Analysis Methods in Atmospheric and Oceanic Science

AOSC 652

Getting to know FORTRAN:
Input/Output, Data Sorting, Simple Statistics
Day 3

- **Review Assignment 3**
- **General help with Assignments 4a & 4b**

AOSC 652: Analysis Methods in AOSC

Programming suggestions:

When commenting subroutines good to indicate input variables, output variables, and reference for the code, i.e.:

```
      subroutine bilinear(y_out,t,u,y1,y2,y3,y4)
C
C  Bilinear interpolation based on Eqn (3.6.5) of Numerical Recipes by Press et al.
C
C  Input   t   Location of x value mapped into the range 0,1
C           u   Location of y value mapped into the range 0,1
C         y1  Input value of field.
C         y2  Input value of field.
C         y3  Input value of field.
C         y4  Input value of field.
C  Output   y_out  , interpolated value.

      y_out = (  1. – t )  * ( 1. – u )    * y1 +
     +              t         * ( 1. – u )    * y2 +
     +              t         *   u           * y3 +
     +           (  1. – t )  *   u           * y4
      return
      end
```

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Source of routine exceedingly helpful

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      return
      end
```

Please use 1. rather than 1 for floating point operations.

1 will not work w/ some compilers

AOSC 652: Analysis Methods in AOSC

Programming suggestions:

If you end up writing code for a living, it will be essential to develop a comment "style" that works for you

```
      subroutine bilinear(y out,t,u,y1,y2,y3,y4)
C*****************************************************************************
C       Below is the bilinear interpolation calculation. This interpolates the
C       ozone at a point by using known values on a fixed grid around this
C       point.
C
C                       x1----Y1--------x2
C                       |     |         |
C                       |     P         |
C                       |     |         |
C                       |     |         |
C                       |     |         |
C                       |     |         |
C                       x3----Y2--------x4
C       Linear interpolation is done between x1-x2 and between x3-x4 to get the
C       values of Y1 and Y2.  Then, linear interpolation is done again in the
C       vertical between Y1 and Y2 to get a value for point P.
C*****************************************************************************
      y_out=((1-t)*(1-u)*y1)+(t*(1-u)*y2)+(t*u*y3)+((1-t)*u*y4)

      return
      end
```

AOSC 652: Analysis Methods in AOSC

Programming suggestions:

If you end up writing code for a living, it will be essential to develop a comment "style" that works for you

```
      subroutine limfnd(xpt,xarray,npt,ilow,iupp)
C
C    This code determines whether xpt is within the limits.
C    If so, call hunt.  Otherwise, tell the user it is out of bounds and quit
C
```

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Which variables are input, which are output ?

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Which variables are input, which are output ?

What is meaning of ilow & iupp ?

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Which variables are input, which are output ?

What is meaning of ilow & iupp ?

What key assumption about the arrays lat & lon is critical for the successful execution of this code ?

AOSC 652: Analysis Methods in AOSC

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C
C   This code determines whether xpt is within the limits.
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C
C   Input variables:
C         xpt : scalar
C         xarray : array
C         npt : dimension of xarray
C   Output variables:
C         ilow & iupp
C       Values of ilow & iupp are determined
C       such that xarray(ilow) < xpt < xarray(iupp); if this condition
C       can not be satisified, ilow & iupp either are set to 0 or npt
```

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C         such that xarray(ilow) < xpt < xarray(iupp); if this condition
C         can not be satisified, ilow & iupp either are set to 0 or npt
C
C    Note: due to conditions of subroutine hunt, xarray must be either
C          monotonically increasing or monotonically decreasing
```

AOSC 652: Analysis Methods in AOSC

Programming suggestions, continued:

We had a block of code that finds a value of total ozone for a specified date, latitude, and longitude:

Best to place “loop structure” around this code to minimize user input rather than having to type info over and over

7 out of 15 students implemented a looping structure

Hopefully everyone will soon be comfortable enough in FORTRAN to let the computer do the work for you!

AOSC 652: Analysis Methods in AOSC

```
      write(6,700)
700   format('Enter start date  (YYYYMMDD) ... 99999999 to end : ',$)
      read(5,*)cdate
702   format(A)
      if(cdate.eq.'99999999') goto 999
      read(cdate,'(I8)')startdate

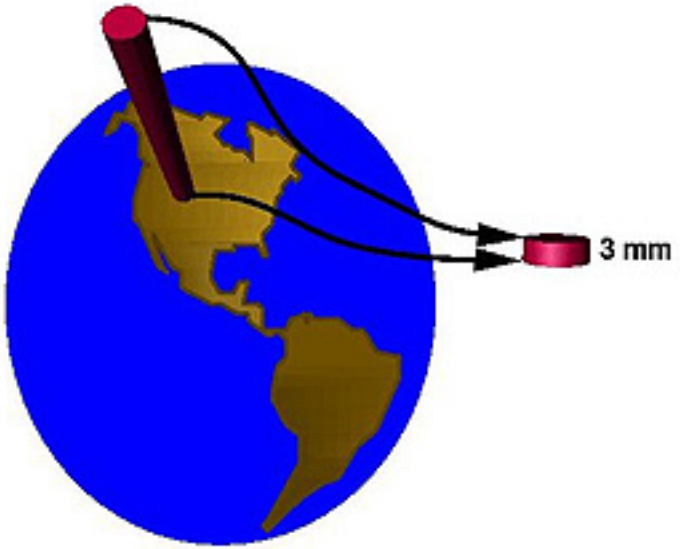
      write(6,705)
705   format('Enter end date (YYYYMMDD) : ', $)
      read(5,*)enddate
```

-
-
-

```
 write(98,799)cdate(7:8),cdate(3:8),ozonept
 if (startdate.lt.enddate) then
      startdate=startdate+1
      write(cdate,'(I8)') startdate
      goto 707
else
     close(unit=98)
     goto 999
endif
```

AOSC 652: Analysis Methods in AOSC

Dobson Units

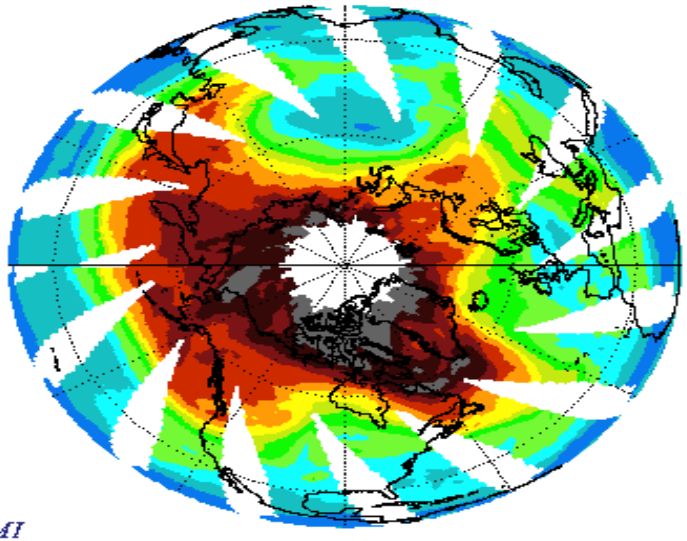


- Bring all ozone above a certain location down to the ground, at $0^{o}C$ and 1 atmosphere pressure.
- The thickness of this layer is about 3 millimeters (~ 0.1 inch), the thickness of two stacked pennies. This corresponds to 300 Dobson Units (approximately the global average).
- 100 Dobson Units is 1 millimeter thick (approximately the thickness of ozone in the Antarctic ozone

☛ The Dobson Unit is a convenient unit of measurement for total column ozone.

http://www.ccpo.odu.edu/SEES/ozone/class/Chap_3/index.htm

OMI Total Ozone for Mar 13, 2016



NIVR–FMI–NASA–KNMI

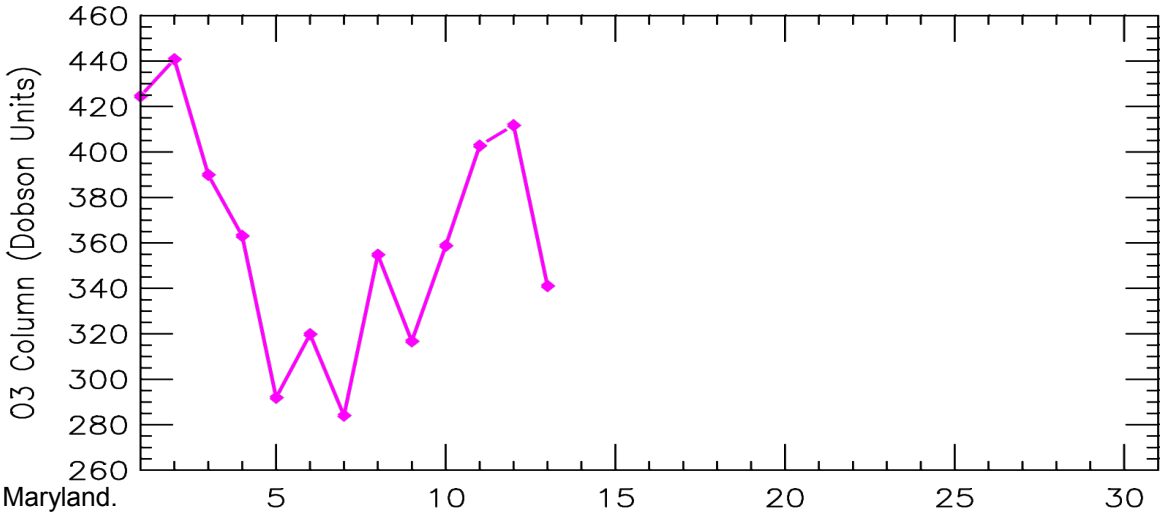
OMI

Dobson Units

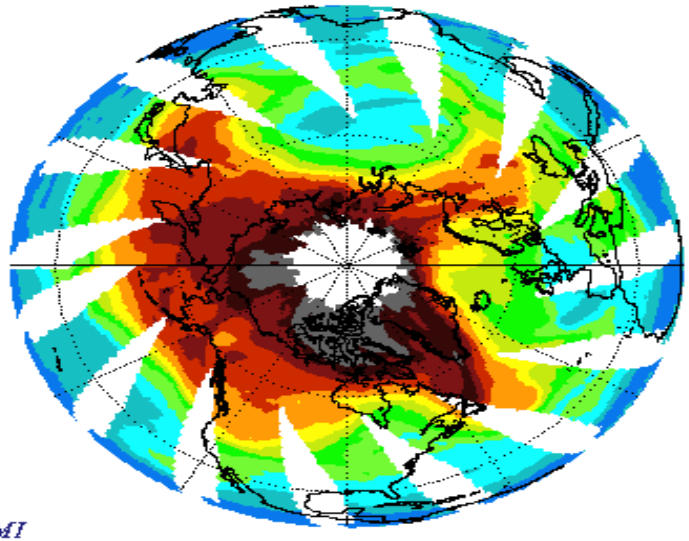
Dark Gray < 100 and > 500 DU

GSFC

Daily Ozone for Reykjavik
64.13 N, 21.82 W
March 2016



OMI Total Ozone for Mar 14, 2016



NIVR–FMI–NASA–KNMI

OMI

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Daily Ozone for Reykjavik
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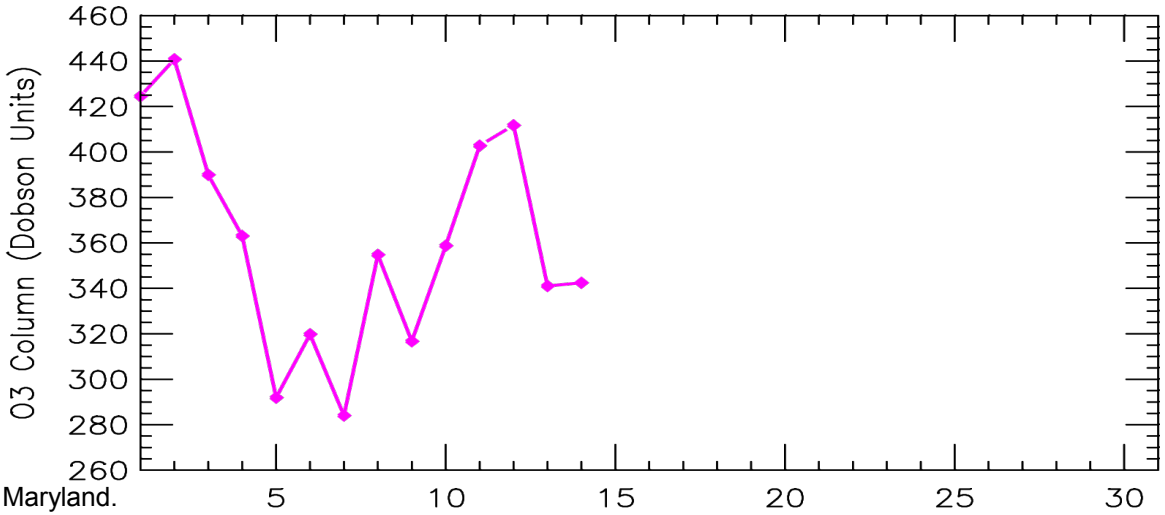
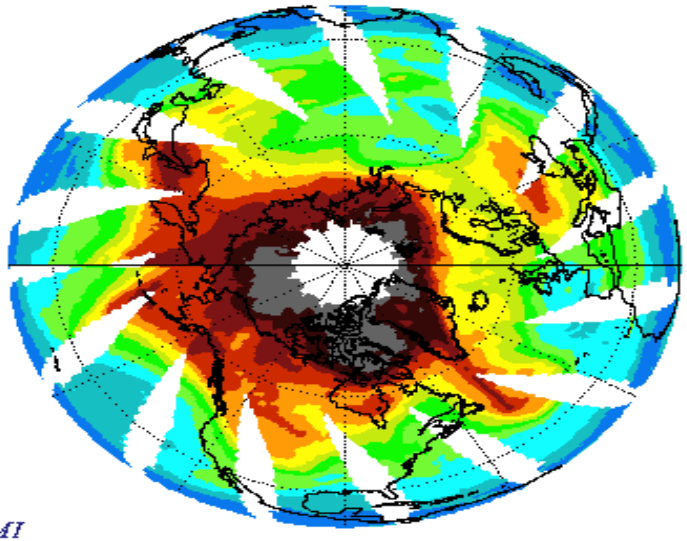
March 2016



OMI Total Ozone for Mar 15, 2016



NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

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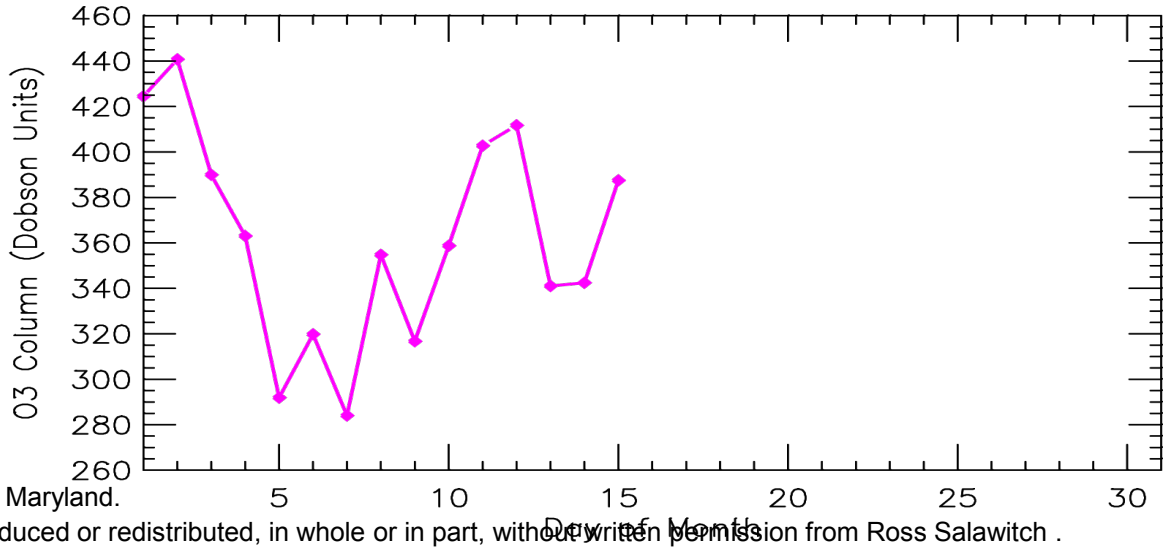
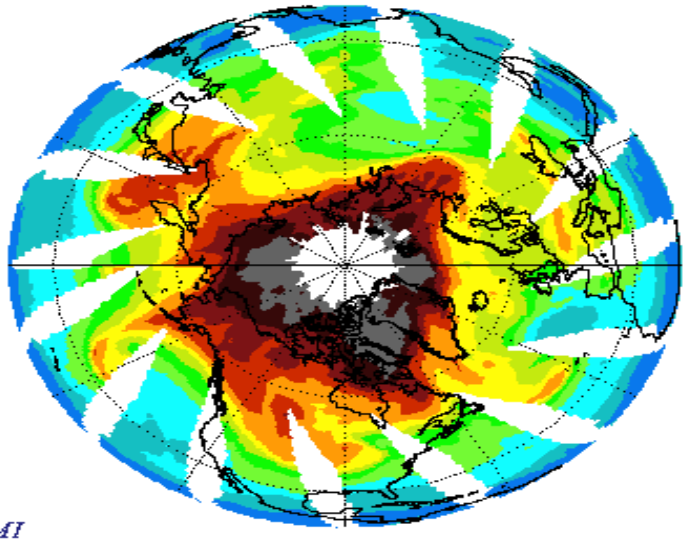
NASA

Daily Ozone for Reykjavik
64.13 N, 21.82 W
March 2016



OMI Total Ozone for Mar 16, 2016



NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

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Daily Ozone for Reykjavik
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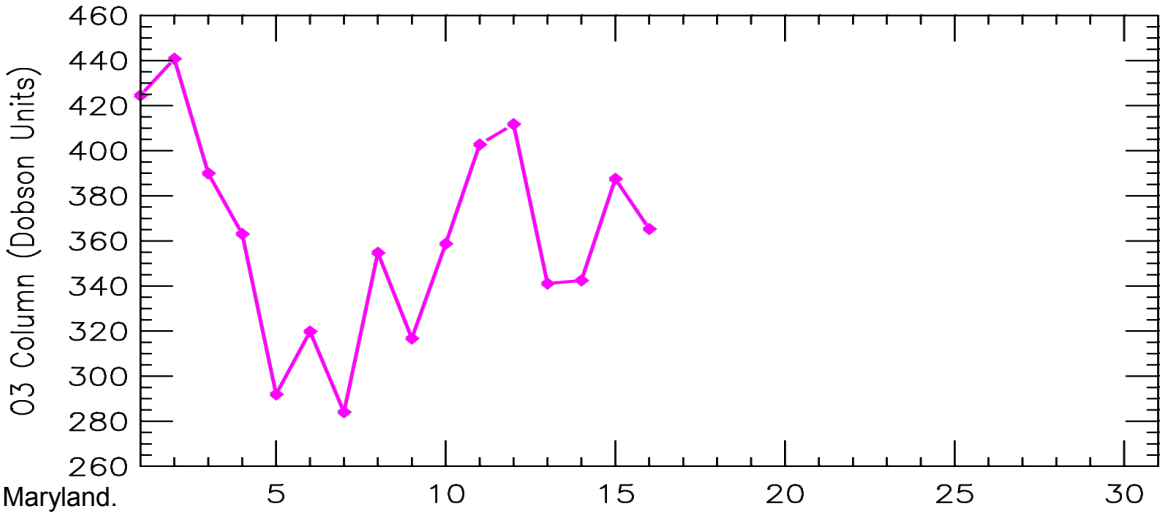
March 2016



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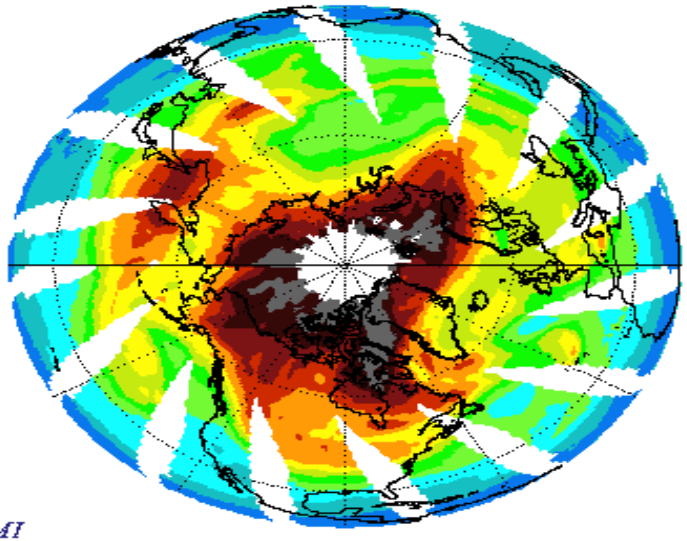

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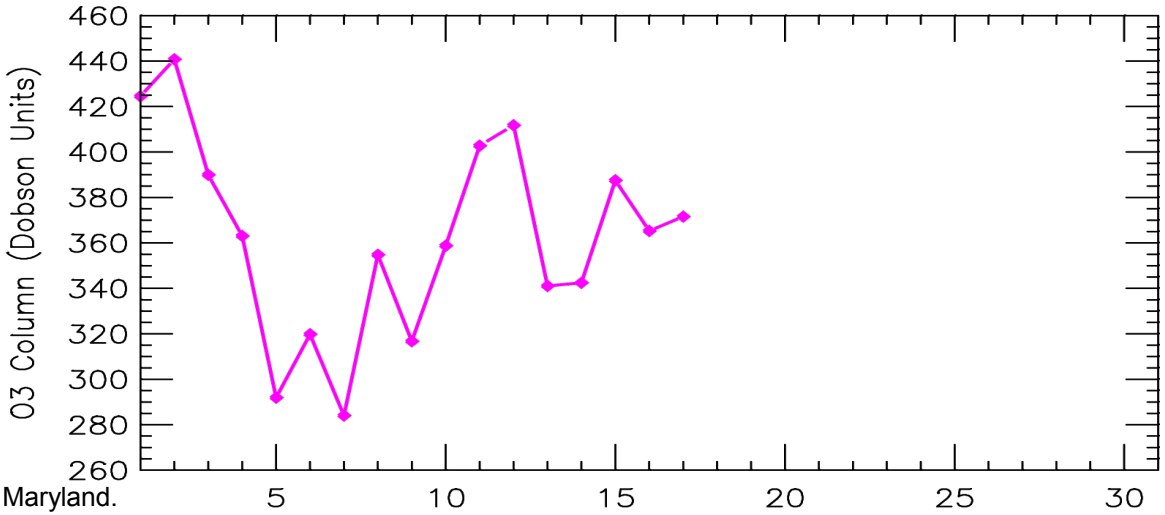
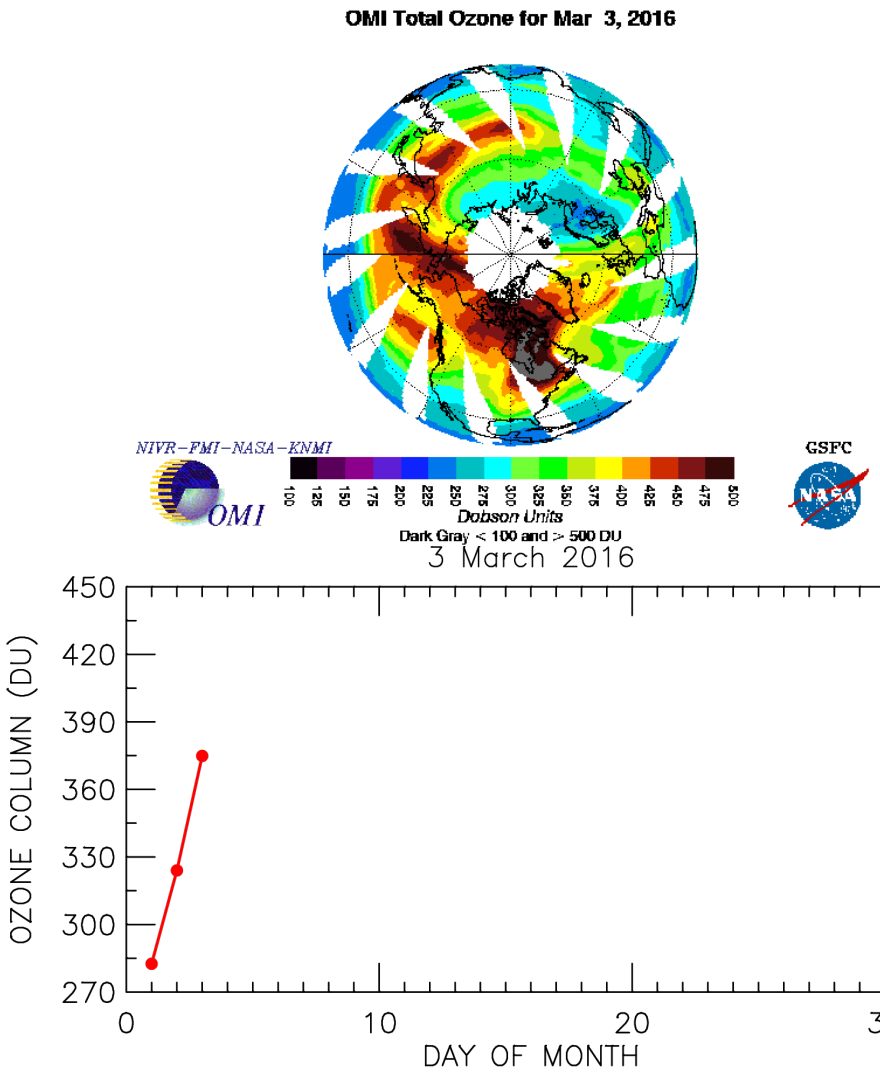
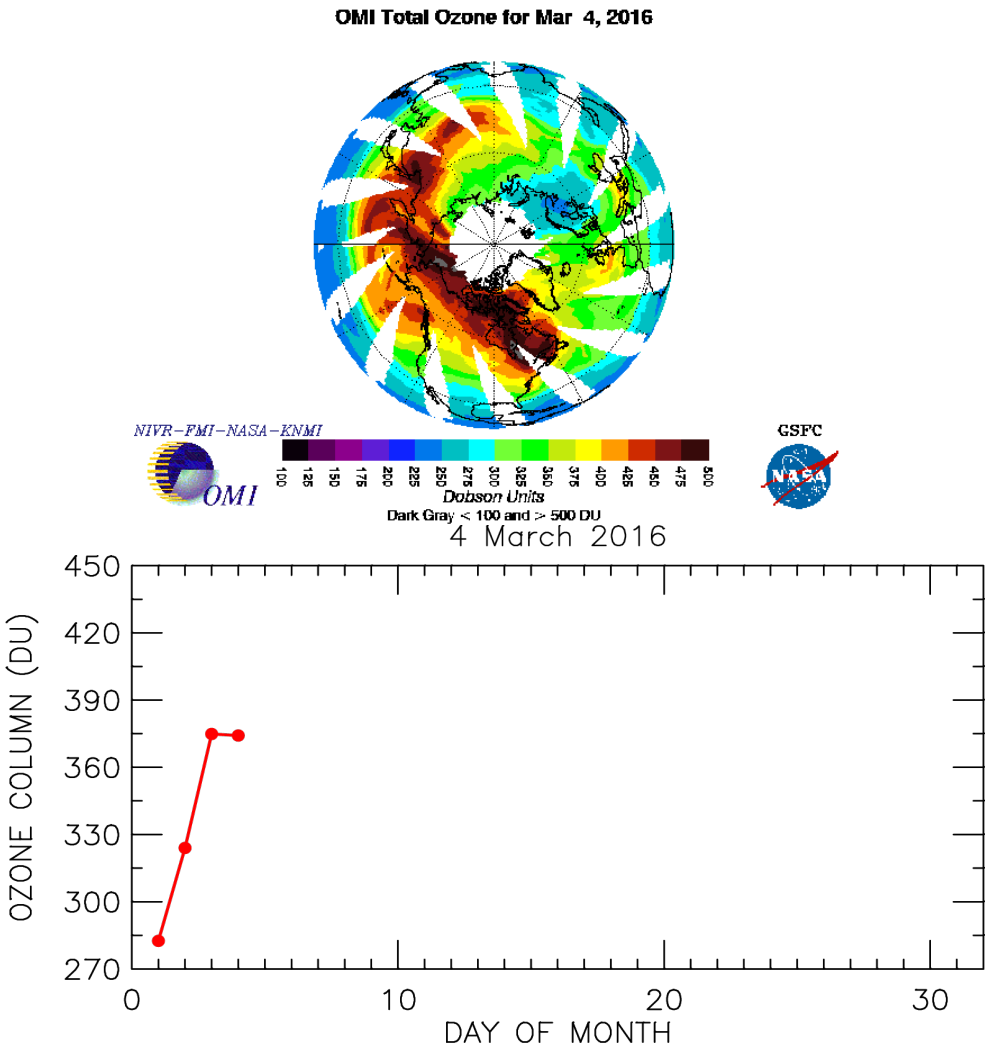
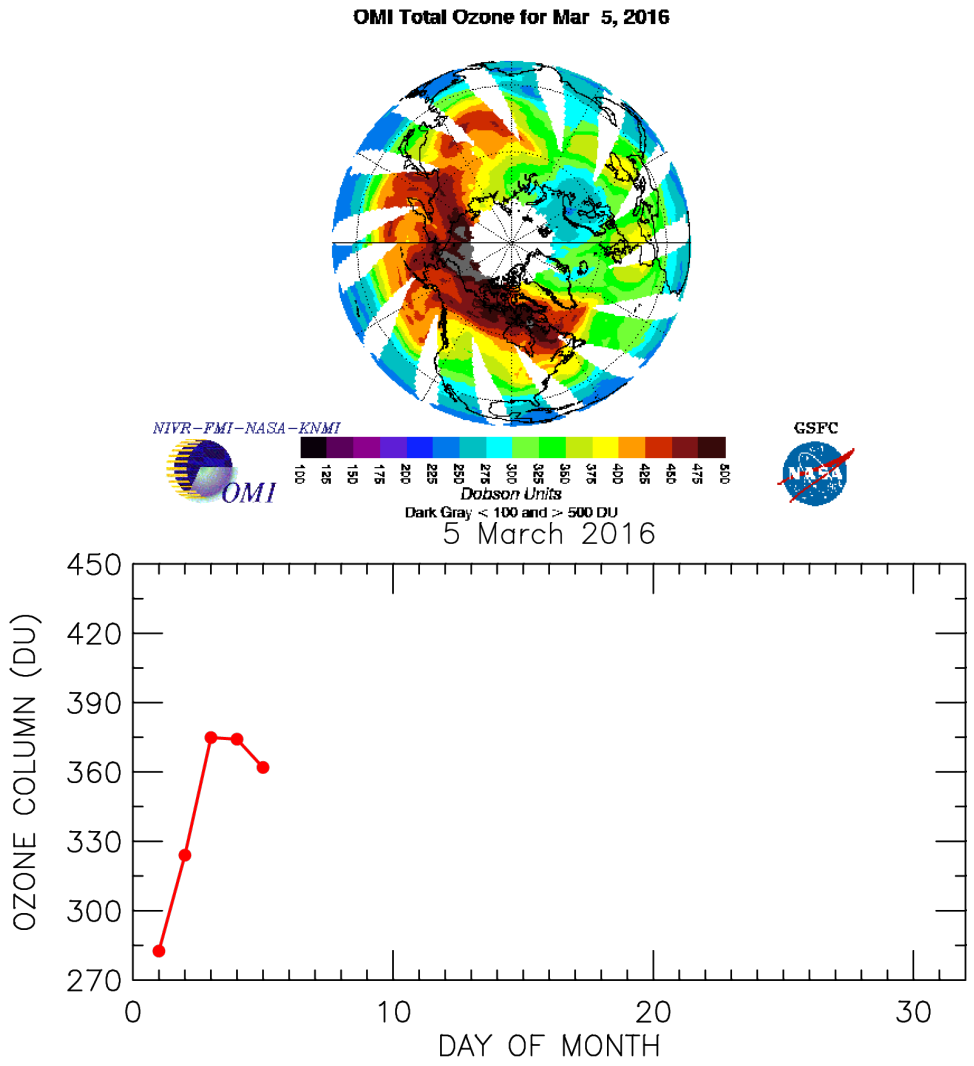
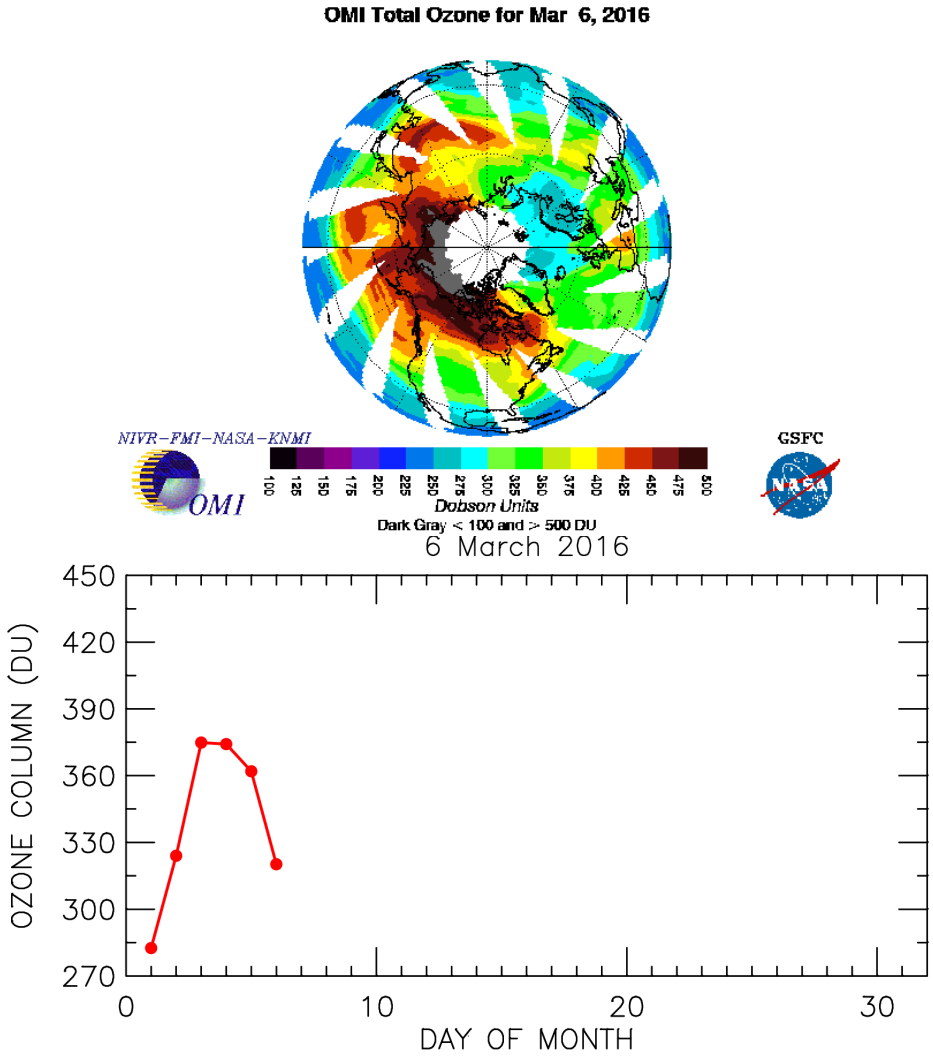


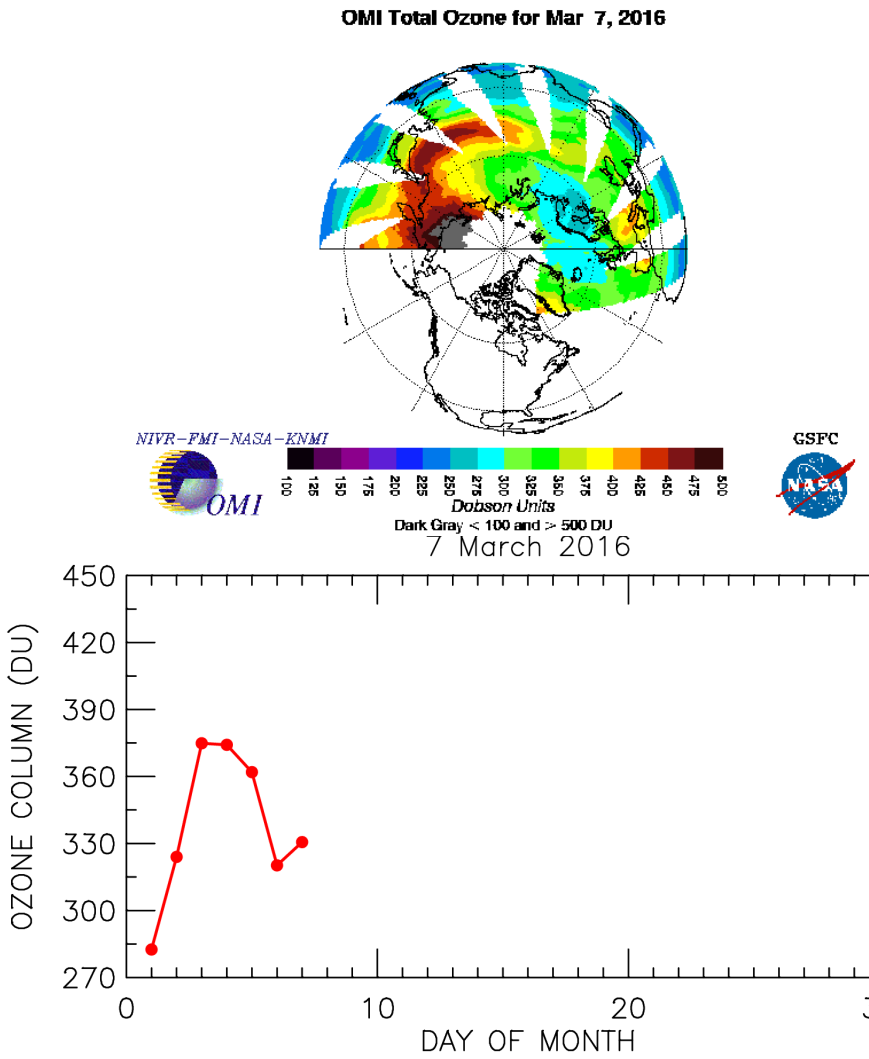
23 Sep 2016

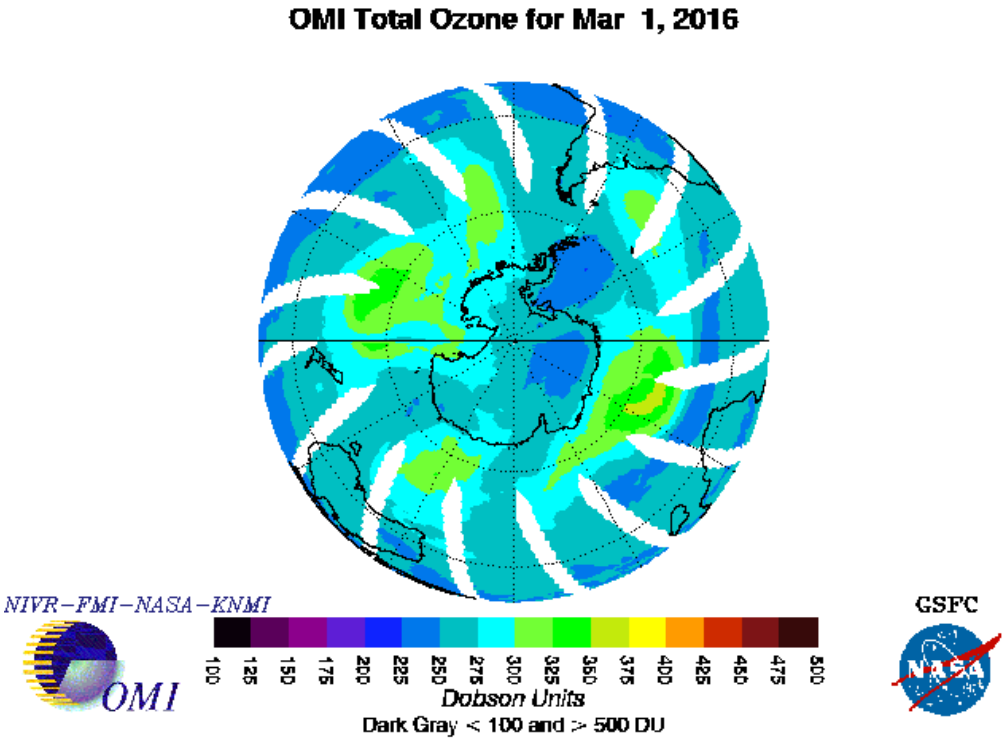


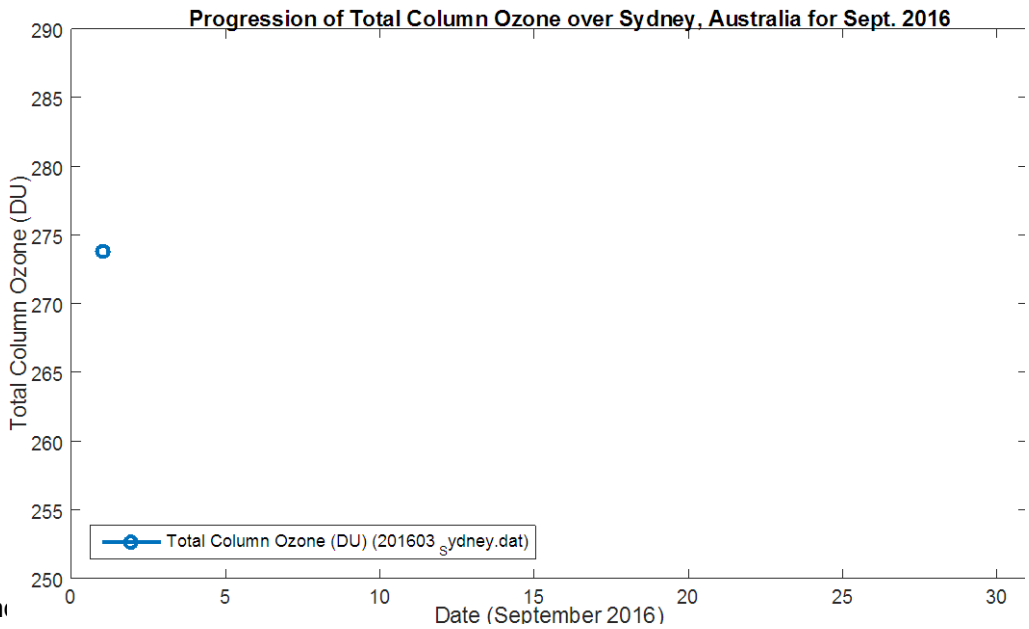


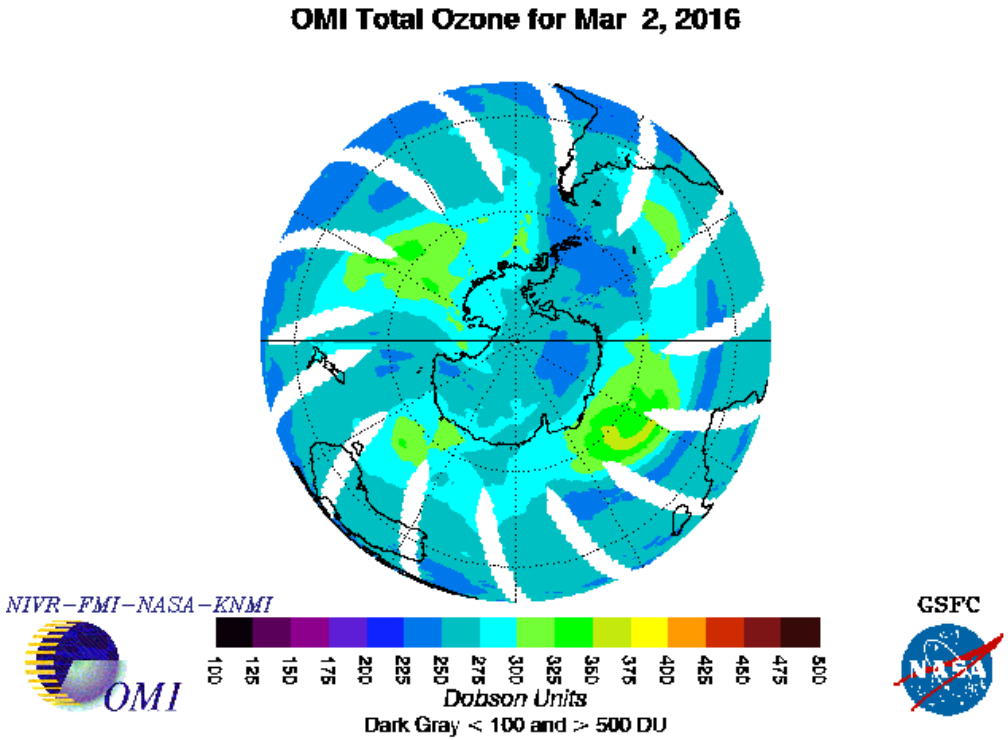


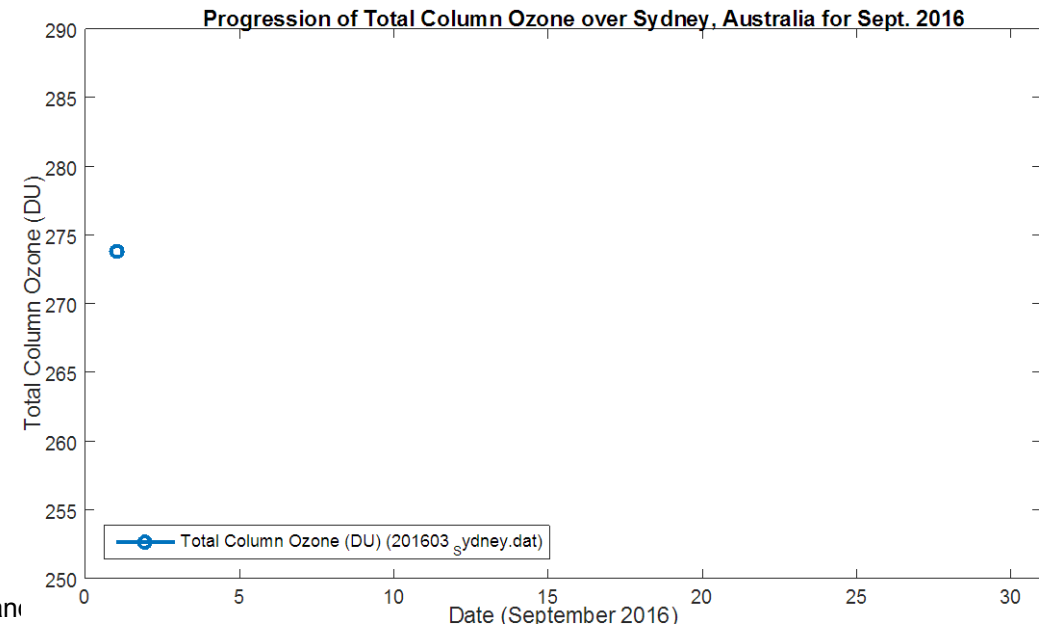




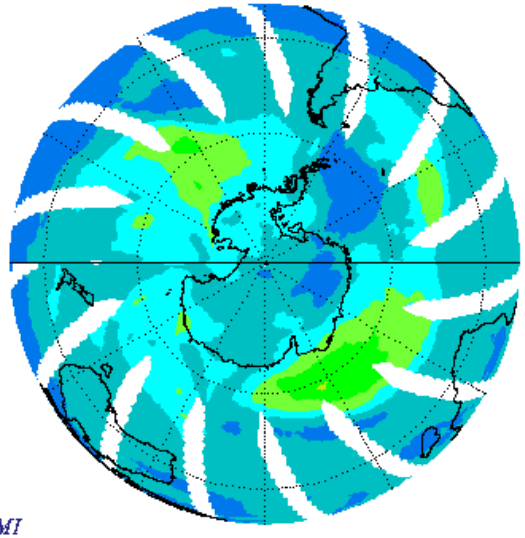








OMI Total Ozone for Mar 3, 2016



NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Dobson Units

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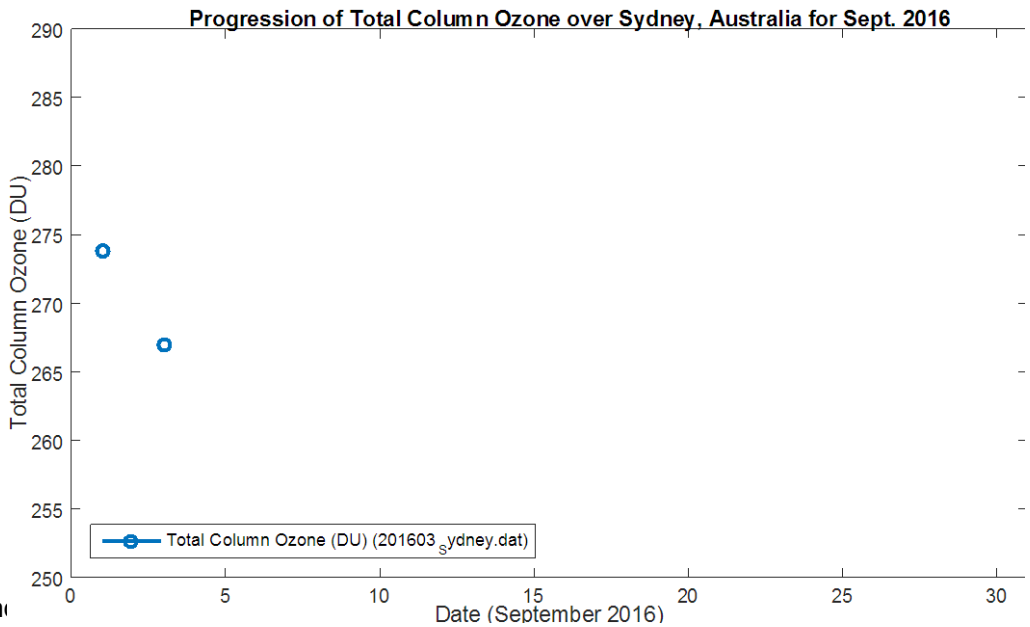
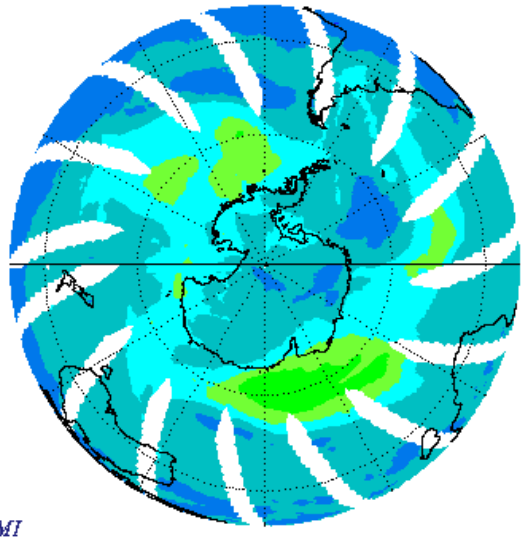


OMI Total Ozone for Mar 4, 2016



NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

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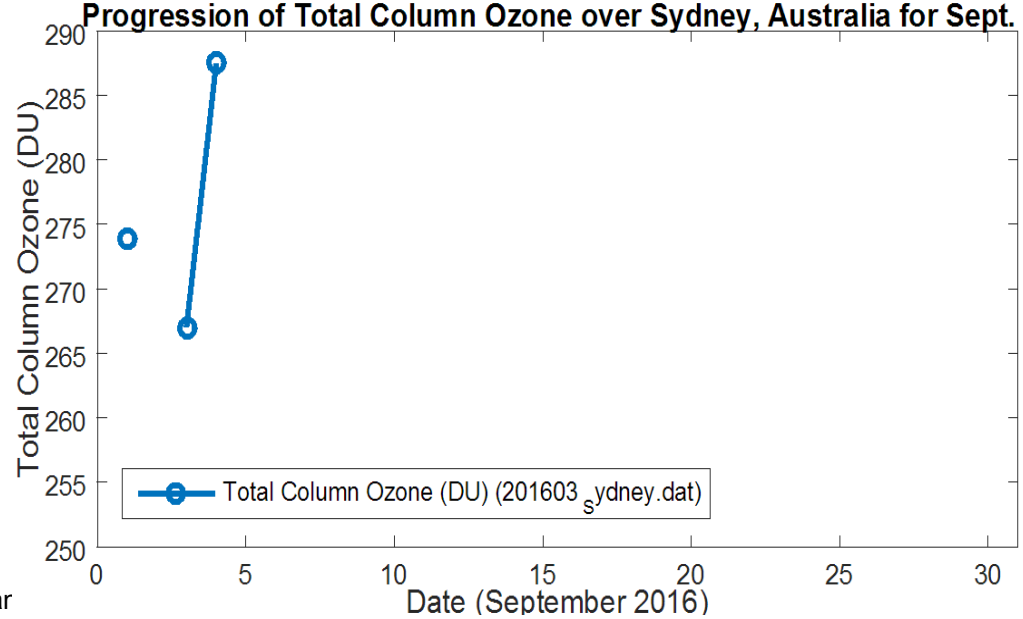
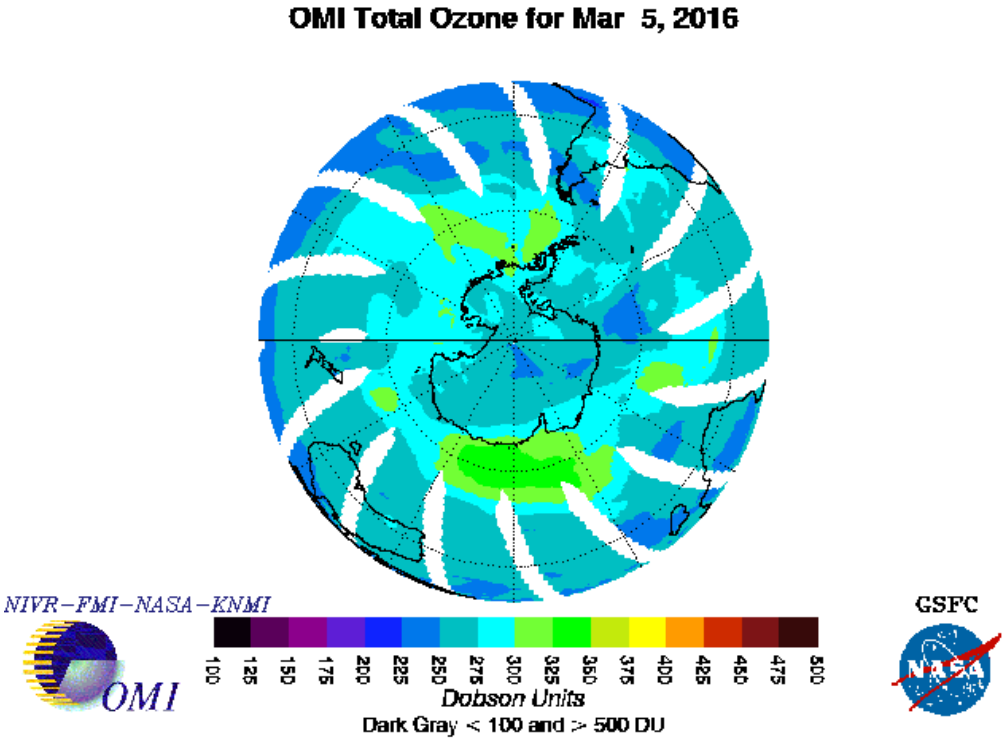
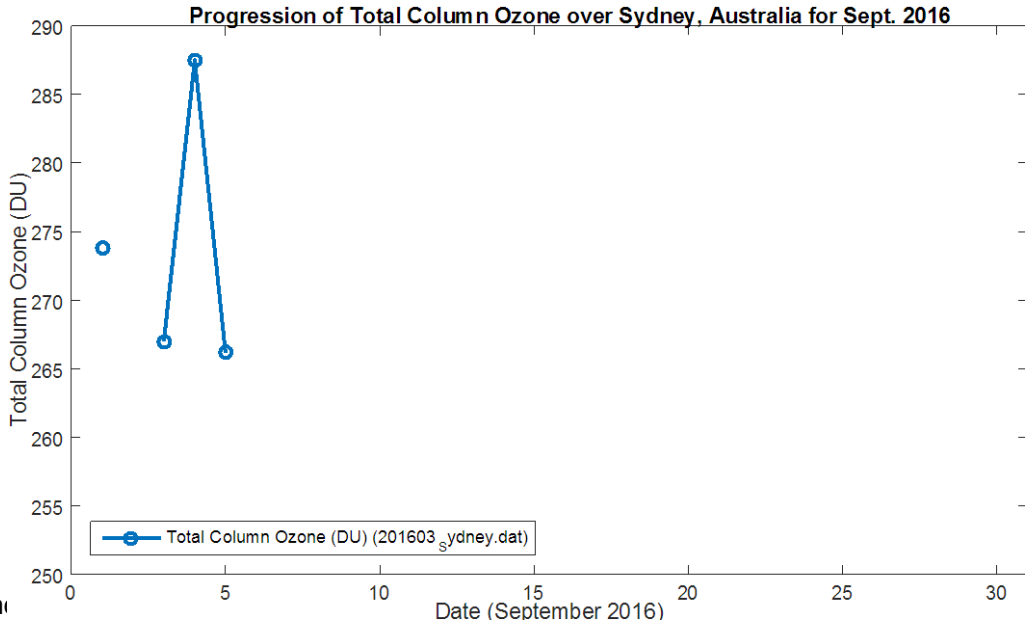
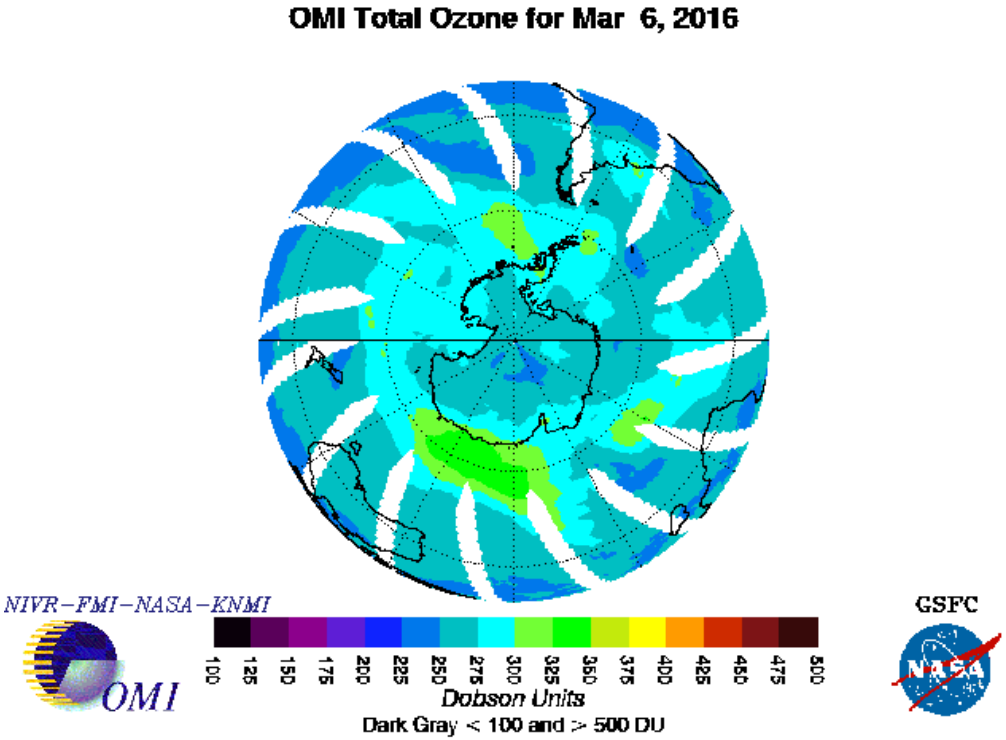
GSFC

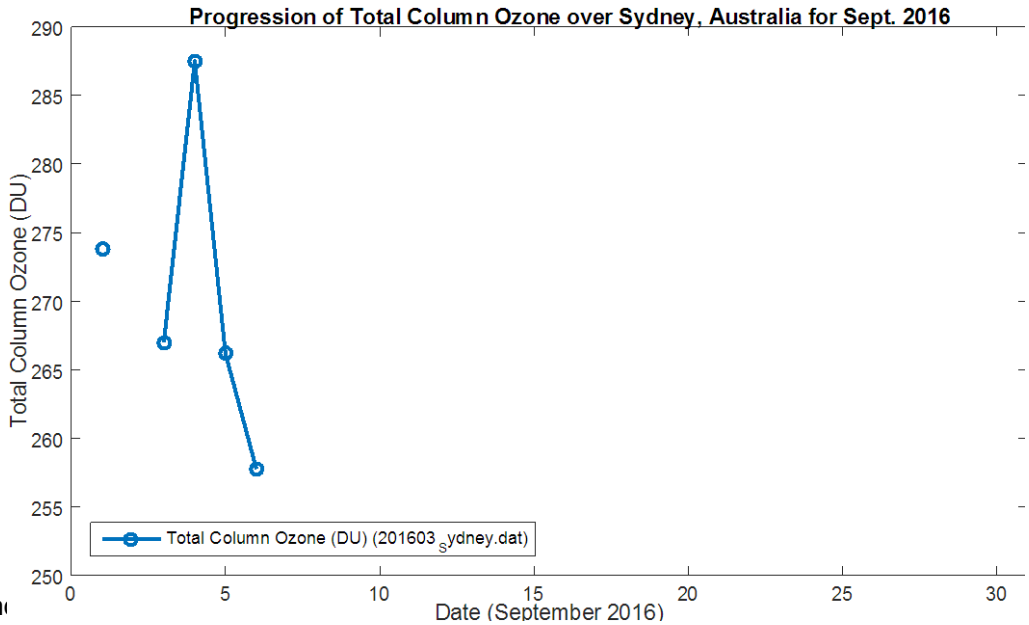
Progression of Total Column Ozone over Sydney, Australia for Sept.

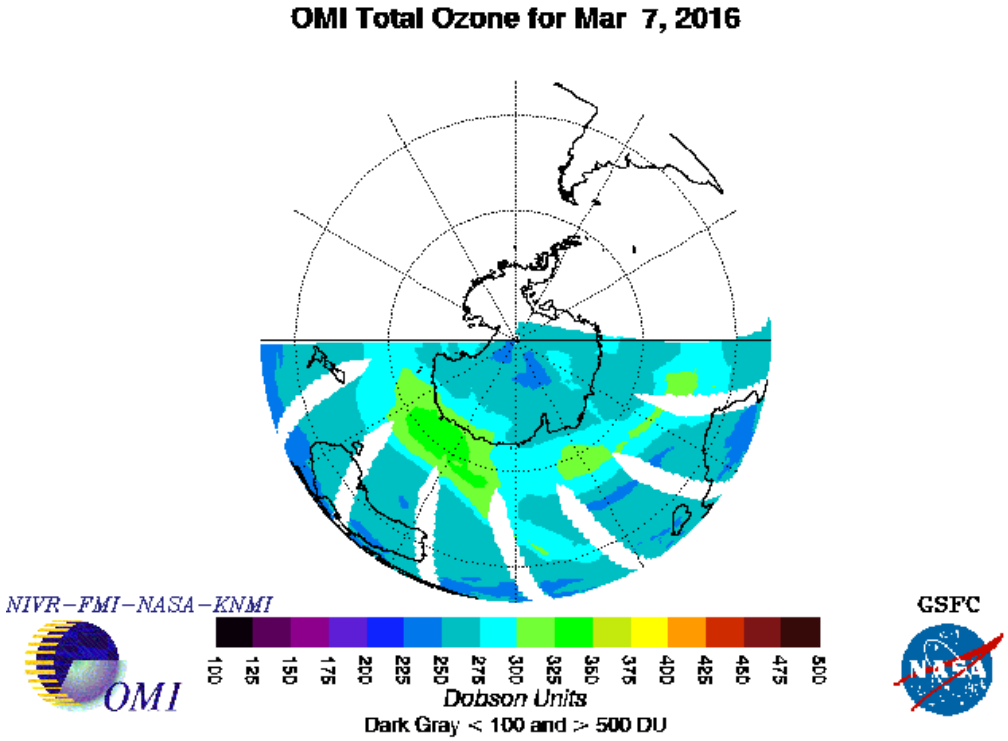


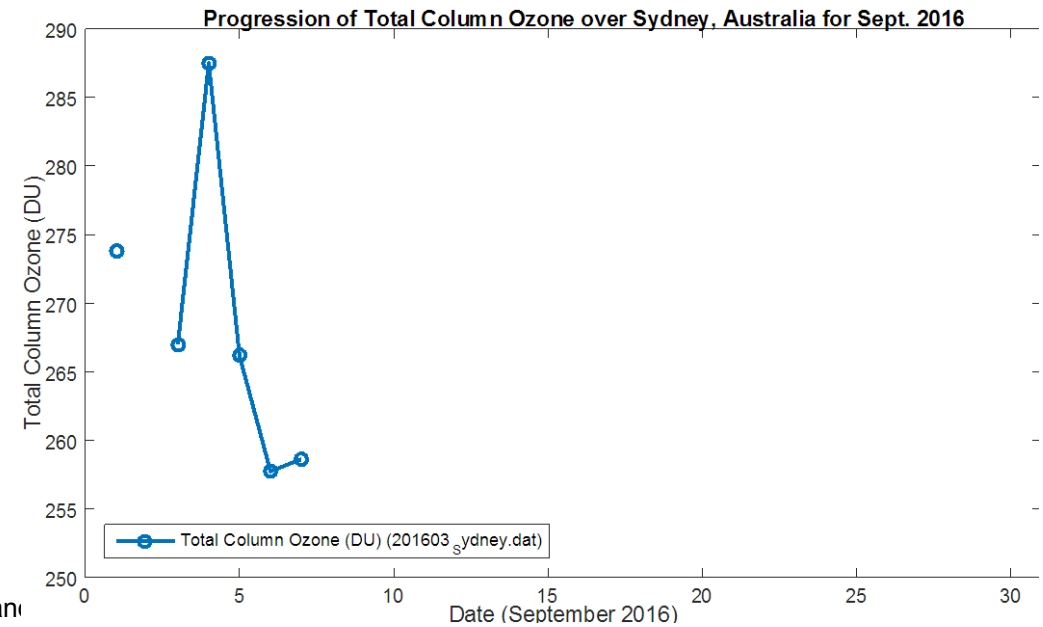


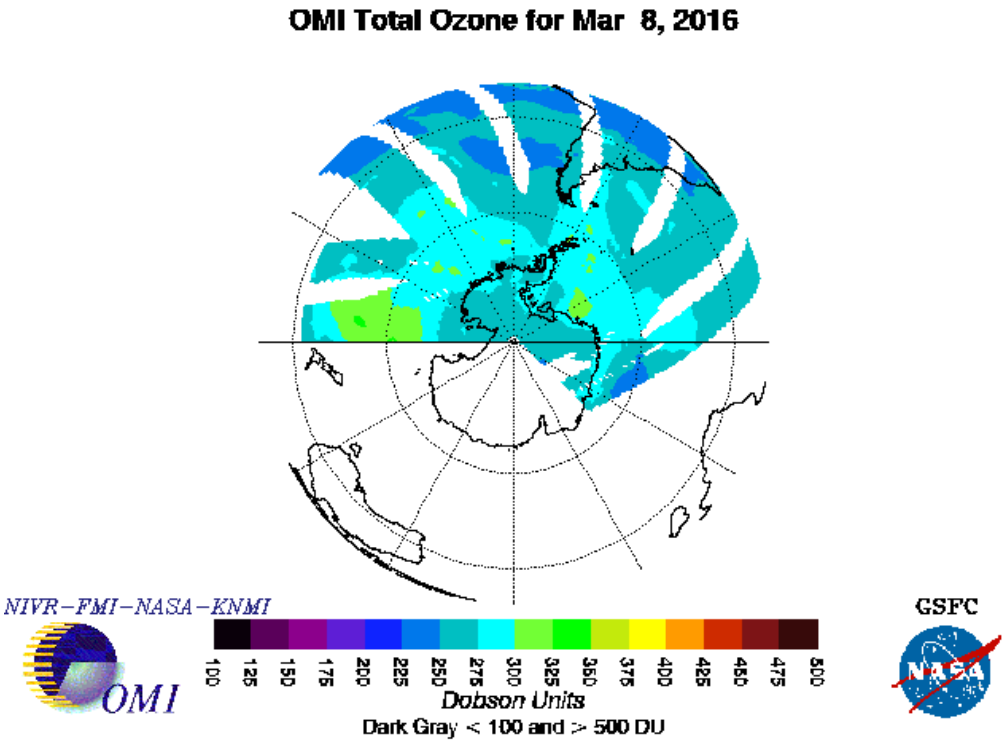


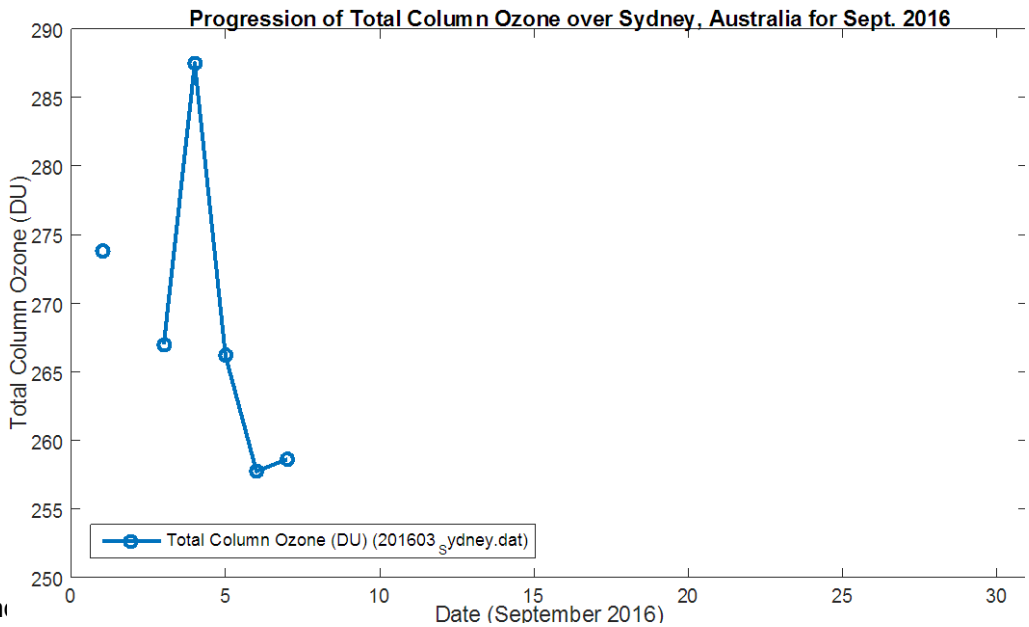


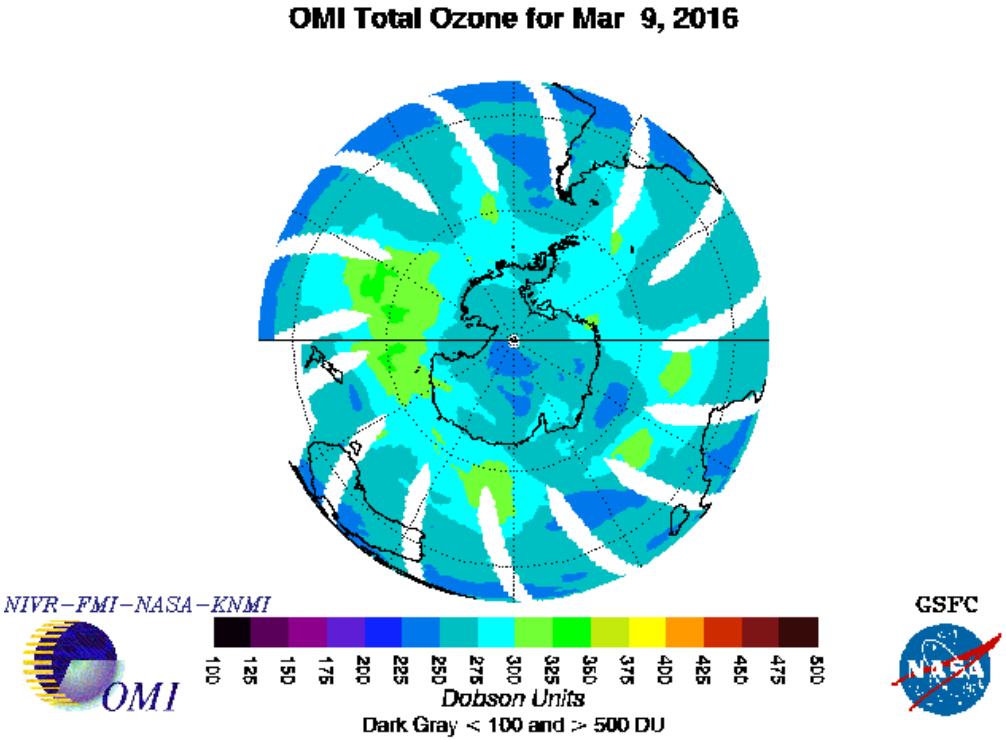


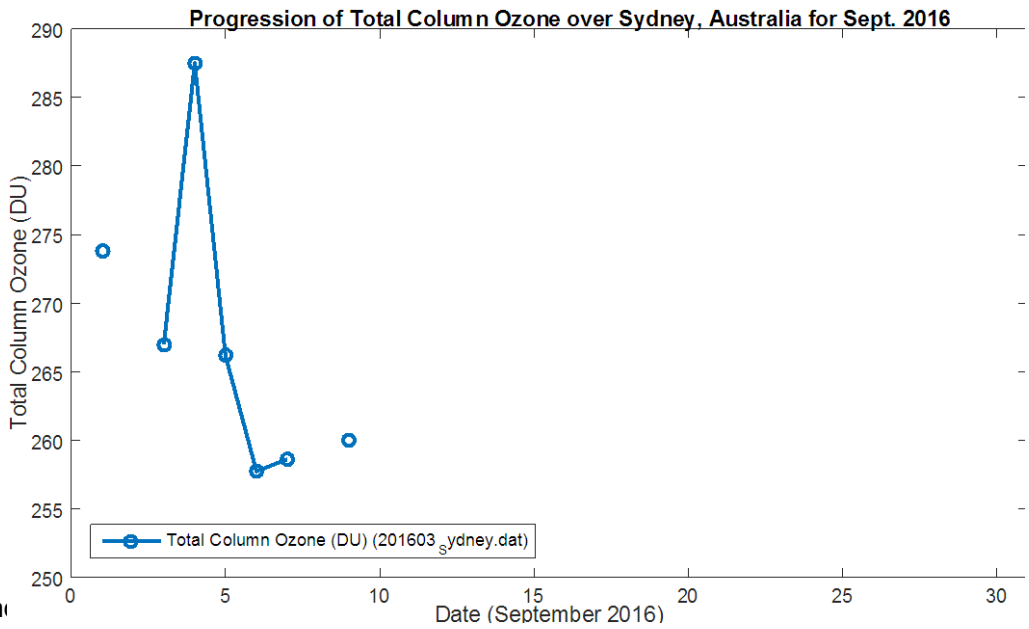


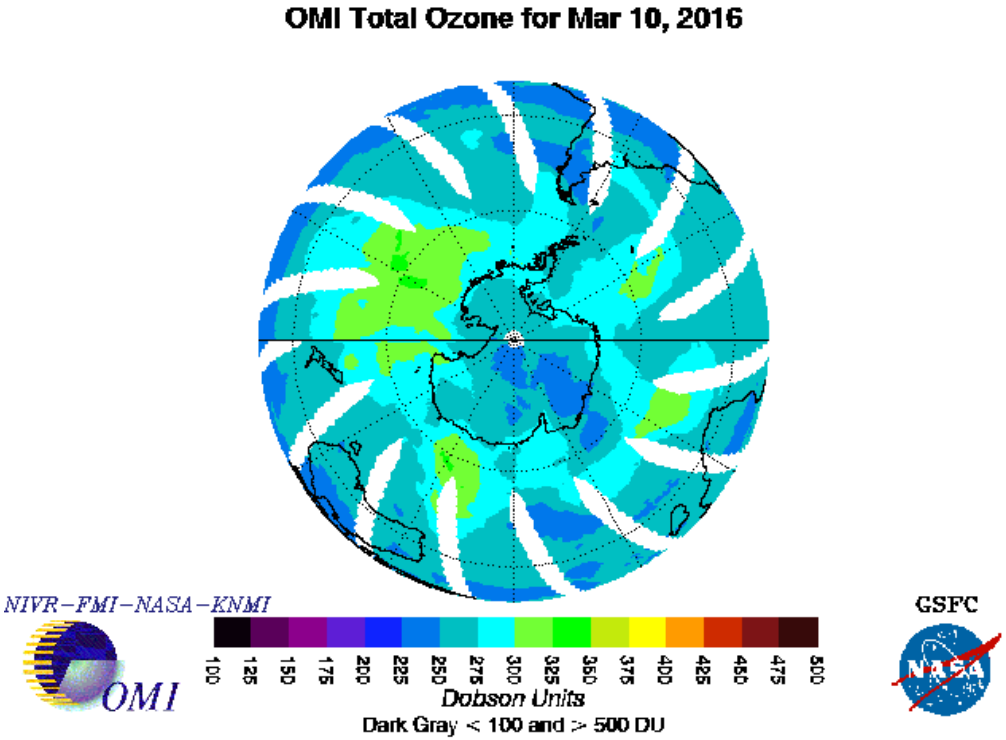


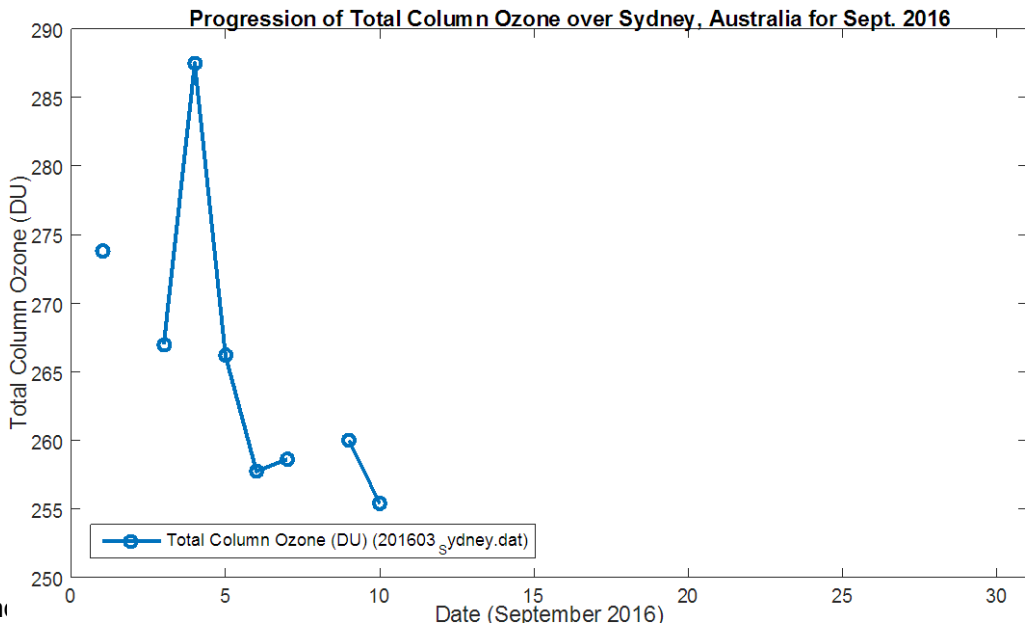


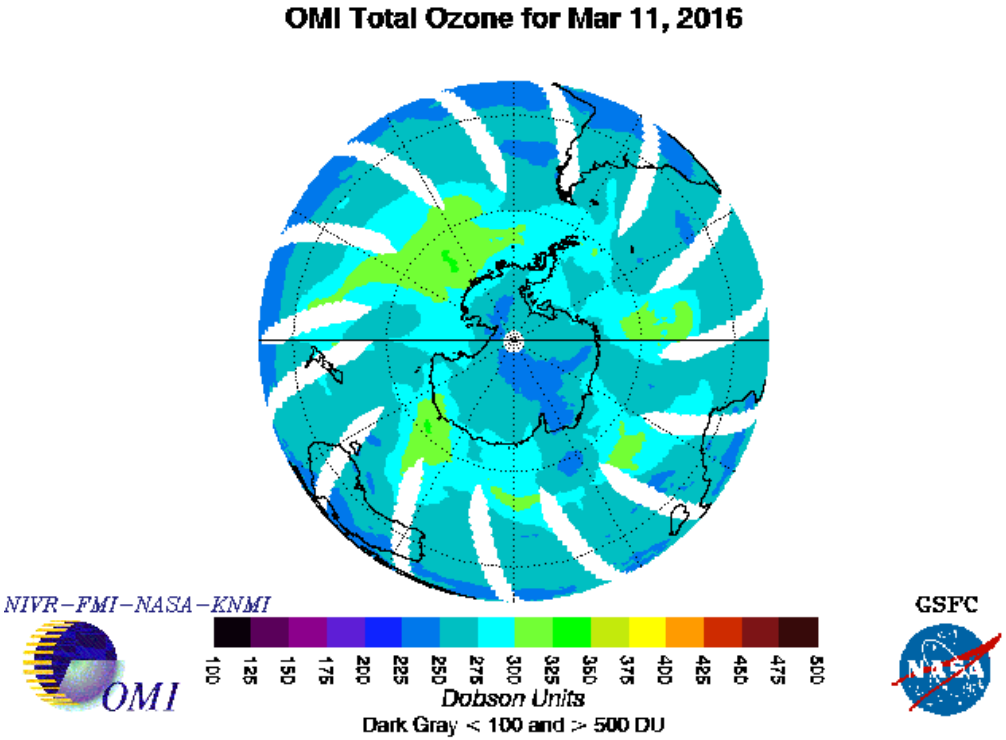


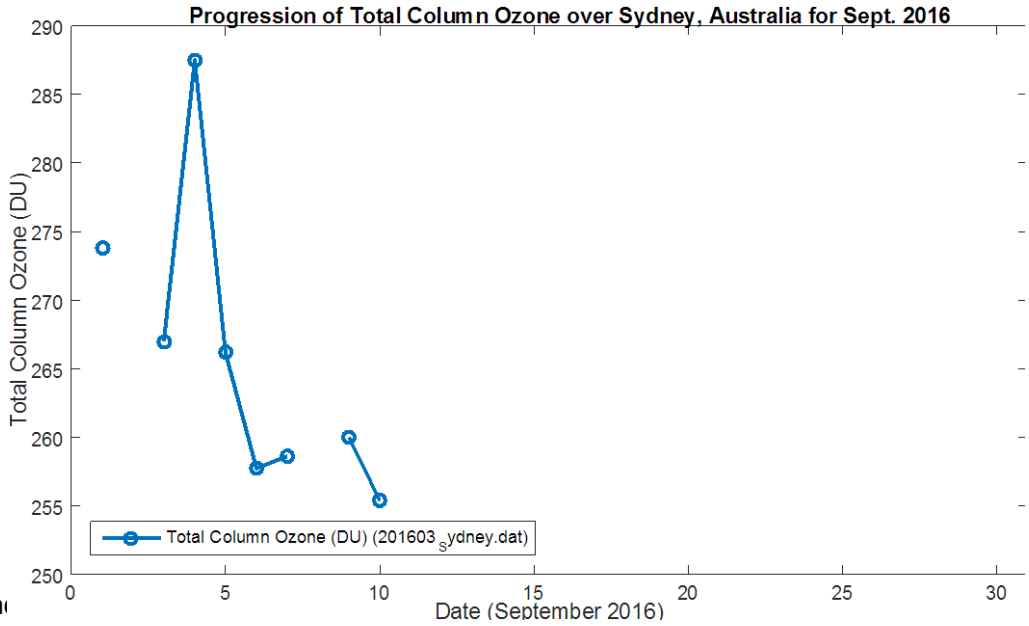


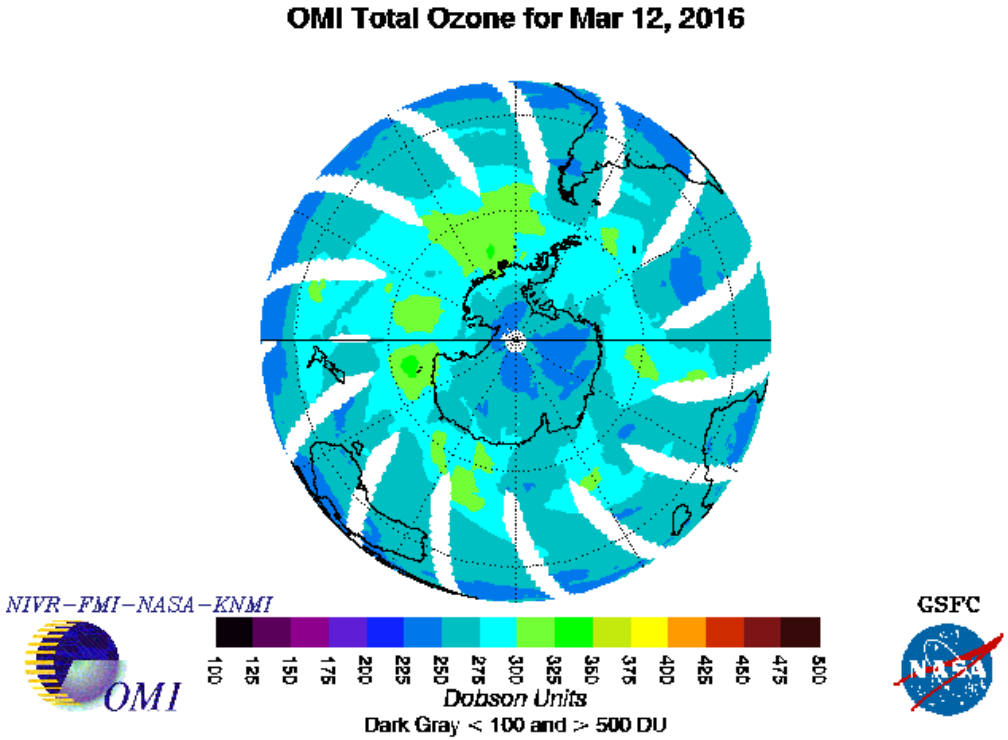


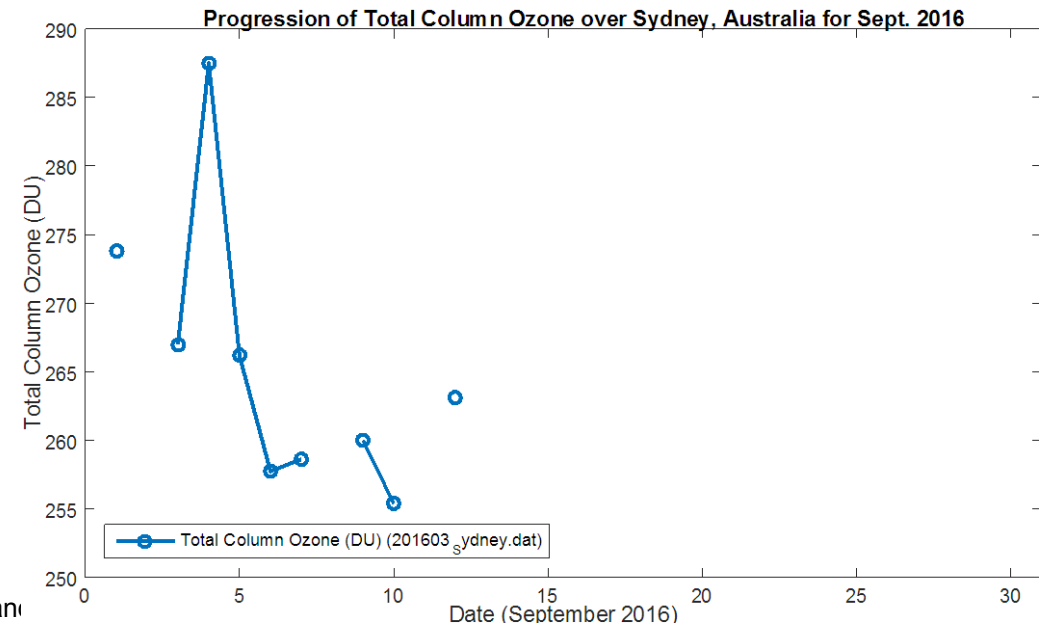




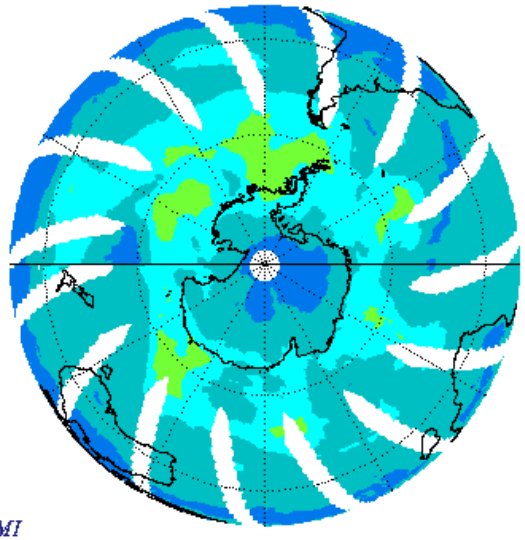








OMI Total Ozone for Mar 13, 2016



NIVR–FMI–NASA–KNMI

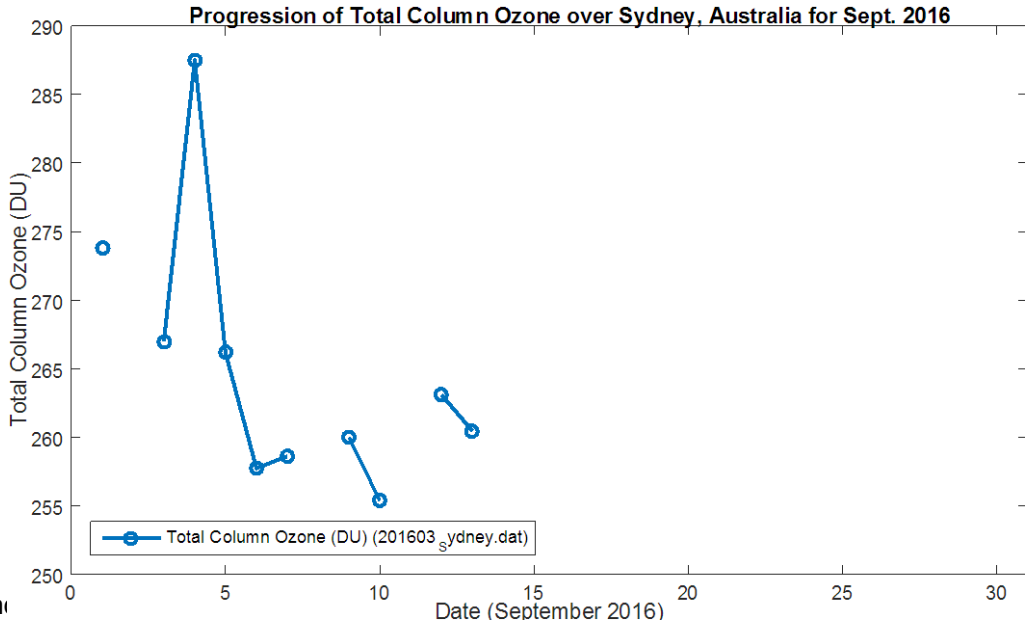
OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

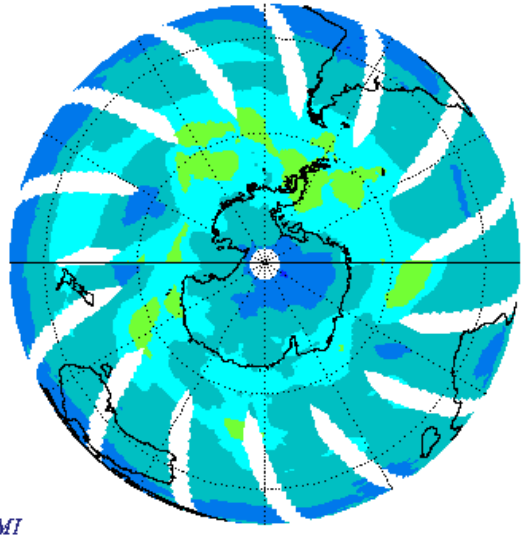
Dobson Units

Dark Gray < 100 and > 500 DU

GSFC



OMI Total Ozone for Mar 14, 2016



NIVR–FMI–NASA–KNMI

OMI

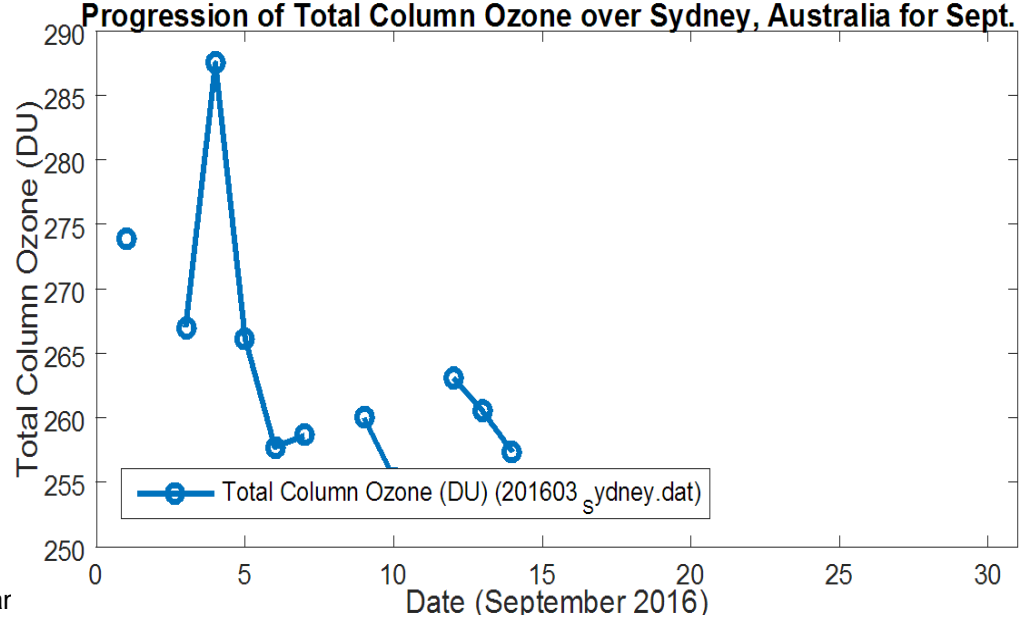
100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

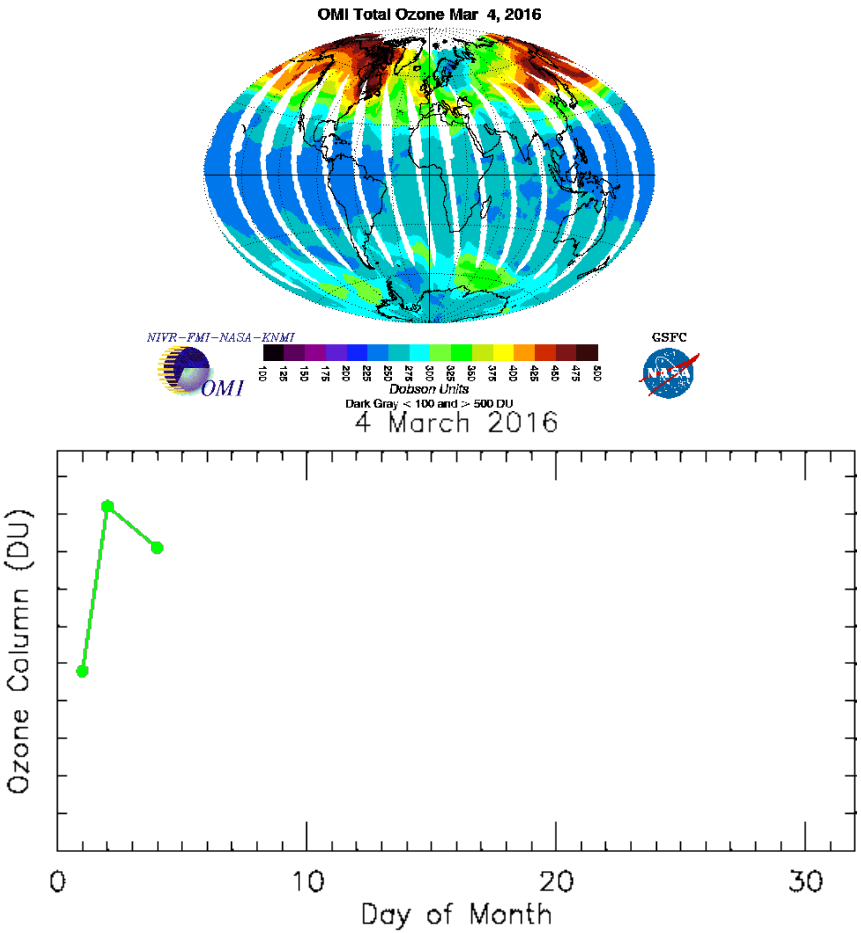
Dobson Units

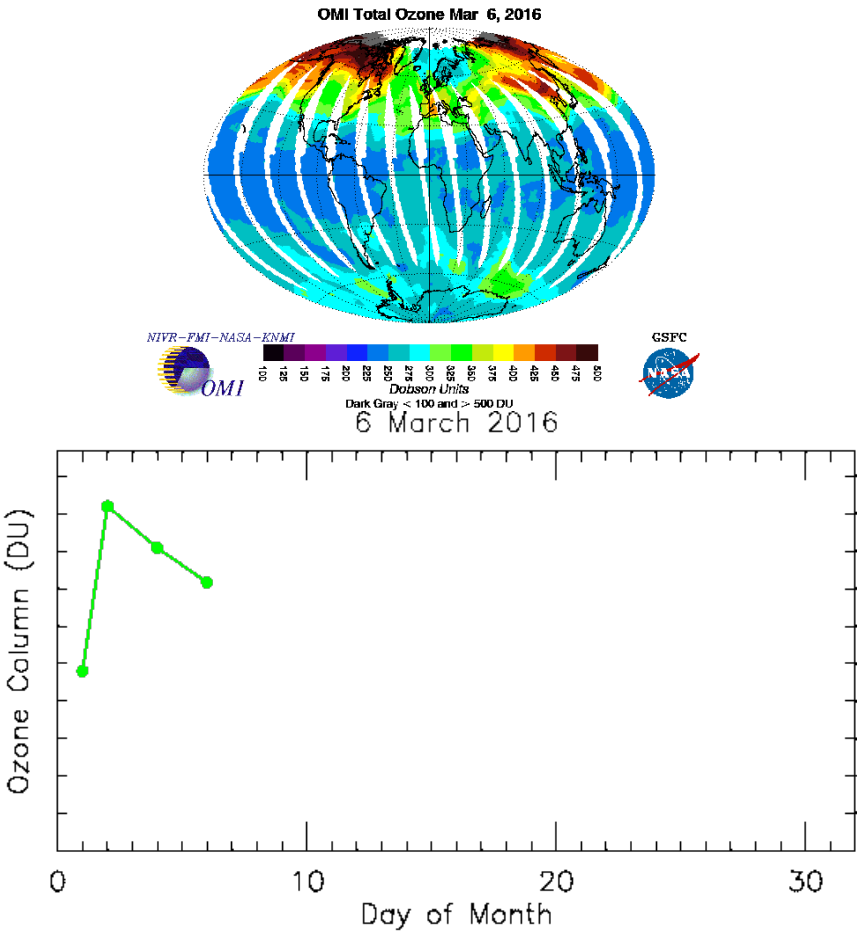
Dark Gray < 100 and > 500 DU

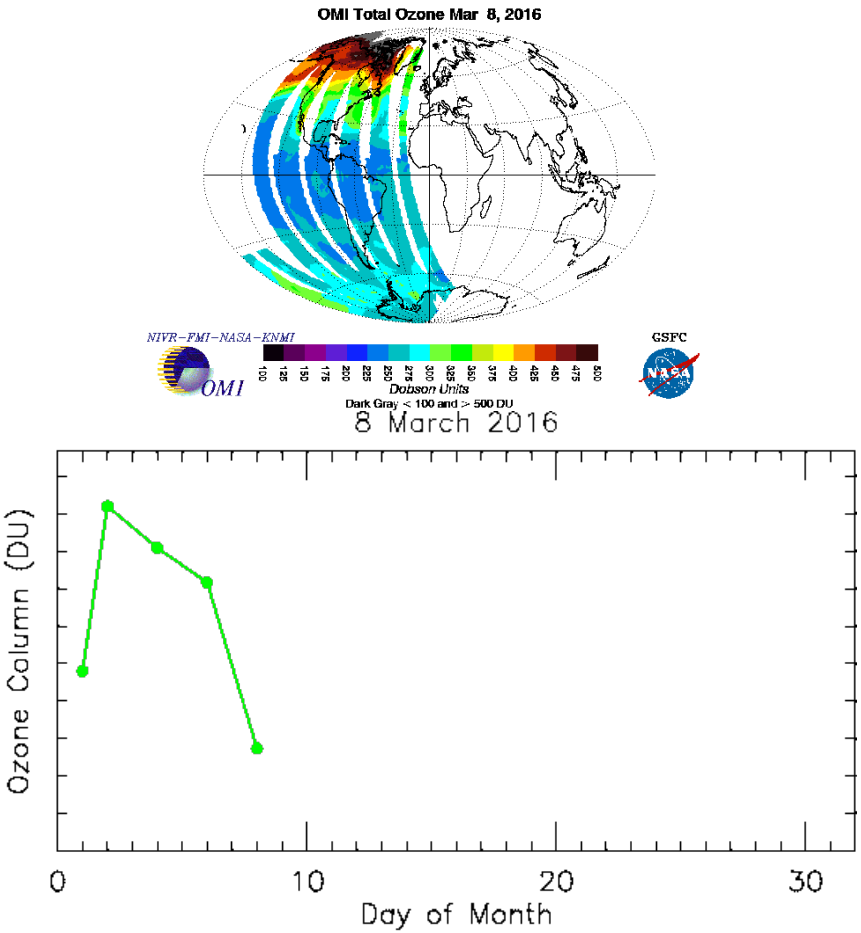
GSFC

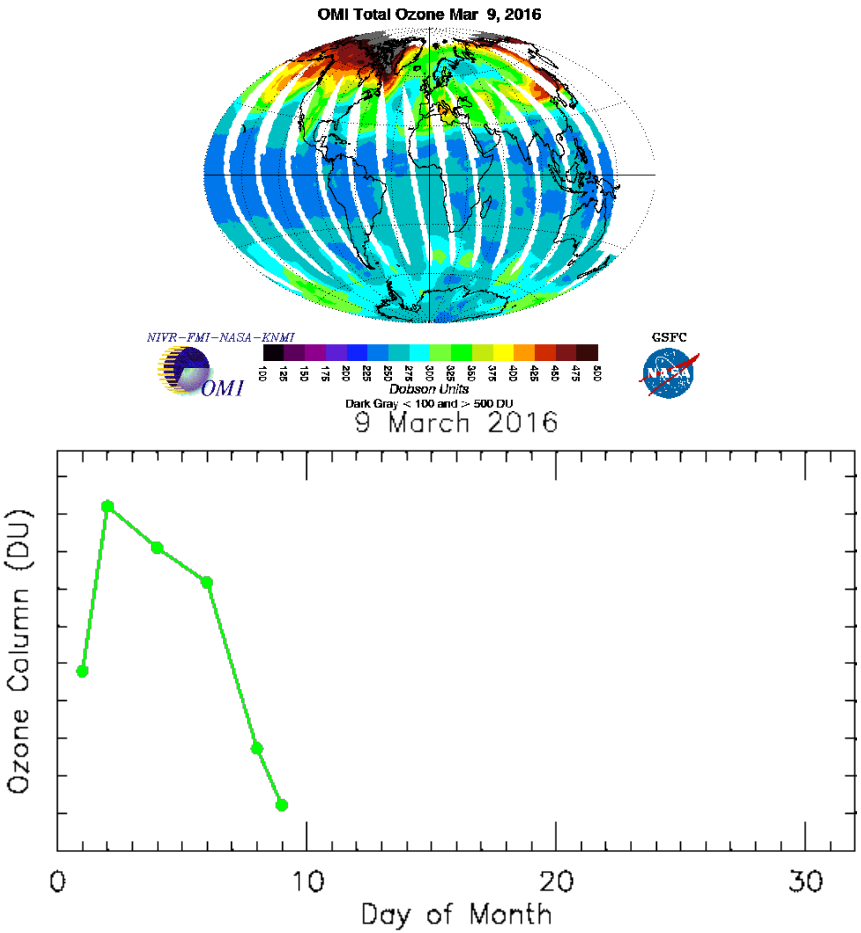
Progression of Total Column Ozone over Sydney, Australia for Sept.

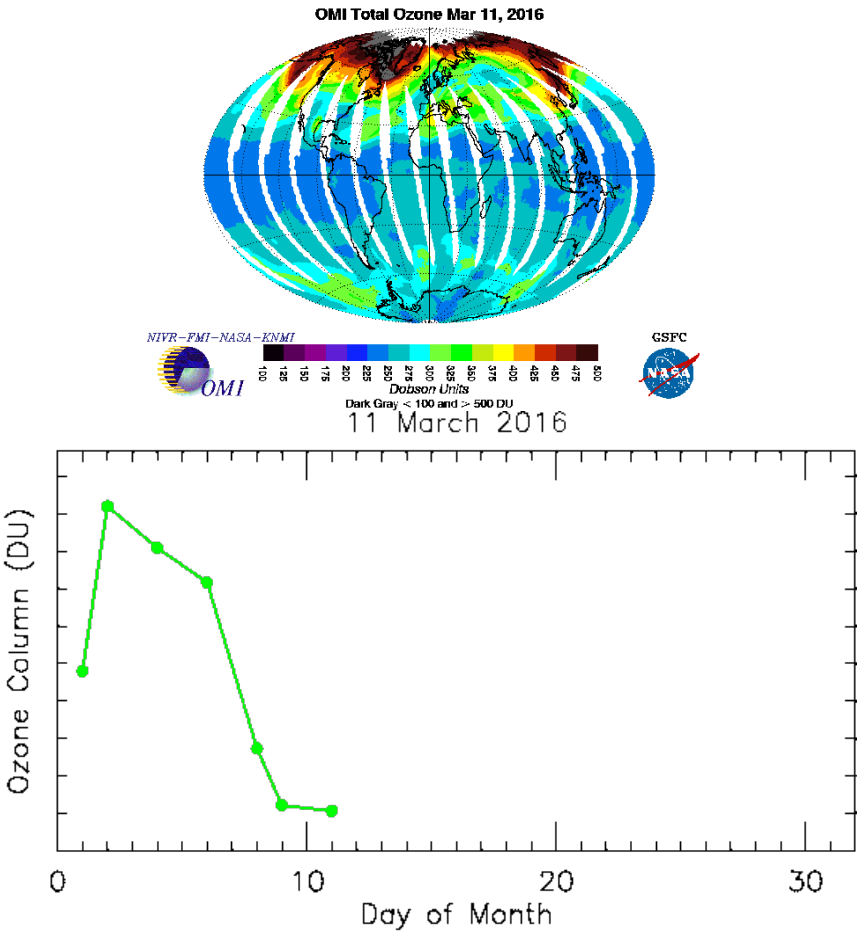


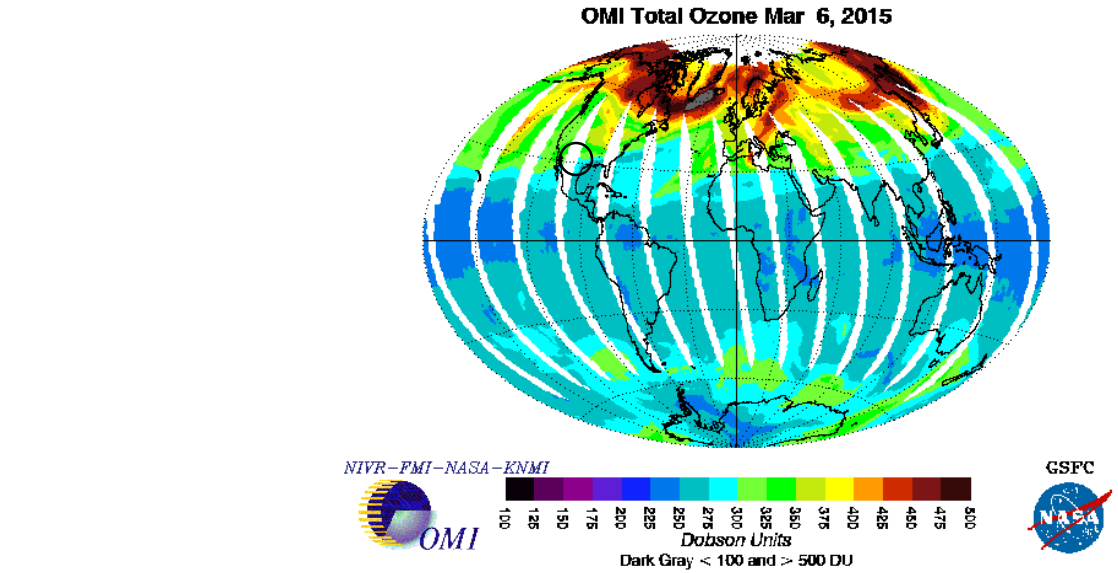


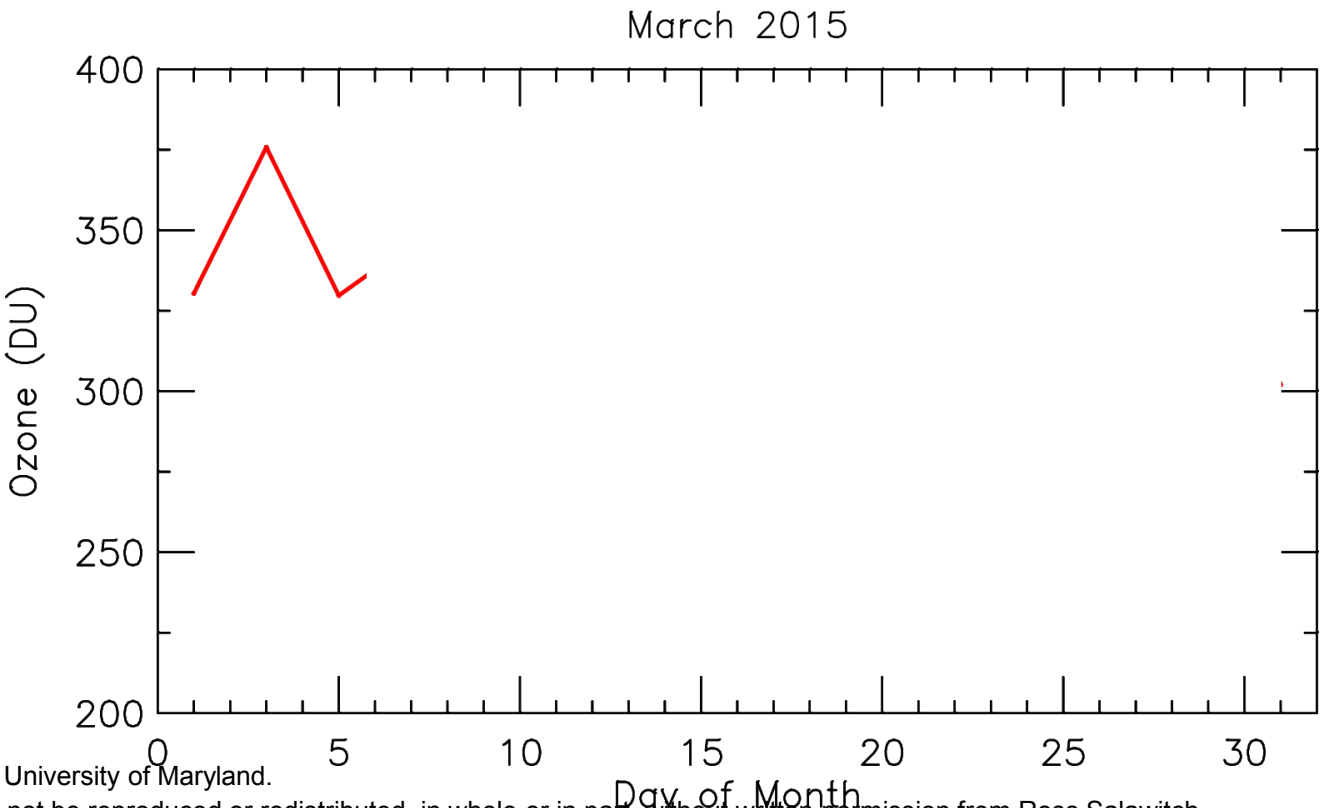




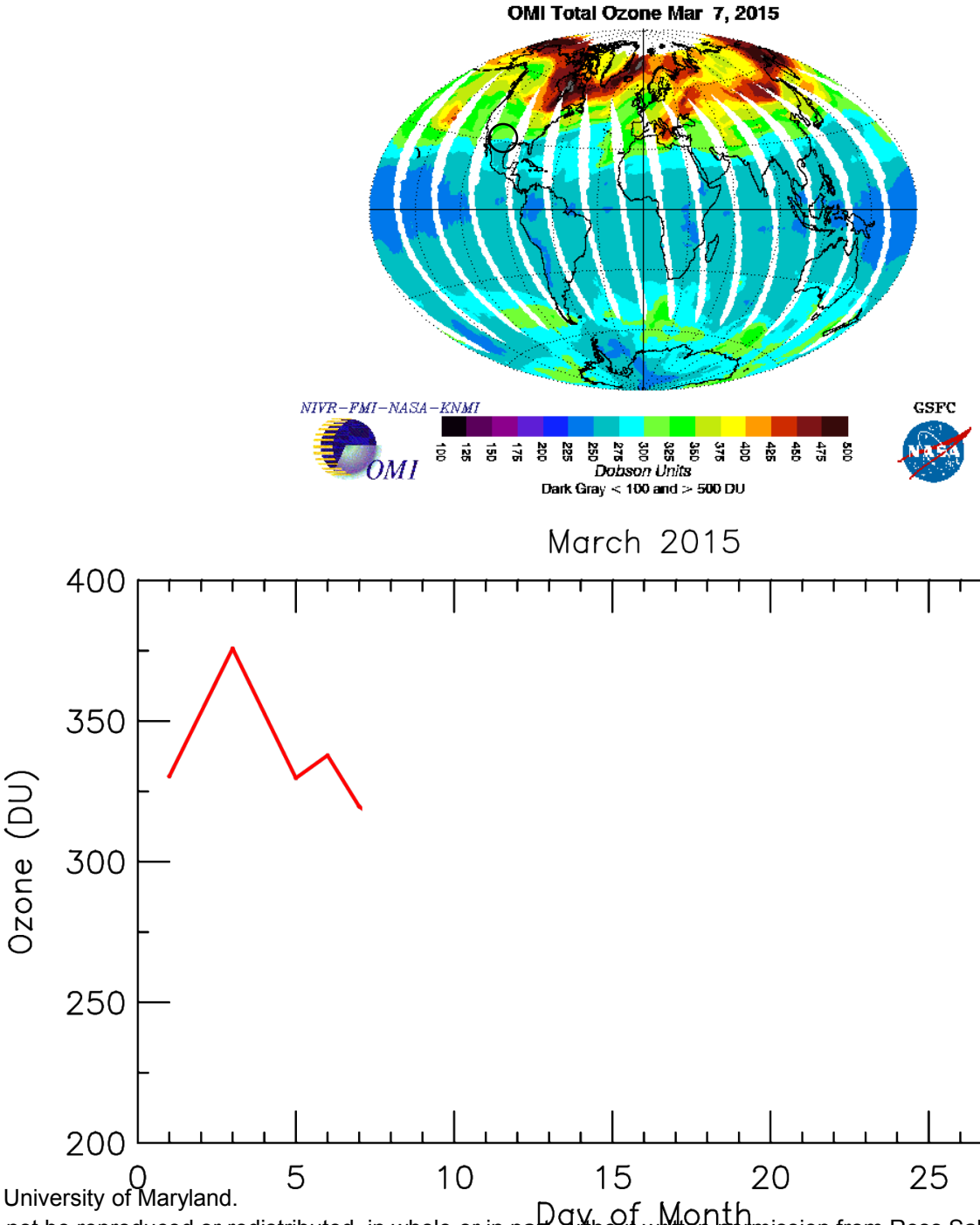


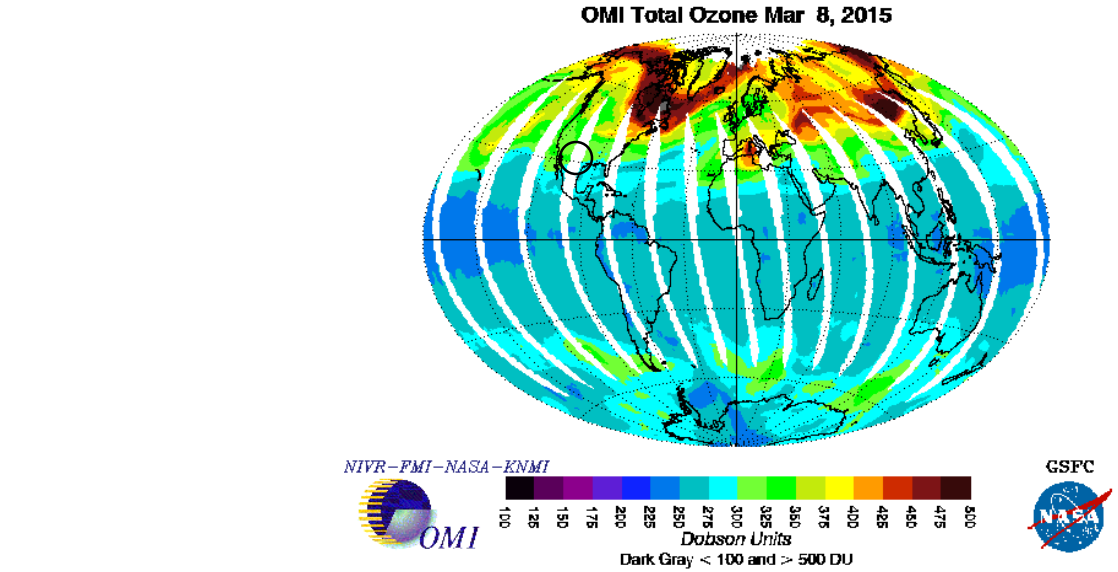


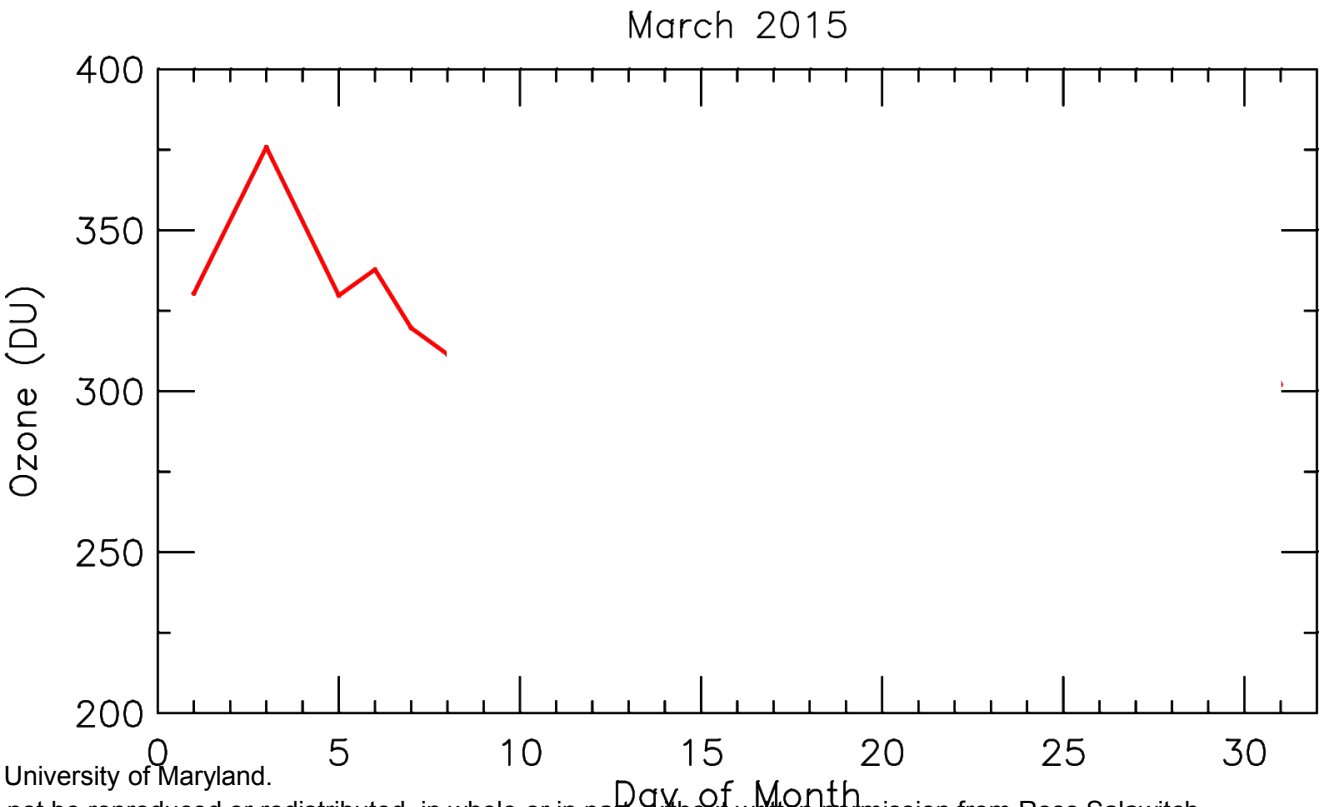




23 Sep 2016

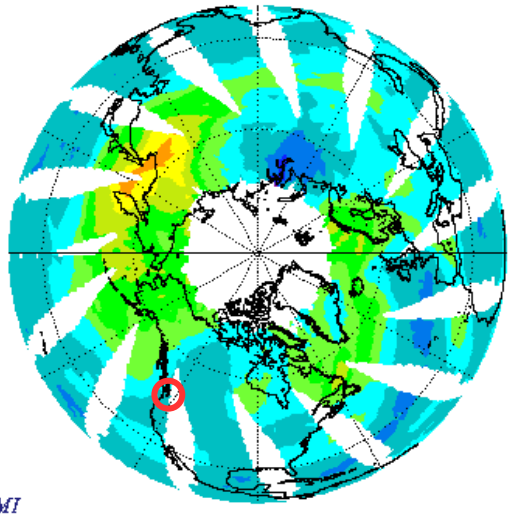






23 Sep 2016

OMI Total Ozone for Oct 21, 2015



Seattle

NIVR–FMI–NASA–KNMI

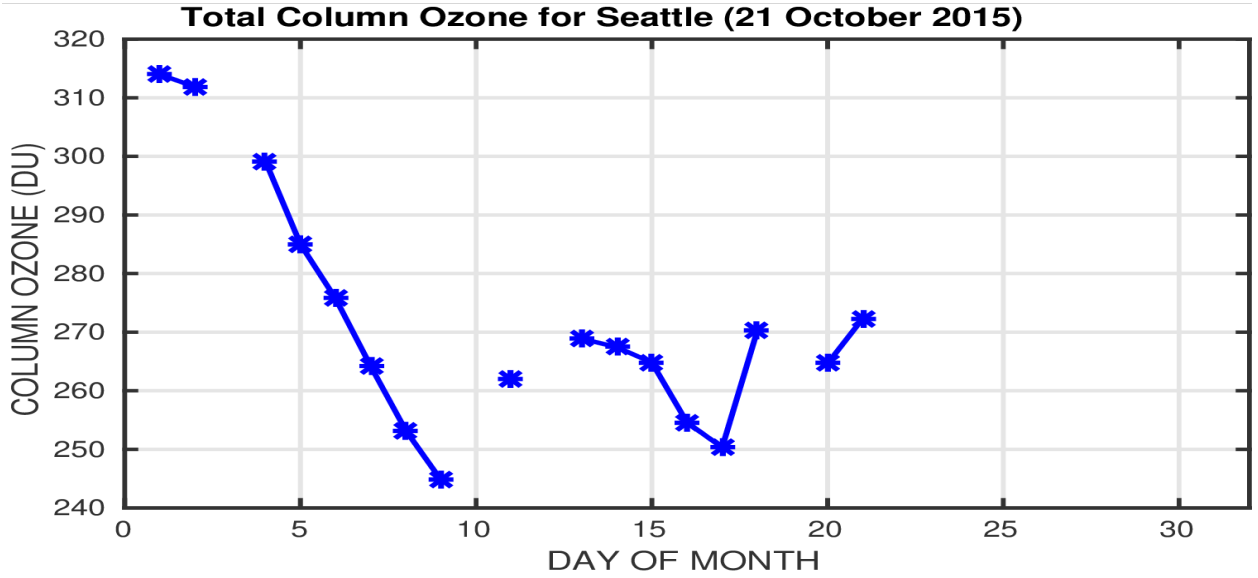
OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

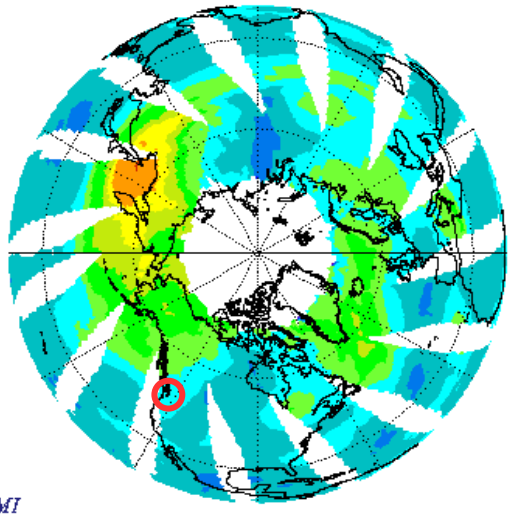
Dobson Units

Dark Gray < 100 and > 500 DU

GSFC



OMI Total Ozone for Oct 22, 2015



Seattle

NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Dobson Units

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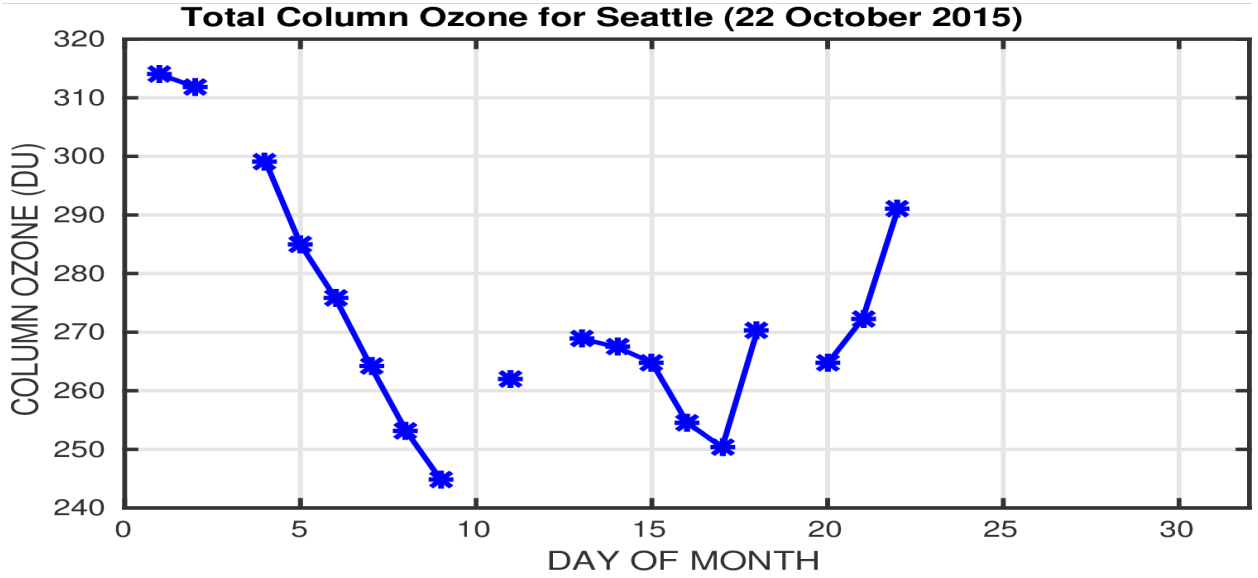
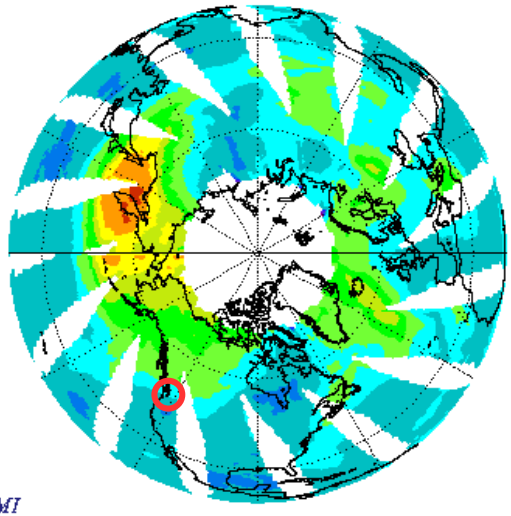
GSFC



OMI Total Ozone for Oct 23, 2015



Seattle

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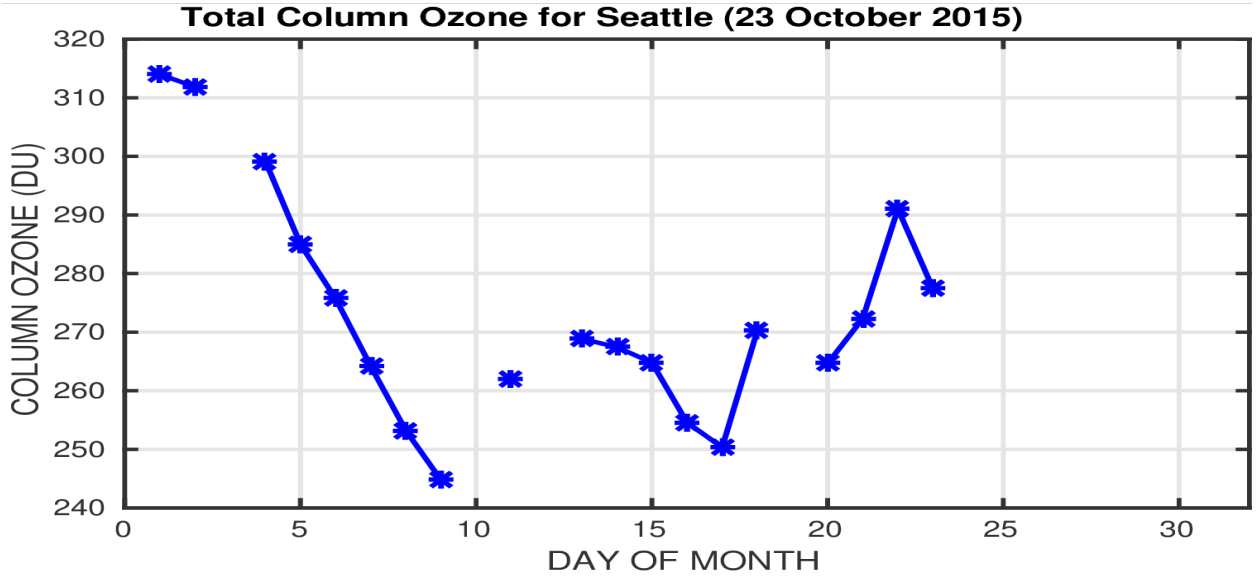
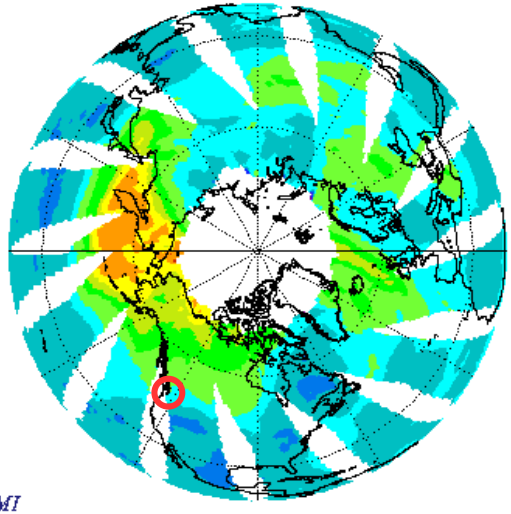


OMI Total Ozone for Oct 24, 2015



Seattle

NIVR–FMI–NASA–KNMI

OMI

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Dobson Units

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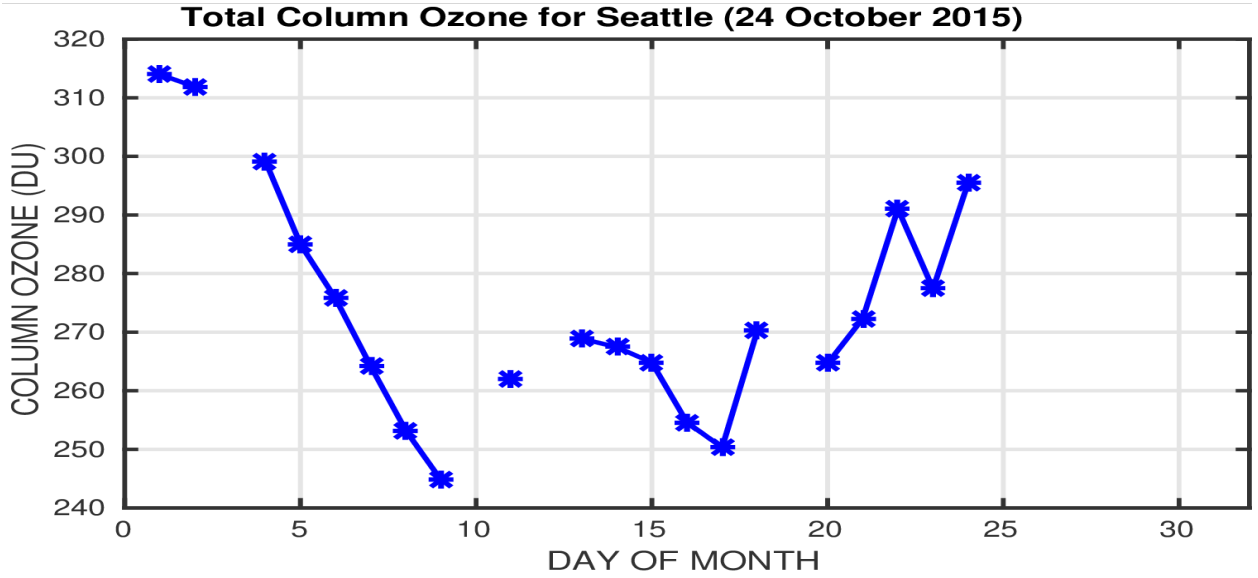
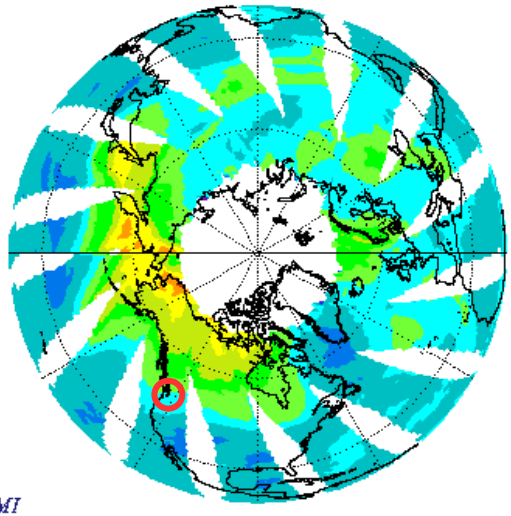
GSFC



OMI Total Ozone for Oct 25, 2015



Seattle

NIVR–FMI–NASA–KNMI

OMI

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Dobson Units

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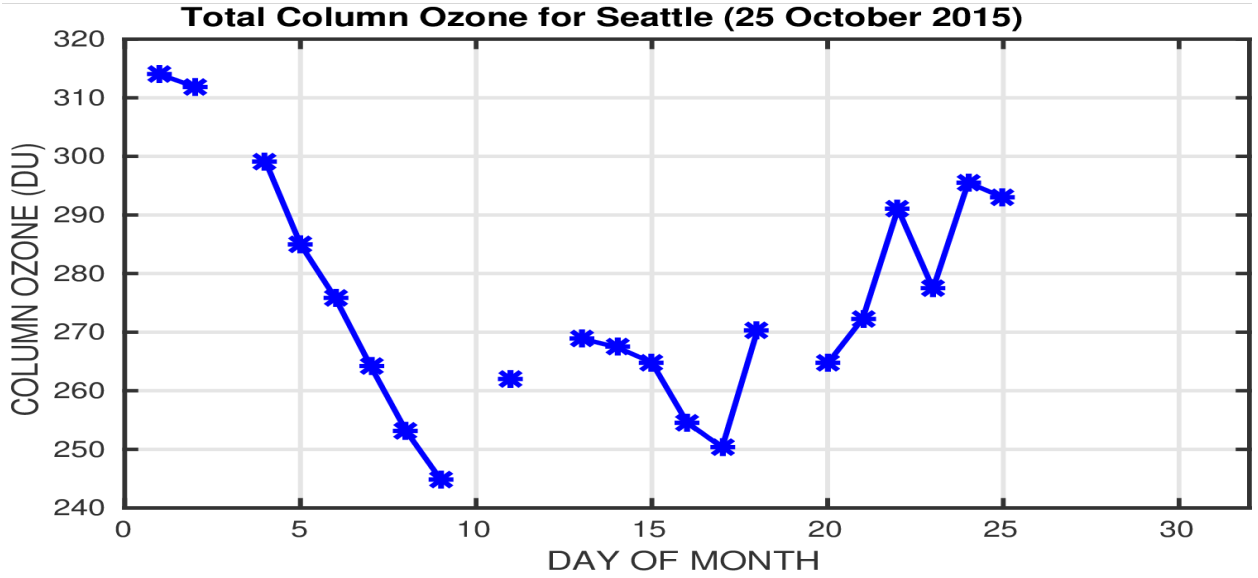
GSFC



AOSC 652: HW 03 Points Subtracted

No symbol around targeted location	2
No indication of missing data on line plot	2
179.375 still in code	3
Latitude and Longitude not in file header	5
No indication, whatsoever, about name of targeted location (except perhaps in filename)	5
Fonts too small to be read	5
Images “jitter”	5
Incorrect values of total ozone found, such that lines plots inconsistent with NASA images	10
Numbers on vertical axis missing from line chart	10

AOSC 652: Analysis Methods in AOSC

Extra Credit #2:

Example we used in class was total ozone over London, March 2016

Latitude = 51.75, Longitude = 0.25

If we go to http://ozoneaq.gsfc.nasa.gov/tools/ozonemap
and enter 51.75, 0.25 for 15 March 2016, we get **262 DU**

For this date, our code outputs:

O3column for four closest points: Lat = 51.50, Lon = −0.50 => O3 = 269 DU
Lat = 51.50, Lon = 0.50 => O3 = 262 DU
Lat = 52.50, Lon = 0.50 => O3 = 264 DU
Lat = 52.50, Lon = −0.50 => O3 = 271 DU

Bilinear Inter O3column for Lat = 51.75 Lon = 0.25 is **264.25 DU**

AOSC 652: Analysis Methods in AOSC

Extra Credit #2:

Example we used in class was total ozone over London, March 2016

Latitude = 51.75, Longitude = 0.25

If we go to http://ozoneaq.gsfc.nasa.gov/tools/ozonemap
and enter 51.75, 0.25 for 16 March 2016, we get **314 DU**

For this date, our code outputs:

O3column for four closest points: Lat = 51.50, Lon = −0.50 => O3 = 314 DU
Lat = 51.50, Lon = 0.50 => O3 = 314 DU
Lat = 52.50, Lon = 0.50 => O3 = 317 DU
Lat = 52.50, Lon = −0.50 => O3 = 318 DU

Bilinear Inter O3column for Lat = 51.75 Lon = 0.25 is **314.81 DU**

AOSC 652: Analysis Methods in AOSC

Extra Credit #2:

Example we used in class was total ozone over London, March 2016

Latitude = 51.75, Longitude = 0.25

If we go to http://ozoneaq.gsfc.nasa.gov/tools/ozonemap
and enter 51.75, 0.25 for 17 March 2016, we get **369 DU**

For this date, our code outputs:

O3column for four closest points: Lat = 51.50, Lon = −0.50 => O3 = 370 DU
Lat = 51.50, Lon = 0.50 => O3 = 369 DU
Lat = 52.50, Lon = 0.50 => O3 = 370 DU
Lat = 52.50, Lon = −0.50 => O3 = 370 DU

Bilinear Inter O3column for Lat = 51.75 Lon = 0.25 is **369.44 DU**

AOSC 652: Analysis Methods in AOSC

Extra Credit #2:

Example we used in class was total ozone over London, March 2016

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Bilinear Inter O3column for Lat = 51.75 Lon = 0.25 is **369.44 DU**

What is going on ?!?

AOSC 652: Analysis Methods in AOSC

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Lat = 52.50, Lon = −0.50 => O3 = 271 DU

Bilinear Inter O3column for Lat = 51.75 Lon = 0.25 is **264.25 DU**

AOSC 652: Analysis Methods in AOSC

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AOSC 652: Analysis Methods in AOSC

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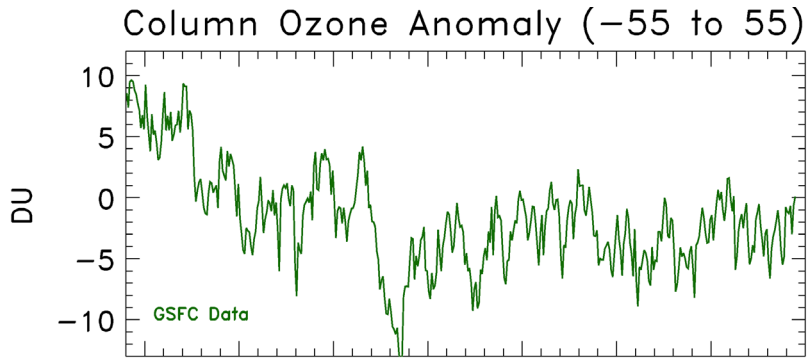
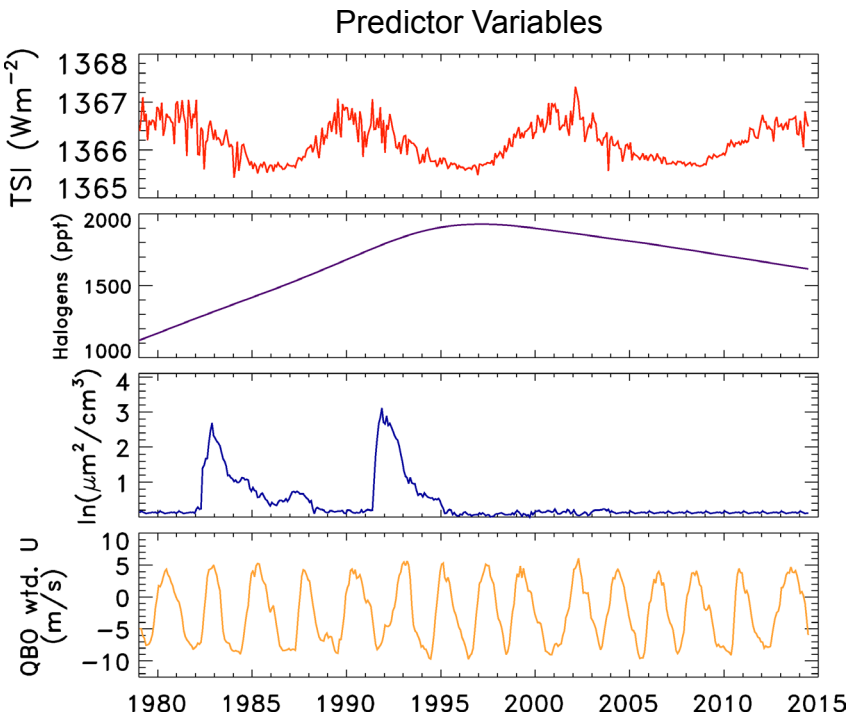
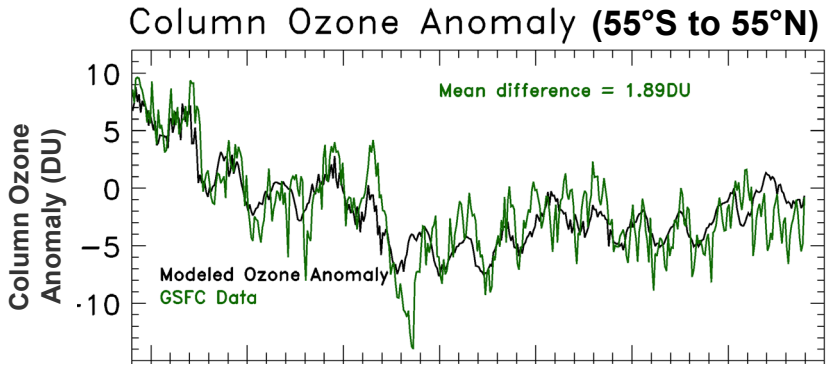
How much "ozone depletion" has occurred over London due to anthropogenic use of halocarbons?



Ozone data from
http://acdb-ext.gsfc.nasa.gov/Data_services/merged



How much "ozone depletion" has occurred over London due to anthropogenic use of halocarbons?



Ozone data from
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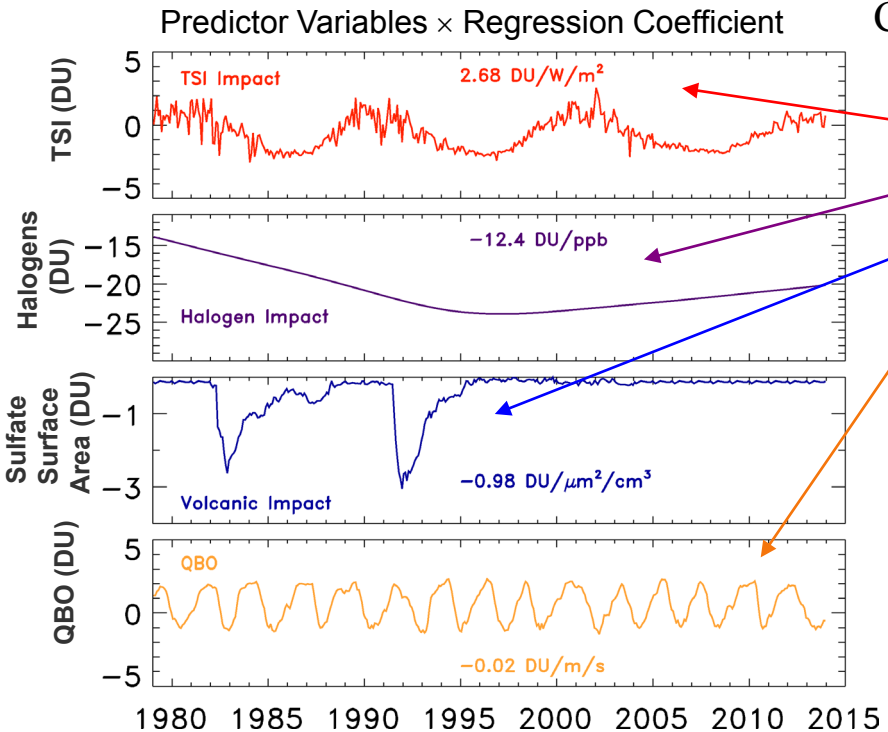
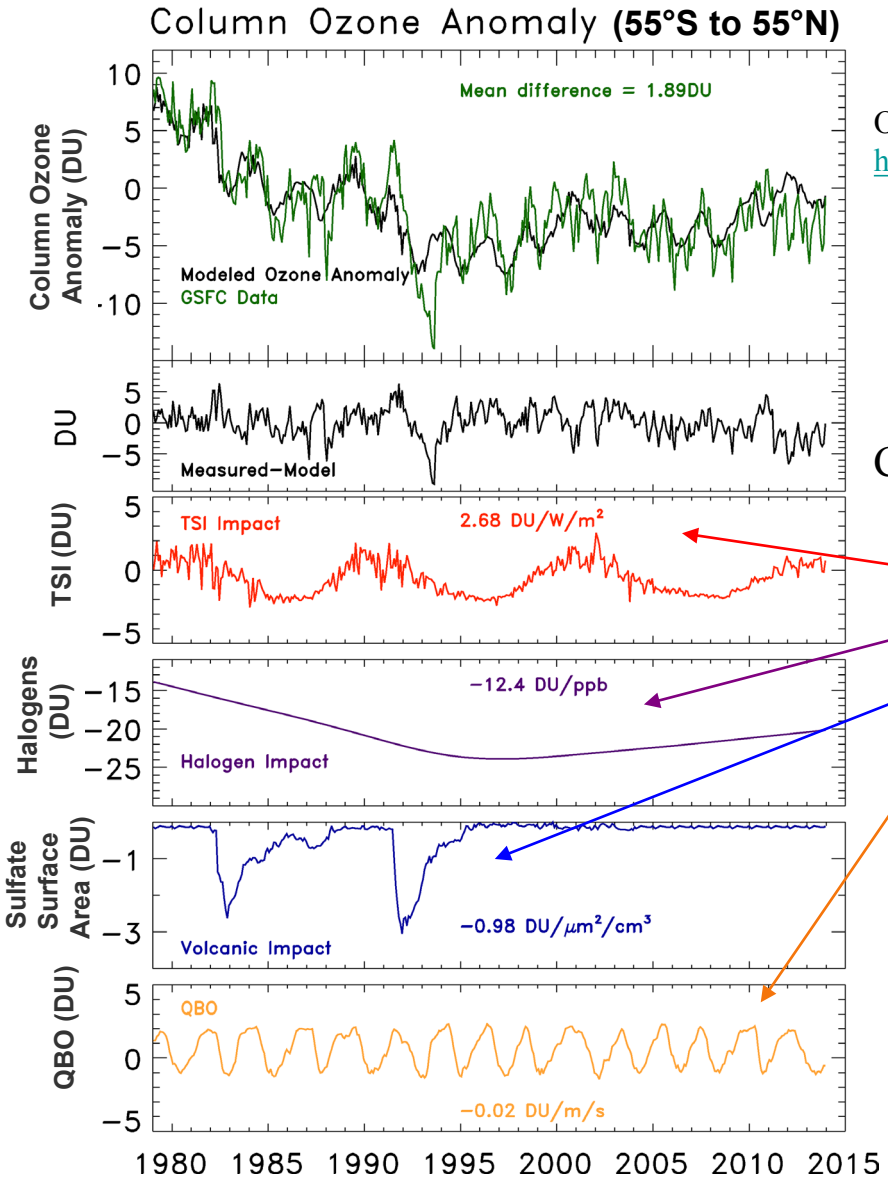


Column Ozone Anomaly (DU) =

19.5	DU +	
2.68	DU / W m^{-2}	× TSI +
−12.4	DU / ppb	× Halogens +
−0.98	DU	× ln (SSA) +
−0.20	DU / m s^{-1}	× QBO

where
TSI = total solar irradiance
Halogens=stratospheric chlorine & bromine loading
SSA = Sulfate Surface Area
QBO = Quasi-biennial oscillation of the direction of winds in the tropical lower strat

How much "ozone depletion" has occurred over London due to anthropogenic use of halocarbons?



Ozone data from
http://acdb-ext.gsfc.nasa.gov/Data_services/merged

Column Ozone Anomaly (DU) =

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2.68	DU / W m^{-2}	×	TSI +
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where

TSI = total solar irradiance

Halogens=stratospheric chlorine & bromine loading

SSA = Sulfate Surface Area

QBO = Quasi-biennial oscillation of the direction of winds in the tropical lower strat