Global and Regional Total Ozone Trends using 20 Years of European Satellite Data

M. Coldewey-Egbers [DLR], D. Loyola [DLR], M. Dameris [DLR], P.Braesicke [KIT], M. van Roozendael [BIRA], C. Lerot [BIRA], M. Koukouli [AUTH], D. Balis [AUTH], and W. Zimmer [DLR]

DLR

Outline

- Motivation
- GOME-type Total Ozone – Essential Climate Variable
- Total Ozone Trends
  - GTO-ECV CCI
  - Dobson Ground-Based Data
  - EMAC Model Simulation
- Summary and Outlook

Motivation

- 1987 Montreal Protocol
- ODSs peaked in the late 1990s
- Ozone levels remain stable since ~2000
- Recovery is expected but masked by large - dynamically induced - interannual variability in the middle and high latitudes

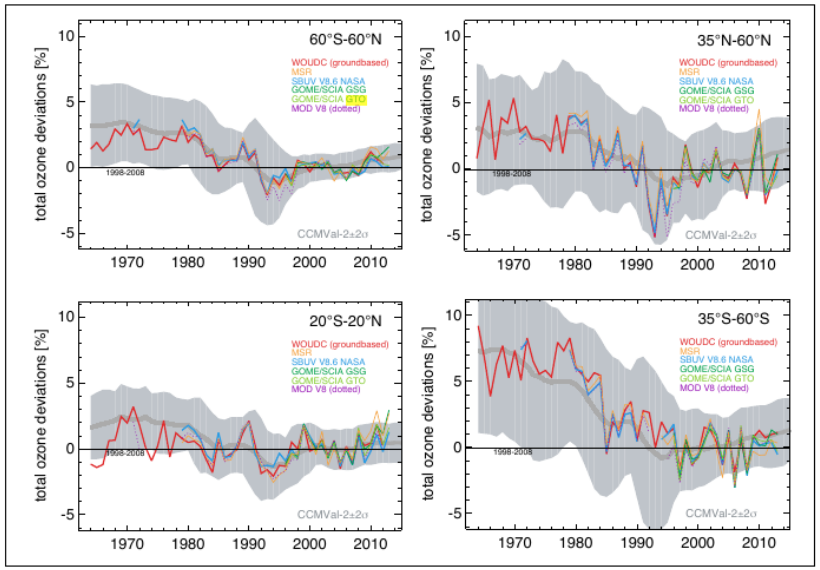


Fig. 2-2, WMO Report, 2014

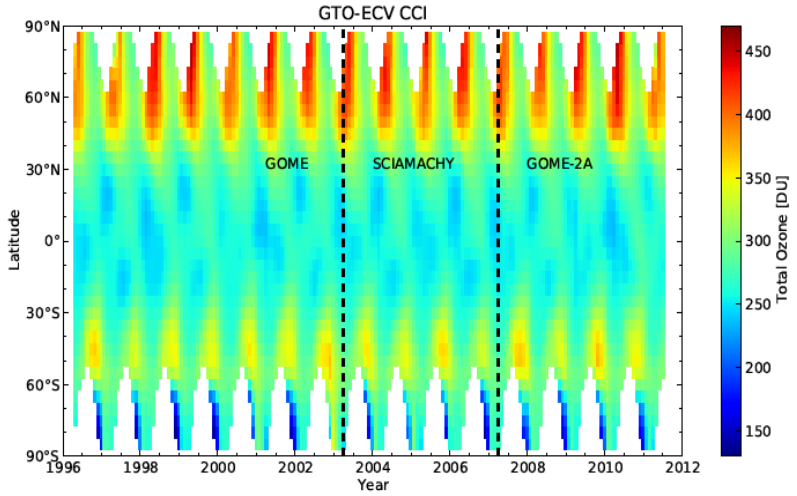
- Need to create global long-term and consistent satellite data records

→ **ESA Climate Change Initiative Ozone_CCI Project**

- Monitor the long-term behavior of total ozone
- Analyze ozone variability and trends on global and regional scales
- Evaluate Chemistry Climate Model simulations

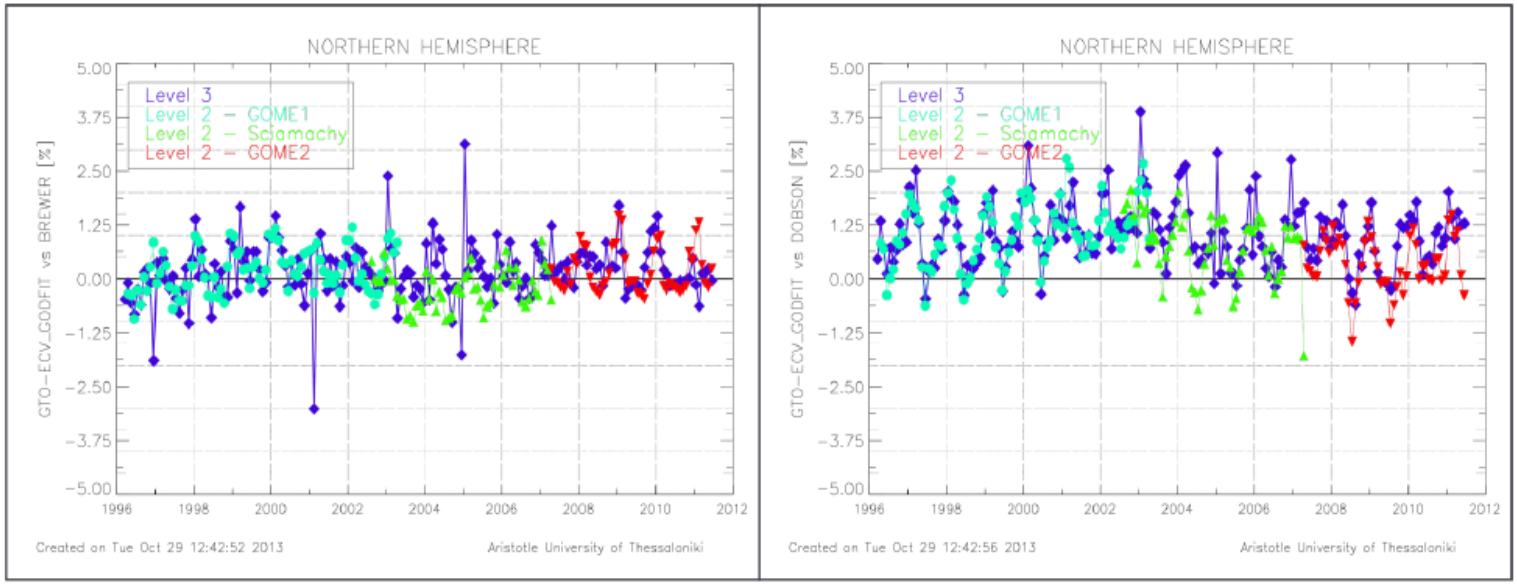
GTO-ECV CCI Total Ozone Data Record

- Combination of **GOME/ERS-2 (1995-2011), SCIAMACHY/ENVISAT (2002-2012),** and **GOME-2/MetOp-A (2007-present)**
- Level 2 based on GODFIT version 3 (Lerot et al., JGR, 2014)
- Use GOME as reference and apply inter-sensor correction factors to SCIAMACHY and GOME-2A.
- Data record contains 1°x1° monthly means (incl. SD and estimated sampling errors) from July 1995 to December 2014.
- Algorithm description and extensive ground-based validation in Coldewey-Egbers et al., AMTD, 2015.
- Data freely available via: http://www.esa-ozone-cci.org



GTO-ECV CCI Ground-Based Validation (AUTH)

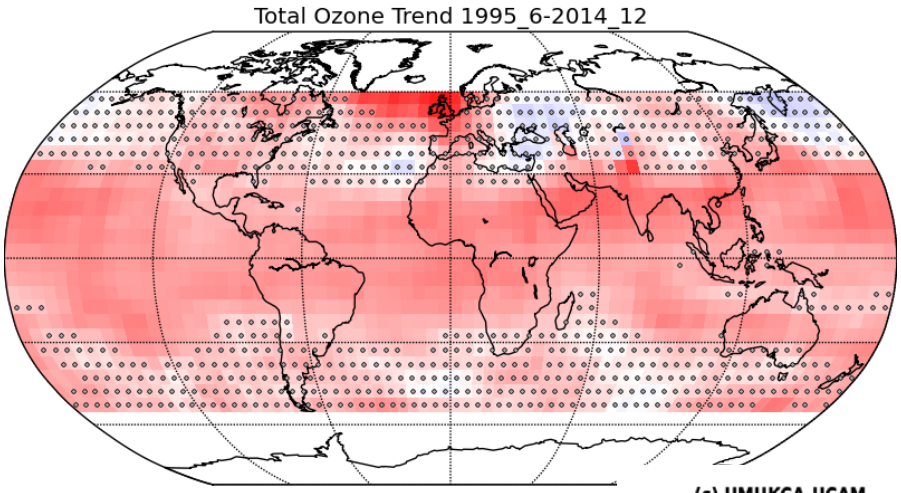
NH Brewer NH Dobson

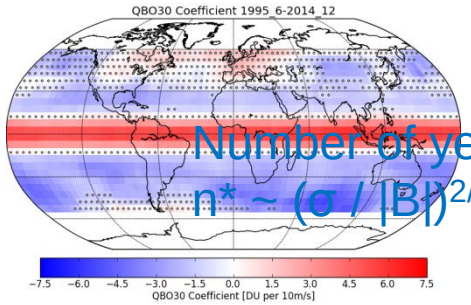


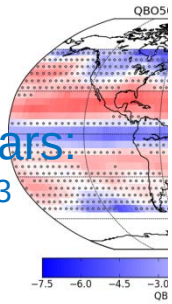
Coldewey-Egbers et al., AMT(D), 2015

→ Level 3 merged product is of the same high quality as the individual level 2 products that constitute it; except for a few outliers mostly related to sampling differences.

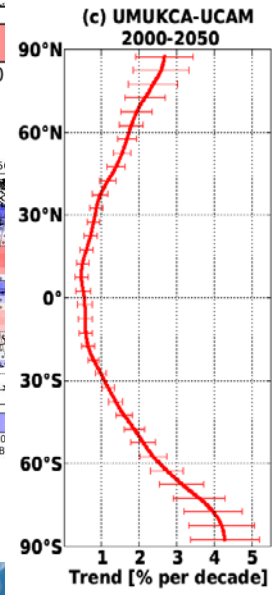
Total Ozone Trends and Variability



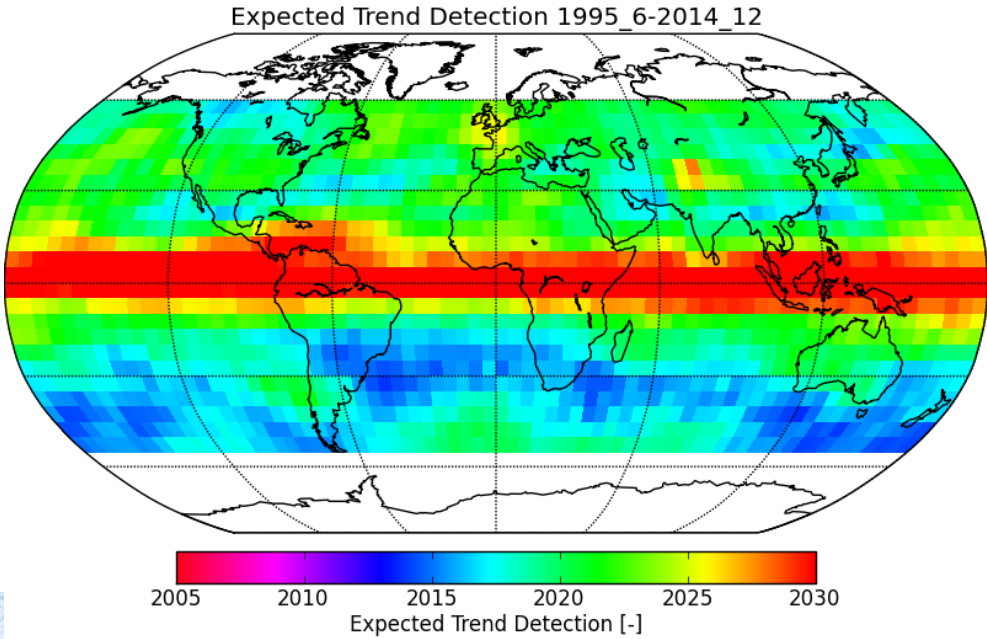




Number of years:
$n^* \sim (\sigma / |B|)^{2/3}$

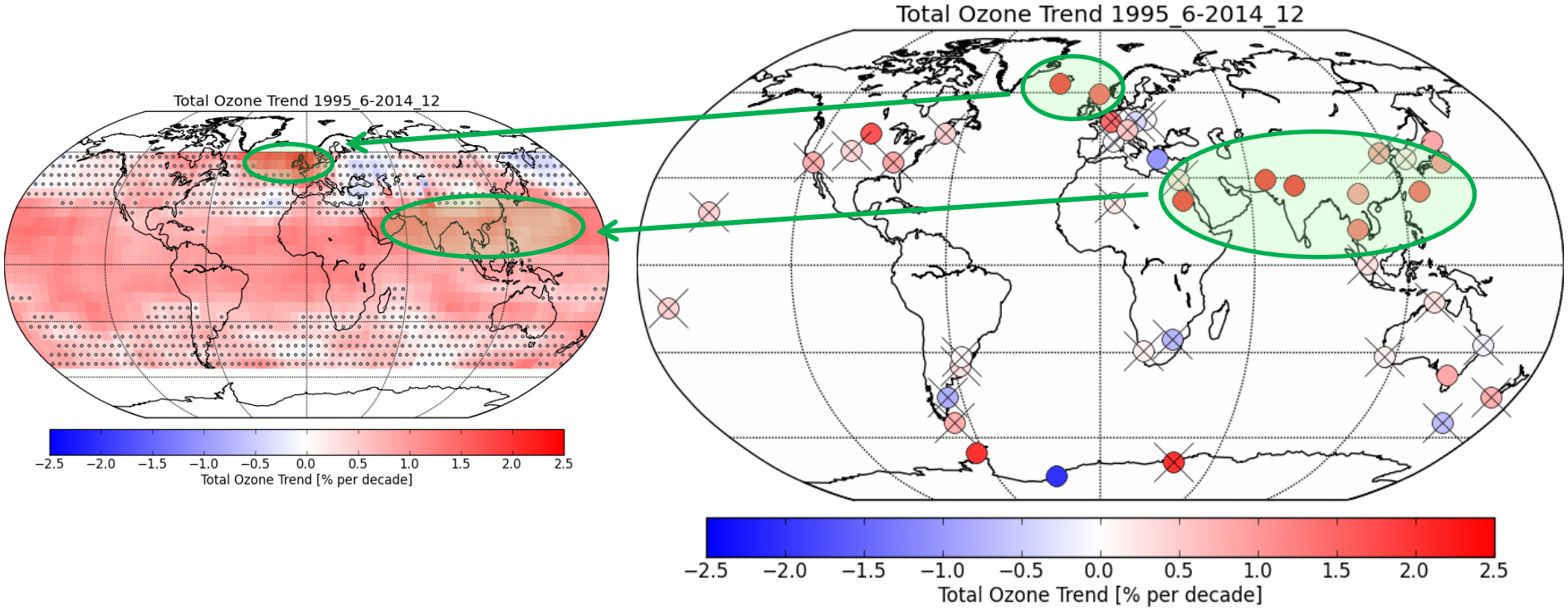


- $O_3(m) = A + B \cdot m + C \cdot SF(m) + D \cdot QBO30 + E \cdot QBO50(m) + F \cdot MEI(m) + X(m)$
- Update of Coldewey-Egbers et al., GRL, 2014
- Linear trend is not significant in the middle latitudes due to strong natural variability that masks expected ozone recovery
- Solar cycle and ENSO impact ozone in the tropics



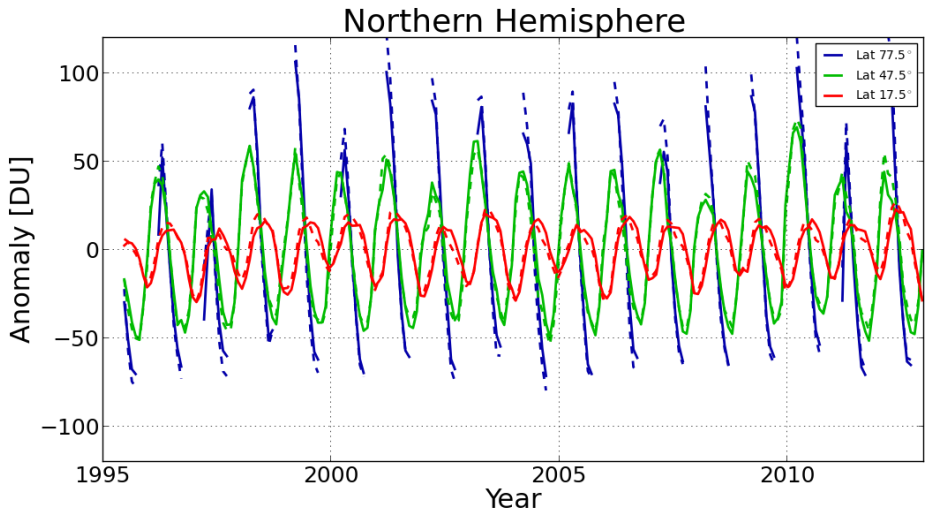
Ground-Based Trends: Dobson Stations

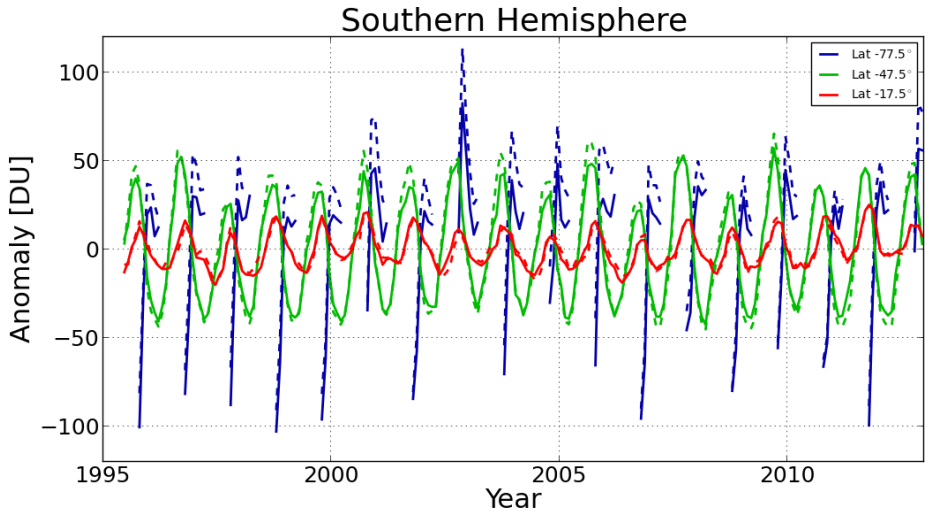
- 42 Dobson stations have been selected (www.woudc.org)
- Some stations confirm the results from the satellite data record
- Trends not significant (crosses) in middle latitudes (North and South America, Europe)



Comparison with EMAC Simulation

- Provided by the Institute for Physics of the Atmosphere / DLR
- **E**CHAM / **M**ESSy **A**tmospheric **C**hemistry, a global atmosphere-chemistry model
- Jöckel et al., GMD, 2010.
- Nudged mode: meteorology constrained to (re-) analysis data.
- Monthly mean total ozone; resolution ~2.8° x 2.8° ; „RC1SD-base-10“ from 1980-2012.
- Total ozone columns: positive bias of ~15DU in Northern Hemisphere and ~15-25DU in Southern Hemisphere compared to GTO-ECV CCI data record
- Ozone anomalies w.r.t. mean (1995-2012) seem well captured by the model, except for the very high latitudes
- Analysis will be extended in the near future

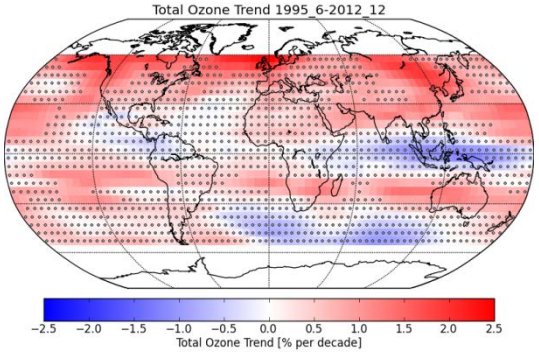


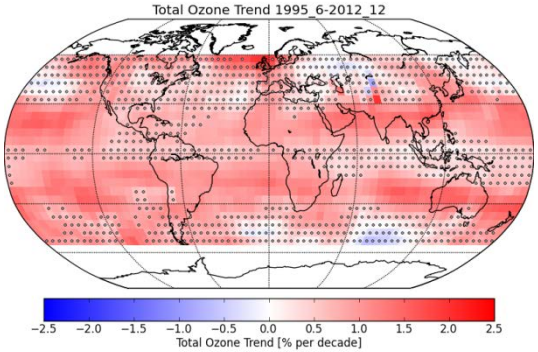


EMAC Total Ozone Trends

Total Ozone Trend

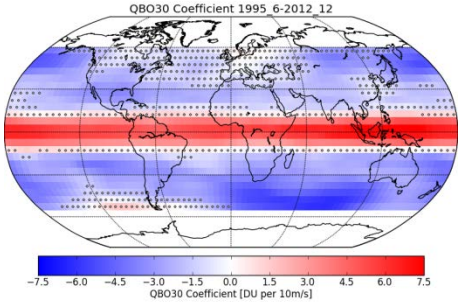
EMAC

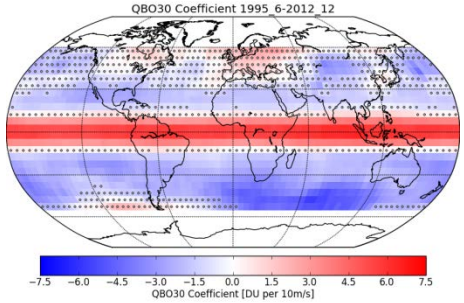




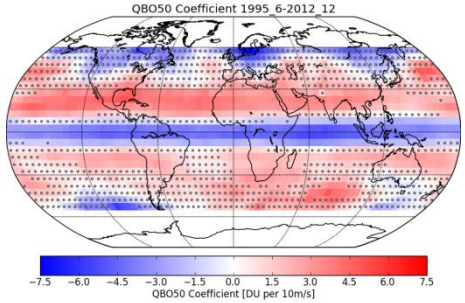
GTO-ECV CCI

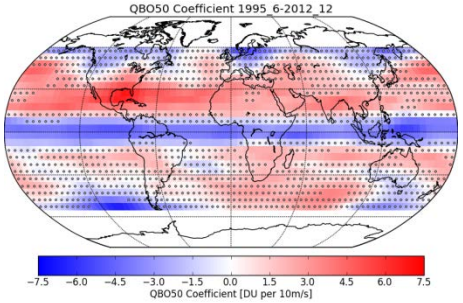
QBO 30



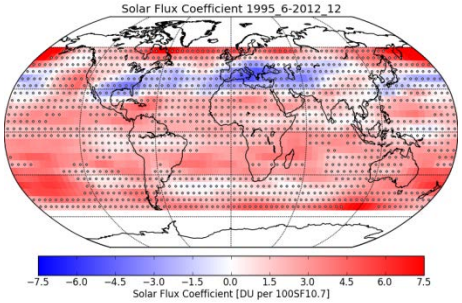


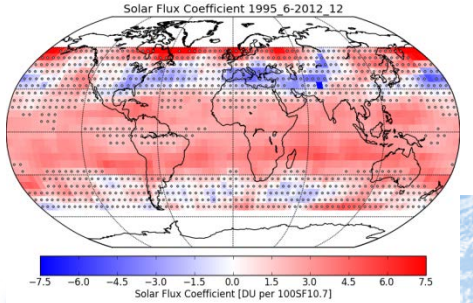
QBO 50



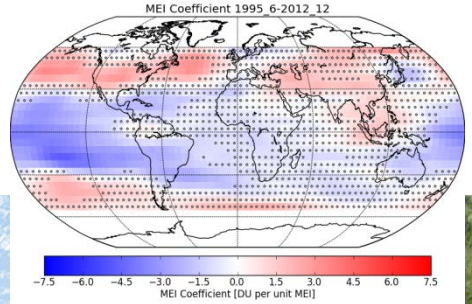


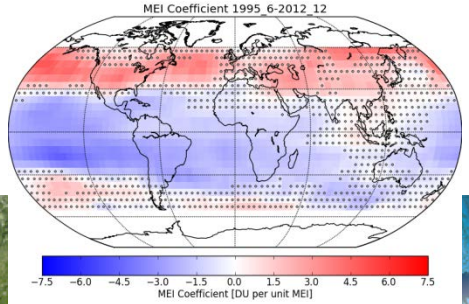
Solar Cycle





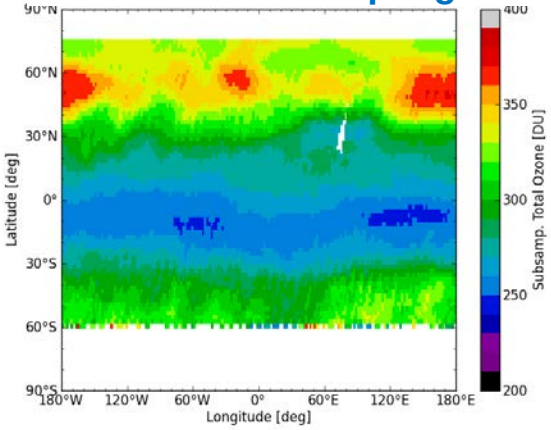
MEI



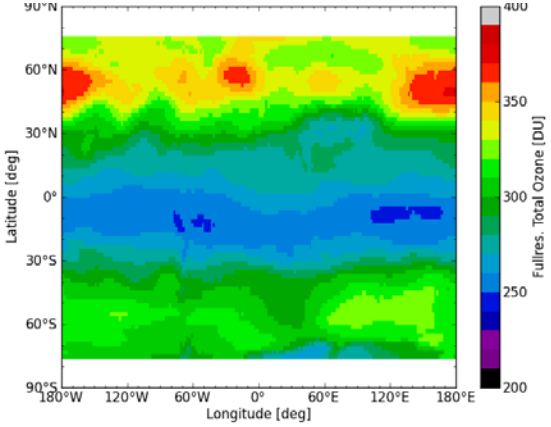


ESA Ozone_CCI Phase II:
Reduction of Sampling Errors using Spatio-Temporal Interpolation

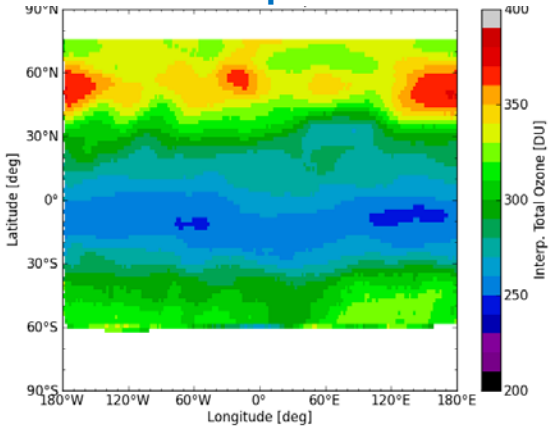
ECMWF Sat Sampling



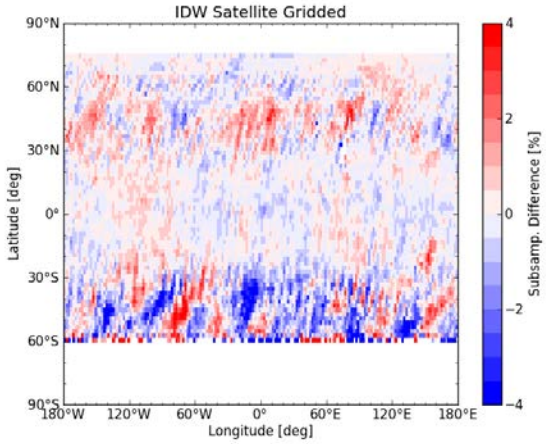
ECMWF Full Resolution



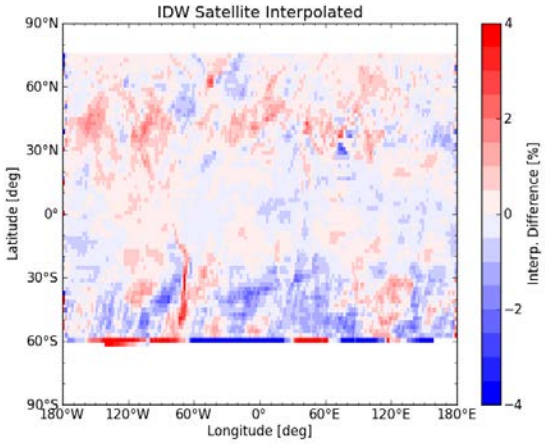
IDW Interpolation



Satellite – Full Resolution



IDW Interpolation – Full Resolution



Summary and Outlook

- GTO-ECV CCI data record (1995-2014) is suitable for monitoring the long-term evolution of total ozone
- Ground-based validation (V1) confirmed the high quality and stability
- Linear total ozone trend is positive in major parts of the globe, but statistical uncertainty is still large due to strong interannual variability
- Changes in Tropics are influenced by the solar activity and by extreme ENSO events
- GTO-ECV data record valuable to evaluate model simulations

- Reduce sampling errors using spatio-temporal statistical tools
- Extend the data records using GOME-2/MetOp-B and OMI/AURA

  → See Posters: No. 6 by C. Lerot et al., No. 30 by Koukouli et al.

- Extension using GOME-2/MetOp-C and the Sentinel series