Local Arctic air pollution

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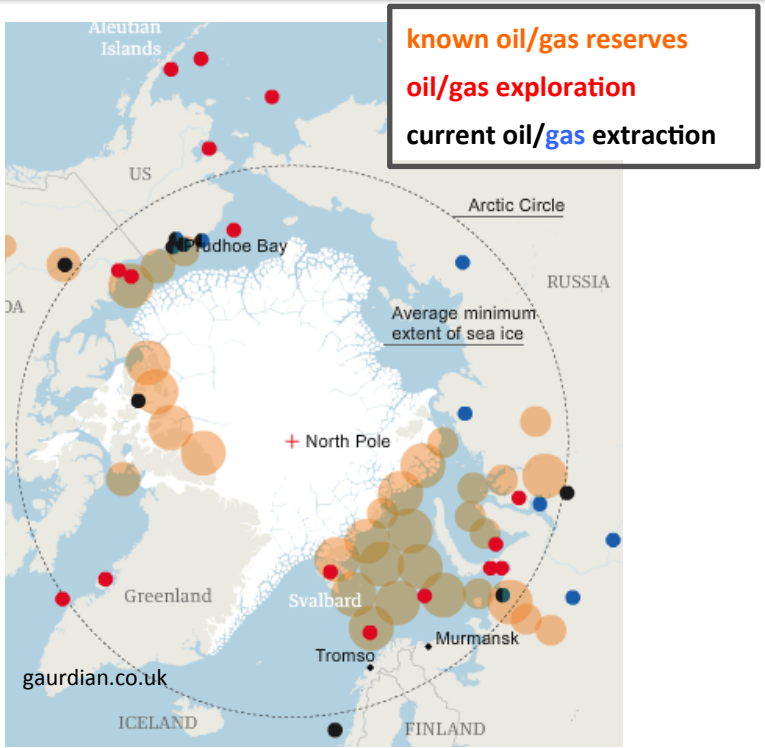
+Many contributions from ACCESS and NETCARE colleagues (DLR, CICERO, U. Toronto, EC)

Arctic Air Pollution Workshop
3 Feb 2015

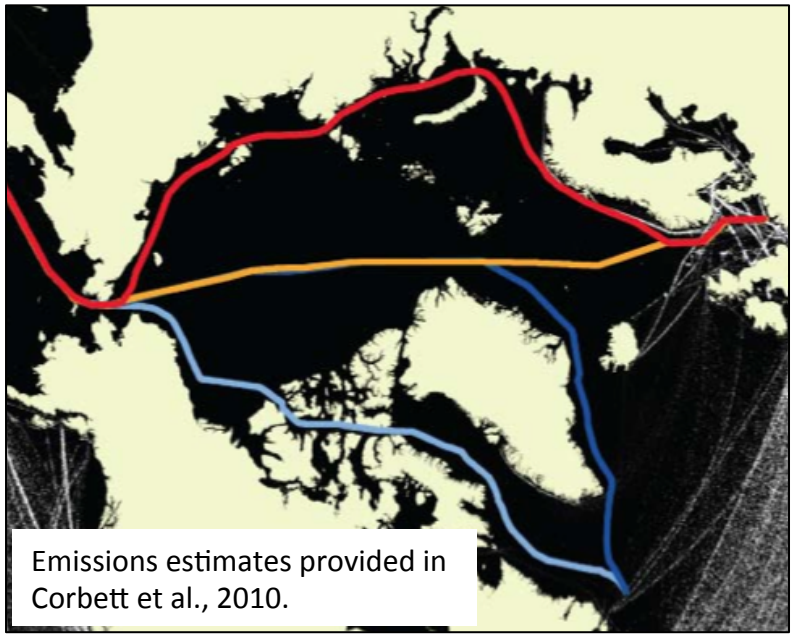
Outline

- Introduction
- Recent studies on local air pollution: emissions, air quality impact, climate impact
- Some examples of recent/ongoing work on local Arctic pollution at LATMOS
  - ACCESS
  - NETCARE
- What do we need in the coming years?

Arctic environmental change is both caused by and has impacts on atmospheric pollution



Arctic oil/gas reserves



Arctic shipping routes

Anthropogenic pollution ➔ Arctic environmental change (sea ice decrease) ➔ increased pollution

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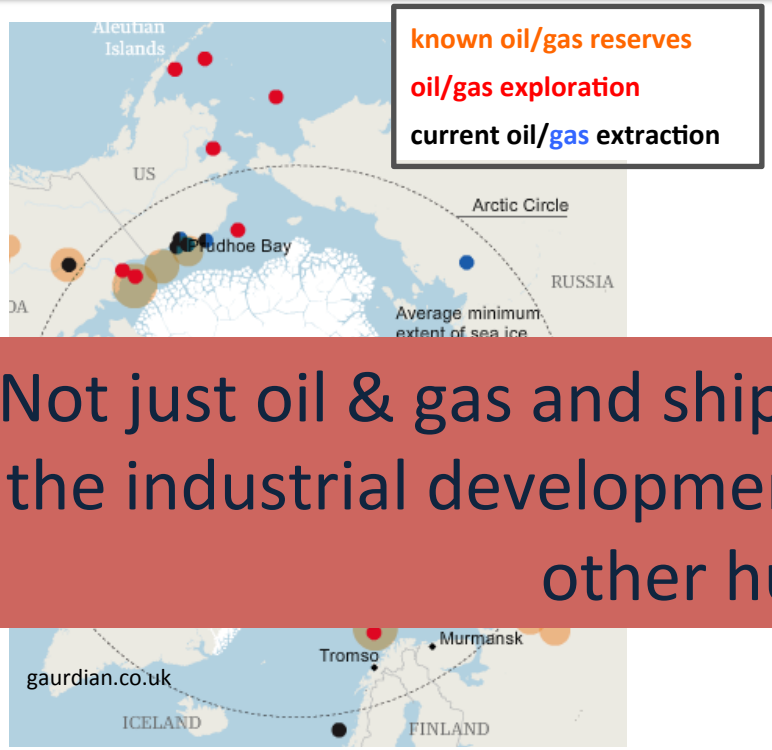

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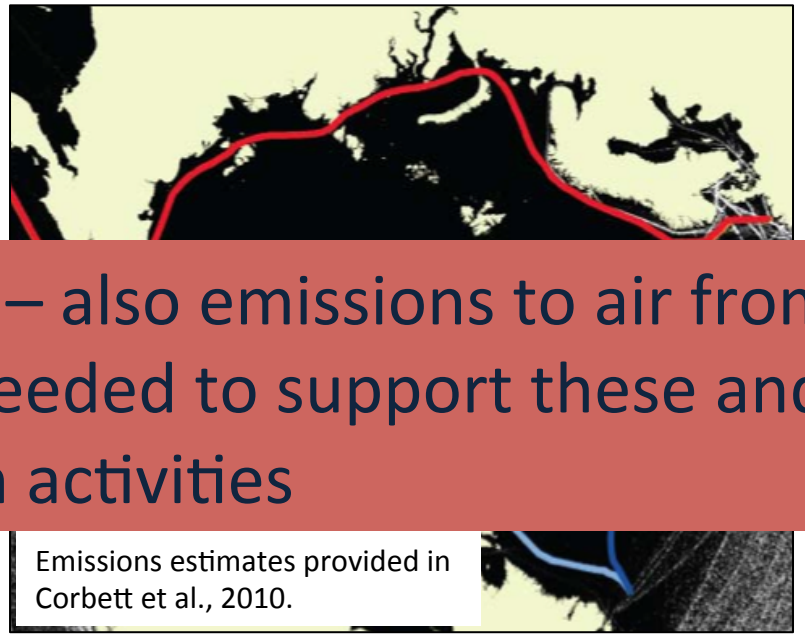

Arctic shipping routes

Not just oil & gas and shipping – also emissions to air from the industrial developments needed to support these and other human activities

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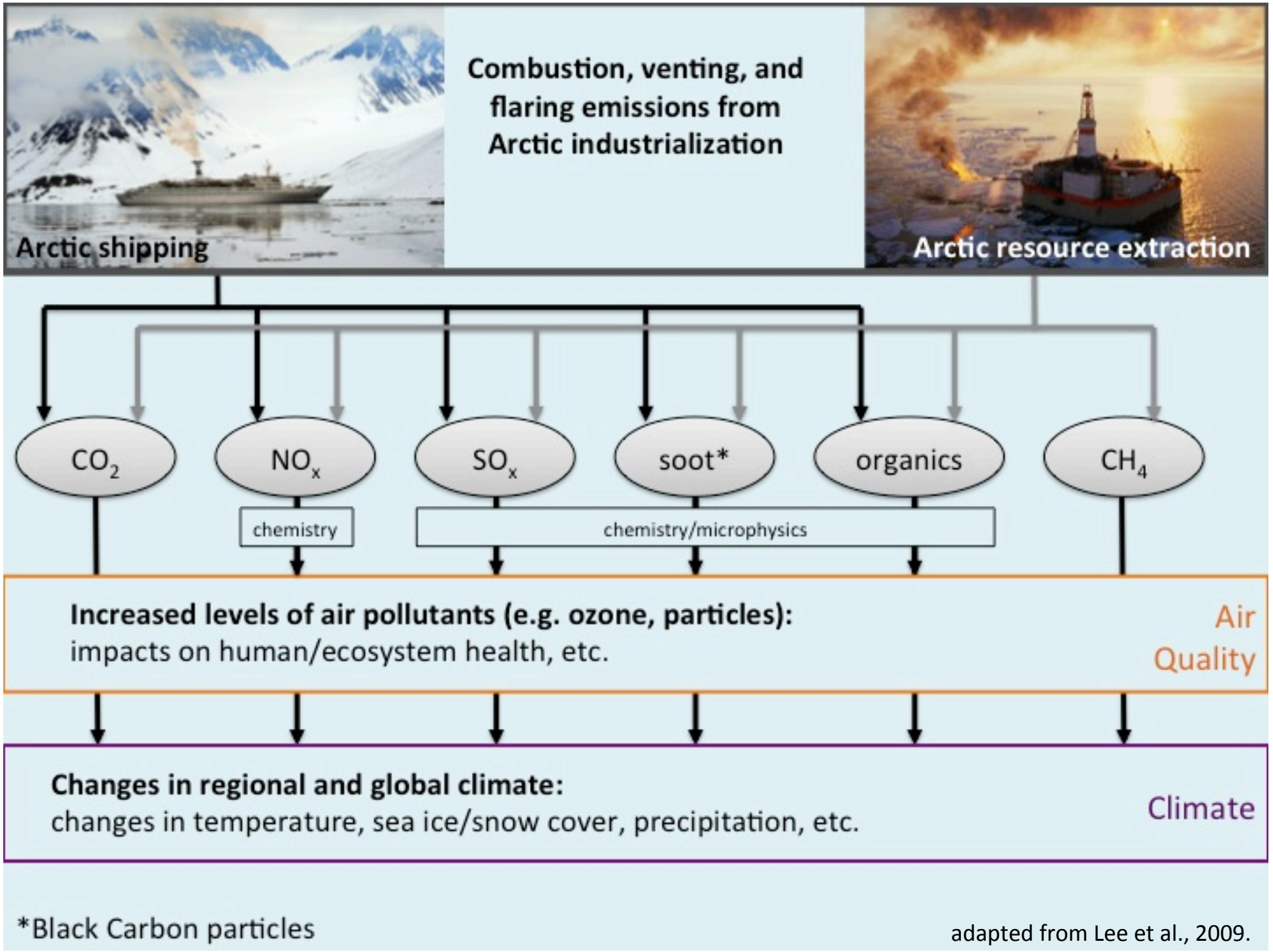
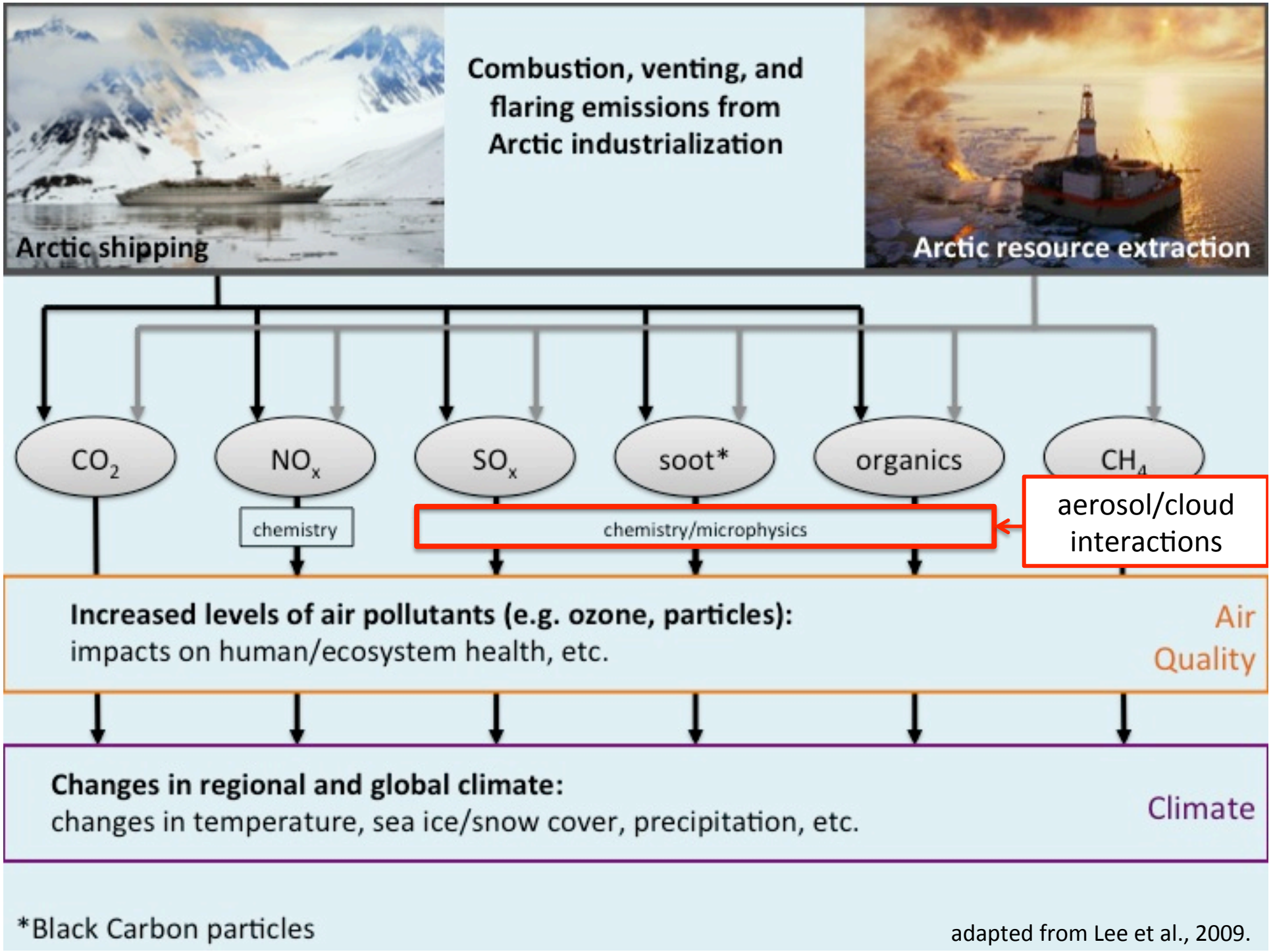

Arctic shipping
Combustion, venting, and flaring emissions from Arctic industrialization
Arctic resource extraction
CO_2
NO_x
SO_x
soot*
organics
CH_4
chemistry
chemistry/microphysics
Increased levels of air pollutants (e.g. ozone, particles):
impacts on human/ecosystem health, etc.
Air Quality
Changes in regional and global climate:
changes in temperature, sea ice/snow cover, precipitation, etc.
Climate
*Black Carbon particles
adapted from Lee et al., 2009.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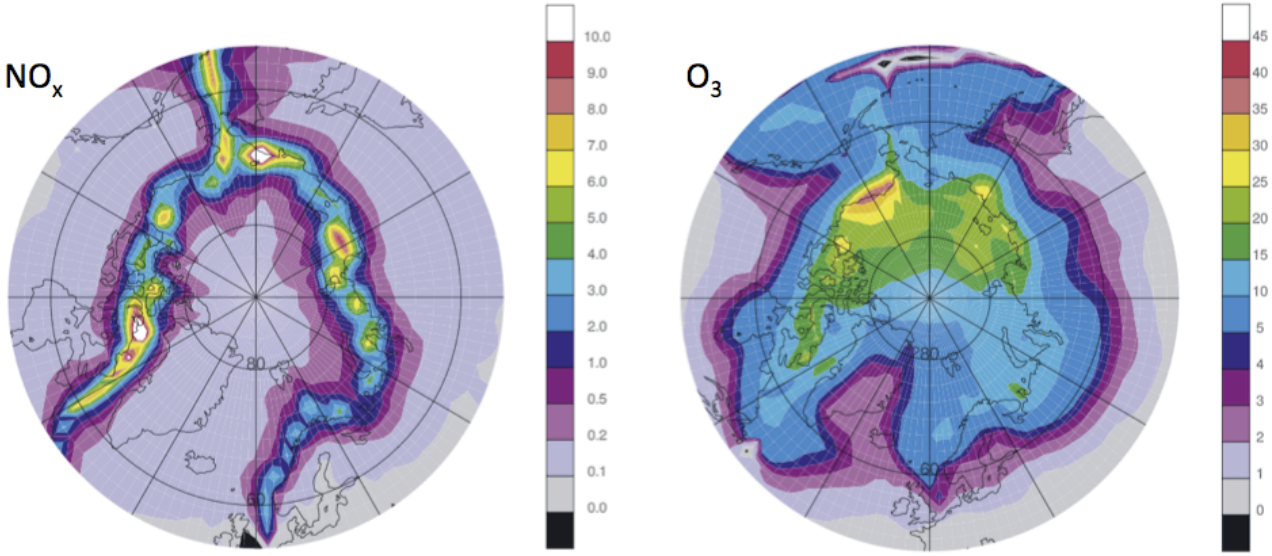
First studies focused on how Arctic shipping will change air quality



Results: Increased surface NO_x and ozone predicted by the global model (MOZART) for July 2050, compared to the case with no Arctic transit shipping (July 2000).

Granier et al., GRL, 2006.

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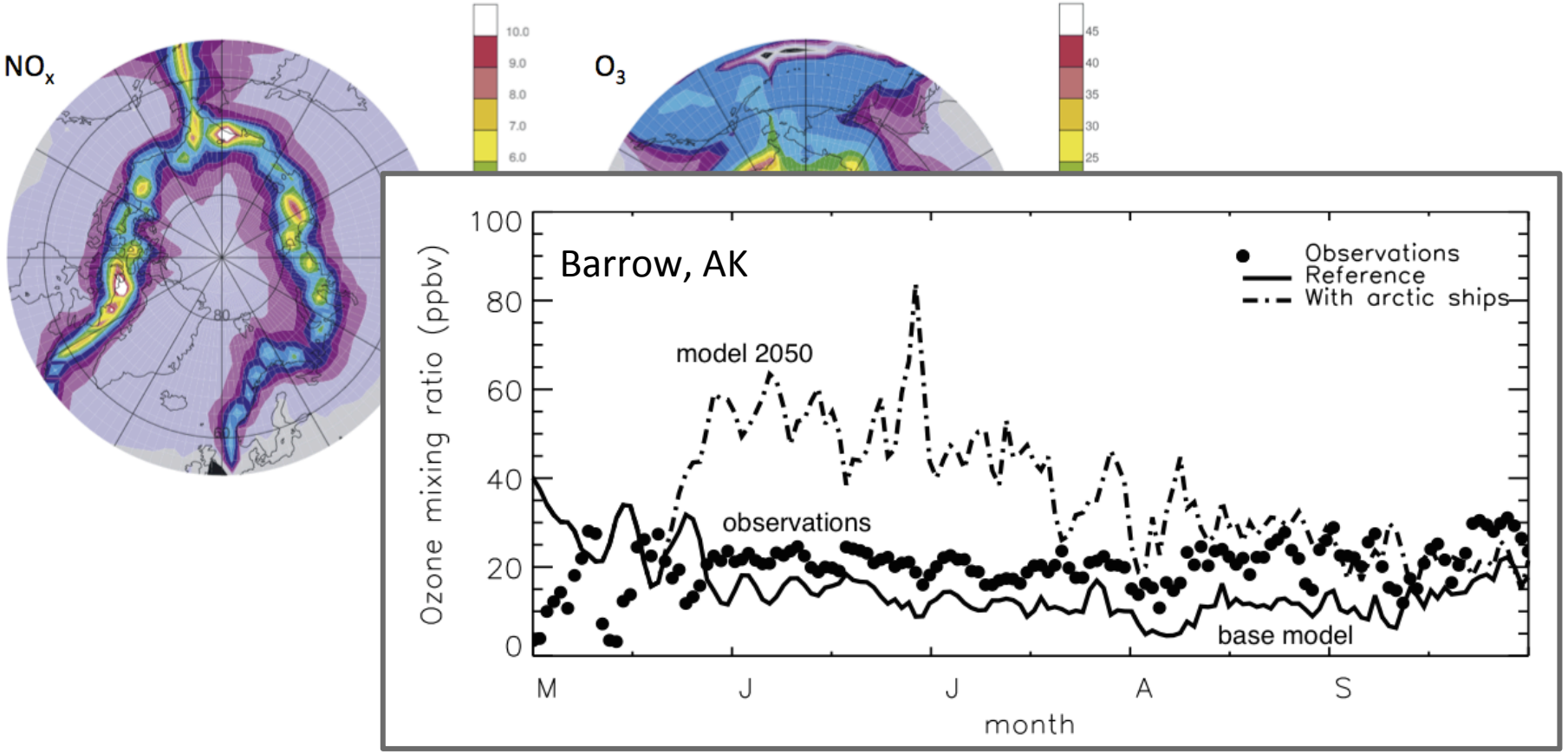

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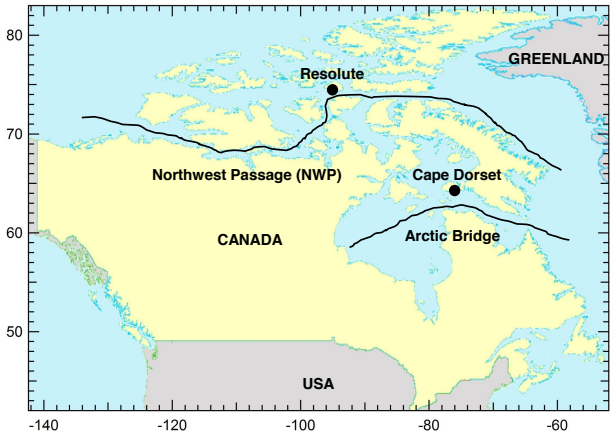
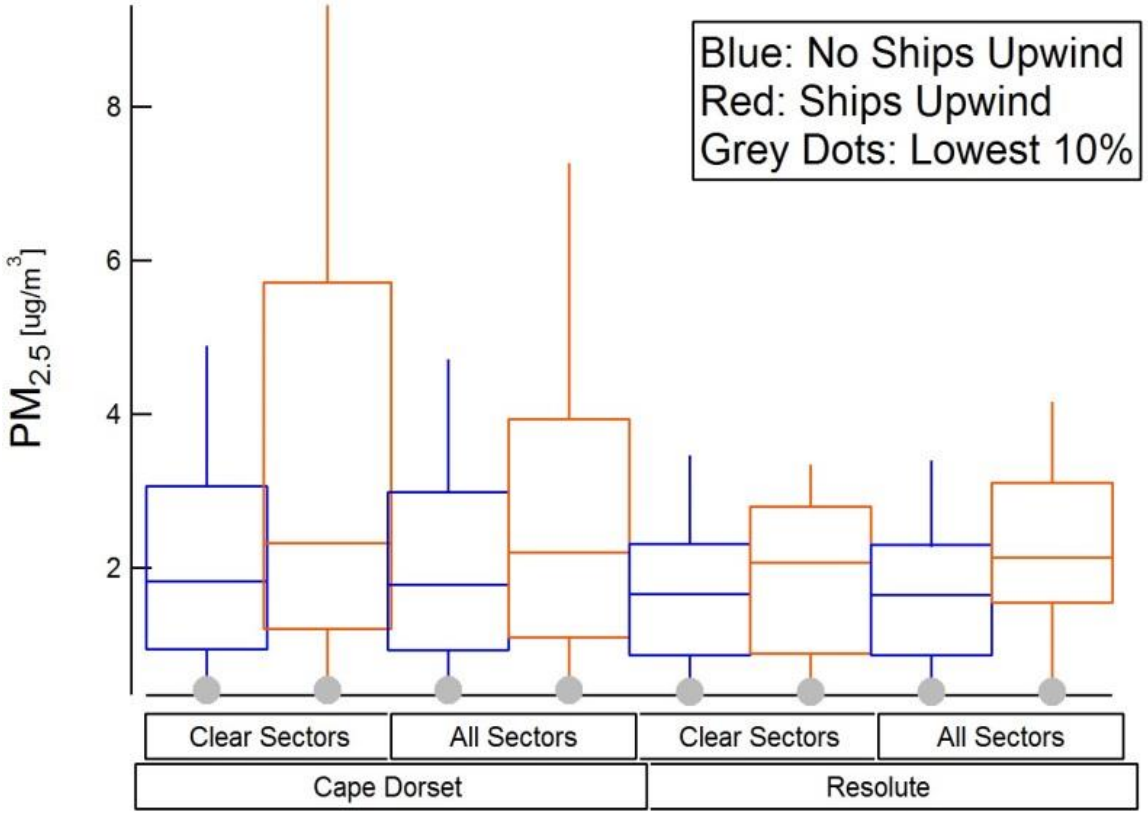
Granier et al., GRL, 2006.

Observational evidence for the negative impacts of shipping on air quality in the Canadian Arctic

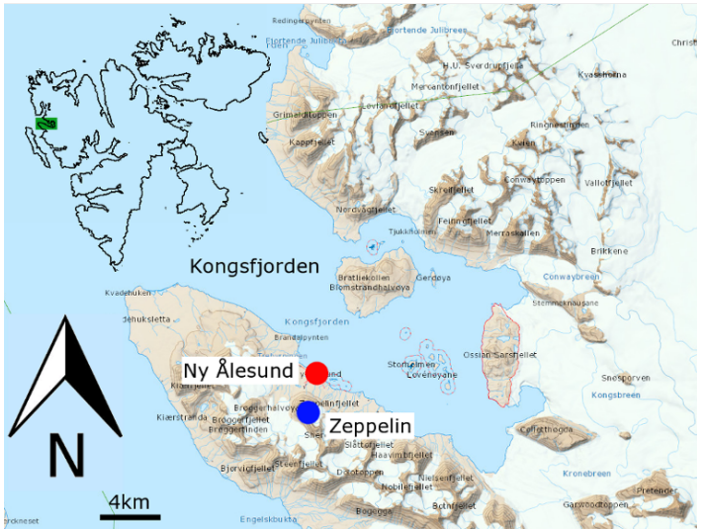




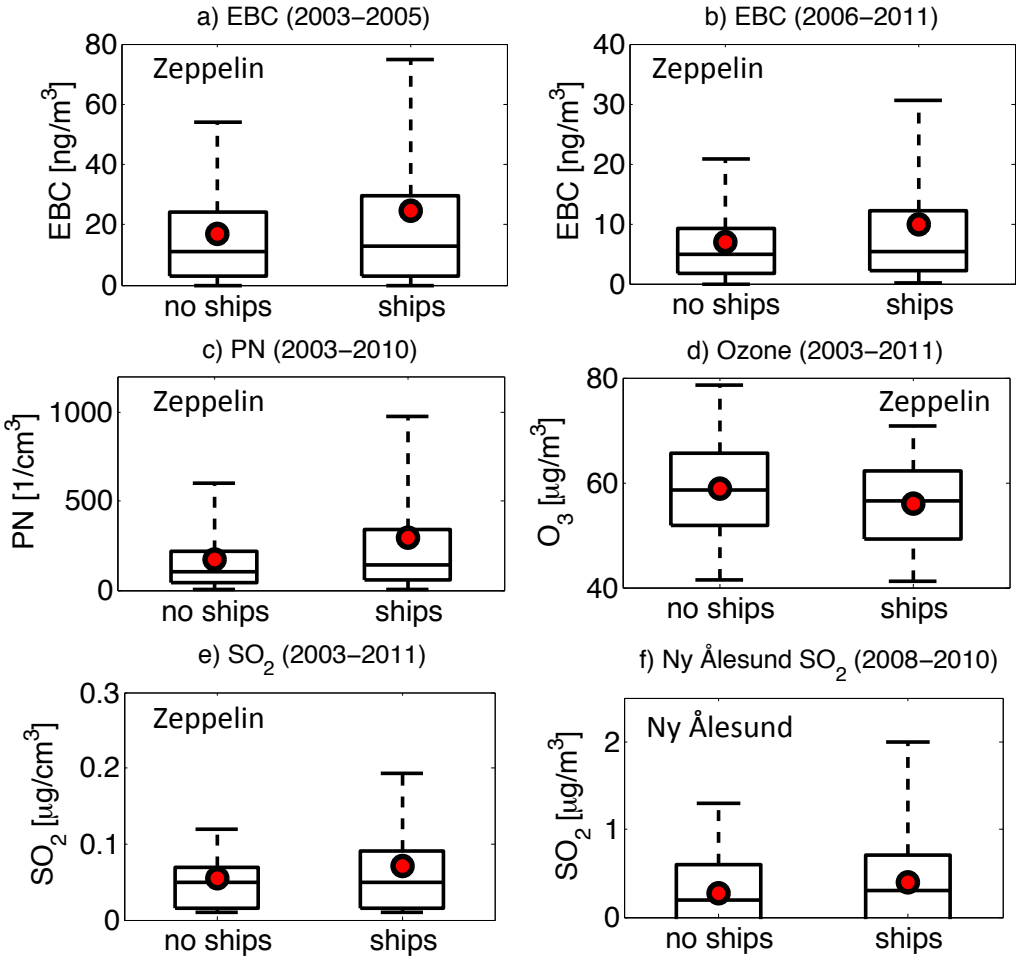
(a) Ship plume age up to 24hr

A. A. Aliabadi, R. M. Staebler, and S. Sharma, ACPD, 2014.

Observation evidence for the influence of cruise ship emissions on air pollution in Svalbard



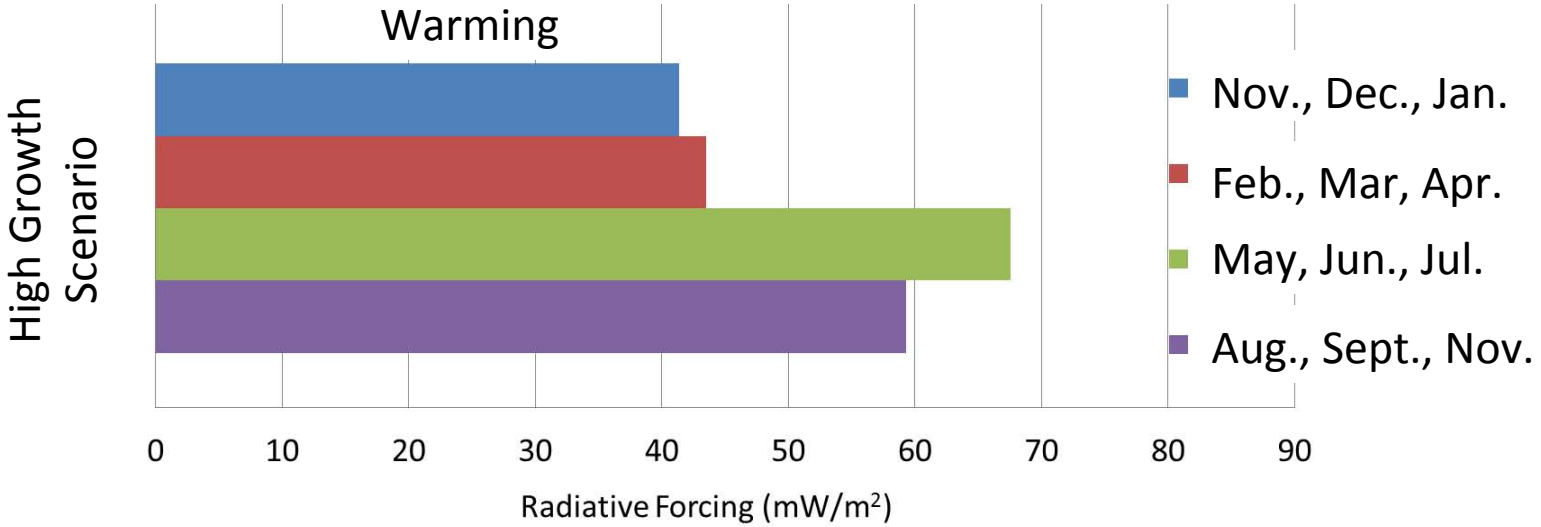
Elevated pollution in 2013 (1 June to 1 November): except for ozone, which is titrated in ship plumes on short time scales



Eckhardt et al., ACP, 2013.

Increased Arctic ship emissions are also predicted to impact climate

Global radiative forcing (2030-2004) due to increased Arctic shipping (using a high growth scenario)

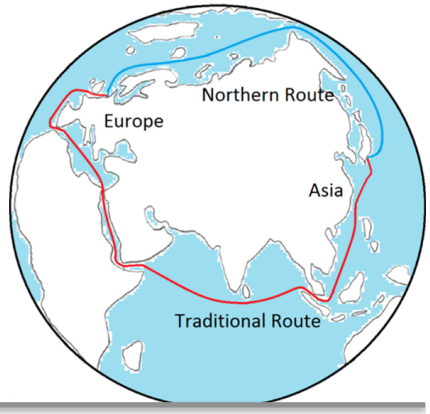


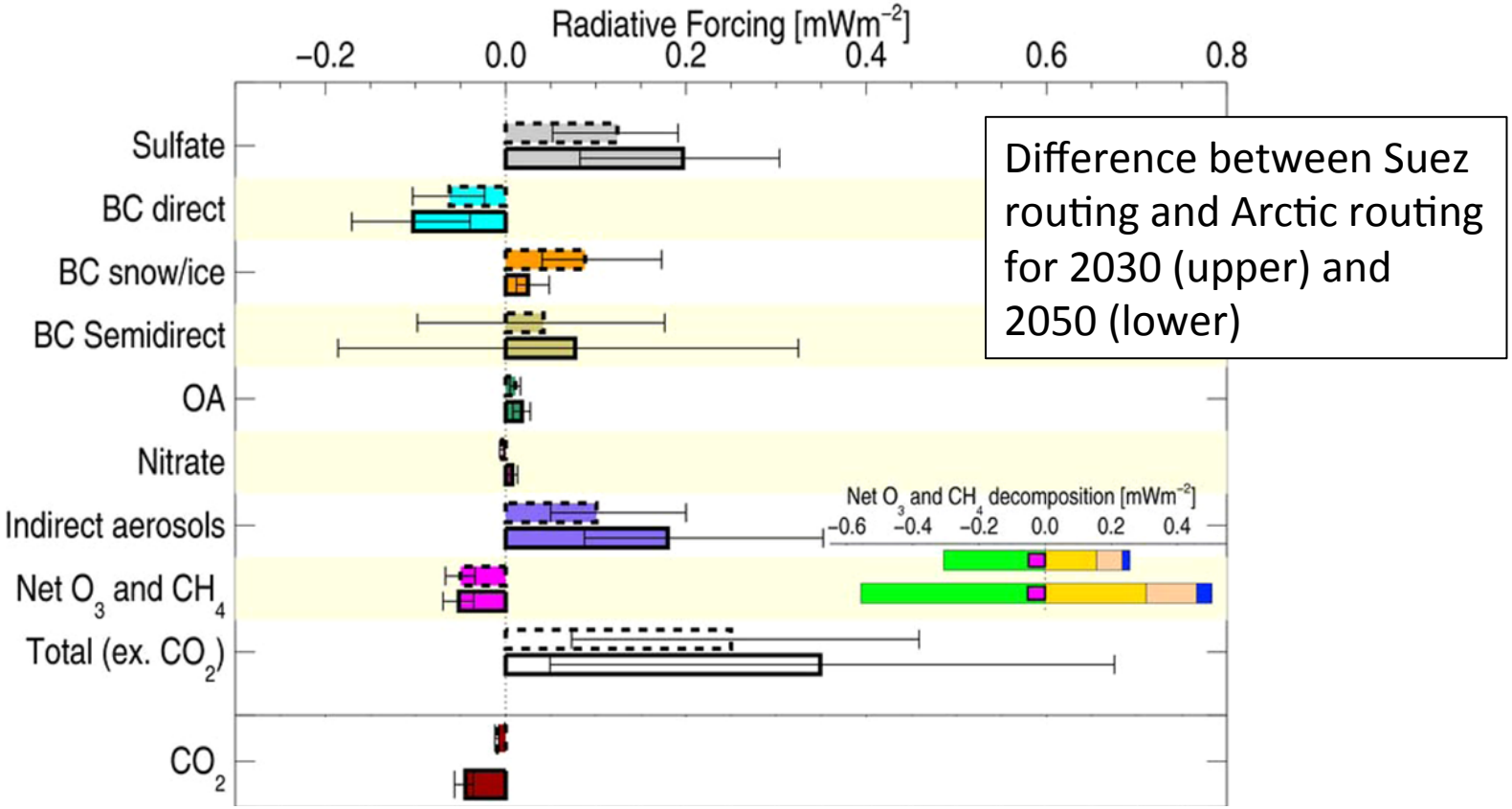
Increased Arctic shipping results in warming, the main cause of warming is decreased SO_2 emissions from ships – direct and indirect aerosol effects

Dalsoren et al., 2013. Based on shipping emissions presented in Corbett et al., 2010.

Does routing matter?

36% (2030) and 45% (2050) of the Rotterdam–Yokohama container trade volume diverts from Suez route to an Arctic transit route



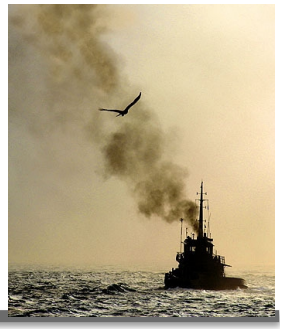


Difference between Suez routing and Arctic routing for 2030 (upper) and 2050 (lower)

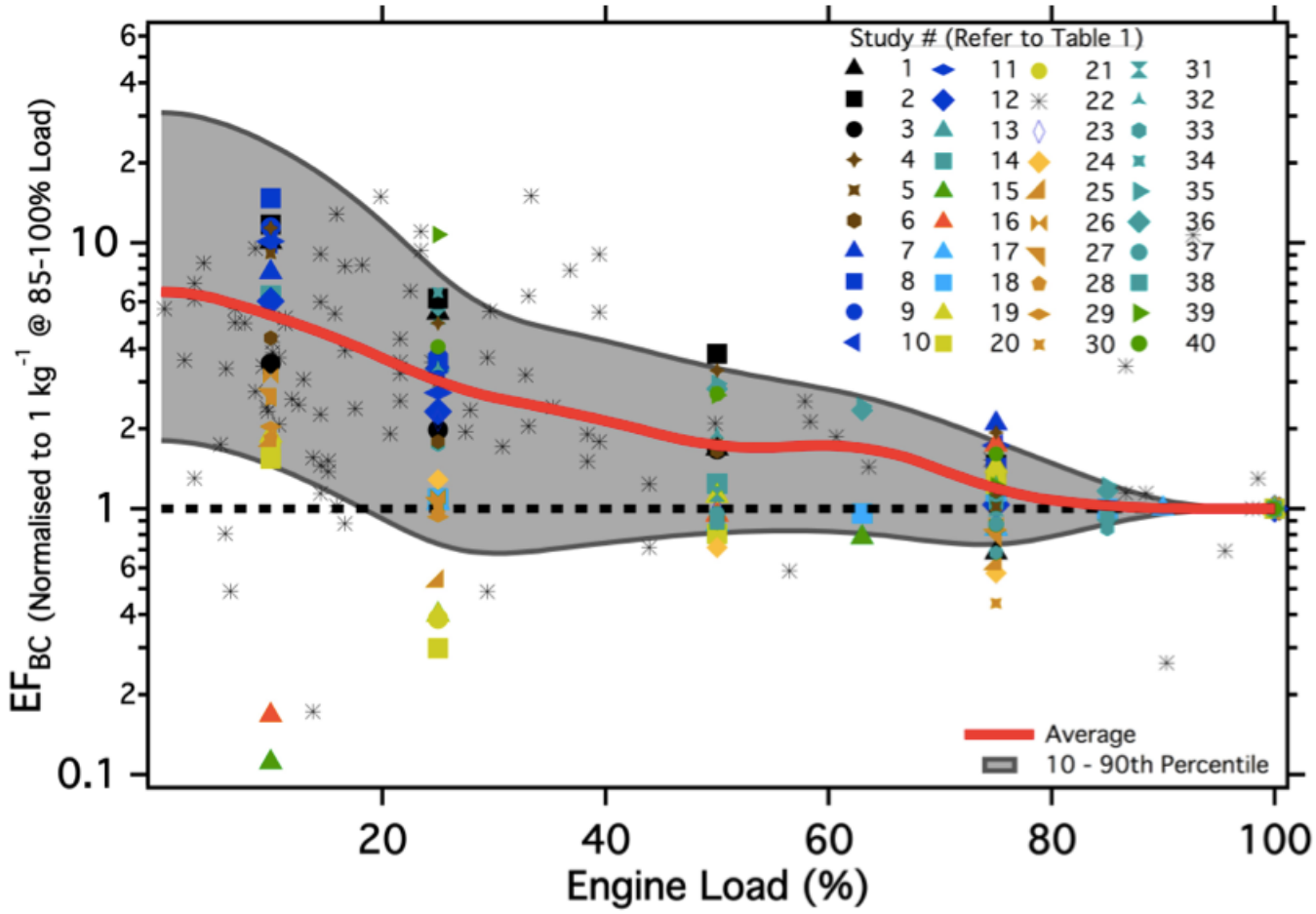
Warming is predicted to be larger – when routing ships through the Arctic

Fuglestvedt et al., EST, 2014.

Shipping emissions – critical for predicting air quality and climate impacts

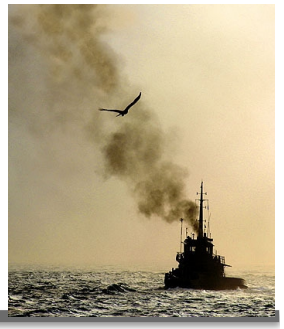


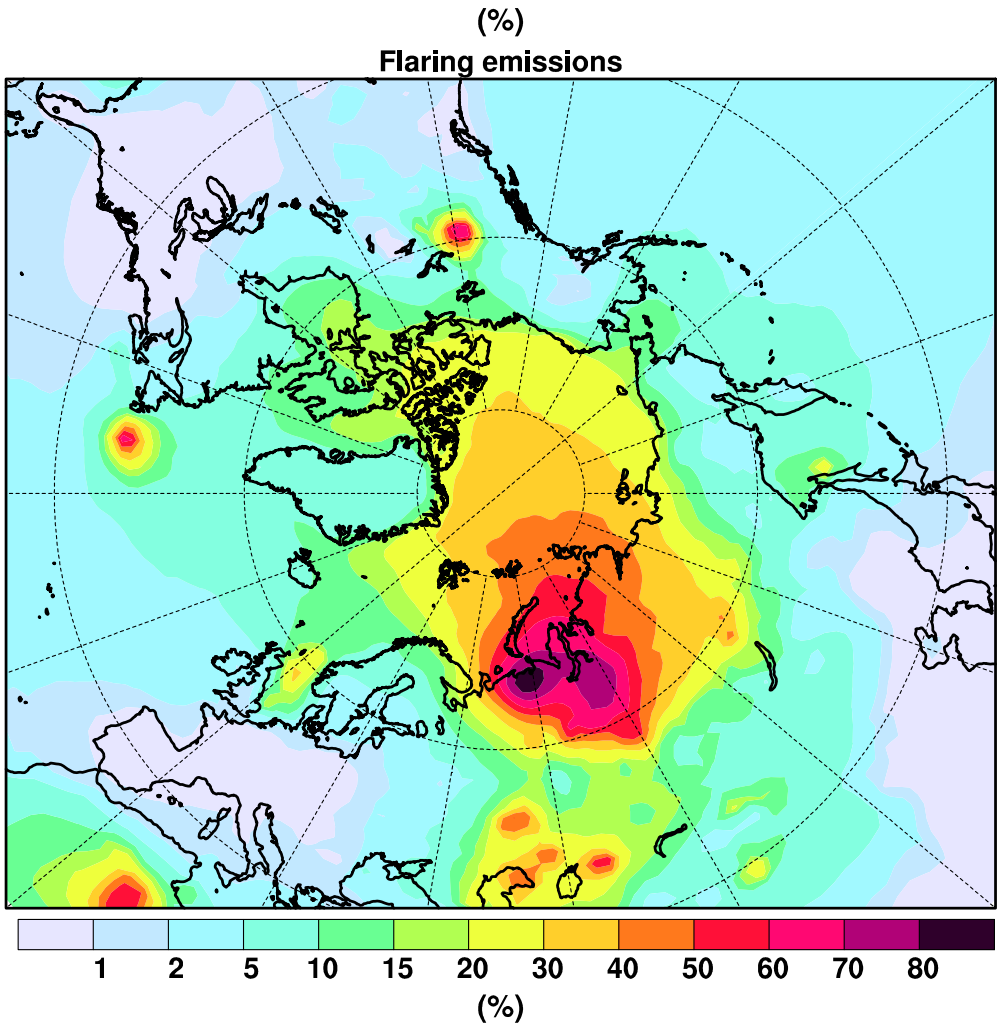
Black carbon emissions factors depend on engine loads.



Lack and Corbett, 2012.

Emissions from hydrocarbon extraction in the Arctic – e.g. flaring emissions



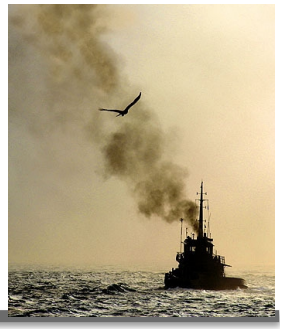


Simulated contribution of flaring emissions (%) to annual mean surface concentrations of BC – using ECLIPSE emissions (including BC from flaring in Russia)

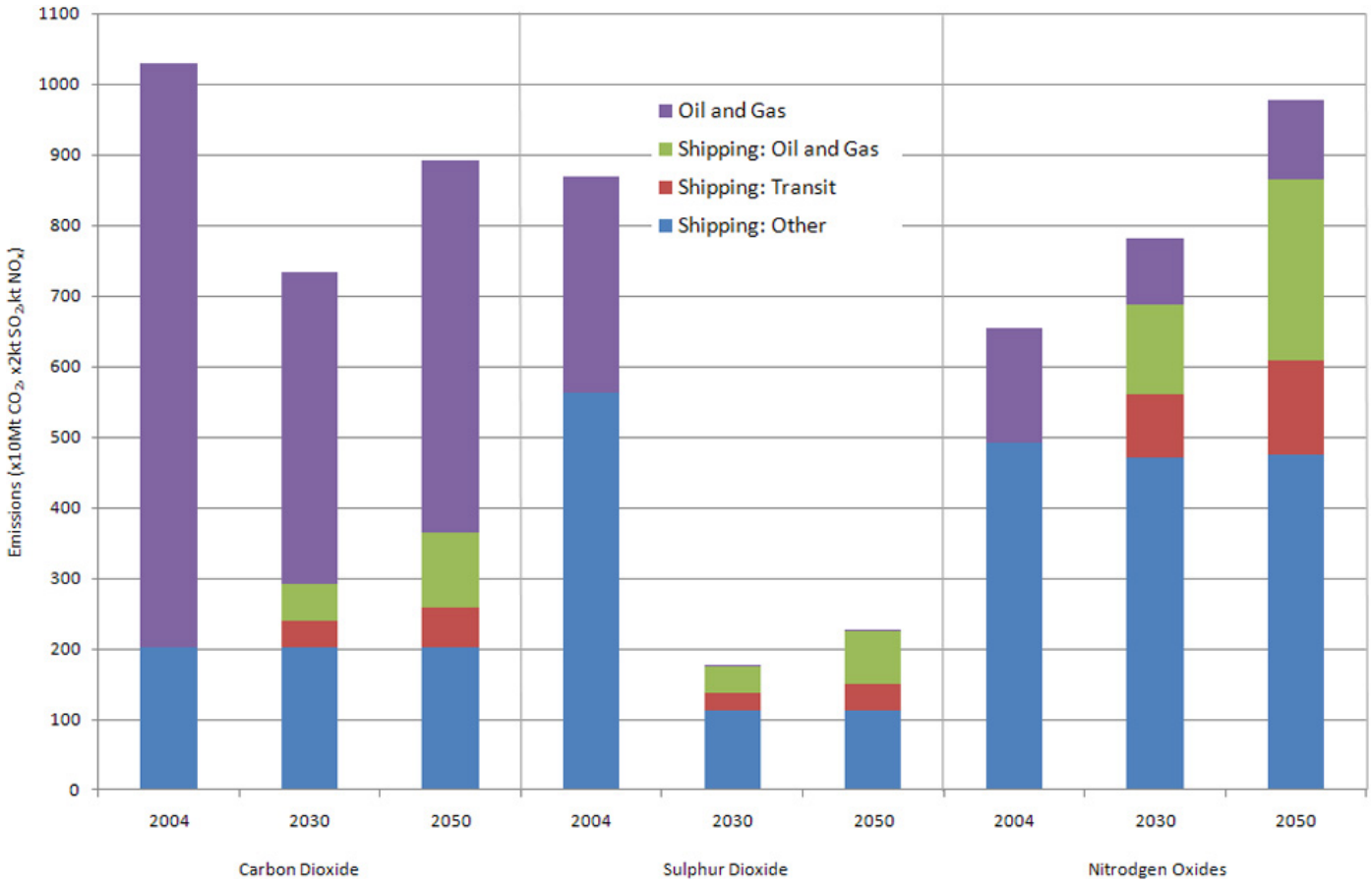
We also know hydrocarbon extraction includes large amounts of VOC and CH_4 emissions, which are poorly quantified. See recent studies from Petron et al.

Stohl et al., 2013.

Current and future emissions estimates from oil/gas extraction and shipping



Peters oil/gas emissions (CICERO)



based on economics modeling for 210 and 2050 using a 2004 base year

1x1 degree Arctic only emissions (also includes aerosol emissions estimates)

Peters et al., 2011.

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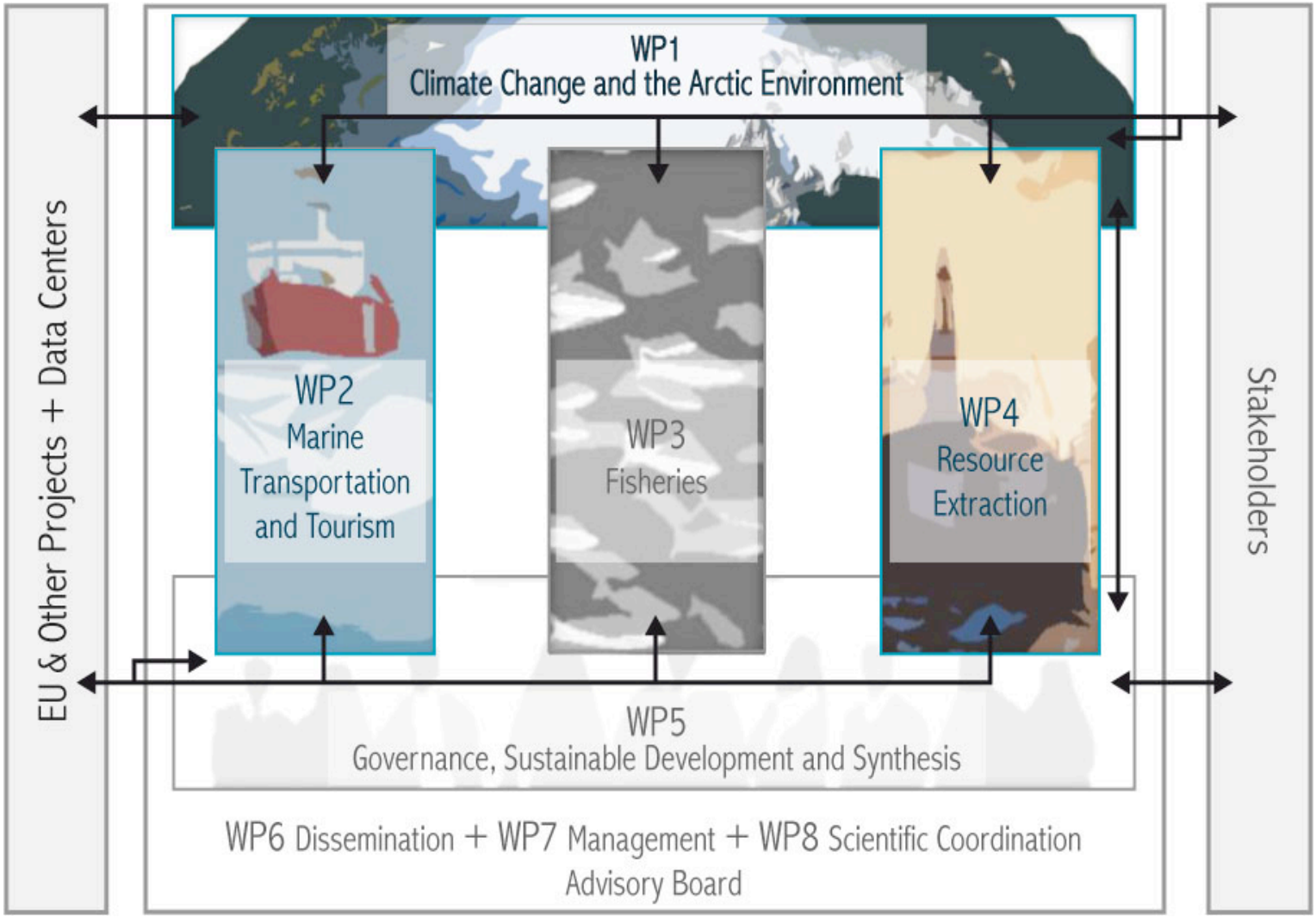
Arctic Climate Change, Economy and Society (ACCESS)



ACCESS
Arctic Climate Change
Economy and Society

SEVENTH FRAMEWORK
PROGRAMME

EU project involving 27 institutions from 9 countries
Project duration: 4 years (2011-2015)

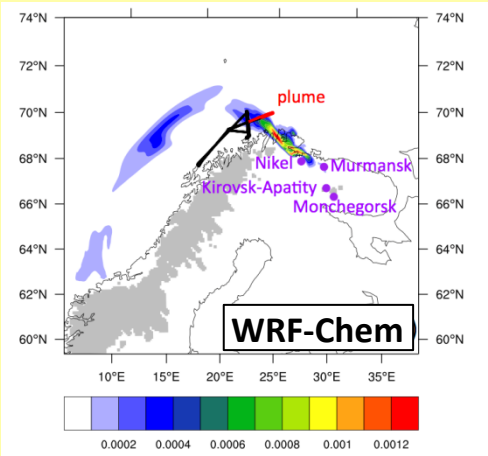
The ACCESS aircraft campaign: Tools and Methods

Forecast tools

Meteorological forecasts

Chemical forecasts

- WRF-Chem
- FLEXPART-WRF, HYSPLIT
- MACC



Satellite products

IASI column CO

LATMOS

Measurements

Trace Gases

NO/NO_2, HNO_3
CO, O_3, SO_2

Aerosol properties

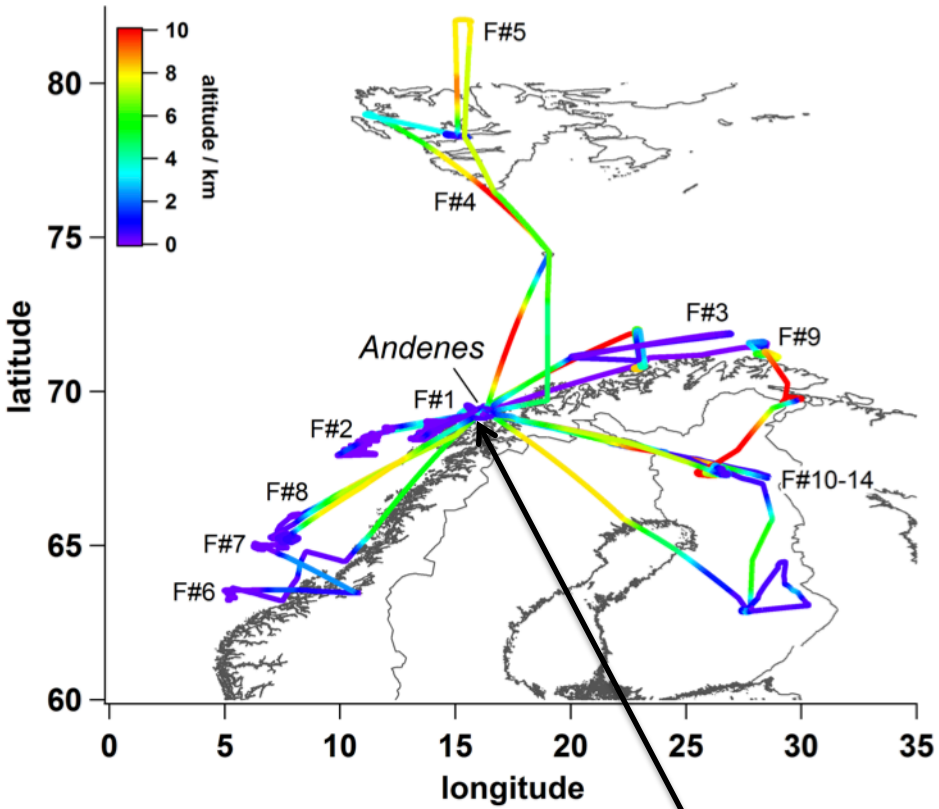
Number concentration
Particle size distribution
Non-volatile fraction of aerosol modes
Aerosol absorption and black carbon

Meteorology

T, p, RH, wind

DLR

The Aircraft ACCESS campaign in July 2012: Flights focused on local pollution sources



Flight	Date	Scientific Objective
F#1	11 Jul 2012	Ship plume sampling
F#2	12 Jul 2012	Single ship plume study
F#3	13 Jul 2012	Kola Peninsula emissions
F#4 & F#5	17 Jul 2012	Siberian biomass burning plumes
F#6	19 Jul 2012	Ship emissions sampling
F#7	19 Jul 2012	Sampling of oil/gas facility emissions in the Norwegian Sea
F#8	20 Jul 2012	Emissions from the *Heidrun* extraction facility
F#9	25 Jul 2012	Sampling of fresh ship emissions including fishing vessels
F#10-14	16, 22, 25 Jul 2012	Finland survey flights

DLR Falcon based in Andøya, Norway

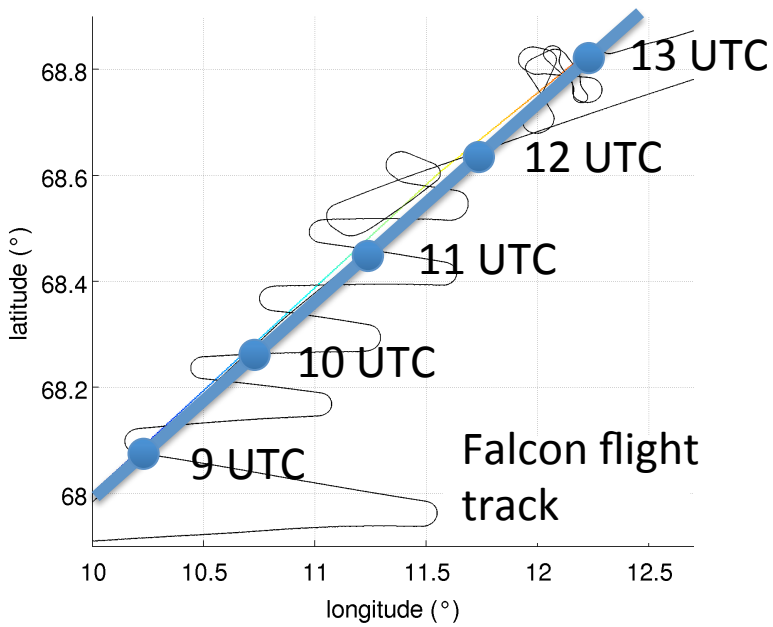
14 Flights – characterizing local and transported pollution

Roiger et al., 2014

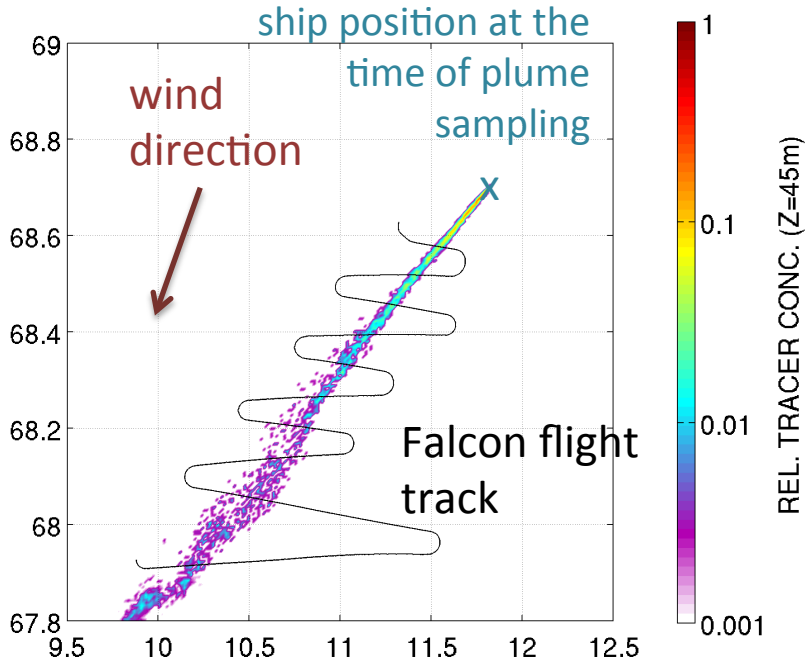
FLEXPART-WRF analysis of flight 12 July 2012 – Emissions from the Wilson Nanjing

The Nanjing's trajectory was divided in 500 equal-time segments to simulate a moving point source, using emissions injection height = 15-45m

Ship route and Falcon flight path



FLEXPART-WRF: 12 July 2012



45 meters (aircraft altitude)

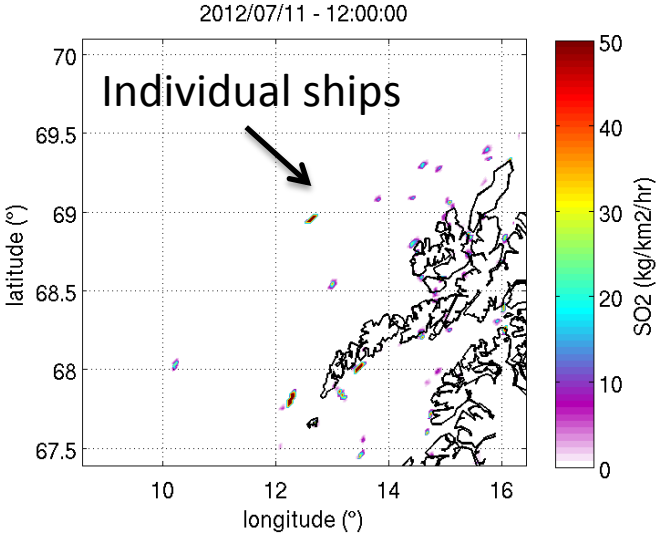
Wilson Nanjing

Vessel type: Cargo ship
Gross tonnage: 6118 tons
Fuel type: RMG380CST
Length x breadth: 123 x 16 m
Summer DWT: 8333 tons
Engine type: Wartsila W8L32

Marelle et al., in preparation, 2015.

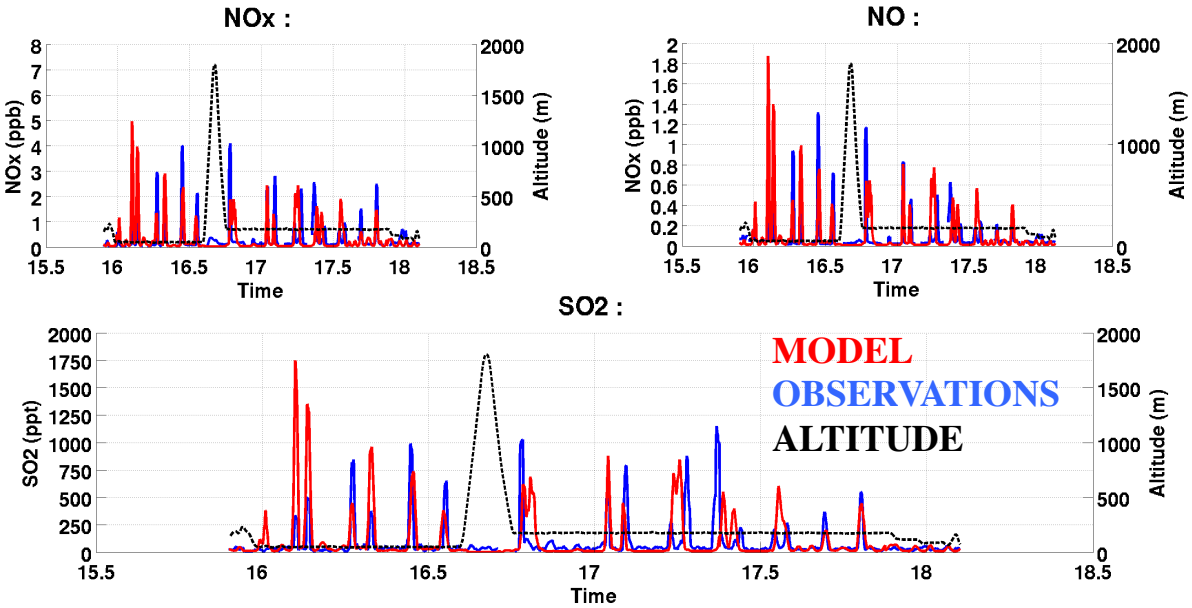
Using chemical transport modeling to study ship emissions and their atmospheric chemistry

STEAM Emissions



1x1 km, 15-minute time intervals
(Jalkanen J.-P. et al., 2009, 2012)

Regional model (WRF-Chem) compared to ship plume measurements: 12 July



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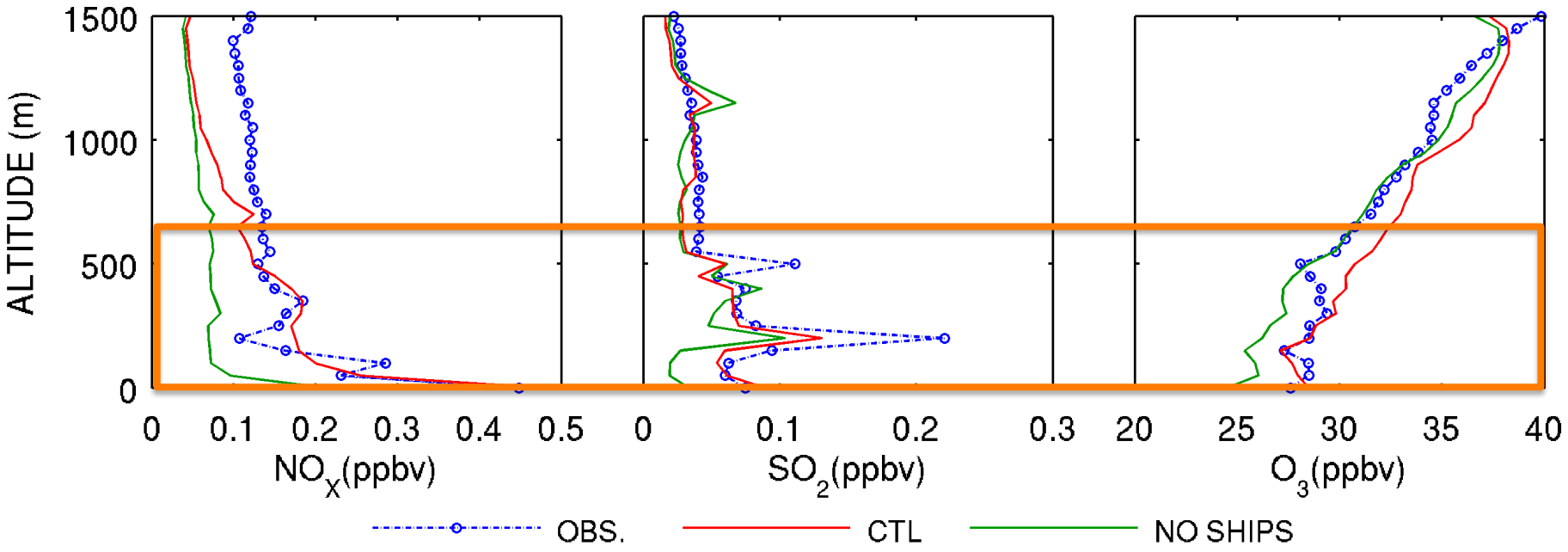
Connection between focused studies and the regional Arctic and global scale

What is the influence of representation of emissions on atmospheric composition?

ACCESS campaign average profiles – excluding flights focused on oil/gas platforms



CTL Run – STEAM v2 emissions for ships, other emissions from HTAP

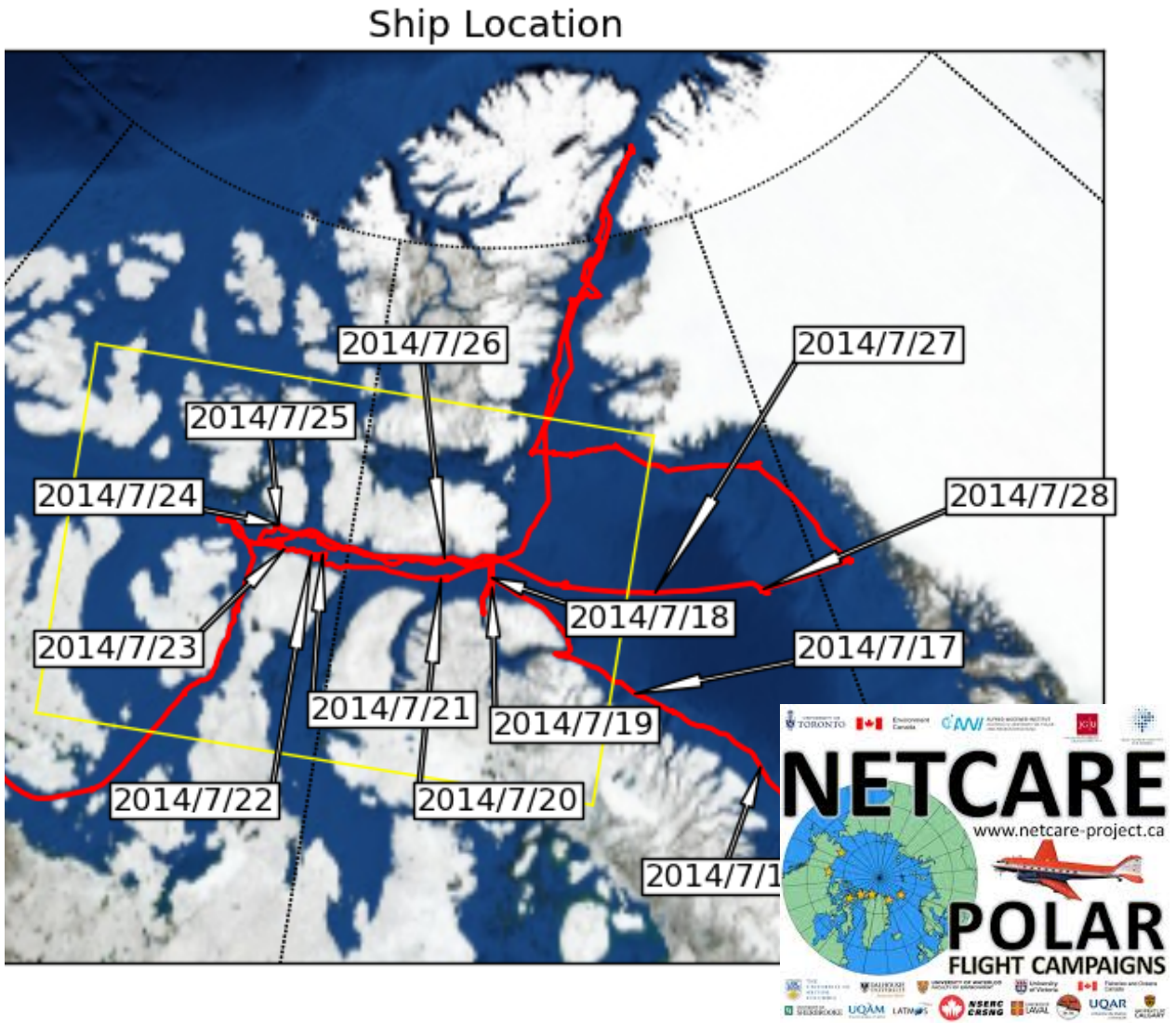
Emissions: Jalkanen J.-P. et al., 2009, 2012

Marelle et al., in preparation, 2015.

NETCARE – Aircraft campaign in July 2014 included several flights focused on ship pollution (J. Abbatt leader)

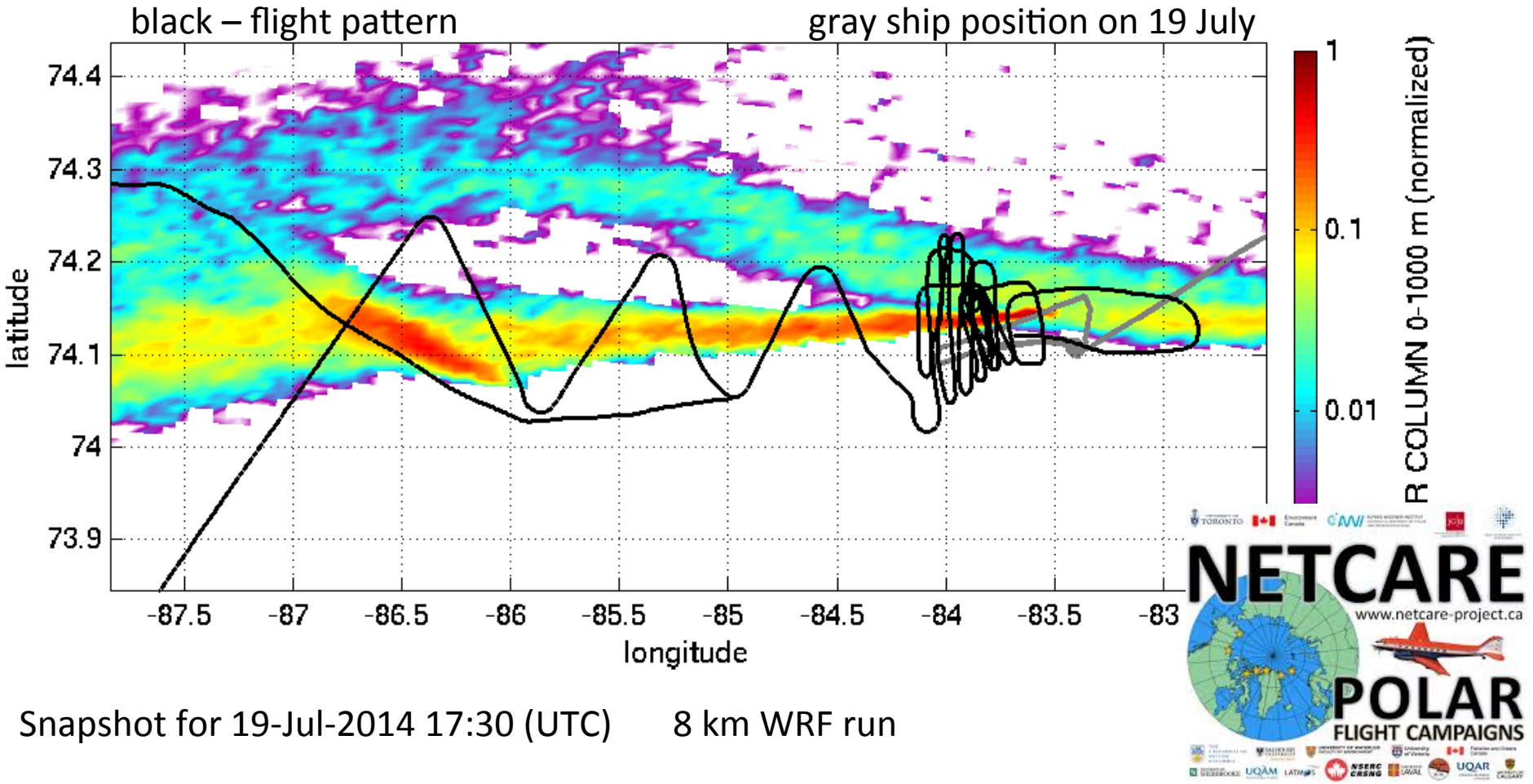
- Post campaign WRF run (domain border in yellow), focus on ship emissions and their fate
- ECMWF ERA Interim reanalysis (0.25 x 0.25 deg.) initial and boundary conditions
- Current run from 10 July – 22 July 2014, can be expanded to include earlier flights and larger region if desired

LATMOS - Participated in the aircraft campaign by providing ship plume forecasts



NETCARE FLEXPART-WRF predicted plume structure for focused ship flight: 19 July 2014

FLEXPART-WRF results – column integrated air tracer concentration (forward from ship track)



Snapshot for 19-Jul-2014 17:30 (UTC) 8 km WRF run

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Research Challenges

- Ship and oil/gas extraction emissions
  - Inconsistency in emissions (location, amounts, mix of gases and aerosols)
  - Harmonizing Arctic ship/hydrocarbon extraction emissions with emissions in the rest of the world (examples: Peters et al. emissions oil/gas emissions, Corbett shipping emissions)
  - Temporal and spatial resolution of emissions vs. reality, plume processing (see Vinken et al. global model studies)
  - Ability to make realistic future scenarios
  - Including influence of mining/other industrial activities in the Arctic
  - Including the impacts of associated industrialization (cities, building, non shipping transport)

Research Challenges

- Instrumentation
  - Characterizing VOCs (time resolution & sensitivity)
  - What is the right platform for studies – flights, ships, ground based campaigns?
  - Aerosol characterization – this is a major challenge!
  - How much BC is really emitted from oil/gas flaring?
  - Some examples from shipping off the the California coast are available: Buffaloe et al., 2014; Cappa et al., 2014
  - What can we learn from past campaigns
    - ACCESS, NETCARE, California studies

Research Challenges

- **Impact studies**
  - Do models have the right processes to predict pollution – e.g. are non-linear plume effects important for air pollution and/or climate?
  - Can we predict climate effects pollution: aerosol – cloud interactions? (e.g. SO_2 reductions in ship fuels)
  - BC deposition – do we have the right atmospheric processes to get deposition rates from local pollution (emitted right into the Arctic the boundary layer) right?
  - Do models have the right vertical resolution to treat these processes?
  - Connection between the model scale and measurement (campaign) scale
  - Connection between long term surface site measurements and focused campaign based studies
- Where to start – improved emissions, measurements, model studies to identify knowledge gaps?