# DISPERSION ANALYSIS AND SIMULATIONS FOR HANDLING OF FUTURE FUELS

**DASH Team**
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*ARES Confidential*

CREATING GROWTH, ENHANCING LIVES

in collaboration with:

# Adopting alternative fuels is important in energy transition

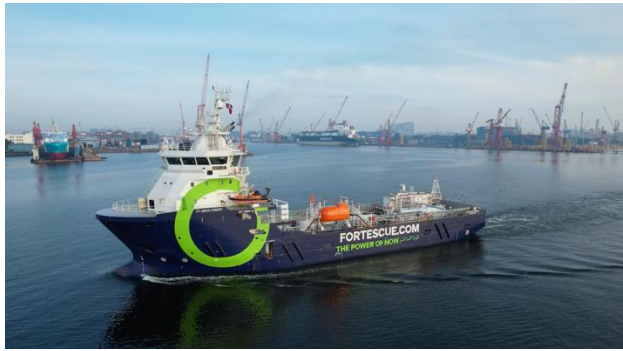
## Applications of Advanced Modelling, Simulations and AI for Risk Assessment


The world's first ship-to-container ship bunkering in Singapore, **July 2023**
First Successful Simultaneous Methanol Bunkering for Container Vessels and Cargo Operation (SIMOPS) , **May 2024**

https://www.mpa.gov.sg/media-centre/details/singapore-is-ready-for-methanol-bunkering-for-container-vessels-at-tuas-port-with-first-successful-simultaneous-methanol-bunkering-and-cargo-operation


Suiso Frontier: world's first bulk liquefied hydrogen carrier, **Aug 2023**

https://www.mpa.gov.sg/media-centre/details/singapore-hosted-the-world-s-first-bulk-liquefied-hydrogen-carrier-suiso-frontier-to-the-port-of-singapore




Green Frontier: a retrofitted vessel with 4-stroke engine running on a blended ammonia-diesel. Fuel transfer and commissioning, **Feb 2024**

https://www.mpa.gov.sg/media-centre/details/world-s-first-use-of-ammonia-as-a-marine-fuel-in-a-dual-fuelled-ammonia-powered-vessel-in-the-port-of-singapore

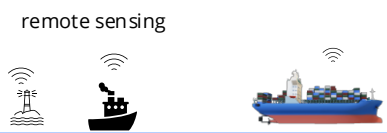
# Physics of accidental releases and dispersions

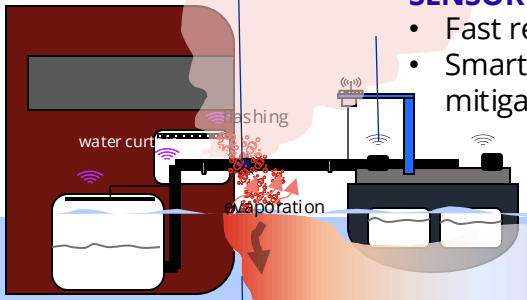
## WEATHER & OCEAN
- Weather forecast (NWP, hybrid models)
- prediction of severe events

## DISPERSION IN AIR
- Dispersion process in O(100s-1000s meters) from sources
- Atmospheric boundary layer (turbulence) effect – thermal stratification

## SOURCE RELEASE DYNAMICS
- Flashing, phase change, two-phase flows
- Pool formation and evaporation/revaporisation

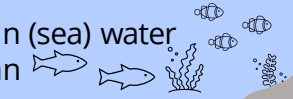
## SENSOR NETWORK
- Fast response and accurate sensors
- Smart sensor network for detection and mitigation




## WEATHER & OCEAN
- ocean hydrodynamic forecast (wind-wave, current + remote sensing)

## DISPERSION IN WATER
- Solubility and dissolution of ammonia/methanol in (sea) water
- Dispersion of ammonia/methanol in water column

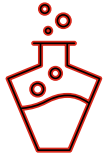


# Advancing Modelling, Simulation & AI for Safe Adoption of Future Fuels

DASH aims at (1) addressing challenges and gaps in modelling & simulations for risk assessment of future fuel bunkering and (2) translating advances in M&S techniques into operational tools.

Coupled mesocale with microscale models; coupled atmosphere-ocean-wave model

- Downscaling; coupled surface boundary conditions
- Near-field and far-field coupled model



Two phase release from accidental leakages of liquid fuels

- Phase change, flashing, rain-out from pressurized or refrigerated states
- Solubility of two-phase mixture in (sea) water
- Effects of humidity on buoyant vapour during dispersion process

**Uncertainties** and **accuracy** of multiphysics coupled models for plume dispersion

- Validation of numerical models with experiment and field trials
- Prediction with uncertain environmental conditions (surface layer wind conditions, wave and current)

Quick detection of leakages and fast prediction of plume dispersion reducing impacts on human, assets and environment.

- Fast response sensors and robust sensor network to detect leakages
- Fast models for emergency response and preparedness

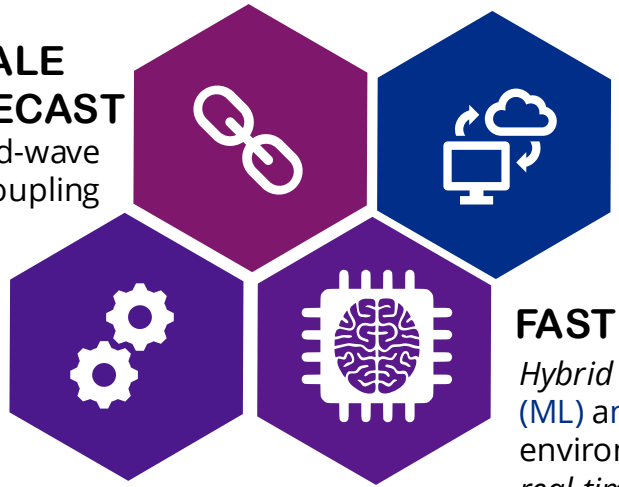
# DASH: Dispersion Analysis and Simulation for Handling of Future Fuels

Empowering *planning, preparedness, mitigation and emergency response* with model-based decision support system using digital tools developed with advances in

- *Near and far field physics: release sources, dispersion, and consequences coupled with weather & ocean forecast*
- *Accelerated prediction with hybrid physics-based and data-driven surrogate modelling*
- *Validation of models with experiment and demonstration effectiveness of mitigation measures*

**MESO/MICRO-SCALE ENVIRONMENT FORECAST**

*down-scaling* forecast; air-sea wind-wave *coupling*; near field-far field coupling



**INTEGRATED SYSTEM**

*Integration* of models for operational tools with practical use-case demonstrations

**ENHANCED & VALIDATED PHYSICS MODELS**

*two-phase physics*; vapour –water interactions; *validation* with field experiments

**FAST SURROGATE MODELLING**

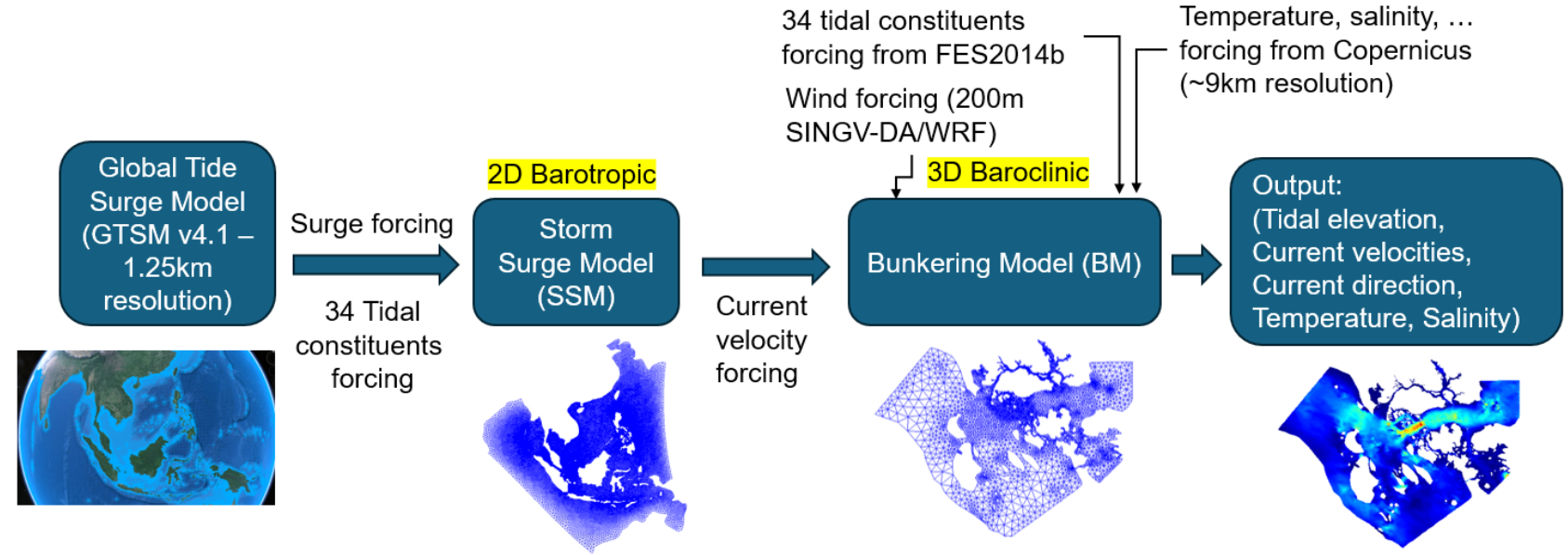
*Hybrid models*: physics-based machine learning (ML) and data-driven predictive models for environmental conditions, dispersion towards *real-time* monitoring

# Coupled mesoscale-microscale forecast of environment conditions

*Developing a suite of models that can be used to dynamically downscale the atmospheric forecasts from the global models to the local Singapore domain.*

*Ocean hydrodynamic forecast from regional to local domain coupled with atmospheric forcing for predictions of tide and current in Singapore strait and beyond*

*Data assimilation techniques to enhance performance of local models for forecasting of environment conditions*



# Enhancing model accuracy with multiphase and coupled physics for plume dispersion simulations

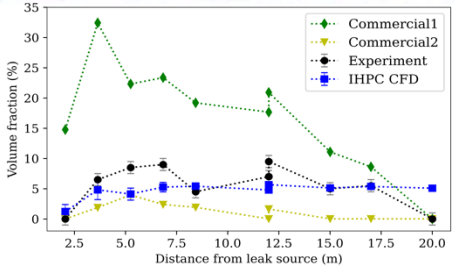
*Advanced models for two-phase release providing more accurate prediction of vapour plume dispersion*

*Coupled weather and hydrodynamic forecast with dispersion in air and dissolution in water for comprehensive consequence analysis of accidental releases.*

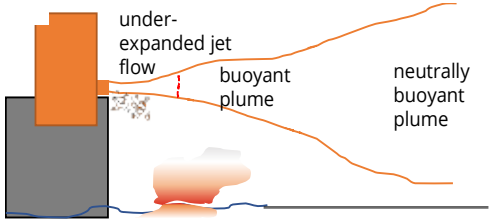
*Validation of models with lab-scale and field release experiment for accuracy and uncertainty quantification*

Argon release @Tuas Yard

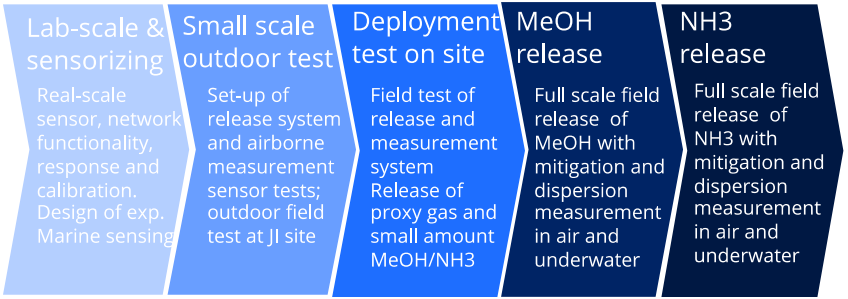
CFD simulation of Argon release




Validation and benchmark of CFD model




Two-phase release of ammonia/methanol over sea surface




Phase-gated field experiment campaign for validation of developed models

- Release over (sea) water surface
- Dispersion both in air and water column
- Effects of local climate conditions

# DASH: Comprehensive verification and validation to quantify *uncertainty* and *sensitivity* in prediction

Tapping on existing/available data and future experiment to comprehensively validate models developed in DASH programme

- Quantifying model errors, uncertainties (epistemic vs aleatory)
- Reports and documentations

## Observational Data

**Existing weather station (AWS)**
Data from 24+ stations across the island for validation/benchmark of atmospheric forecast model

**Tidal Gauges, ADPC**
Current and wave monitoring stations around Singapore for validation of hydrodynamic forecast models

**Onsite sensors (MESN, NEPTUNE,etc)**
Both surface wind + hydrodynamic monitoring for validation of near field wind map, hydrodynamic models

## Experiment Data

**ASTI experiment** (MESD/IHPC [TBC] ammonia release on land, release under water.

**Post release impact and mitigation evaluation** (LCER2 funded):
lab-scale experiment for ammonia absorption and mitigation effectiveness

**Texas A&M Experiment [TBC]** (TAMU/ABS/IHPC/MESD): lab-scale controlled experiment for ammonia

**Literature database**

## Field Release Exp

**WP5: controlled release of ammonia and methanol:**
Field release of ammonia/methanol in tropical climate for validation of developed models
Local experiment with tropic conditions

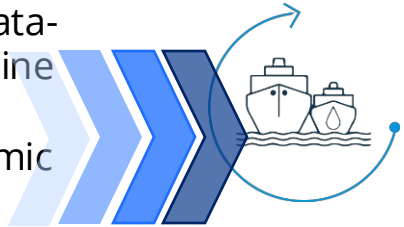
**Chemspill exercises**: releases of proxy liquids and collecting data for validation of models + testing of monitoring and mitigation technologies (drones, water spray)

# DASH: Translating advances in modelling and simulations into operational outcomes for future fuel handling

**Validation** of the developed models with experiment; **benchmark** with existing tools commonly used in the industries.

**Acceleration** prediction with data-driven and physics-based machine learning surrogate models for localized weather & hydrodynamic forecast, plume dispersion

**Coupling and integration** of **models** for risk assessment and development of effective mitigation measures



Integrated tools for capacity & operational planning, incident management & emergency response

Future *bunkering trials*, *chemspill exercises* as live test best for demonstration of capabilities

Industrial use-cases: Newly designed and built alternative fuel powered vessels, Proof-of-concept tools for commercialization

## Translatable Outcomes

*some stock images from www

# Outlook

Atmospheric and ocean forecast coupled with environmental impact assessment

- **Assessment and identification potential bunkering sites**

Understanding and modelling complex physics associated with pressurized or refrigerated alternative fuels upon release into environment

- **Phase change and two phase release: flashing, rain-out**
- **Solubility of two-phase mixture in (sea) water**

Fast detection and subsequent response to accidental leakages reduces impacts on human, assets and environment.

- **Fast models for emergency response and preparedness**

***Our Research Partners and Collaborators***

# THANK YOU

for your attention

POWERING DISCOVERIES