Instrument-based monthly zonal mean ozone profiles

Data description and user manual

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1 Introduction

This Technical Note is dedicated to the description of the monthly zonal mean data from individual instruments (MZM hereafter for short) created in the framework of the ozone-CCI project. These instrument-based monthly zonal data are stored and delivered as one of the ozone-CCI products.

This Technical Note describes details of computing these MZM data (Section 2) and the parameters of the created netcdf files (Section 3). Compared to the analogous datasets produced within the SPARC Data Initiative, the MZM datasets are characterized by:

- Different latitude zones used for averaging;
- Extended altitude range (which is instrument-dependent);
- Characterization of spatial inhomogeneity within spatio-temporal bins.

2 Data processing and parameters

The harmonized datasets of ozone profiles [Sofieva et al., 2013; Rahpoe and Lloyd, 2013] are used as an input for computing monthly zonal mean data. For averaging, 10° latitude zones from 90°S to 90°N are used.

For all sensors, the monthly zonal average is computed as the mean of ozone profiles x_k:

$$\bar{x} = \frac{1}{N}\sum x_k \ , \tag{1}$$

where N is number of measurements. This estimate has been chosen in order to minimize artificial biases, which might appear when using weighted mean or median estimates. MZM ozone profiles are presented in two forms: as mixing ratio and mole concentration on the ozone-CCI pressure grid. The uncertainty of the monthly mean σ^2_{mean} can be estimated as the standard error of the mean:

$$\sigma^2_{mean} = \frac{s^2}{N}, \tag{2}$$

where $s^2 = \left\langle (x_k - \bar{x})^2 \right\rangle$ is the sample variance[1]. Both sample standard deviation s and the standard error of the mean σ_{mean} are stored in the netcdf file. An example of zonal mean data is shown in Figure 1 and an example of uncertainties σ_{mean} is presented in Figure 2.

For SMR, only the data having measurement response larger than 0.75 have been used.

The mean of individual error estimates e_k:

[1] Eq.(2) is valid for random samples of uncorrelated data. As shown in the recent study by *Toohey and von Clarmann* (2012), some deviations of the real standard error of the mean from that predicted Eq.(2) can be observed for satellite observations. In our study, Eq.(2) is used as the approximate and the only available at the moment estimate of the standard error of the mean.

$$\overline{e} = \frac{1}{N}\sum e_k \,, \qquad (3)$$

are also provided in the netcdf files.

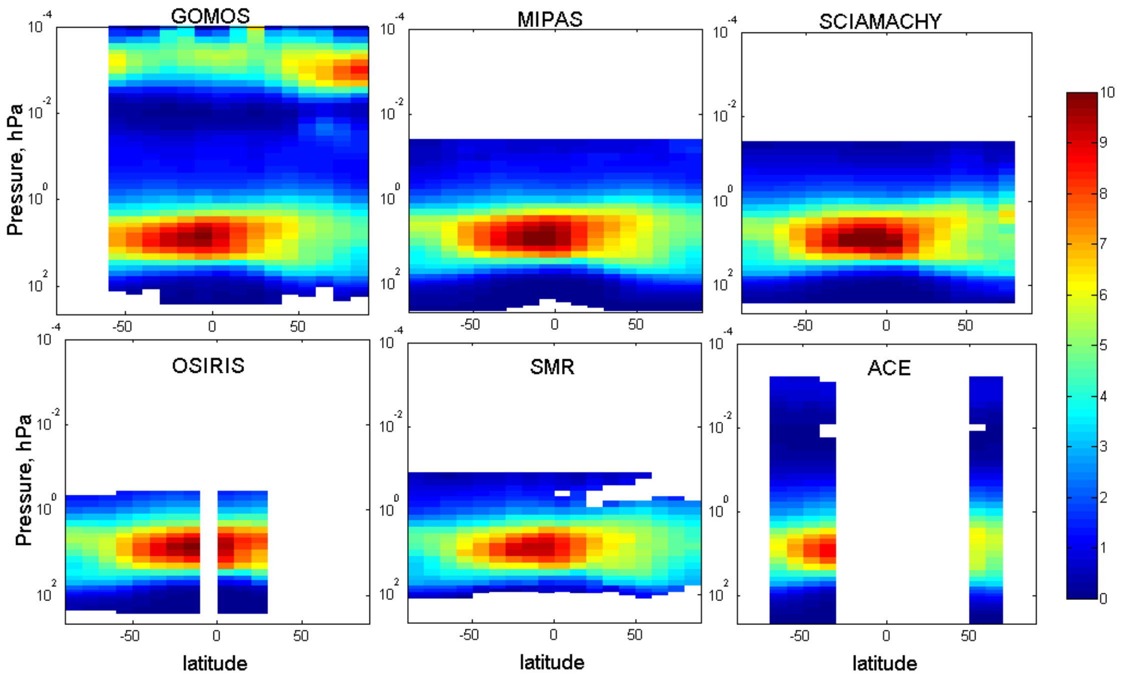

Figure 1 Monthly zonal mean profiles of ozone mixing ratio (ppmv), for January 2008. The vertical axes is intentionally taken the same, in order to illustrate the altitude range of each instrument

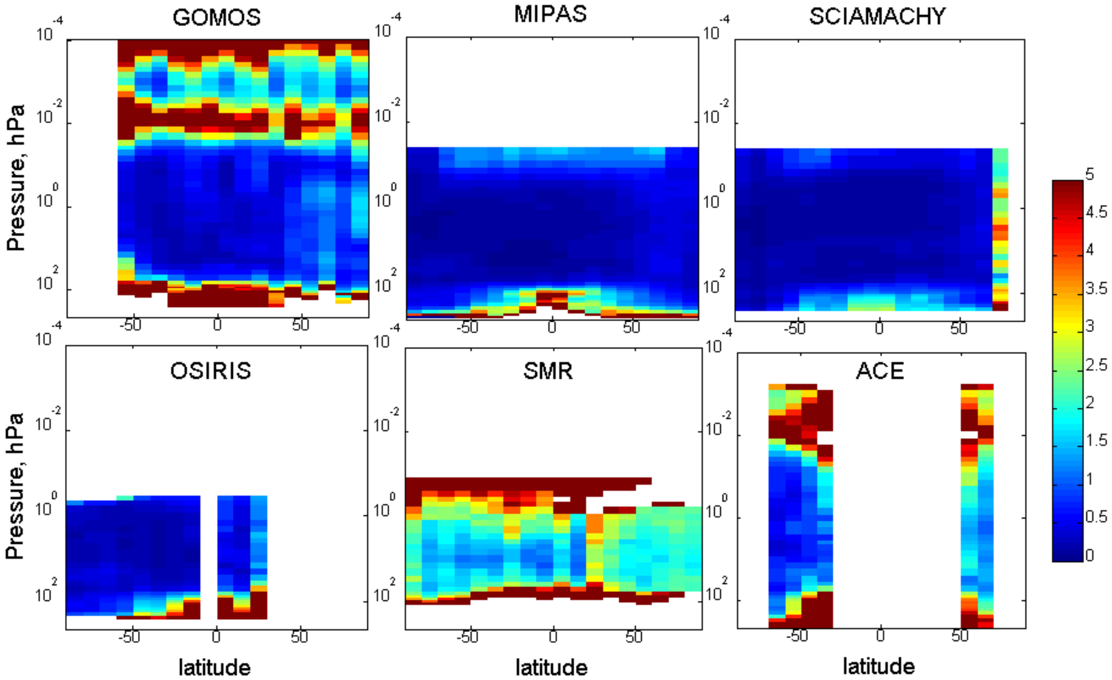

Figure 2. Error of monthly mean data (in %) according to Eq.(2), for January 2008

Satellite measurements sample a continuous ozone field at some locations and times. To characterize the non-uniformity of sampling, we provide inhomogeneity measures in latitude, H_{lat}, and in time, H_{time}. Each inhomogeneity measure H is the linear combination of two classical inhomogeneity measures, asymmetry A entropy E:

$$H = \tfrac{1}{2}(A + (1 - E)), \tag{4}$$

where asymmetry is defined as

$$A = \left| \frac{\bar{x} - x_0}{\Delta x} \right|, \tag{5}$$

where x_0 is the central point, Δx is the half-width of the bin, and $\bar{x}$ is the mean value. Asymmetry ranges from 0 for symmetric distributions to 1 for strongly asymmetric distributions. The entropy is defined as

$$E = \frac{-1}{\log(N)} \sum_i \frac{n(i)}{n_0} \log\left(\frac{n(i)}{n_0} \right), \tag{6}$$

where N is the number of bins, $n(i)$ is the number of observations in the bin i, and n_0 is total number of measurements. Perfectly homogeneous distributions have E=1.

The inhomogeneity measure H also ranges from 0 to 1 (the more homogeneous, the smaller H). This measure can be used in characterization of sampling uncertainty of the monthly mean data [Sofieva et al., 2012].

Figures 3 and 4 illustrate inhomogeneities H_{lat}, H_{time} in January 2008, for ozone-CCI instruments.

3 The data format

The monthly zonal mean data are structured into yearly netcdf files, for each instrument separately. The self-explaining name indicates the instrument and the year. For example, the file "ESACCI-OZONE-L3-LP-GOMOS_ENVISAT-MZM-2008.nc" contains monthly zonal mean data for GOMOS in 2008. The variable that are included into netcdf files are collected in Table 1. An example of the full structure of the netcdf file is presented in Appendix A.

References

Rahpoe, N., and N. D. Lloyd (2013), *Ozone Limb Level 2 Harmonized Single Instrument Document*

Sofieva V.F., Kalakoski N., and Päivärinta S.-M. (2012): Sampling error of satellite instruments, Technical Note

Sofieva et al., (2013): Harmonized dataset of ozone profiles from ESA Envisat and Third Party Missions limb measurements, Technical Note.

Toohey, M., and T. von Clarmann (2012), Climatologies from satellite measurements: the impact of orbital sampling on the standard error of the mean, *Atmos. Meas. Tech. Discuss., 5*(6), 8241–8269, doi:10.5194/amtd-5-8241-2012.

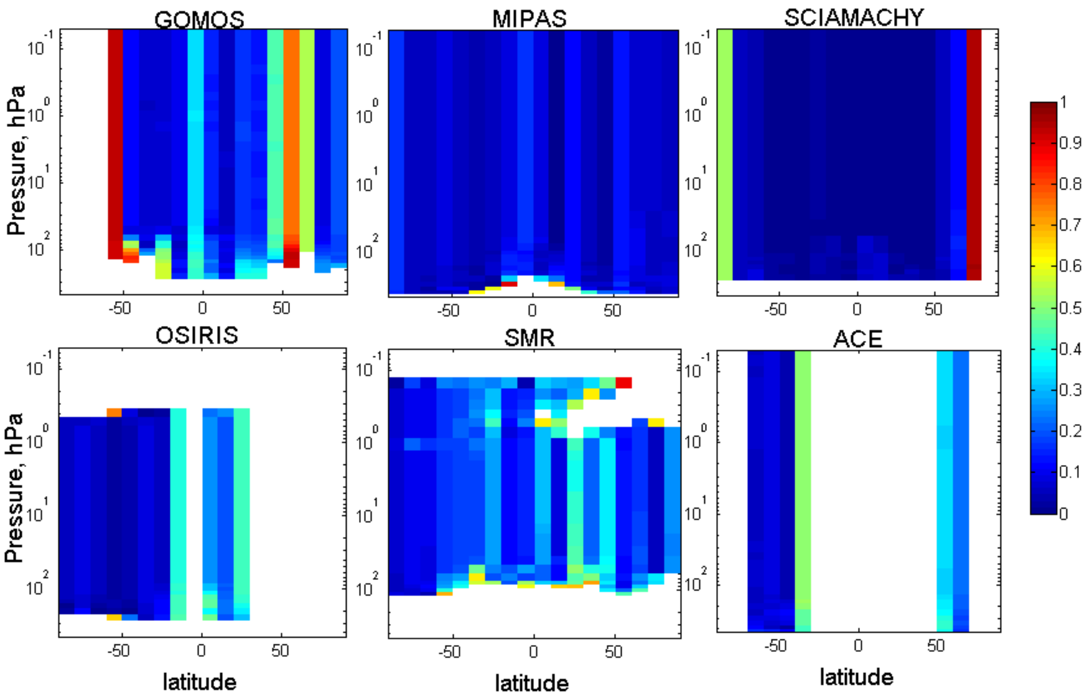

Figure 3. Inhomogeneity measures H_{lat} , for January 2008. The vertical range is from 450 to 0.05 hPa.

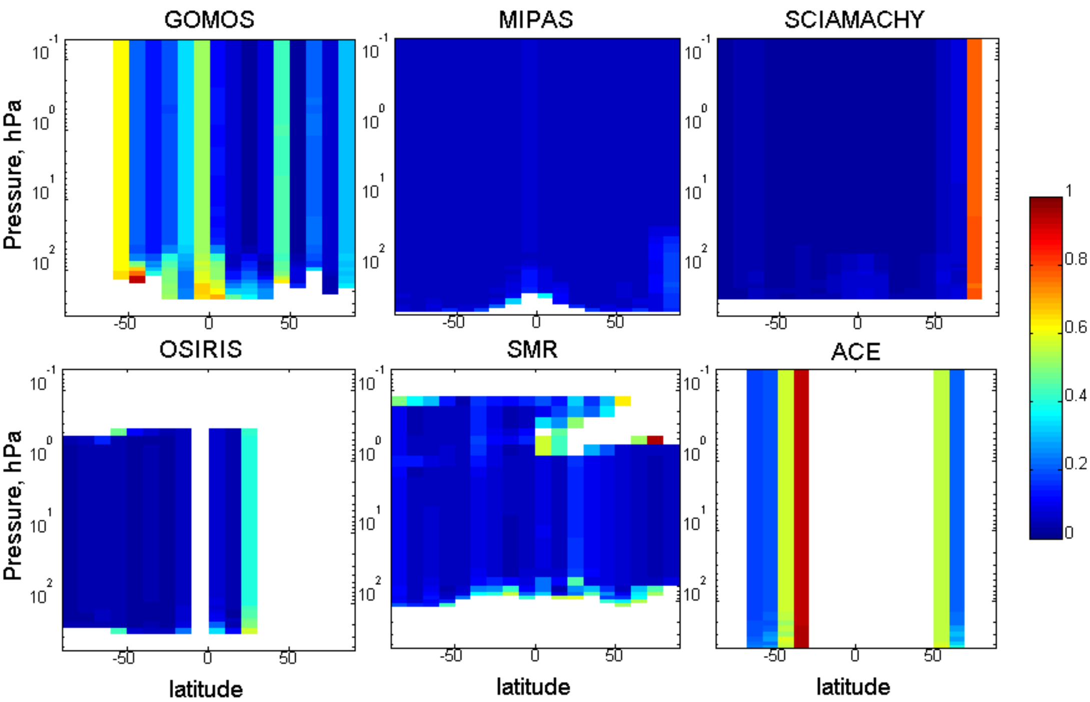

Figure 4. Inhomogeneity measures H_{time} for January 2008.

Table 1 The variables in MZM netcdf files. N_{month}, N_{alt}, N_{lat} are number of months, pressures levels and latitude zones, respectively.

Parameter and unit	*Dimensions*	*Description*
Time	$N_{month}\times1$	The parameter to index the months. The time is assigned to the middle of month and presented in "'days since 1900-01-01 00:00:00"
air_pressure (hPa)	$N_{alt}\times1$	The vertical coordinate
approximate_altitude (km)	$N_{alt}\times1$	Approximate altitude at pressure levels computed as $z = 16\log_{10}(1013/P)$, P is pressure in hPa
latitude_centers (degree_north)	$N_{lat}\times1$	Centers of latitude bins: -85°: 10°:85°
ozone_mixing_ratio	$N_{lat}\times N_{alt}\times N_{month}$	Monthly zonal mean ozone mixing ratio vertical profiles
ozone_mole_ concentration (mol/cm^3)	$N_{lat}\times N_{alt}\times N_{month}$	Monthly zonal mean ozone mole concentration vertical profiles
standard_error_of_the_ mean (%)	$N_{lat}\times N_{alt}\times N_{month}$	Uncertainty of the monthly zonal mean, σ_{mean}, Eq. (2)
sample_standard _deviation (%)	$N_{lat}\times N_{alt}\times N_{month}$	Sample standard deviation in 1 month ×10° spatio-temporal bins, for each pressure level
mean_uncertainty_ estimate (%)	$N_{lat}\times N_{alt}\times N_{month}$	Monthly zonal mean of error estimates, Eq.(3)
inhomogeneity_in_time	$N_{lat}\times N_{alt}\times N_{month}$	Inhomogeneity measure in time, Eq. (4)
inhomogneity_in_latitude	$N_{lat}\times N_{alt}\times N_{month}$	Inhomogeneity measure in latitude, Eq. (4)

Appendix A: The structure of the netcdf file

The example of the structure of netcdf file is presented for GOMOS, year 2008

```
Global Attributes:
        title                = 'ESA CCI ozone  monthly zonal mean data from individual instrument '
        summary              = 'Monthly zonal mean ozone profiles in 10-deg latitude zones and data uncertainty characterization'
        comment              = 'Definitions of parameters and data processing is described in the dedicated Technical Note'
        sensor               = 'GOMOS'
        platform             = 'Envisat'
        year                 = '2008'
        number_of_months     = '12'
        number_of_pressure_levels = '51'
        number_of_latitude_bins   = '18'
        geospatial_lat_resolution = '10 deg '
        geospatial_lat_min   = '-90'
        geospatial_lat_max   = '90'
        value_for_nodata     = 'NaN'
        date_created         = '20130412T105205'
        creator_name         = 'Viktoria Sofieva'
        creator_email        = 'viktoria.sofieva@fmi.fi'
        address              = 'P.O.Box 503, 00101 Helsinki, Finland'
        naming_authority     = 'FMI - Finnish Meteorological Institute'
```

```
        Conventions            = 'CF-1.5'
        standard_name_vocabulary  = 'NetCDF Climate and Forecast(CF) Metadata Convention version 18'
        license                = 'ozone_cci guidelines'
        restriction            = 'Restricted under the use of ozone cci guidelines'
        file_version           = 'fv0001'
Dimensions:
        air_pressure     = 51
        latitude_centers = 18
        time             = 12
Variables:
    air_pressure
        Size:       51x1
        Dimensions: air_pressure
        Datatype:   single
        Attributes:
                units         = 'hPa'
                standard_name = 'air_pressure'
    latitude_centers
        Size:       18x1
        Dimensions: latitude_centers
        Datatype:   single
        Attributes:
                units         = 'degrees_north'
                standard_name = 'latitude'
                long_name     = 'centers of latitude bins'
    time
        Size:       12x1
        Dimensions: time
        Datatype:   single
        Attributes:
                units         = 'days since 1900-01-01 00:00:00'
                calendar      = 'standard'
                standard_name = 'time'
    approximate_altitude
        Size:       51x1
        Dimensions: air_pressure
        Datatype:   single
        Attributes:
                units         = 'km'
                standard_name = 'altitude'
                long_name     = 'approximate altitude corresponding to pressure levels'
    ozone_mixing_ratio
        Size:       18x51x12
        Dimensions: latitude_centers,air_pressure,time
        Datatype:   double
        Attributes:
                units         = '1'
                standard_name = 'mole_fraction_of_ozone_in_air'
    ozone_mole_concentation
        Size:       18x51x12
        Dimensions: latitude_centers,air_pressure,time
        Datatype:   double
        Attributes:
                units         = 'mol cm-3'
                standard_name = 'mole_concentration_of_ozone_in_air'
    standard_error_of_the_mean
        Size:       18x51x12
```

```
    Dimensions: latitude_centers,air_pressure,time
    Datatype:   single
    Attributes:
                units     = '%'
                long_name = 'uncertainty of the monthly zonal  mean data'
sample_standard_deviation
    Size:       18x51x12
    Dimensions: latitude_centers,air_pressure,time
    Datatype:   single
    Attributes:
                units     = '%'
                long_name = 'Sample standard deviation in 1 month x10 deg bins'
mean_uncertainty_estimate
    Size:       18x51x12
    Dimensions: latitude_centers,air_pressure,time
    Datatype:   single
    Attributes:
                units     = '%'
                long_name = 'mean of error estimates'
inhomogeneity_in_time
    Size:       18x51x12
    Dimensions: latitude_centers,air_pressure,time
    Datatype:   single
    Attributes:
                units     = '1'
                long_name = 'inhomogeneity measure in time'
inhomogeneity_in_latitude
    Size:       18x51x12
    Dimensions: latitude_centers,air_pressure,time
    Datatype:   single
    Attributes:
                units     = '1'
                long_name = 'inhomogeneity measure in latitude'
```

Acronyms and abbreviations

ESA	European Space Agency
ozone-CCI	Ozone Climate Change Initiative
GOMOS	Global Ozone Monitoring by Occultation of Stars
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
SCIAMACHY	Scanning Imaging Spectrometer for Atmospheric Chartography
OSIRIS	Optical Spectrograph and InfraRed Imaging System
SMR	Sub-Millimeter Radiometer
ACE-FTS	Atmospheric Chemistry Experiment – Fourier Transform Spectrometer
MZM	Monthly Zonal Mean