SEVIRI Fire Radiative Power and the MACC Atmospheric Services

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Abstract

Monitoring and forecasting of the atmospheric composition in the GMES atmospheric environmental services will require boundary condition estimates of the smoke flux to the atmosphere due to biomass burning. The EUMETSAT Land SAF provides an operational fire radiative power (FRP) product based on the SEVIRI observations. The smoke flux calculated from this product is suitable for use in atmospheric services because (1) the product is available operationally in real time, (2) it has sufficient temporal and spatial resolutions and (3) FRP can be directly linked to the smoke emission rate. A case study of the Greek fires of August 2007 confirms that the aerosol optical depth is simulated accurately by combining the SEVIRI FRP observations with the GEMS/MACC atmospheric aerosol model. However, the geographical coverage of SEVIRI is limited to Africa and Europe (and a small part of South America). Therefore, MACC currently merges the SEVIRI FRP product with that from MODIS polar orbiting data in order to provide information on worldwide open vegetation fire activity variations and thus calculate the total global biomass burning smoke emission rate in real time. However, since the MODIS instrument cannot resolve the short-term and diurnal variations of the fire intensity appropriately enough for our purposes, the provision of FRP products from the other geostationary satellites currently operating around the globe would be highly beneficial for MACC.

INTRODUCTION

EU's FP7 MACC project is developing and providing a set of atmospheric environmental services in preparation for operational GMES services (Hollingsworth et al. 2008, Engelen et al. 2009). MACC monitors and forecasts the atmospheric concentrations of various reactive gases and aerosols. These components and greenhouse gases are also monitored retrospectively. The MACC global component is an extension of the ECMWF Integrated Forecasting System. It models the atmospheric composition and assimilates mostly satellite-based related observations. The regional component of MACC consists of an ensemble of regional air quality models that produce forecasts for the European domain. MACC is the follow-up to the GEMS and PROMOTE projects, see http://www.gmes-atmosphere.eu. The atmospheric analyses and forecasts require fire smoke emission fluxes from the surface to the atmosphere as a boundary condition. An investigation of existing smoke flux products has shown that none meets all the requirements of GEMS/MACC, but that several are complementary and thus a merged product can, and needs to, be developed (Kaiser et al. 2006). This development is now being conducted within MACC.

The EUMETSAT Land Surface Analysis Satellite Application Facility (LSA SAF) is has recently started the operational production of a Fire Radiative Power (FRP) product (Roberts & Wooster 2008; http://landsaf.meteo.pt). The product is based on 15-minute temporal resolution observations made by the SEVIRI instrument aboard the geostationary satellites Meteosat-8 and -9. FRP products have been shown to be generally well suited for fire emission flux estimation because FRP is approximately proportional to the biomass combustion rate and thus the smoke emission rate (Ichoku & Kaufman 2005, Wooster et al. 2005, Roberts et al. 2005). The rapid temporal sampling of SEVIRI with four observations per hour offers the additional advantage (over polar orbiting systems) of resolving the strong diurnal variability of the fires and making use of any short gaps in mostly persistent cloud cover to provide views of otherwise obscured fire events.

GREECE IN AUGUST 2007

The catastrophic Greek fires in August 2007 were selected as a test case to investigate the feasibility of using the SEVIRI FRP product to calculate the fire smoke emission input for the GEMS/MACC atmospheric monitoring system. The total FRP record observed over Greece during the huge fire event in August 2007 is shown in Figure 1 and highlights the high temporal resolution of the SEVIRI data. It exhibits strong diurnal and day-to-day variations with the maximum fire intensity occurring on the afternoon of 25 August 2007, around 15:45 local time. The fires burnt continuously through the night, and this is typical for large fire events in middle and high latitudes, whereas the majority of tropical fires SEVIRI observes are mostly extinguished during nighttimes (or burn so weakly as to be undetectable). The largest fires were located on the Greek island of Peloponnese, but there were some smaller events on the mainland also.

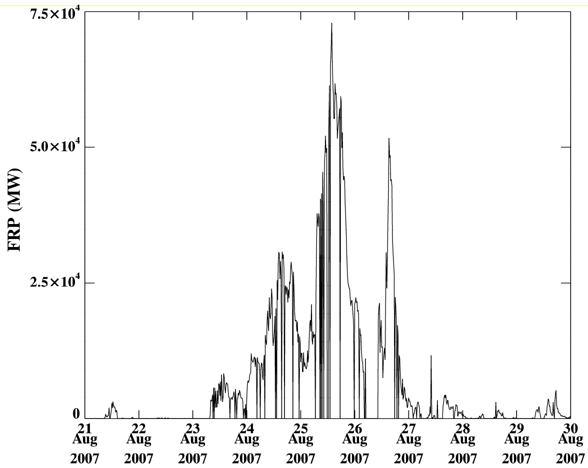
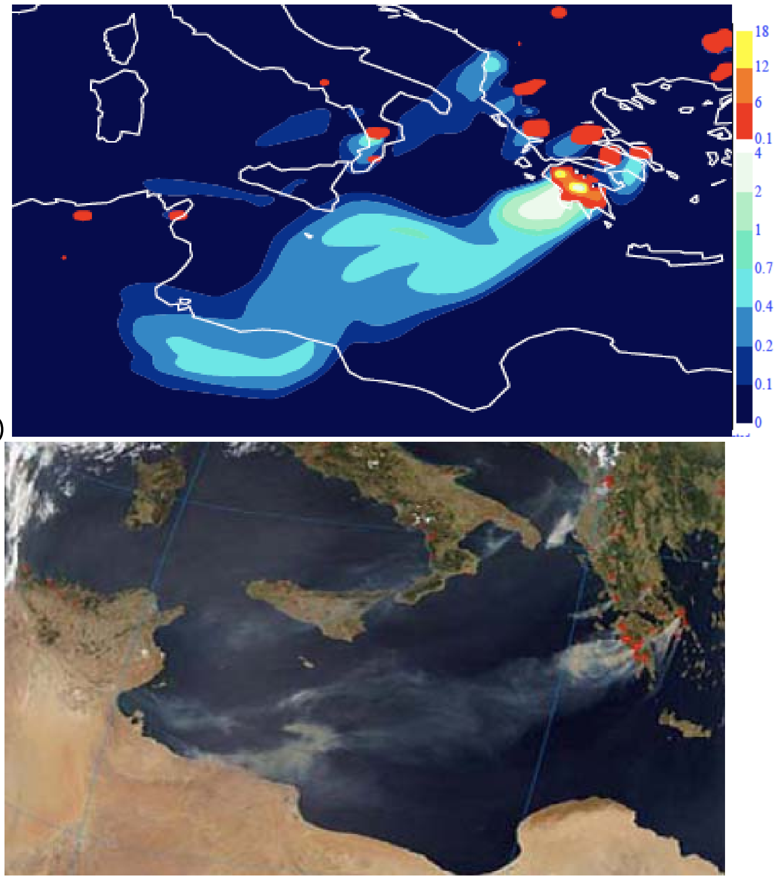


***Figure 1*: Total Fire Radiative Power (FRP) observed over Greece by SEVIRI. Date ticks at 00 UTC, 2 a.m. local time. The data is derived from a test version of the operational Land SAF product. Short data gaps are represented by vanishing values.**

Smoke aerosols are represented as black carbon and organic matter in the global GEMS model (Morcrette et al. 2009). The emission coefficient relating FRP (W m^{-2}) to the total aerosol emission rate (kg s^{-1} m^{-2}) has been taken from a previous study of FRP and aerosol optical depth (AOD) observed by MODIS (Ichoku & Kaufman 2005). The partitioning of the aerosol species is prescribed according to the Global Fire Emissions Database (GFED; van der Werf et al. 2006). The smoke aerosol fluxes for the entire fire episode have been calculated from the SEVIRI data with a spatial resolution of 25 km (T799) and a temporal resolution of 1 hour.

For this study we have operated the atmospheric model with the resolution of 25 km (T799) because it is typical of present-day regional air quality models. The atmospheric simulation was set up in a 'cycling' mode, in which the meteorological fields are calculated in a series of consecutive 12-hour forecasts that are initialised from the operational analysis. In contrast the aerosol fields are solely governed by the model parameterization of transport, chemistry, sinks and the surface flux sources. The SEVIRI-derived fluxes were injected into the lowest model level.

Figure 2a shows the observed FRP at 25-km spatial resolution and the AOD of the modelled smoke aerosols at 12 UTC on 25 August. For comparison, Figure 2b shows a visible composite of the concurrent MODIS observations that is overlaid with red markers where MODIS detected "hot spot" fire pixels using the MODIS MOD14 algorithm. The imagery indicates that the SEVIRI FRP product and the MODIS hotspot product agree well on the locations of the fires.



(a)

(b)

Figure 2**: (a) FRP observed by SEVIRI (reddish, W m^{-2}) and modelled smoke column optical depth (blueish) compared to (b) observed hot spots (red) and true colour image by MODIS aboard Aqua at 1205 UTC on 25 August 2007 (http://rapidfire.sci.gsfc.nasa.gov).**

Figure 2b shows that the smoke from the Greek fires was blown in a south-westerly direction over the Mediterranean Sea to Northern Africa. The modelled smoke plumes in Figure 2a reproduce the main observed features rather well. In particular, the observations show that the plume is structured in a series of ‘pulses’ originating from the daily fire intensity maxima. Clearly visible just off the Peloponnesian coast is the pulse emitted by the fire intensity peak earlier in the day. The pulse emitted the day before just reaches Libya; the landfall is well reproduced while the timing is slightly shifted. The widening of the plume over the central Mediterranean Sea is also well represented.

The clear separation of the plume into pulses indicates that the accuracy of the simulation depends on the high temporal resolution and quantitative nature of the SEVIRI FRP product that is used to specify the combustion rate (and thus smoke emission rate) and its variation over the diurnal cycle. Also the good representation of the plume transport is a testament to the accuracy of tropospheric winds produced by ECMWF’s Integrated Forecast System. The remaining discrepancies are primarily attributed to shortcomings of our approach in the very active research fields dealing with plume rise and emission factors that scale FRP to the individual species fluxes, depending on fuel type and meteorological conditions.

MERGED FRP FIELDS IN REAL TIME

Based on the success of the case study concerning the Greek fires, a global fire assimilation system is under development in the MACC project to merge FRP observations from SEVIRI and other satellite-based instruments to achieve global coverage. It provides real-time estimates of pollutant fluxes from fires that are intended for use in all global atmospheric composition and regional air quality systems in MACC.

Outside the SEVIRI disk, the MODIS instruments aboard the polar orbiting Aqua and Terra satellites currently provide global coverage, albeit with a relatively low observation frequency (Justice et al. 2002). As a first development step, the FRP products of SEVIRI and MODIS are acquired and pre-processed for use in the fire assimilation system. We obtain the SEVIRI FRP pixel product with a time lag of 30 minutes via EUMETCast and the MODIS fire products with a time lag of 3–4 hours by ftp from NOAA. The Fire Radiative Power (FRP) products from each are merged in a weighted averaging procedure that compensates for missing observations due to partial cloud cover and takes the representativity errors of the observations into account (Kaiser et al. 2009 AIP). The observations are currently merged to generate daily observed averaged FRP maps with 125 km (T159) resolution that are published on the MACC web site, see Figure 3 for an example. The daily average FRP maps are used to calculate the average emission fluxes of various species, e.g. CO_2, CO, black carbon, organic matter.

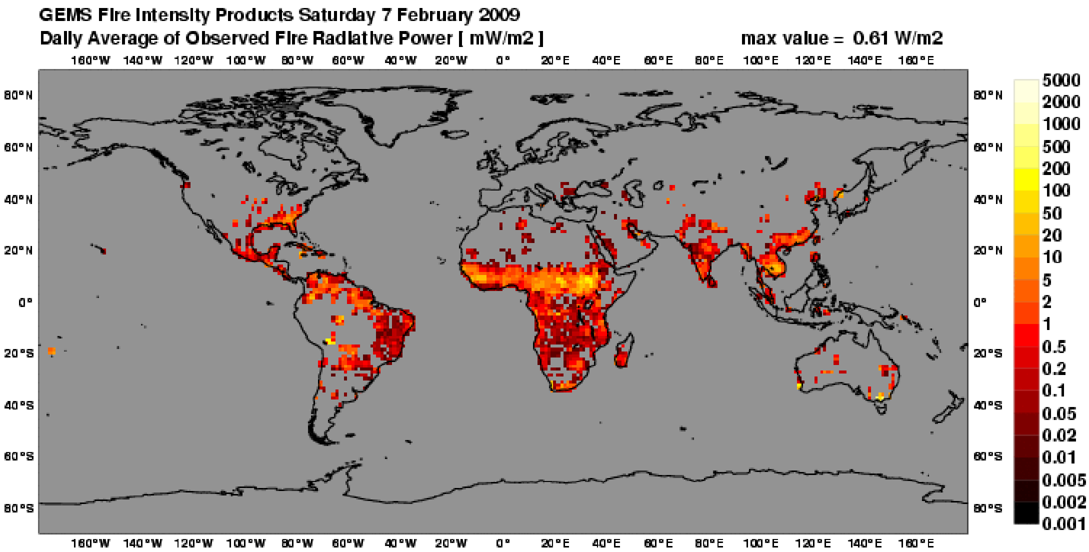


***Figure 3*: Daily averaged fire intensity (mW m^{-2}) observed by the two MODIS instruments and SEVIRI on 7 February 2009. (http://www.gmes-atmosphere.eu/fire)**

OUTLOOK

The Global Fire Assimilation System is currently restricted to a resolution of 24 hours because, outside the disk observed by the geostationary SEVIRI instrument, only the polar orbiting MODIS observations are available. However, the geostationary sensors covering the Americas, Asia and Australia also observe fire and their observation frequencies are sufficient to resolve the diurnal variability of fires. Unfortunately, FRP products such as are available from SEVIRI are not yet generated in real time from these other geostationary observations. This is planned to be the subject of future work, and assuming such FRP products do become available then the MACC system will be updated to provide global hourly fire emission estimates of the various smoke constituents, which would allow a more accurate simulation of global smoke plumes, similar to the one presented for Greece above. Additionally, a statistical model of the diurnal and day-to-day variability of detected fires will be developed to fill any remaining gaps in the observational coverage, e.g. due to cloud cover, and to provide forecasts of the temporal evolution of detected fires for several days ahead. Also, use of the fire assimilation system at a spatial resolution of 10 km (0.1 deg) is planned to meet the requirements of regional air quality modelling.

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