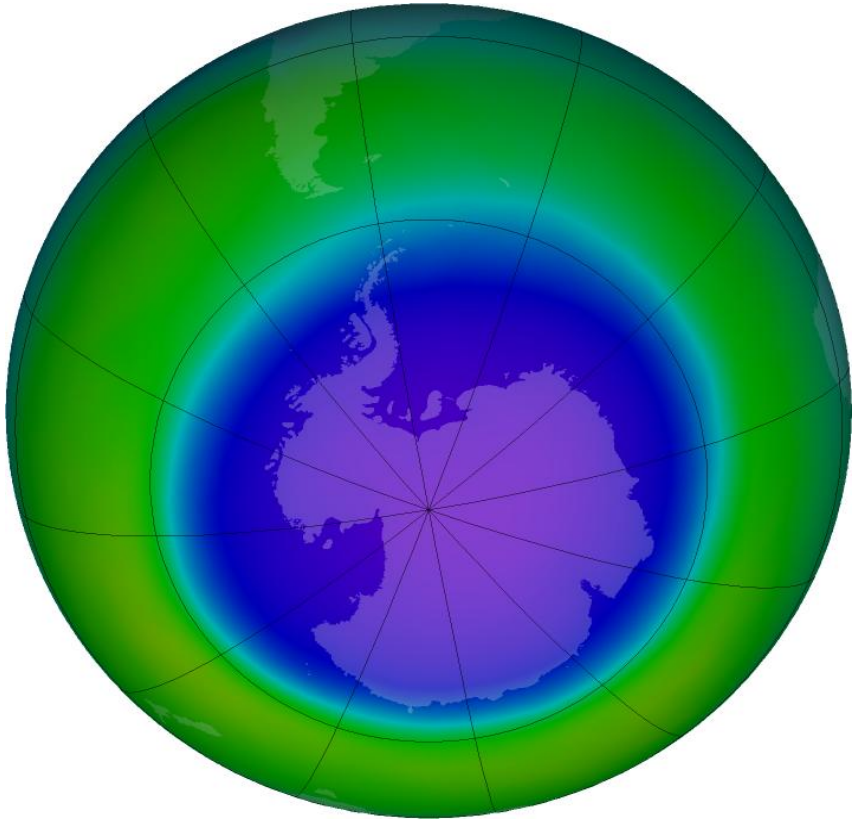
Evaluation of limb ozone retrieval algorithms by studying the 2015 Antarctic ozone hole



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1- Science Systems and Applications Inc.;
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3- Science Applications International;
4-Universities Space Research Association;
5 - University of Saskatchewan, Canada

OMPS Science meeting, June 2, 2016

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Algorithms description

Level 1 v2 gridded radiances

NASA GSFC OMPS-LP v2 algorithm (LP v2)

- Ozone profiles are independently retrieved from UV and VIS spectral ranges;
- 43 UV pairs and 17 VIS triplets;
- UV normalization altitude is 65 km and VIS 45 km;
- Optimal Estimation technique + Tikhonov regulization;
- The aerosol correction module is turned off

D. Rault and R. Loughman, 2013

University of Saskatchewan 1D algorithm (USask1D)

- Ozone profiles are simultaneously retrieved from UV and VIS spectral ranges;
- 7 UV pairs and 1 VIS triplets;
- VIS triplets are normalized near 33 km;
- UV pairs normalized at varying altitudes from 45-65 km
- UV normalization altitude is varying;
- Levenberg-Marquardt retrieval scheme;
- Aerosol and albedo are retrieved concurrently

Degenstein et al., ACP 2009

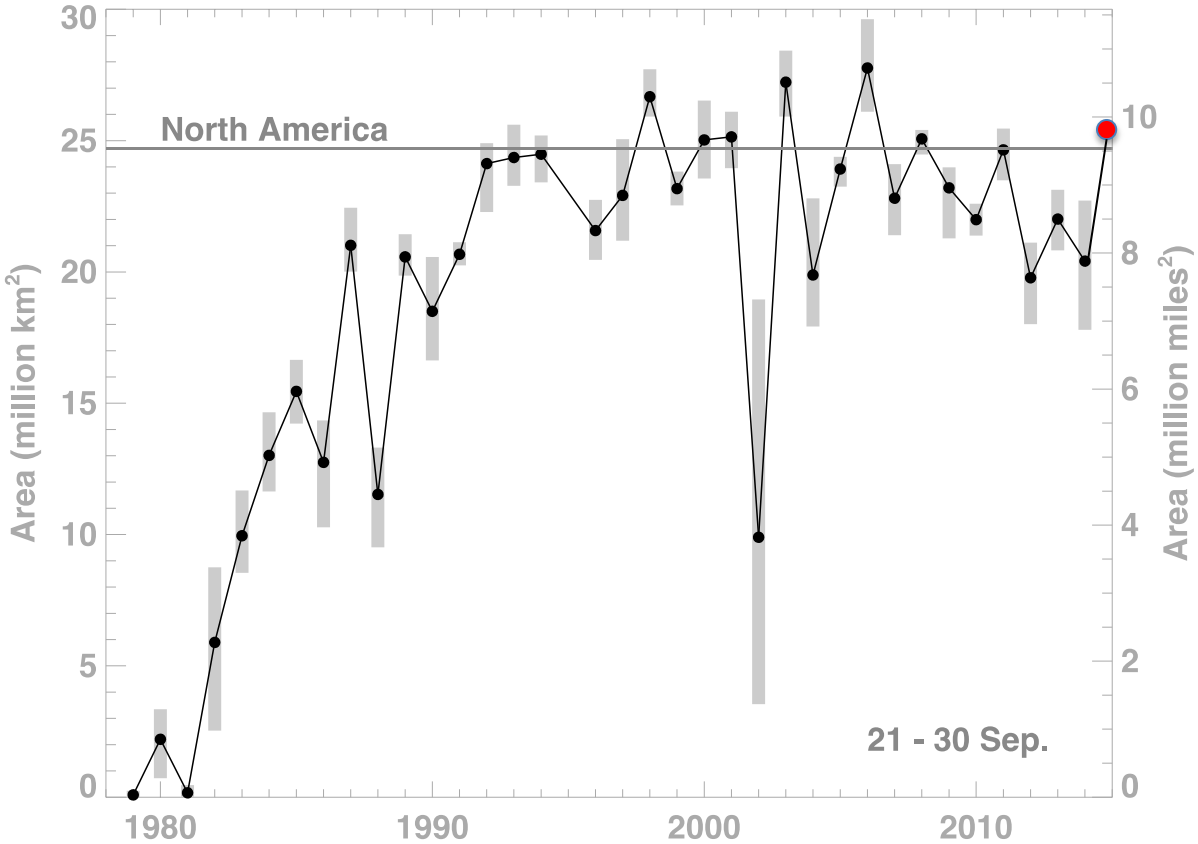
University of Saskatchewan 2D algorithm (USask2D)

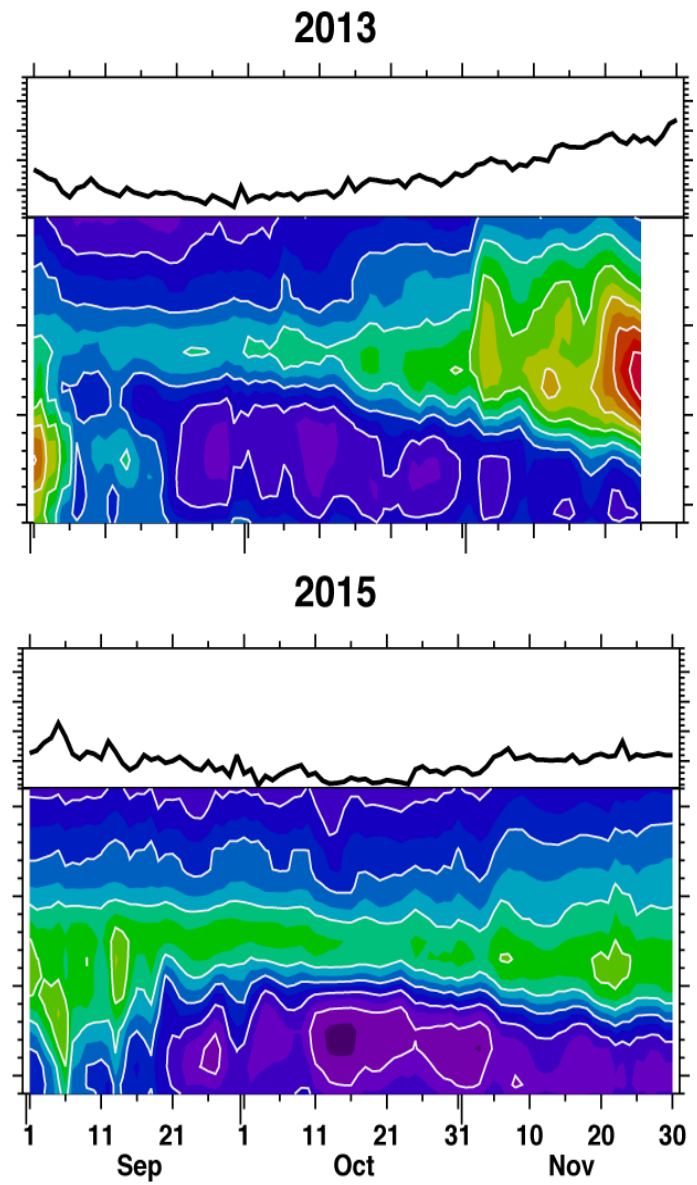
- Ozone profiles are simultaneously retrieved from UV and VIS spectral ranges;
- 8 UV pairs and 2 VIS triplets;
- UV normalization altitude is varying and VIS 33 km;
- Levenberg-Marquardt retrieval scheme;
- 2D effect is modelled by considering several LP frames simultaneously
- Aerosol and albedo are retrieved concurrently

2015 Antarctic ozone observations

2015 Antarctic ozone hole is the 4st largest on the record

25.6 million km^2





2015 Antarctic ozone observations

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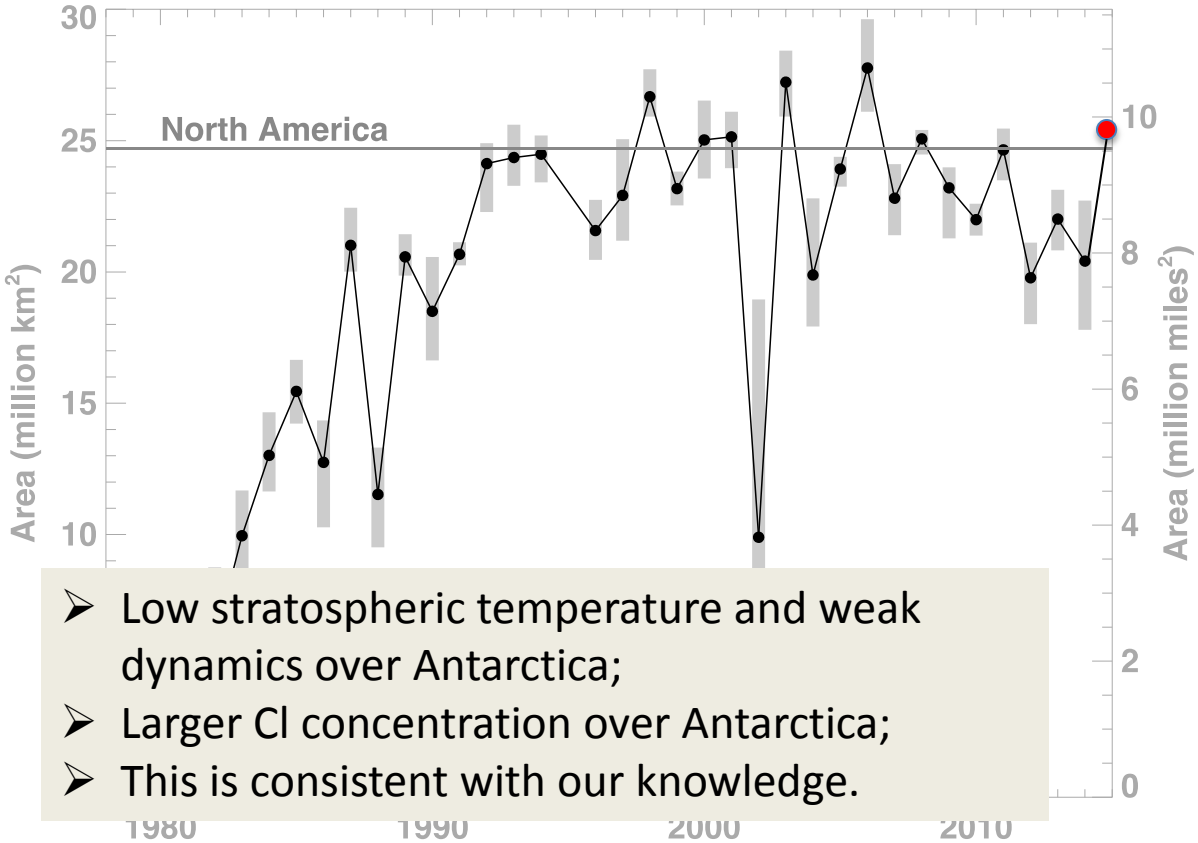
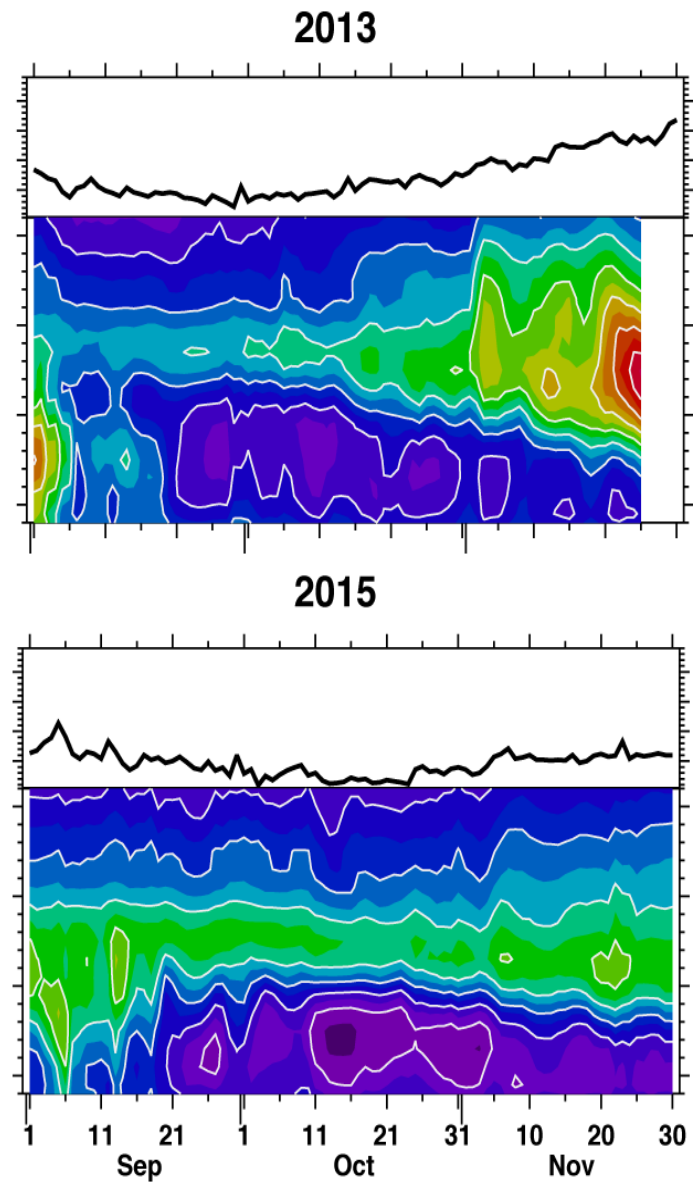
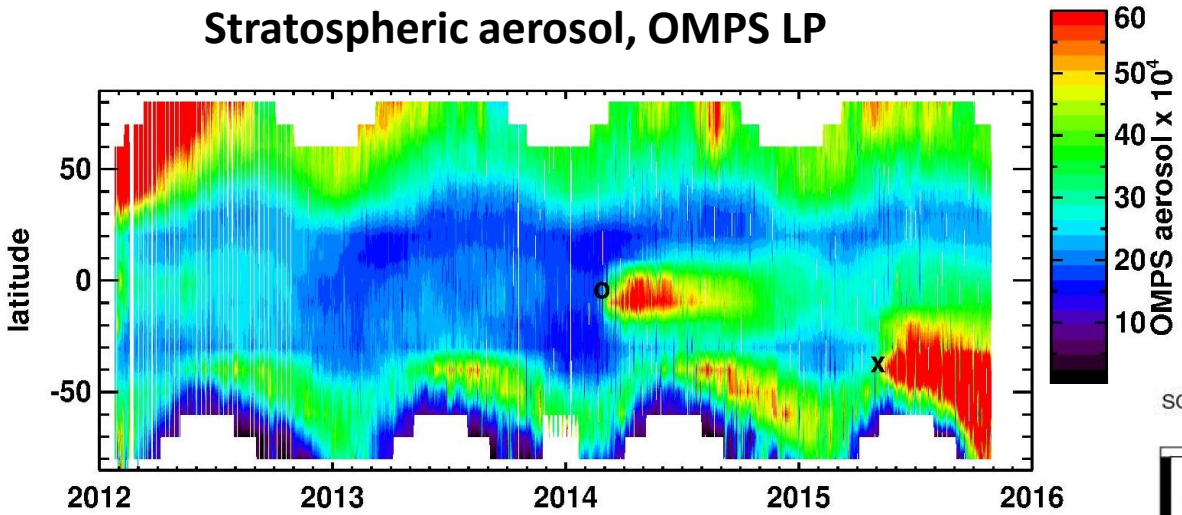


- Low stratospheric temperature and weak dynamics over Antarctica;
- Larger Cl concentration over Antarctica;
- This is consistent with our knowledge.



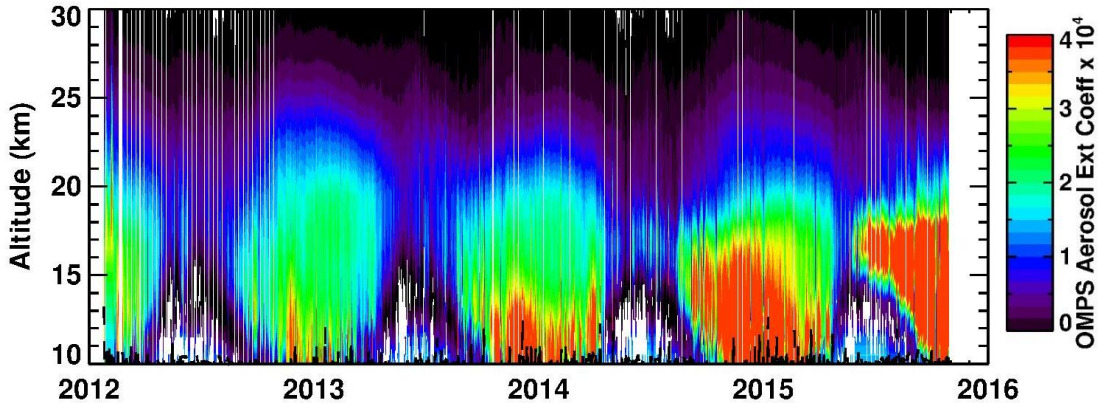
Calbuco eruption [41S,72W]

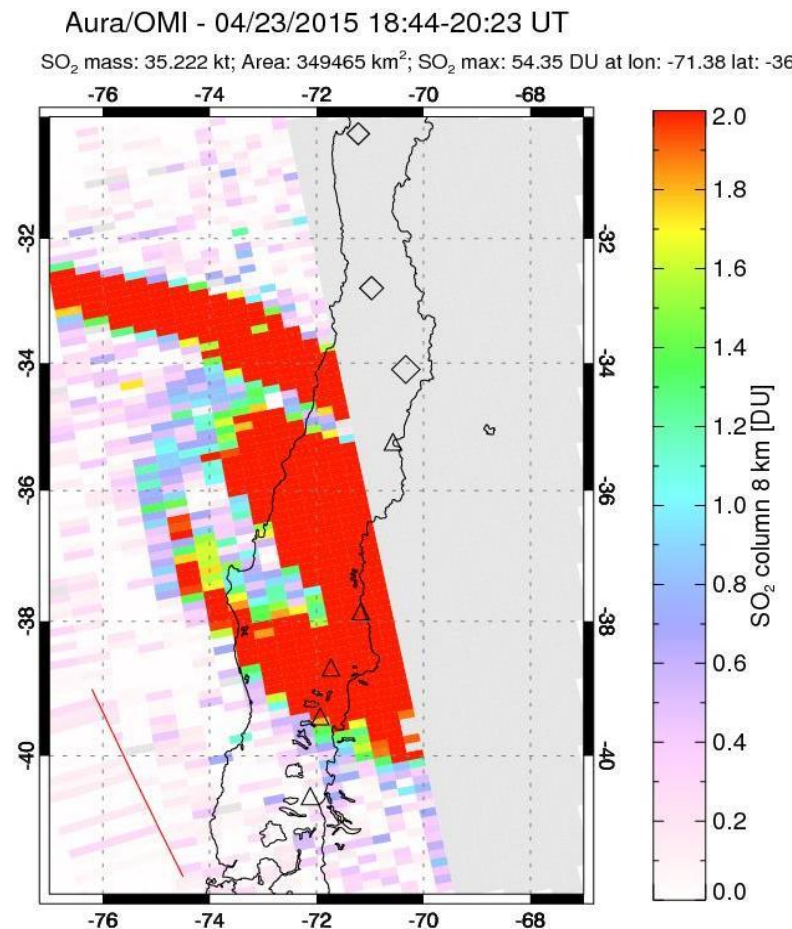
Stratospheric aerosol, OMPS LP



April 22, 2015, followed by two smaller eruptions on April 24 and April 30

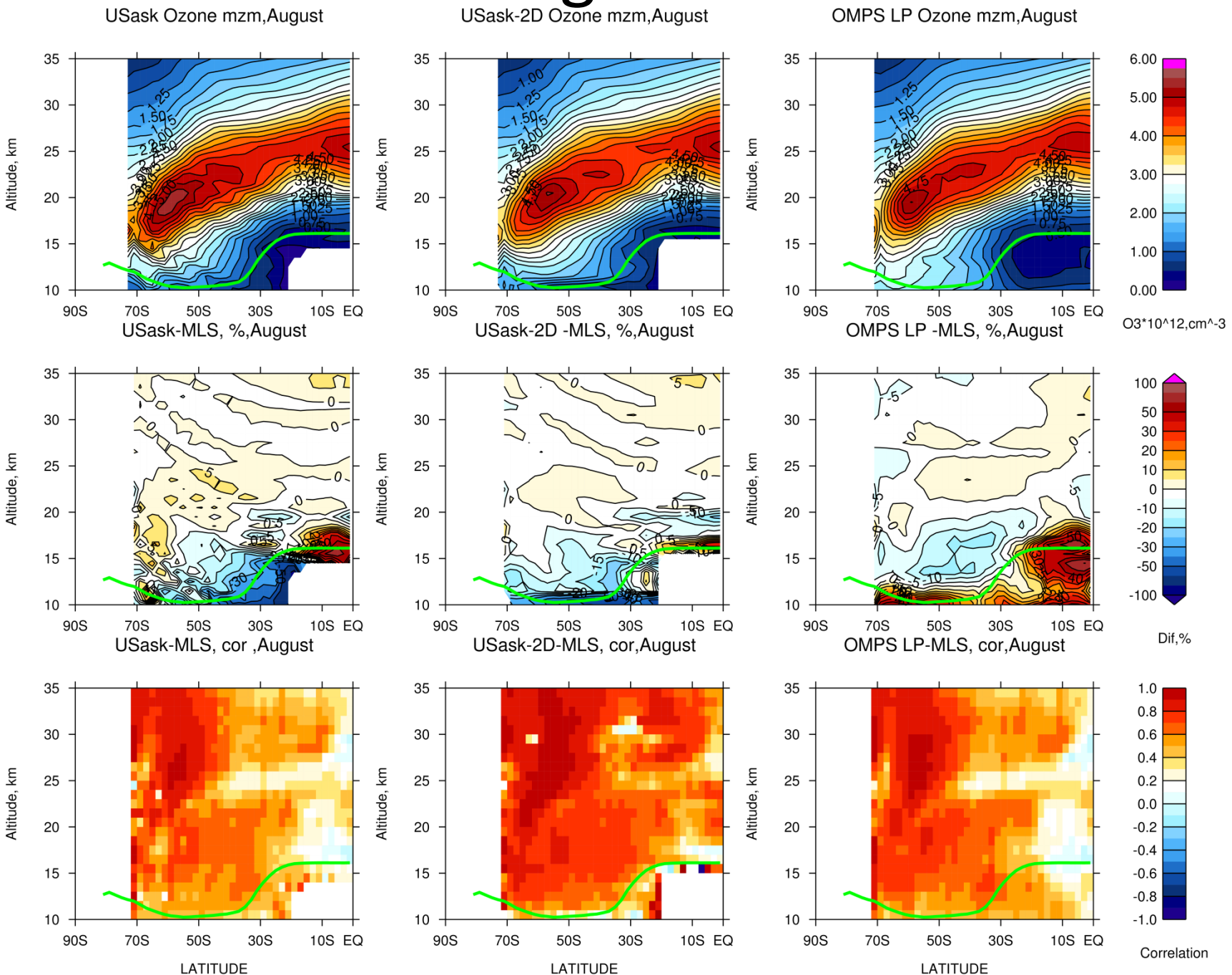
Zonal mean aerosol [50S,60S], OMPS LP



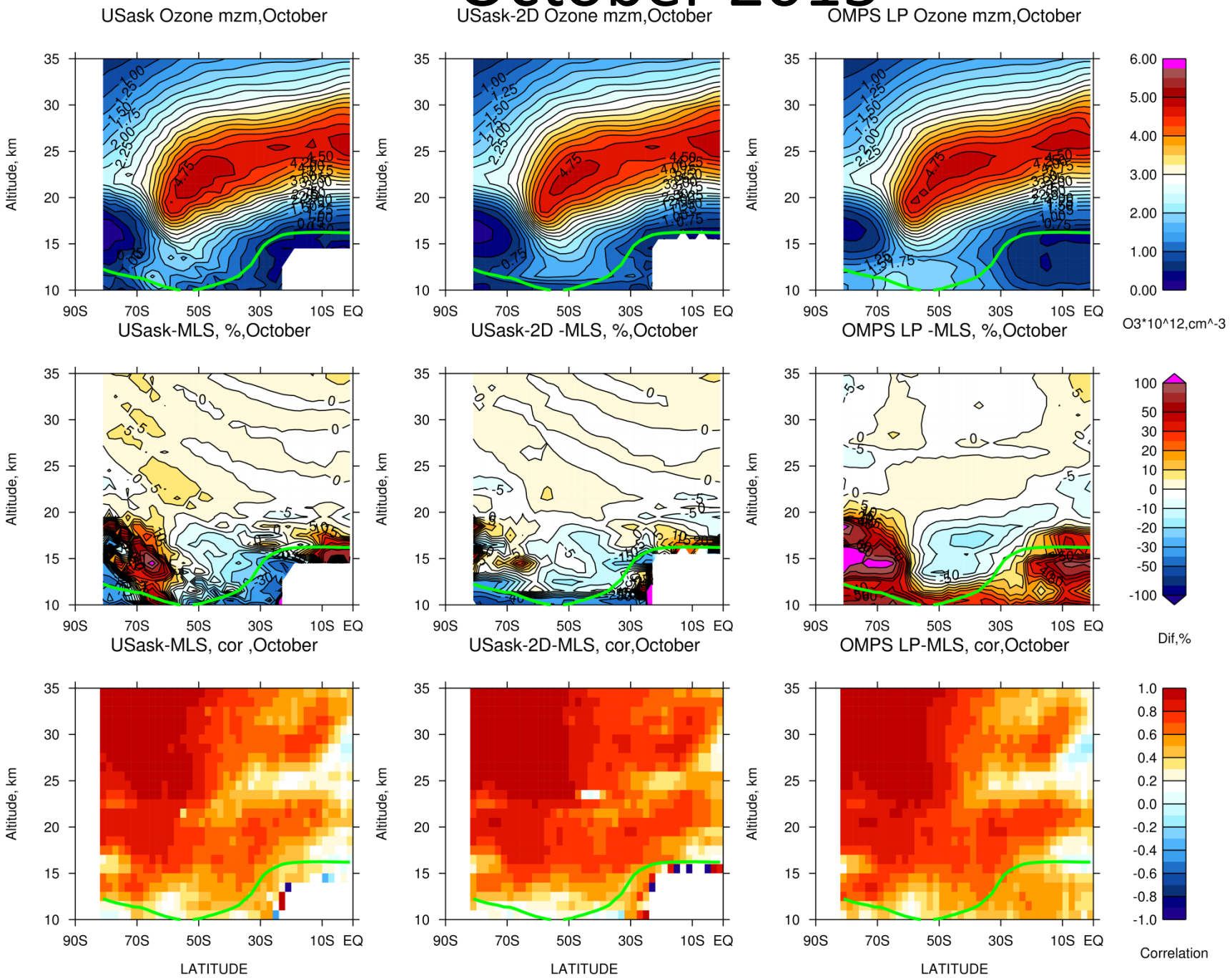


OMPS Science meeting, June 2, 2016

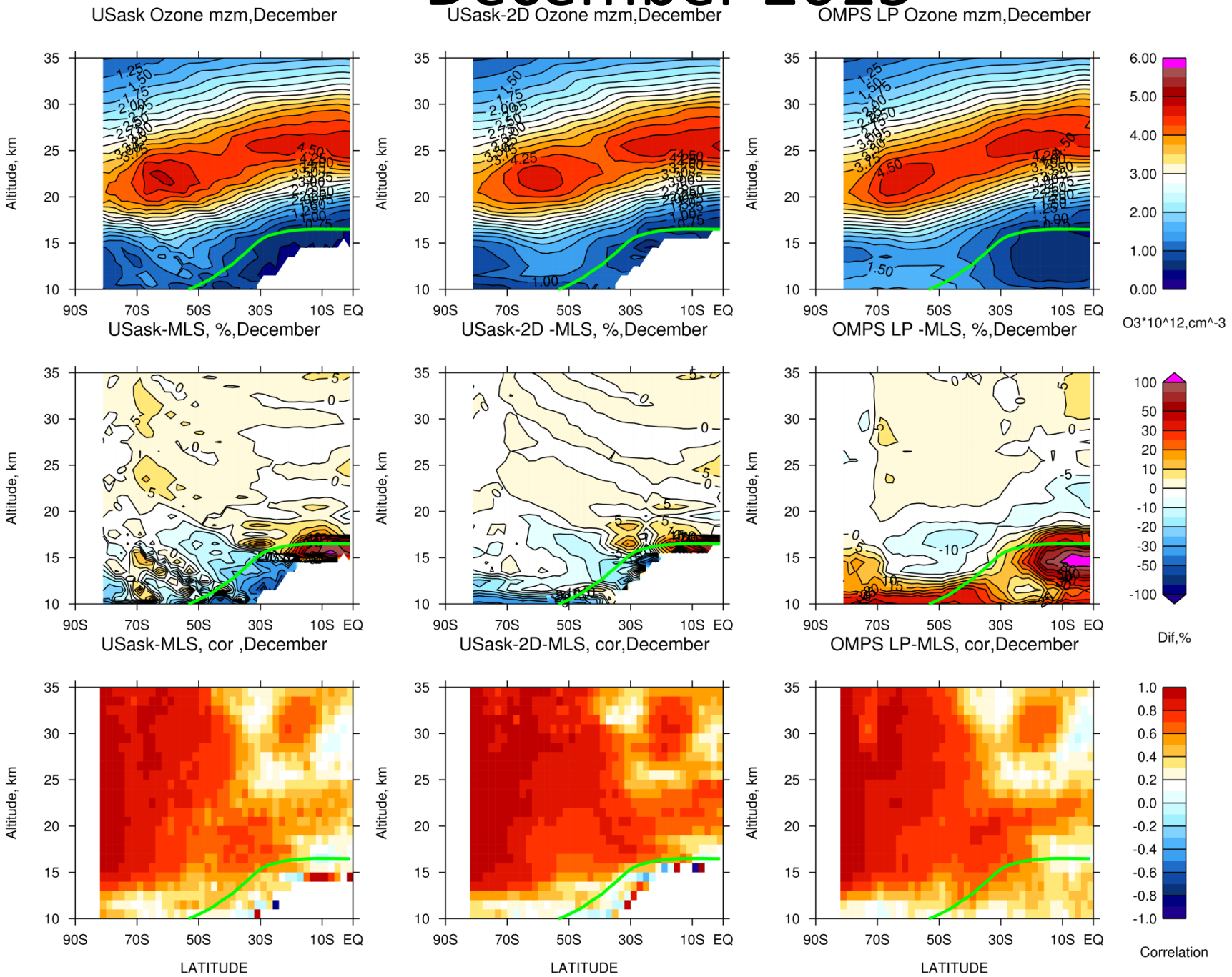
August 2015


USask Ozone mzm,August
USask-2D Ozone mzm,August
OMPS LP Ozone mzm,August
USask-MLS, %,August
USask-2D -MLS, %,August
OMPS LP -MLS, %,August
O3*10^12,cm^-3
USask-MLS, cor ,August
USask-2D-MLS, cor,August
OMPS LP-MLS, cor,August
Dif,%
Correlation
Altitude, km
LATITUDE
90S
70S
50S
30S
10S
EQ

October 2015

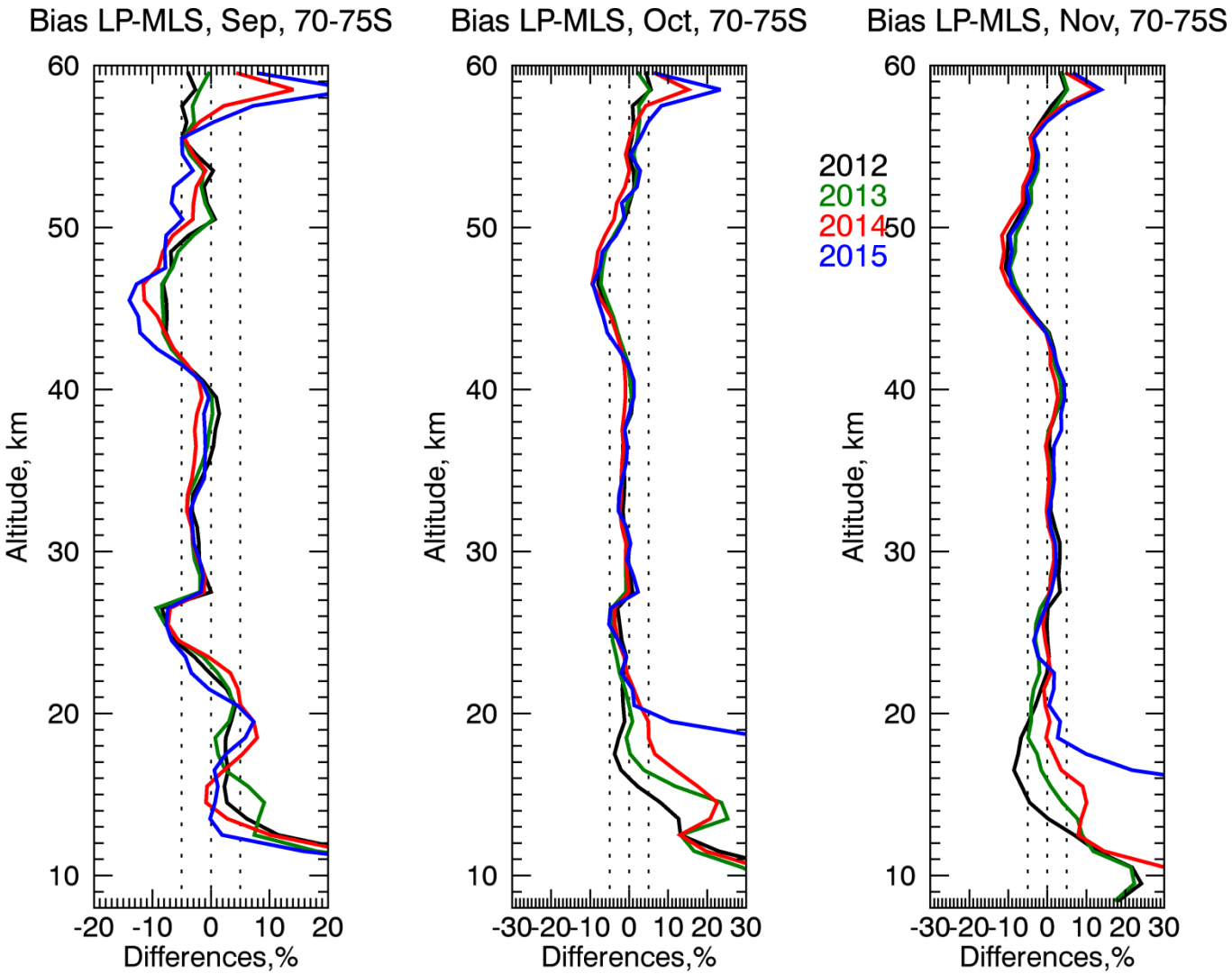


December 2015

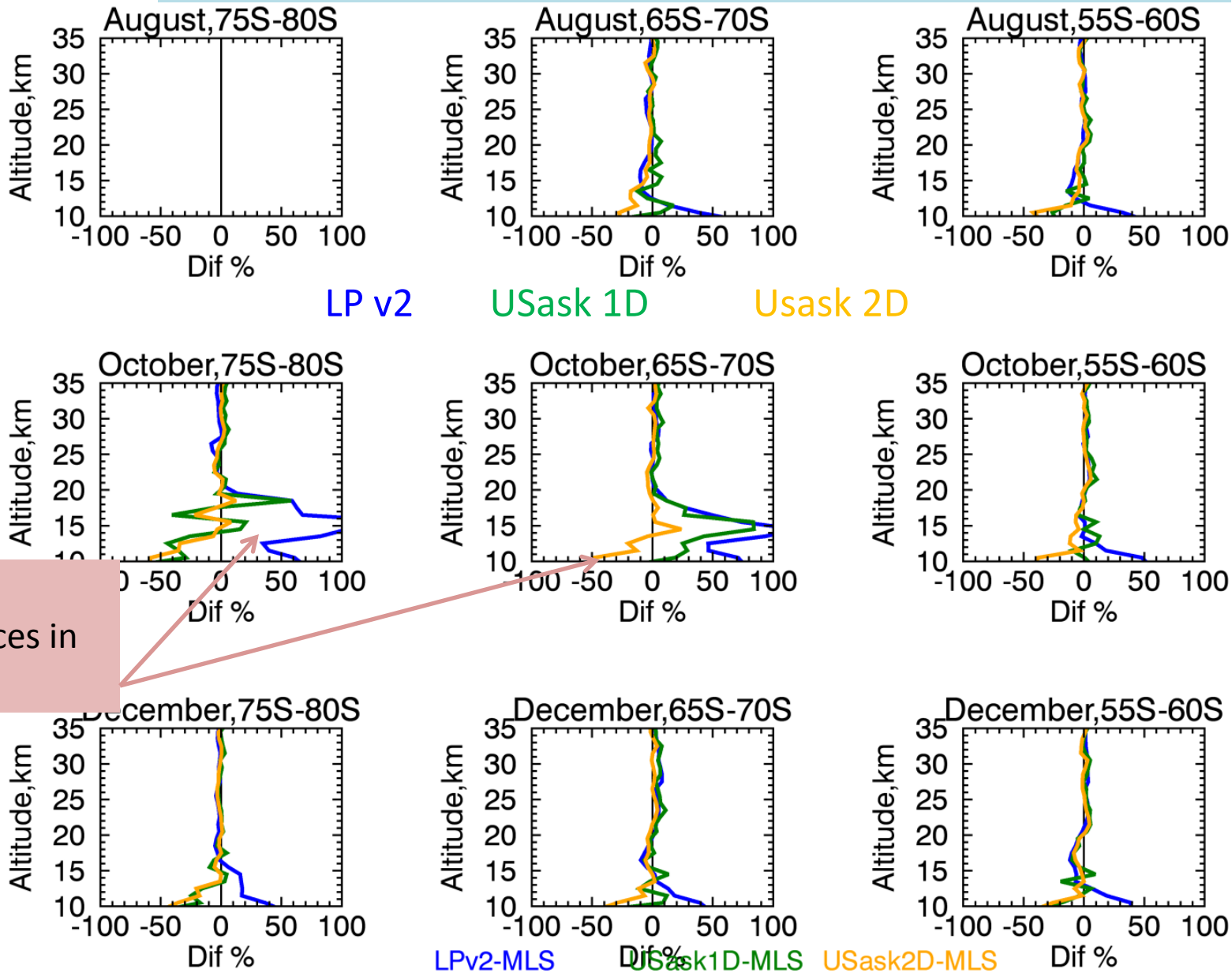


Zonal mean biases, LP v2-MLS v4

What did happen in 2015?

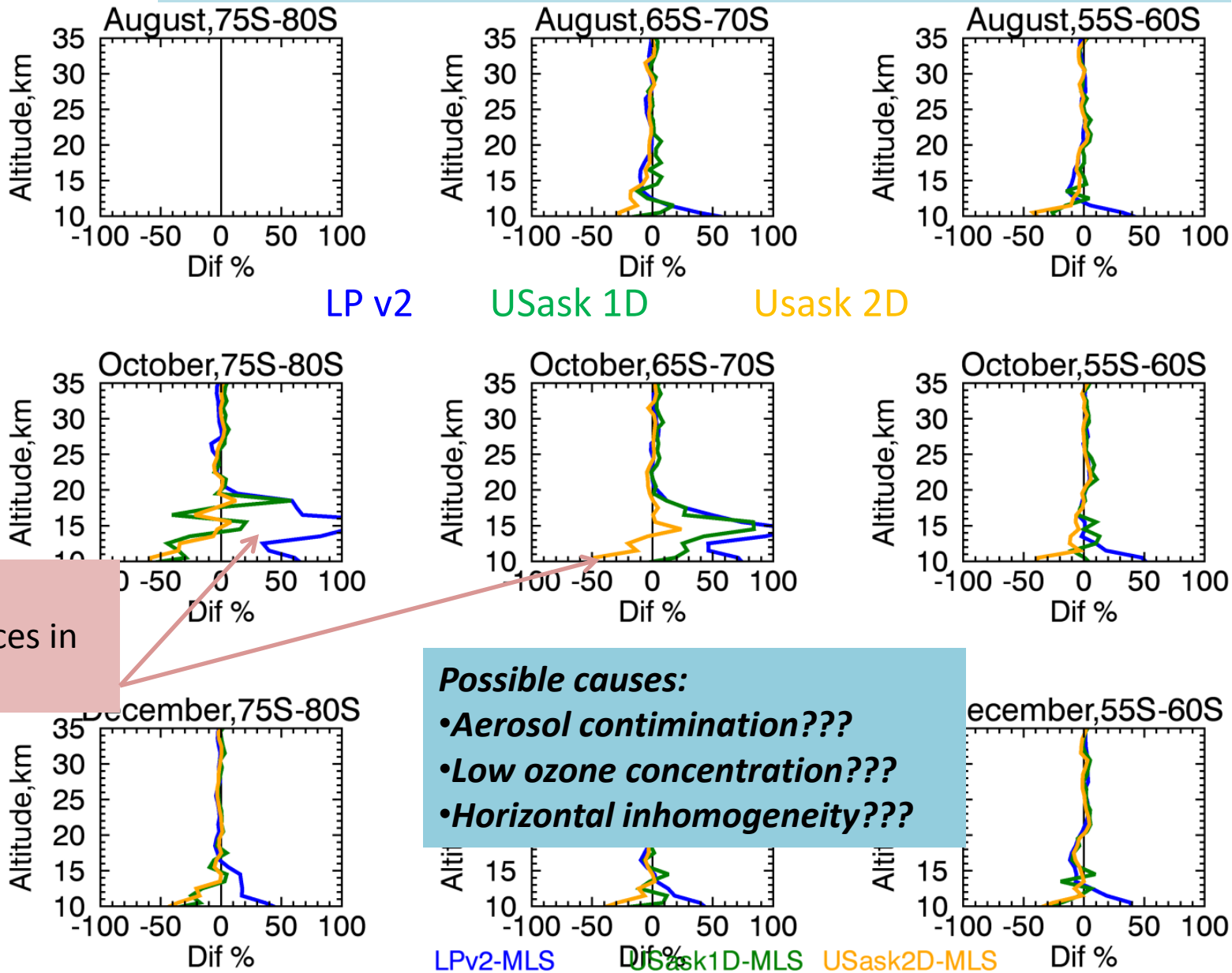


MZM differences relative to MLS in 2015



Larger differences in October

MZM differences relative to MLS in 2015



Larger differences in October

Possible causes:

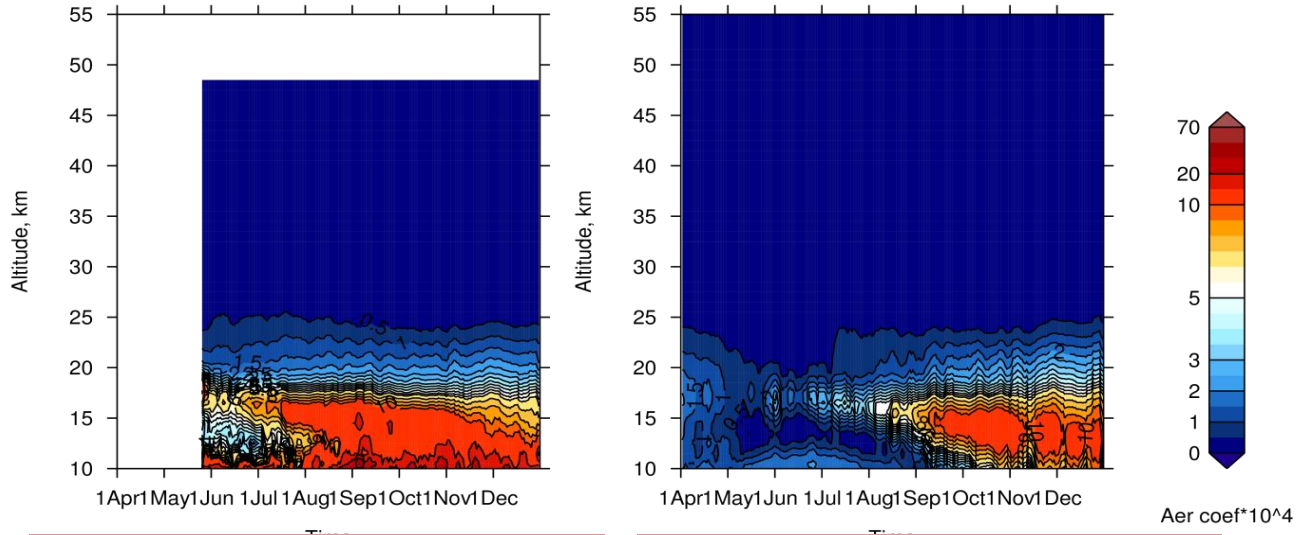
- ***Aerosol contimination???***
- ***Low ozone concentration???***
- ***Horizontal inhomogeneity???***

Could Calbuco aerosol affect LP O3 retrievals?

USask 2D aerosol, dzm, 55S

LP v0.5 aerosol, dzm, 55S

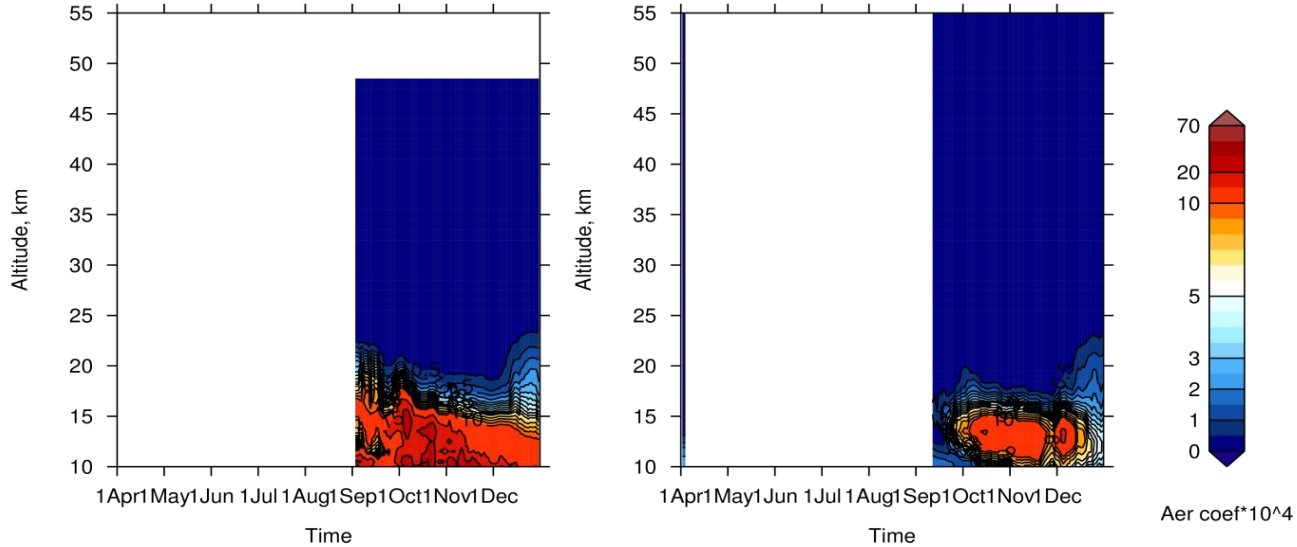
55 S



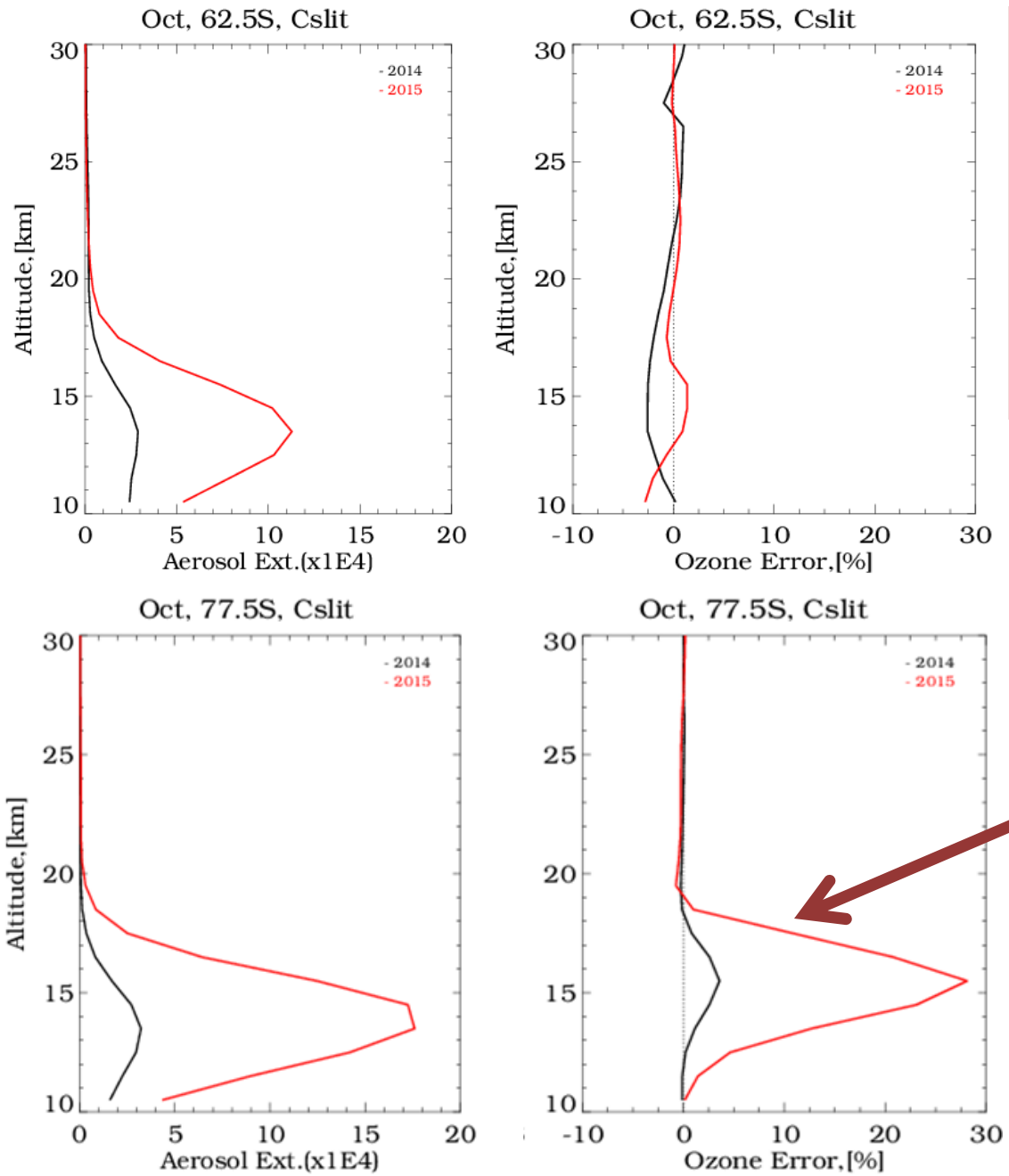
USask 2D aerosol, dzm, 75S

LP v0.5 aerosol, dzm, 75S

75 S

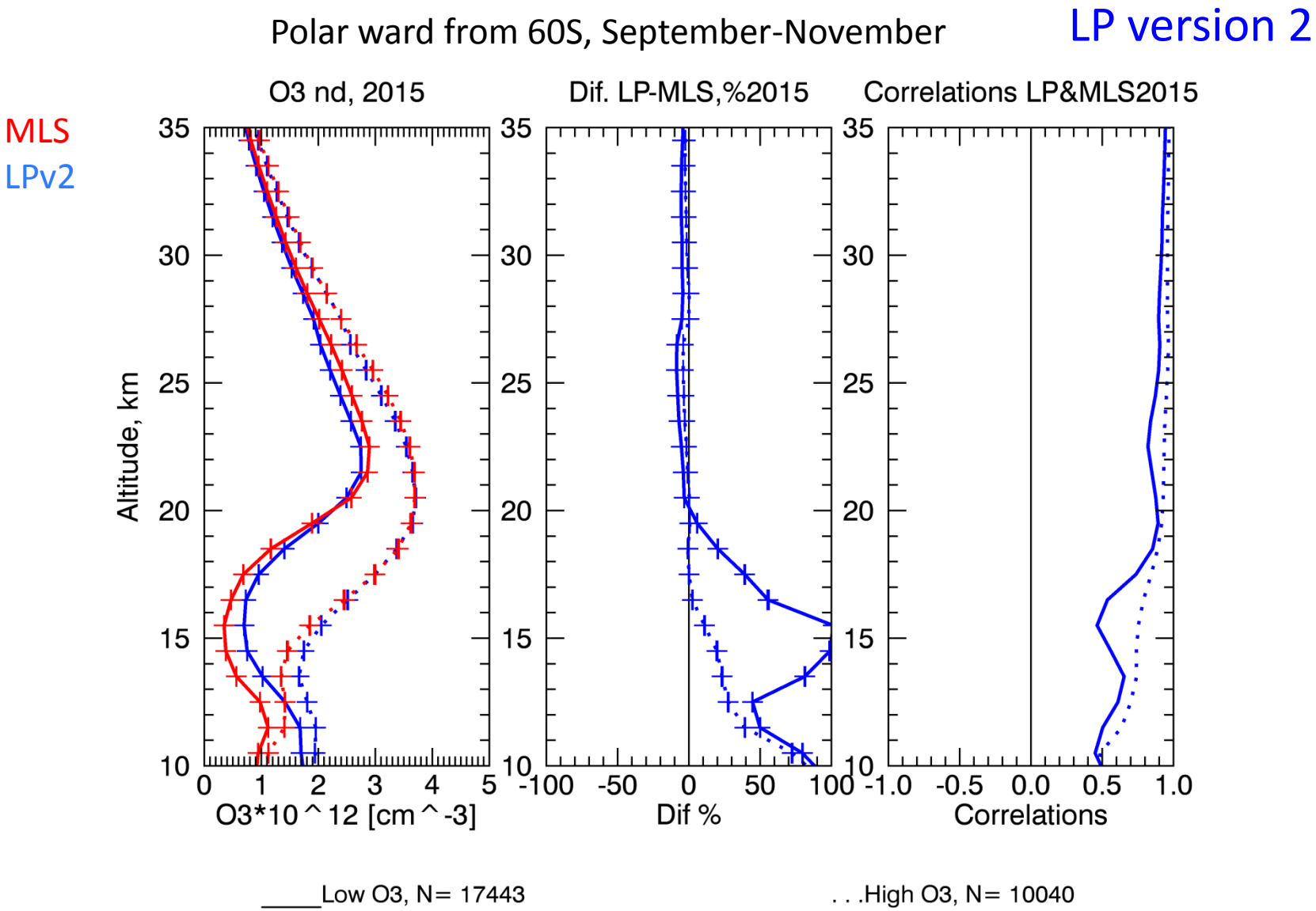


Theoretically estimated errors in O3 due to aerosol for mzm profiles



Up to 30% of error in mzm biases can be explained by the aerosol contamination

Differences (LP-MLS) as functions of ozone amount

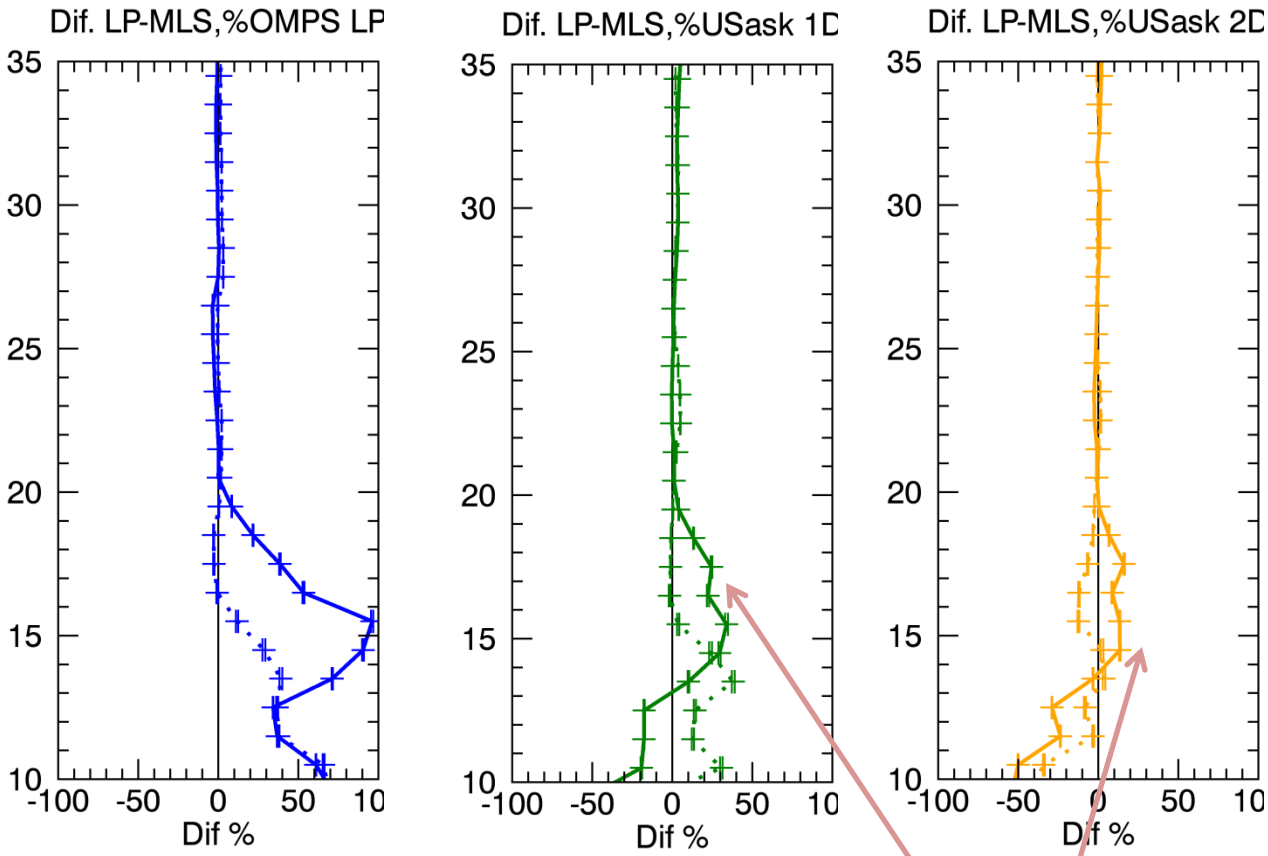


Differences (LP-MLS) as functions of ozone amount

Polarward from 60S, September-November

LPv2
Usask-1D
Usask-2D

___ Low O3
…….High O3

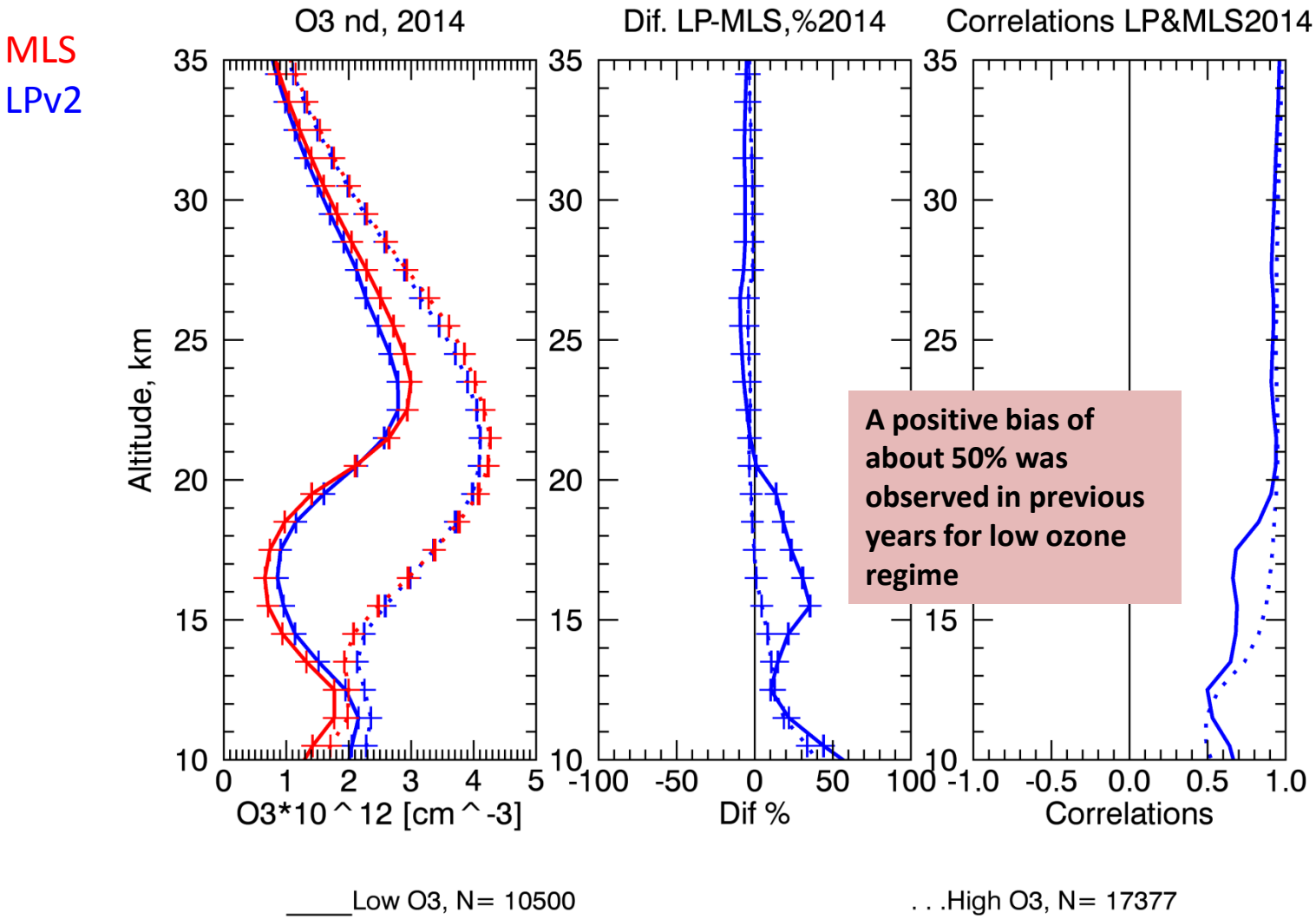


The aerosol correction, used in USask 1D and 2D, helps to significantly reduce ozone differences for low ozone regime

Differences (LP-MLS) as functions of ozone amount in 2014

Polar ward from 60S, September-November

LP version 2

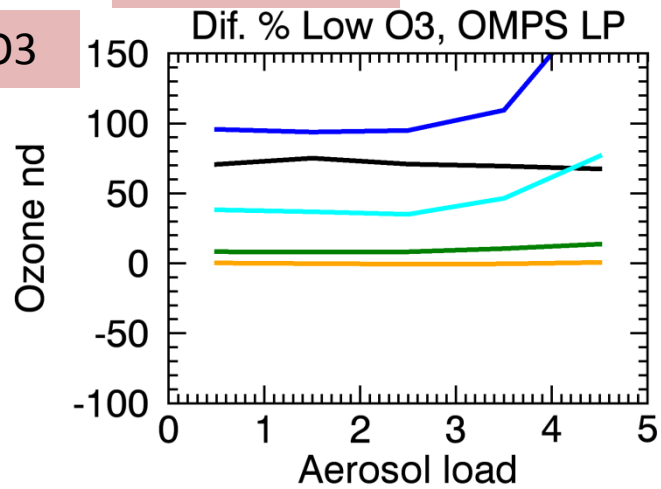


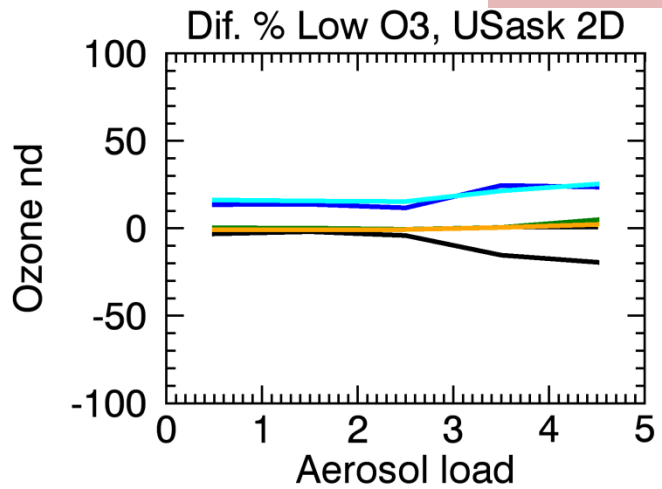
Sensitivity to aerosol, 2015

OMPS LP v2

USask 2D

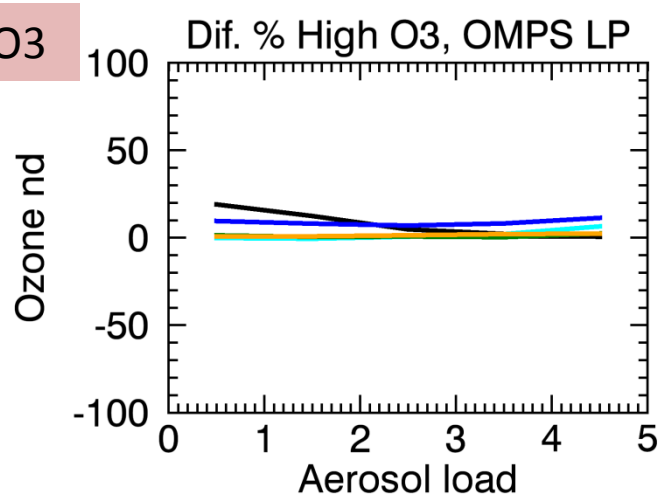
Low O3

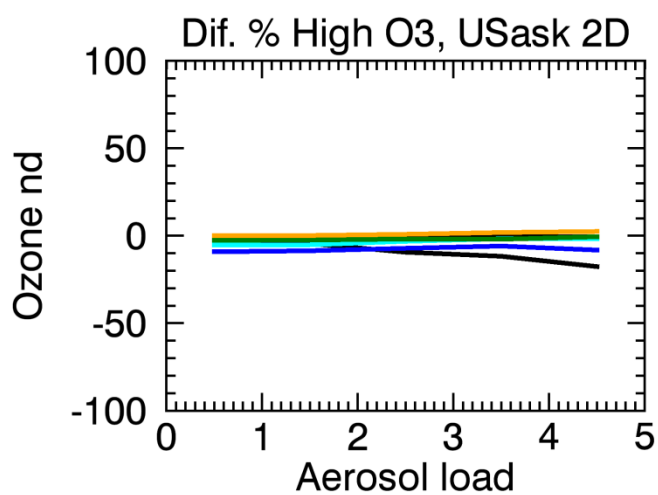




13 km 15 km 17 km 19km 21km

High O3





Aerosol load:

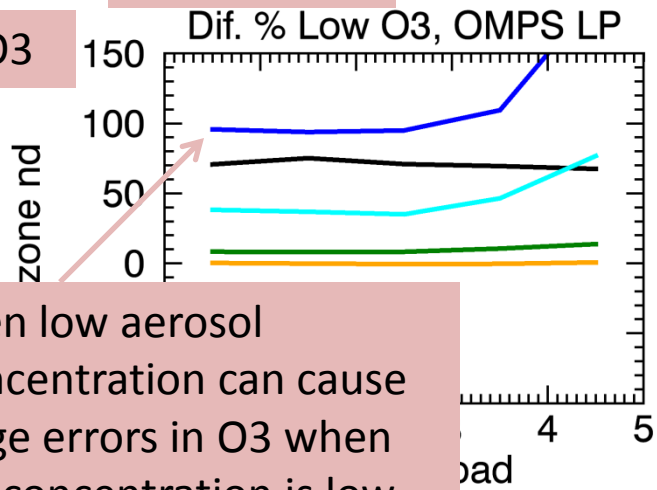
1 [less than 3*1.e-4]
2 [3*1.e-4;6*1.e-4]
3 [6*1.e-4;9*1.e-4]
4 [9*1.e-4;12*1.e-4]
5 [>12*1.e-4]

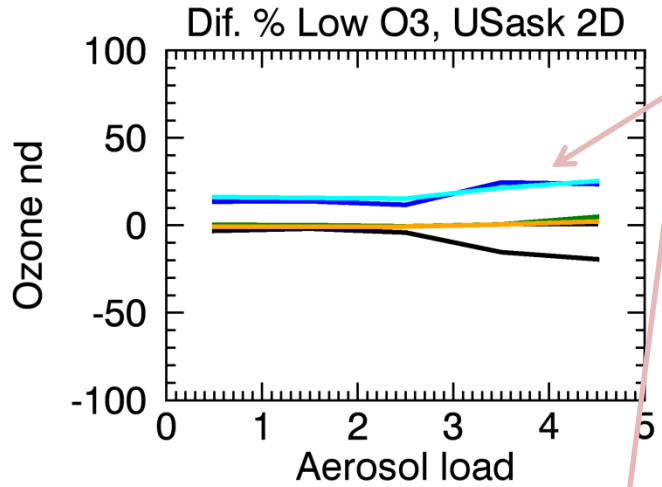
Sensitivity to aerosol

OMPS LP v2

USask 2D

Low O3



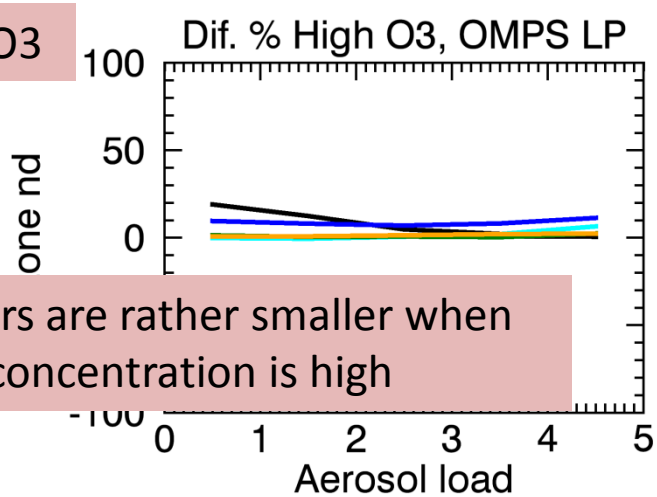


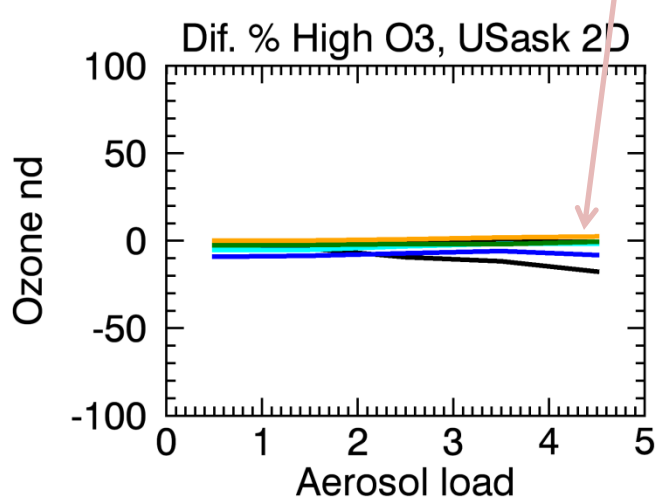
USask aerosol correction works very well

Even low aerosol concentration can cause large errors in O3 when O3 concentration is low

13 km 15 km 17 km 19km 21km

High O3



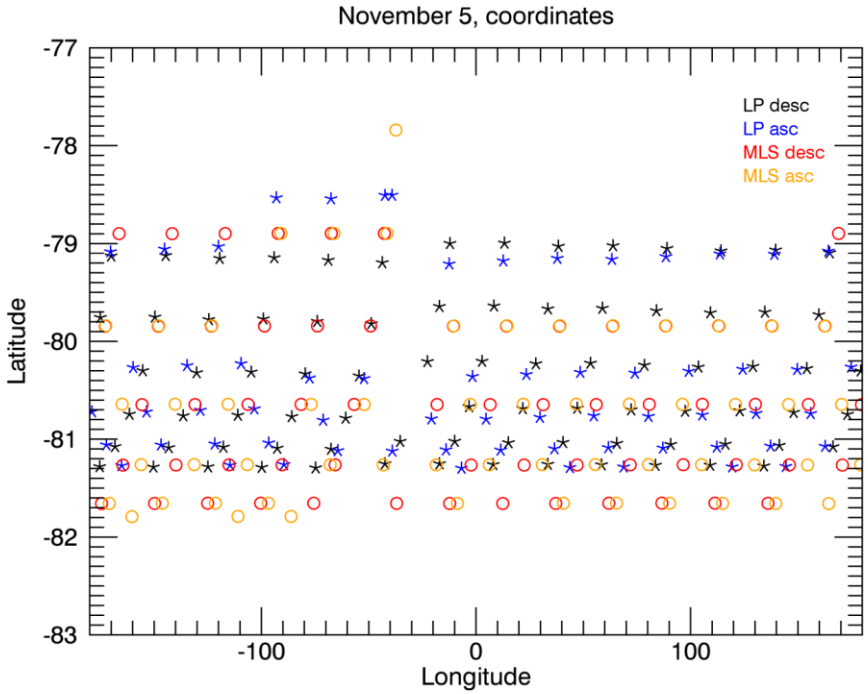


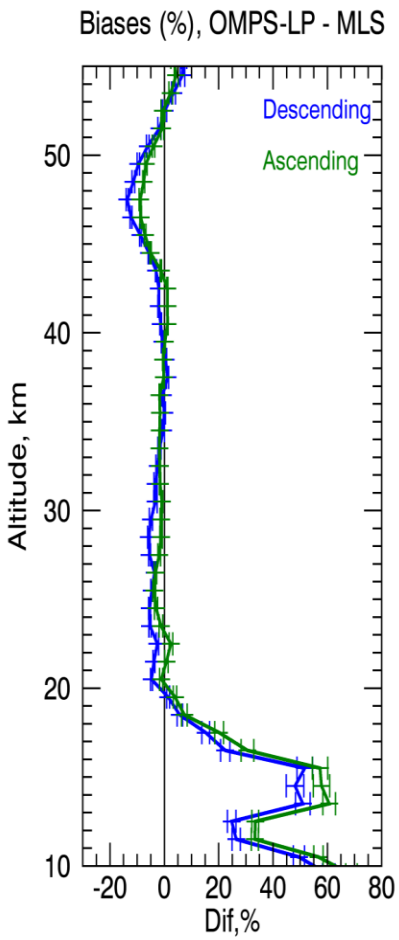
Errors are rather smaller when O3 concentration is high

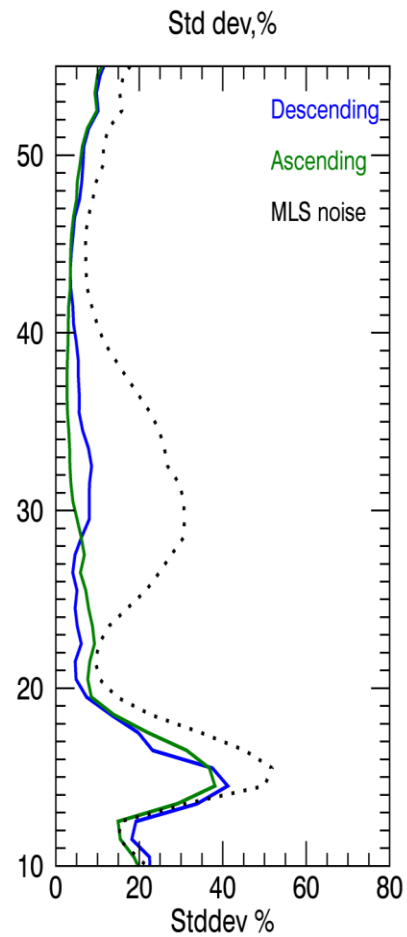
Aerosol load:

1 [less than 3*1.e-4]
2 [3*1.e-4;6*1.e-4]
3 [6*1.e-4;9*1.e-4]
4 [9*1.e-4;12*1.e-4]
5 [>12*1.e-4]

Can we isolate errors in LP retrievals due to negligence of horizontal inhomogeneity (2D effect)



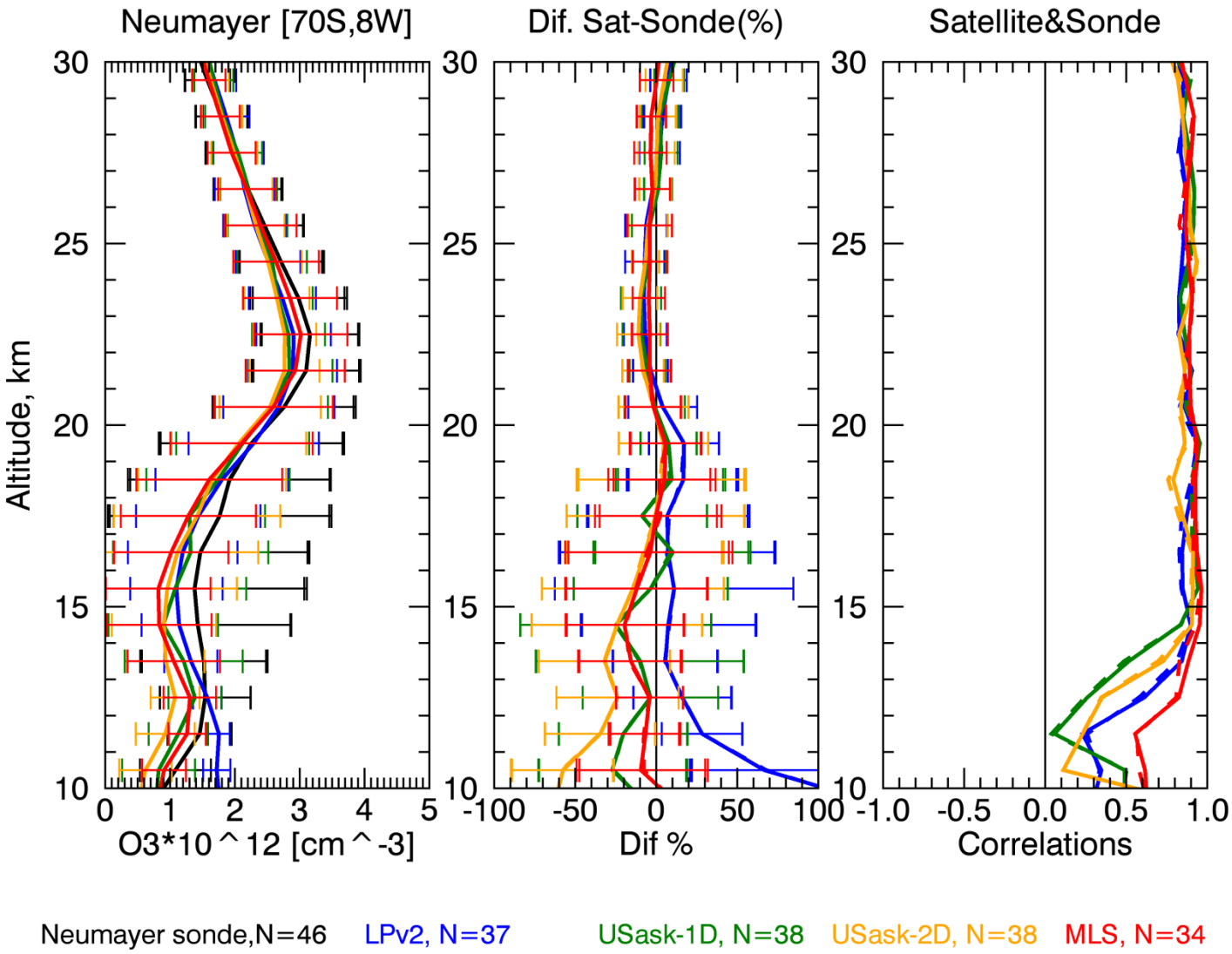


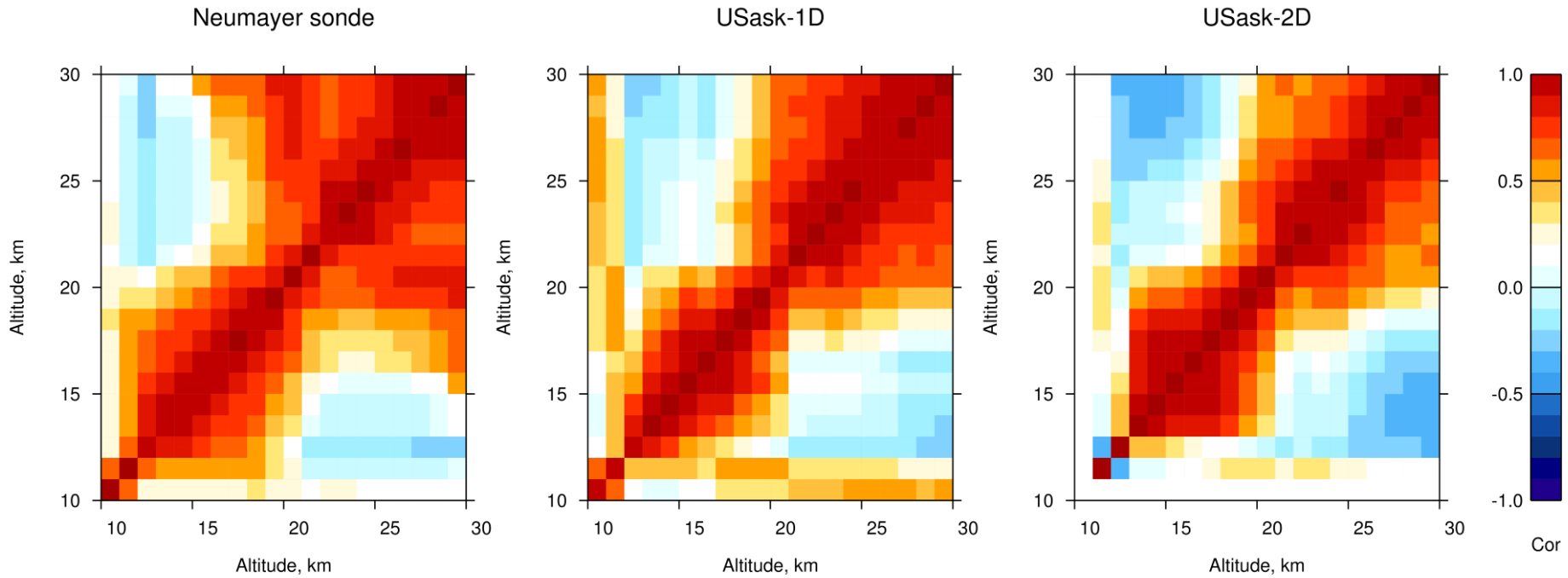


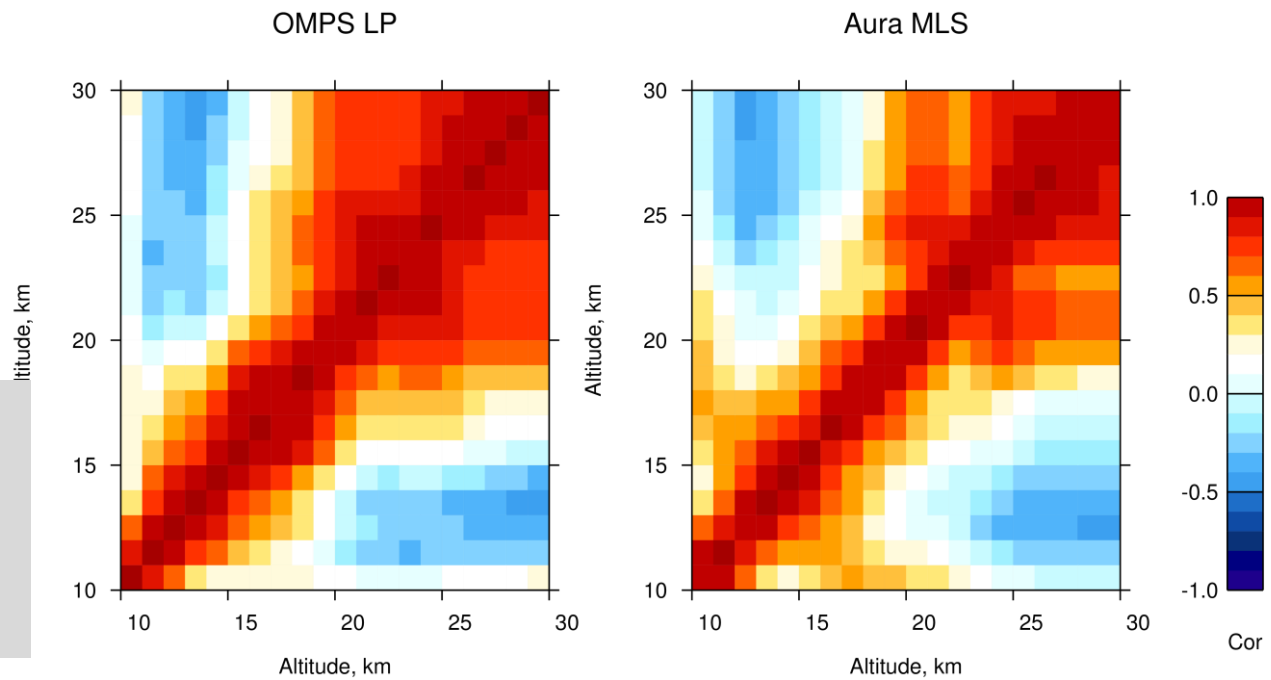
There is no statistically significant differences between LP v2 ascending and descending retrievals that can directly link the error in O3 to the ignorance of horizontal inhomogeneity

Comparisons against Neumayer sonde observations

August-December 2015





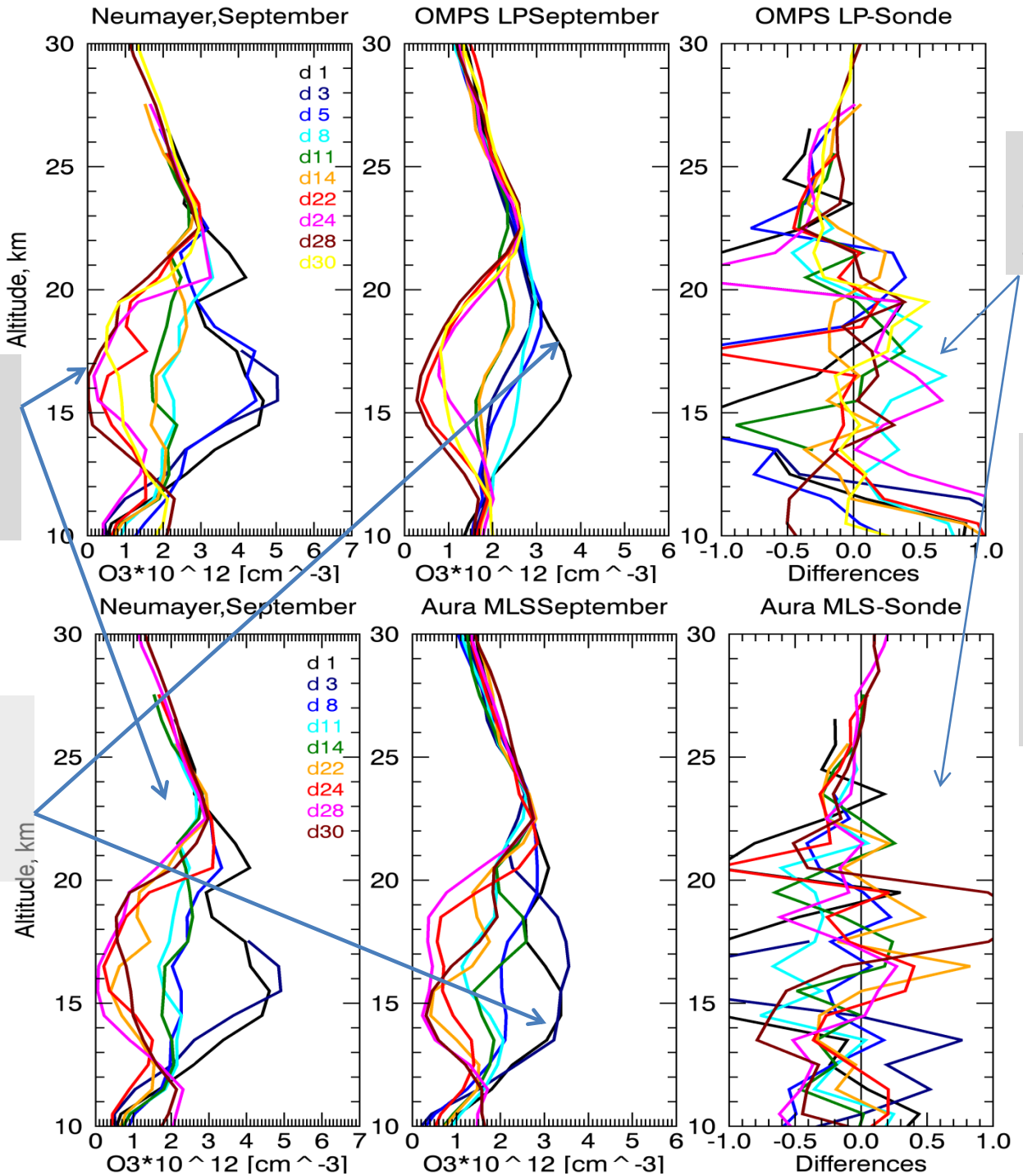


Inter-level correlations calculated independently for each instrument

All instruments/algorithms show clear definition between dynamically driven layers > 21 km and photochemically controlled 12-20 km

Conclusions

- Three independent limb algorithms has been tested over SH in 2015. We found that all retrievals agree within +/-10% down to 15 km in mid- and high southern latitudes, except for the time period Sep-Nov;
- In September-November differences between algorithms (as well as differences against MLS) substantially increase between 15-20 km over the region polarward from 60S;
- Analysis of differences against MLS revealed a strong dependence on the ozone concentration. All LP retrieval algorithms show positive biases against MLS when ozone concentration is low (depleted O3 profiles) with smaller biases for USask algorithms which explicitly account for the aerosol contamination in the O3 algorithms;
- Significant fraction of the O3 errors in NASA OMPS-LP v2 retrievals can be corrected by including the aerosol correction in the retrieval algorithm



Individual sonde measurements in September

Differences for each satellite-sonde pair

Vertical structures in differences are mostly due to a lot of structures in sonde profiles

Corresponding satellite matches (LPv2&MLS)