European Operational Program for Exchange of Weather Radar Information (OPERA)

Description of differences between NIMBUS and ODYSSEY composite production

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Project:	OPERA NIMBUS and ODYSSEY
Production Centre:	GeoSphere Austria, Météo-France
Development by:	Météo-France and UKMO (ODYSSEY) and KNMI, SMHI and GeoSphere Austria (NIMBUS)
Application Domain:	European weather radar composites
Processing Software:	ODYSSEY, BALTRAD v.3.1.0-73, NIMBUS v.2024.04

1. Overview

This report gives a short overview of the differences between the generated pan-European instantaneous surface rain rate (in mm/h, RR) and 1-hour rainfall accumulation (in mm, ACC) composites generated in years 01/2011- 06/2024 by ODYSSEY and 06/2024 by NIMBUS productions.

2. Composite domain

Both ODYSSEY and NIMBUS RR and ACC composite products have a spatial coverage over a pan-European region as defined with the corner coordinates approximately: (70 N 30 W), (70N 50E), (32N 15W), (32 N 30E) with the horizontal resolution grid size of 2 km by 2 km. The image size is therefore 2200 by 1900 pixels. The composites cover most of Europe in a Lambert Equal Area projection.

ODYSSEY is limiting the radar coverage to be 250 km. This is not applied in NIMBUS, but the coverage of the original data is maintained.

3. Update cycle and data reference window

Both ODYSSEY and NIMBUS production have the same update cycle of 15 minutes. However, the data reference windows are different. In ODYSSEY, data used in compositing must have a validity time between -10 minutes and + 5 minutes around composite validity time and data older than 18 minutes are not used. For the 15-minute composite in NIMBUS, the currently used time widow is - 12 minutes before and + 7 minutes after the nominal times of HH:00, HH:15, HH:30, and HH:45. Note that for a given radar, NIMBUS takes the input data that is closest to the nominal time for production of the composites.

4. Composite availability

ODYSSEY composites are produced by 13 minutes after the nominal time (NT) of composite while NIMBUS equivalent composite is available at NT+8minutes with current data flow and setup.

5. Radar configuration tables

The radar configuration tables include the list of the incoming radar data used for compositing and which filters are applied. ODYSSEY and NIMBUS productions are controlled with their own configuration tables. The update of the NIMBUS production table is done twice a year (May and November), while the ODYSSEY database contains old configurations that were last updated in December 2022. Note that this may result in differences because several countries have indicated that some of the quality control filters should not be applied to their data since this last update.

6. Production software

The technical differences of the ODYSSEY and NIMBUS productions are summarized on Table 1.

ODYSSEY production is based on OPERA in-house developed software by UKMO and Météo-France, while maintained after 2019 only by Météo-France. ODYSSEY is produced on the operational production platform at Météo-France.

The NIMBUS software is built upon the open-source BALTRAD software (Michelson et al., 2018). It utilizes a NIMBUS-specific data ingestion tailored to the OPERA network, followed by the BALTRAD toolbox for preprocessing the incoming data and, subsequently, the BALTRAD software is utilized to create the Pan-European radar reflectivity composite. The NIMBUS software is developed by KNMI, SMHI and GeoSphere Austria. This production system is implemented on the operational platform at GeoSphere Austria.

Table 1. Differences in terms of criteria, software and resources used to run operationally ODYSSEY on Météo-France and NIMBUS on GeoSphere Austria production platforms. NT stands for nominal time of corresponding composite.

	ODYSSEY	NIMBUS
Launch of production	NT+9min	NT+7min
Selection criterion for incoming data	Files arrived within the 18-minute interval: NT-9min to NT+9min	Files arrived between 12 minutes before and 7 minutes after NT; only input data closest to the nominal time is used
Preprocessing of selected incoming data by toolbox	BALTRAD version 2013 (rave, bropo and beamb) and satellite filter version 2018	BALTRAD v.3.1.0-73, NIMBUS v.2024.04
Compositing	Odyssey compositing algorithm in C++98 and use of PROJ.4	BALTRAD v.3.1.0-73, NIMBUS v.2024.04
Production environment	CentOS 6.5	Docker container running CentOS Stream 8, running on CentOS 7.9.2009
Computing resources	2 computing servers dedicated to Odyssey, each with 32 CPUs	2 redundant production machines (40 CPUs) 1 development machine (20 CPUs)

7. Compositing method

ODYSSEY compositing

In the ODYSSEY surface rain rate composite product, the value of the composite rain rate pixel is calculated by taking the quality-weighted mean reflectivity of the lowest valid pixels (no undetect nor nodata values are included) of the contributing radars. Polar cells within a search radius of 2.5 km of the composite pixel are considered and data measured below 200 m altitude are not used.

The quality-weighted mean reflectivity (reflectivity in linear scale) is calculated by

$$\frac{\sum DBZH(radar\ pixel) * qi(radar\ pixel) * weight(radar\ pixel)}{\sum qi(radar\ pixel) * weight(radar\ pixel)}$$

- with the quality index for each range gate is $qi = exp^{(-alpha*h(r)-h\_0)}$,
  where *h(r)* is the height as a function of range *r* from the radar, *alpha* is a constant chosen such that *qi*(*h*=1000.0 m) = 0.5*qi(*h*=*h_0*) and where *h_0* = 200.0 m is a threshold height above the radar, below which the radar observations are rejected (Matthews et al. 2012).

  If the height of the pixel is equal to the minimum height of the radar, the quality index is equal to 1. There is a problem with negative elevations in the quality index calculation resulting to values of quality index above 1.
- the weight of the pixel, which depends on the horizontal distance of the radar pixel to the composite pixel.

The rain rate estimate is then performed by applying the Marshall Palmer Z–R relationship ($Z=aR^b$, with coefficients a=200 and b=1.6) to obtain rainfall intensity (mm/h) from the weighted mean reflectivity factor (dBZ).

NIMBUS compositing

NIMBUS compositing is based on the functions included in the BALTRAD software. Currently, the compositing of incoming volume radar data is performed by using the lowest elevation angle scan for each radar. The reflectivity factor (Z) of a given composite pixel is then set to that measured by the radar that provides data closest to sea level for that pixel. Hence, no averaging of reflectivities is done in computing the composite. The conversion to rain rate (R) is performed by applying the Marshall-Palmer Z–R relationship ($Z=aR^b$, with coefficients a=200 and b=1.6). The hourly ACC composite is the sum of the previous four 15-minute RR composites.

Examples of ODYSSEY and NIMBUS rain rate products are shown in Figure 1. As can be observed the compositing methodology is seen in ODYSSEY more averaging of the data than in NIMBUS (no averaging). In NIMBUS, the precipitation has higher values, the spatial distribution of NIMBUS precipitation is smaller when the low values of rain rate related to averaging are missing.

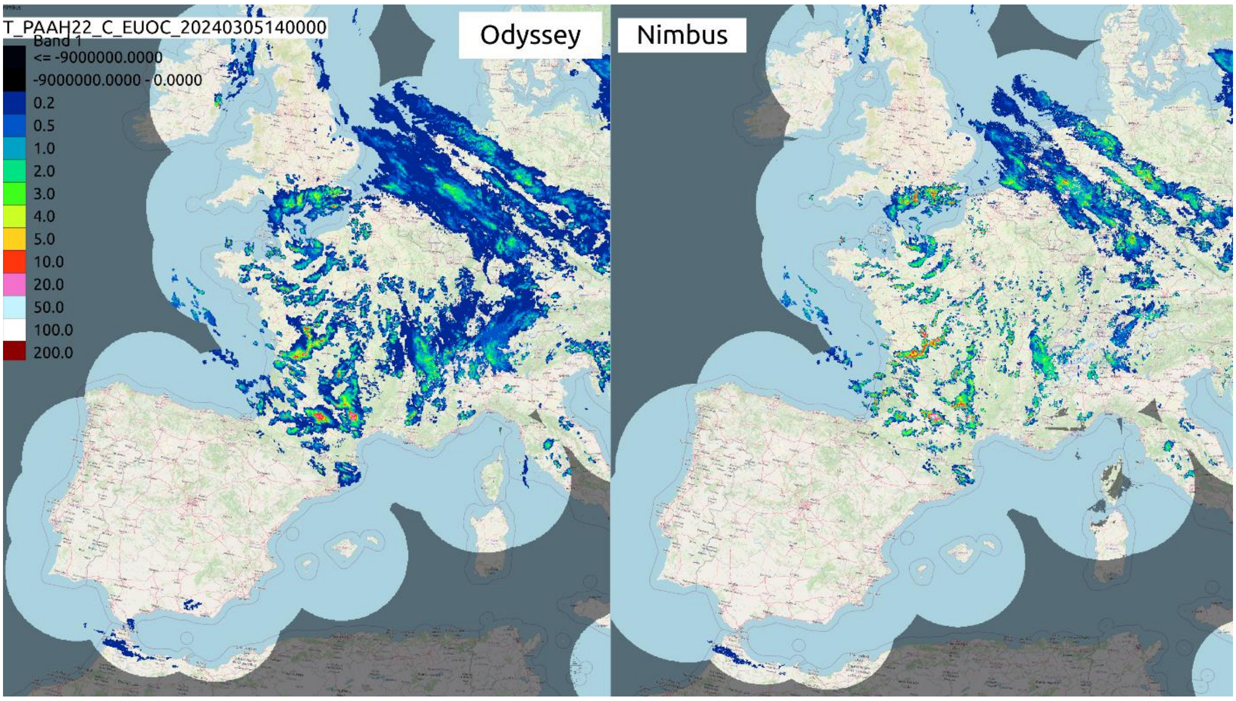

Figure 1. ODYSSEY rain rate composite on the left and NIMBUS rain rate composite on the right on 5 March 2024.

8. Applied data filters

Both in ODYSSEY and NIMBUS, during processing of incoming OPERA files, default BALTRAD toolbox software modules such as hac, bropo, beamb, satfilter, and qi-total are applied to all selected files.

Each radar data provider can choose which quality process is applied to their radar data. While the applied filters are the same in ODYSSEY and NIMBUS, there may be differences in implementation due to upgrades in the BALTRAD software used in NIMBUS but not in ODYSSEY. In addition, the configuration of the filters might differ e.g. the order they are applied.

It's important to note here that a common definition for dry pixels is necessary, and two terms are defined in ODIM documentation (ODIM 2.4) which OPERA production both in ODYSSEY and NIMBUS are following:

- "nodata" refers to pixels that are out of range or in a blanked sector.
- "undetect" indicates that the received radar signal is at or below the noise level (this is generally associated with dry weather).

As a summary, the centrally used filters are described below following the explanations and references within Saltikoff et al. (2019). Three filters (excluding the hit-accumulation clutter filter) also provide quality information used in calculating the respective quality index.

The anomaly-removal module (bropo) (Peura, 2002) uses computer imaging methods to identify patterns (e.g., straight lines or single pixels) often associated with non-weather-related sources. The module assigns a probability of precipitation, added to the metadata as the first quality indicator, and rejects non-precipitation pixels by setting values exceeding a threshold to nodata.

The hit-accumulation clutter filter (hac) (Scovell et al., 2013) calculates a normalized echo count (occurrence frequency) each month. This filter identifies all pixels where the normalized echo count exceeds a threshold as residual clutter. A value of 0.6 is typically used. During hit accumulation file building, a pixel is considered a hit if it is not undetect or nodata. In case of dimension inconsistency (nbins or nrays) between the hit accumulation file compiled and the examined scan, the scan is not processed by the hit accumulation filter, and the radar is not composited unless the hit accumulation file is erased. Hit accumulation files older than 63 days are erased.

The beam blockage correction (beamb) (Henja and Michelson, 2012) calculates the percentage of beam blockage, in polar coordinates, using a 1-km digital elevation model (GTOPO30) and a geometric propagation model that oversamples the radar beam. Pre-calculated values are used to correct the reflectivity for each scan and are added to the metadata as the second quality indicator. Reflectivity values in sectors with partial blockage (up to 70%) are corrected and used in composite products with lower weight than those in unblocked sectors. Reflectivity values in sectors with blockage exceeding 70% are set to nodata and are not used for compositing.

The satellite filter (satfilter) is based on the EUMETSAT Nowcasting SAF Precipitating Clouds (PC) product (Marcos and Rodríguez, 2017), which provides a probability of precipitation. For each radar pixel where an echo is detected, the 49 surrounding satellite pixels are considered. This integration of the satellite product accounts for the time gap between radar and satellite observations and the effects of parallax in the satellite observations. The maximum probability is used as the third quality indicator. If the probability of precipitation is 0 -5%, the reflectivity is set to undetect. With the current setup in ODYSSEY, the quality index of PC product has not been considered in the filtering process.

The quality index (QI) is a measure of data quality and is a more detailed characteristic than a flag, providing quantitative assessment using numbers in a range from zero (bad data) to value of 1 (good data).

9. Quality Index of composites

The quality indices are calculated differently between ODYSSEY and NIMBUS composites. The quality index definition may be modified as part of future developments.

The quality index of the composite pixel in ODYSSEY is the mean quality index of the contributing pixels whose reflectivity is not nodata or undetect:

$$\frac{\sum qi(radar\ pixel)}{\sum radar\ pixel}$$

In ODYSSEY composite products, if all contributing pixels are undetect, the pixel value is set to undetect and the quality set to nodata. If all contributing pixels are nodata, the rainrate is set to nodata and the quality set to nodata. If all contributing pixels are either nodata or undetect, the rainrate is set to undetect and the quality index set to nodata.

The accumulated precipitation product is simply an integral of the previous four 15-minute precipitation intensity products without considering the undetected values. For each pixel, if at least one of the four rainrate values is nodata, then accumulation and quality index have value of nodata. If all the four rain rate values are undetect, then accumulation has value of 0 mm and quality index undetect.

The NIMBUS quality index follows the total QI function of BALTRAD (Szturc et. al., 2011), which sets the QI to the minimum of the three quality indicators of the BALTRAD toolbox (bropo, beamb, and satfilter). If none of these filters have been applied, the quality index is set to 1. The quality index value range is between 0 (poorest quality) and 1 (best quality). Note that the quality index calculation may be renewed in the near future, so the current value should be used with caution.

10. Metadata structure

ODYSSEY uses ODIM 2.0 format while NIMBUS follows ODIM 2.4. The differences of the metadata structure are illustrated in Figure 2.

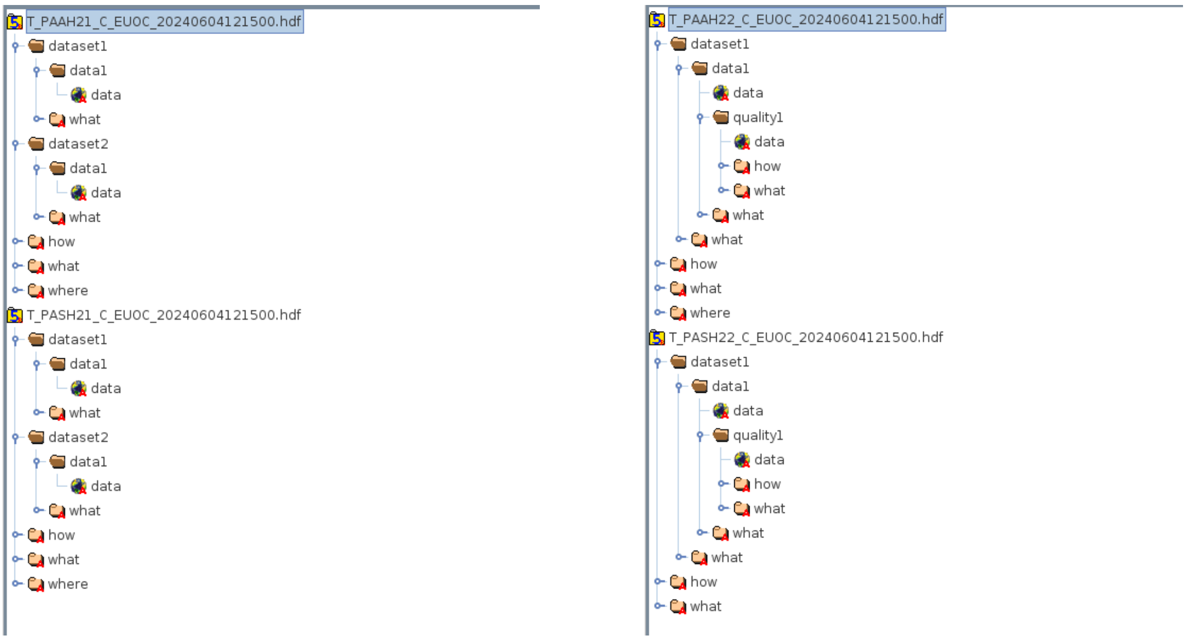

Figure 2: File structure of instantaneous surface rain rate and 1-hour rainfall accumulation composites from ODYSSEY (left, T_PAAH21* and T_PASH21*) and NIMBUS (right, T_PAAH22* and T_PASH22*).

11.References

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