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SILAM update

Andreas Uppstu, Mikhail Sofiev, Rostislav Kouznetsov, Julia Palamarchuk, Risto Hänninen, Tero Partanen, Sebastian Heinonen

Outlook

- Climate impact of cleaner ship fuels
- Data-assimilation of volcanic eruptions

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Cleaner fuels for ships provide public health benefits with climate tradeoffs

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2. Rochester Institute of Technology, USA.
3. Energy and Environmental Research Associates, LLC, USA.
4. University of Delaware, Newark, DE 19711, USA.

MARPOL VI regulations: cleaner ship fuel

- MARPOL VI, an IMO regulation: by 2020 to reduce max sulphur content of ship fuel from 2.7% to 0.5%

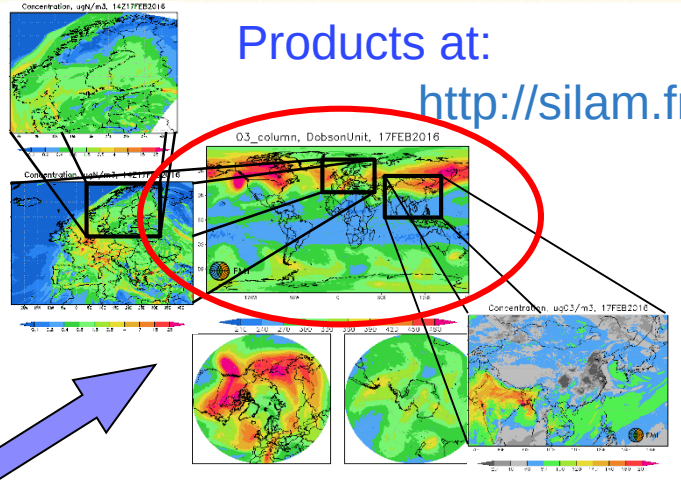
POLLUTANT (000 TONNES)	THIRD IMO GHG STUDY ESTIMATE FOR 2012	2015 ESTIMATE	2020 BAU WITHOUT IMO STANDARD	2020 ACTION WITH IMO STANDARD	2010 NON-SHIPPING EMISSONS HTAPV2/MEIC[19]
NO_X	19,000	20,100	21,300	21,300	75,310
SO_X	10,200	11,500	11,000	2,500	99,071
PM^1	1,400	1,540	1,500	770	17,338
CO_2	938,000	814,000	860,000	870,000	-
FUEL USED*	254,000 (t-d) 300,000 (b-u)[2]	263,000	277,000	274,000	-

Ship emissions (and fuel consumption) of STEAM for 2020 compared with Third IMO GHG Study (Smith et al., 2014) and all non-shipping emissions

SILAM AQ assessment and forecasting platform

IS4FIRES

Products at:
http://silam.fmi.fi



Physiography, land use forest mapping

Fire emission model

Desert dust emission model

Phenological model

BioVOC emission model

Sea salt emission model

SILAM CTM

EVALUATION and DATA ASSIMILATION 3D-, 4D-VAR

STEAM emission model

AIS ship data

Anthropogenic emission data

Global boundary cond. + own simulations

Meteorological data pool

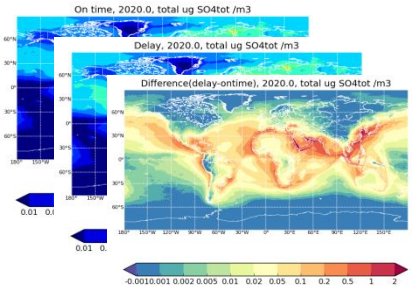
Global: ECMWF
Regional: HIRLAM, WRF
Meso-scale: HARMONIE, AROME,WRF
Climate scenarios: ECHAM, RCA, G/RCM

Online AQ monitoring

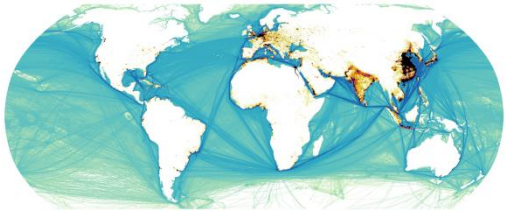
Aerobiological observations

Assessment setup

Concentrations



Health effects



IS4FIRES

Fires

Health models

Global, 10km × 3hrs
- BAU 2015 +1.5% yr^{-1}
- Action MARPOL
- NoShips

Fire emission model

Desert dust emission model

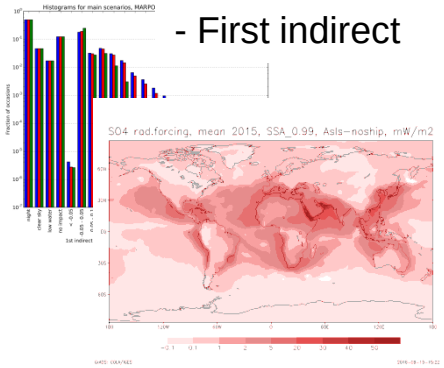
Sea salt emission model

SILAM CTM

LibRadTran

AOD, meteo

Aerosol effects
- Direct
- First indirect



STEAM emission model

AIS ship data

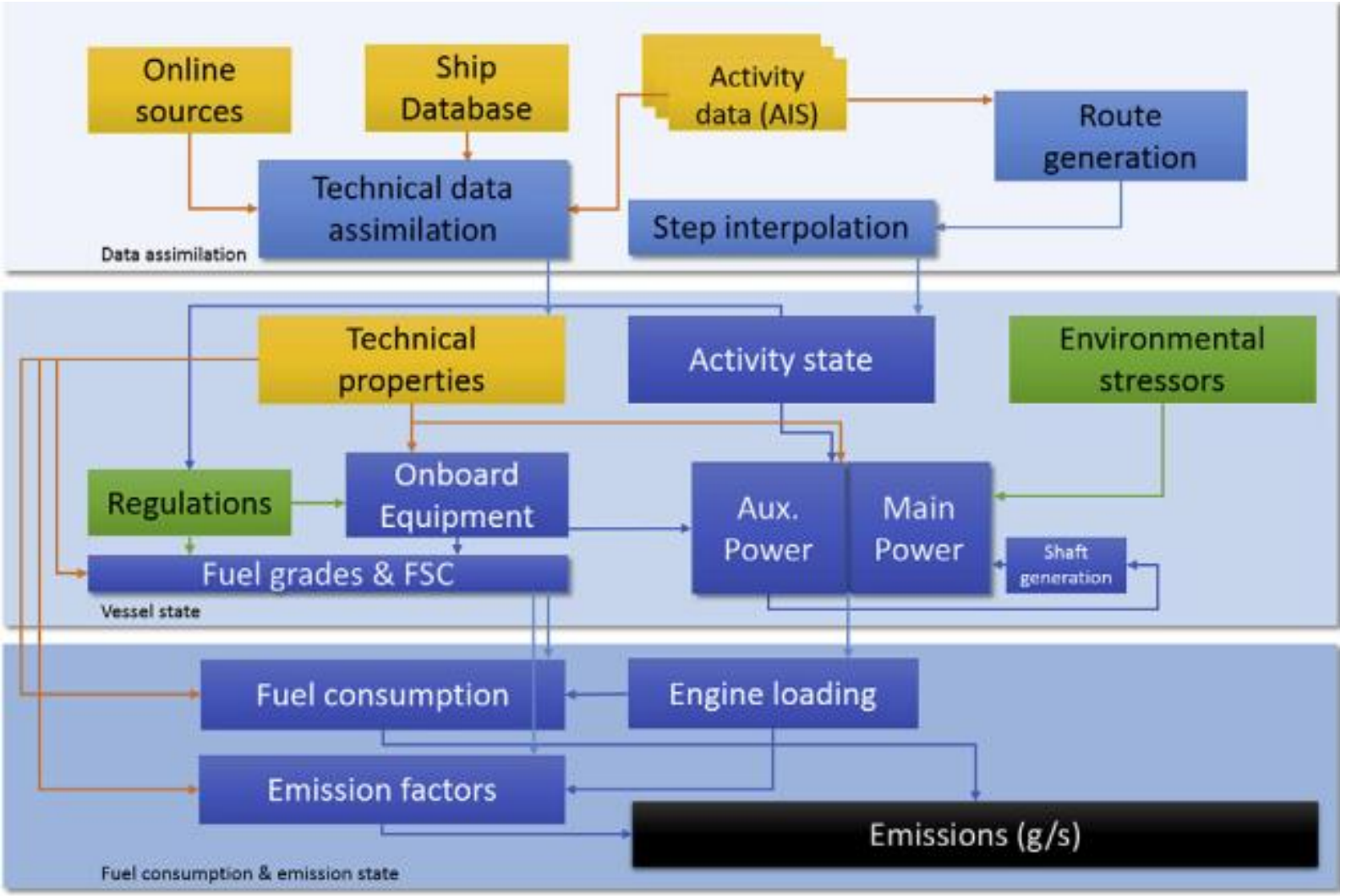
HTAPv2+MEIC
MEGANE

Anthropogenic emission

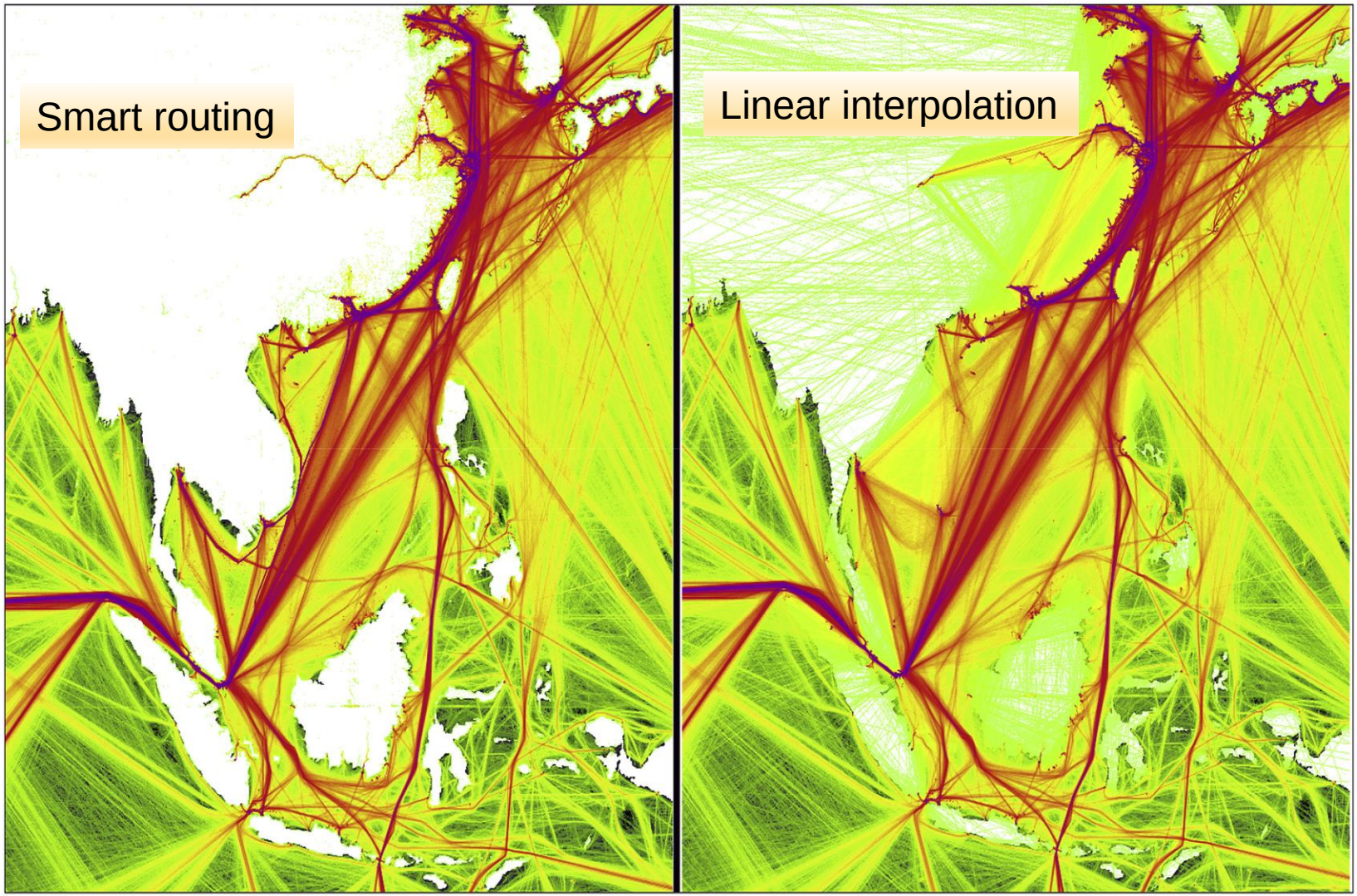
Global 2015
~15km × 3hrs

Meteorological data ECMWF

STEAM at a glance



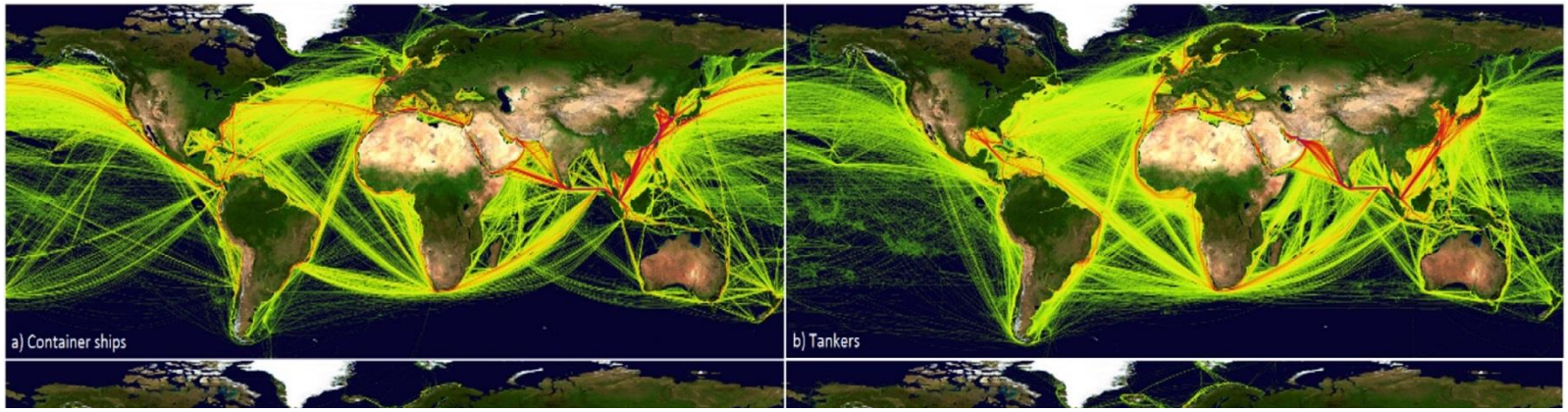
Less than perfect traffic data coverage



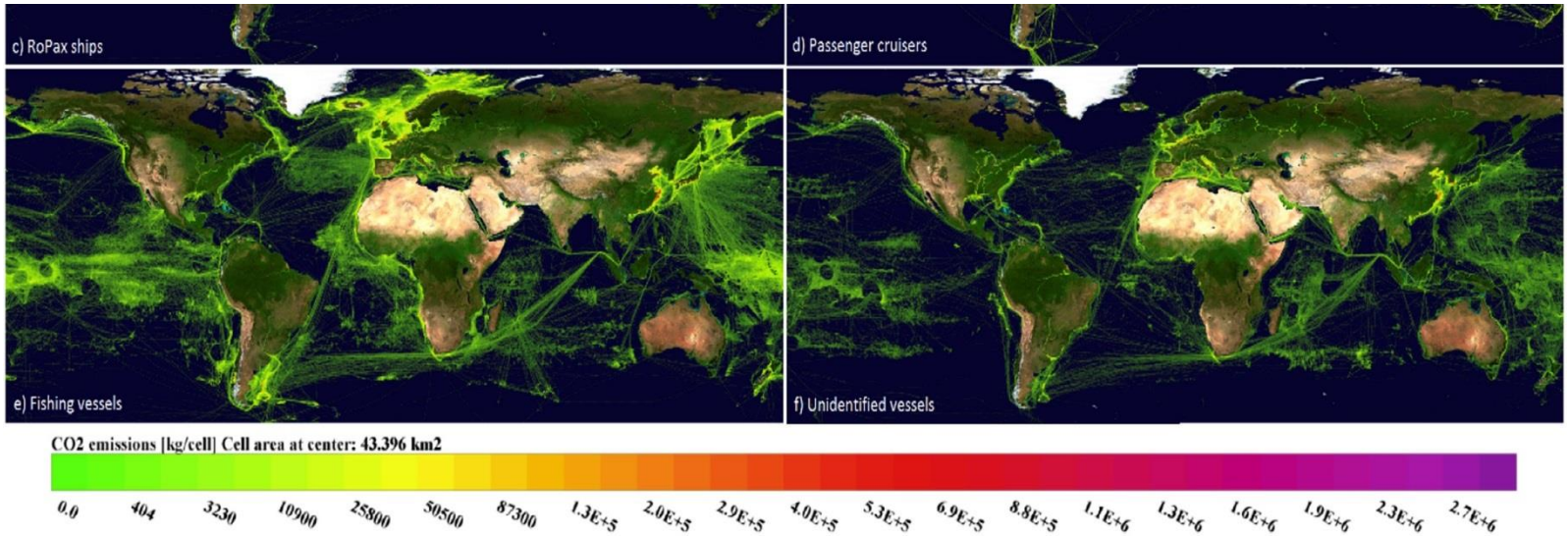
Johansson et al., ”Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution”, Atm. Env., 167 (2017) 403.

What do we get?

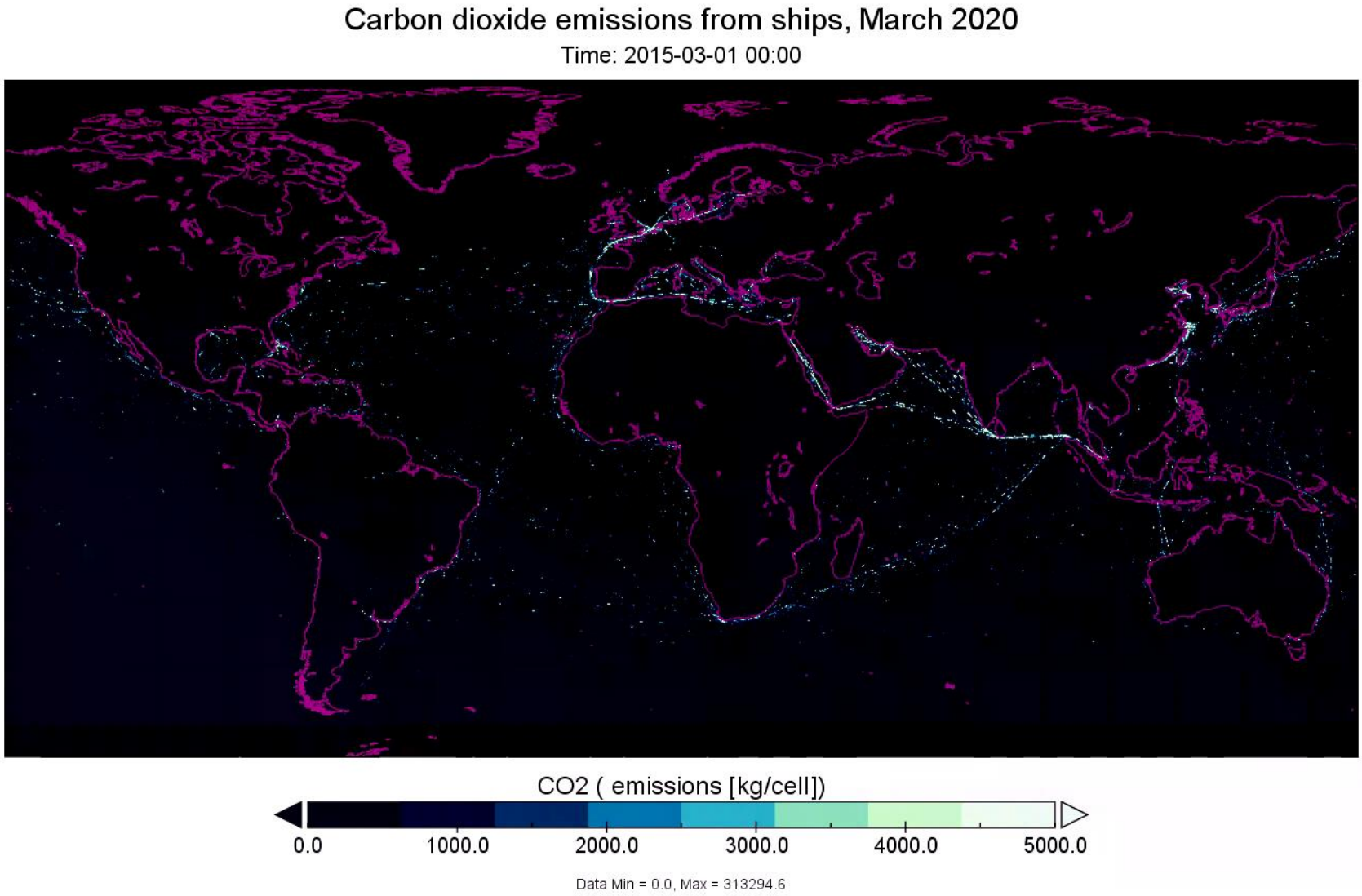
- Ability to model any ship, anywhere, anytime, based on real vessel traffic
  - Vessel specific inventories of emissions, fuel consumption
- Emission grid resolution defined by computer memory
  - 10 km global, updates 8 times/day, for 2015 (+ future annual growth)
- From local to global scale
  - 100m grids for local scale studies
- Fully dynamic system, spatial variation as a function of time
  - Or use temporal profiles
- CO_2, CO, NO_x, SO_x, EC, OC, Ash, SO_4, speciated VOCs...
- Ability to patch the incomplete geographical coverage of AIS
  - Use smart routing
- Advanced scenarios
  - Introduction of regional limitations, fuel type restrictions, changes in traffic network…



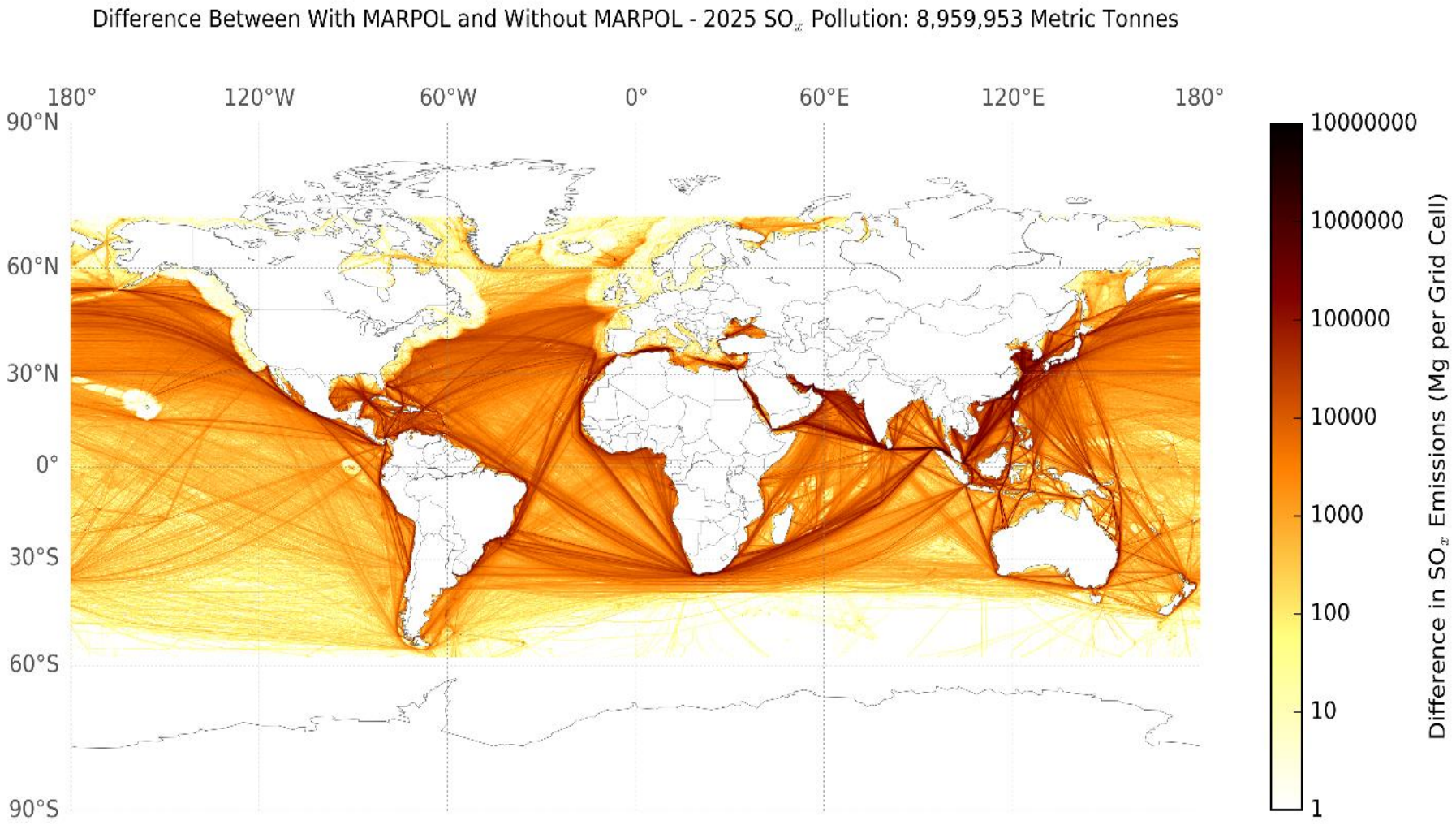
These images were generated with 8 billion position reports from over 300 000 individual vessels.
Emissions of each of these are fully separable from the whole + can be verified with measurements



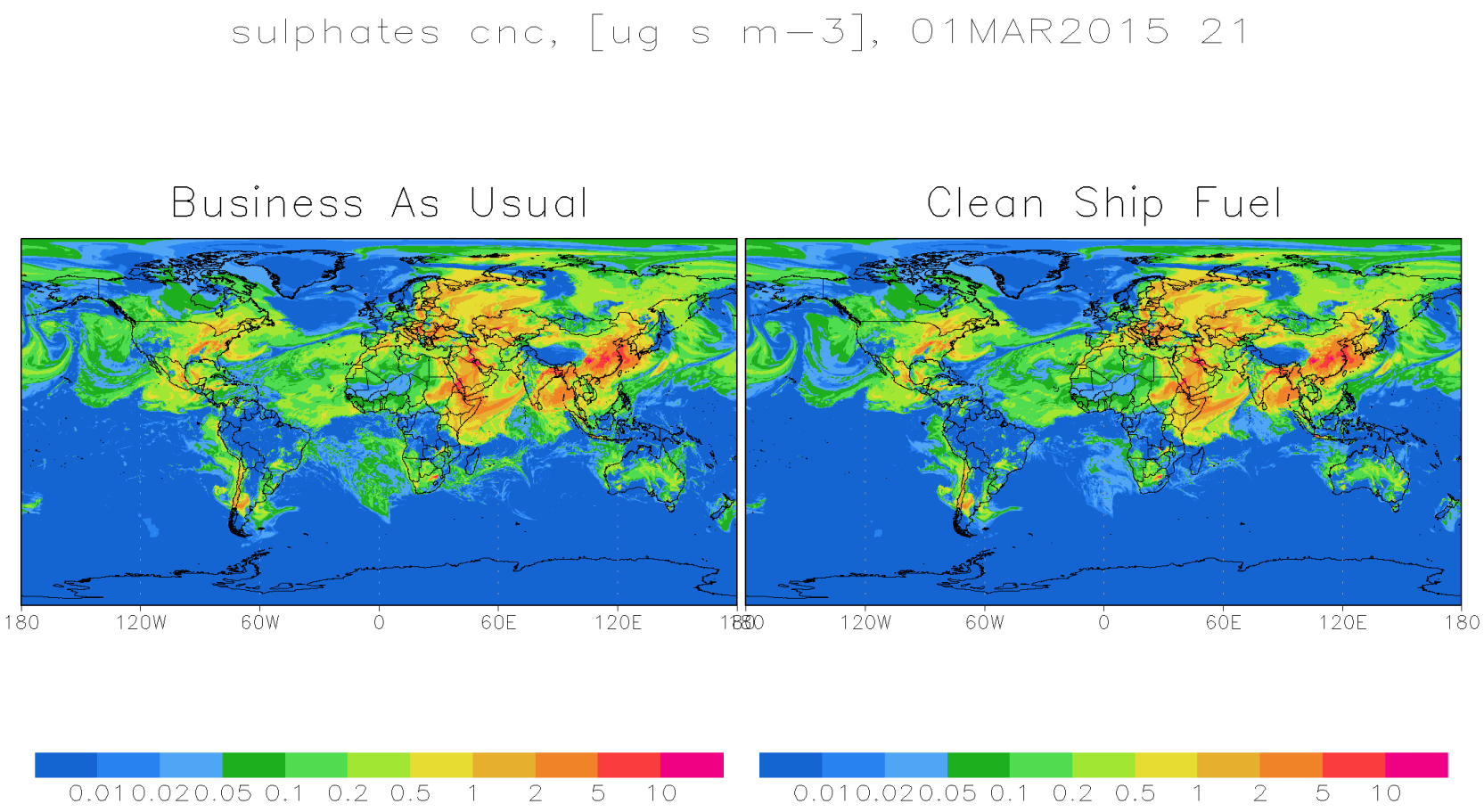
Ship emission: CO_2 example



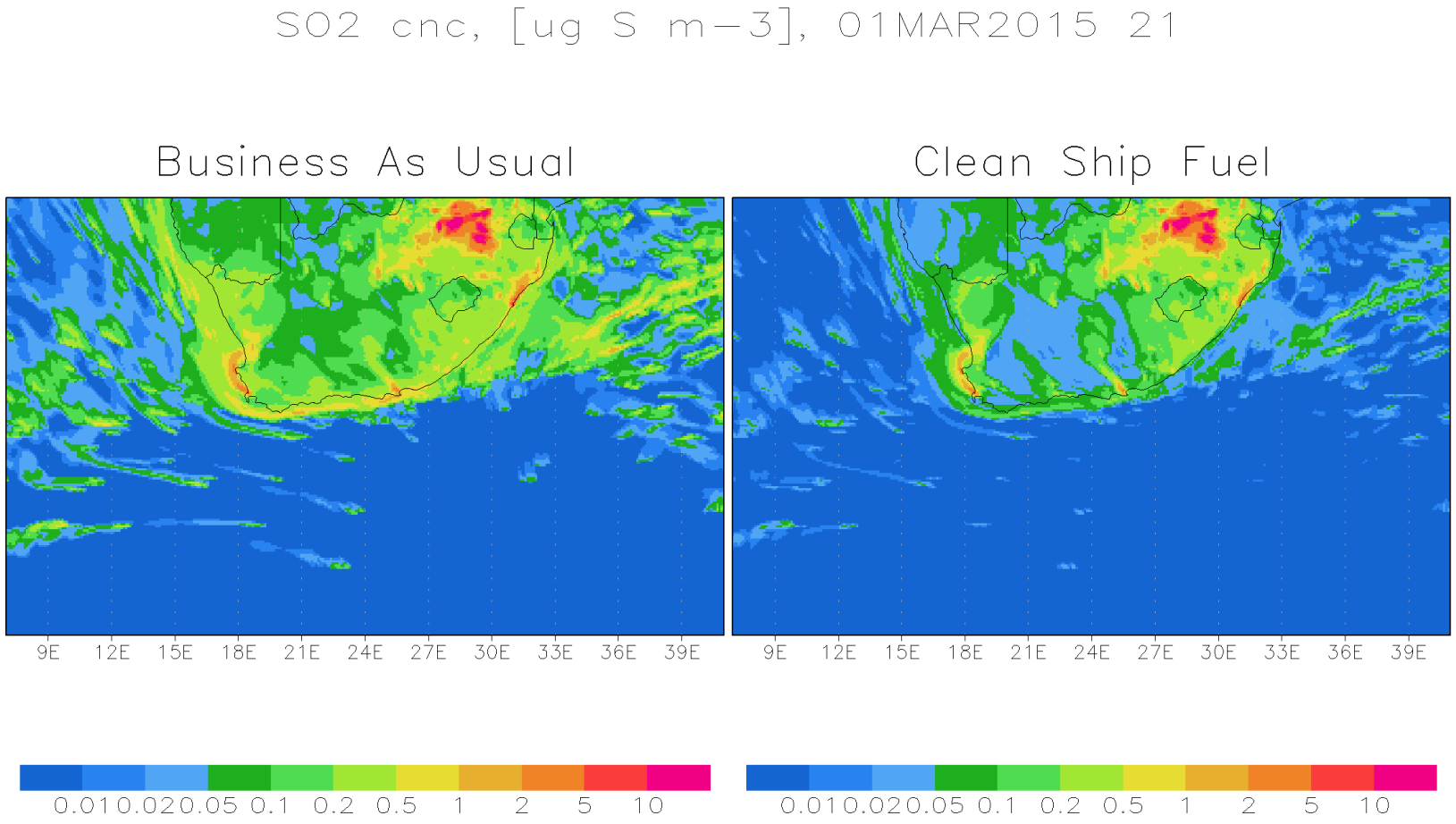
Eliminated sulphur emission, 2020, BAU-Action



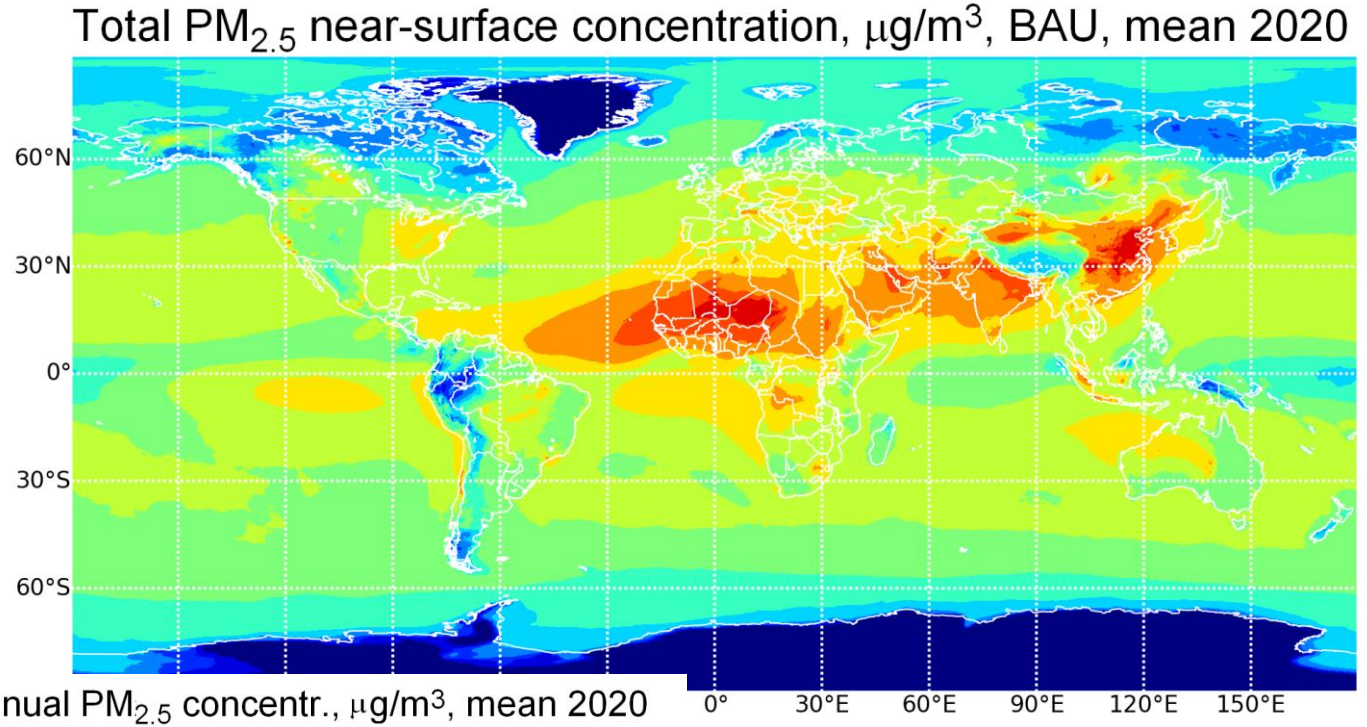
Result of emission reduction: world

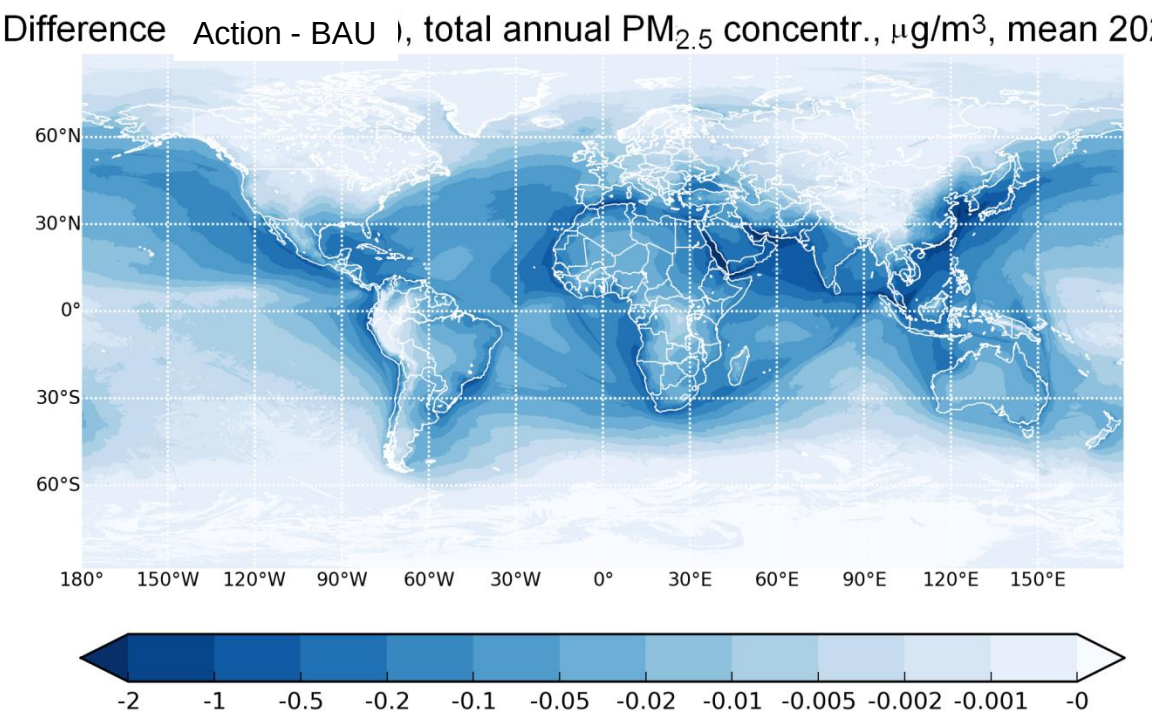


Result of emission reduction: South Africa



BAU 2020 vs Action

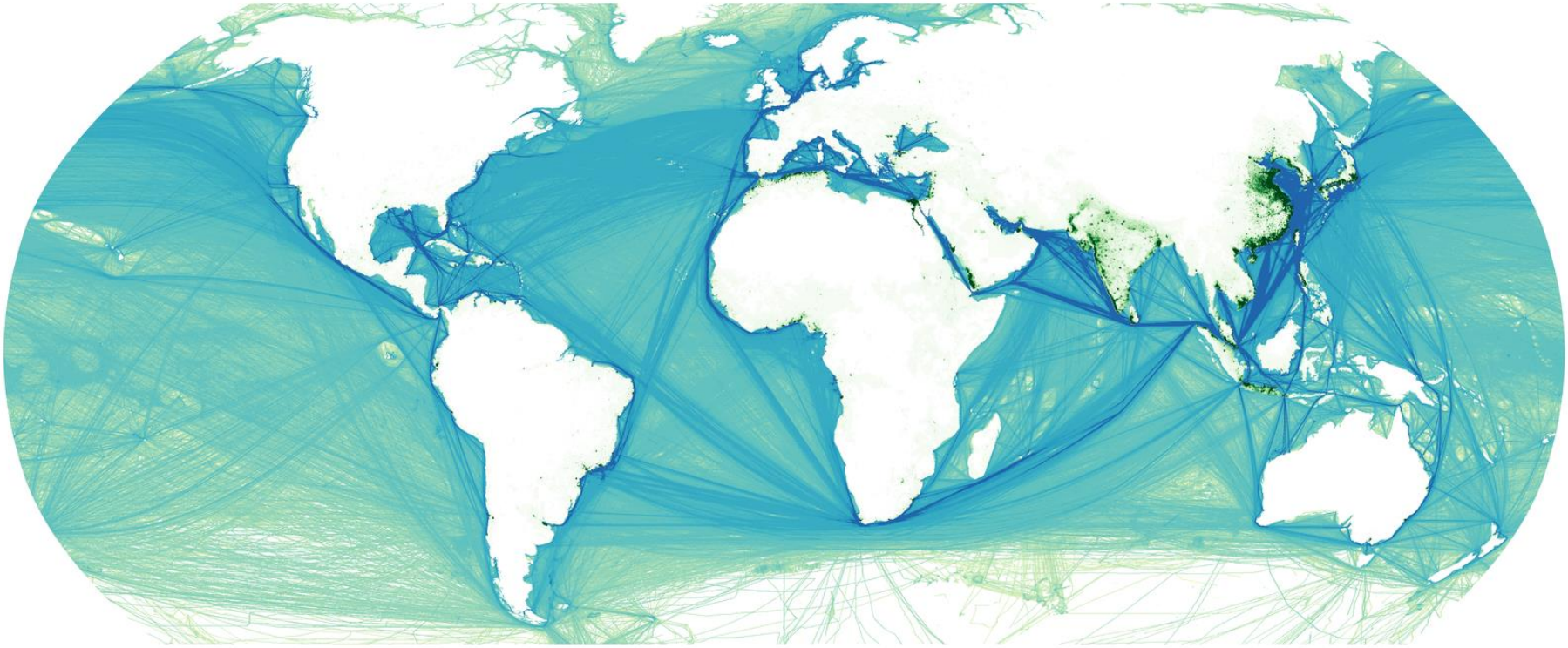




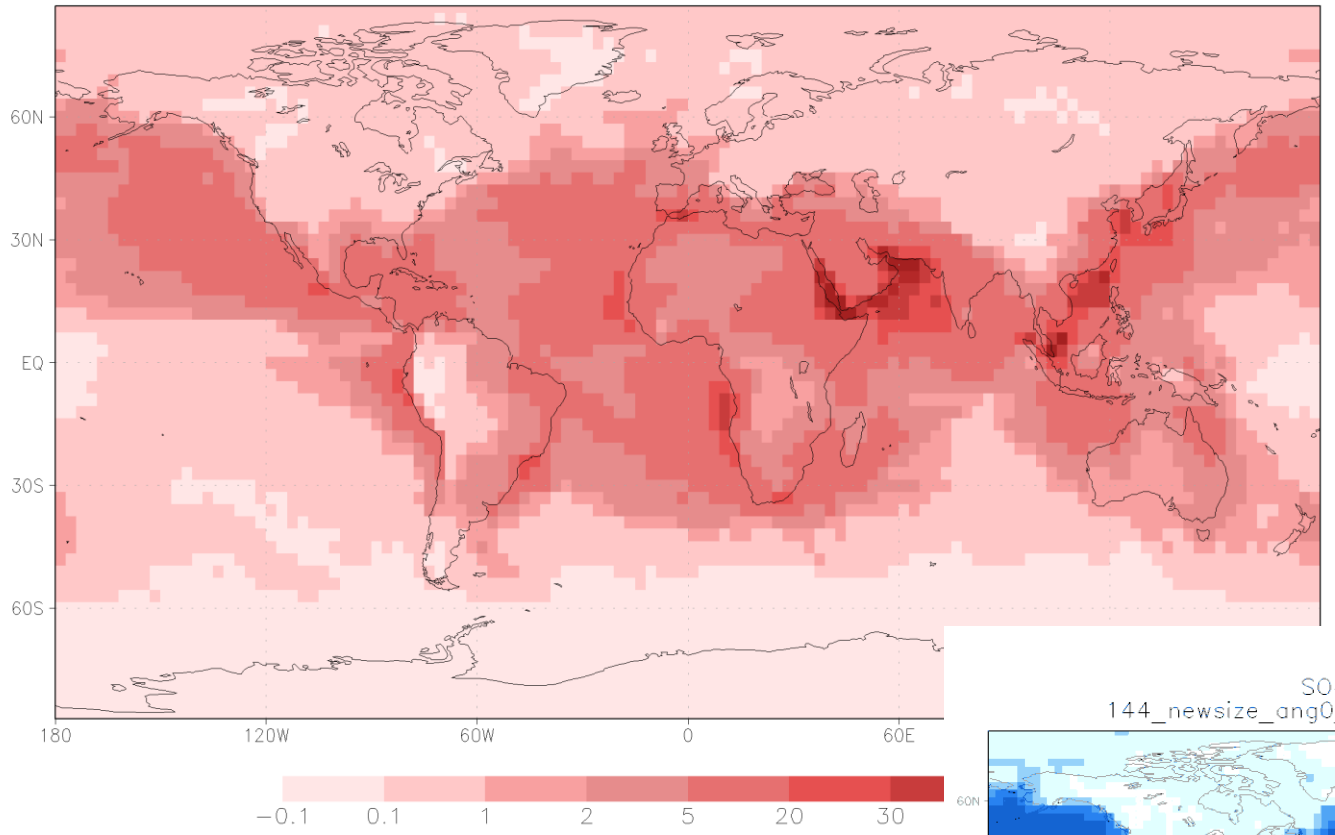
Health impact

BAU mortality, lung cancer + cardiovascular

Avoided mortality, BAU - Action



Difference in sulphates + nitrates direct rad.forcing, SSA=0.9999, BAU-Ontime
mW/m^2, mean 2020



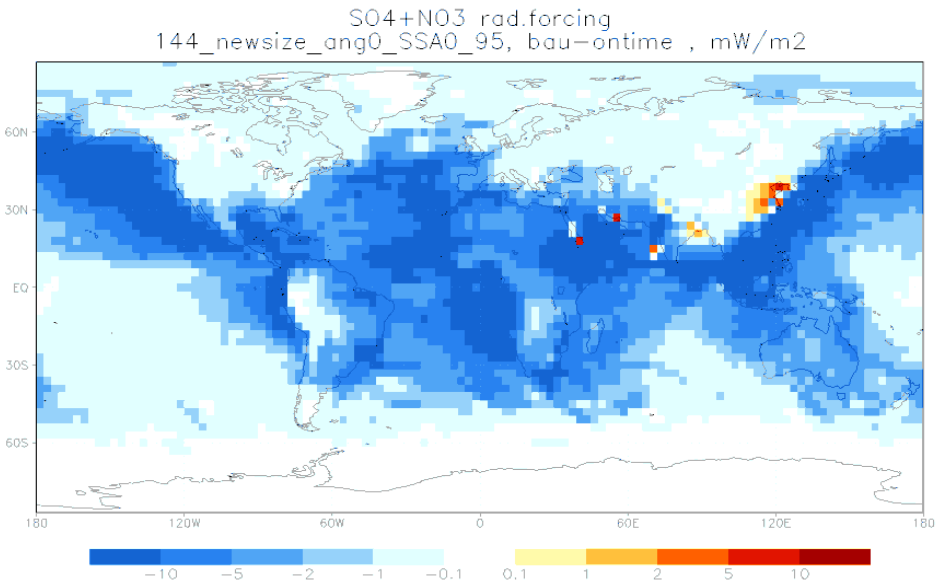
ine oceanic

ght back to space

rface

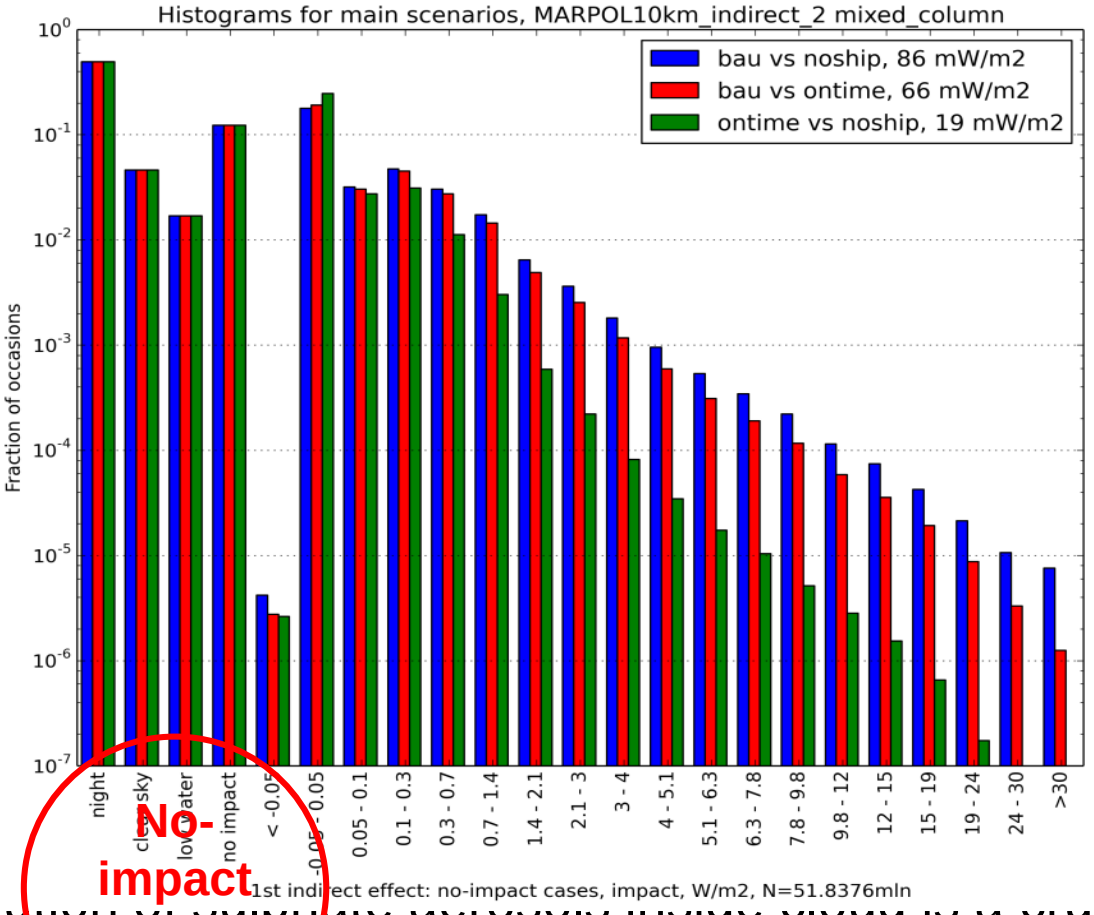
ring Albedo, SSA)

~ 4 mW / m2



First indirect aerosol effect

- Reducti … ecreases the num … d conden…
- Droplet… …edo and increasi…
- Mean v… strongly non-line…
  - >90% … ship lanes, etc.
  - distrib… …cial but poorly known characteristic
    - well-mixed cloud: strong in-cloud convection: ~67 mW / m2
    - sulphates mainly at the bottom weak in-cloud convection: 19 mW / m2



Summary

- MARPOL VI effects
  - large positive health effects, mainly in Asia
    - ~7,000,000 childhood asthma cases per year
    - ~140,000 premature deaths
  - noticeable reduction of the aerosol cooling effect
    - lost direct aerosol cooling is ~4 mW / m2, mainly subtropical sunny areas, (Persian Gulf)
    - lost first-indirect cooling due to reducing cloud albedo is ~67 mW / m2, mainly in cloudy areas (Asia)
- Methodology: aerosol direct and first indirect effects were made with offline SILAM CTM + LibRadTran radiative transfer model
  - very high spatial and temporal resolution (10km $\times$ 1 hrs globally)
  - quite sophisticated chemistry and aerosol formation description
  - simplified parameterization of CCN(PM) dependence

Ensemble-based assimilation and forecasting of aviation hazards

Andreas Uppstu, Julius Vira, and Mikhail Sofiev

FINNISH METEOROLOGICAL INSTITUTE

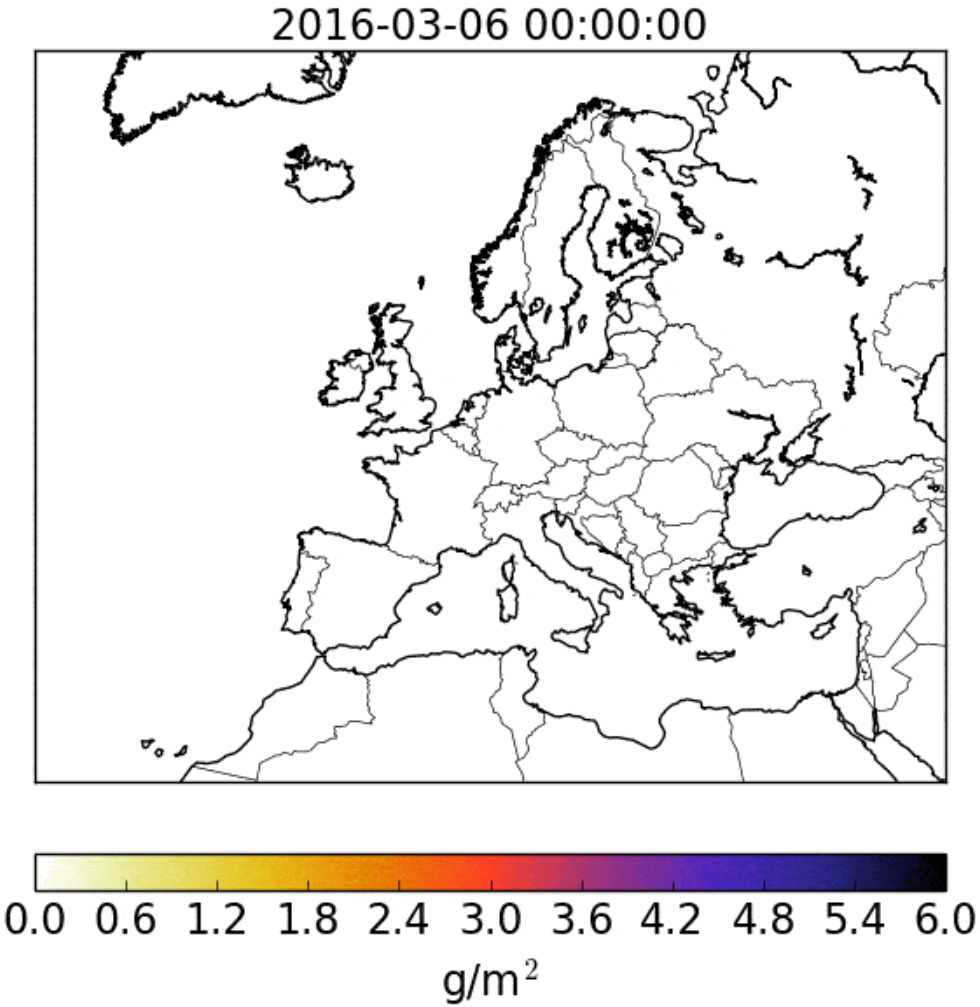
EUNADICS-AV

EmbIA

The EUNADICS-AV project

- The European Natural Airborne Disaster Information and Coordination System for Aviation
- The goal of the project is to create a prototype product for real-time analysis of aviation hazards through data-assimilation
- The hazards considered are volcanoes, nuclear releases, desert dust and vegetation fires
- 21 organizations from 12 countries
- Four atmospheric transport models: MATCH, MOCAGE, SILAM and WRF-Chem/FLEXPART

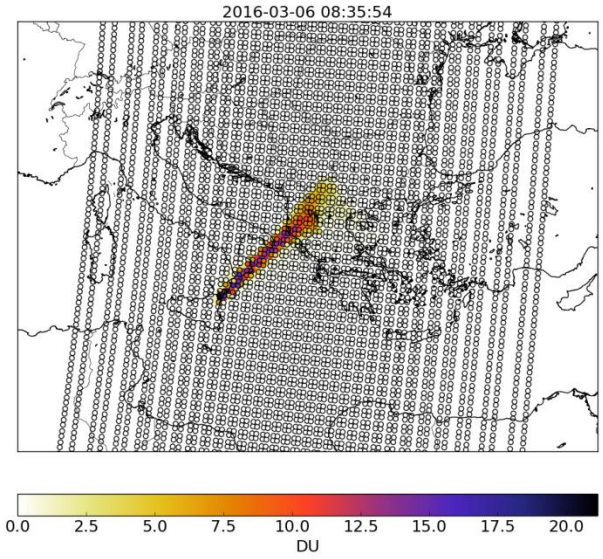
A simulated eruption of Etna



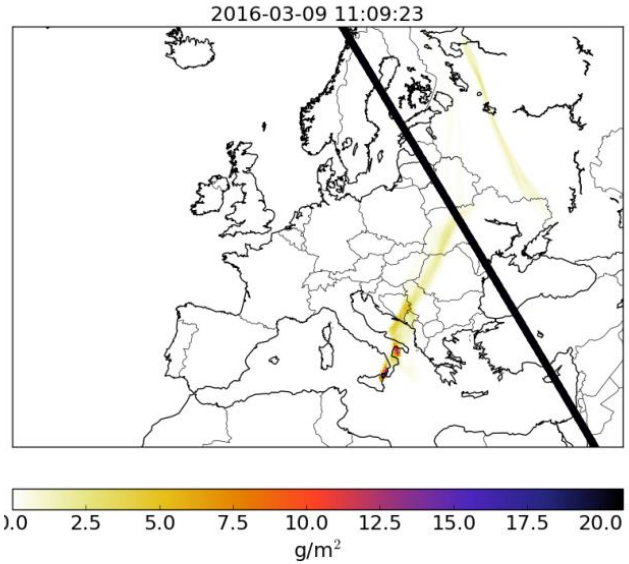
- The source term for ash is based on an estimation of the source term of the Eyjafjallajökull eruption (Stohl *et al*., Atmos. Chem. Phys., 11, 4333–4351, 2011)
- The meteorology is based on the ERA Interim reanalysis

Simulated lidar and interferometer retrievals

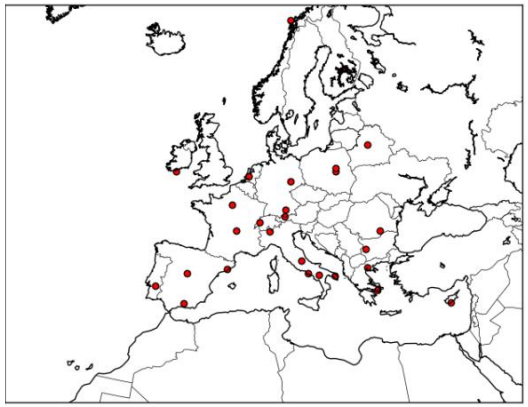
IASI



CALIOP



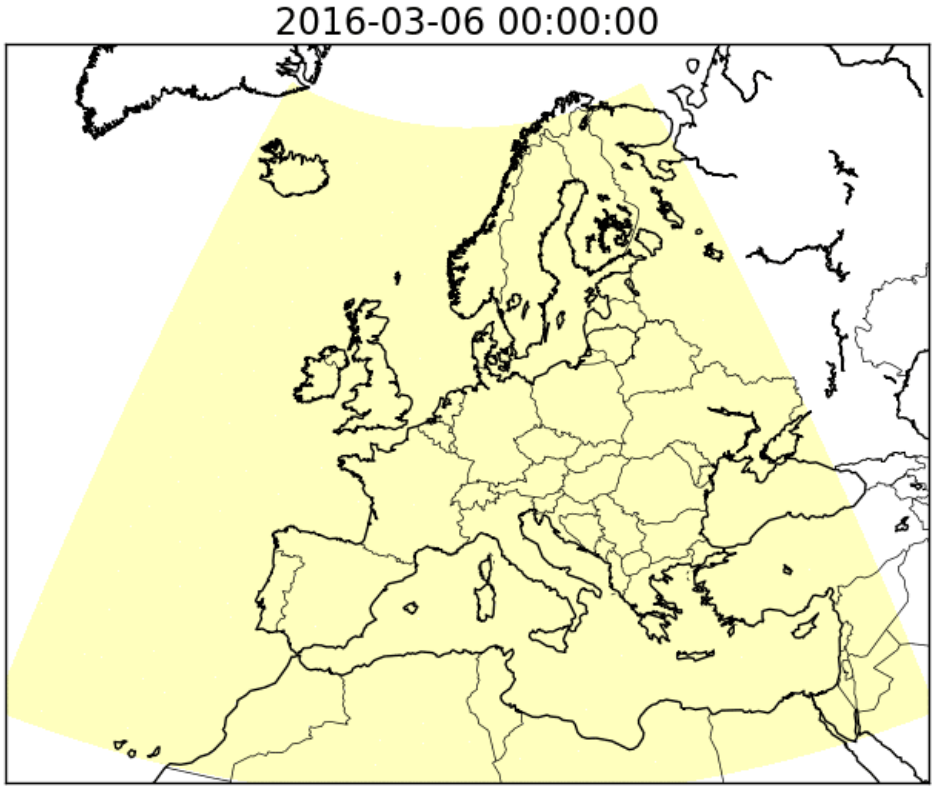
EARLINET



- Normally distributed and uncorrelated errors with standard deviations of 10 % plus 0.04 mg/m3 for the lidars and 20 mg/m2 for the column integrated IASI retrievals) are assumed

Model perturbation

- Both the emissions and the meteorology are perturbed
- A simple eruption model based on the Mastin equation (Mastin *et al*., J. Volc. Geoth. Res., 191, 245, 2009) is applied, together with a simple vertical distribution model
- An ensemble of 80 members is run



- The distribution of the perturbed emission is set to be log-normal

Blue: ERA Interim
Red: ECMWF operational

DA results quantified

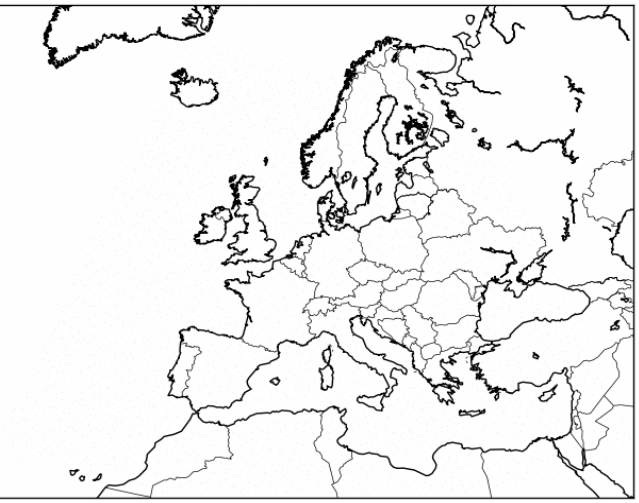
The contingency matrix below indicates possible outcomes of the simulation. ’Present’ indicates the number of grid cells where the threshold value is exceed in the truth, while ’Prediceted’ indicates the number of grid cells where the threshold value is exceeded in the outcome of the data assimilation

	Present	**Not present**
Predicted	*a*	*b*
Not predicted	*c*	*d*

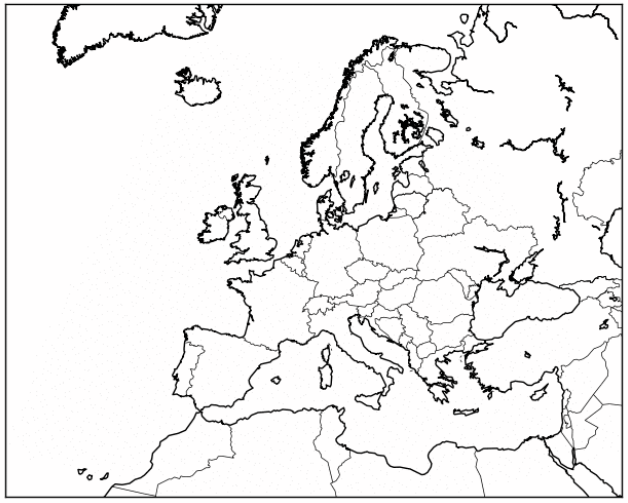
Model accuracy = (*a*+*d*)/(*a*+*b*+*c*+*d*)
Probability of detection = *a*/(*a*+*c*)
Probability of false detection = *b*/(*b*+*d*)
False alarm rate = *b*/(*a*+*b*)
Bias = (*a*+*b*)/(*a*+*c*)-1
Odds ratio = *ad*/*bc*

	ensemble average	90th percentile	98th percentile	entire ensemble
Model accuracy (%)	99.5	99.4	98.7	97.7
Probability of detection (%)	55	74	84	89
False alarm rate (%)	43	54	72	81
Probability of false detection (%)	0.24	0.50	1.25	2.28
Bias (%)	-3	60	199	379
Odds ratio	504	572	419	356

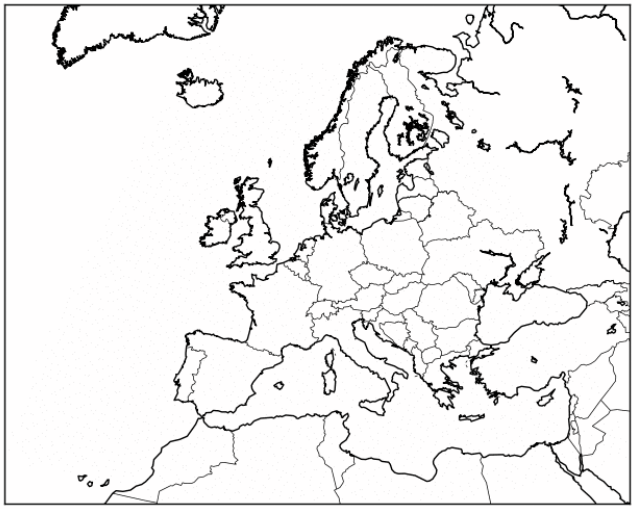
Data assimilation results



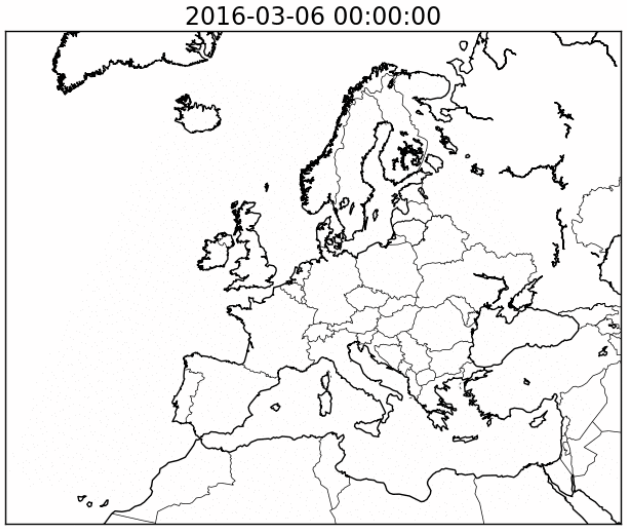
0–2250 m



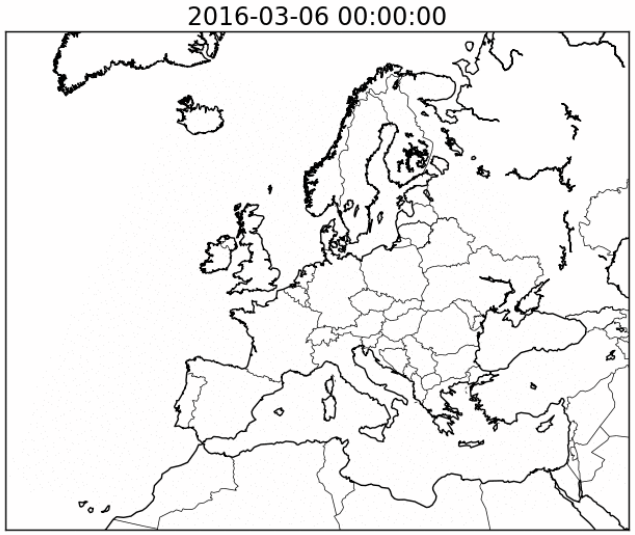
2250–4250 m



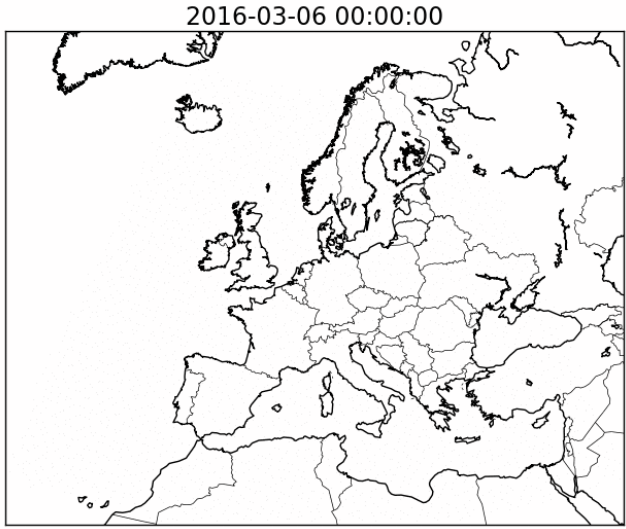
4250–6250 m



6250–8250 m

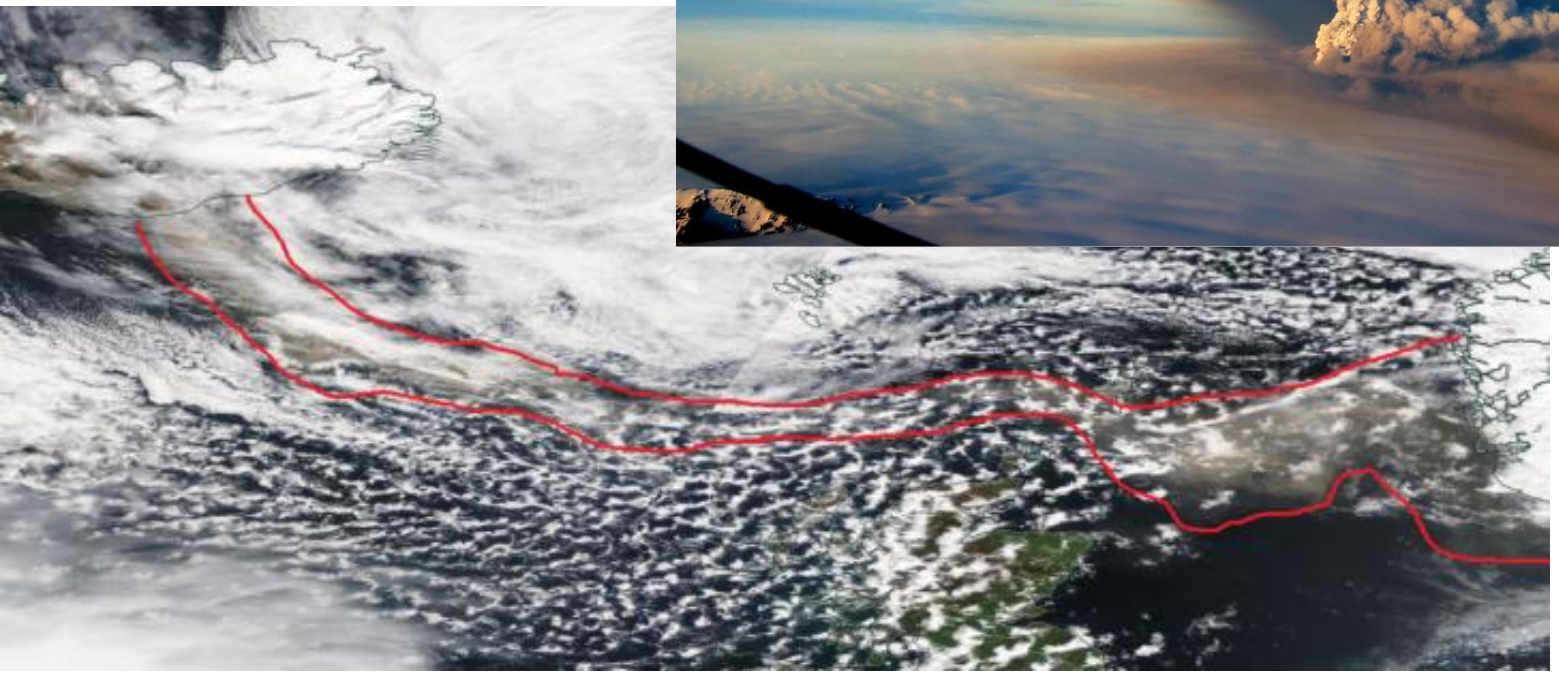


8250–10250 m

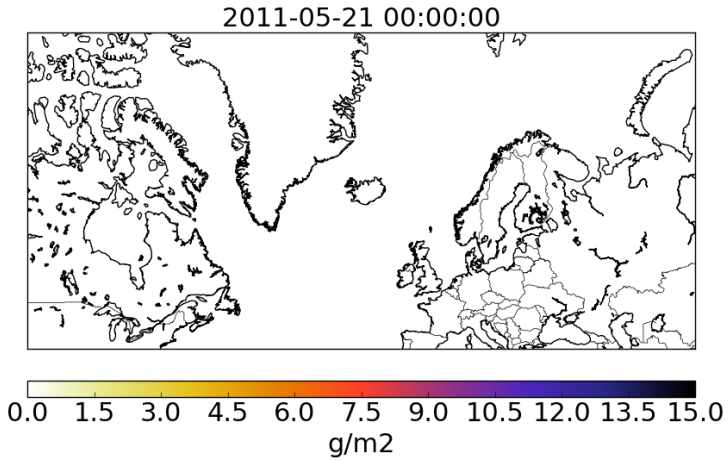


10250–12250 m

The Grimsvotn eruption in 2011: Separation of ash and SO2

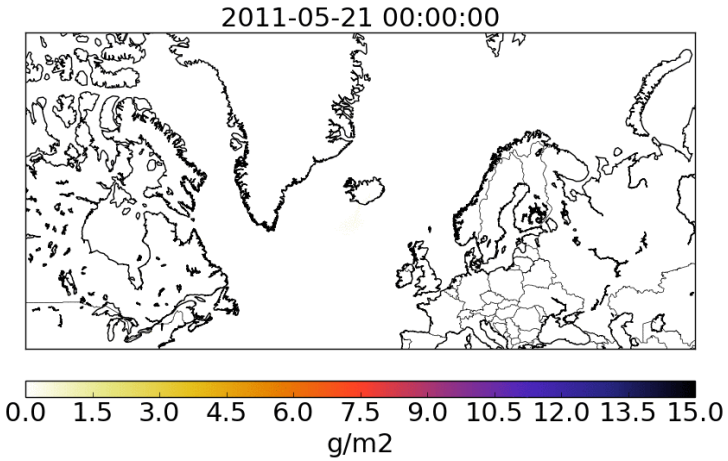


Assimilation of ash



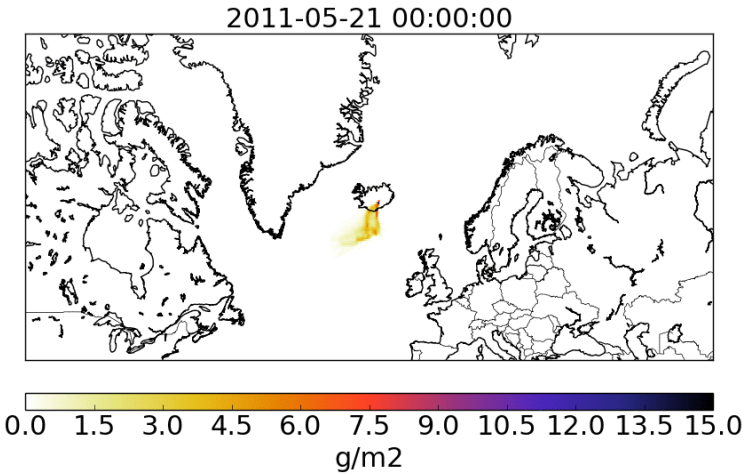
50th percentile

The assimilation is based on MODIS AOD retrievals (Terra coll. 5.1 Dark Target)

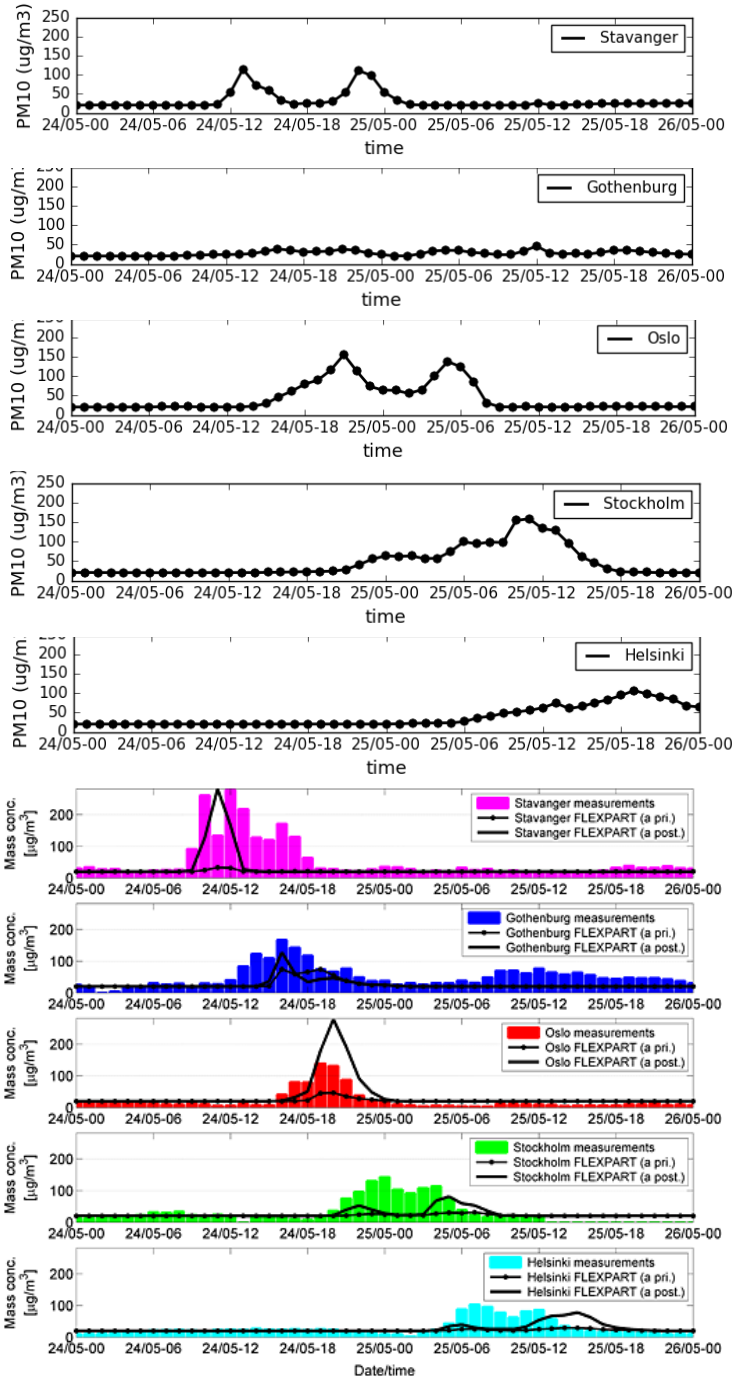


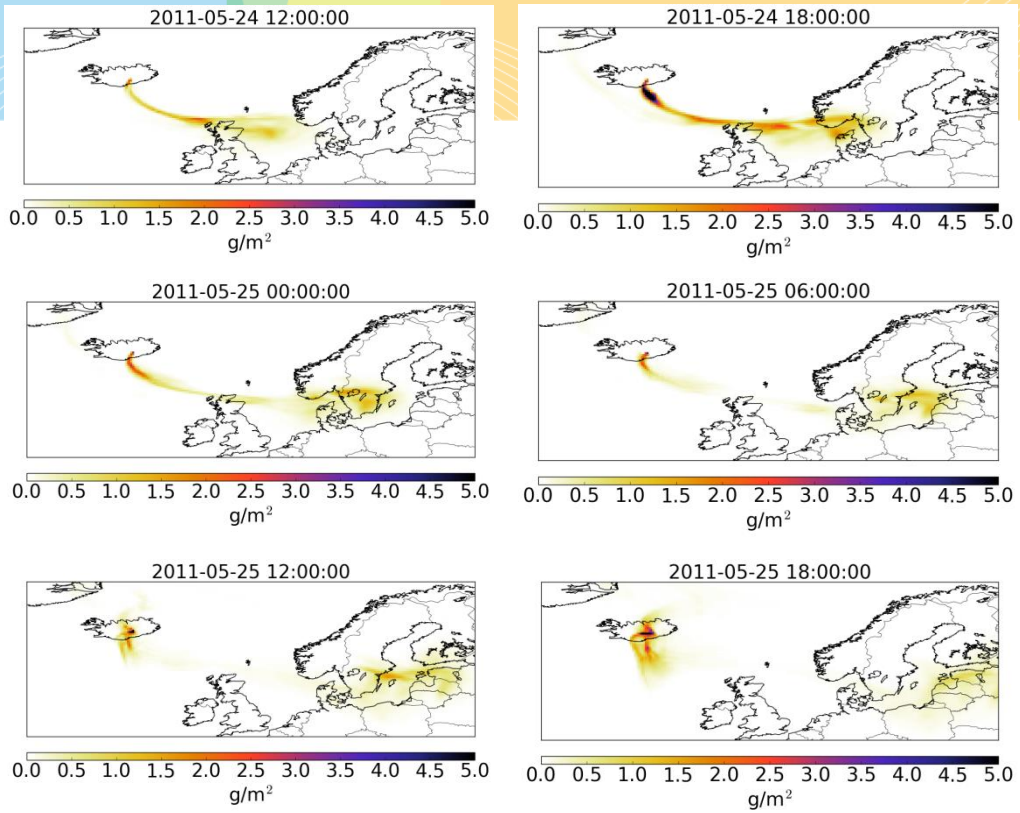
75th percentile

The source term is based on the Mastin equation. The vertical distribution is assumed to be uniform. The start of the eruption is missed due to the sparsity of Terra overpasses. The ash source is not coupled to the SO2 source in the assimilation.



99th percentile

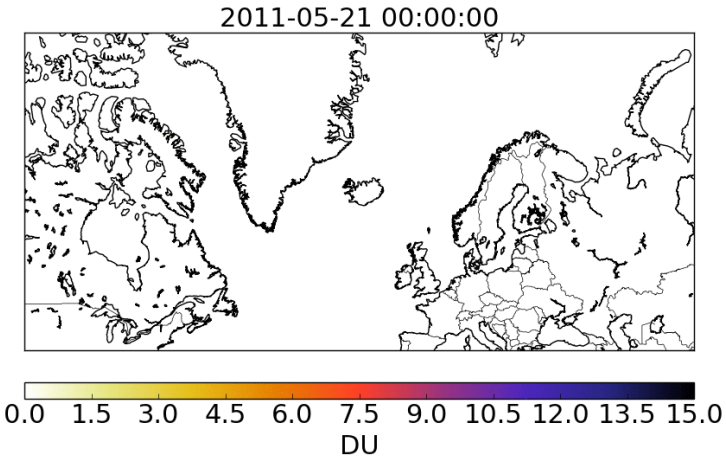




Above: SILAM EnKF data assimilation of MODIS AOD retrievals (median of an ensemble of 80 members). The plumes close to the volcano in the last two figures are the result of random eruptions in the model that account for the prior probabilities.

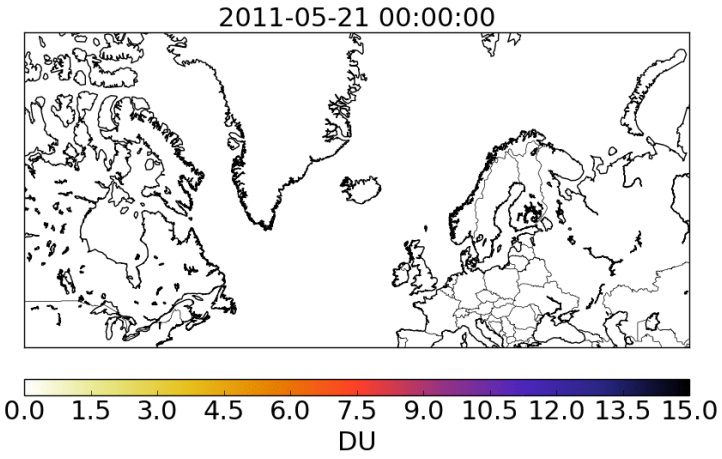
Left: Comparison of model ground level results and ground measurements. A constant background PM 10 concentration of 20 ug/m3 has been added to the model results. The top figure shows SILAM results and the bottom one is from Moxnes et al. (2014).

Assimilation of SO2



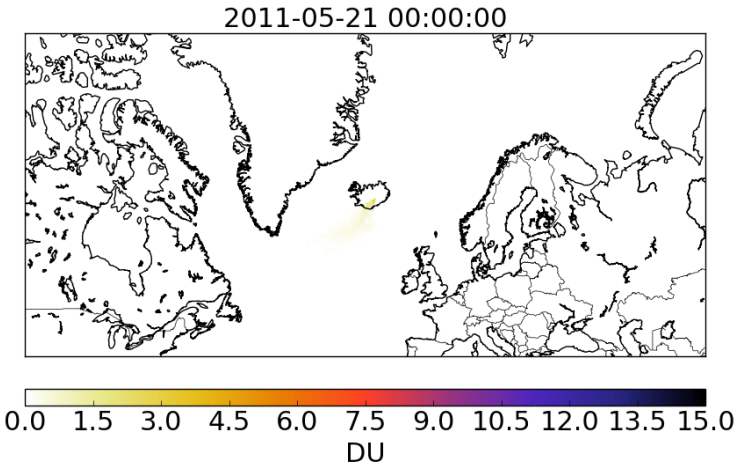
50th percentile

The assimilation is based on OMI, GOME-2, and Keflavik radar data.



75th percentile

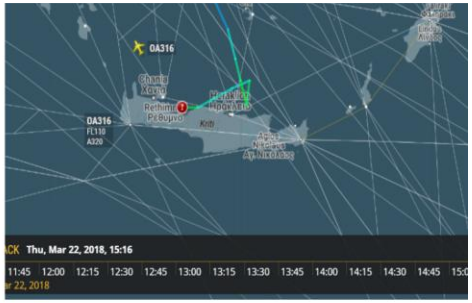
The source term is based on the Mastin equation, with ash being converted into SO2 using a constant conversion factor. The vertical distribution is assumed to be uniform.



99th percentile

Better forecasts of dust storms needed

Herakleion airport did not have any approach available for eight hours on 22/3/2018, no warning from the met service.



Thank you!