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# **Multi Sensor Reanalysis (MSR) of total ozone and ozone profiles**

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(KNMI)**

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# Introduction

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## **MSR version 1:**

- Total ozone data record 1979-2008
- van der A et al. ACP, 2010



## **MSR version 2:**

- Total ozone data record extended to 1970-2012
- van der A et al. AMT, 2015

## **Operational MSR updates:**

- Part of Copernicus Climate Change Service (C3S-ozone)
  - Will start soon
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**Methodology:**

**Constructing the Multi-Sensor Reanalysis of ozone**

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# Multi Sensor Reanalysis (MSR) of ozone

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## Assumption:

- The ground observations are on average a good approximation for the true values.

## Procedure:

- All UV-VIS satellite data in the period 1970-2012 is used.
- Step 1 : Correct satellite data to avoid biases. The reference data that is chosen are ground data observations from reliable WOUDC stations.
- Step 2 : Satellite data is assimilated in a chemical-transport model to achieve complete global and temporal coverage.

## Availability:

- Multi Sensor Re-analysis (MSR) data available at [www.temis.nl](http://www.temis.nl)
- Published in:

*R.J. van der A , Allaart, M. A. F., and Eskes, H. J.: Extended and refined multi sensor reanalysis of total ozone for the period 1970–2012, Atmos. Meas. Tech., 2015.*

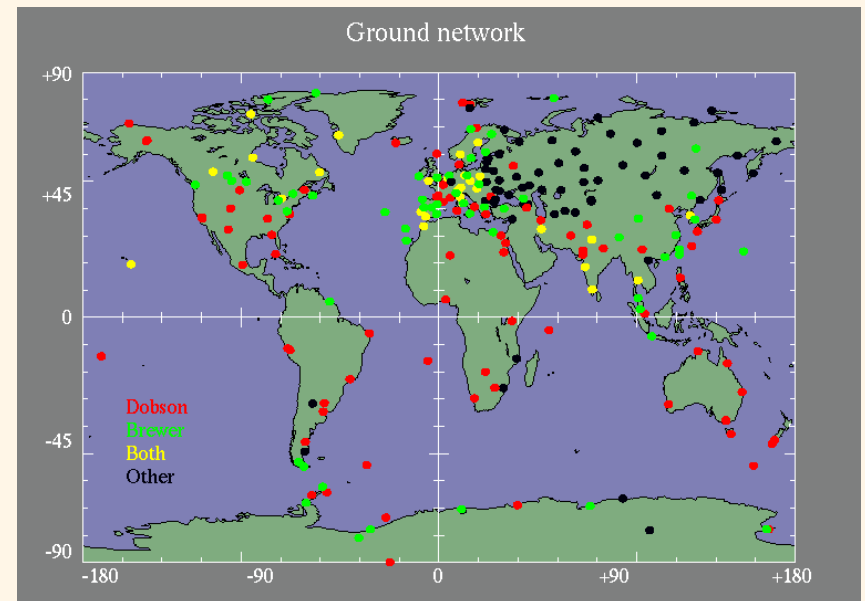
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# Reference data

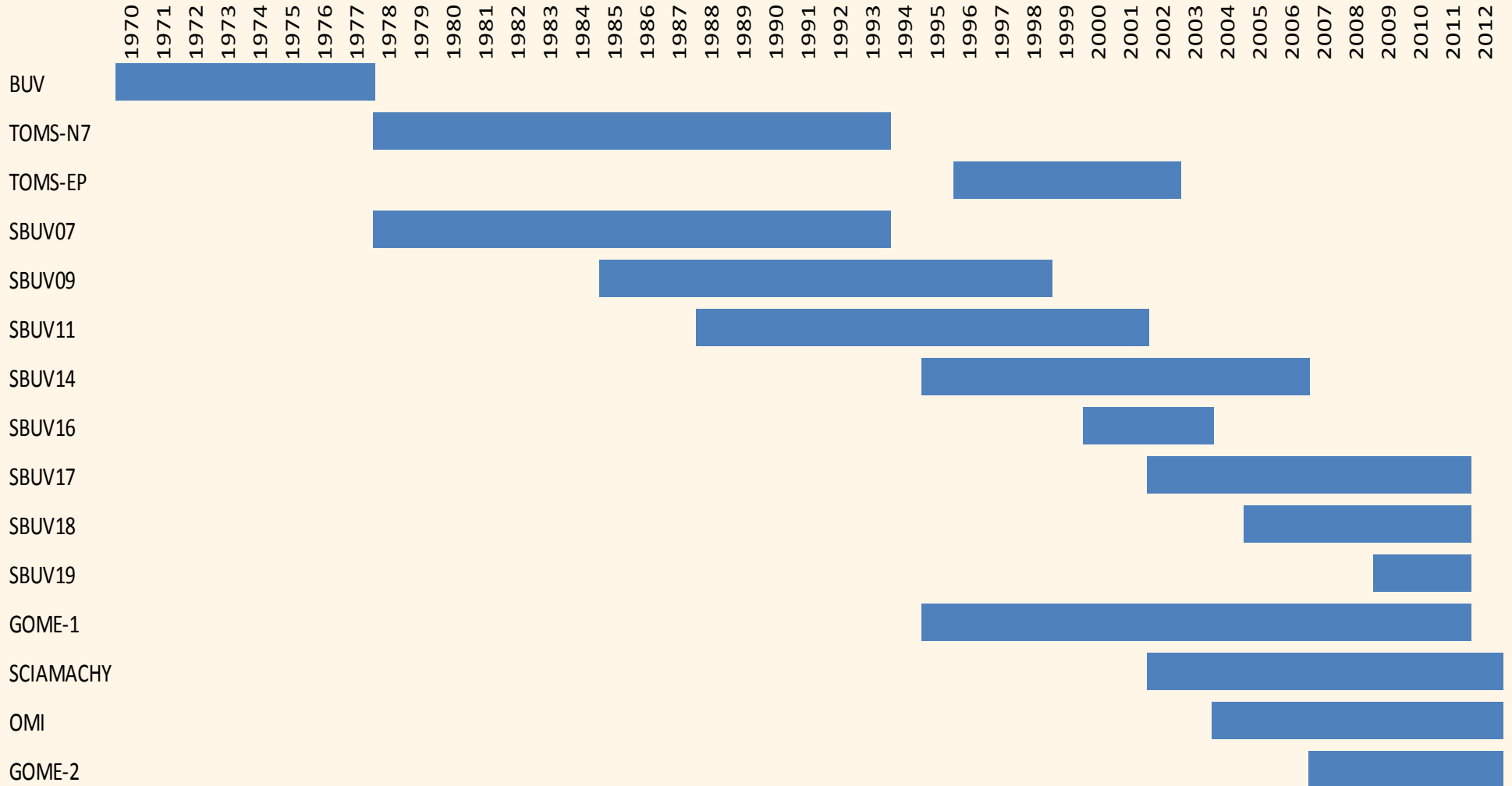
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## Reference data set:

- From WOUDC 91 ground stations are selected with a long and reliable dataset (*Fioletov et al.*, 2008)
- Dobson & Brewer instruments
- Dobson data corrected for temperature dependence (*Kerr et al.*, 2002)



# Satellite instruments



# Corrections satellite data

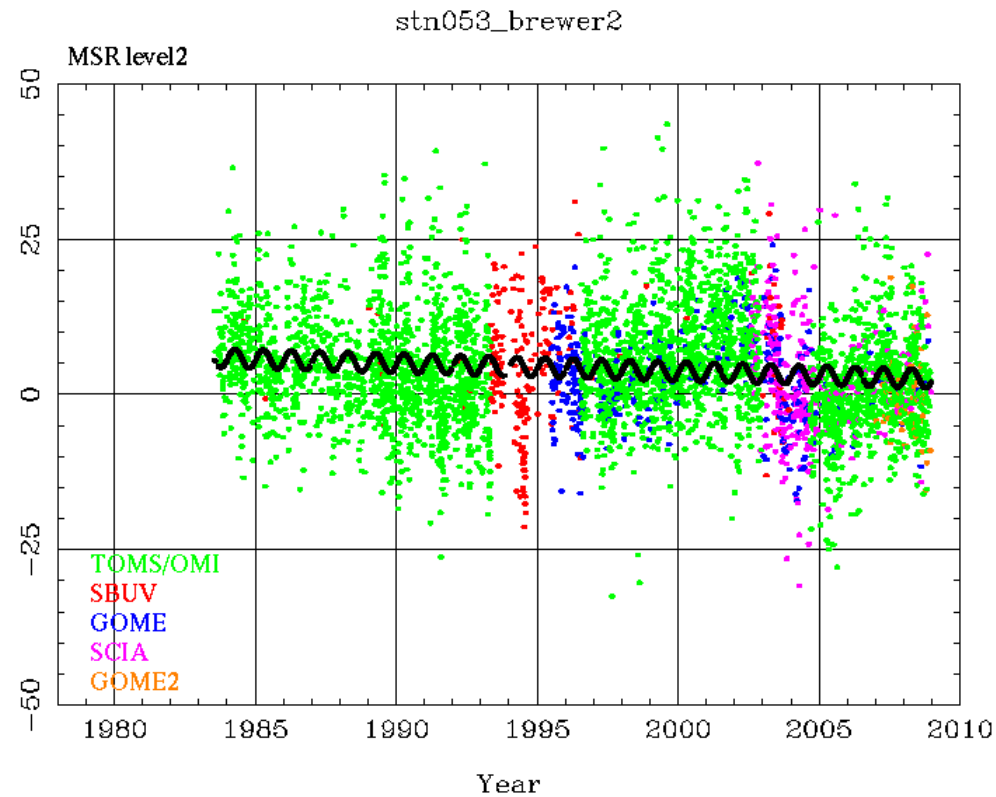
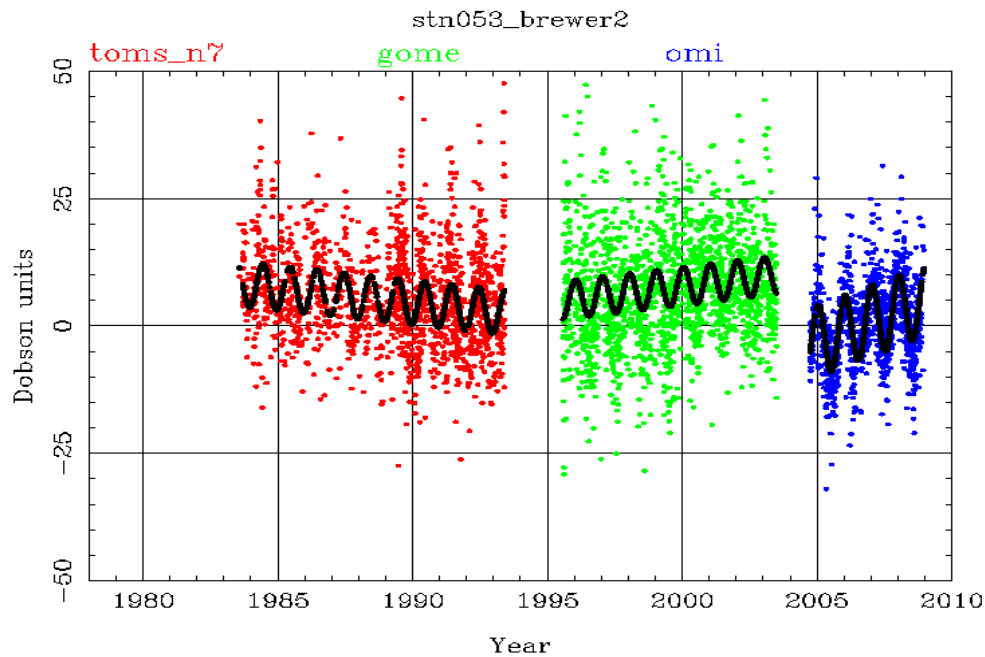
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Expected dependencies of satellite data:

<b>Parameter</b>	<b>Physical mechanism</b>
Solar zenith angle	Light path
Viewing zenith angle	Scan mirror
Effective temperature	O3 cross-section
Time (trend)	Instrument degradation
Offset	Calibration

- Generate time series of the satellite data sets for all stations.
  - Fit all time series as function of the 5 parameters.
  - Apply corrections as function of the fit parameters to construct the Multi-Sensor Reanalysis (MSR) level 2 data
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# Correction of level 2 data



*Satellite minus Brewer observations  
for the Uccle ground station*



# Data assimilation of the MSR level 2 data

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- Level 2 data is on satellite footprint. Location measured on irregular times. Regions without observations exist.

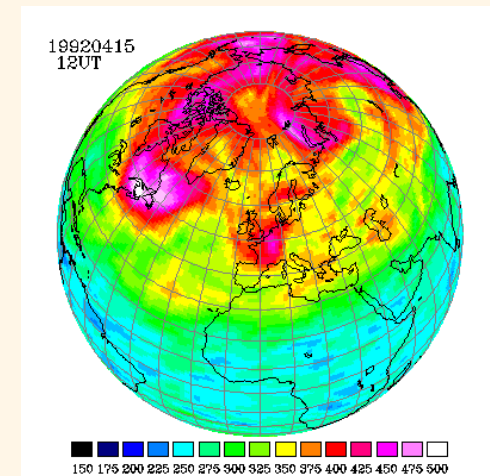
## Therefore, data assimilation used to create a homogene data record

### Data assimilation:

- Kalman-type data assimilation scheme using the TM model
- Meteo: ECMWF ERA-interim winds, temperatures
- Stratospheric chemistry parametrizations (Cariolle v. 2.9)
- Starting in 1970 by including BUUV data. The reanalysis period is 43 years (!).

- Output:

- Total ozone field every 6 hours
- Spatial grid is 1 x 1 degree (resolution is 0.5 degree)
- Daily local time ozone field at noon (for UV index)



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## **Analysis of results for the MSR version 2**

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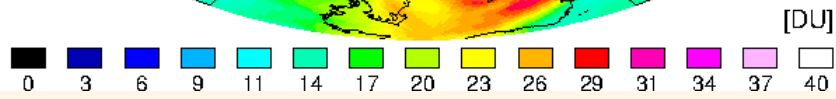
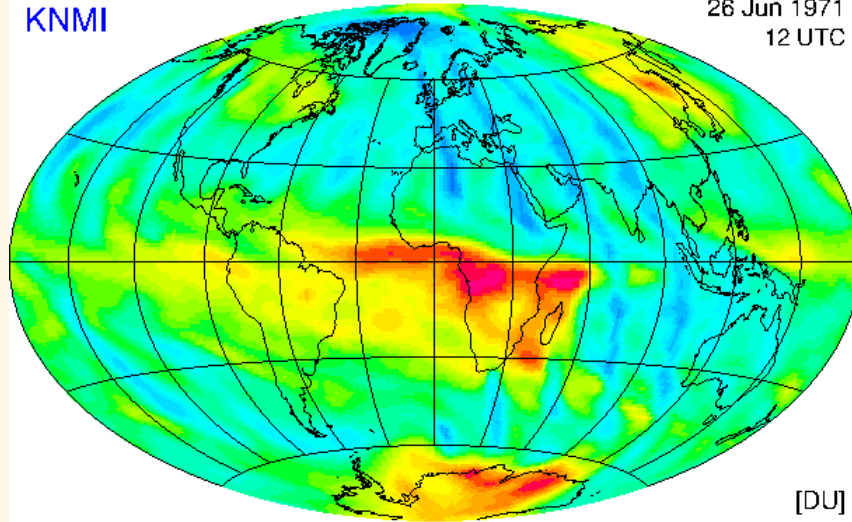
Multi Sensor Reanalysis 2

KNMI

Error of assimilated ozone

26 Jun 1971

12 UTC



## Examples of **error** fields for

- 26-06-1971 (BUV)
- 26-06-1984 (TOMS)
- 26-06-2006 (almost all sat.)

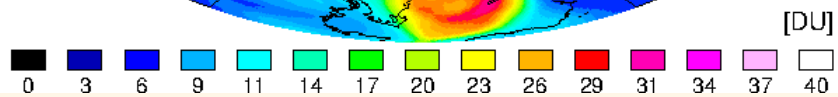
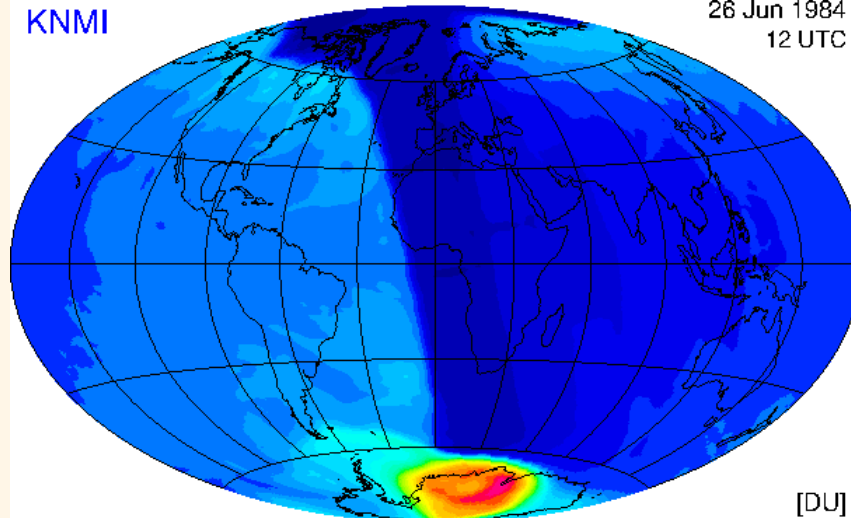
Multi Sensor Reanalysis 2

KNMI

Error of assimilated ozone

26 Jun 1984

12 UTC



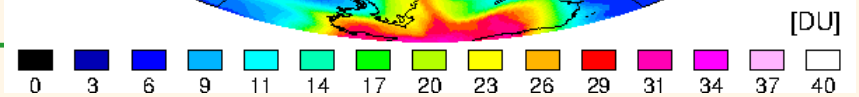
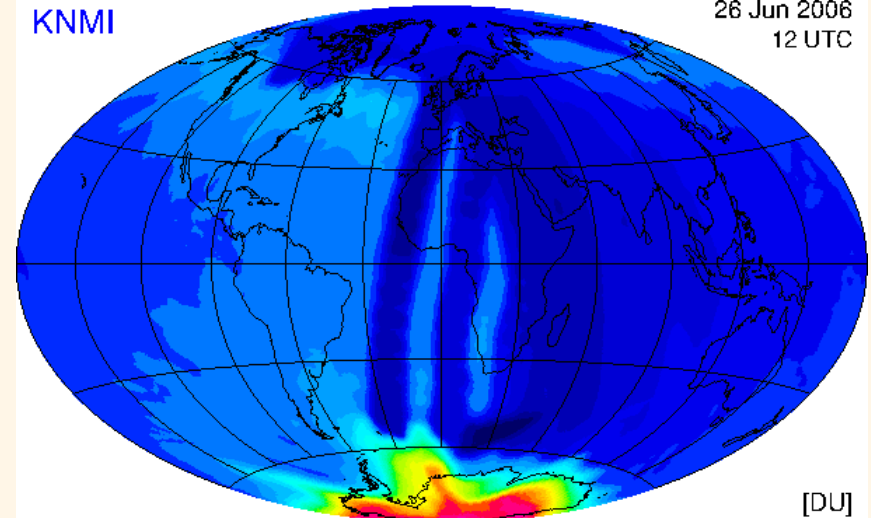
Multi Sensor Reanalysis 2

KNMI

Error of assimilated ozone

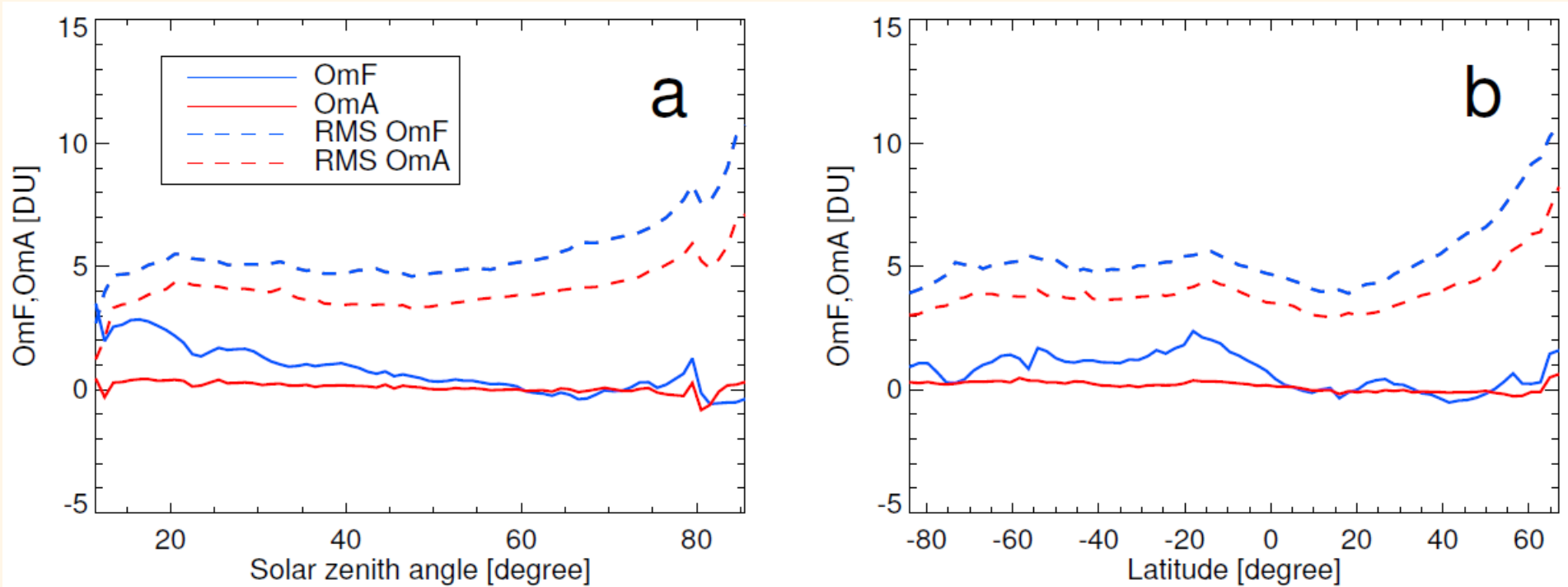
26 Jun 2006

12 UTC



# OmF, OmA as function of latitude and solar zenith angle in January 2008

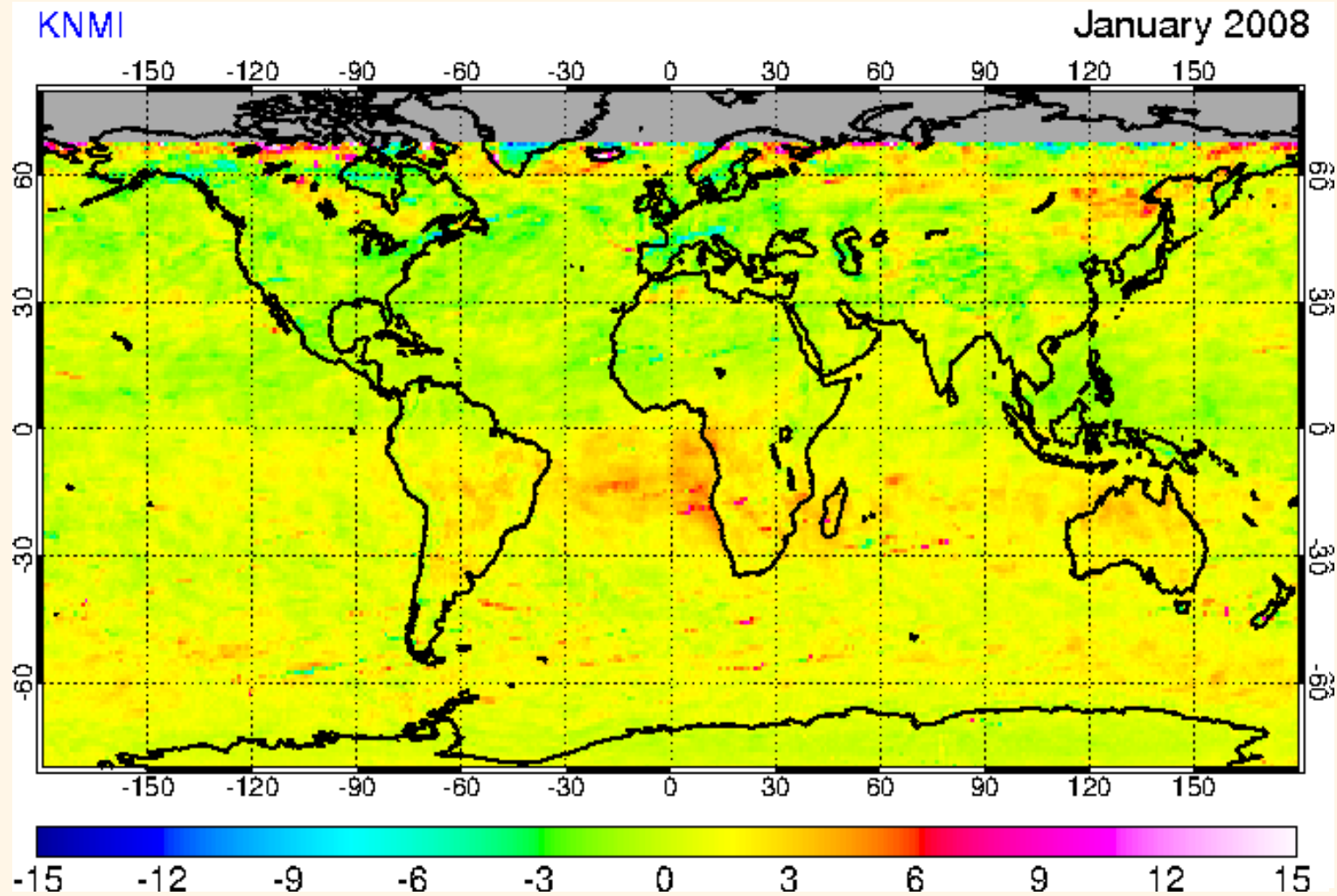
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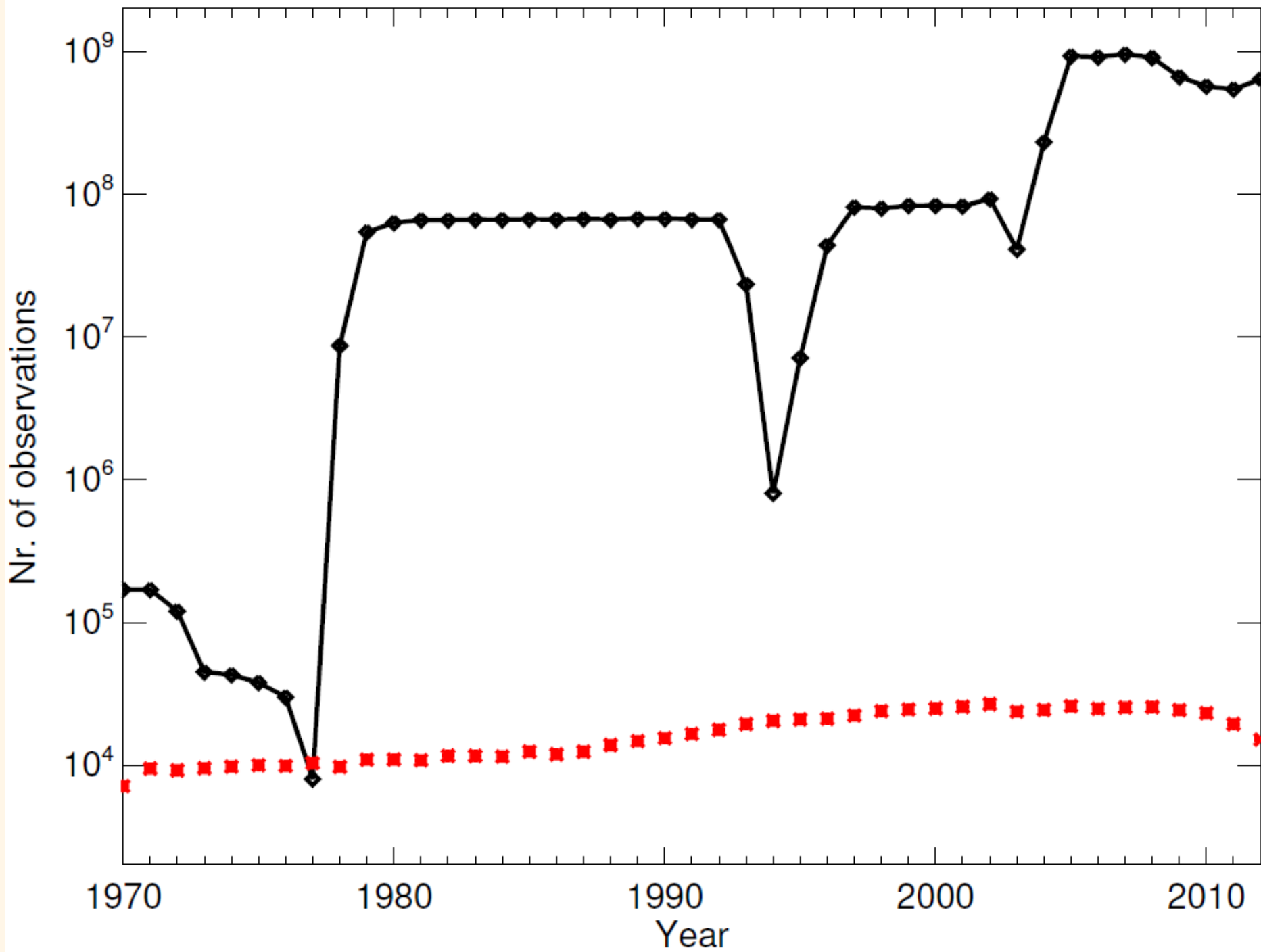


# OmF of the Multi-Sensor Reanalysis (MSR2)

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Gridded for  
January 2008

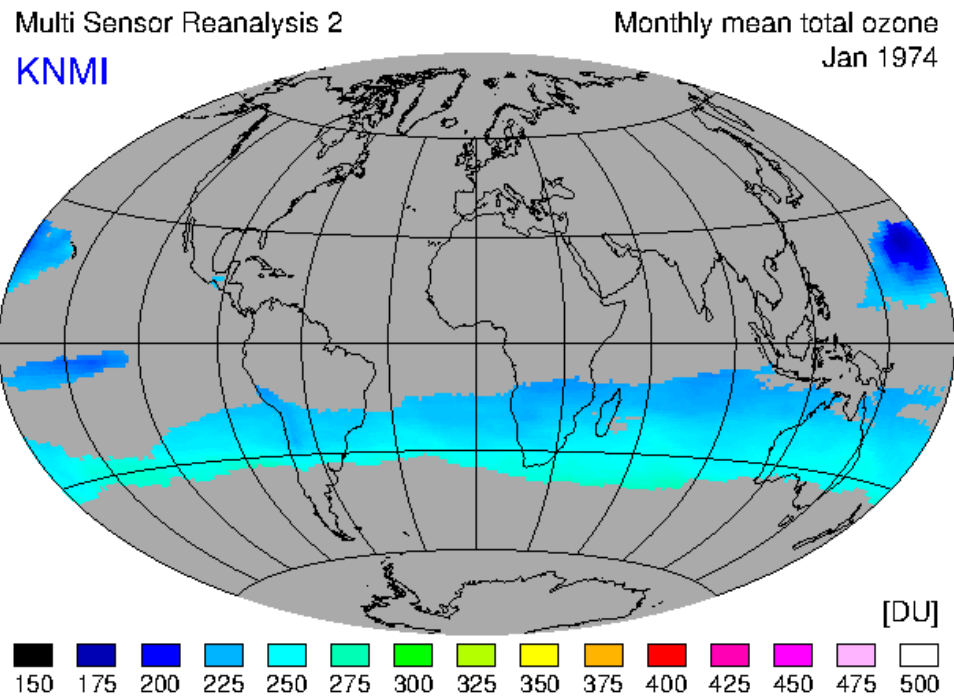




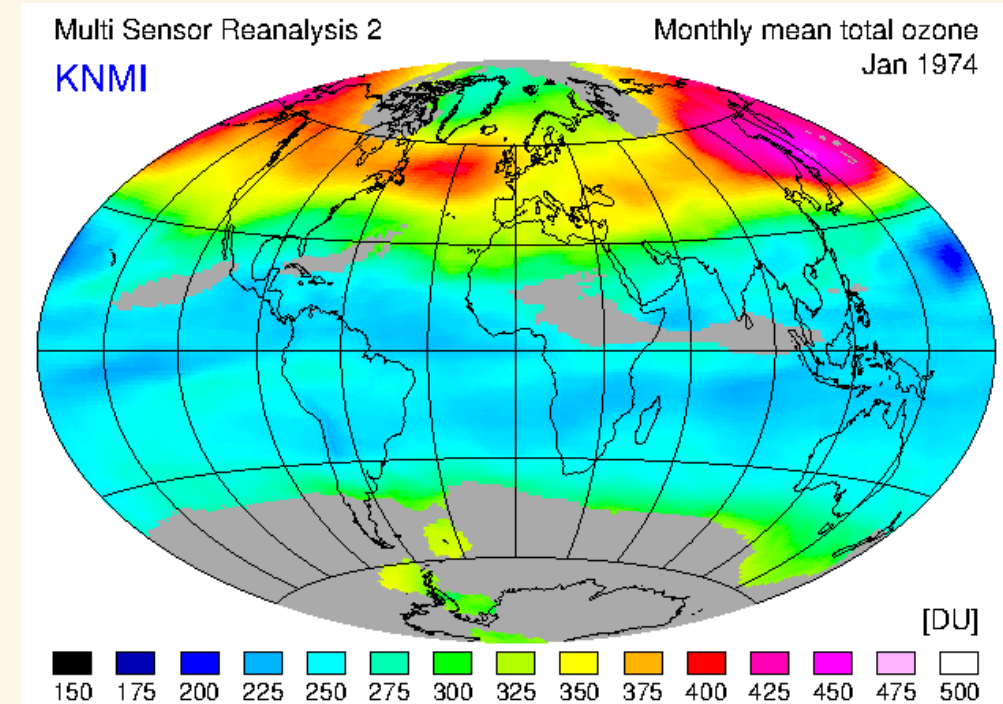
# MSR 2 extended with Dobson ground observations

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## MSR2



## MSR2 extended with Dobson

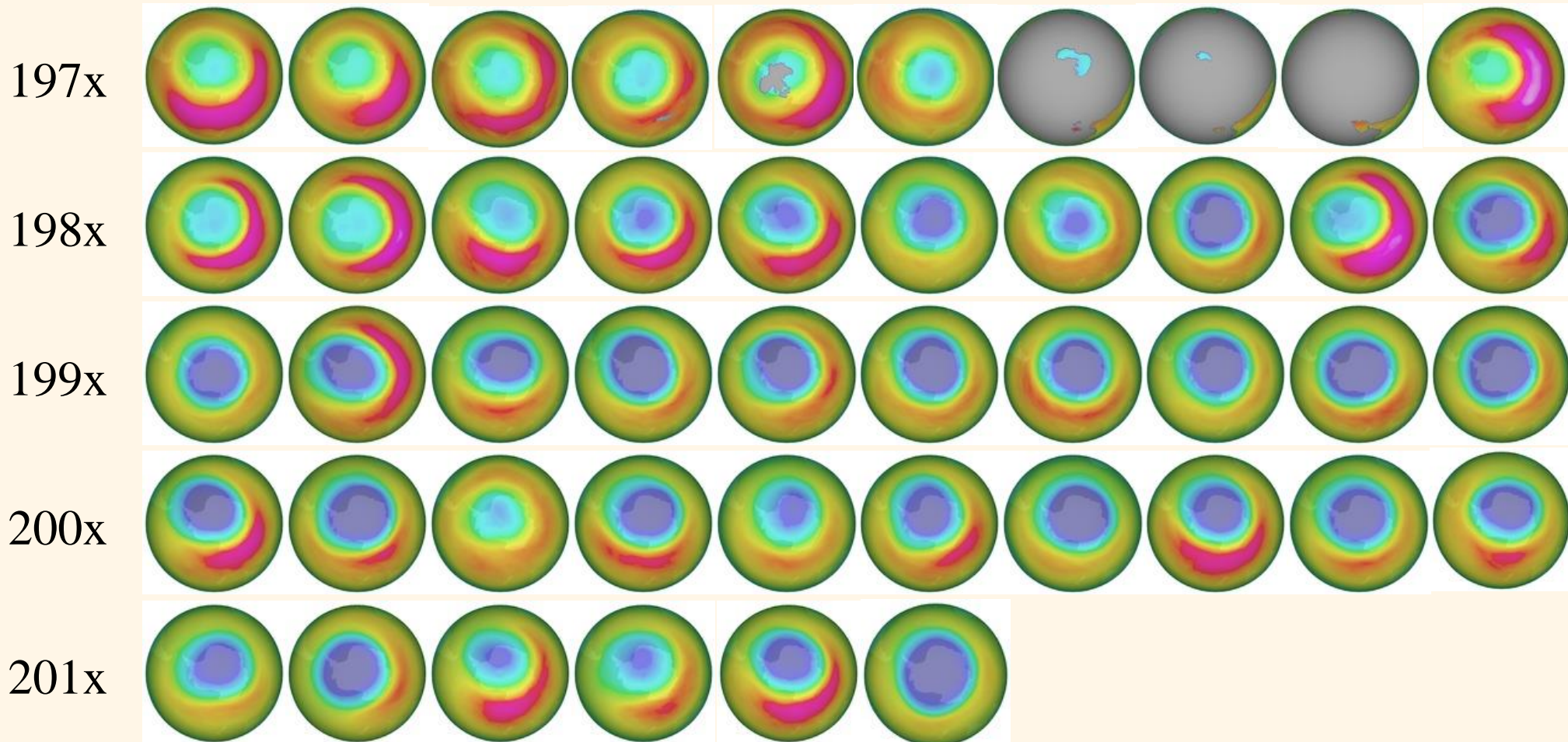




# October monthly mean 1970-2015 (MSR2+)

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## **Comparison to AC&C/SPARC database**

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# Comparison of MSR and AC&C/SPARC

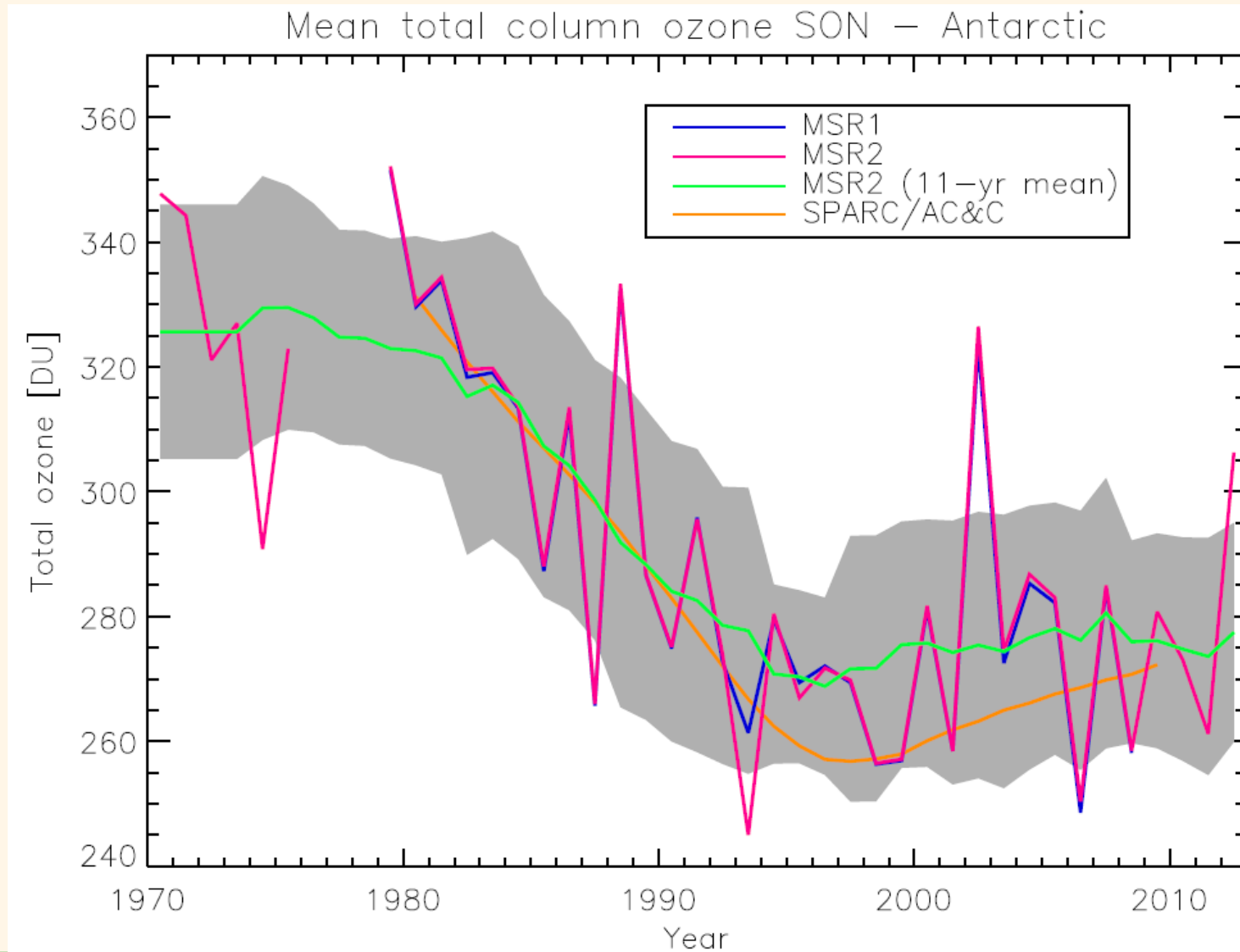
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ECV ozone comparison for 1980-2010:

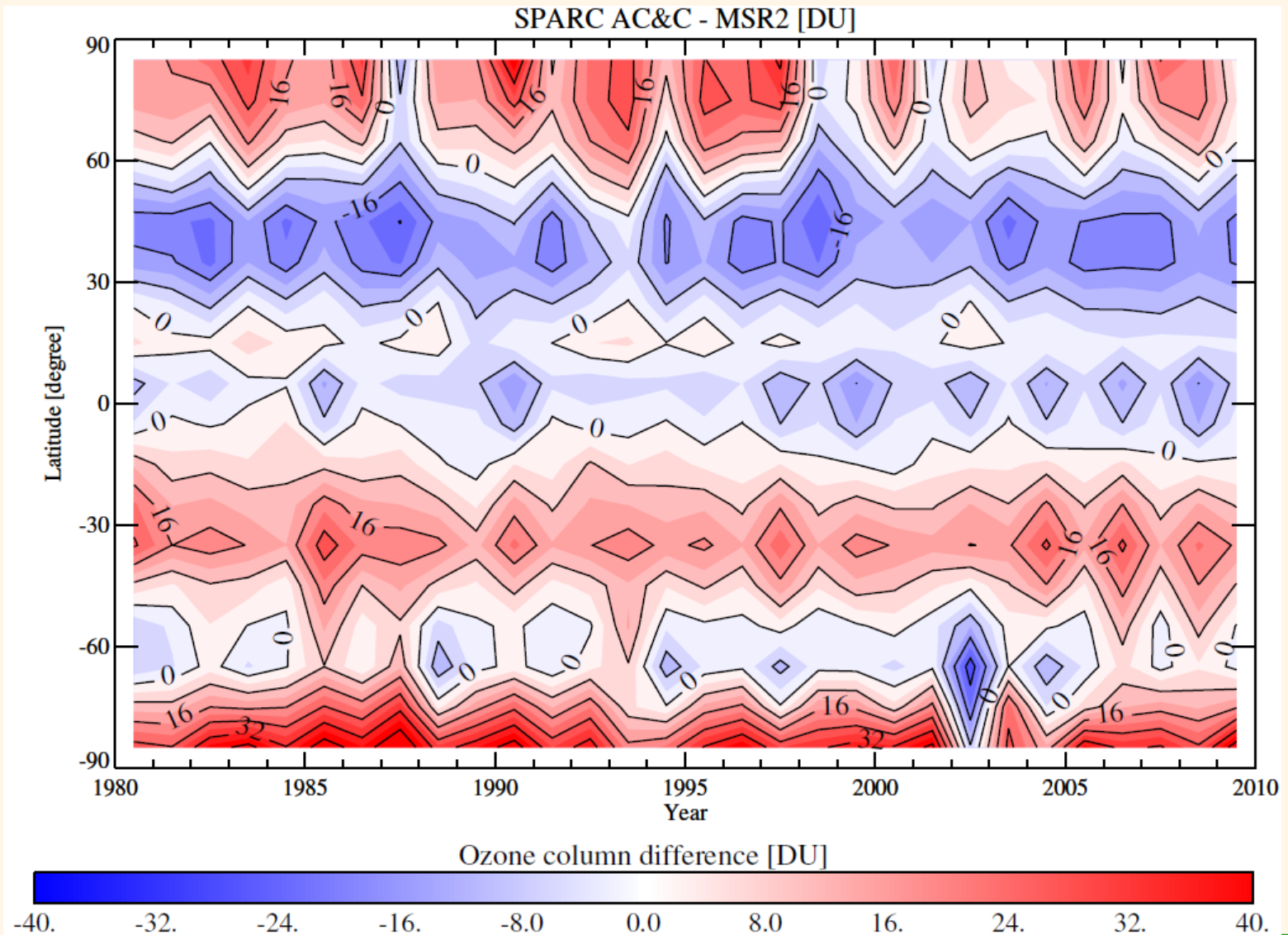
- Ozone satellite observations: MSR2
- Ozone database from AC&C/SPARC (for CMIP5)
  - No dynamics included
  - Zonal averaged stratosphere



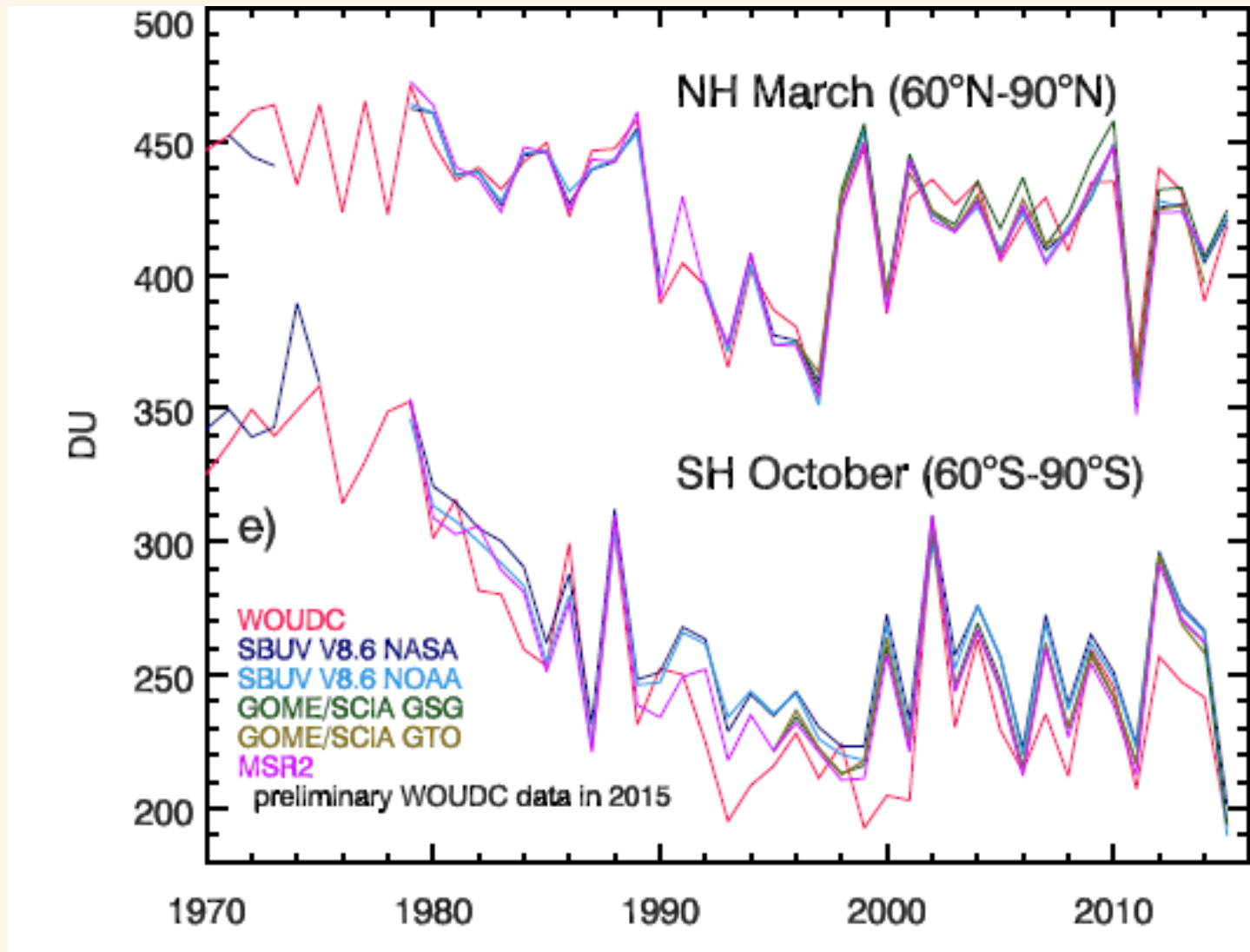
# Intercomparison with SPARC data over the Antarctic (Sep.-Nov.)



# AC&C SPARC ozone versus MSR2 (annual zonal mean)



# BAMS climate report 2015



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- 1. Application to ozone profiles**
  - 2. Conclusions**
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# We apply a similar method to ozone profiles

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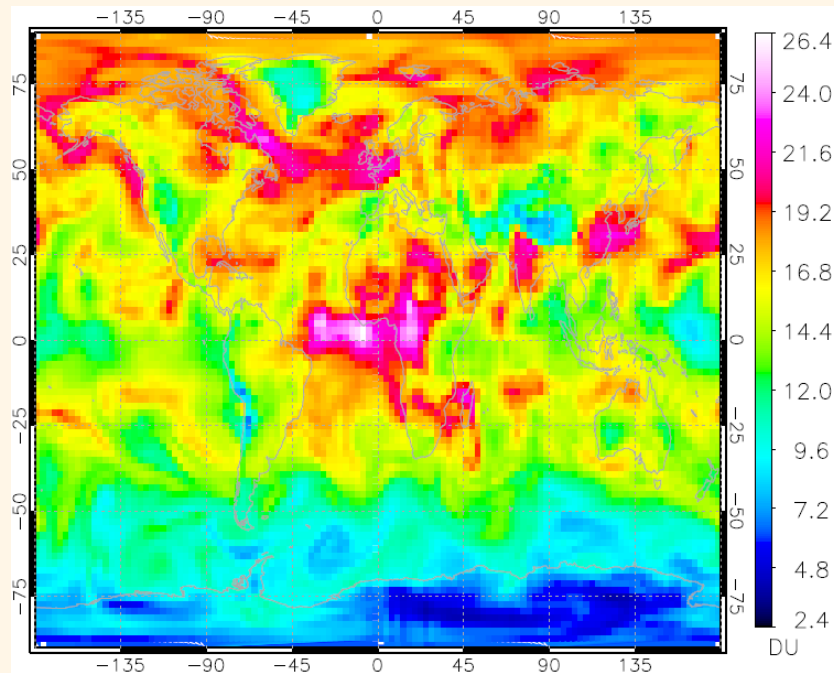
- Reference is ozone sonde database (WOUDC)
  - Correction per layer as function of SZA, VZA, and time
  - 3D data assimilation of simultaneous instruments.
  - To be processed within O3-CCI project:  
1995-2012 (GOME, GOME2, OMI, SCIA, IASI)
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# First results of 3D ozone field (1)

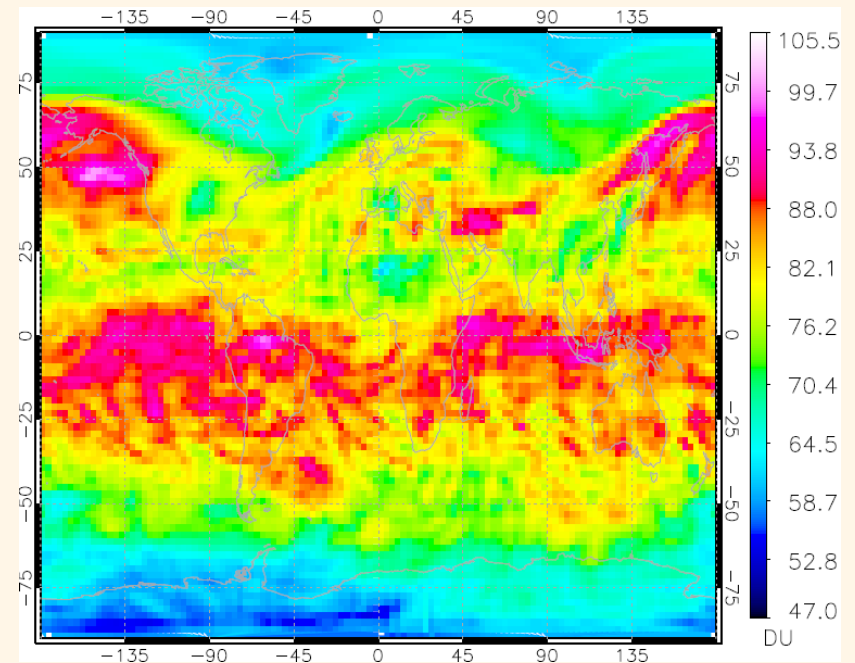
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Examples of retrieved ozone layers on 7 January 2008

**Ozone in 0-6 km layer**



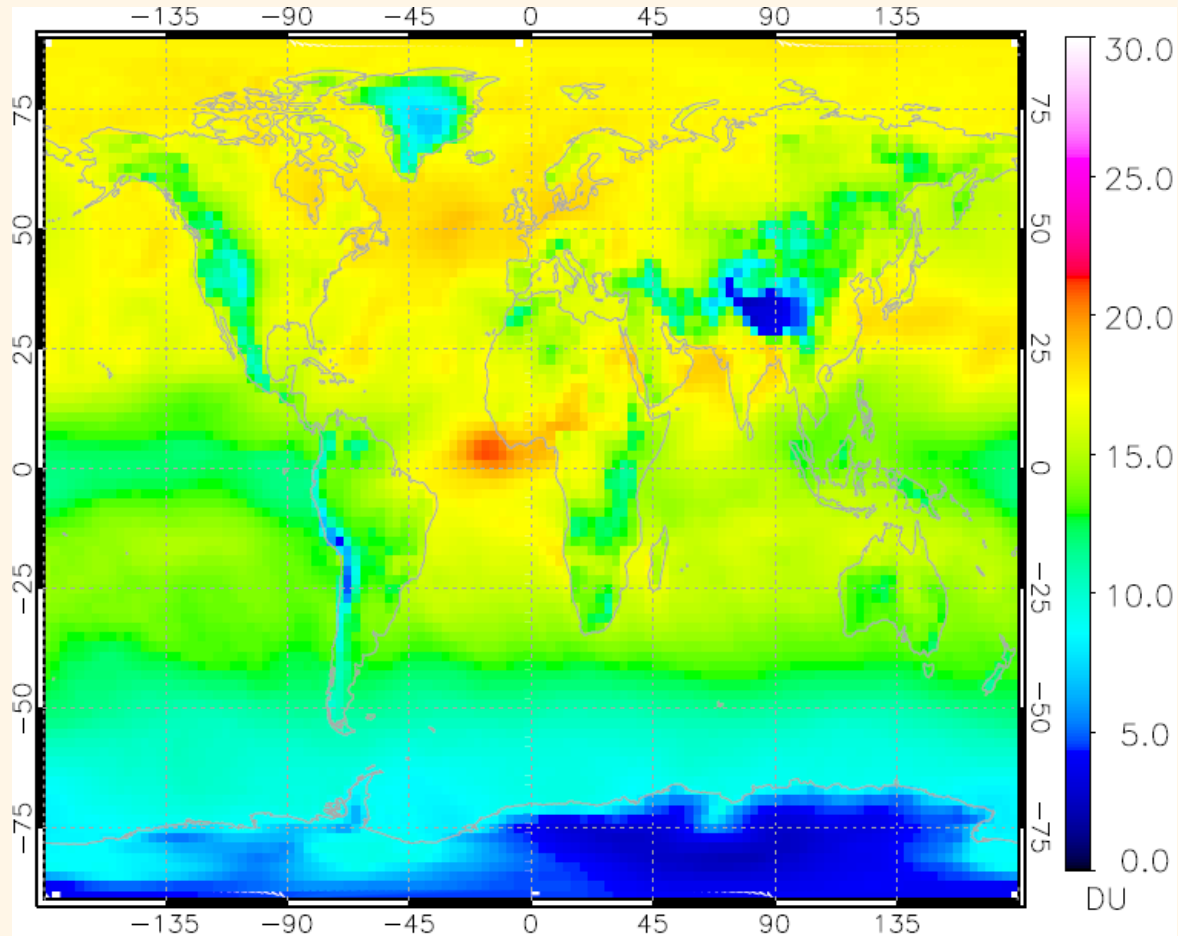
**Ozone in 25-30 km layer**





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## Monthly mean ozone of January 2008 in 0-6 km layer



# Summary

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1979



## Multi Sensor Reanalysis (MSR2) of total ozone:

- 18 total ozone data sets from BUV, TOMS, SBUV, GOME, SCIAMACHY, OMI and GOME-2 are corrected by comparison with Brewer and Dobson data (WOUDC).
- An improved data assimilation scheme has been developed and verified by detailed OmF analysis.
- The MSR data record is extended to the period **1970-2012** on a 1x1 degree grid (0.5 degree resolution) and 6 hour time steps.
- A similar method has been applied to nadir ozone profiles. First results are available.

1984



1989



1994



1999



## Outlook

- MSR-methodology applied to ozone profiles observed by satellite (results available via CCI-ozone project)
- Operational MSR updates via the Copernicus Climate Change Service (C3S)

2004



2009

