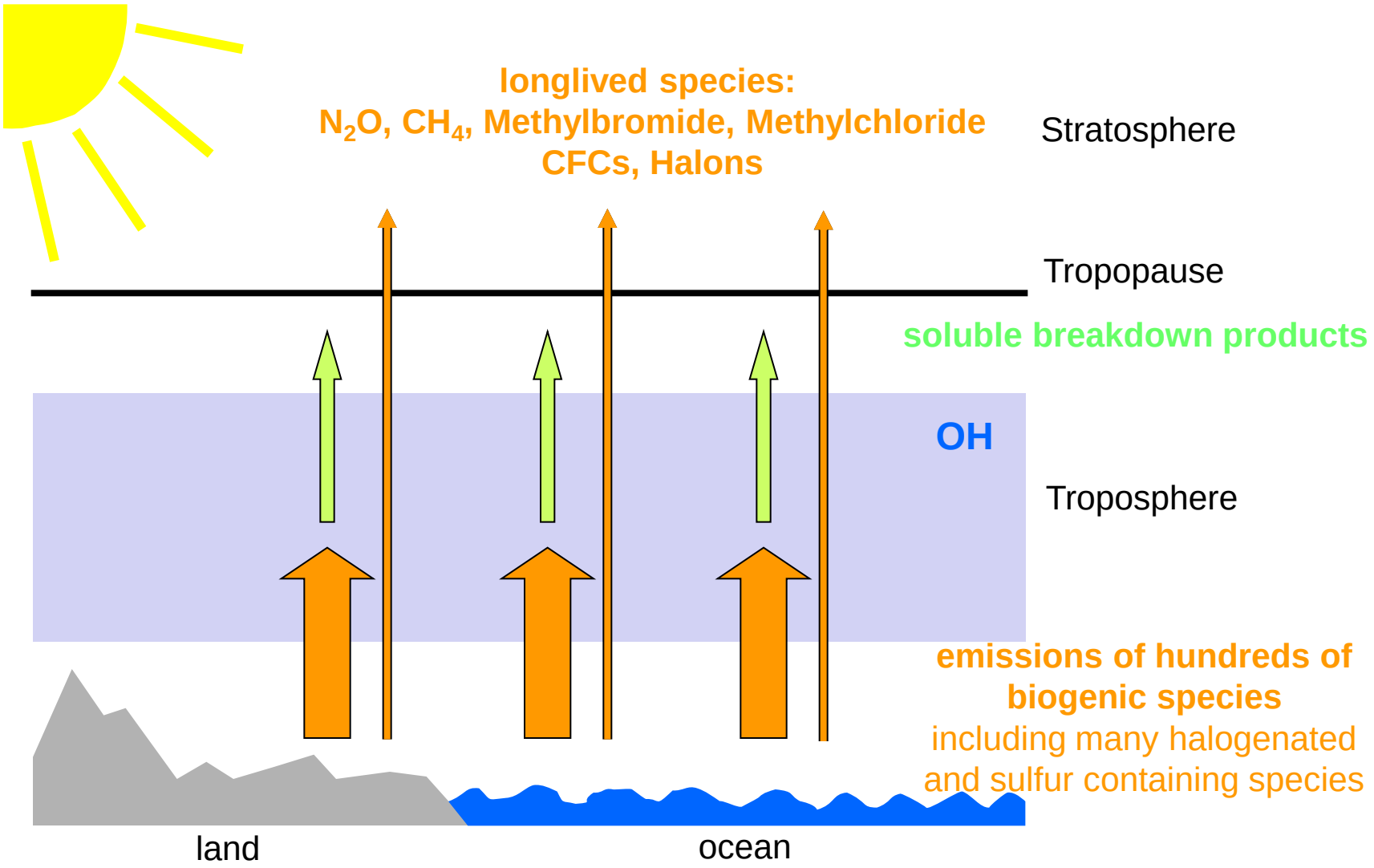
Pronounced ozone and OH minima in the tropical West Pacific troposphere

Implications for transport of chemical species into the stratosphere

Markus Rex, Ingo Wohltmann, Theo Ridder, Ralph Lehmann, Ru-Shan Gao, Karen Rosenlof, Paul Wennberg, Debra Weisenstein, Justus Notholt, Kirstin Krüger, Viktoria Mohr, Susann Tegtmeier

Paper accepted for ACPD

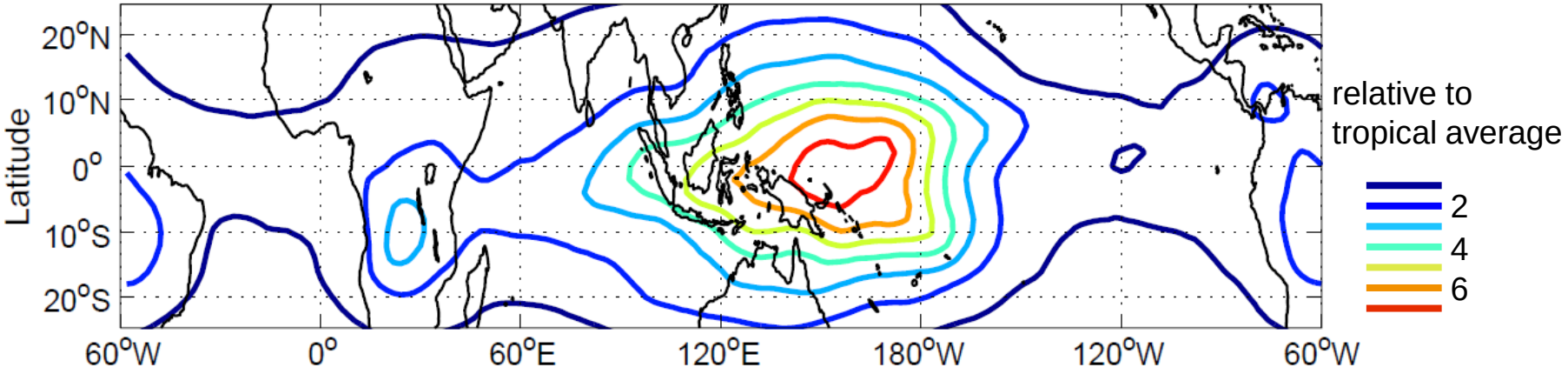
The „OH shield“



Source region for stratospheric air in NH winter

For air that reaches the stratosphere: Transit area through troposphere during transport from the boundary layer to the LCP

Based on fully lagrangian chemical transport model ATLAS
(ATLAS: Wohltman & Rex, GMD, 2009)



What determines OH?

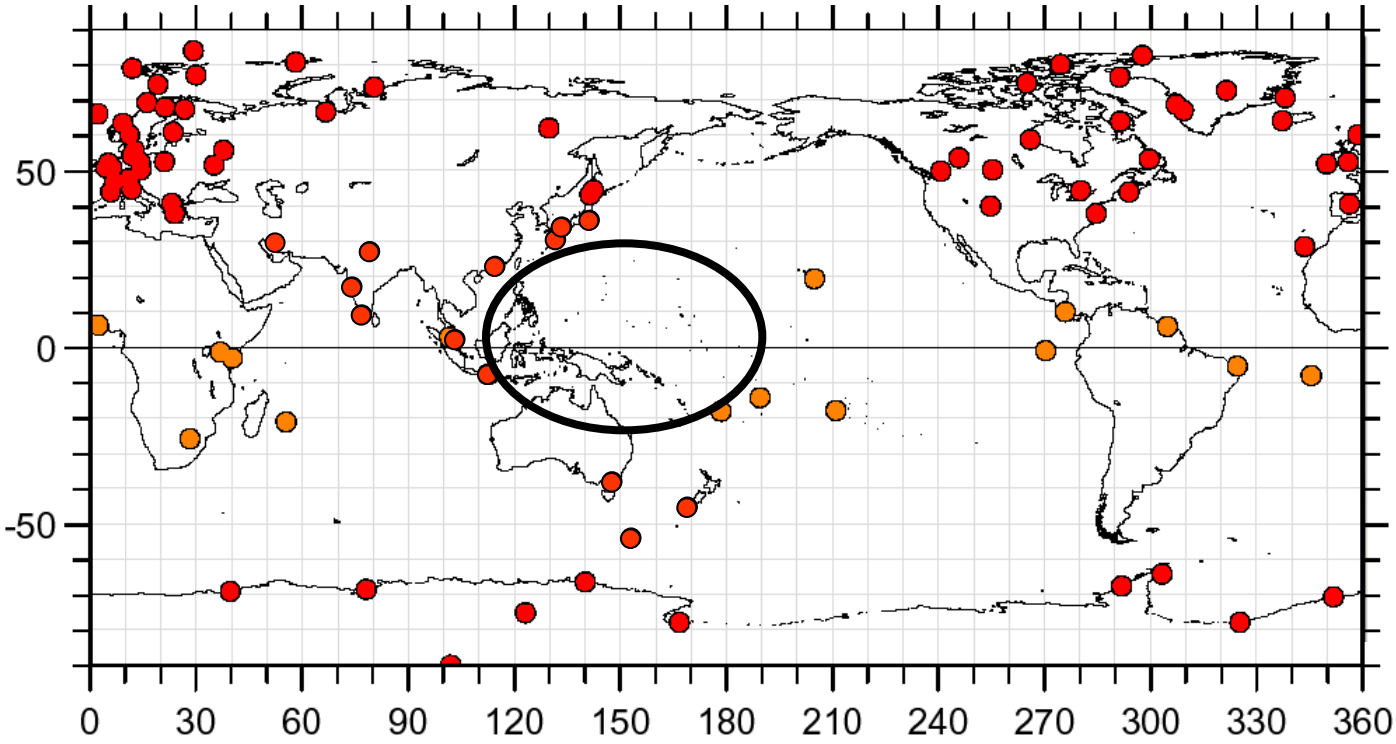
Major source of HO_x in "clean" (NMHCs poor) air:

$O_3 + h\nu\ (\lambda<340nm) \rightarrow O_2 + O(^1D)$

$O(^1D) + H_2O \rightarrow OH + OH$

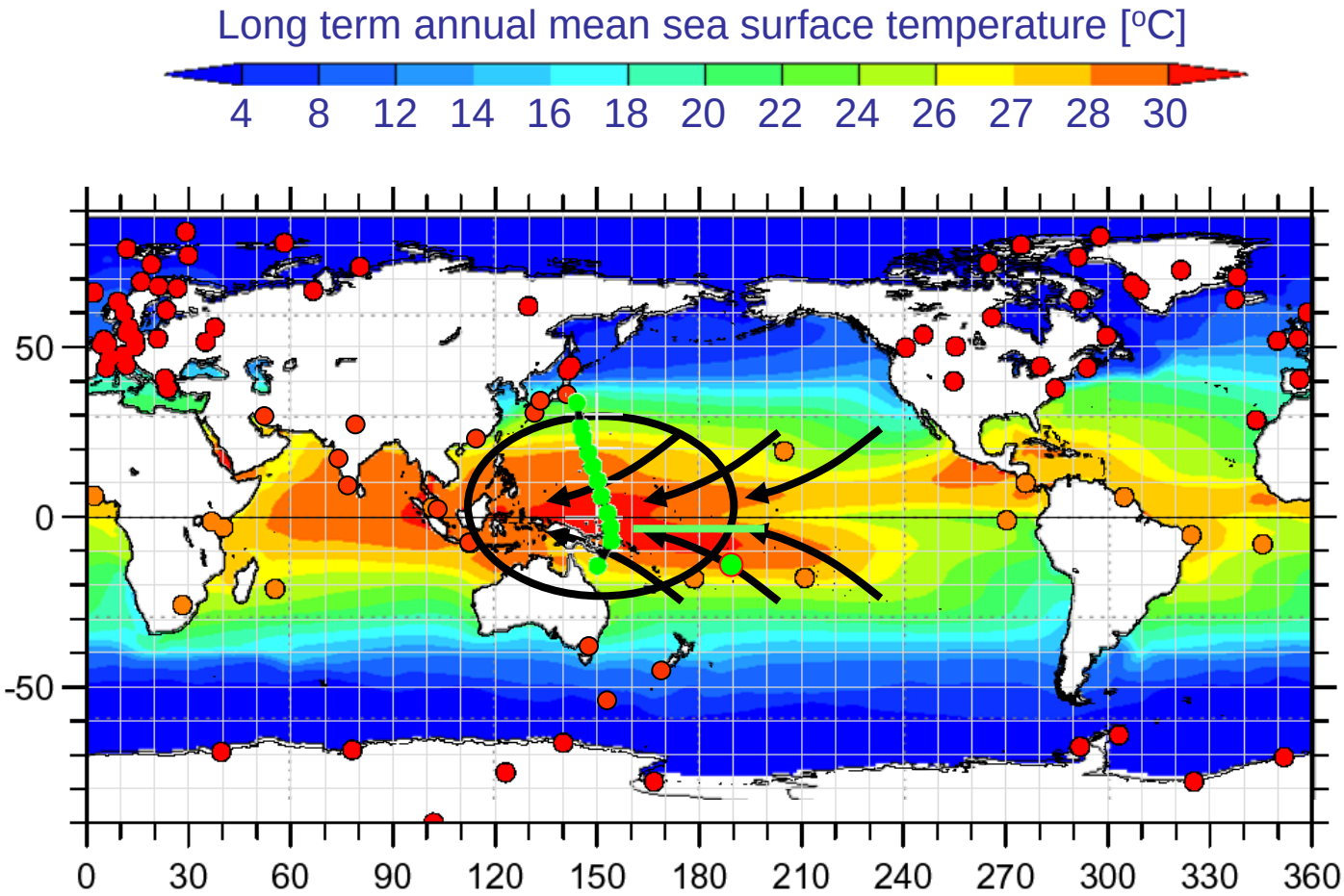
=> HO_x (and hence OH) depends on ozone
but complicated by the effect of NO_x on the OH/HO_x balance, see Ru-Shan's talk

Global ozonesonde station network



Global ozonesonde station network and SSTs

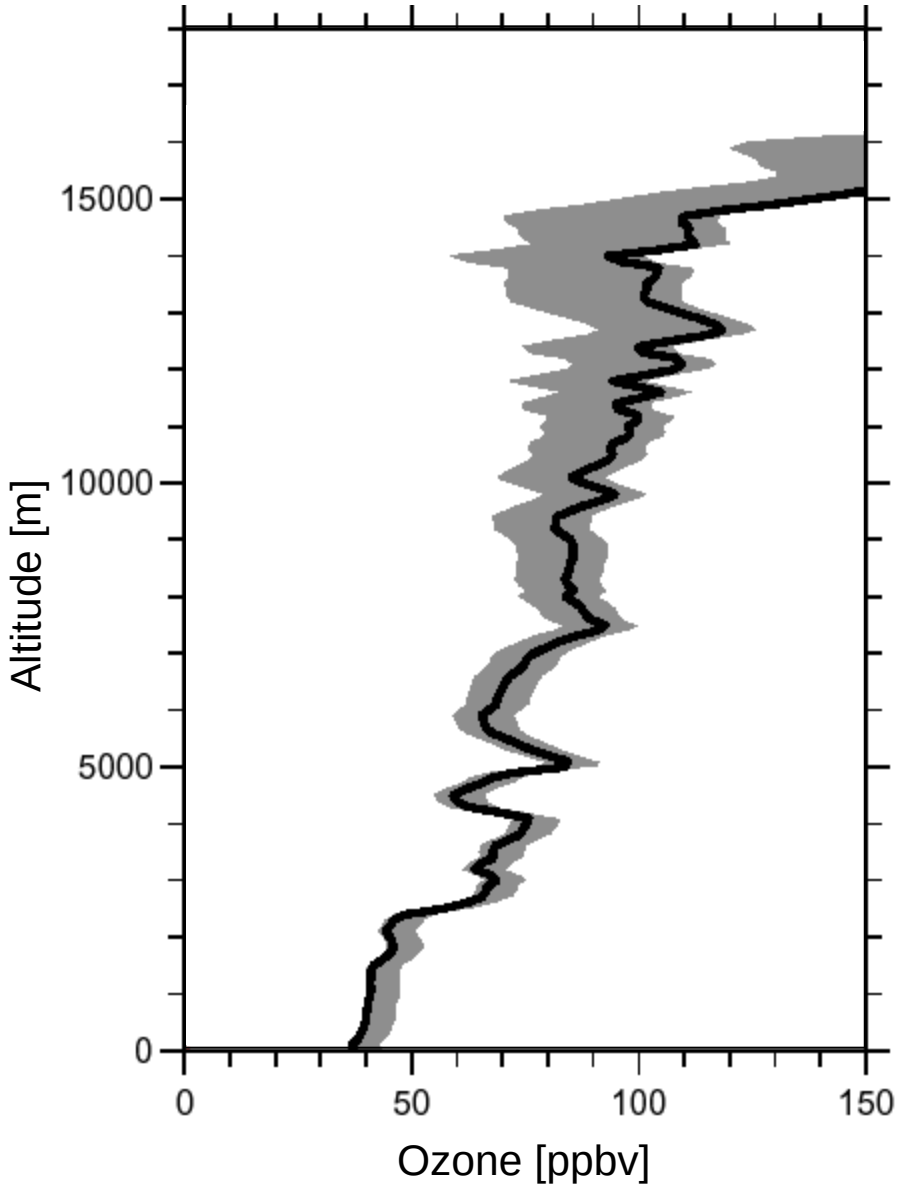
TransBrom cruise with RV Sonne, Japan-Australia, October 2009



Central Equatorial Pacific Experiment (CEPEX), *March* 1993

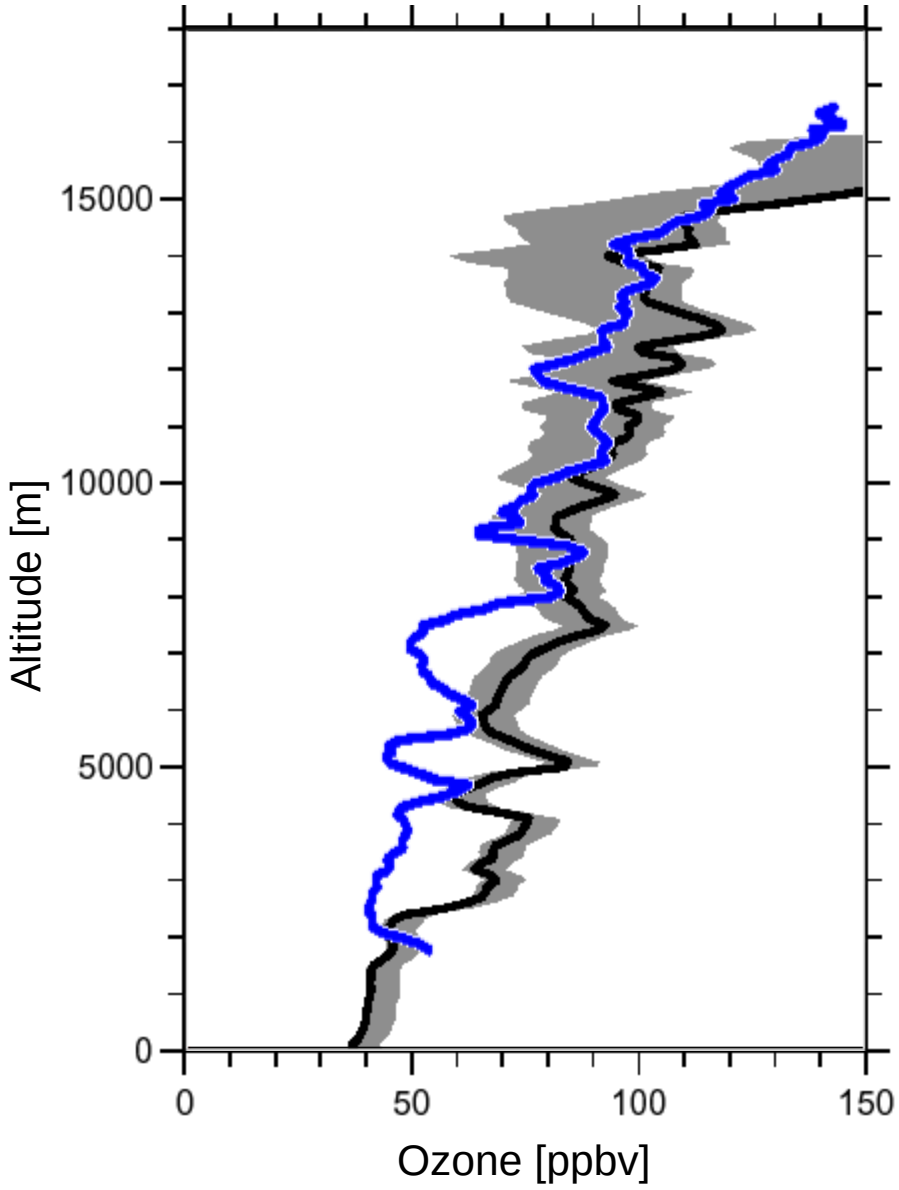
Samoa ozone sonde data

Ozone profile measurements in the West Pacific



Extratropical
West Pacific ~30°

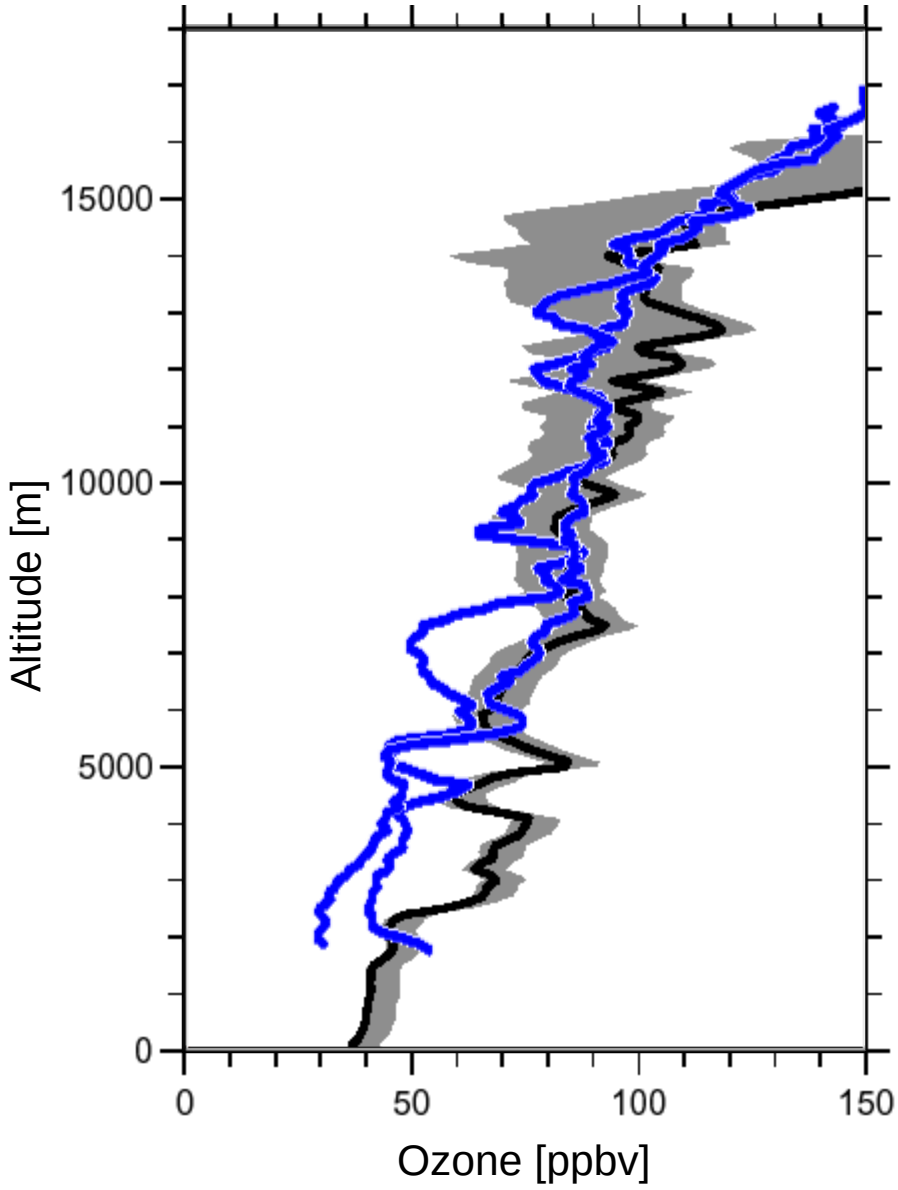
Ozone profile measurements in the West Pacific



Extratropical West Pacific ~30°

Tropical Atlantic

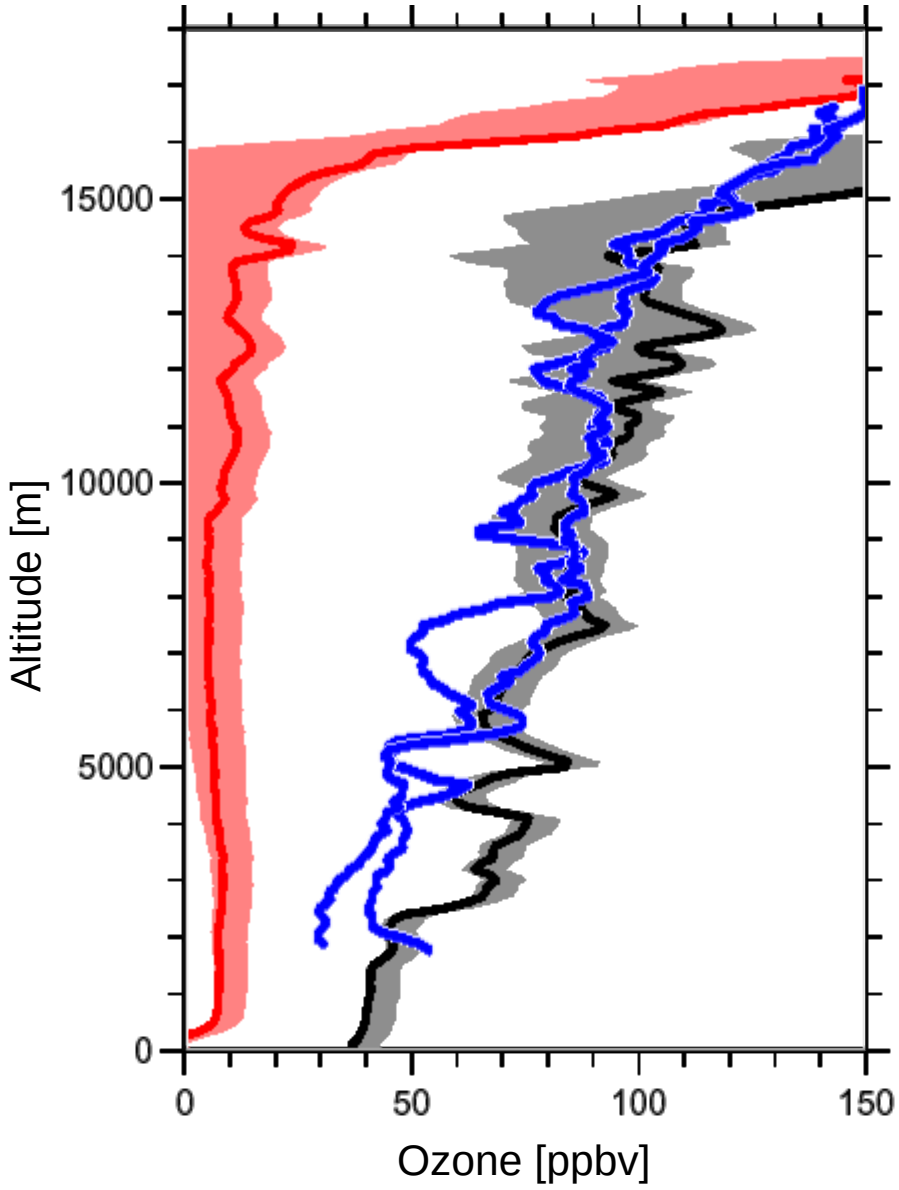
Ozone profile measurements in the West Pacific



Extratropical West Pacific ~30°

Tropical Atlantic

Ozone profile measurements in the West Pacific

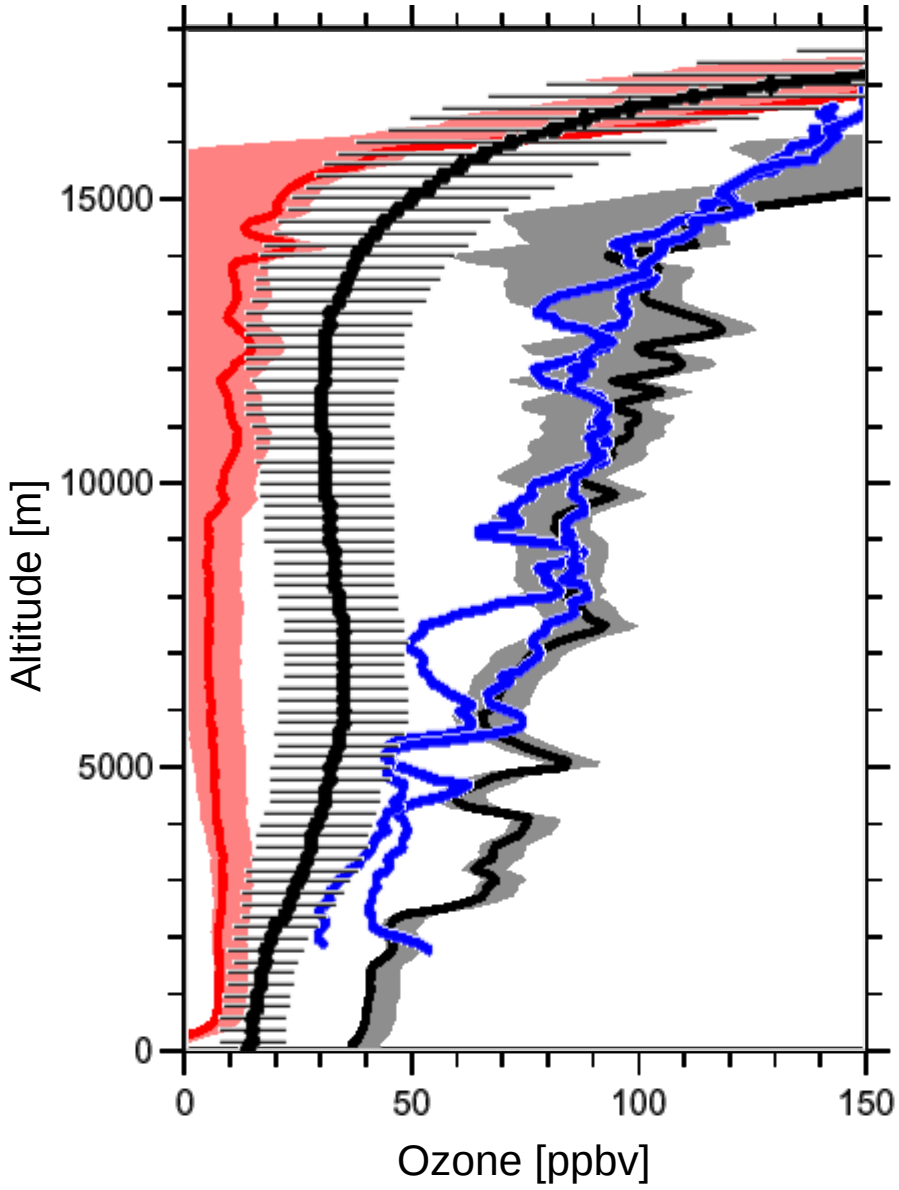


Extratropical West Pacific ~30°

Tropical Atlantic

Tropical West Pacific

Ozone profile measurements in the West Pacific



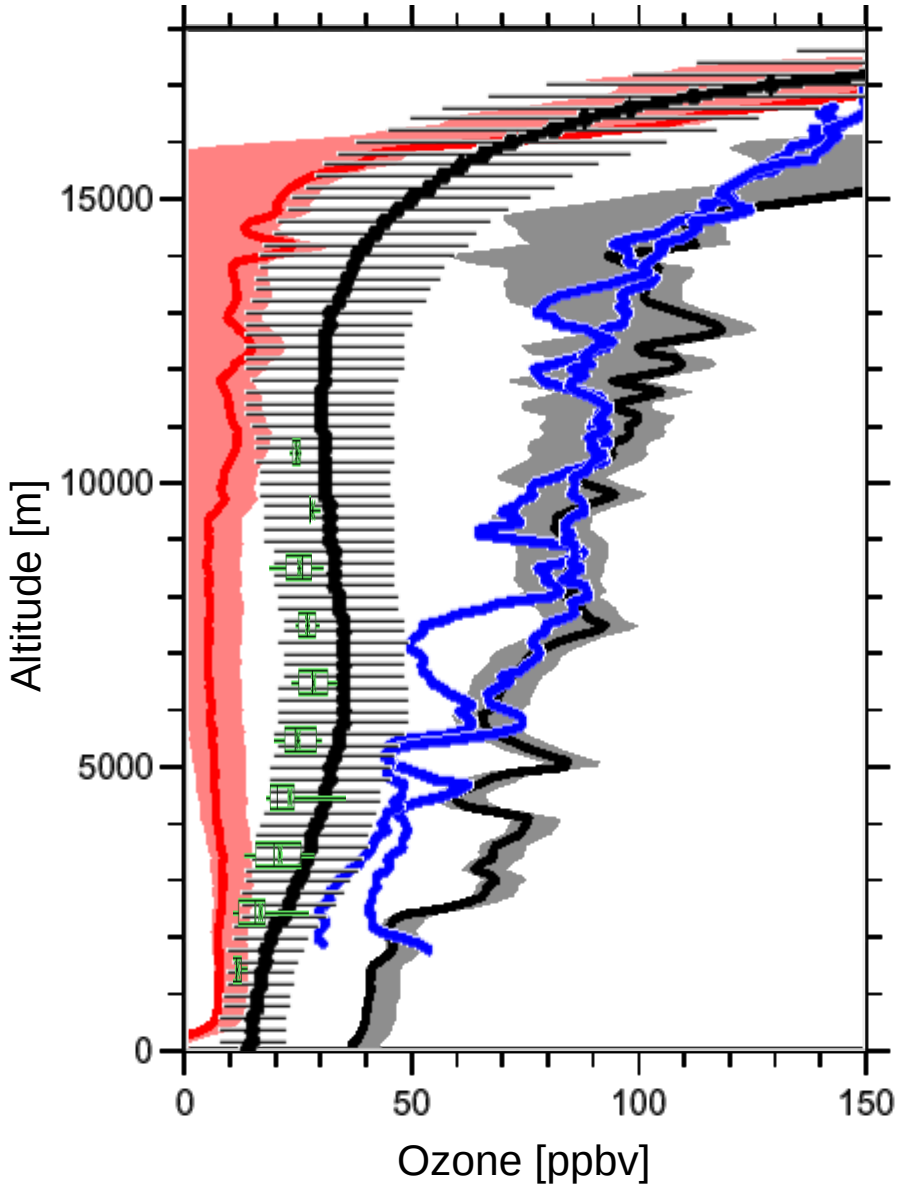
Extratropical West Pacific ~30°

Tropical Atlantic

Tropical West Pacific

Samoa, CEPEX similar (if realistic background current correction is applied)

Ozone profile measurements in the West Pacific



Extratropical West Pacific ~30°

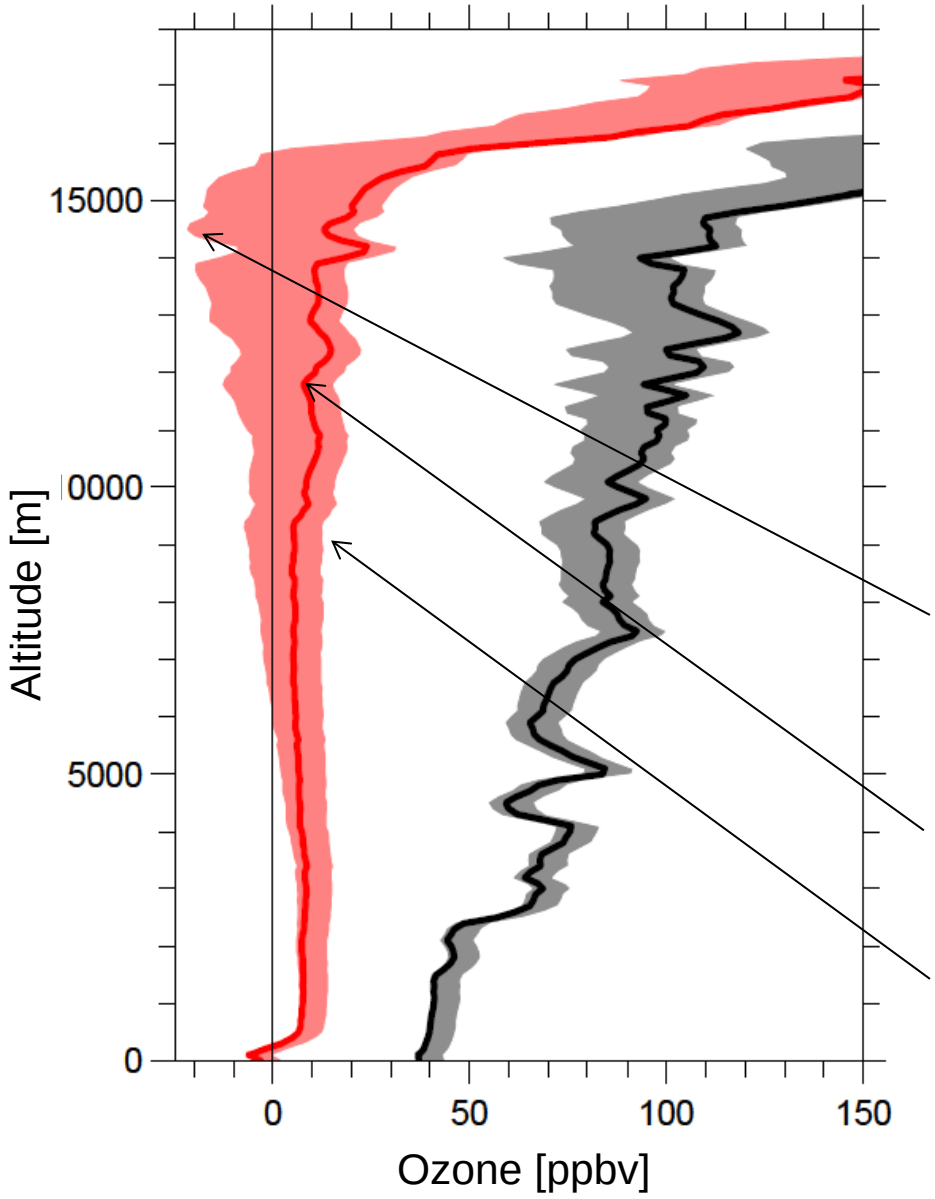
Tropical Atlantic

Tropical West Pacific

Samoa, CEPEX similar (if realistic background current correction is applied)

PEM-West (DC-8) West tropical Pacific

Ozonesonde uncertainties at low concentrations



Extratropical
West Pacific ~30°

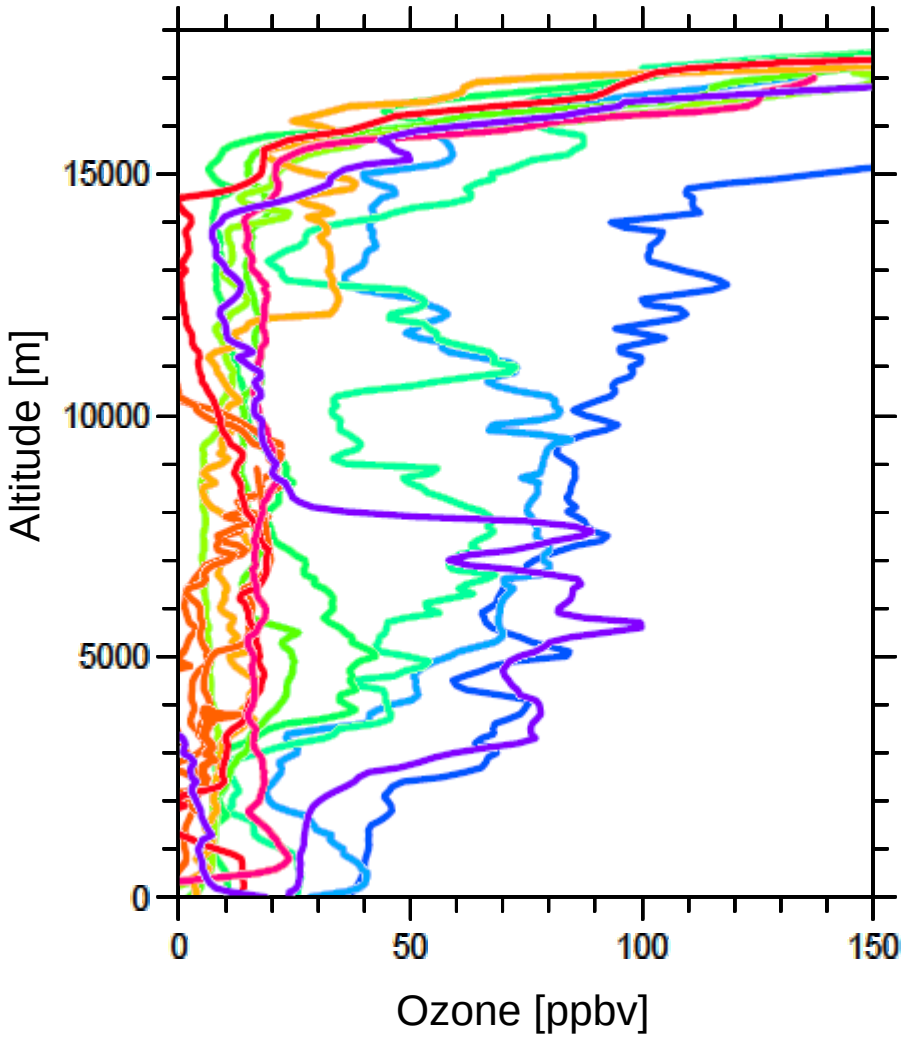
Tropical
West Pacific

Standard approach:
Constant background current correction

Pressure dependent background current correction

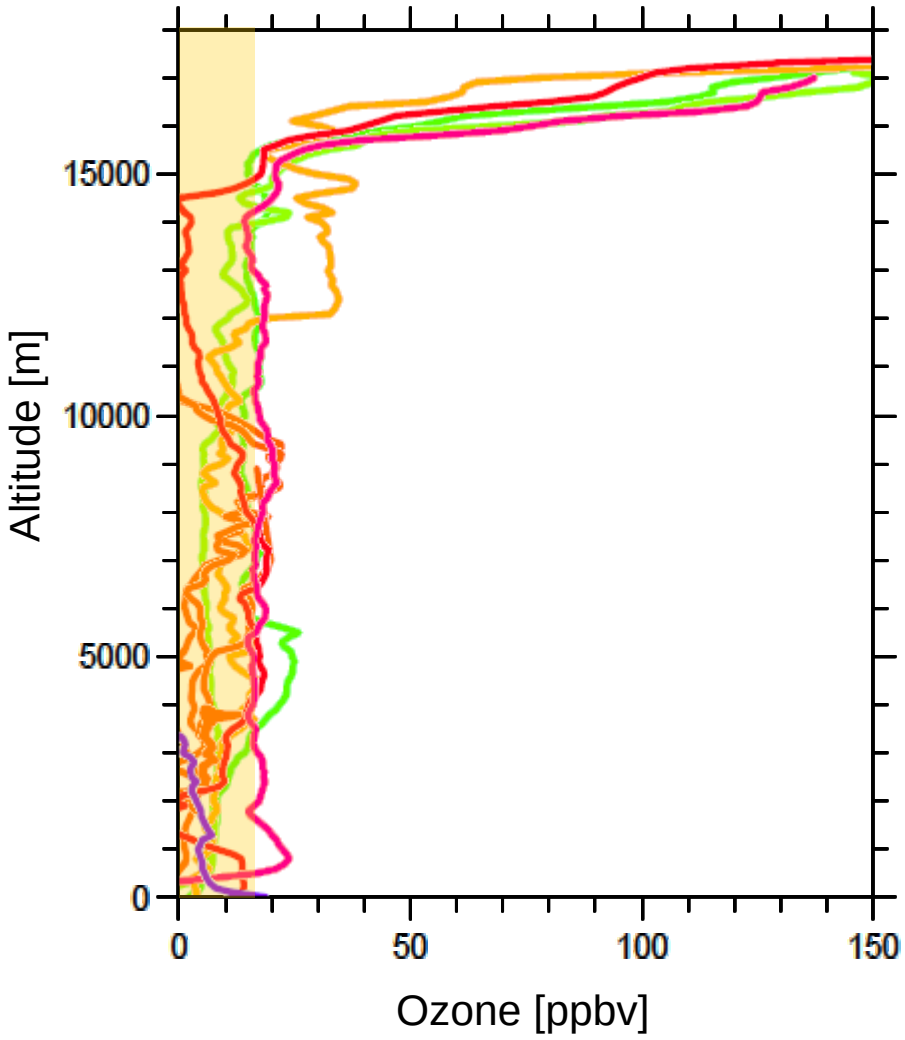
Robust upper limit:
No background current correction

Ozone profile measurements in the West Pacific



091011: 33.5°N
091012: 26.2°N
091013: 23.1°N
091014: 18.8°N
091015: 14.9°N
091016: 10.5°N
091017: 6.2°N
091018: 1.1°N
091019: 3.1°S
091020: 7.2°S
091021: 11.8°S
091022: 14.4°S

Ozone profile measurements in the West Pacific



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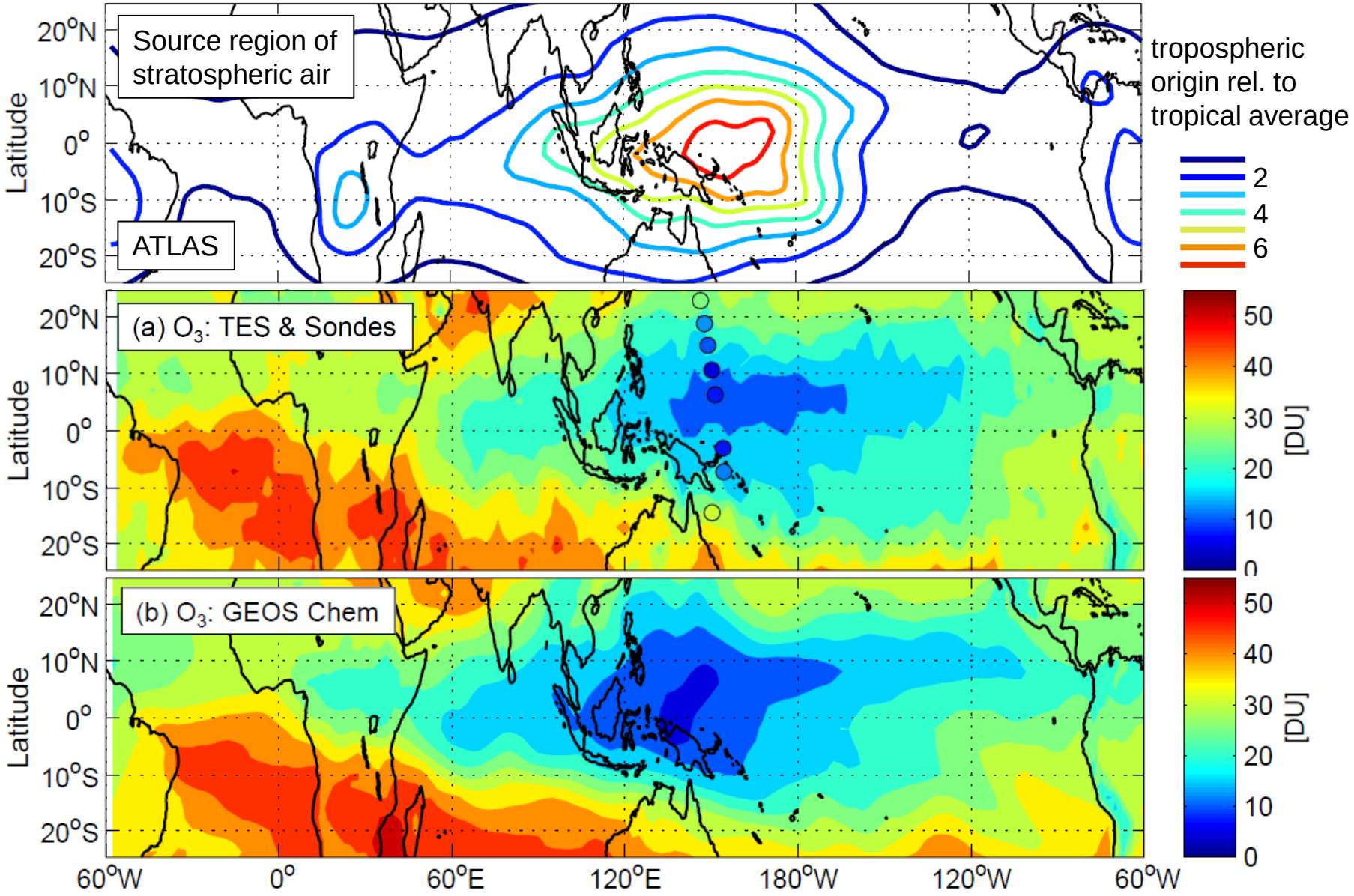
091021: 11.8°S

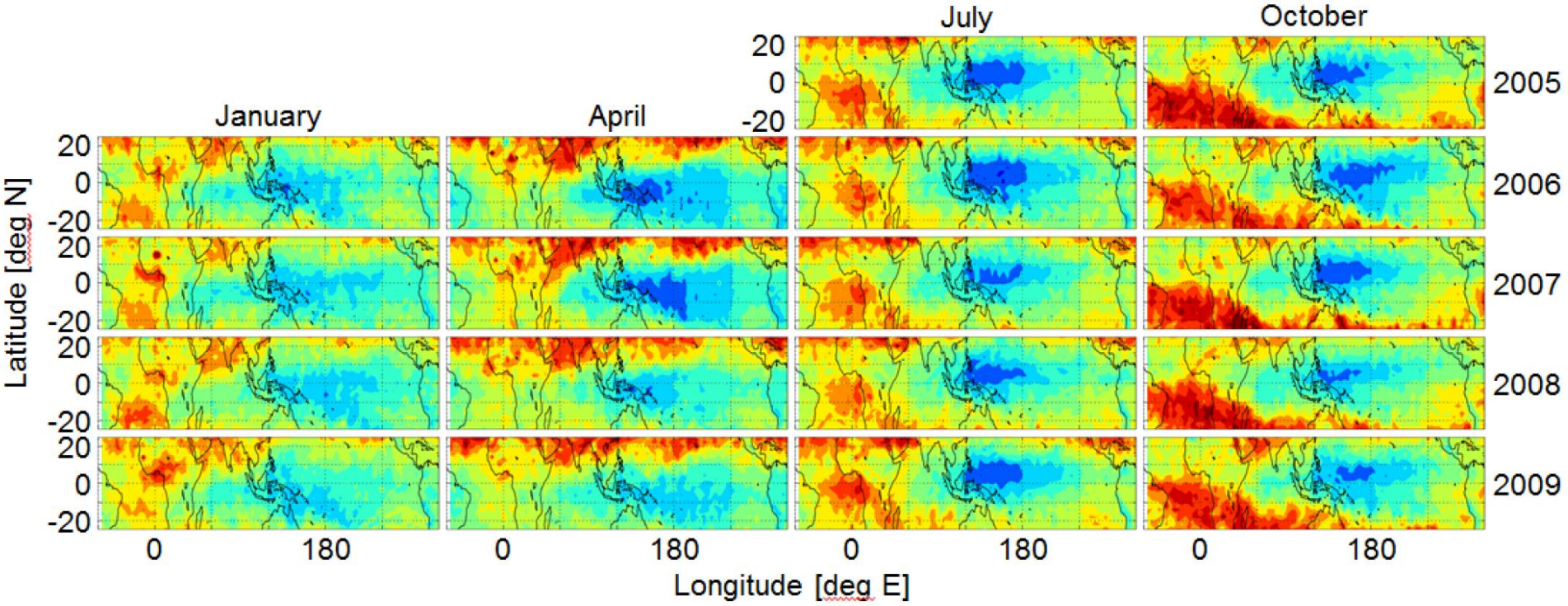
Troposph. ozone below 15~20 ppbv

091022: 14.4°S

Tropospheric columns (October 2009)

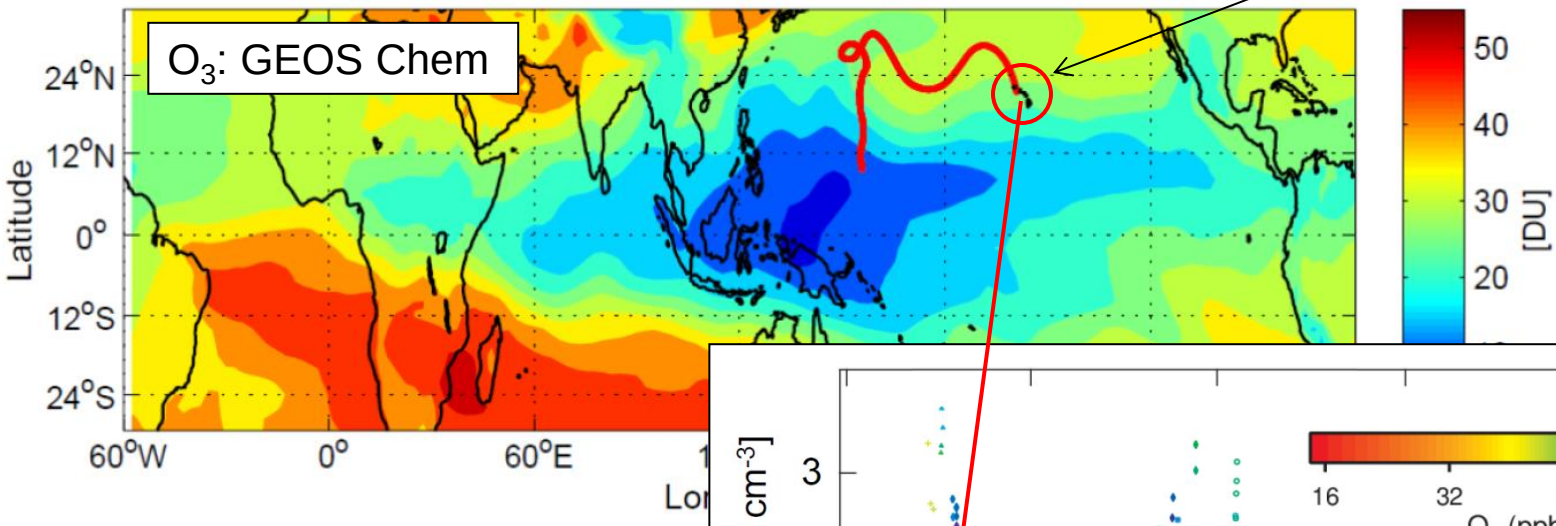


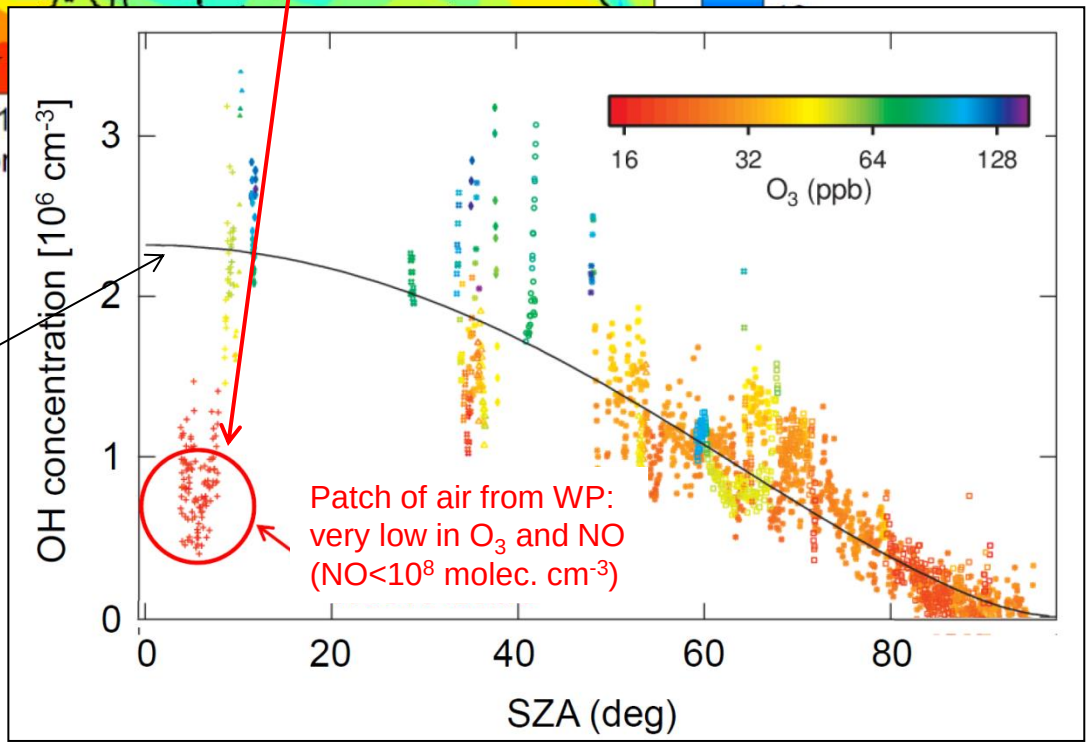
Multi-annual TES data set



- Minimum is persistent
- Exists year round (strongest in NH summer & fall)
- Is affected by ENSO (follows the warm pool)

OH measurements by the ER-2 during STRAT

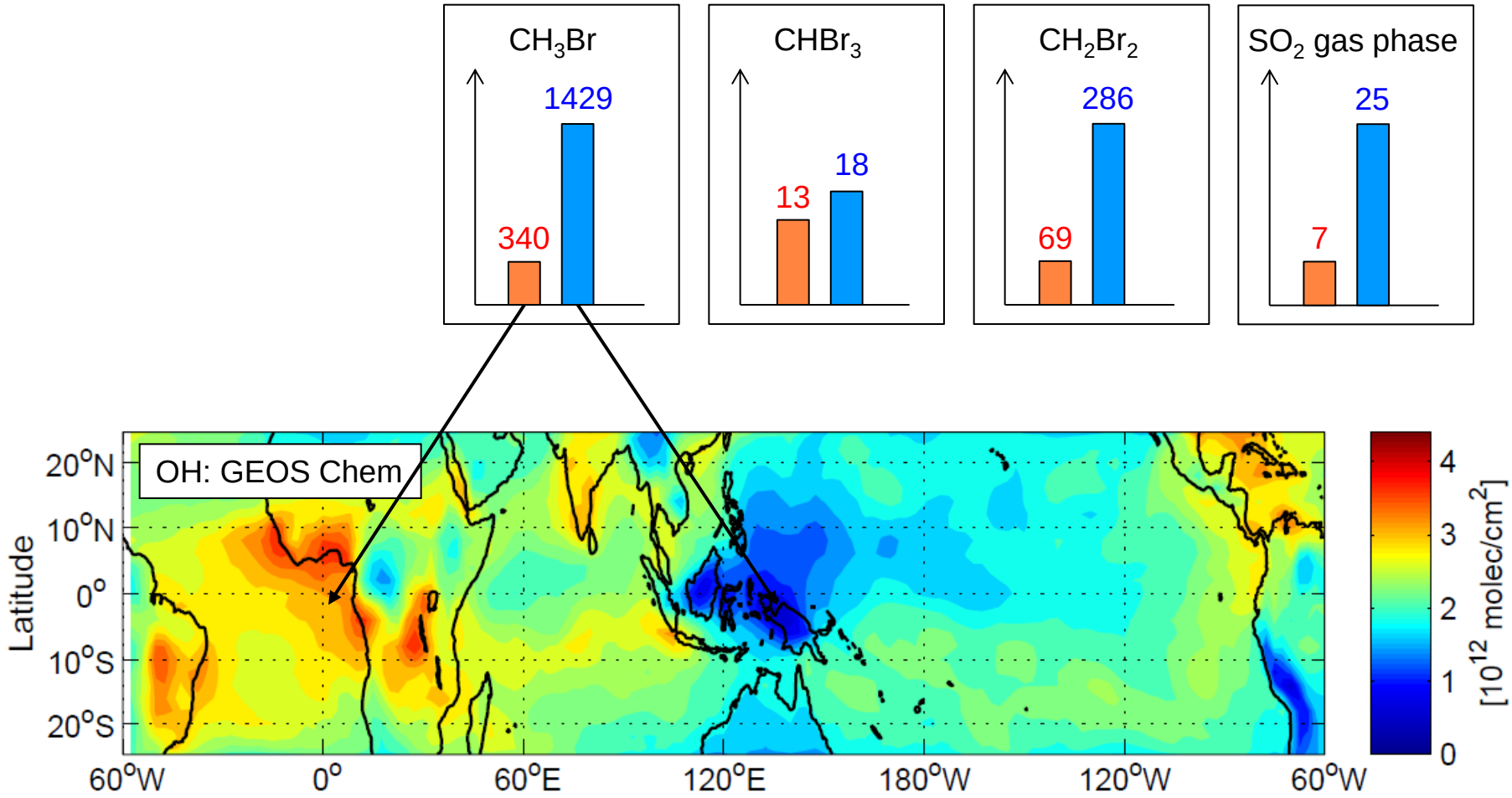




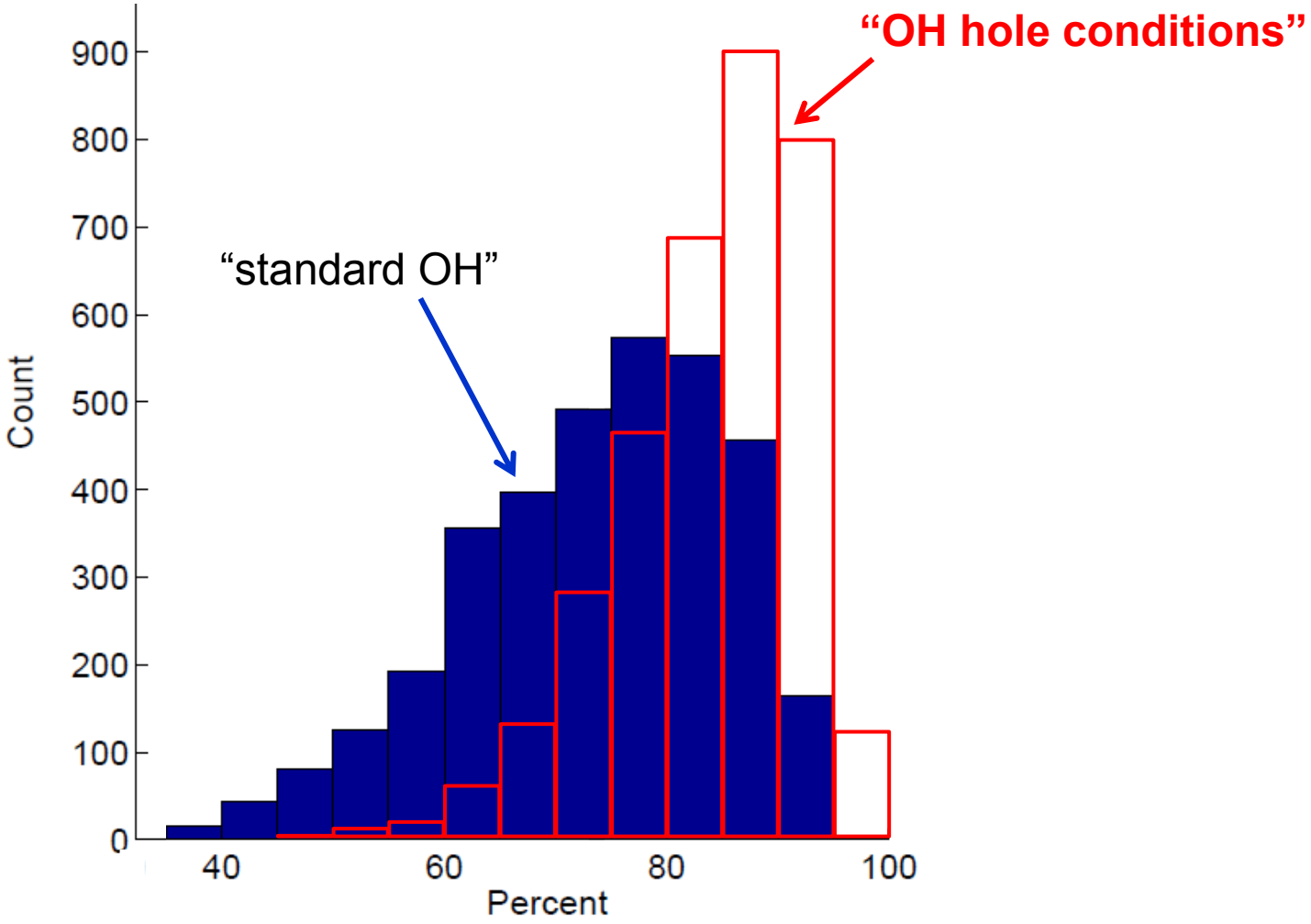
Black line is the “canonical” relation between OH and sza in “clean” tropopause level air (Hanisco et al., 2001)

Lifetimes of key species for stratospheric composition

In days: “standard OH” “OH hole”



Fraction of CH_2Br_2 reaching the LCP



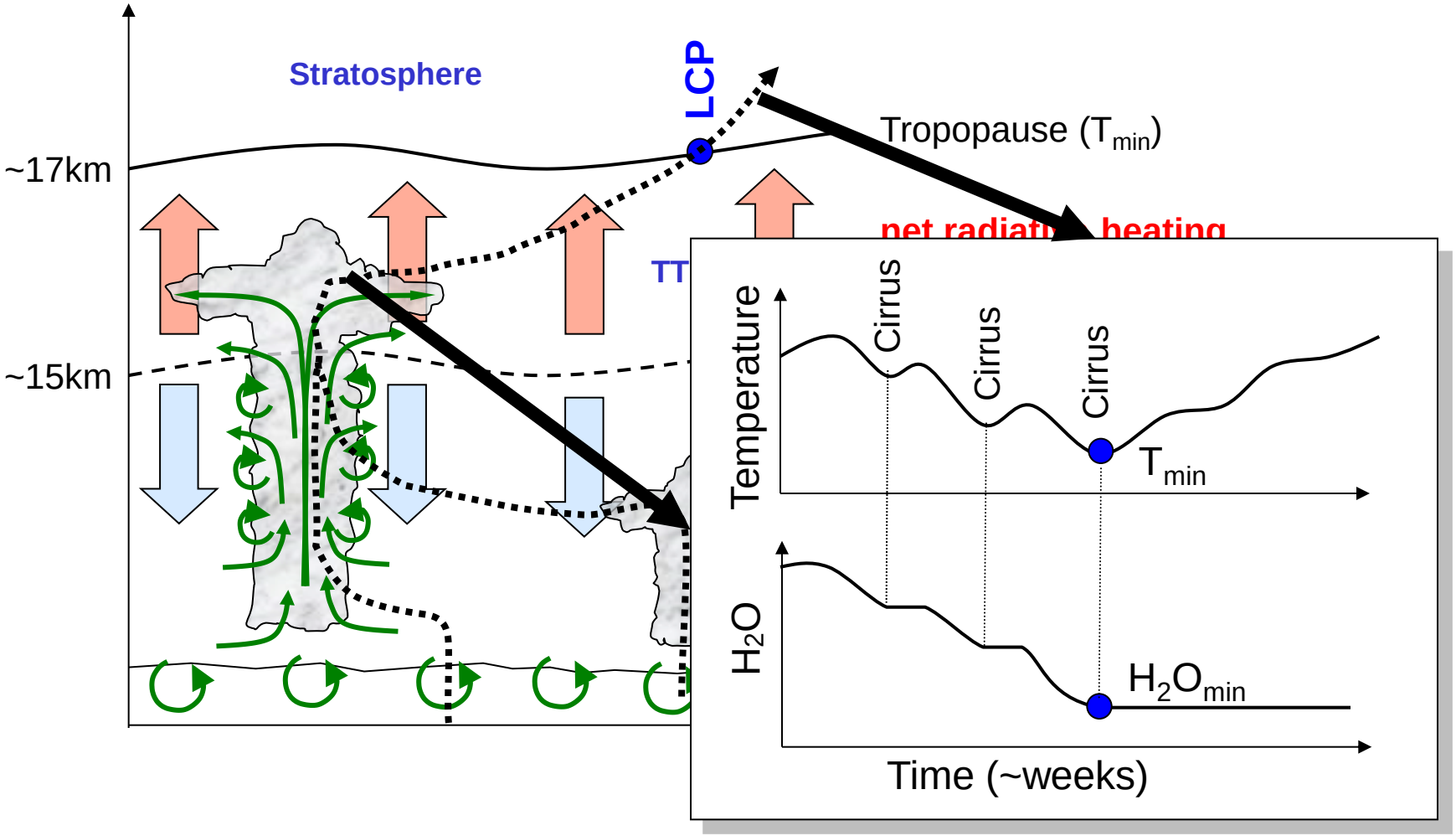
Conclusions

- Ozone below the detection limit of ECC ozonesondes suggest a pronounced minimum of OH throughout the troposphere over the tropical West Pacific.
- Such an “hole” in tropospheric OH levels cause lifetimes of key tropospheric species to be substantially longer over the tropical West Pacific than in other parts of the tropics.
- This region of the globe may therefore provide a more efficient pathway for shorter lived biogenic species and for SO_2 to reach the stratosphere than currently thought.
- More detailed and longer term measurements of atmospheric composition are needed in this region.

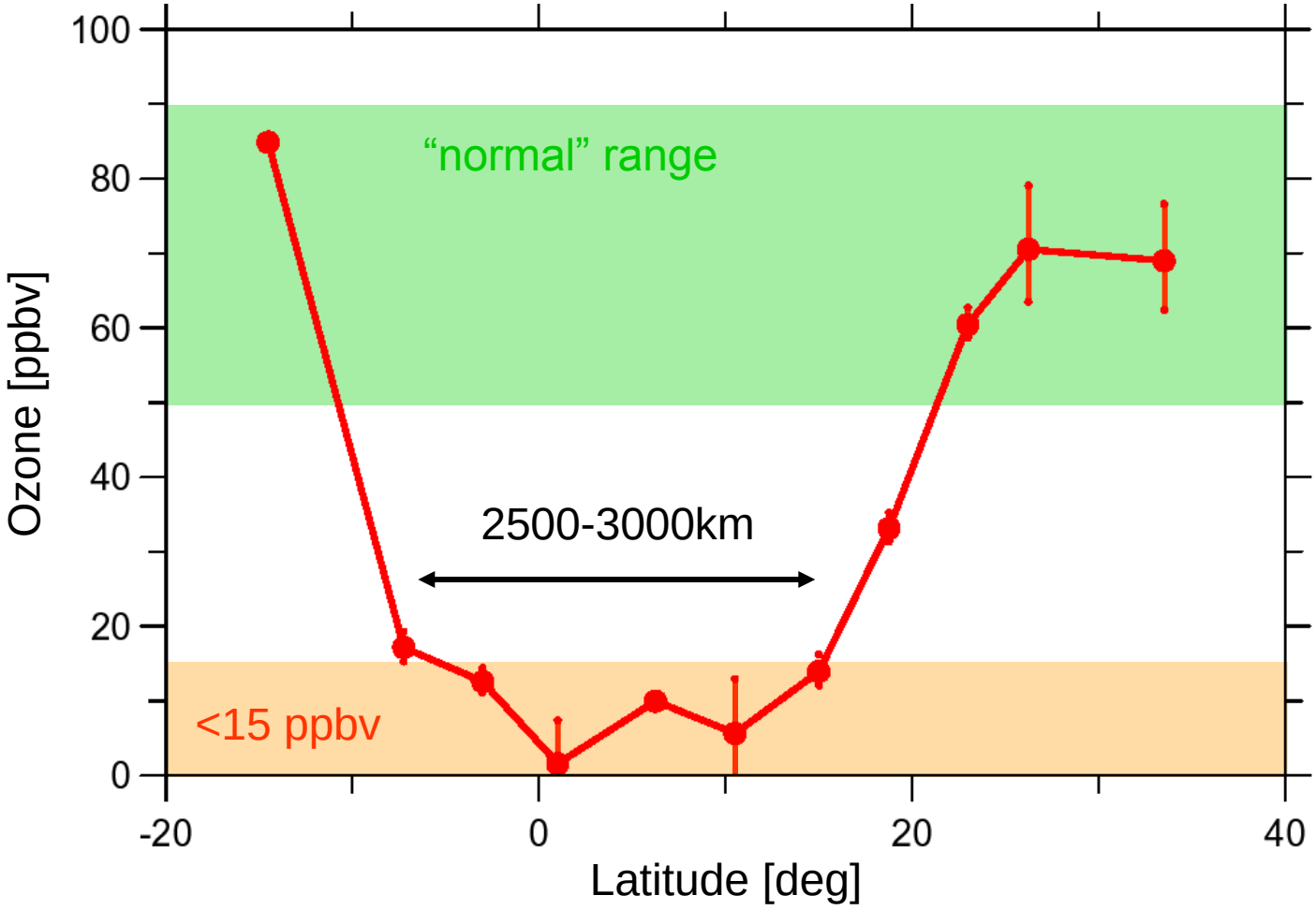
ATTREX
CONTRAST
CAST

StratoClim

Transport into the Stratosphere

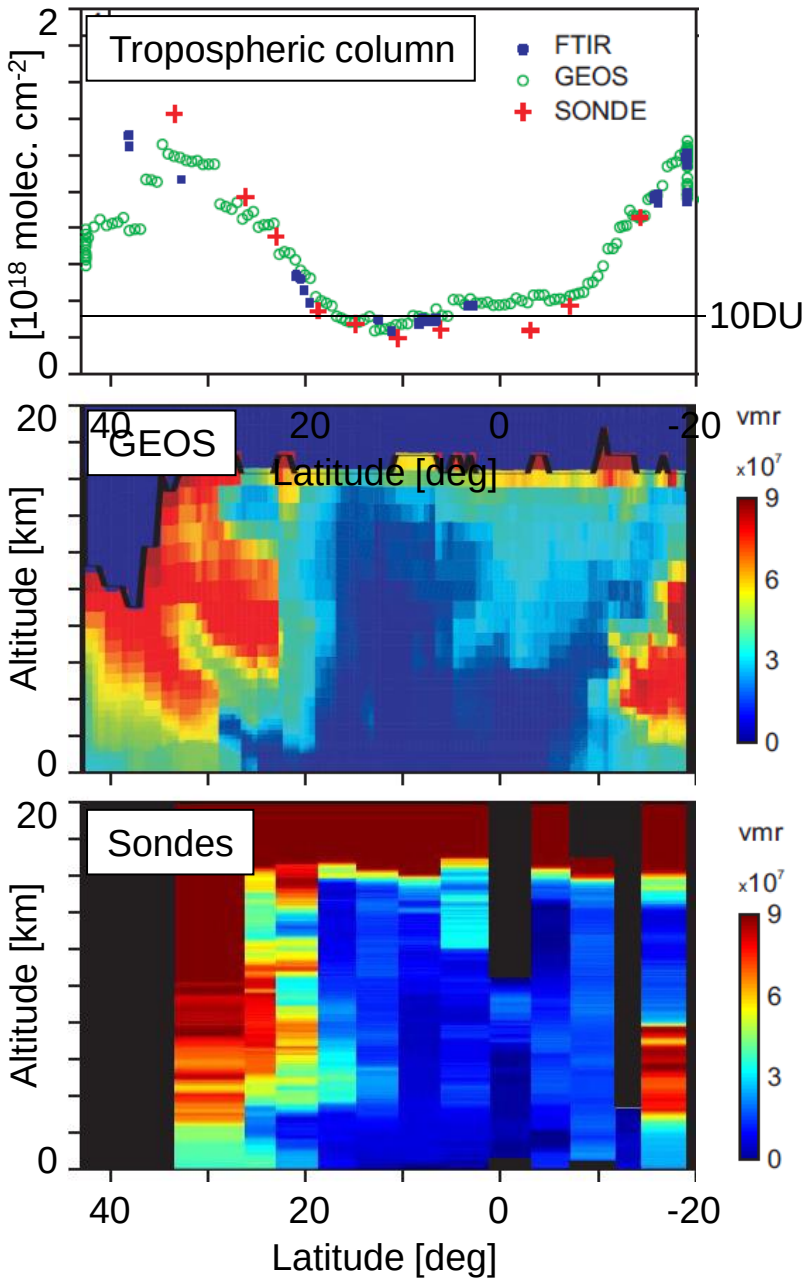


Latitudinal section of ozone VMR at ~6 km



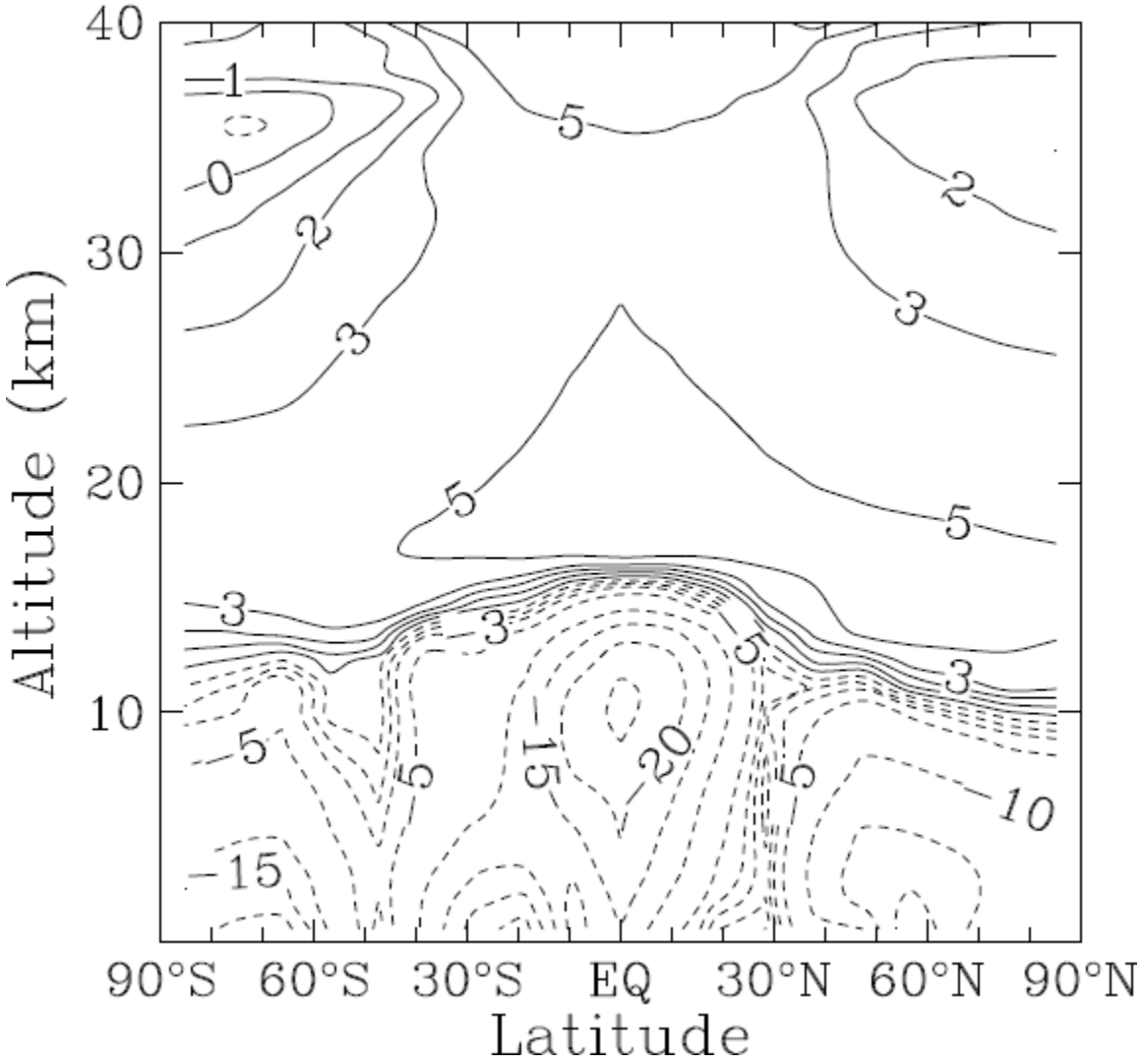
Ozone over the western Pacific warm pool

- Ozone sondes
- FTIR
- GEOS Chem CTM

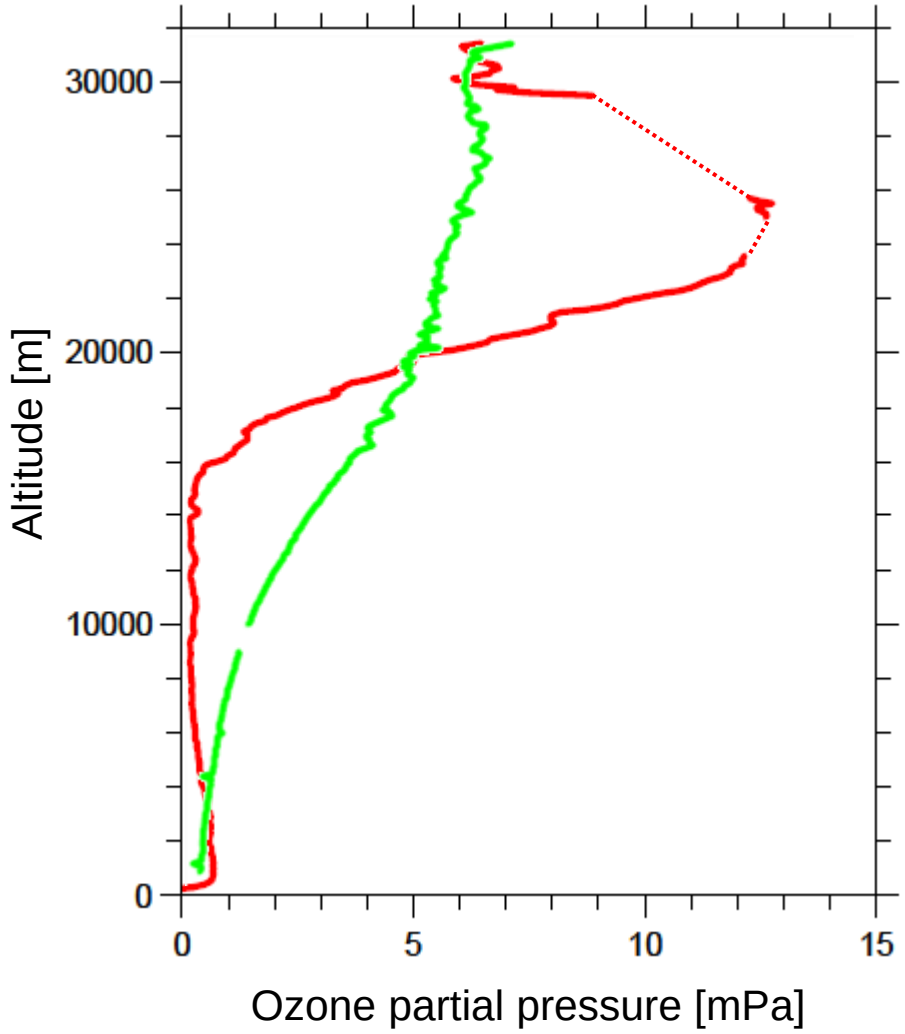


Aerosol surface area density

"strandard OH" versus "OH hole" conditions in %



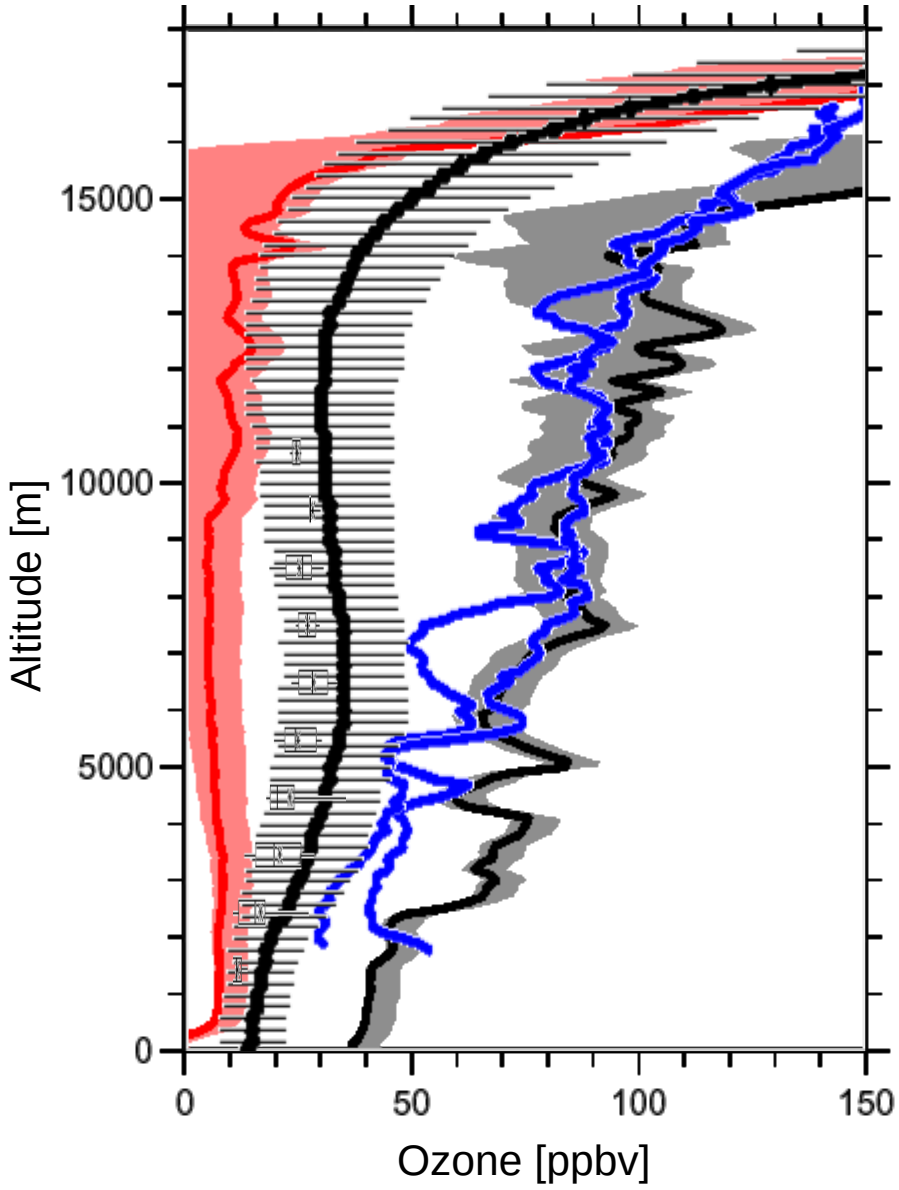
Ozone profile measurements in the West Pacific



Ascent

Descent

Ozone profile measurements in the West Pacific



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Global ozonesonde station network and SSTs

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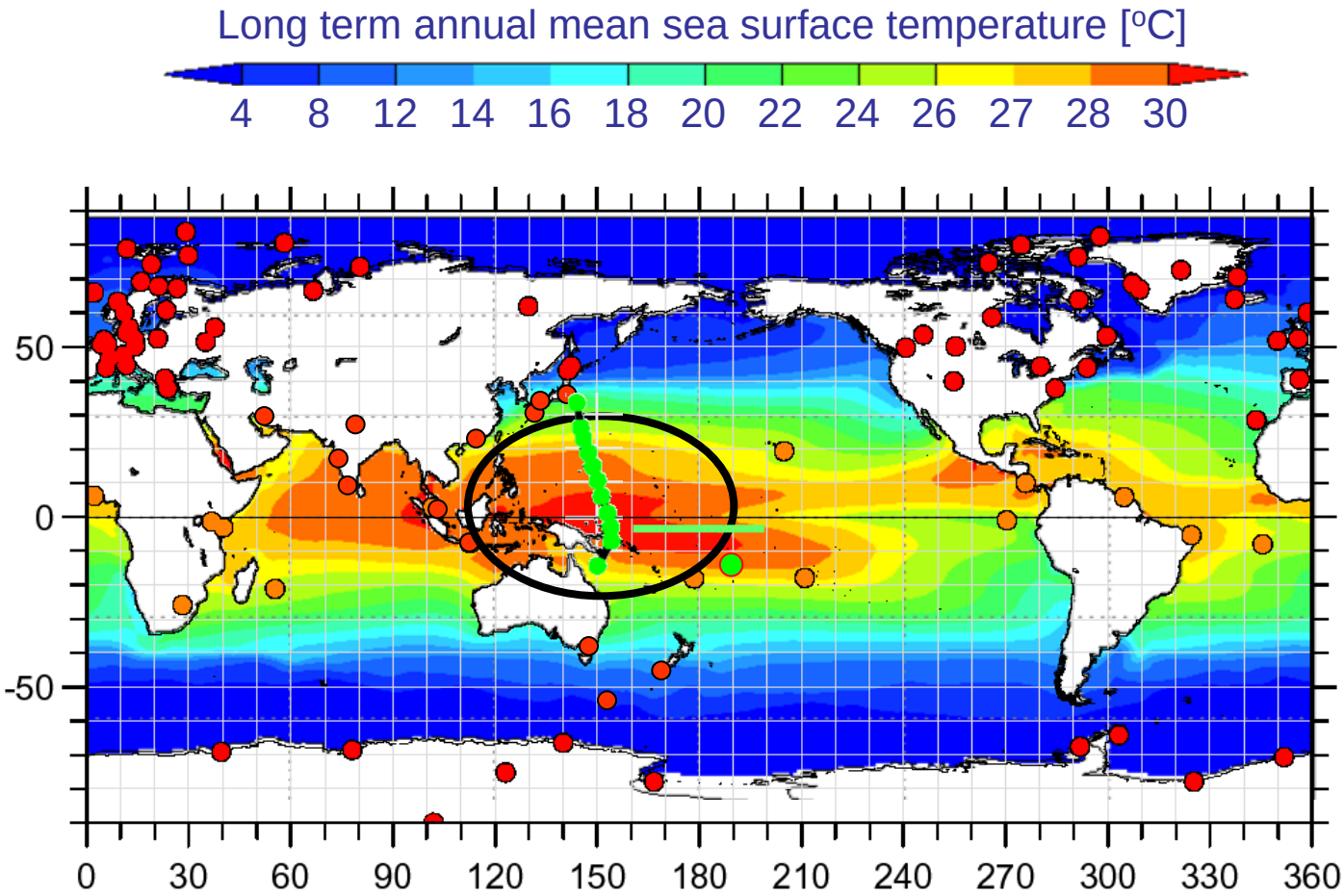
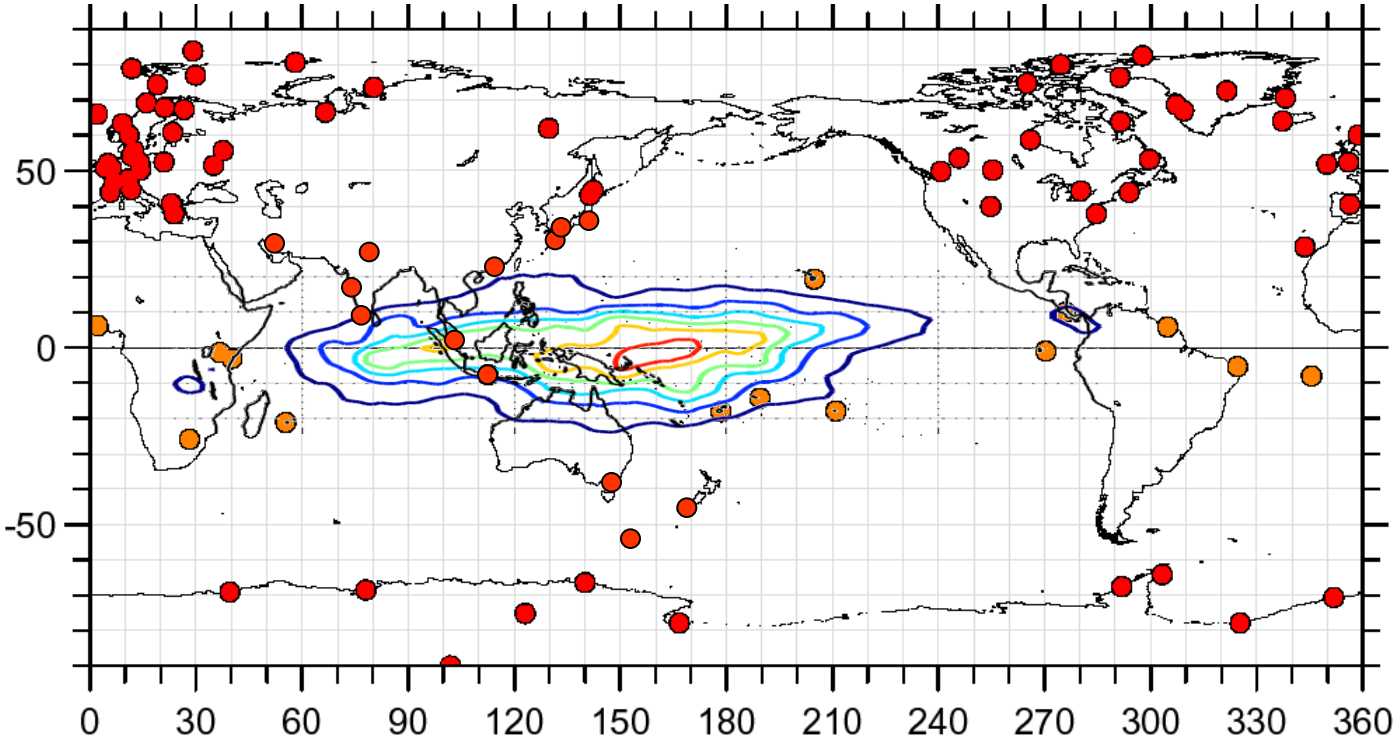


Central Equatorial Pacific Experiment (CEPEX), *March* 1993

Samoa ozone sonde data

- **Global ozonesonde station network**



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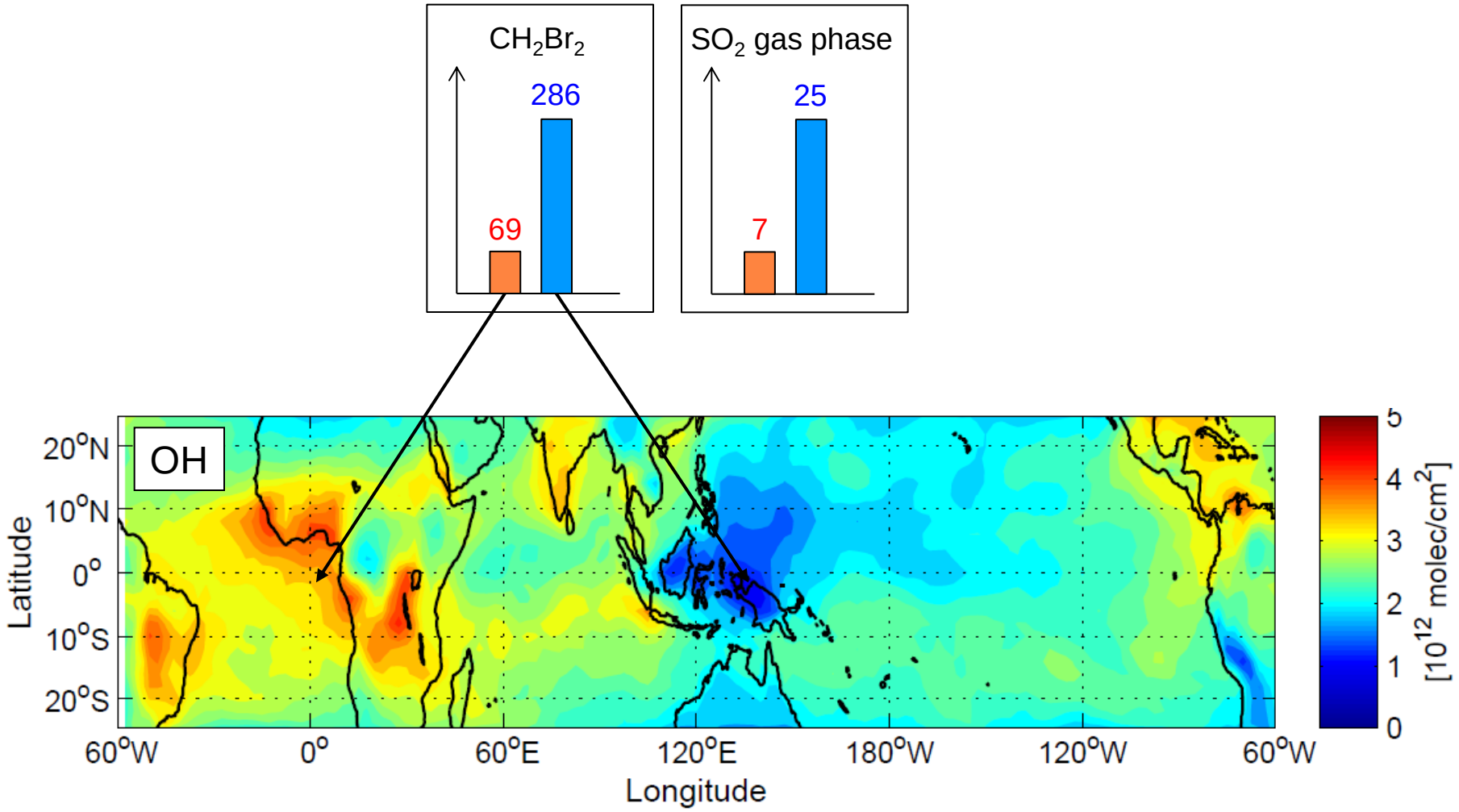
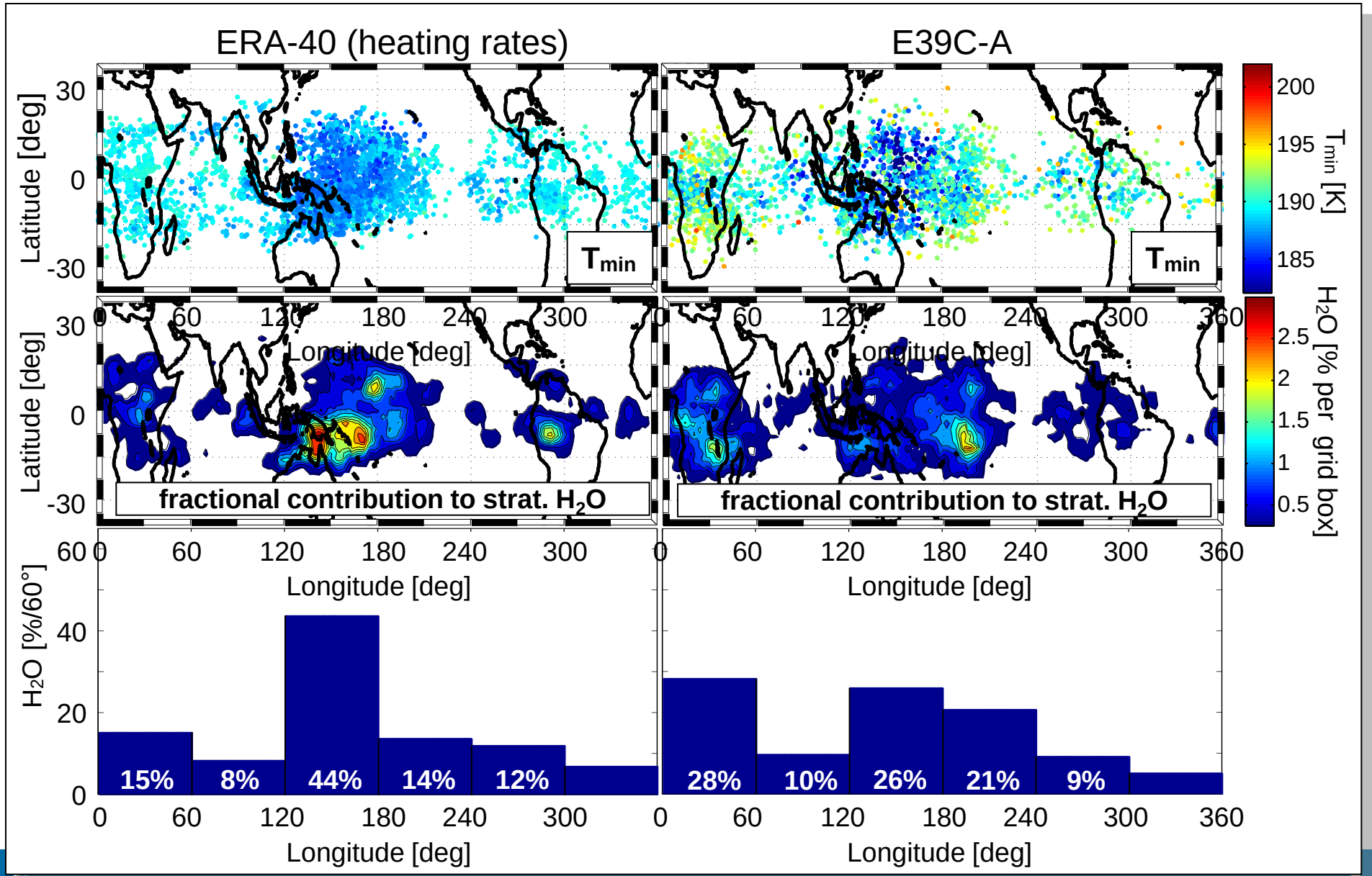


NH winter 1995-1996



Ozone over the western Pacific warm pool

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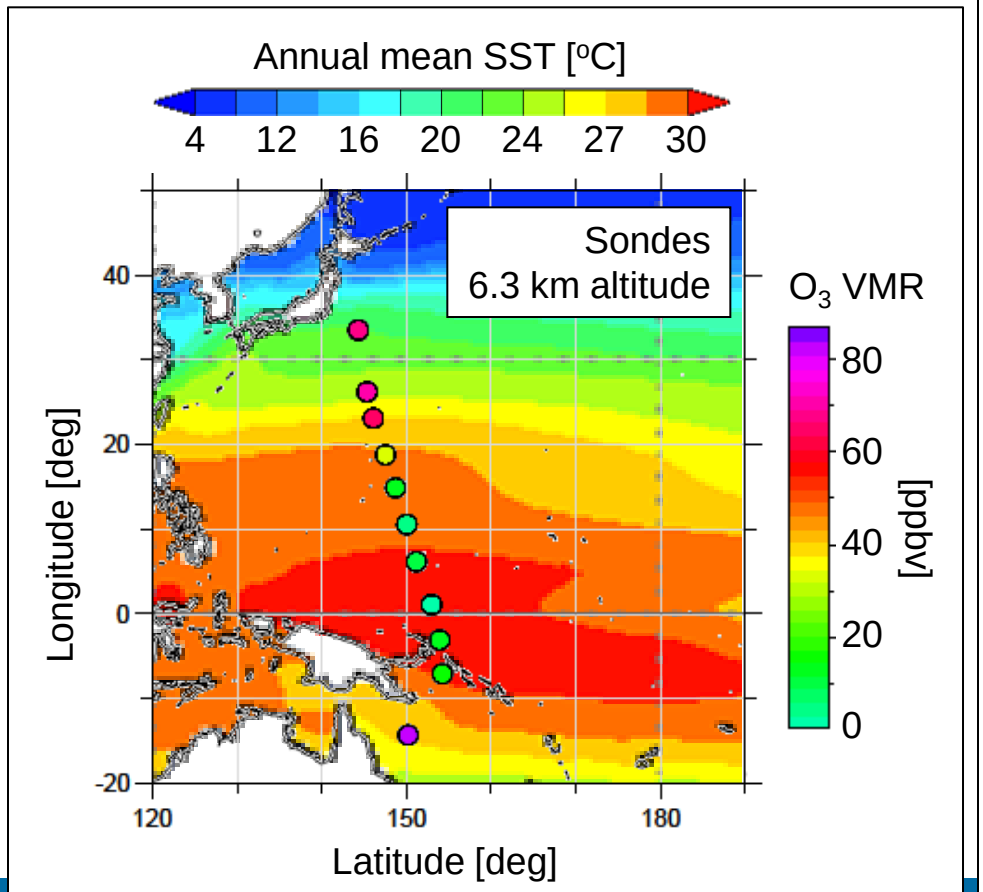
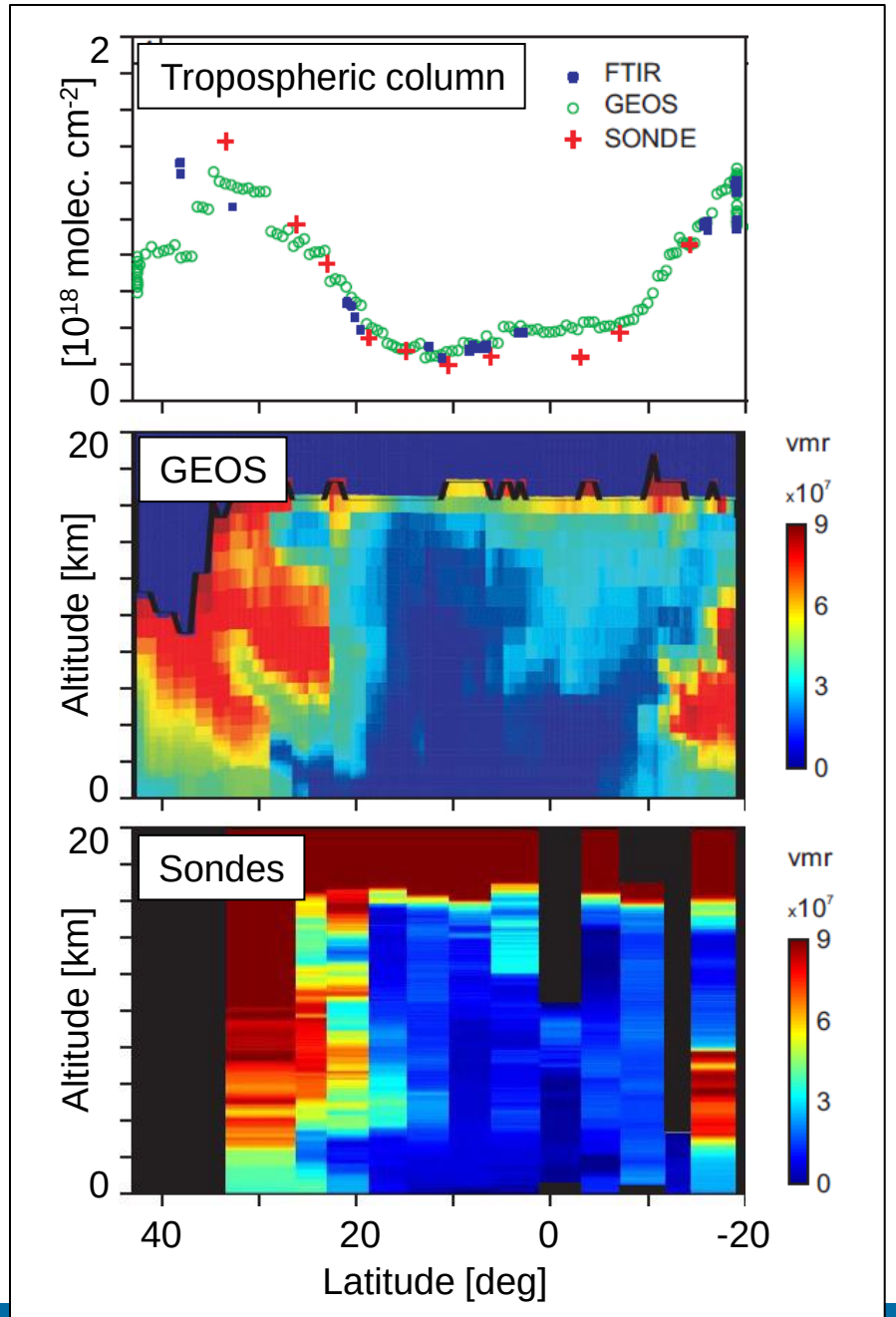
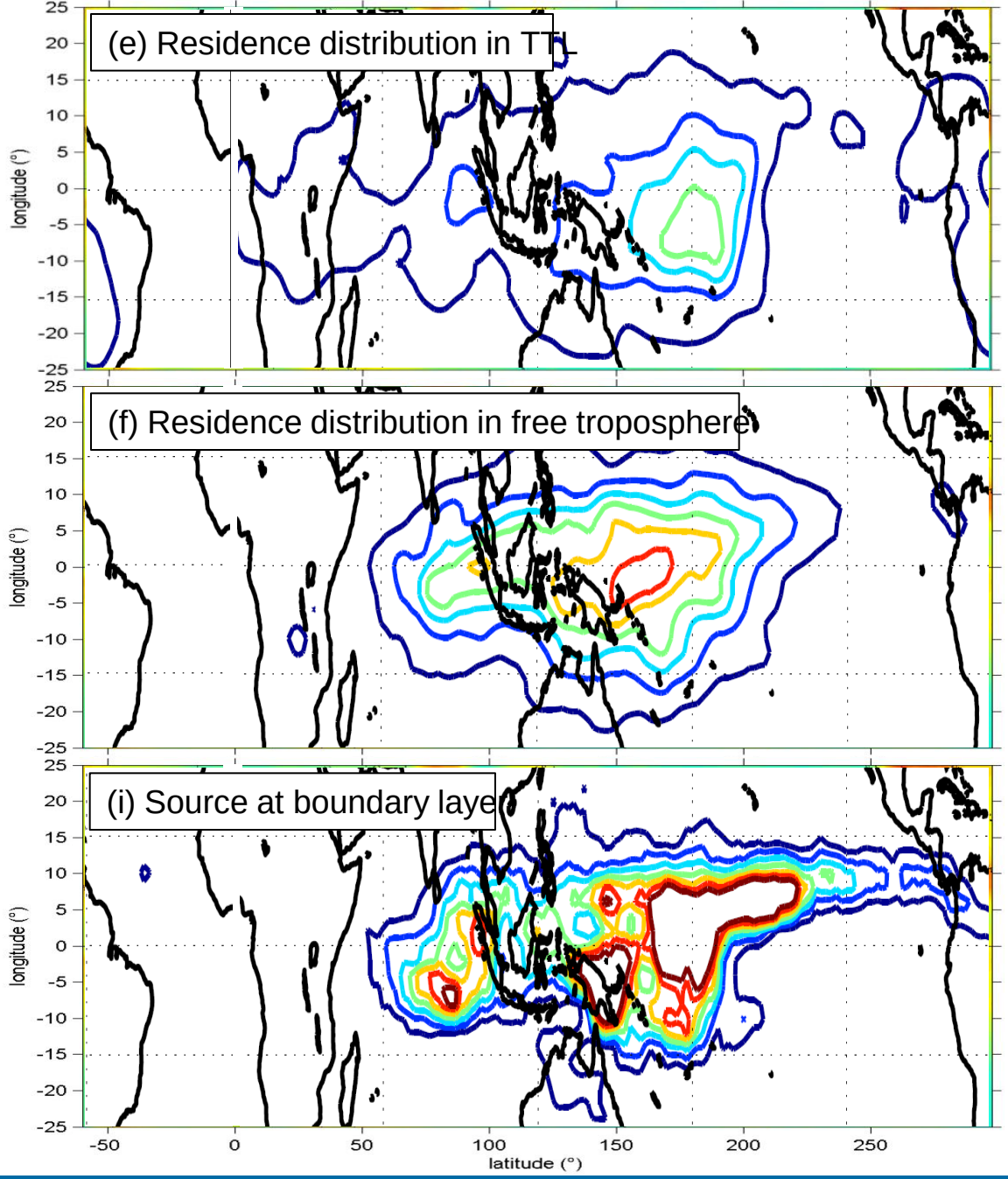
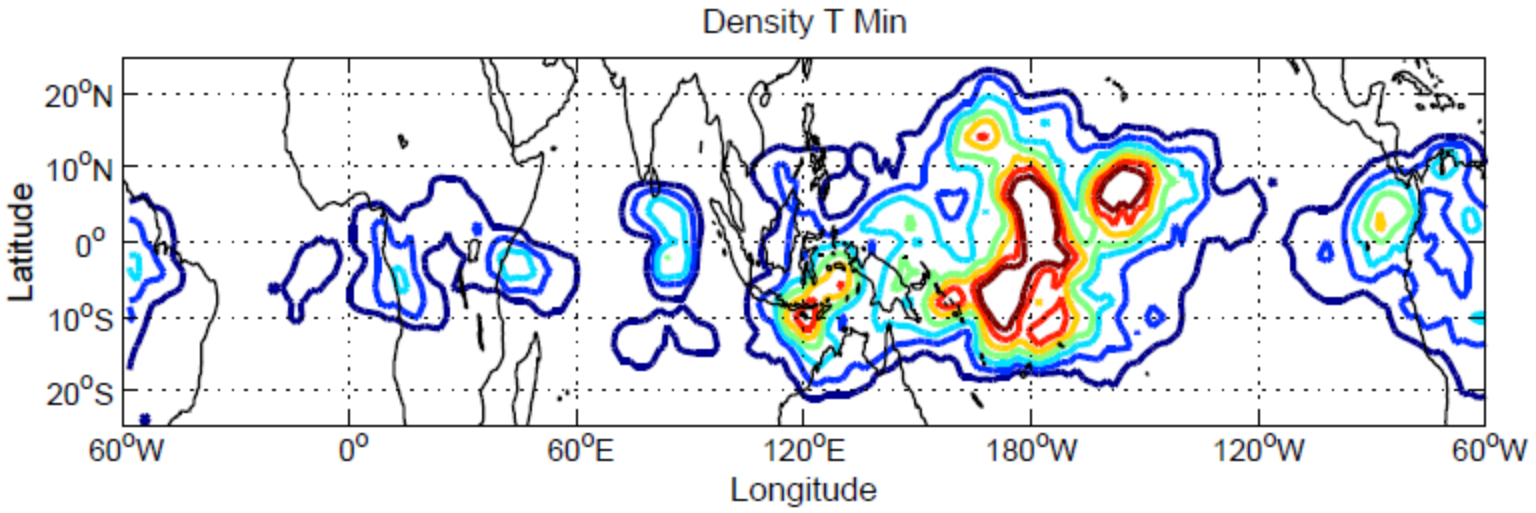
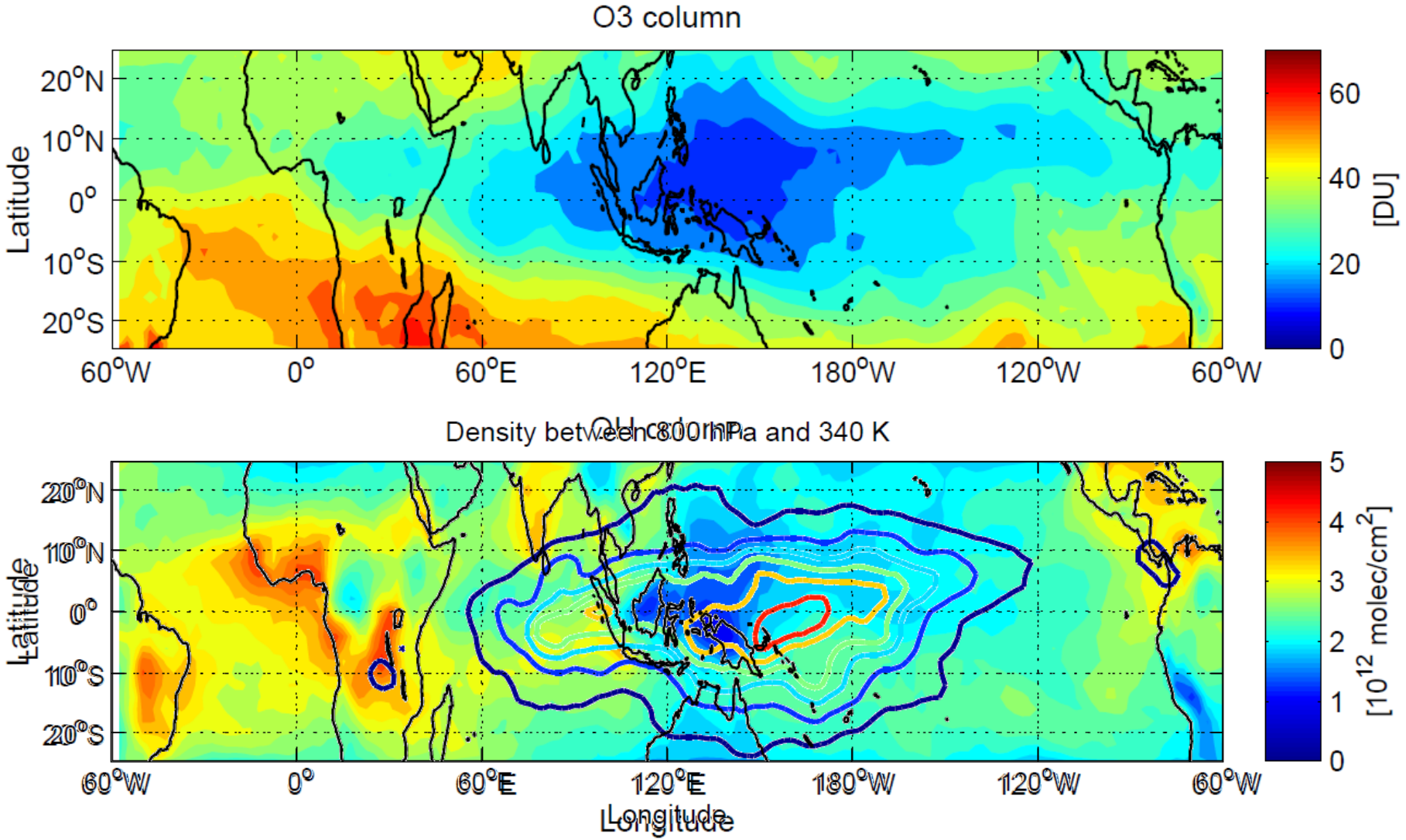
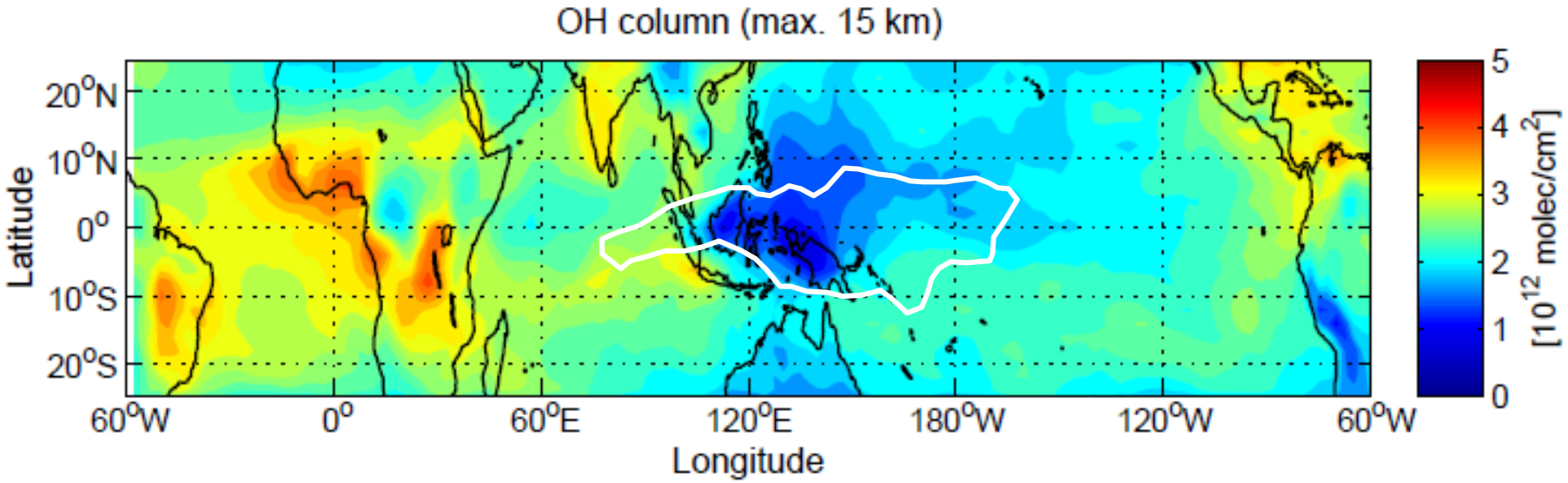


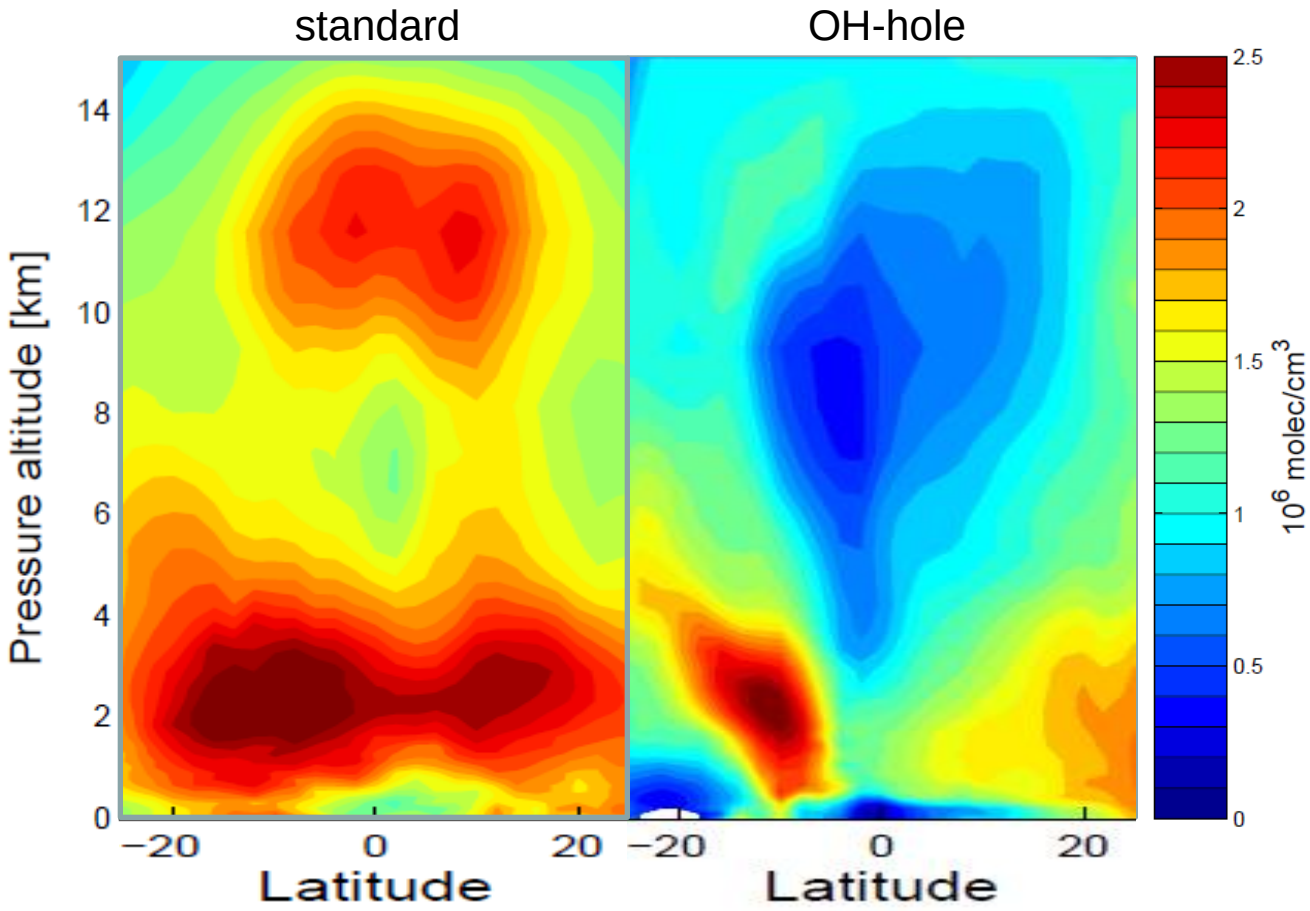


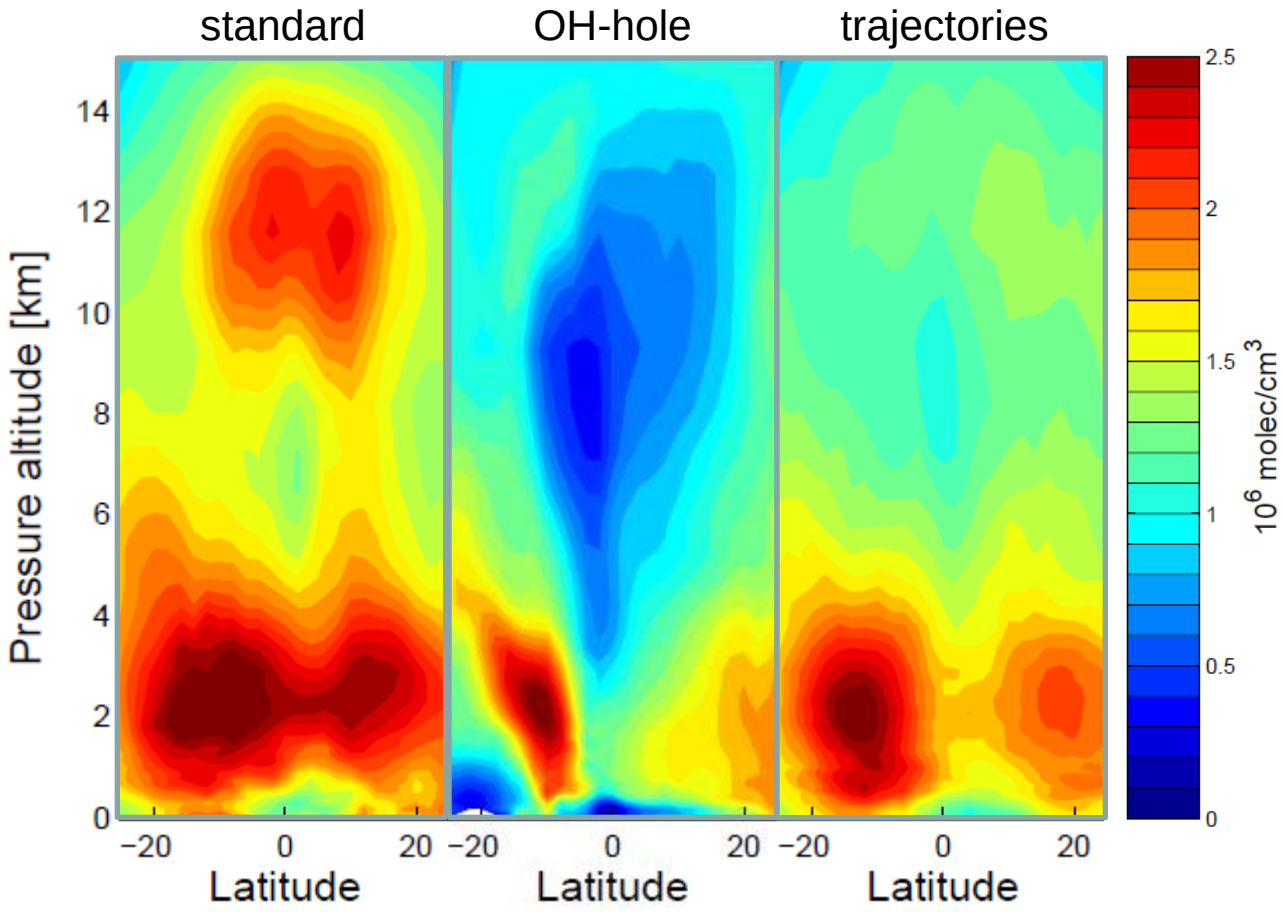

(e) Residence distribution in TTL
(f) Residence distribution in free troposphere
(i) Source at boundary layer
longitude (°)
latitude (°)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-50
0
50
100
150
200
250


Density T Min
20°N
10°N
0°
10°S
20°S
Latitude
60°W
0°
60°E
120°E
180°W
120°W
60°W
Longitude

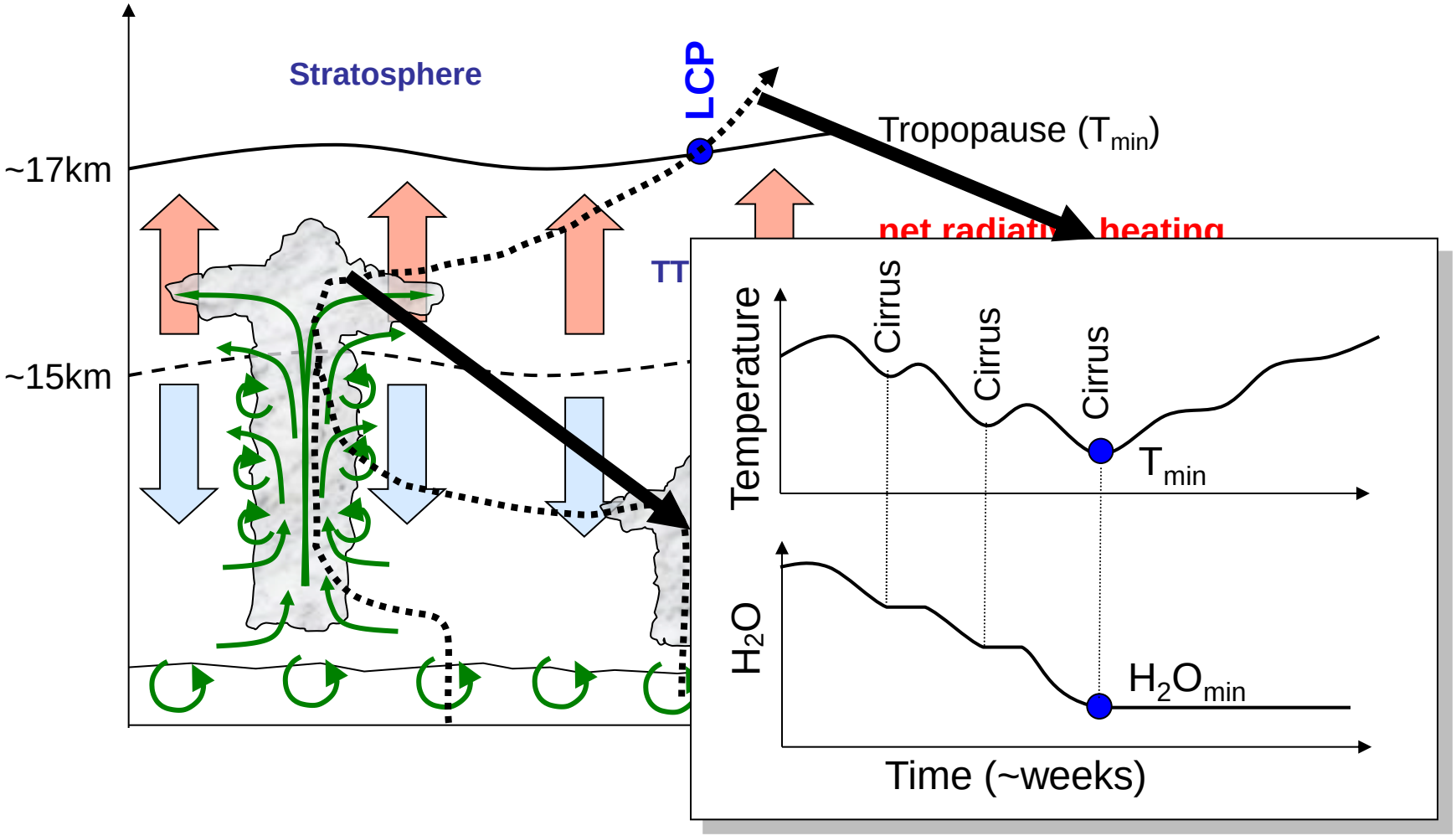

O3 column
20°N
10°N
0°
10°S
20°S
Latitude
60°W
0°
60°E
120°E
180°W
120°W
60°W
60
40
20
0
[DU]
Density between 800 hPa and 340 K
20°N
10°N
0°
10°S
20°S
Latitude
60°W
0°
60°E
120°E
180°W
120°W
60°W
Longitude
5
4
3
2
1
0
[10^12 molec/cm^2]


OH column (max. 15 km)
20°N
10°N
0°
10°S
20°S
Latitude
60°W
0°
60°E
120°E
180°W
120°W
60°W
Longitude
5
4
3
2
1
0
[10^12 molec/cm^2]


standard
OH-hole
Pressure altitude [km]
0
2
4
6
8
10
12
14
−20
0
20
Latitude
2.5
2
1.5
1
0.5
0
10^6 molec/cm^3

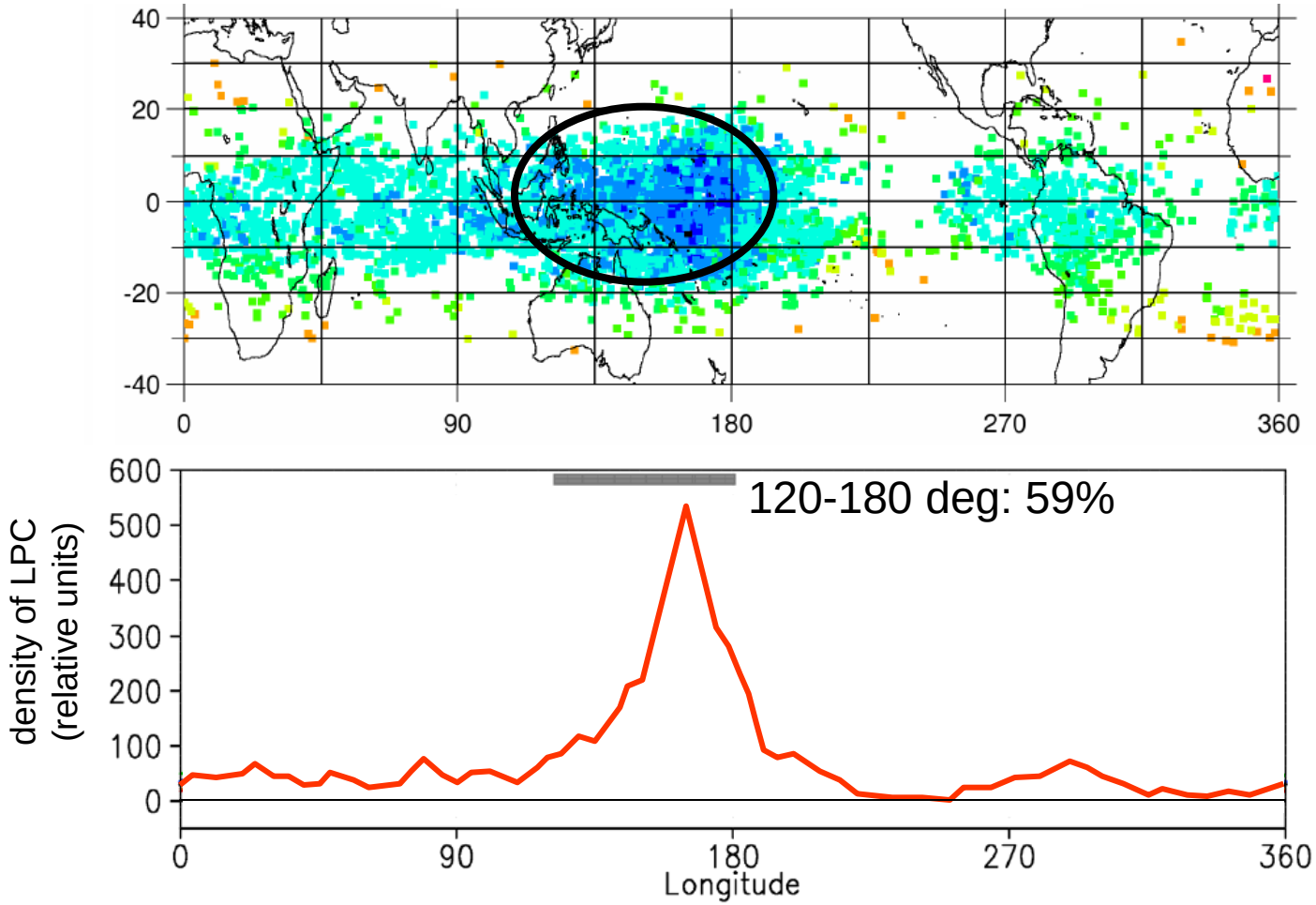

standard
OH-hole
trajectories
Pressure altitude [km]
0
2
4
6
8
10
12
14
−20
0
20
Latitude
2.5
2
1.5
1
0.5
0
10^6 molec/cm^3

Transport into the Stratosphere



Geographical distribution of LCPs

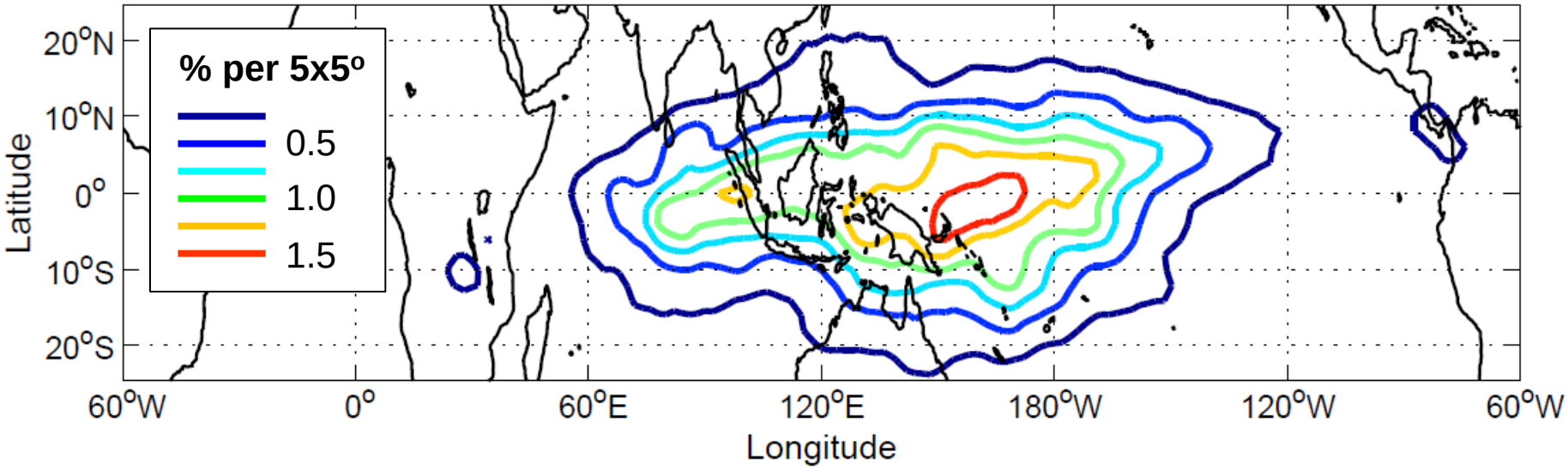
NH winter 2000/2001



Results from the fully Lagrangian ATLAS model, Wohltman&Rex, 2009; Wohltmann et al. 2010
Krüger et al., ACP, 2008

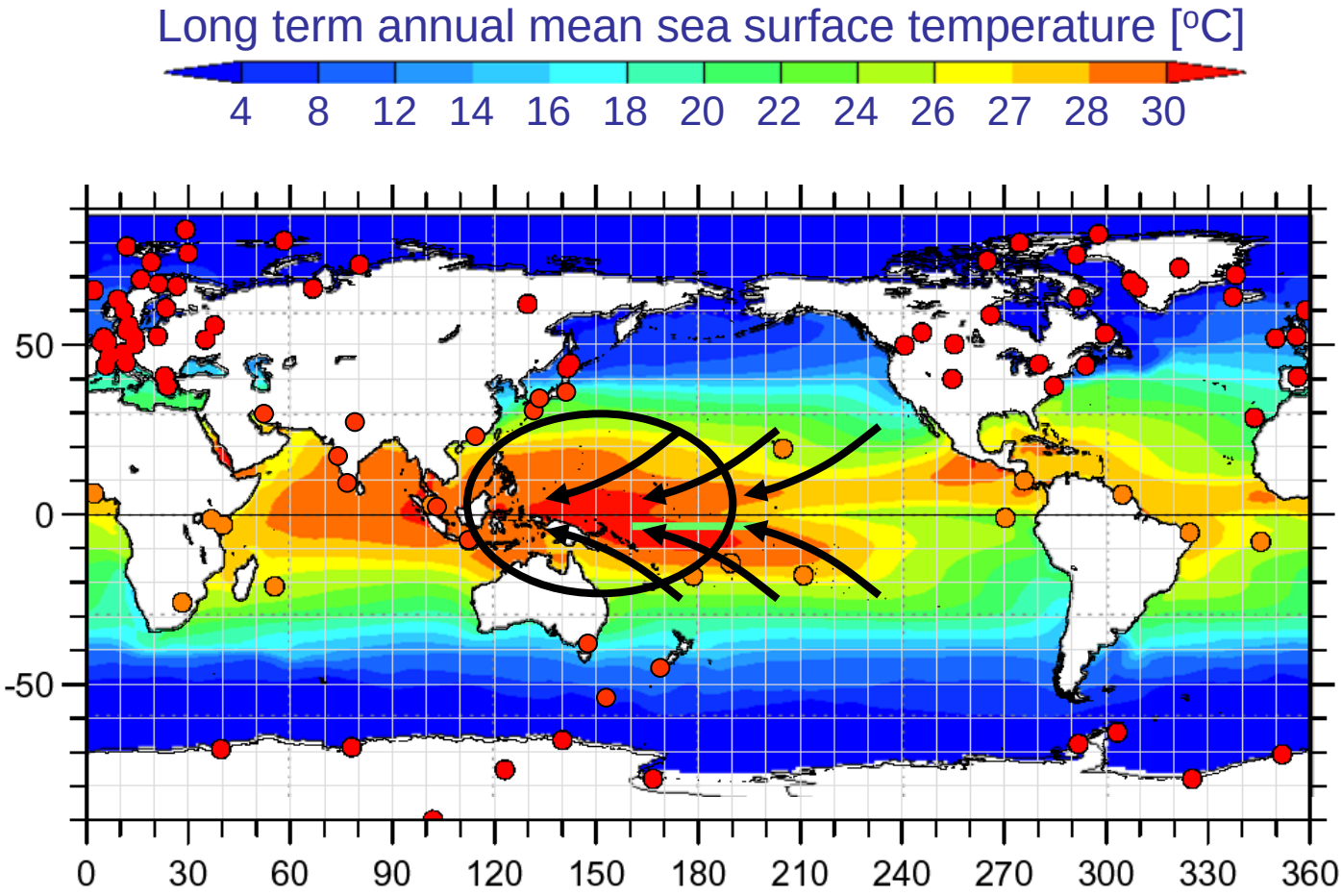
Geographic distribution of time spent in the troposphere for stratospheric air

During transport from the boundary layer to the LCP
Based on ATLAS

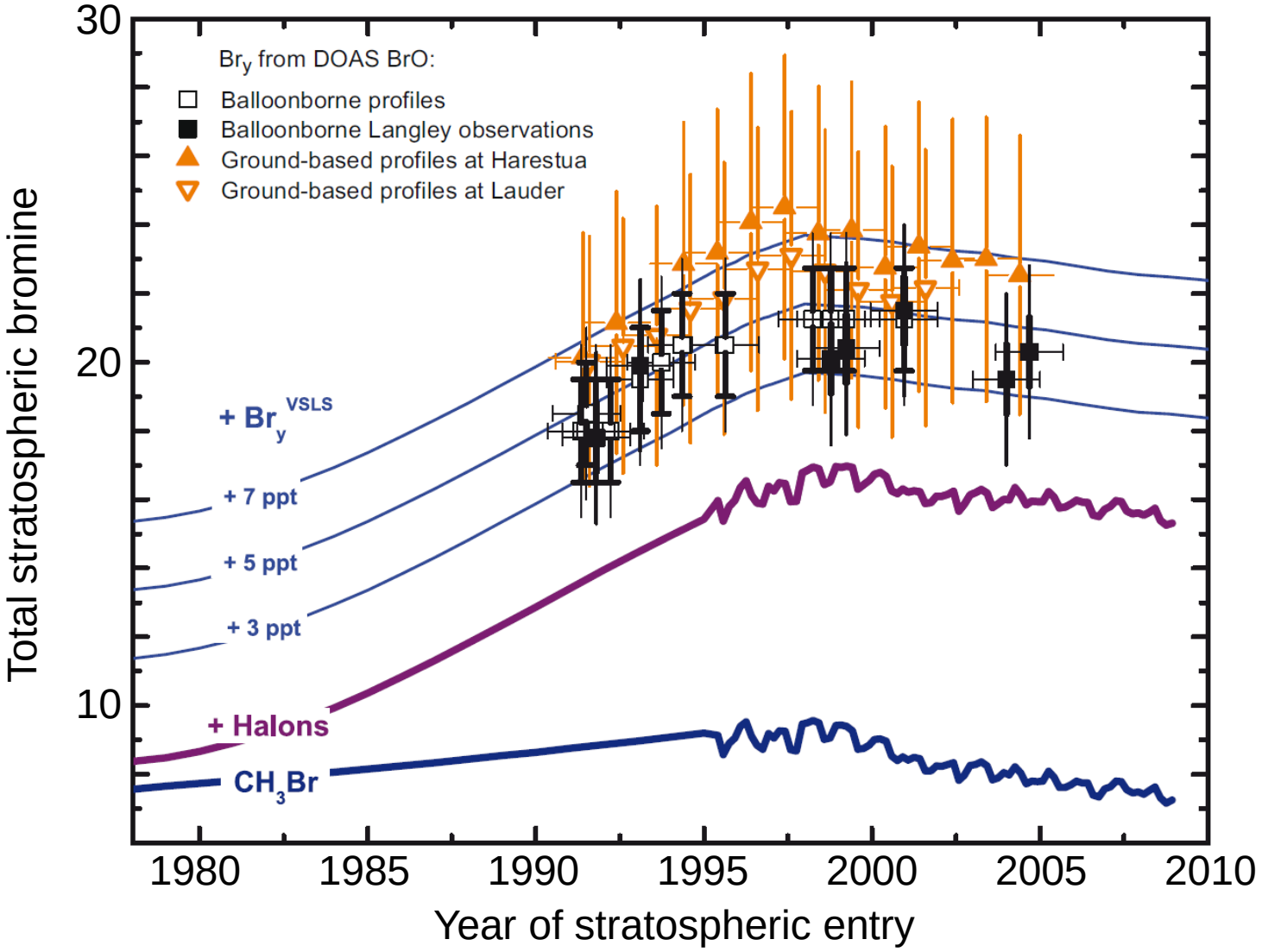


Global ozonesonde station network and SSTs

Central Equatorial Pacific Experiment (CEPEX) 1993

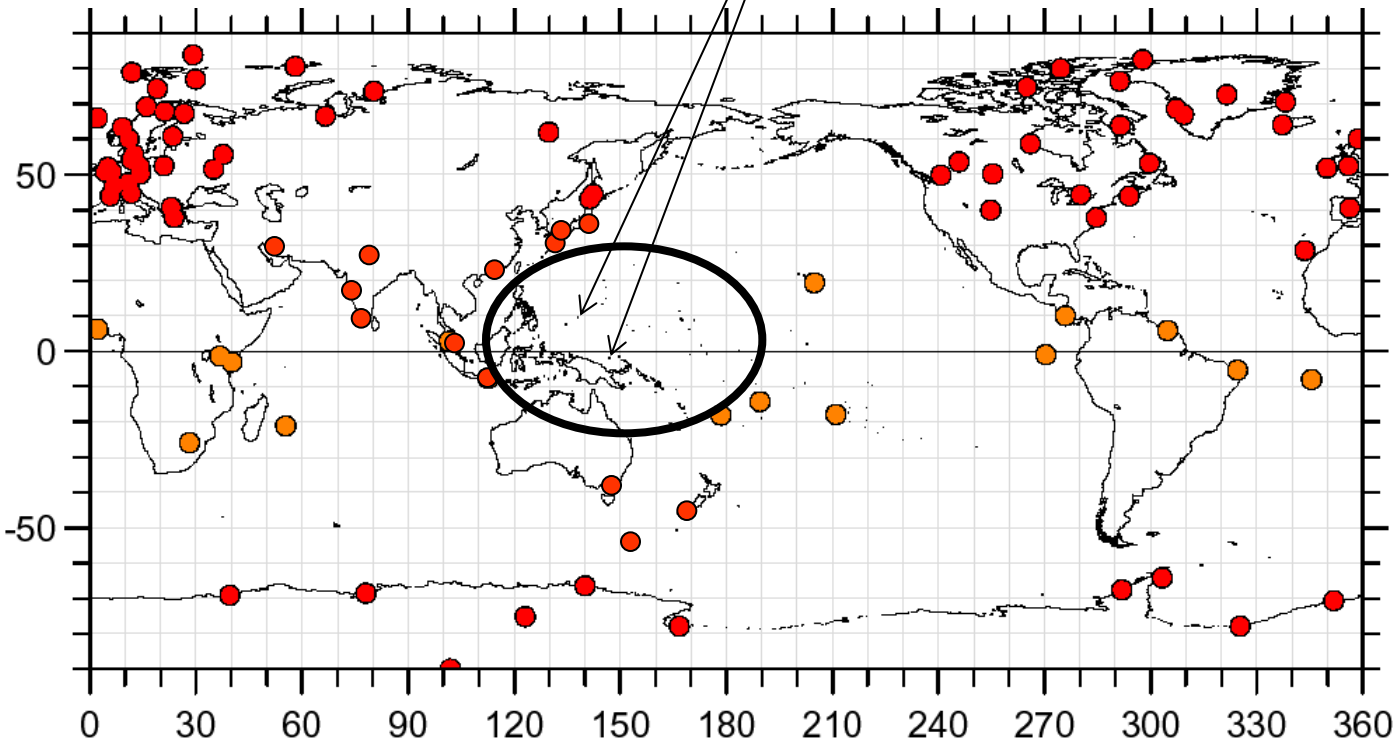


Stratospheric bromine



WMO, 2011

Will submit proposal for temporary station:
Ozonesonde, FTIR



Tropospheric OH column from GEOS Chem