Rapid burned area assessment in Indonesia using Sentinel-1 data

F. Siegert[a,b], S. Englhart[a]

Vast desastrous forest and peat fires are currently raging across Sumatra and Borneo putting Indonesia on track to be one of the world's largest carbon emitters this year (Global Emission Fire Database[1]). Especially peat fires are smoldering underground and produce thick haze drifting to neighboring countries Malaysia, Singapore and Thailand (Figure 1). The thick haze causes not only economic, health but also pollution issues by raising the Pollutant Standards Index (PSI) to record levels exceeding the value 300 which is rated as "hazardous" (Singapore's National Environment Agency[2]). In Central Kalimantan, an alarming PSI value of 1,801 was recorded on 1st October 2015[3]. It is assumed that the fires are mostly started deliberately and illegally for large scale plantation development for pulp wood and oil palm. The drainage of peatland areas increases the susceptibility to fires which is further enhanced by strong El Niño episodes causing a prolonged draught period. This year, the region is currently experiencing a very strong El Niño climate phenomenon similar or even stronger compared with the severest one in 1997/1998 which is also confirmed by NASA's side-by-side animation of the two events (Van der Werf[4,5], NOAA Climate Prediction Center[6], NASA[7]). The emissions from Indonesia during the record forest and peat fires of 1997 are estimated at between 0.81 and 2.57 Gt (Gigatonnes) of carbon which is equivalent to 13-40% of the entire world's annual fossil fuel emissions (Page et al. 2002[8]). More recent estimates from the Global Emission Fire Database indicate that Indonesia's fire emissions from 1997 released app. 4.27 Gt of carbon dioxide which is equivalent to 1.63 Gt of carbon. Mid of October, Indonesia's fire emissions from 2015 have already exceeded 0.33 Gt of carbon (GFED[1]).

These estimates contain a substantial amount of uncertainty related to the complex fire situation and the fact that they are based on fire detections derived from MODIS. NASA's two MODIS satellites Aqua and Terra make active fire data available every day by applying a fire and thermal anomalies algorithm (Giglio et al. 2003[9]). Thermal anomalies or active fires represent the center of a 1km pixel containing one or more fires within the pixel. This is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. However, thick haze and clouds prevent sometimes the detection of active fires which in turn result in substantial underestimation of fire events (see Figure 1). Active fires were only detected in areas where the blanket of haze was thin enough.

In contrast, imagery of the European SAR satellite Sentinel-1 is capable to penetrate the thick blanket of haze and deliver data on burned areas. The lower panel in Figure 1 shows the swath of a Sentinel-1 acquisition at the same day as the MODIS image was taken. In this color composite green-grey colors indicate forest cover, purple indicates bare soils (land cleared for plantations or very recently planted plantations). Black and dark grey indicate water bodies.

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[1] http://www.globalfiredata.org/updates.html
[2] http://www.nea.gov.sg/anti-pollution-radiation-protection/air-pollution-control/psi/historical-psi-readings/year/2015/month/9/day/25
[3] http://www.straitstimes.com/asia/se-asia/thick-haze-grounds-firefighting-copters
[4] http://news.mongabay.com/2015/10/carbon-emissions-from-indonesias-peat-fires-exceed-emissions-from-entire-u-s-economy/
[5] https://medium.com/@climatesociety/indonesia-on-track-to-have-the-worst-fire-season-since-1997-49b55e19be5f
[6] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf
[7] http://sealevel.jpl.nasa.gov/elnino2015/index.html
[8] http://www.nature.com/nature/journal/v420/n6911/full/nature01131.html
[9] http://www.sciencedirect.com/science/article/pii/S0034425703001846

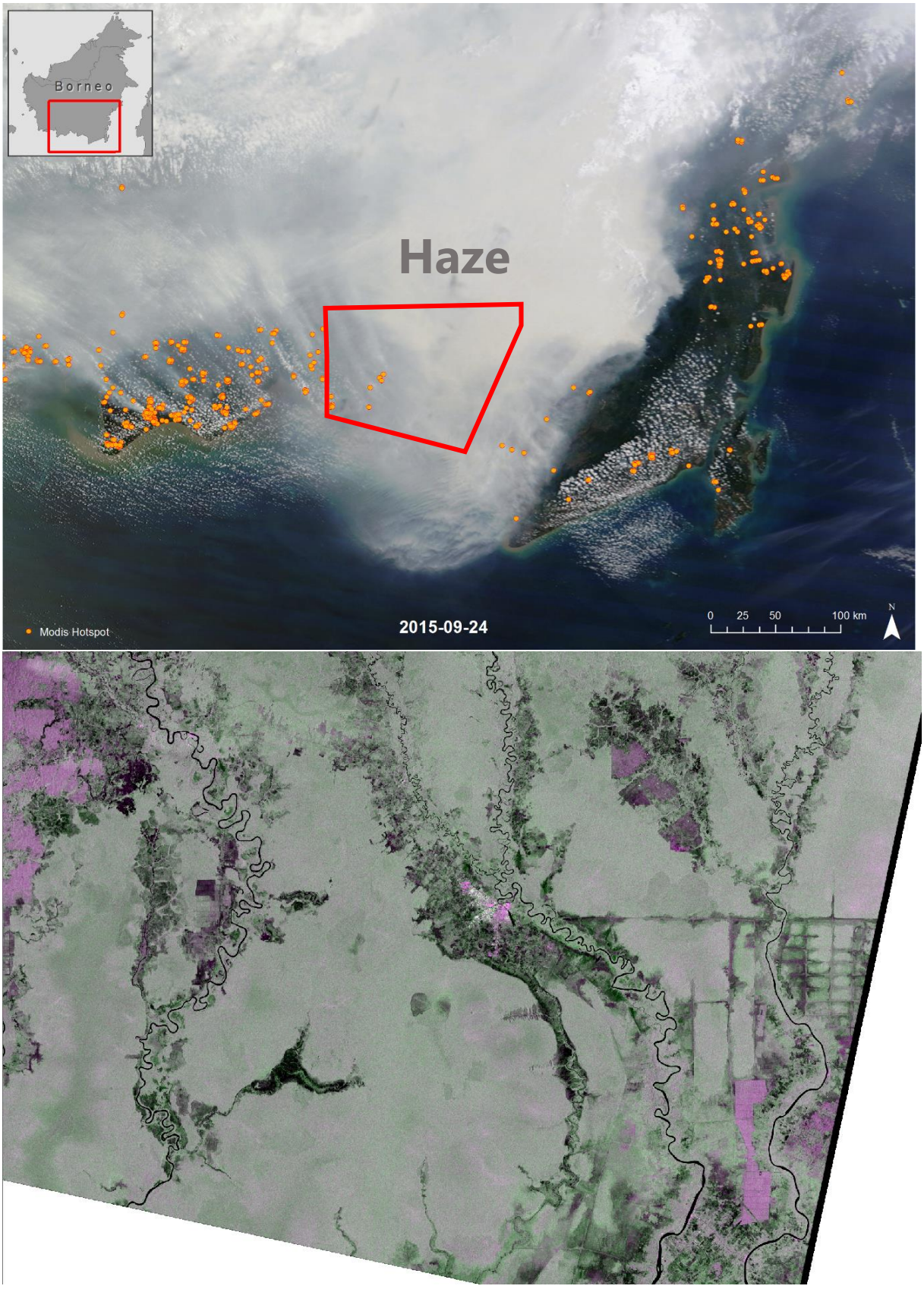

Figure 1: Comparison of MODIS imagery with MODIS hotspots (upper panel) and a sentinel-1 color composite (VV-VH-VV). Acquisition date: 30. 9. 2015.

Figure 2 shows a color composite of a pre-fire Sentinal-1 image (acquisition date: 13.8.2015), a post-fire Sentinal-1 image (acquisition date: 30.9.2015) and the result of a Principal Component Analysis of the pre and post-fire image. Blue colors indicate forests, dark brown indicate water bodies and very low growing vegetation.

Through the analysis of a pre and post-fire image it is possible to detect burned areas. In Figure 2 bright amber colors indicate areas, which have been impacted by fire. Severe burns, which destroy the vegetation cover completely, result in a dramatic change towards a very low backscatter from reduced volume scattering and bare and dry soil and a decreasing dielectric constant.

The quantitative assessment of burned areas and the comparison with a pre-fire high resolution vegetation map such as the Global Forest Change 2000–2014 by Hansen et al., 2013[10] will allow improved estimates of Co2 emissions caused by these fires. In conjunction with a detailed map of peatland (which we have) we will be able to assess the area of peatland which has been burned and the huge emissions caused by peat fires.

The method for a rapid assessment of burned areas has been successfully applied in the case of the vegetation and forest fires in Indonesia during the El Nino episode of 1997/98. Results of the work have been published in two articles in the most renowned science journal *Nature*.

1. Page S. E., **Siegert F**., Rieley J. O., Boehm H-D.V.and A. Jaya (2002). Carbon released during peatland fires in Central Kalimantan, Indonesia in 1997. *Nature*, 420, 61-65
2. **Siegert, F.,** G. Rücker, A. Hinrichs & A. Hoffmann (2001). Increased fire impacts in logged over forests during El Niño driven fires. *Nature,* 414, 437-440
3. **Siegert, F**. & A. Hoffmann (2000). The 1998 Forest Fires in East-Kalimantan (Indonesia): A Quantitative Evaluation Using High Resolution, Multitemporal ERS-2 SAR Images and NOAA-AVHRR Hotspot Data. *Remote Sensing of Environment*, Vol. 72, 64-77.

[10] https://www.sciencemag.org/content/342/6160/850

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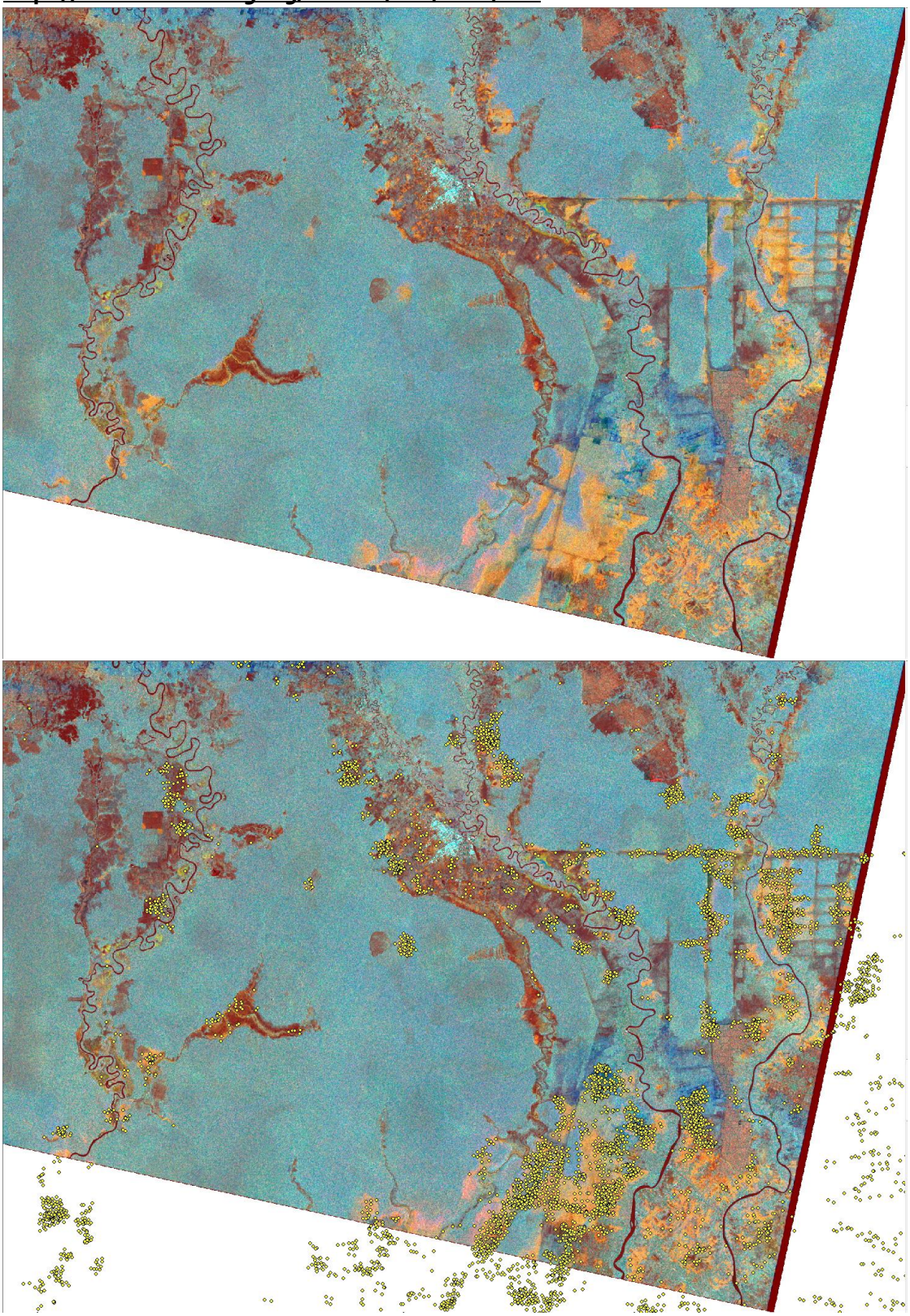

Figure 2: Color composite of a pre-fire Sentinal-1 image (acquisition date: 13.8.2015), a post-fire Sentinal-1 image (acquisition date: 30.9.2015) and the result of a Principal Component Analysis of the pre and post-fire image. Bright amber indicates burned areas. Blue colors indicate forests while dark brown indicate water bodies and very low growing vegetation..

About the authors

[a] **RSS - Remote Sensing Solutions GmbH** is one of the leading value-adding companies for earth observation in Germany. RSS is specialized in satellite image processing and interpretation, photogrammetry and geoinformation system (GIS) in the fields of environmental monitoring, nature conservation, forestry, REDD+ and carbon accounting and natural hazards. RSS is currently involved in various forestry and climate change mitigation projects in Eastern Europe, SE Asia, the Brazilian Amazon and Africa with special focus on REDD+, MRV, REL, and capacity building. Customers are national and international authorities, the GIZ (German international cooperation), the German space Agency (DLR), the European space agency (ESA), NGO's like WWF and FFI and private companies. In this study RSS is responsible for data analysis.

For further information visit www.rssgmbh.de

[b] **GeoBio Center of Ludwig-Maximilians-University** (LMU) is a Munich-/Bavaria-based working group organisation of researchers, reflecting the fact that the understanding of the interactive System Earth demands a transdisciplinary approach. Shared focus of the research and educational activities is the analysis and understanding of mutual interactions of the geosphere and the biosphere.