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ON-LINE DUST FORECASTS FOR THE MONTE MARTANO GROUND SITE: AN INTEGRATED MULTI-MODEL SERVICE

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Abstract

This report describes an automated web service reporting integrated observations and forecasts of dust, PM_{10}, $PM_{2.5}$ and O_3 concentrations related to the Monte Martano rural regional background site accredited as a European reference site.

1. Introduction

When winds are strong, large amounts of sand and dust can be lifted from bare, dry soils into the atmosphere and transported downwind affecting regions hundreds to thousands of kilometres away. A dust storm or sand storm is a meteorological phenomenon common in arid and semi-arid regions and arises when a dust front passes or when the wind force exceeds a threshold value where loose sand and dust are removed from the dry surface. In desert areas, sand and dust storms are most commonly caused by either thunderstorm outflows, or by strong pressure gradients which cause an increase in wind velocity over a wide area. Drought and wind contribute to the emergence of dust storms, as do poor farming and grazing practices by exposing the dust and sand to the wind.

For countries in and downwind of arid regions, airborne sand and dust presents serious risks to the environment, property and human health. Impacts on health include respiratory and cardio-vascular problems, eye infections and, in some regions, diseases such as meningitis and valley fever. Dust can carry irritating spores, bacteria, viruses and persistent organic pollutants. It can also transport nutrients to various parts of the world oceans and affect marine biomass production. Other impacts include negative effects on the ground transport, aviation, agriculture and visibility. The Inter-governmental Panel on Climate Change (IPCC) recognizes dust as a major component of atmospheric aerosol that is an essential climate variable. More and more dust particles are considered by atmospheric researchers to have important effects on weather through feedback on atmospheric dynamics, clouds and precipitation formation. Thus, there is a need for promoting internationally coordinated efforts aimed at guaranteeing a deliver of timely forecasts and observations of the effect of dust on air quality. This is indeed the goal of the coordinated action of Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) and of the Global Atmosphere Watch (GAW) that was prompted by the steering body of the World Weather Research Programme (WWRP) in 2005.

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Following the above mentioned action, a network of monitoring sites has been established for related observations and some of them, particularly independent of local contamination, have been selected as background ground sites. Among them is the Monte Martano station located in the Umbria region that is the one considered for our investigations. In order to evaluate the suitability of the mathematical models to accurately reproduce the particulate matter (PM) concentration (particularly during dust episodes) and to chemically and physically characterize the particles collected during such episodes, a dust monitor and alert system was set up. Every day dust and PM_{10} (with 10 being its maximum diameter in μm) concentrations forecast by different models are downloaded and made available as two-and three-dimensional plots on a web page.

The most likely path that will be followed by air parcels reaching the site in the subsequent three days are also forecast. In addition, thanks to the fact that the monitoring station is reachable on the internet, measurements can be electronically collected and values of the past related 30 days graphically represented in various plots (including the tracing out on a map of the most likely path followed by the corresponding air parcels).

2. Chimere dust forecasts

The forecasts used in the on-line service are produced by the CHIMERE package out of the Prevair (http://www.prevair.org/eu/index.php) Europe daily outcomes. Prevair estimates of European pollutants' concentrations are downloaded at 8 am and the particulate dust components (pDUST) expected for the Monte Martano, Terni (piazza Tacito) and Rome (CNR Tor Vergata) cells are extracted. Related concentrations shown in the plots are, therefore, cell average values (cell size 40x50 km^2) with no interpolation.

The dependence on time of the average hourly concentration of dust (pDUST) for the various vertical levels at three different ground stations of Central Italy are given in two different sets of representations: the first set of Figures (A1 (Monte Martano), A3 (Terni) and A5 (Tor Vergata)) plot the concentrations of the first 5 lower levels while the second set of Figures (A2 (Monte Martano), A4 (Terni) and A6 (Tor Vergata)) plot the concentrations (as false colours) at different values of the logarithm of the altitude above the ground level.

The height of the Chimere levels (with respect to ground) slightly varies with time. As an example, we quote in Table 1 those of a typical Terni winter day.

level	height
1	25.
2	71.
3	156.
4	318.
5	625.
6	1225.

level	height
7	2473.
8	5377.

Table 1 Typical Chimere levels height in Terni at winter time.

In addition to the forecasts for the next 72 hours (starting from hour 00:00 of the current day), Figures A1 – A6 show the previous day pDUST concentrations. They slightly differ from the previous ones because in their computation (made by Prevair) the forecasts were integrated using the Emilia Romagna and Piemonte ARPA field measurements[1]. Accordingly, the reliability of the concentrations shown for the previous day (day ”-1”) is expected to be higher.

A similar procedure has been adopted for the O_3 concentrations and for the $PM_{2.5}$ and PM_{10} concentrations ratio ($PM_{2.5}$ /PM_{10}) and difference (PM_{10}-$PM_{2.5}$) though only those of the Monte Martano cell were extracted and plotted in Figures B and C.

3. Hysplit forecast backtrajectories

In order to better single out forthcoming dust episodes, an automatic calculation of the backward trajectories of air parcels is performed so as to trace back the origin and the path followed by the transported contaminants. To this end use is made of the Hysplit (Hybrid Single Particle Lagrangian Integrated Trajectory, http://ready.arl.noaa.gov/HYSPLIT.php) package designed for computing trajectories of air particles, complex dispersions and depositions. The adopted version of Hysplit is identified as follows:

Last Changed Author: roland
Last Changed Rev: 513
Last Changed Date: 2013-08-05 14:53:00 +0200 (Mon, 05 Aug 2013)

The meteo files are downloaded every morning at 7:00 from the NOAA (National Oceanic and Atmospheric Administration, http://www.noaa.gov/) site. The program needs 4 files containing the meteo analysis data (measure integrated forecasts) related to previous days. Meteo data is already directly usable from Hysplit and is used to carry out the same computations of the Hysplit web service so as to be able to make a direct comparison of the plots. The 4 files have the same name hysplit.t00z.gfsa yet they are located in different directories (the instant one and the ones of the three previous days). Each file, of size of about 160 MB, contains the meteo data of the two previous days, at intervals of 3 hours starting from hour 00.

The file hysplit.t00z.gfsf containing instant previsions having a dimension of 640 MB is also downloaded. Despite the fact that such file contains forecasts starting from hour 00, as it appears from the last modification date of the file, it becomes available only after hour 6:30[2]. When one of the input files is unavailable plots are not drawn.

An example of plots of the backtrajectories are show in Figure D. Their correctness was checked by comparison with those produced by the hysplit web service. Each plot shows 4 trajectories ending on the Monte Martano site 50, 500, 1000 and 3000 m above ground, respectively. Obviously, trajectories related to the first hours are computed using mainly analysis data while those related to the last ones make large use of the forecasts.

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4. SDS-WAS PM_{10} forecast

The SDS-WAS PM_{10} forecasts based on the results of the models executed by the SDS-WAS (http://sds-was.aemet.es/forecast-products/dust-forecasts/compared-dust-forecasts) centre of Barcelona are shown in Figure E. Every day at 1:00 the output files for the entire computational domain are automatically downloaded for:

- the bsc-dream8b model
- the median of all the models used by the centre[3].

Out of the downloaded netcdf formatted files:

- cell coordinates are extracted;
- the Monte Martano cell and its nearest neighbor are identified;
- related forecast concentrations are extracted;
- bilinear interpolation of the concentrations to better estimate the value that will be measured by the station is performed;
- the plot of hourly trends is produced.

Contrary to the Chimere forecasts, SDS-WAS provides data with a 12 hours delay (daily downloads are dated as from the previous day with hour 12:00 of the current day being the first one considered). For this reason the starting time of the plots is noon. Moreover, the bsc-dream8b output spans 25 hours while the median is referred to 21 hours.The interval between two forecasts is 3 hours. Accordingly, the bsc-dream8b line of the plots covers 12 more hours than the median. The median of the models' domain has cells of size 0.5x0.5 degrees while that of bsc-dream8b has a resolution of 0.3x0.3 degrees.

5. Monte Martano PM_{10} and $PM_{2.5}$ measured concentrations

Every 4 hours, starting from 00:35, the PM_{10} and $PM_{2.5}$ measures of the Monte Martano station for the last 4 days are transferred from the Arpa Umbria server. The format of the related file is:

```
IT2099A 20130830 11 3.1716670990 1.8350000381
```

The first column contains the identity of the station, the second the date and the third the hour of the measure. The fourth and fifth columns contain the PM_{10} and the PM_5 measured concentrations both given in $\mu g/m^3$. The station transfers the data to its computer every 4 hours whereas the data is updated on the ARPA web page every 30 minutes. Accordingly, at 00:35 the most recent measure is that of hour 22:00 of the previous day.

The measures are automatically inserted in the proper place of the text file used to archive and that, actually, starts on 1:00 of day 1/5/2013. Finally, the pdf plot of the last 30 days of PM measurements is produced. An example is given in Figure F1.

6. Monte Martano O_3 measured concentration

Every 4 hours, starting from 00:35, the measurements of O_3 and of the granulometric fractions of PMs (taken by the Monte Martano station in the last 4 days) are transferred from the ARPA Umbria server. The format of the file is:

```
  IT2099A 20131119 7 47.7678489685 3979.6330566406 2239.4160156250
1768.0980224609 1048.5319824219 638.6165161133 205.9333038330 36.7000007629
2.3499999046
```

The first column contains the identity of the station, the second the date and the third the hour of the measure. The fourth column contains the concentration of O_3 in $\mu g/m^3$ and the following ones the numerical densities (n/l) of PMs having diameter: >0.28, >0.4, >0.5, >0.7, >1.1, >2.0, >3.0 e >5.0. The station transfers the data to its computer every 4 hours, whereas the data is updated on the ARPA server every 30 minutes. Accordingly, at 00:35 the most recent measure is that of hour 22:00 of the previous day.

The measures are automatically inserted in the proper place of the text file used to archive and that, actually, starts on 1:00 of day 1/5/2013. Finally, the pdf plot of the last 30 days of O_3 measurements is produced. An example is given in Figure F2.

7. Monte Martano measured volume distribution and PM density

The numerical densities (given in n/l) transferred using the procedure described in the previous section are subtracted each other to the end of determining the number of particles present in each dimensional class. The resulting values are then multiplied times the average volume of each class assuming that:

- the particles have a spherical shape;
- the representative diameter of the class is given by the geometrical average of the delimiting values;
- the maximum diameters of the particles is 10. μm (accordingly the class of the largest particles is the one bracketed between 5.0 and 10.0 μm).

In this way, the volume distribution of PM among the different classes represented in Figure F3 is computed. The measured concentrations of PM_{10} e $PM_{2.5}$ are then divided by the volume concentration (respectively those obtained by summing over all the fractions and summing over all the fractions less the largest one). Hourly densities expressed in g/cm^3 are shown in Figure F4.

8. Past Hysplit backtrajectories

At the end of the downloading procedure of the 4 Hysplit input files described in section 3 an additional file is transferred from the NOAA server. Its purpose is to allow the calculation of the backtrajectories starting from hour 00:00 of day "-1" (the day previous to the initial one of the simulation) having the same number of points as those of the next days.

The files produced by the backtrajectories of day "-1", all computed using analysis data (and therefore more reliable than the forecast ones), are stored in a way that provides a history of the backtrajectories of the last 30 days. The produced pdf file whose aspect closely rensembles the plots produced for the forecasts shown in Figure D, can be usefully compared with the measurements of the last month and therefore used to evaluate whether a saharian has occurred.

Notes and reference:

[1]: "PREVAIR. An Operational Forecasting and Mapping System for Air Quality in Europe", American Meteorological Society, Jan 2009

[2]: From the analysis of the standard ftp protocol specifications it appears that it is impossible to determine the reference time of the server and the NOAA server does not state the hour in the daily message. For this reason in order to determine the date of the last modification of the files we adopted the solution of waiting for the new file to be created on the server.

[3]: According to the daily published compared dust forecast maps, the models adopted for the calculation of the median are: BSC-DREAM8Bv2.0, MACC-ECMWF, NMMB/BSC-Dust, MetUM, NASA-GEOS-5, NCEP-NGAC.

Figures:

FORECASTS

- Fig. A1 - Chimere Monte Martano pDUST forecast concentration plotted as a function of time for different vertical levels.
- Fig. A2 - Chimere False color Monte Martano pDUST forecast concentration maps plotted as a function of the altitude and time.
- Fig. A3 - Chimere Terni pDUST forecast concentration plotted as a function of time for different vertical levels.
- Fig. A4 - Chimere False color Terni pDUST forecast concentration maps plotted as a function of the altitude and time.
- Fig. A5 - Chimere Tor Vergata pDUST forecast concentration plotted as a function of time for different vertical levels.
- Fig. A6 - Chimere False color Tor Vergata pDUST forecast concentration maps plotted as a function of the altitude and time.
- Fig. B - Chimere Monte Martano O_3 forecast concentration plotted as a function of time at different vertical levels.
- Fig. C - Chimere Monte Martano (upper panel) ratio PM2.5/PM10 forecast concentration plotted as a function of time for different vertical levels; (lower panel) difference PM10 - PM2.5 forecast concentration plotted as a function of time for different vertical levels.

- Fig. D – Hysplit backward trajectories of air particles ending at 50, 500, 1000 and 3000 m above ground at the background station of Monte Martano.
- Fig. E - BSC-DREAM8Bv2.0 (green line) and median (red line) of the models SDS-WAS Monte Martano dust forecasts for PM10 concentration plotted as a function of time.

MEASUREMENTS

- Fig. F1 – Monte Martano PM_{10} (red line) and $PM_{2.5}$ (green line) measured concentrations plotted as a function of time
- Fig. F2 - Monte Martano O_3 measured concentrations plotted as a function of time
- Fig. F3 - Monte Martano measured volume distributions of PM
- Fig. F4 – Monte Martano PM_{10} (red line) and $PM_{2.5}$ (green line) densities estimated from measurements plotted as a function of time

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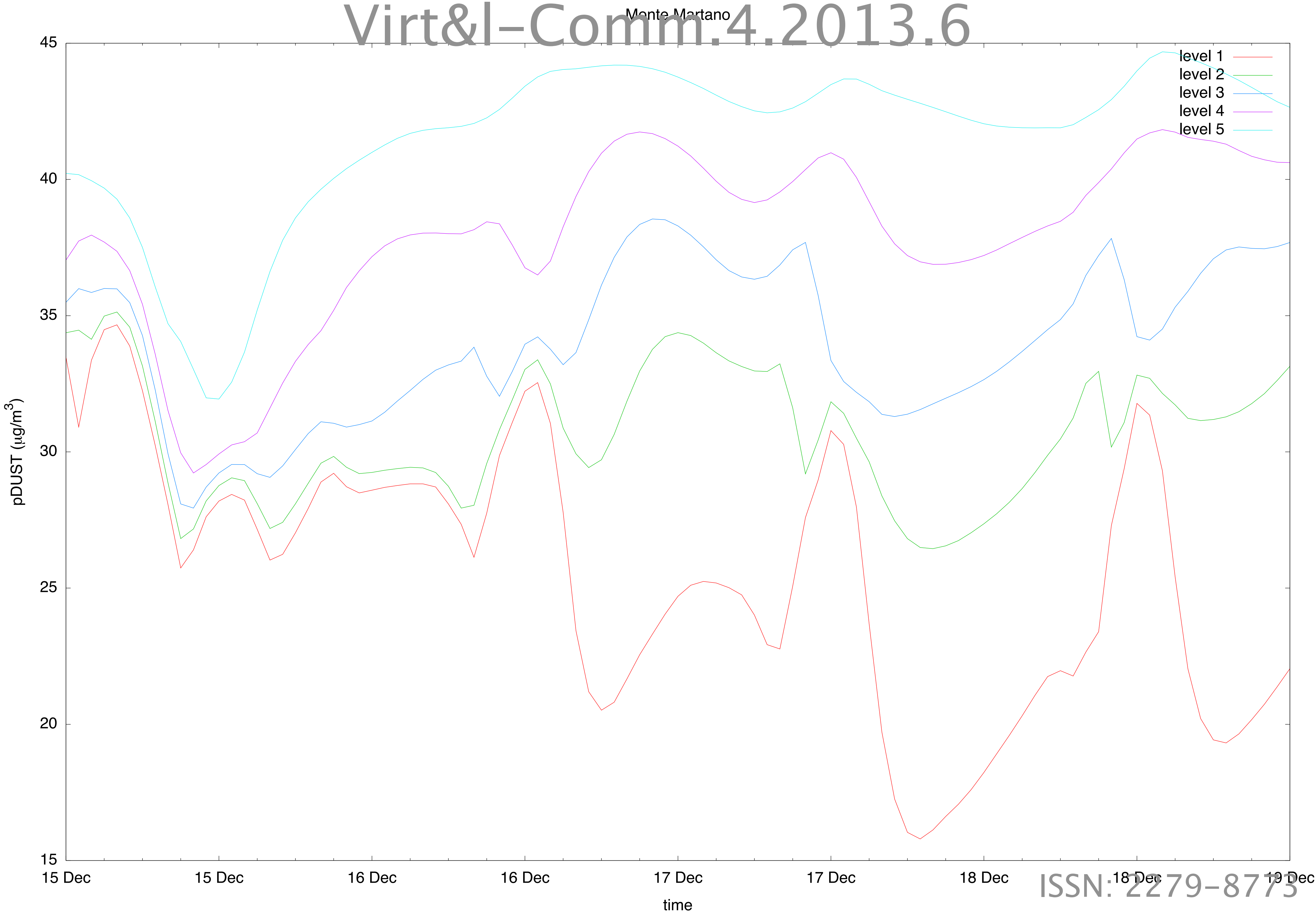

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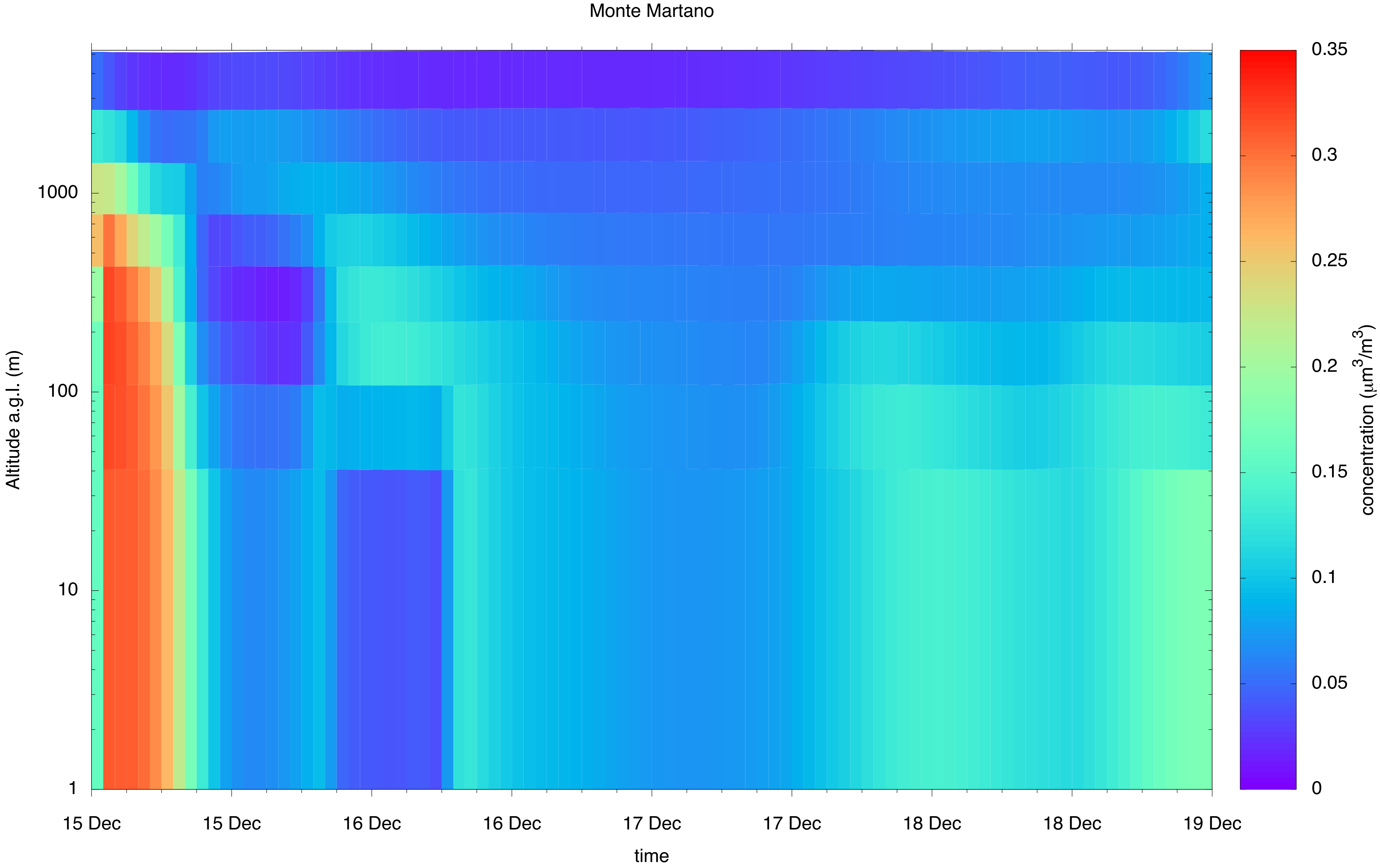

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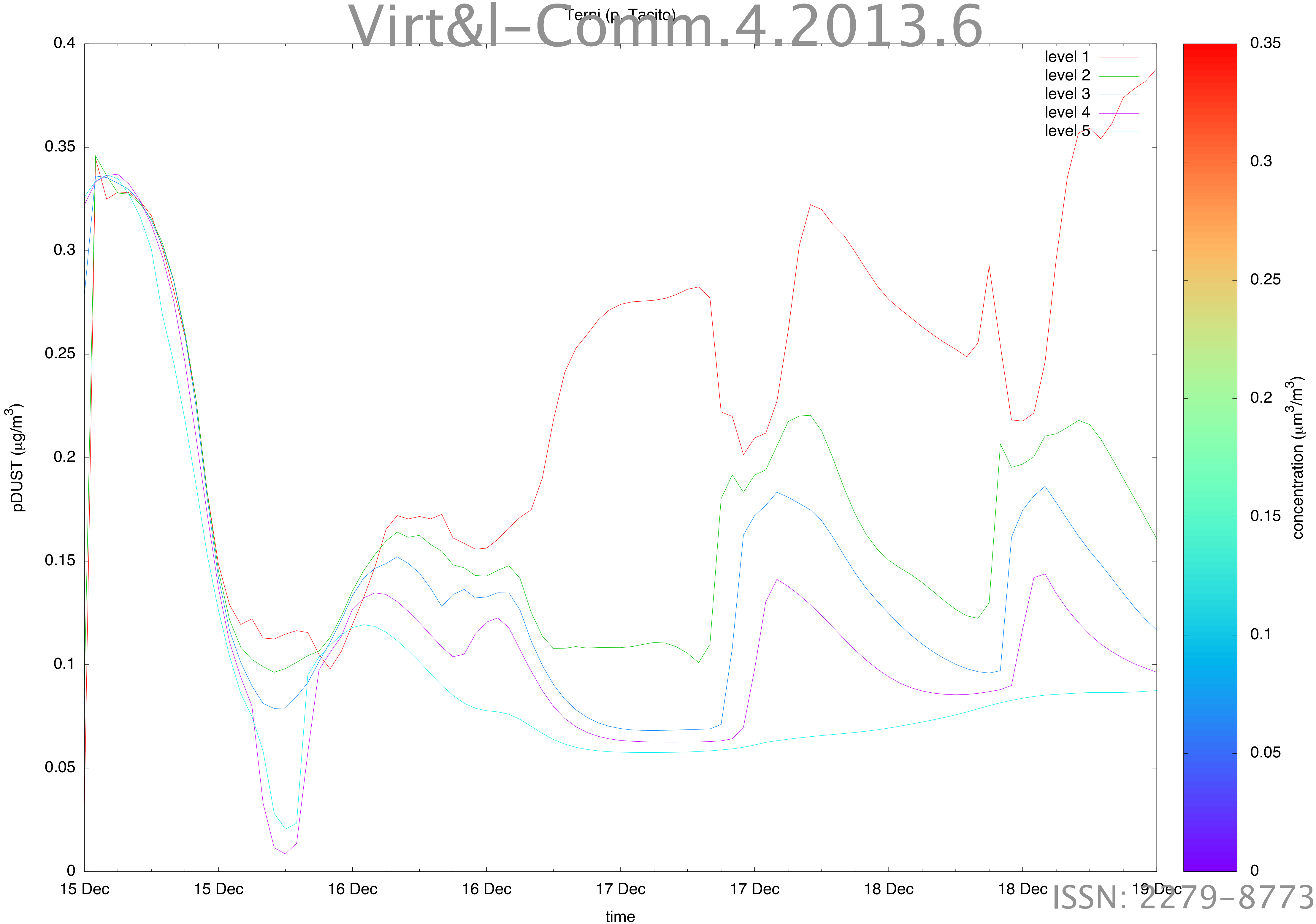

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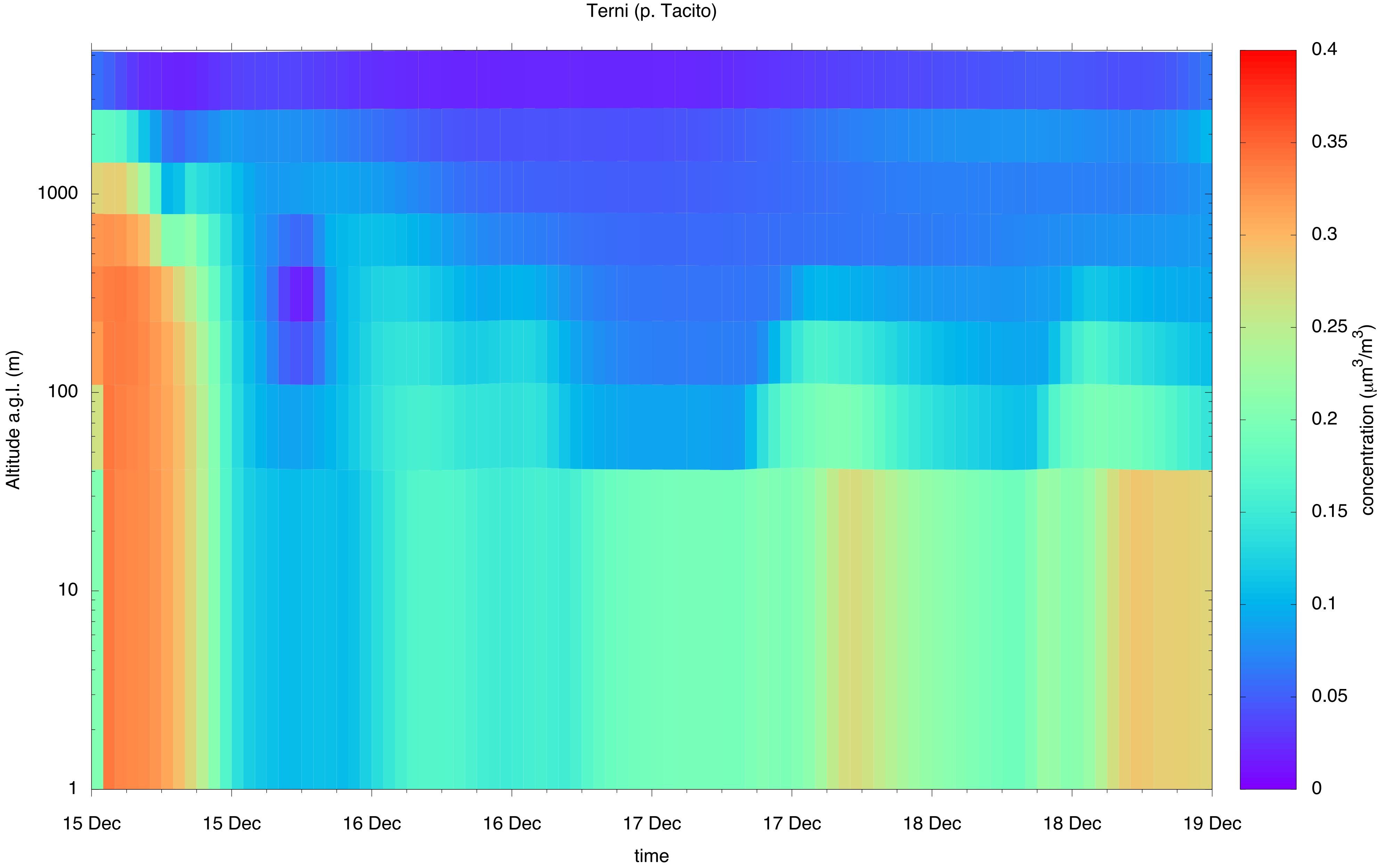

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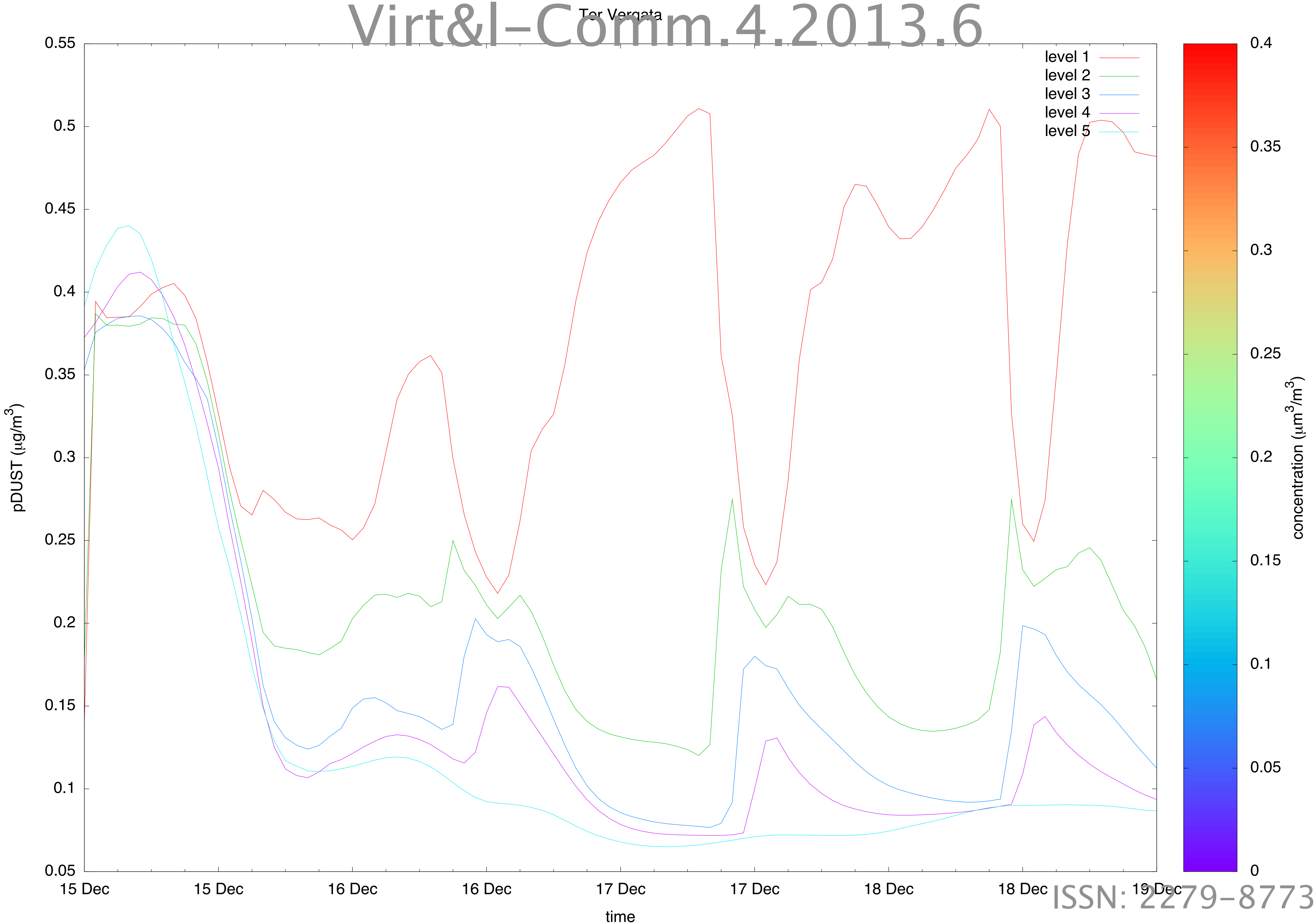

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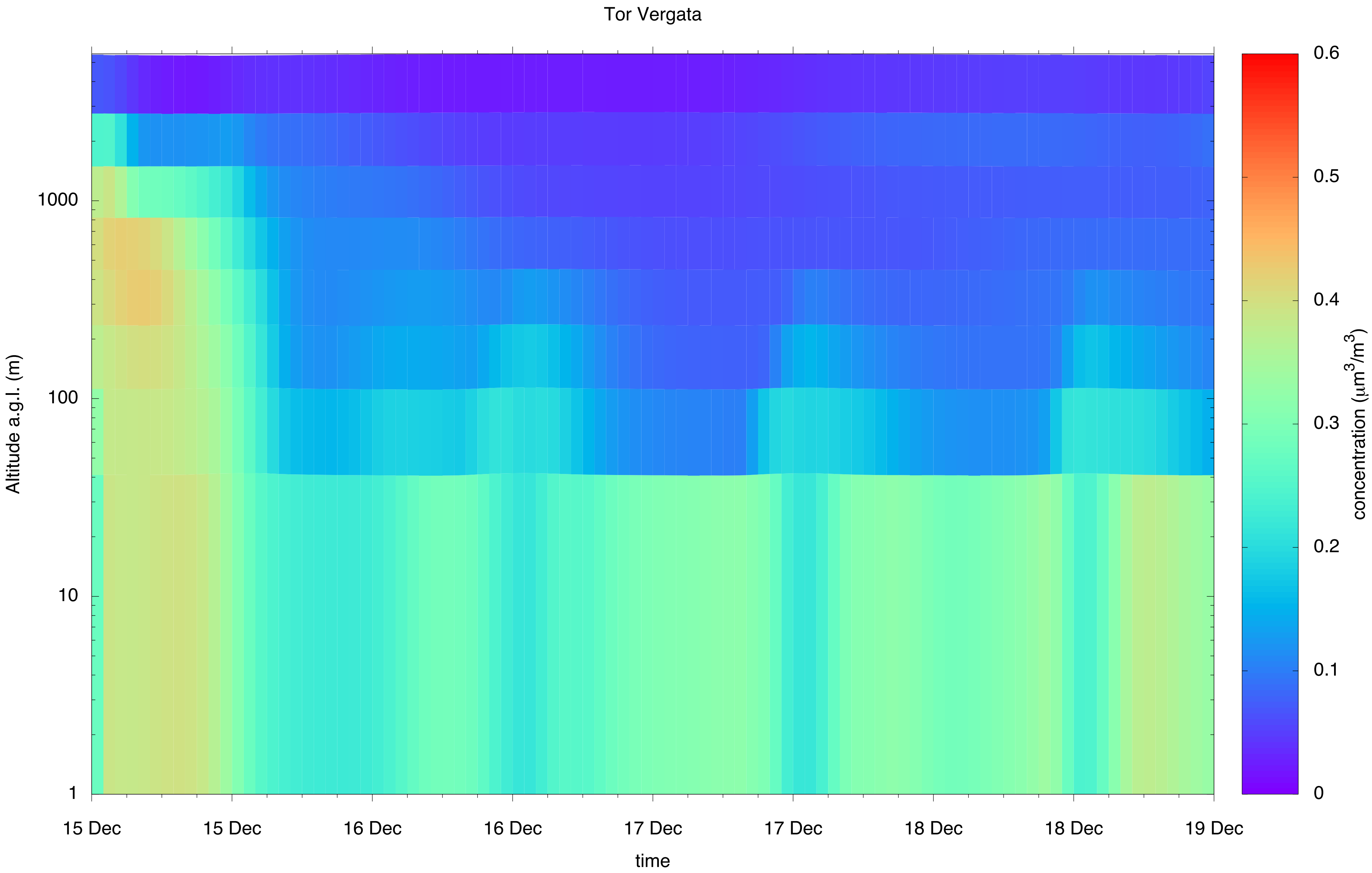

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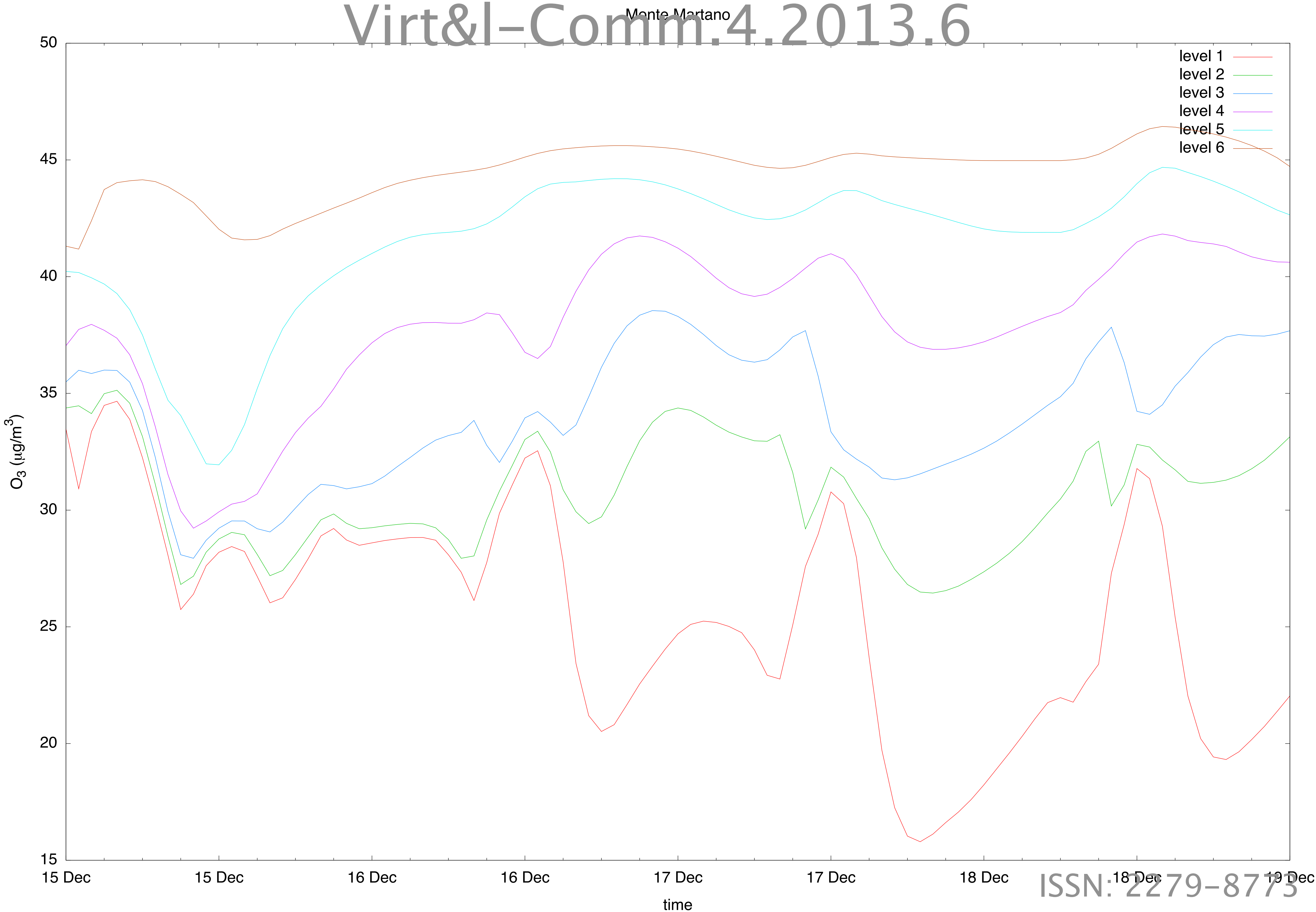

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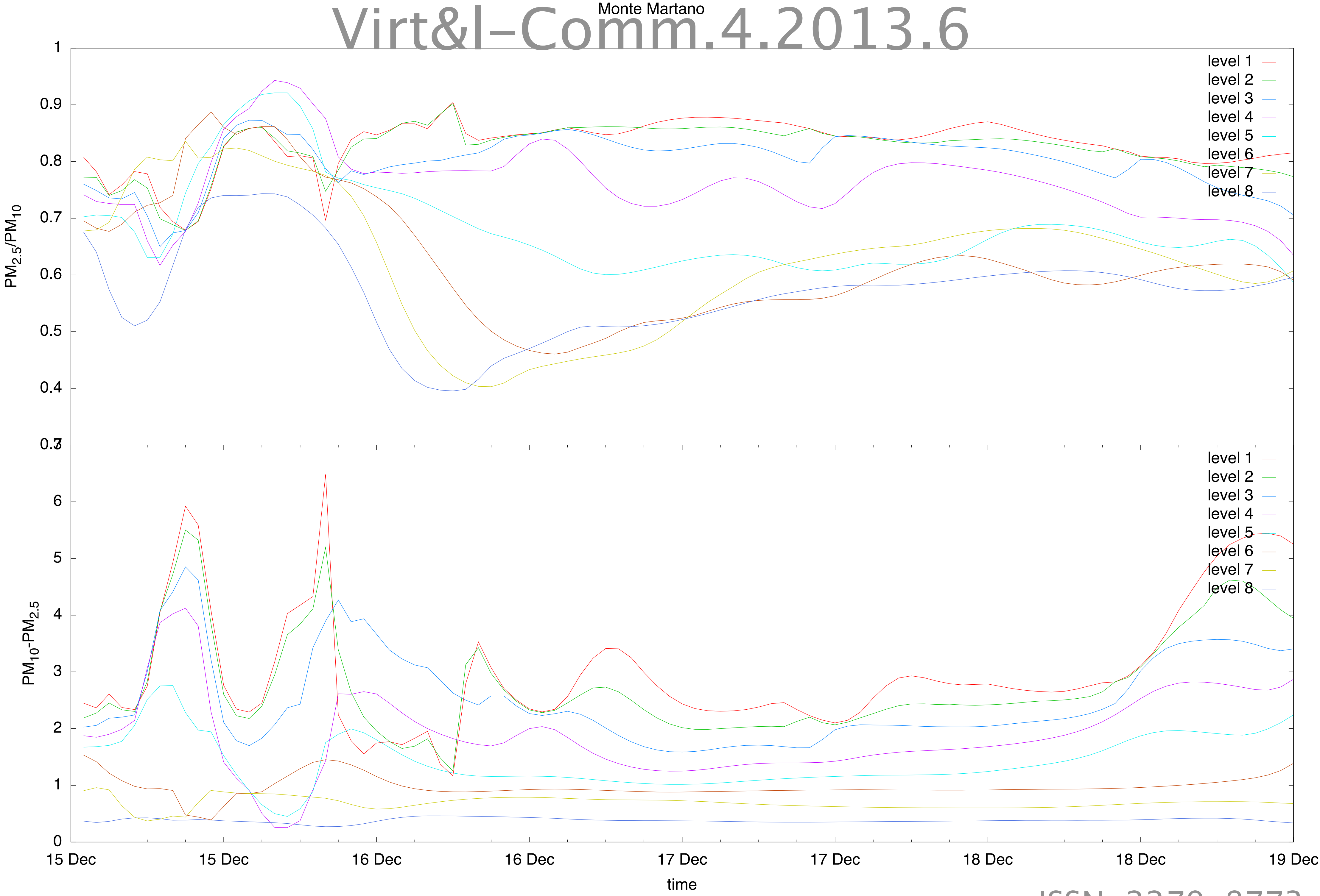

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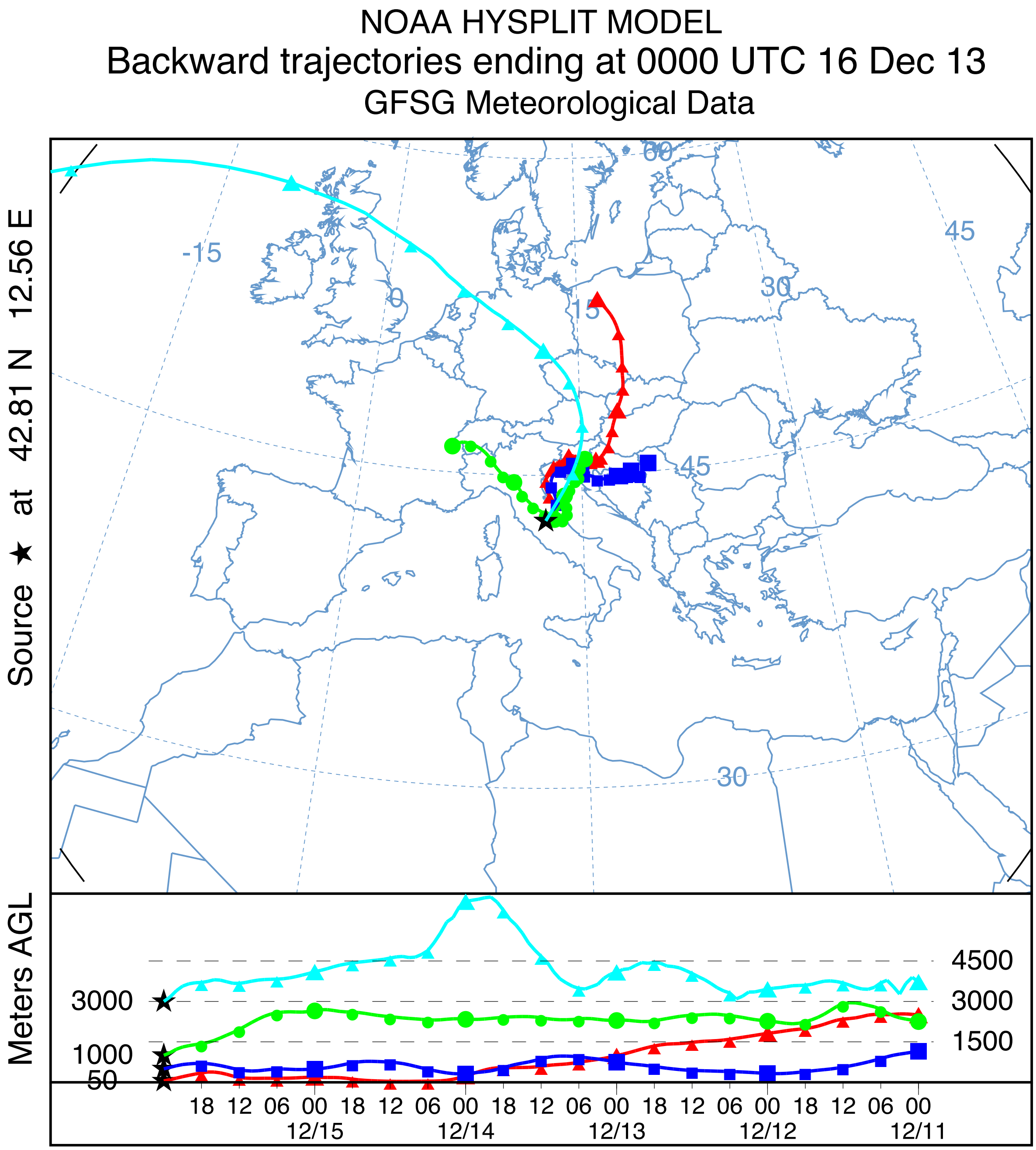

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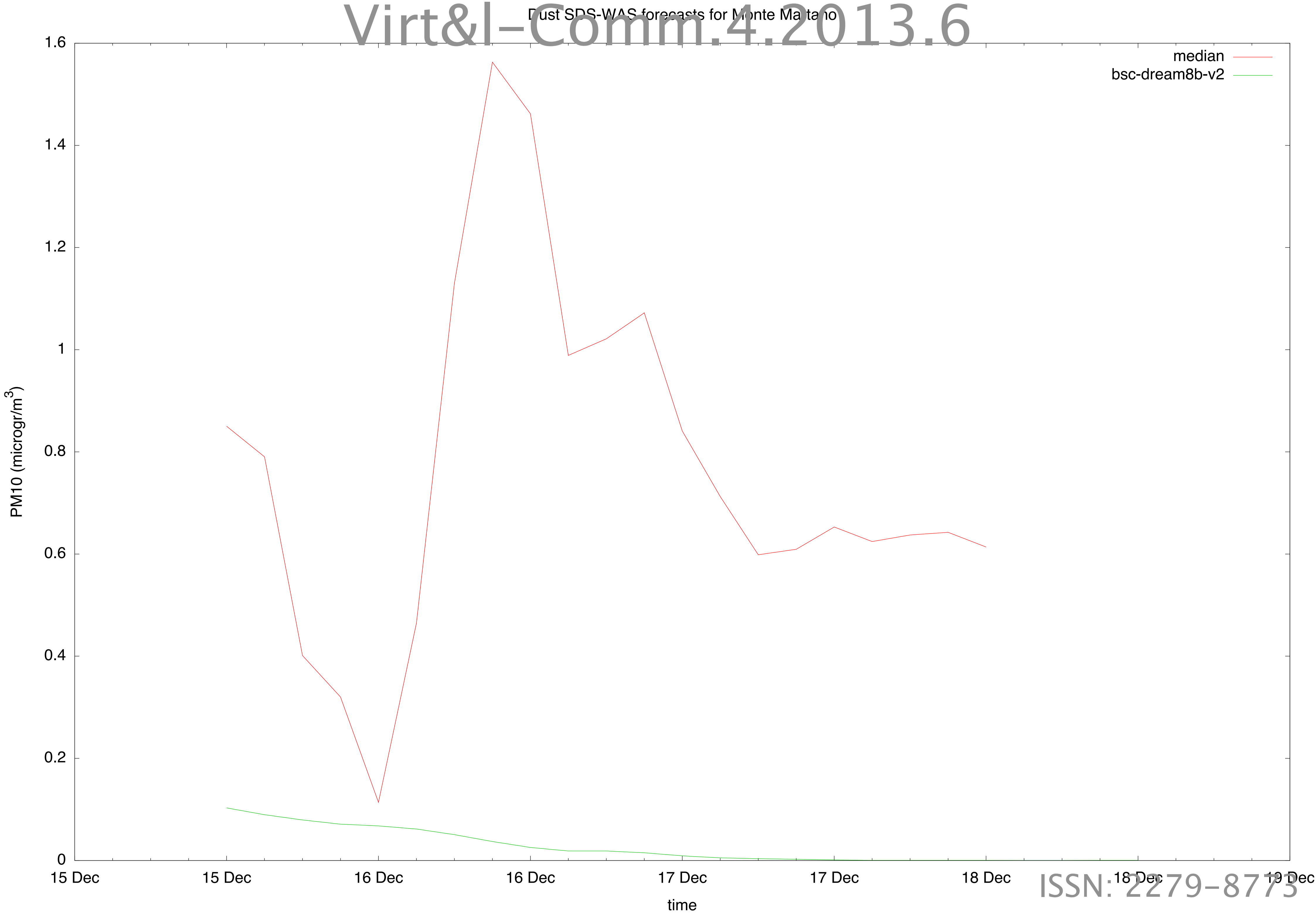

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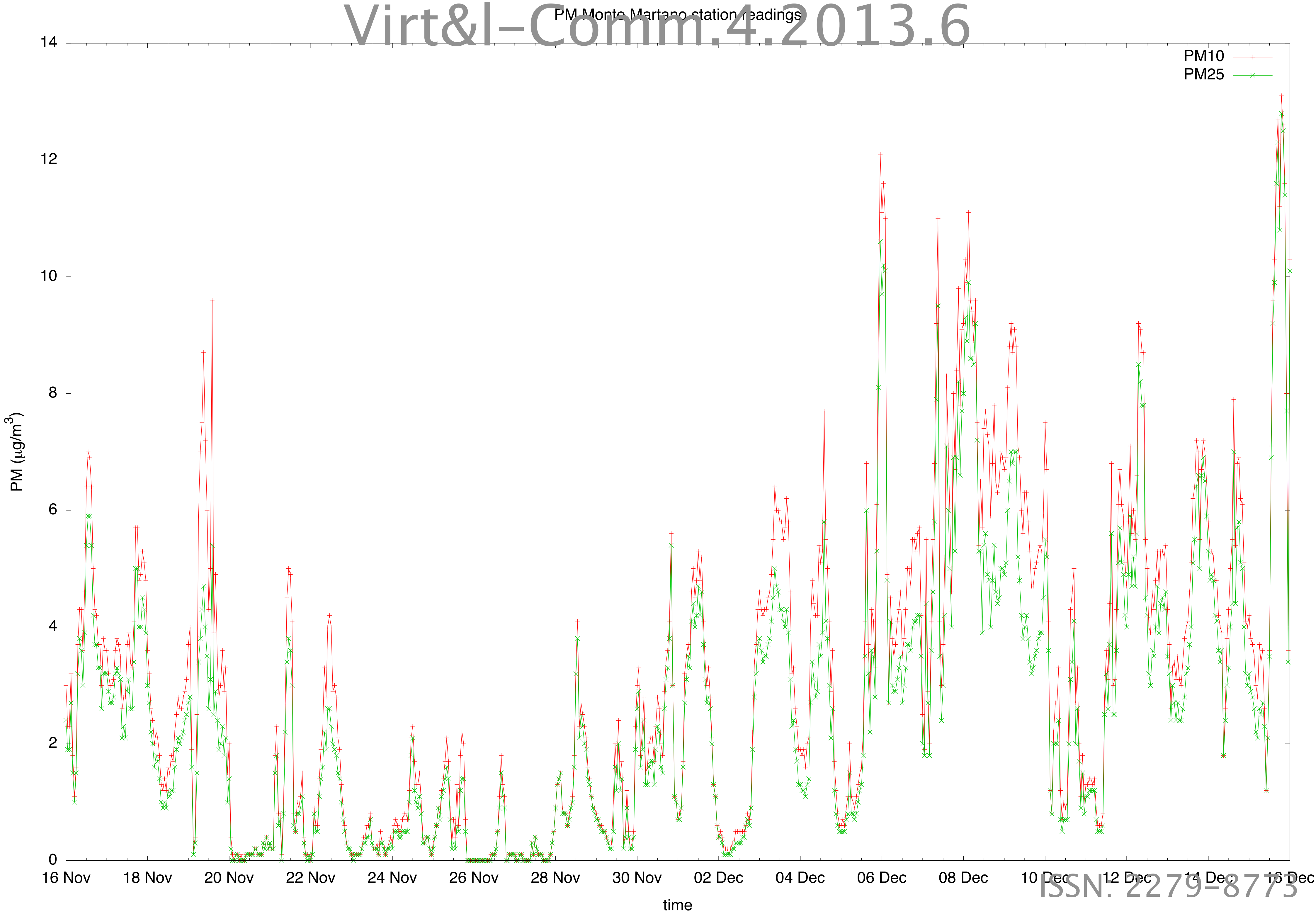

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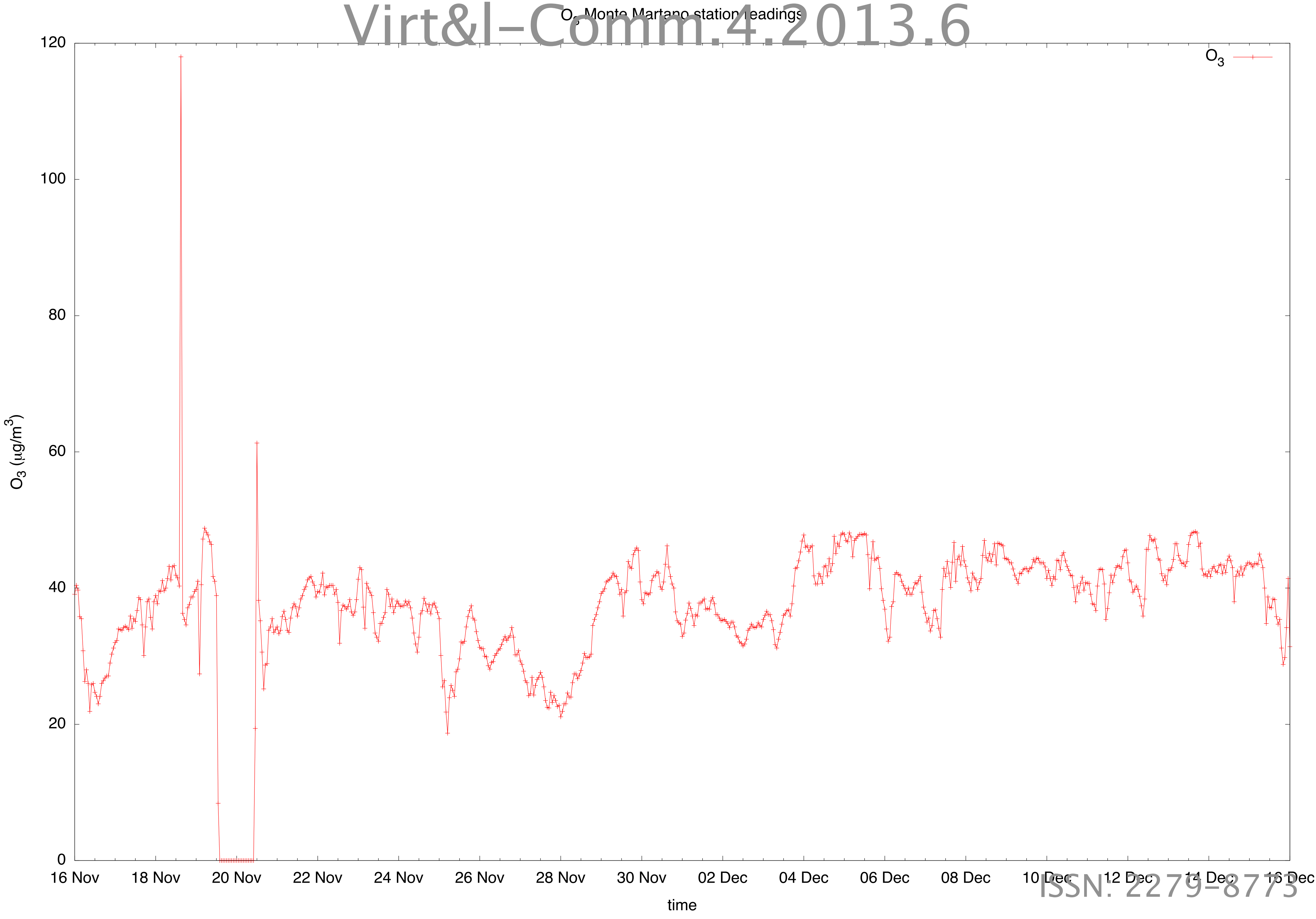

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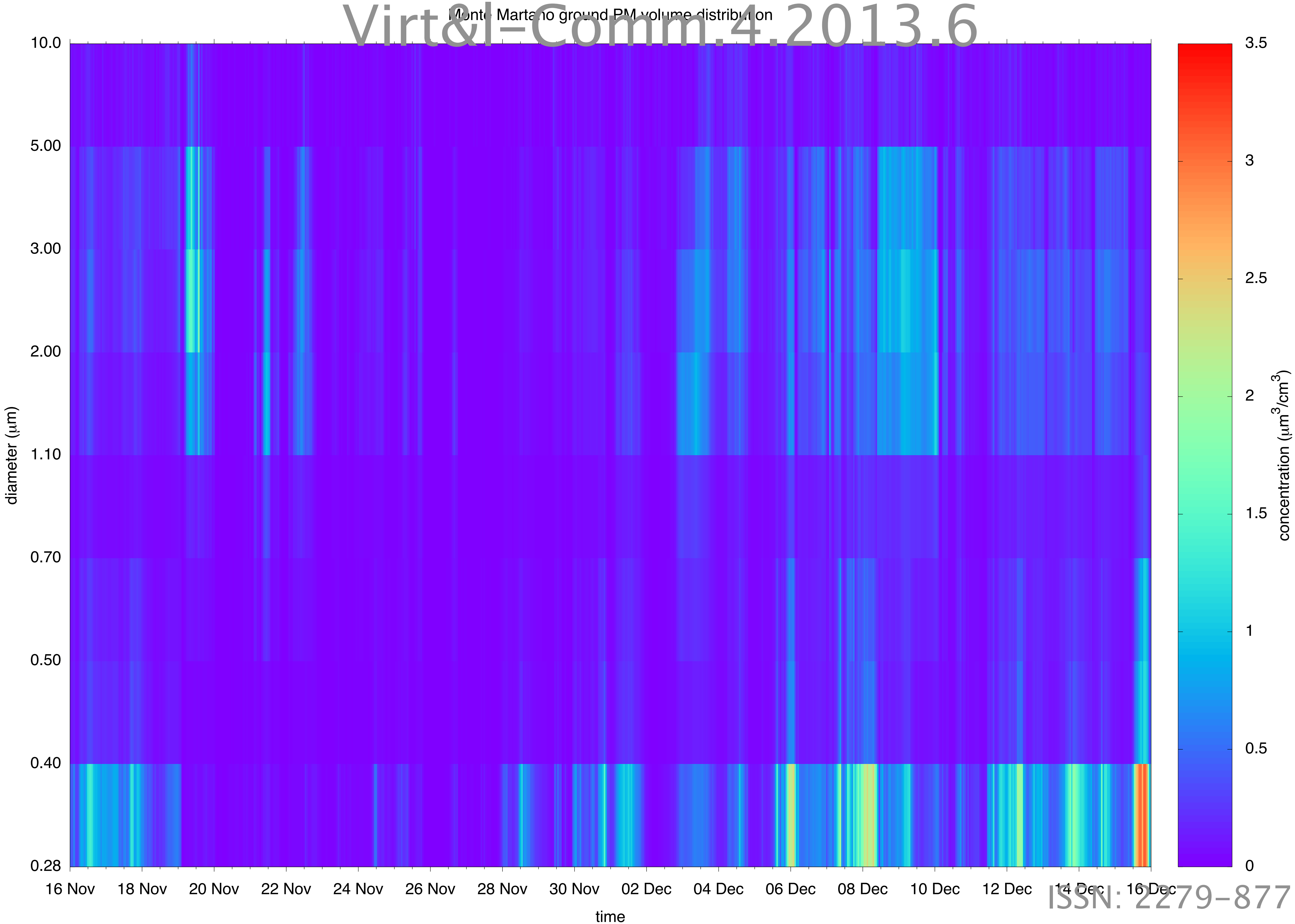

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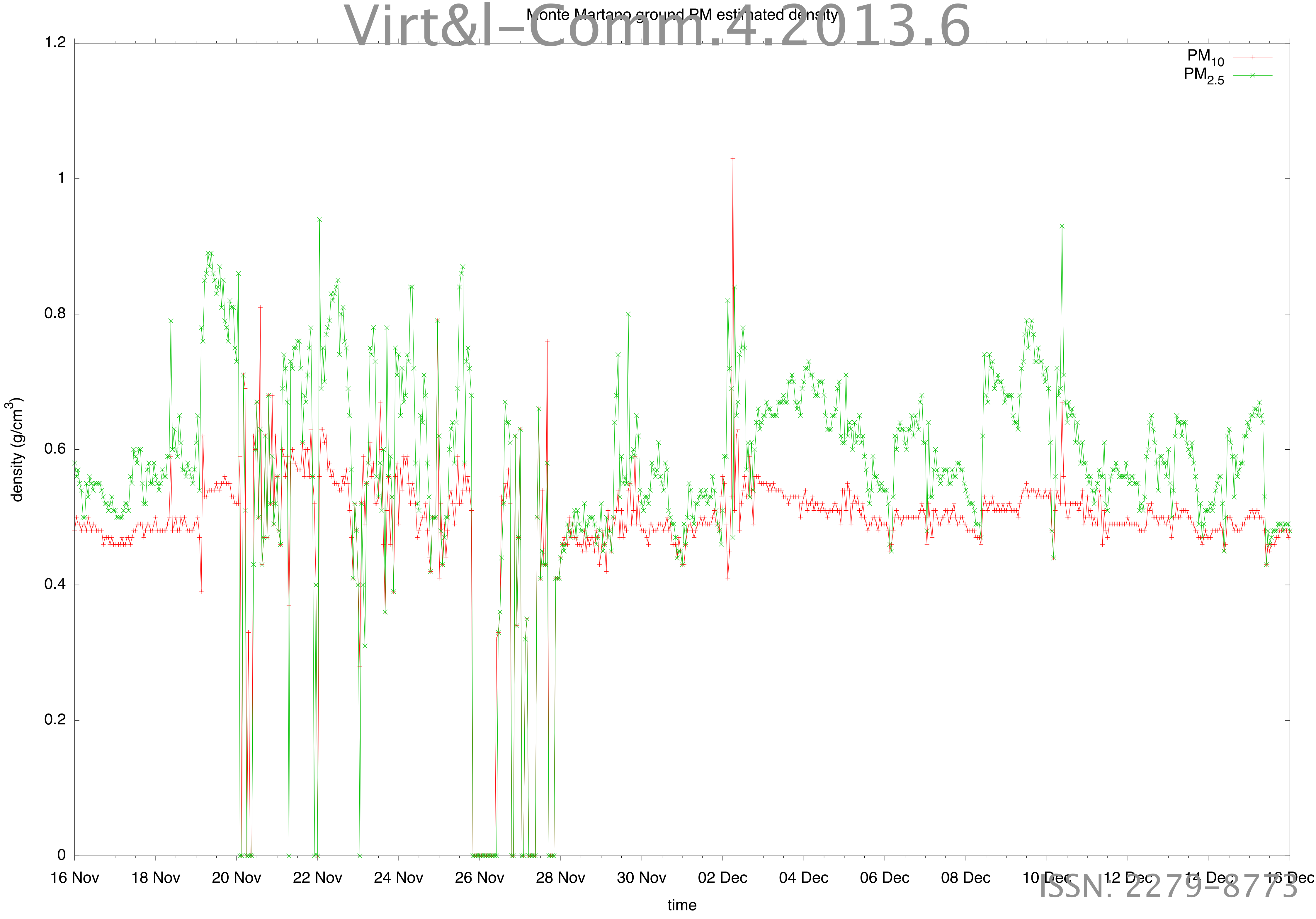
Monte Martano ground PM estimated density
PM10
PM2.5
density (g/cm3)
time
1.2
1
0.8
0.6
0.4
0.2
0
16 Nov
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