
# Ocean liming in pratica: scenari di spargimento di $Ca(OH)_2$ dalle navi

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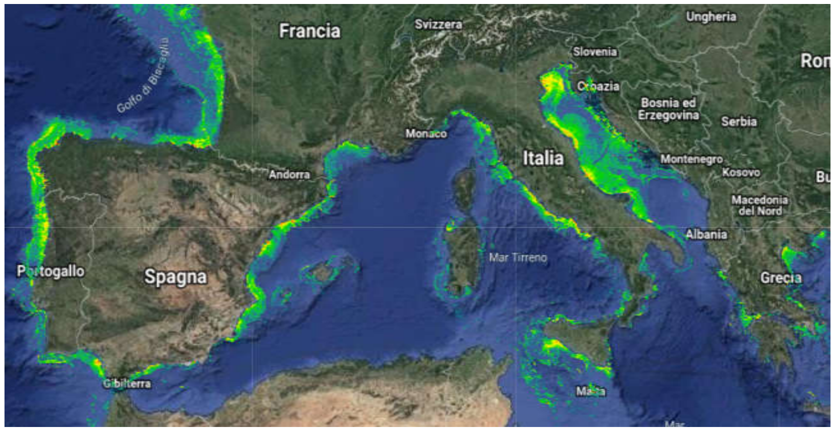
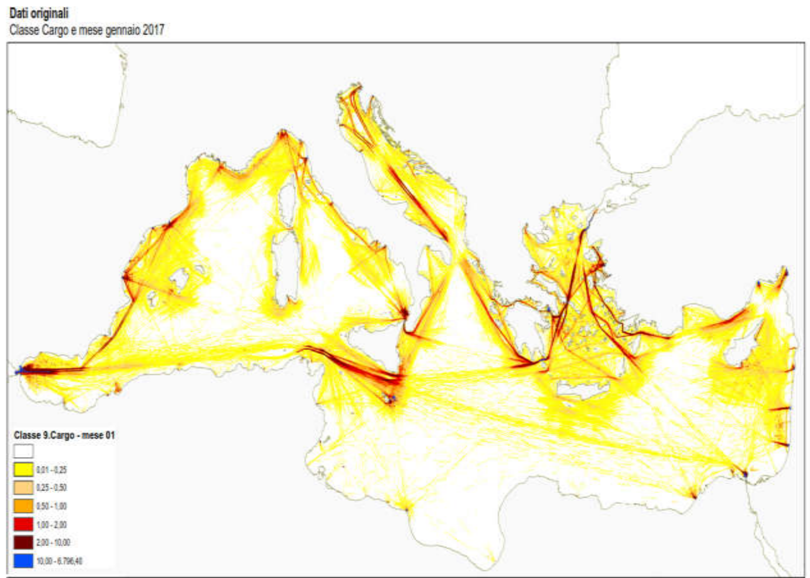
# Summary of presentation

- Analysis of maritime traffic data in the Mediterranean Sea
- Analysis of the global maritime traffic
- Estimation of the potential slaked lime discharge
  - ✓ Scenario 1: new or bought on purpose dedicated ships
  - ✓ Scenario 2: partial use of cargo capacity of existing commercial fleet
- Conclusions and future perspectives

# Marine traffic in the Mediterranean Sea- EMODnet's portal data elaboration

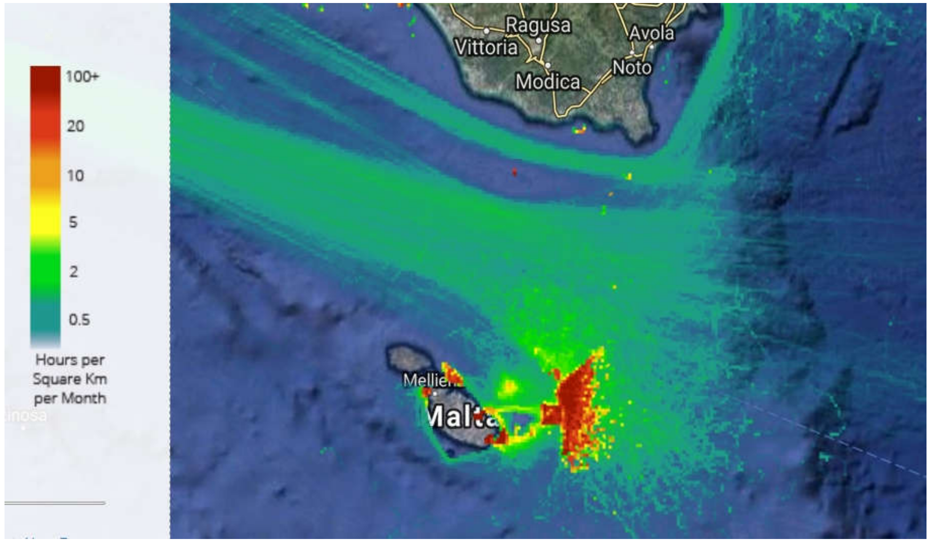
- Traffic density data, 12 months (2017) – EMODnet Project
  Ship categories: **Cargo**, **Passenger** and **Tanker**.
- Other vessel categories discarded:
  - ➢ very limited number of vessels;
  - ➢ unsuitability for the slaked lime discharge operations (small size, too small cargo capacity, navigation too close to the coastline).

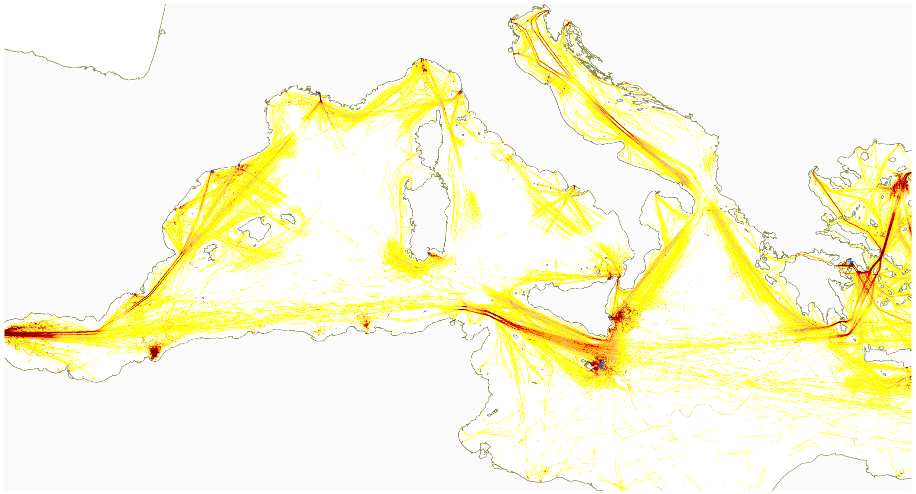


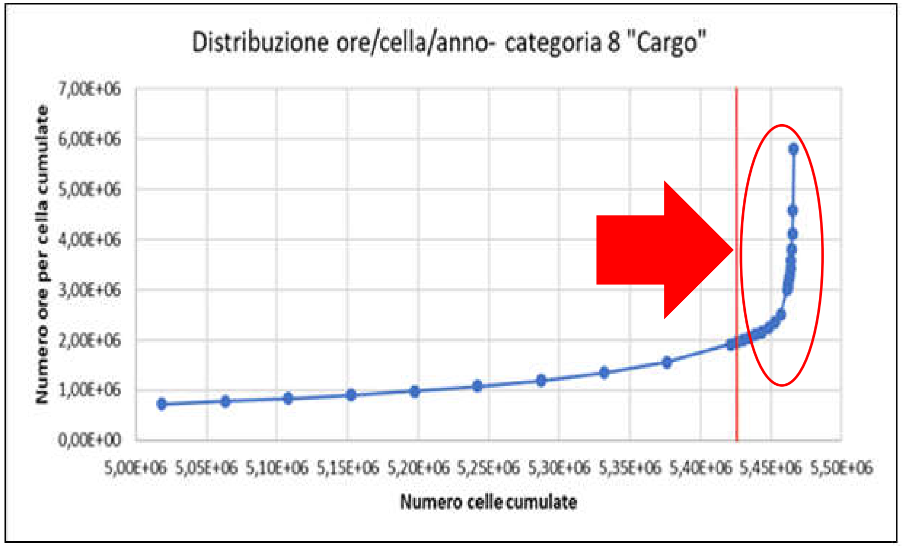
# Elaboration of EMODnet data

- **E**uropean **M**arine **O**bservation **D**ata **NET**work: geographical position, spatial extent of a wide array of marine and maritime human activities
- Data processing:
  1. Elimination of ships' stationarity data ( i.e. cells with hours/month >10)
  2. Elimination of cells too close to the coastline (centroid <5km from the coastline)



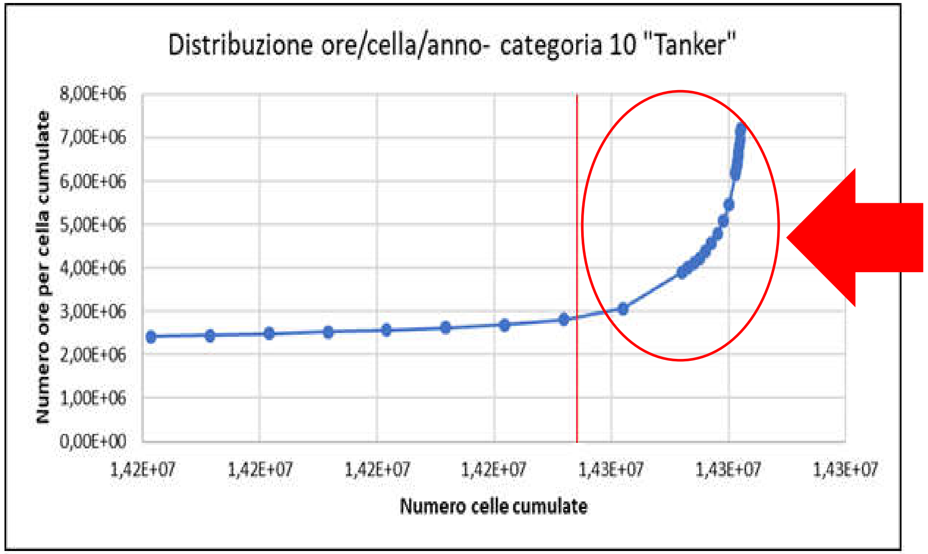



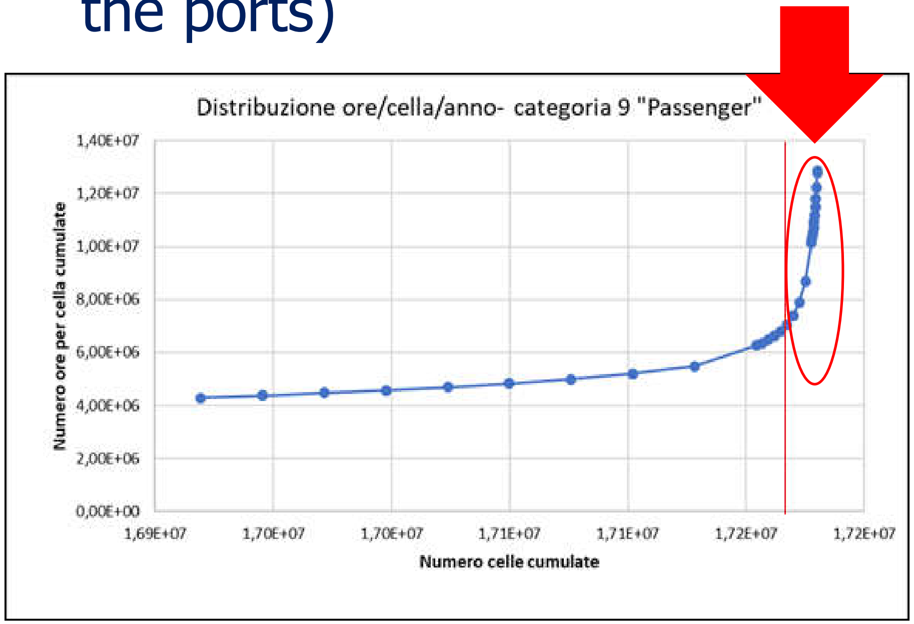
# Elaboration of EMODnet data




Data processing:

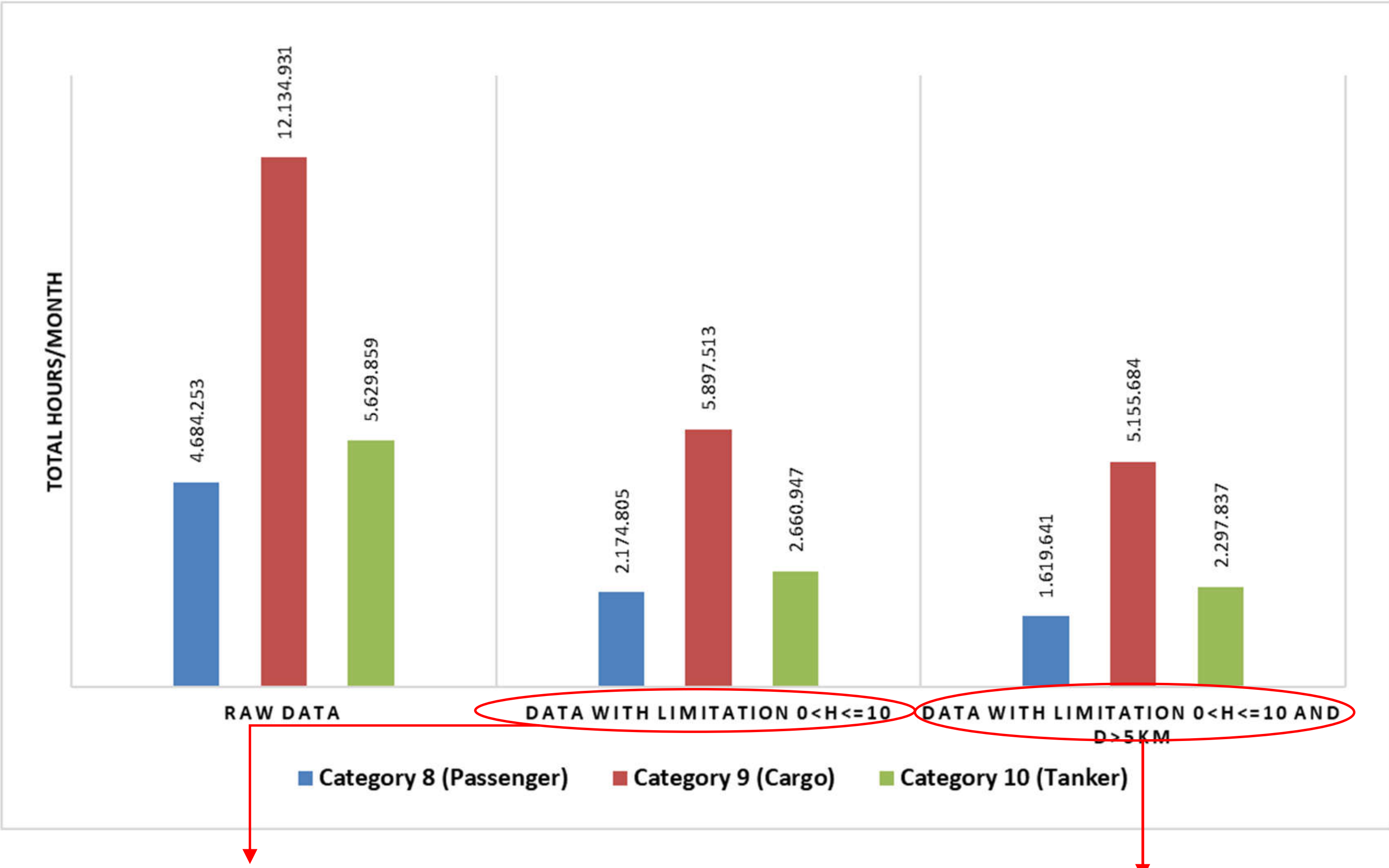
- Elimination of ships' stationarity data ( i.e. cells with hours/month >10)
- Many hours/cell concentrated in few cells (berth areas close to the ports)



# RESULTS : Exploitable hours for the discharge of $Ca(OH)_2$

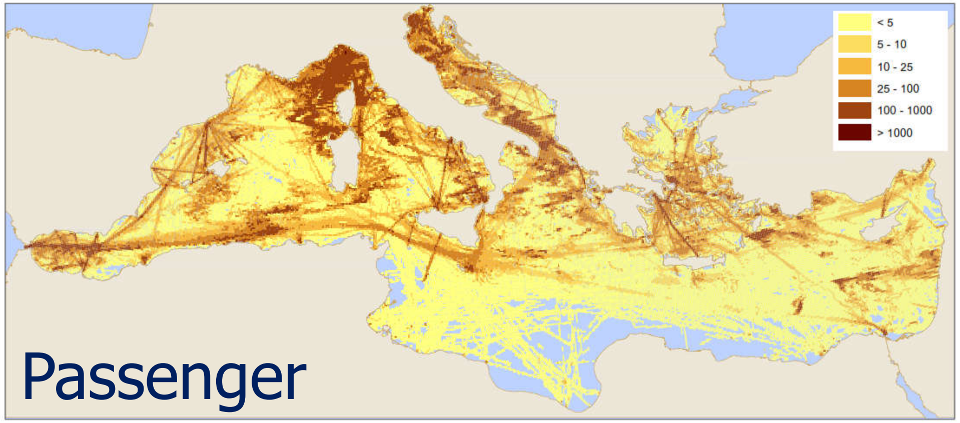
Total: **9 million hours/year of navigation in the Med. Sea**
(18% Passenger ships; 57% Cargo ships; 25 % Tankers)

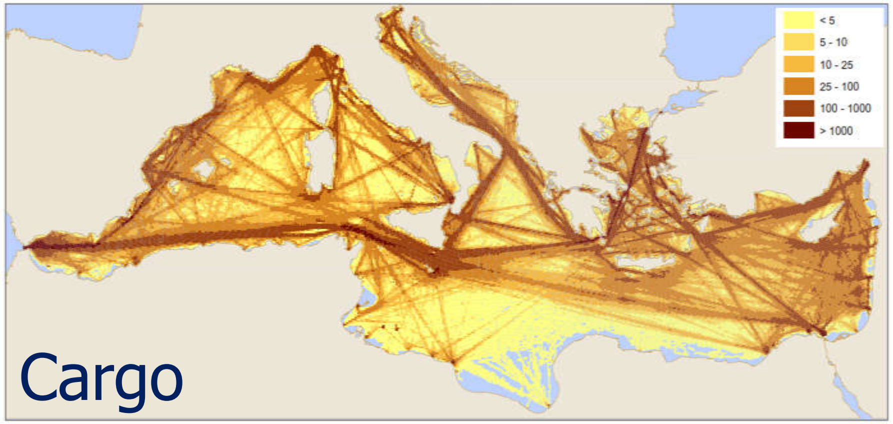


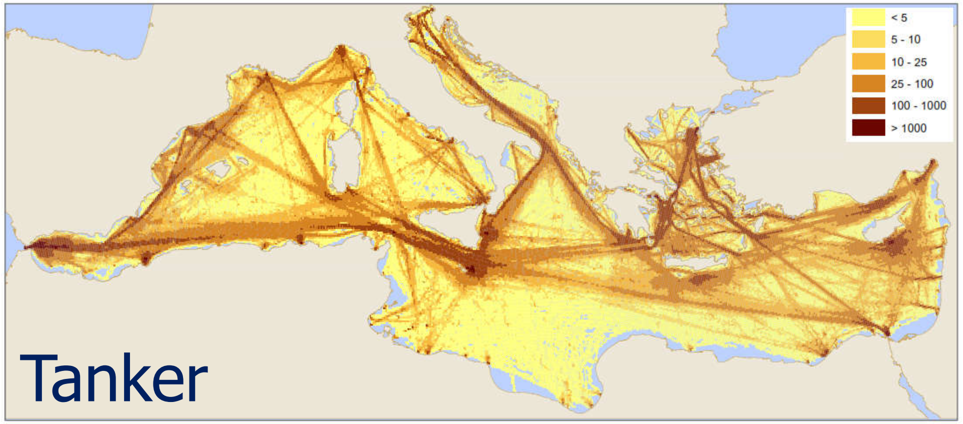

**-52% hours per year**

**-15% hours per year**

# Final data delivered to CMCC*: hours/year of navigation



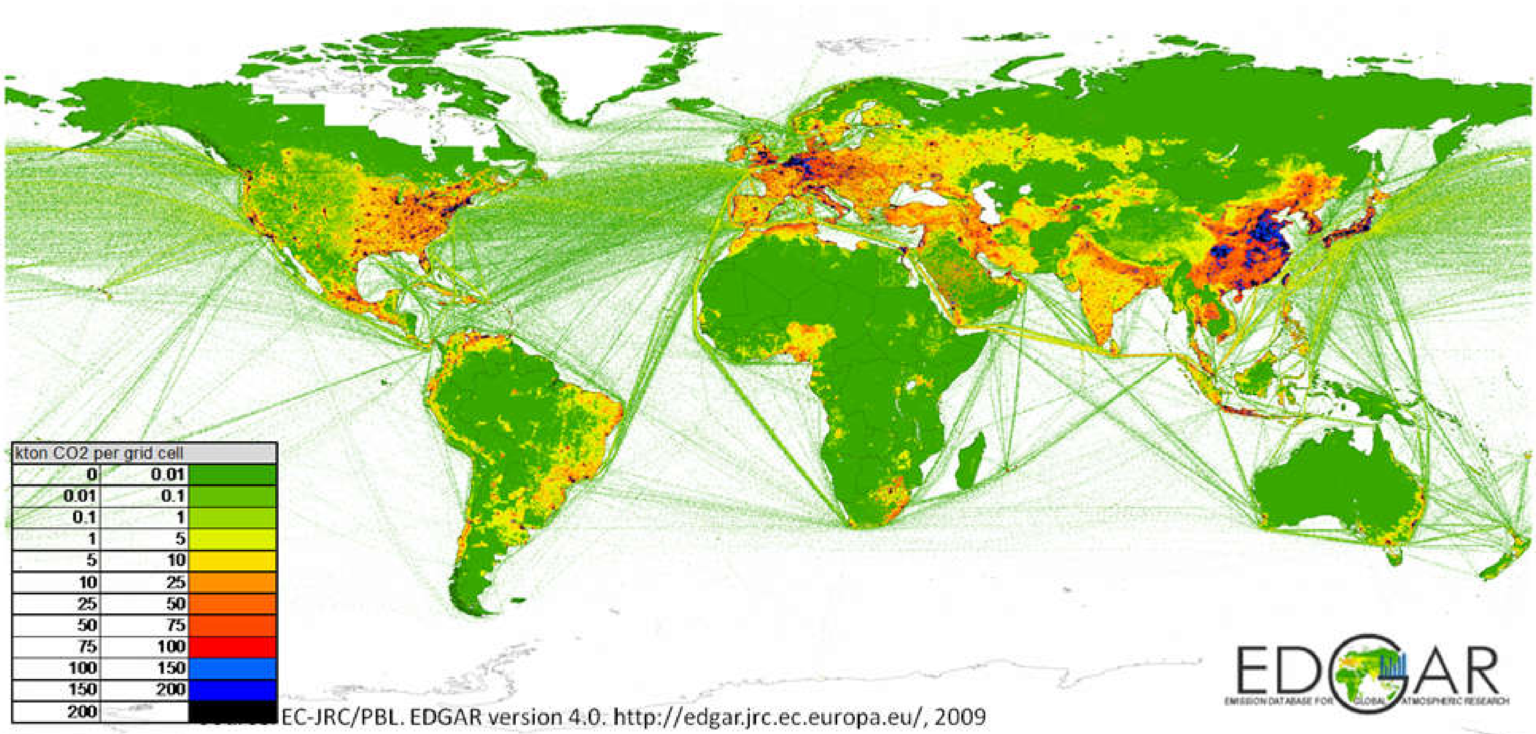




** **Momme Butenschön (Fondazione CMCC) -** Simulazione di scenari di alcalinizzazione del Mediterraneo – 5 febbraio h 9.15*

# EDGAR's database

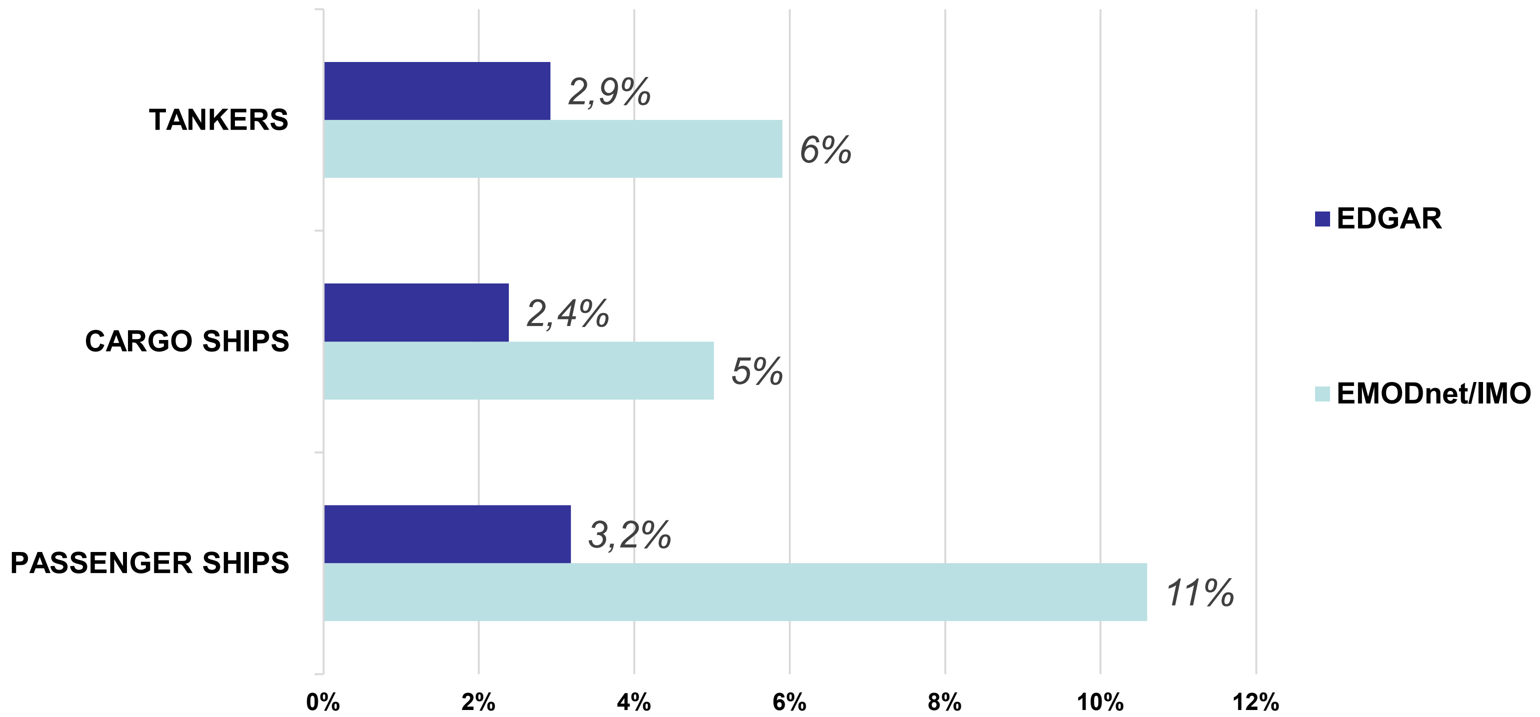
- **E**mission **D**atabase for **G**lobal **A**tmospheric **R**esearch – past and present anthropic greenhouse gas and atmospheric pollutant emissions
- Global emissions map for international shipping transportation using navigation lines of vessels as a proxy data
- Spatial allocation of ship emissions globally on 0.1°x0.1° grid (lon, lat)



# Comparison EMODnet - IMO's vs EDGAR's data

- Relevant difference between EMODnet and EDGAR data
- Reason: EDGAR only considers ships flying flags belonging to the European Union.

**Percentage of hours of navigation in the Mediterranean Sea on the total of global oceans surface**




**N.B. : Surface area of Mediterranean Sea: 2,51 mln. Km$^2$ - 0,7% of global ocean surface area**

# Ocean liming: scenarios of the discharge of $Ca(OH)_2$ into seawater

1. **Dedicated vessels** - new or bought on purpose

2. **Existing commercial vessels** - using part of the cargo capacity

# Technical parameters of the discharge of $Ca(OH)_2$ slurry (slaked lime) into seawater

**Objectives**

- Keeping discharge rate range as low as possible
- Limiting water volume used
- Efficient management of $Ca(OH)_2$

Maximize the amount discharged → use of a $Ca(OH)_2$ slurry (exceeded limit of solubility)

**Technical parameters of discharge**

- Solubility of $Ca(OH)_2$ in water: 1.73 kg/m$^3$
- Weight ratio $H_2O:Ca(OH)_2$ at solubility: 578:1
- Weight ratio $H_2O:Ca(OH)_2$ during discharge: 11:1
- Concentration of $Ca(OH)_2$ in the discharge: 87 kg/m$^3$
- **Discharge rate:** ≤100 kg/s *(1000 kg/s proposed by other researches)*

# Scenario 1: new dedicated ships

- 1000 new vessels
- Tonnage: 75,000 dwt
- Percentage of tonnage used for $Ca(OH)_2$: 85%
- Average distance per typical sea-leg: 3.542 km
- Number of yearly trips per vessel: 39
- Average speed: 25km/h
- **$Ca(OH_2)$ Discharge rate: 100 kg/s**

**Total potential discharge :**
**2.5 Gt $Ca(OH)_2$ /year with 1000 ships**

# Scenario 1: new dedicated ships

Advantages

- Enhanced flexibility in the choice of discharge parameters
- High efficiency of water use
- Higher amount of $Ca(OH)_2$ discharged
- Better logistic management
- Dedicated routes

Disadvantages

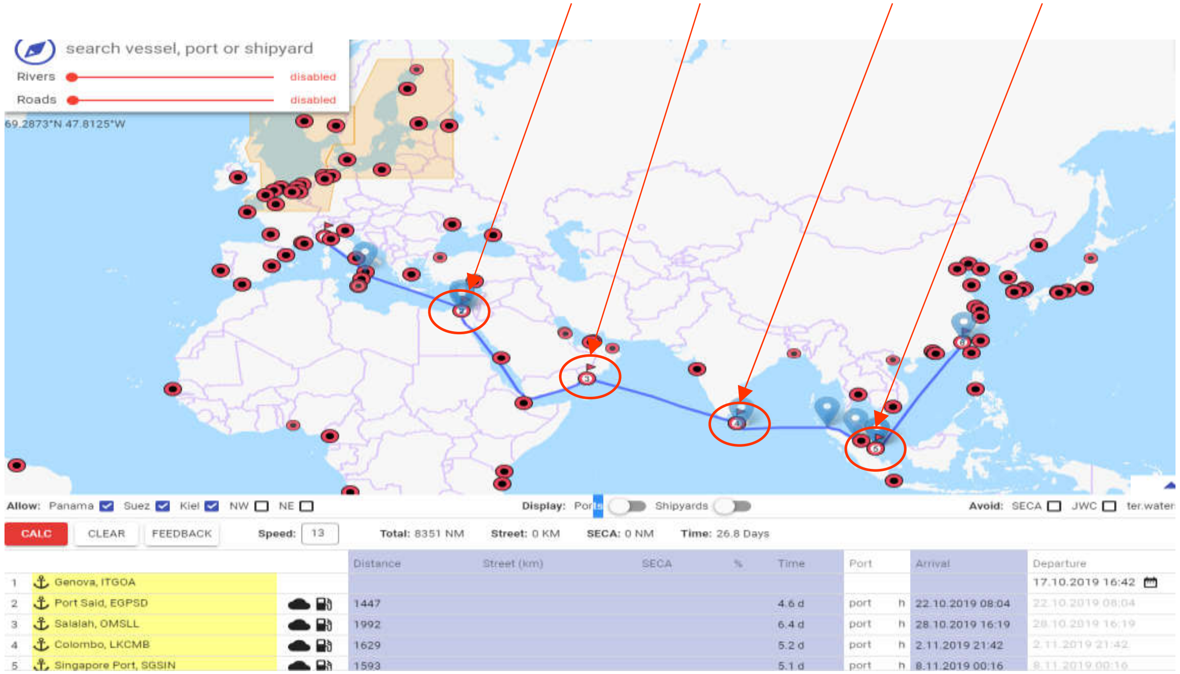
- Higher capital costs
- Longer project execution times

***(but…USA built 2700 Liberty ships in 5 years during WWII)***

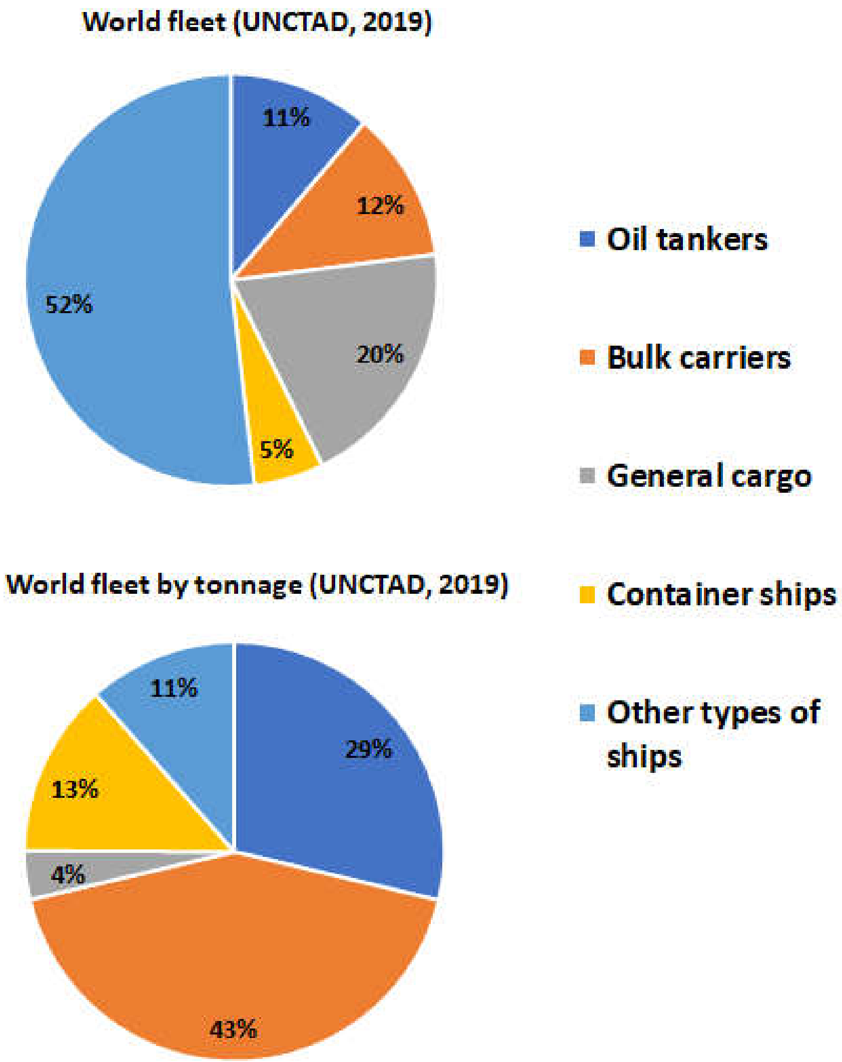
# Scenario 2: partial cargo of the existing ships



- Partial use (15%) of cargo capacity for the transport of $Ca(OH)_2$
- **Subscenario 2A**: Route with load of slaked lime on the ships only at the departure port
- **Subscenario 2B**: Route with intermediate stops to reload the slaked lime



# Scenario 2: why bulk carriers and container ships?




- Bulk carriers and container ships are the most suitable for $Ca(OH)_2$ discharge.
- Bulk carriers: long journeys (up to 20,000 km) without intermediate stops
- Container ships: intermediate fixed stops
- Bulk carriers and container ships: only 17% of total fleet, but 56% of total tonnage of the global commercial fleet.

# Scenarios 2A and 2B: partial cargo of the existing ships



Advantages

- Minor modifications of the ships for the purpose
- Lower operative costs
- Bulk carriers : long journeys allow low discharge ratios
- Containers: intermediate stops exploitable to reload the $Ca(OH)_2$

Disadvantages

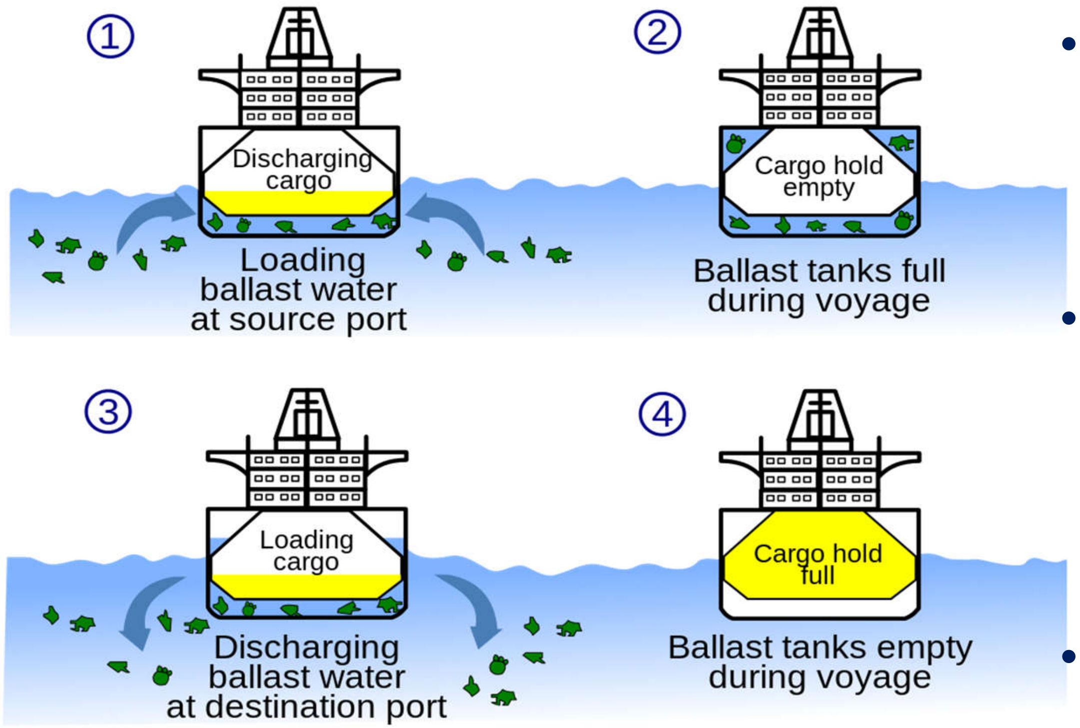
- Need of dedicated $Ca(OH)_2$ loading facilities in ports
- Additional time for vessel loading and unloading in the ports (2B)

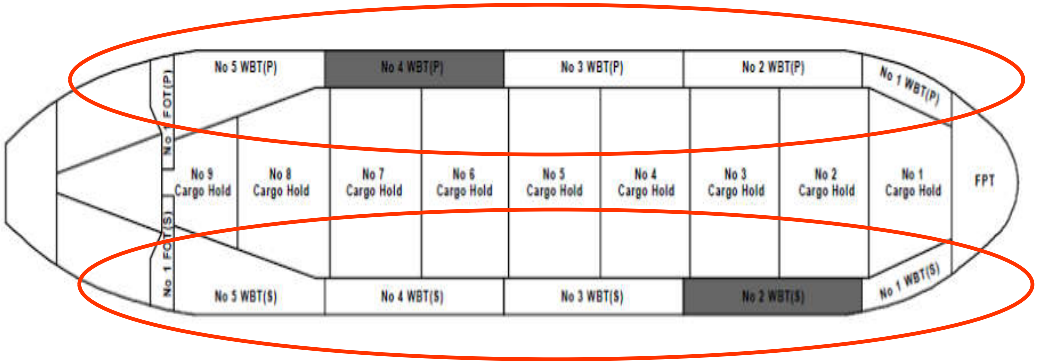
# Scenarios 2A and 2B: partial cargo of the existing ships

- 85% of tonnage used for the cargo (bulk carriers: 74,000 dwt; containers: 50,420 dwt – UNCTAD, 2019)
- $Ca(OH)_2$ load: 13% of tonnage
- Discharge during the whole route
- Discharge rate (kg/s) ruled by the sea-leg length
- Sea route with 1 $Ca(OH)_2$ load (2A)→ Discharge rate: 4-7 kg/s
- Sea route with 2 or more $Ca(OH)_2$ reloads(2B)→ Discharge rate: 16-22 kg/s
- Global fleet: 11,373 bulk carriers + 5,269 containers

| Scenario | 2A | 2B | 2-Average |
|---|---|---|---|
| Total potential discharge<br>Gt $Ca(OH)_2$/year (with 16,642 ships) | 2,3 | 5,3 | 3,8 |

# Alternative option: use of ballast water tanks of existing ships




- Ballast water is water carried in ships' ballast tanks to improve stability, balance and trim.
- It is taken up or discharged when cargo is unloaded or loaded, or when a ship needs extra stability in poor weather.
- A ballast voyage is a voyage with no cargo on board to get a ship in position for the next loading port or docking. On voyage the ship is said to be "in ballast".

# Alternative option: use of ballast water tanks of existing ships

Advantages

- Cheaper ballast water management (no needs of a disinfection system) → slaked lime kills the aquatic alien species
- Use of existing pumps
- Potential revenues from ballast travels

Disadvantages

- **Difficult prevention of precipitation of $Ca(OH)_2$**
- **International legislative constraints**
- Ship loading and unloading require additional time in the ports
- Much lower amounts of $Ca(OH)_2$ than in the previous scenarios

# Total potential $Ca(OH)_2$ discharge and $CO_2$ removal

- Scenario 1 (1000 new ships): **2,5** Gt/year
- Scenario 1 (16,600 existing ships): **3,8** Gt/y (2,3 - 5,3 Gt/y)
- **Total: 6,3 Gt $Ca(OH_2)$/year**

- Theoretical $CO_2$ removal by $Ca(OH)_2$: 2 mol / 1 mol of $Ca(OH)_2$
- Efficiency is also limited by the air-sea gas exchange
- A conservative value of 1.4 mol of $CO_2$ / mol of $Ca(OH)_2$ added has been assumed (*)
- 0.83 tons of $CO_2$ removed per each ton of $Ca(OH)_2$ added in the ocean

**5,2 Gt of $CO_2$ removed per year**

(100 new ships and 10% of existing ships): 0,5 $GtCO_2$/year

(*) Source: Keller et al.(2014) Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario. Nature Commun 5:3304

# Conclusions

- High maritime traffic density in the Mediterranean Sea
- 8 millions of exploitable navigation hours (40% of the total)
- Very high potential discharge → several Gt/year of $CO_2$ removal with low discharge rate using 8% of global commercial fleet tonnage
- Main potential constraints:
  - implementation of loading facilities in the port
  - potential environmental impact in case of high discharge
  - elevated costs (→ need of a higher $CO_2$ price)
- Still many aspects to be examined in greater depth (i.e. international legislative constraints)

# *Grazie per l’attenzione!*

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DESARC MARESANUS

**DESARC-MARESANUS**

Contrastare l'acidificazione dei mari rimuovendo carbonio dall'atmosfera