



Earth System simulations of the Arctic region

3rd CRAICC/PEEX workshop

Climate Change for Arctic Seas and Shipping

UHEL: R. Makkonen, M. Boy, A. Malkamäki,
V.-M. Kerminen, M. Kulmala

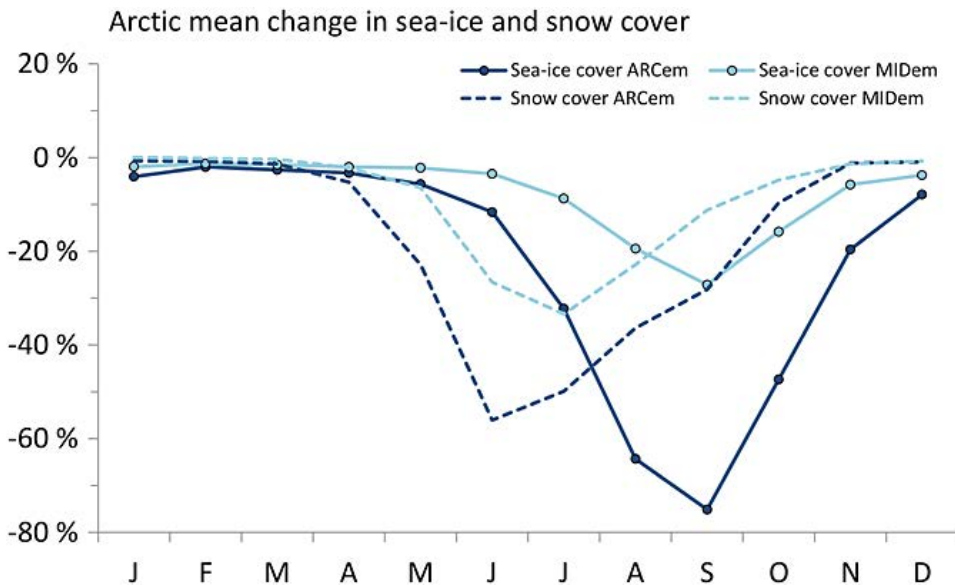
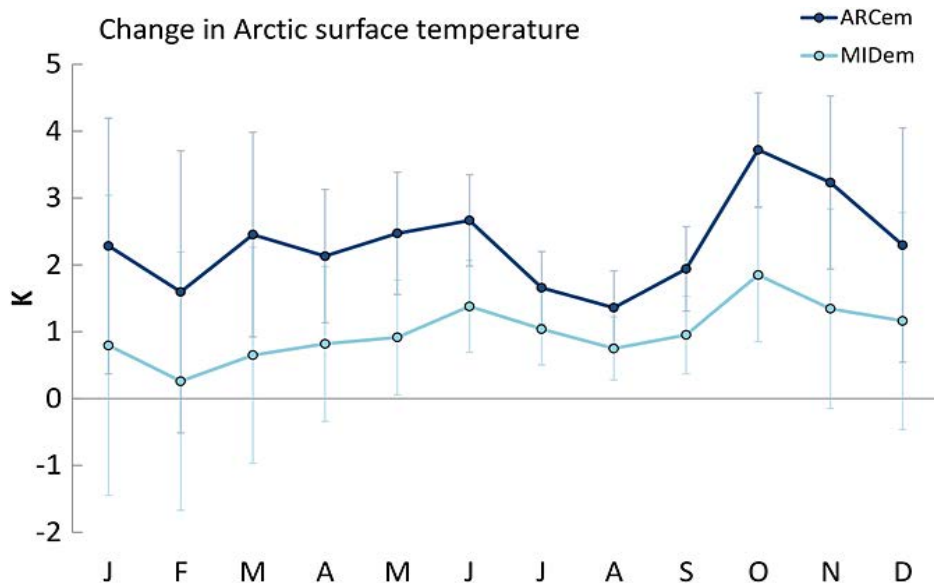
UiO: J.E. Kristjansson, M. Sand (CICERO)

MetNO: A. Kirkevåg, Ø. Seland, T. Iversen

SU: I. Riipinen, J. Acosta-Navarro

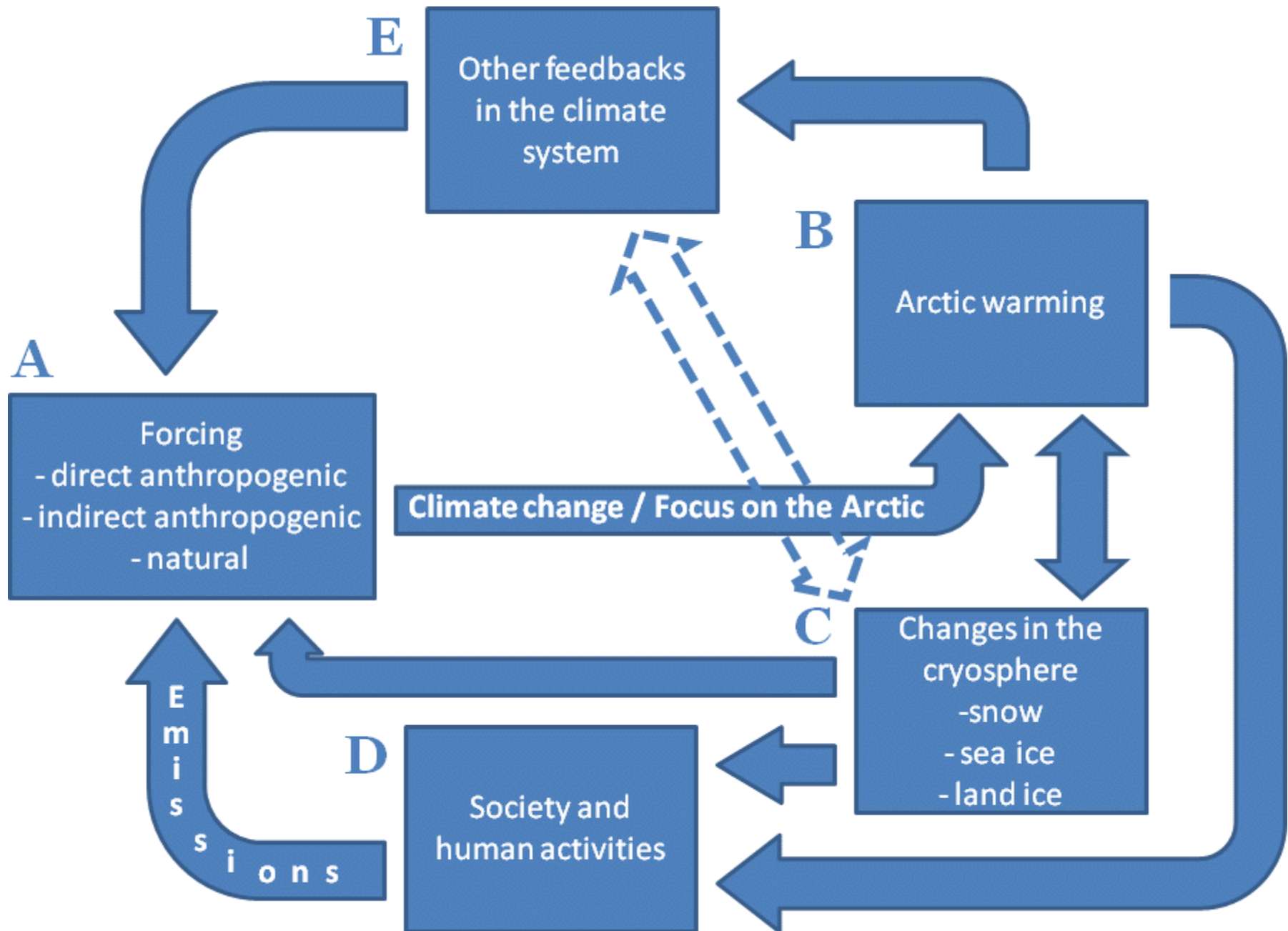
FMI: J. Pietikäinen, A. Laaksonen

“...BC emitted within the Arctic has an almost five times larger Arctic surface temperature response (per unit of emitted mass)”



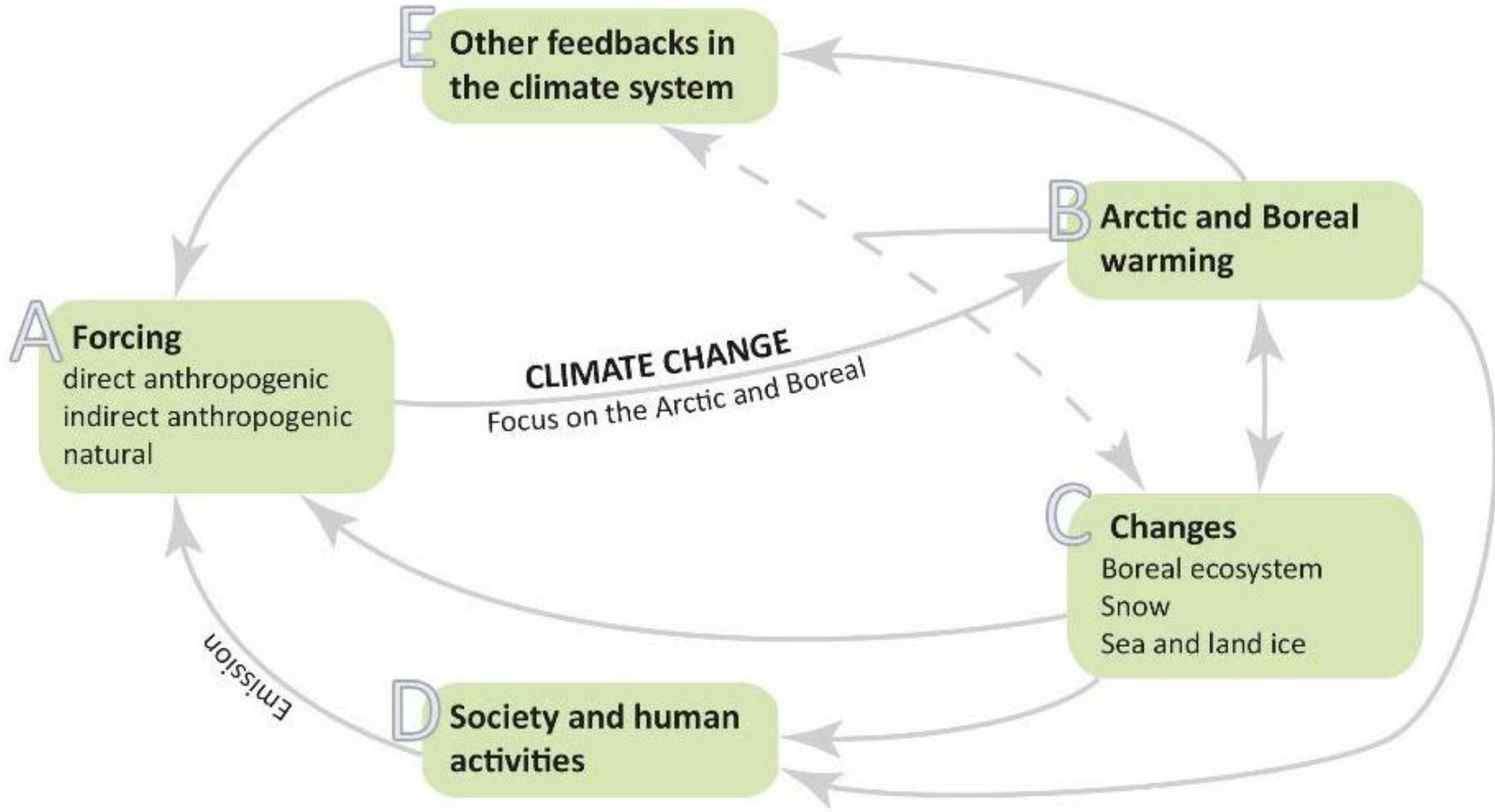
ARCEM = BC emission in the Arctic
MIDEM = BC emission in the mid-latitudes

CRAICC: interactions and feedbacks



CRAICC: Interlinks between different components in climate change and cryosphere

PEEX: large-scale schematics



Building a CRAICC-version of the Norwegian Earth System Model (NorESM)

Aerosols

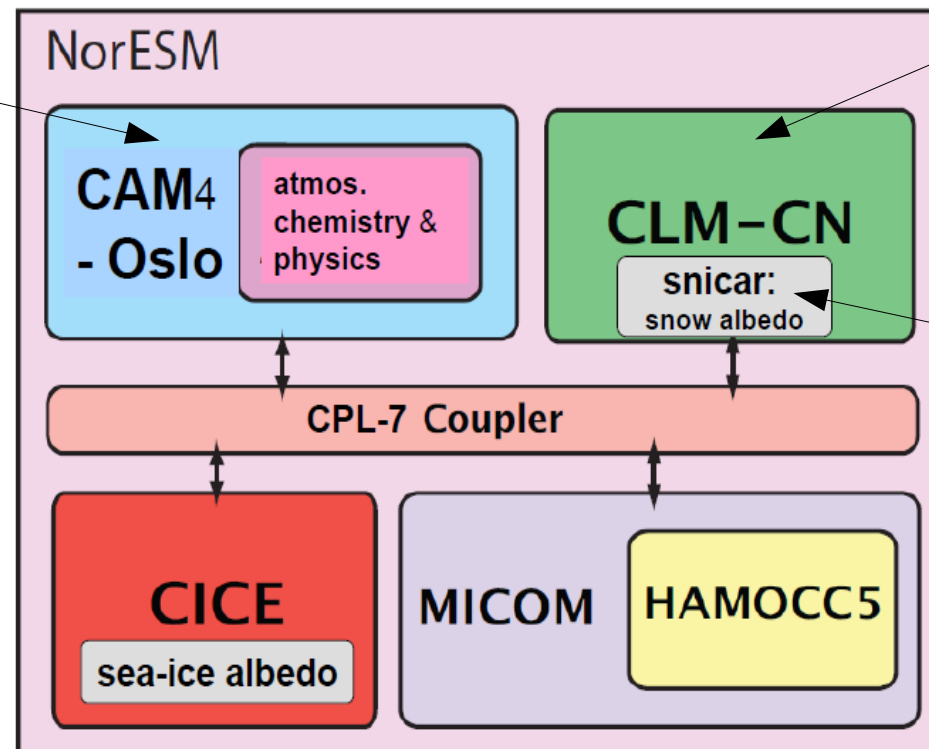
- Secondary organic aerosol formation
- nucleation
- ...

Chemistry

- Interactive MOZART
- Using MOZART oxidant fields for ESM runs

Emissions

- Interactive DMS
- Interactive sea spray

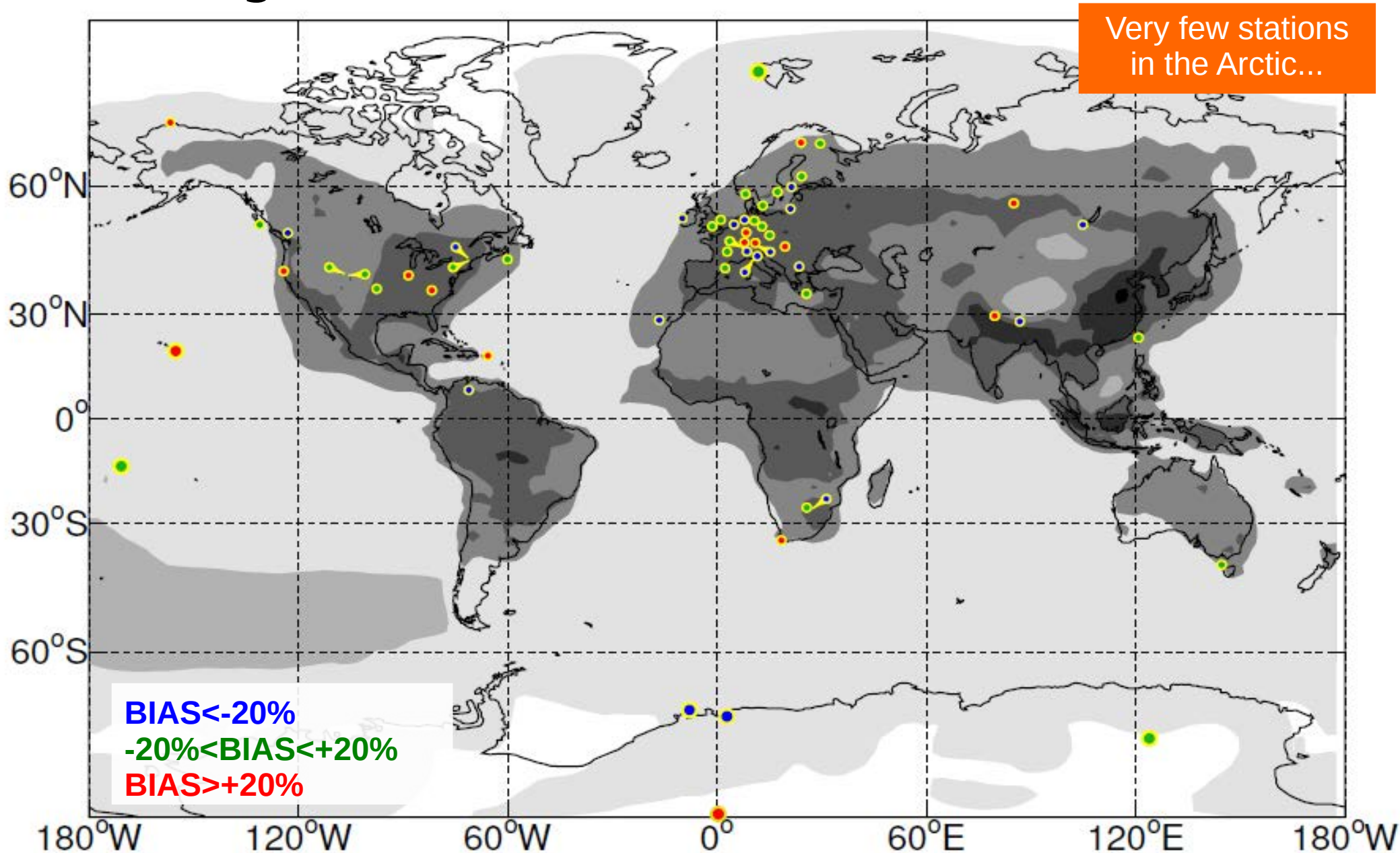


MEGAN

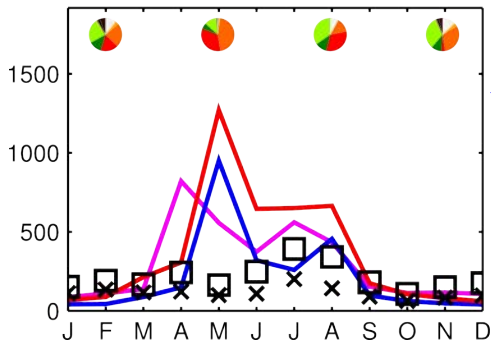
(Model of Emissions of Gases and Aerosols from Nature)
BVOC emission

Improved treatment of snow-albedo and aerosol-snow effects

Evaluation of aerosol number concentration against 60 measurement stations

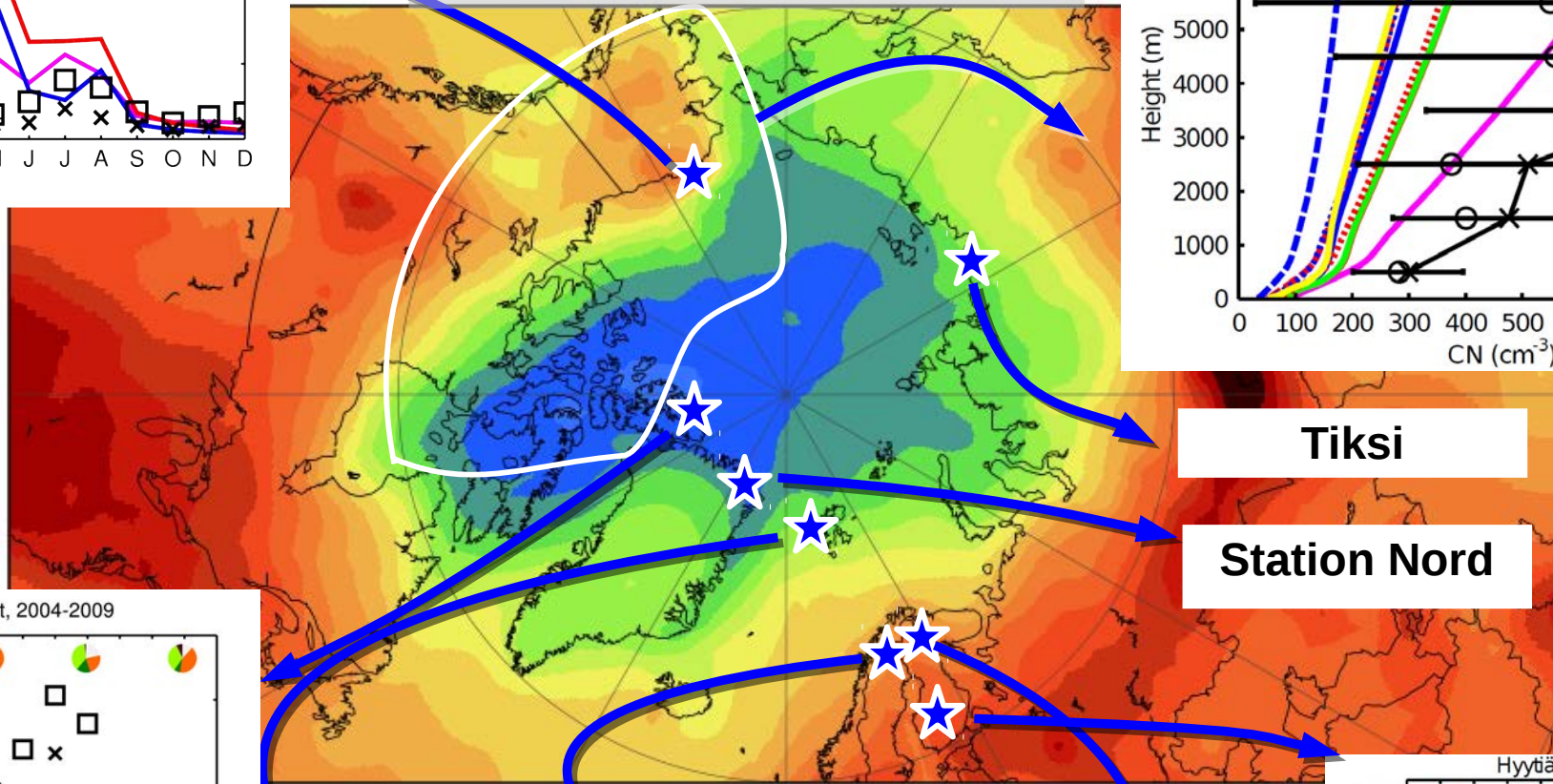
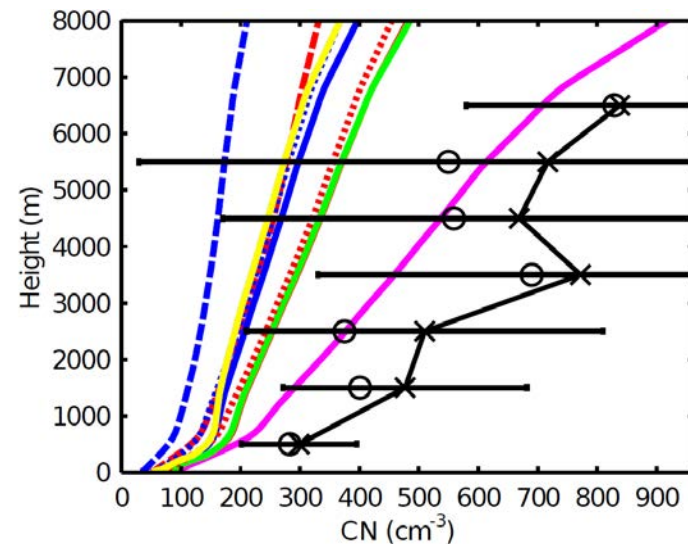


Point Barrow, 1997-2011

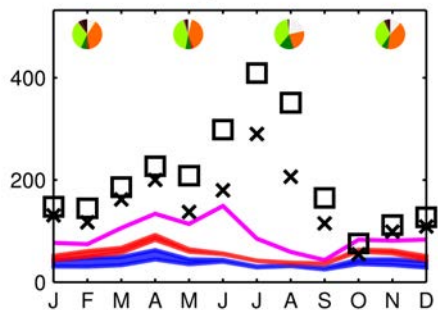


Simulating Arctic aerosol number concentrations

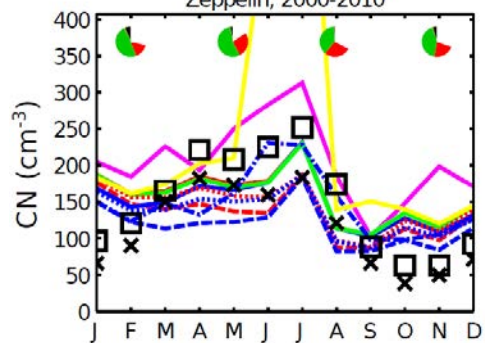
Arctas flight campaign



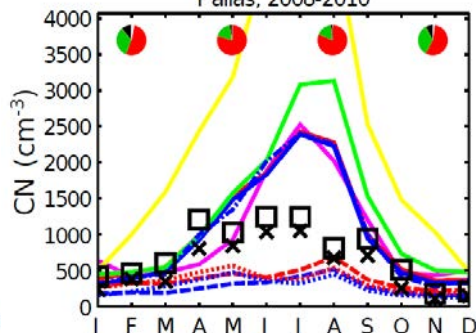
Alert, 2004-2009



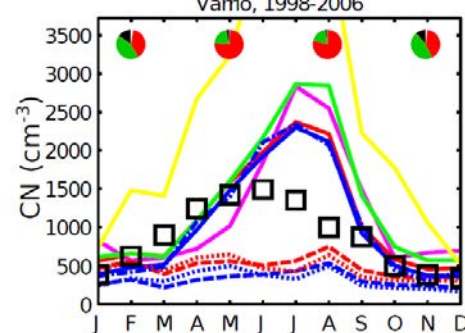
Zeppelin, 2000-2010



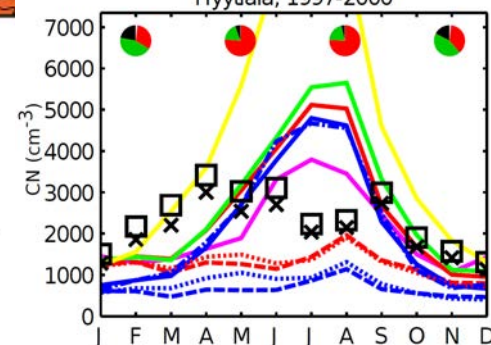
Pallas, 2008-2010



Väneri, 1998-2006



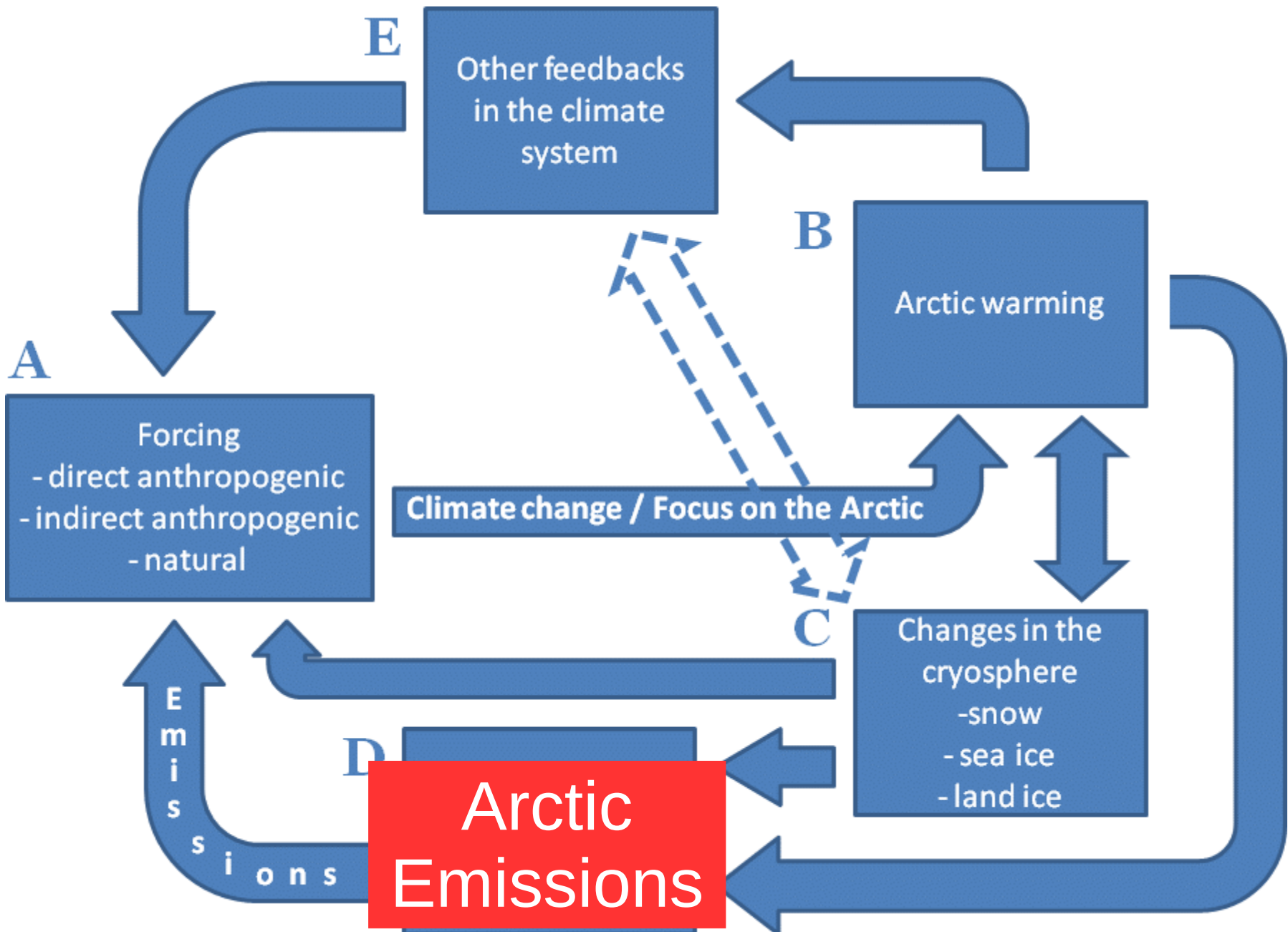
Hyytiälä, 1997-2000



Tiksi

Station Nord

CRAICC: interactions and feedbacks



CRAICC: Interlinks between different components in climate change and cryosphere

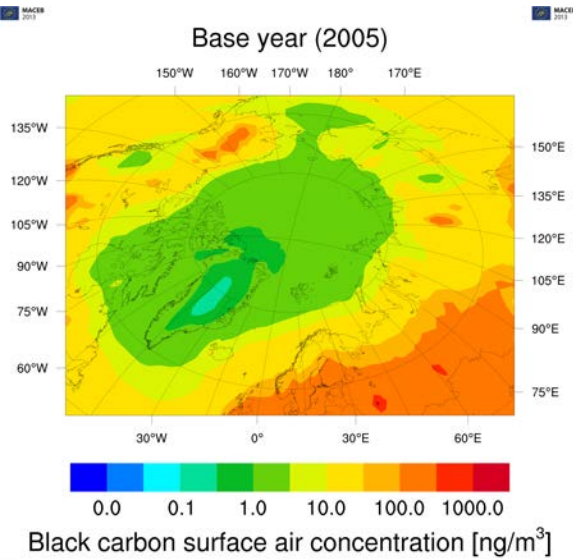
Black carbon concentrations over Arctic

2005

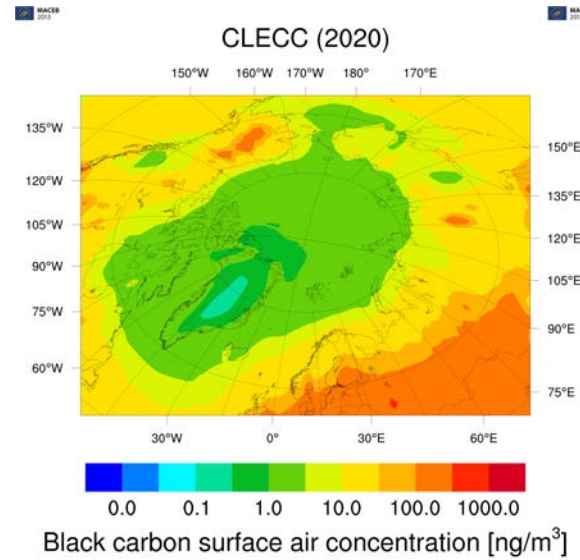
2020

2030

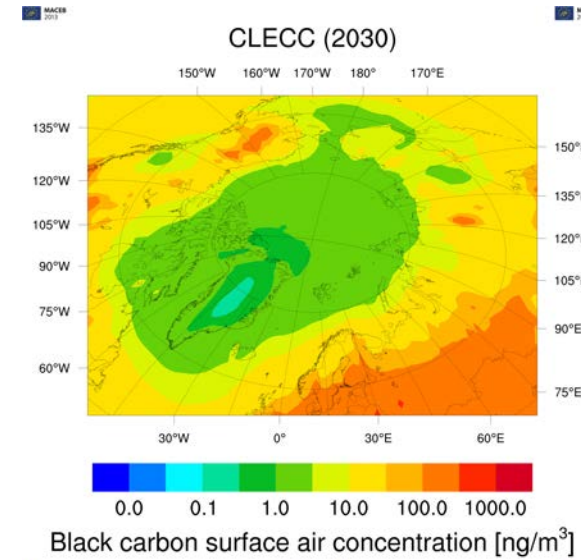
Base year (2005)



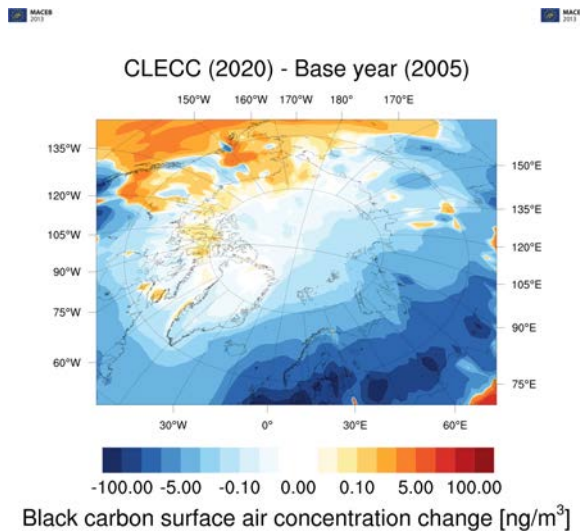
CLECC (2020)



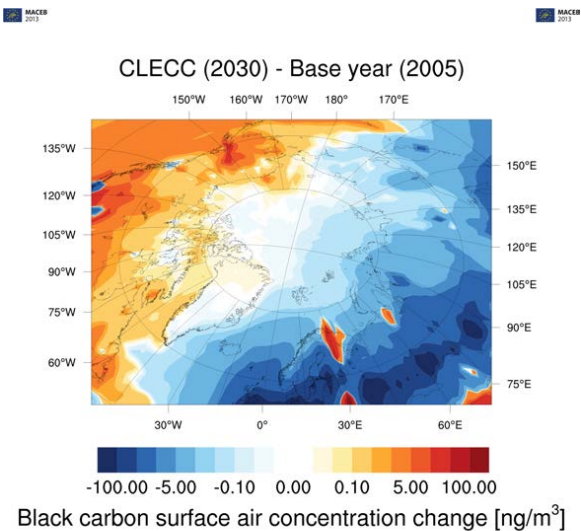
CLECC (2030)



CLECC (2020) - Base year (2005)

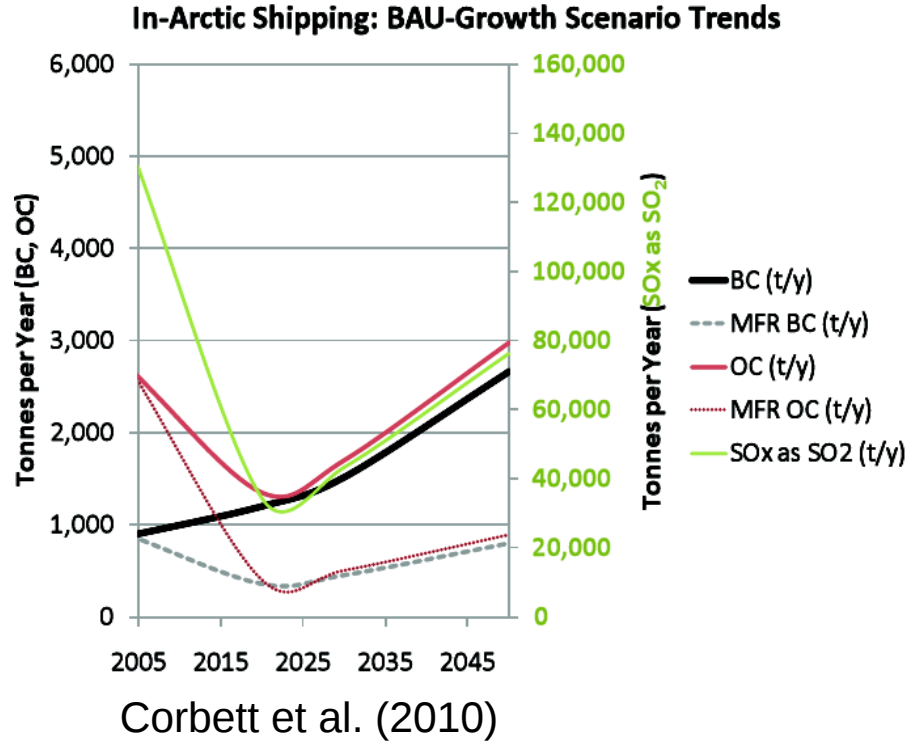


CLECC (2030) - Base year (2005)

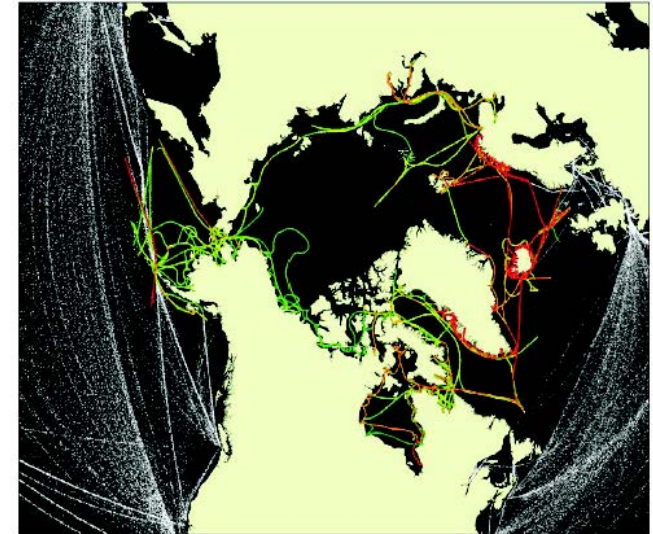


CLEC = agreed legislation
 CLECC = CLEC + CO₂ < 450 ppm
 BCAdd = extra BC reduction
 MTRF = Maximum Technologically Feasible Reduction

Shipping scenarios for the Arctic from Corbett et al. (2010)



2030 Black Carbon Emissions - No Control

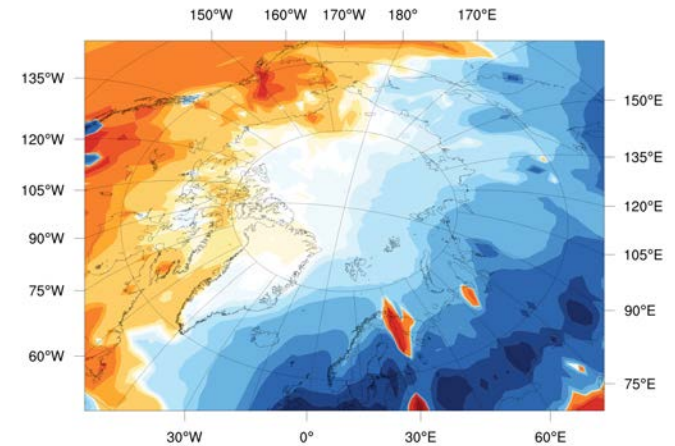


Corbett et al. (2010)

MACEB 2013

MACEB 2013

CLECC (2030) - Base year (2005)



Black carbon surface air concentration change [ng/m³]

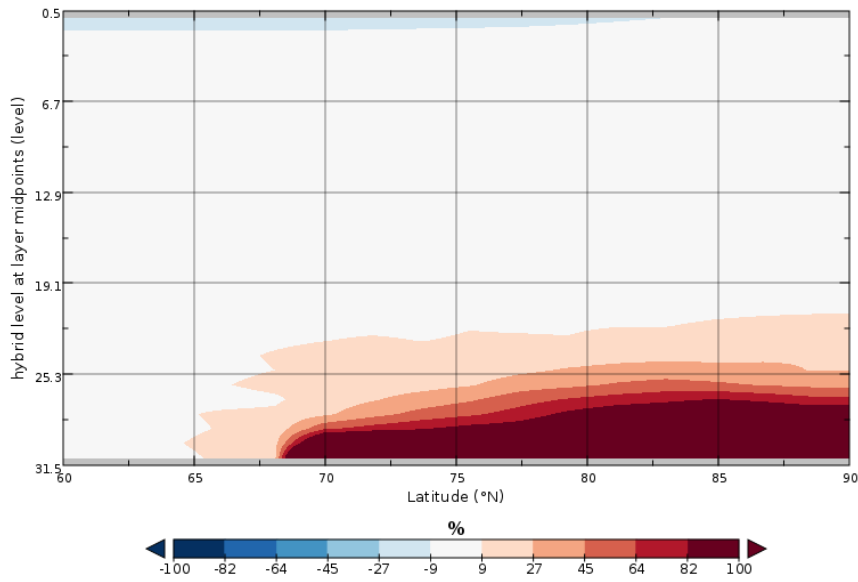
MACEB 2013

maceb.fi

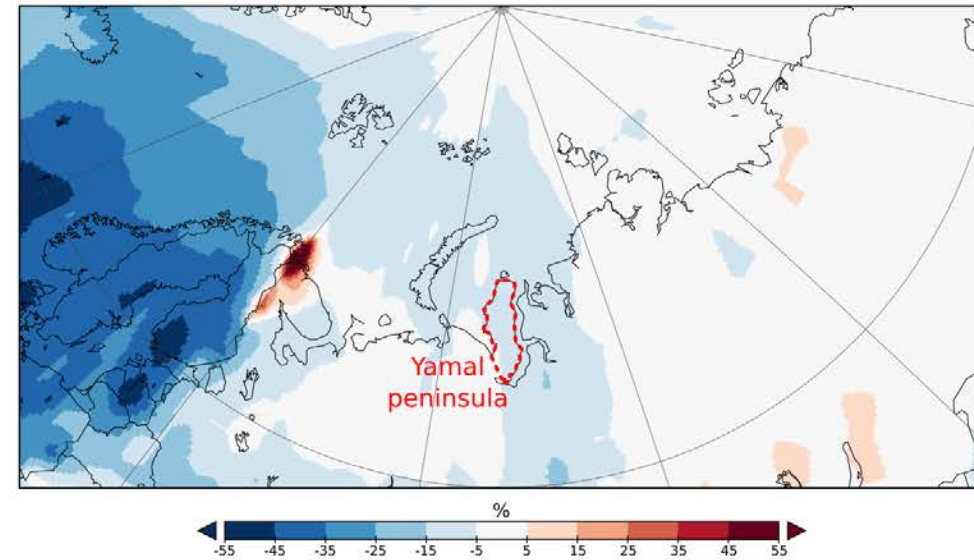
MACEB 2013

CLEC = agreed legislation
 CLECC = CLEC + CO₂ < 450 ppm
 BCAdd = extra BC reduction
 MTFR = Maximum Technologically Feasible Reduction
 ECHAM5-HAMMOZ
 MACEB-project. Pietikäinen et al., ACP, 2015

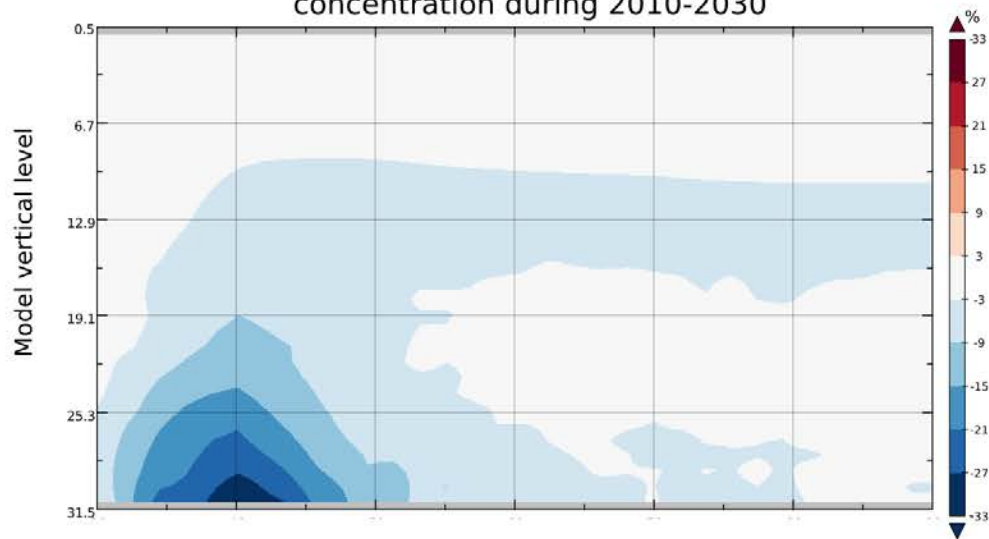
Increasing activities in Yamal peninsula



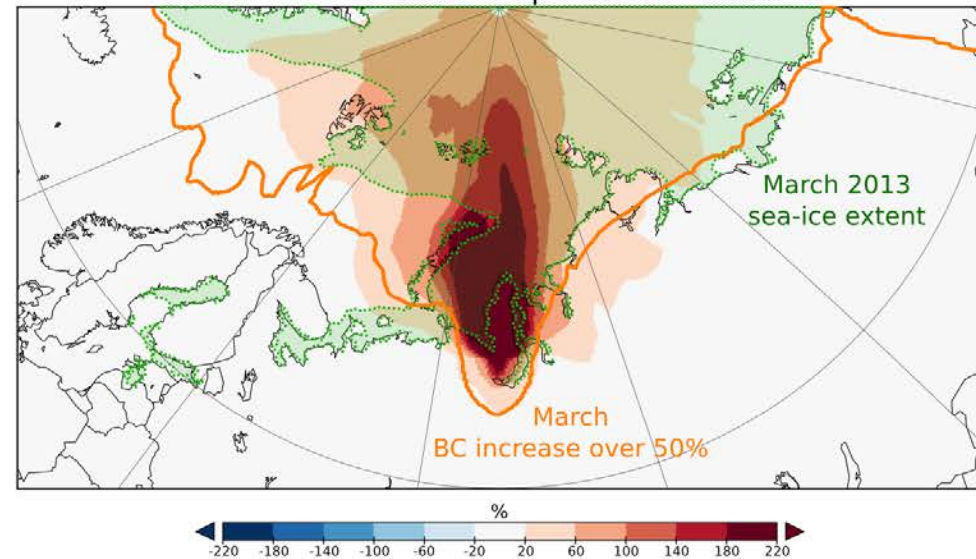
Change in annual average BC concentration during 2010-2030



Change in annual average BC concentration during 2010-2030

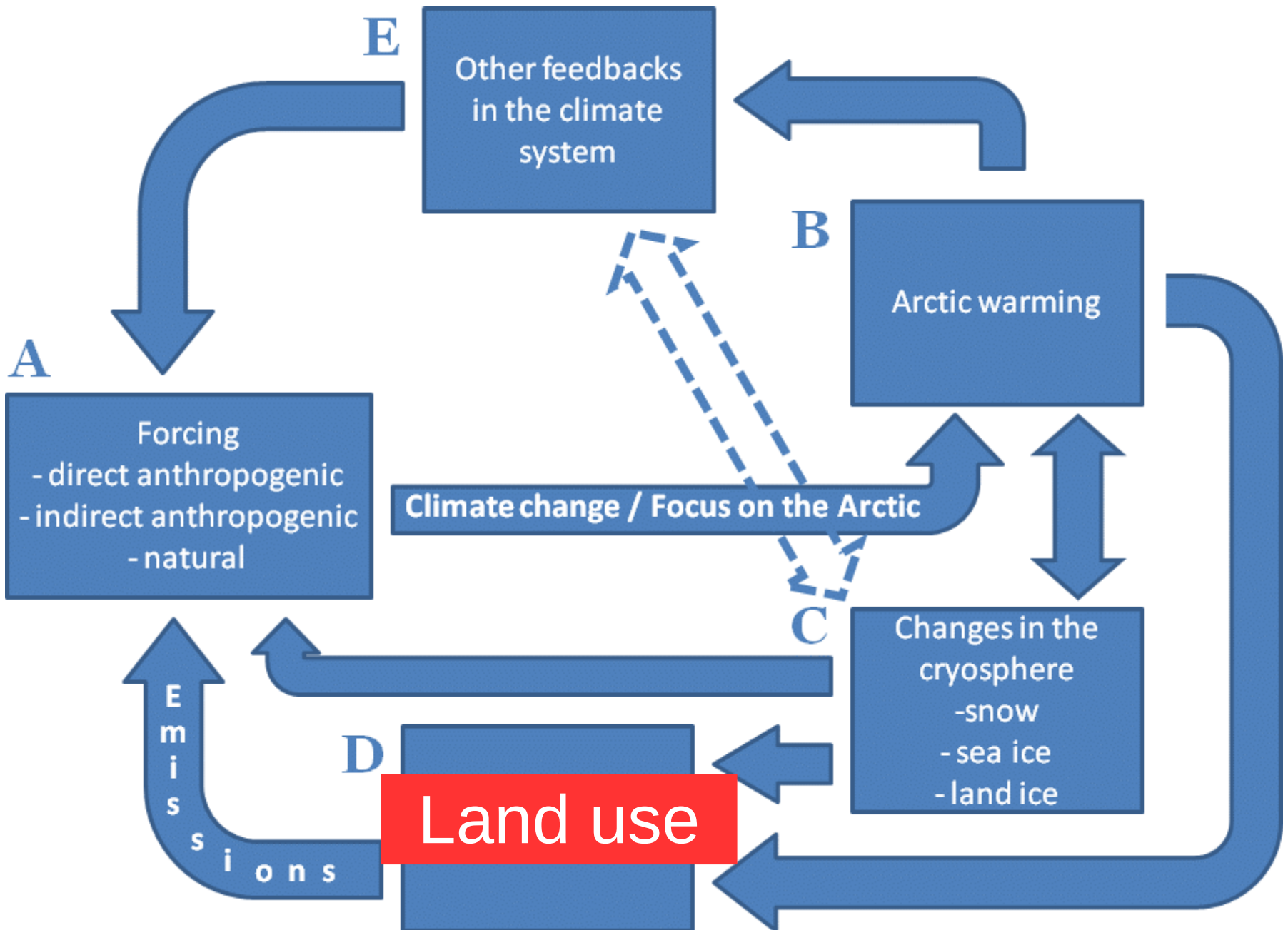


Increase in BC concentration due to increasing activity in Yamal peninsula



+12 kt/year BC
+12 kt/year SO₂

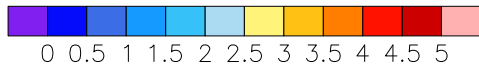
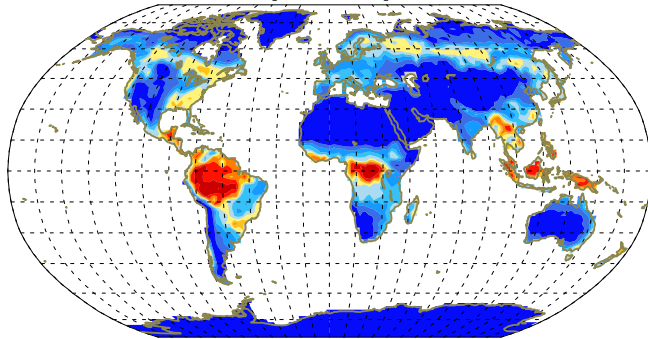
CRAICC: interactions and feedbacks



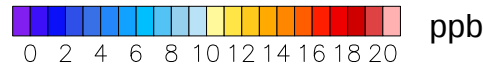
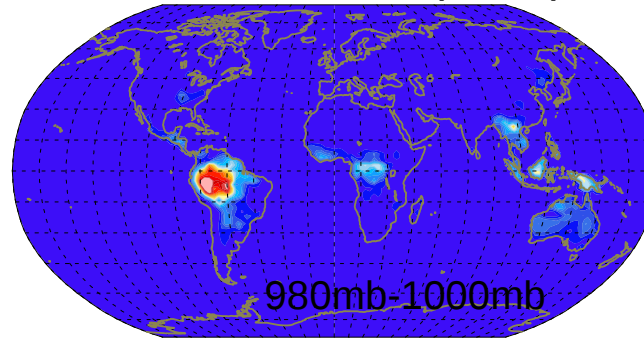
CRAICC: Interlinks between different components in climate change and cryosphere

Land Use effects on total leaf area index, isoprene and monoterpene concentrations

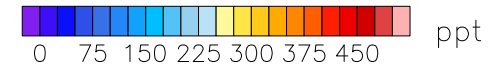
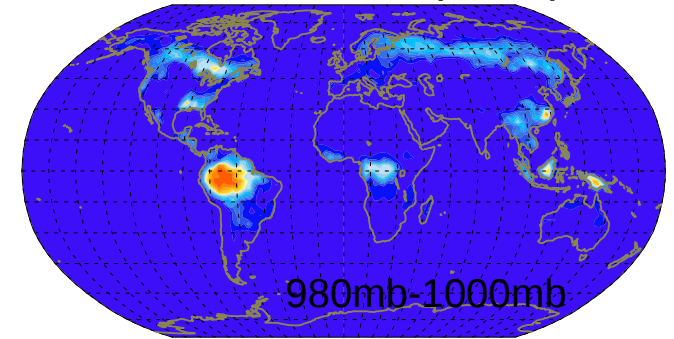
Total leaf area index
(1850)



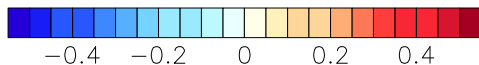
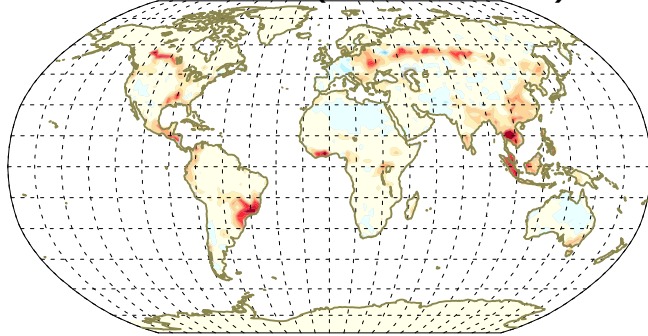
Isoprene
concentration (1850)



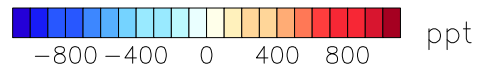
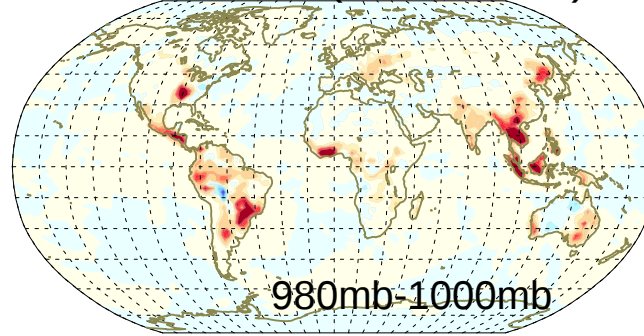
Monoterpene
concentration (1850)



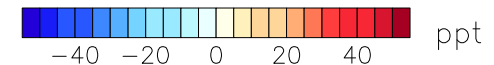
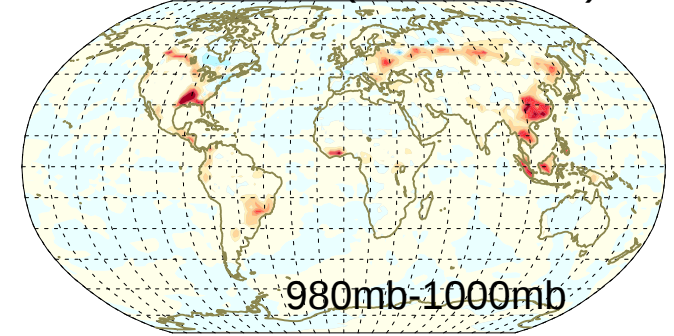
Total leaf area index
difference (1850-2000)



Isoprene concentration
difference (1850-2000)

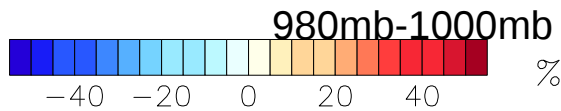
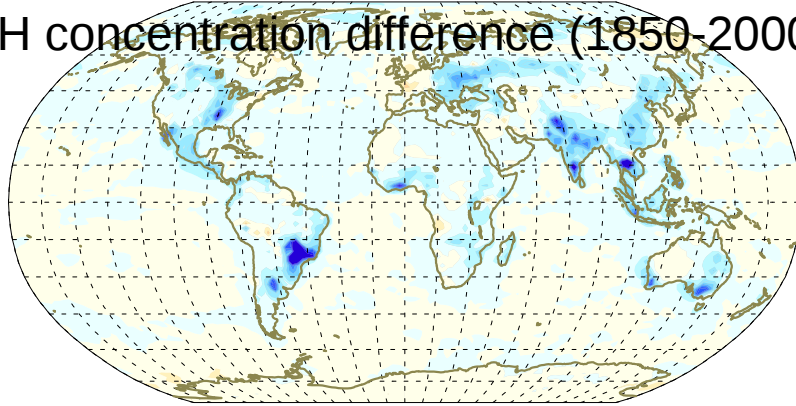


Monoterp. concentration
difference (1850-2000)

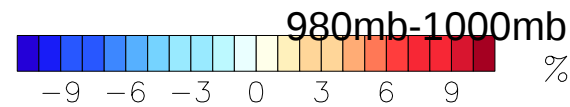
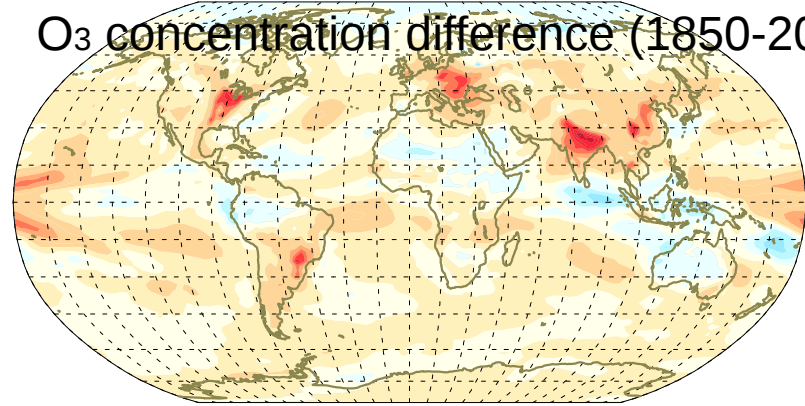


Land Use effects on OH, tropospheric ozone, SOA and TOA radiation budget

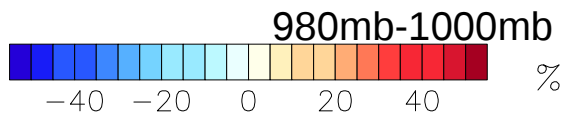
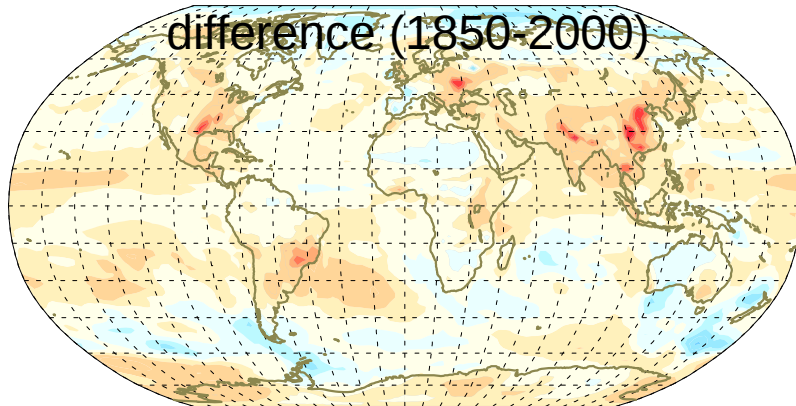
OH concentration difference (1850-2000)



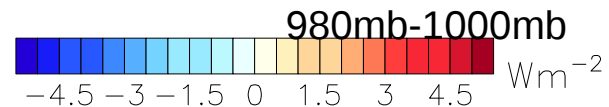
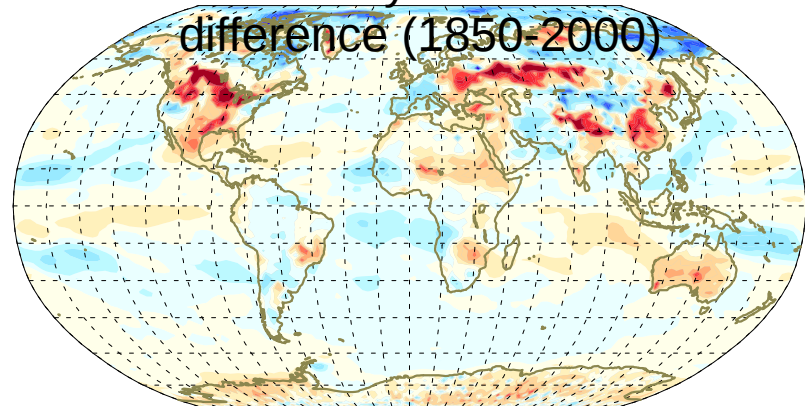
O₃ concentration difference (1850-2000)



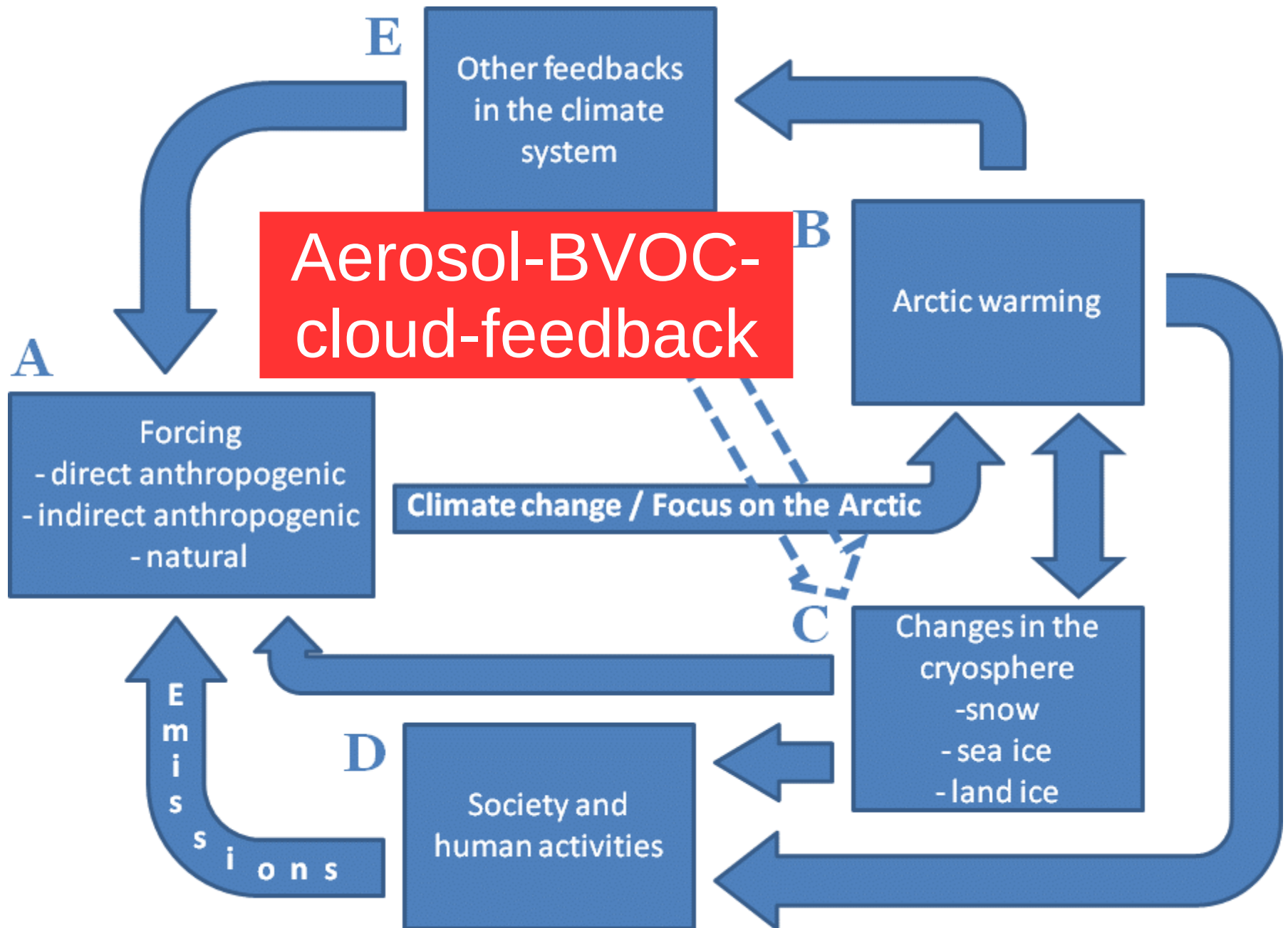
SOA mass concentration difference (1850-2000)



Net clear-sky TOA radiation difference (1850-2000)



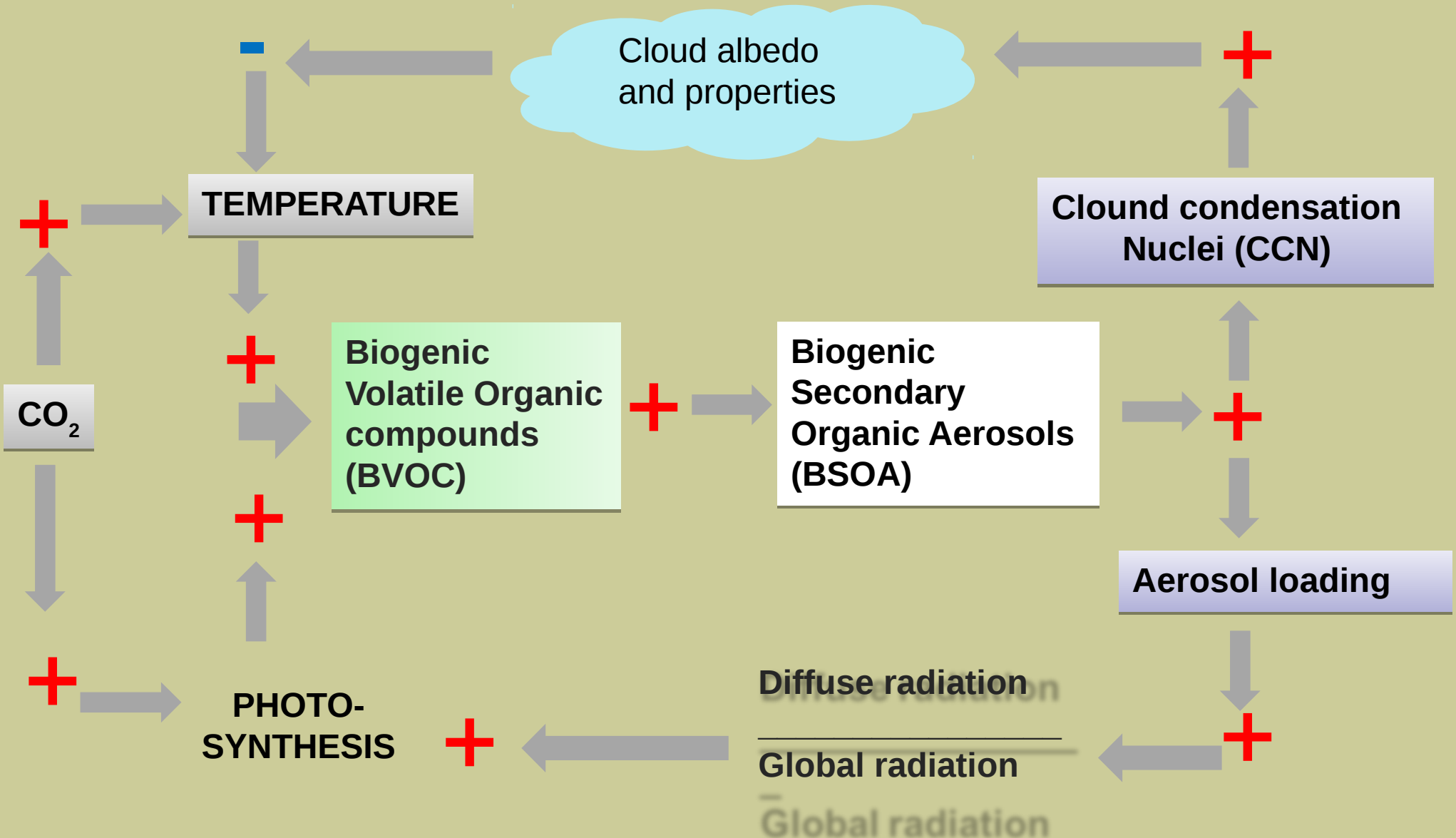
CRAICC: interactions and feedbacks



CRAICC: Interlinks between different components in climate change and cryosphere

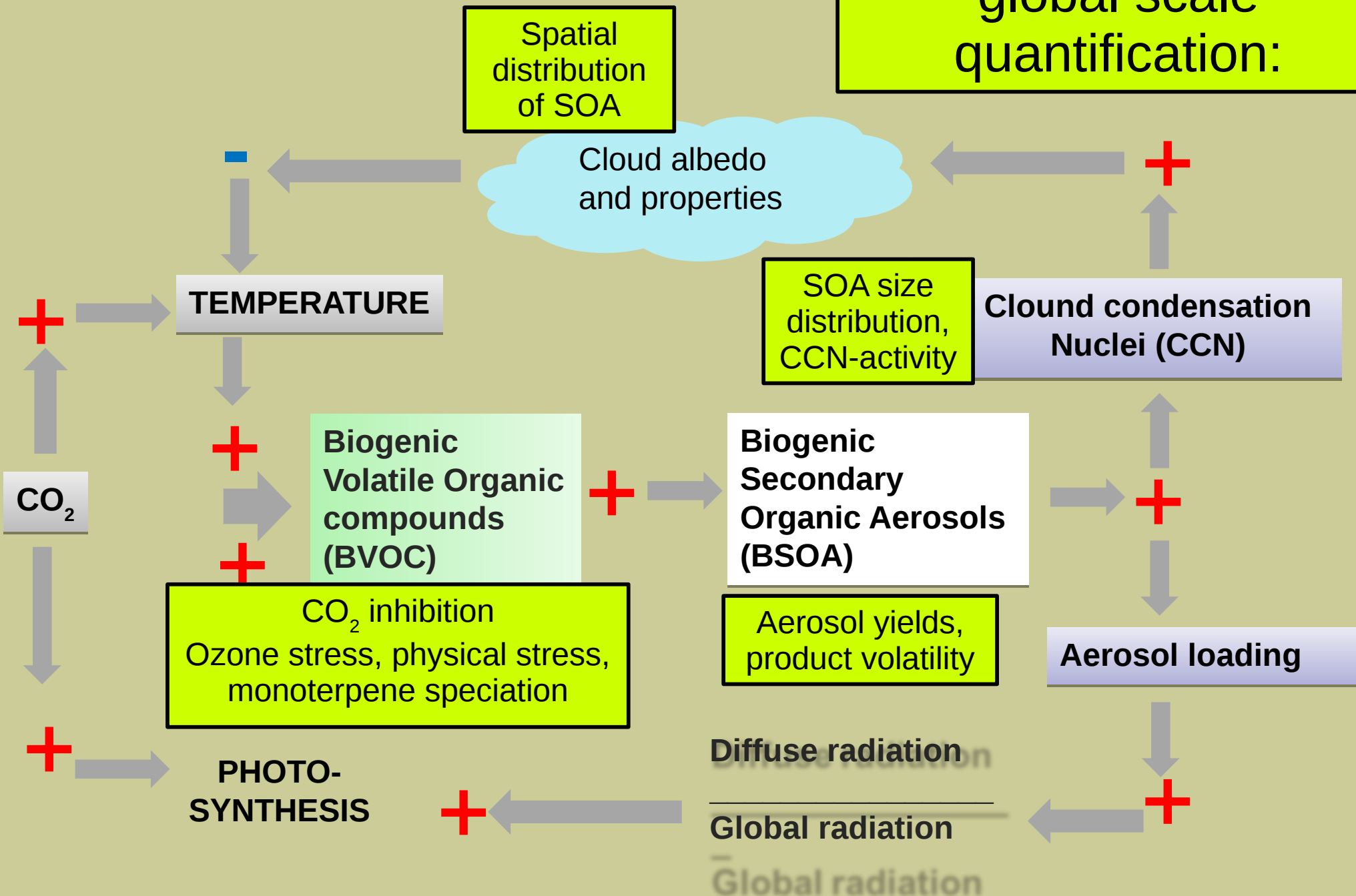
COBACC feedback mechanism

(continental biosphere-aerosol-cloud-climate feedback)

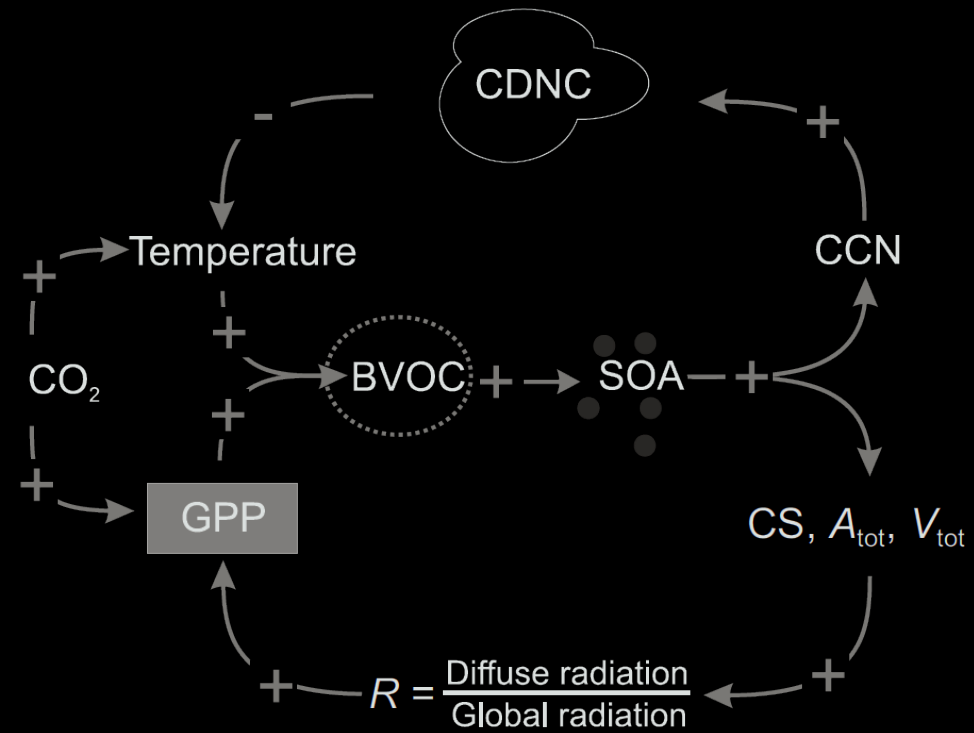
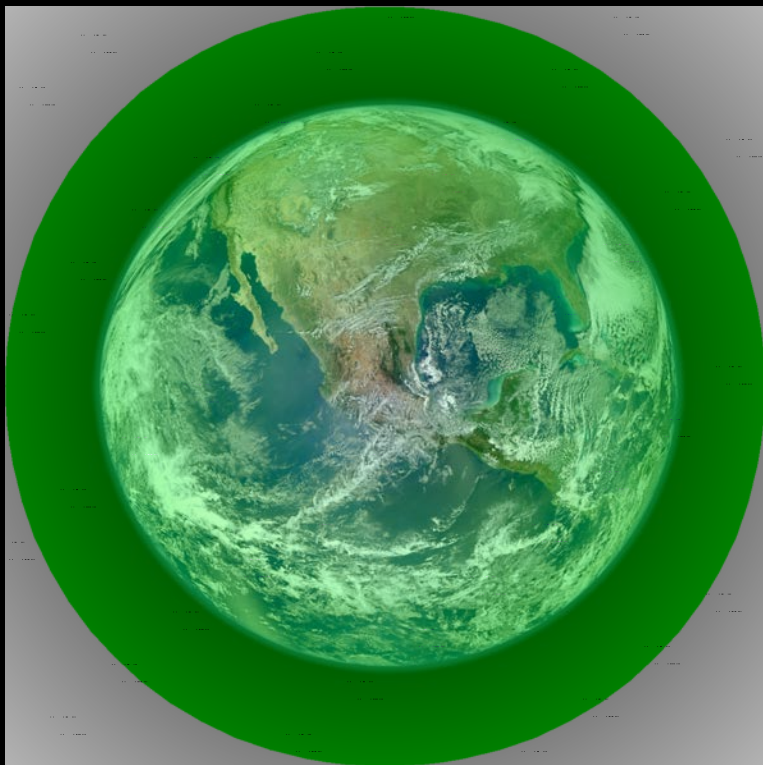
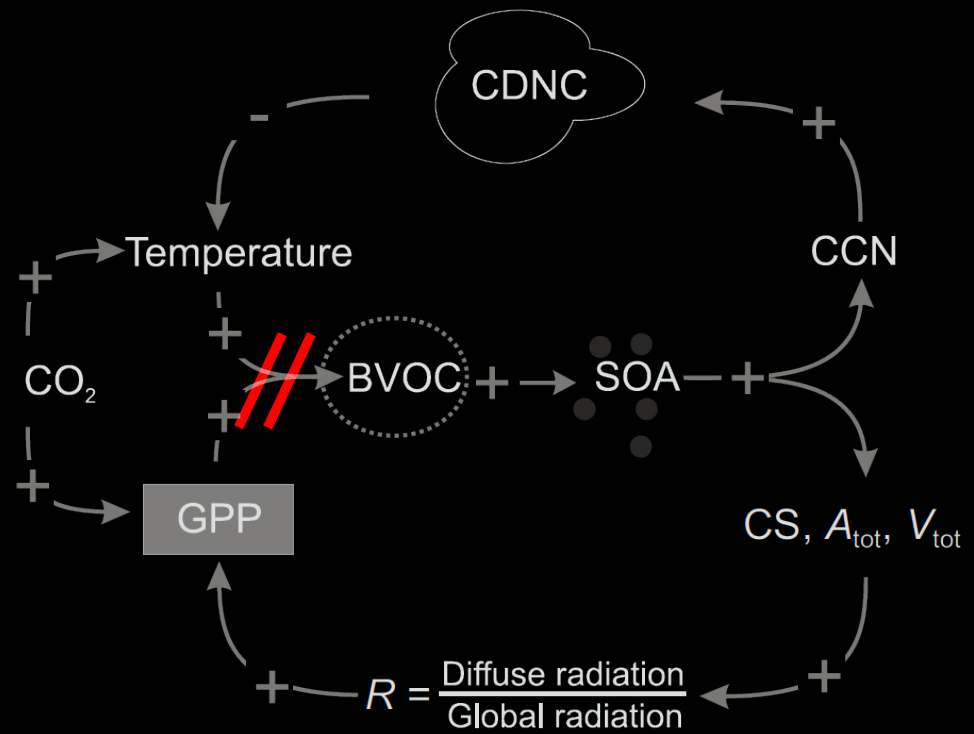
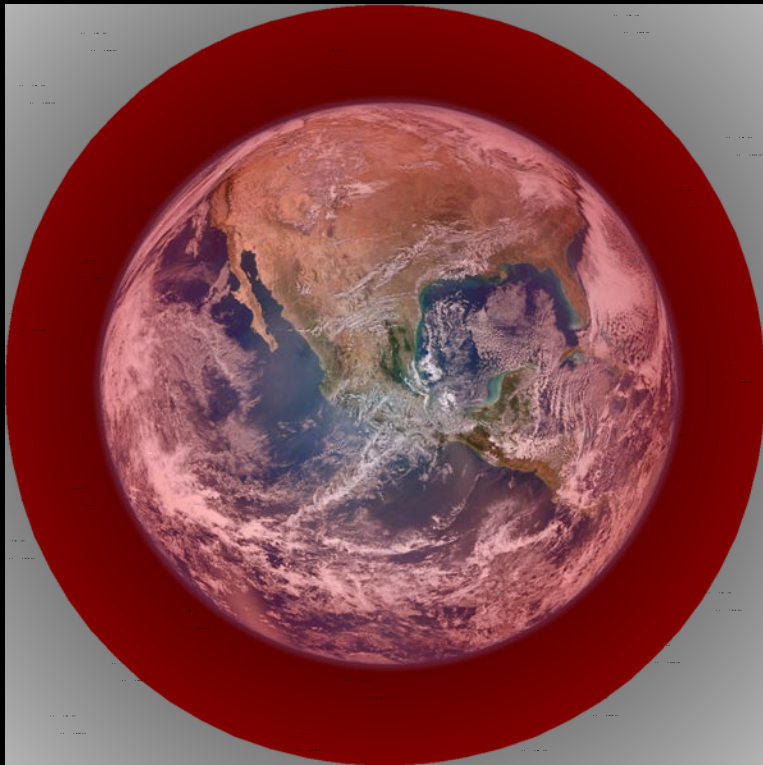


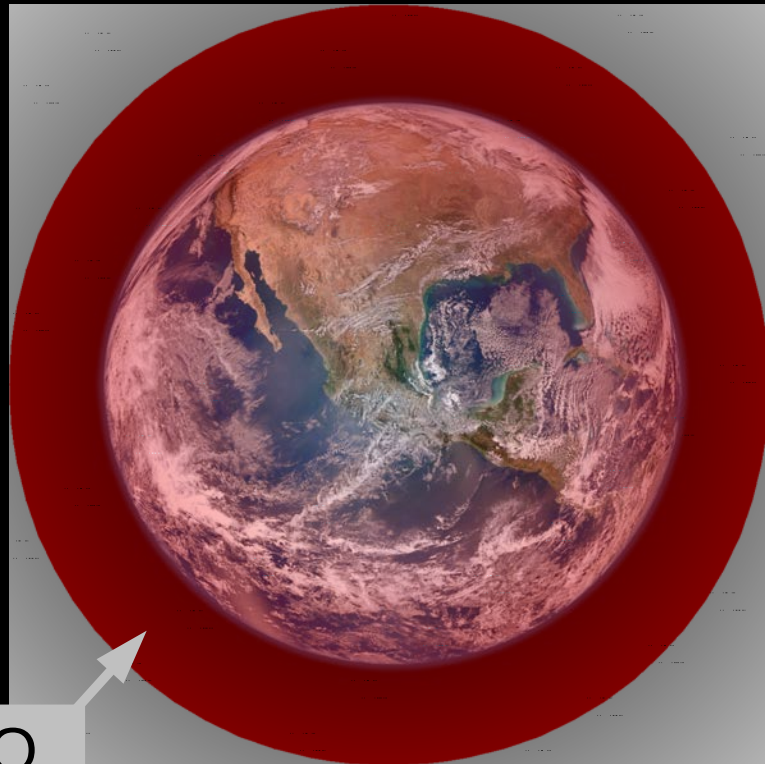
COBACC feedback mechanism

Some uncertainties in global scale quantification:

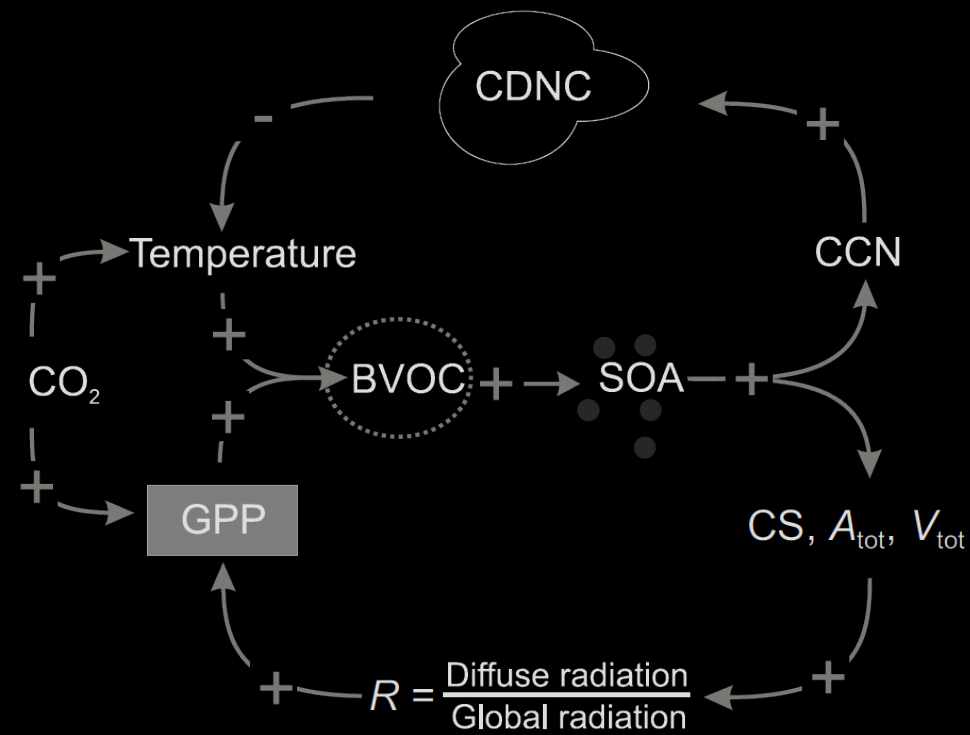
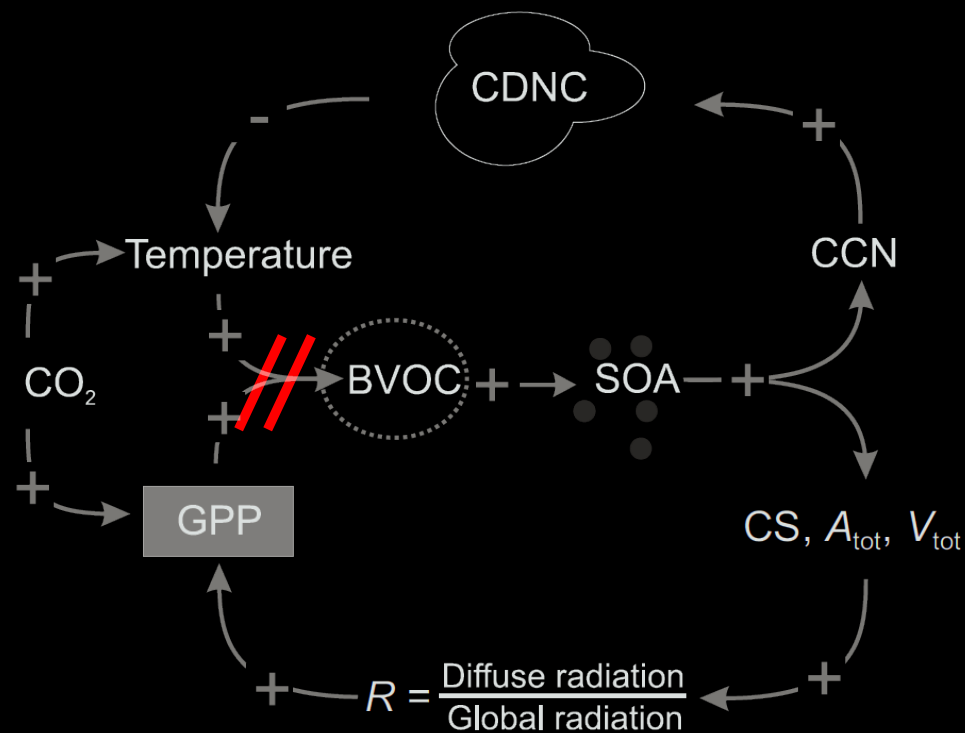
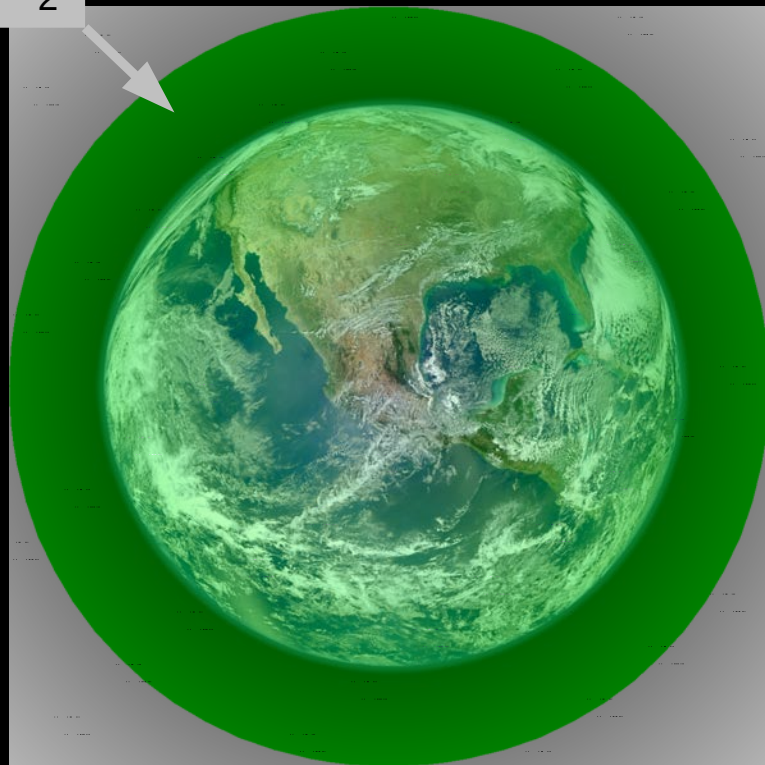




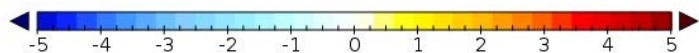
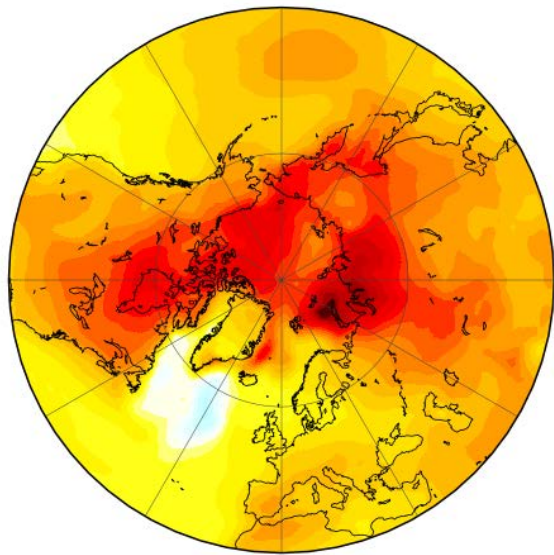




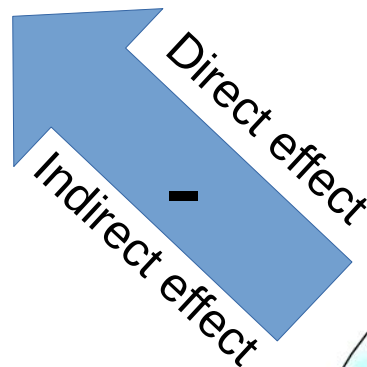
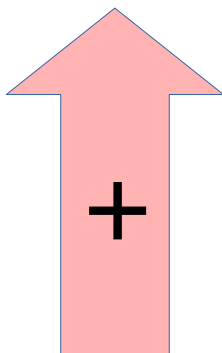
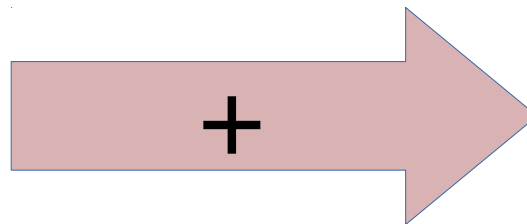
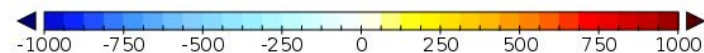
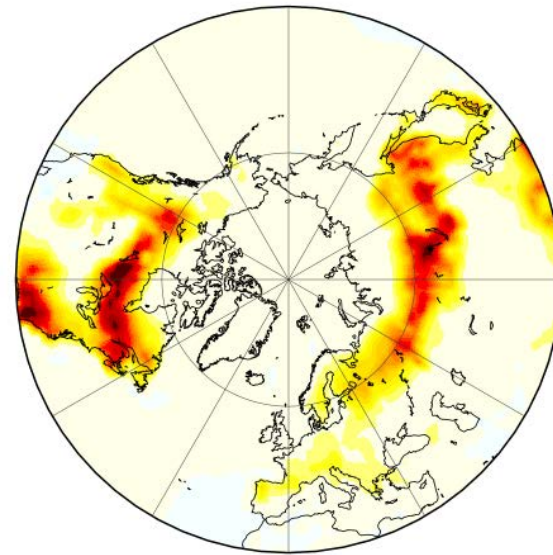
2xCO₂



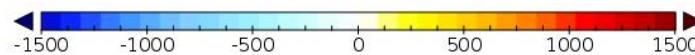
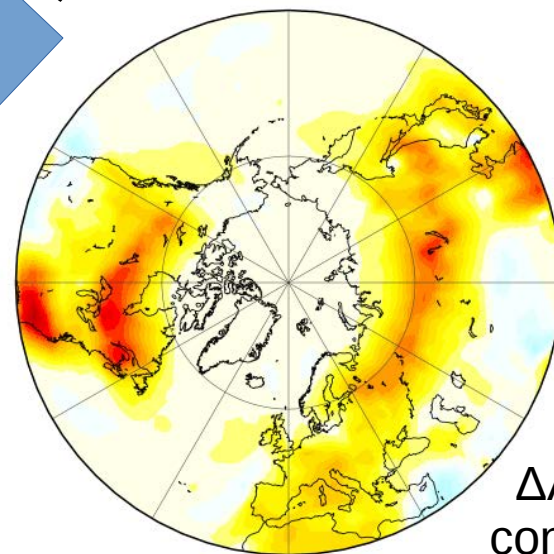
Δ Temperature (K)



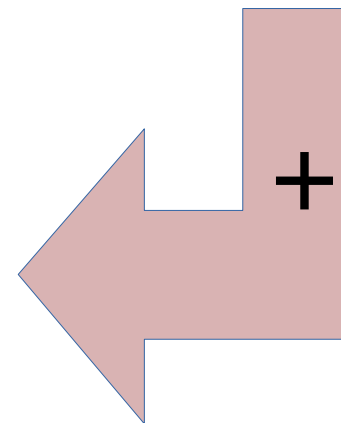
Δ Monoterpene concentration (ppm)



Doubling CO₂
concentration



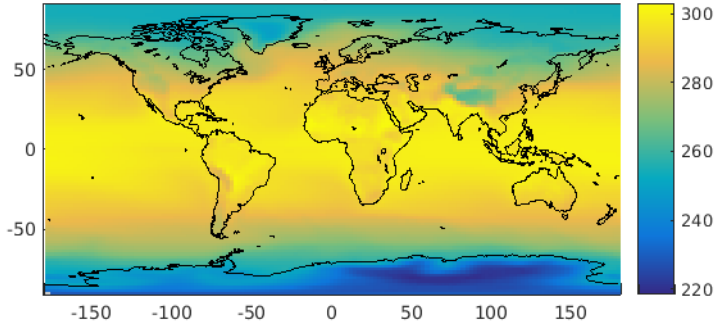
Δ Aerosol number
concentration (cm⁻³)



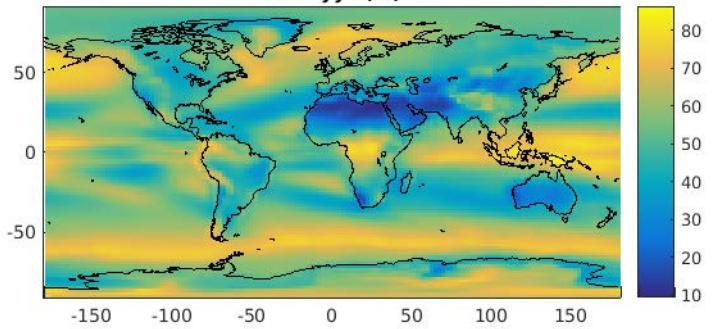
Climate change in doubled CO₂ NorESM simulations

1xCO₂

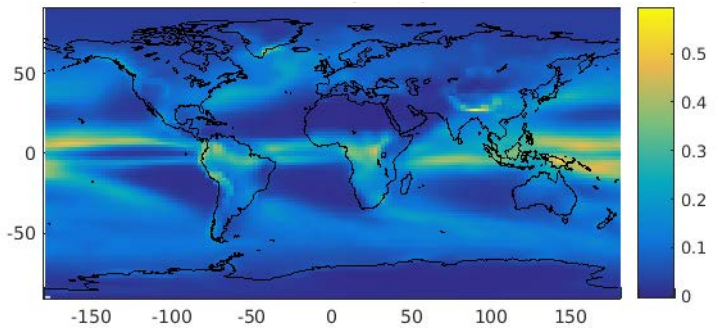
Temperature (K)



Cloud cover (%)

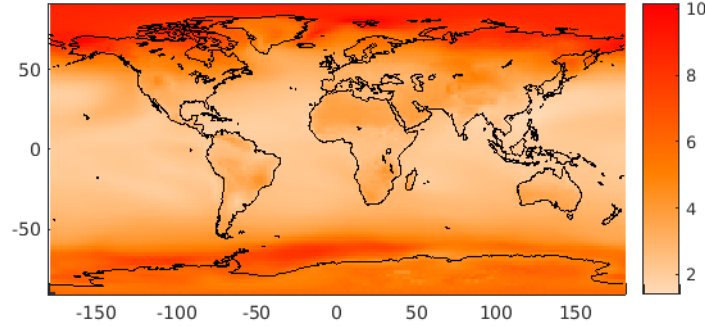


Precipitation (mm/h)

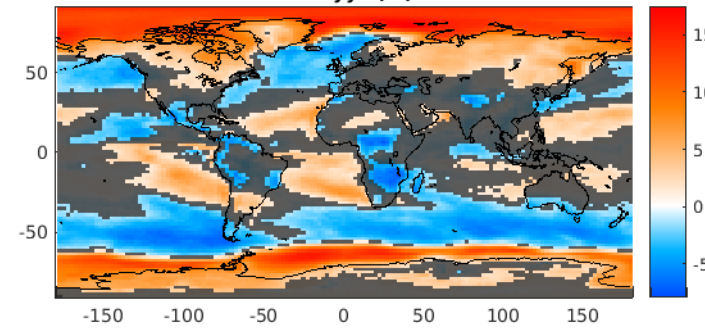


2xCO₂

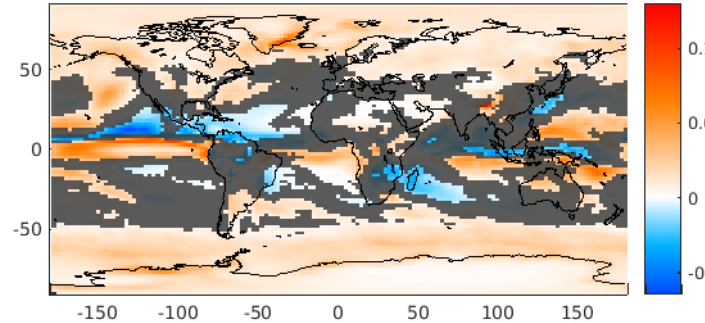
Temperature (K)



Cloud cover (%)



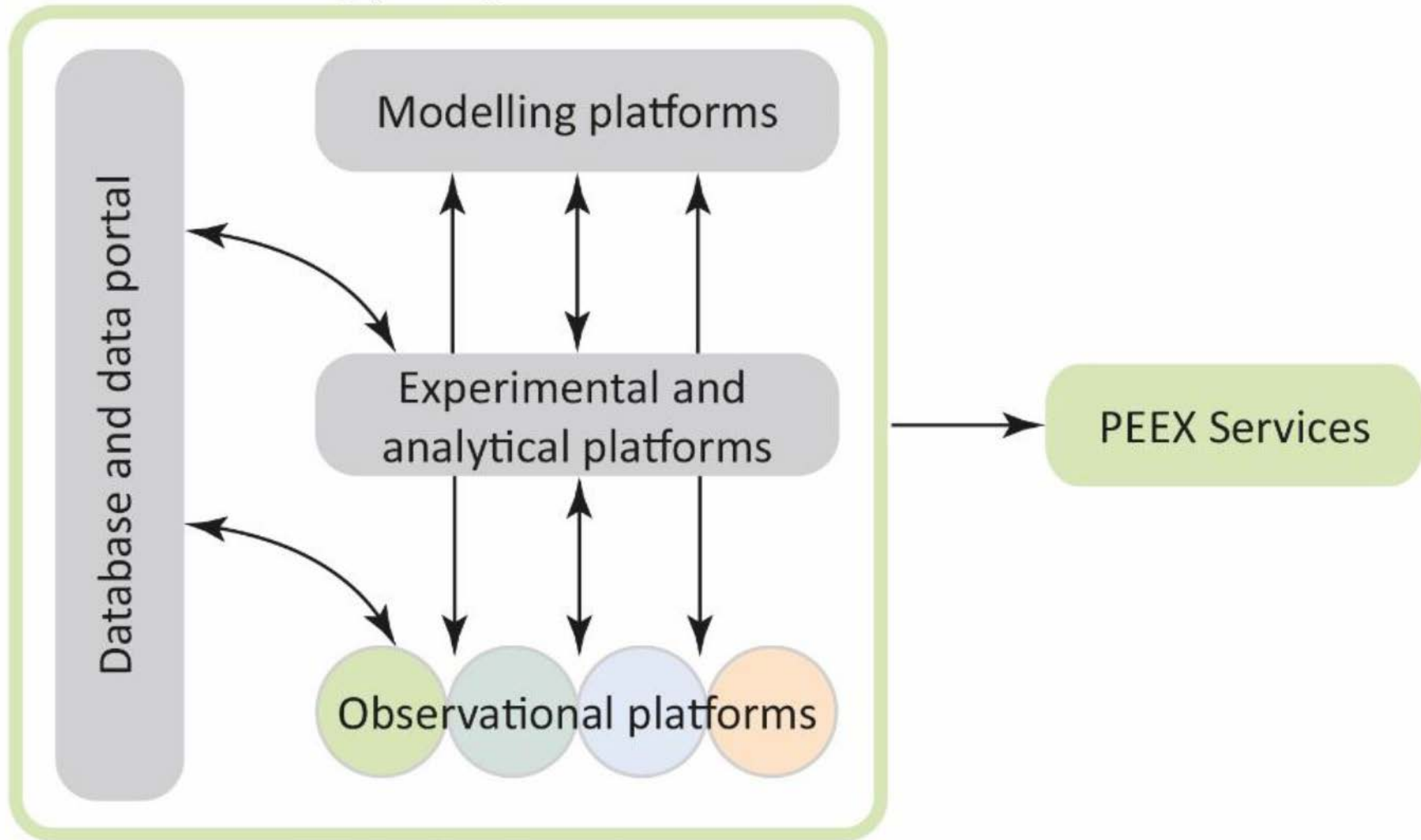
Precipitation (mm/h)



Aerosols and chemistry are affected by the climate variables!

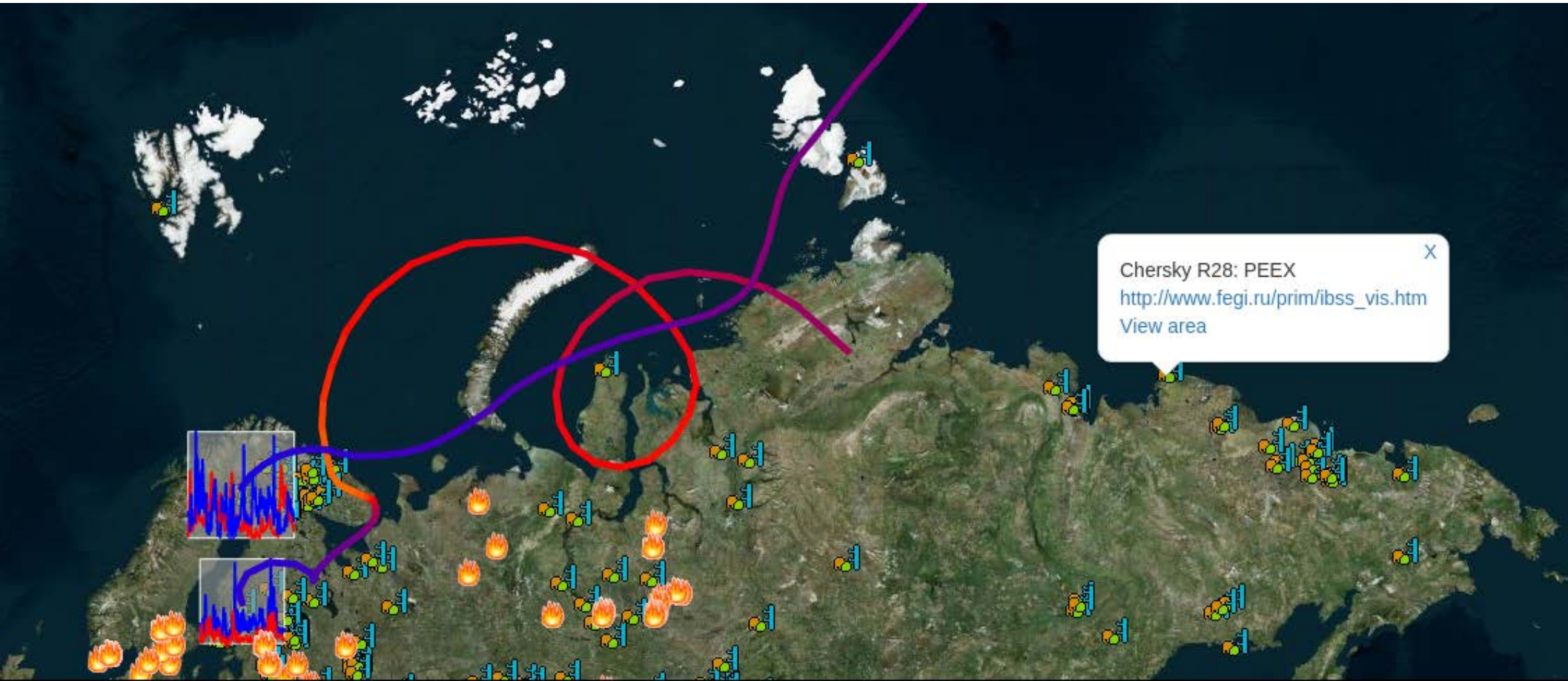
PEEX Infrastructure

Highly integrated



Highly distributed

PEEXView – Visualize and analyze PEEX big data products

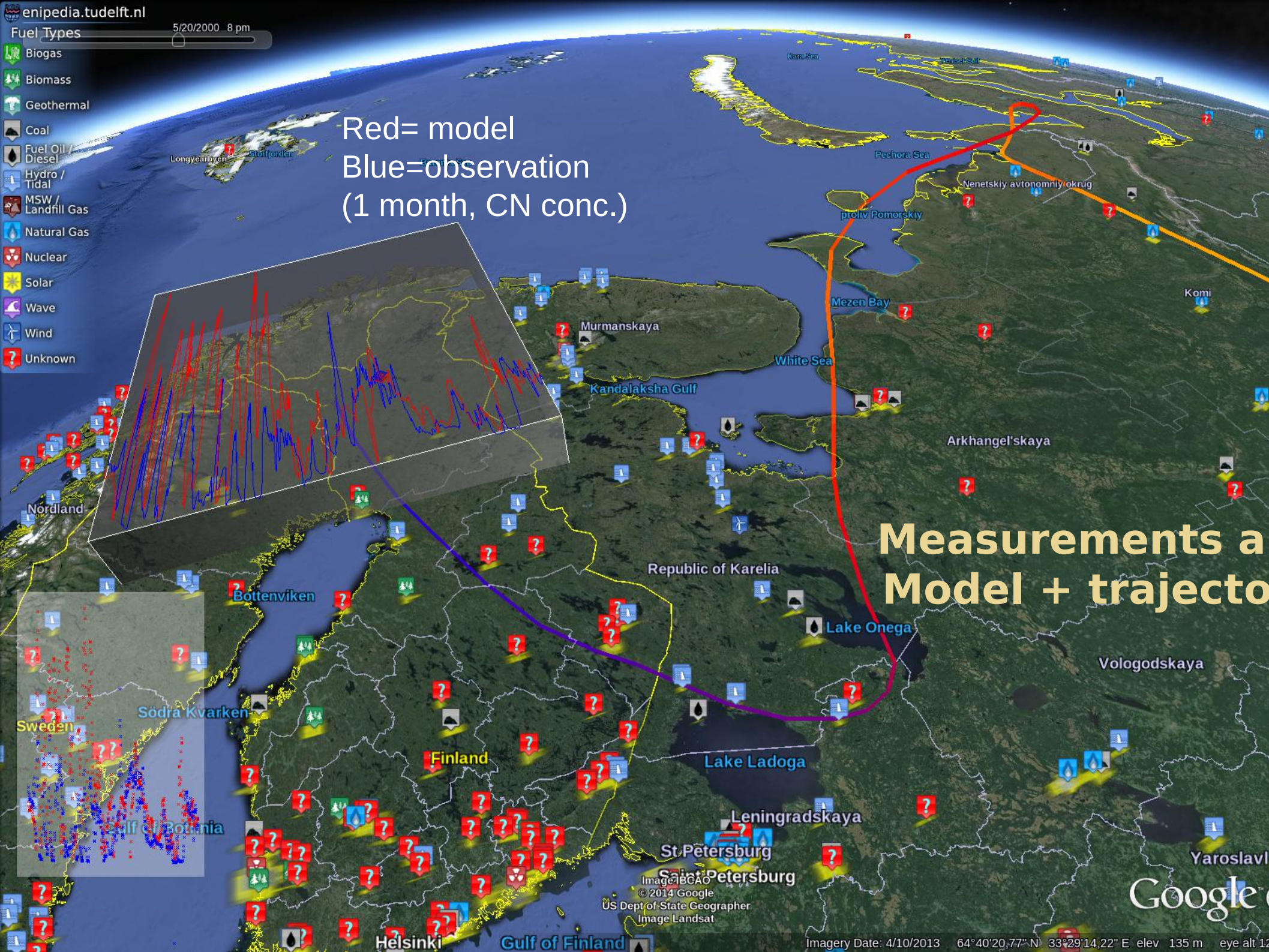
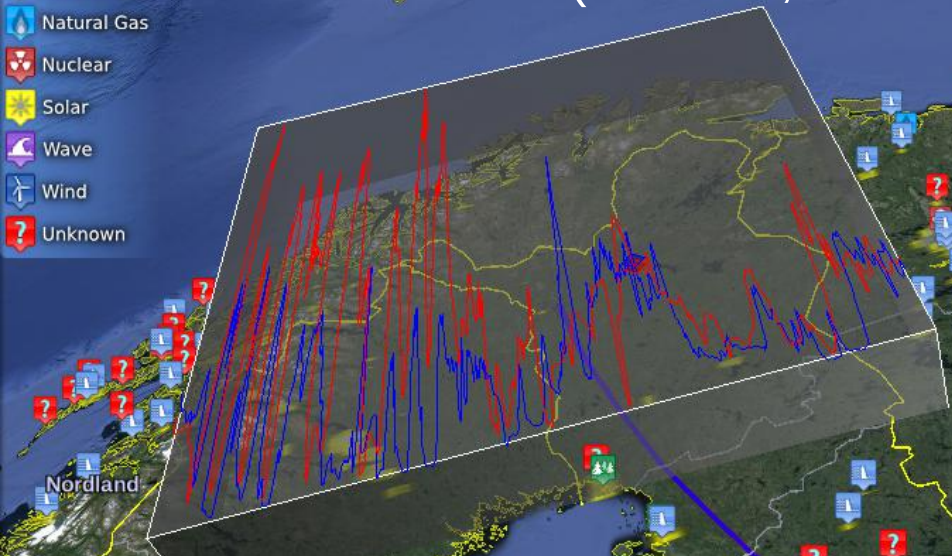


<https://www.atm.helsinki.fi/peex> → INFRA

- Biogas
- Biomass
- Geothermal
- Coal
- Fuel Oil / Diesel
- Hydro / Tidal
- MSW / Landfill Gas
- Natural Gas
- Nuclear
- Solar
- Wave
- Wind
- Unknown

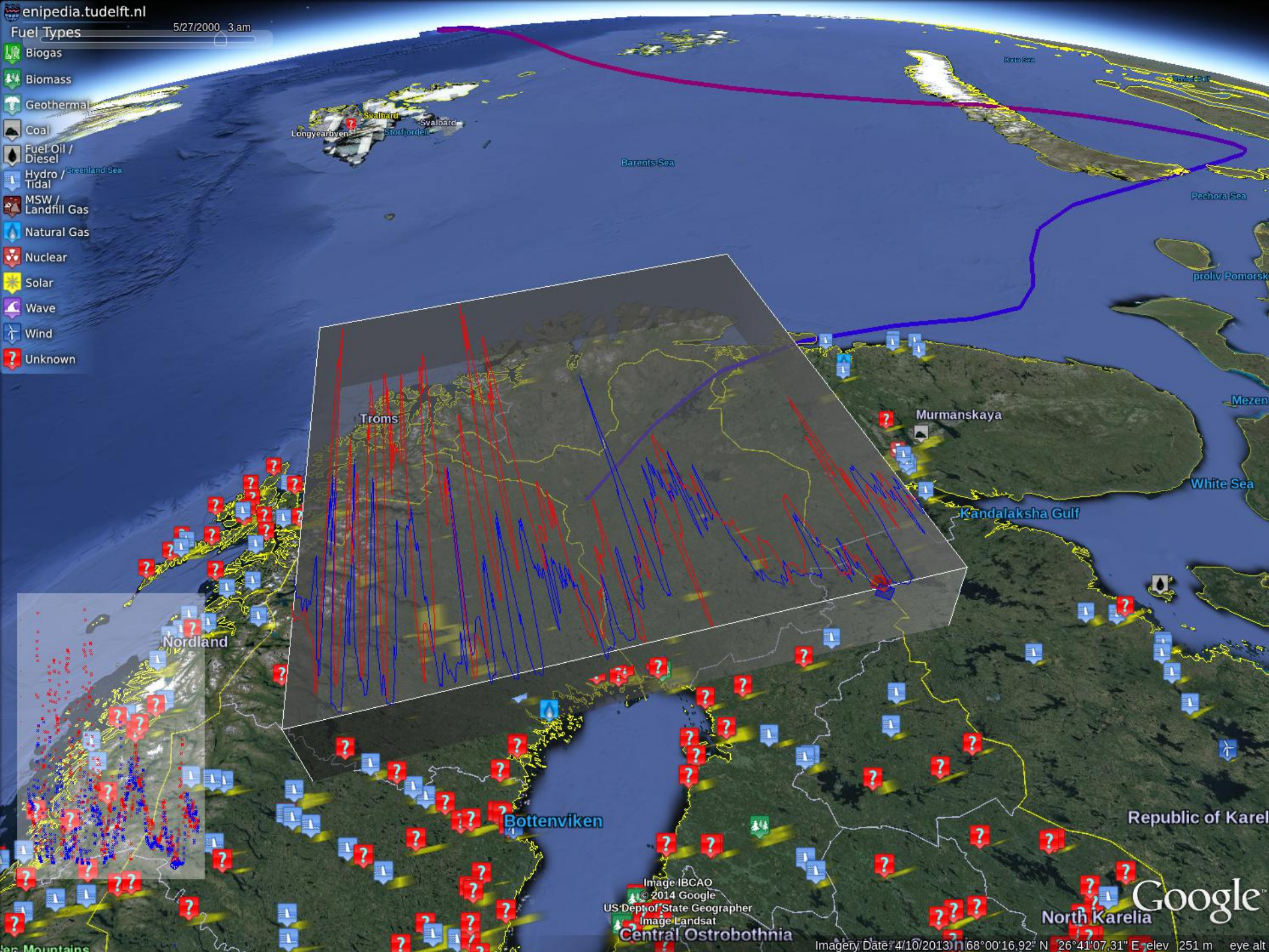
Red= model
 Blue=observation
 (1 month, CN conc.)

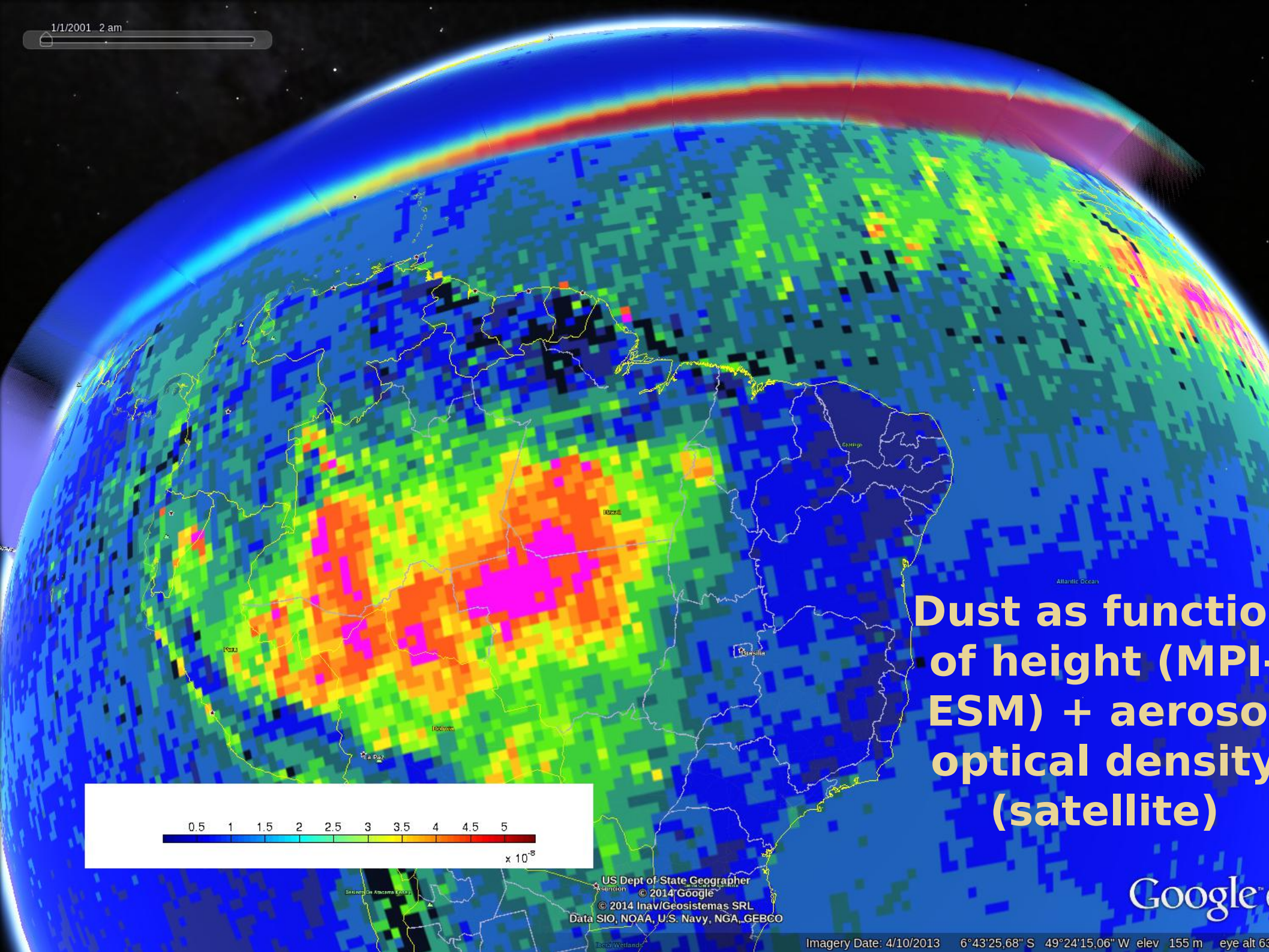
Measurements and Model + trajectory



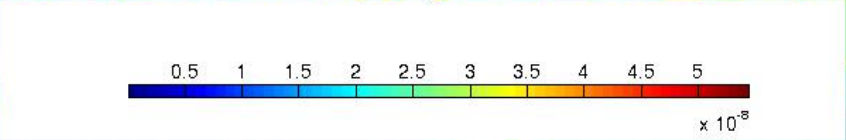
Fuel Types

-  Biogas
-  Biomass
-  Geothermal
-  Coal
-  Fuel Oil / Diesel
-  Hydro / Tidal
-  MSW / Landfill Gas
-  Natural Gas
-  Nuclear
-  Solar
-  Wave
-  Wind
-  Unknown





**Dust as function
of height (MPI-
ESM) + aerosol
optical density
(satellite)**



US Dept of State Geographer
© 2014 Google
© 2014 Inav/Geosistemas SRL
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google

What can be included?

(all data with geospatial reference point)

- Trajectories
- ESM data, 2D, 3D (+t)
- Satellite data (chlorophyll, AOD products, ...)
- Power plants, industry locations, metadata for emission sources
- Ship AIS data (+metadata)
- Socioeconomic indicators (GDP, IPIs, as a function of time)
- Wildfire location/timing from satellites
- ...

Summary

- CRAICC has developed a specific version of NorESM focusing on Arctic response to climate change
 - NorESM-CRAICC is used to evaluate Arctic climate change, human influence and feedback mechanisms
- Global aerosol-climate model ECHAM-HAM has been used to study e.g. Arctic shipping and gas exploration
- For a holistic view of Arctic change, traditional climate feedbacks must be complemented with chemistry-aerosol-cloud-climate feedbacks
 - Less sea-ice → increased sea-spray emission
 - Boreal warming → increased BVOC emission
- UHEL has developed an online platform to serve as an interface to PEEEX big data: model simulations, in-situ observations, satellite data...