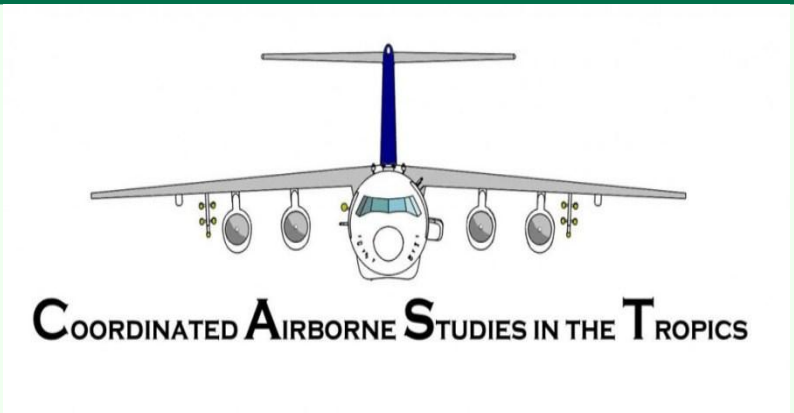


Ozone in the Tropical Tropopause Layer

Geraint Vaughan

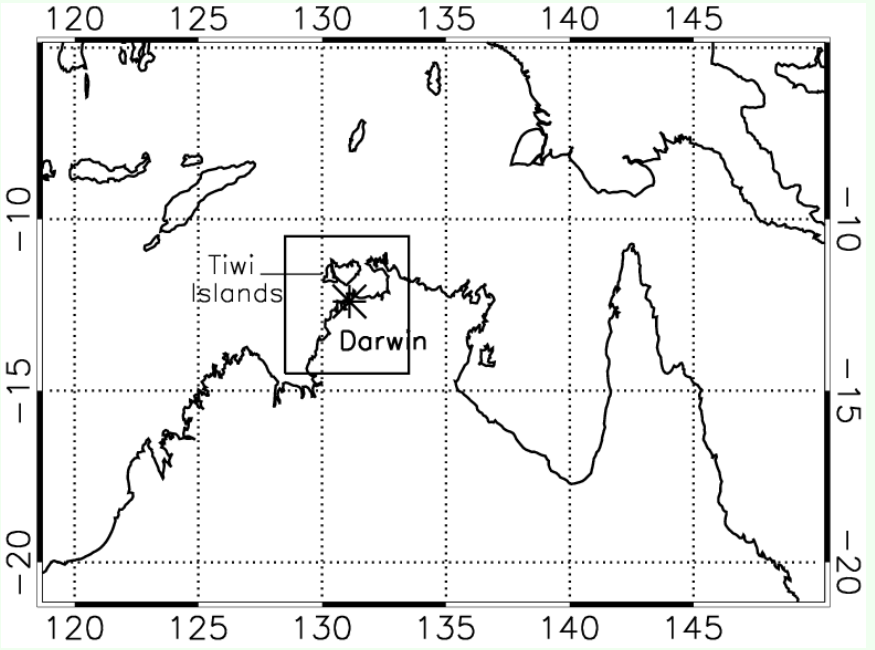
What determines the ozone concentration in the tropical upper troposphere?

Do we see extensive evidence of uplift from the boundary layer?

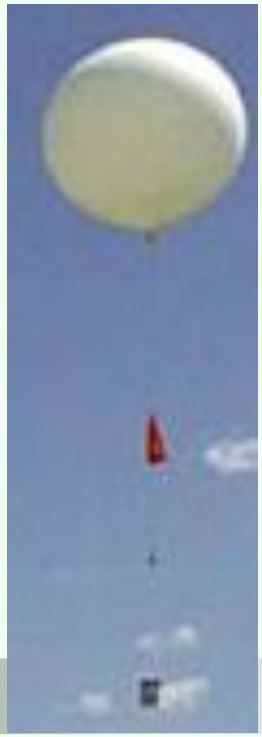
Evidence from previous campaigns

TWP-ICE/SCOUT-O3/
ACTIVE campaign

Darwin 2005-6



First examine ozonesonde profiles (Heyes et al 2008) – 28 sondes over four months sampling different meteorological conditions



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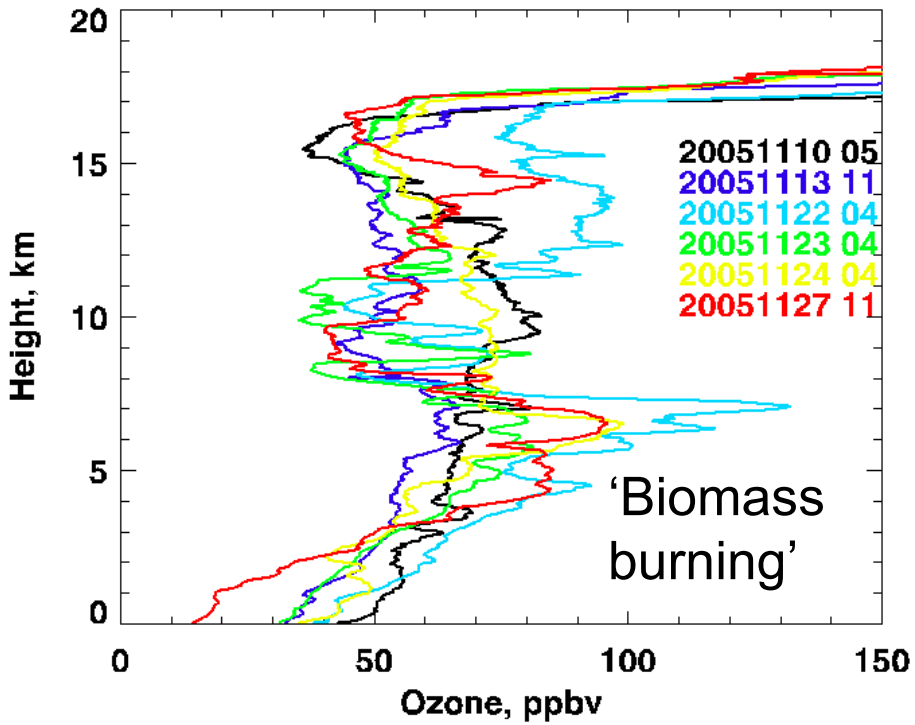
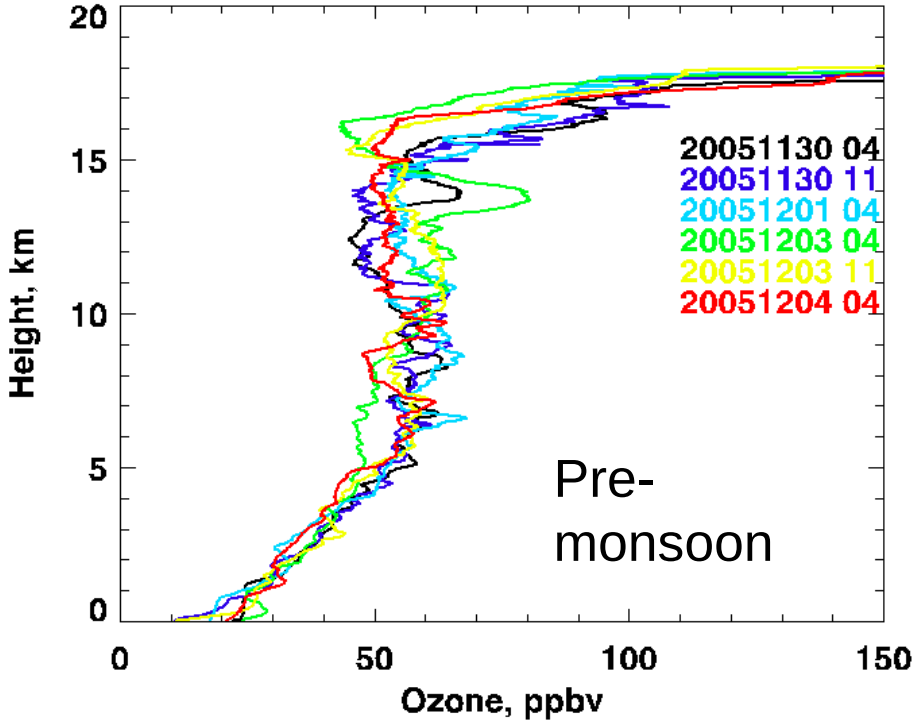
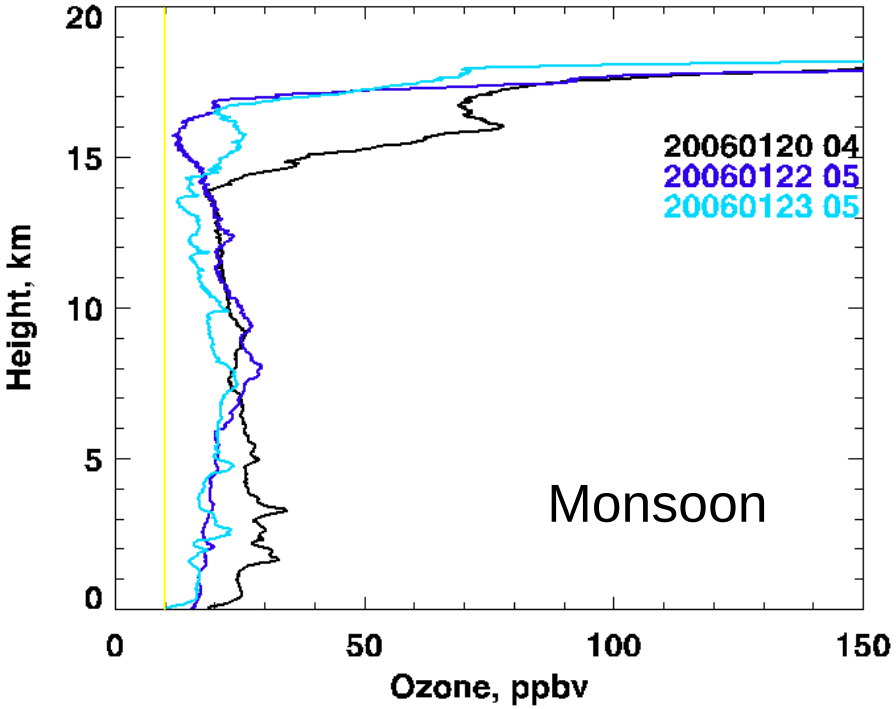
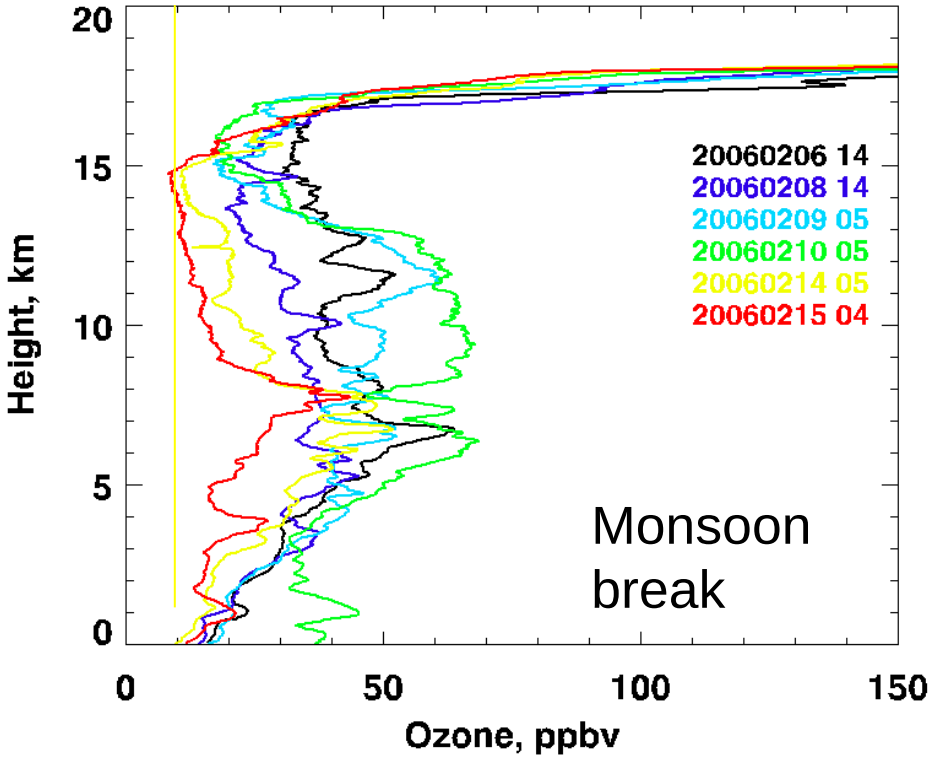

20051110 05
20051113 11
20051122 04
20051123 04
20051124 04
20051127 11
'Biomass burning'
Height, km
Ozone, ppbv
0
5
10
15
20
0
50
100
150

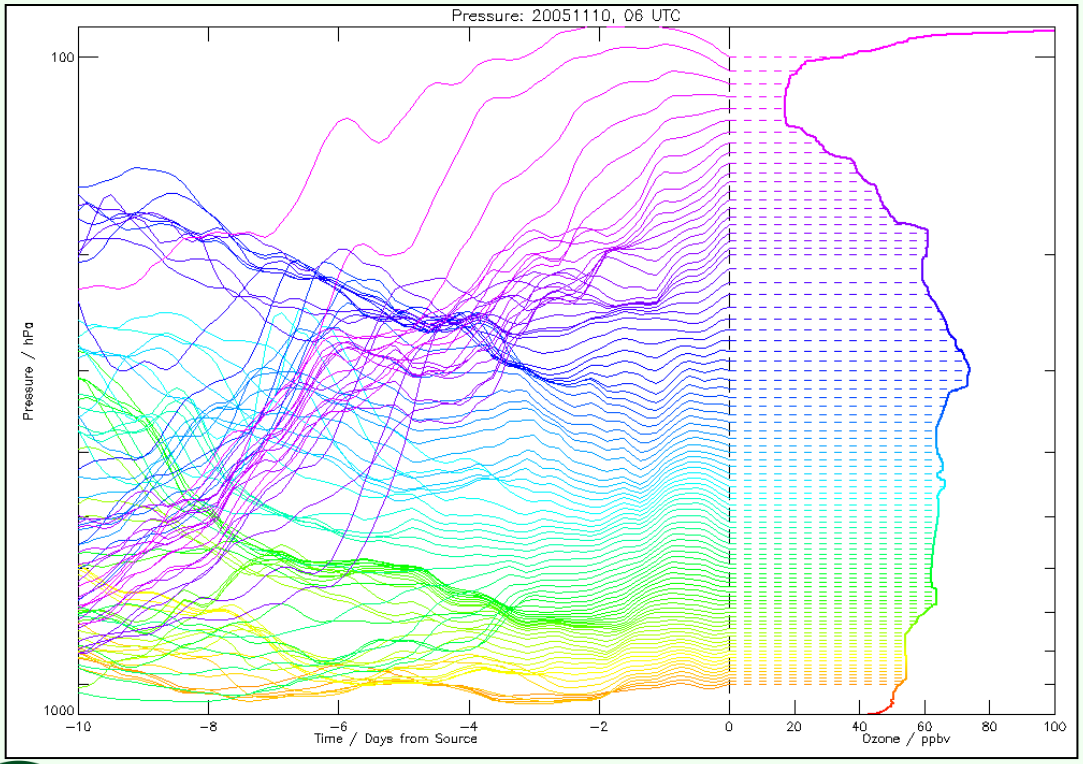

20051130 04
20051130 11
20051201 04
20051203 04
20051203 11
20051204 04
Pre-monsoon
Height, km
Ozone, ppbv
0
5
10
15
20
0
50
100
150


20060120 04
20060122 05
20060123 05
Monsoon
Height, km
Ozone, ppbv
0
5
10
15
20
0
50
100
150


20060206 14
20060208 14
20060209 05
20060210 05
20060214 05
20060215 04
Monsoon break
Height, km
Ozone, ppbv
0
5
10
15
20
0
50
100
150

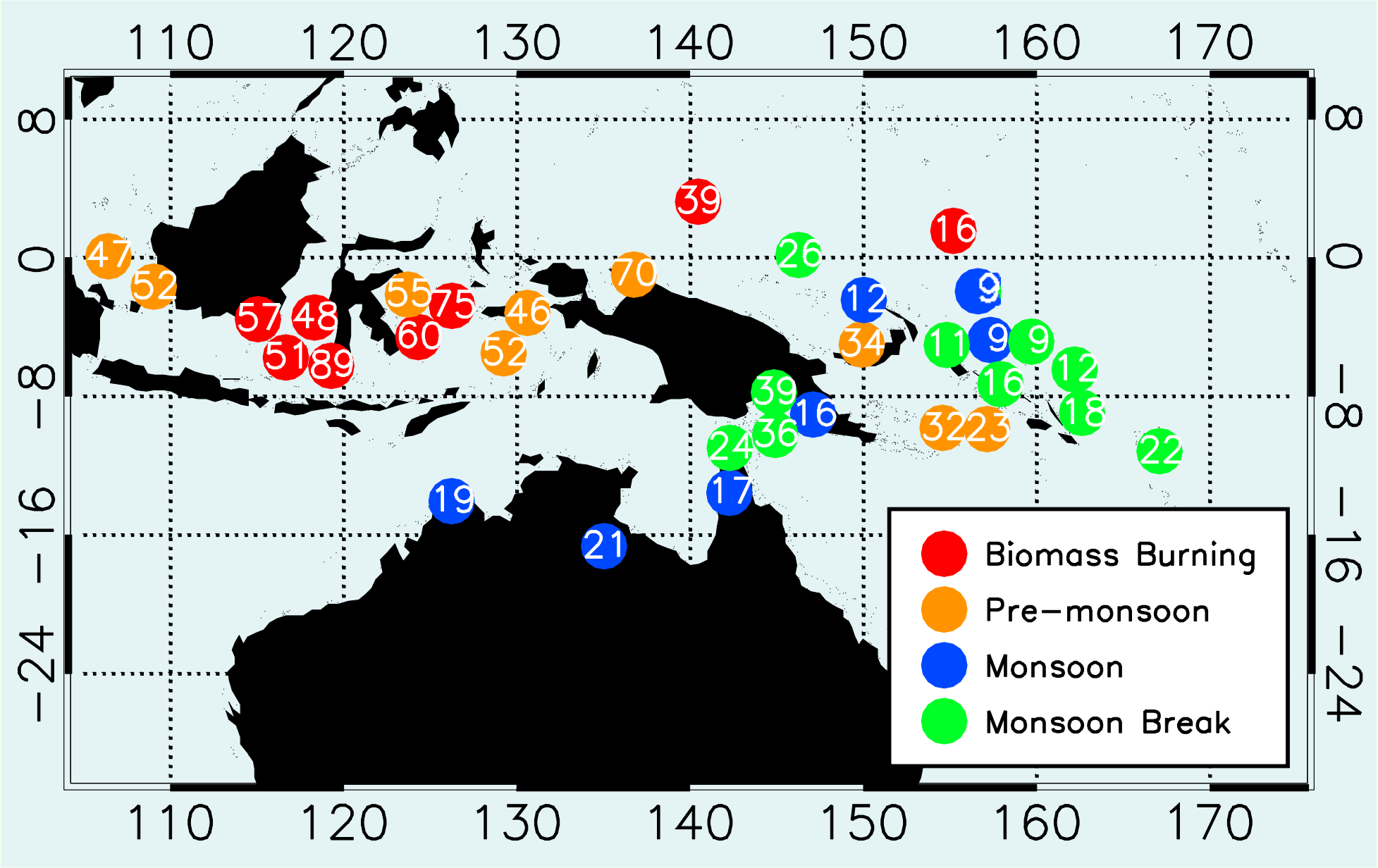
Back-trajectory analysis based on ozonesonde ascents

- 10-day back trajectories performed using ECMWF analyses
- Performed for every ozone sounding (~30) at every 10 hPa between 900 and 200 hPa, and every 5 hPa between 200 and 100 hPa
- Clustered trajectories were performed to check for consistency initially, with only the central trajectory used thereafter



Many of the trajectories ending in the TTL have ascended from low levels in the previous few days

Ozone Concentrations and locations where trajectories ascended through 500 mb



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Conclusions 1

- Origin of back-trajectories show a consistent and coherent pattern
- In general elevated ozone can be attributed to sources over Indonesia, with reduced concentrations observed from the remote maritime Pacific
- Suggests the TTL above Darwin is governed by the wider tropical warm pool region as opposed to transport from the local boundary layer

Conclusions 2

- Evidence from measurements in and near the anvils points to the mid-troposphere being the main source region for air lifted into the TTL by continental convection
- Uplifted boundary-layer air found at lower levels

Are these conclusions correct for large MCSs such as those found in the Tropical Warm Pool? Is this how air with very low ozone concentrations reached the TTL?

CAST measurements, Manus Is, PNG, February 2014

Manus chosen because of **support from the US ARM programme** in this Tropical Warm Pool site

39 ozonesondes launched in February 2014, 35 of them produced good profiles

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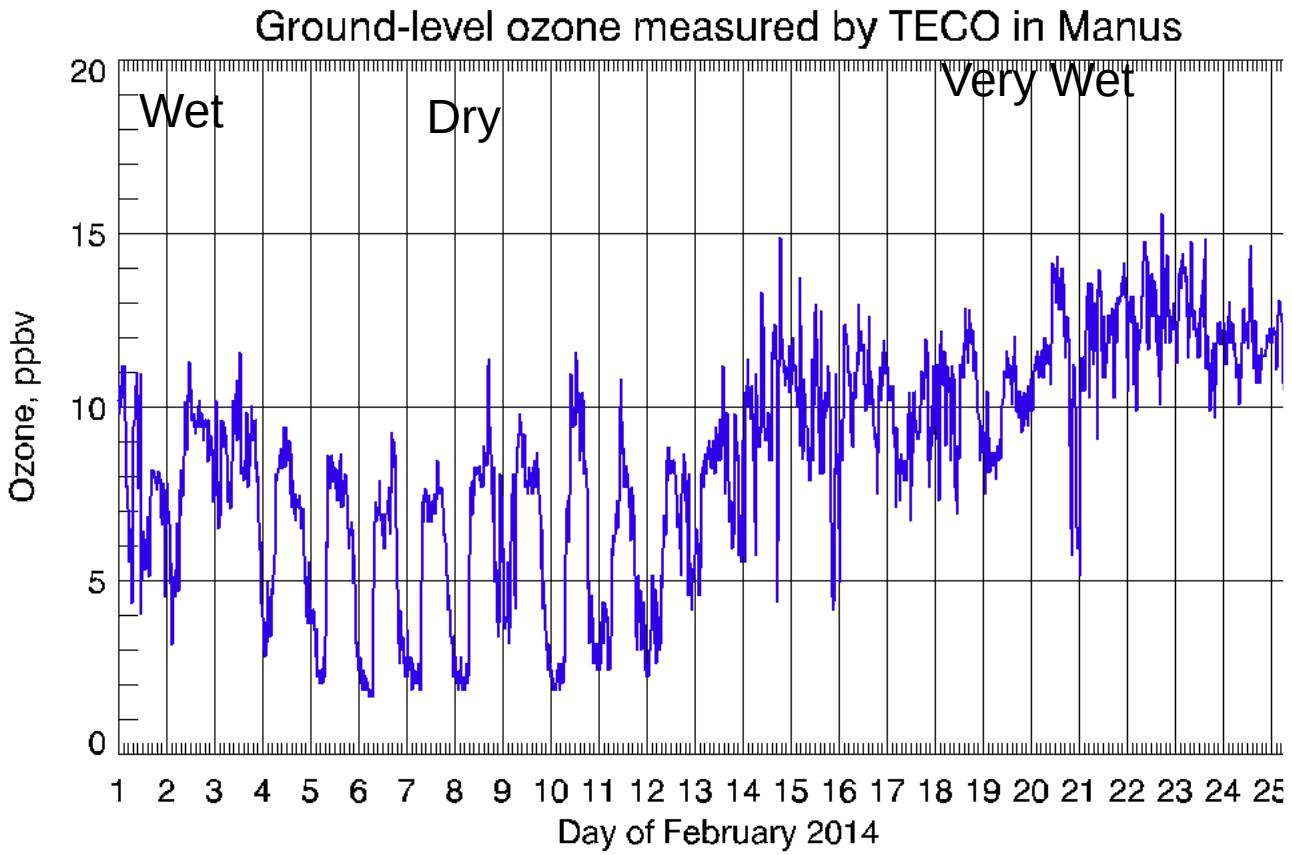
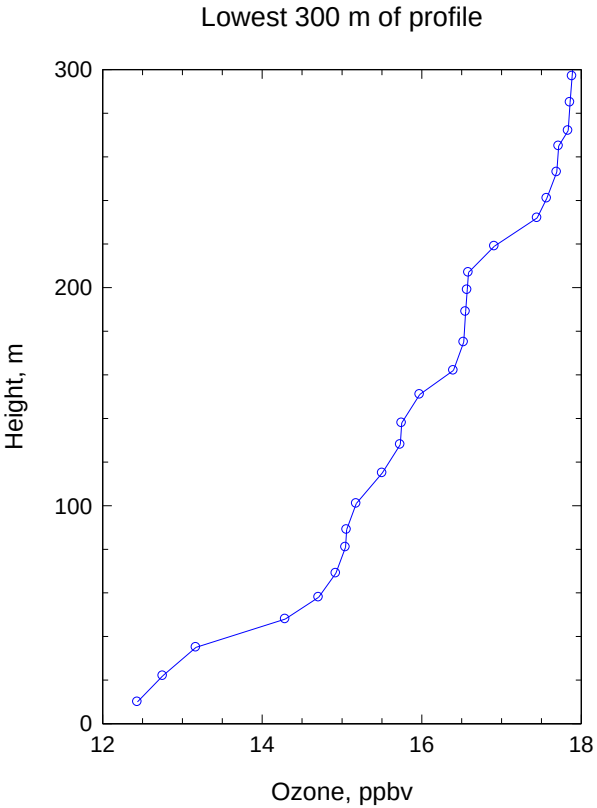
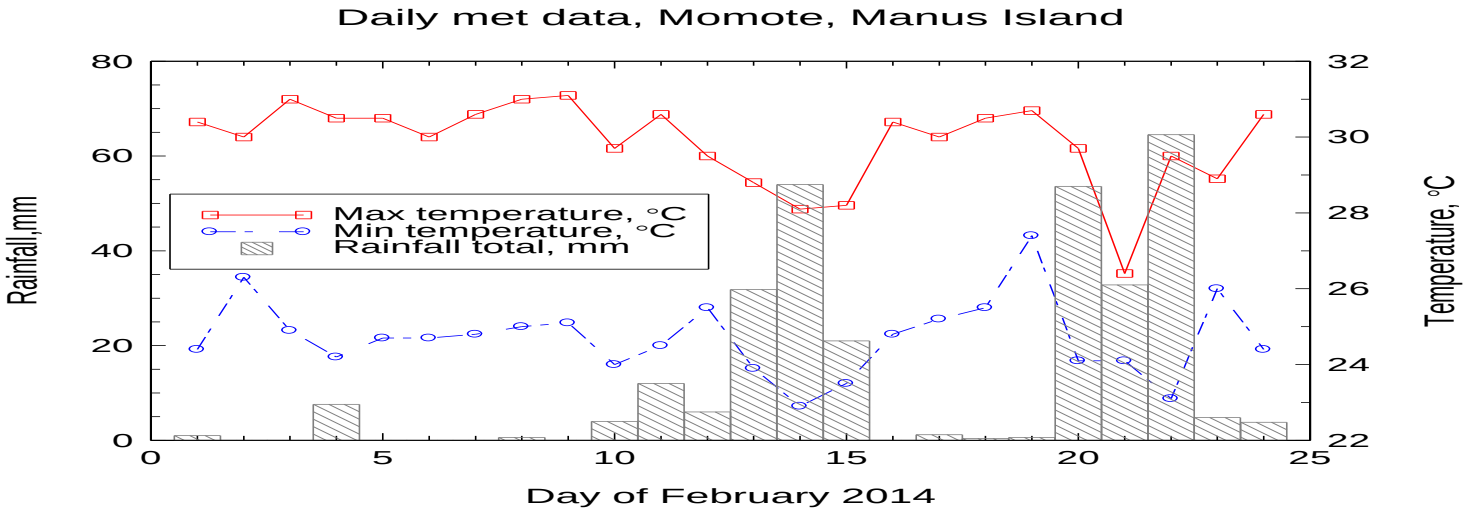
Ground-level ozone







Ongoing issue: background current

Ozonesonde measures CURRENT from cell. To derive ozone conc we have to subtract a background current measured during prep. Background current is a vexed problem with ozonesondes. It should be around 50 nA

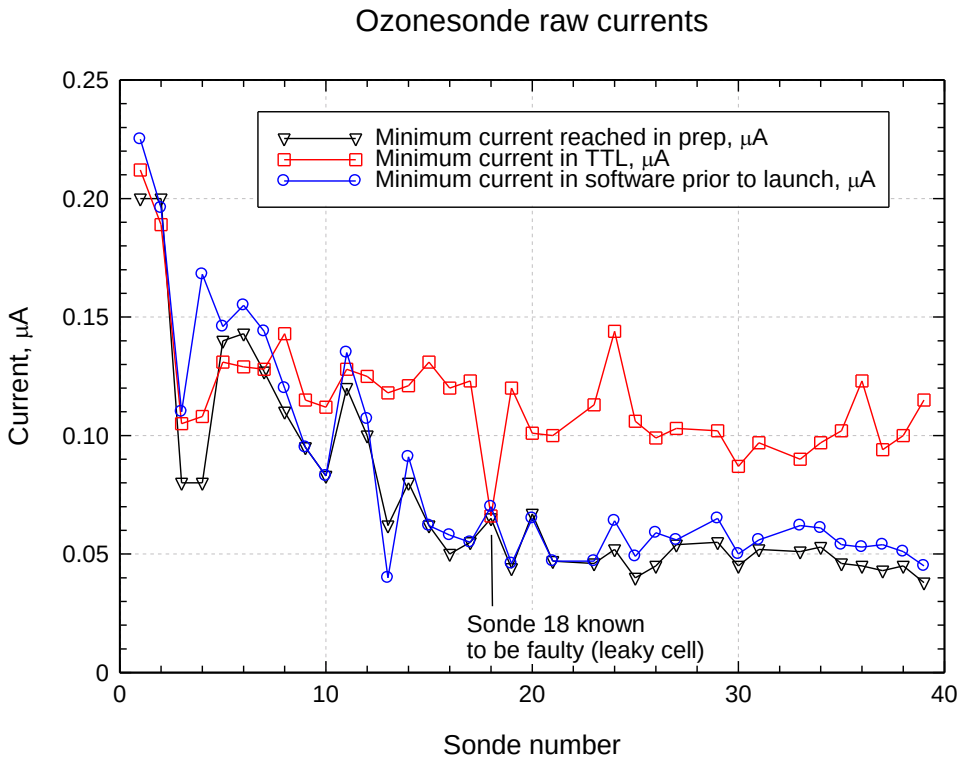
First dozen sondes had higher background current BUT minimum current in the TTL hardly changed after the first two. Problem with contamination (see poster by Richard Newton)

Uncontaminated sondes – use constant background current as measured just before launch

Contaminated sondes analysed using a hybrid background current

$I_b = I_{b0} + (I_{bm} - I_{b0})p/p0$ if $I_{bm} > I_{b0}$

$I_b = I_{bm}$ otherwise



I_b = background current used in analysis

I_{b0} = 50 nA (arbitrary)

I_{bm} = background current measured just before launch

P = pressure; p0 = surface pressure

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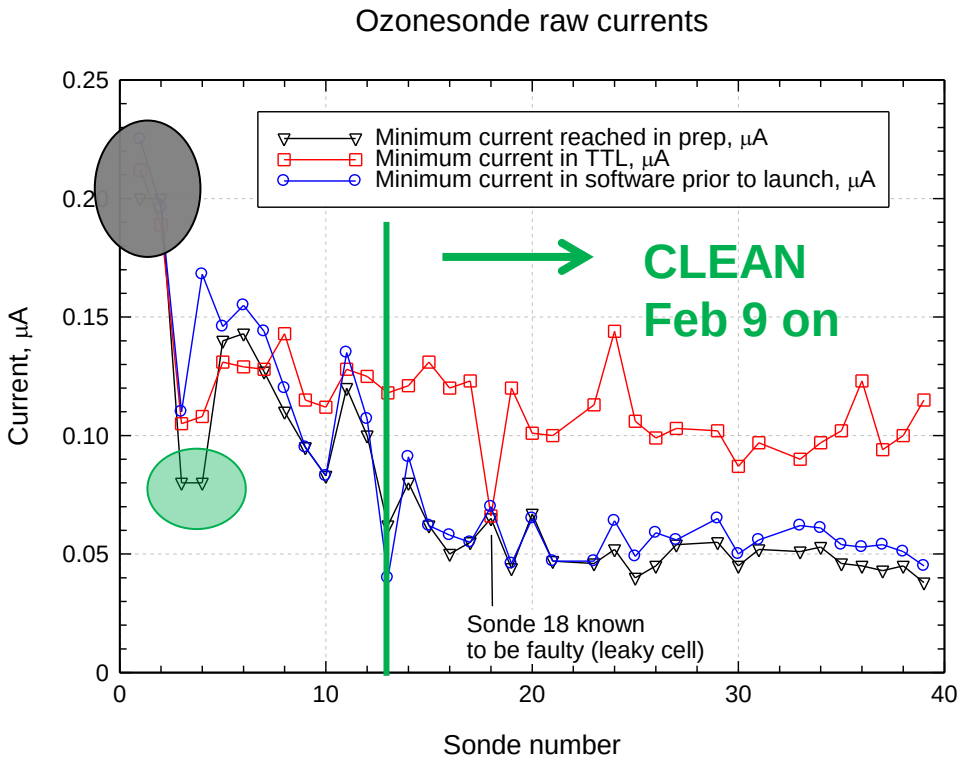

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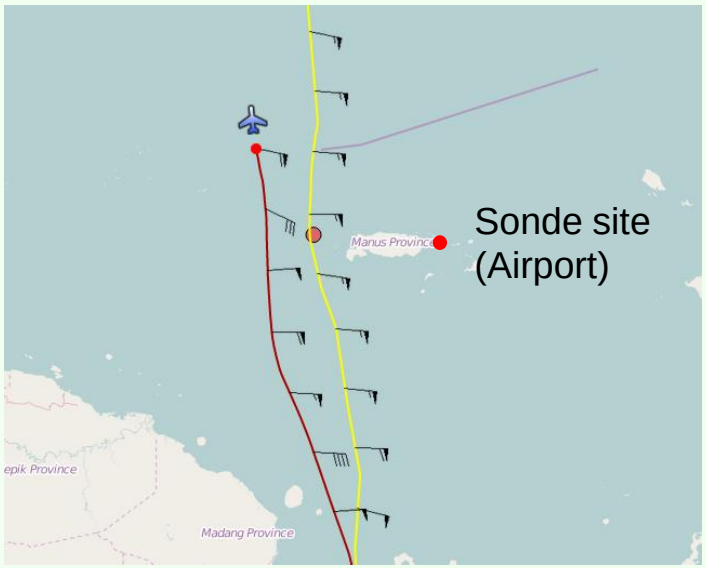
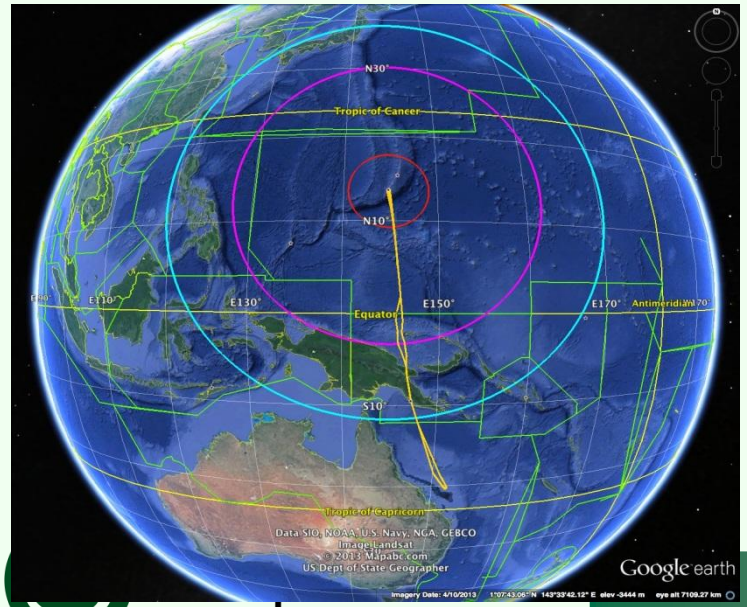
P = pressure; p0 = surface pressure

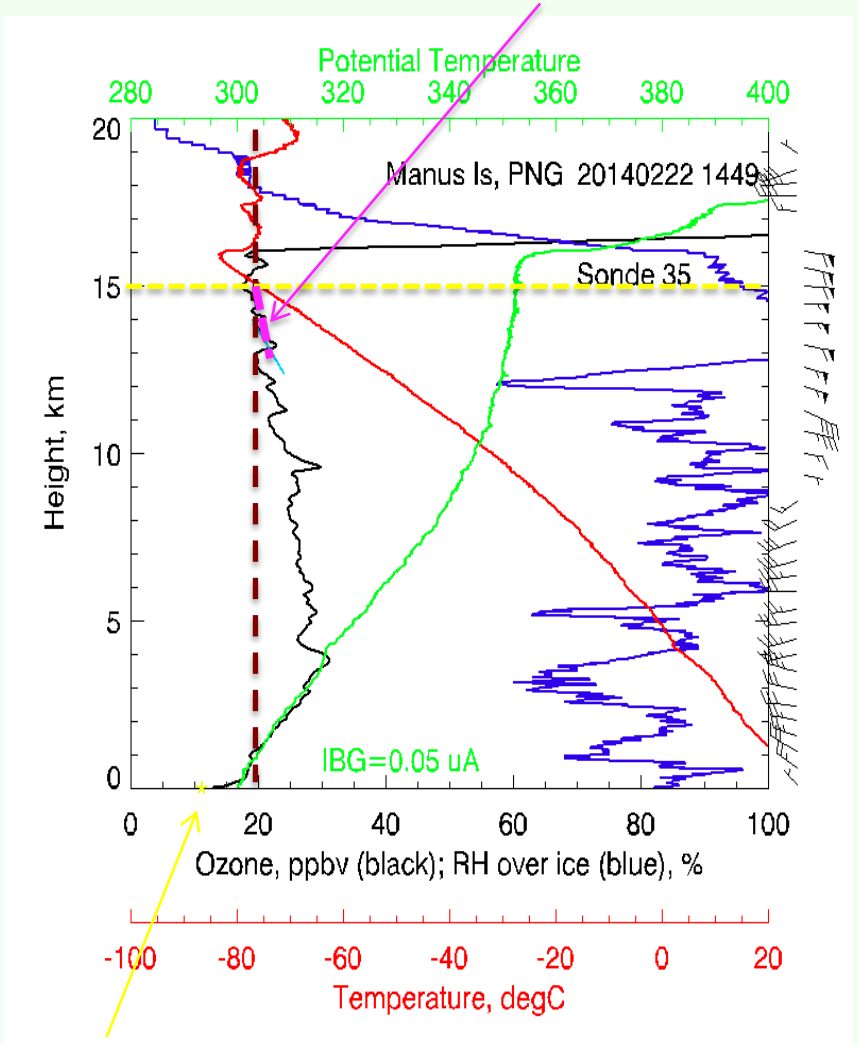
Ozonesonde profile validation: 22 Feb 2014

Gulfstream V flypass of Manus Island



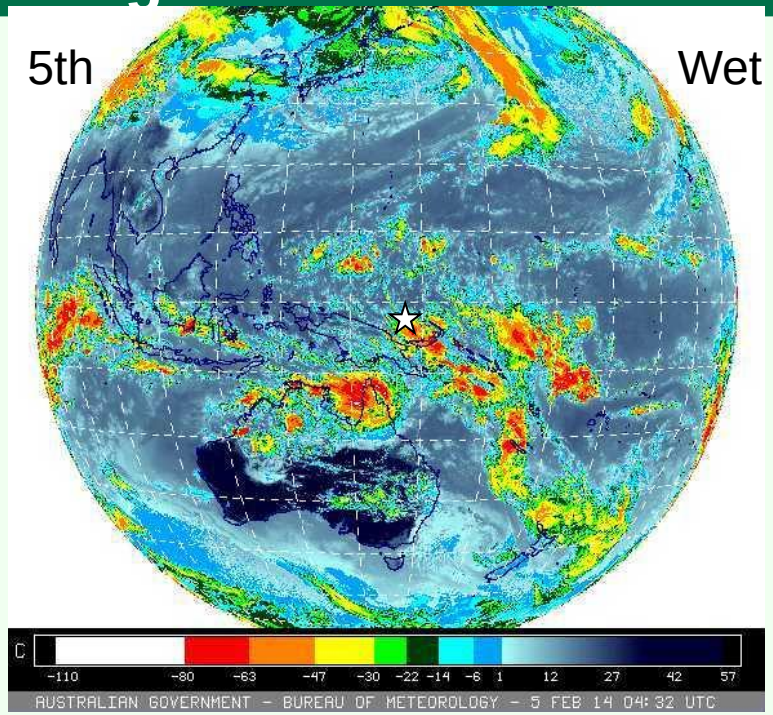


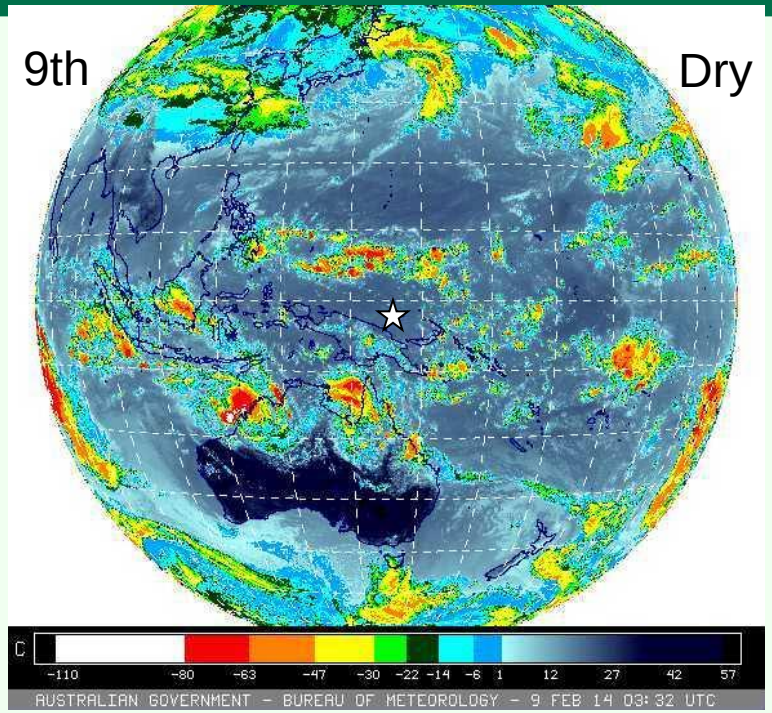
GV ozone, hand-drawn

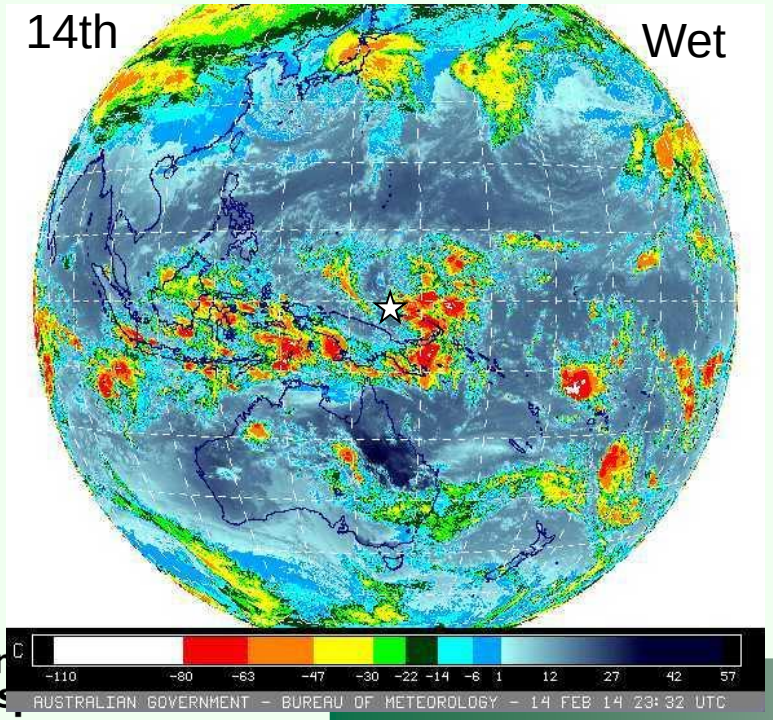


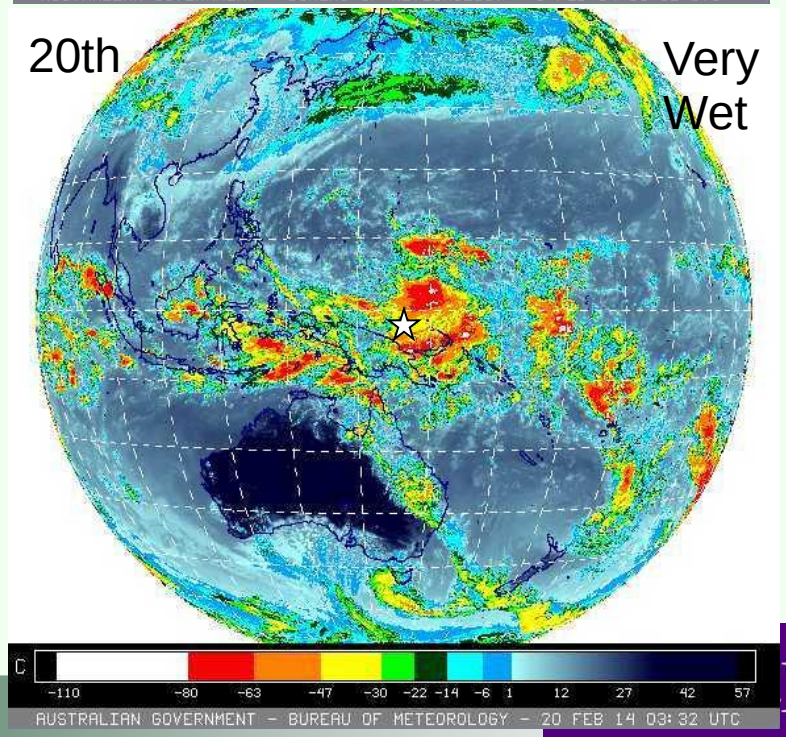
TECO ground-based ozone

Satellite images



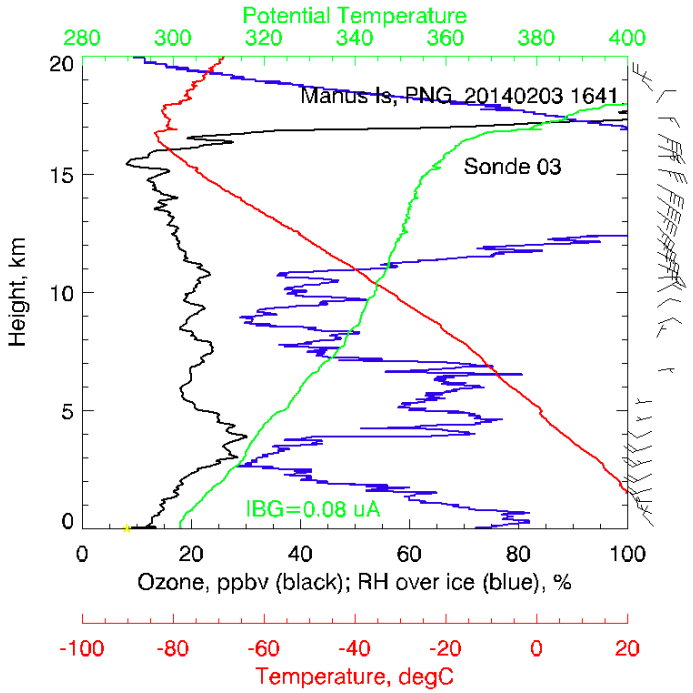


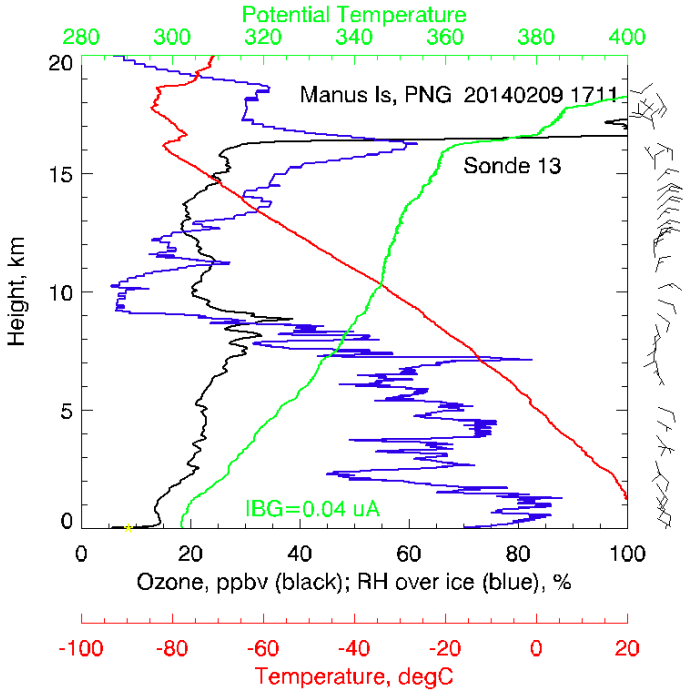




Profiles under different conditions

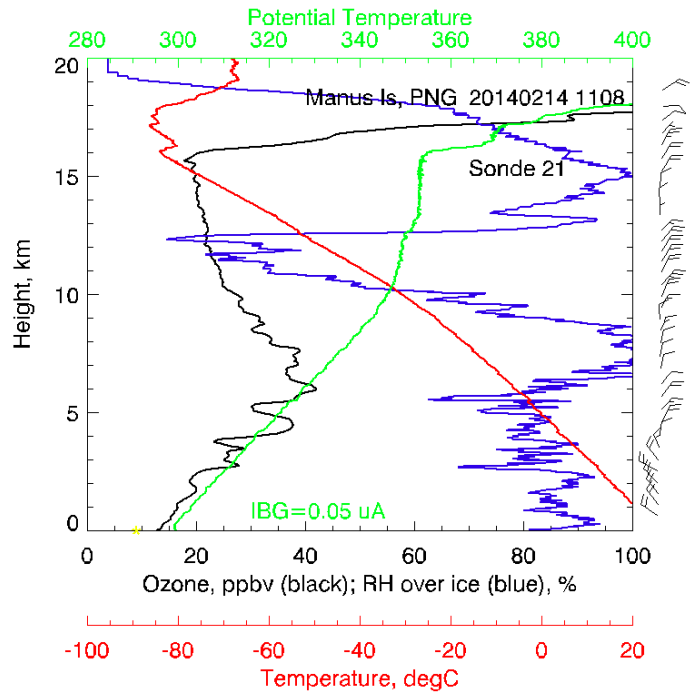
WET

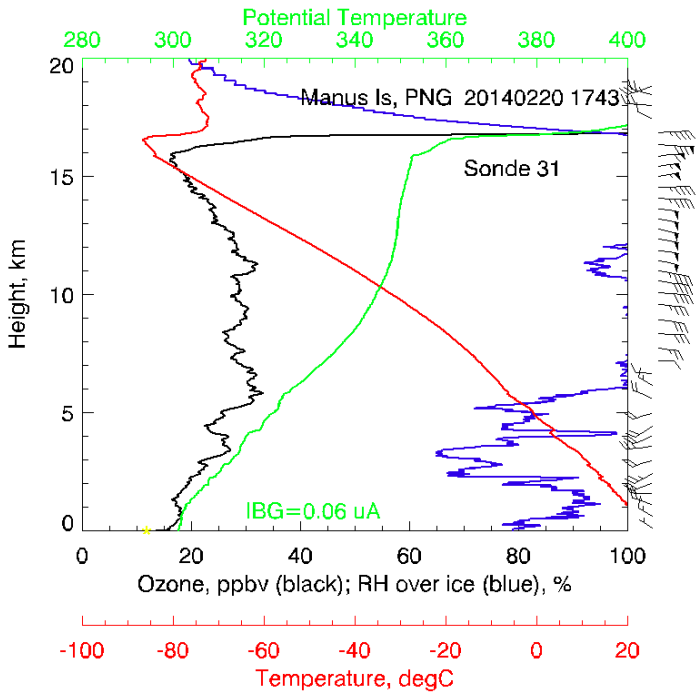




DRY

WET





VERY WET

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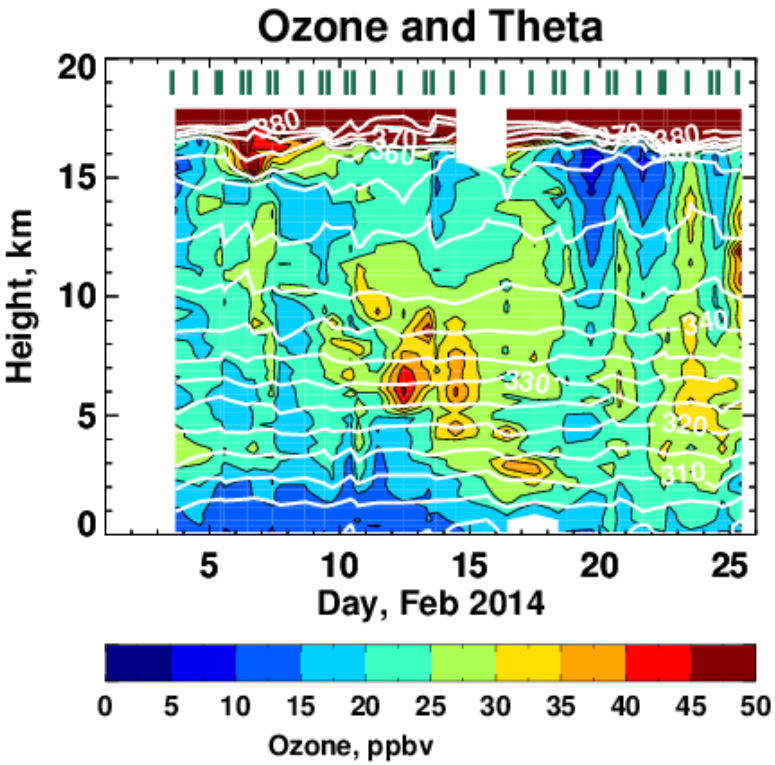
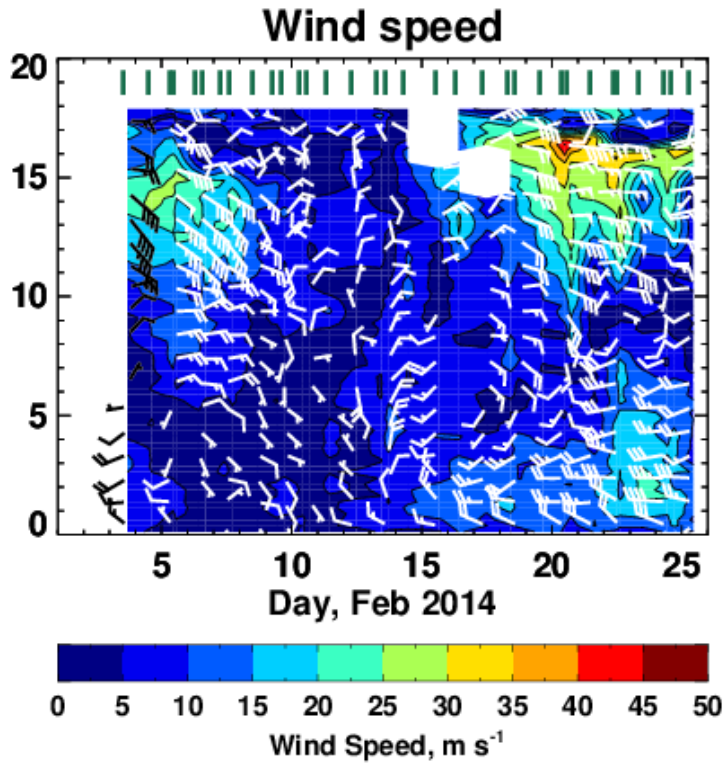
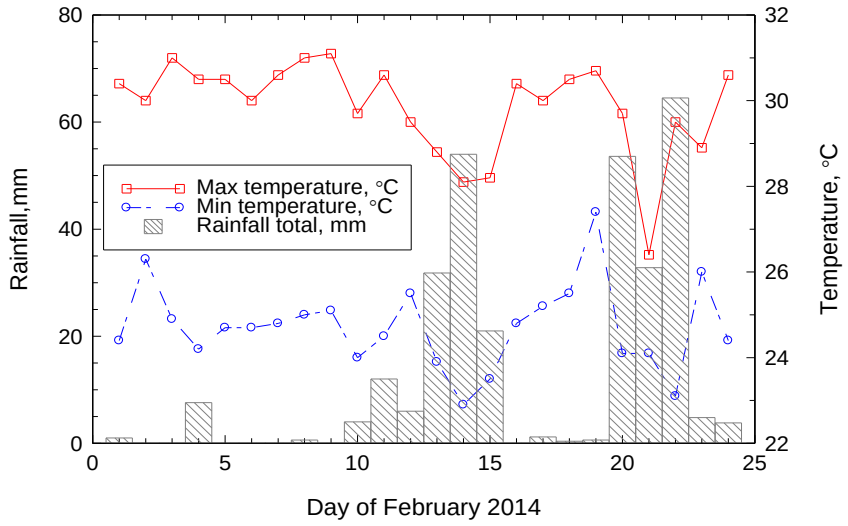
Summary of measurements





Daily met data, Momote, Manus Island

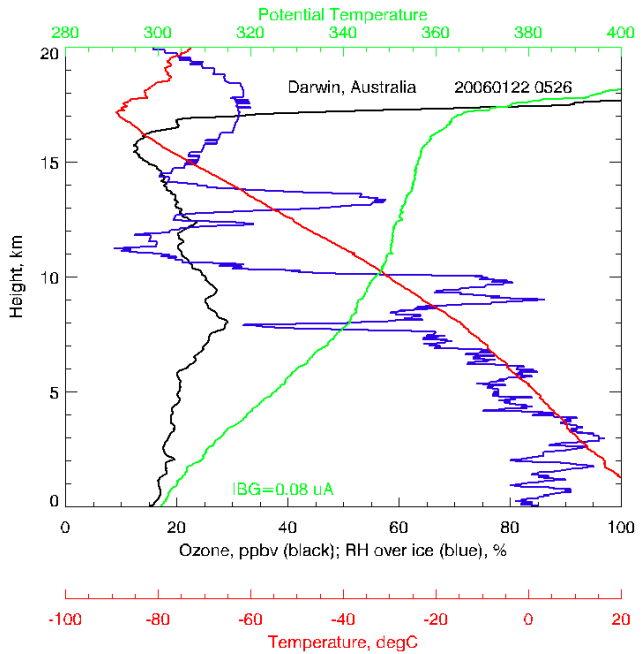


Lowest ozone in TTL occurs during the very wet period and coincides with strong easterly winds

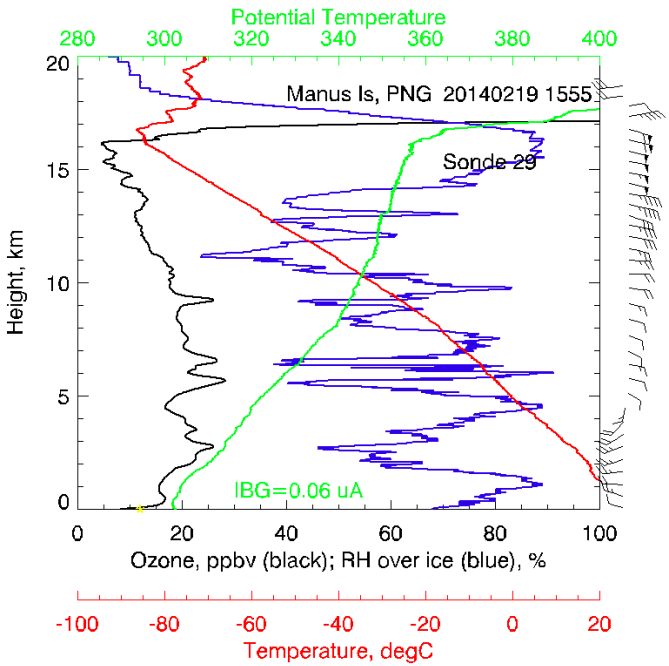
Higher TTL ozone during dry period and earlier, less wet period.

Preliminary conclusions

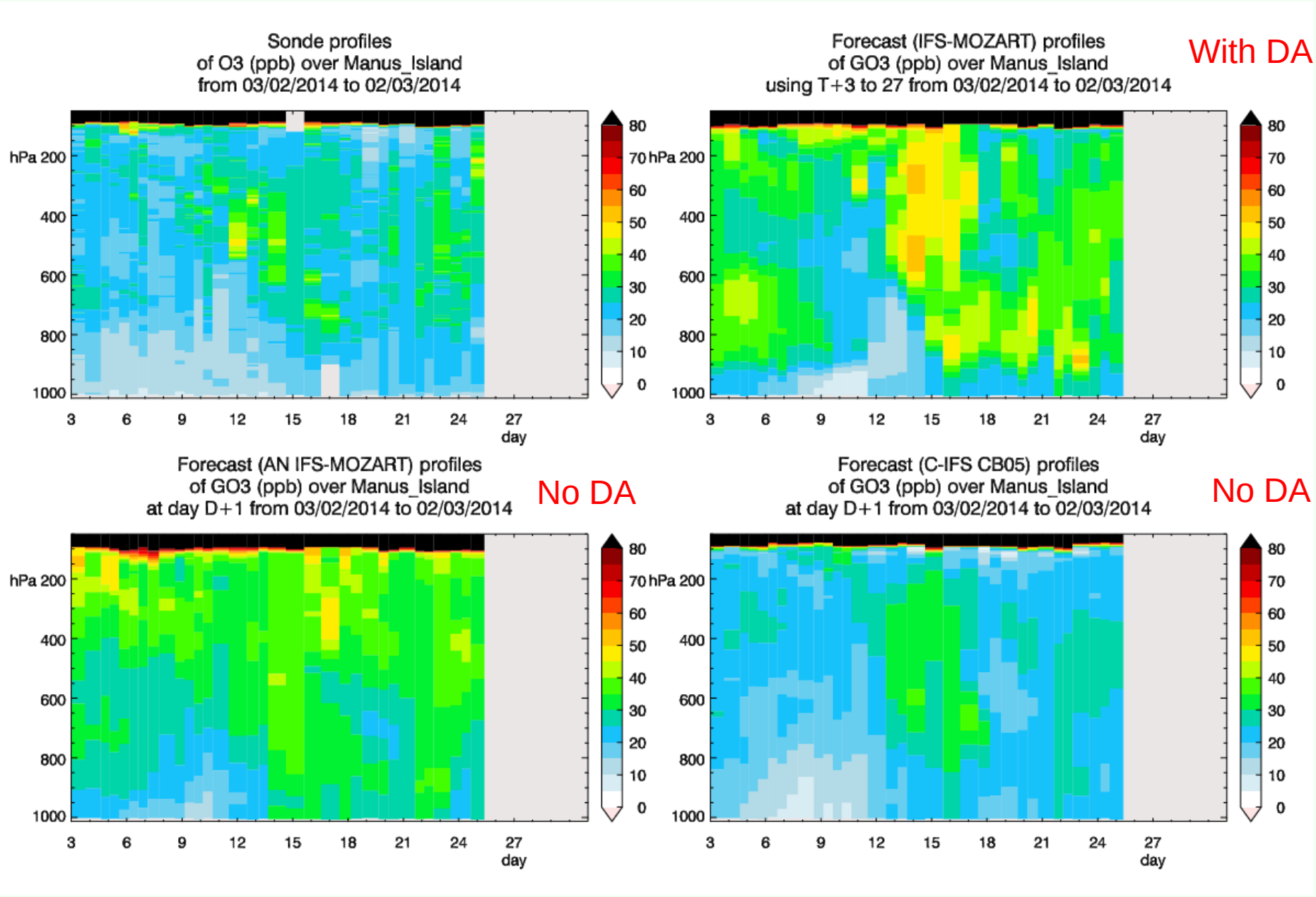
- Excellent agreement between sondes and Gulfstream, as well as good low-level agreement with TECO.
- Very low surface ozone confined to the very lowest layers of the profile
- Lowest TTL ozone, 10-15 ppbv, coincides with widespread convective conditions around Manus



Results verify the hypothesis that low ozone concentrations ARE lifted to the TTL by widespread MCS convection in the warm pool region around the Solomon Islands



Comparison with ECMWF model at 100 km resolution



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With thanks to Johannes Flemming

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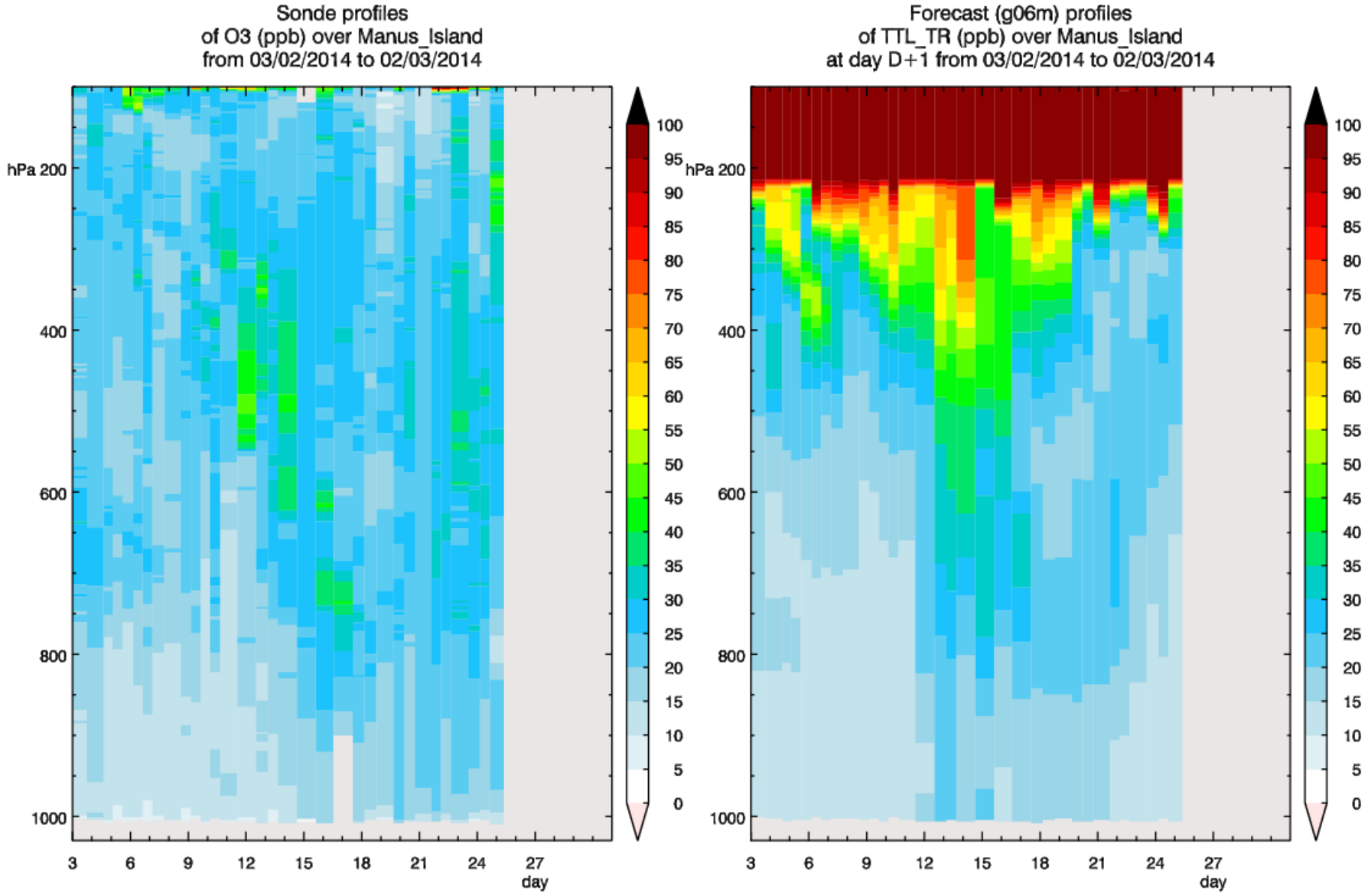
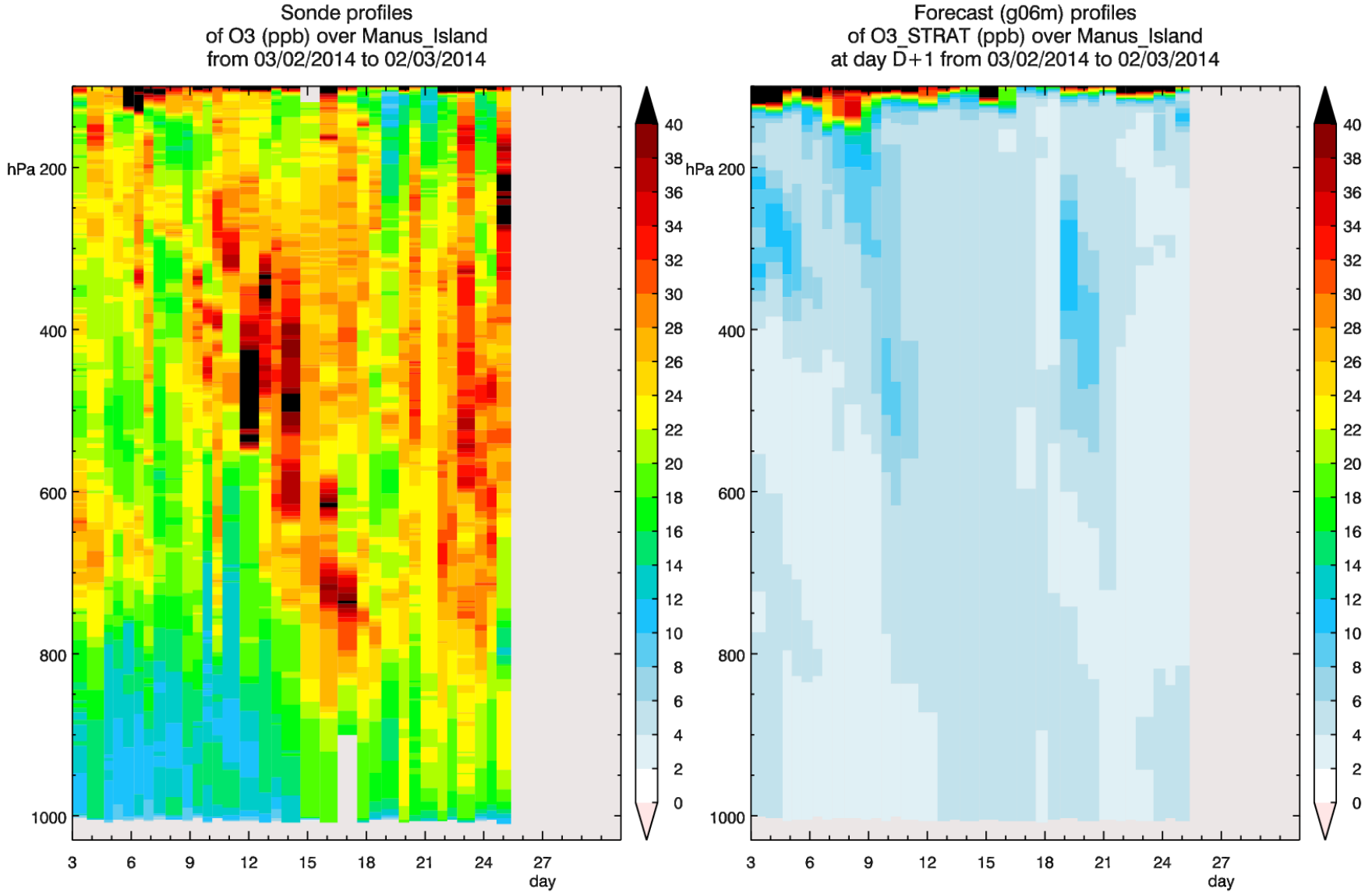
TTL tracer


Sonde profiles
of O3 (ppb) over Manus_Island
from 03/02/2014 to 02/03/2014
hPa 200
400
600
800
1000
3
6
9
12
15
18
21
24
27
day
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Forecast (g06m) profiles
of TTL_TR (ppb) over Manus_Island
at day D+1 from 03/02/2014 to 02/03/2014
hPa 200
400
600
800
1000
3
6
9
12
15
18
21
24
27
day
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

Stratospheric tracer



Relative humidity