OR 11/2013

WP 1.4.1: Visualization of modelled SEVIRI IR-scenes for quality control

Arve Kylling

Scientific report

WP 1.4.1: Visualization of modelled SEVIRI IR-scenes for quality control

Arve Kylling
NILU-Norwegian Institute for Air Research
Kjeller, Norway

May 15, 2013

1 Introduction

The Spinning Enhanced Visible and Infrared Imager (SEVIRI[1]) records Earth images every 15 minute. In the infrared (IR) images ash clouds may be identified both day and night. The EEMEP model calculates the dispersion of volcanic ash from a given eruption and is operationally running at met.no. The calculated ash fields may be input to a radiative transfer model to simulate what SEVIRI would measure for the given scenario with volcanic ash present in the atmosphere. Such simulated SEVIRI images constitutes an important quality check of the ash detected in SEVIRI measurements and of the transport in the EEMEP model.

For the radiative transfer simulations a fast and accurate model is needed. The Radiative Transfer for TOVS (RTTOV) developed by the UK Met Office[2] satisfies both these requirements.

Below the adoption of the EEMEP ash fields to the RTTOV required ash input format is described. The RTTOV application developed for EEMEP ash clouds and SEVIRI simulations is outlined and sample results provided for an imaginary Etna volcano eruption. The developed software and data flow to and from met.no and NILU is documented. Finally, suggestions for further improvement are given.

2 EEMEP ash concentration file

The EEMEP model provides ash concentration files in the units of μg/m^3 at sigma (σ) levels. RTTOV needs the ash concentration as number density (cm^{-3}) as a function of pressure (or altitude).

2.1 EEMEP to RTTOV ash concentration conversion

To convert from EEMEP ash concentration ρ_{EEMEP} in units of μ/m^3 to number density in cm^{-3} some knowledge about the radii of the ash particles are needed. Here it is assumed that the particles are monosized with radius $r_m = 50\mu$m. Furthermore the ash density is $\rho = 3000$ kg/m^3. Then the number density ρ_{RTTOV} as needed by RTTOV is

$$\rho_{\text{RTTOV}} = \frac{\rho_{\text{EEMEP}}}{\frac{4}{3}\pi r_m^3 \rho} \text{m3tocm3} \tag{1}$$

where the factor m3tocm3 convert from units of m^3 to cm^3.

2.2 Altitude from sigma levels

EEMEP ash concentration is given at σ levels defined as:

$$\sigma = \frac{p - p_T}{p_S - P_T}, \tag{2}$$

where $p_S = 100$hPa and $p_T = 1000$hPa. For radiation calculations the ash concentration is needed at altitude levels. Solving Eq. 2 for p gives:

$$p = \sigma(p_S - P_T)p_T. \tag{3}$$

By using the hydrostatic equation

$$\frac{dp}{dz} = \rho g, \tag{4}$$

[1] More information about the SEVIRI instrument is available from http://www.eumetsat.int/Home/Main/Satellites/MeteosatSecondGeneration/Instruments/index.htm?l=en.

[2] RTTOV is available from http://research.metoffice.gov.uk/research/interproj/nwpsaf/rtm/index.html. The site also provides further information including documentation.

where g is the gravitational acceleration and ρ the density of air, and the ideal gas law

$$p\rho = RT, \tag{5}$$

where R is the ideal gas constant and T the temperature, the altitude may be approximated as

$$z = H(\ln p - \ln p_0), \tag{6}$$

where the scale height $H = RT/g = 7.64$km and $p_0 = 1000$hPa.

For the present application the assumptions inherent in the above conversion is considered sufficient.

3 Radiative transfer calculation

The RTTOV model calculates radiation as measured by various satellites. In the infrared it covers the spectral range 3-20 μm. It thus includes the 8 SEVIRI IR channels in Table 1.

Table 1: Characteristics of SEVIRI IR channels. Information adopted from `http://www.eumetsat.int/Home/Main/Satellites/MeteosatSecondGeneration/Services/SP_20100628161120510`.

SEVIRI Channel	RTTOV number	Short name	Comments
4	1	IR 3.9	Infrared band centered on 3.9μm
5	2	WV 6.2	Water Vapour band centered on 6.2μm
6	3	WV 7.3	Water Vapour band centered on 7.3μm
7	4	IR 8.7	Infrared band centered on 8.7μm, SO_2 absorption
8	5	IR 9.7	Ozone band centered on 9.7μm
9	6	IR 10.8	Infrared band centered on 10.8μm
10	7	IR 12.0	Infrared band centered on 12.0μm
11	8	IR 13.4	Carbon Dioxide band centered on 13.4μm

The RTTOV model is restricted to viewing angles less than 75°. The area for which RTTOV may calculate SEVIRI IR channel brightness temperatures, is shown in Fig. 1. The latitude and longitude resolution of the EEMEP-model used here is 1°. For the area covered by SEVIRI with viewing angle less than 75°, this corresponds to a total of 17645 grid points. For each of these grid points a one-dimensional (1D) radiative transfer model calculation must be made for each channel. RTTOV accomplishes this in the order of 10 s for all 8 SEVIRI IR channels.

Emissivity is included using the emissivity atlas of Borbas and Ruston. (2010). An example of the emissivity for the month of May is provided in Fig. 2.

4 Data flow and software description

Calculation of SEVIRI-like brightness temperatures from EEMEP volcanic ash data is a two step process. First, EEMEP ash is converted to RTTOV ash (see section 2), next the radiative transfer calculation is carried out (section 3). The first step is carried out by a python script named EEMEPAsh2RTTOVAsh.py. Execute `python EEMEPAsh2RTTOVAsh.py --help` to see how to use it. The radiative transfer calculation is done by the `SEVIRI_BT_from_EEMEP_ash` program. It is written in Fortran 90 and requires that RTTOV is available. Description of the program is given in the code it self (`SEVIRI_BT_from_EEMEP_ash.F90`).

All the software is available at `svn.nilu.no/NVAP`.

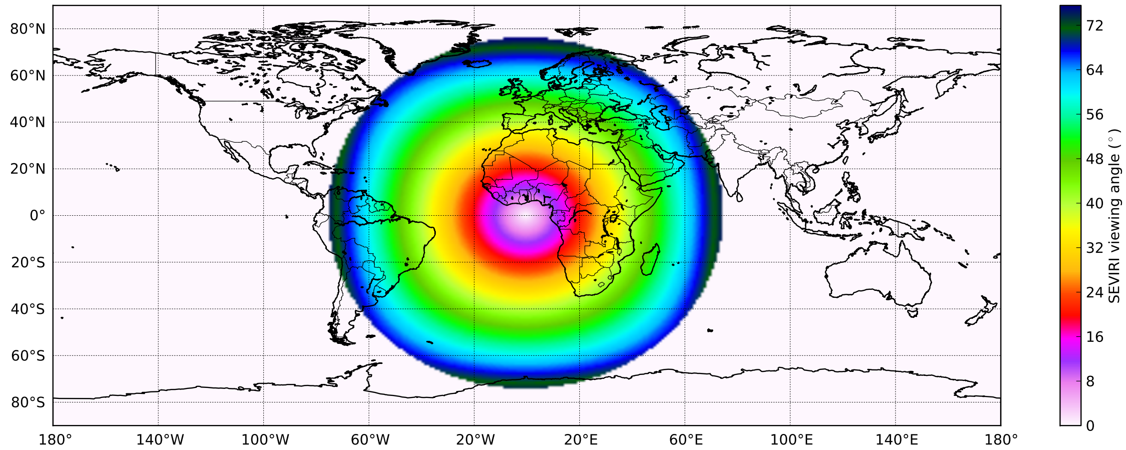

Figure 1: The area covered by the SEVIRI instrument when the viewing angle is less than 75°.

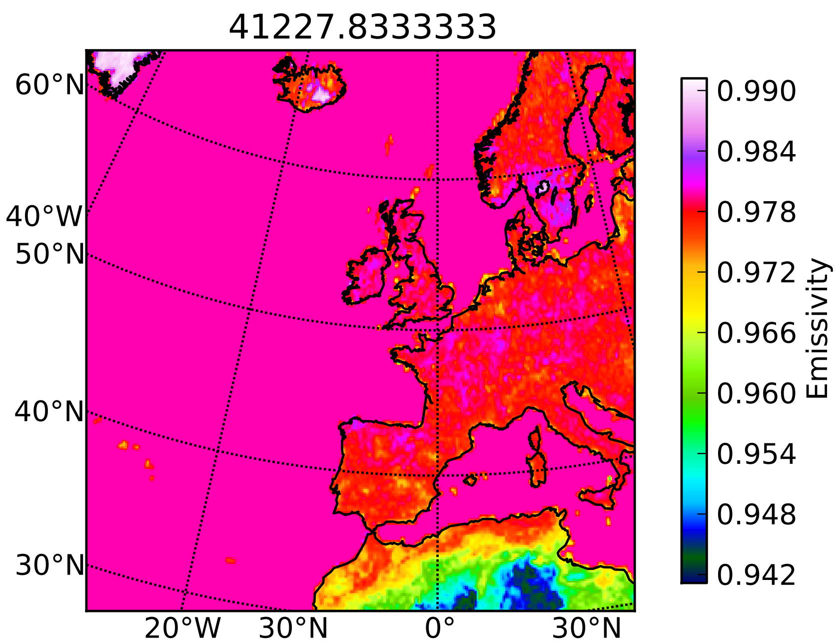

Figure 2: The emissivity from Borbas and Ruston. (2010) for the month of May for the 10.8 um channel.

4.1 Examples

The ash mass loading from an imaginary eruption of the Etna volcano as calculated by the EEMEP model is shown in logarithmic scale in Fig. 3. The ash concentration was converted layer by layer to RTTOV input and RTTOV then calculated the SEVIRI brightness temperatures. The difference (dBT) between the 10.8 and 12.0 μm brightness temperatures are presented in Fig. 4. A negative dBT indicates the presence of volcanic ash. It is clearly seen that the modelled ash cloud (Fig. 3) and the simulated SEVIRI image (Fig. 4) are consisten. In the case of a real eruption these two images may be compared with the real satellite image and thus provide validation and

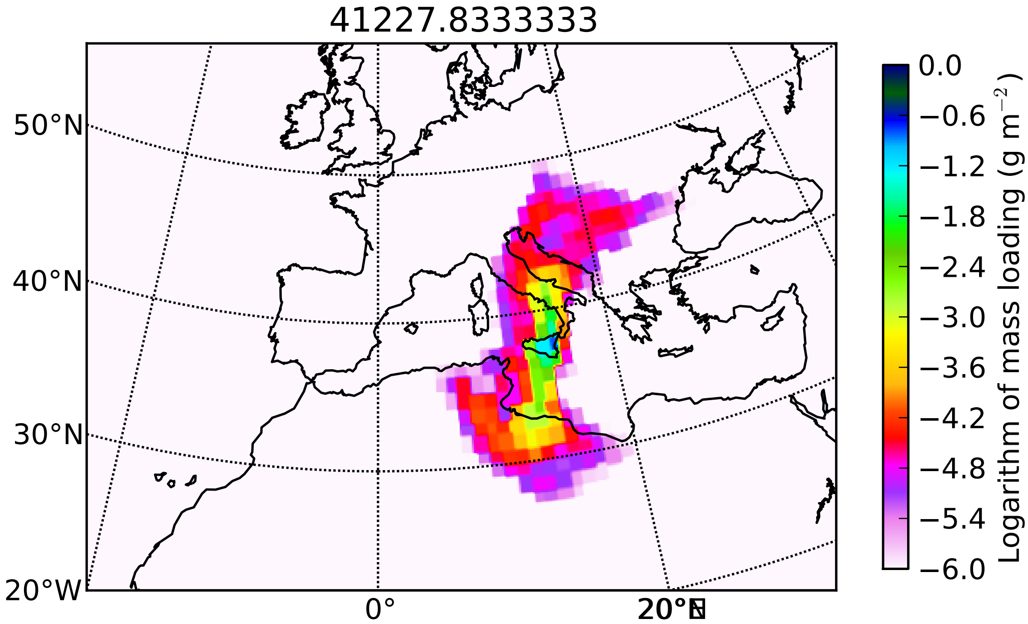

Figure 3: The mass loading from the EEMEP model for a test Etna eruption scenario.

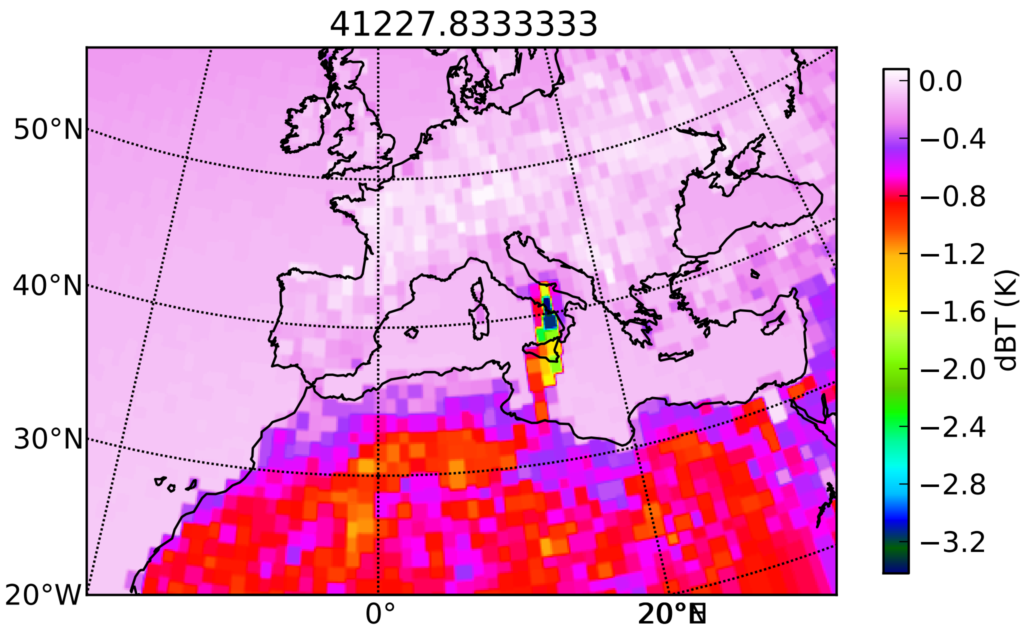

Figure 4: The brigthness temperature difference as calculated from RTTOV SEVIRI channel 10.8 and 12.0 μm brightness temperatures. Ash field input is shown in Fig. 3.

additional evaluation of the model and satellite products.

5 Suggestions for further improvement

Below is a non-prioritised list of improvements that may be made to the simulation of SEVIRI type images from EEMEP calculated ash fields.

- Liquid water clouds from weather forecast models may be included in the RTTOV simulations. This will make the simulated SEVIRI images more realistic.
- Ice water clouds from weather forecast models may be included in the RTTOV simulations. This will make the simulated SEVIRI images more realistic.
- RTTOV may include individual water vapour profiles for each grid point. Such water vapour profiles may be obtained from weather forecasting models at met.no.
- Topography is presently not included. It may be included by using information from for example the GTOPO30 data set (http://www1.gsi.go.jp/geowww/globalmap-gsi/gtopo30/gtopo30.html).

References

Borbas, E. E. and Ruston., B. C. (2010) The RTTOV UWiremis IR land surface emissivity module, EUMETSAT (NWPSAF-MO-VS-042). URL: http://research.metoffice.gov.uk/research/interproj/nwpsaf/vs_reports/nwpsaf-mo-vs-042.pdf.

NILU – Norwegian Institute for Air Research
P.O. Box 100, N-2027 Kjeller, Norway
Associated with CIENS and the Fram Centre
ISO certified according to NS-EN ISO 9001/ISO 14001

REPORT SERIES SCIENTIFIC REPORT	REPORT NO. OR 11/2013	ISBN: 978-82-425-2567-3 (print) 978-82-425-2568-0 (electronic) ISSN: 0807-7207	
DATE	SIGN.	NO. OF PAGES 7	PRICE NOK 150.-
TITLE WP 1.4.1: Visualization of modelled SEVIRI IR-scenes for quality control		PROJECT LEADER Nina I. Kristiansen	
		NILU PROJECT NO. O-112109	
AUTHOR(S) Arve Kylling		CLASSIFICATION * A	
		CONTRACT REF. [Skriv ref]	
QUALITY CONTROLLER: Nina I. Kristiansen			
REPORT PREPARED FOR Ministry of Transport and Communications and Avinor AS			

ABSTRACT
The SEVIRI instrument produces infrared images. The report describes how the RTTOV radiative transfer model is used to simulate SEVIRI images for an ash situation.

NORWEGIAN TITLE

WP 1.4.1: Visualisering av satellittdata for kvalitetskontroll

KEYWORDS		
Volcanic ash	Remote sensing	Radiative transfer

ABSTRACT (in Norwegian)
SEVIRI-instrumentet leverer blant annet infrarøde bilder. Rapporten beskriver hvordan strålingsmodellen RTTOV brukes til å modellere SEVIRI infrarøde bilder for askeskysituasjoner.

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

REFERENCE: O-112109
DATE: MAY 2013
ISBN: 978-82-425-2567-3 (print)
978-82-425-2568-0 (electronic)

NILU – Norwegian Institute for Air Research is an independent, nonprofit institution established in 1969. Through its research NILU increases the understanding of climate change, of the composition of the atmosphere, of air quality and of hazardous substances. Based on its research, NILU markets integrated services and products within analyzing, monitoring and consulting. NILU is concerned with increasing public awareness about climate change and environmental pollution.