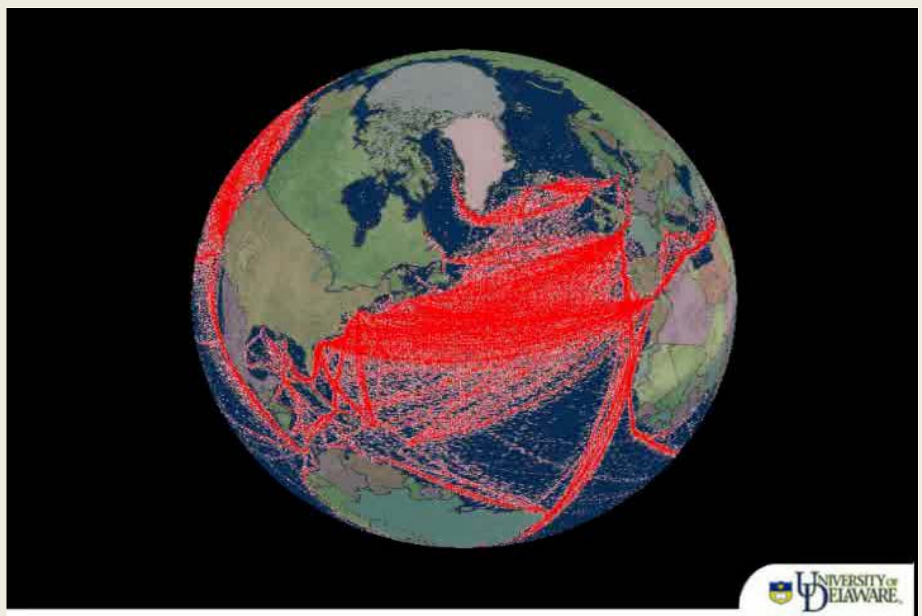
ICCT Black Carbon Workshop
Marine policy strategies

Sustainable Intermodal Freight Transportation Research (SIFTR)

University of Delaware, Rochester Institute of Technology
National Partnership for Intermodal Infrastructure Improvement (PI3)

6 January 2009



Containership
Tanker
Bulk Carrier
General Cargo
Refrigerated Cargo
Ro-Ro
Passenger

FUTURE FREIGHT
CLEAN & AGILE

EE RA

Concluding thoughts

- Ship BC emissions context: large or just important?
- Trends in ship emissions will increase CO2, BC
- CLE ↓ sulfur by 2020 (dramatic unmasking), ↓ NOx slower
- Reductions for health benefits do not appear optional
- Control technologies and ops options exist, but expensive
  - This may not fit the onroad/nonroad paradigm of ULSD first
- Policy resolve slow to emerge at IMO without "help"
  - Urgency helps: unmasking sounds like urgency increases
- Discussion question (for my source anyway):

What impact metric(s) would reveal that BC from [ships] deserves to be first/last on the list for BC quick-action?

What do we want for the Future of Freight?

- **Modernize** existing fleets

  … replace fleet with best technology

- **Maximize** current fleet usage

  … use current fleet to maximum performance

- **Optimize** system performance

  … logistics, infrastructure, operation

Might these be shared goals, depending on targets, timeframe?

Business Goals ⟷ Environmental Goals

VISUALIZING GOALS MODELING ALTERNATIVES

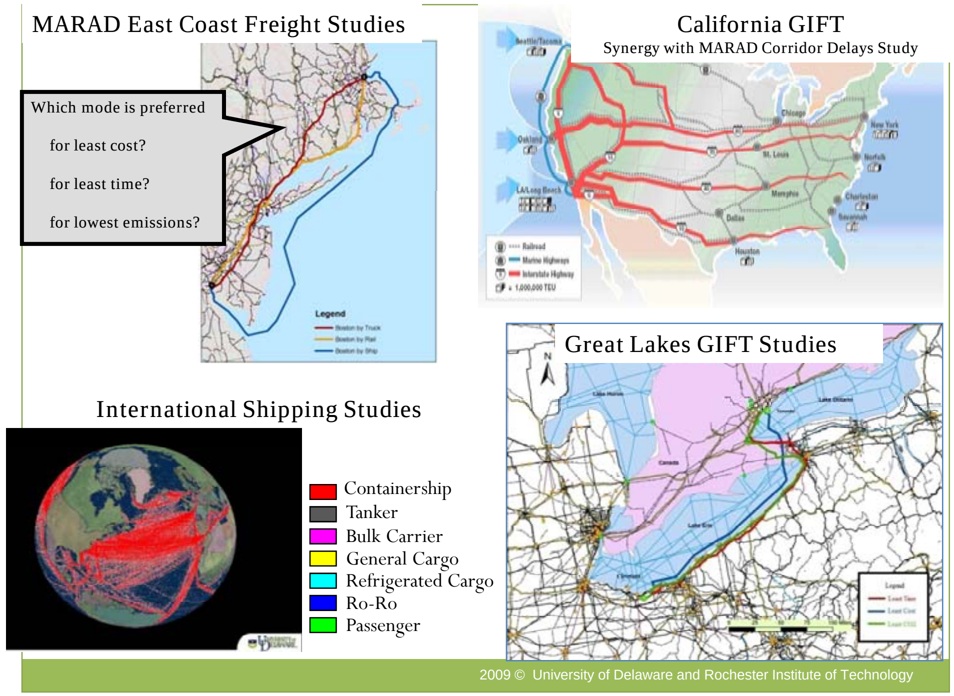
Intermodal freight network optimization model to evaluate objective tradeoffs.

Developing resources for “table-top” exercises with industry and agencies.

Evaluates performance against *benchmarks* and optimizes with respect to possible ***targets***

Web-version in development.

Geospatial Intermodal Freight Transportation (GIFT) Model



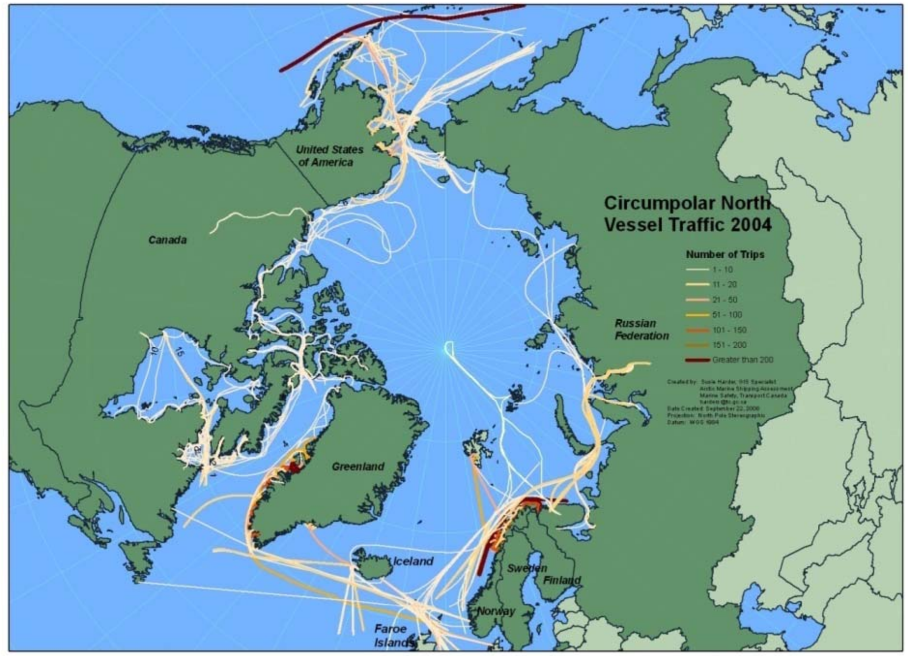
Decision makers can ***explore tradeoffs*** *among* ***alternative routes****,* ***across modes****, and* ***identify optimal routes*** *for economic, energy and environmental objectives.*

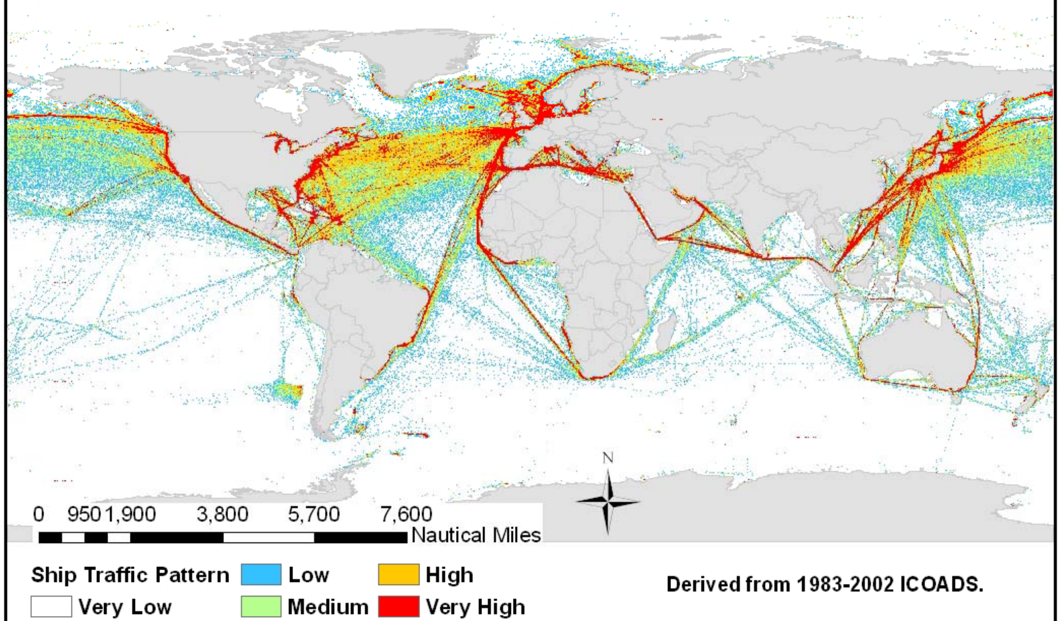
Winebrake, James J., James J. Corbett, Aaron Falzarano, J. Scott Hawker, Karl Korfmacher, Sai Ketha, and Steve Zilora, “Assessing Energy, Environmental, and Economic Tradeoffs in Intermodal Freight Transportation,” *Journal of the Air and Waste Management Association*, 2008 (August).

BC more than a ships issue: a freight systems problem. Today's focus is on shipping mode

Outline

- BC formation in marine engines (review)
- Global inventory overview
- Arctic as potential area of importance for BC impacts
- Technology options
- Issues and challenges
- Toward policy strategies (discussion starter)





Particle formation in HTHP engines

- Particle formation: complex, dynamic, confusing
  - Classification challenge of primary and secondary particles, semivolatiles. Not only mass, but size and number matter.
- Basic constituents of PM (at least from ships)
  - Ash and other stuff (e.g., trace metals) in fuel (0.1-0.2% m/m)
  - Cylinder lube oil consumption (~1 g/kWh)
  - Flame generated PM (BC is flame generated)
  - Particles formed from gaseous oxidation and hydration (sulfates, nitrates, etc.), called secondary except when measured in stack rather than plume rather than marine air
- Marine diesel BC forms in HTHP lean combustion

Marine engine combustion and BC emission rates

Consensus BC rates still uncertain but converging
- Lack et al observed BC rates in field (2008, 2009 in press)
- Others making stack tests (measurement issues)

- Slow speed diesels (SSDs) produce BC particles in small size ranges
- Medium speed diesels (MSDs) produce more BC mass (~2x)
- BC varies more with engine combustion; other PM varies more with sulfur changes

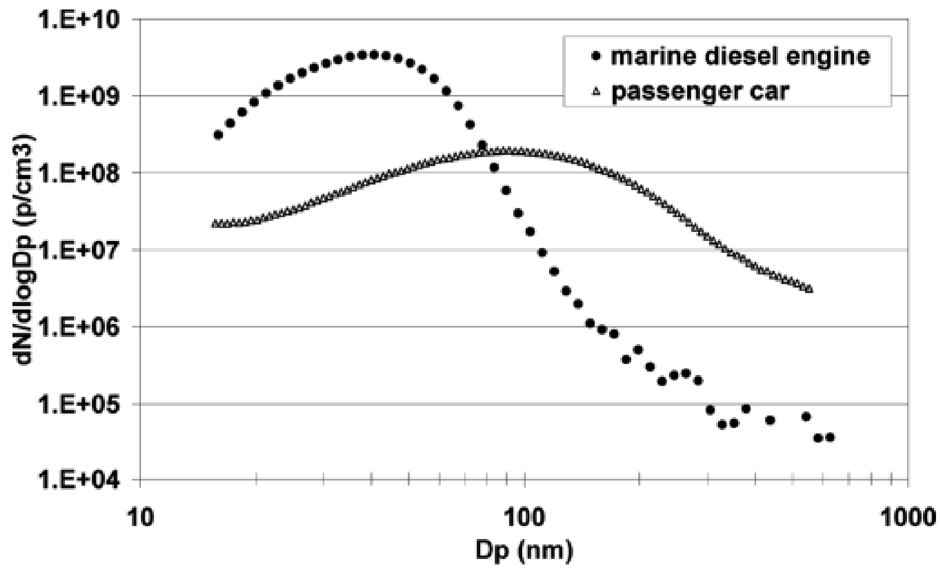
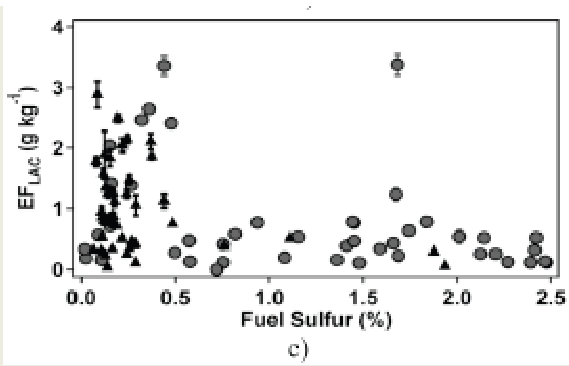


FIG. 10. Typical number size distributions for this marine diesel engine (circles) at 100% load and a diesel passenger car (triangles) at 100% load.

Kasper, A., S. Aufdenblatten, et al. (2007). "Particulate Emissions from a Low-Speed Marine Diesel Engine." Aerosol Science and Technology **41(1): 24-32.**



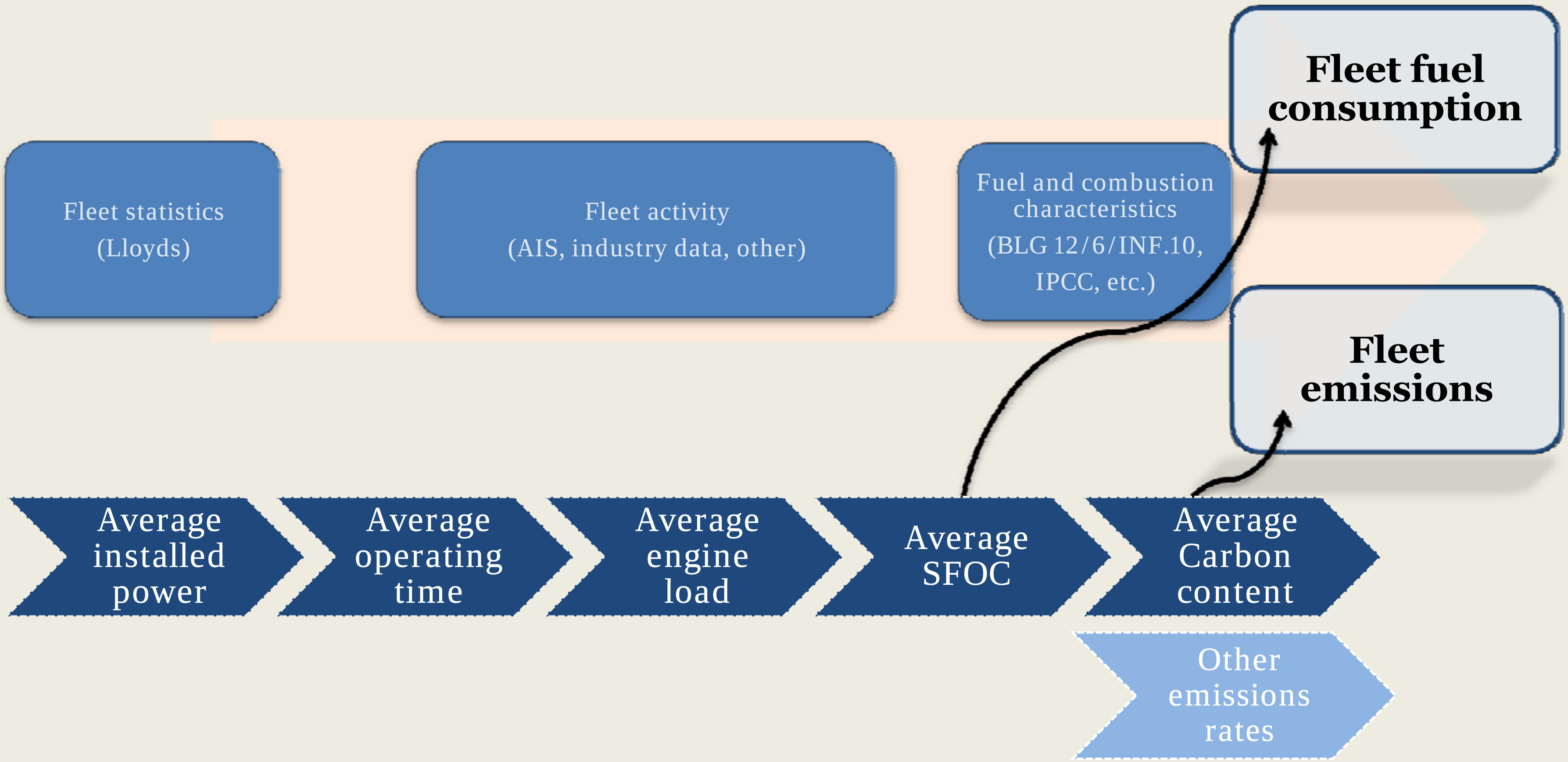
Lack, D., J. Corbett, T. Onasch, B. M. Lerner, P. Massoli, P. K. Quinn, T. S. Bates, D. S. Covert, D. Coffman, B. Sierau, S. Herndon, J. Allan, T. Baynard, E. Lovejoy, A.R. Ravishankara, and E. J. Williams (2009), Particulate Emissions from Commercial Shipping. Chemical, Physical and Optical Properties, J. Geophys. Res., doi:10.1029/2008JD011300, in press (accepted 12 December 2008).

Ocean shipping uses very advanced engines designed to combust very low-cost fuels

Marine diesel engines are among the most thermally efficient (fuel-efficient) combustion systems ever built; efficiency has been devoted to economic more than environmental performance to date.

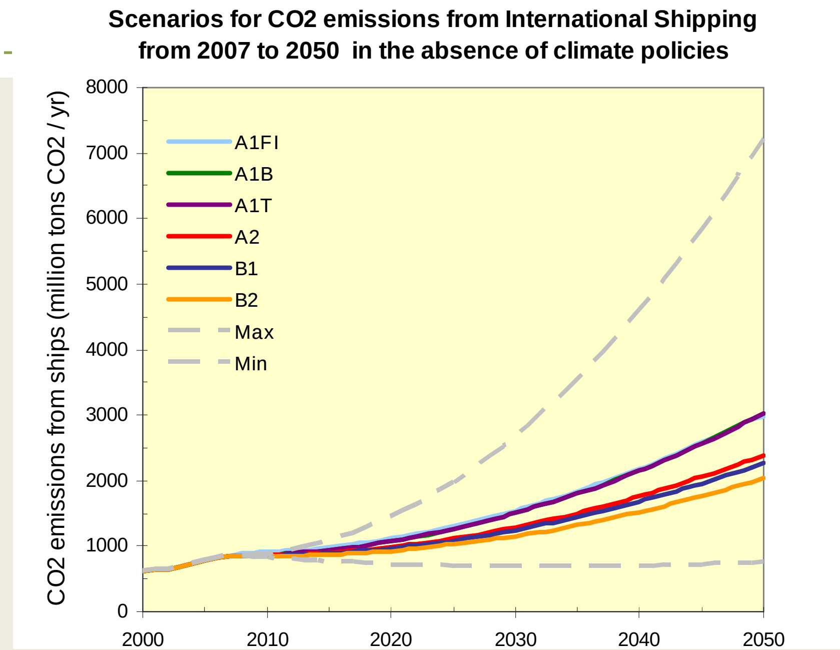
Intuition: less BC mass per fuel input than other diesels (but size matters)

Activity-based methodology



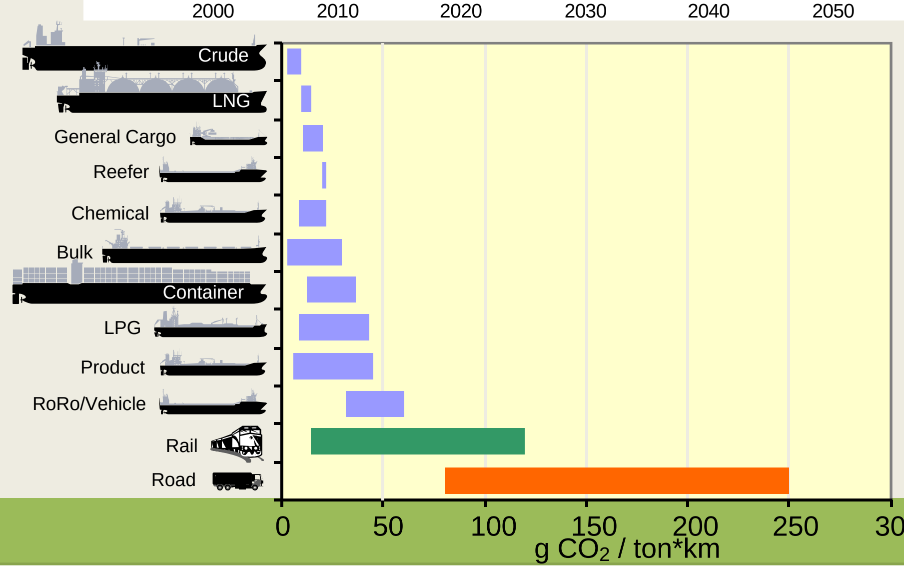
Global shipping inventories being updated

Pollutant (2007)	Annual metric tons
BC	104,000 to 118,282
CO	2,500,828
NMVOC	811,079
CH_4	101,385
NOx	25,315,540
N_2O	27,036
SOX	18,249,284
POM	1,470,000
SO_4 (primary)	1,086,442



BC rates among modes should differ from CO2 modal comparisons:

Probably more BC mass, larger size ranges in onroad/nonroad diesels



2004 Arctic BC Emissions (flux)

Ships may be important source of local BC (and other GHGs) in sensitive Arctic region

Growth is likely, although perhaps at lower rate than suggested by comparison with prior projections .

New routes likely to emerge as ice melts

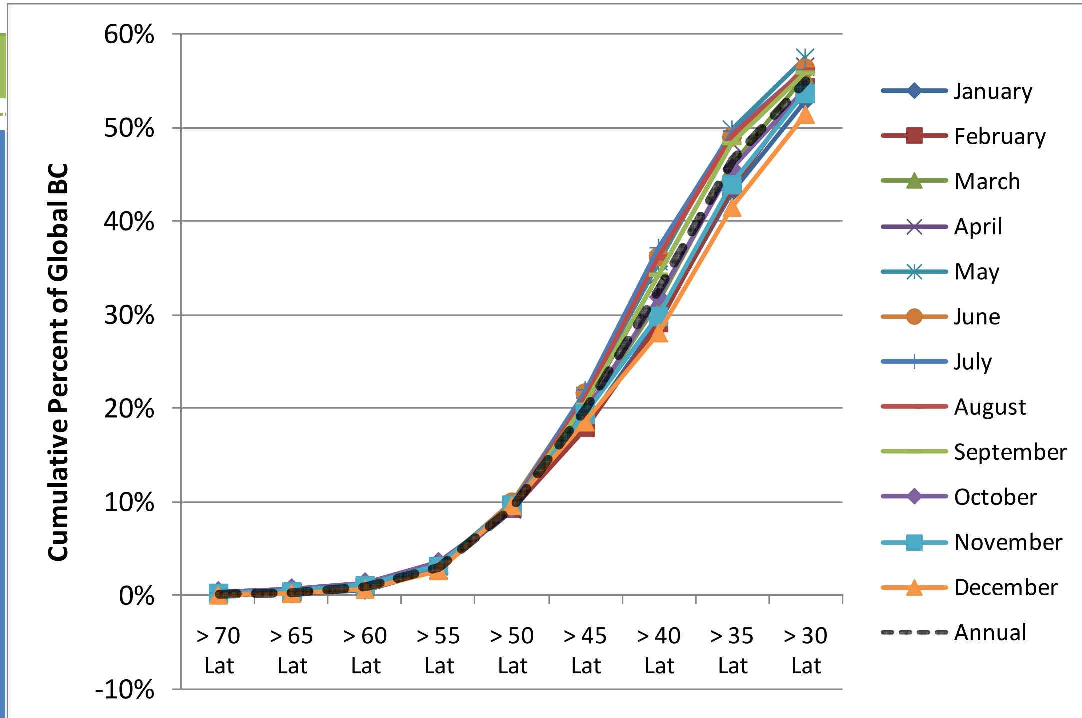
More importantly ?: Potential impacts to Arctic may not be from local activity by ships, but from major shipping lanes.

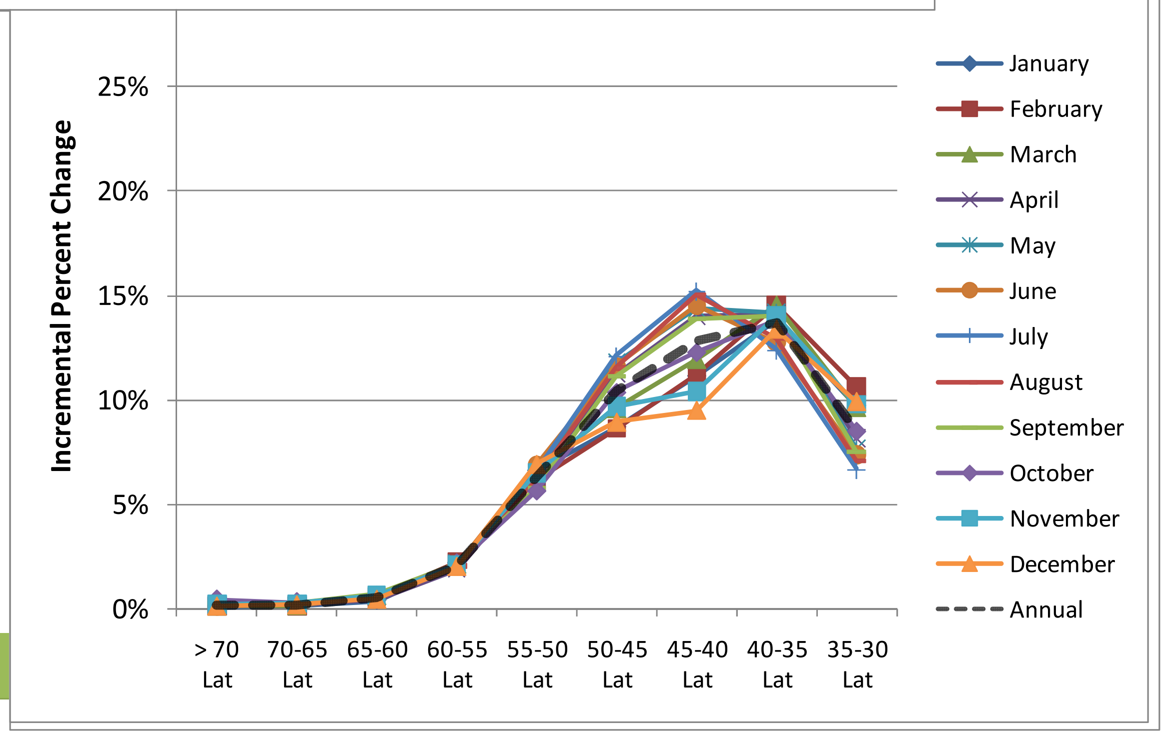
Arctic BC Impacts

Potential impacts to Arctic may not be from local activity by ships, but from major shipping lanes. Consider roughly the contribution by latitude.

Question: Where is the latitude of diminishing impact to Arctic?

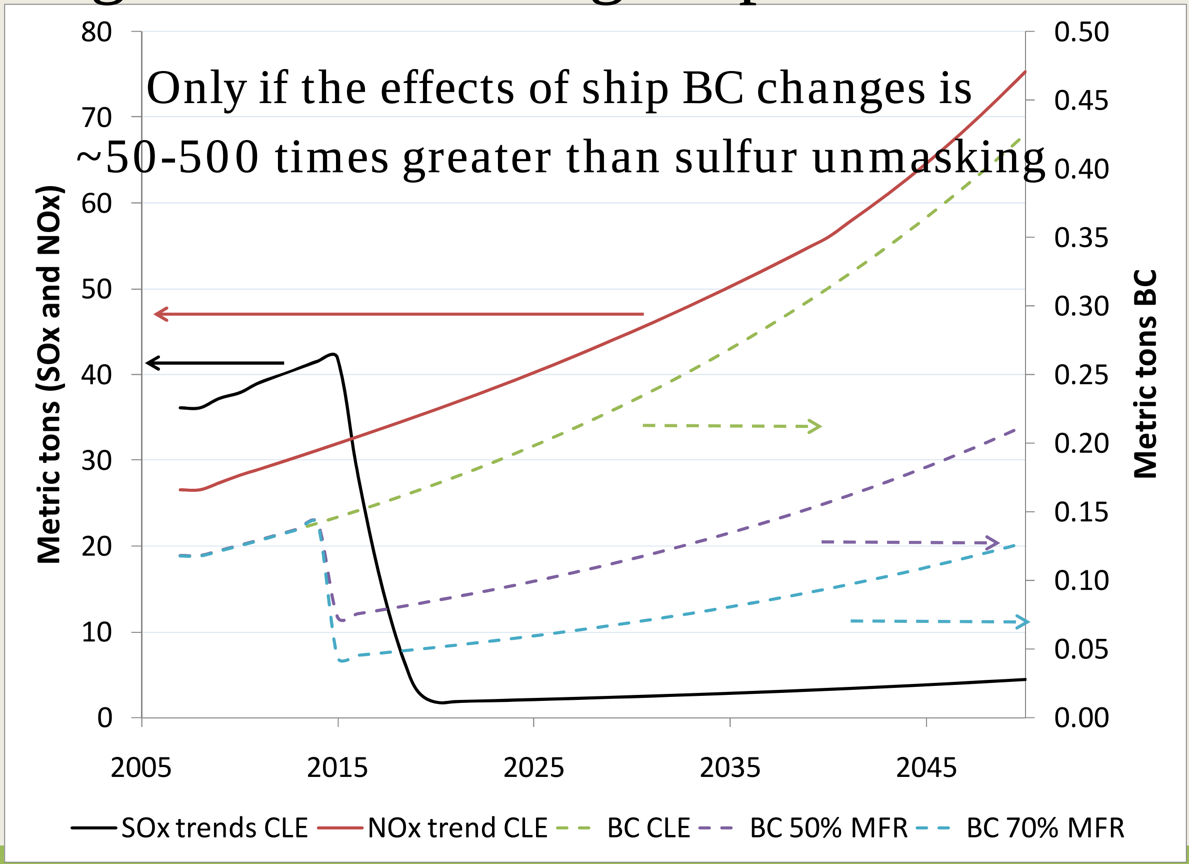
Question: Does fast reduction of BC globally or in some region(s) address unmasking concerns for ship fuel sulfur changes?





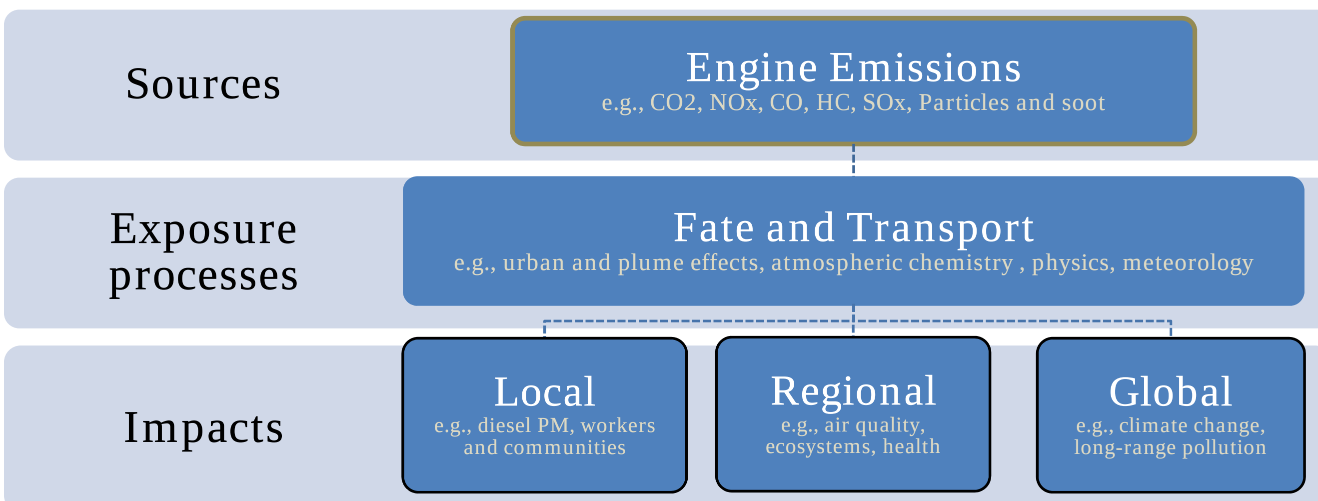
Big Policy Question from Ram's presentation

Would a "rapid" decrease in BC from ships offset some "unmasking" from reducing ship sulfur?



Freight Impacts Motivate Policy Action

AIR QUALITY
CLIMATE CHANGE
ECOSYSTEMS
HUMAN HEALTH



Mortality from Ship Emissions: A Global Assessment

ENVIRONMENTAL SCIENCE & TECHNOLOGY

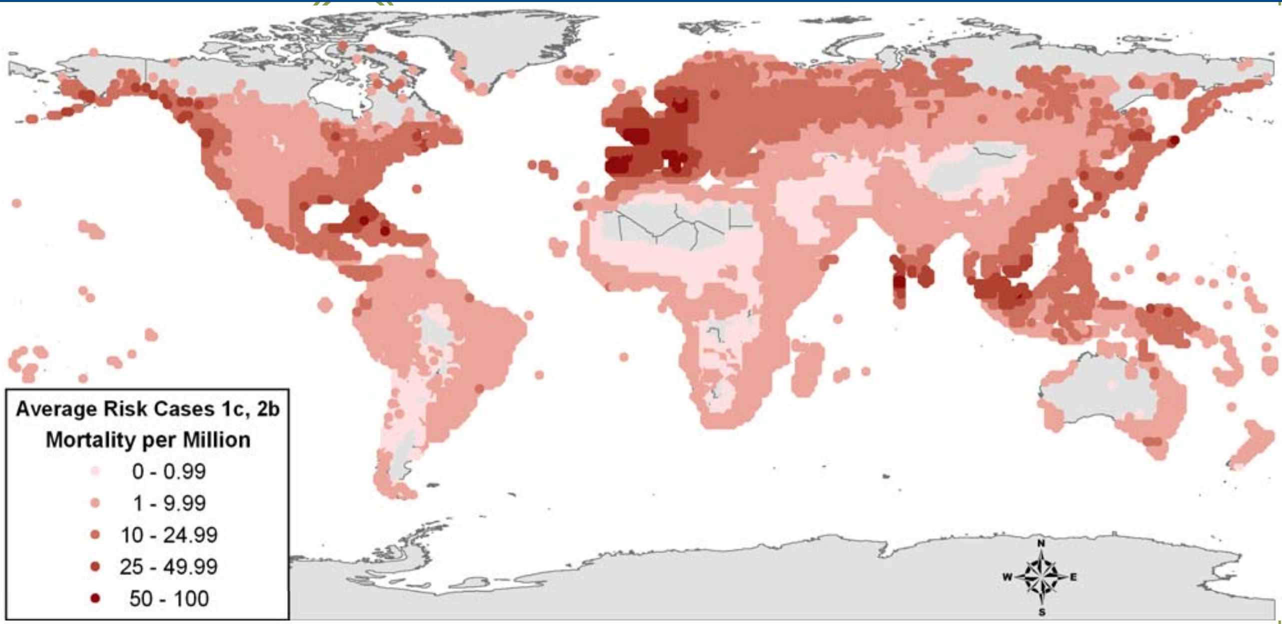
James J. Corbett, James J. Winebrake, Erin H. Green,
Prasad Kasibhatla, Veronika Eyring, and Axel Lauer

Increased risk is broadly distributed

Ship emissions increase mortality risk for significant populations across the globe

Most coastal regions and many inland regions face a mortality risk greater than 10 in a million (1:100,000)

Key regions face greater mortality risk from ship emissions



Initial results from ongoing work show that sulphur and PM reductions substantially decrease in human health risk

Corbett et al., ES&T, 2007

Can anything feasible reduce BC from ships?

The Phoenicians were great sailors for their time, and ventured further than any before. Their ships were known for being well designed for carrying both cargo and supplies needed by the sailors.

http://maritime-history.suite101.com/article.cfm/the_phoenicians_great_sailors

If the Phoenicians did not invent it, the industry has resisted it.

Anonymous ---

Phoenicians

Age of Sail

Coal-fired steam

Marine diesel

Ships of the 21st Century?

What options do we have to control BC? Do metrics primarily need to be in science impact terms or also in terms of control?

REDUCE PM MASS, REDUCE PM2.5 MASS
SELECTIVELY REDUCE NON-BC PM MASS, REDUCE BC MASS
CONTROL SIZE OR NUMBER OR OTHER THAN MASS?
REDUCE GWP, ΔT, OTHER IMPACT METRIC?

Fuels
- IMO Low-sulfur (☺?)
- Onroad compliant sulfur
- Ultra low sulfur

Combustion
- Water-fuel Emulsions

After treatment
- CDPFs
- ADPFs
- Scrubbers, etc.

Operations
- Speed reduction

What could change during BC policy timeframe?

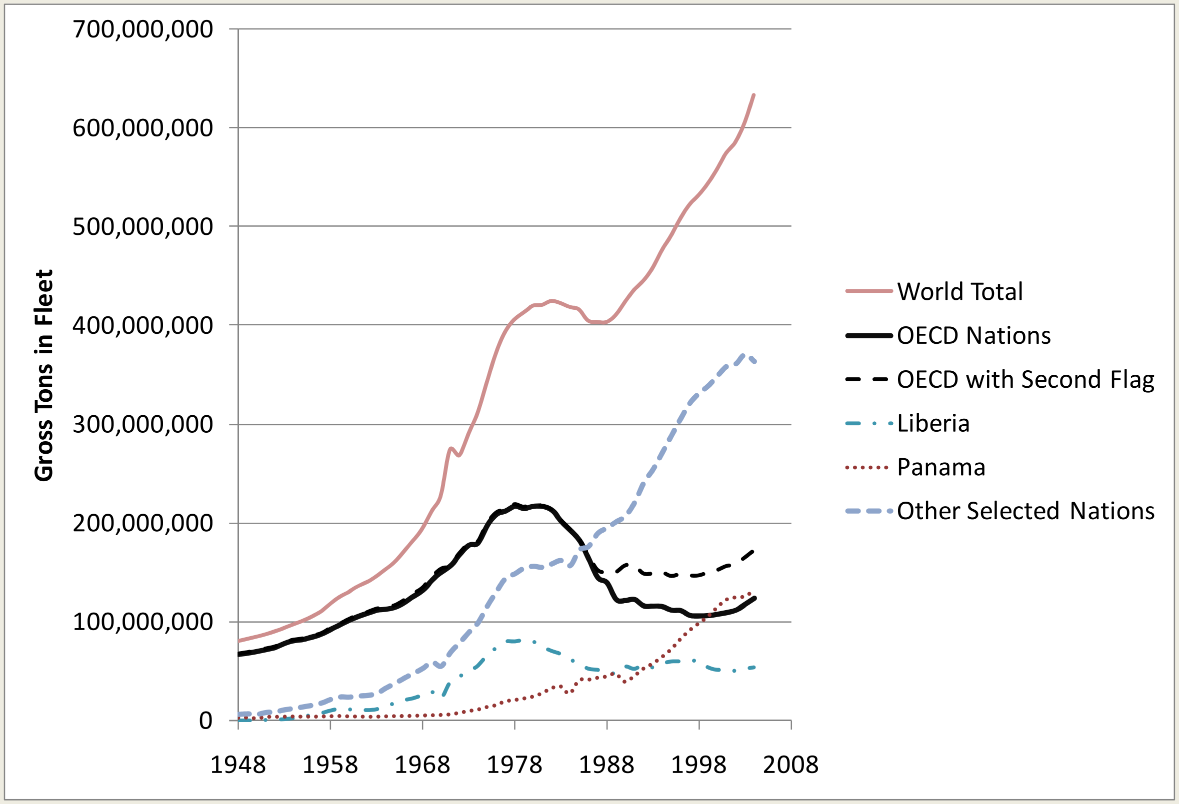
- National registry of ships, crew nationalities, etc.
- Ship technologies
- Ship fuels
- Patterns of shipping

Question 1: will these change without policy anyway?

Question 2: will efficacy of GHG or BC or Annex VI instrument be modified if changes occur in any case?

Setting Policy at IMO: Trends in global fleet cargo capacity

- Fleet capacity (gross tonnage) increased significantly with globalization
- Vessel flags have largely transitioned from OECD nations to others



- Is there an Annex 1 advantage supporting CBDR claims?

Policy action at IMO now focused on GHGs

One short list of policy instruments (grossly general)

- Ship design index (mandatory for new ships, with or without phase out requirement)
- Ship operational index (voluntary or mandatory?)
- Arbitrary (Regulatory-based) Levies, fees, taxes, etc.
- Market-based instruments (ETS)

All these can be debated on merits, but their ability to be implemented by IMO, regionally, unilaterally may determine which one(s) get chosen.

Possible "Rules of thumb"

- Urgency helps policy – unmasking sounds urgent
  - The time for half measures has passed. We are entering a period of consequences. Winston Churchill
- Control targets more often set in terms of emissions than in terms of endpoint goals (at first anyway)
- Technology enablers for other transport may be blinders for full set of feasible options in shipping
  - ULSD helps CDPFs to work more cost-effectively than ACDPs, but new source may not be controlled same as the old source
- Remember: industry is a partner in IMO process

For discussion: Can we move forward based on good that uncertain science suggests we can achieve?

In physics the truth is rarely perfectly clear, and that is certainly universally the case in human affairs. Hence, what is not surrounded by uncertainty cannot be truth. Richard Feynman

It is not the clear-sighted who rule the world. Great achievements are accomplished in a blessed, warm fog.

Joseph Conrad 1904-06: http://www.gutenberg.org/dirs/etext97/tmots10h.htm

Phoenicians

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Ships of the 21st Century?

Discussion Welcome

More, better, cleaner, sustainable goods movement

CONTACT:

JAMES J. CORBETT, P.E.
UNIV. OF DELAWARE
JCORBETT@UDEL.EDU
TEL: 302-831-0768