

## Marine Black Carbon inventories:

### Objective of the session:

Identify specific elements that require investigation or refinement to improve global marine BC inventory

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# Overview

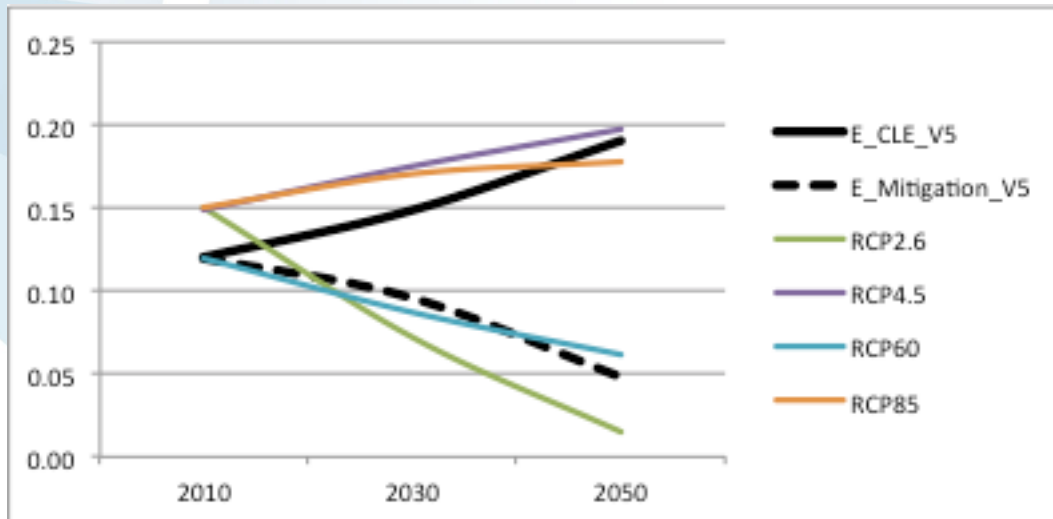
- Several global inventories in the last decade estimated marine BC at ~50 – 200 kt, with best estimate ~130 kt
- To put in perspective: it is about 1-2% of global anthropogenic BC; similar for Europe; at the same time shipping in Europe contributes about 25 and 30% of SO<sub>2</sub> and NO<sub>x</sub> emissions.
- A number of regional studies focusing on US, Europe, Arctic available; shipping emissions within Arctic (watch definition!) estimated at 1-1.5 kt BC; for comparison: Nordic countries total ~25 kt, Canada ~ 50 kt, total >60°N ~ 15-65 kt (anthropogenic) and 100-160 kt (incl. forest fires)
- Recent discussion of SLCP (short lived climate pollutants) mitigation has not addressed shipping yet but interest is growing at a regional (Arctic) and global level, also in perspective of expected SO<sub>2</sub> reduction

# Inventory elements

- Activity data:
  - Fuel consumption derived from statistics or estimated from ship movements, ship and engine info, load, speed (recently satellite data used at regional and global level)
  - Some regional inventories based on travelled km by specific ship types
- Emission factors:
  - Per unit of fuel; often one factor is used per fuel type
  - Per unit of fuel but considering also load, speed, etc.
  - Per km travelled and ship type
- Spatial distribution:
  - EDGAR developed first global patterns based on the 90's data
  - An update considering traffic intensity (COADS); Corbett et al, 1999
  - Adding ship size (AMVER), Endresen et al, 2003
  - Differences in patterns, limited ship sample biases in coastal areas between ICOADS and AMVER; Wang et al, 2007.
  - Most recently, commercial data using LRIT and AIS; should allow for improved precision and resolution

# Inventory is essential for projections and is used in air pollution and climate simulations and policy

- International shipping inventories used in global modeling work are about a decade old, e.g., Representative Concentration Pathways (RCP) used in IPCC AR5.
- Some of the regional studies, e.g., for the Arctic region (AMAP) use also RCP global scenarios or recently ECLIPSE derived from QUANTIFY inventory (Endresen et al, 2007).
- Recent European Union discussion on revision of air quality policy uses new inventory and projections for European area (VITO, 2013)



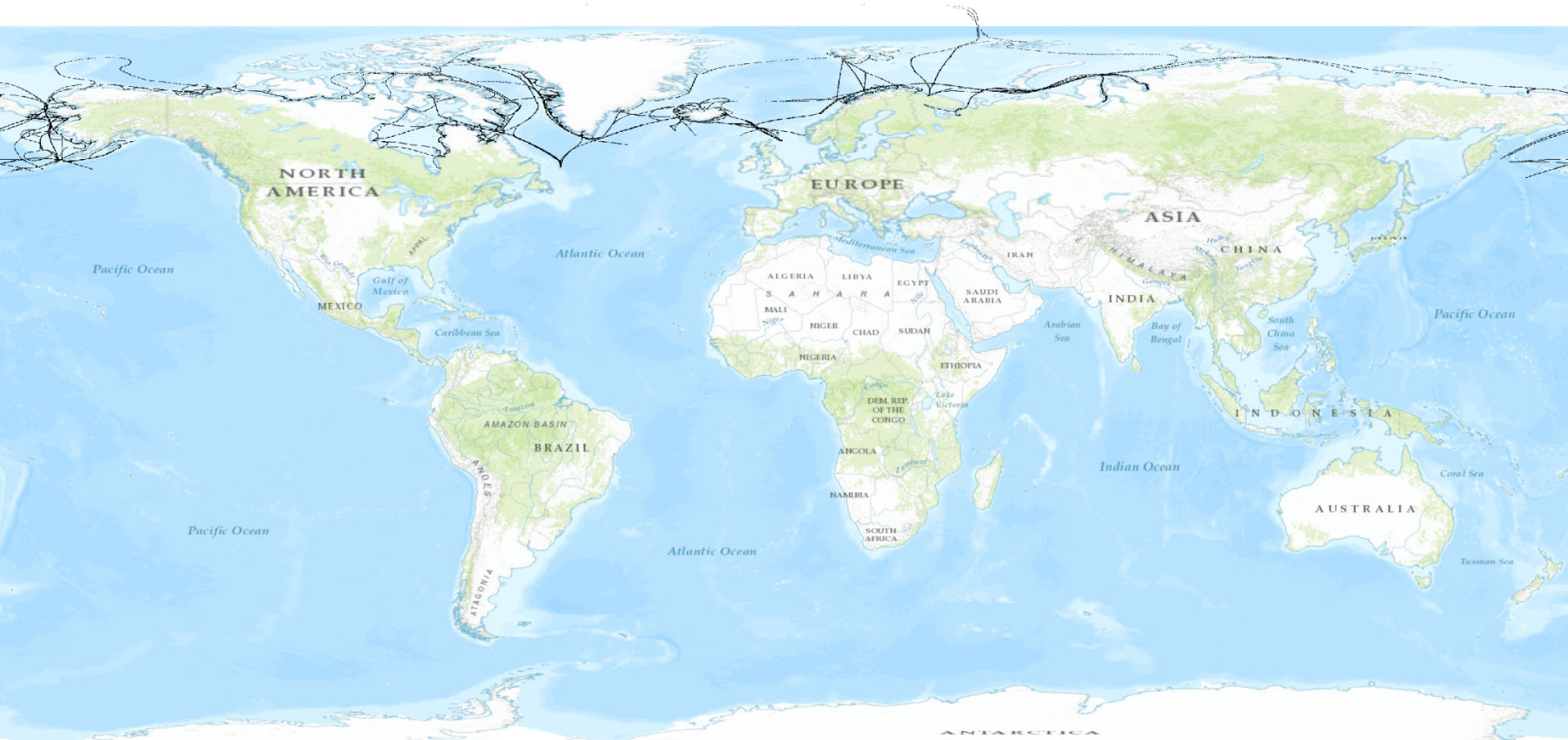
Source: E\_...scenarios from ECLIPSE project; GAINS, 2014; RCP scenarios from IIASA database

# European air quality policy and shipping

- Analysis of shipping emissions (VITO, 2013) has been included in ongoing discussion on new emission ceiling for revised air quality regulations
- 1/3 of emissions within the 12 nm zone
- Apart from baseline, several mitigation scenarios have been produced exploring SO<sub>2</sub>, NO<sub>x</sub>, PM mitigation, including also impacts of slow steaming, LNG used on short trips
- Includes fleet dynamics, e.g., age and size structure change over time
- Resolution 12nm, 200 nm, ports, high-sea

# Uncertainties and other issues

- Do we need more measurements of emission factors (EFs)?  
Currently few datasets are used (often averaged) and extrapolated across the globe. Do we understand the errors?
- Sulfur fuel content impact on BC Efs?
- Impact of 'slow steaming' on BC EFs?
- It would be useful to systematically compare outcomes of inventories with simple fuel based EFs with those supported with AIS and EFs considering speed, load, etc.
- Is there enough data to justify vessel age specific EFs?
- Shipping=international shipping?
  - Consistency between international shipping and national shipping
  - What about mapping global inland navigation and coastal recreation
- Improve temporal resolution; the models can use it; atmospheric lifetime of BC up to few weeks; proper representation more important regionally than globally

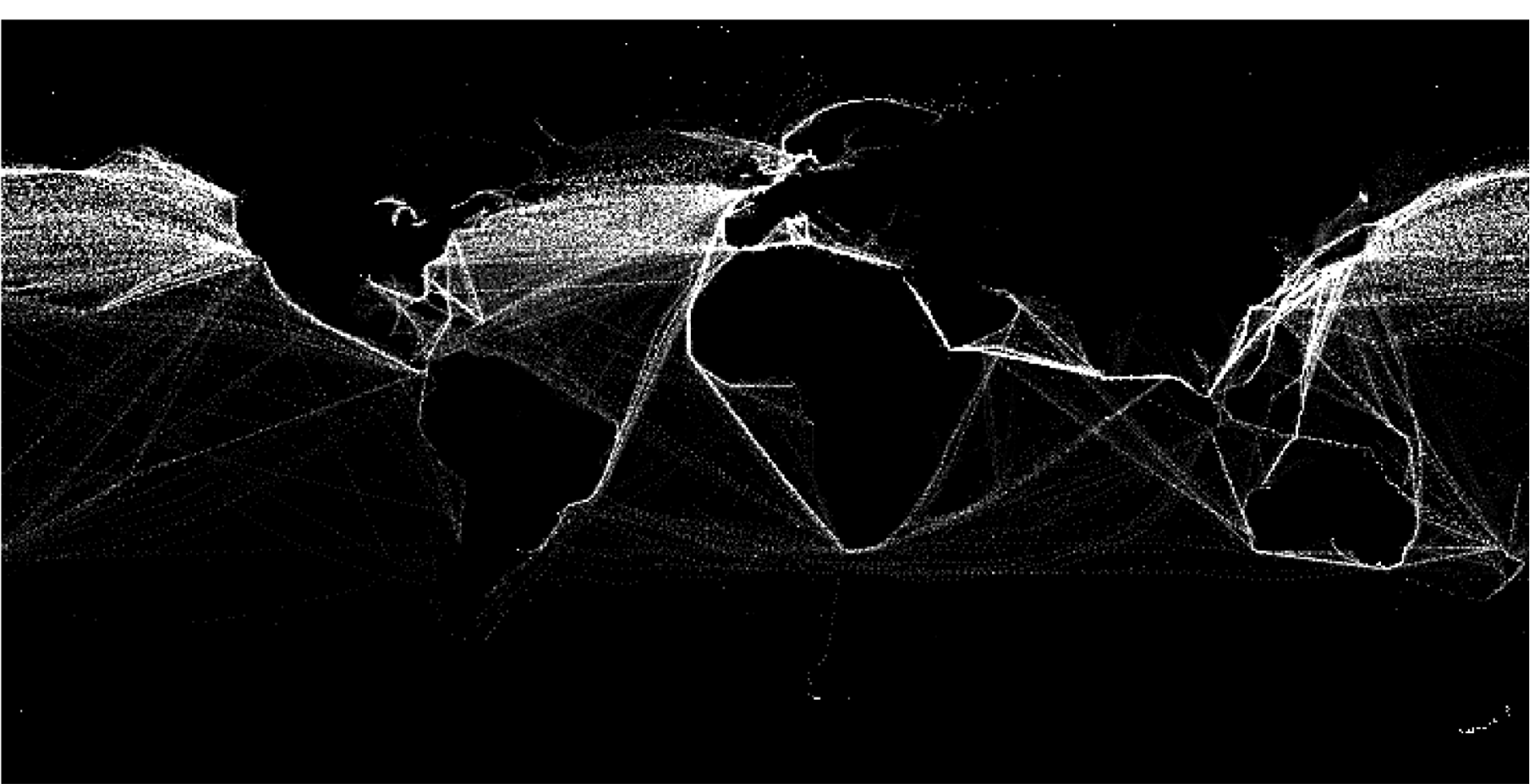


J. Corbett, presentation at AMAP meeting 2010. Arctic shipping Winter (top) Summer, bottom

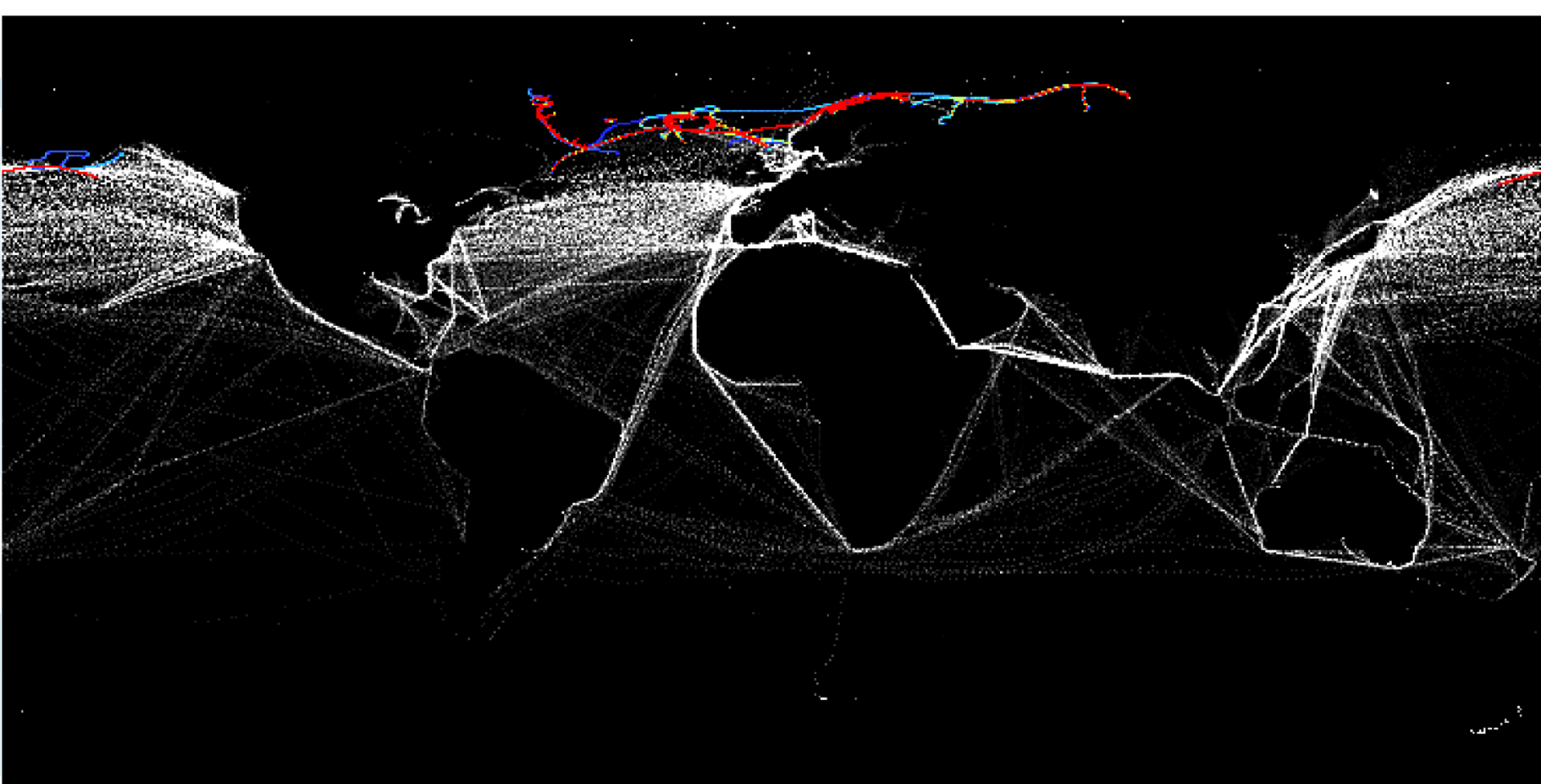
# Other issues

- What is the possible and desired spatial/temporal resolution of a global inventory?
- Some regional inventories have much higher resolution but ‘sticking’ them to global work is not straightforward
- Future inventories need to consider extent and impact of targeted PM mitigation
- Should we think of drivers of future developments, might be regionally different, e.g., oil production in the Arctic, accelerated melting, tourism
- Work is ongoing to update historical anthropogenic inventories; Should the findings of this work be feeding into that process? Do we need update of historical data- can we do better?
- Findings of this work should help to produce better projections used in SSPs (Shared Socioeconomic Pathways)





RCP 6.0, 2005

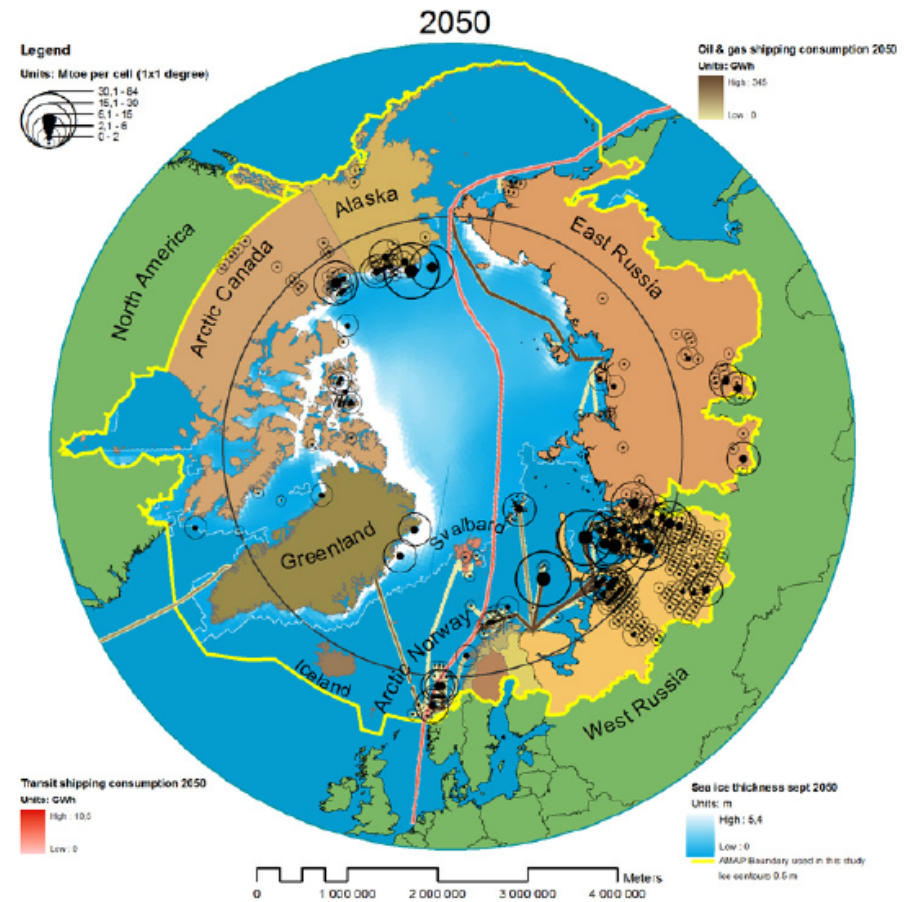
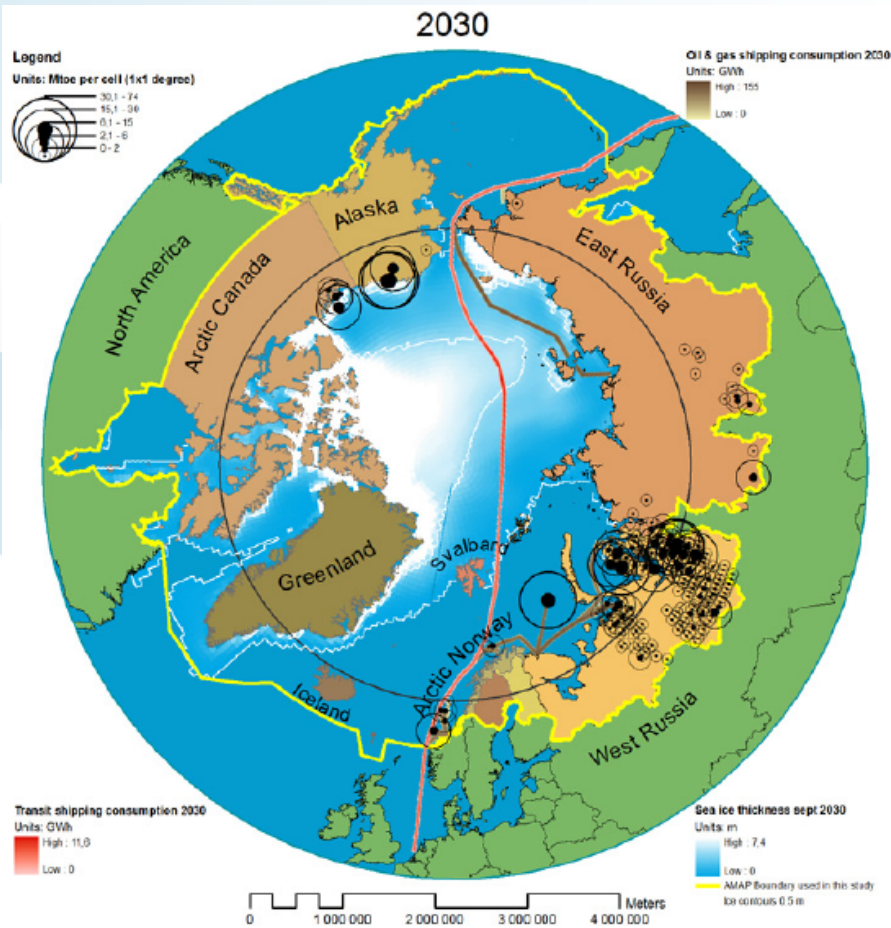


RCP 6.0, 2005  
And  
Corbett Arctic Grid (Winter), 2004

J. Corbett, presentation at AMAP meeting 2010.

# Oil and gas production, energy consumption in transit and petroleum shipping and the September sea-ice extent in 2030 and 2050;

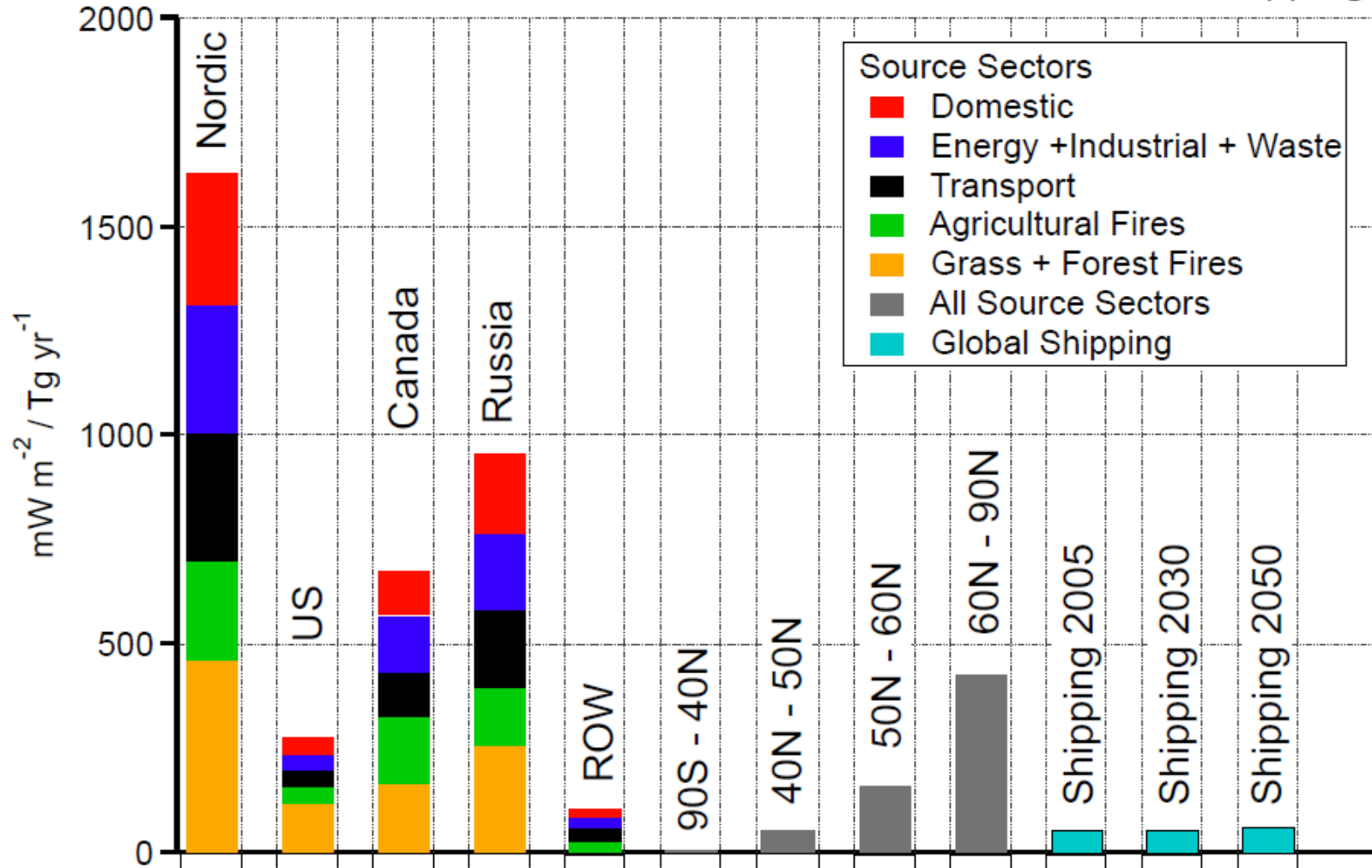
Source: Peters et al. (2011, ACP)



# What can be done better?

- Use fuel, vessel, load, speed specific emission factors?
- Consider penetration of PM measures and their real-life impact on BC emissions
- Including age distribution might help also to improve assessment of future mitigation potential
- Harmonize the international shipping inventory with coastal, ports inventories
- In fact I wish there was a 'shipping inventory' and not international shipping inventory; the former would include international, national-coastal, port, inland shipping.

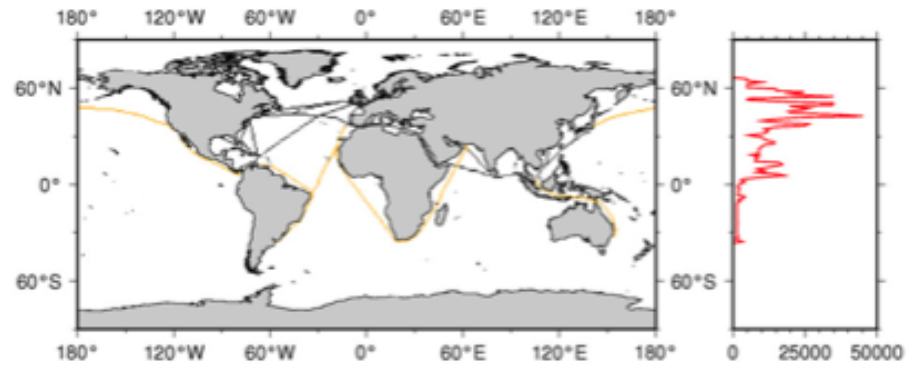
## *Forcing per Unit of Emission* by BC + OC Mixture for Arctic Council Nations, Rest of World, Latitude Bands, and Shipping



- Driven by proximity to the Arctic
- Forcing due to shipping is normalized by global emissions so doesn't show true impact of Arctic-only emissions
- Currently running the model with Arctic-only shipping emissions

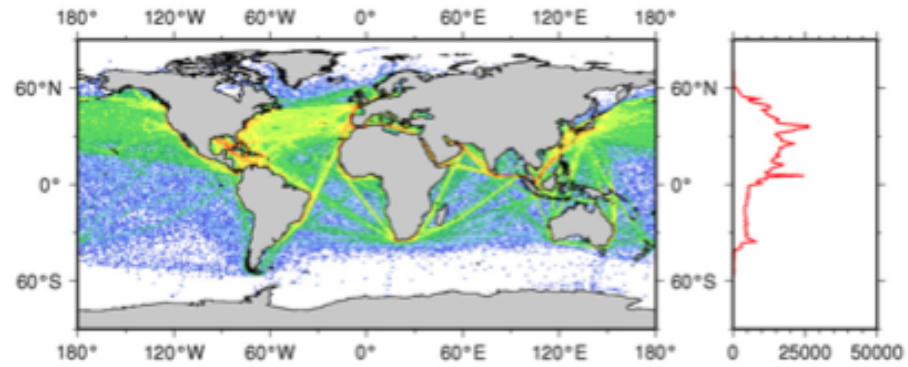
M. Flanner, NCAR & SNICAR Models

### EDGAR



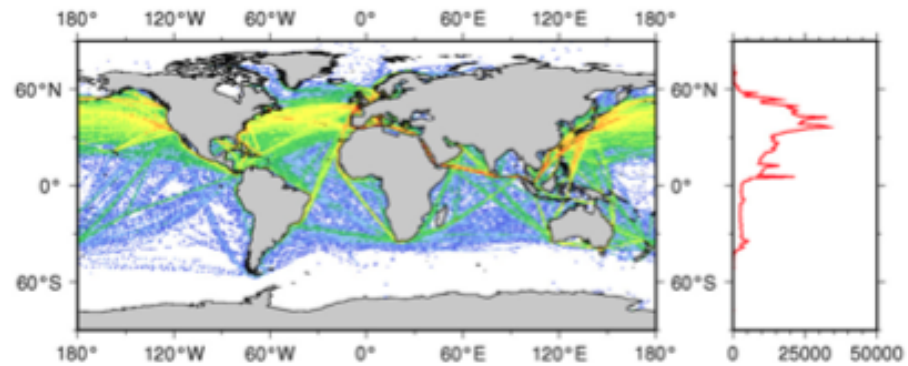
### zonal sum

### AMVER

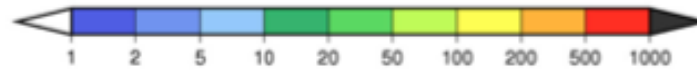


### zonal sum

### ICODAS



### zonal sum



Ship Emissions Allocation Factor (millionth of global total)