Quadrennial Ozone Symposium, Edinburgh, 04.-09. September 2016

Measuring the Tropospheric Ozone Minimum in the Tropical West Pacific

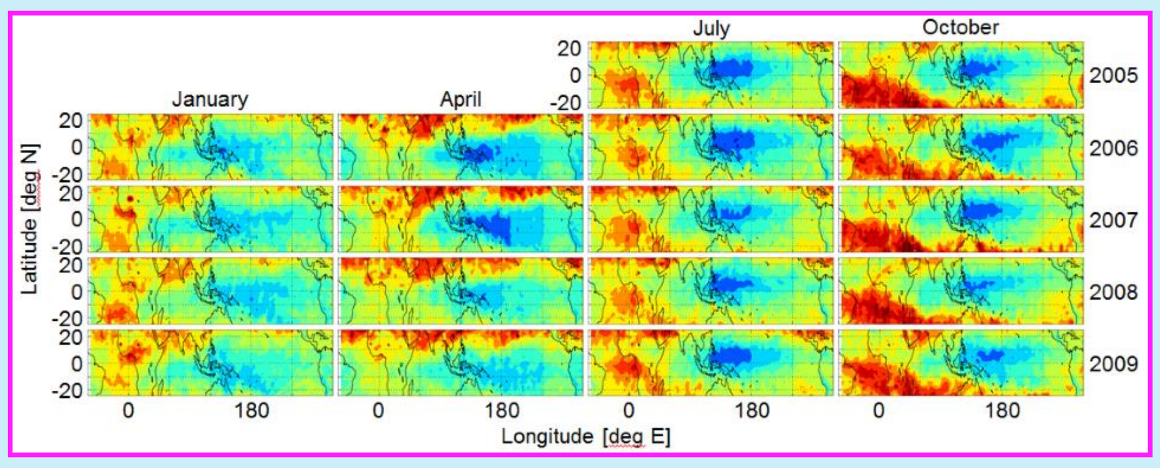
Katrin Müller, Peter von der Gathen, Ingo Wohltmann, Ralph Lehmann und Markus Rex

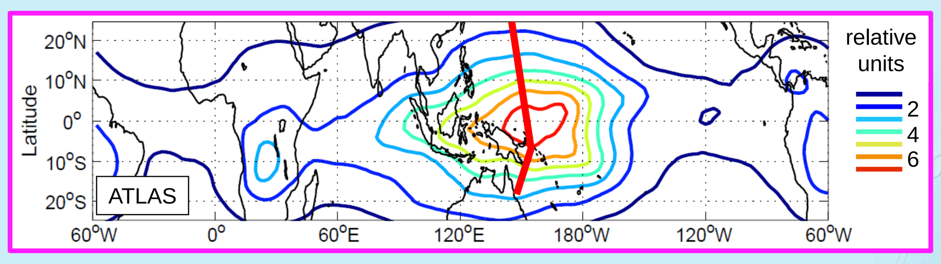
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

The Tropical West Pacific

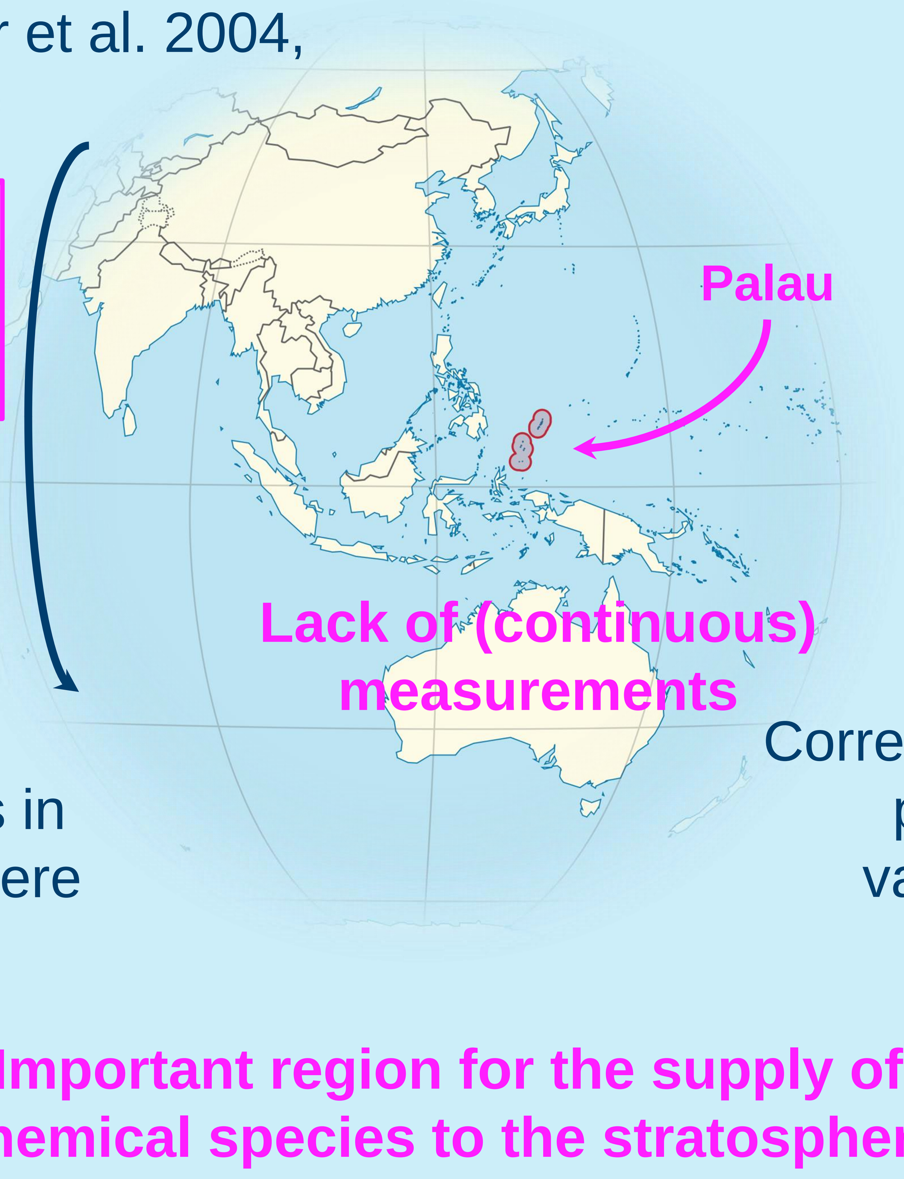
Major source region for stratospheric air in boreal winter (e.g. Fueglistaler et al. 2004, Kremser et al. 2009)

Persistent tropospheric ozone minimum (Rex et al. 2014)

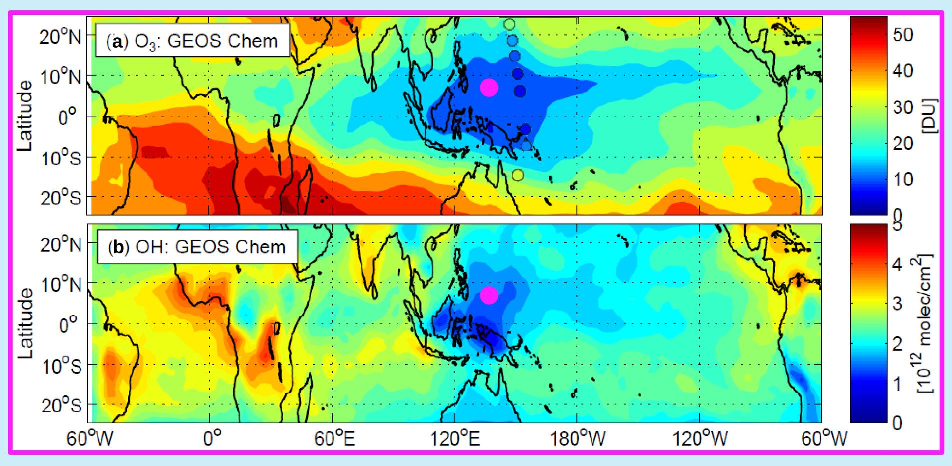




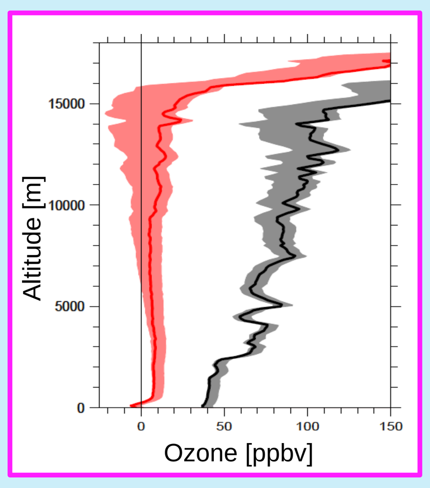
▲ Fig.1: Density distribution function of the horizontal positions of the trajectories between boundary layer and LCPs from 4-months ATLAS runs; thick red line: TransBrom cruise October 2009 (Rex et al. 2014).



Lack of (continuous) measurements



▲ Fig.2: TES monthly mean tropospheric ozone columns for January, April, July, October 2005-2009 (Rex et al. 2014).
◄ Fig.3: Tropospheric columns for (a) ozone and (b) OH from GEOS Chem for October 2009; open circles in (a) TransBrom balloon soundings; pink circle: Palau (Rex et al. 2014).
▼ Fig.4: Tropospheric ozone profiles from TransBrom (black: extratropical ~30°N, red: ~10°N), shading: see fig. 5 (Rex et al. 2014).



Origin and transit region of corresponding air masses in boundary layer and troposphere (Rex et al. 2014)

Corresponding OH minimum and prolonged life times of various chemical species (e.g. Kley et al. 1996)

Oxidizing Capacity

- Major source of OH formation in clean tropospheric air: $O_3 + h\nu \rightarrow O(^1D) + O_2$
  $O(^1D) + H_2O \rightarrow OH + OH$
- Couples ozone concentration and oxidizing capacity
- Efficient loss mechanism for ozone, favored in the tropical West Pacific

Important region for the supply of chemical species to the stratosphere

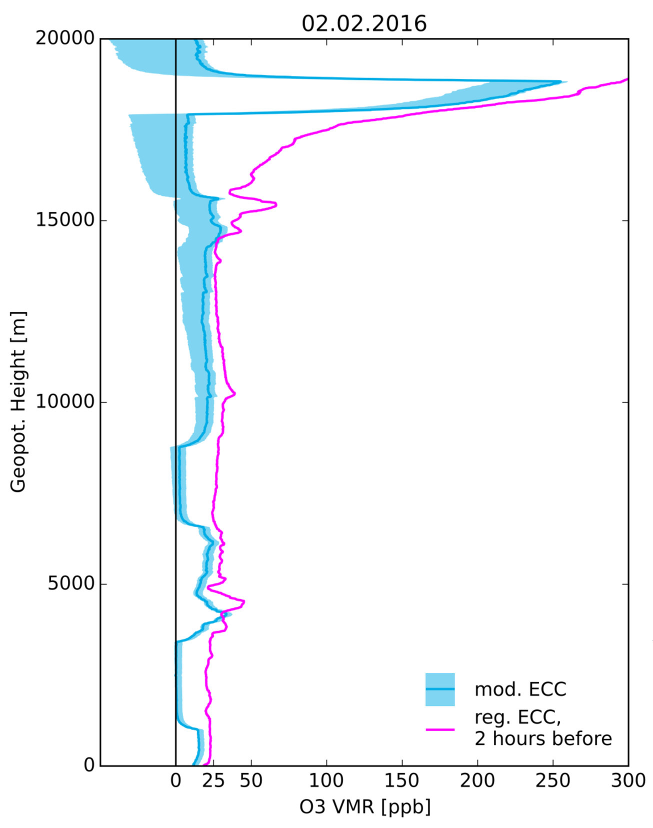
Objectives

Motivated by measurements from the TransBrom campaign in October 2009 with RV Sonne a new research station was established on **Palau (7° N, 135° E)** as part of the StratoClim EU-project: since January 2016 intensive measurement periods and regular ozone soundings to improve limited data pool.

Development of a new device to monitor the background current of ECC ozone sondes in flight to lower the instrumental detection limit and

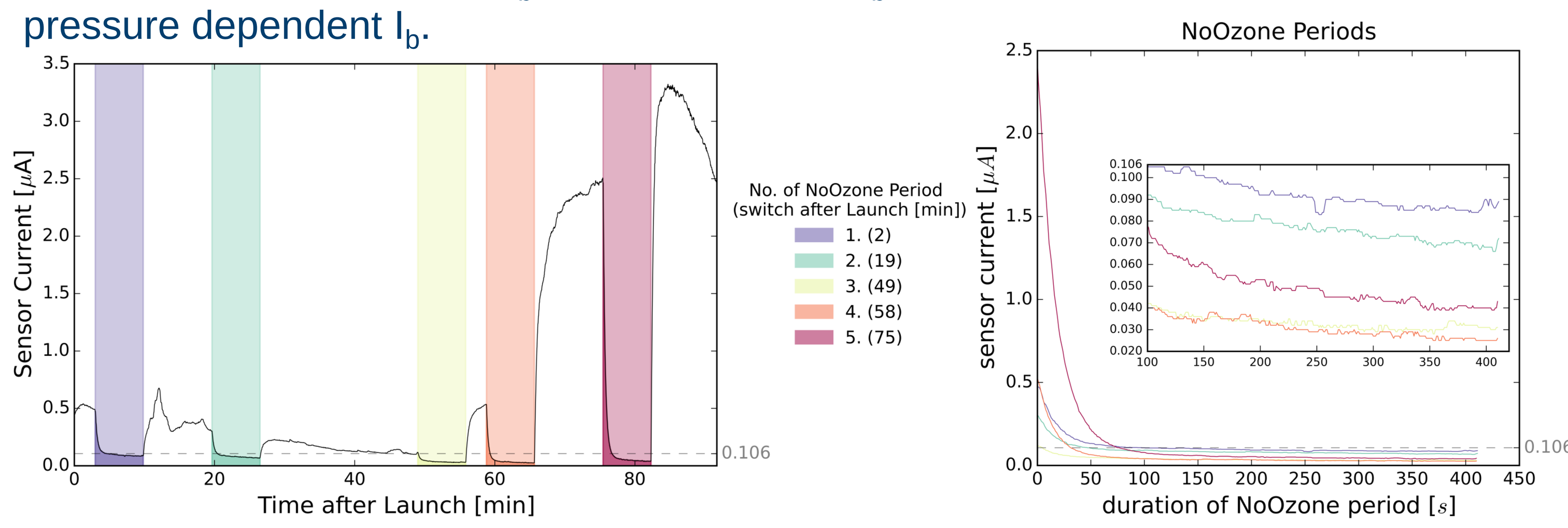
- improve measurements at mixing ratios near detection limit (~15ppbv)
- Improve the overall understanding of this yet controversial bias (see Vömel und Diaz,2010).

Background Current and Modification of ECC Sondes

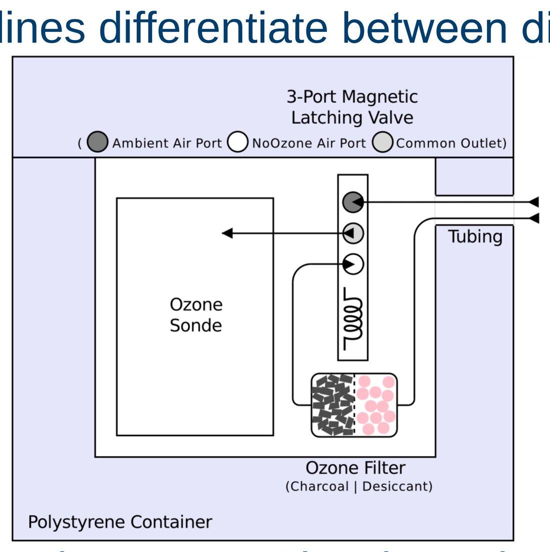


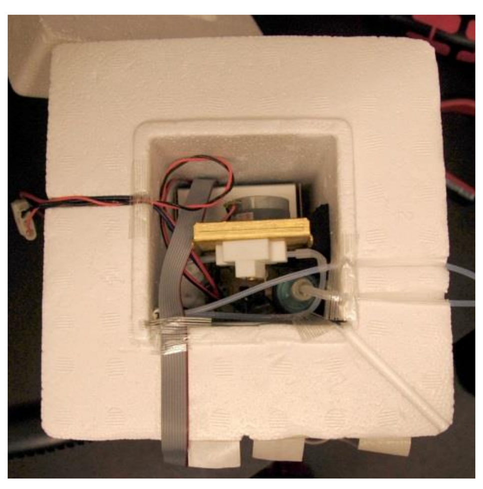
Hypothesis: for each trajectory of one specific individual sonde in a 5-dim. parameter space (t, T, p, c[O_3], 'shaking') the background current develops in one specific way.
Practical approach: in-flight monitoring of the background current in regions of interest (e.g. tropical upper troposphere)

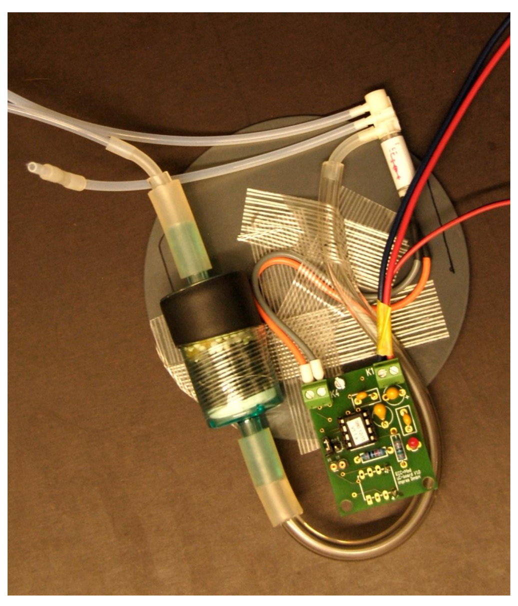
◄Fig. 5. Tropospheric ozone profile from the first modified ECC sonde launch (blue) in Palau. For comparison: profile from a regular launch 2 hours prior (magenta). Shading illustrates the effect of different background current (I_b) treatments (see also fig.4). Lowest values: subtraction of a constant I_b; highest values: I_b equals zero; lines: subtraction of a pressure dependent I_b.



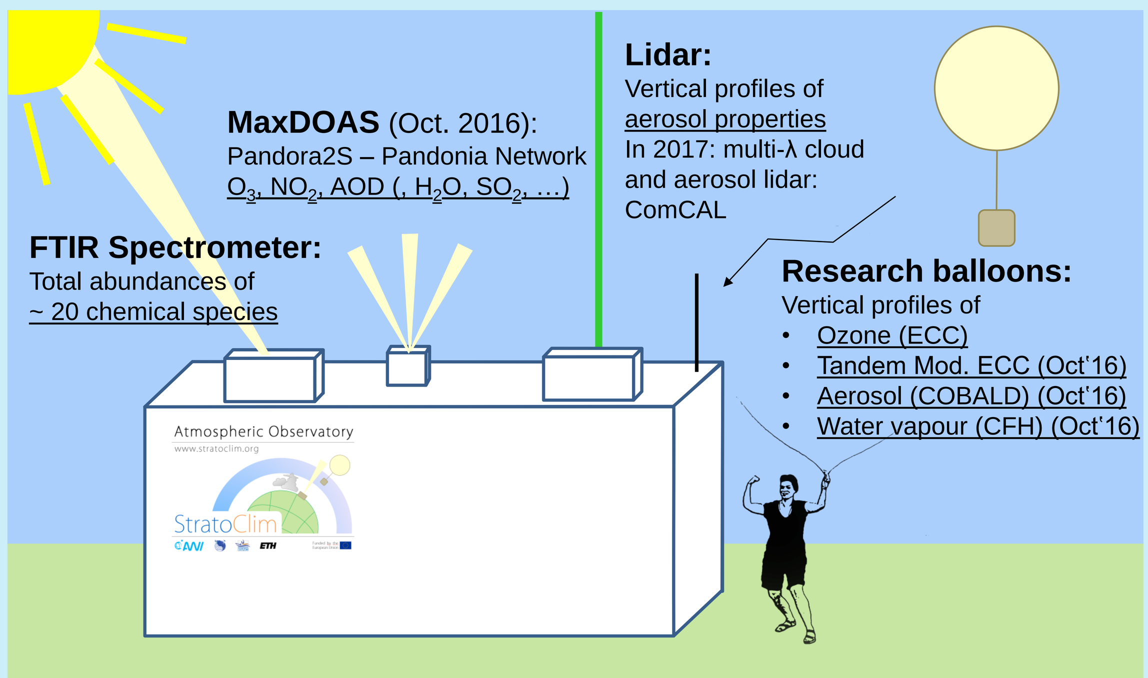
▲Abb.6: Sensor current during the complete sounding (left) and comparison of all 'NoOzone' periods (right), grey dashed line: pre-launch background; colours of shading or lines differentiate between different "NoOzone"-periods.





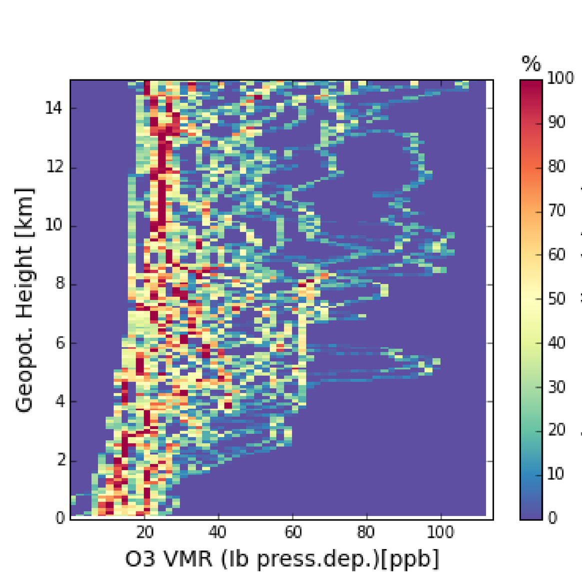


▲►Fig. 7,8,9: Sketch and photos of the ECC sonde modification for in-flight-monitoring of I_b .

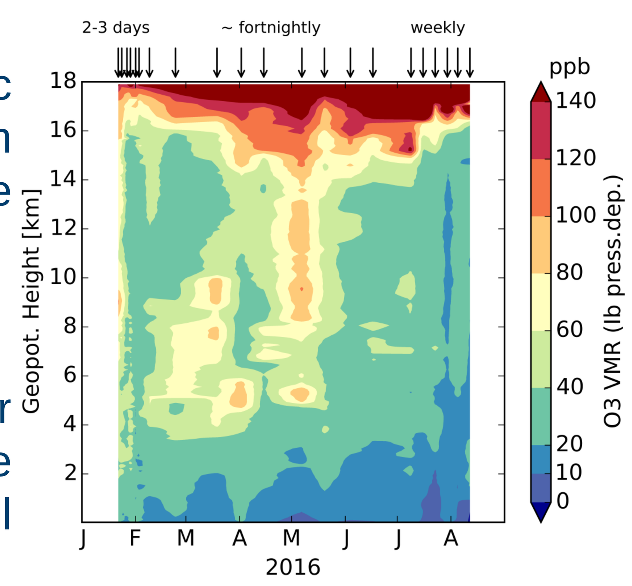


◄Fig. 10. Instrumental setup at the StratoClim Atmospheric Observatory in Palau; next month: ECC-COBALD-CFH soundings during POSIDON (in coop. with NOAA, NASA) and installation of Pandora 2S; continuation of the station after StratoClim with new funding is aspired.

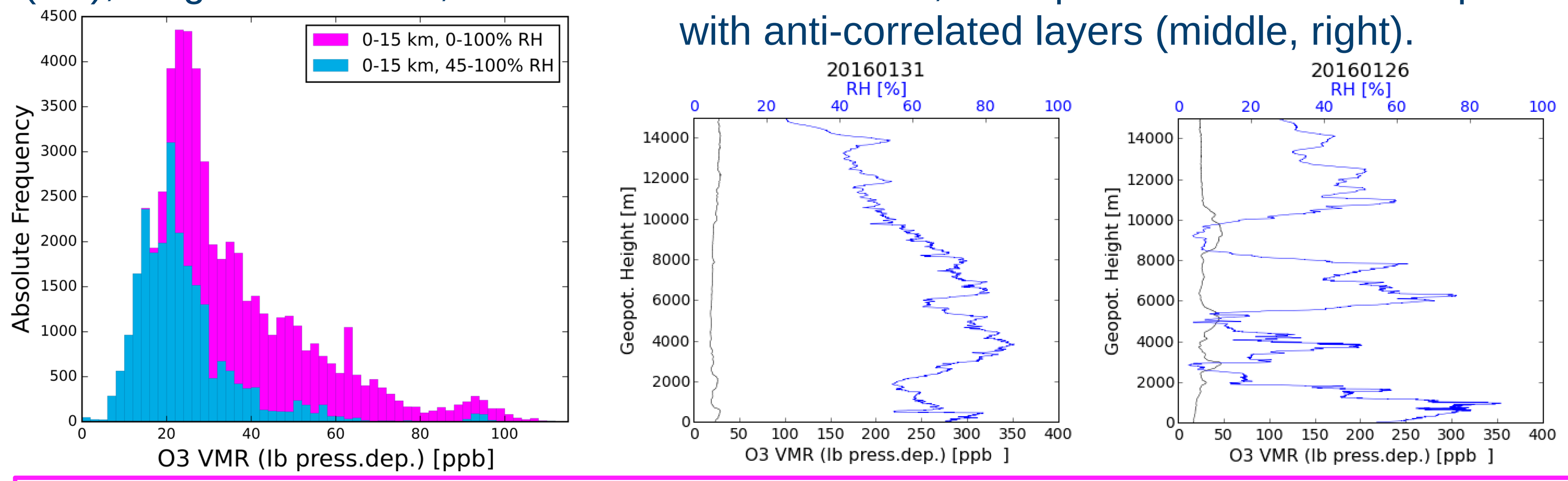
First Ozone Measurements from Palau



►Fig. 11. Seasonal variation of tropospheric ozone VMR from preliminary ECC sonde data for 2016.
◄ Fig. 12. Relative frequency distribution (normalized by layer maximum) of ozone VMR (0-15km) from all (21 prelim.) profiles.



▼ Fig. 13. Comparison of ozone distributions with respect to relative humidity (RH) (left), magenta: all data, blue: data with RH > 45 %; examples of ozone and RH profiles with anti-correlated layers (middle, right).



Summary: Successful establishment of the new Palauan research station: growing data set from 01/2016 until 2018(+).
Under investigation: seasonal variation (incl. El Niño), relation of tropos. O_3 and H_2O, chemical and dynamical processes in the TTL.

References
Fueglistaler, S., Wernli, H., and Peter, T.:Tropical troposphere-to-stratosphere transport inferred from trajectory calculations, J. Geophys. Res., 109, D03108, doi:10.1029/2003JD004069, 2004.
Kley, D., Crutzen, P. J., Smit, H. G. J., Vömel, H., Oltmans, S. J., Grassl, H., and Ramanathan, V.: Observations of near-zero ozone concentrations over the convectice Pacific: Effects on air chemistry, Science, 274, 230-233, 1996.
Kremser, S., Wohltmann, I., Rex, M., Langematz, U., Dameris, M., and Kunze, M.: Water vapour transport in the tropical tropopause region in coupled Chemistry-Climate Models and ERA-40 reanalysis data, Atmos. Chem. Phys., 9, 2679-2694, 2009.
Pan, L.L., Honomichl, S.B., Randel, W.J., Apel, E.C., Atlas, E.L., Beaton, S.P., Bresch, J.F., Hornbrook, R., Kinnison, D.E., Lamarque, J.-F., Saiz-Lopez, A., Salawitch, R.J., and Weinheimer, A.J.: Bimodal distribution of free tropospheric ozone over the tropical western Pacific revealed by airborne observations, Geophys. Res. Lett., 42, 7844-7851, doi:10.1002/2015GL065562, 2015.
Rex, M., Wohltmann, I., Ridder, T., Lehmann, R., Rosenlof, K., Wennberg, P., Weisenstein, D., Notholt, J., Krüger, K., Mohr, V., Tegtmeier, S.: A tropical West Pacific OH minimum and implications for stratospheric composition, Atmos. Chem. Phys., 14, 4827-4841, 2014.
Vömel, H. and Diaz, K.: Ozone cell current measurements and implications for observations of near-zero ozone concentrations in the tropical upper troposphere, Atmos. Meas. Tech., 3, 495, doi:10.5194/amt-3-495-2010, 2010.

Figure „Globe": Wikipedia.

StratoClim: Stratospheric and upper tropospheric processes for better climate predictions
StratoClim is funded by the European Union

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
HELMHOLTZ GEMEINSCHAFT
BREMERHAVEN
Am Handelshafen 12
27570 Bremerhaven
Telefon 0471 4831-0
www.awi.de