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WP 1.2 Operationalization of satellite-based volcanic ash measurements

Arve Kylling, Espen Sollum and Paul Eckhardt

Scientific report

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1 Introduction

Infrared measurements by the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on board the geostationary Meteosat Second Generation (MSG-2) satellite, may be used to detect volcanic ash. Subsequent analysis of pixels identified as ash, provide information about the ash mass loading and ash particle size. The high temporal resolution (15 minutes) of the measurements, gives a unique capability to monitor the evolution of volcanic ash clouds. This document describes the ash detection and retrieval software and data flow for SEVIRI data as implemented at NILU for the project "Målinger/modellering av vulkanaske i norsk luftrom".

2 Volcanic ash detection and retrieval

Several methods are available for detection of pixels affected with ash in SEVIRI IR-channels (Prata and Prata, 2012; Francis et al., 2012; Pavolonis, 2010). The present approach is based on the reverse absorption effect using the method described by Prata and Prata (2012). First the brightness temperature difference, dBT,

$$dBT = T_{10.8} - T_{12.0} \quad (1)$$

is calculated. $T_{10.8}$ and $T_{12.0}$ are the brightness temperatures of the SEVIRI 10.8 and 12.0 μm channels respectively. Examples of the 10.8 μm brightness temperature and the brightness temperature difference dBT, are provided in Figs. 1-2 for an episode during the Eyjafjallajökull 2010 eruption.

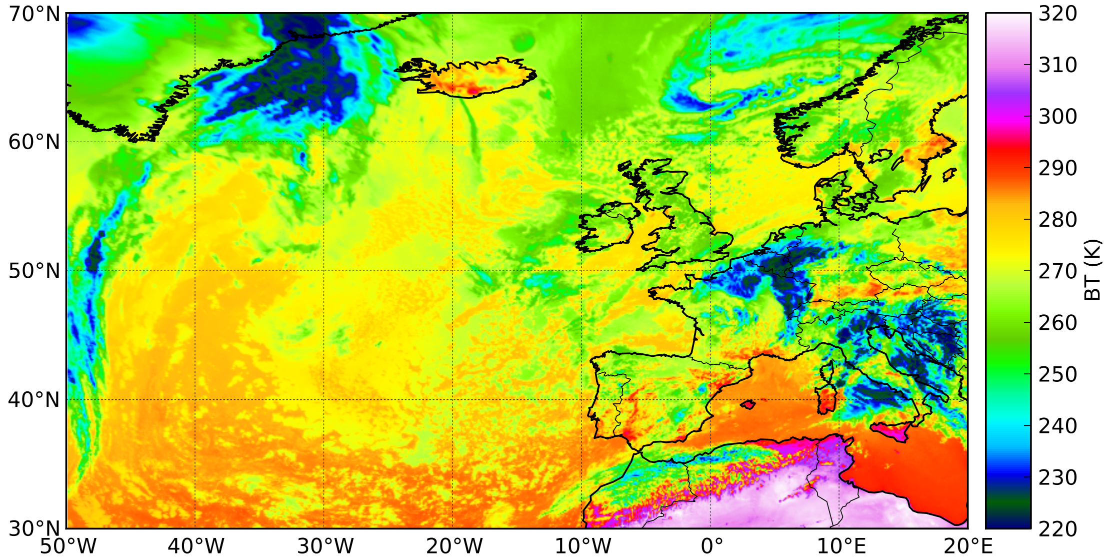

Figure 1: The 10.8 μm brightness temperature for 1200UTC,11 May, 2010.

Water vapor absorption will affect the brightness temperature difference. The is corrected for by the approach of Yu et al. (2002).

Due to the differences in optical properties (refractive index) between ash clouds and meteorological liquid water and ice clouds, the ash clouds give negative brightness temperature differences while the liquid water and ice clouds give positive brightness temperature differences. Thus, pixels are identified as being ash-affected if

$$T_{10.8} - T_{12.0} < \Delta T_{cut}, \quad (2)$$

The cut-off temperature difference ΔT_{cut} is prescribed and may be different for different eruptions. It is typically below zero. For the Eyjafjallajökull eruption Prata and Prata (2012) used a value of -0.8 K. Applying this cut-off

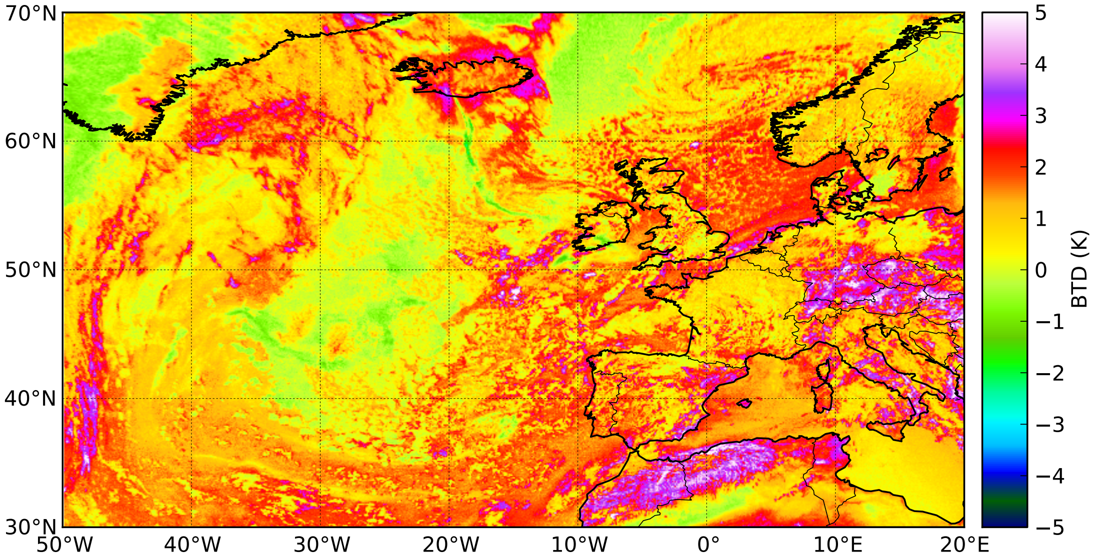

Figure 2: The brightness temperature difference, $dBT = T_{10.8} - T_{12.0}$, for the same situation as in Fig. 1.

limit to the brightness temperature difference in Fig. 1 identifies the pixels as ash. These pixels are shown in the upper right panel of Fig. 3. Clearly volcanic ash is present in the image with a plume strectching southwards from the south tip of Iceland. However, also some noise is seen east of Iceland. By applying a limit on the 7.3 μm brightness temperature (shown in the upper left panel of Fig. 3) and running the resulting pixels through the ash retrieval algorithm of Prata and Prata (2012), the mass loading and effective radius are obtained as shown in the lower left and lower right panels of Fig. 3, respectively.

For high latitudes the SEVIRI viewing angles become large, see Fig 4. At the sub-satellite point the SEVIRI spatial resolution is 3 km $\times$ 3 km and increases as the viewing angle increase (see Fig 1, Prata and Prata (2012)). To avoid possible problems at the scan edges data with view angles larger than a limit, typically around 68°, are excluded from the analysis.

3 SEVIRI data handling

NILU receives SEVIRI data from EUMETCast (`http://www.eumetsat.int/Home/Main/DataAccess/EUMETCast/index.htm`). The SEVIRI data in the Low/High Rate Information Transmission (LRIT/HRIT or XRIT) format are converted into *raw files. The resulting raw files are named as `Platform-Channel-Area-DateTime.Datatype.raw`, where

`Platform` Refers to the satellite, either MSG1 or MSG2 are recognised.

`Channel` Is the SEVIRI channel id. One of HRV, IR_016, IR_039, IR_087, IR_097, IR_108, IR_120, IR_134, VIS006, VIS008, WV_062, WV_073.

`Area` is the area covered by the image.

- `FES` (old: FullDisk, –> 3712x3712)
- `RSS` (–> 3712x1237)
- `AreaName_<Startpixel>_<Startrow>_<Pixels>x<Rows>`

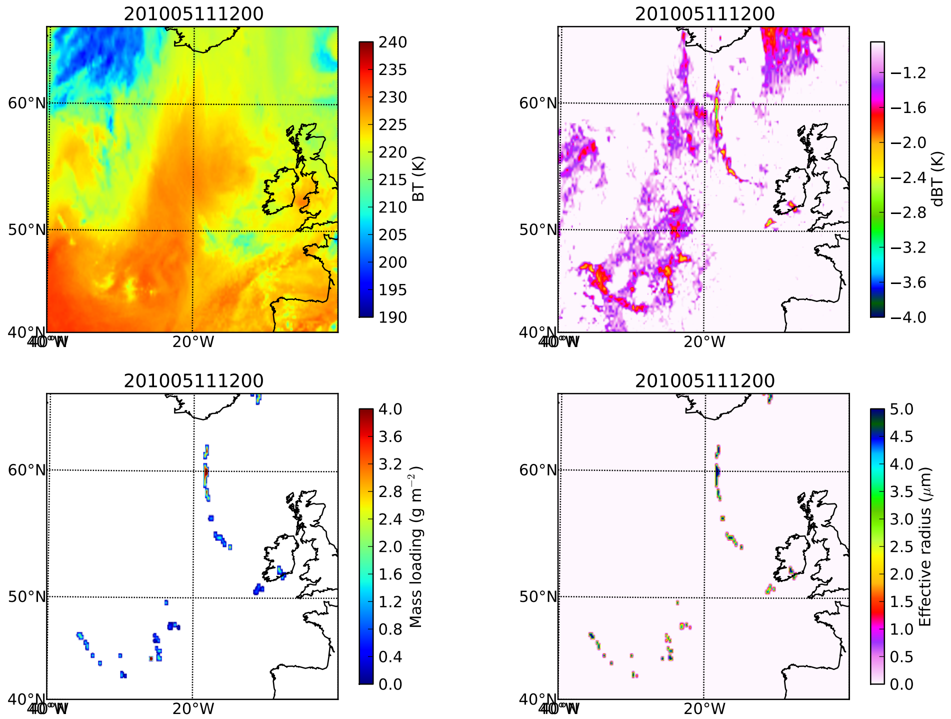

Figure 3: Upper left: The 7.3 μm brightness temperature for 1200UTC,11 May, 2010. Upper right: The corresponding brightness temperature difference, $dBT = T_{10.8} - T_{12.0}$. Lower left: The retrieved ash mass loading. Lower right: The retrieved effective ash particle radius.

Pixels vary in the longitude direction while rows vary in the latitude direction.

`DateTime` YYYYMMDDHHMI, where YYYY is year, MM is month, DD is day in month, HH is hour (0-23) and MI is minute (0-59).

`Datatype` `counts.int2` counts, short int

`calib.float4` calibrated radiance as 4 byte float

`calib.float8` calibrated radiance as 8 byte float

In practice the float4 format is used.

Example of filenames following the above convention are:

```
MSG2-VIS008-FES-201208300945.calib.float4.raw
MSG2-WV_073-IcelandEurope_1088_0088_1537x494-201005252345.calib.float4.raw
```

Subsets of the full disk are made with the in-house developed `xRITsubset.pl` script.

For selected events the $*$.raw files are stored at `/xnilu_wrk/sat_data/events`. Specifically the raw files for the Eyjafjallajökull 2010 eruptions are found under `/xnilu_wrk/sat_data/events/2010-03_Eyjafjallajokull/products` and `/xnilu_wrk/sat_data/events/2010-04_Eyjafjallajokull/products`

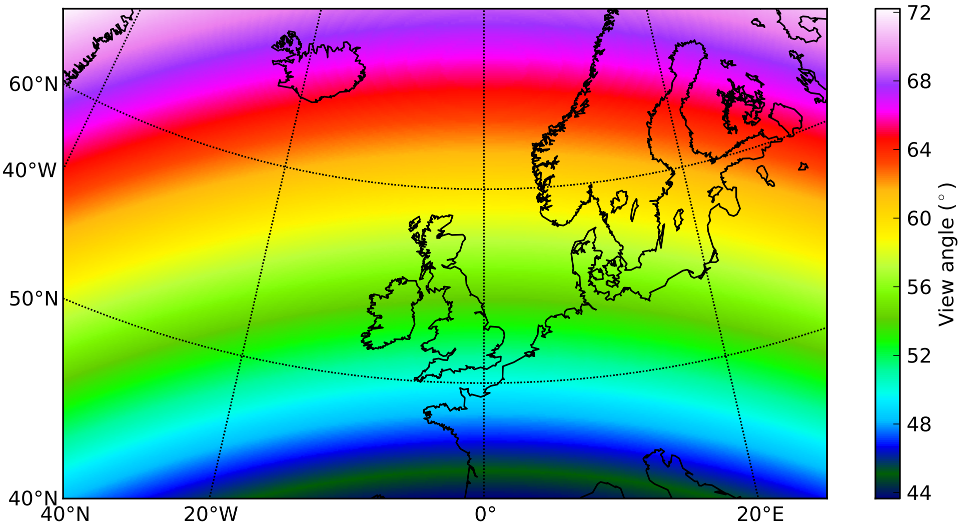

Figure 4: The viewing angle of the SEVIRI instrument for north-west Europe, north-Atlantic and Iceland.

4 SEVIRI data analysis chain as implemented at NILU.

Technical details of the ash detection and retrieval chain as implemented at NILU is given below. This includes what software is used and the location of this software in the NILU file system. For specific details the user is encouraged to consult the software itself and the comments in the code.

A visualization of the analysis chain is provided in Fig. 5. The contents of the various boxes are described below.

4.1 xrit2raw

SEVIRI data from EUMETCast are in the in the Low/High Rate Information Transmission (LRIT/HRIT or XRIT) format. They are converted into *raw files by the `xrit2raw` program which is available from `http://www.icare.univ-lille1.fr/wiki/index.php/Xrit2raw`. The raw format is a simple floating point array of either counts or calibrated radiances in units of mW m^{-2} sr^{-1} (cm^{-1})$^{-1}$.

4.2 Read raw files

Raw files (with extension `.calib.float4.raw`) are in binary format and read as `float32` using the `ReadRaw` function in the `NVAP.py` module.

4.3 Convert radiance to Brightness Temperature

Raw files are in units of mW m^{-2} sr^{-1} (cm^{-1})$^{-1}$ and converted to brightness temperature by the function `Convert2BT` in the module `NVAP.py`. The data are converted to Brightness temperature (Kelvin) using tables from `http://www.eumetsat.int/Home/Main/DataProducts/Calibration/MSGCalibration/index.htm`.

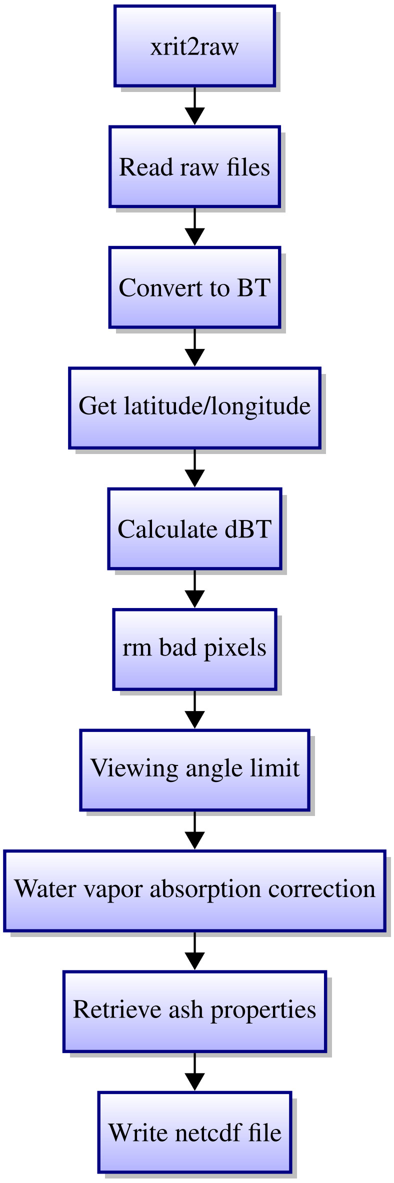

Figure 5: The SEVIRI data analysis chain as implemented at NILU.

4.4 Get latitude/longitude

As the SEVIRI-instruments are on geostationary satellites their location is fixed as is the geolocation of the pixels. Thus, there is no need to recalculate the pixel coordinates over and over again. SEVIRI geolocation data were obtained from `ftp://ftp.eumetsat.int/pub/EUM/out/OPS/User/VOLE_Navigation_Data_May_2012/`. The geolocation data are read by the `LatLon` function in the `NVAP.py` module.

4.5 Calculate brightness temperature differences

Brightness temperature differences, $dBT = T_{10.8} - T_{12.0}$, are calculated in the main `AshDetection.py` script.

4.6 Identify Earth pixels

Some of the SEVIRI pixels view space. Pixels viewing the Earth are identified in the function`GetIndexOfEarthPixels` in the module `NVAP.py`.

4.7 Viewing angle limit

The viewing angle for a pixel is calculated by the function `CalculateVZA` in the module `NVAP.py`. For a given area, for example a full disk or part of the disk, the viewing angle is calculated once and stored to a file with extension `.vza`. Subsequent analysis of similar areas will not repeat the viewin angle calculation, but read info from the file to save computing time.

4.8 Water vapor absorption correction

The brightness temperature difference is corrected for absorption by water vapor following the approach of Yu et al. (2002). This is done in the function `CorrectdBTForWaterVapourAbsorption` in the module `NVAP.py`.

4.9 Retrieve ash properties

The retrieval of ash mass loading and effective radius is described by Prata (1989); Prata and Prata (2012). The function `RetrieveAshProperties` in the module `NVAP.py` performs the retrieval.

4.10 Write netcdf file

Output from the ash detection and retrieval is given in netcdf files (`http://www.unidata.ucar.edu/software/netcdf/`). Two types of netcdf files may be output:

- The Volcanic Ash Detection product (VOLE) product is described in `http://www.eumetsat.int/Home/Main/News/ProductServiceNews/821496?l=en`. Data, mass loading and effective radius, are provided for each SEVIRI pixel.
- VOLE-like data are gridded to a user specified grid and thus ready to be displayed on the Diana platform used by met.no. The data available are the same as for the VOLE-like product.
- The resulting files are available for registered user via ftp to `nilu-projects.nilu.no`. The data are found under `/viper/nadir/nvap/`.

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ABSTRACT
Data from the SEVIRI instrument is available at NILU through EUMETCast. These data are processed at NILU to retrieve volcanic ash loading in a satellite pixel. The report describes operationalization and automatization of the data processing algorithms at NILU including how the data are made available for the Norwegian Meterological Institute.

NORWEGIAN TITLE

WP 1.2 Operasjonalisering av satellittbaserte askemålinger

KEYWORDS		
Volcanic ash	Remote sensing	Radiative transfer

ABSTRACT (in Norwegian)
Data fra SEVIRI-instrumentet innhentes automatisk og direkte til NILU via EUMETCast. Disse satellittdataene prosesseres på NILU ved hjelp av algoritmer som beregner mengden vulkanaske i et observert satellittpixel. Rapporten beskriver operasjonalisering og automatisering av disse algoritmene ved NILU, samt tilgjengeliggjøring av data for Meteorologisk institutt.

** Classification*	*A*	*Unclassified (can be ordered from NILU)*
	B	*Restricted distribution*
	C	*Classified (not to be distributed)*

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