Prediction of Fuel Consumption of Ships in Actual Seas

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IMO

Reduction of Greenhouse Gas Emissions from International Shipping

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) has adopted mandatory measures to reduce emissions of greenhouse gases.

Energy Efficiency Design Index (EEDI)
Ship Energy Efficient Management Plan (SEEMP)

Start from 1st, Jan., 2013

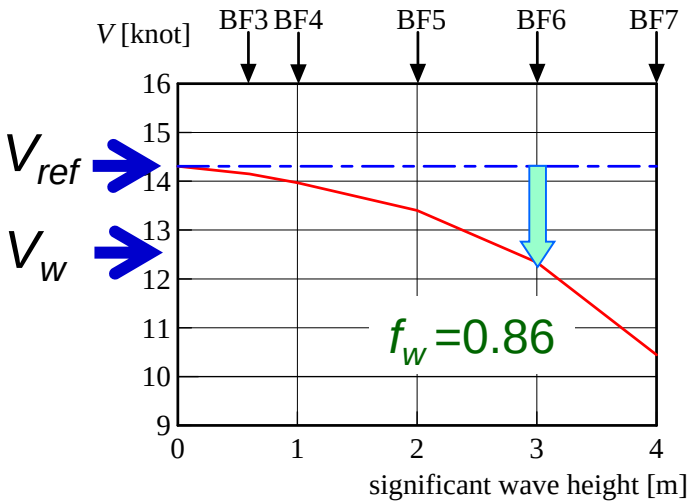
Importance of $EEDI_{weather}$

Considering the sailing condition....

EEDI is the design index in a calm sea condition.
Ship owners/operators fear of performance optimization in a calm sea condition.
They need $EEDI_{weather}$ with f_w as complementary index.

f_w is non-dimensional coefficient for decrease of ship speed in representative sea conditions; BF6 of head winds/waves.

$$f_w = V_w / V_{ref}$$

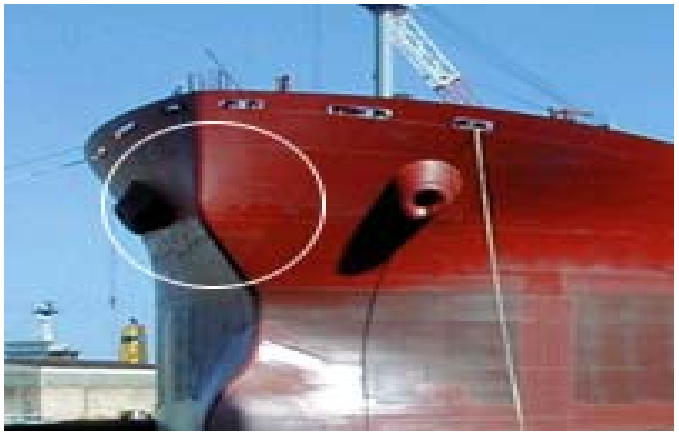


Backgrounds

Evaluation for the technology

to reduce added resistance in waves

Special bow shape



Energy saving device

At present, methods combined with tank tests are necessary for the accurate evaluation of energy saving technology above water

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SEEMP is PDCA cycle

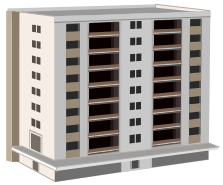
PLAN

Planning

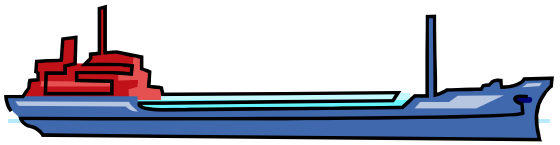
DO

Implementation

weather routeing, optimum trim etc.



ship management office



ACTION

Self-evaluation and improvement

CHECK

Monitoring

How to reduce fuel consumption by the operation?

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Prediction of ship speed/fuel consumption in actual operational conditions is expected for SEEMP cycle.

Calculation of FOC in actual seas

Operating Point of M/E

(A) No winds and no waves（calm sea）

in winds and waves

(B) M/E power is increased at the same rev. due to governor (FOC increase)

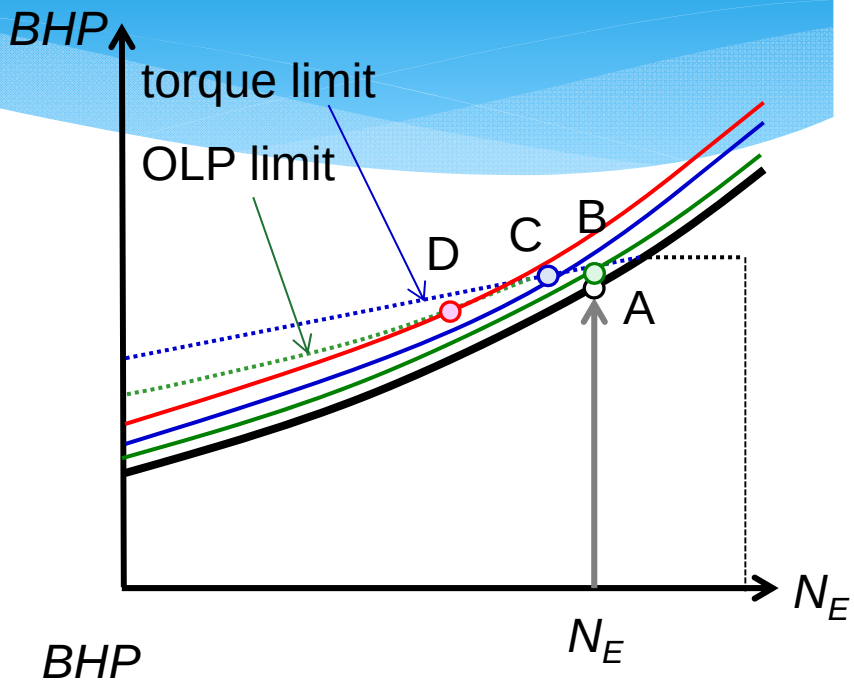
winds and waves become larger

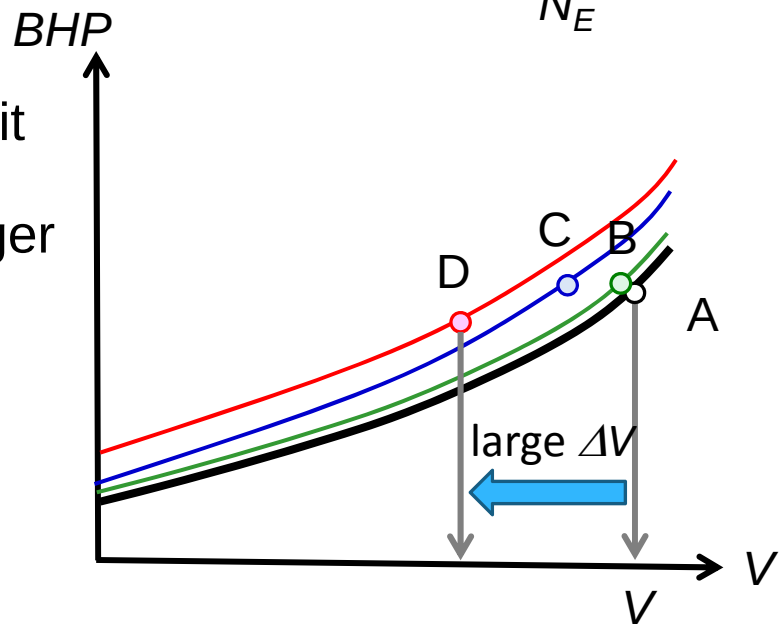
(C) M/E rev. is decrease due to torque limit

winds and waves become more larger

(D) M/E rev. is decrease due to OLP limit

Another operation limits, *Fuel Index limit*, is used for fuel saving.





Calculation of FOC in actual seas

Fuel Index is non-dimensional value of fuel injection

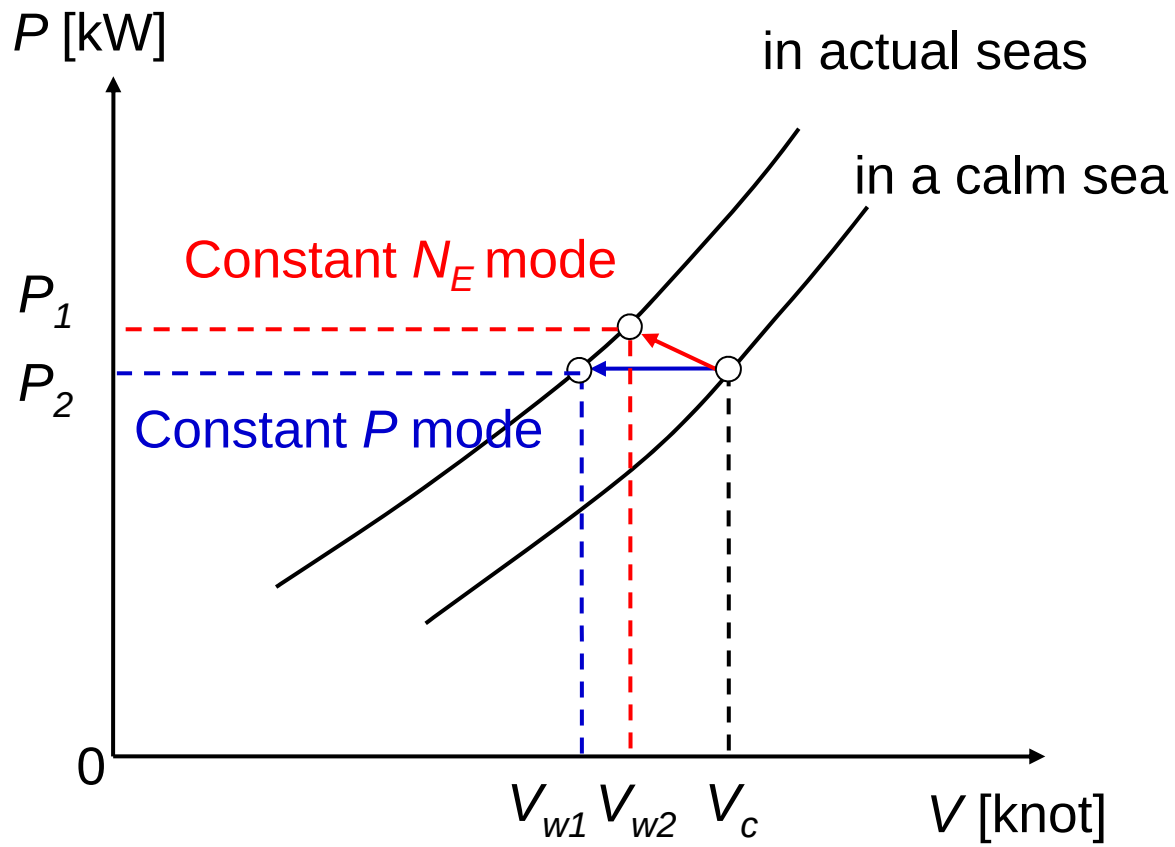
FI : Fuel Index expressed as 100% at *MCR*

$$FI = \frac{\lambda BHP}{\lambda_{MCR} MCR} \frac{N_{EMCR}}{N_E} \times 100\ (\%)$$

λ: SFC
BHP: brake power
N_E: M/E revolution

Calculation of FOC in actual seas

Different engine characteristics cause different ship speed/fuel consumption, governor control as well.

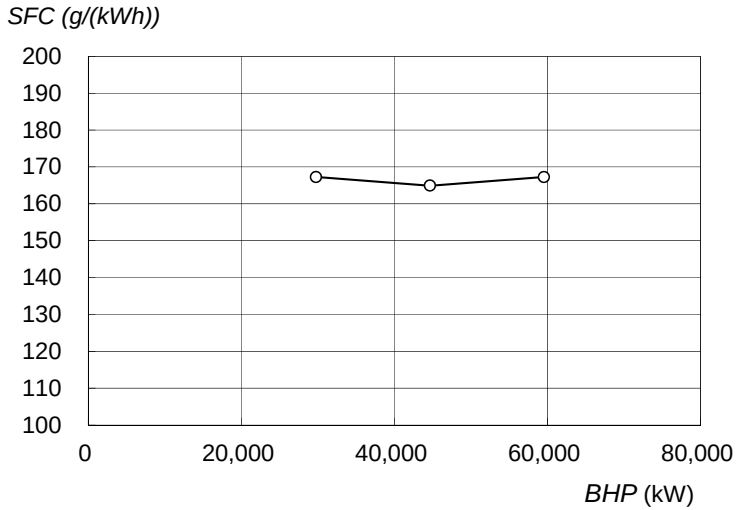


Calculation of FOC in actual seas

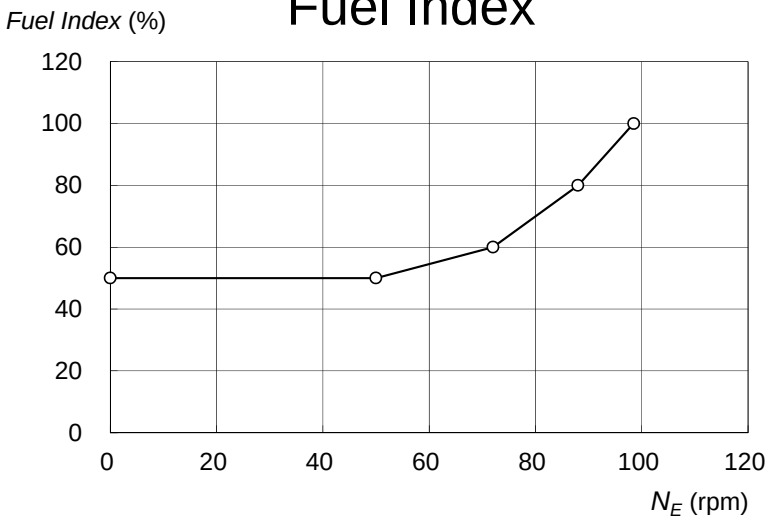
Calculation
-FOC and ship speed-

Container ship of 300m length

SFC



Fuel Index

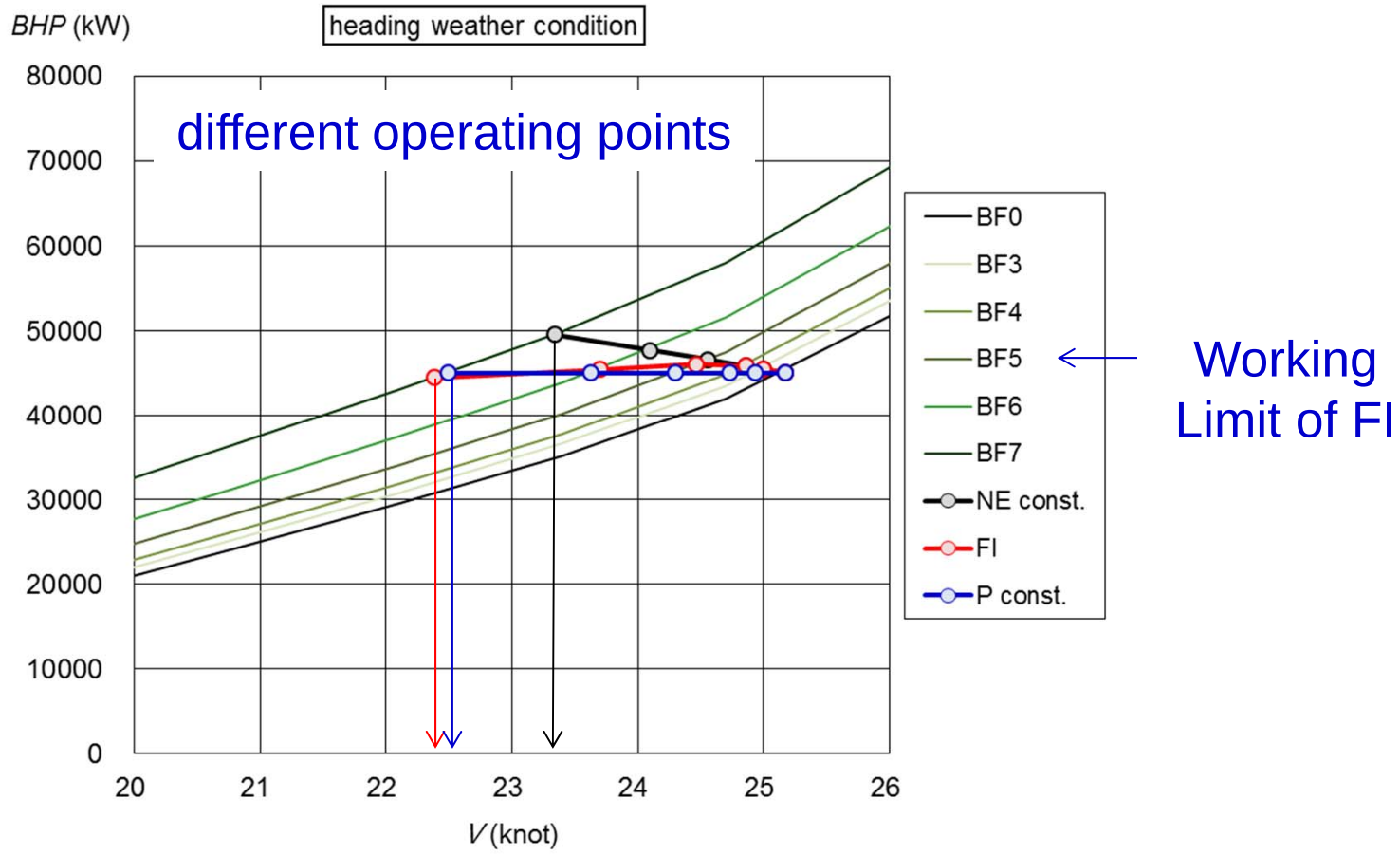


Calculation of FOC in actual seas

(1) constant M/E rev. mode

(2) constant M/E rev. mode with limit of Fuel Index

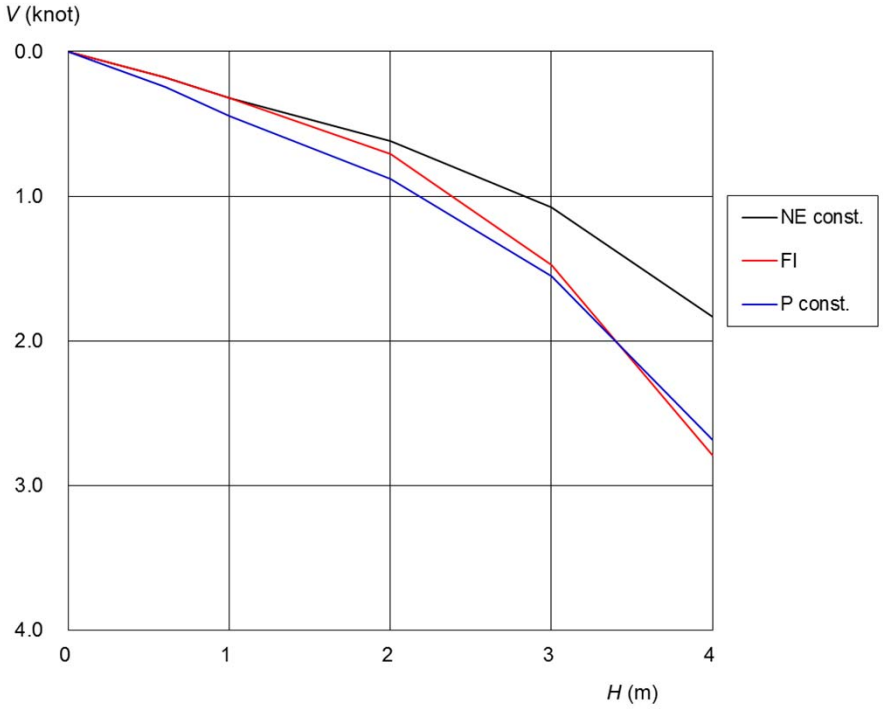
(3)constant M/E power mode



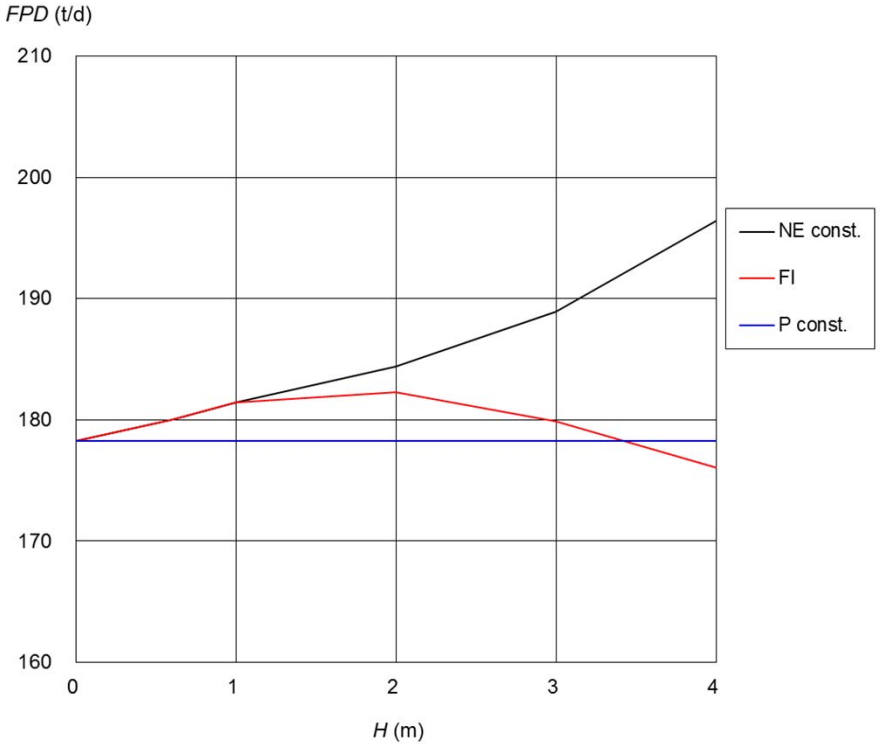
power curves in actual seas

Calculation of FOC in actual seas

decrease of ship speed

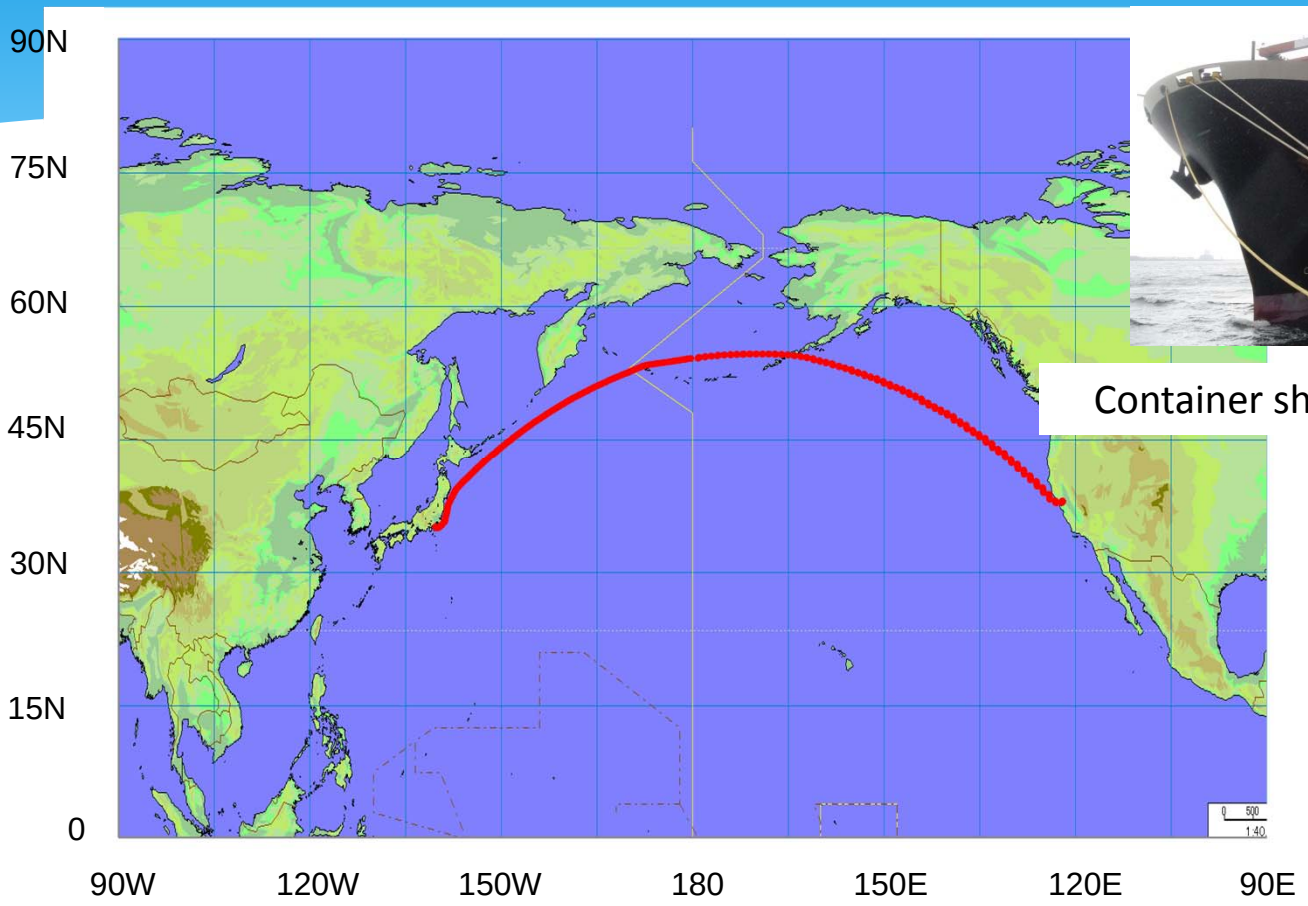


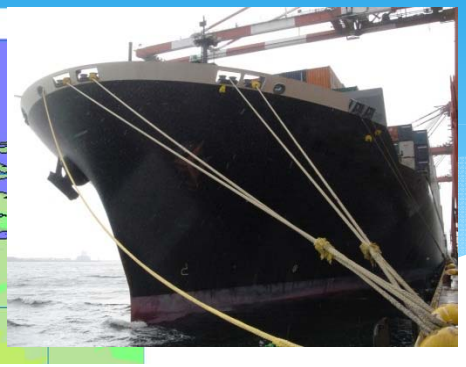
FOC per day



Limit of Fuel Index causes decrease of M/E rev.

Validation by onboard measurements





Container ship of length 300m

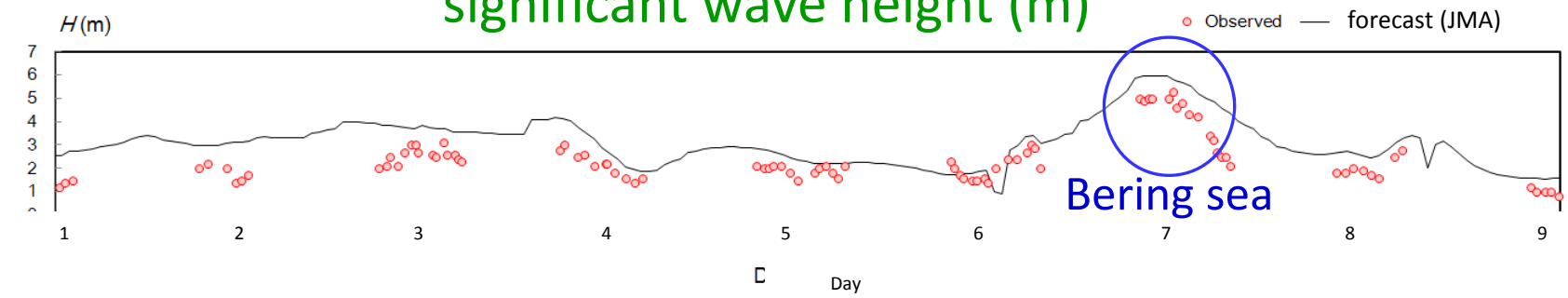
Route; Oakland (U.S.A.) to Tokyo (Japan)

Embarkation; March, 2012

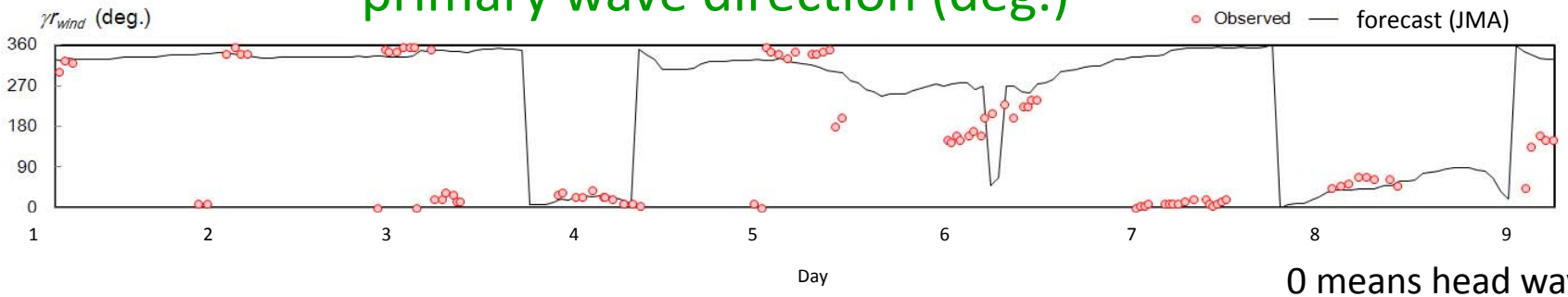
Validation by onboard measurements

Waves

significant wave height (m)

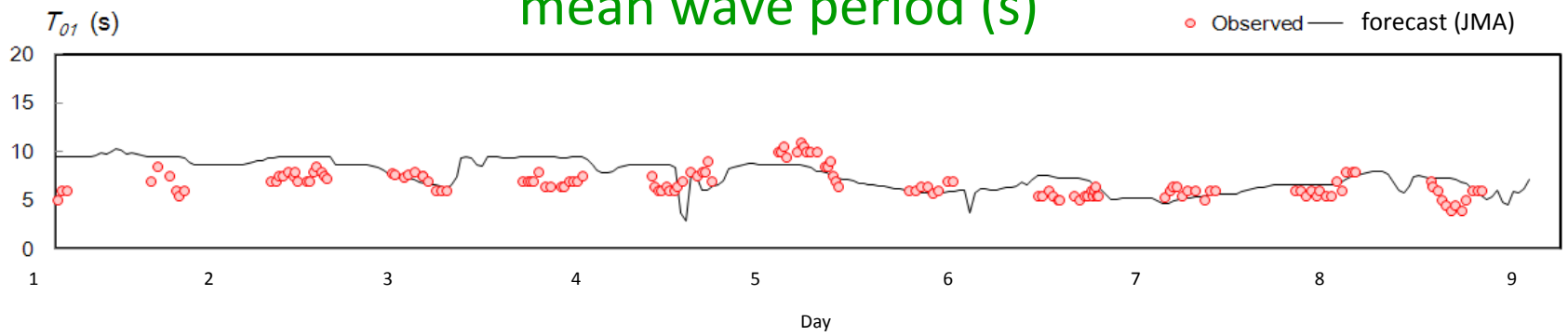


primary wave direction (deg.)



0 means head waves

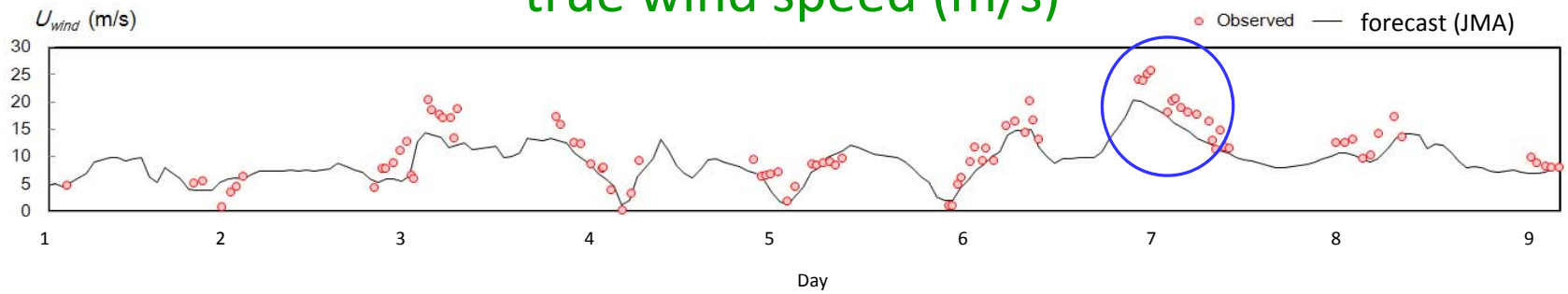
mean wave period (s)



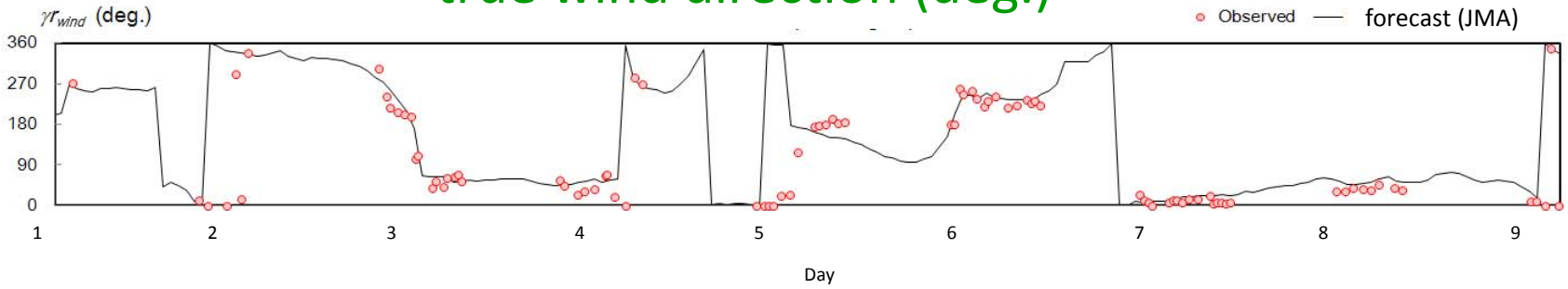
Validation by onboard measurements

Winds

true wind speed (m/s)



true wind direction (deg.)



0 means head winds

Validation by onboard measurements

Bering Sea (H=5.0m U_{wind}=25m/s)

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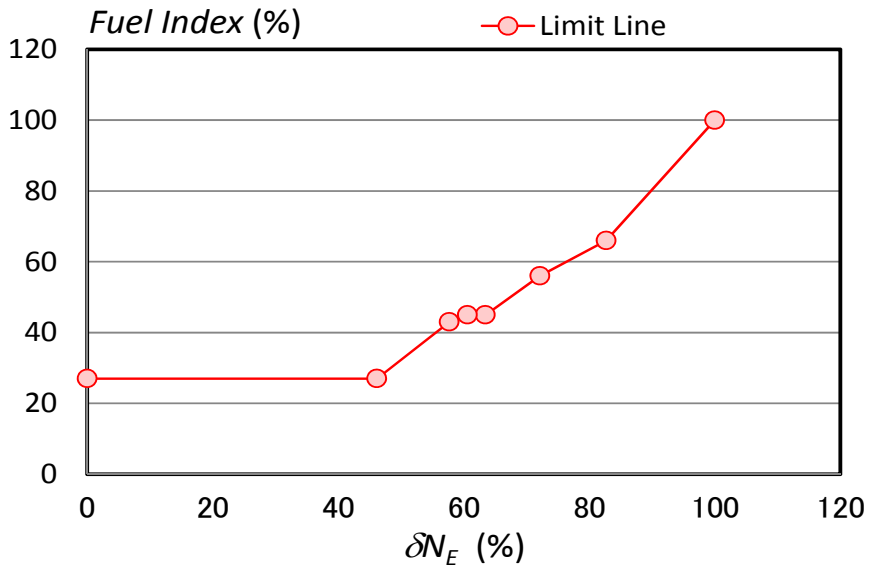
Validation by onboard measurements

Calculation: constant M/E rev. mode with Fuel Index

Weather: observed data

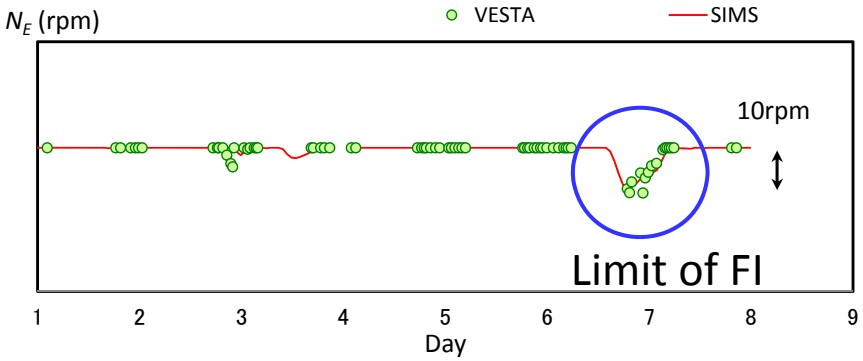
Setting of Fuel Index of the container ship



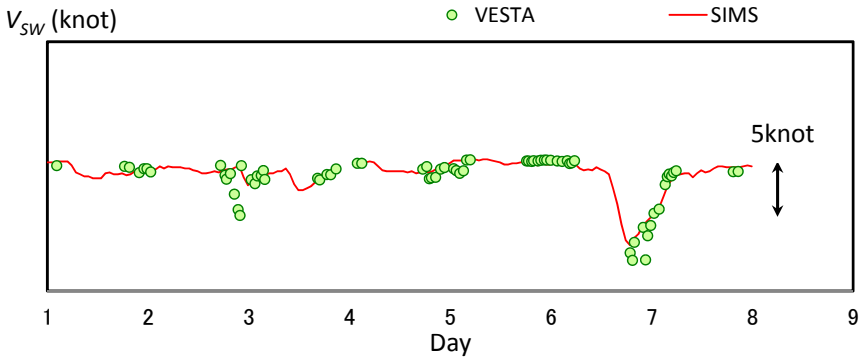
$$\delta N_E = N_E / N_{E\ at\ MCR}$$

Validation by onboard measurements

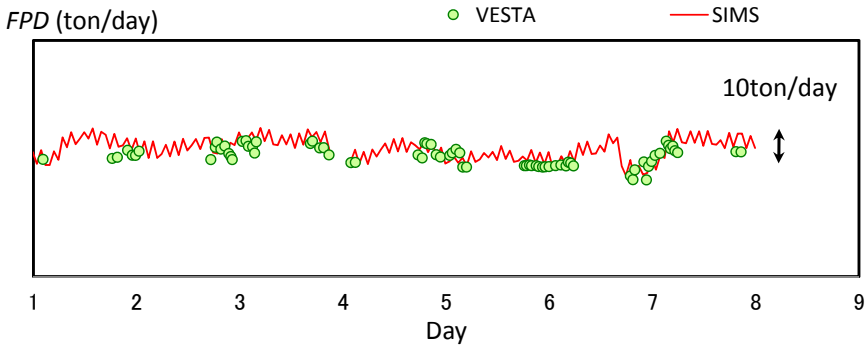
Comparison between prediction and measured



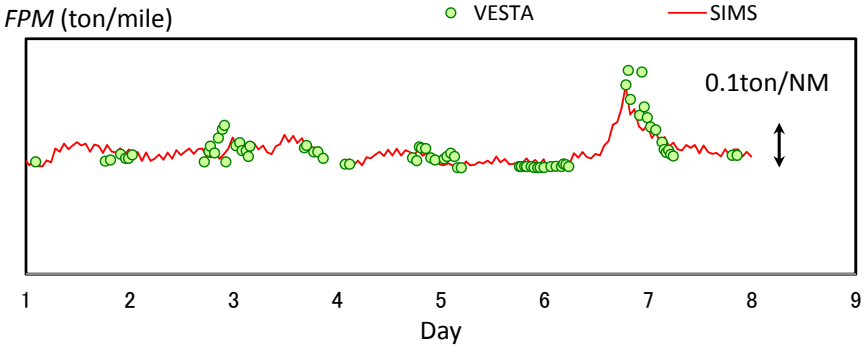
M/E rev.



ship speed



FOC per day



FOC per NM

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These are generally good agreement.

Conclusions

A prediction model of fuel consumption in actual seas is developed for the purpose of evaluation of that in actual seas.

The model considers the operating characteristics of M/E; especially Fuel Index.

Effectiveness of the model is validated through onboard measurements by a container ship under the sea conditions are relatively rough.

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Thank you for your attentions.