Hydrologic response to Black Carbon deposition in seasonally snow covered catchments in Norway

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John F. Burkhart [1,2]

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UiO : University of Oslo

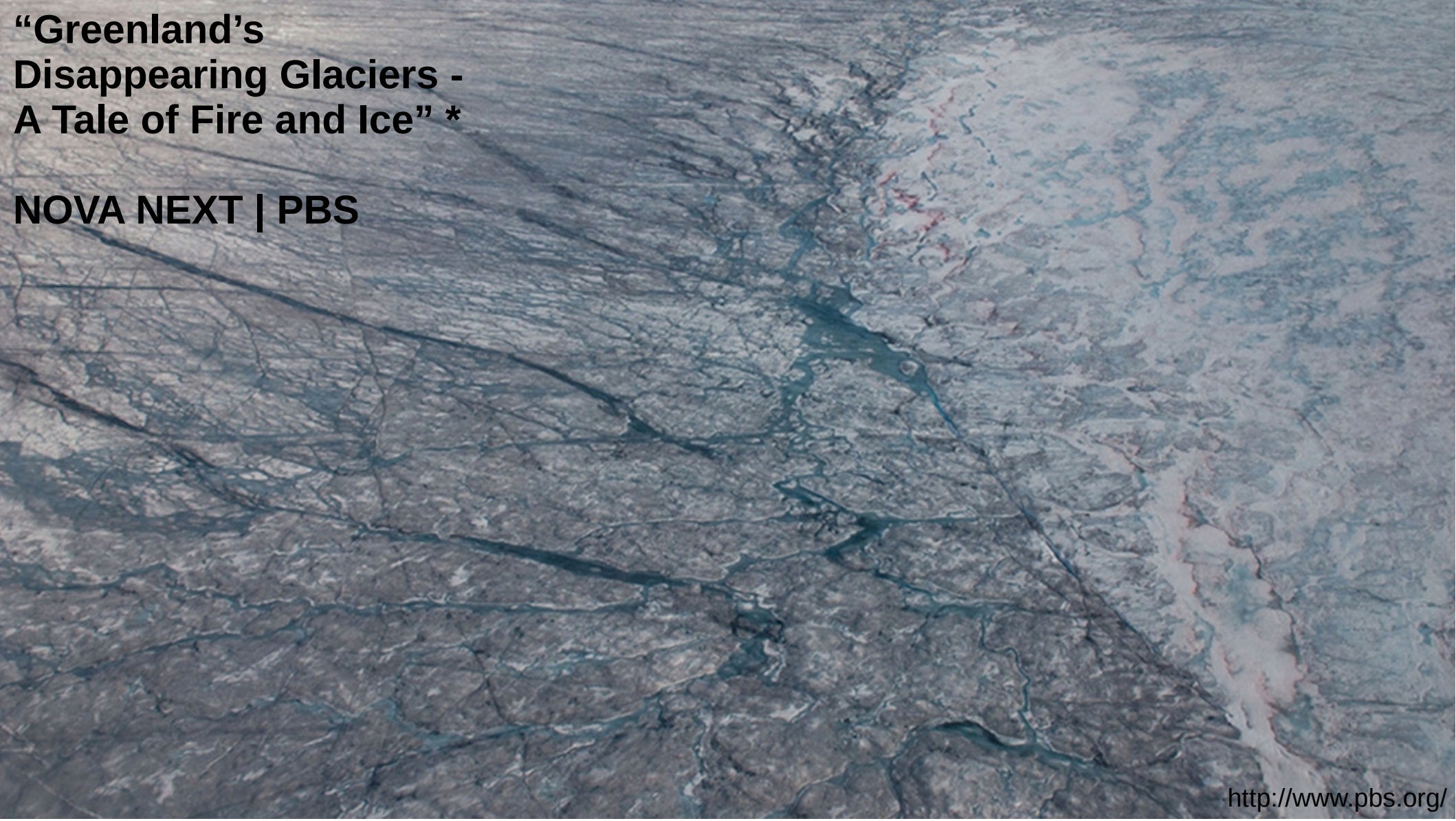
2 Statkraft

The Research Council of Norway

With funding from
The Research Council of Norway

“Greenland’s Disappearing Glaciers - A Tale of Fire and Ice” *

NOVA NEXT | PBS



* Article by Hannah Hoag; 19/05/2014;
http://www.pbs.org/

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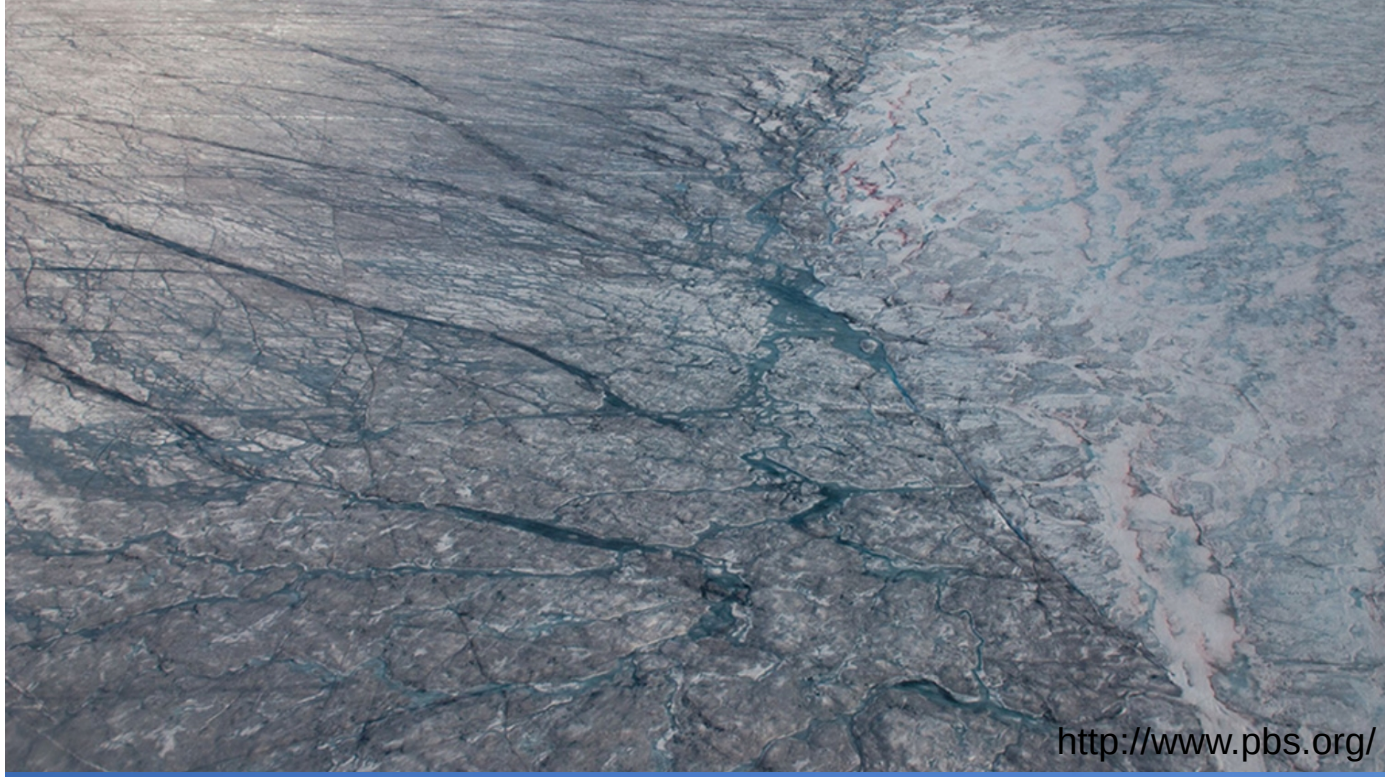


Photograph: John F. Burkhart; Summit Greenland

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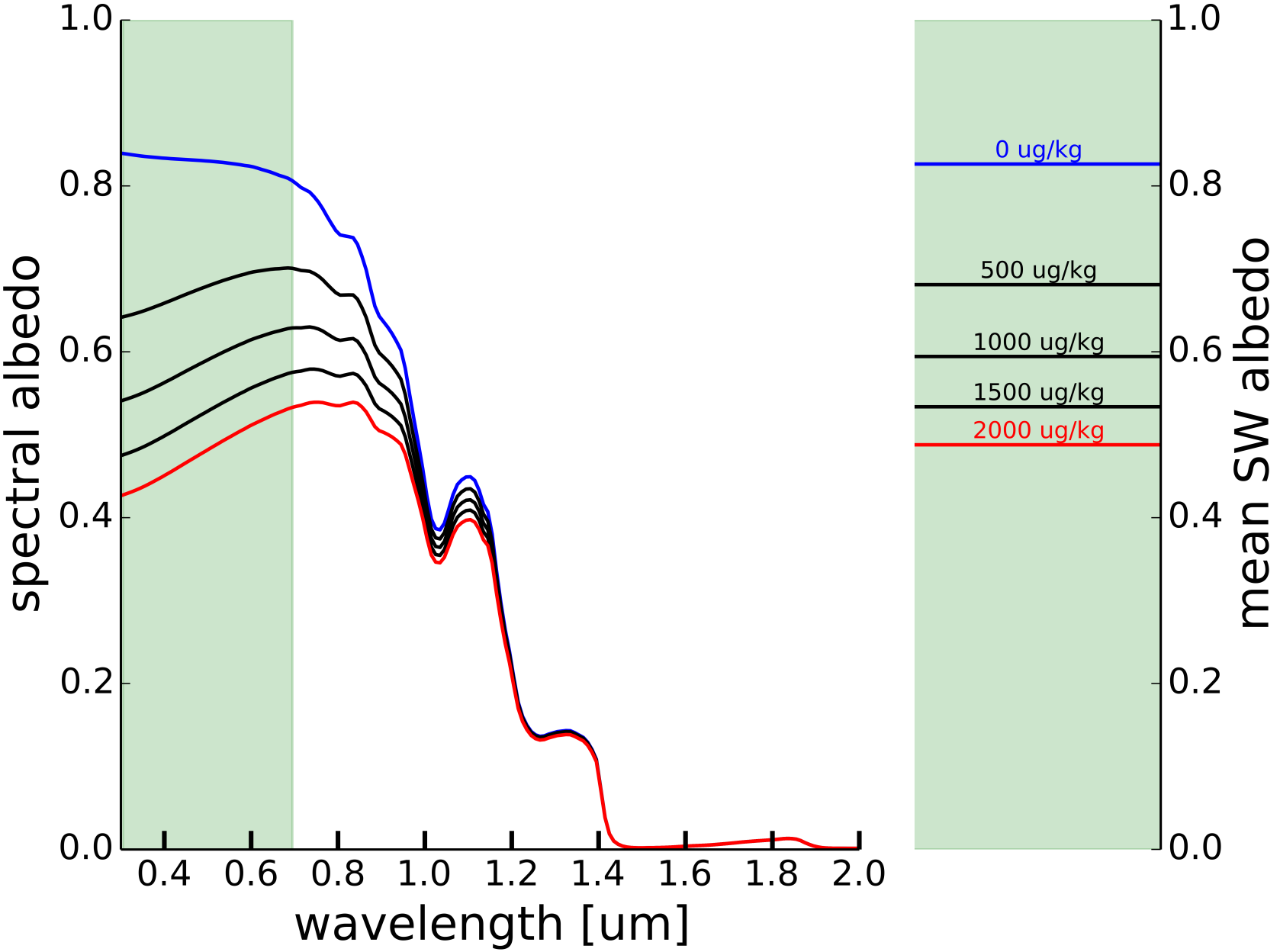
BC in snow



Simulations with the SNICAR model; Flanner et al., 2007; Flanner et al., 2009

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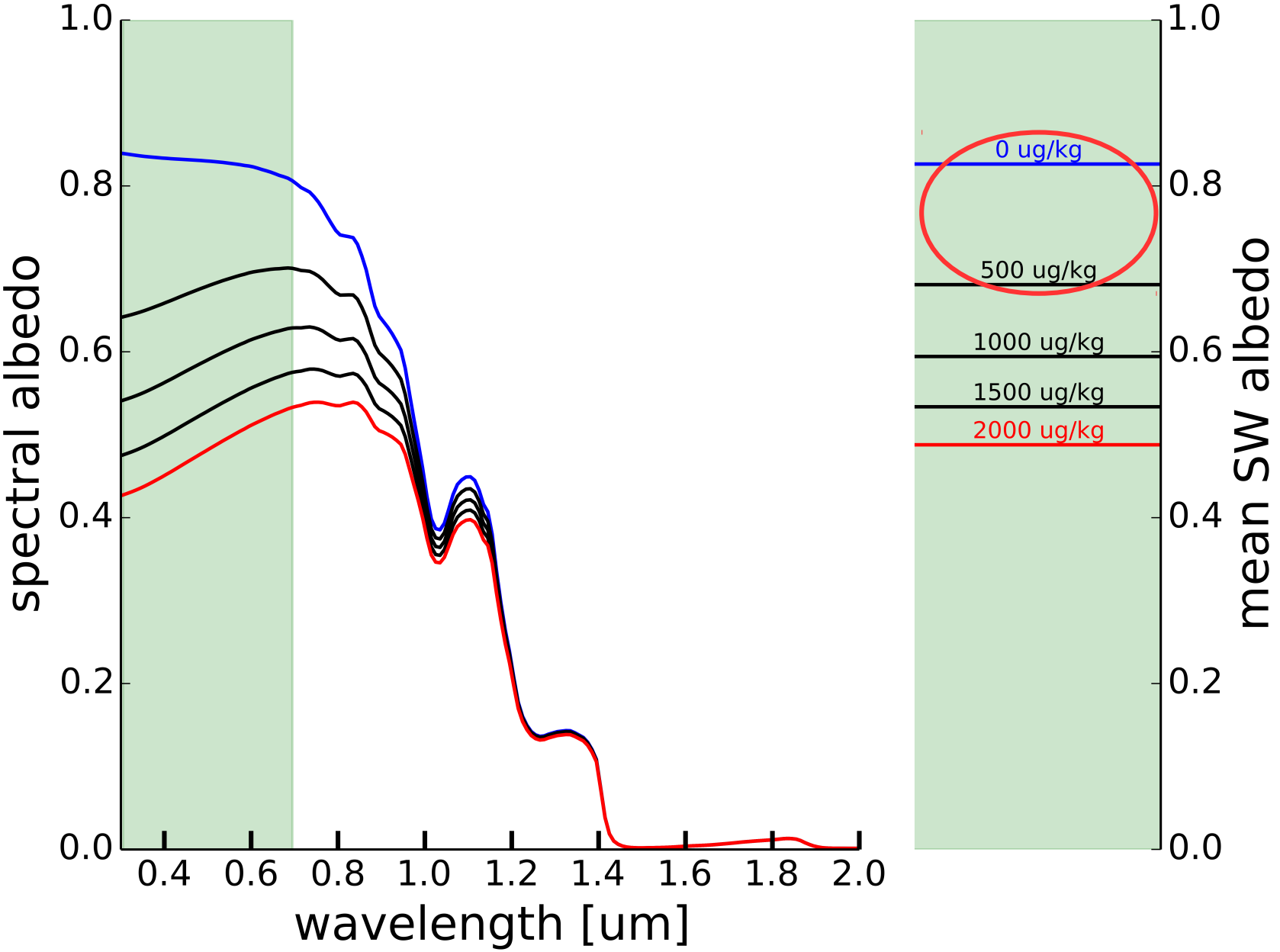

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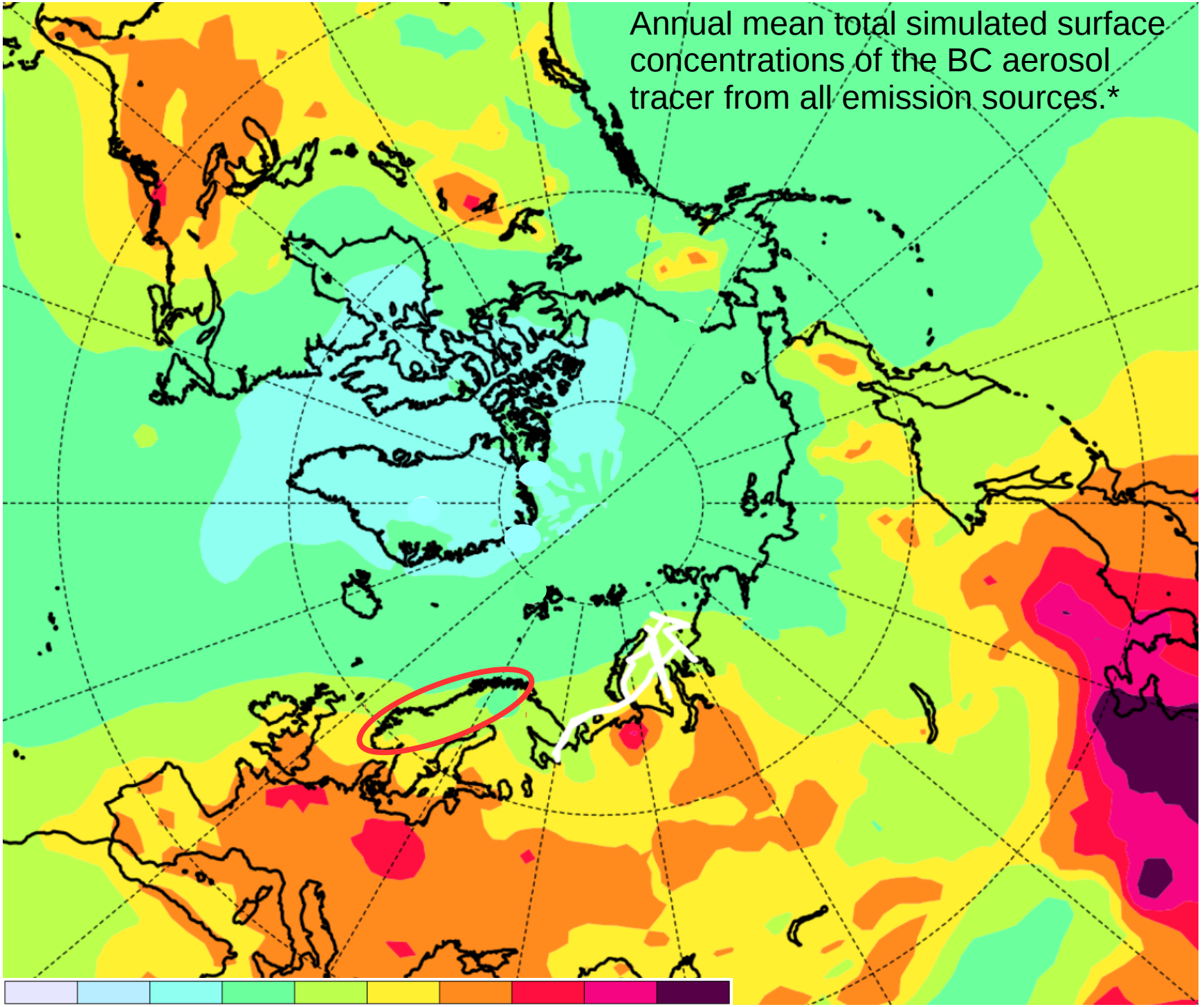

* From Stohl et al., 2013: Black carbon in the Arctic: The underestimated role of gas flaring and residential combustion emissions

Outline

- Methods
  - Models
  - Coupling
- Hydrologic simulations
  - Catchments and input data
  - Preliminary Results
- Caveats and Conclusion

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Methods - Models

Distributed hydrological model:

ShyFT Statkraft's Hydrologic Forecasting Toolbox [1)]

- Priestley Taylor for potential evaporation [2)]
- Snow storage and melt via depletion curve [3)]
- Kirchner model for discharge [4)]
- NO routing (!)

1) https://github.com/statkraft/SHyFT
2) Priestley and Taylor (1972)
3) Kolberg and Gottschalk (2010)
4) Kirchner (2009)

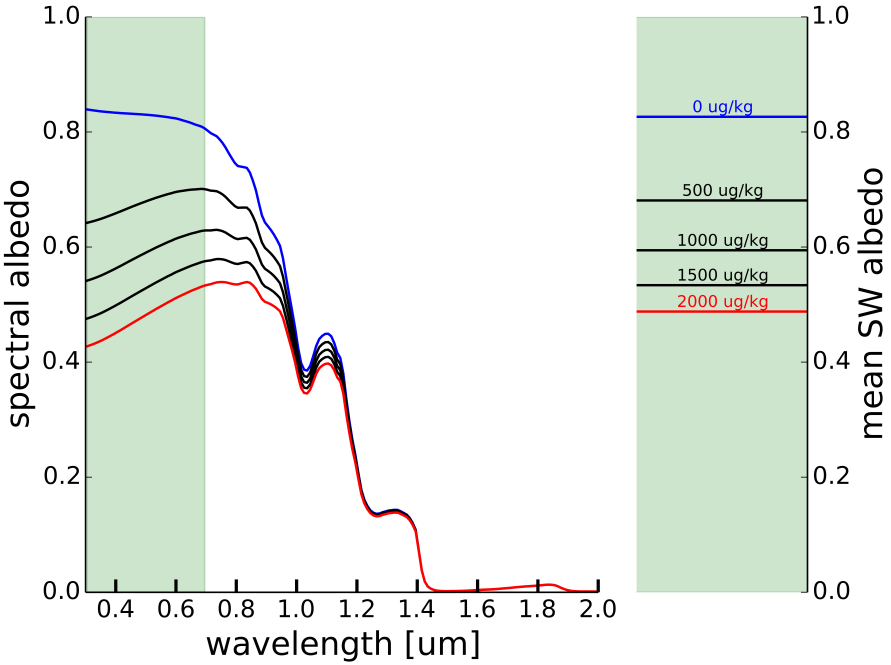
Methods - Models

Radiative Transfer model for snow:

SNICAR* - Snow, Ice, and Aerosol Radiation model

Hemispheric reflectance of snow from

- impurity content:
  black carbon, dust, and volcanic ash
- snow optical grain size
- incident solar flux characteristics



* Flanner et al., 2007; Flanner et al., 2009

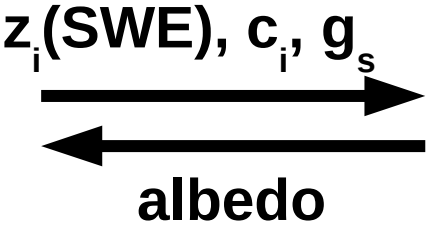
Methods - Coupling

Snow routine

- Grain size model

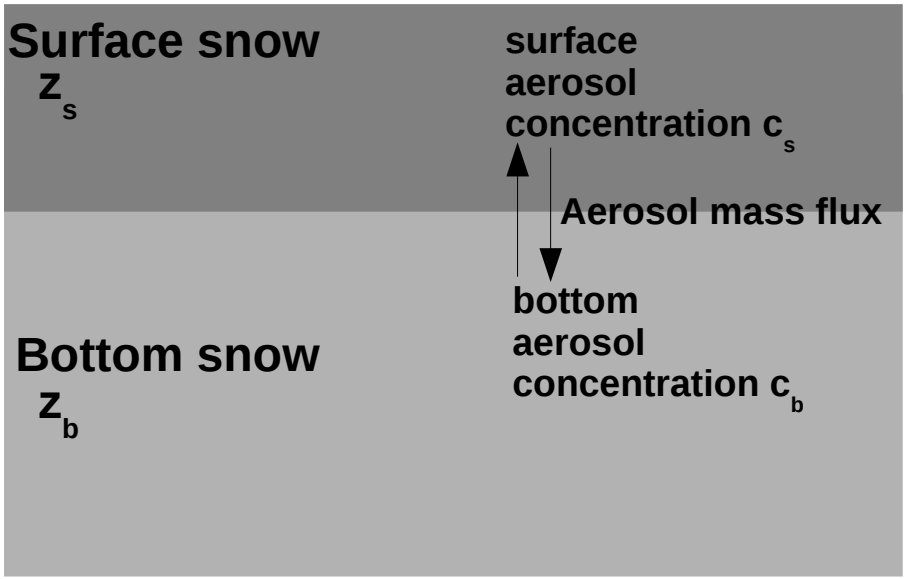
$$\frac{g_s}{dt} = f(T)$$

- Aerosol concentration model *



SNICAR

implementation with 5 spectral bands



*** From Krinner et al., 2006: Ice-free glacial northern Asia due to dust deposition on snow**

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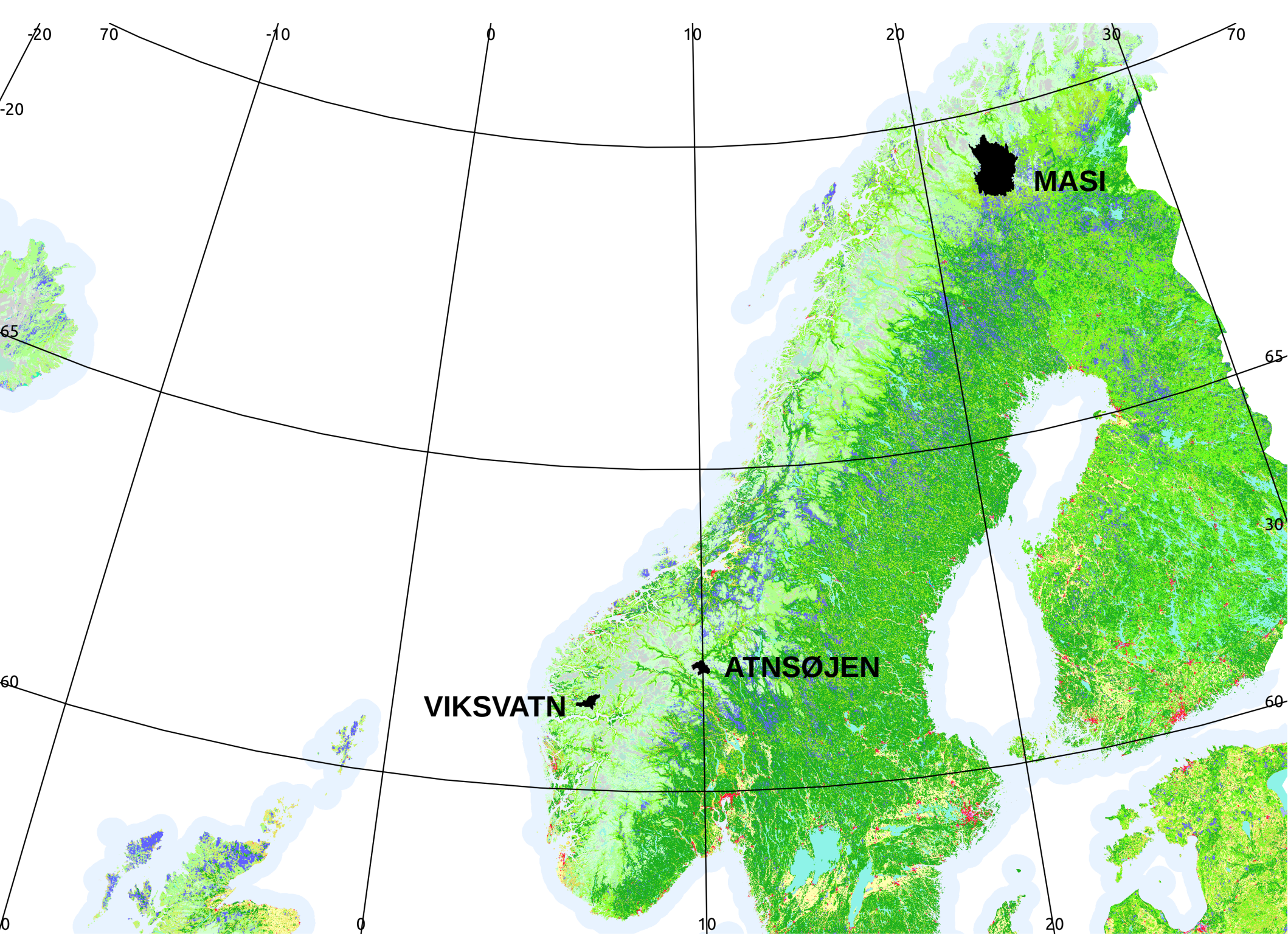
MASI
ATNSØJEN
VIKSVATN

Input data

DATA TYPE	SOURCE	INTERVAL
Discharge	**Observations** from NVE	2006 - 2012
Meteorological forcing - Temperature - Precipitation - Relative humidity - Wind speed	**Observations** from Met.no + NVE	2006 - 2012
Radiation (SW)	**WATCH-Forcing-Data (**EI)	2006 - 2012
BC deposition data	**Flexpart (ECLIPSE data set)** **Remo-Ham (ECLIPSE data set)**	2008 - 2010 2010 - 2012

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MODEL SCENARIOS

- Model Calibration with different deposition input
  - FLEXPART
  - REMO-HAM
  - CLEAN (no deposition)
    - still dynamic albedo model!
- Effect of Black Carbon on hydrology
  - Comparison of simulations with deposition (FLEXPART and REMO-HAM) to CLEAN case

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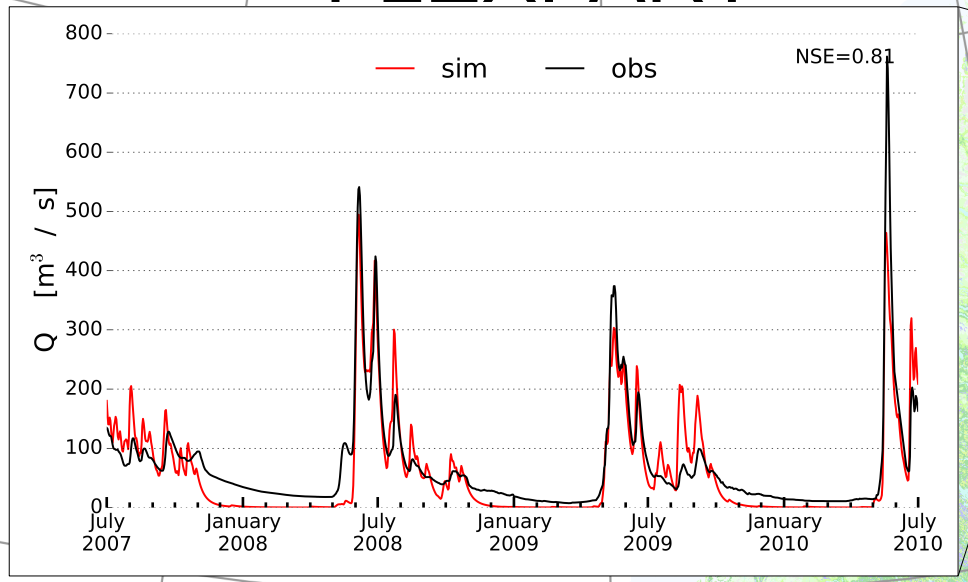
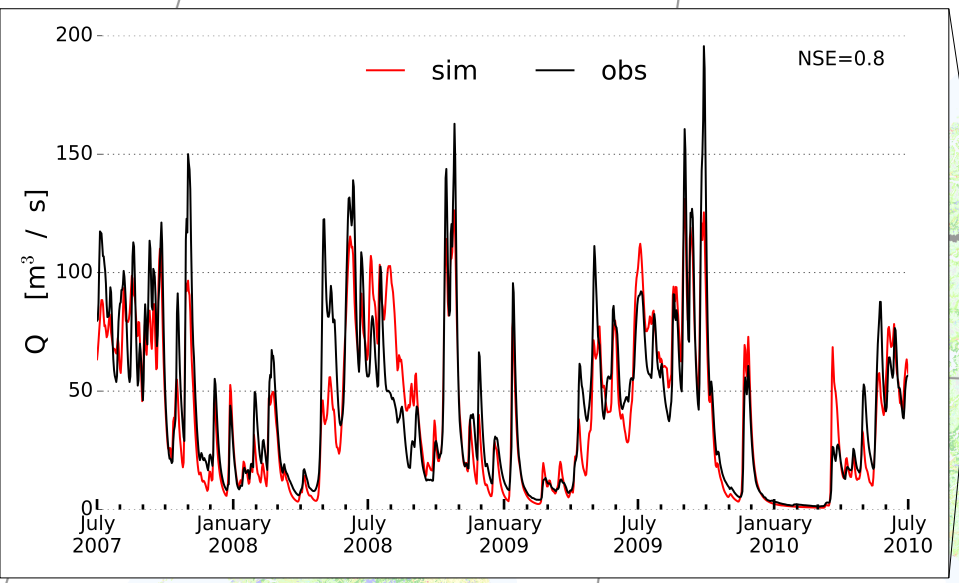
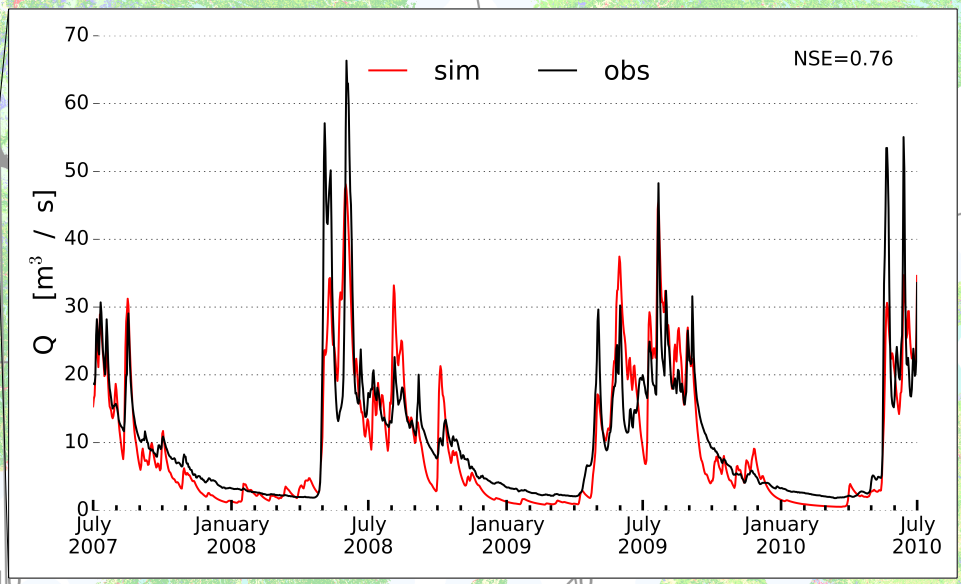
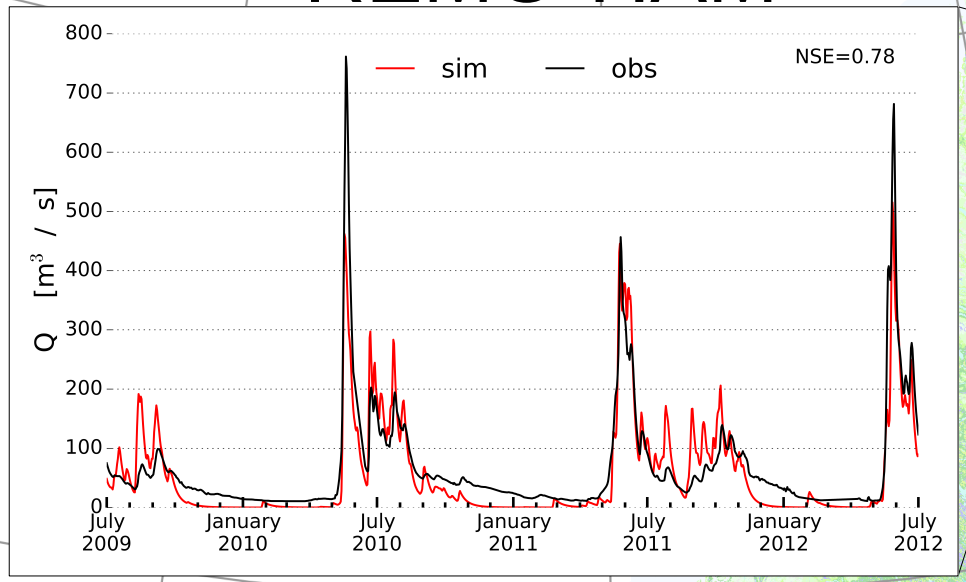
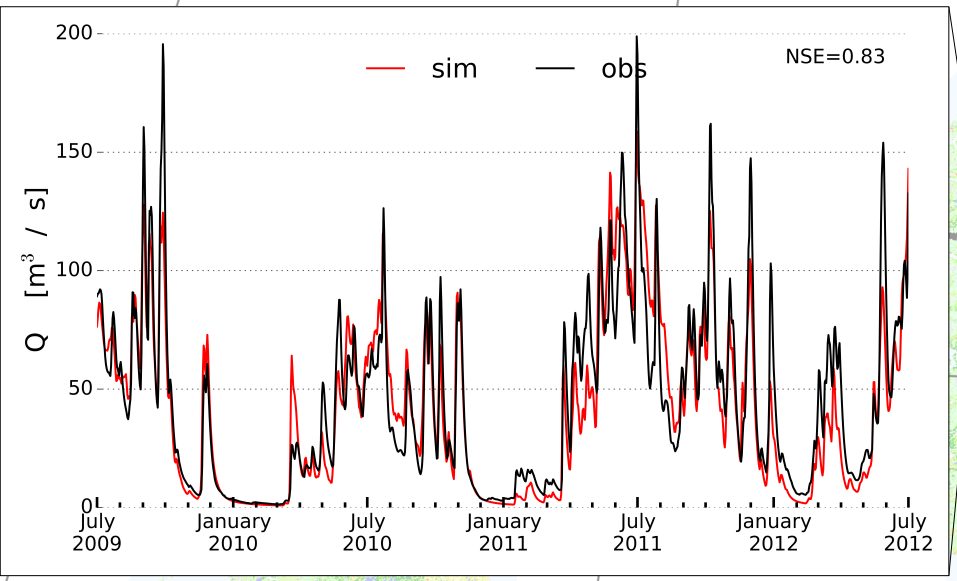


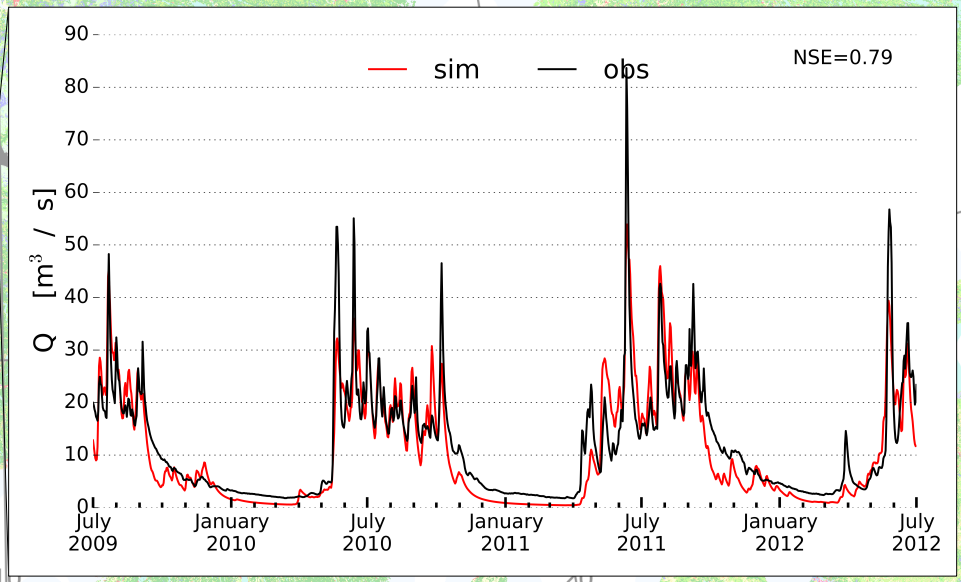




Model Calibration with different deposition input REMO-HAM







Model Calibration with different deposition input

Nash-Sutcliffe model efficiency (calibration):

	CLEAN	FLEXPART	Remo-HAM
Atnsjoen	**0.73**	**0.76**	**0.79**
Viksvatn	**0.76**	**0.80**	**0.83**
Masi	**0.53**	**0.81**	**0.78**

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- Including BC deposition makes a difference!
- Simulations seem to be better when BC is included!

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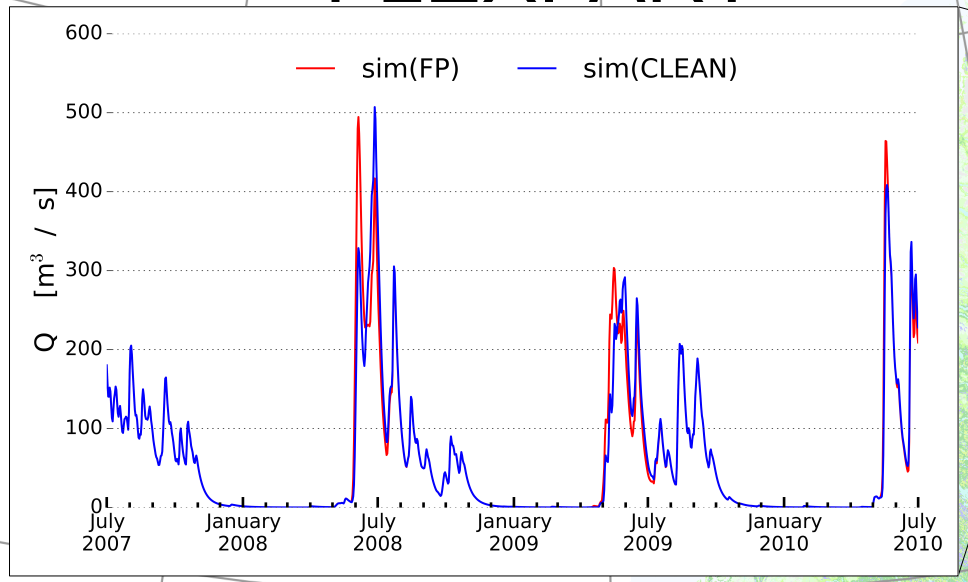
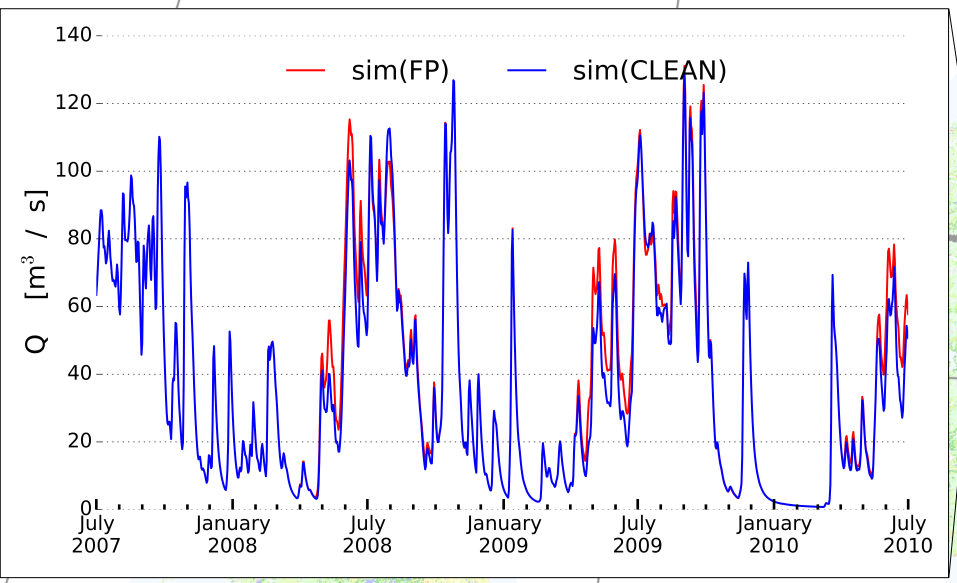
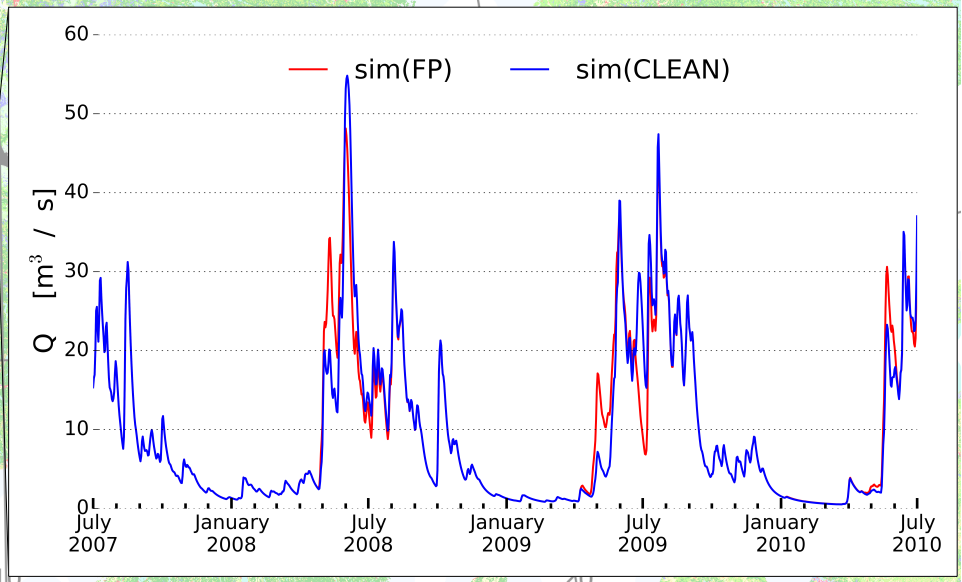
Effect of BC on catchment hydrology FLEXPART



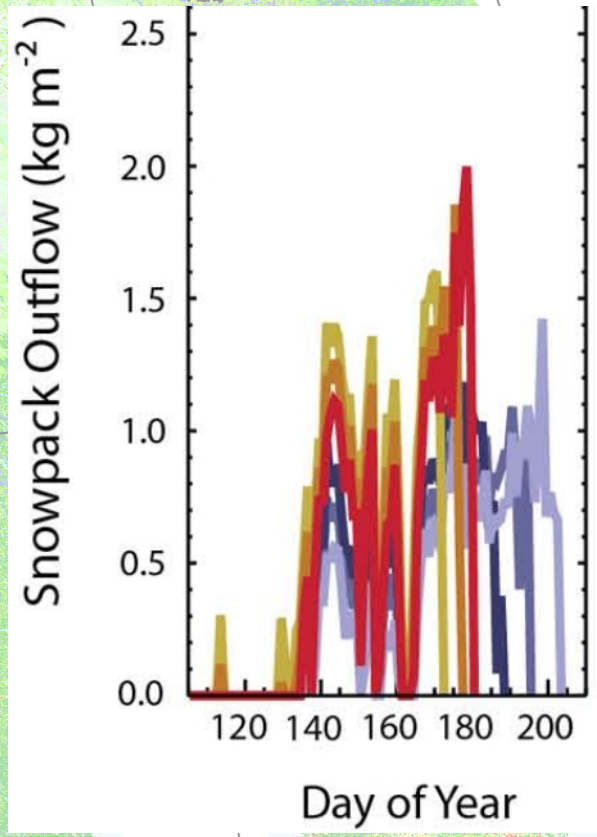




Effect of BC on catchment hydrology

1-D model study by Skiles et al. (2012) *:

“The clean snow cases reach a lower peak 1 to 2 weeks after the …” [cases with aerosol forcing] “... with a less rapid decrease to melt-out ...”



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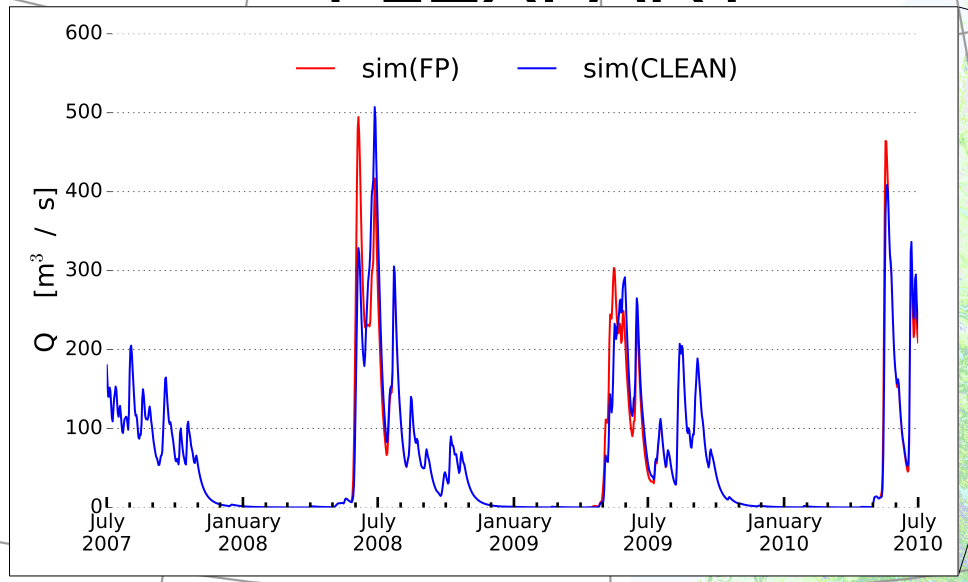
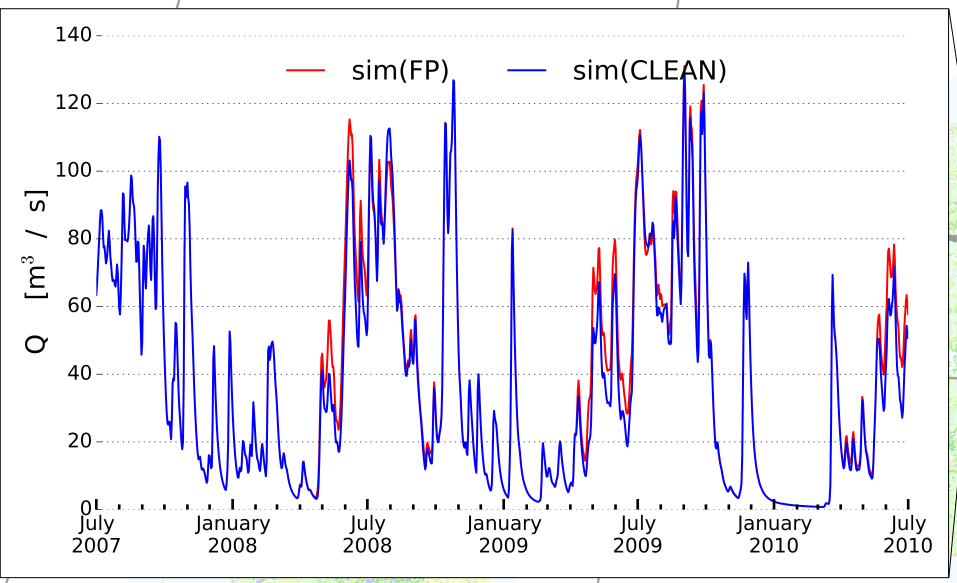
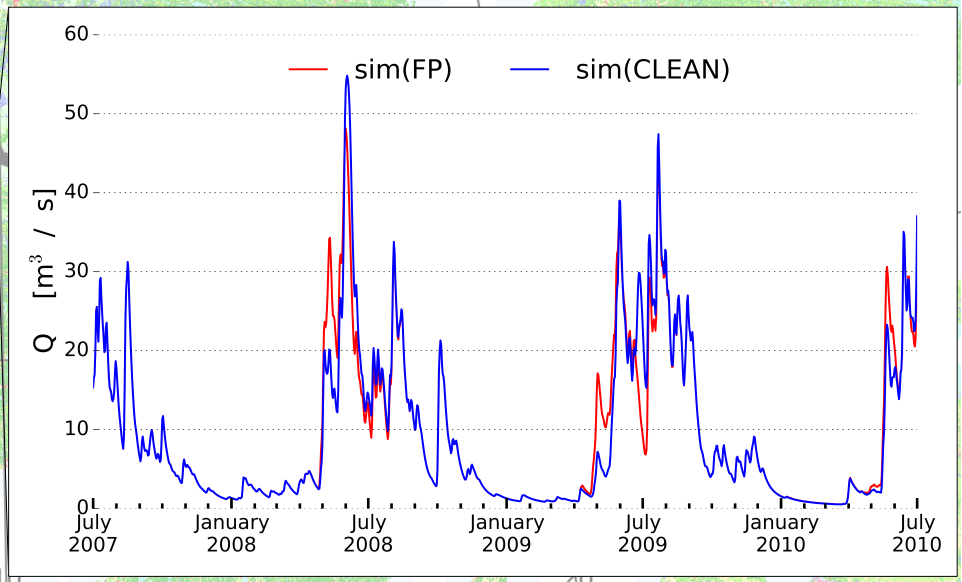
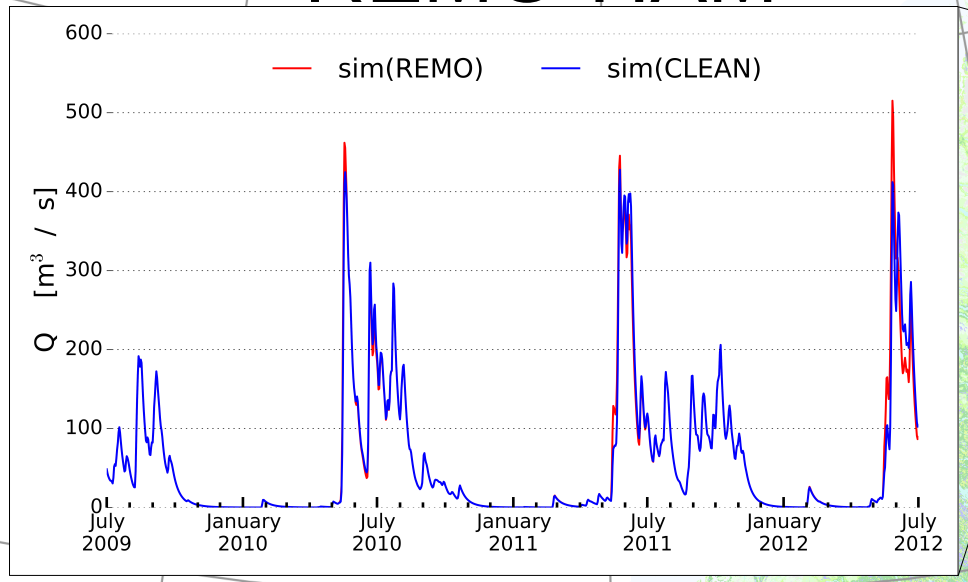
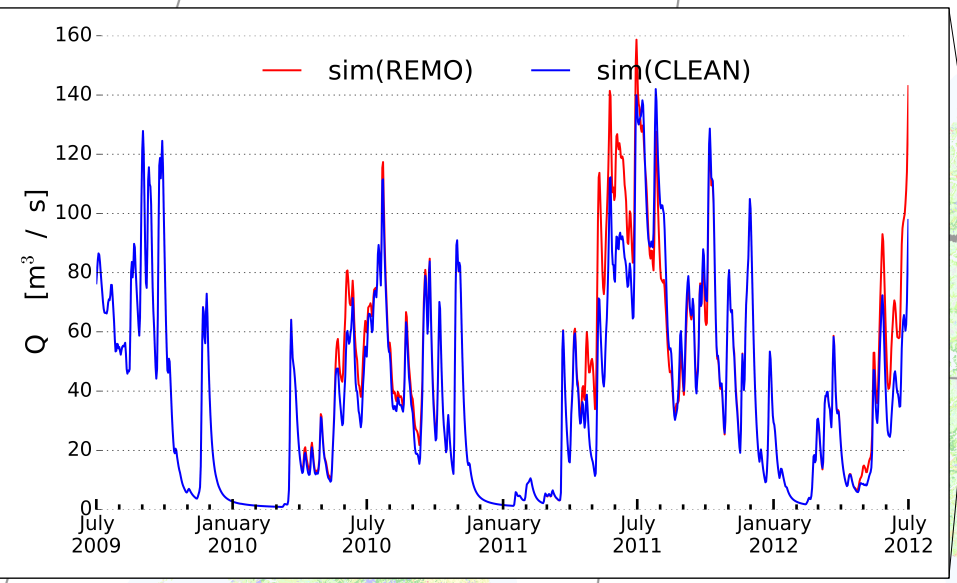


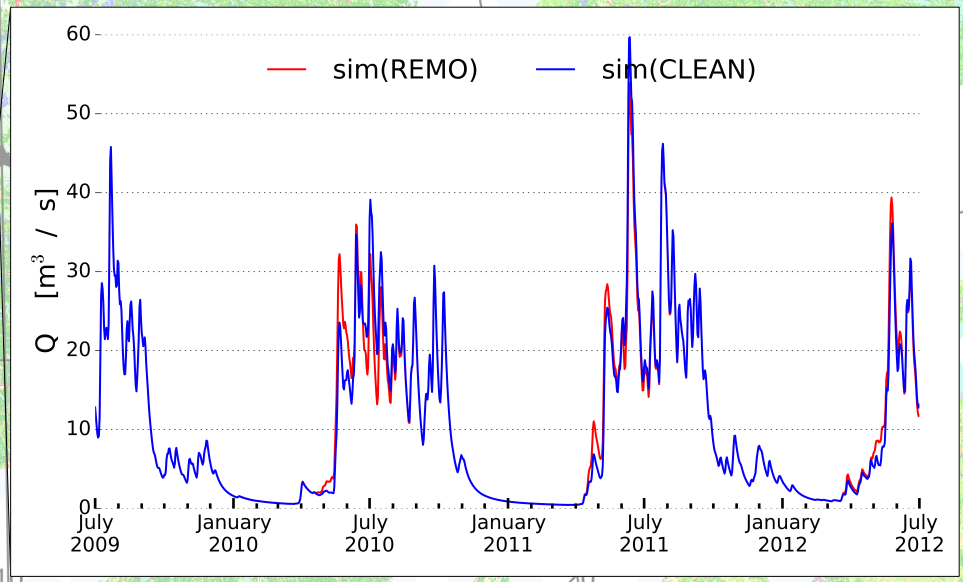




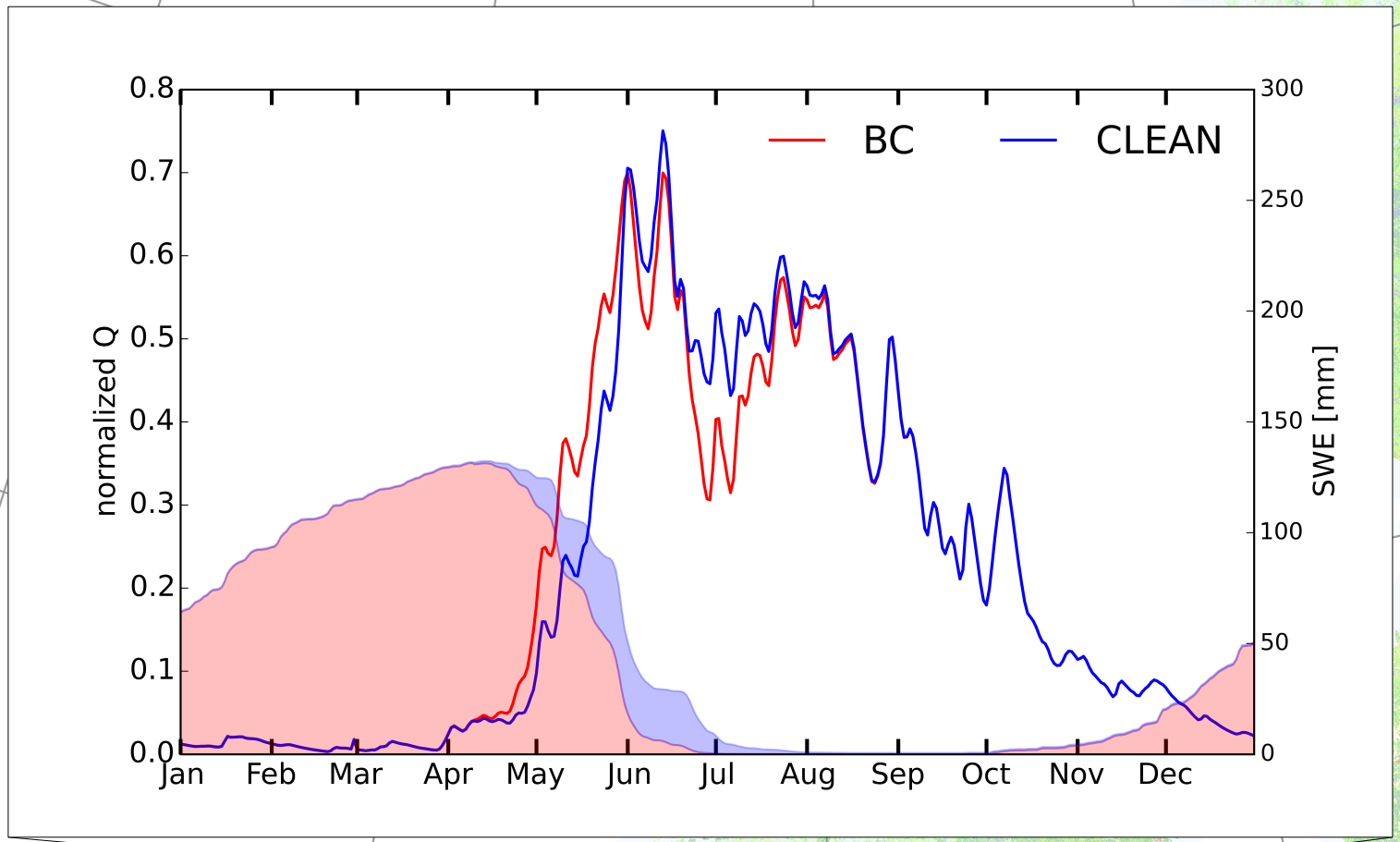
Effect of BC on catchment hydrology REMO-HAM







Effect of BC on catchment hydrology



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Caveats

- Lack of understanding in micro-physics (grain size growth, entrainment in melt, ...)
- Deposition data (so far) too little for long calibration and evaluation period
- Other light absorbing aerosols (dust, …)?
- Lacking observational data

Conclusion

- Low deposition rates over Norway can significantly impact catchment hydrology
- Simulations are better when including deposition of BC
- BC responsible for a shift in hydrograph:
  - Earlier melt compared to CLEAN case
  - Lower discharge later in melt season due to shift of melt season

Acknowledgement

- Kaarle Kupiainen and Zbigniew Klimont from IIASA (Austria) provided the emission data for the REMO-HAM simulations.

IIASA
Science for Global Insight

- REMO-HAM simulations were carried out with the support MACEB project (Mitigation of Arctic warming by controlling European black carbon emissions); Finnish Meteorological Institute.

FINNISH METEOROLOGICAL INSTITUTE

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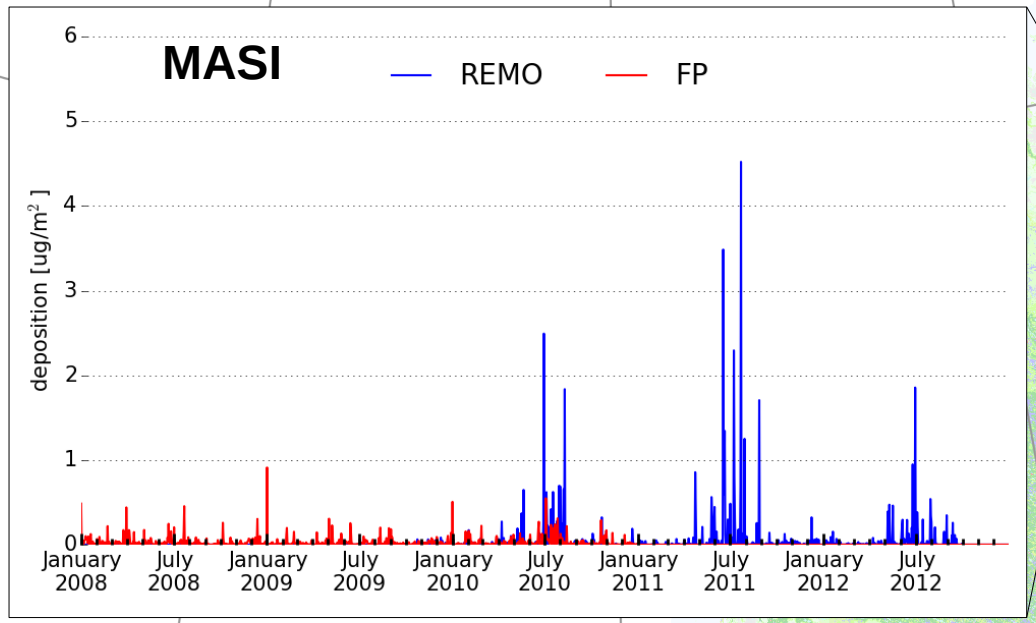
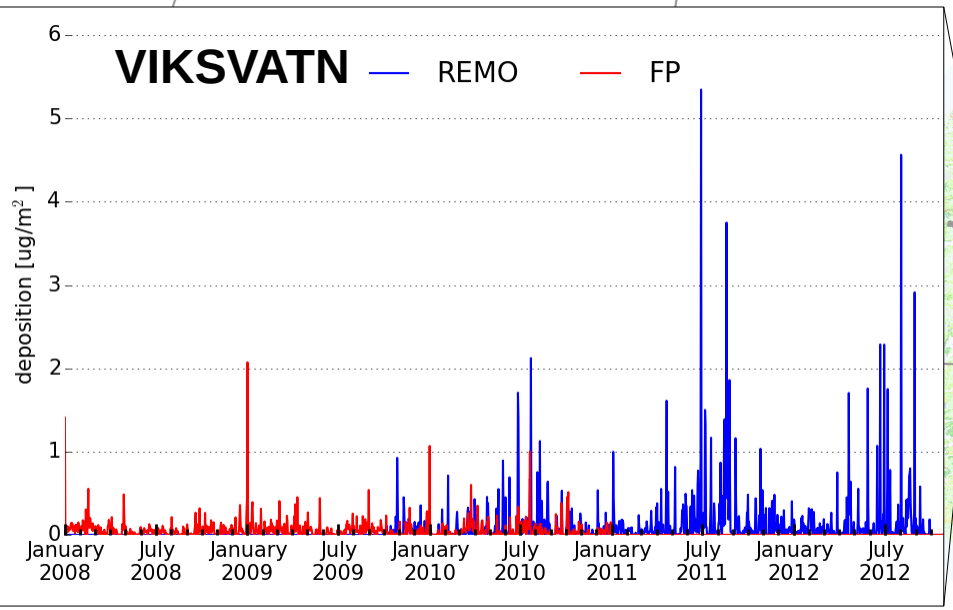
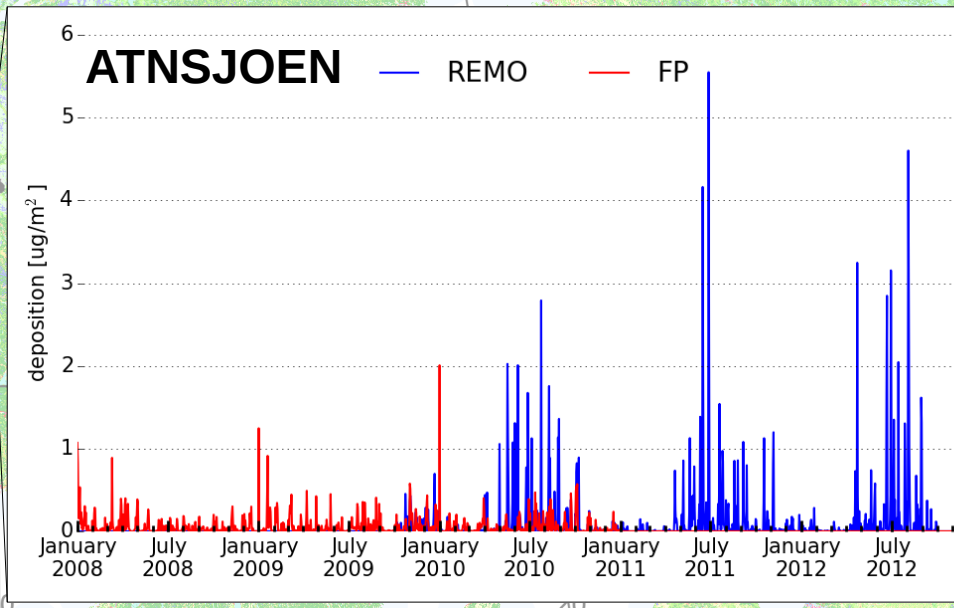
Stohl, A., Klimont, Z., Eckhardt, S. et al. (2013), *Black carbon in the Arctic: the underestimated role of gas flaring and residential combustion emissions*. Atmospheric Chemistry and Physics. 13: 8833–8855. DOI:10.5194/acp-13-8833-2013.

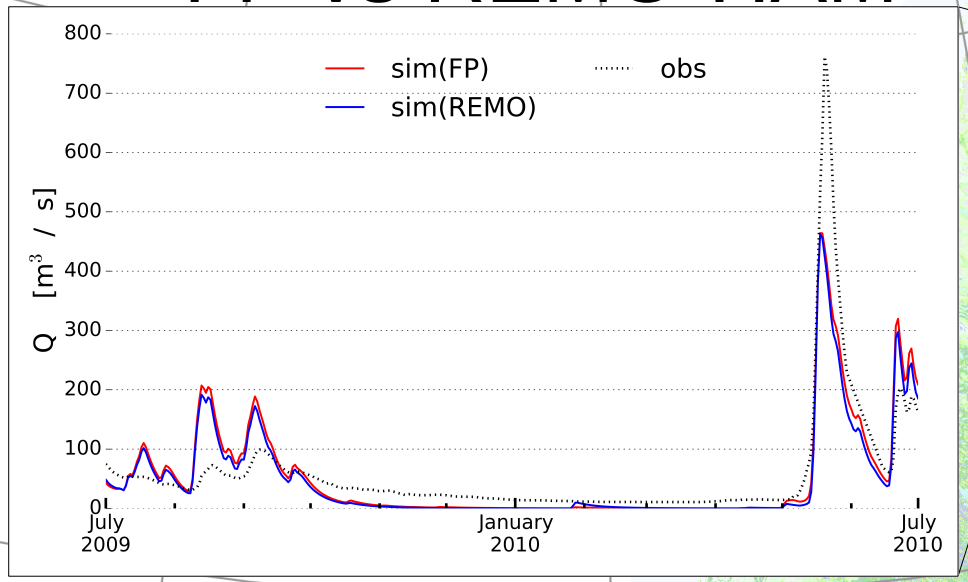
Input: Black Carbon deposition

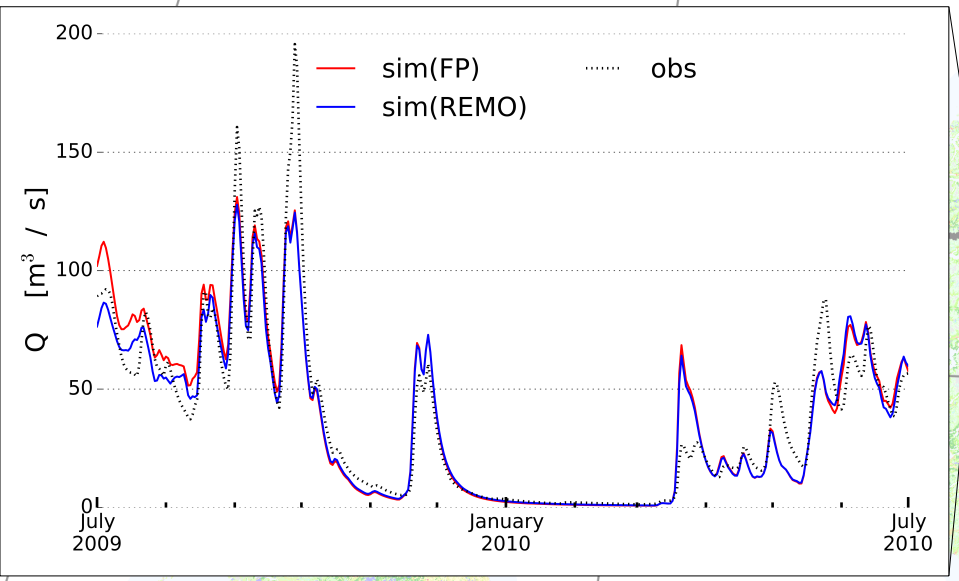


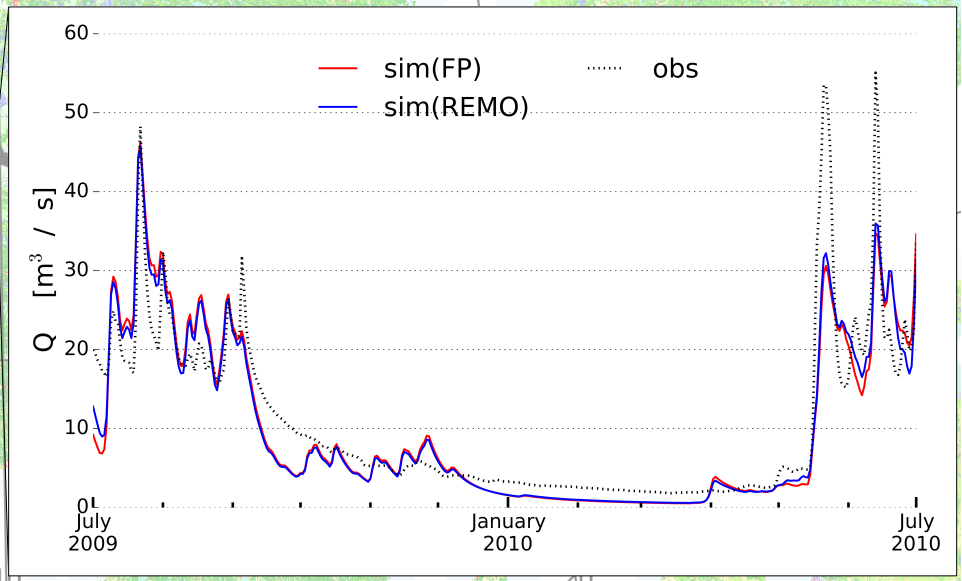




Effect of BC on catchment hydrology
FP vs REMO-HAM

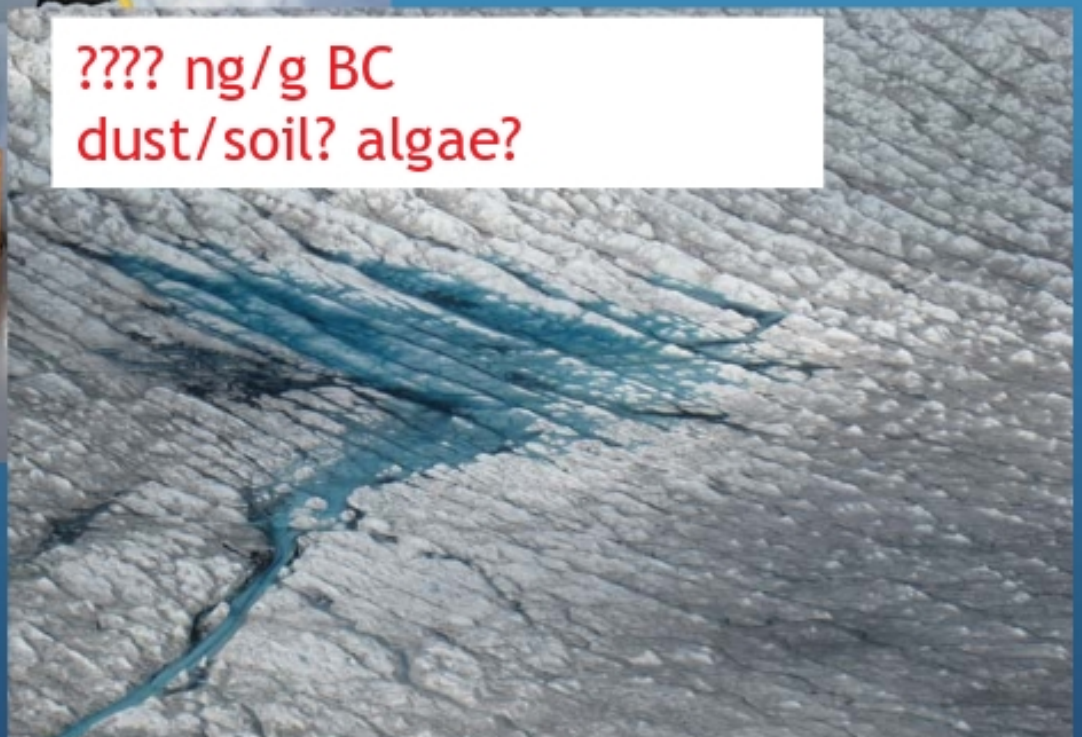


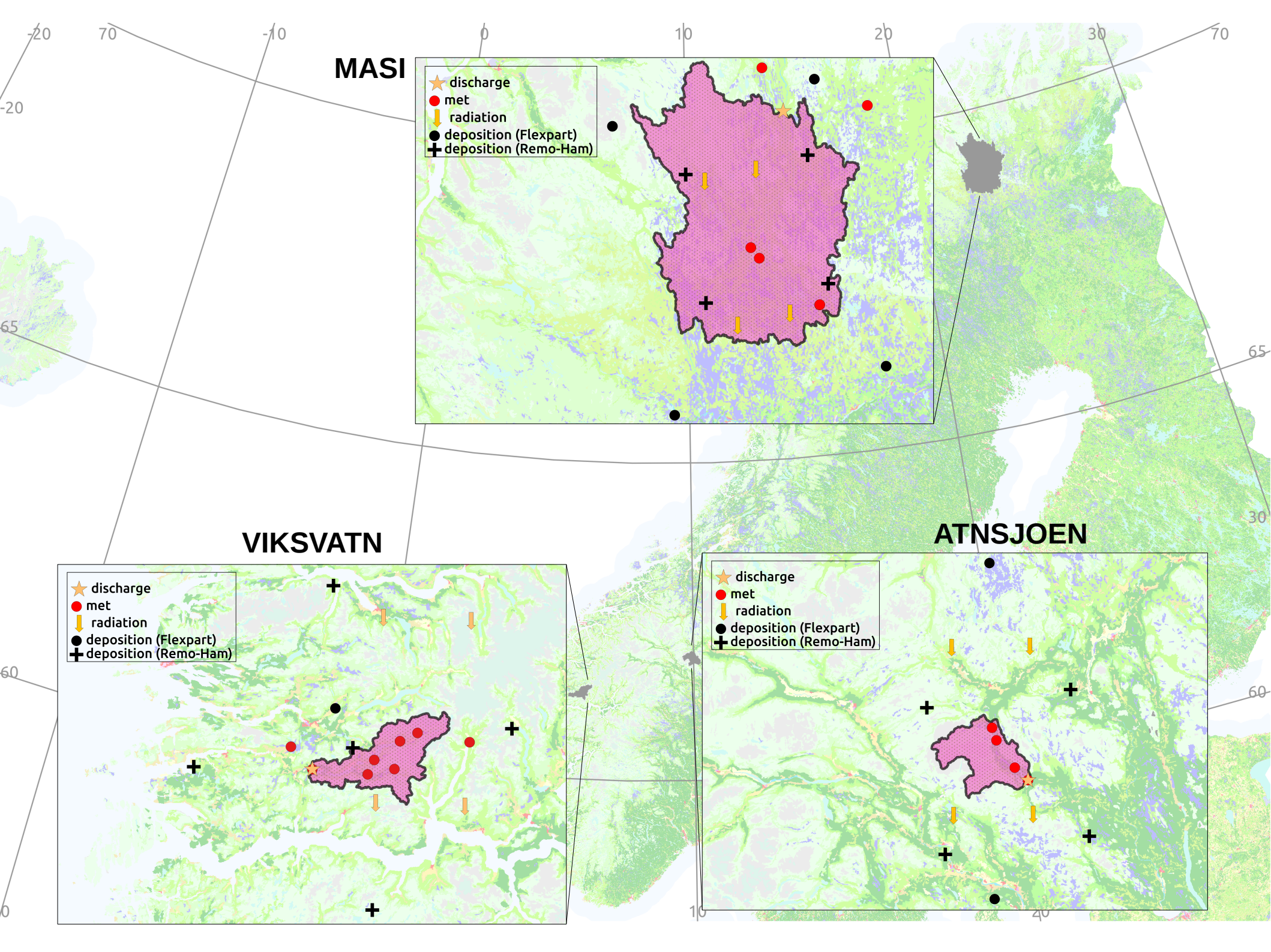





~2-30 ng/g BC


~1100ng/g BC
2010/02/07


???? ng/g BC
dust/soil? algae?


MASI
discharge
met
radiation
deposition (Flexpart)
deposition (Remo-Ham)
VIKSVATN
discharge
met
radiation
deposition (Flexpart)
deposition (Remo-Ham)
ATNSJOEN
discharge
met
radiation
deposition (Flexpart)
deposition (Remo-Ham)
-20
70
-10
0
10
20
30
70
65
60
30