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Analysis of Normalised Differential Spectral Attenuation (NDSA) technique for Inter-Satellite Atmospheric Profiling
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Analysis derived Global Database and Radiosonde Database for the ANISAP Project

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ANISAP Analysis derived databases

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1 Introduction

Within the scope of the ANISAP project, two atmospheric databases were compiled. One database includes globally equally distributed atmospheric profiles which were derived from atmospheric analysis data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). This database is called "global database of analysis derived profiles" or shortly "global database" below. In ANISAP, this database will be applied in the calibration procedure of the NDSA program.

The second database consists of radiosonde profiles which were selected from radiosonde data contained in the ERA-Interim reanalysis database [**Art:eraInterim2011**]. The best resolved profiles of a few days were selected having a representative latitudinal distribution over the Earth. This database is shortly called "radiosonde database" below and will serve for validation in the Normalised Differential Spectral Attenuation (NDSA) technique.

This technical note describes how the databases were compiled and provides also an illustrative insight into the data. The details about the global database are contained in section 2 and the details about the radiosonde database are provided in section 3.

2 Global database of analysis derived profiles

The global database was compiled from ECMWF T511L91 analysis data (grib2 data format) of four days, namely the 15th January 2011, the 15th April 2011, the 15th July 2011 and the 15th October 2011. For each of those days, two time layers were included: 00:00 UTC and 12:00 UTC. Hence, eight different datasets, also called "climatologies" are available in the global database. Each climatology contains data on an equidistant grid with a horizontal sampling of $5° \times 5°$ and a vertical sampling of 0.5 km. The grids range from 180° W to 180° E and from 90° S to 90° N. The vertical axis ranges from 2 km to 80 km. The atmospheric variables contained in the climatologies are pressure, temperature, specific humidity, liquid water content, ice water content, u component of wind and v component of wind. An overview of the database is given in table 2.1. Figure 2.1 shows temperature maps as an example for the data fields contained in the global database.

The ECMWF analysis grib2 data were retrieved using the Meteorological Archival and Retrieval System (MARS), which is the main repository of meteorological data at the ECMWF [**Rep:mars2012**]. The retrieved analyses contained surface level data (geopotential, logarithm of surface pressure, 2 metre temperature, 2 metre dewpoint temperature, skin temperature) and model level data (temperature, specific humidity, specific cloud liquid water content, specific cloud ice water content, u component of wind [positive from west to east], v component of wind [positive from south to nord]).

Those ECMWF data were processed using Fortran-90 routines available in the End-to-End Generic Occultation Performance Simulation and Processing System (EGOPS) [**Rep:EGOPS55SUM**] to select the climatologies for the global database. In particular, a new routine called "fillTheCube.f90" was added to the developmental part of EGOPS. This new routine calls several atmospheric functions of EGOPS and selects the climatology data on the equidistant grid.

The fillTheCube.f90 routine is structured as follows. First, the grid points are defined, where atmospheric data shall be calculated. In particular, latitude range, longitude range, height range and respective step sizes in those dimensions can be determined. The settings used for ANISAP were mentioned above.

Afterwards, the atmosphere model needs to be defined. In our case, we used the so-called EGOPS GCM3Atm model, which is currently being developed at the Wegener Center for Climate and Global Change (WEGC) within the scope of the ESA-OPSGRAS project [**Rep:opsgras2010**]. This model is able to calculate profiles of atmospheric refractivity, pressure and geometric height from the ECMWF surface data and the geopotential. In our case, we used the WGS84 earth figure model [**Rep:wgs84**] as the basis for those calculations. Furthermore, the GCM3Atm model allows to determine the values of several atmospheric variables contained in the ECMWF data as well as derived variables at arbitrary points in the atmosphere. Thereby, the atmospheric variables at specific grid points are determined via interpolation in space and time of the original ECMWF analysis input fields.

This atmosphere model is then used repeatedly in nested loops over the grid dimensions to calculate the atmospheric variables at all grid points defined. For ANISAP, the variables listed in

Table 2.1: Overview of the data contained in the global database of ANISAP.

dates	15th January 2011
	15th April 2011
	15th July 2011
	15th October 2011
time layers	00:00 UTC
	12:00 UTC
variables	pressure (Pa)
	temperature (K)
	specific humidity (kg kg^{-1})
	liquid water content (kg m^{-3})
	ice water content (kg m^{-3})
	u component of wind (m s^{-1})
	v component of wind (m s^{-1})
latitude range	90° S to 90° N, 5° stepsize
longitude range	180° W to 180° E, 5° stepsize
height range	2000 m to 80 000 m, 500 m stepsize

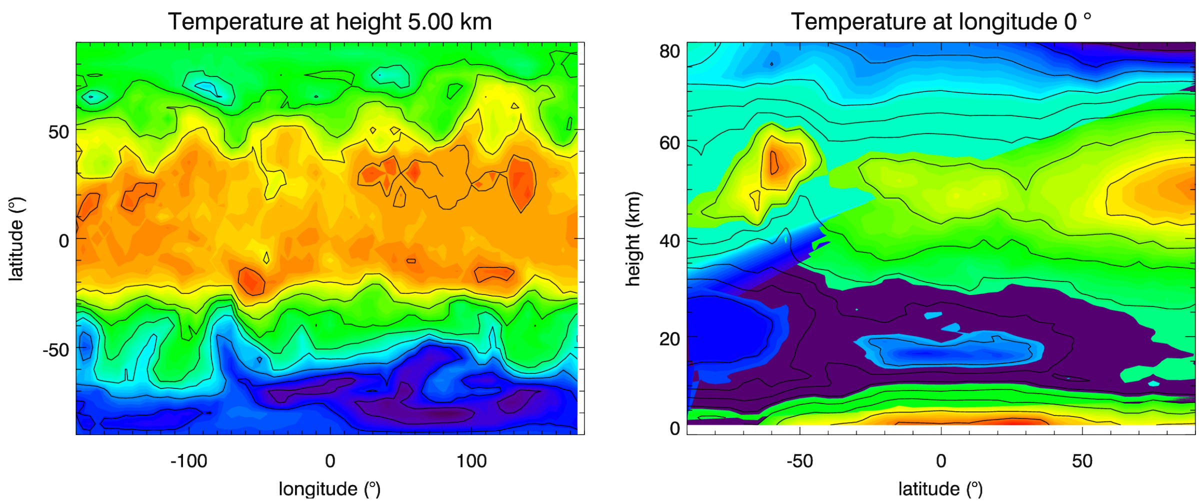

Figure 2.1: Exemplary temperature slices from the temperature field of the 15th July 2011 (12:00 UTC) contained in the ANISAP global database. The panel on the left shows the temperature field at a height of 5 km and the panel on the right shows a latitude-height slice at longitude 0°.

table 2.1 were derived.

Finally, the compiled data are passed to a specifically written routine to save the climatology data in netCDF data format which can easily be read by the NDSA software.

3 Radiosonde database

As basis for the radiosonde database served radiosonde data which are contained in the ERA-Interim reanalysis database. Those data were kindly provided by Prof. L. Haimberger from the Department of Meteorology and Geophysics of the Univ. of Vienna. A detailed description of the ERA-Interim database can be found in [**Rep:eraInterimDatabase**]. The main advantage of this database over other databases, like the data distributed e.g. by the British Atmospheric Data Centre (BADC) (http://badc.nerc.ac.uk/home/index.html) or the Integrated Global Radiosonde Archive (IGRA) (http://www.ncdc.noaa.gov/oa/climate/ igra/), is that the data in the ERA-Interim database are all homogeneous.

In total, we received the ERA-interim radiosonde data of eight days in two years (15$^{\text{th}}$ January, 15$^{\text{th}}$ April, 15$^{\text{th}}$ July, 15$^{\text{th}}$ October; years 2010 and 2011) at two time layers (00:00, 12:00). The data were provided in ASCII data format and contain profiles of pressure, geopotential, temperature, specific humidity, relative humidity, u component of wind and v component of wind. In addition, geographical information on the station altitude, latitude and longitude is contained. Besides, also information on the respective radiosonde type and others is provided.

One day of profiles typically contains more than 600 radiosonde profiles which are well distributed over the Earth; especially they represent very well the continents. The vertical sampling of the profiles differs from station to station. Typically, about 100 profiles per day are composed of more than 100 to 200 pressure levels ranging from the Earth's surface up to about 20 km to 30 km. Useful atmospheric observables, like temperature or specific humidity, are typically available for more than every second pressure level.

For the ANISAP radiosonde database, we decided to select all those profiles having more than 100 pressure levels. Two data files for each of the eight days available, one representing the 0:00 h data and the other representing the 12:00 h data, were produced. Regarding the atmospheric variables, pressure, geopotential, temperature, specific humidity, relative humidity, u component of wind and v component of wind were included. For the vertical coordinate, geopotential height and geometric height were calculated. In addition, geographic latitude and longitude of the stations are available, as well as date, time, radiosonde type, WMO radiosonde station number and station altitude. An overview of the data included in the database is given in table 3.1. An illustrative insight into the geographical distribution of the radiosonde profiles contained in the sixteen datasets is provided in figure 3.1 and figure 3.2.

The database was compiled using routines which were developed in the Interactive Data Language (IDL). First, a reading routine was written to read in the ERA-Interim radiosonde data. Afterwards, the data were sorted and all data of the stations containing more than 100 pressure levels were selected. The next step was to calculate the geopotential height and the geometric height, as the ERA-Interim data contain the geopotential only. An algorithm described by M. J. Mahoney was used for that purpose (http://mtp.mjmahoney.net/www/notes/altitude/altitude.html) which is based on a WGS84 Earth figure and which yields results comparable to other algorithms proposed

Table 3.1: Overview of the data contained in the radiosonde database of ANISAP.

dates	15^{th} January 2010 (73 stations around midnight, 71 around noon)
	15^{th} April 2010 (80 stations around midnight, 94 around noon)
	15^{th} July 2010 (98 stations around midnight, 112 around noon)
	15^{th} October 2010 (97 stations around midnight, 81 around noon)
	15^{th} January 2011 (105 stations around midnight, 89 around noon)
	15^{th} April 2011 (92 stations around midnight, 84 around noon)
	15^{th} July 2011 (99 stations around midnight, 102 around noon)
	15^{th} October 2011 (100 stations around midnight, 105 around noon)
time layers	about 00:00 h (some measurements are taken one hour before or after)
	about 12:00 h (some measurements are taken one hour before or after)
variables	pressure (Pa)
	geopotential (m^2 s^{-2})
	temperature (K)
	specific humidity (kg kg^{-1})
	relative humidity (1)
	u component of wind (m s^{-1})
	v component of wind (m s^{-1})
vertical grids	geopotential height (geopotential m)
	geometric height (m)
horizontal grid	geographic latitude (°)
	geographic longitude (°)
additional information	date (yyyymmdd)
	time (hhmss)
	radiosonde type
	WMO radiosonde station number
	radiosonde station altitude (m)

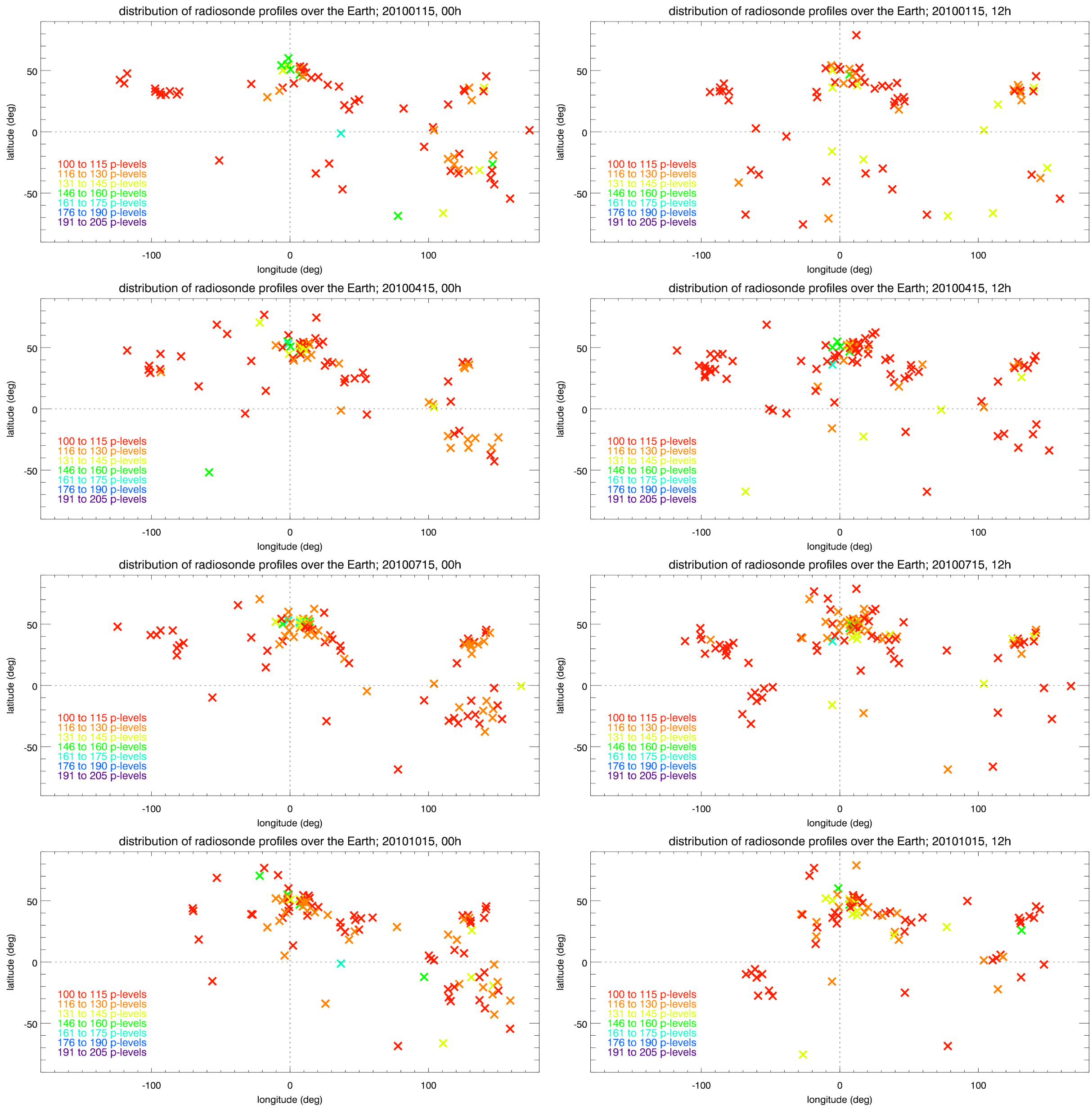

Figure 3.1: Distribution of the ANISAP radiosonde profiles in year 2010 over the Earth. The number of vertical pressure levels is indicated by the use of different colours.

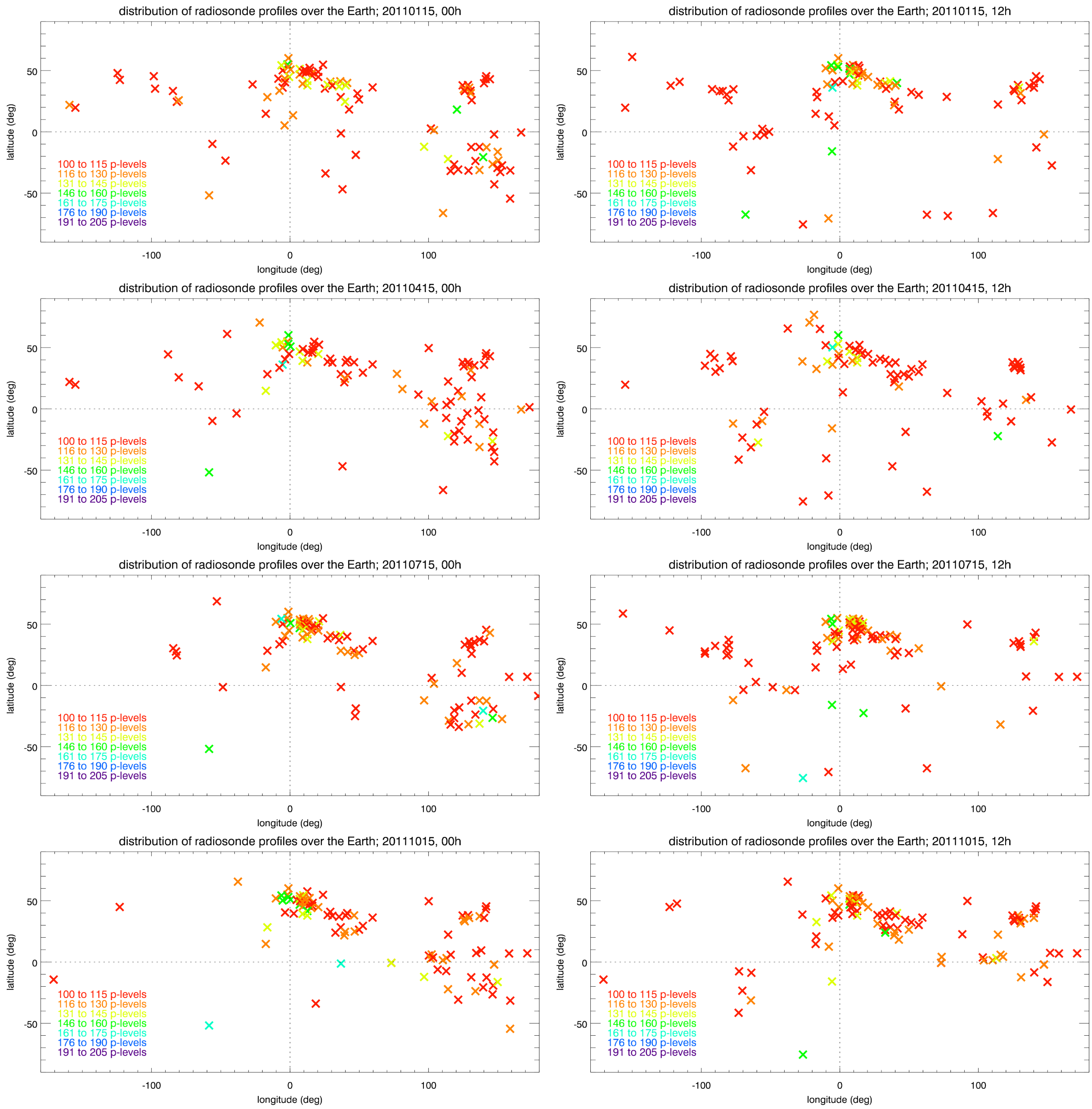

Figure 3.2: Distribution of the ANISAP radiosonde profiles in year 2011 over the Earth. The number of vertical pressure levels is indicated by the use of different colours.

by several organizations. Finally, a writing routine was created to save the selected radiosonde data in NetCDF format, which can easily be read by the NDSA software.

The geopotential height and the geometric height were calculated as described in detail below. First, the geopotential height, h_Z (m), was derived from the geopotential, Z ($\mathrm{m^2\,s^{-2}}$) by dividing the standard gravity at mean sea level, g_{45} ($\mathrm{m\,s^{-2}}$):

$$h_\mathrm{Z} = \frac{Z}{g_{45}}. \tag{3.1}$$

The geometric height, h (m), was then calculated from the geopotential height via

$$h = \frac{r_\phi \cdot Z}{\frac{g_\phi}{g_{45}} \cdot r_\phi - Z}, \tag{3.2}$$

where r_ϕ (m) is the radius of the Earth at latitude ϕ, which was calculated assuming the WGS84 Earth figure,

$$r_\phi = \frac{a}{1 + f + m_\mathrm{r} - 2 \cdot f \cdot \sin(\phi)^2}, \tag{3.3}$$

and g_ϕ ($\mathrm{m\,s^{-2}}$) is the gravity at the surface of the ellipsoid at latitude ϕ,

$$g_\phi = g_\mathrm{E} \cdot \left(\frac{1 + k_\mathrm{S} \cdot \sin(\phi)^2)}{\sqrt{1 - \epsilon^2 \cdot \sin(\phi)^2}} \right), \tag{3.4}$$

where $a = 6378137$ m is the semi major axis of the WGS84 ellipsoid (equatorial radius), $b = 6356752.3142$ m is the semi minor axis of the WGS84 ellipsoid (polar radius), $f = \frac{a-b}{a}$ is the flattening of the Earth, $\epsilon = \frac{\sqrt{a^2-b^2}}{a}$ is the eccentricity, $m_\mathrm{r} = 0.003449787$ is the gravity ratio, $g_\mathrm{E} = 9.780\,325\,335\,9\,\mathrm{m\,s^{-2}}$ is the equatorial gravity, $g_\mathrm{P} = 9.832\,184\,937\,8\,\mathrm{m\,s^{-2}}$ is the polar gravity and $k_\mathrm{S} = \frac{b}{a} \cdot \frac{g_\mathrm{P}}{g_\mathrm{E}} - 1$ is the Somigliana's constant.

4 Summary and Outlook

This technical report presented a global database of analysis derived profiles and a radiosonde database, which were compiled for the ANISAP project. The compilation procedures for the databases were explained and some illustrative insights were provided. The databases will be used later in the ANISAP project to calibrate and to validate the NDSA technique.

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