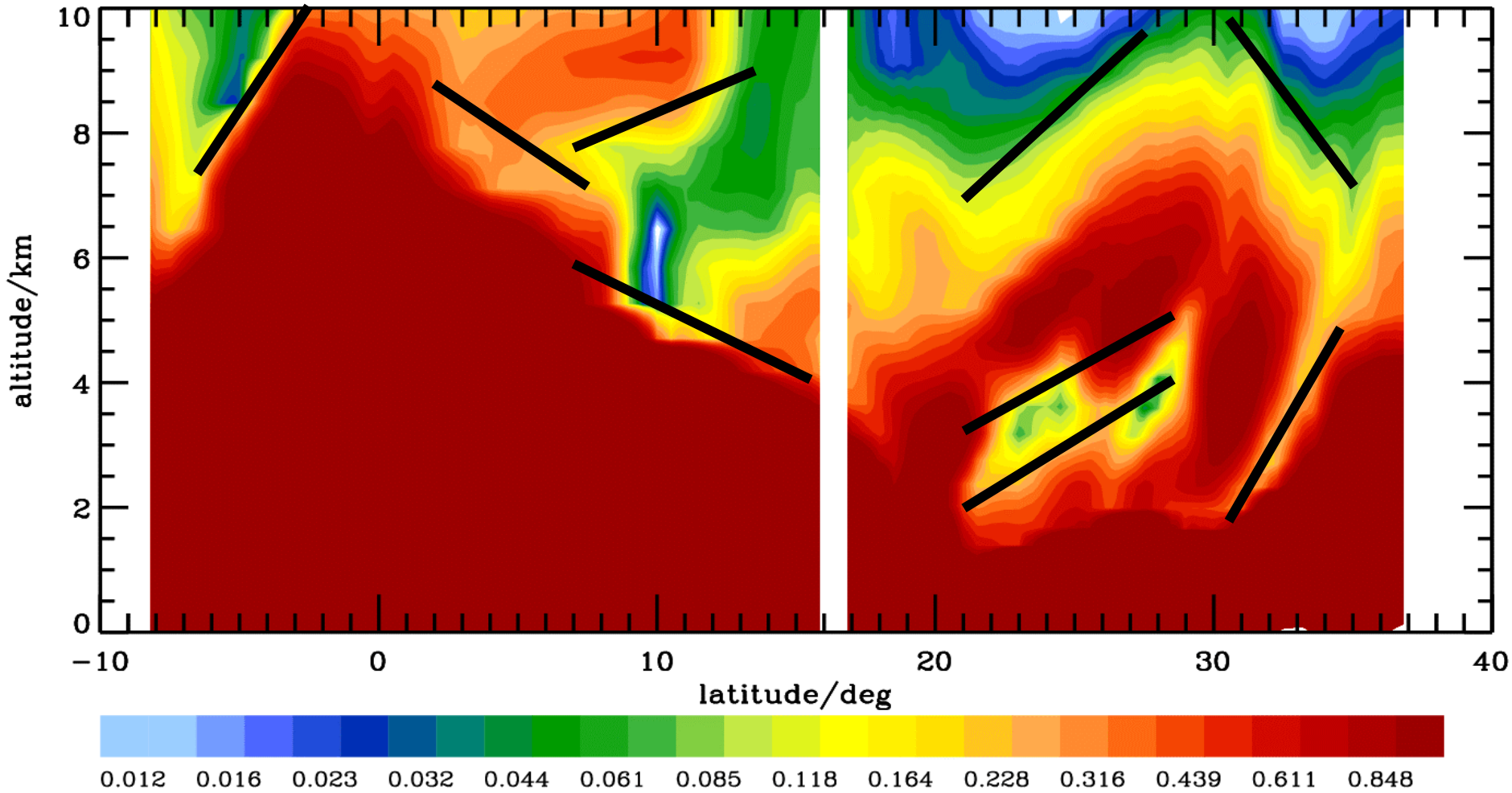
1000 and 1400 UTC

1500 and 1900 UTC



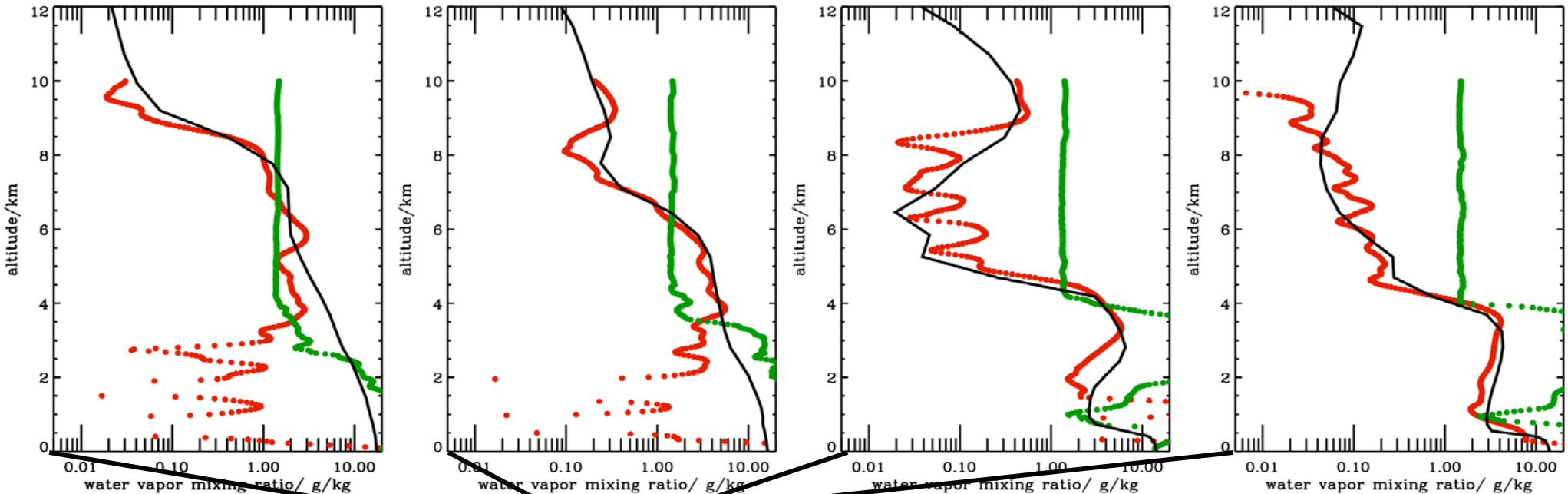
H_2O Mixing Ratio (g/kg) on March 14

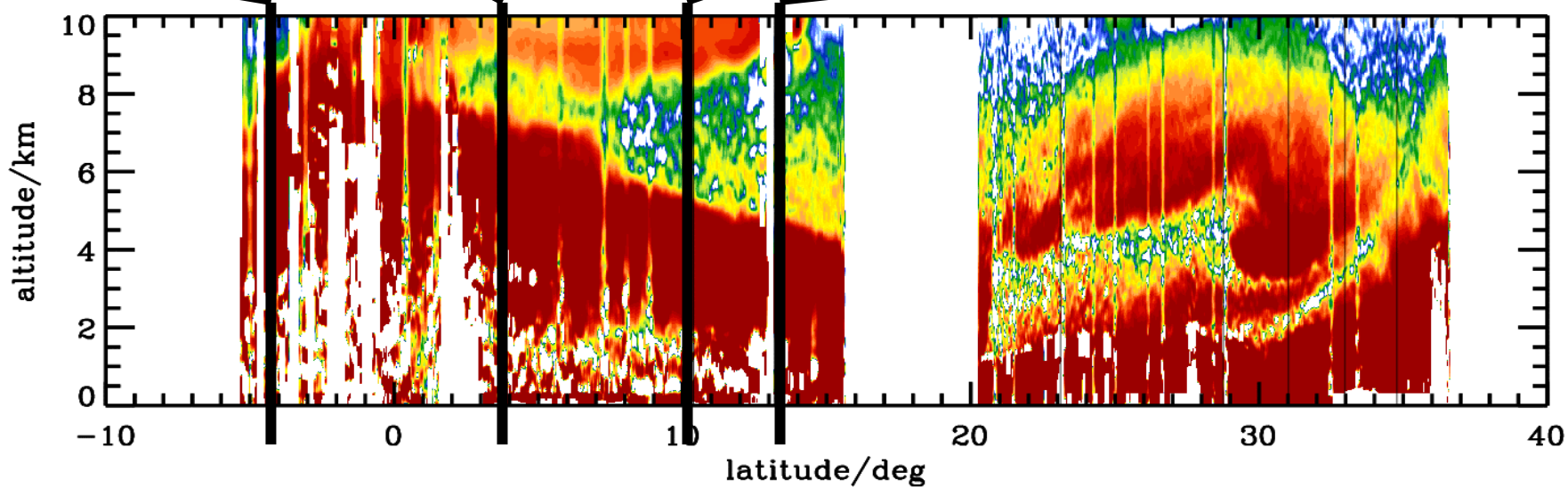
ECMWF T511/L60 operational analyses on model levels (~30)
(interpolated to the flight tracks)



Comparison of individual profiles

DIAL water vapor observation
ECMWF water vapor profile
Aerosol Backscatter Ratio





16.09.2004

TROCCINOX/WALEX II: Summary/Outlook

- Dynamical signature of Hadley circulation in H_2O during back-transfer
- Good agreement with ECMWF on large scales
- Large H_2O variability in tropical UT
- Characterization of Cb outflow
- Validation MIPAS, ICESAT-GLAS

- Comparison with Radiosondes (HIBISCUS)

- TROCCINOX II (2005)

Conclusion

- In the past years the airborne DLR lidar systems have been successfully employed in many field campaigns under various atmospheric conditions from the Arctic to the Tropics
- Stratosphere to Boundary Layer
- The data have proven to give valuable information to the scientific goals of each campaign.

- Several campaigns already planned for the future (TROCCINOX II, SAMUM, SCOUT, AMMA, COPS, ...)

- Ongoing improvements:
  Increase the dynamic range by adding 2 wavelengths.

-> DLR WALES Project