HYDRODYNAMIC MODEL DOWNSCALING FOR SPILL TRAJECTORY FORECASTS IN SINGAPORE

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MAKING COMPLEX EASY

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The incident: *Marine Honour* spill

- Occurred 14 June 2024 ~14:30 (UTC +08:00)
- Collision between a drifting dredger, *Vox Maxima*, and a stationary bunker vessel, *Marine Honour*
- Impacted vessel was alongside a container ship berthed at the Pasir Panjang Terminal
- Bulbous bow of dredger punctured the cargo tank leaving a large hole – oil release began instantly
- High sulphur fuel oil (HSFO) – heavy, viscous, and persistent in the marine environment
- Release rate unknown so assumption of 3 hours for tank to empty – below the waterline, oil was gradually displaced by water sloshing in

Source: Maritime and Port Authority (MPA) of Singapore

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The response

- Singapore's Maritime and Port Authority (MPA) set up a joint emergency operation centre to coordinate inter-agency activities
- Mobilisation of 18 response craft equipped with oil booms, skimmers and dispersants
- Patrol craft sprayed dispersants onto visible slicks
- Drone and satellite imagery was used to spot oil
- Tank rupture eventually contained, but ~400 tonnes was estimated to already have been lost
- RPS was engaged by ITOPF for oil spill trajectory forecast modelling to aid an assessment of marine pollution impacts – needed rapid model delivery

Source: Maritime and Port Authority (MPA) of Singapore

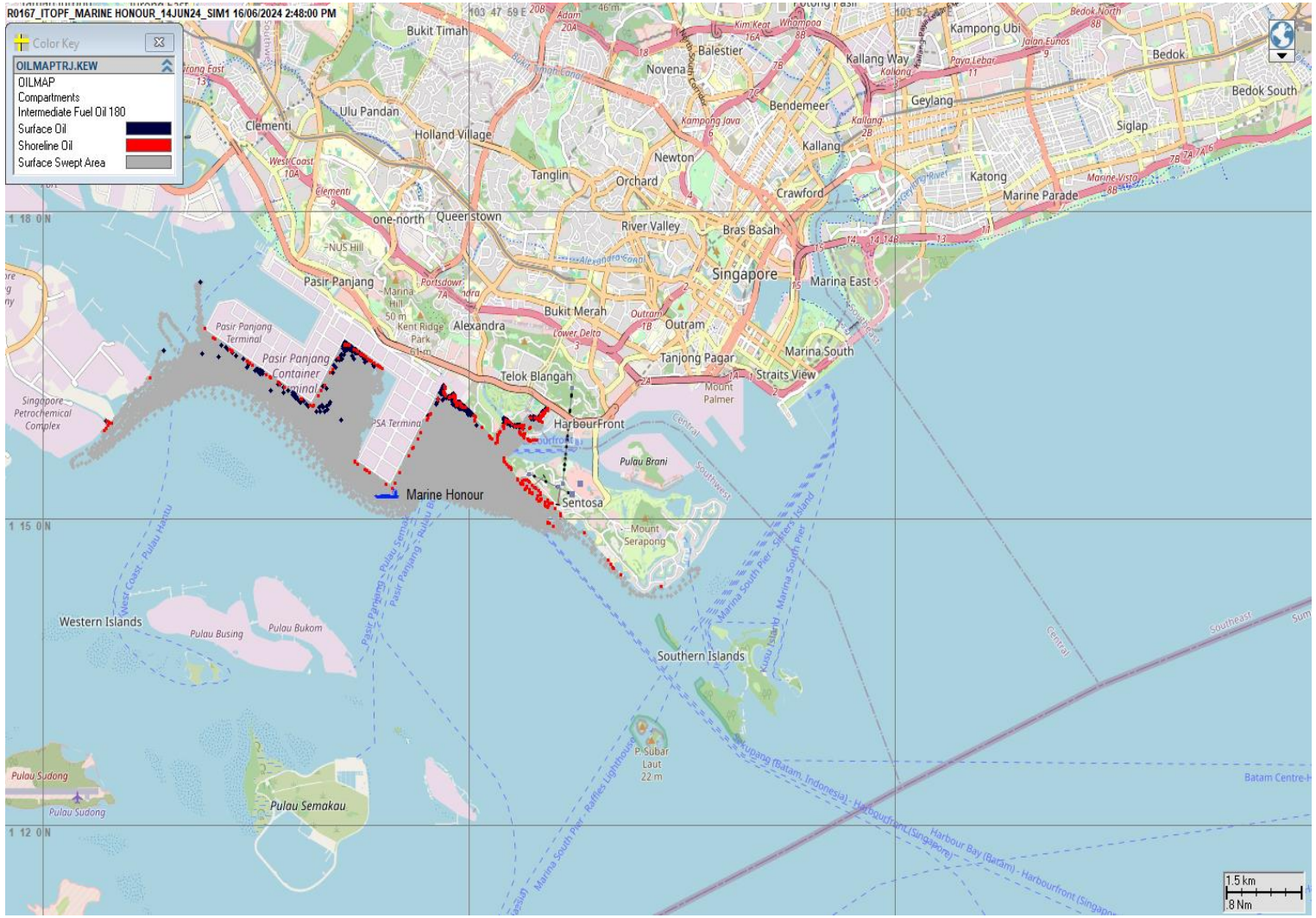
Regional circulation

- Strait of Singapore has complex hydrodynamics
- The strait links the South China Sea in the east to the Malacca Strait in the west
- Tides transition from semi-diurnal in the east to diurnal in the west – a mixed regime in SoS
- Hydrodynamic pressure gradient often present across the strait – residual flow direction dictated by prevailing seasonal monsoon winds
- Tidal timings and flows are also affected by prevailing monsoon conditions
- Singapore coastline continually being modified and expanded, affecting local circulation patterns

1984 vs 2024

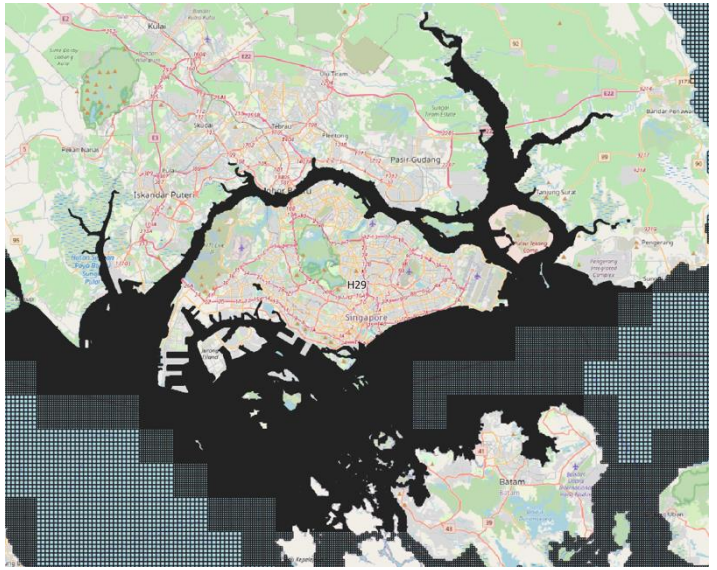
Initial model – forcing by tides and winds

- Start simple…
- Hydrocarbon spill model (OILMAP) trajectory and fate predictions initially driven by tidal circulation data (HYDROMAP) and wind forecast data (ACCESS G3)
- Winds are a key factor in the transport oil floating on the water surface
- Simulated a 48-hour forecast from the time of spill commencement
- Forecast trajectories were tidally dominated and initially moved eastwards then west, not leaving the immediate area
- First observations indicated floating oil was found further east than initially forecast
- Investigation of the wind data found ACCESS G3 predictions matched well with local observations at the Marina Barrage
- Forcing with alternative wind products had minimal influence on oil trajectories

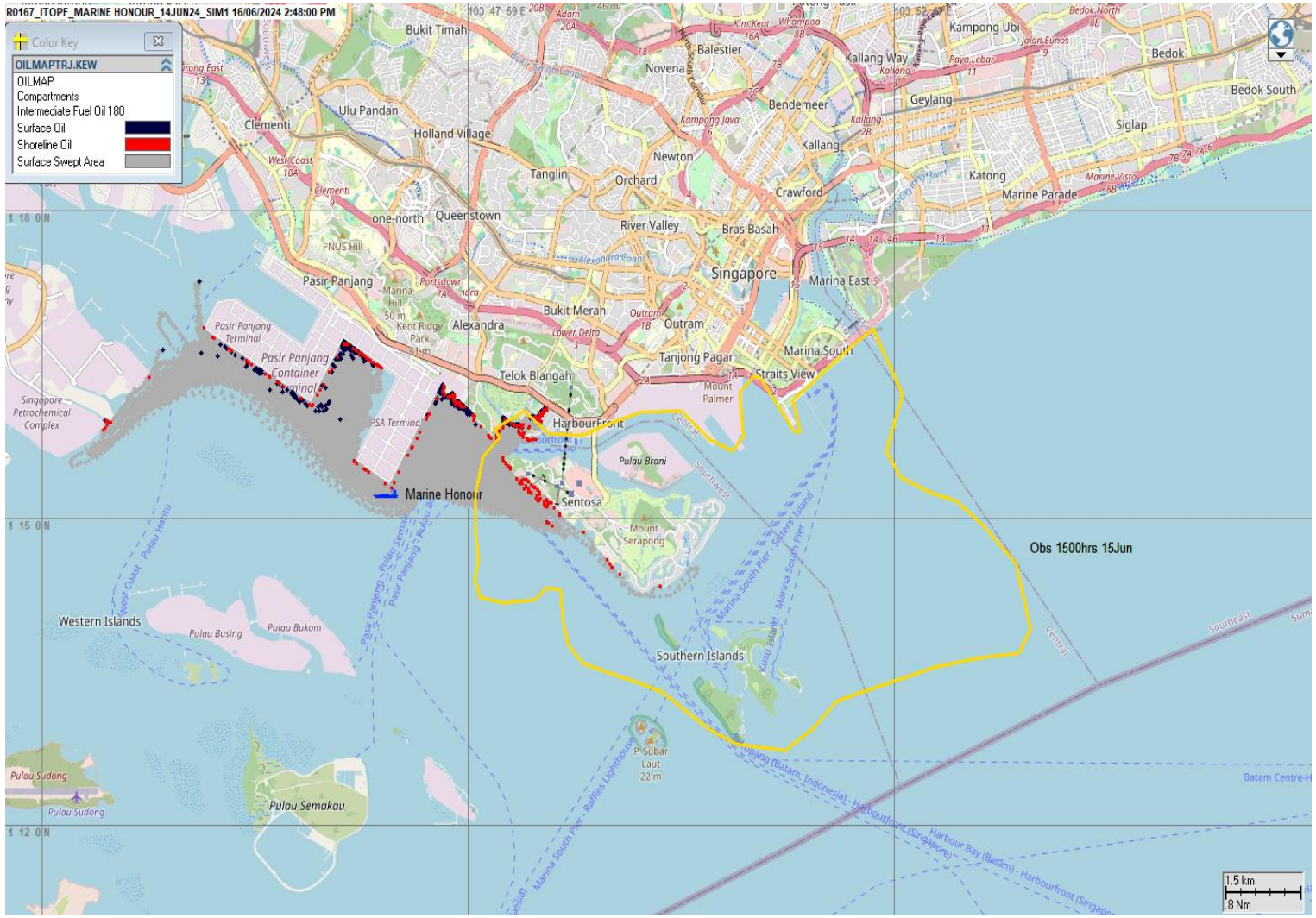


First 48-hr swept area and shoreline oiling forecast

Tidal circulation model framework in south Singapore

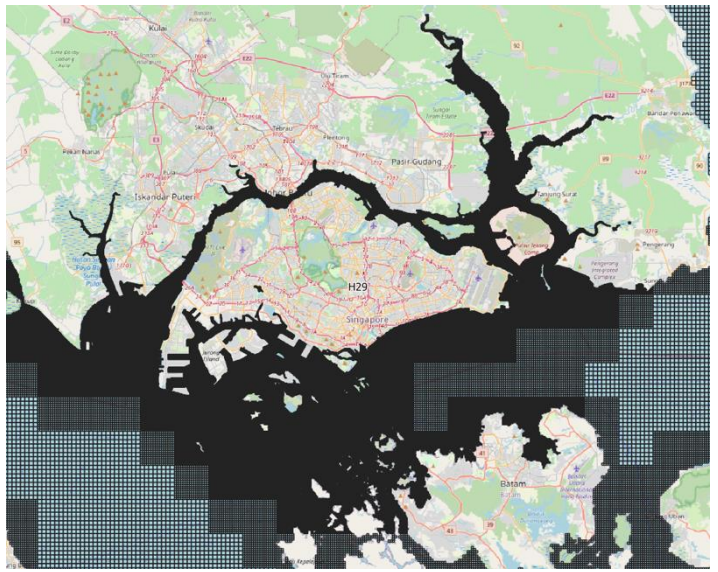


Tidal circulation model framework in Singapore Strait



First 48-hr swept area and shoreline oiling forecast – but patchy oil slicks observed within large zone to east by 15 Jun ~15:00

Tidal circulation model framework in south Singapore



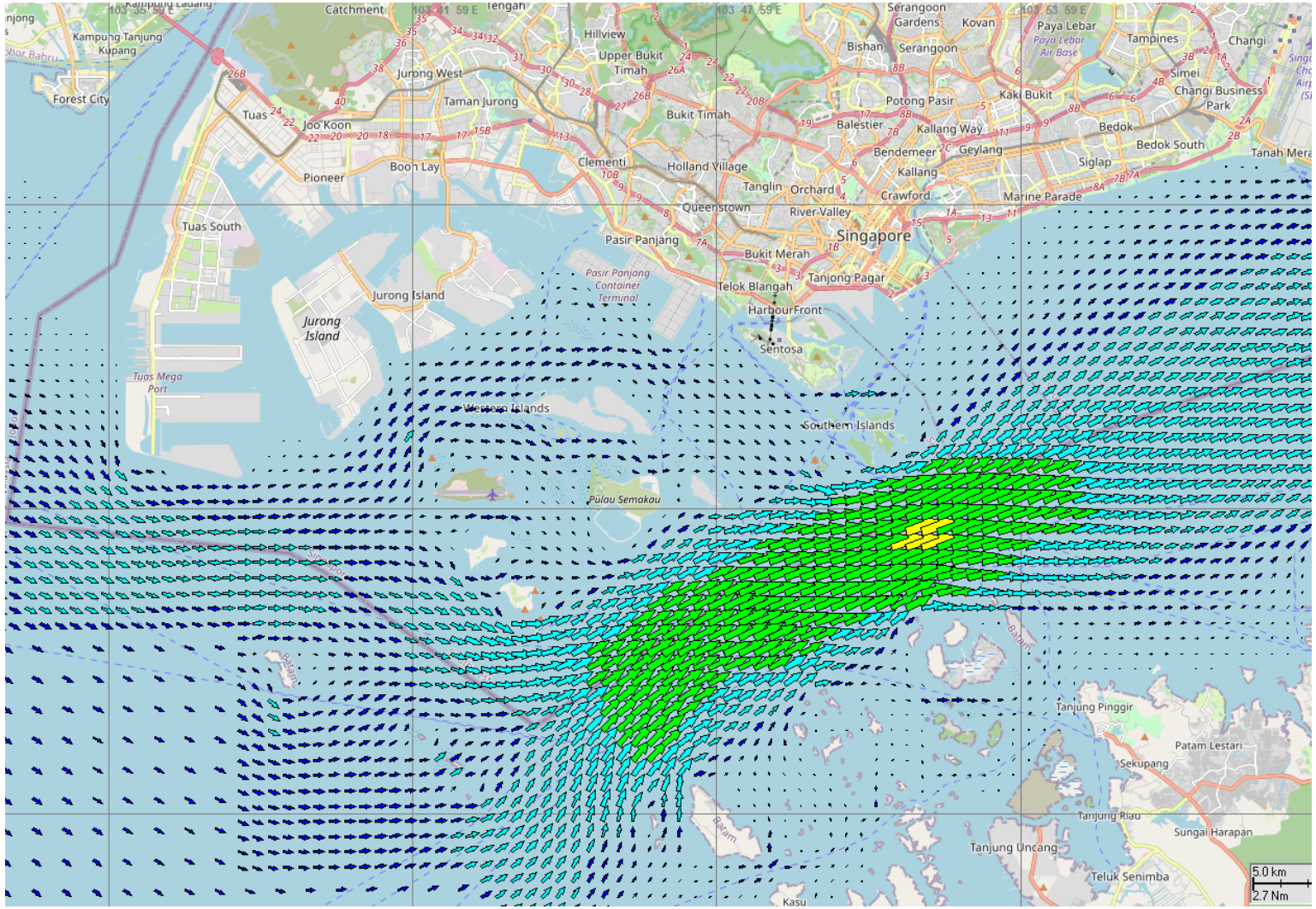
Tidal circulation model framework in Singapore Strait

Updated model – adding residual circulation

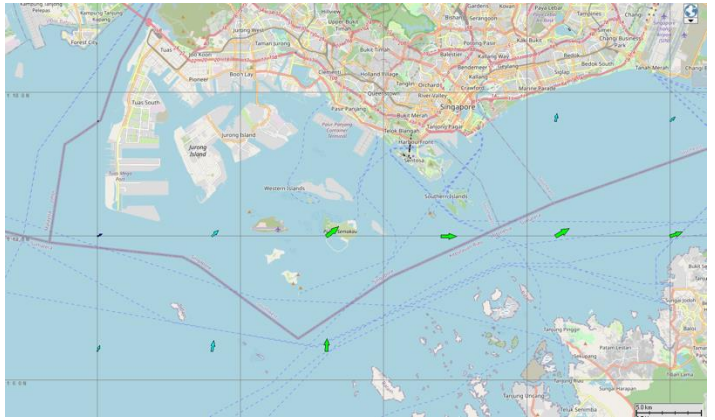
- We might have expected a generalised easterly flow, with the spill occurring in the SW monsoon season
- Operational forecasts of ocean circulation are available from global models (e.g. HYCOM NCEP)
- Global models aim for reproduction of large-scale dynamics in open oceans, but can struggle in narrow straits or around complex coastlines
- At a synoptic scale global models may conserve mass and heat flux between connected water bodies, but grid scales are insufficient to represent precise pathways of circulation
- Nonetheless, they can provide good boundary forcing to more regionally focused models

Updated model – hybrid approach

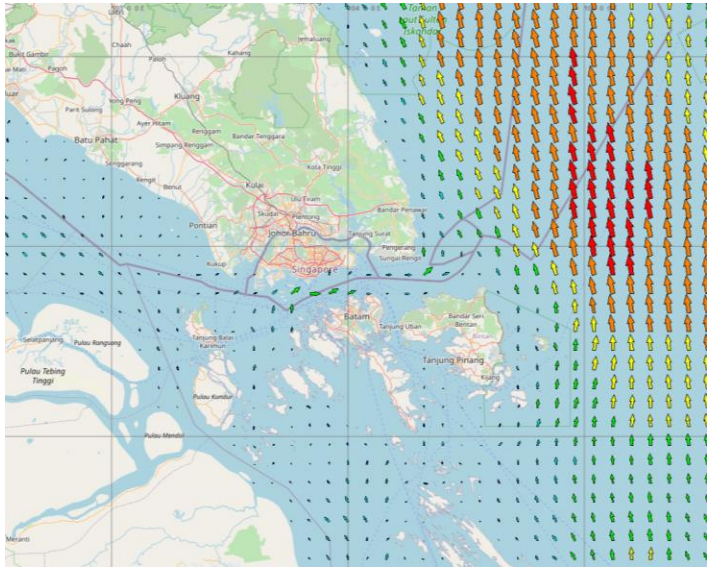
- We needed a hybrid circulation model, one that drives water mass through the strait but accounts for the influence of coastal features at appropriate spatial resolutions
- HYDROMAP has a capability for high-resolution coastal current and water level predictions using a Stepwise-Continuous-Variable-Rectangular grid nesting scheme
- Integrated HYCOM forecast data as boundary conditions – zonal/meridional velocity vectors introduced momentum to HYDROMAP model
- Gridding, download/embedding of boundary data, and simulations are all done rapidly (<30 minutes)
- Momentum is propagated and conserved in the model
- Surface layer flow predictions are the focus because oil will be floating or shallow-entrained



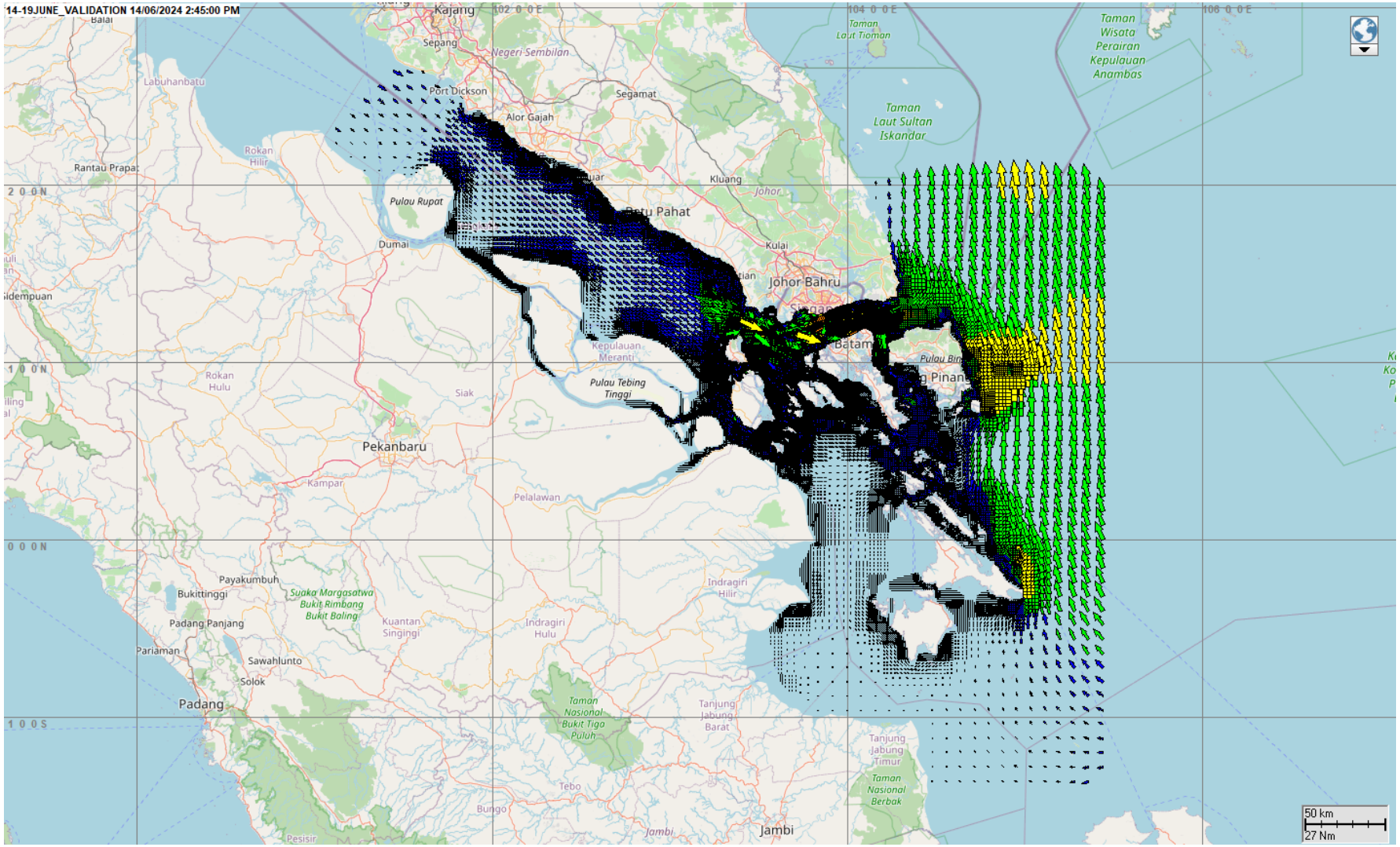
HYCOM vectors in Strait of Singapore after downscaling onto HYDROMAP grid



HYCOM vectors in Strait of Singapore at native resolution



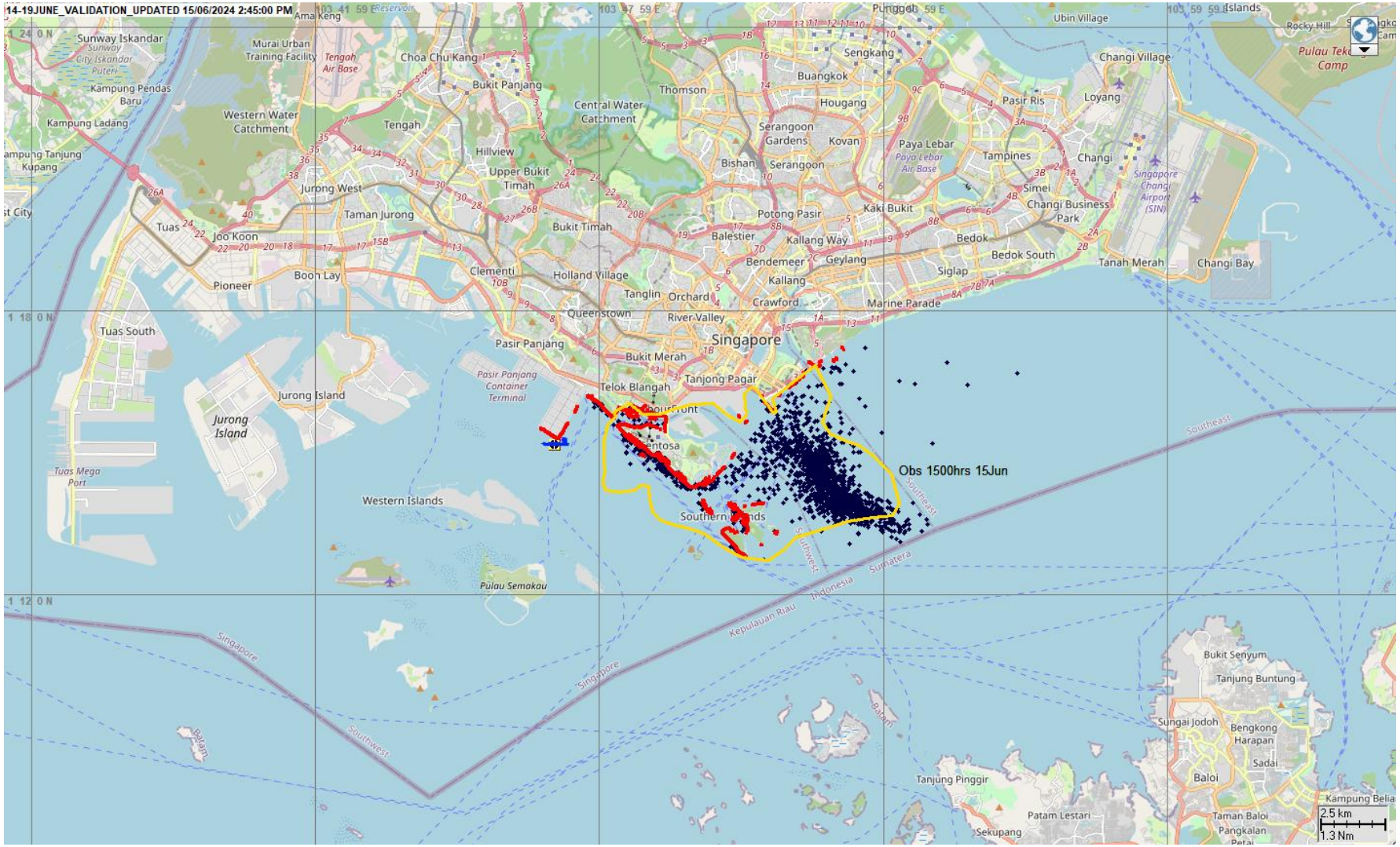
HYCOM vectors in region at native resolution



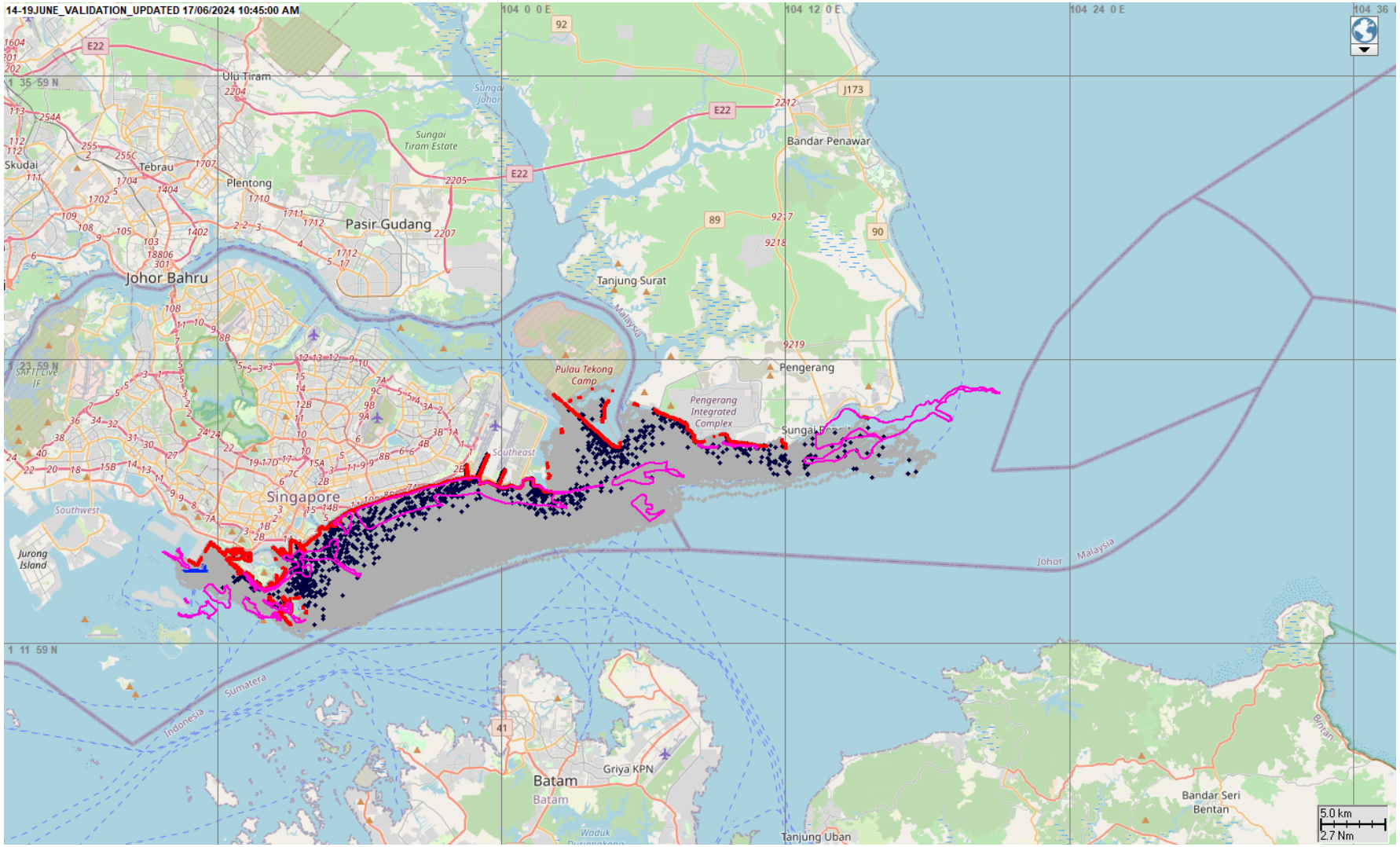
HYCOM vectors in region after downscaling onto HYDROMAP grid

Updated model – trajectory adjustments from initial forecast

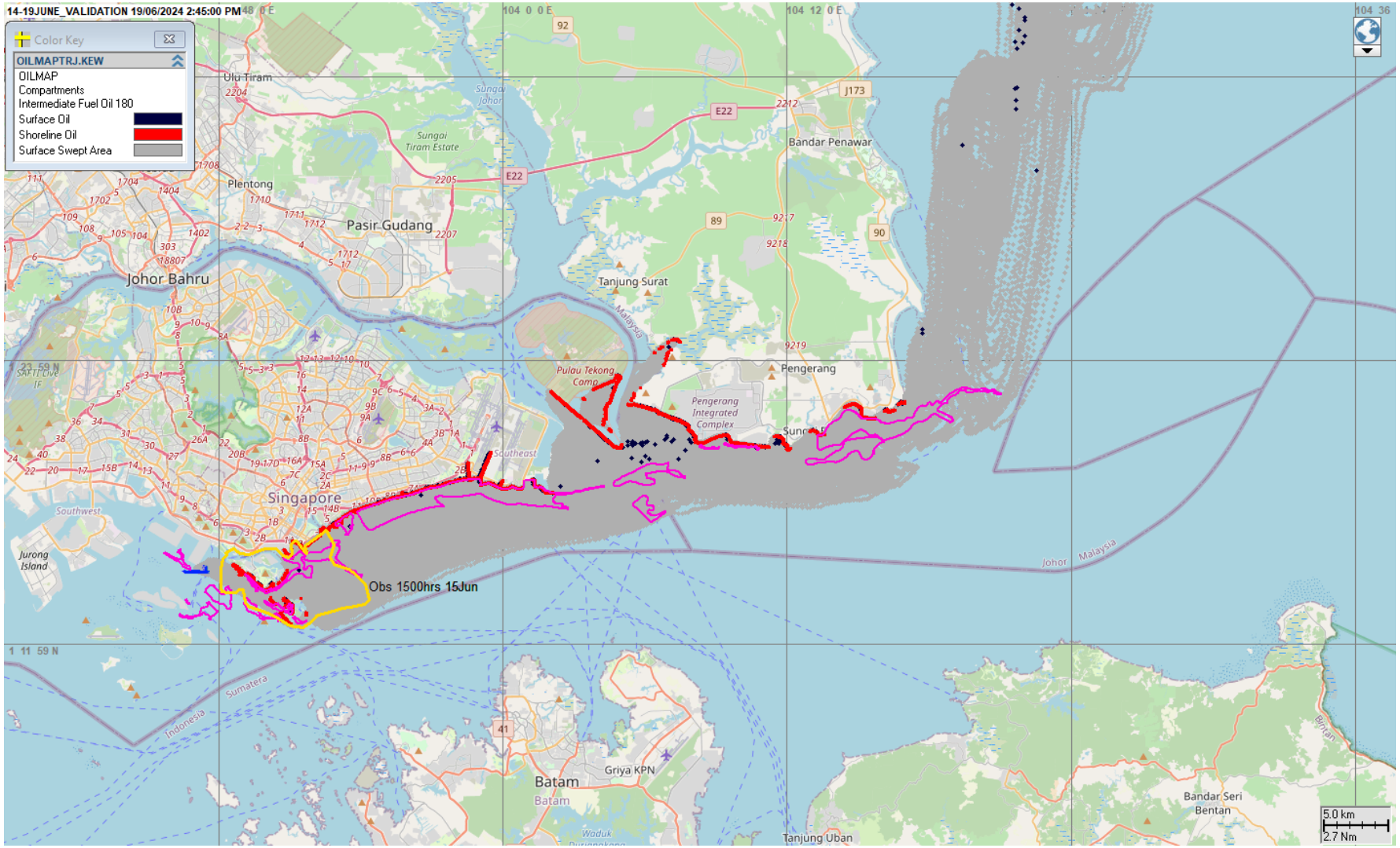
- Hydrocarbon trajectory model forecast run again for 48 hours from the time of spill commencement
- Forecast trajectories were still tidally influenced but saw more consistent drift towards east and north
- Early forecasts were now better ground-truthed against initial slick observations
- We moved forward with greater confidence in forecasts for the remainder of the incident
- Forecasts of slick positions over the next 120 hours continued to correlate well with observations, including drone and satellite imagery



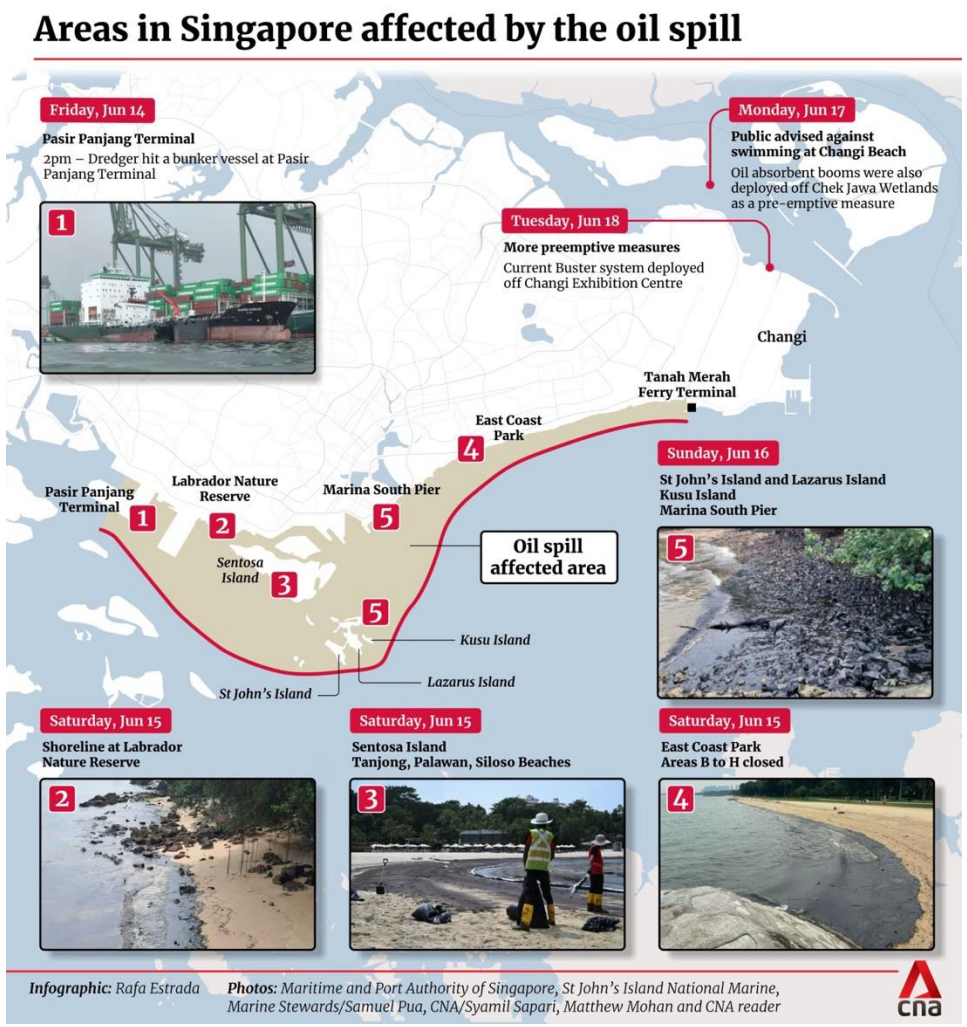
Updated forecast of floating oil and shoreline oiling by 14:45 on 15 Jun - now matching well with zone of observations



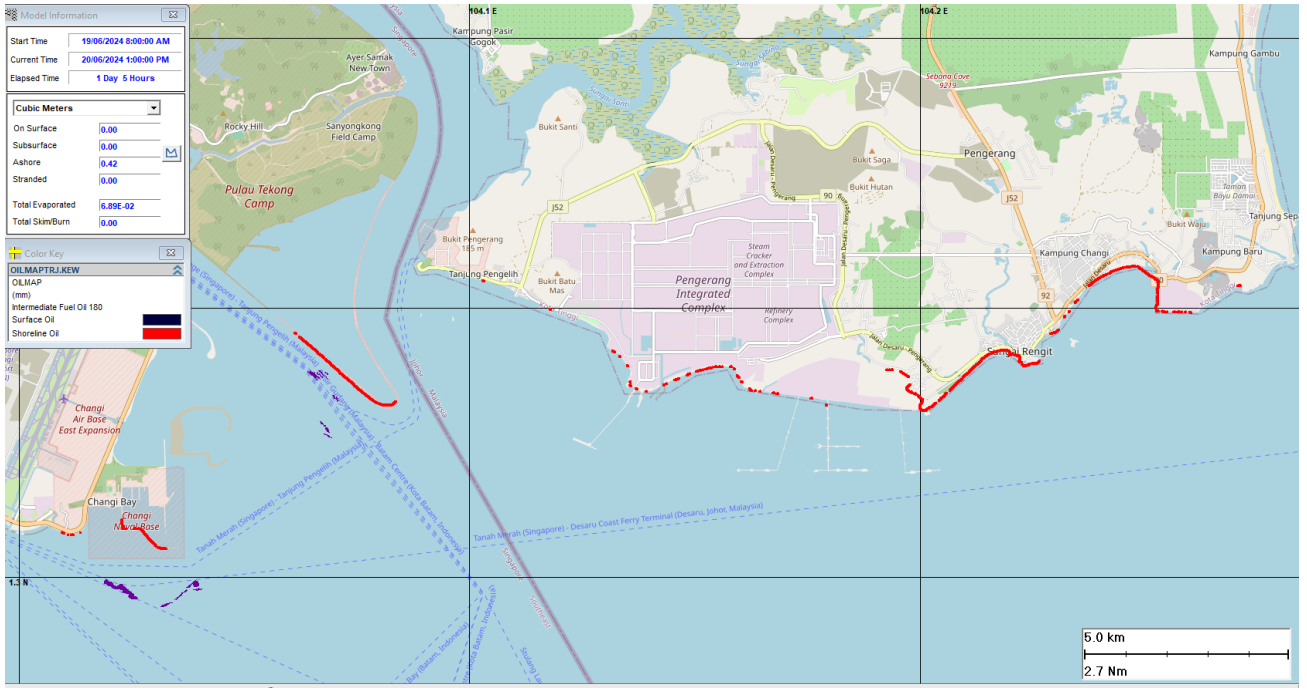
New forecast of swept area and shoreline oiling by 10:45 on 17 Jun – correlated well with satellite estimations of slicks



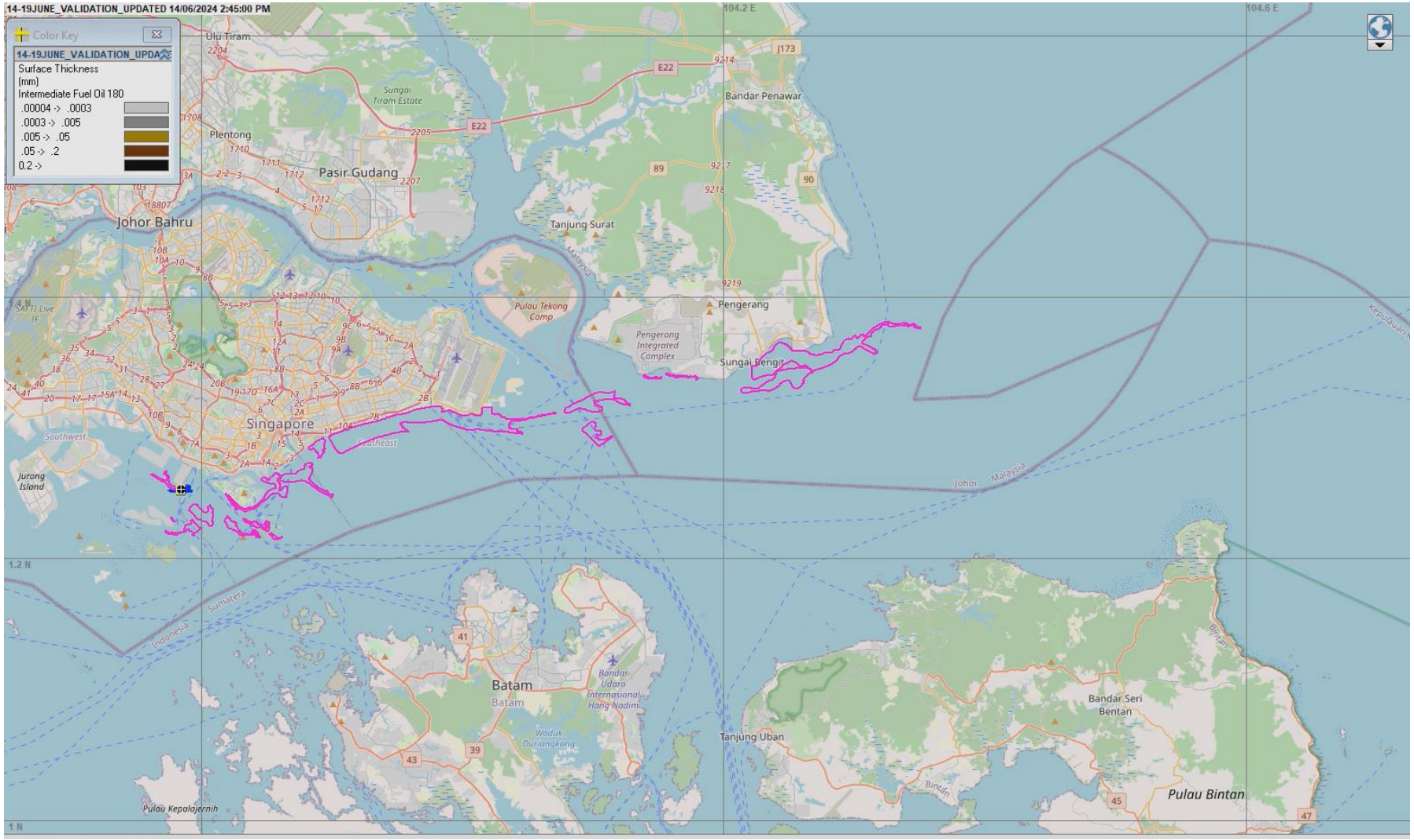
New forecast of swept area and shoreline oiling by 14:45 on 19 Jun – residual oil tracked into South China Sea



Media report of affected areas as of 18 Jun (source: CNA)



Further forecast of shoreline oiling by 13:00 on 20 Jun



Full simulation of floating oil thickness and shoreline oiling over 120 hours (14 Jun to 19 Jun)

Summary

- Spill response and mitigation requires rapid oil trajectory forecasts – turnaround times are measured in hours
- Forecasts need accurate hydrodynamic data at scales of interest to affected areas
- In situ observations allow ground-truthing of model trajectories and correction of the first forecast – not all incidents play out nicely
- Flexible and quick frameworks for refining coastal grid scales and incorporating boundary forcing from ocean models is a key factor
- Ongoing updates to forecasts can help to direct efficient and effective deployment of response resources

Thank you!

Acknowledgement…