Modeling ship emissions

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Outline

• Building blocks
  • Vessel activity
  • Vessel technical description
  • Emission model

• Example outputs
  • General
  • Local
  • Regional
  • Global

• Future work

Smith et al, 2014 (3rd IMO GHG report)

Figure 16: Geographical coverage in 2007 (top) and 2012 (bottom), coloured according to the intensity of messages received per unit area. This is a composite of both vessel activity and geographical coverage; intensity is not solely indicative of vessel activity.
Vessel activity

• Primary source of activity: **Automatic Identification System (AIS)**
  • Local scale studies: Single base station
  • National/Regional scale: Cooperation with relevant maritime authorities
  • Global: Maritime authorities + commercial providers

• Other data sets:
  • **Long-Range Identification and Tracking (LRIT):** Authorities only, restricted to own Economic Zone & vessels flying your flag
    • Global fleet LRIT → agreement of IMO MEPC/MSC needed
  • **Vessel Monitoring System (VMS):** Mainly fishing vessels, restricted access
  • **Harbor arrival/departure times:** Commercially available
  • **ICOADS, AMVER:** Possible

• Bare minimum needed: Timestamp, location, identity, (speed)

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Automatic Identification System

• Built for ship traffic management and collision avoidance
  • Complements radar
• Automatic transponder system
  • Update vessel position every two seconds (max)
  • **Mandatory** for all vessels over 300 tons (30 m length) since 2005
    • Voluntary for the rest
      • All waterborne traffic NOT included in AIS
• Large volume of data
  • Baltic Sea 2015: > 1 terabyte
• Based on VHF radio transmissions
  • Terrestrial network of base stations
  • Beyond line of sight → Satellite AIS
Vessel technical description

• Not just "a cargo ship" with average engine power
• Every vessel is a unique case
  • Hull form
  • Machinery concepts
  • Fuels
• Strong link to shipbuilding
  • How does it work?

<table>
<thead>
<tr>
<th>Physical dimensions</th>
<th>Machinery setup</th>
<th>Propulsors</th>
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<td>Power transmission</td>
<td>Weather impact</td>
<td>Fuels</td>
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<td>Emission abatement</td>
<td>Payload capabilities</td>
<td>Legislation</td>
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Emission model

- Ship Traffic Emission Assessment Model (STEAM)
- Vessel performance prediction
  - Semiempirical approach
- Fully dynamic system
  - Temporal variation retained
  - Traffic pattern changes
- Vessel specific inventories → MRV
  - Fuel
  - Emissions to air
  - Emissions to water
- Resolution limited by GPS accuracy
  - EU: 5 km, temporal profiles
    - 15 MB/pollutant/year
  - EU: 20 km, 1 h
    - 2 GB/pollutant/year
  - Global: 10 km, daily values
    - 25 GB/pollutant/year
Outputs; General

• Outputs
  • Gridded datasets (NO$_x$, SO$_x$, CO, CO$_2$, EC, OC, Ash, SO$_4$)
  • Vessel specific summaries
  • Emissions by
    • Flag state
    • Vessel type
    • Vessel age
    • Stroke type
  • Fleet statistics

Baltic Sea, 2006-2012
Example: Local scale

- Port scale studies
- Helsinki area
  - Soares et al, GMD, 7 (2014) 1855-1872
- Any port can be studied
- Emission factors for short time scale studies

Tallinn, Estonia
Example; Regional

CO2 emissions from ships in European sea areas 1.-5.7.2011

Data provided by the European Maritime Safety Agency
Example; Global

MARINE ENVIRONMENT PROTECTION COMMITTEE
67th session
Agenda item 6

REDUCTION OF GHG EMISSIONS FROM SHIPS
Third IMO GHG Study 2014 – Final Report

Note by the Secretariat

SUMMARY

Executive summary: This document provides in the annex the complete final report of the "Third IMO GHG Study 2014", which provides an update of the estimated GHG emissions for international shipping in the period 2007 to 2012. The executive summary can also be found in document MEPC 67/6.

Strategic direction: 7.3
High-level action: 7.3.2
Planned output: 7.3.2.1
Action to be taken: Paragraph 1
Related document: MEPC 67/6

Action requested of the Committee

1. The Committee is invited to note the complete final report of the Third IMO GHG Study 2014, as the basis of the findings of the report's executive summary, set out in document MEPC 67/6.
Future work

- Technical capability for annual global ship emission inventories exists
  - Acquisition of global AIS dataset(s)
- Emission factors
  - Detailed measurements with various fuels, load points, duty cycles…
    - Running conditions of engines, fuel flow, emissions must be observed together
    - Black Carbon
  - Local vs regional
- Auxiliary engines → Port scale studies
- Incorporation of weather data during emission calculations
  - Other contributions (bathymetry, fouling) also possible
- Inland waterways vs sea traffic; National vs International navigation
- Traffic not visible in AIS → Small boats
  - Finland: Over 190 000 with an engine
  - About 1/3 of those along the Baltic Sea coastline
Further reading


Comparison to plume chasing measurements


Plume chasing: Berg et al., AMT 5 (2012) 1085-1098

Vessel specific predictions

- Clockwise:
  - SIRENAS-R campaign of JRC (top left)
  - BSR InnoShip project, measurements of Maritime University of Szczecin (bottom left)
  - Jalkanen et al., ACP 12 (2012) 2641. (right)