

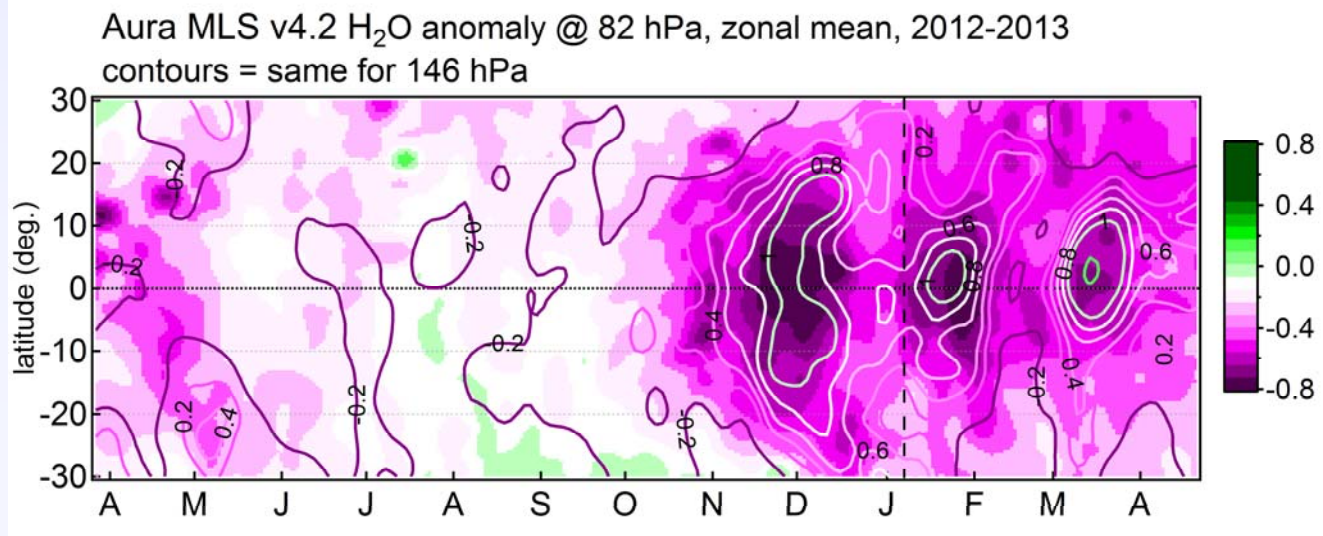
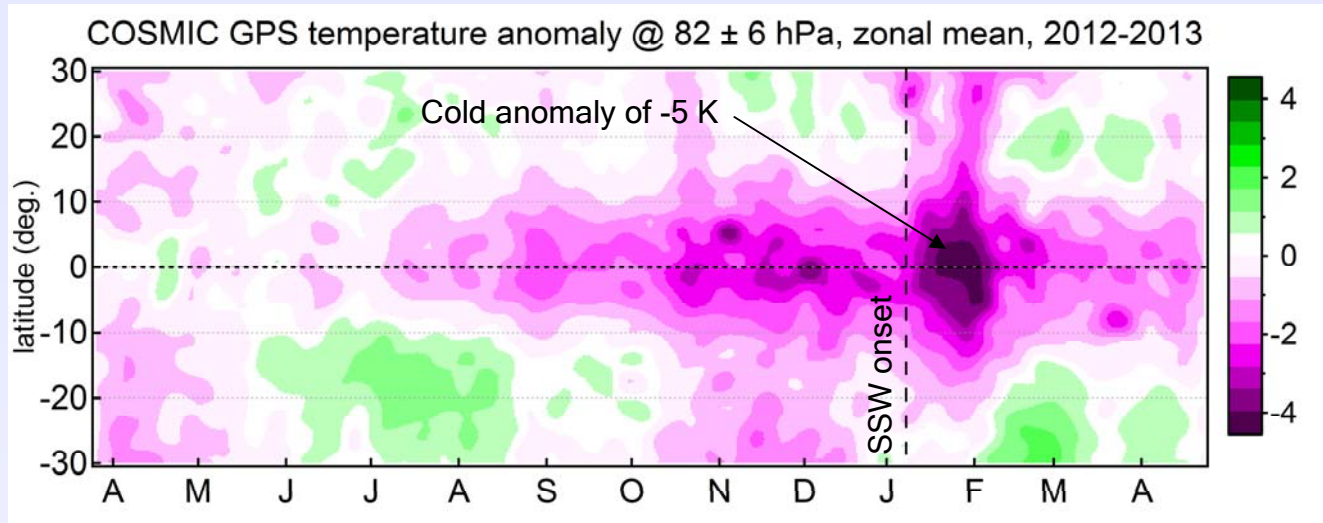
# Anomalous dehydration of the TTL during January 2013: evidence from balloon, aircraft and satellite observations

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G. Held<sup>4</sup>, S. Evan<sup>5</sup>, T. Thornberry<sup>6,7</sup>, A. Rollins<sup>6,7</sup>, D. Fahey<sup>7</sup>, H. Vömel<sup>8</sup>, M. Fujiwara<sup>9</sup>, and K. Rosenlof<sup>7</sup>*



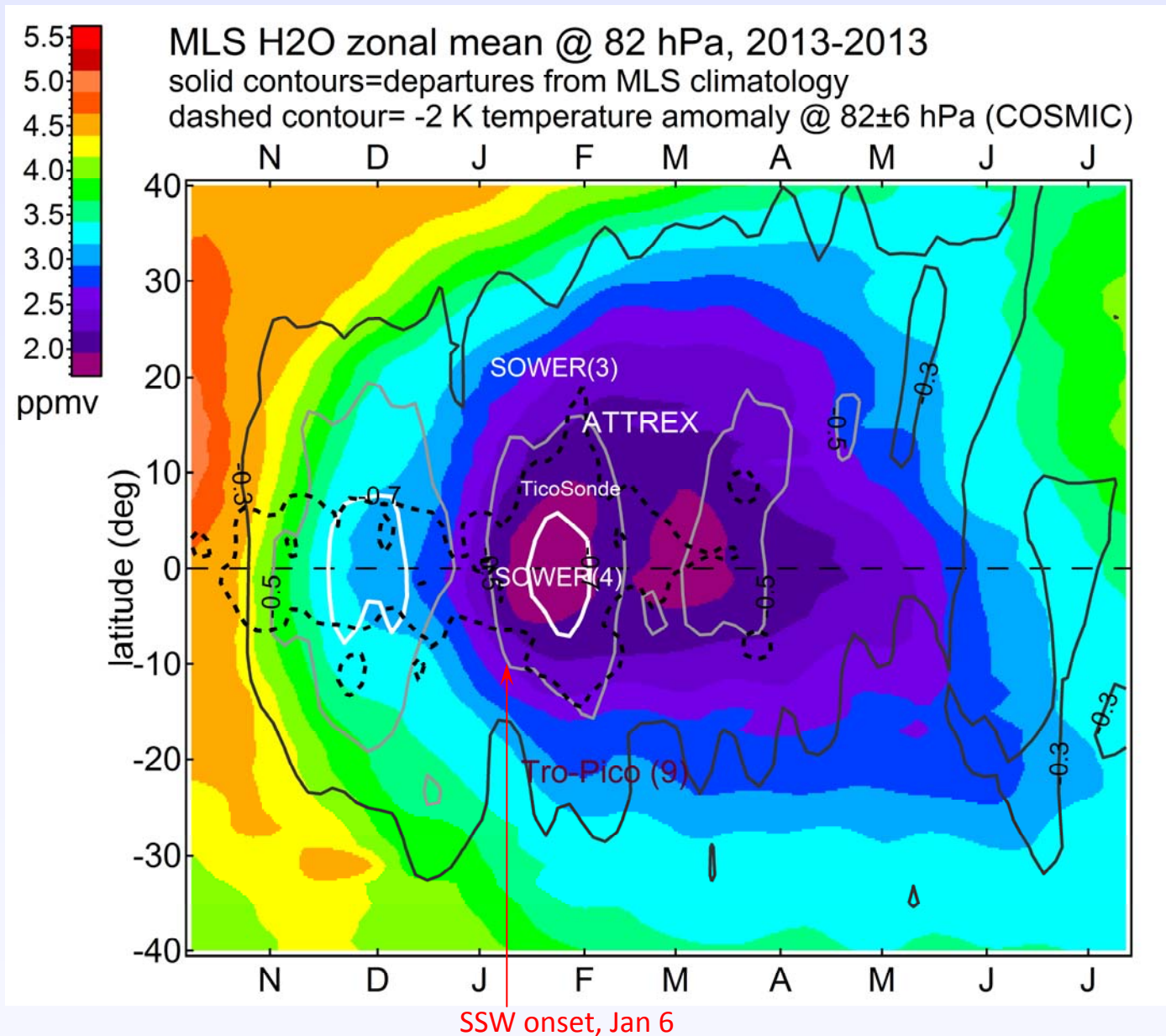
CT<sub>3</sub>LS workshop, Boulder CO, July 2013

# Temperature and water vapour anomalies, 2012-2013



**Collocated dry anomalies at 82 hPa and wet anomalies at 146 hPa**

# Measurement campaigns in Jan-Feb 2013





# Measurement campaigns in Jan-Feb 2013

## **SOWER-2013 balloon campaign.**

**Biak, Indonesia (1.4 S, 136 E) and Hanoi, Vietnam (21 N, 106 E):**  
CFH sondes.



## **ATTREX aircraft campaign. Tropical Central Pacific.**

NOAA water instrument onboard Global Hawk

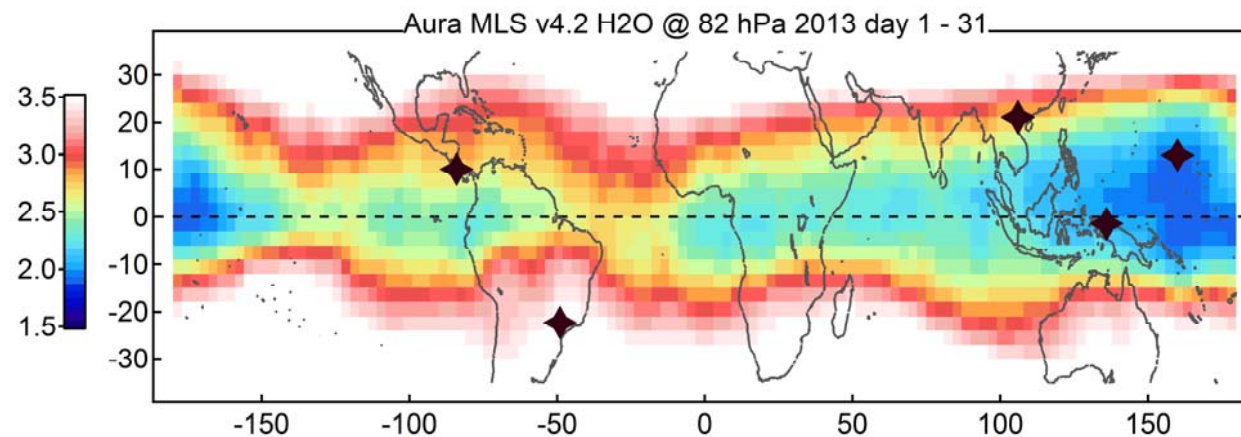
## **TroPico-2 balloon campaign. Bauru, Brazil (22 S, 49 W):**

FLASH-B Lyman-alpha and Pico-SDLA TDL balloon-borne  
hygrometers



## **TicoSonde balloon campaign. San Jose, Costa-Rica (10 N, 84 W).**

CFH sondes.



# ATTREX – Central Pacific

NOAA H<sub>2</sub>O on Global Hawk (13 N, 160 W) 27 Feb 2013  
13 s averages

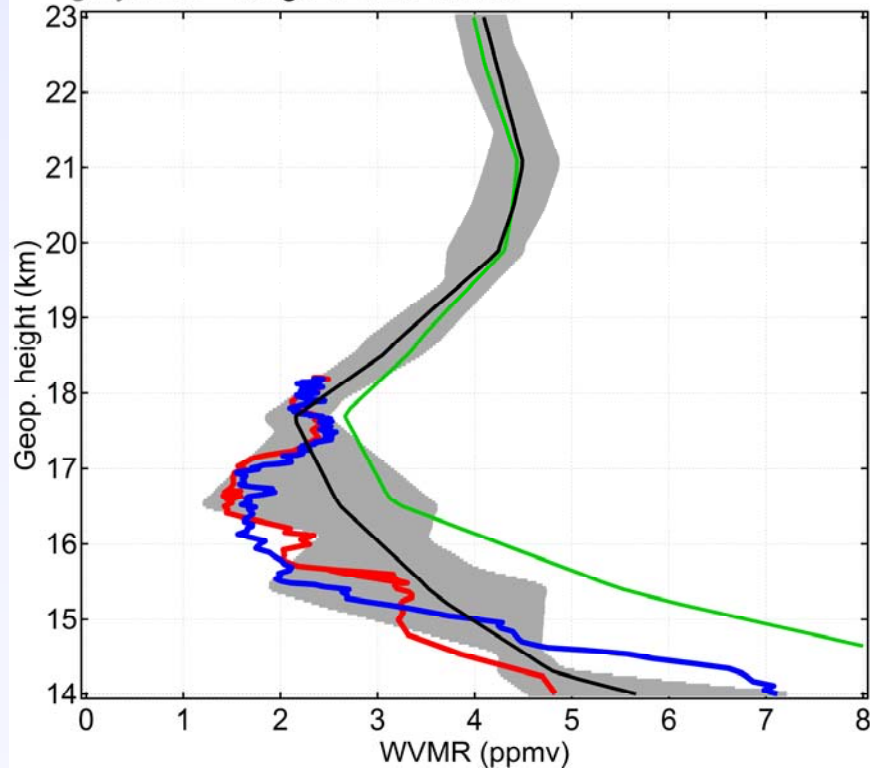
— ascent leg — descent leg

MLS v4.2, 27 Feb 2013, 5° (lat) x 10° (long) x 5d

— climatology (91 profiles)

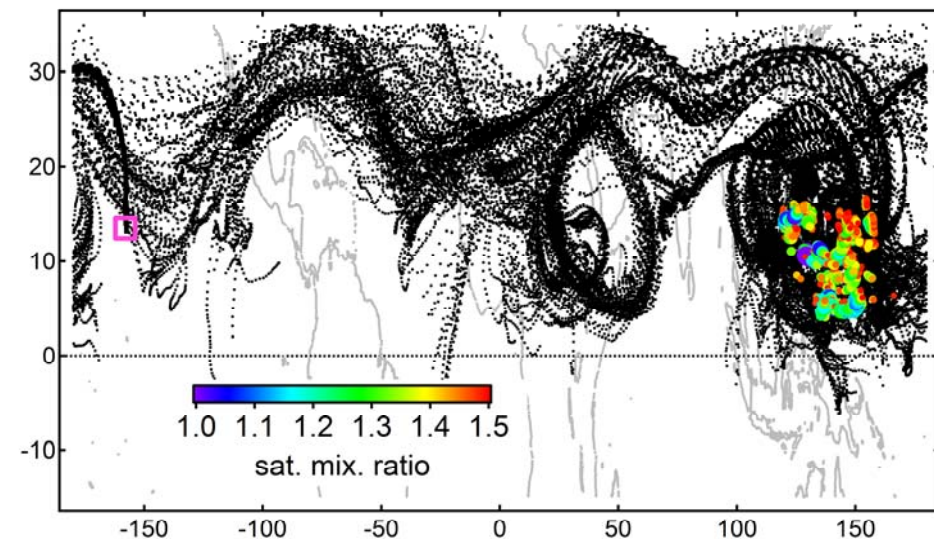
— mean over period/domain (6 profiles)

grey area = range of MLS values



- Hysplit model driven by GDAS meteorological analysis ( $0.5^\circ \times 0.5^\circ$  horizontal resolution, 55 pressure levels up to 10 hPa, ~ 5 levels in TTL)
- Ensembles of 500 trajectories spaced by  $0.1^\circ / 100$  m steps from a  $1^\circ \times 1^\circ \times 1$  km domain centered at the driest level at each sounding location
- Calculation of saturation mixing ratio along each trajectory shows where the sampled air could have been dehydrated

21 days backward traj. from ATTREX GH flight 27 Feb 2013  
sub-frost point exposure dates: 18 - 23 Feb 2013  
max. time below frost point for 1.5 ppmv: 11 h



# SOWER – Hanoi, South-East Asia

CFH @ Hanoi (21 N, 106 E) 12 Jan 2013, 40 s running mean

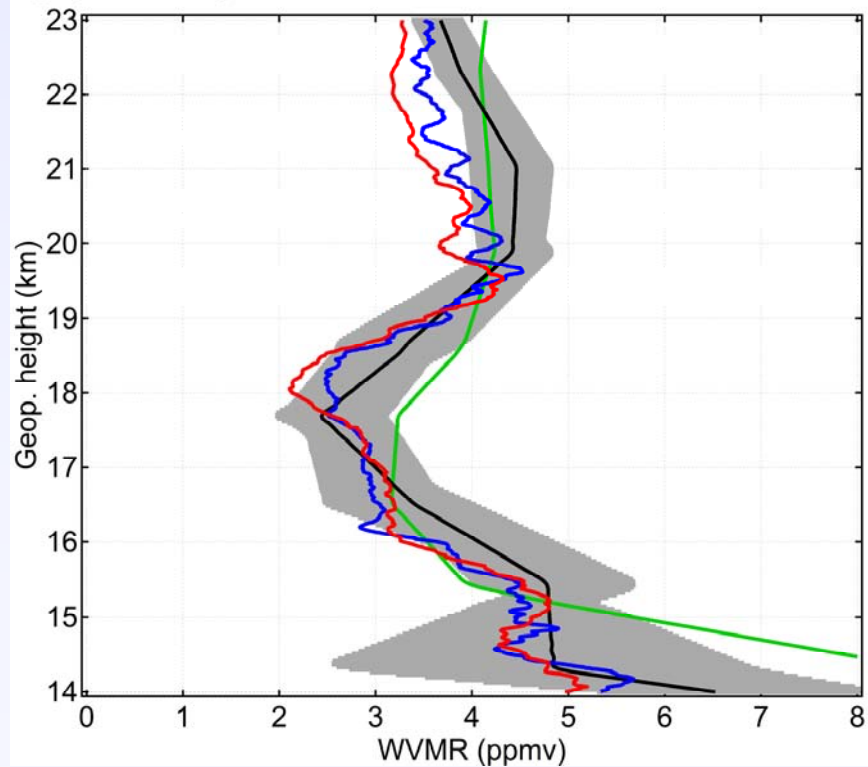
— ascent  
— descent

MLS v3.3, Hanoi, 12 Jan 2013, 5° (lat) x 10° (long) x 5d

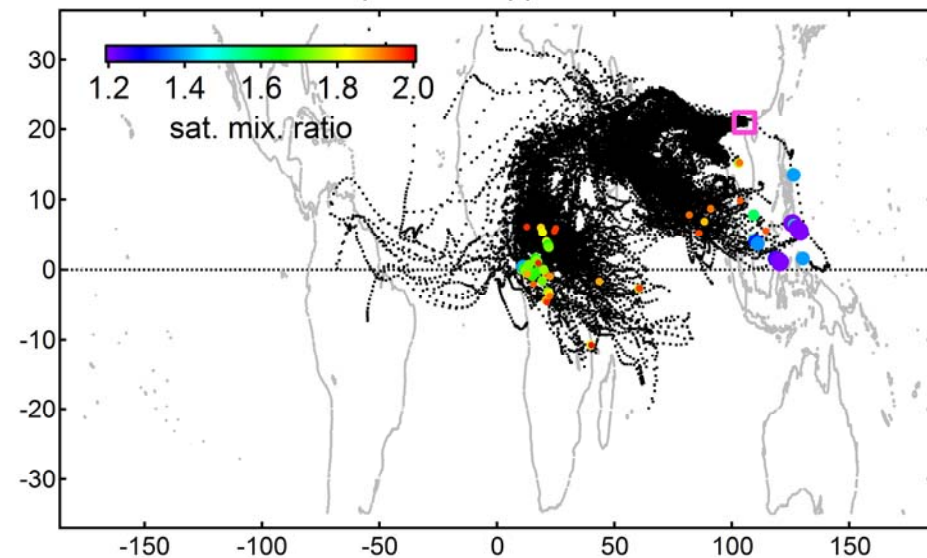
— mean over period/domain (6 profiles)

— climatology (119 profiles)

grey area = range of MLS values



10 days backward trajectories from Hanoi 12 Jan 2013  
sub-frost point exposure dates: 4 - 6 Jan 2013  
max. time below frost point for 2 ppmv: 9 h





# SOWER – Biak, Western Pacific

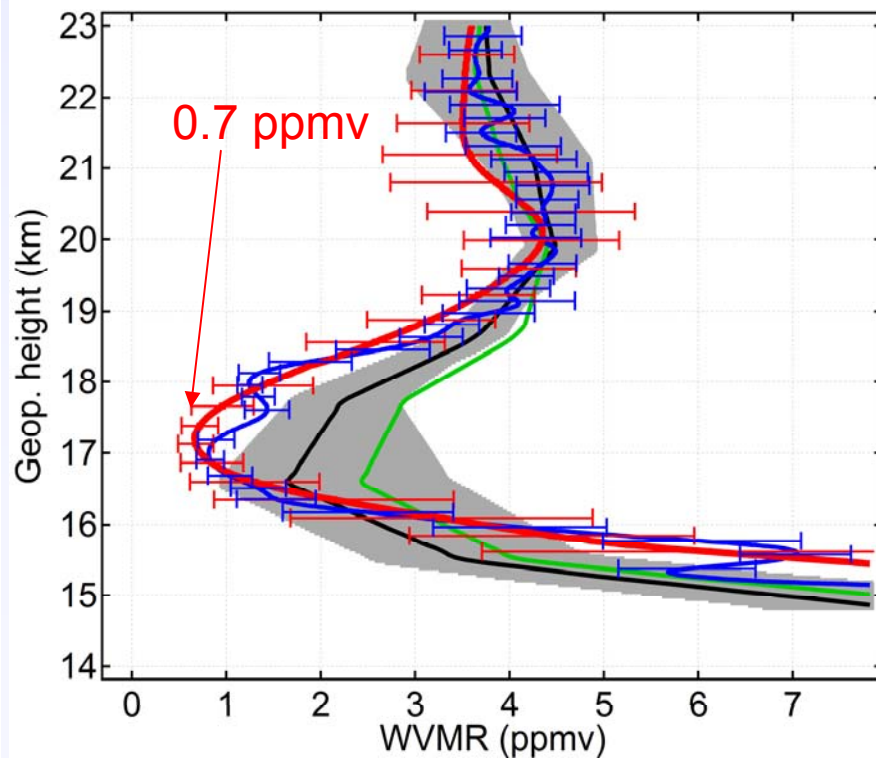
CFH @ Biak (1.4 S, 136 E) 10 Jan 2013 low pass

- ascent 14h
- descent 14h

MLS v3.3, Biak, 10 Jan 2013, 4° (lat) x 10° (lon) x 3d

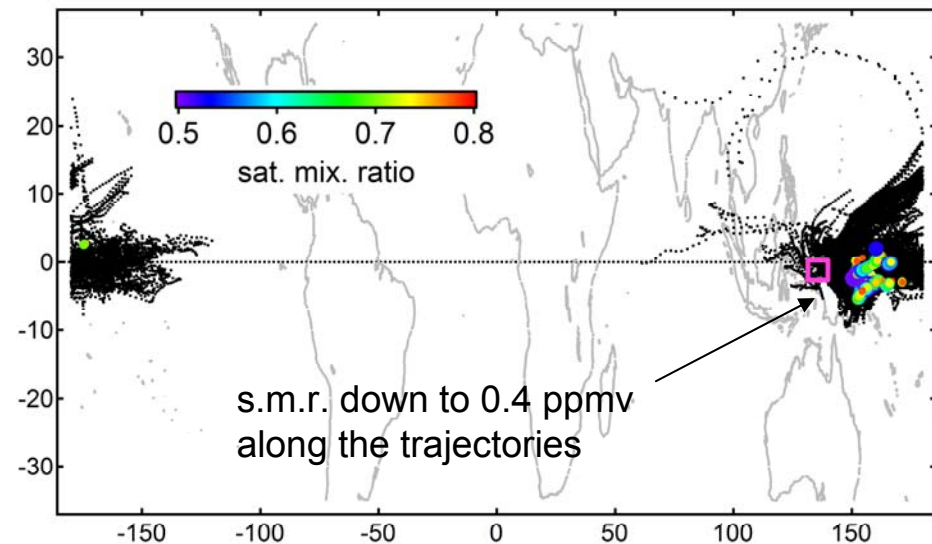
- mean over period/domain (7 profiles)
- climatology (50 profiles)

grey area = range of MLS values



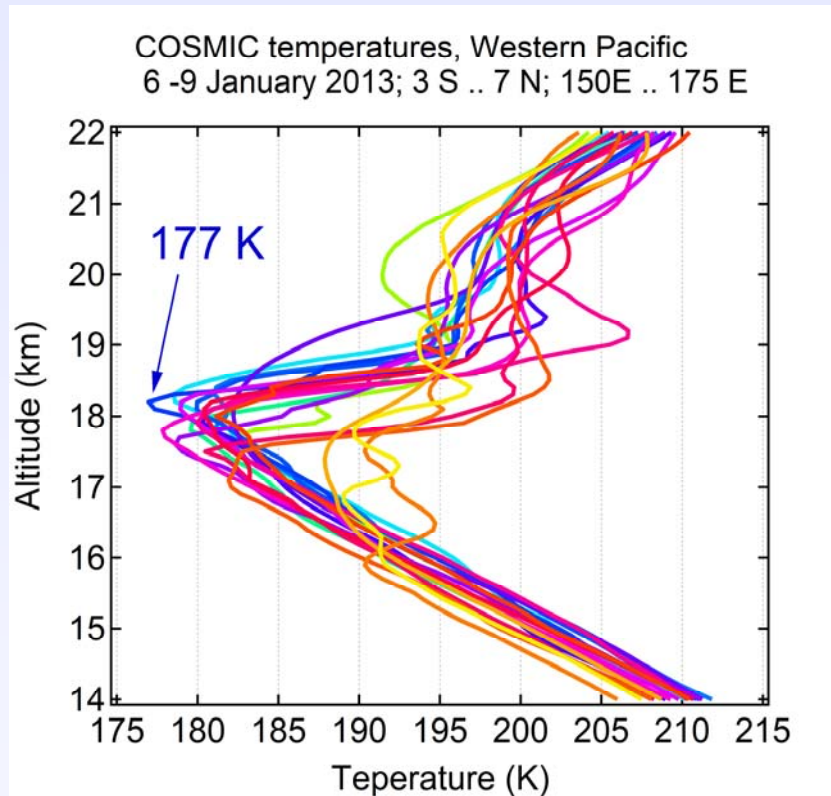
0.66±25% ppmv: is it realistic?

8 days backward trajectories from Biak 10 Jan 2013  
sub-frost point exposure dates: 5 - 8 Jan 2013  
max. time below frost point for 0.8 ppmv: 27 h

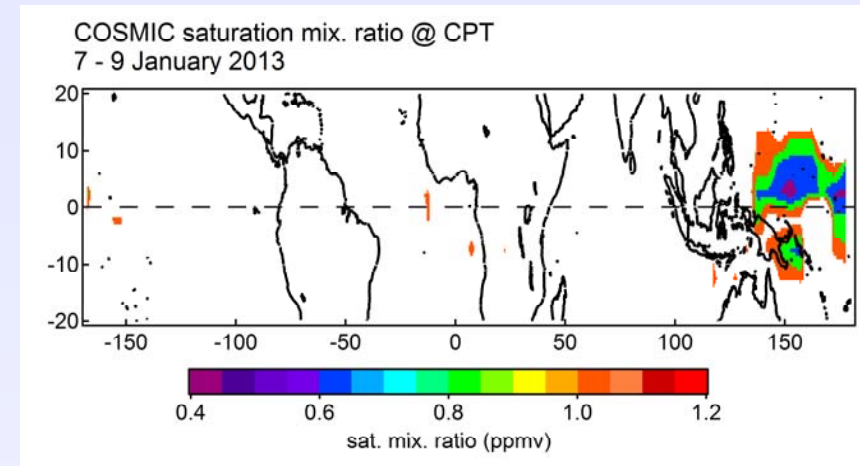


# COSMIC measurements above Western Pacific

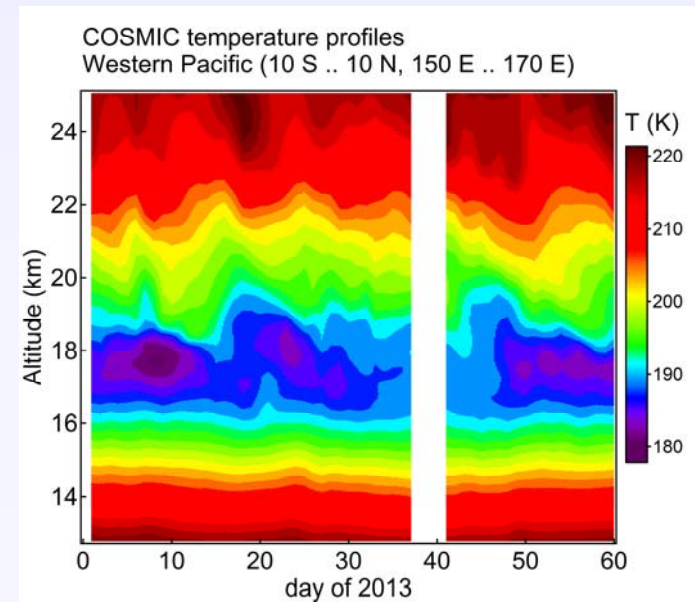
How cold?



Where coldest?



How long?





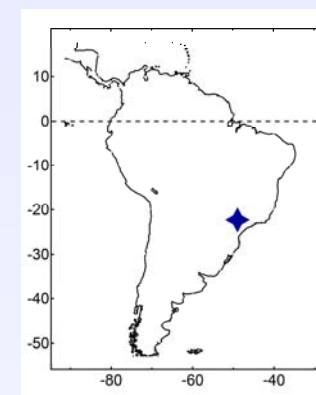
# Tro-Pico balloon soundings

## TRO-Pico balloon campaigns, Brazil, 22°S, Feb-Mar 2012, Jan-Feb 2013

*to study the impact of convective overshooting on stratospheric water budget*

- Zero-pressure plastic 500 and 1500 m<sup>3</sup> balloons
- 500, 800 and 1200 g Totex rubber balloons

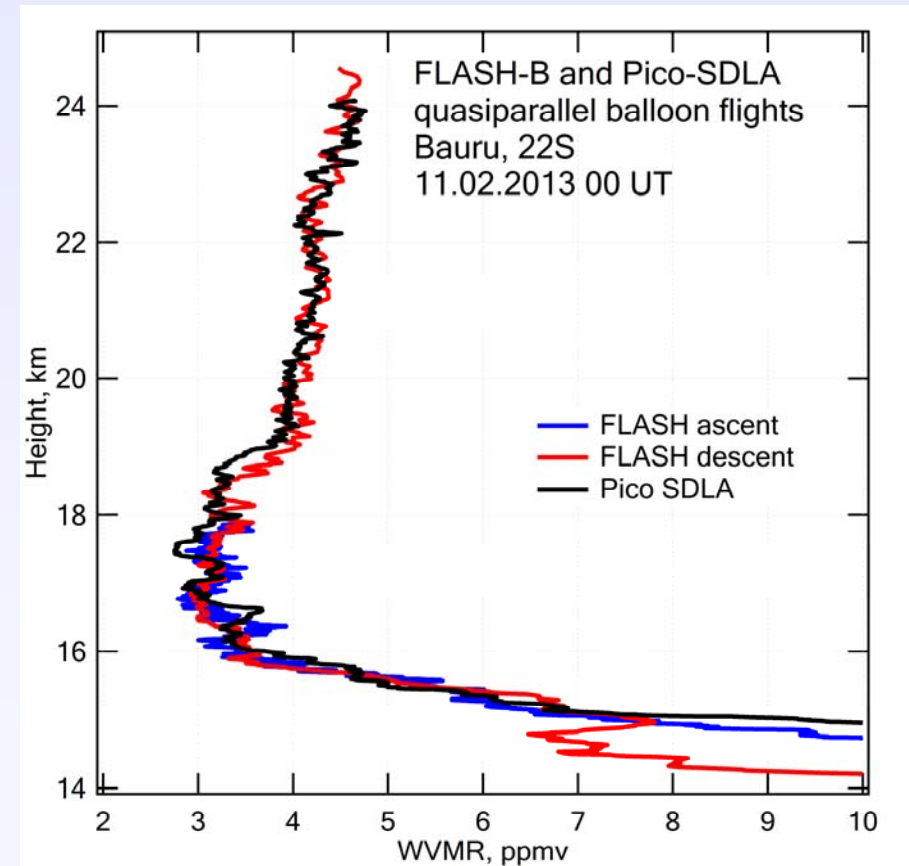
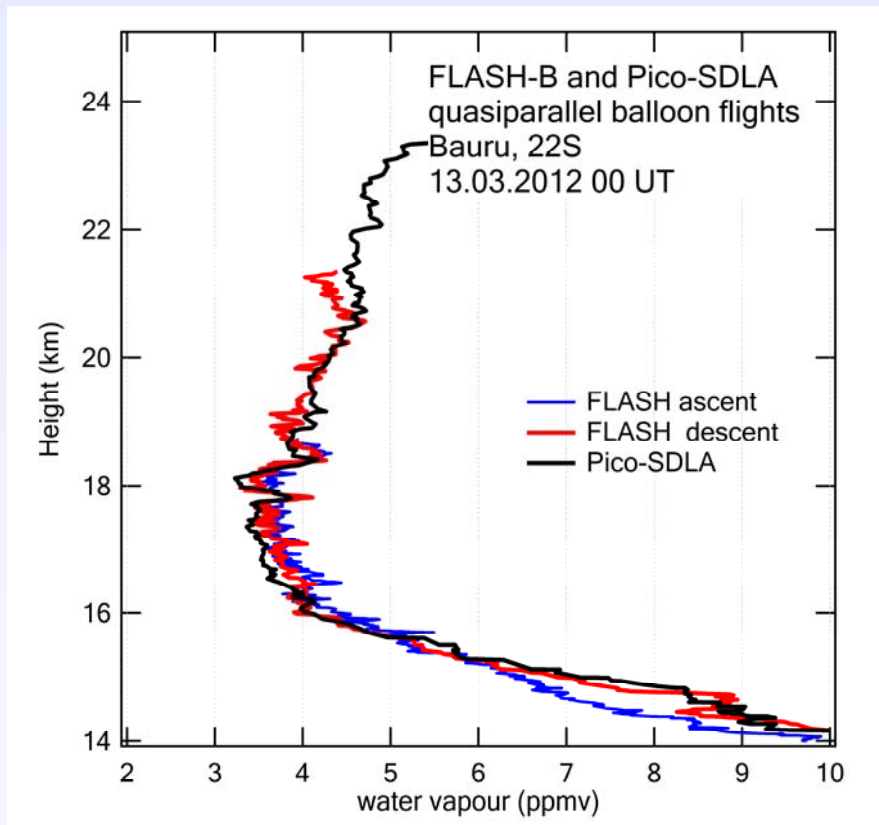
	Flight train	Species	Nb of flights in		
			2012	2013	
Plastic balloons	Pico-SDLA H <sub>2</sub> O + LOAC	H <sub>2</sub> O and aerosol	1	1	2
	Pico-SDLA CH <sub>4</sub>	CH <sub>4</sub>	1	1	2
	Pico-SDLA CH <sub>4</sub> +Pico-SDLA H <sub>2</sub> O	H <sub>2</sub> O and CH <sub>4</sub>	0	2	2
	Pico-SDLA CO <sub>2</sub> +Pico-SDLA H <sub>2</sub> O	H <sub>2</sub> O and CO <sub>2</sub>	0	3	3
	<b>Pico-SDLA H<sub>2</sub>O</b>	H <sub>2</sub> O	2	1	3
	pico-SDLA H <sub>2</sub> O dry wet / wet dry transition period (SMOP)	H <sub>2</sub> O	4	3	7
	Mini-SAOZ	O <sub>3</sub> , NO <sub>2</sub> , H <sub>2</sub> O, H <sub>2</sub> CO, BrO	2	0	2
Rubber balloons	<b>FLASH</b> and COBALD	H <sub>2</sub> O and aerosol	7	6	13
	FLASH + COBALD + LOAC	H <sub>2</sub> O and aerosol	0	2	2
	COBALD	aerosol	0	1	1
	RS92 radiosonde, series of ~4 RS a day ( <i>in number of days</i> )	P, T, U	10	15	25



# Balloon soundings in Brazil

TroPico-II balloon campaign, Brazil, 22°S, Jan-Feb 2013

Comparison between FLASH-B and Pico-SDLA hygrometers

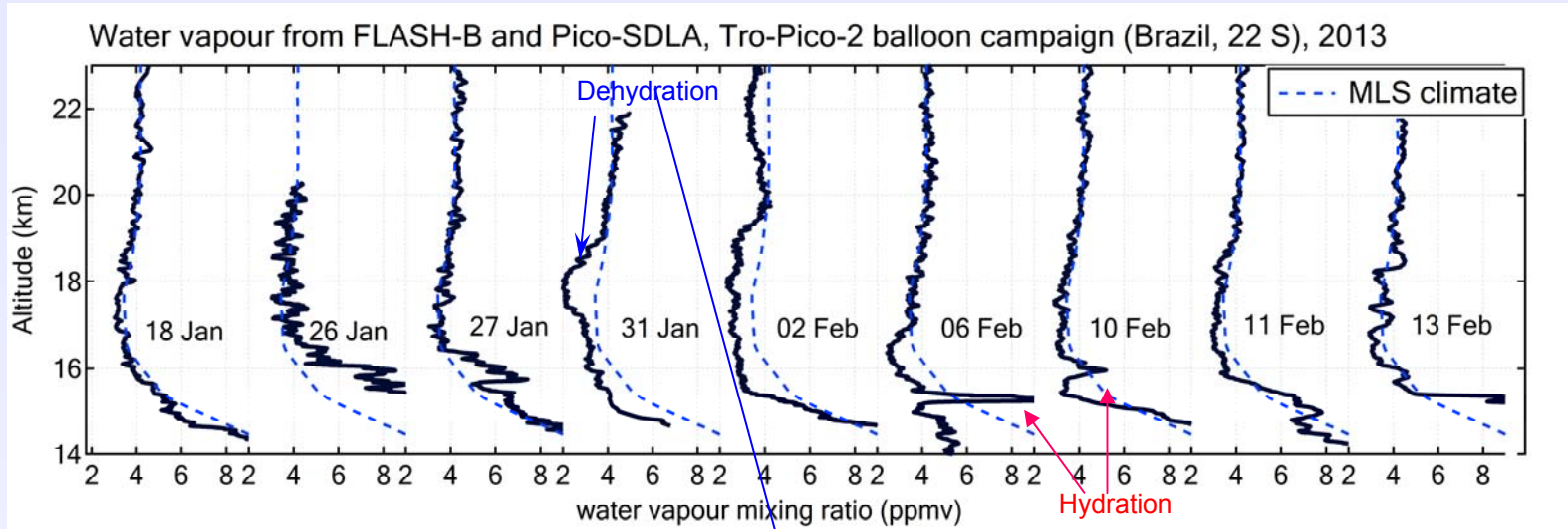


Excellent agreement between FLASH and PicoSDLA

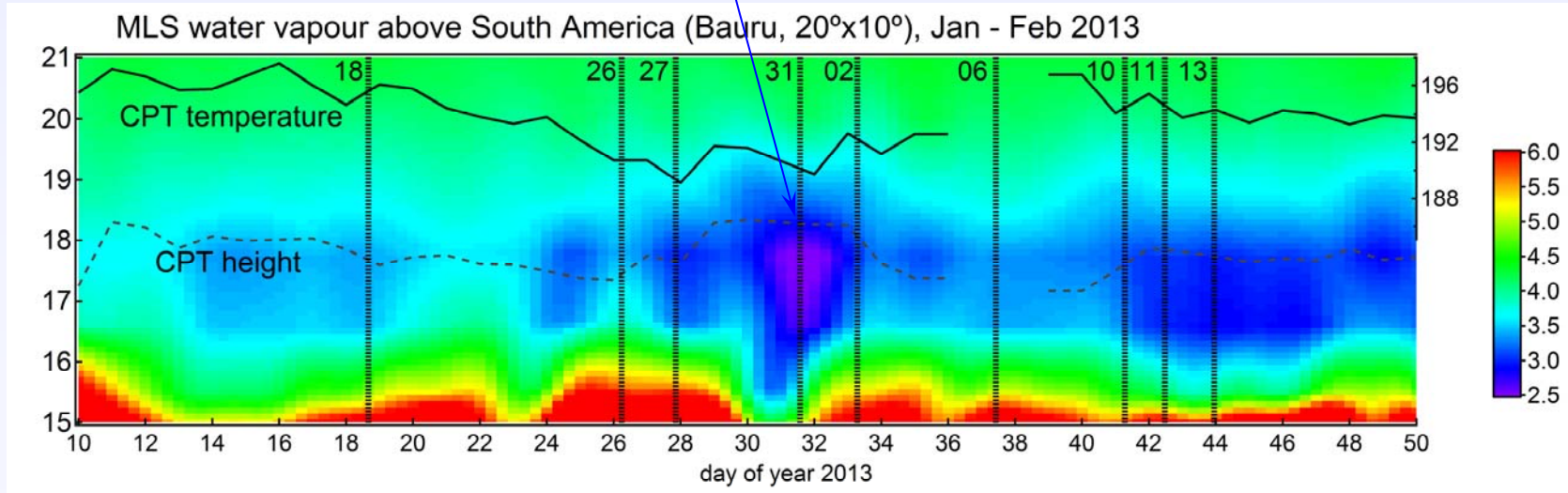
# Balloon soundings in Brazil

## TroPico-II balloon campaign, Brazil, 22°S, Jan-Feb 2013

Local scale



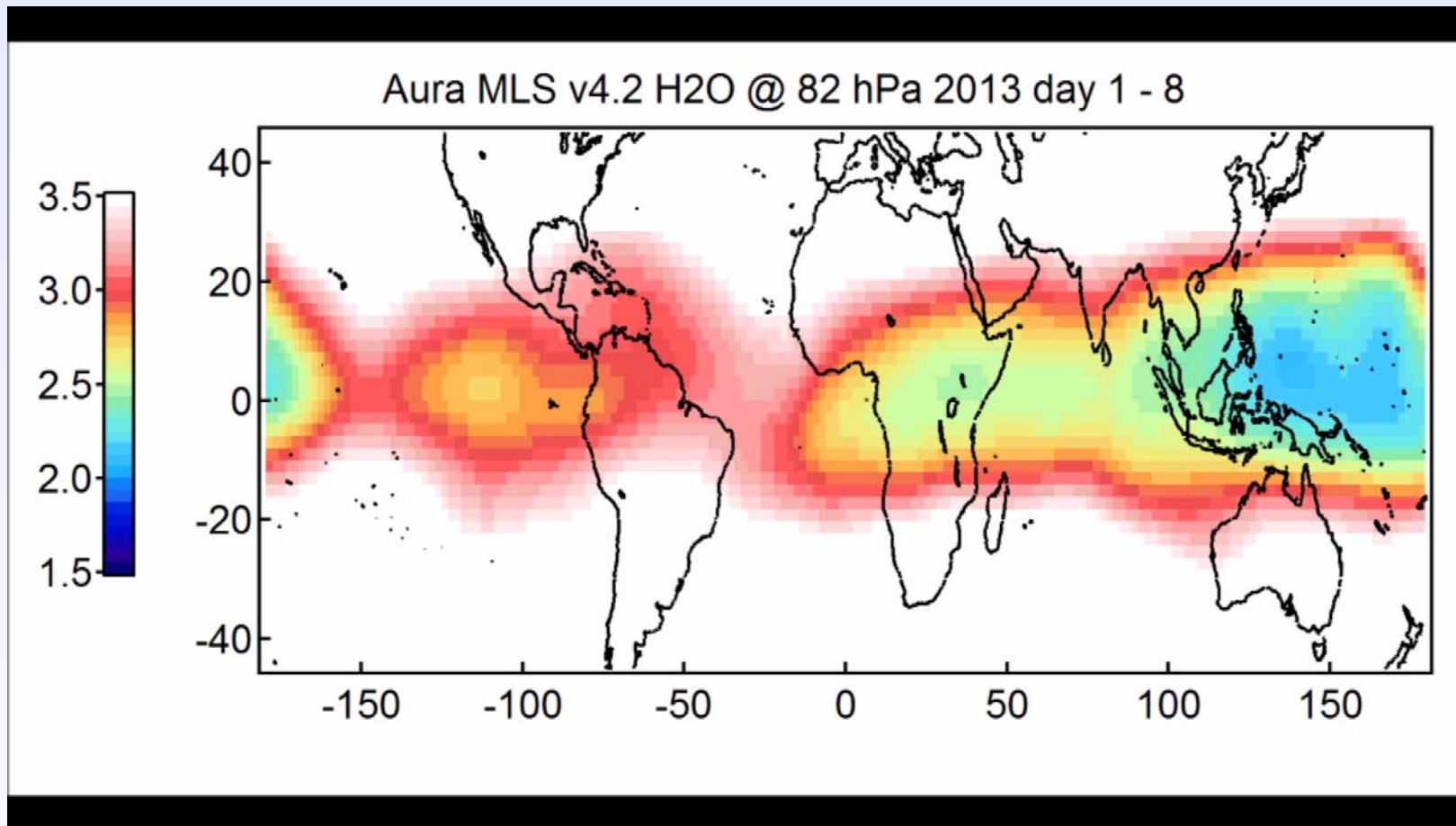
Synoptic scale



Rapid drop of water from 4 to 2 ppmv over a few days



# Global evolution of water vapour fields

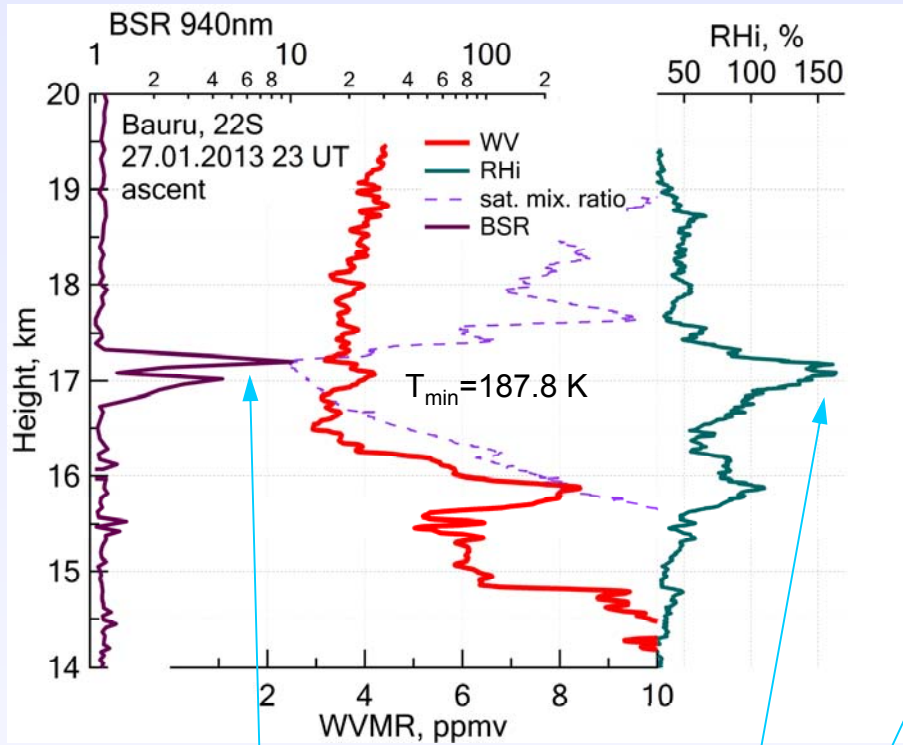


7-day averages, stepping forward by 1 day

# Clouds and dehydration

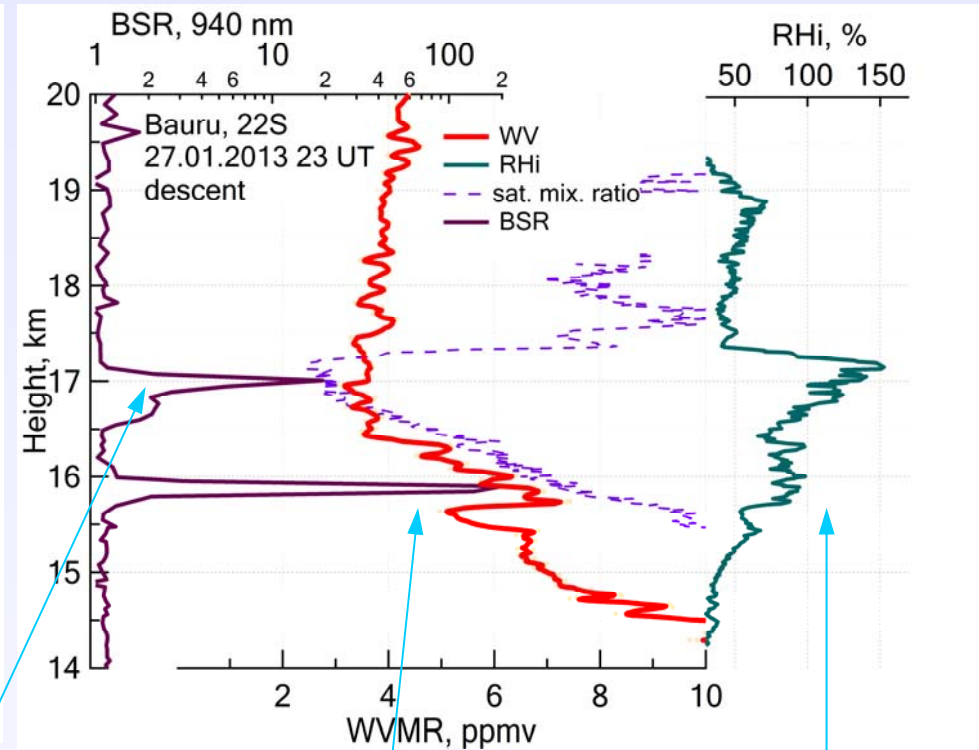
## FLASH and COBALD flight sampling the same air mass at CPT twice

Balloon ascent



Cirrus with extreme supersaturation (165%) and low backscatter

Balloon descent



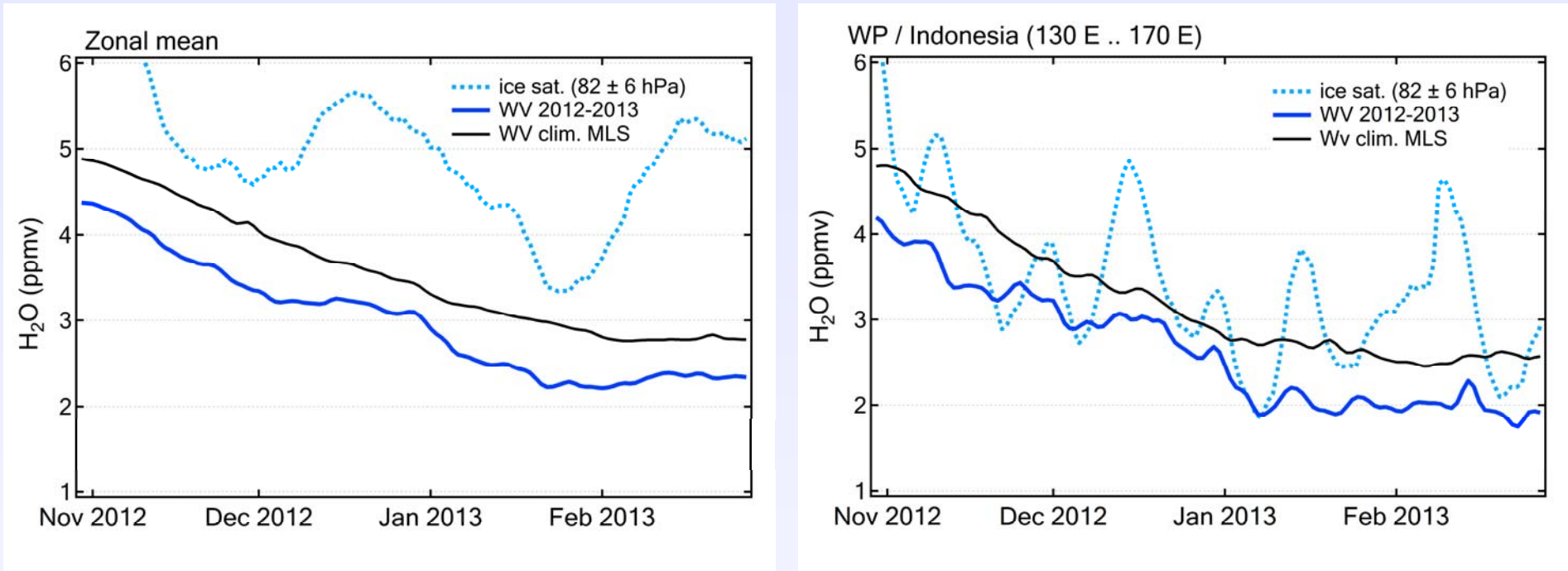
Subsaturated cirrus with high backscatter

## Summary

- As a result of enhanced tropical upwelling (PW activity related) in January 2013 the LS was anomalously cold (- 5 K) and dry (-0.8 ppmv) in the zonal-mean
- High-resolution in situ measurements of water vapour at different tropical locations consistently show large negative anomalies compared to MLS climatology , reaching - 2 ppmv (70%);
- A record-low mixing ratio of 0.66 ppmv ( $\pm 25\%$ ) was detected by CFH above Biak in the Western Pacific region, where cooling and drying were largest according to satellite observations by COSMIC and MLS
- Trajectory analysis suggests that the air sampled by in situ instruments at different locations has been processed by sub-frost point temperatures predominantly above Western Pacific
- Balloon soundings in Brazil within TroPico-2 campaign:
  - Excellent agreement between FLASH and Pico-SDLA allows combining their profiles into a single WV series
  - Temporal evolution of dehydration revealed by the balloon profiles is captured by MLS synoptic-scale averages
  - Simultaneous water and aerosol measurements by FLASH-B and COBALD sondes reveal two types of TTL cirrus clouds with different dehydration potential



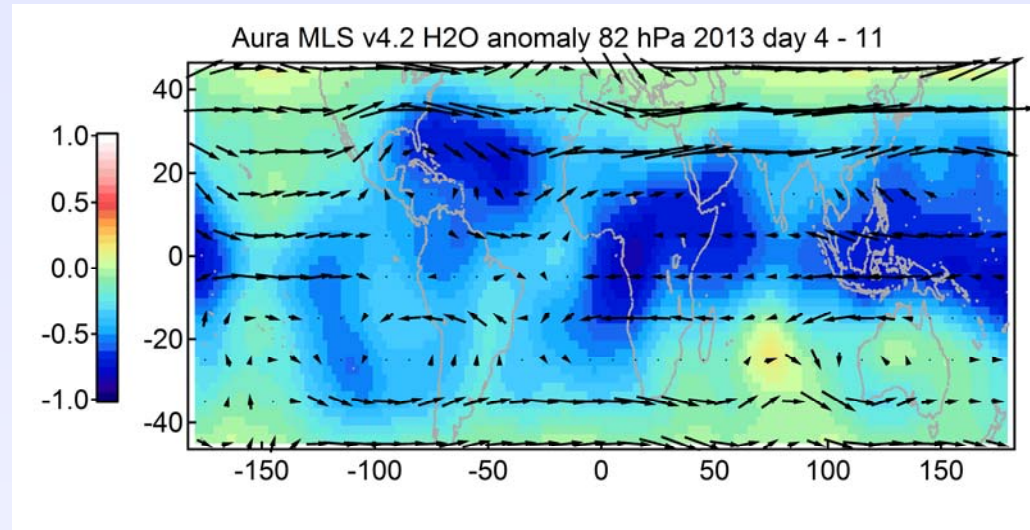
# Relationship between temperature and water



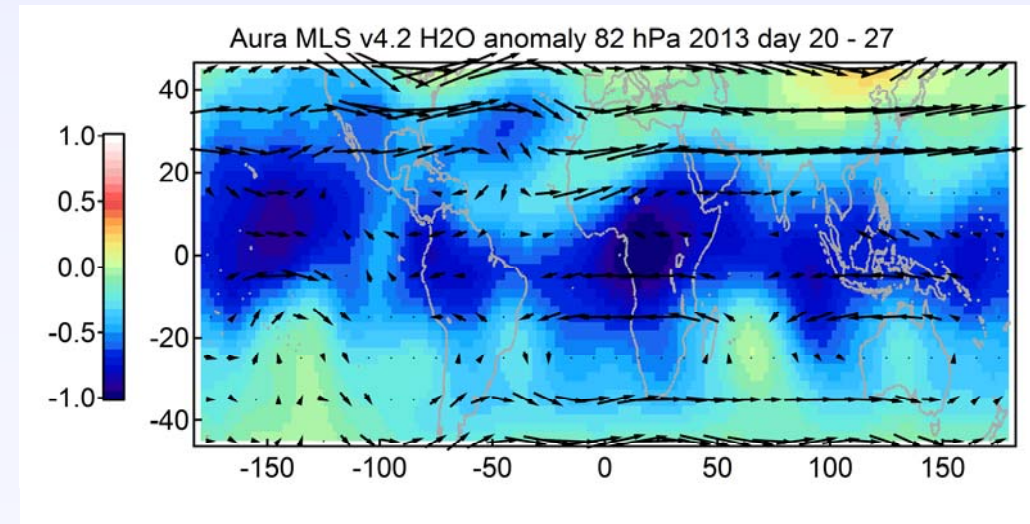
MLS tropical (15 S .. 15 N) water vapour at 82 hPa during Austral summer 2012/2013 (blue), 10 year MLS climatology (black) and saturation mixing ratio (dashed blue) calculated from COSMIC GPS temperature and pressure.

# Highlights of water vapour anomaly spatial distribution

Early Jan 2013: second drying episode, SSW-related. Maximum drying above most convective regions



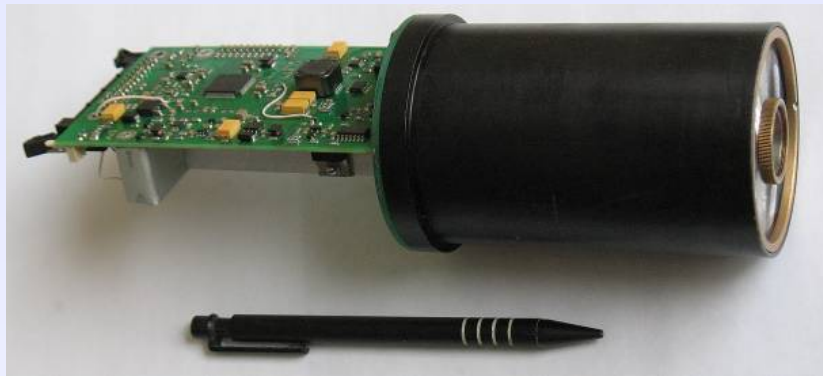
Late Jan 2013: development and spreading of dehydration



# Light-weight instrumentation for water vapour and aerosol

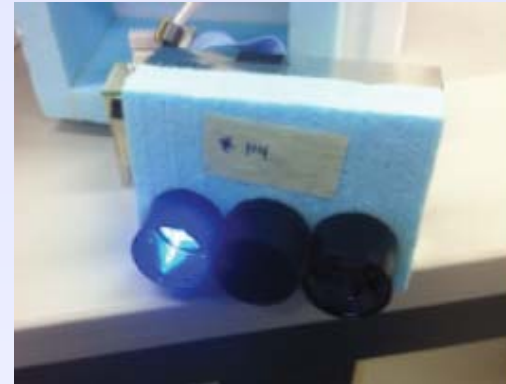
## FLASH-B

Fluorescence Lyman-Alpha Stratospheric Hygrometer



## COBALD

Compact Optical Backscatter Aerosol Detector



Range of water vapour measurements	<b><i>0.5...1000 ppmv</i></b>
Detection limit	<i>0.1 ppmv</i>
Integration time	<i>4 s</i>
Vertical resolution	<i>~ 20-150 m</i>
Measurement precision	<i>5 %</i>
Total uncertainty	<i>&lt;10 % (1<math>\sigma</math>)</i>
Height range	<i>350... 5 hPa</i>
Weight	<i>0.4 kg w/out batteries</i>

Light sources	2 LED's $\lambda_1 = 455 \text{ nm}$ , $\lambda_2 = 870 \text{ nm}$
Detector	Wide range silicon detector
Angle	$\theta = 174^\circ.. 180^\circ$
Response time	1s
Weight	~ 0.5 kg