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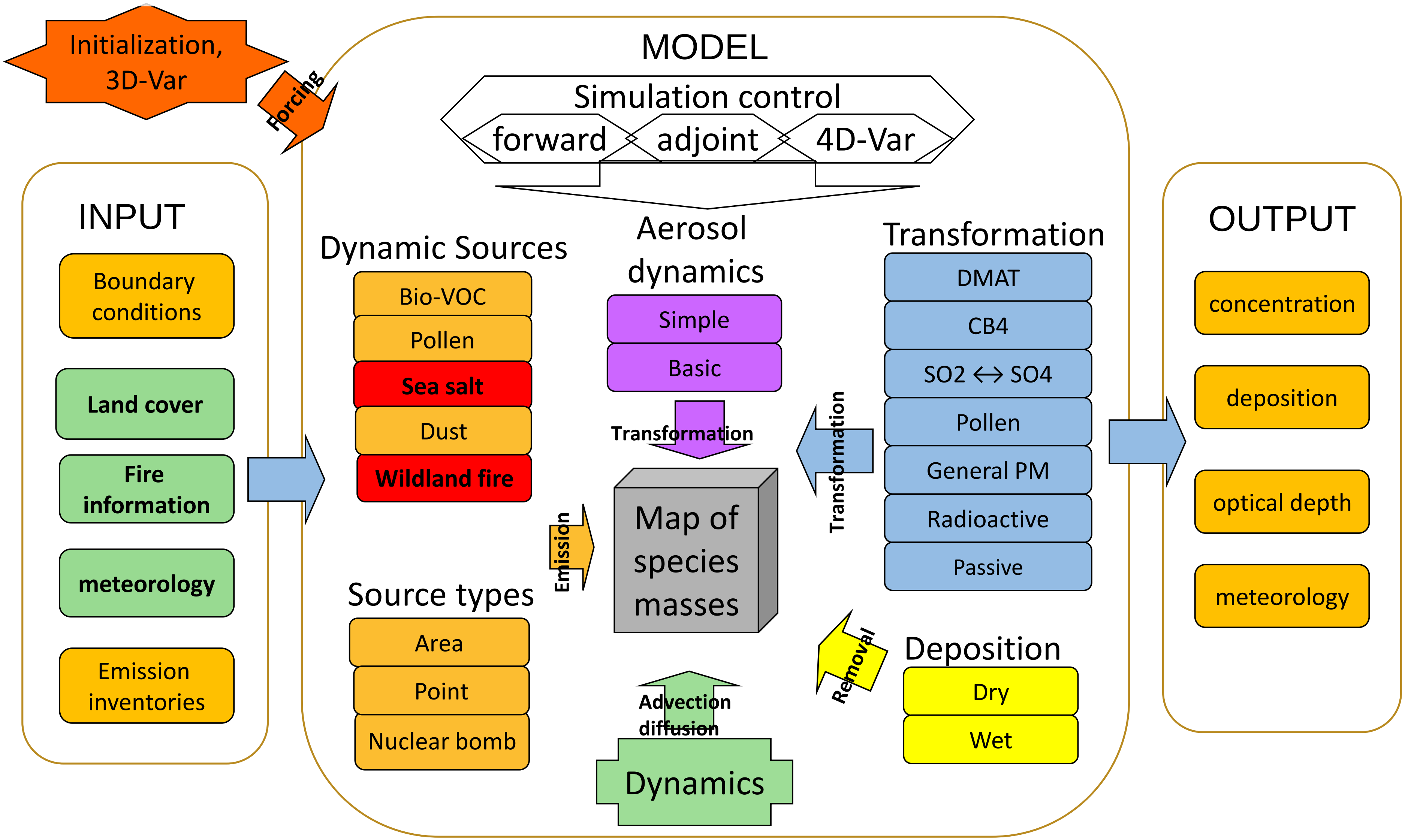
Methods for improving emission estimates for regional *and local* scale AQ-modeling

Ari Karppinen

ResMan. /FMI

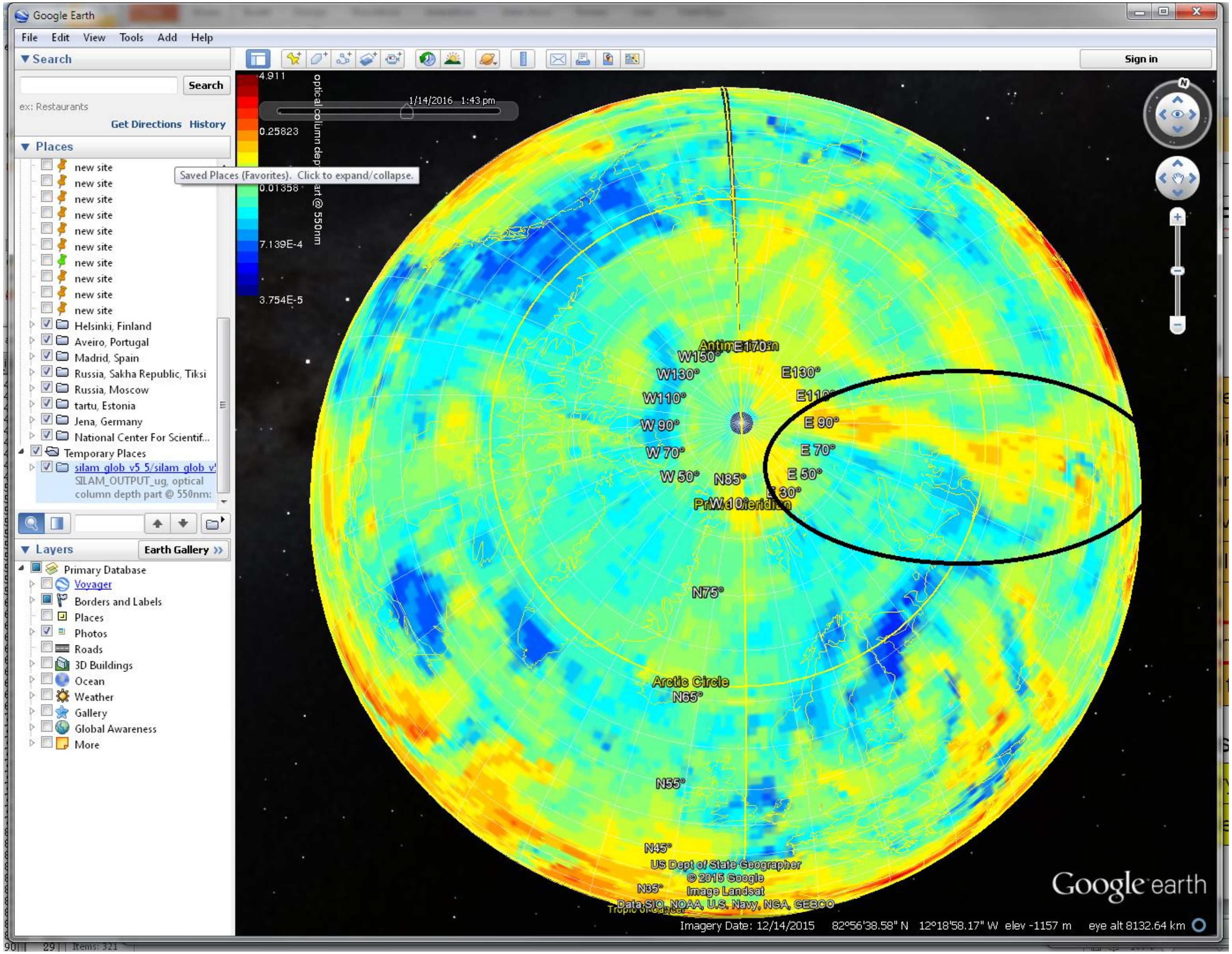
FMI atmospheric composition assessment & forecasting tool: SILAM



Air pollution

- Sources:
  - Anthropogenic
  - Biogenic from vegetation
  - Natural (e.g. **sea salt** and dust)
  - **Wildland fires**
- General motivation:
  - Sea salt:
    - high contribution to total burden; can be an exclusive contributor to air composition in remote places
    - Costal places, high contribution in-situ atmospheric measurements
  - Wild-land fires:
    - on average contribute 10-50% of European emission of PM and gases (e.g. CO)
    - easily long-range transported

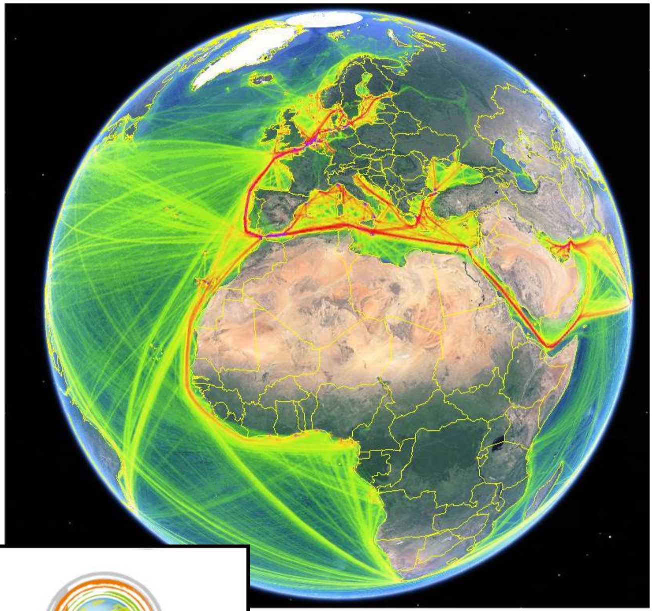
Global AOD forecast, 12-14.01.2015



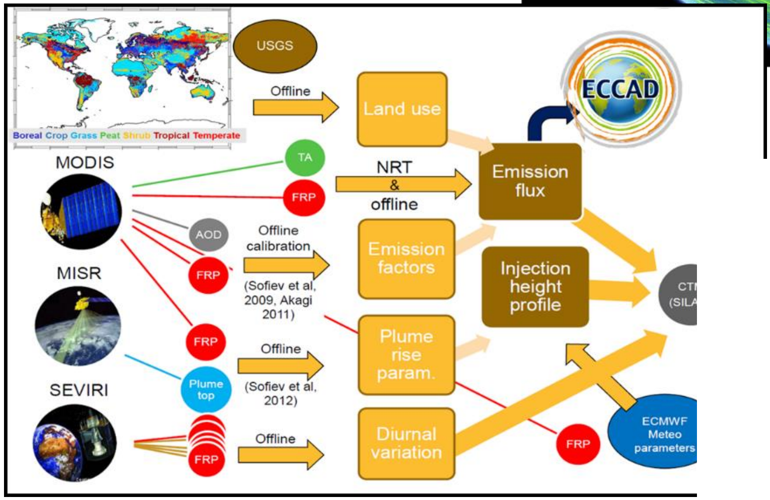
Contents

- Sea Salt

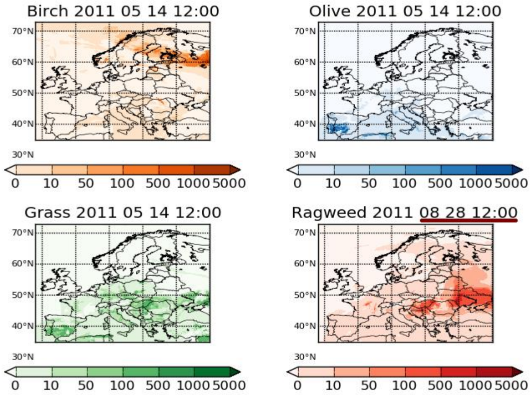
- Ship emissions



- Forest Fires



- Pollen

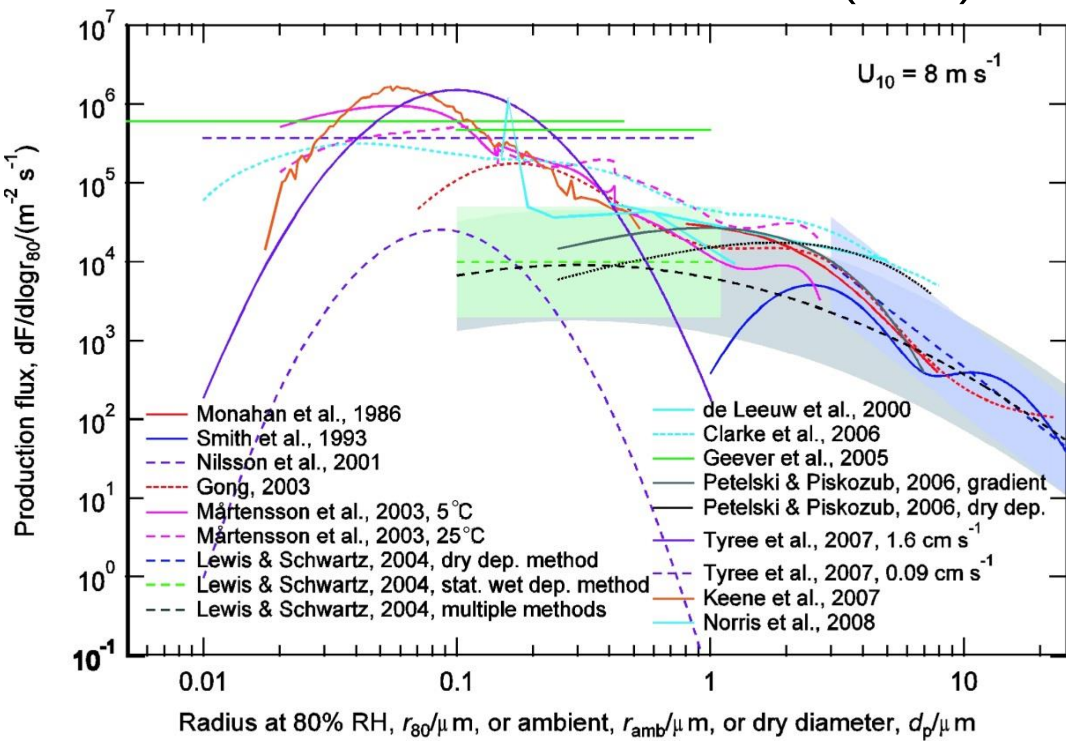


- Inverse modeling

A new sea salt emission parameterisation

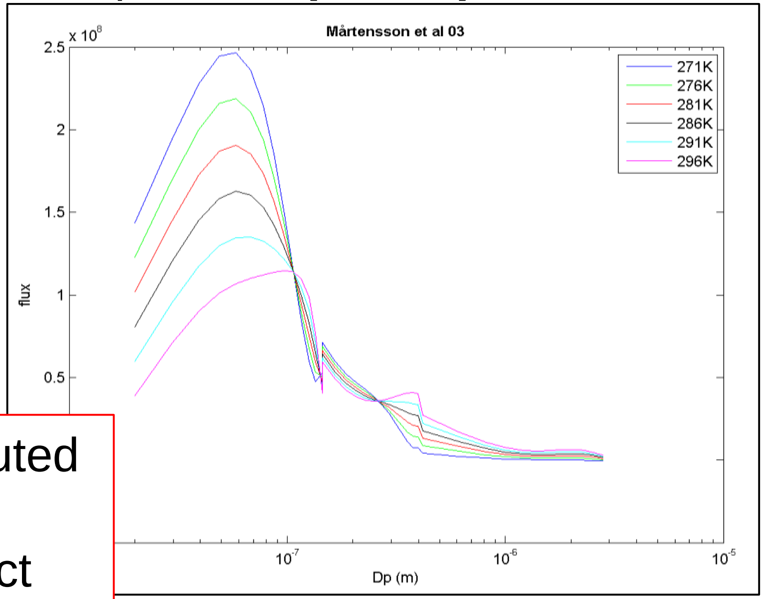
Motivation:

de Leeuw et al. (2011)



Most widely used approaches:

- super-micron sizes: Monahan et al. (1986) **(red)**
- sub-micron sizes: Mårtensson et al (2003), temperature dependent **(fuchia)**



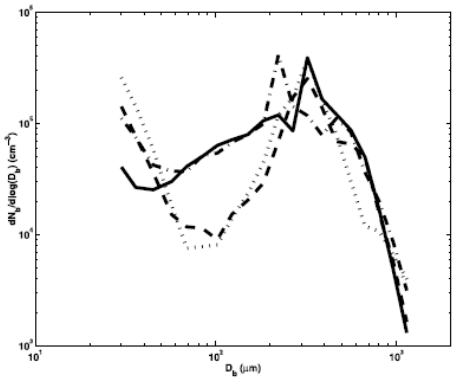
emission is computed by 6th order polynomial for strict size ranges

Sea salt emission

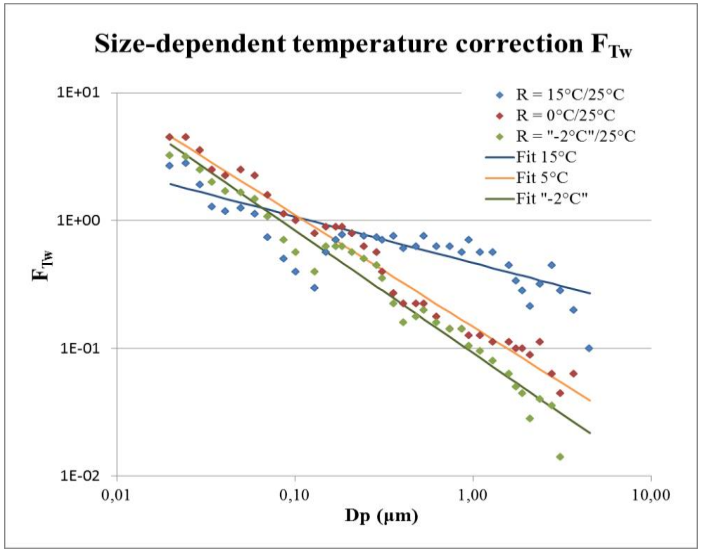
Sea salt flux = white-cap ($U^{3.41}$) * ($F_{Dp,25°,33‰}$) * $F_{Dp,Twater}$ * $F_{Dp,Swater}$

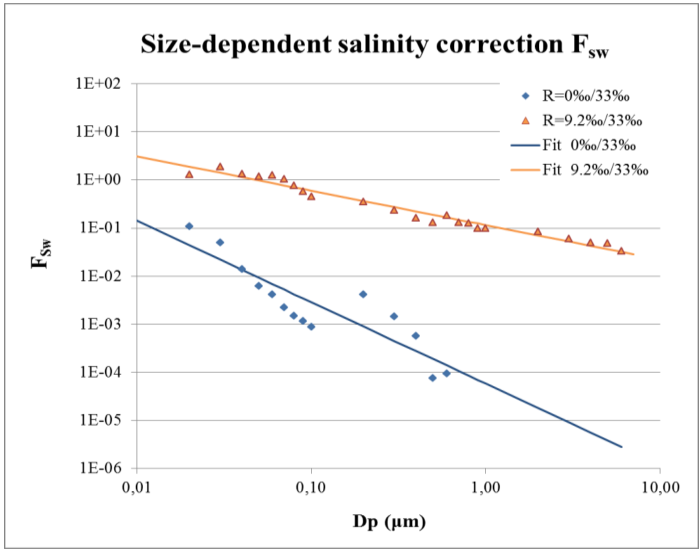
Particle size dependent correction functions for seawater temperature & salinity

Linear fits based on Mårtensson et al. (2003) laboratory simulations for different seawater temperature & salinity



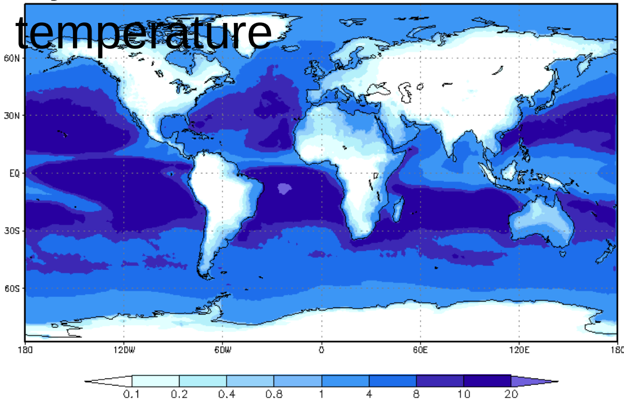
Spectra of bubbles
-2°C (dotted)
5°C (dashed)
15°C(dot-dashed)
25°C (solid)



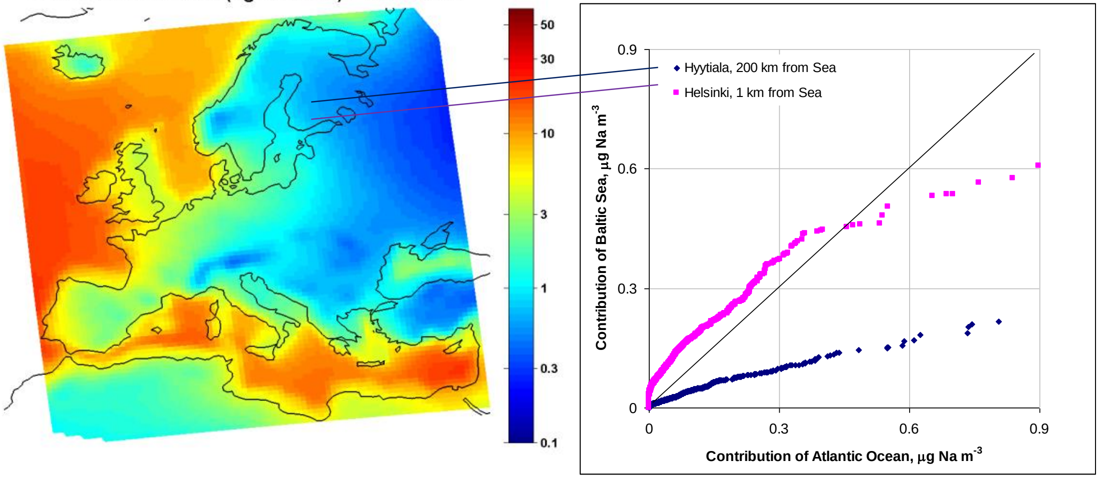


seawater temperature/salinity impact on concentrations

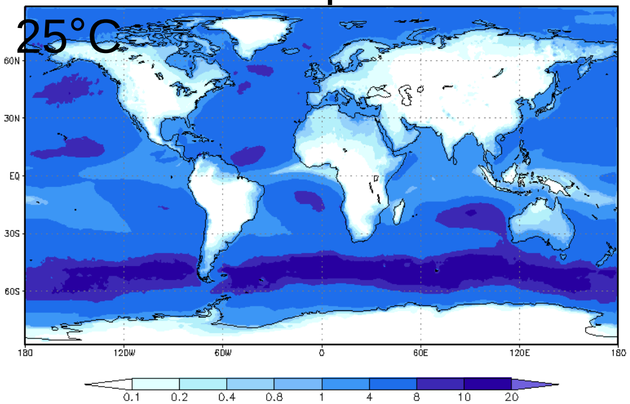
Dynamic seawater temperature



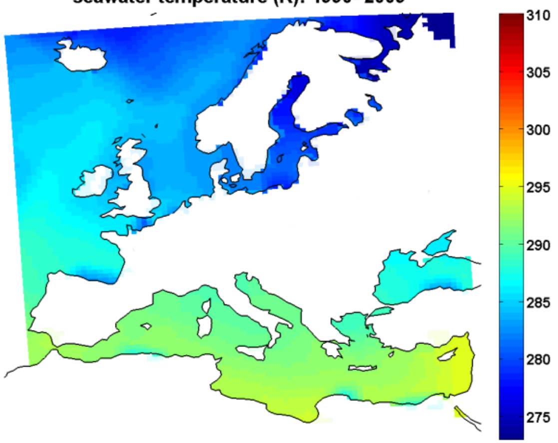
SILAM concentration (ugPM10/m³) : 1990 -2009



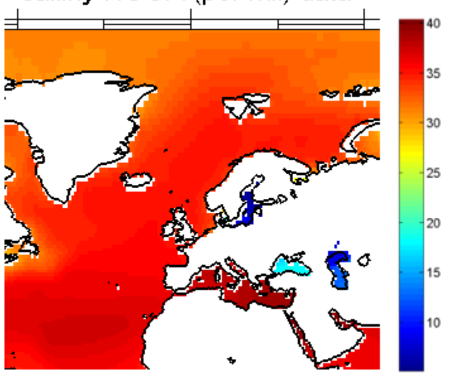
Seawater temperature = 25°C



seawater temperature (K): 1990- 2009

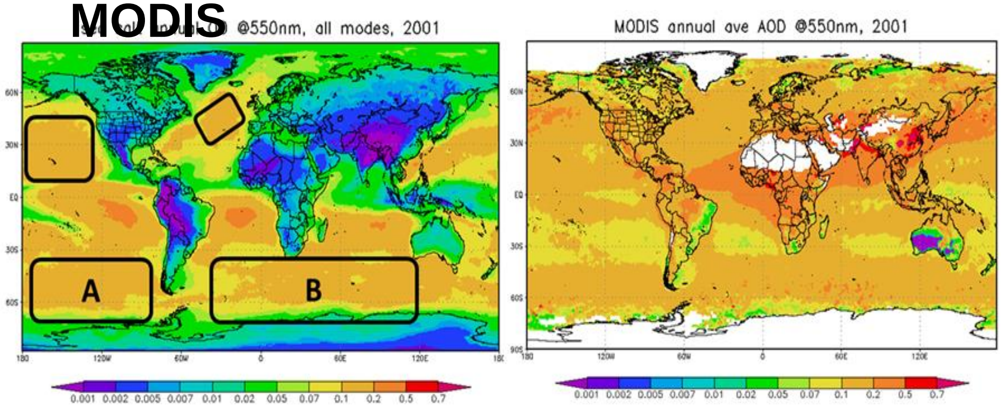


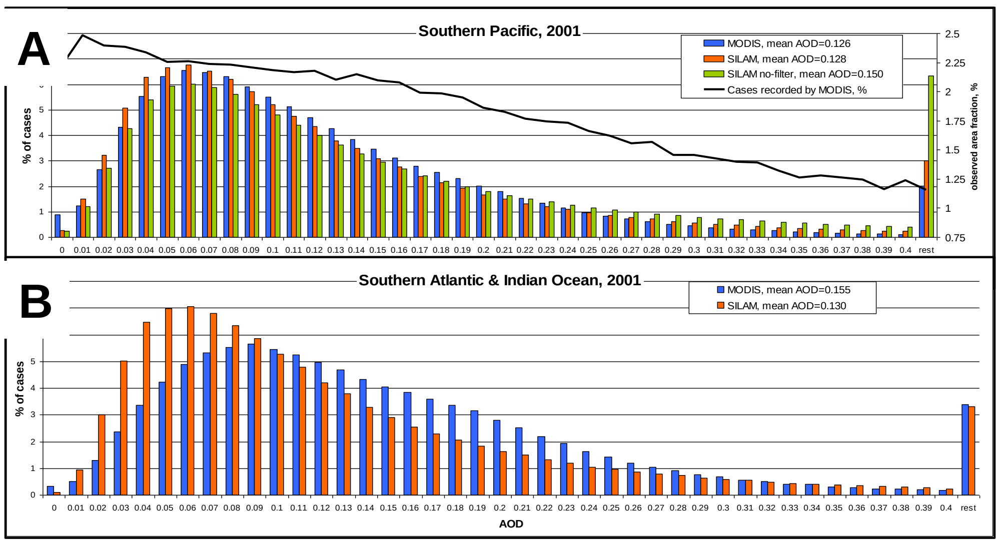
sailiny NOOA (per mil) data



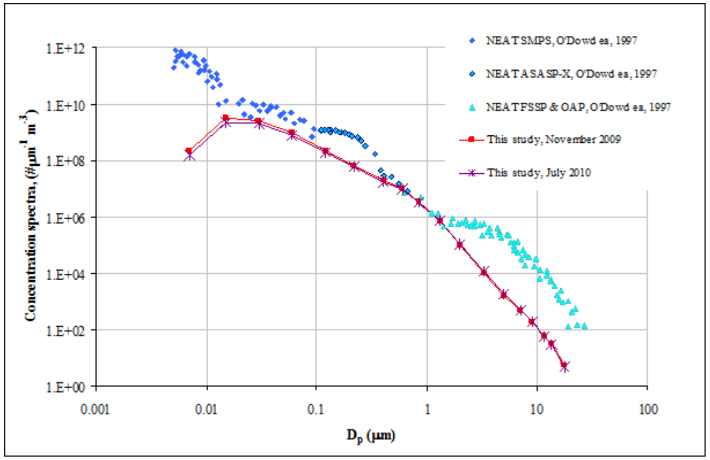
Evaluation of the parameterisation

Aerosol Optical Depth: SILAM vs MODIS

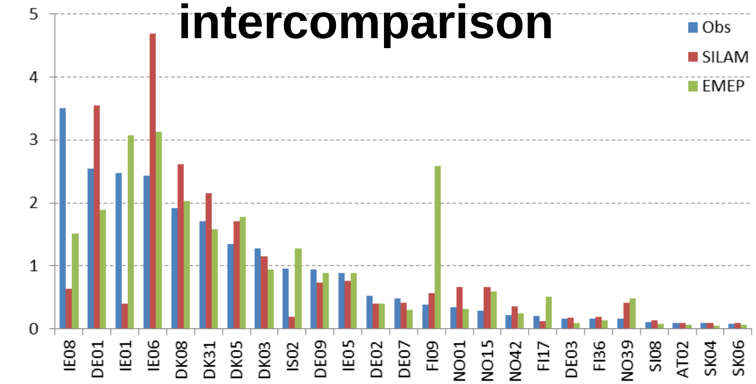




Mass concentration: SILAM vs in-s



Model intercomparison



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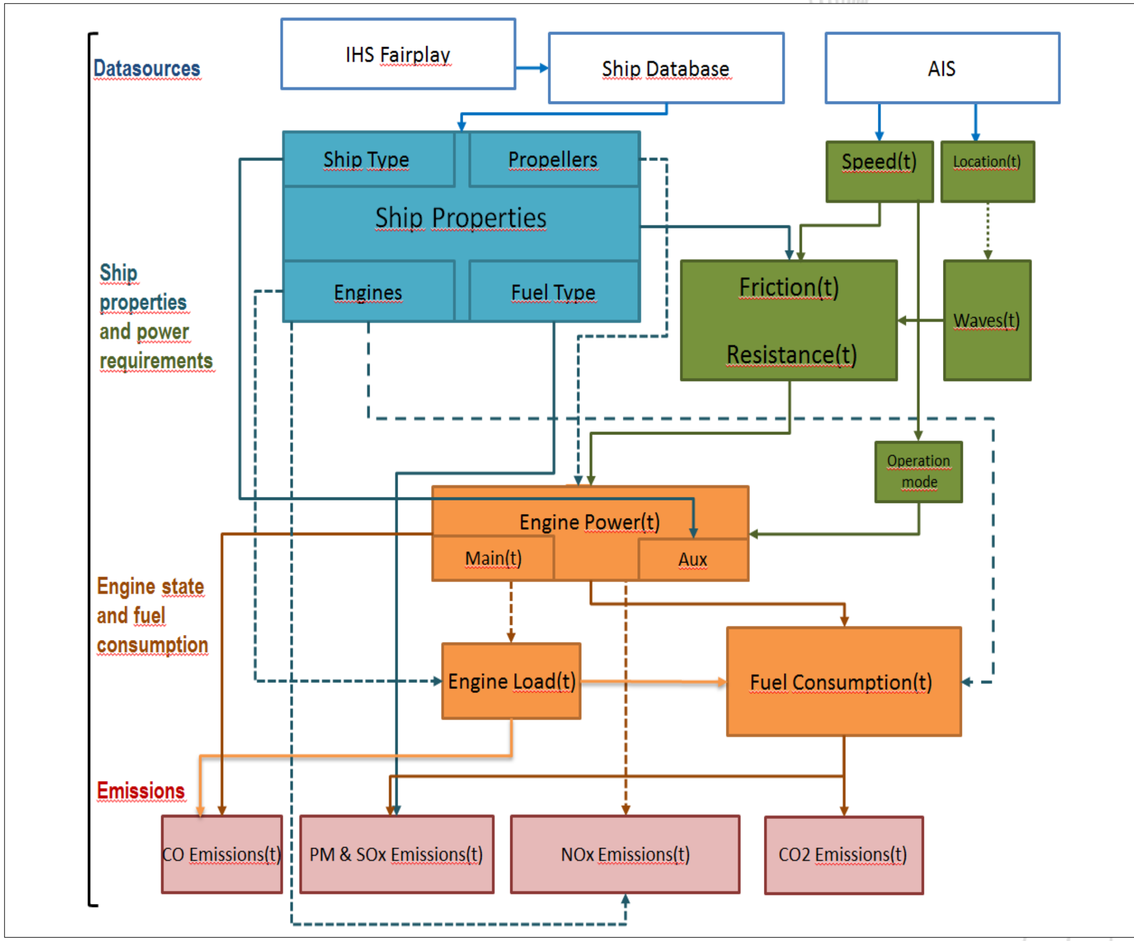
STEAM 2: Emission model

- Ship Traffic Emission Assessment Model (STEAM)
- Vessel performance prediction
  - Semiempirical approach
- Fully dynamic system
  - Temporal variation retained
  - Traffic pattern changes
- Vessel specific inventories → MRV
  - Fuel
  - Emissions to air
  - Emissions to water
- Resolution limited by GPS accuracy
  - EU: 5 km, temporal profiles
    - 15 MB/pollutant/year
  - EU: 20 km, 1 h
    - 2 GB/pollutant/year
  - Global: 10 km, daily values
    - 25 GB/pollutant/year



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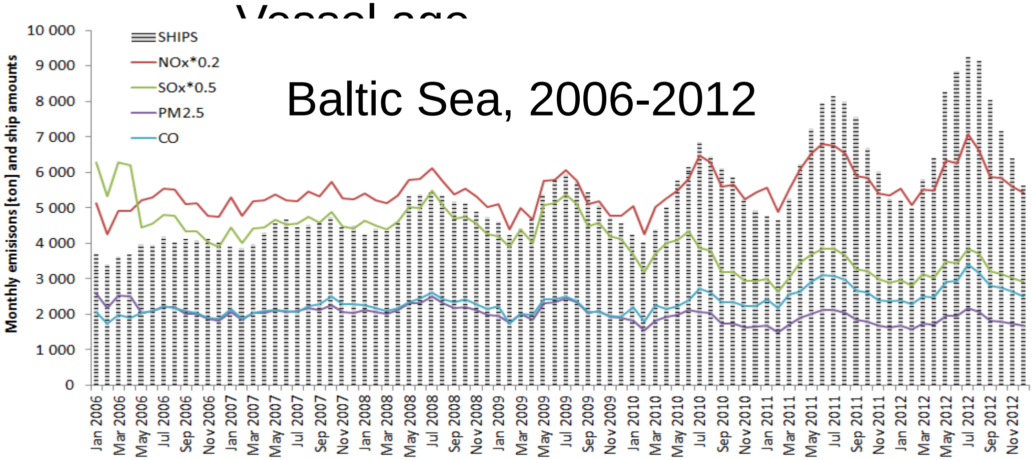
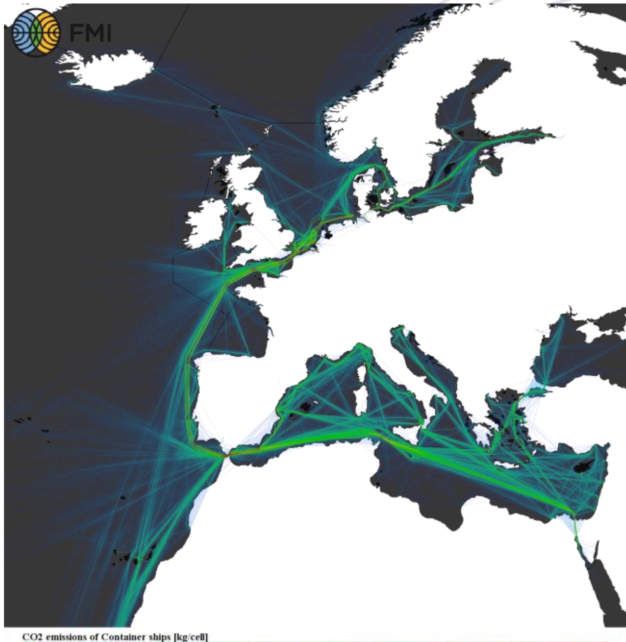
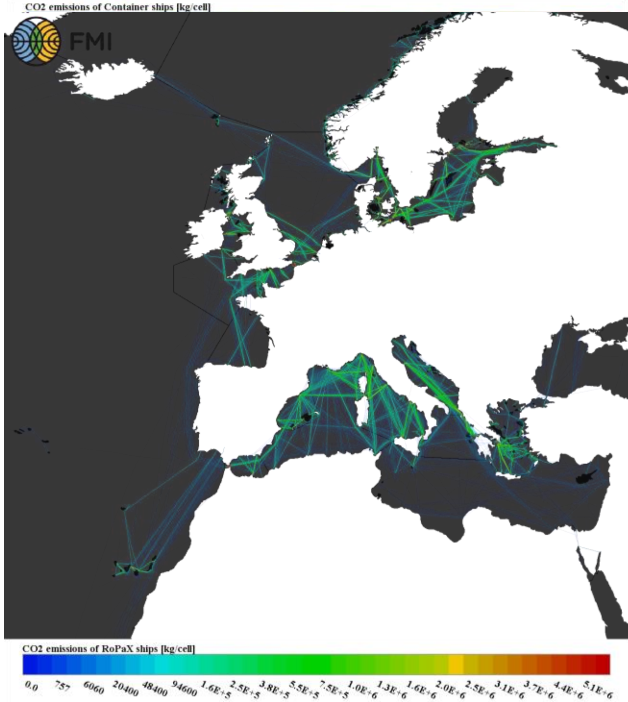
Outputs; General

- Outputs
  - Gridded datasets (NO_x, SO_x, CO, CO_2, EC, OC, Ash, SO_4)
  - Vessel specific summaries
  - Emissions by
    - Flag state
    - Vessel type
    - Vessel age

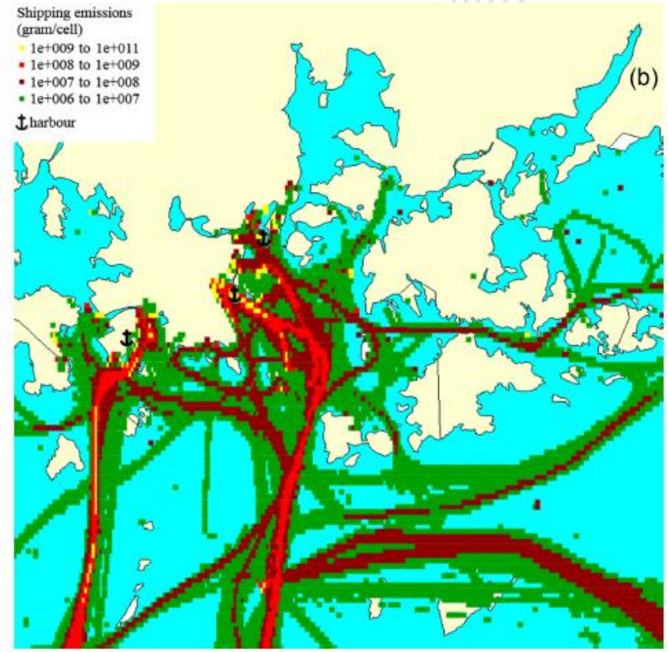




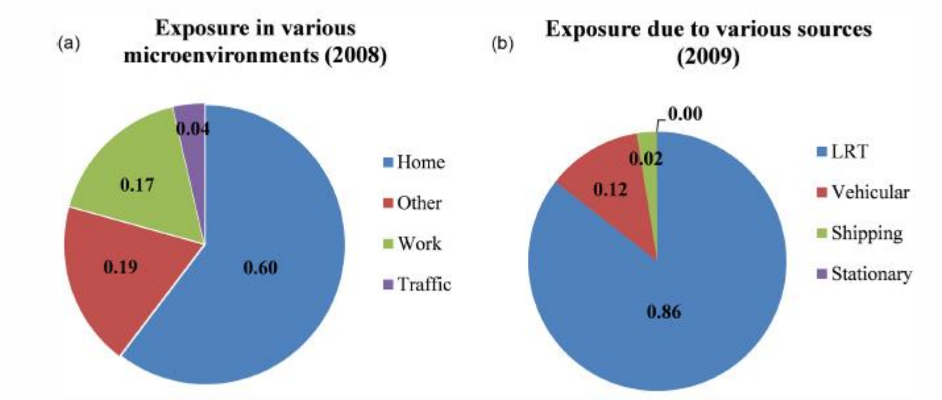


Example; Local scale

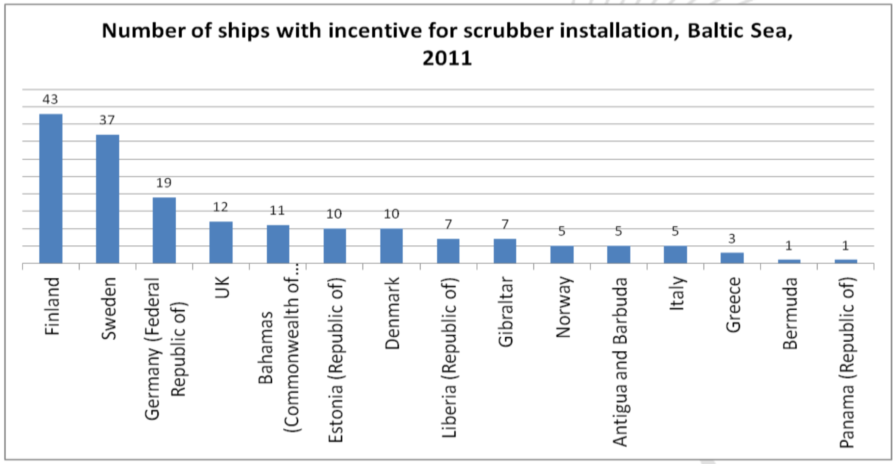
- Port scale studies
- Helsinki area
  - Soares et al, GMD, 7 (2014) 1855-1872
- Any port can be studied
- Emission factors for short time scale



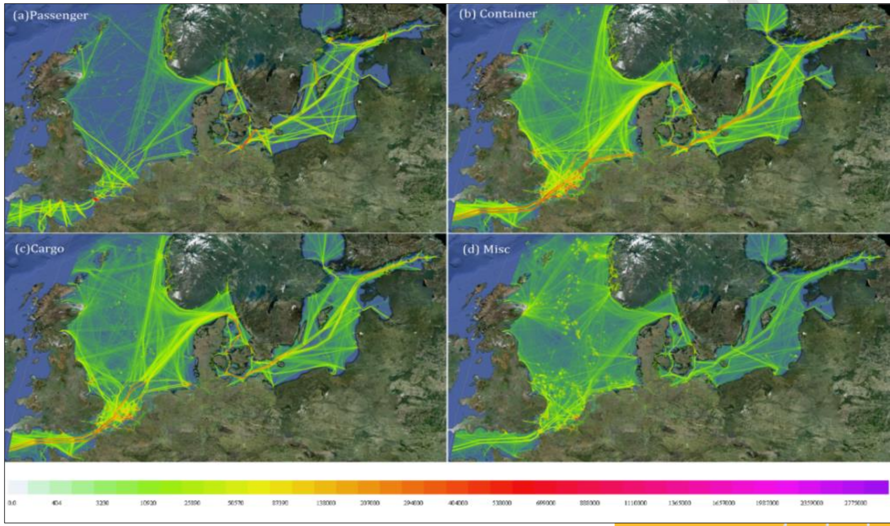
Tallinn, Estonia



Example; Regional



CO2 emissions from ships in European sea areas 1.-5.7.2011



Data provided by the European Maritime Safety Agency

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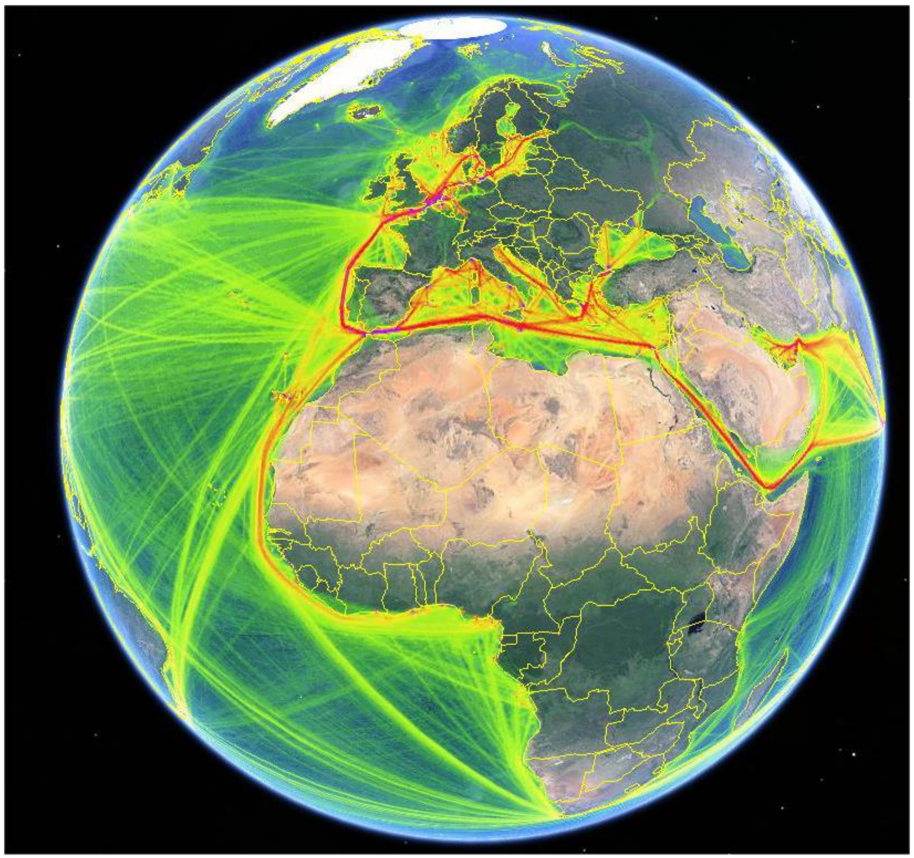
Example; Global



INTERNATIONAL MARITIME ORGANIZATION

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MARINE ENVIRONMENT PROTECTION COMMITTEE
67th session
Agenda item 6

MEPC 67/INF.3
25 July 2014
ENGLISH ONLY

REDUCTION OF GHG EMISSIONS FROM SHIPS

Third IMO GHG Study 2014 – Final Report

Note by the Secretariat

SUMMARY

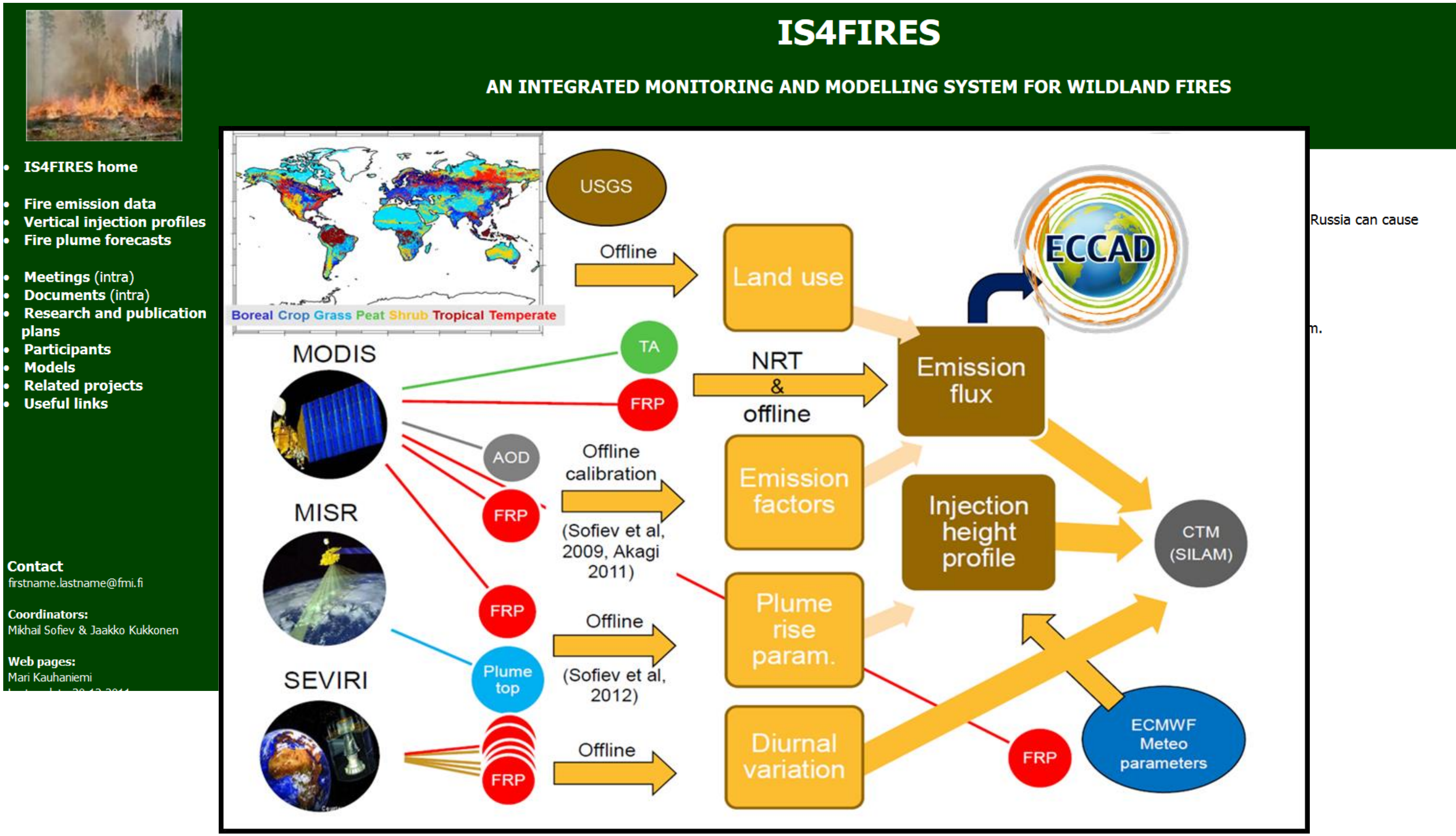
Executive summary:	This document provides in the annex the complete final report of the "Third IMO GHG Study 2014", which provides an update of the estimated GHG emissions for international shipping in the period 2007 to 2012. The executive summary can also be found in document MEPC 67/6.
Strategic direction:	7.3
High-level action:	7.3.2
Planned output:	7.3.2.1
Action to be taken:	Paragraph 1
Related document:	MEPC 67/6

Action requested of the Committee

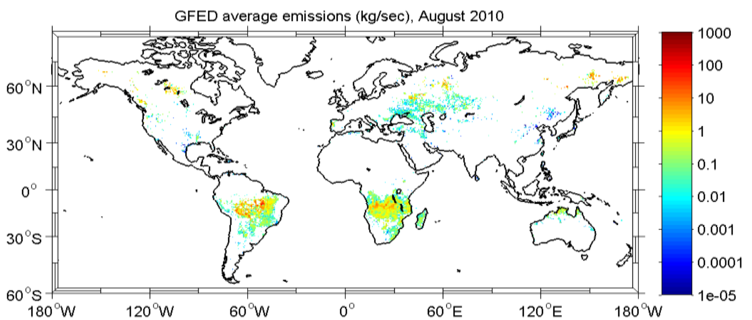
1 The Committee is invited to note the complete final report of the Third IMO GHG Study 2014, as the basis of the findings of the report's executive summary, set out in document MEPC 67/6.

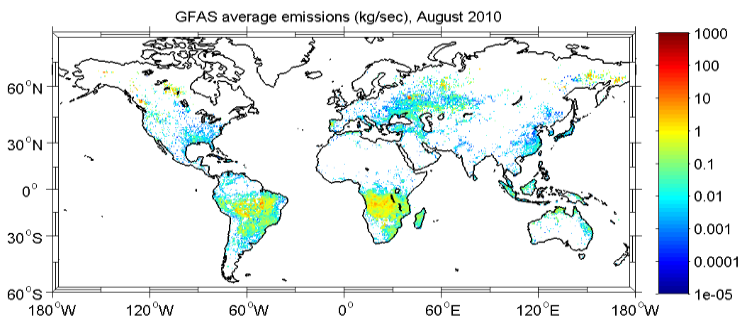
Fire information to emission: IS4FIRES

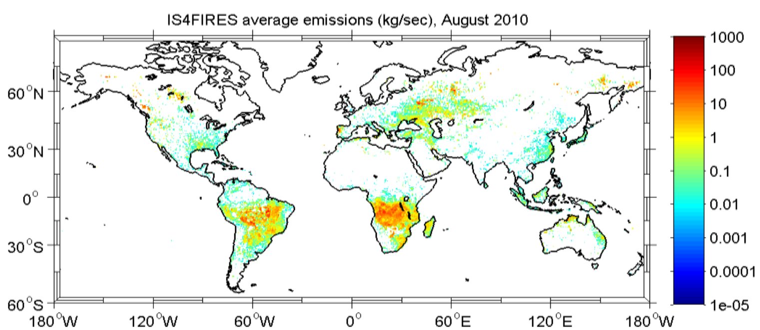
is4fires.fmi.fi



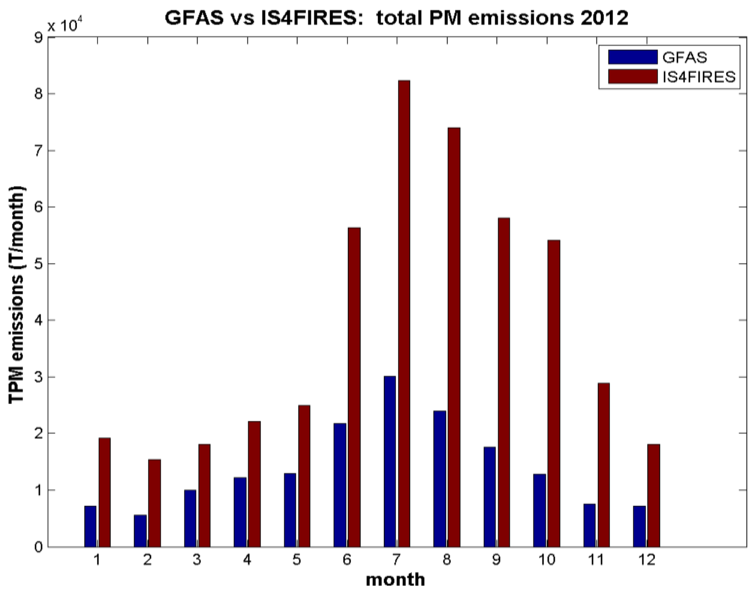
IS4FIRESv1: motivation for improvement



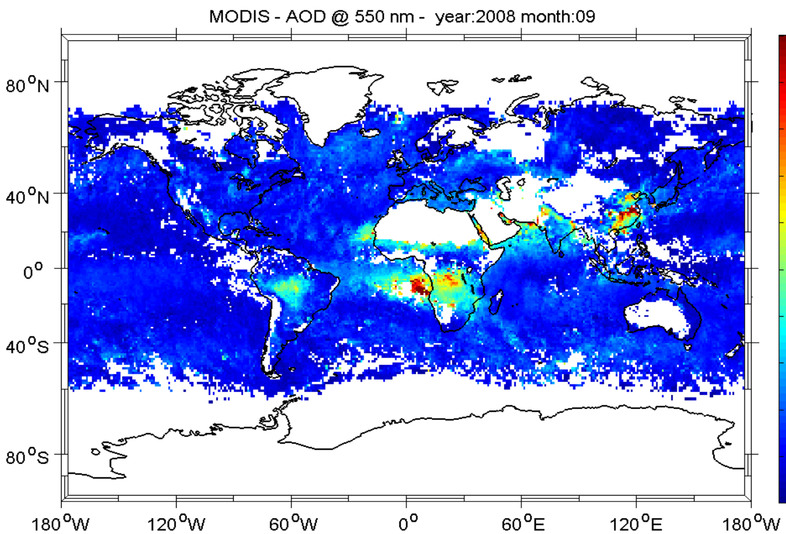


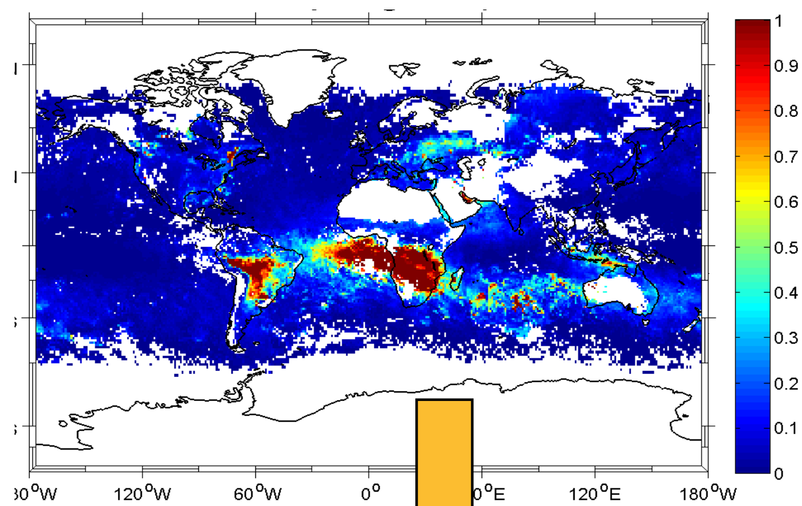


- ✓ actual-fire observations and empirical calibration gets 3-5 times the total emission of the GFED-like approaches.
- ✓ numerous small fires are visible when active but the burnt scars are probably too small to be distinguished.

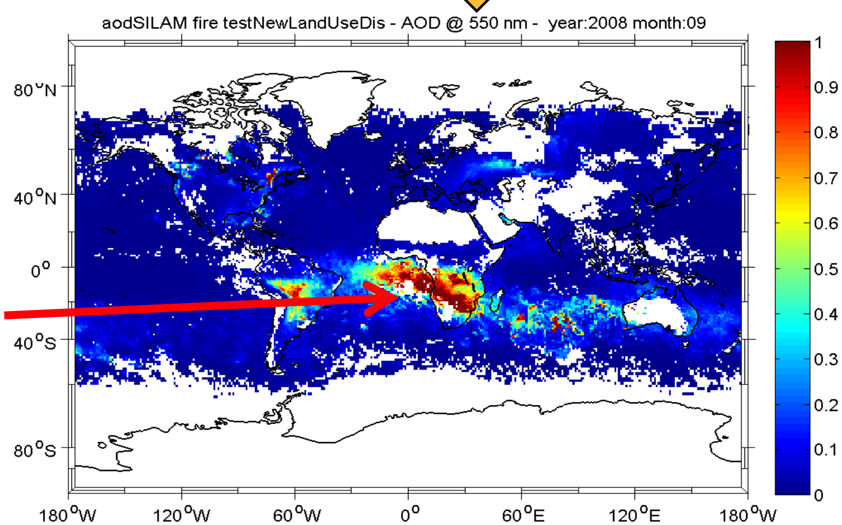


Land-use (re)distribution





Re-distribution

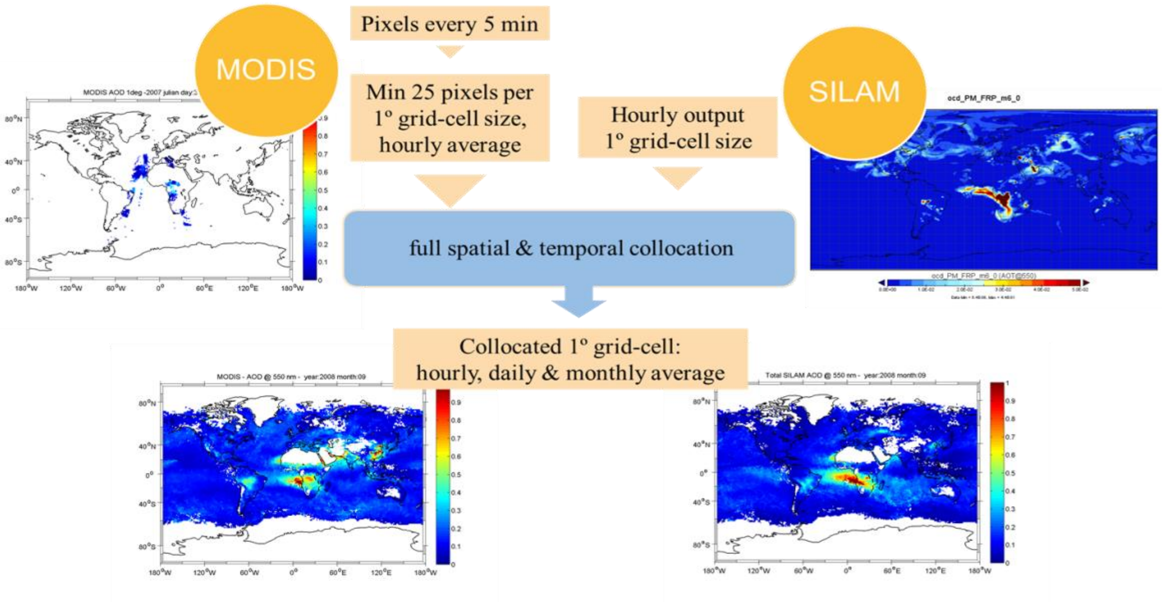


Misattribution contributes ~10%, in average, for the overestimation of the plumes.

Remains: under-representation of local phenomena facilitating fast dispersal of plumes such as deep convection

Validation

- ✓ Long-term reanalysis: 2002- 2012
- ✓ MODIS (AQUA & TERRA) vs modelled (SILAM) AOD @550nm

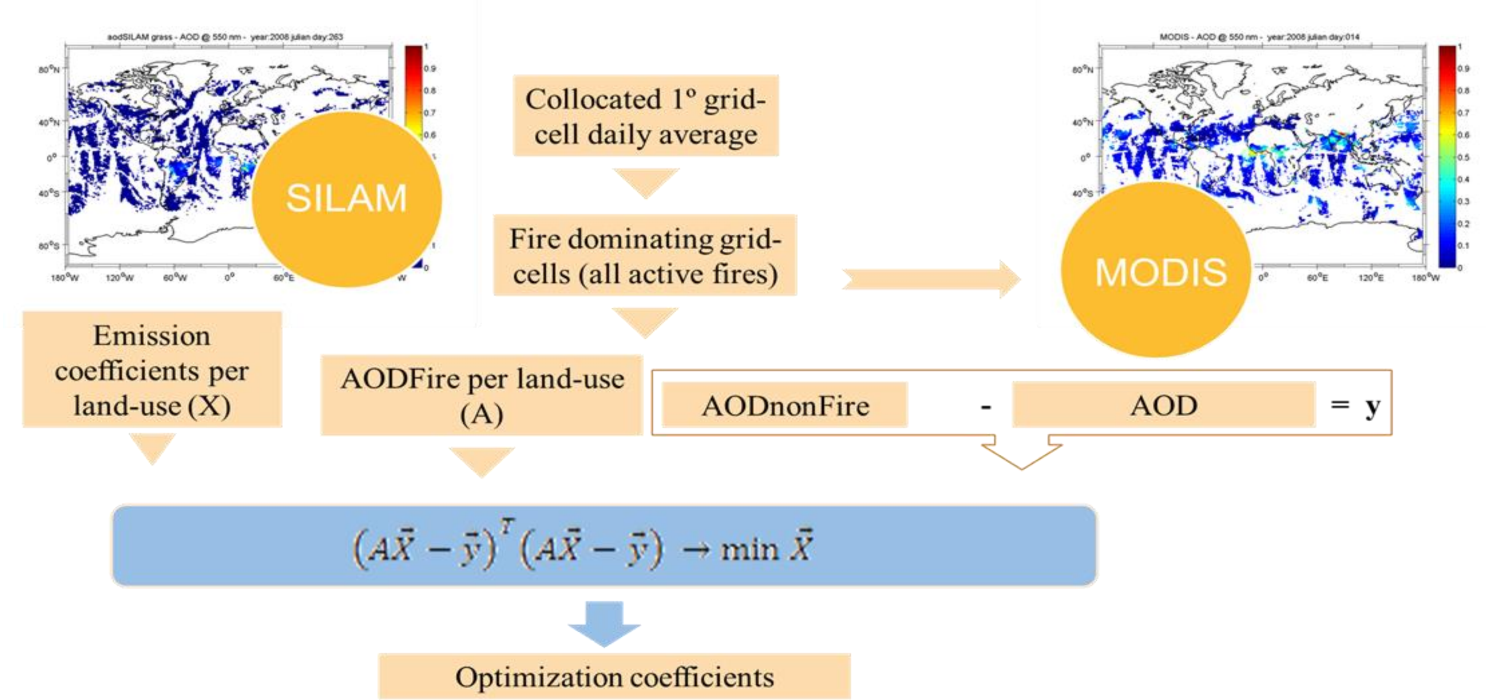


- ✓ **PM Emissions:** Fires, anthropogenic (MACCcity) & natural (sea salt, dust)
- ✓ **Meteorology:** ECMWF (91 vertical levels; 1ºx1º grid-cell size)
- ✓ **Spatial resolution:** 9 uneven vertical levels (up to ~10km); 1ºx1º grid-cell size
- ✓ **Time resolution:** 15 minutes internal, 1hr output

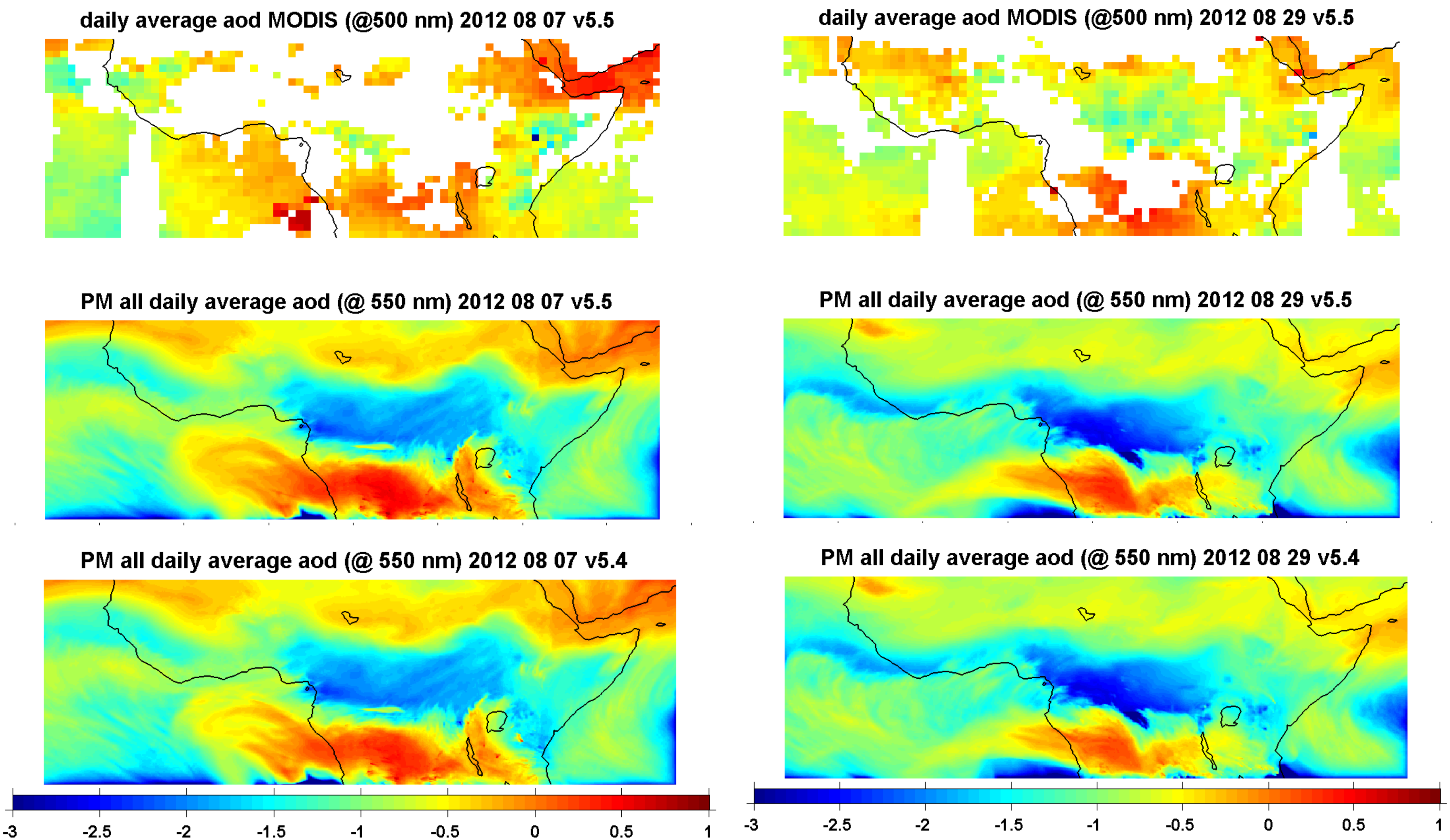
Emphasis: total-emission bias as the most-important parameter for large-scale assessment of the fire impact.

Optimization

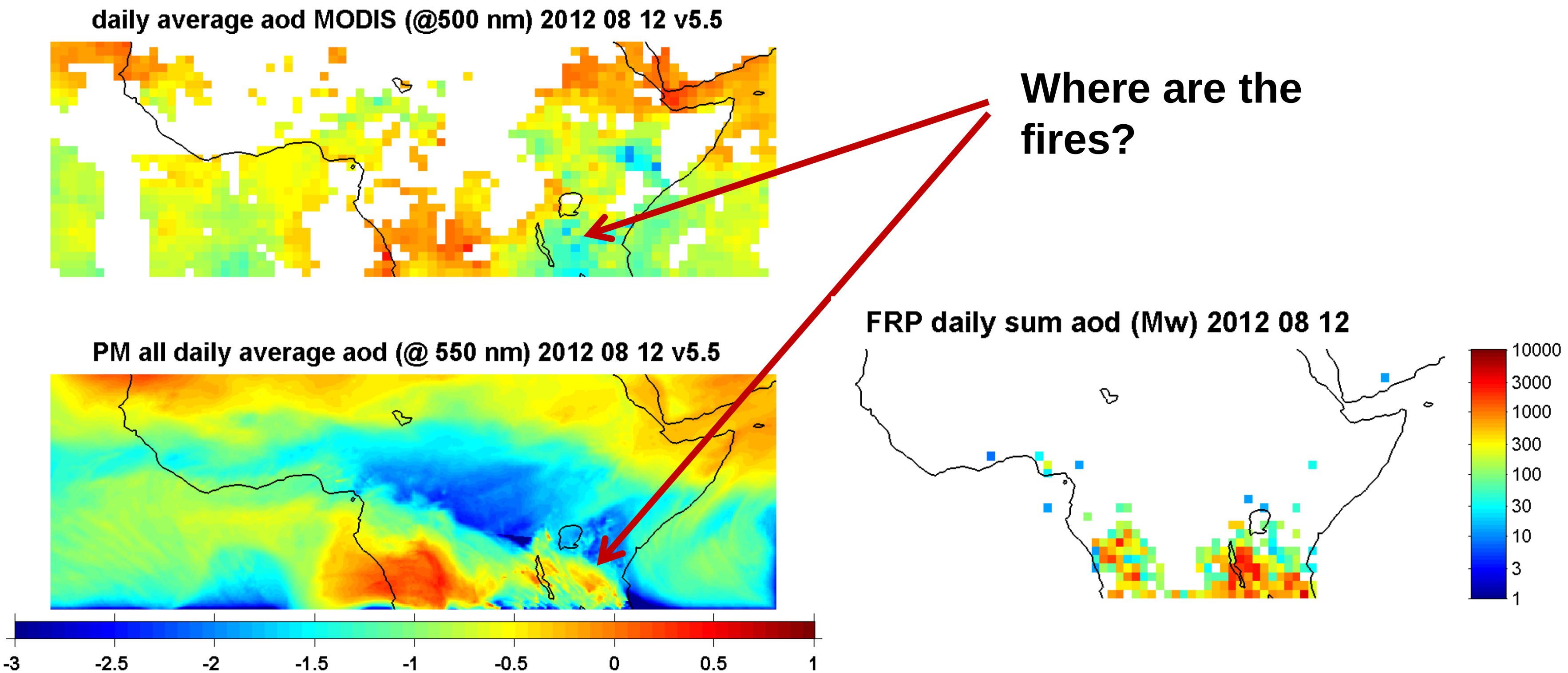
- ✓ Long-term reanalysis: 2002- 2012
- ✓ emission coefficients per land-use type
- ✓ MODIS (AQUA & TERRA) vs SILAM AOD @550nm



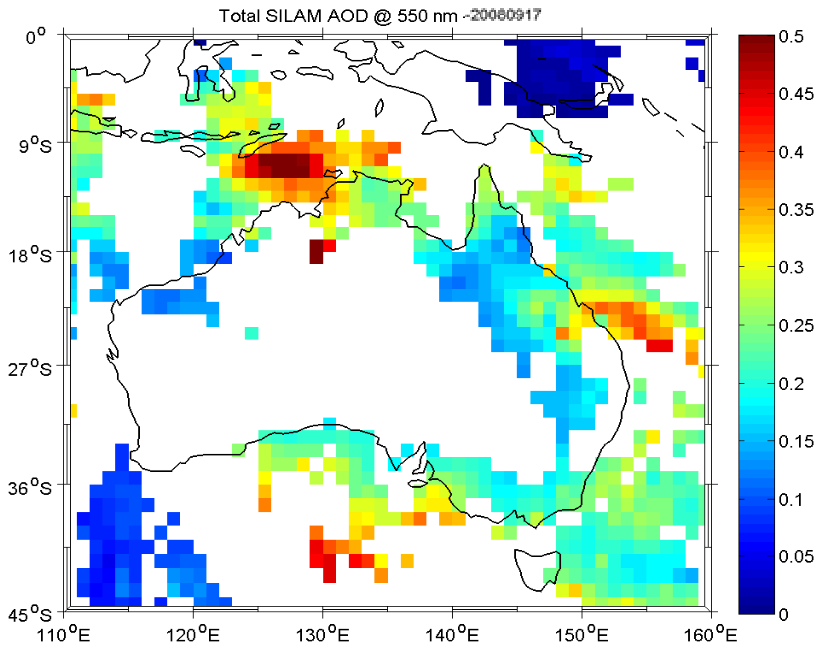
IS4FIRESv2 vs ISFIRESv3 vs MODIS

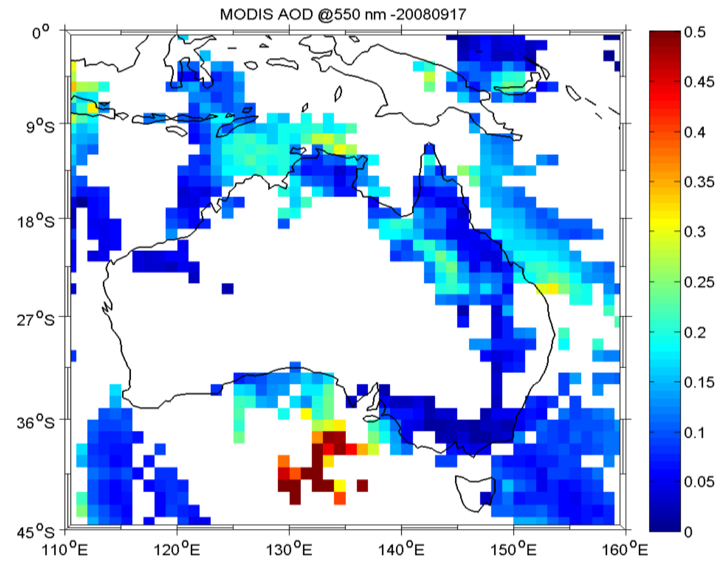


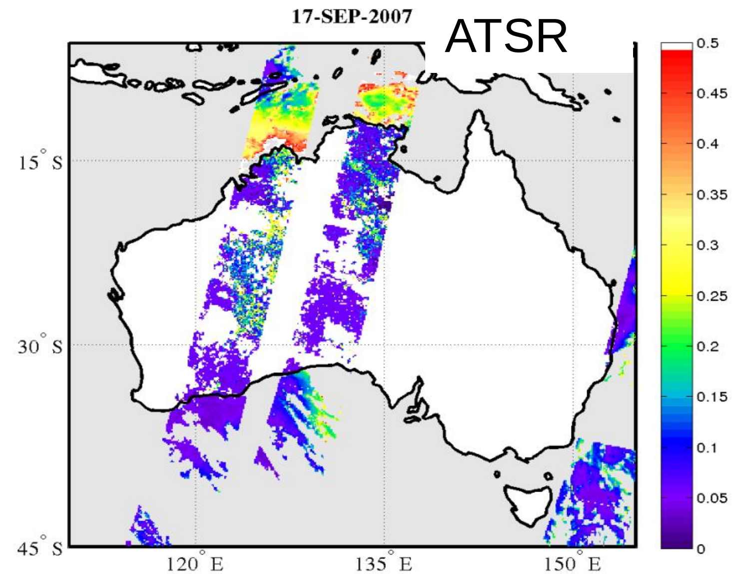
Open questions



Open questions







MODIS misses out some of the fire plumes, leading to over-reduction of the emissions

Most important airborne allergens in Europe:

- **Pollens:**
  - **Betula (birch)** – first pollen in SILAM
  - **Poaceae (grasses)**
  - **Olea (olive)**
  - **Ambrosia (ragweed)**
  - **Alnus (alder) –** added for this season
  - **Artemisia (mugwort) –** added for this season

Exist now in SILAM

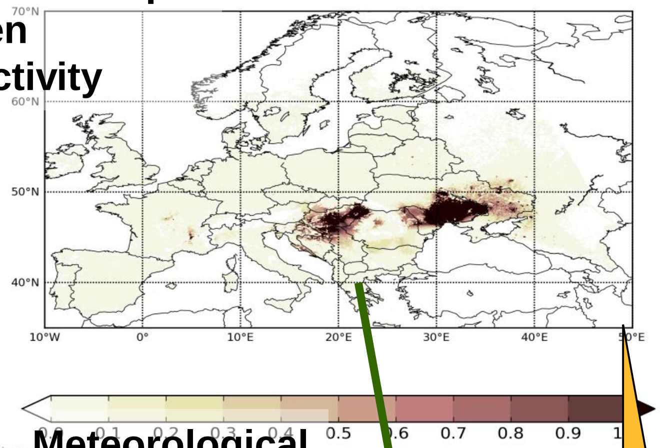
  - Chenopodiaceae (goosefoot family, beets etc)
  - Corylus (hazel)
  - Cupressaceae/Taxaceae (cypress, juniper, jew etc)
  - Platanus (plane)
  - Quercus (oak)
  - Urtica/Parietaria (nettle family)

To be implemented

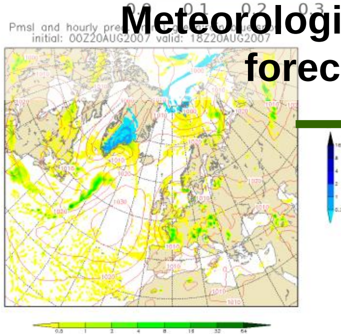
- Fungal spores:
  - Alternaria, chladosporium

How to model pollen dispersion?

Vegetation map + pollen productivity



Meteorological forecast



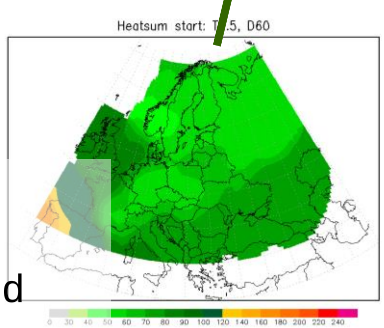
Dispersion model

SILAM

release

transport

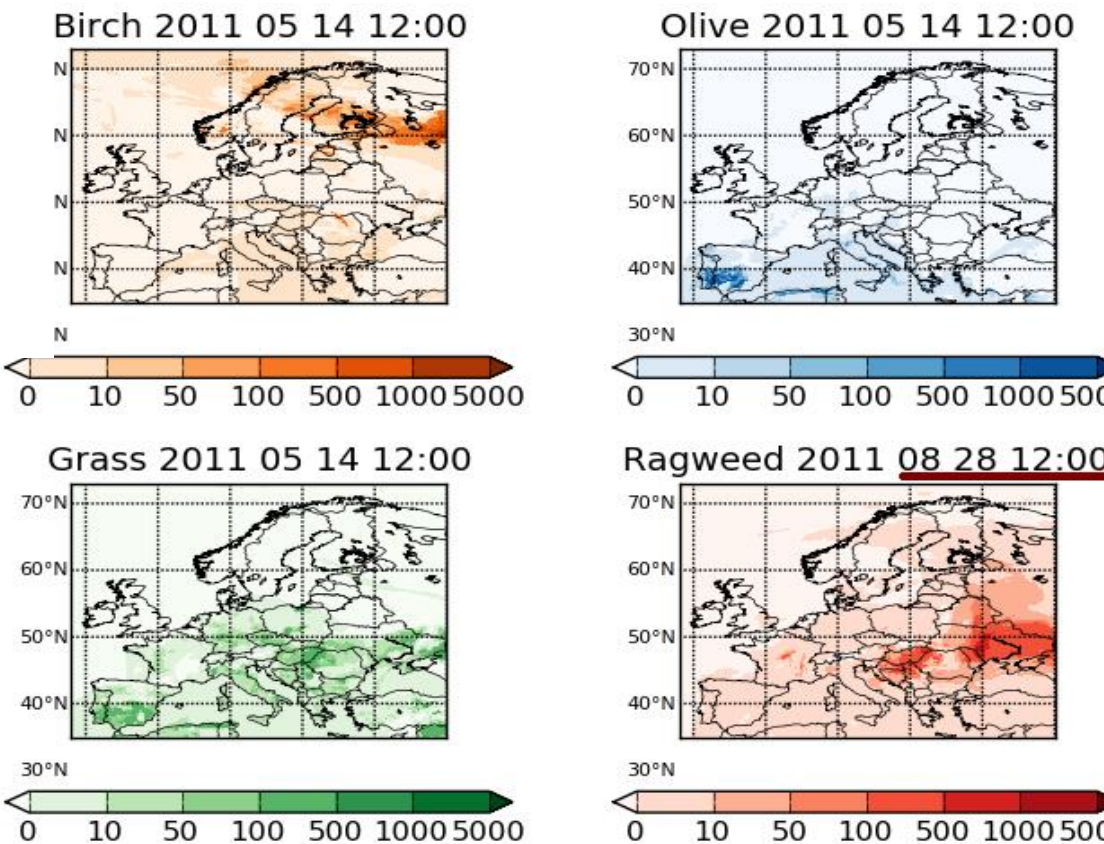
sinks



Flowering intensity

Multi-threshold model

Pollen concentration [#/m3]



Components of pollen emission model

- Habitat map
  - ➢ Climatic suitability
  - ➢ Land cover
- Phenological model
  - ➢ Dependencies of the timing of flowering on external forcings
  - ➢ Ripening of the pollen grains in inflorescences
- Model for pollen release from the inflorescences
  - ➢ Wind & turbulence
  - ➢ Plants can regulate pollen release to prefer good transport conditions

Phenological model

- SILAM currently allows several parameters to influence the flowering:
  - accumulated temperature (degree days, degree hours)
  - photoperiod (calendar day)
  - soil humidity (drought)
  - instant temperature (frosts)

- All trees are represented as temperature-sum dependent species.
- Annuals are assumed to mainly depend on photoperiod

- Calibration ideally based on phenological data
  - Pollen counts if phenology not available

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Model performance

	Birch	Grass	Olive	Ragweed	Mugwort	Alder
Seasonal pollen index						
Correlation	0.52	0.02	0.66	0.91	0.72	0.65
Norm bias	-0.19	1.53	-0.06	0.08	0.02	-0.09
Start 5% day						
Bias (days)	0.31	4.60	-9.51	3.02	4.49	-0.47
<3Day	0.50	0.25	0.28	0.54	0.39	0.35
<7Day	0.73	0.46	0.46	0.81	0.69	0.55
End 95% day						
Bias (days)	2.25	-2.00	-18.89	-1.53	-5.69	-13.11
<3Day	0.38	0.20	0.19	0.45	0.27	0.23
<7Day	0.61	0.40	0.36	0.77	0.51	0.40

Seasonal pollen index (***SPI***) sum of daily average pollen concentrations over the flowering season

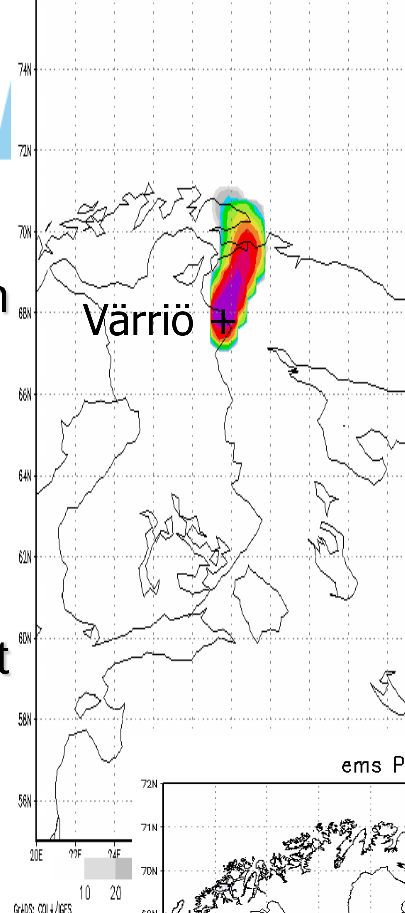
Norm. bias – bias/observed average concentration

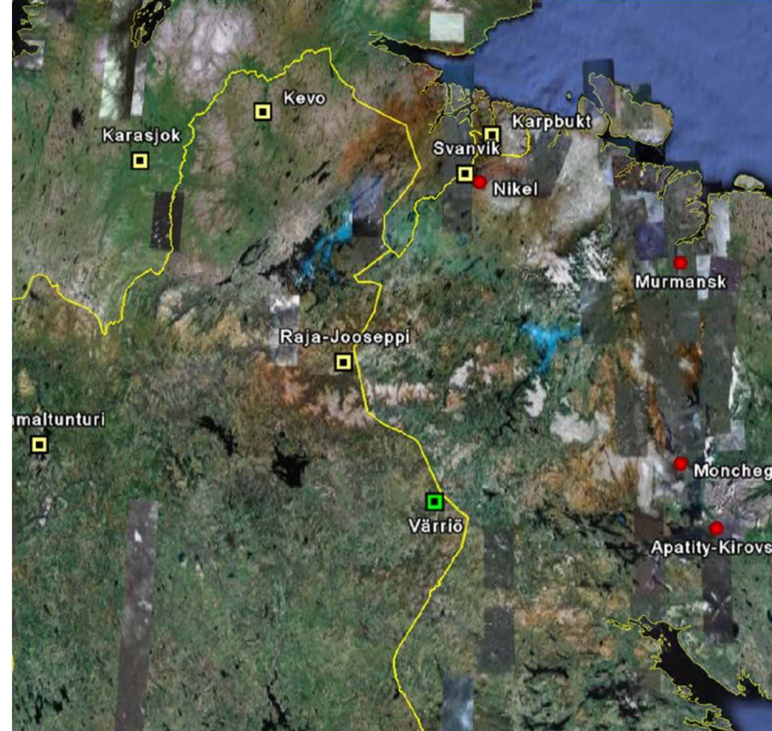
Season start/end – day when 5/95% of SPI has been rached

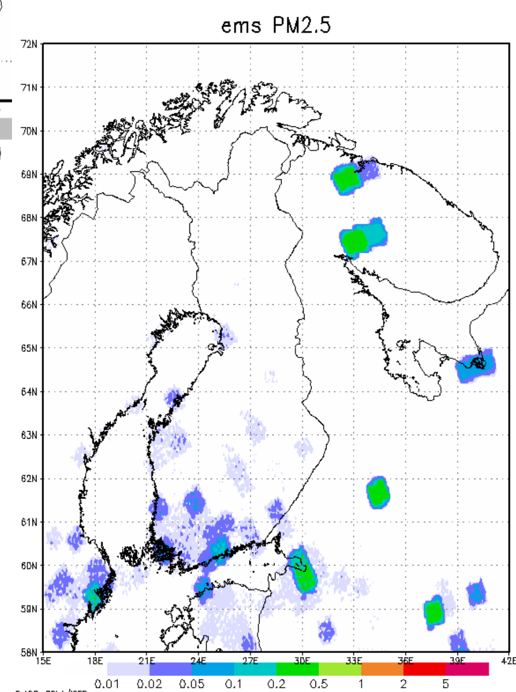
<3Days, <7Days – Fraction of cases when model is within 3/7 days from the observed season start/end

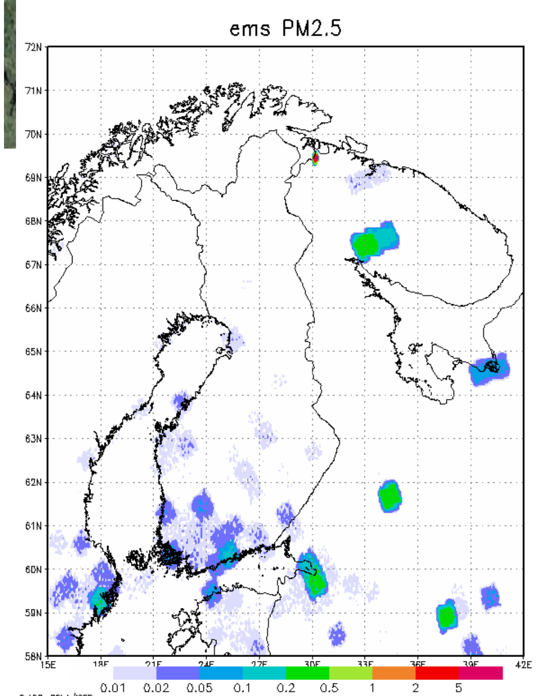
Birch – flowering model calibrated on real phenological data
Ragweed – habitat map from ecological modelling
Olive – no calibration for source map
Grass – many different species, soil water ignored, no calibration with pollen counts

- SILAM failed to reproduce an aerosol peak observed in a measurement campaign in Värriö
- Inverse modelling showed the peak originating from the area of Nikel metallurgy plant
- No emissions were reported in Nikel location in EMEP database, while large industrial emissions were reported around Murmansk
- In the revised emission data the emissions related to large industry were moved from Murmansk to the location of the Nikel plant

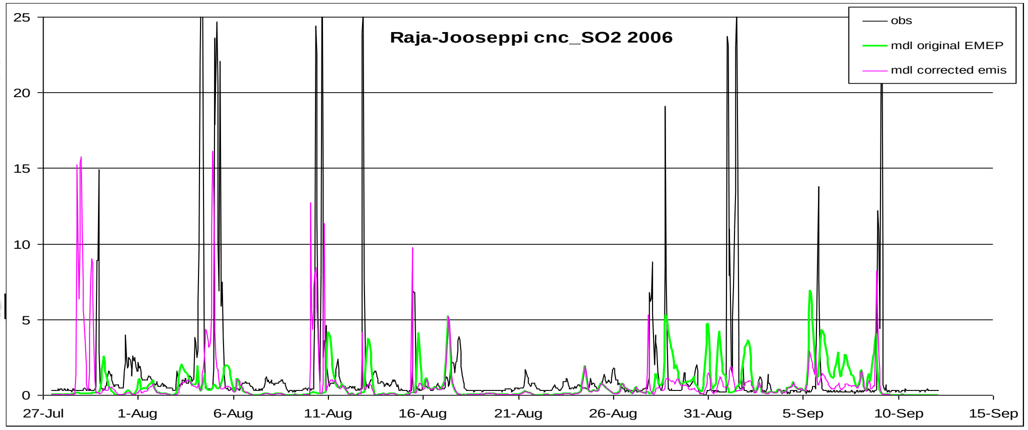


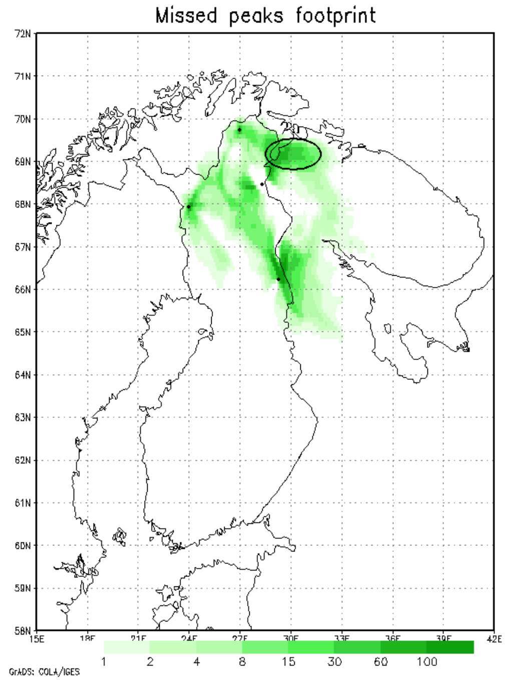






- SILAMs ability to reproduce the SO_2 peaks in nearby stations improved considerably with the refined emissions
- SO_2 and sulphate concentrations wer still underestimated
- Inverse modelling indicated that the underestimation was related to the emissions in the Nikel location
- Too sparse observations and too large model uncertainties did not allow further refinement of the emission data
- SO_2 emission estimates published by AMAP and Nikel plant operators that we were not aware of during the study, were 25-30% higher than our estimate, confirming the results of the inverse modelling





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Conclusions

- Developing, correcting and fine-tuning emission models is one of the main tasks of model developer ?!
- Although some important improvements in advection algorithms ,numerics (parallelization) , deposition routines , chemistry, aerosol process modules etc. has taken place in past few years..

the **real/major** improvements are related to emission modelling:

- completly new models : ship emission, pollen..
- improved modelling: forest fires, sea salt..