StratoClim update

Markus Rex,
the StratoClim consortium
& partners: IITM, Dhaka Univ., ICIMOD, LAGEO,
Univ. Chicago

StratoClim

Role of aerosols at higher atmospheric levels

DACCIWA

Aerosols in air quality and climate in West Africa

BACCHUS

Interaction between aerosols and clouds

ClimPol

Pathways to Policy implementation

European Research Cluster „Aerosol and Climate“

- 2013 – 2018, Budget: ~36 Mill. €
- Jointly coordinated by:
  Markus Rex (AWI), Peter Knippertz (KIT), Ulrike Lohman (ETH)

Stratospheric and upper tropospheric processes for better climate predictions – StratoClim –

Overarching goal:

To improve climate projections by improving the representation of the main climate relevant processes of the UTS in Earth System Models and assess the role of the UTS in surface climate change.

- 28 partners from 11 European countries
- 4 assossiated partners on the Indian subcontinent
- Additional partners from the US, Australia and Palau
- 1 Dec 2013 – 30 Nov 2018

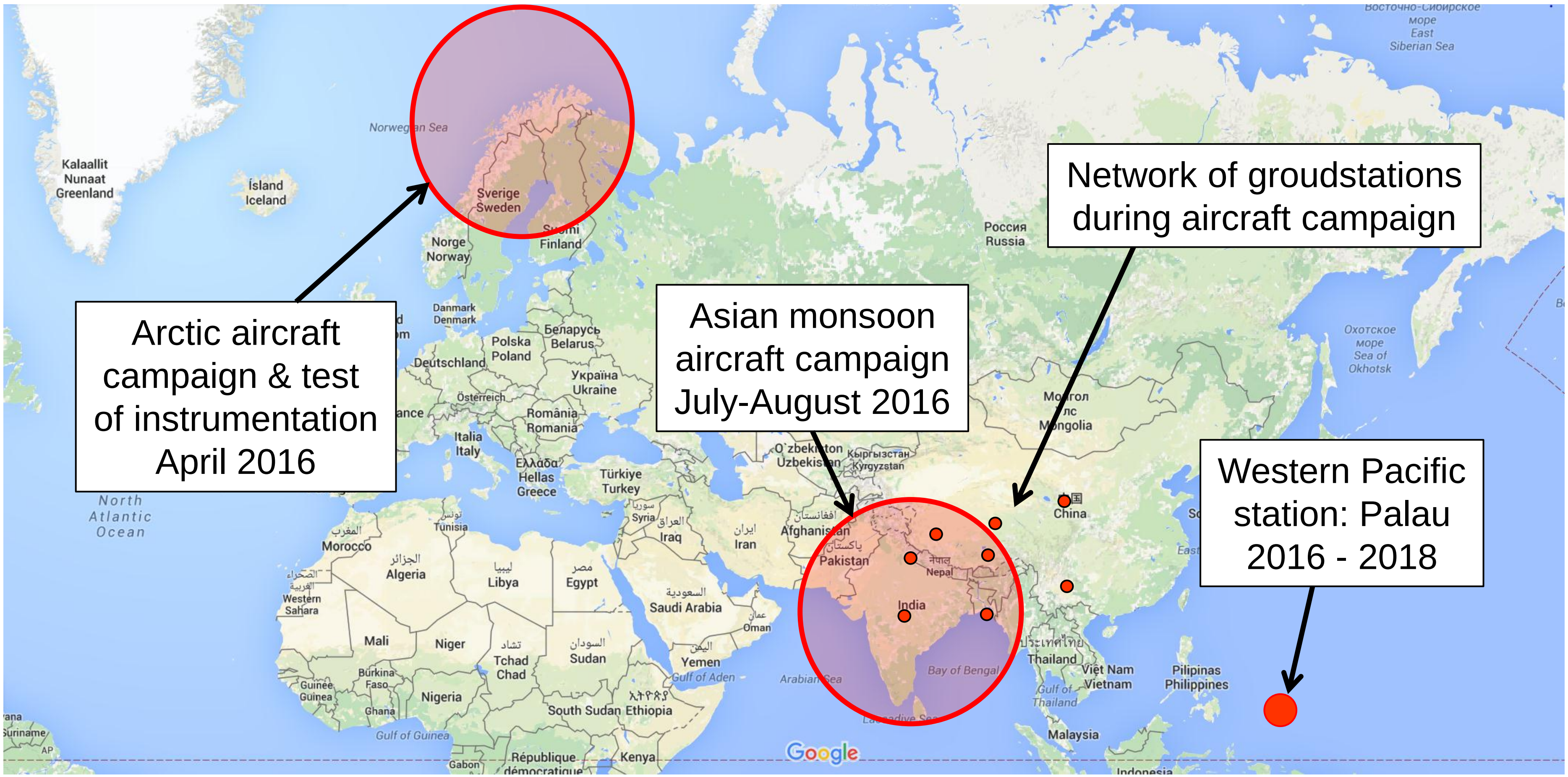
Stratospheric and upper tropospheric processes for better climate predictions – StratoClim –

Main objectives:

- To improve understanding of the processes that determine the UTS sulfur and aerosol budget, including non-sulfate aerosol,
- To develop and to improve detailed schemes for stratospheric sulfur and aerosol in CTMs and CCMs,
- To develop fast schemes to ozone in ESMs,
- To assess the impact of climate change on stratospheric aerosol and ozone and the effect of such changes on surface climate.

will be addressed by <u>field activities</u> combined with satellite data analysis and process modeling

StratoClim field activities



High altitude research aircraft Geophysica

Crew:	1 Pilot	Empty Weight:	16,900 kg
Engines:	2 turbo fan	Max. Take-Off Weight:	24,500 kg
Max. Speed:	750 km/h	Max. Payload Weight:	2,000 kg
Max. Altitude:	21,500 m	Wing Span:	37.46 m
Endurance:	4,800 km	Total Length:	22.87 m
Runway Length:	1,800 m	Height:	4.83 m

Asian monsoon aircraft campaign

- Full coverage of TTL and lowest stratosphere (up to ~20km altitude)

- New instruments include:
  - SO_2/H_2SO_4 CIMS instrument (sensitive to background conc.)
  - Cavity-enhanced spectrometer for COS
  - aerosol mass spectrometers (single particle and bulk)

- Measurements will include

  Active species:
  - O_3, nitrogen oxides, (active halogen species tbd)

  Aerosol/microphysics:
  - COS, SO_2, H_2SO_4, H_2O, HDO
  - CN, size distribution (0.4-3500µm), imager, optical properties chemical composition (MS for bulk and single particle), filters

  Tracers:
  - CO, CO_2, large set of traces from GC, whole air sampler

Asian monsoon aircraft campaign

- Campaign during mid-Juli to late August 2016 on the Indian subcontinent

- Primary campaign base:
  - Nagpur (central India)
  - Import of aircraft through Delhi

- Alternative campaign bases:
  - Kathmandu (Nepal)
  - Dhaka (Bangladesh)

- Options for transfers:
  - Integration of instruments in Paphos (Cyprus)
    - Transfer to Nagpur via stops in Egypt and on the Arabic Peninsula
    - Negotiations with Egypt, Saudi Arabia, Emirates, Oman ongoing
  - Alternatives:
    - Uninstrumented transfer to Kathmandu
      - Integration and some local flights, then via Delhi to Nagpur
    - Uninstrumented transfer to Nagpur

Asian monsoon aircraft campaign

Status for Nagpur:

- Support from partner IITM
  Collaboration developed over several years
- Memorandum of understanding with MOES signed
- Detailed implementation agreement signed
- Work on technical implementation ongoing, issues with hangar rental, customs procedures, provisions for non-scheduled operations of aircraft, etc. are currently being addressed
- Hangar available from Air India, costs under negotiations, situation at Nagpur airport perfect for scientific campaign

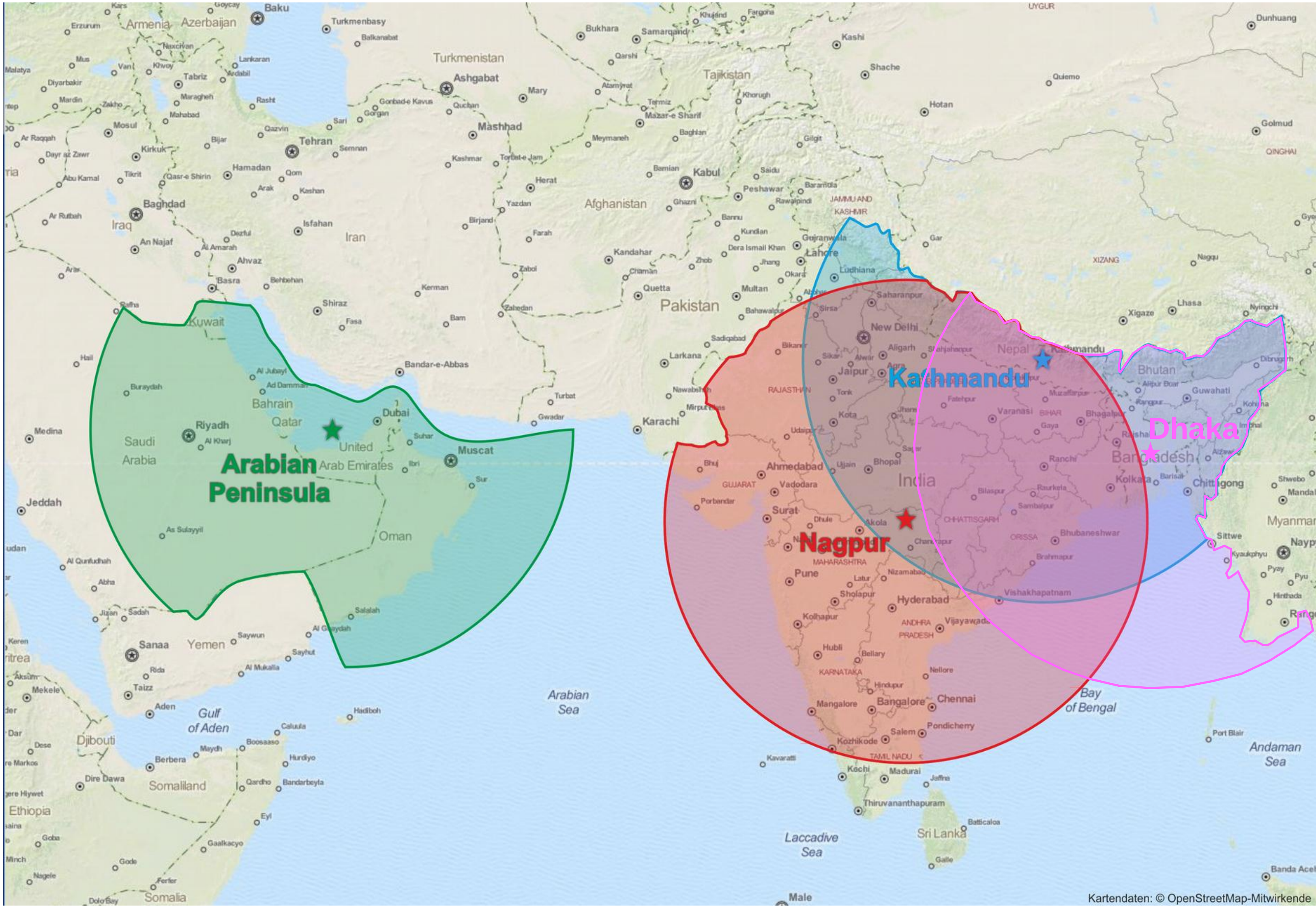
Asian monsoon aircraft campaign

Status for alternatives:

- Kathmandu:
  - Support from partner ICIMOD
  - Issues after earthquake and tensions with India now resolved
  - All relevant ministries, the military and the Civil Aviation Authority indicated support during meetings in early 2016
  - Hangar available from Buddha Air, dense commercial air traffic is an issue at Kathmandu airport

- Dhaka:
  - Support from partner Dhaka University
  - Relevant ministries and Civil Aviation Authorities indicated support during meetings in 2015
  - Hangar available from the military

Operation areas



Payload 1: In-Situ Instruments

Instrument	Parameter	P.I.	Technique	References
		IN SITU INSTRUMENTS, GAS PHASE		
FOZAN	O_3	Ulanovsky, CAO	Dye chemiluminescence+ECC	(Ulanovsky et al., 2001; Yushkov et al., 1999)
FISH	H_2O (total)	Krämer, JUELICH	Lyman-a	(Zöger et al., 1999)
FLASH	H_2O (gas phase)	Khaykin, CAO	Lyman-a	(Sitnikov et al., 2007)
SIOUX	NO, Noy, Particle Noy	Schlager, DLR	Chemiluminescence, Au converter, subsonic inlet	(Voigt et al., 2005)
HALOX t.b.d.	ClO, BrO	Stroh, FZJ	Chemical Conversion Resonance Fluorescence	(von Hobe et al., 2005)
HAGAR	N2O, CFC12, CFC11, CH4, H2, SF6, Halon1211, CO2	Volk, BUW	Gas Chromatography (GC) with electron capture detector (ECD) IR absorption	(Homan et al., 2010; Werner et al., 2010)
WAS	Long lived trace gases and isotopo-logues	Röckmann, UTRECHT	Whole air sampling with lab GC and MS analysis	(Kaiser et al., 2006; Laube et al., 2010)
COLD	CO	Viciani, CNR	TDL	(Viciani et al., 2008)
STRATOMAS	H2SO4 / SO2	Schlager, DLR	CIMS	
AMICA	OCS, CO, CO_2, HCN(t.b.d.)	von Hobe, JUELICH	ICOS	
CHIWIS	H_2O / HDO ratio	Moyer, Univ. Chicago	CEAS	

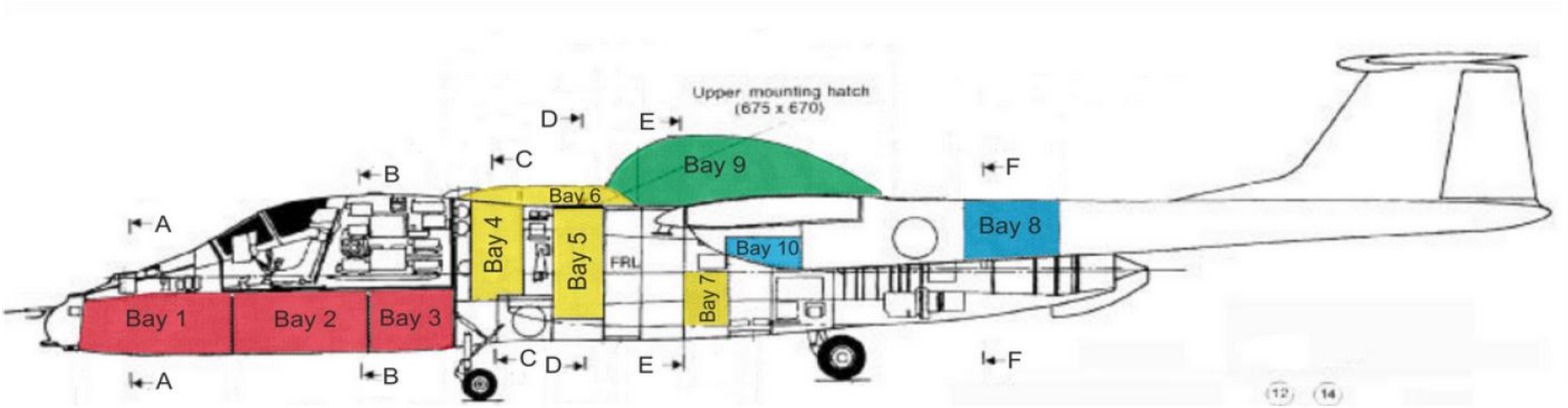
Payload 2: Particle Instruments

Instrument	**Parameter**	**P.I.**	**Technique**	**References**
		PARTICLE INSTRUMENTS		
COPAS	Condensation nuclei (CN-total, CN-non-volatile)	Weigel, MPI-C	2-channel CN counter, one inlet heated	(Weigel et al., 2009)
FSSP	Cloud particle size distrib. (0.4-47µm)	Borrmann, MPI-C	Laser-particle spectrometer	(de Reus et al., 2009)
CCP	Cloud particle size distrib. (3-47µm)	Borrmann, MPI-C	Laser-particle spectrometer	
CIP	Cloud particle size distrib. (25-1600µm) Particle Images	Borrmann, MPI-C	Laser-particle spectrometer	(Baumgardner et al., 2001)
MAS	Aerosol optical properties	Cairo, CNR	Multi-wavelength Scattering	(Buontempo et al., 2006)
HAPACO	Particle Filter Collection, Electron microscopy, nano-SIMS	Ebert, TU-Darmstadt		
ERICA	Aerosol chemical composition	Borrmann, MPI-C	Bulk phase and single particle Aerosol Mass Spectrometer	
PIP	Particle size	Borrmann, MPI-C	Laser Particle Spectrometer	

Payload 3: Remote Sensing Instruments

Instrument	Parameter	P.I.	Technique	References
		REMOTE SENSING INSTRUMENTS		
MAL 1	Remote Aerosol Profile (2km upwards from aircraft altitude)	Mitev, CSEM	Microjoule-lidar	(Matthey et al., 2003)
MAL 2	Remote Aerosol Profile (2km downwards from aircraft altitude)	Mitev, CSEM	Microjoule-lidar	(Matthey et al., 2003)
GLORIA	Cloud Index, T, HNO_3,O_3,$ClONO_2$, CFCs,H_2O and minor species	FelixFriedl-Vallon, KIT PeterPreusse, JUELICH	Imaging FTIR limb sounder	(Riese et al., AMT, 2014)
MARSCHALS	O_3, H_2O, CO, HNO_3, N_2O	Moyna, RAL	Millimetre Wave spectrometer in limb geometry	(Moyna et al., 2006)
		PHYSICAL PARAMETERS		
Rosemount probe (TDC)	T, P, horiz. Wind	Beliaev, MDB	PT100, 5-hole probe	
Aircraft Data System (UCSE)	T, P	Beliaev, MDB		

Payload Configurations



„In-Situ Configuration“

Bay1: STRATOMAS
Bay2: ERICA

„Remote-Sensing Configuration“

Bay1: GLORIA
Bay2: MARSCHALS

Asian monsoon aircraft campaign
Science objectives for individual flights

1) Deep convection: Vertical transport, chemical properties of convective outflow, chemical processing in the outflow at different stages (match type flights), particle formation → Bernard Legras

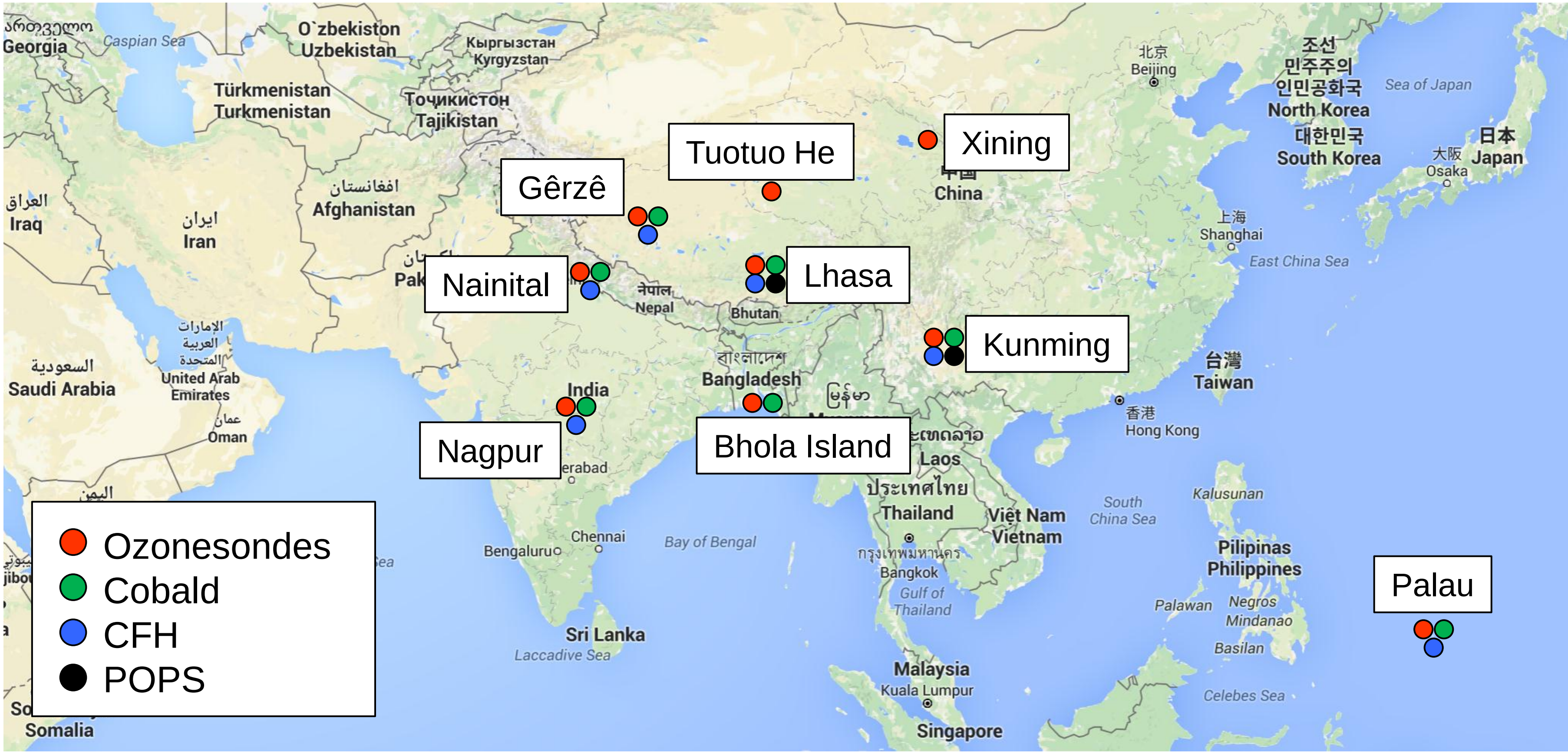
2) Structure of cold point tropopause, properties and microphysical/chemical processes in subvisible cirrus → Stephan Borrmann

3) Horizontal and vertical structure of the chemical composition of air inside the AMA → Federico Fierli

4) Horizontal and vertical structure of the AMA Barrier and associated transport and mixing → Bärbel Vogel

5) Chemical composition and physical properties of the ATAL and its precursors → Hans Schlager

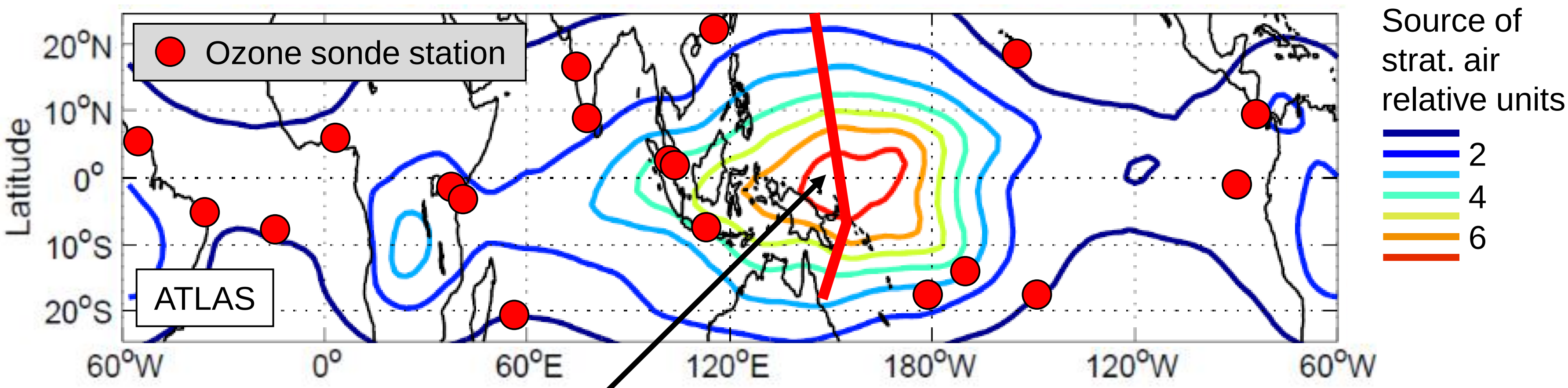
Ballooning program during aircraft campaign



Chinese stations: LAGEO/CAS
Indian stations: ETH, NASA, IITM

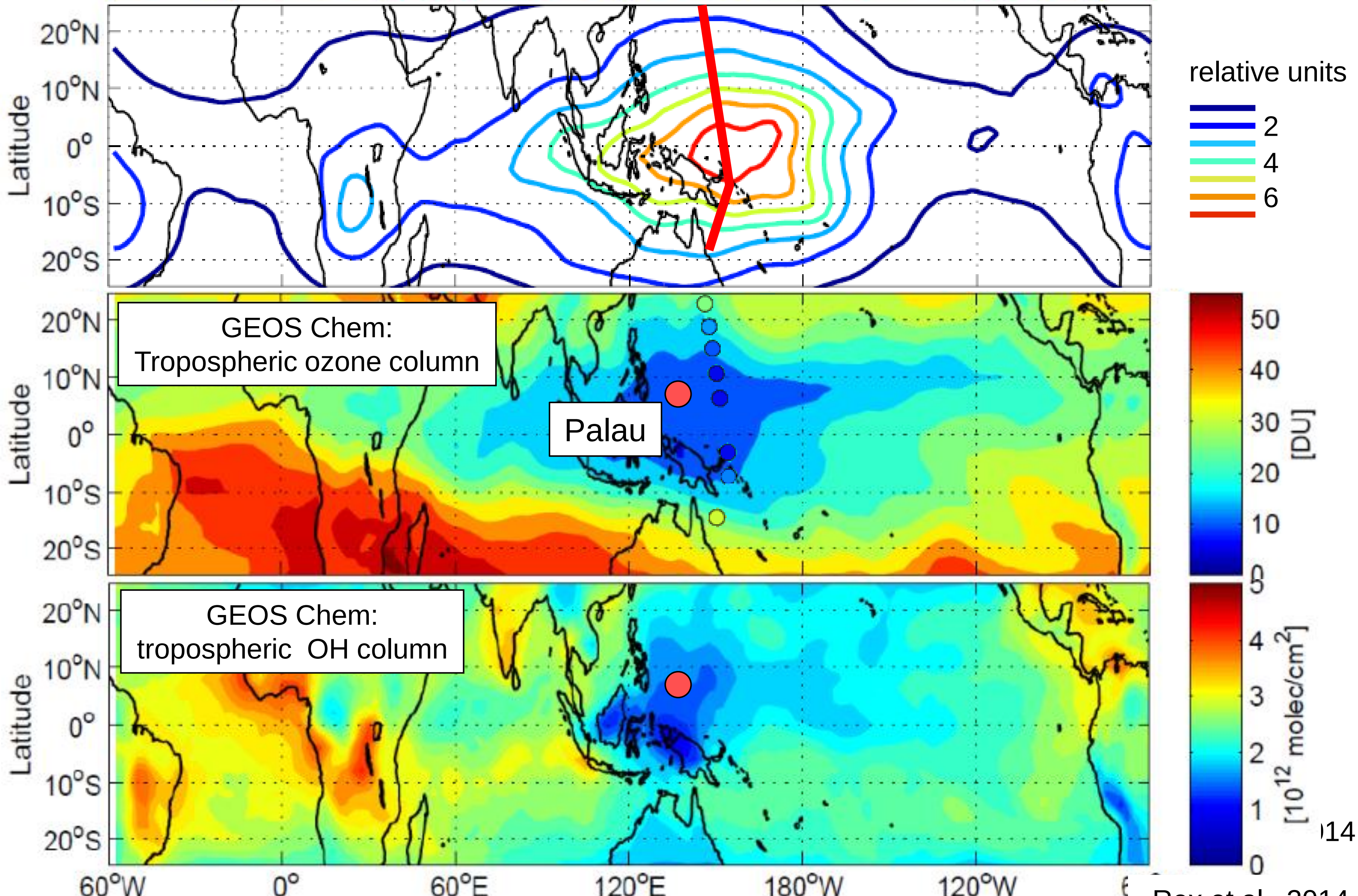
Bhola Island: AWI, Dhaka University
Palau: AWI, CNR, PCC

Palau Atmospheric Observatory



Rex et al., ACP, 2014

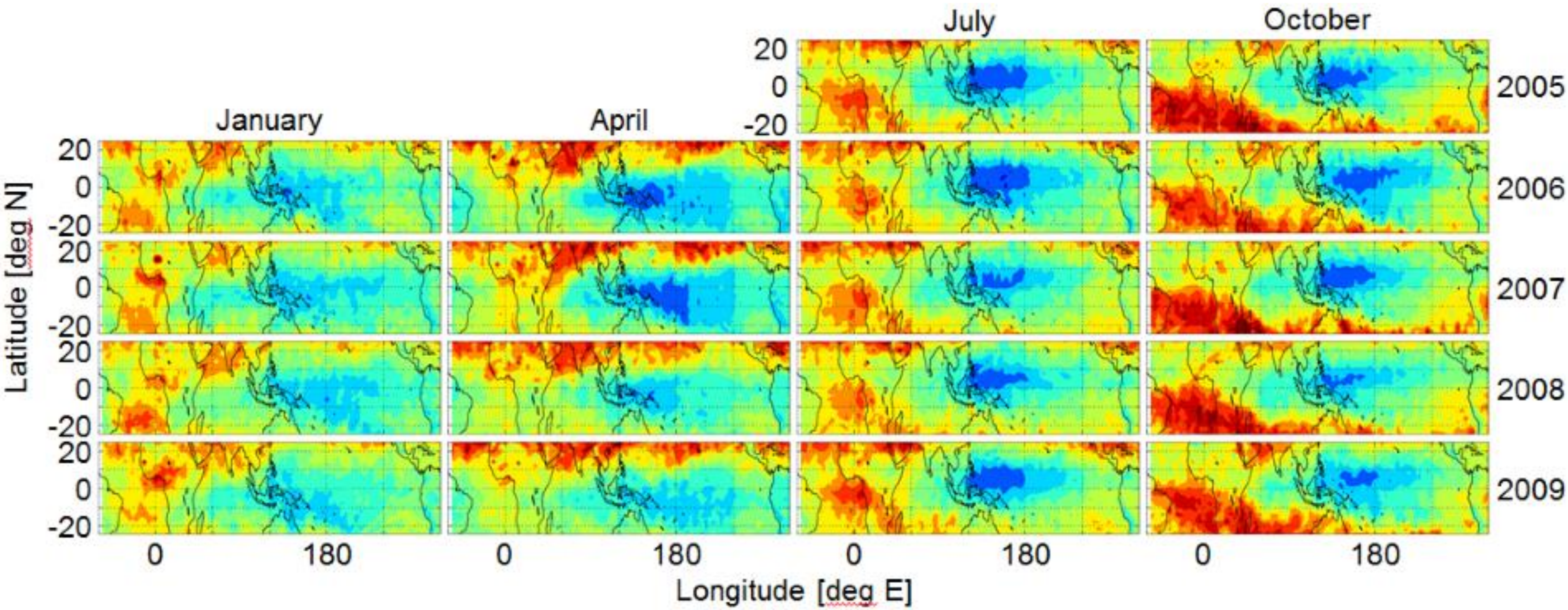
Palau Atmospheric Observatory



Rex et al., 2014

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Multi-annual TES data set



- Considerable seasonal and interannual variability
- Clear ENSO signal (minimum follows the warm pool)

=> Longer term observations required

Rex et al., 2014

Palau Atmospheric Observatory

Set up of station: Nov 2015 – Jan 2016
Official opening: 15 Jan 2016

Instrumentation nearly complete

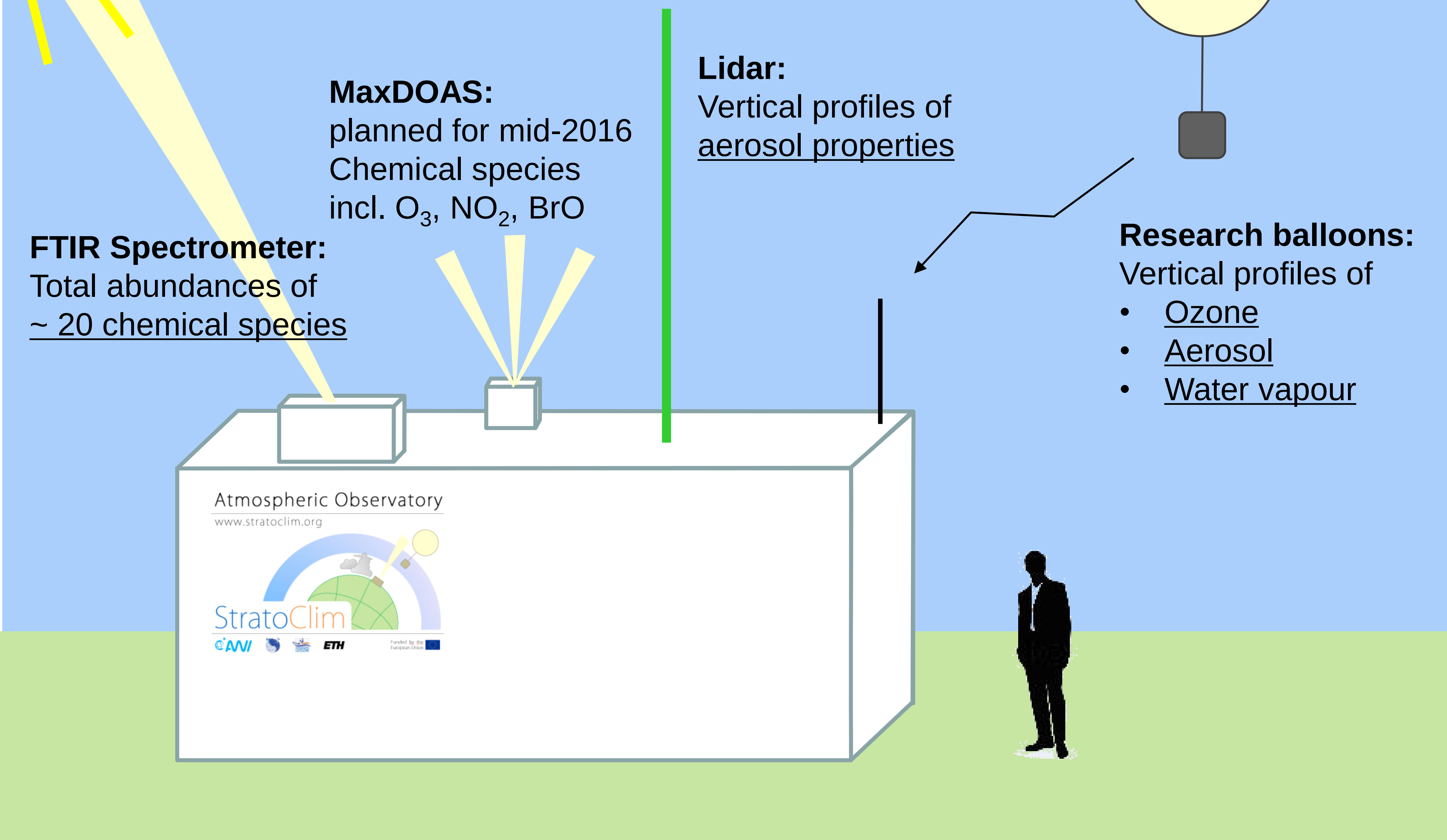
Regular measurements performed by local partners

- Palau Community College (PCC)
- Coral Reef Research Foundation (CRRF)

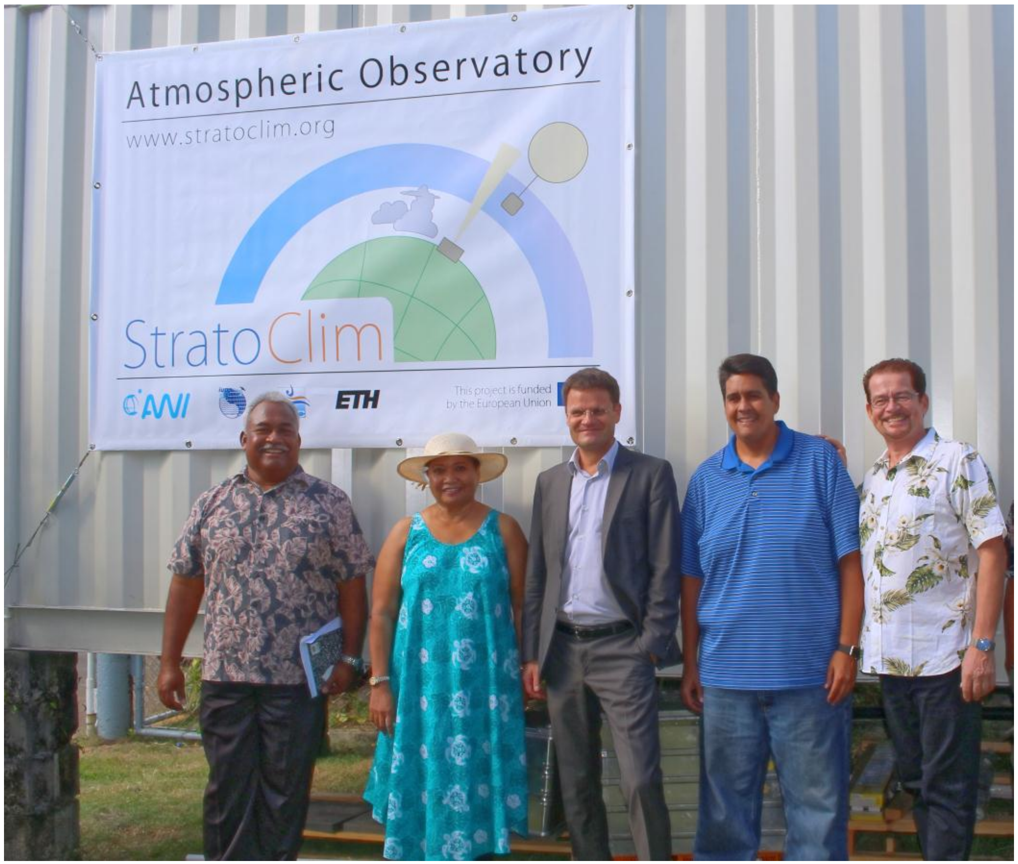
3-4 intense observational periods planned per year

Parallel educational program at PCC

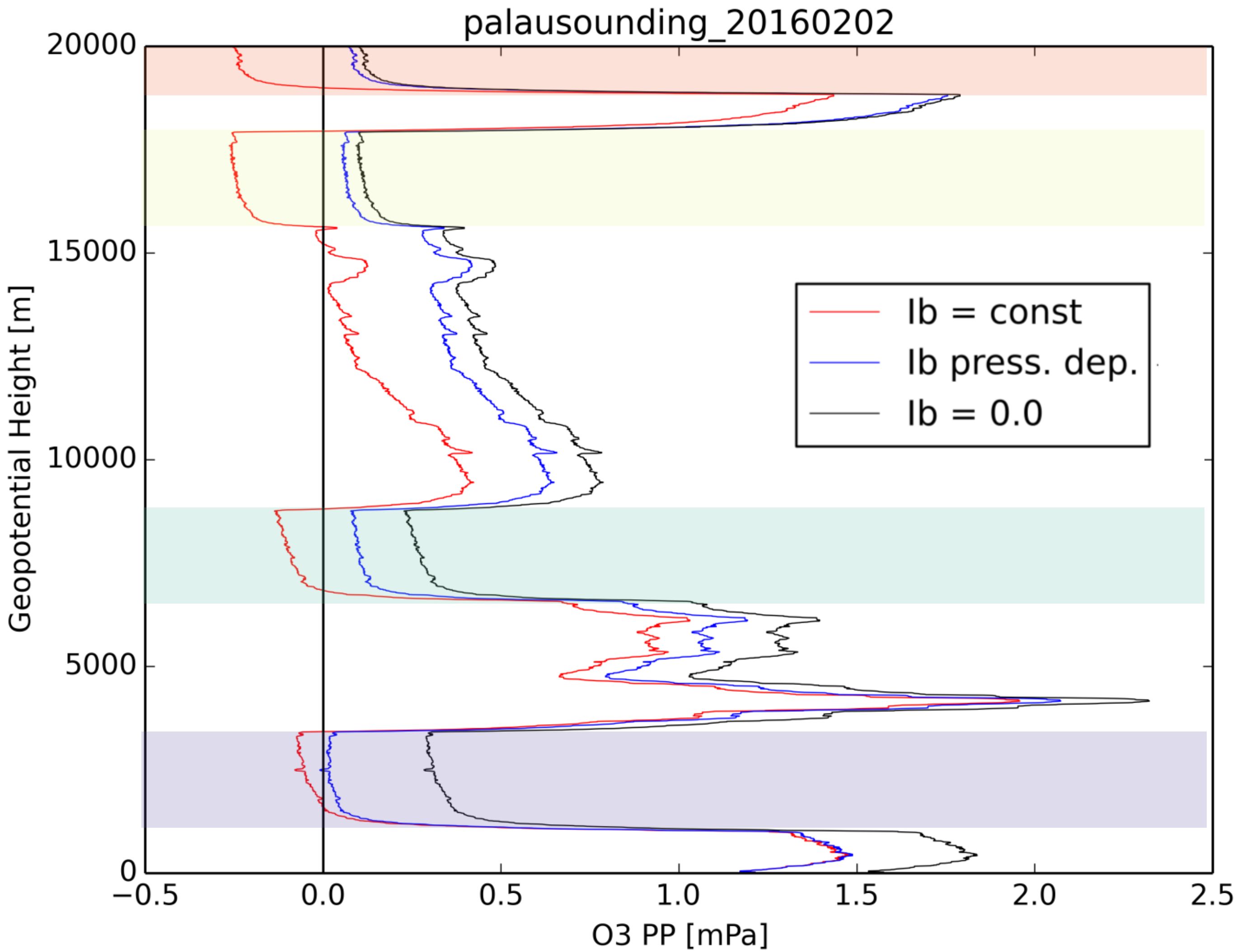
The Palau Atmospheric Observatory



The Palau Atmospheric Observatory



Ozonesondes:
In flight background current measurements



PhD project
Katrin Müller

Summary

Aircraft campaign:

- Situation in India (Nagpur) very promising
- Fallback plans exist on the Indian subcontinent (Kathmandu, Dhaka)

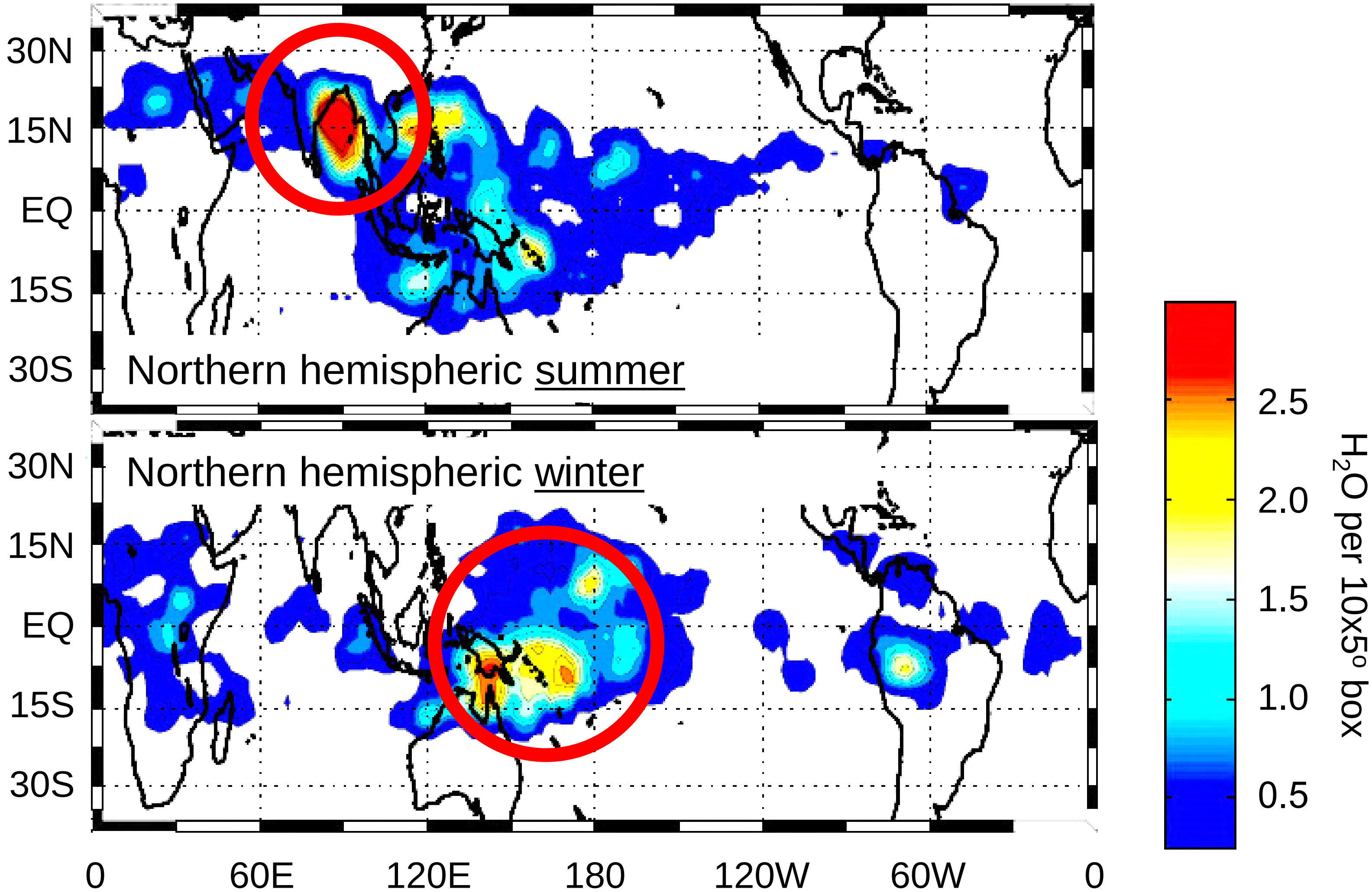
⇒ Still a lot of work to do, but we are optimistic for a campaign in the monsoon area in the coming summer

Ground stations:

- Palau observatory is up and running
- New station on Bhola island (Gulf of Bengal)
- Equipment for monsoon network is on its way

End

Source regions for stratospheric air

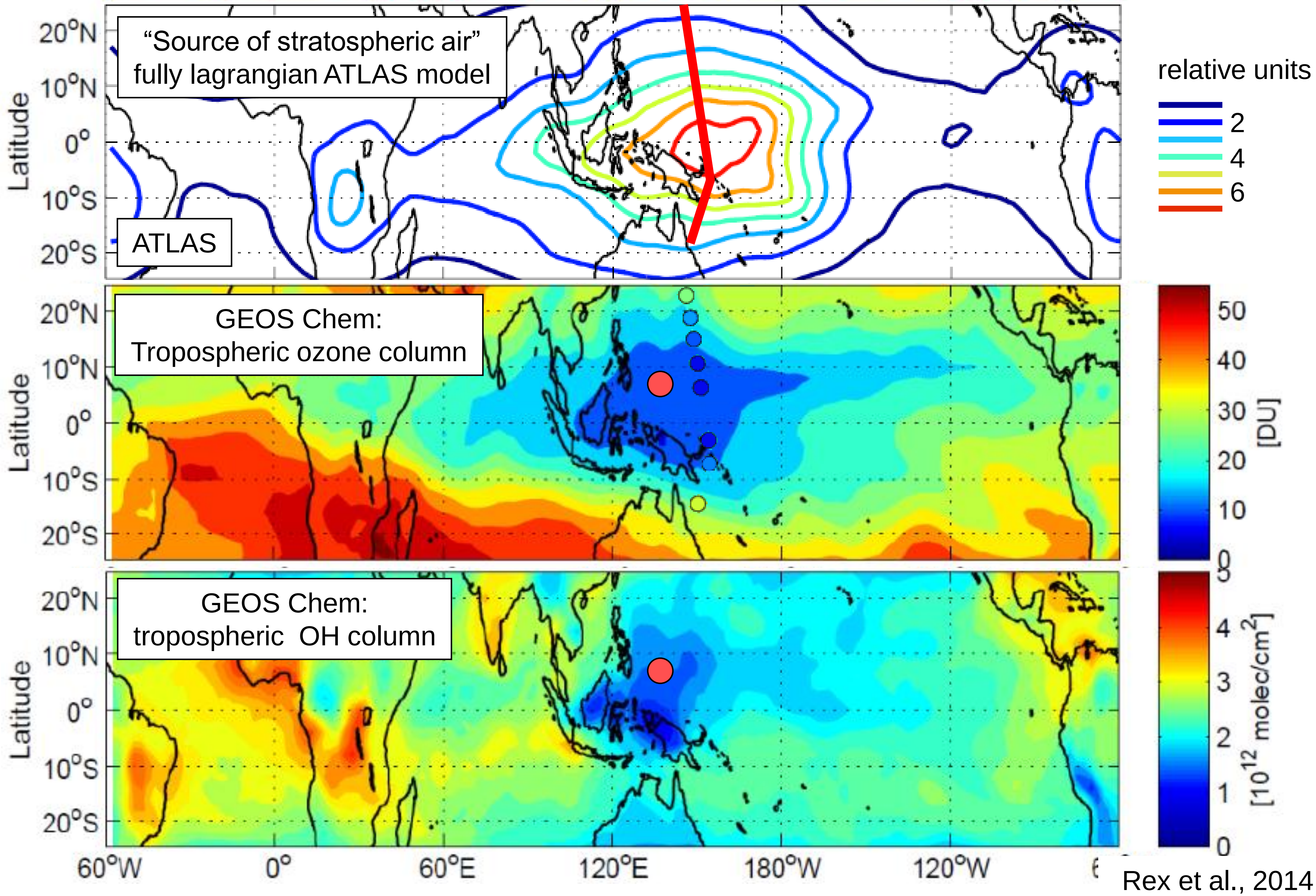


Kremser et al. (2009)

Stratospheric and upper tropospheric processes for better climate predictions – StratoClim –

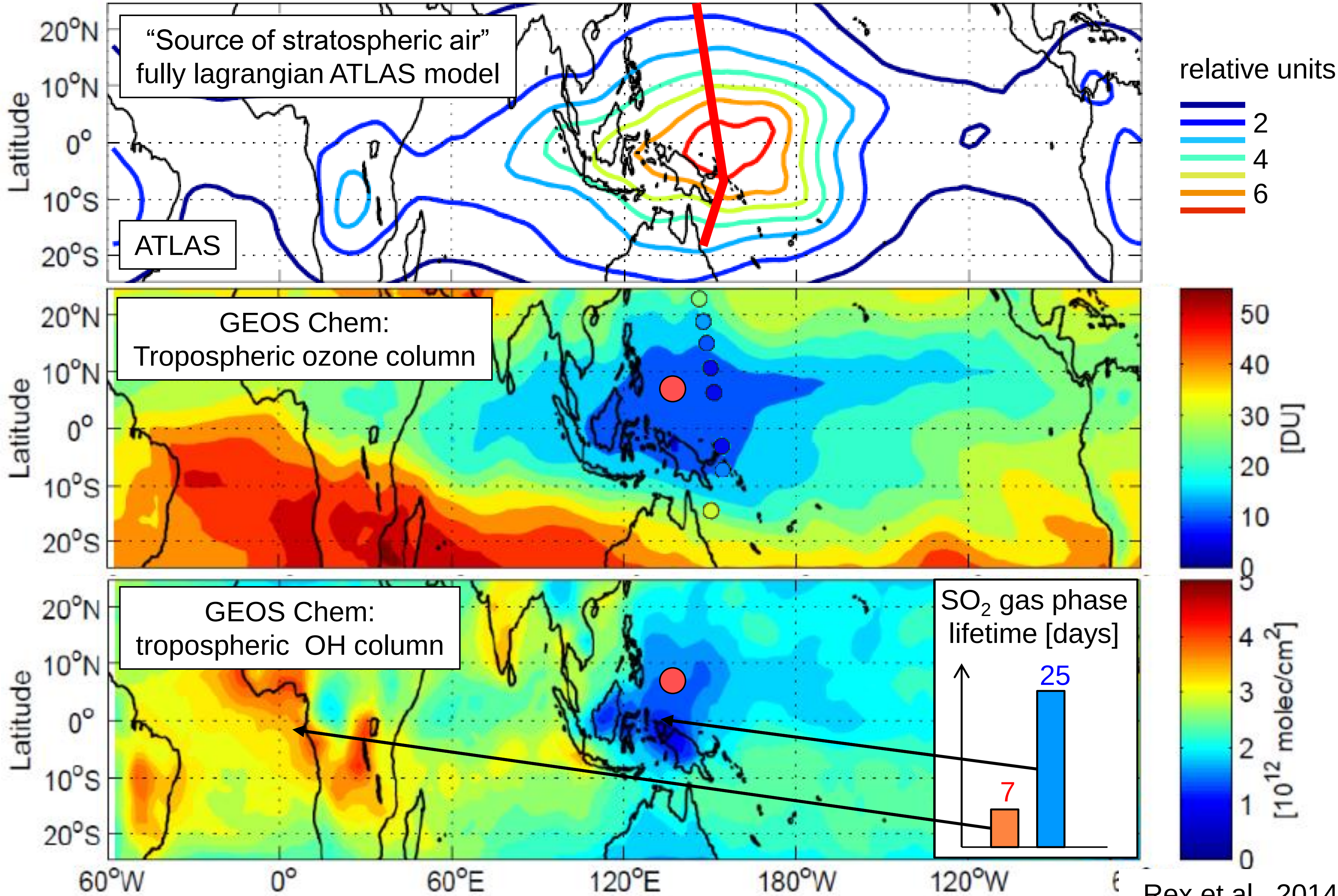
- 28 partners
- 11 countries
- 12 million Euro budget
- 1 Dec 2013 – 30 Nov 2018

Processes at stratospheric entry point in NH winter



Rex et al., 2014

Processes at stratospheric entry point in NH winter



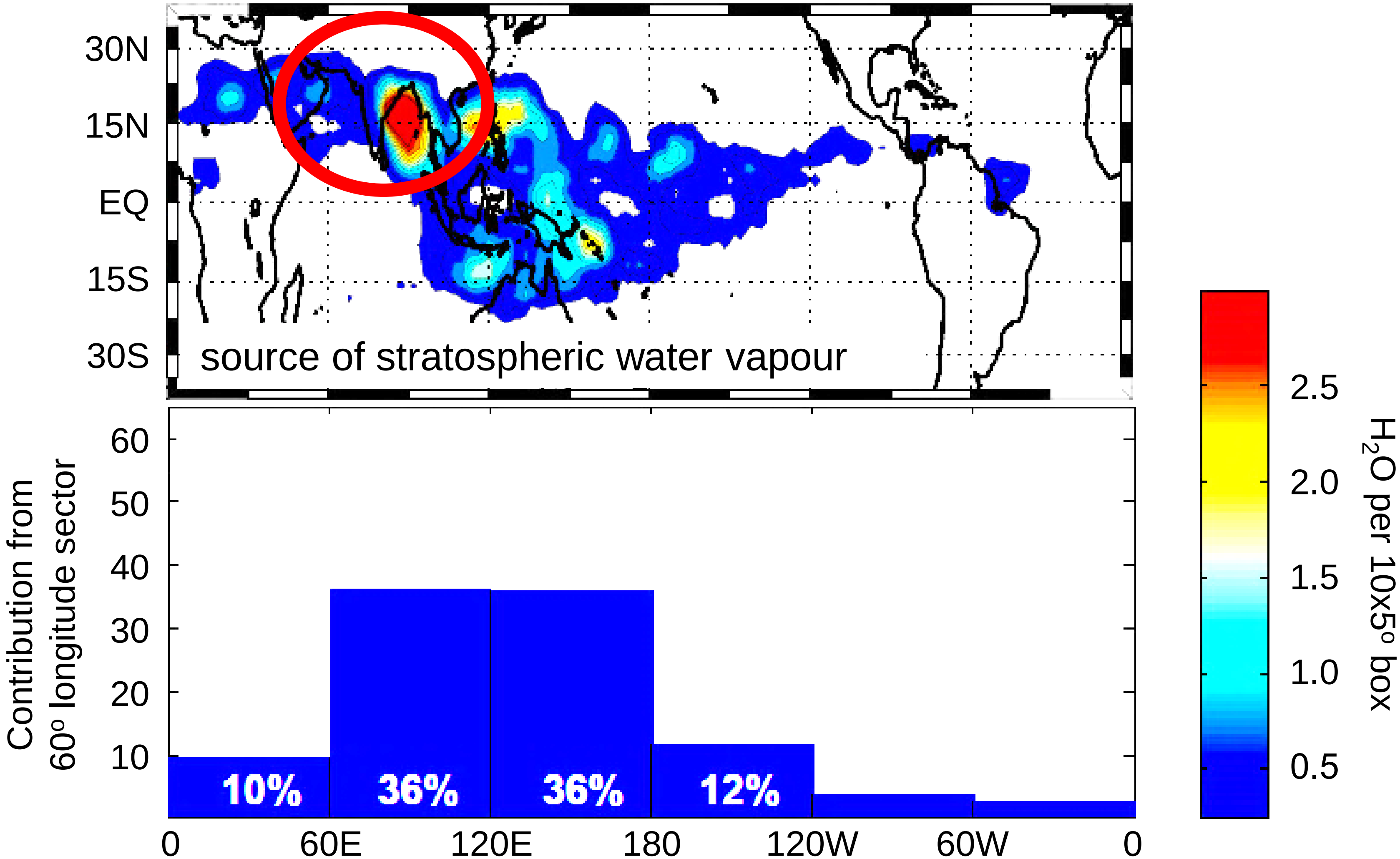
Rex et al., 2014

StratoClim
Major field activities

Asian monsoon
aircraft campaign
India, Nepal, Bangladesh
Jul/Aug 2016

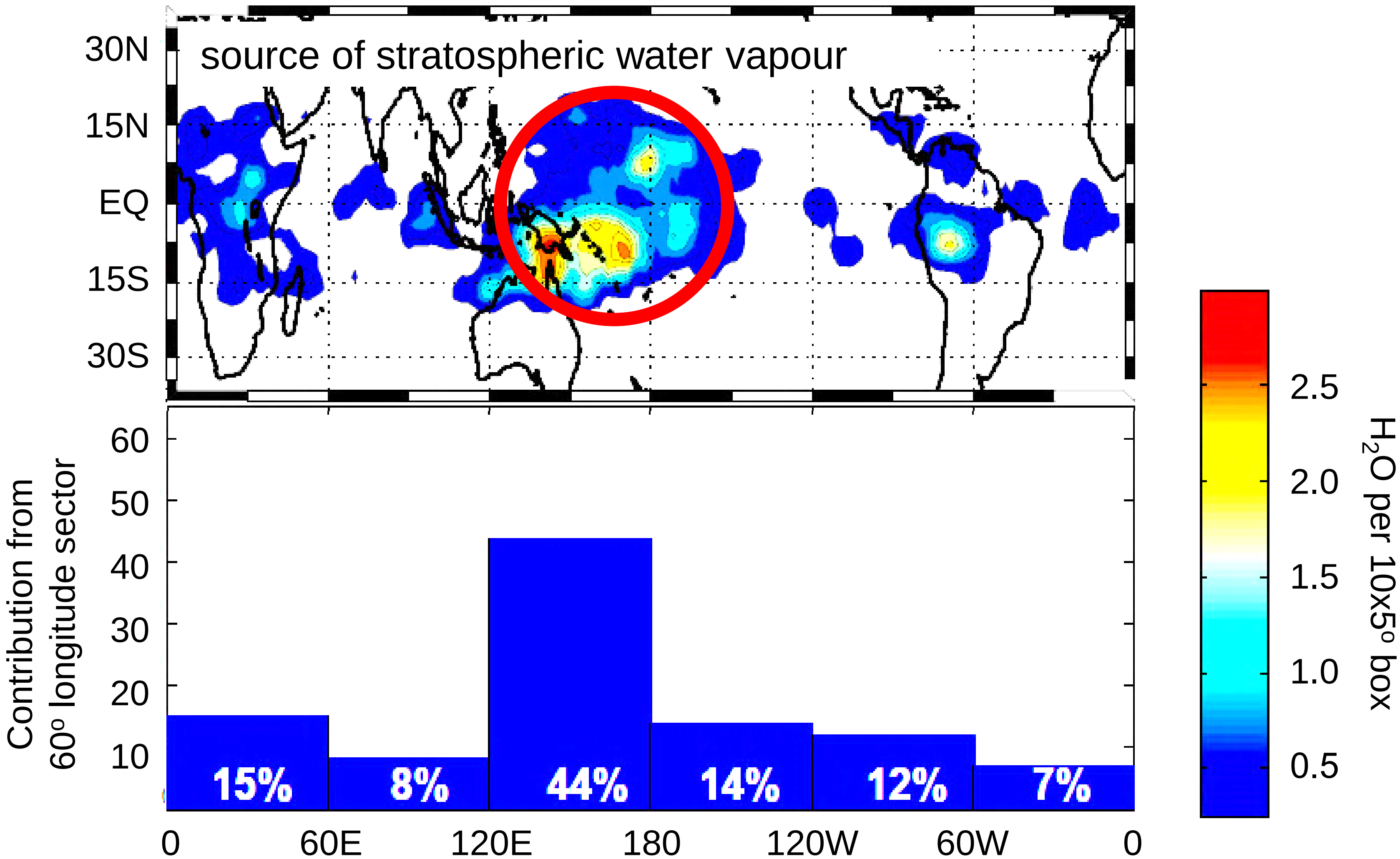
Western Pacific
ground station
Palau, ongoing

Source regions for stratospheric air
- NH summer -



Kremser et al. (2009)

Source regions for stratospheric air
- NH winter -



Kremser et al. (2009)

High altitude research aircraft Geophysica

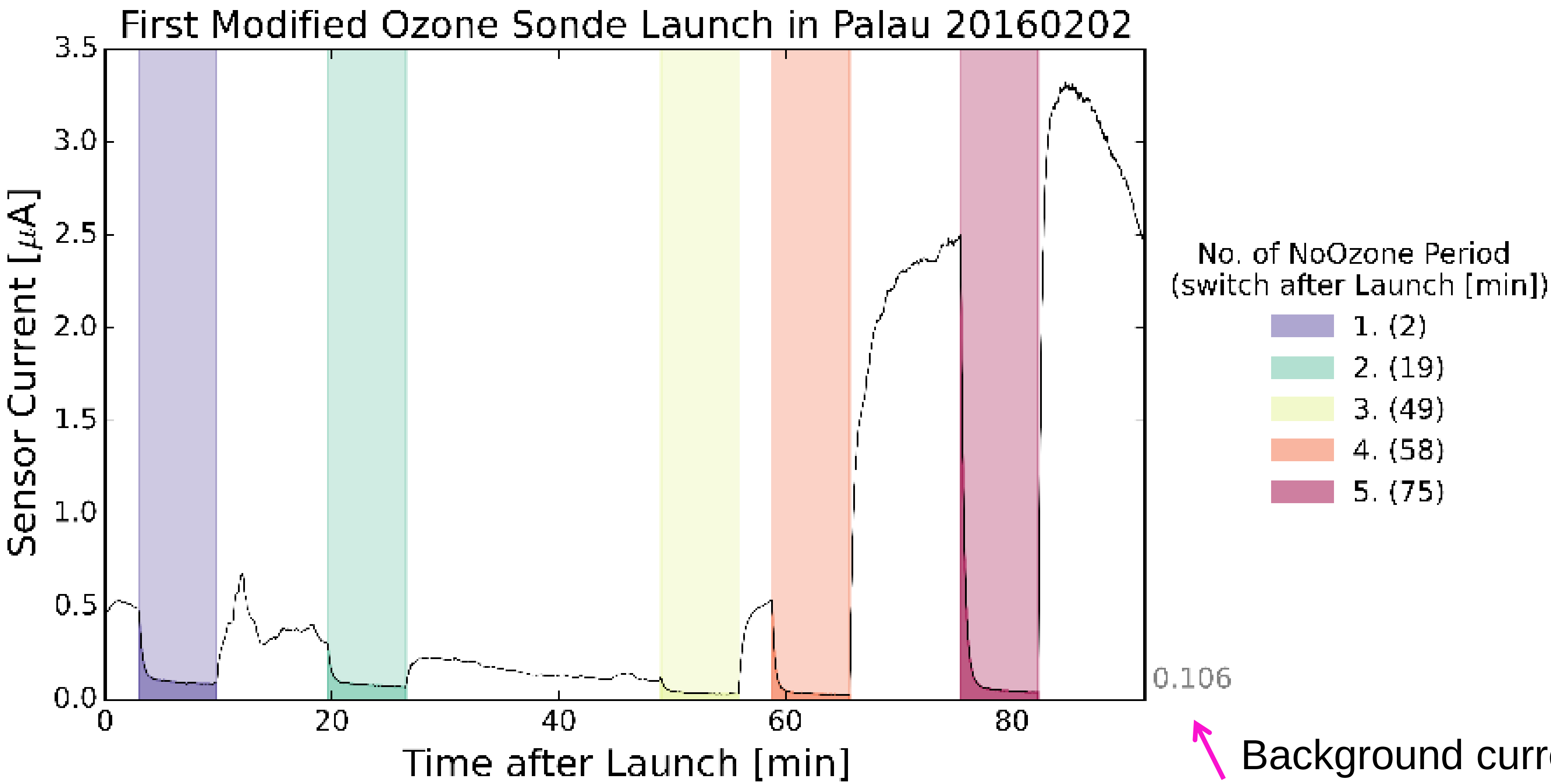
Max. Altitude:	~20km
Range:	3500km
Max. Payload Weight:	2,000kg
Wing Span:	37.46m

WP 2: Ground Stations

WP leader: Justus Notholt

- Palau Atmospheric Observatory
- Arctic ozonesonde station network, Match campaigns

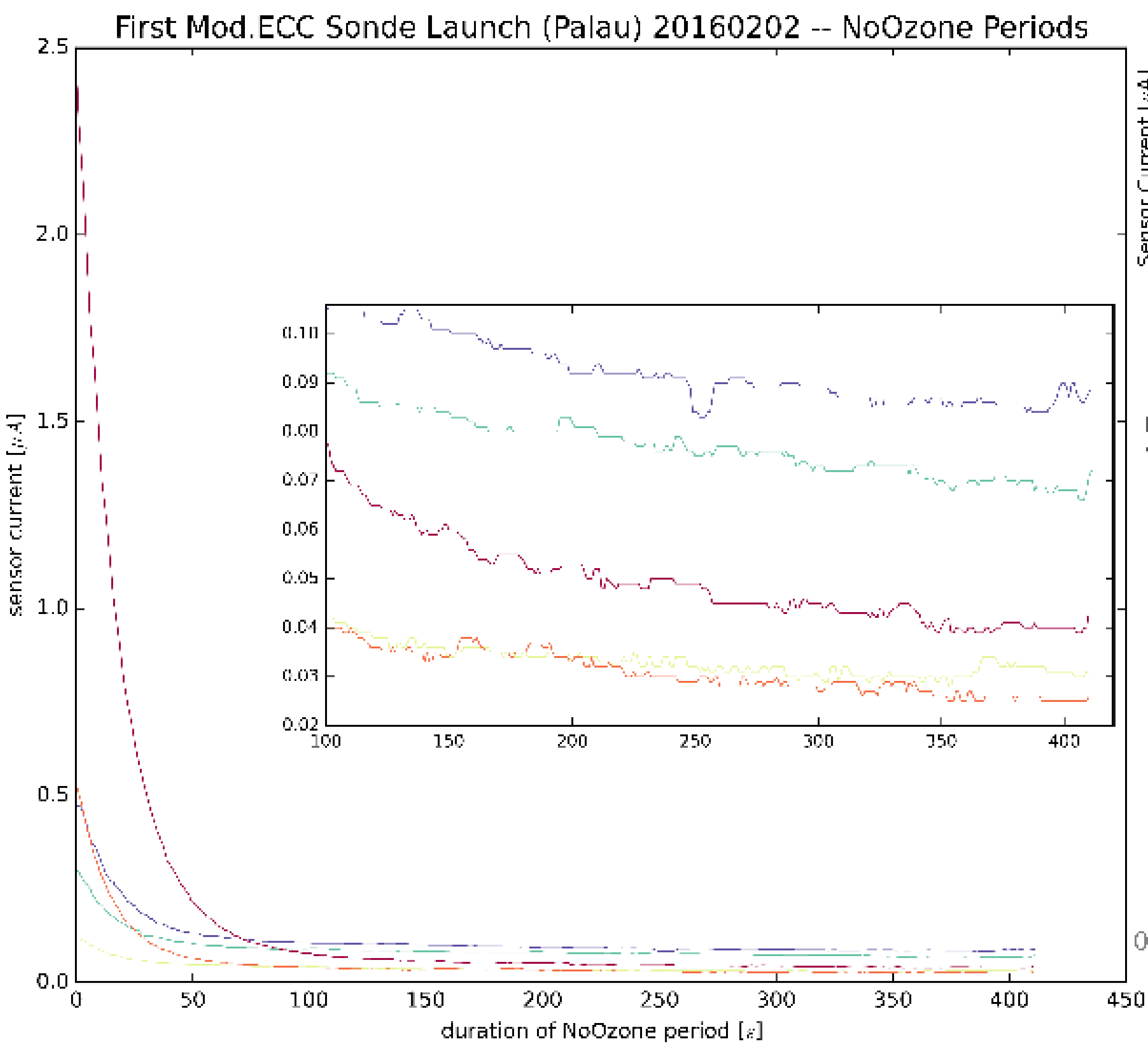
First modified ECC Sounding

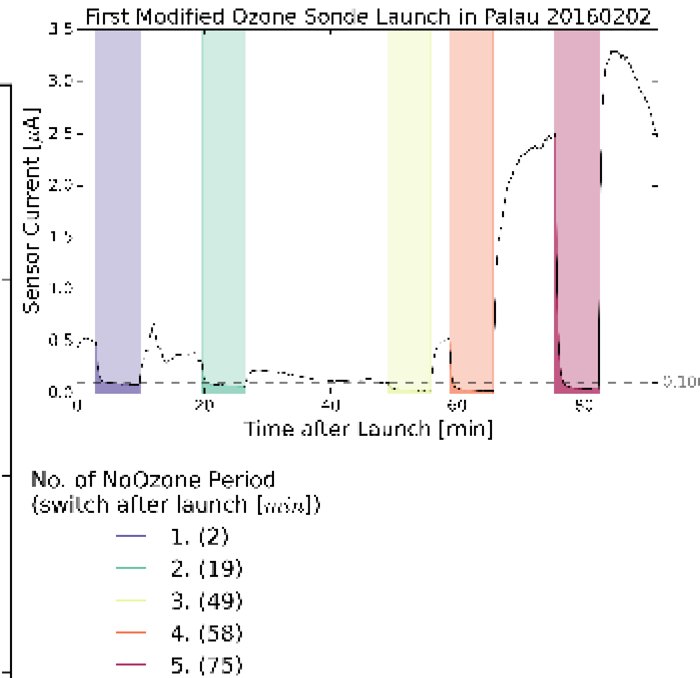


Background current before launch

- Each “Zero Ozone”-period: 7 minutes
- The measured background current decreases with time and height until reaching the ozone layer

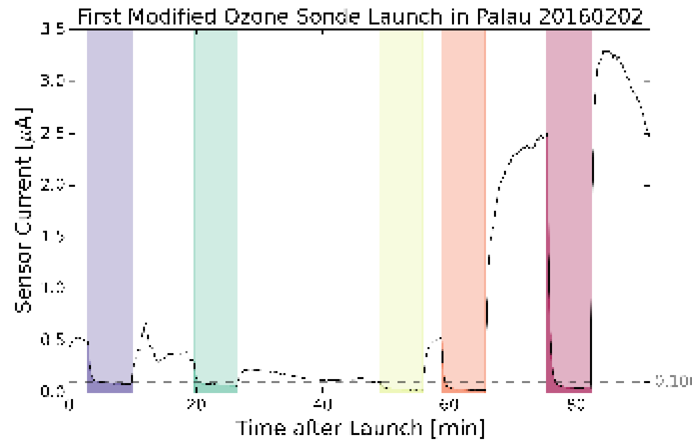
Zero Ozone Response





- All Zero Ozone period currents reached the pre-launch background current after 100 seconds and continued decreasing

Conclusions from first modified ECC Sounding



- First measurements reveal a non-constant I_b throughout flight
- I_b is decreasing with height and time, but seems to be affected by enhanced ozone concentrations in the stratosphere

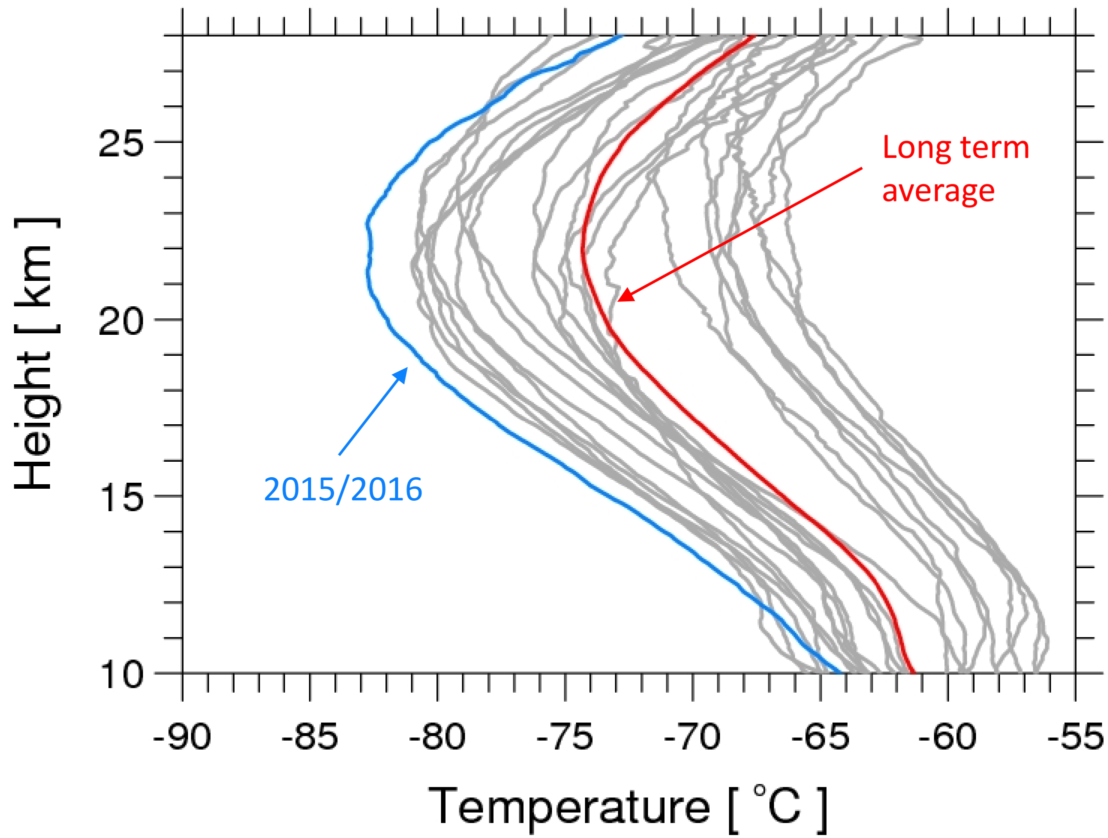
  → To improve ECC soundings in the TWP, I_b should be measured in flight every time using a balloon train with two instrument:

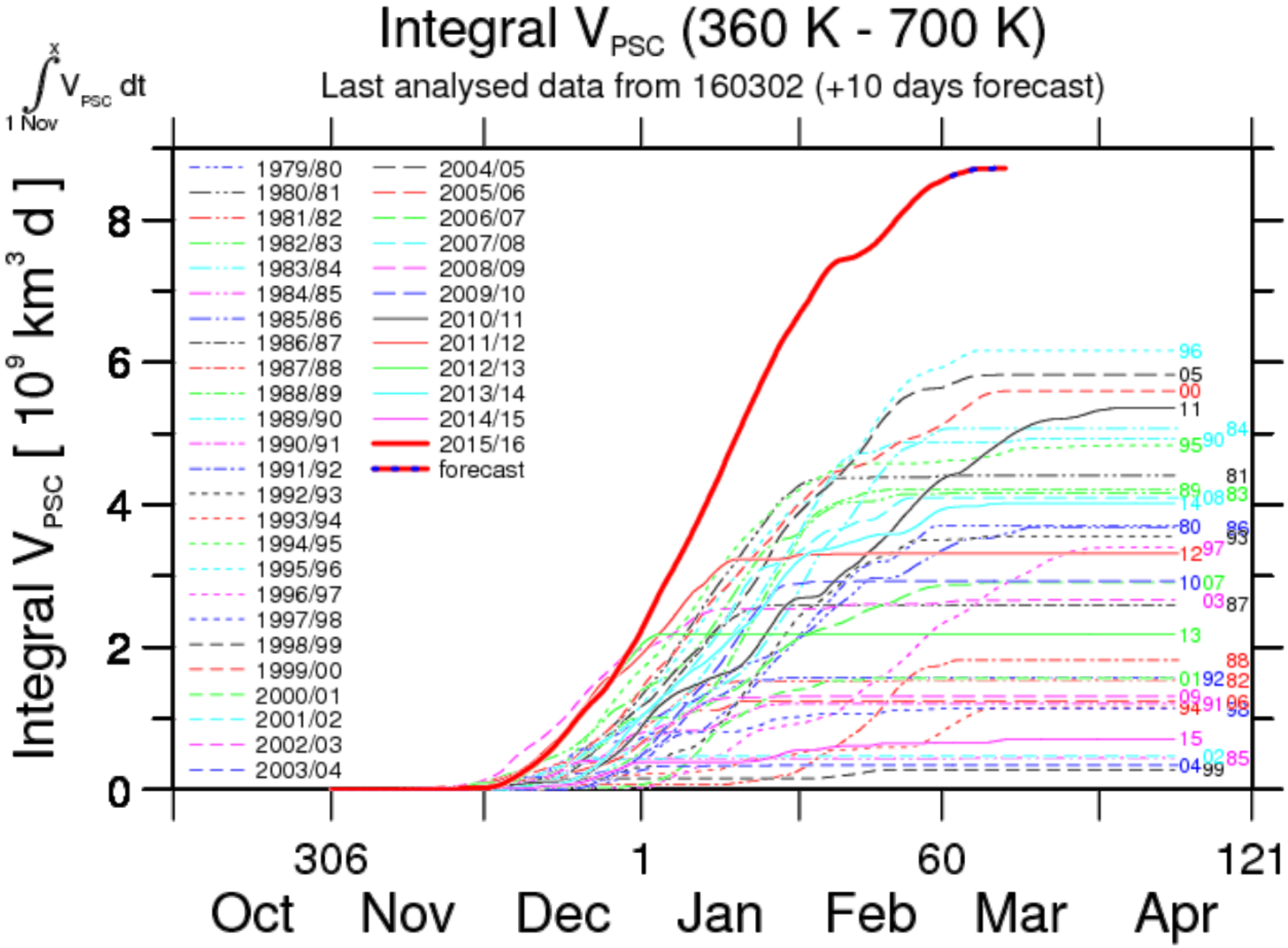
  - 2 mod. ECC sondes with alternating zero ozone periods
  - 1 regular and 1 mod. ECC sonde
- Better characterization of the new devise in laboratory studies is needed

Situation in Arctic winter 2015/2016

Ny Alesund Dec-Feb mean temperature profiles

Gruan radiosonde data

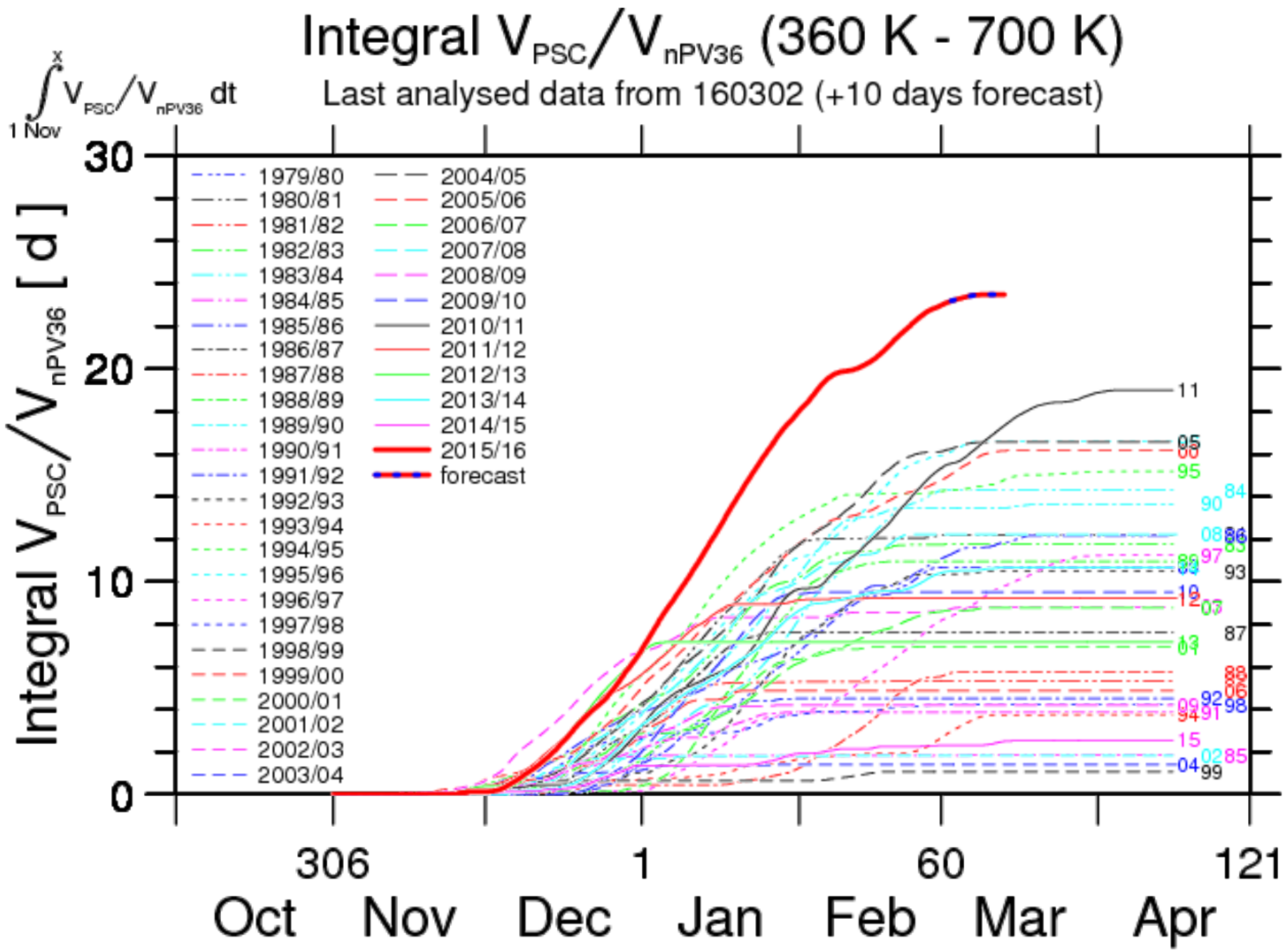




Caveat:
2015/16: operational data
Other years: ERA-interim

But:

- > 2K offset needed to bring 2015/2016 close to the range of previous variability
- Results agree with Ny Alesund GRUAN radiosonde data



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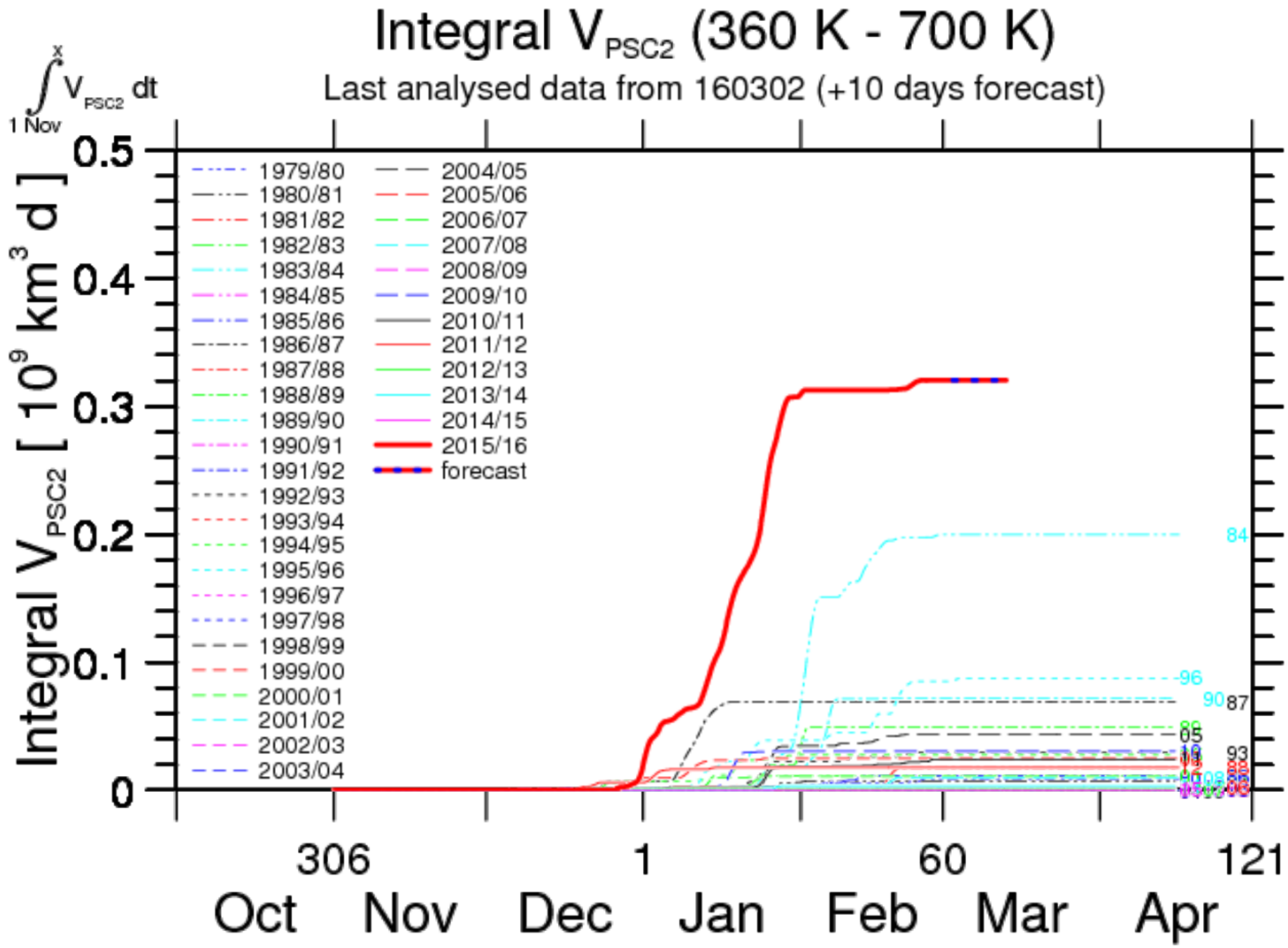
Integral V_{PSC2} (360 K - 700 K)
Last analysed data from 160302 (+10 days forecast)
$\int_{1 Nov}^{x} V_{PSC2}\, dt$
Integral V_{PSC2} [10^9 km^3 d]
0.5
0.4
0.3
0.2
0.1
0
1979/80
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1988/89
1989/90
1990/91
1991/92
1992/93
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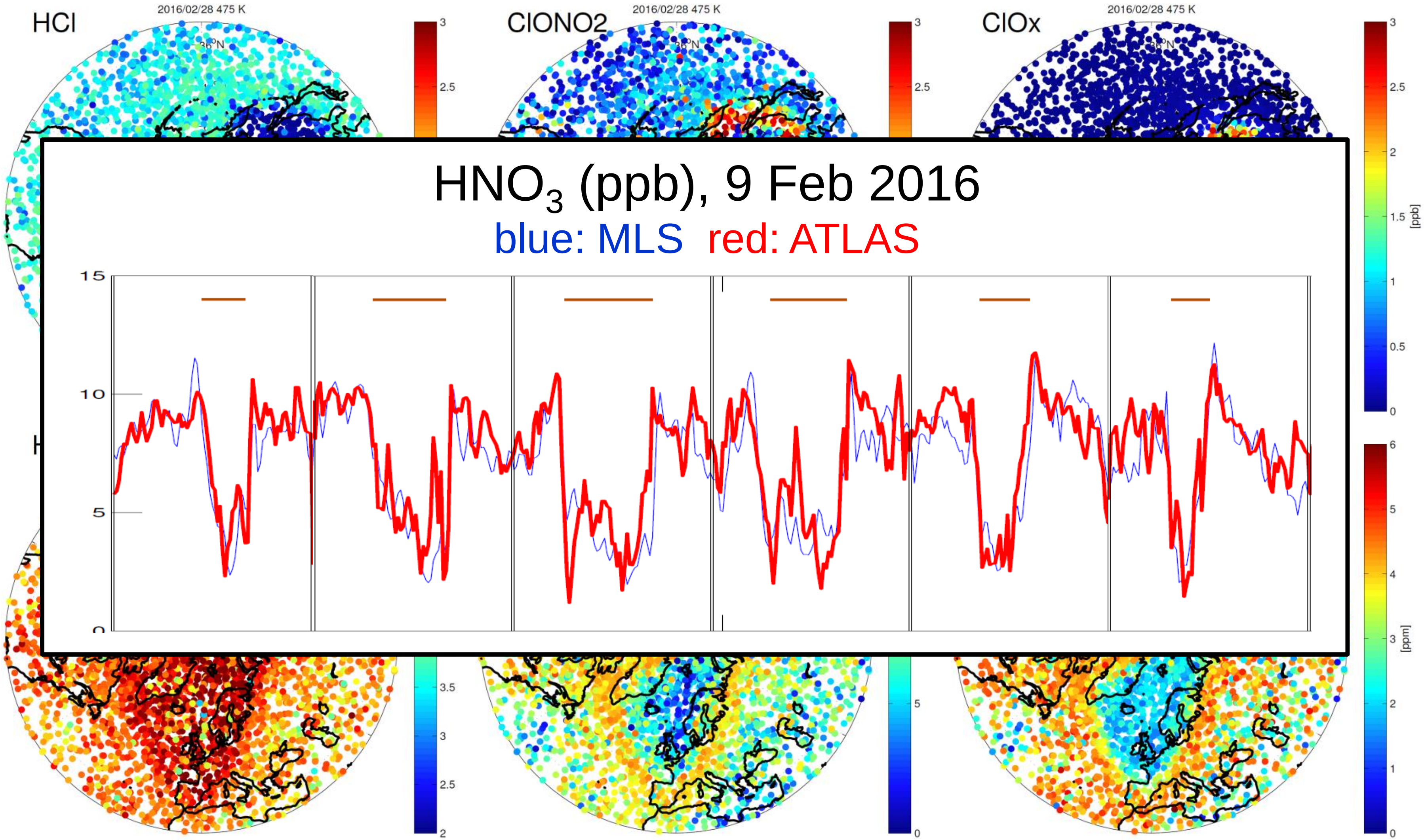
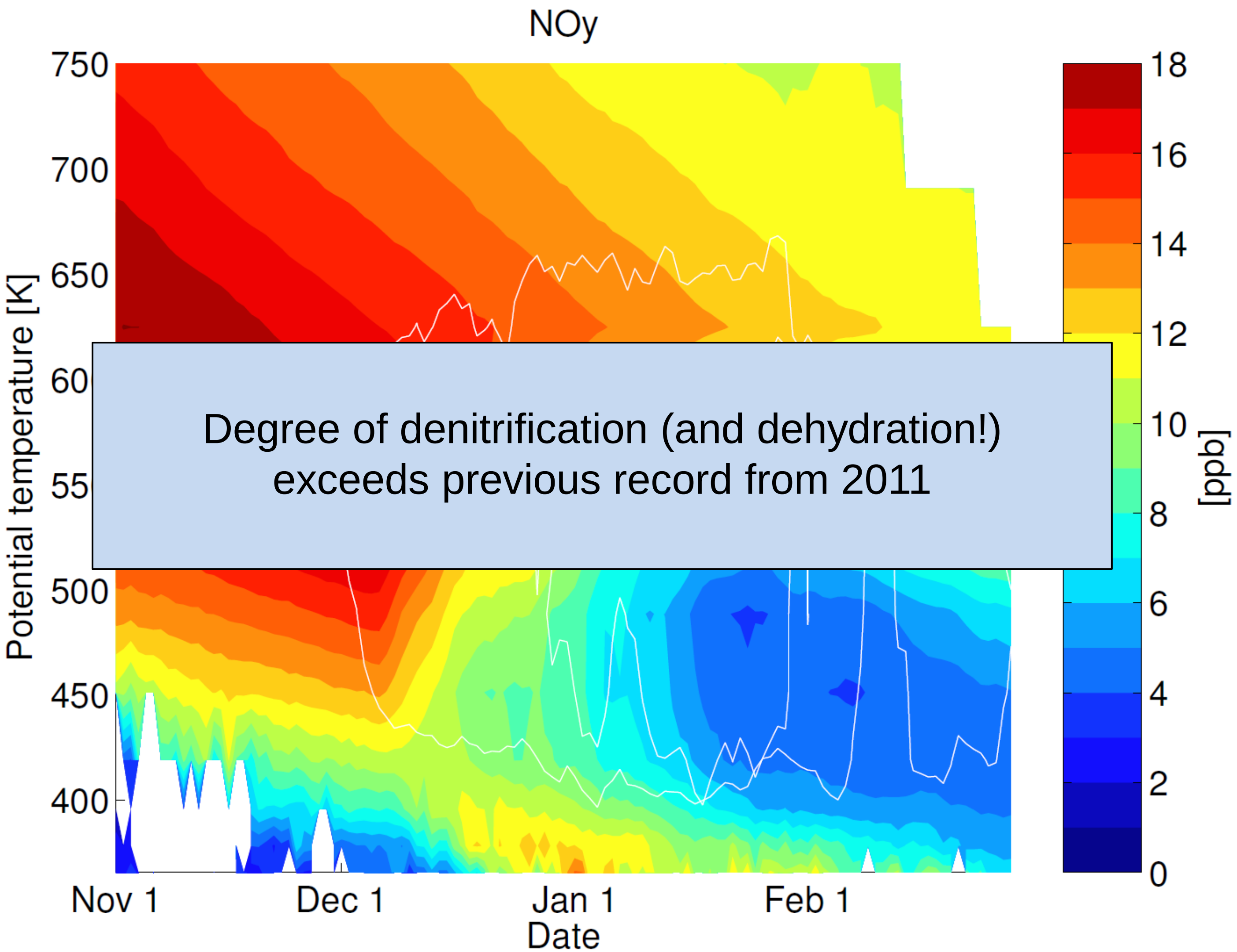
2004/05
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
forecast
84
96
90
87
05
93
306
1
60
121
Oct
Nov
Dec
Jan
Feb
Mar
Apr

Conditions for 17 February 2016 - ATLAS



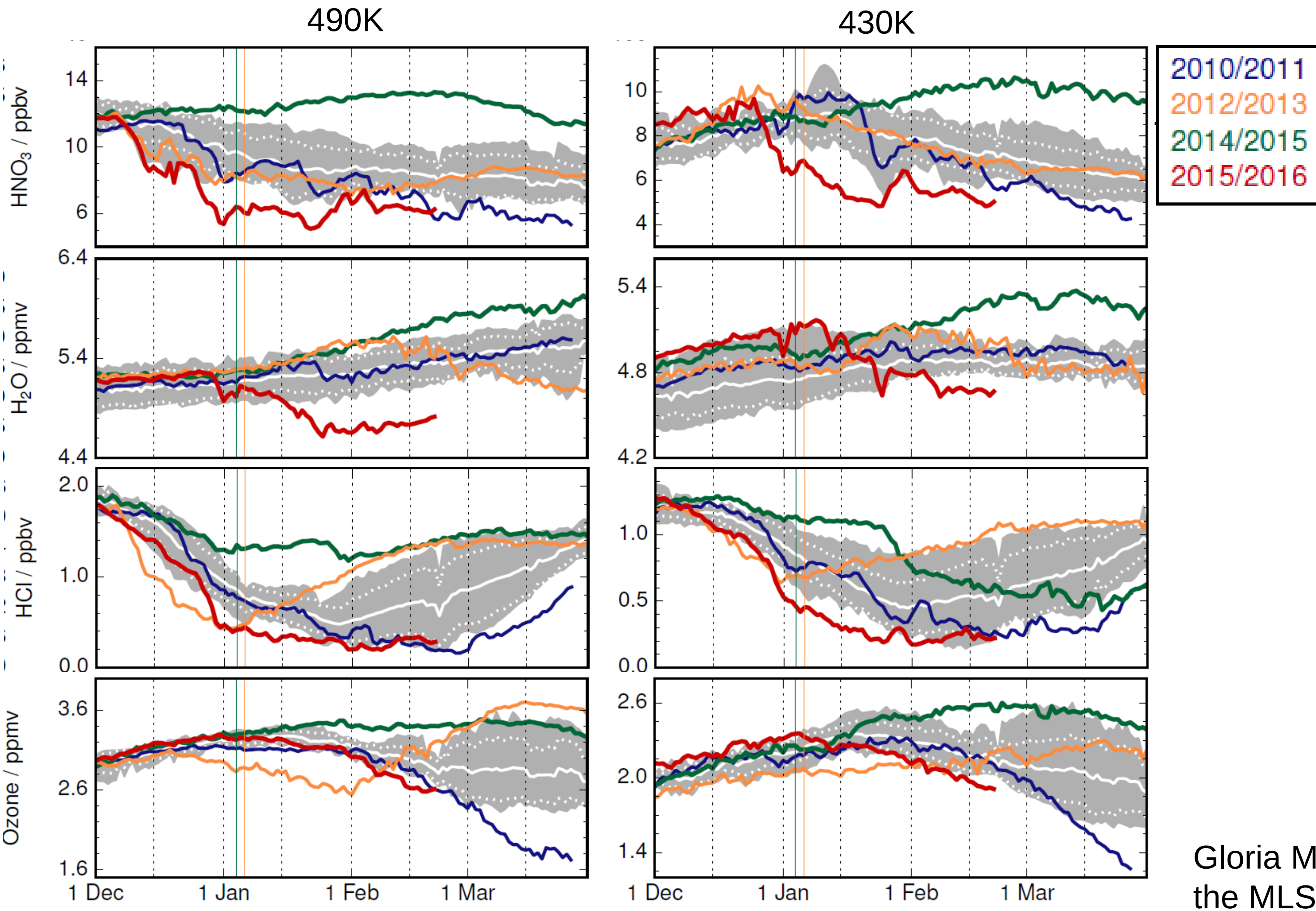
Vortex average irreversible denitrification from ATLAS

(vortextracer > 50%, ten day forecast)



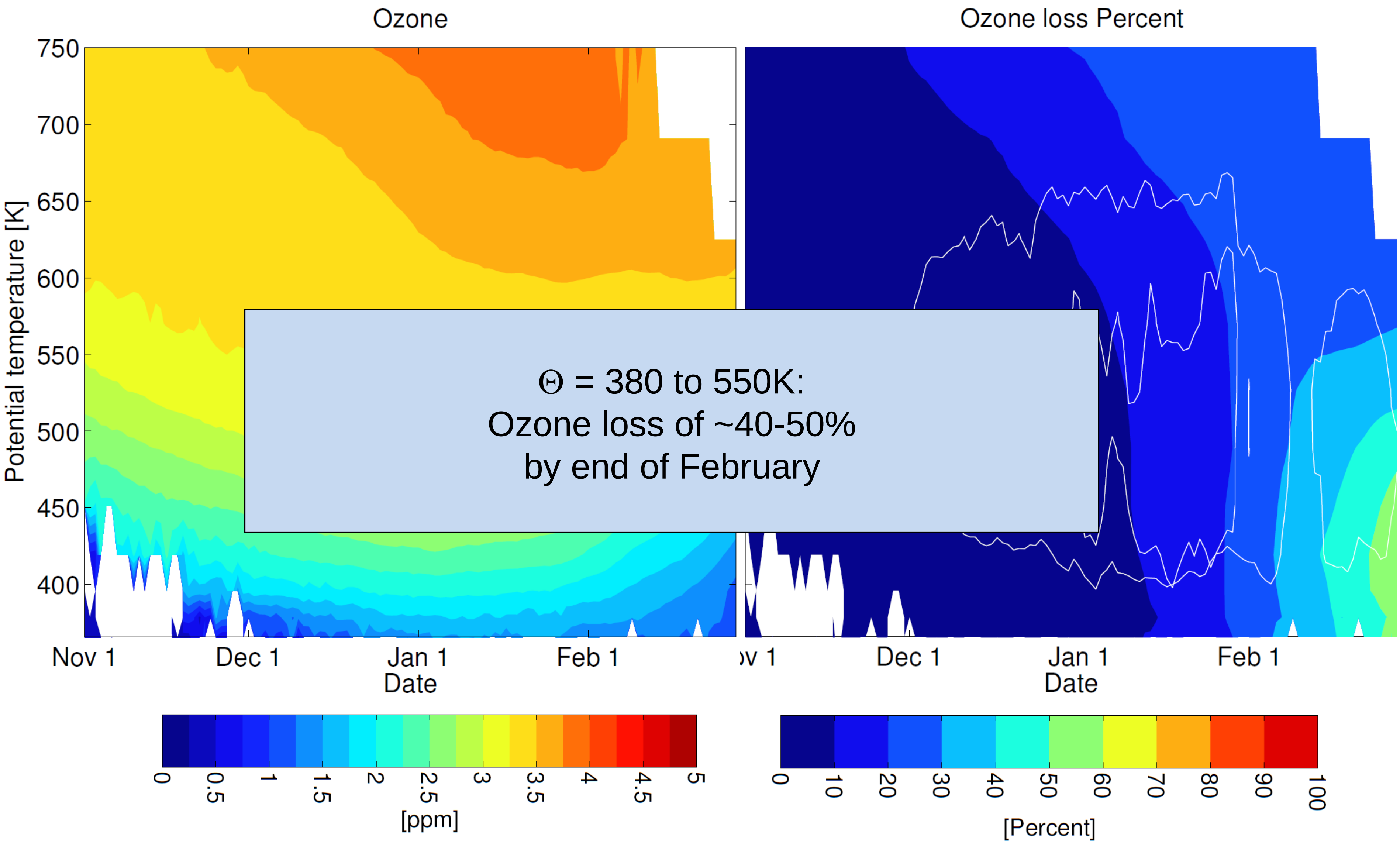
Degree of denitrification (and dehydration!) exceeds previous record from 2011

Vortex average chemical conditions from MLS



Gloria Manny & the MLS team

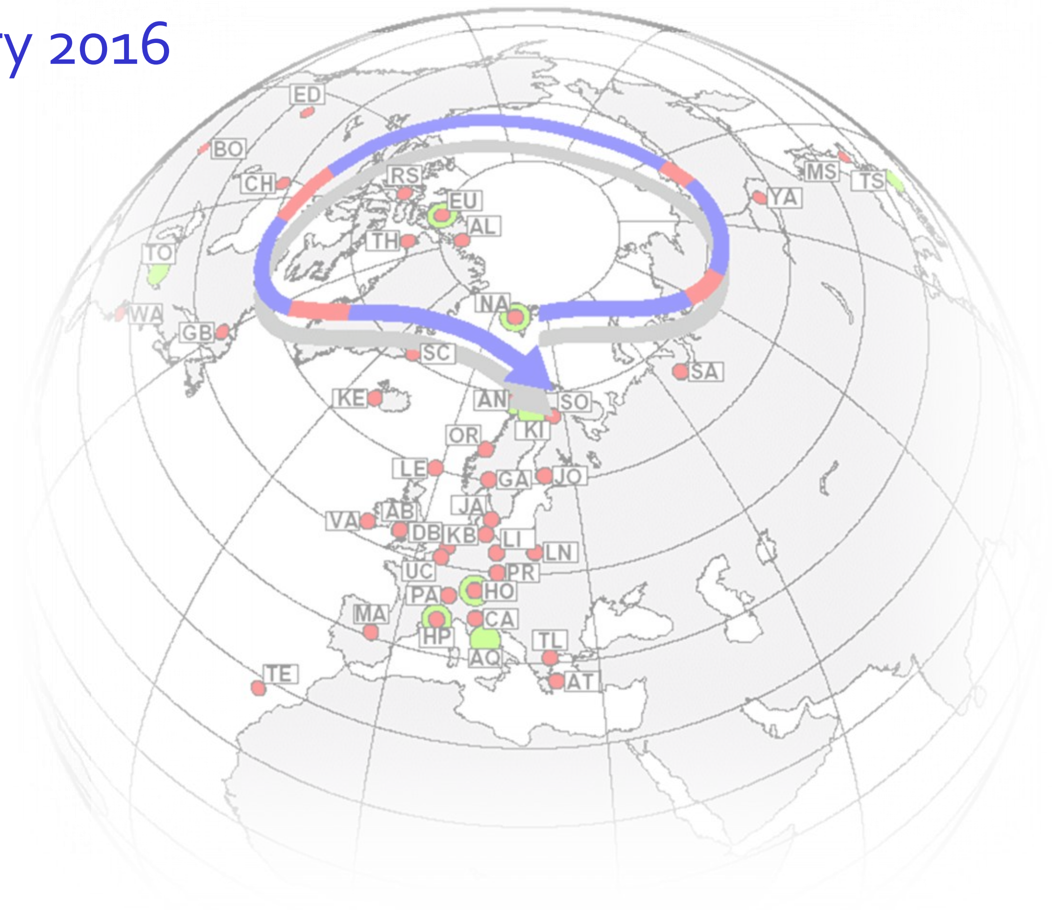
Vortex average ozone and ozone loss from ATLAS
(vortextracer > 50%, ten day forecast)



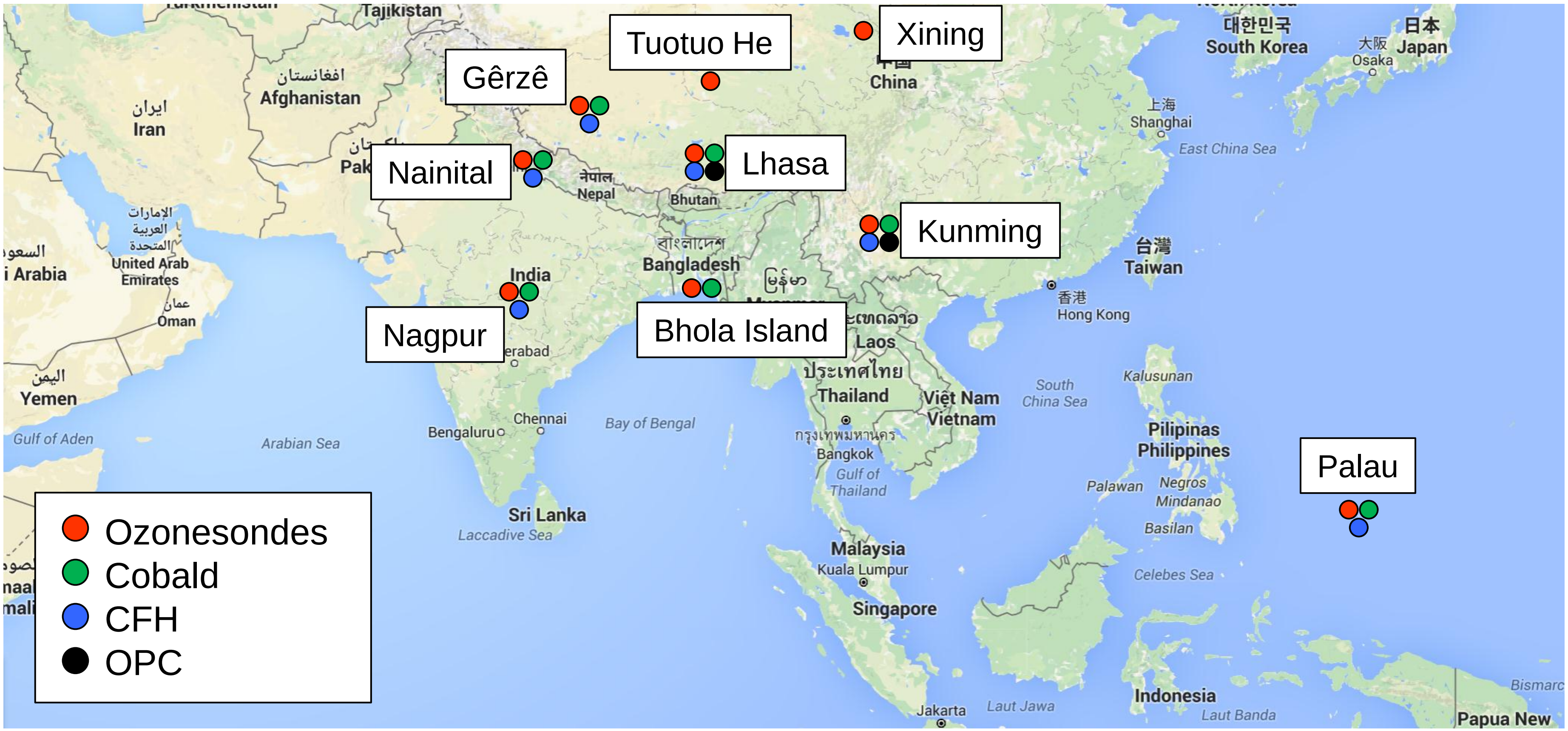
Θ = 380 to 550K:
Ozone loss of ~40-50%
by end of February

Match campaign 2015/2016

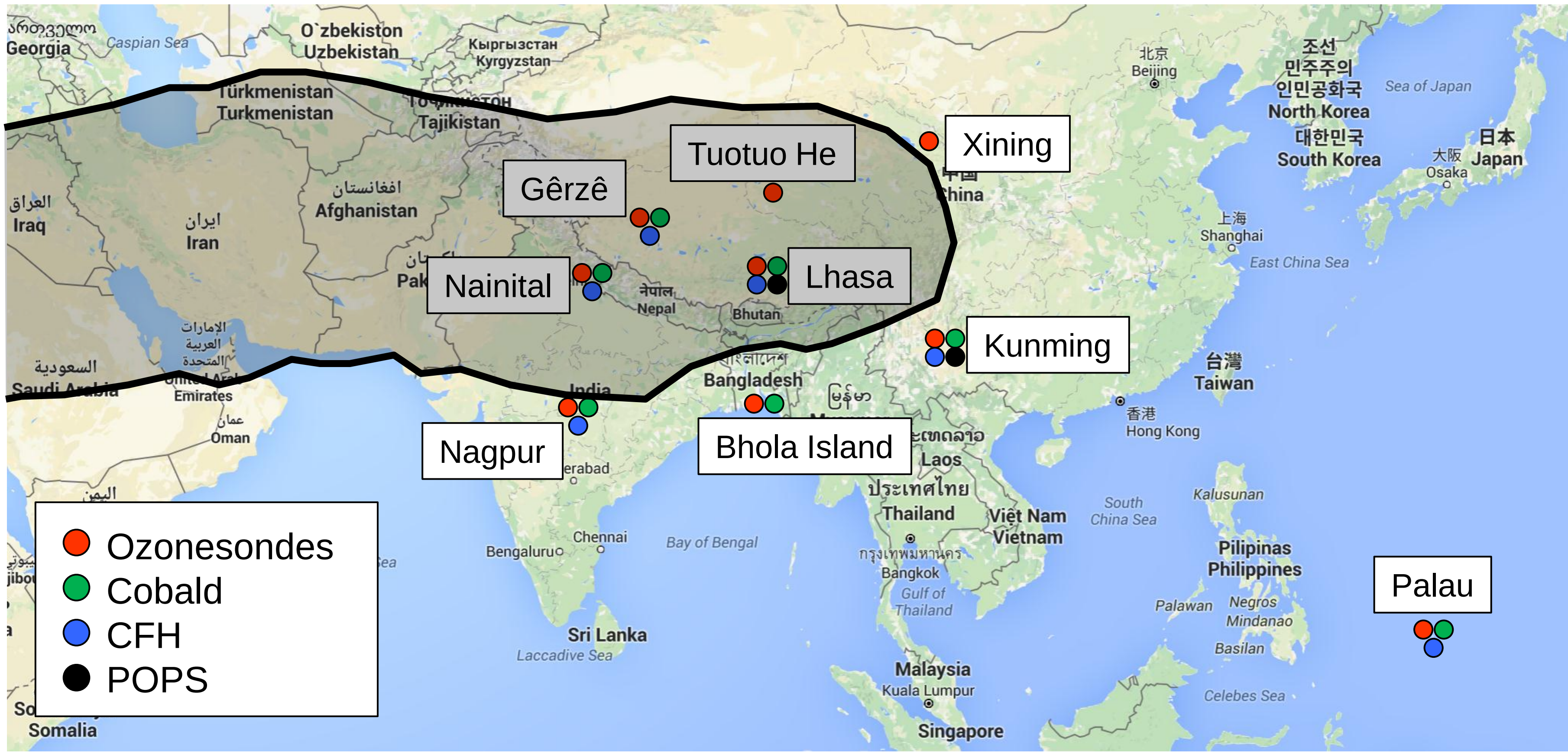
- Running since mid-January 2016
- 23 stations active
- ~500 Sondes launched



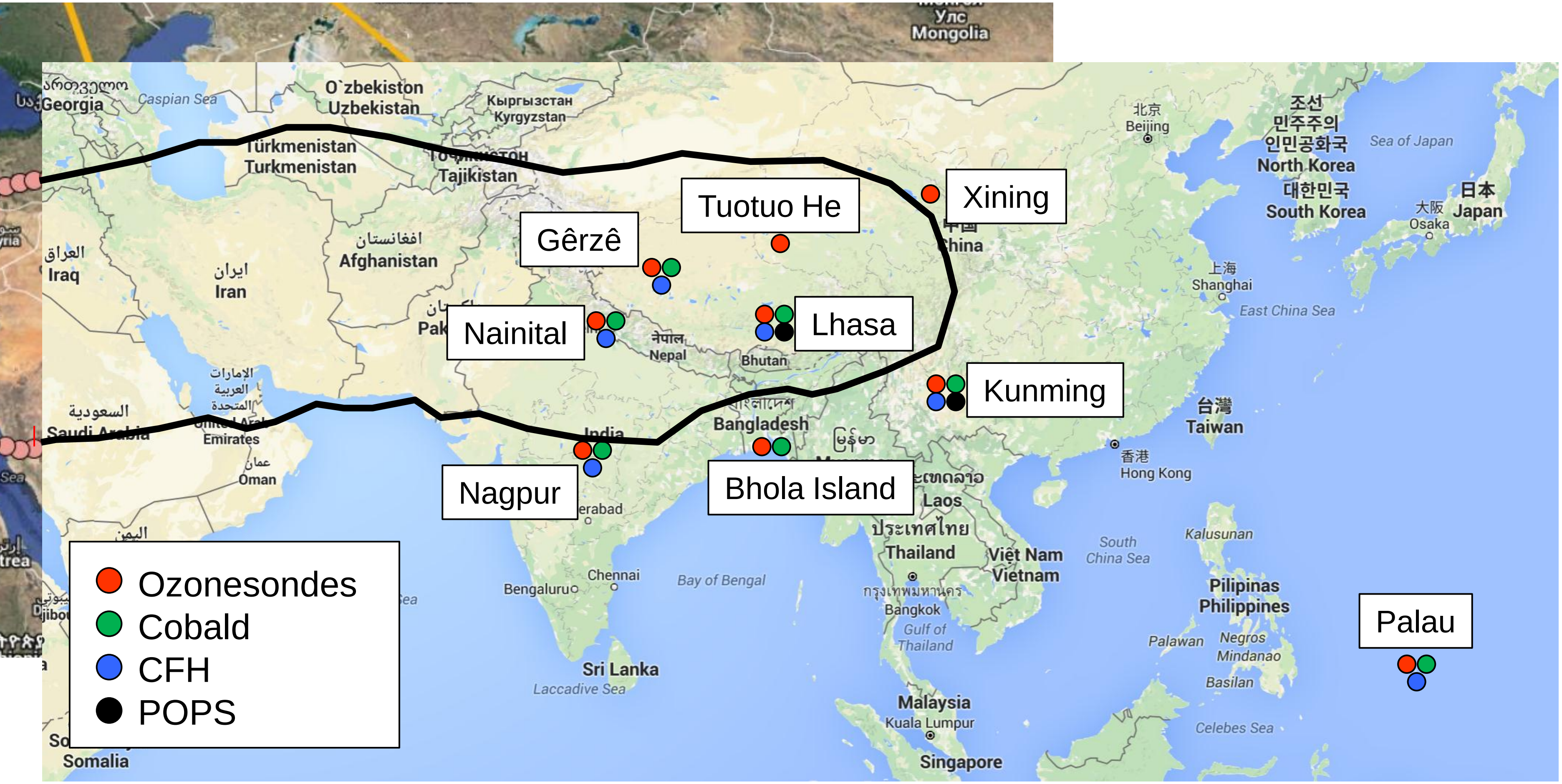
StratoClim ballooning program



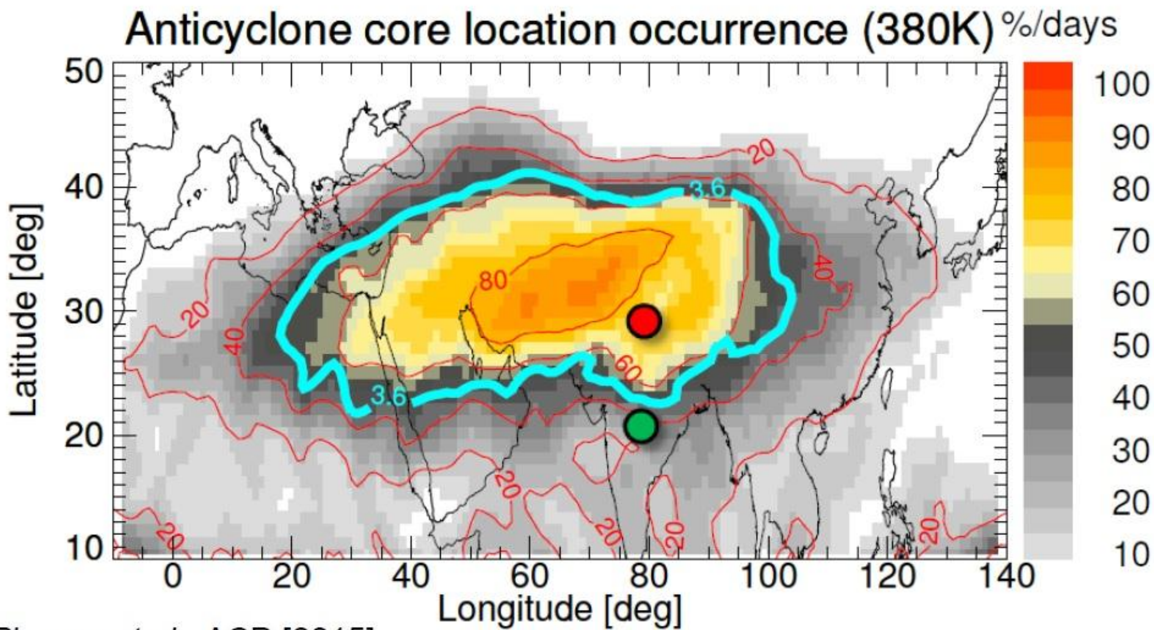
Ballooning program during StratoClim



Ballooning program during StratoClim



Ground stations



Ploeger et al., ACP [2015]

Campaign stations:

- **Nainital**, northern India
  79.45°E, 29.40°N
- **Nagpur**, central India
  79.08°E, 21.15°N