

solas event report

Report 22 | February 2022

Workshop on “Remote Sensing for Ocean-Atmosphere Interactions Studies and Applications”

1-3 December 2021
Online

The Remote Sensing for Ocean-Atmosphere Interactions Studies and Applications Workshop, co-organised by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Copernicus programme and SOLAS was held online on 1-3 December 2021. The workshop was facilitated by EUMETSAT.

The workshop was intended to support and encourage collaboration to explore and promote the use of readily available remote sensing data sets that can support both research into ocean-atmosphere interactions, and the use of the satellite-derived data in operational environments. The workshop was pitched to be of value to scientists and educators at all levels of seniority in a wide range of disciplines: climate studies and monitoring, remote sensing, atmospheric physics and chemistry, physical oceanography, ocean biology; it also provided the mechanism for dialogs with representatives of services and data provider agencies. This connection between researchers, educators and data providers was an important aspect of this workshop.

The primary objectives were to a) report and inform about ongoing research in the thematic area using satellite-based data; b) discuss un-



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Figure 1: Invited speakers at the Remote Sensing for Ocean-Atmosphere Interactions Studies and Applications Workshop. From upper left to lower right: Aida Alvera-Azcaráte, Samantha Burgess, Carol Anne Clayson, Nicolás Cosentino, Pavla Dags-son Waldhauserova, Minhan Dai, Corinne Derval, Hayley Evers-King, Federico Fierli, Chelle Gentemann, Claire Macintosh, Salvatore Marullo, Luciani Ponzi Pezzi, Marie-Helene Rio, Paolo Ruti, Jamie Shutler, Christopher Stewart, Christine Träger-Chatterjee, Julia Wagemann, Hongbin Yu.

explored potential of satellite-derived data in the field and identify gaps in terms of monitoring capability; c) inform on developments, tools, ways of access, available and upcoming training material and training opportunities by satellite product providers; and d) identify needs and associated material and collaborations for improved data access, usage, training and capacity building.

The workshop included short, invited overview presentations, supplemented by a poster session and round-table discussions with questions and answers. The presentations included tutorials on the characteristics of selected data sets available at European data centres, how the data sets are derived, and how to access them. Overviews of online software packages for data processing, analysis and display were also presented. The first two days of the workshop were timetabled to extend over three hours, with the third day being one hour shorter. There were 117 participants on Day 1, 108 on Day 2, and 63 on Day 3. Recordings of all sessions are available at <https://training.eumetsat.int/course/view.php?id=421>, where the detailed agenda and more detailed information about the workshop can be found. Four-

teen posters are available at <https://padlet.com/TrainingEUMETSAT/imt89nkvonxi02vs>.

Following introductory presentations at the start of the workshop by Paolo Ruti (Chief Scientist of EUMETSAT), Minhan Dai (Co-Chair of the SOLAS Scientific Steering Committee), and Christine Träger-Chatterjee (EUMETSAT), the invited speakers gave their presentations:

- Carol Anne Clayson, Woods Hole Oceanographic Institution, Falmouth, USA, “Satellite-derived climate data records of air-sea fluxes: progress and issues”
- Chelle Gentemann, Farallon Institute, Petaluma, USA, “Butterfly - air-sea heat and moisture fluxes from space”
- Hongbin Yu, National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC), USA, “Satellite perspectives of trans-continental transport and deposition of mineral dust”
- Nicolás Cosentino, Instituto de Geografía, Pontificia Universidad Católica de Chile. “Satellite tools to explore the relationship between dust and primary producers’ biomass”

- Pavla Dagsson Waldhauserova, The Agricultural University of Iceland, “High Latitude Dust observation with focus on Iceland and Antarctica”
- Jamie Shutler, University of Exeter, UK, “Satellites are now critical for observing the air-sea interface, CO₂ fluxes and the CO₂ sink: recent advances and new opportunities”
- Luciani Ponzi Pezzi, Laboratory of Ocean and Atmosphere Studies, National Institute for Space Research, Brazil, “Mesoscale oceanic eddy-induced modifications to air–sea heat and CO₂ fluxes”
- Salvatore Marullo, Climate and Modelling Laboratory, ENEA Centro Ricerche Frascati, Italy, “Air-Sea Interaction in the Central Mediterranean Sea: Assessment of Reanalysis and Satellite Observations”

In terms of agency presentations, Federico Fierli of EUMETSAT presented “Overview on the EUMETSAT product portfolio for Marine – Atmosphere Exchanges” and Corinne Derval of the Copernicus Marine Environment Monitoring Service (CMEMS) presented “Overview on the CMEMS product portfolio”. On the third day, Marie-Helene Rio of European Space Agency (ESA) gave the presentation “Satellite observation to monitor Air-Sea interaction – European Space Agency” and Samantha Burgess of European Centre for Medium-Range Weather Forecasts (ECMWF) presented “The Copernicus Climate Change Service”.

Presentations on data discovery were given by Hayley Evers-King, and colleagues explained “EUMETSAT data access for ocean-atmosphere applications” and Corinne Derval of CMEMS explained the “Copernicus Marine MyOcean Viewer”.

The workshop provided a very useful opportunity to bring together researchers and students, operational practitioners, and educators and trainers specialising in remote sensing data sets with the focus on satellite data useful for studying and applying information on air-sea exchanges. Despite the workshop having been held online because of precautions against coronavirus disease 2019 (COVID-19), with the consequent loss of opportunities for face-to-face discussions and the benefits these bring, the online format permitted participation from many countries without the cost and time necessary to travel to the venue. The recorded presentations are an additional benefit which we hope many will exploit.

The workshop Organising Committee members were Peter Minnett, University of Miami, USA; Jessica Gier, SOLAS Project Office, Galway, Ireland; Li Li, SOLAS Project Office, Xiamen, China; Maria Kanakidou, University of Crete, Heraklion, Greece; Santiago Gassó, NASA/GSFC, Greenbelt, USA; Aida Alvera-Azcárate, University of Liege, Belgium; Jamie Shutler, University of Exeter, UK; Estelle Obligis, EUMETSAT, Darmstadt, Germany; Anna Rutgersson, Uppsala University, Sweden; Marie-Helene Rio, ESA- European Space Research Institute (ESRIN), Frascati, Italy; Hayley Evers-King, EUMETSAT, Darmstadt, Germany; Christine Träger-Chatterjee, EUMETSAT, Darmstadt, Germany; Federico Fierli, EUMETSAT, Darmstadt, Germany.

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Satellite tools to explore the relationship between dust and primary producers' biomass

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Net primary productivity (NPP) in some surface oceans is limited by iron (Fe), which may be supplied to these oceans by dust, promoting atmospheric carbon dioxide (CO₂) drawdown. This mechanism, coupled with export of organic matter to the deep ocean, constitutes a millennial-scale atmospheric CO₂ sink (Martin, 1990). 20-25% of the rise in atmospheric pCO₂ during the last deglaciation (~19-12 kyr BP) may be due to reduced dust-Fe flux to the oceans (Stoll, 2020). The identification of increases in NPP associated with present-day dust deposition would partially confirm this hypothesis.

Southern South America is the main present-day dust source to the Southern Ocean and Antarctica (Neff & Bertler, 2015). During the last deglaciation, the Atlantic sector of the Southern Ocean (> 34°S) is estimated to have contributed 41% of dust-induced global CO₂ drawdown through Fe fertilization (Lambert *et al.*, 2021).

A series of small deflation pans in southernmost Patagonia (~54° South) emit dust, mostly concentrated in austral summer (Cosentino *et al.*, 2020). Using surface visibility data and dust sampling, dust emission from these sources was constrained, while Hybrid Single-Particle Lagrangian

Integrated Trajectory (HYSPLOT) 4 was used to model particle trajectories. Surface chlorophyll-a concentration ([Chl-a]) data from the Ocean Colour - Climate Change Initiative (OC-CCI) v4.2 (Sathyendranath *et al.*, 2019) was used as a proxy of primary producers' biomass. Between December 2008 and February 2019, 73 dust events were identified in southernmost Patagonia. Of these, 32 took place during peaks in dust mass accumulation. These 32 events were simulated. Based on our methodology, no evidence is found for an influence of dust on [Chl-a] (Figure 2).

A major limitation of this methodology is that the modelled dust deposition fields for individual events cannot be validated with satellite data, given that Aerosol Optical Depth (AOD) cannot be resolved vertically to isolate near-surface concentrations (i.e., deposition). Vertically well-resolved AOD data may help overcome this limitation. Another limitation is related to the quantification of the contribution of phytoplankton functional types to total [Chl-a] (e.g., Brewin *et al.*, 2021). This would be useful for linking dust chemistry, ocean chemistry and nutrient requirements. While some sensors already have such capabilities, to the best of my knowledge no such data products are yet publicly available.

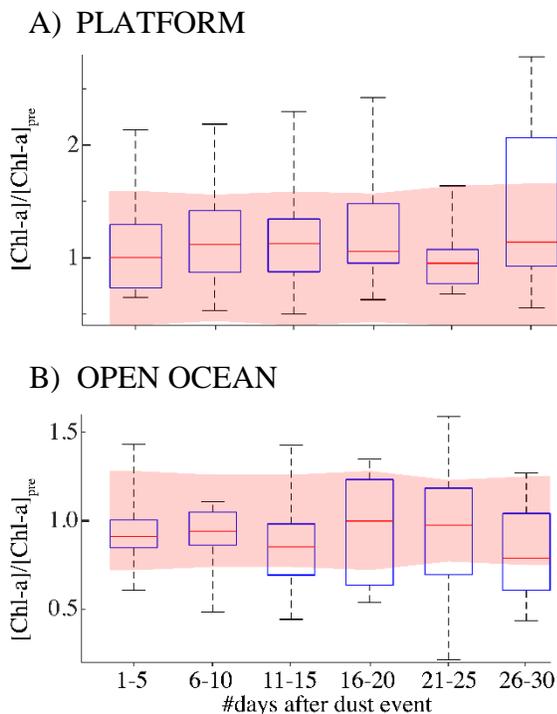


Figure 2: Response of surface ocean chlorophyll-a concentration ($[Chl-a]$) to deposition of dust emitted from southernmost Patagonia during 32 events between November 2012 and February 2019. Values are normalised to the mean $[Chl-a]$ previous to each dust event. On each box, the central red mark represents the median, the bottom and top blue edges indicate the 25th and 75th percentiles, respectively, and the whiskers extend to the most extreme data points. Data points separated more than 3σ from the mean were previously discarded. The pink area represents the mean 95% confidence interval around the pre-event means.

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High Latitude Dust observations with focus on Iceland and Antarctica

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High Latitude Dust (HLD) contributes 5% to the global dust budget and active HLD sources cover > 1,500,000 km². They are located in both the Northern Hemisphere (Iceland, Alaska, Canada, Greenland, Svalbard, North Eurasia) and Southern Hemisphere (Antarctica, Patagonia, New Zealand). Iceland is the largest Arctic as well as European desert with high dust event frequency (~135 dust days annually). Several studies have shown that Icelandic dust can travel > 3,500 km towards the High Arctic (> 80°N) and to Europe (evidence from Ireland and Balkan Peninsula – Serbia). An example of dust plume over the North Atlantic is depicted in Figure 3.

Icelandic dust has impacts on atmosphere, cryosphere, marine and terrestrial environments, as well as socio-economic sectors. Extreme dust storms in Iceland showed that air quality and visibility are impaired, PM₁₀ concentrations exceeding 50,000 µg m⁻³ (one-min mean) while aeolian transport of 11 tons m⁻¹ during a single storm measured. There is also an evidence that volcanic dust particles scavenge efficiently sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) to form sulphites/sulfates and nitrous acid. Long-term measurements from Antarctica resulted in impaired air quality due to local dust storms with PM₁₀ exceeding 120 µg m⁻³.

DREAMS-Iceland: Surface dust concentration (µg/m³) and 10m wind (m/s)
Forecast base time: 24OCT2019 00UTC Valid time: 24OCT2019 21UTC (+21)

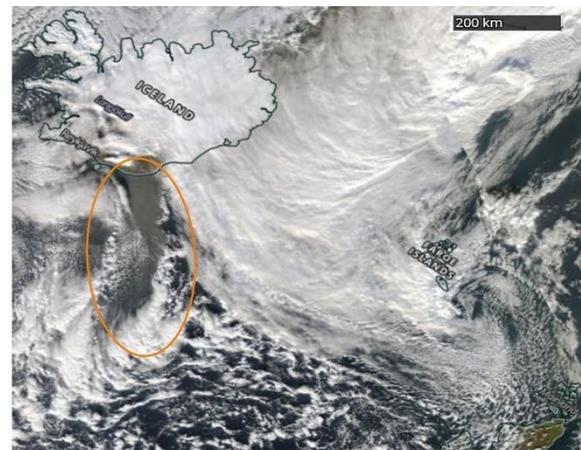
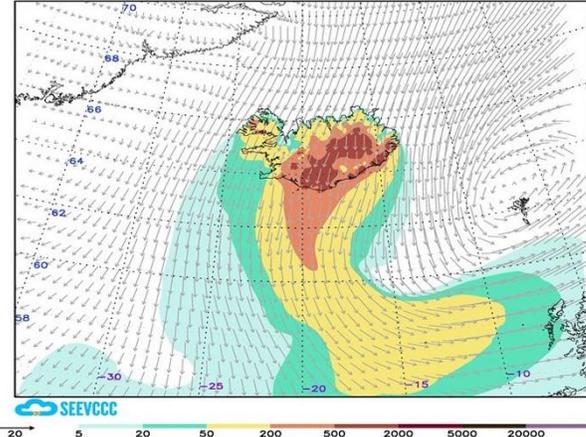


Figure 3: Icelandic dust plume over the North Atlantic on 24th October 2019. Above: Dust Regional Atmospheric Model (DREAM), Below: Moderate Resolution Imaging Spectroradiometer (MODIS) true colour satellite image.

HLD was recognised as an important climate driver in Polar Regions in the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate in 2019. Volcanic dust has similar impacts on snow/ice as Black Carbon in terms of albedo reduction and water retention capacity of snow. In atmosphere, Icelandic dust is an efficient ice-nucleating particle (INP) having impacts on the mid-to high-latitude mixed phase clouds, exhibiting an activity comparable to or exceeding common desert dust. HLD providing increased INP concentrations can lead to a reduction in supercooled water and a decrease in shortwave reflectivity of clouds to produce a positive climate feedback. In the marine environment, Icelandic dust with high total Fe content (10-13 wt%) and the initial Fe solubility of 0.08-0.6%, can impact primary productivity and nitrogen fixation in the North Atlantic Ocean, leading to additional carbon uptake.

First operational dust forecast for Icelandic dust is available at the World Meteorological Organization Sand/Dust Storm Warning Advisory and Assessment System (WMO SDS-WAS) at <https://sds-was.aemet.es/forecast-products/dust-forecasts/icelandic-dust-forecast> (Figure 3). Detailed information on HLD research and publications referred in this abstract can be found through the Icelandic Aerosol and Dust Association (IceDust) on the IceDust website: <https://icedust-blog.wordpress.com/>.

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