Japan’s Geographic Concept for NO_x Regulations

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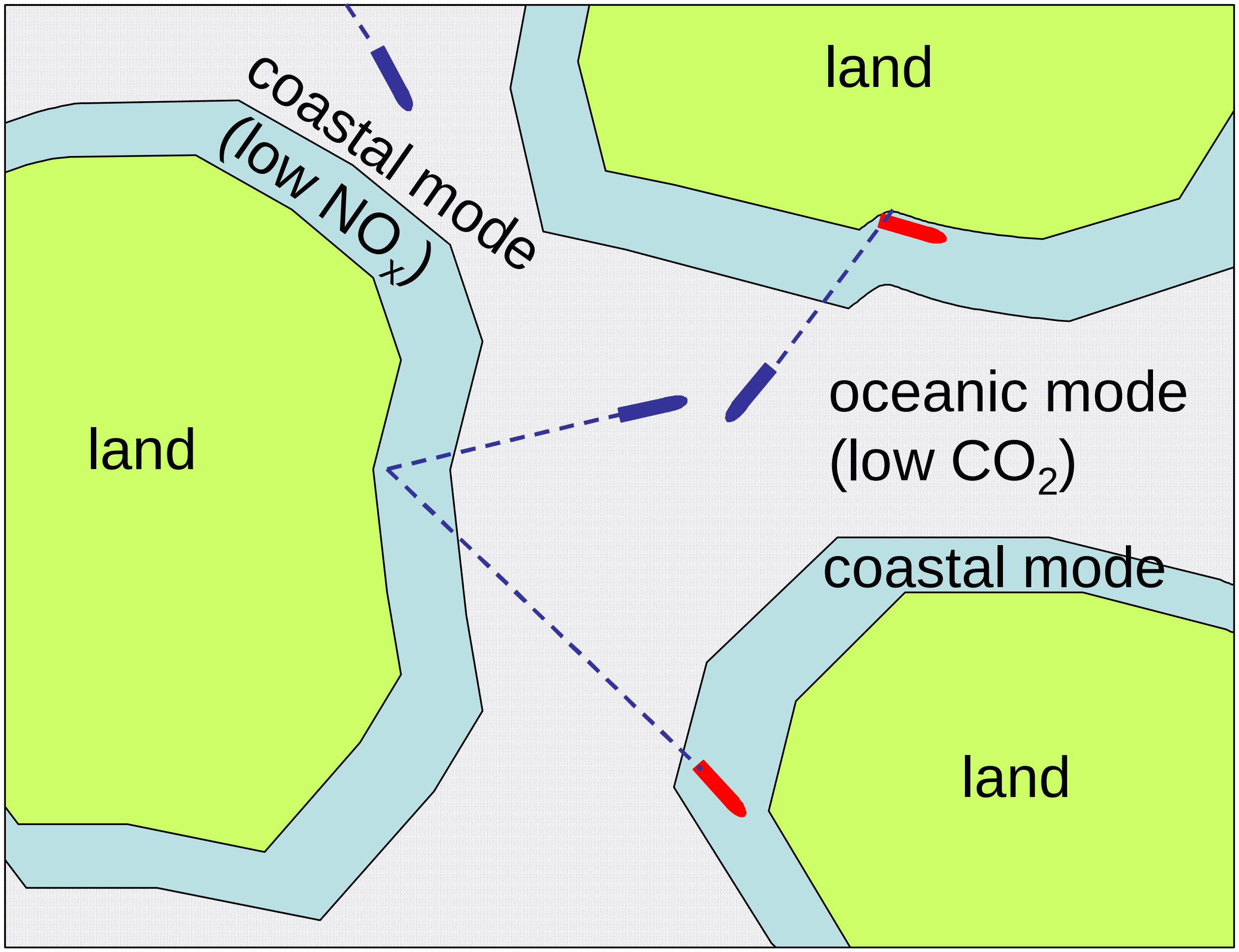
Background

- Reduction of NO_x emission is often accompanied by increase in CO_2 emission.
- NO_x affects locally while CO_2 globally.
- NO_x is rapidly removed from atmosphere while CO_2 stays longer.

- Geographical concept:
  - Std 1: NO_x emission is reduced near shore.
  - Std 2: CO_2 emission is reduced in the ocean.

Schematic of the concept



red ships: in the coastal mode for Std 1 (Low NO_x)

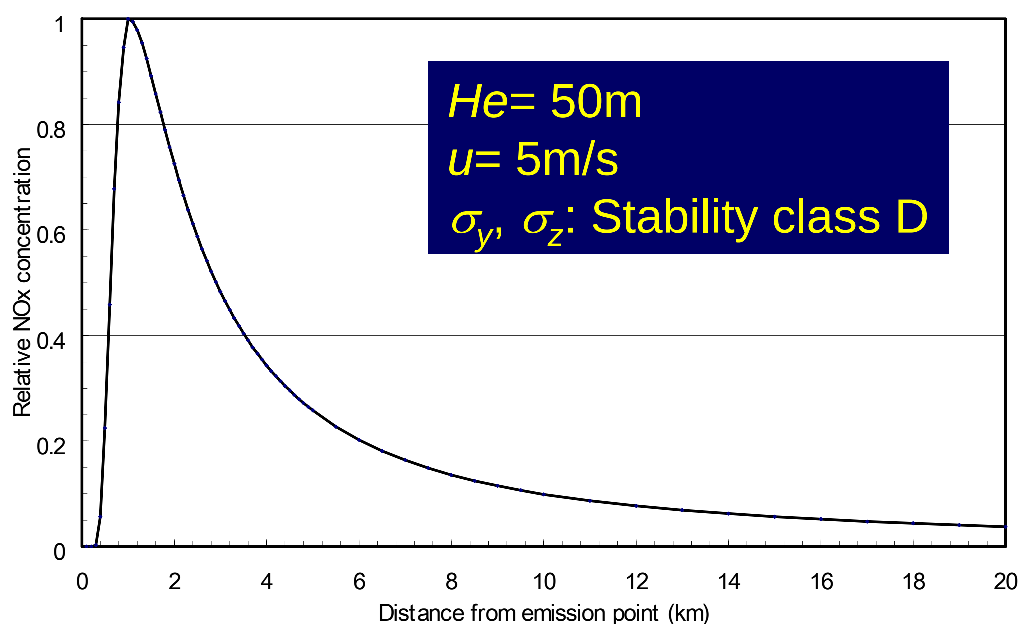
blue ships: in the oceanic mode for Std 2 (low CO_2)

Diffusion of NOx

- Effect of NOx for human health is primarily related to its concentration as photochemical oxidant formation.
- Gaussian plume model:
  Concentration decreases exponentially with increase of distance from the emission point.

$$C = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z-He)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+He)^2}{2\sigma_z^2}\right)\right]$$

Q: emission intensity (m^3/s)
u: wind velocity (m/s)
H_e: plume height (m)
y: direction perpendicular to wind (m)
z: vertical distance (m)
σ_y: horizontal dispersion parameter(m)
σ_z: vertical dispersion parameter(m)



Increase in CO_2 emission
- Fuel penalty -

Technologies	NO_x reduction	CO_2 increase
In-Engine	10-15%	1-2%
EGR	30-40%	2-3%
Emulsification	15-25%	Up to 2%, Need to heat water
Water injection	40%	Up to 4% Need to heat water
Humidification	Up to 40%	Up to 2-8%
S.C.R.	80-85% or higher	Back pressure 1% reaction product from urea to ammonia

revised from BLG 10/WP.3

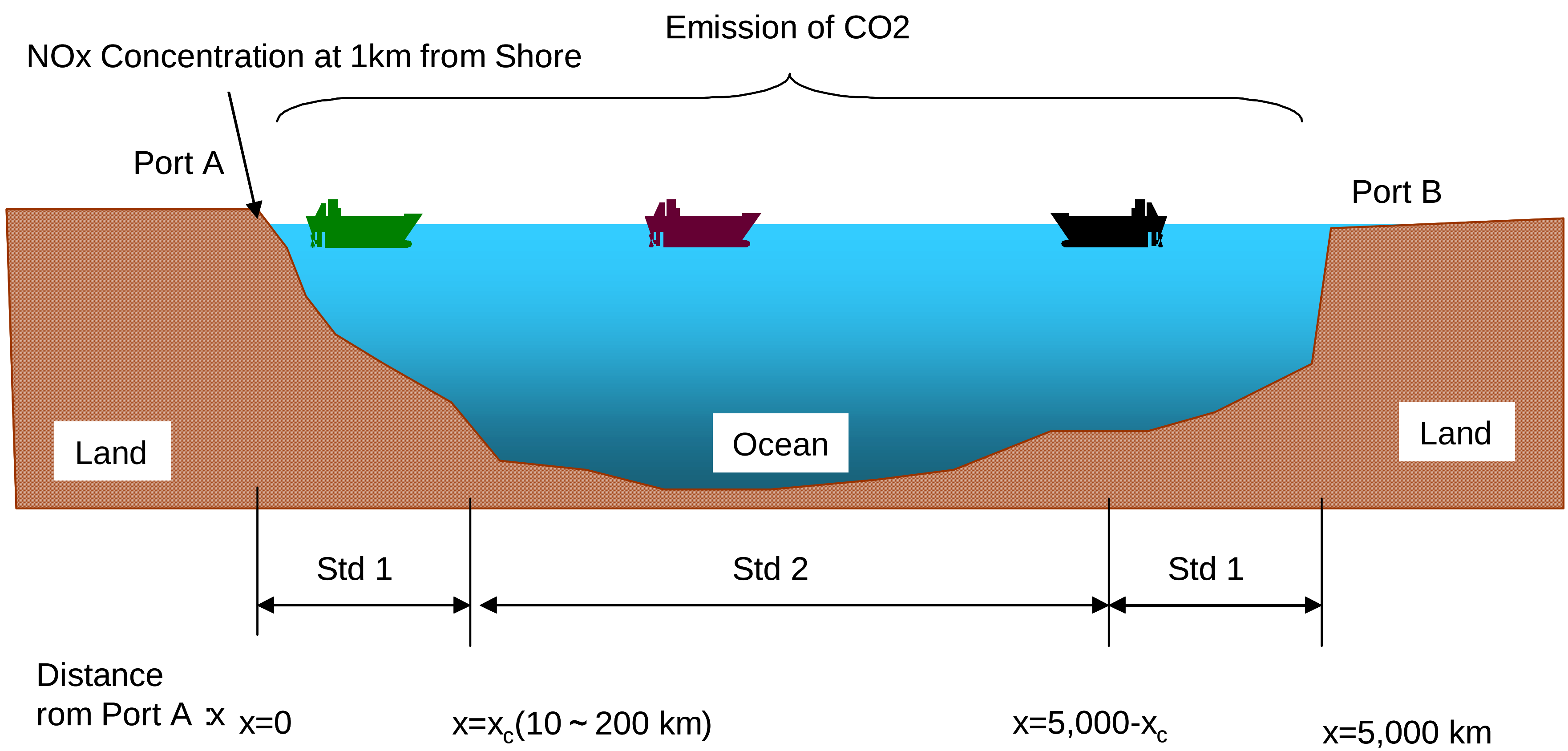
Uniform and Geographic Stds.
- A case study -

- Basic standard (*e.g.* IMO Tier II)
- Advanced standard (*e.g.* IMO Tier III)
  - Case I: Uniform standard
  - Case II: Geographical standard

    In oceanic area, the basic standard is applied while advanced one for other area.

- How much does NO_x concentration increase? How much does total CO_2 emission decrease? What is the optimum distance from shore for the boundary between the two standards?

A simulation

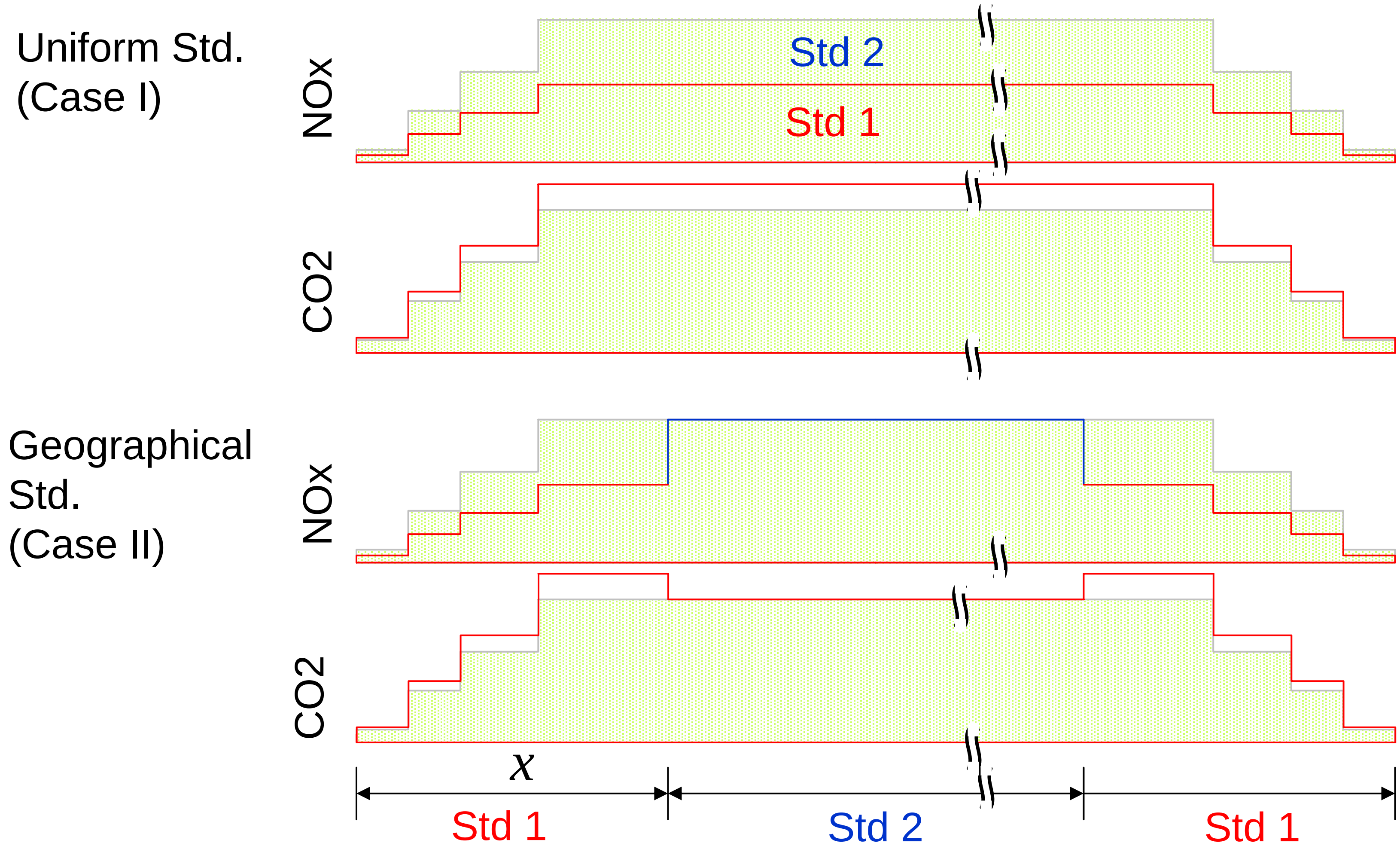


- NO$_x$ concentration on the ground at 1 km from shore
  Total CO$_2$ emission during voyage

Calculation conditions

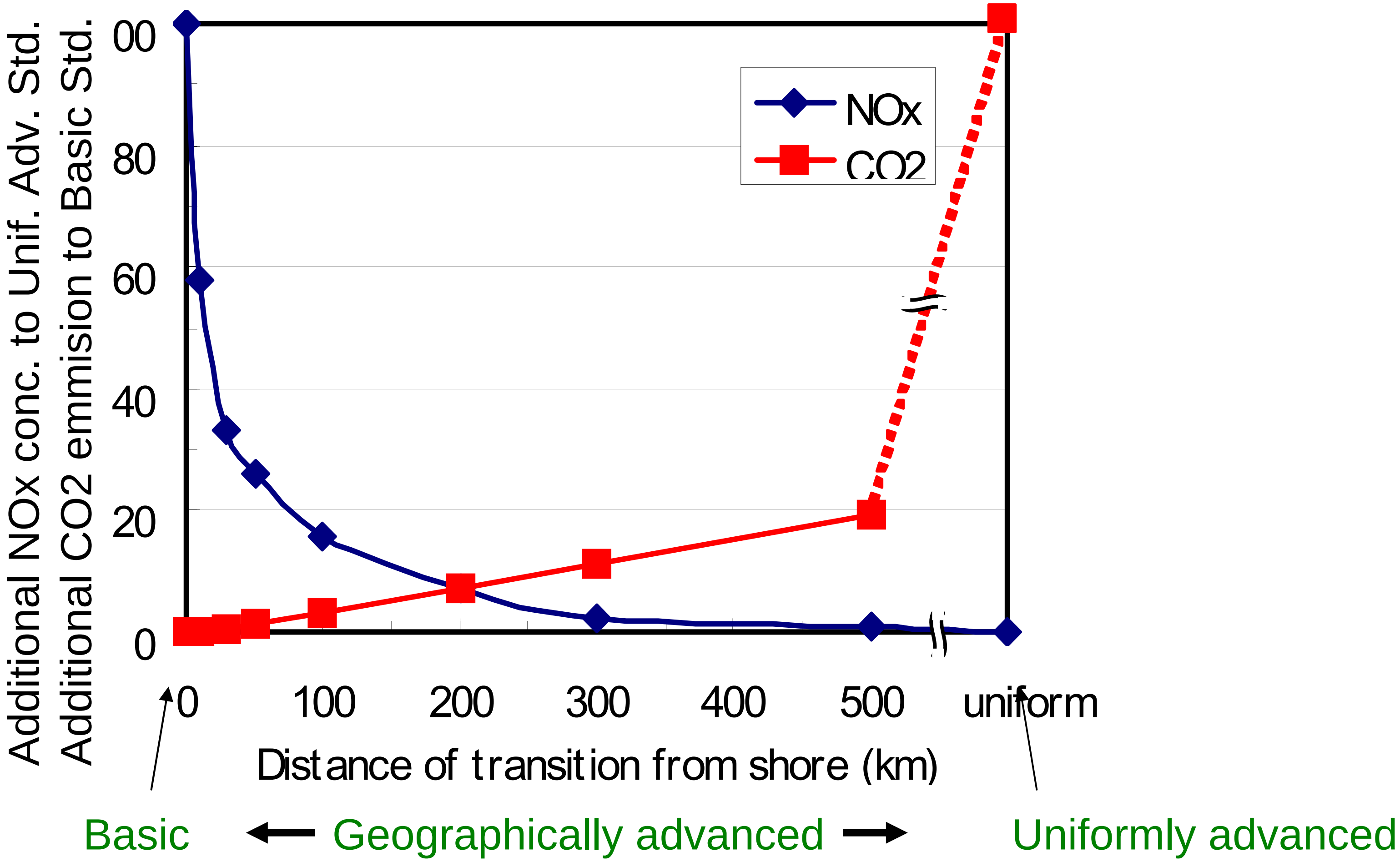
- Ship operations
  - constant traffic of container ships for 5,000 km sailing along a linear route from Port A to Port B
  - ship’s speed and engine power are low near ports (<20 n.m.) while full (85%) in ocean (27 kt)
  - auxiliary engines for generators are operated in low-speed operations
- Atmospheric conditions:
  - wind velocity: 5 m/s (constant)
  - wind direction: unidirectional from ocean to shore
  - Pasquill’s stability class: D (neutral)
- METI-LIS
  - a simulation model based on Gaussian plume model modified from ISC (Iudustrial Source Complex Dispersion Models) and evaluated by METI (Ministry of Economy Trade and Industry Japan)

Emission profiles



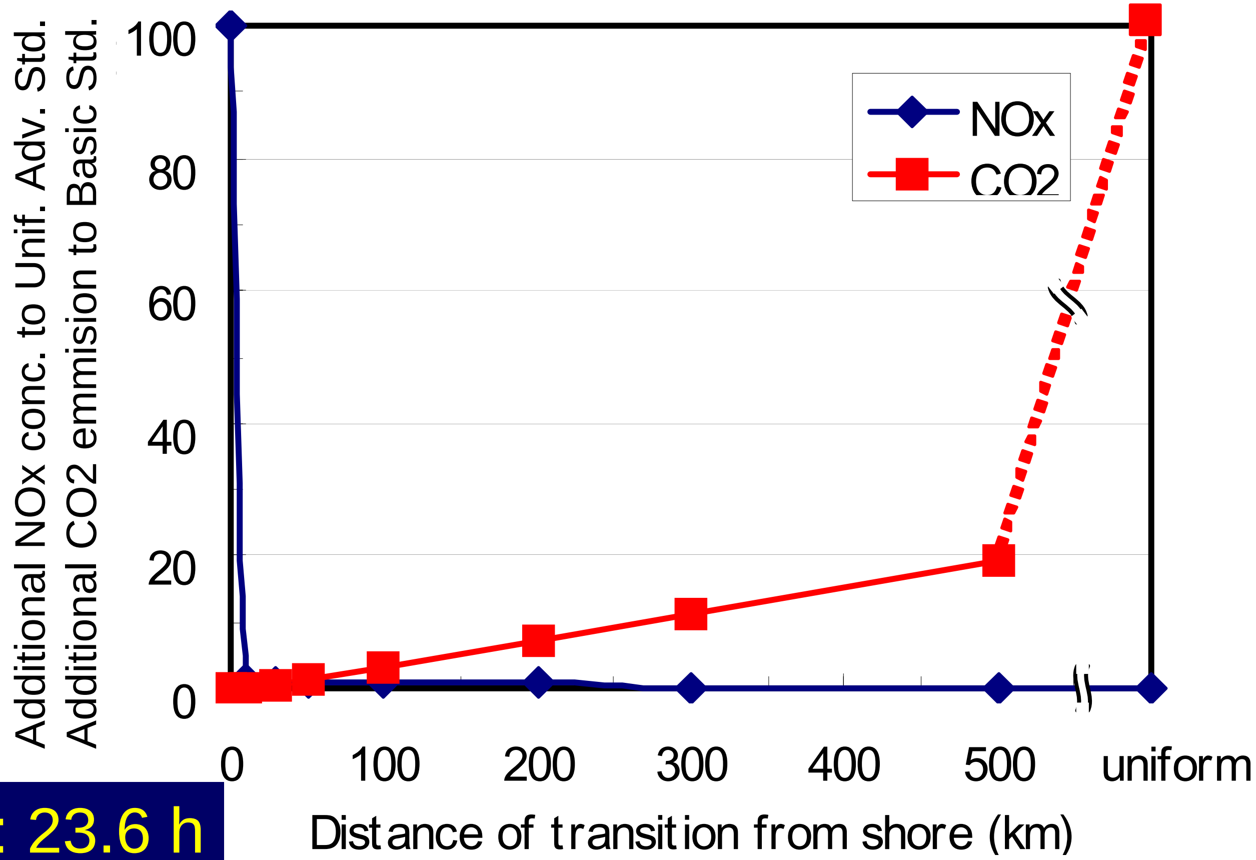
Effects of transition distance
- Calculations for sailing period -

- NO_x concentration decreases exponentially.
- Total CO_2 emission increases linearly.



Effects of transition distance - including hotelling at port-

- Emission from auxiliary engines operated during hotelling at the port is critical.



mooring time: 23.6 h

Discussion on the model

- A plume model is usually applied for short distance simulations.
  - Atmosphere is stable on the ocean.
  - Surface roughness is small.
- A worst case scenario
  - Plume model gives overestimation.
  - Uni-directional wind is assumed (less diffusive).
  - No reaction or deposition is considered.

The model can be available for the present estimation.

Implementation

- Switching technologies between coastal and oceanic modes

Coastal Waters		Ocean
Electronically controlled fuel Injection		
Low NOx position	⇔	Low BSFC position
Emulsion fuel		
Emulsification system operated	⇔	Emulsification system not operated
Selective Catalytic Reduction		
Operated	⇔	Not operated/by-passing

- Compliance

- Record books
- On-board monitoring log

Conclusions

- Applying the geographical concept for NO_x regulations, CO_2 emission can be considerably reduced with a minimized increase of NO_x concentration.
- The concept can be applied as an *optional* choice for ship owners when advanced standards are introduced (*e.g.* Tier III).
- It would be recommendable to take 50 n.m. (100 km) as the transition distance from coastal to oceanic modes.

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