Performance Predictions of Wind-Powered Ships in Waves: a Step Towards a Multipurpose Seakeeping Software

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INTEGRATION OF TOOLS

CAESES

made by FRIENDHSHIP SYSTEMS

- Shape variations
- Optimization methods
- Resource management

+

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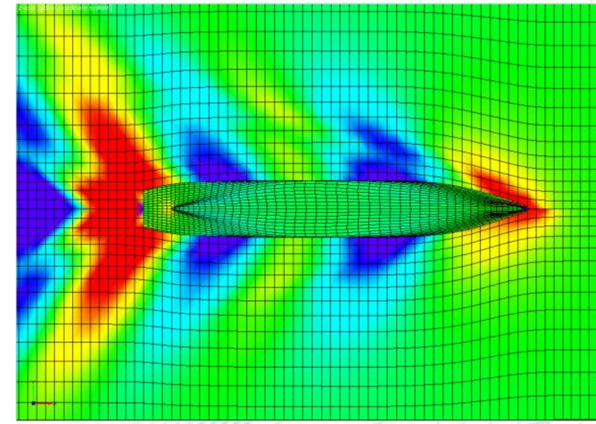
- Grid Generation
- Flow simulations
- Result processing

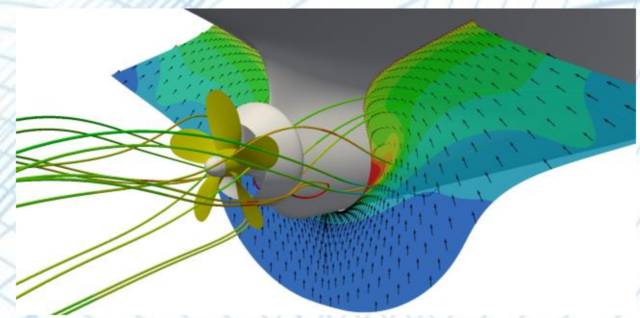
THE SHIPFLOW SYSTEM

Flow solvers

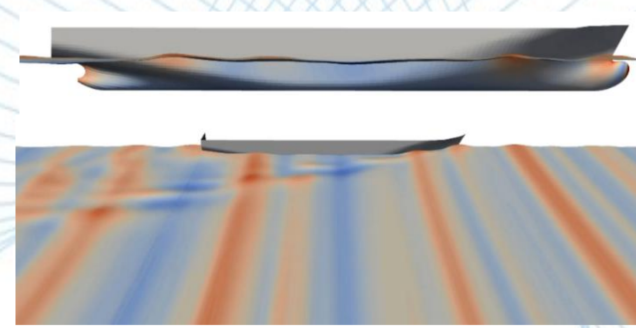
- BASIC
  - XPAN potential flow solver.
    wave pattern, wave resistance, pressure, sinkage&trim
  - XBOUND thin boundary layer method
    surface streamlines, friction drag, b.l. thickness
  - **Best suited for wave resistance optimizations**



- RANS
  - XCHAP RANS equations solver
    flow field, viscous resistance, self-propulsion, free-surface
  - **Applied successfully to delivered power optimizations**



- MOTIONS
  - time dependent potential flow solver
  - **motions and added resistance in waves**



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SHIPFLOW MOTIONS

- **Original purpose**
  - Calculate the added resistance of a hull in regular or irregular waves
  - Calculate ship motions and ship accelerations
- **Extended capabilities**
  - Free sailing – self propelled models
  - Manouevering
  - Wind Assisted Propulsion
  - Multiple bodies
  - Mooring, springs, fenders etc.

WHAT IS SHIPFLOW MOTIONS?

- **Potential Flow:**

  Flow is incompressible, irrotational and inviscid

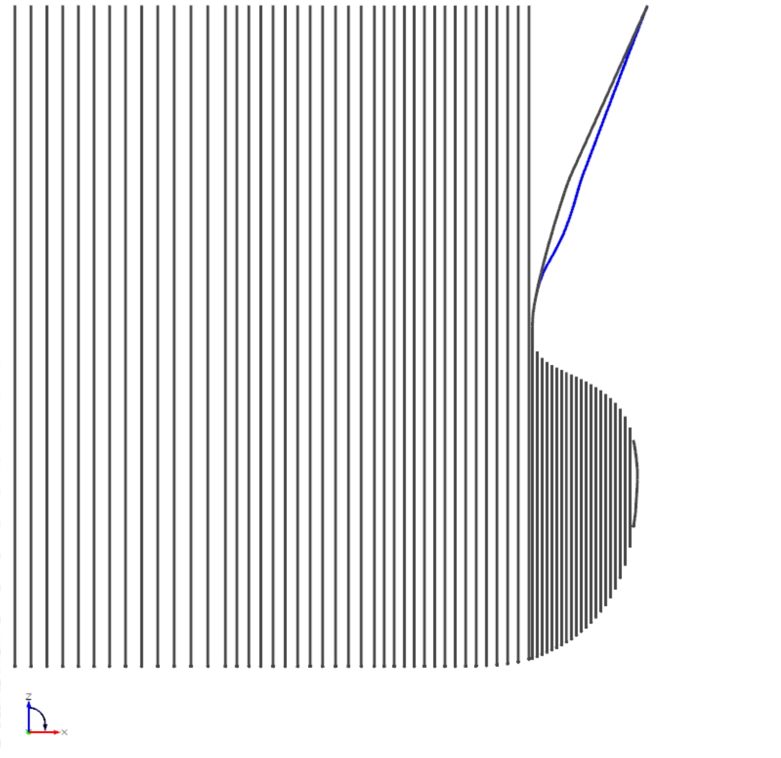
- **Fully Nonlinear:**

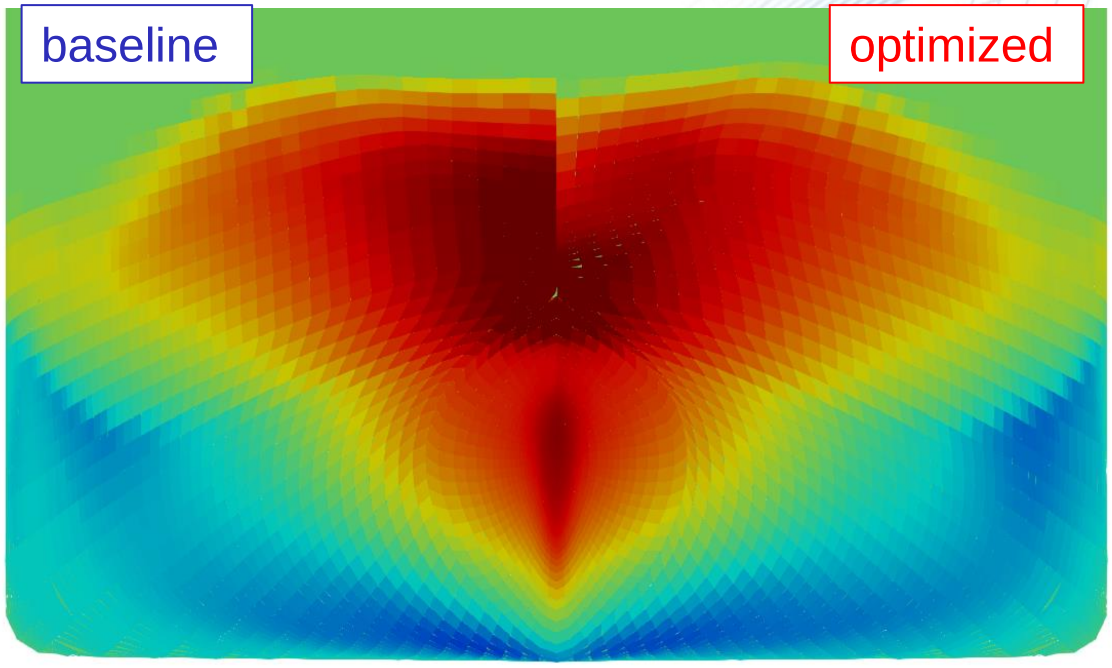
  Boundary conditions are considered with higher order terms. Forces obtained with pressure integration

- **Unsteady:**

  Time domain. Unsteady Bernoulli to evaluate pressure

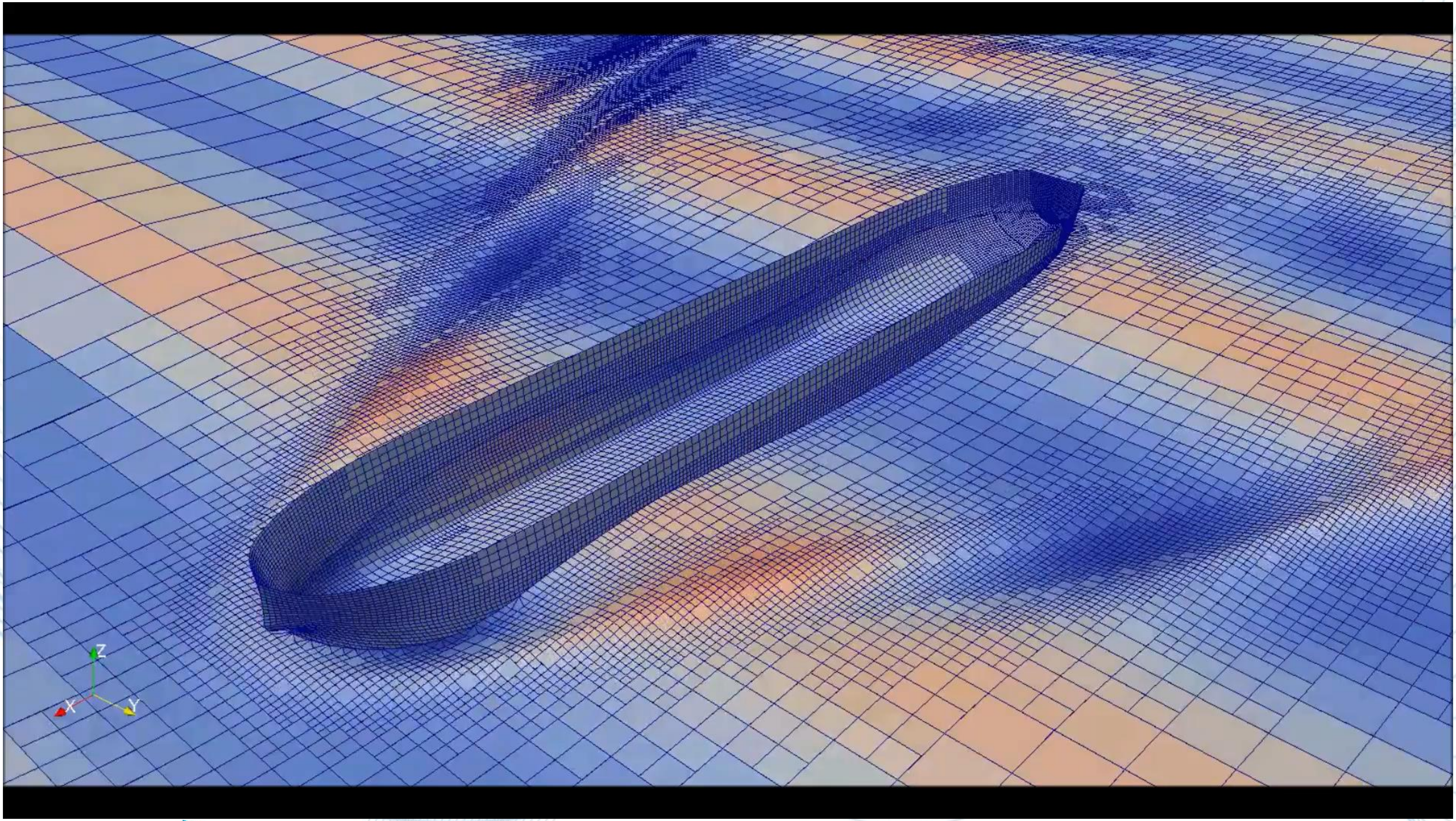
CAESE AND SHIPFLOW MOTIONS





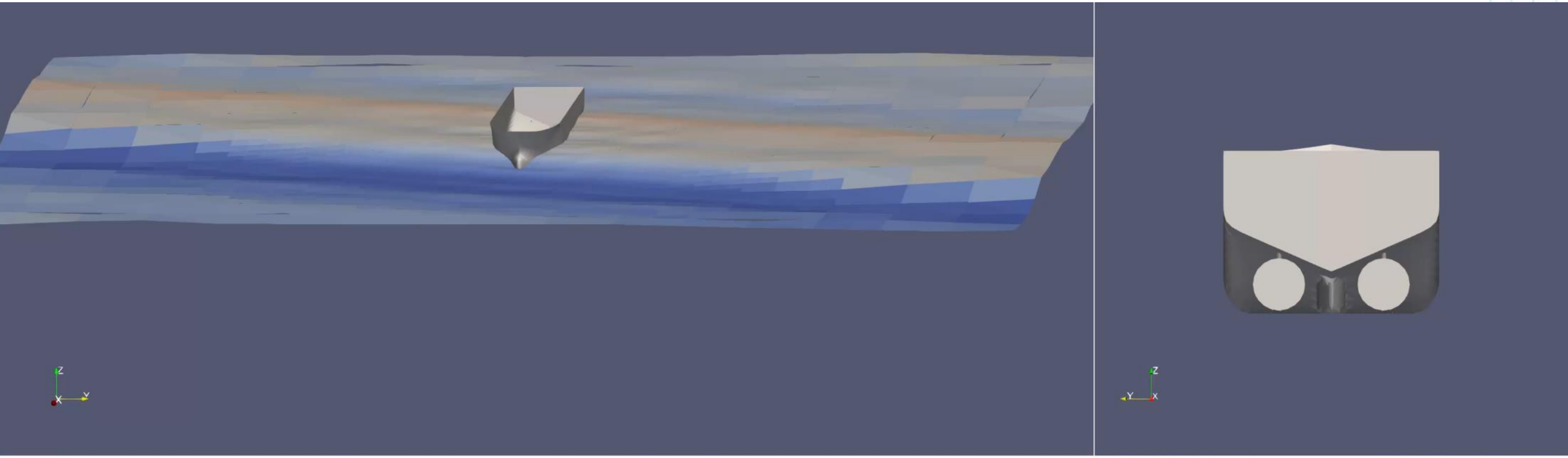
SHIPFLOW MOTIONS

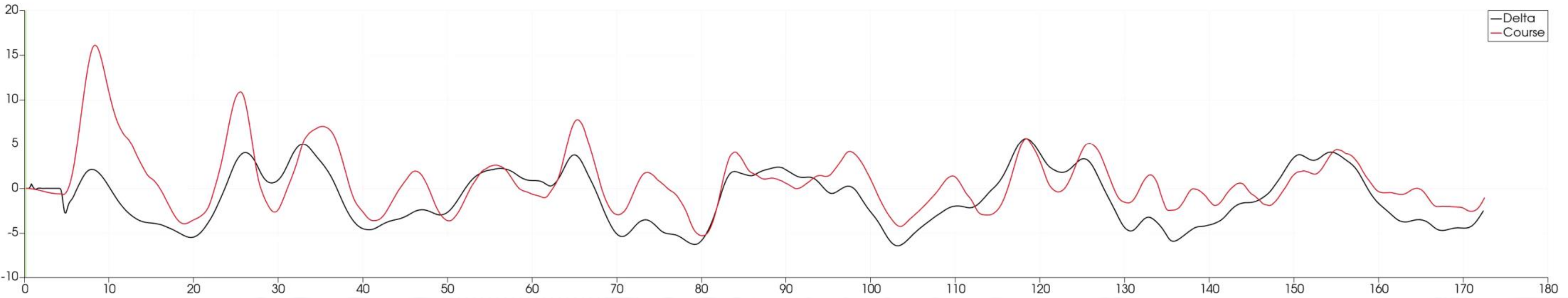
How do we go from here:



MANOEUVRING SIMULATIONS – COURSE KEEPING

To here:





HOW TO DEAL WITH MANOEUVRING?

- **Potential Flow** → **Manoeuvring derivatives**

  Sway, roll and yaw are heavily affected

- **Towed model** → **Sub-bodies for rudder and propeller**

  Need for self propulsion and steering

- **Hull without appendages** → **Sub-bodies for fins and bilge keels**

  Need to include bilge keels, fins, ...

- **Wind** → **Wind model and sub-bodies for Flettner rotors**

  Need to model interaction with wind

MANOEUVRING DERIVATIVES

- Virtual Captive Tests with XCHAP using Ensemble investigation with CAESES:
  - Pure drift
  - Turning Circle
  - Turning Circle with fixed drift angle
  - Rudder tests
- Fitting with a Least Square Method to obtain forces in Prime or Bis system:
  - $X = f(X_{vv}, X_{vr}, X_{rr})$
  - $Y = f(Y_v, Y_r, Y_{vvv}, Y_{rrr}, Y_{vvr}, Y_{vrr})$
  - $N = f(N_v, N_r, N_{vvv}, N_{rrr}, N_{vvr}, N_{vrr})$
- Manoeuvring coefficients added in MOTIONS to model viscous effects

VIRTUAL CAPTIVE TESTS

CASE	Drift [deg]	Turning Radius [Lpp]	Rudder Angle [deg]
Rudder	0	-	[-35, -15, 0, 5, 10, 15, 20, 30, 35]
Turning Circle	0	[4, 5, 8, 10]	0
Drift	[-20,-15, …, 15, 20]	-	0
TC + Drift	[-10, 2, 4, 6, 8, 10, 15]	[4, 5, 8, 10]	0

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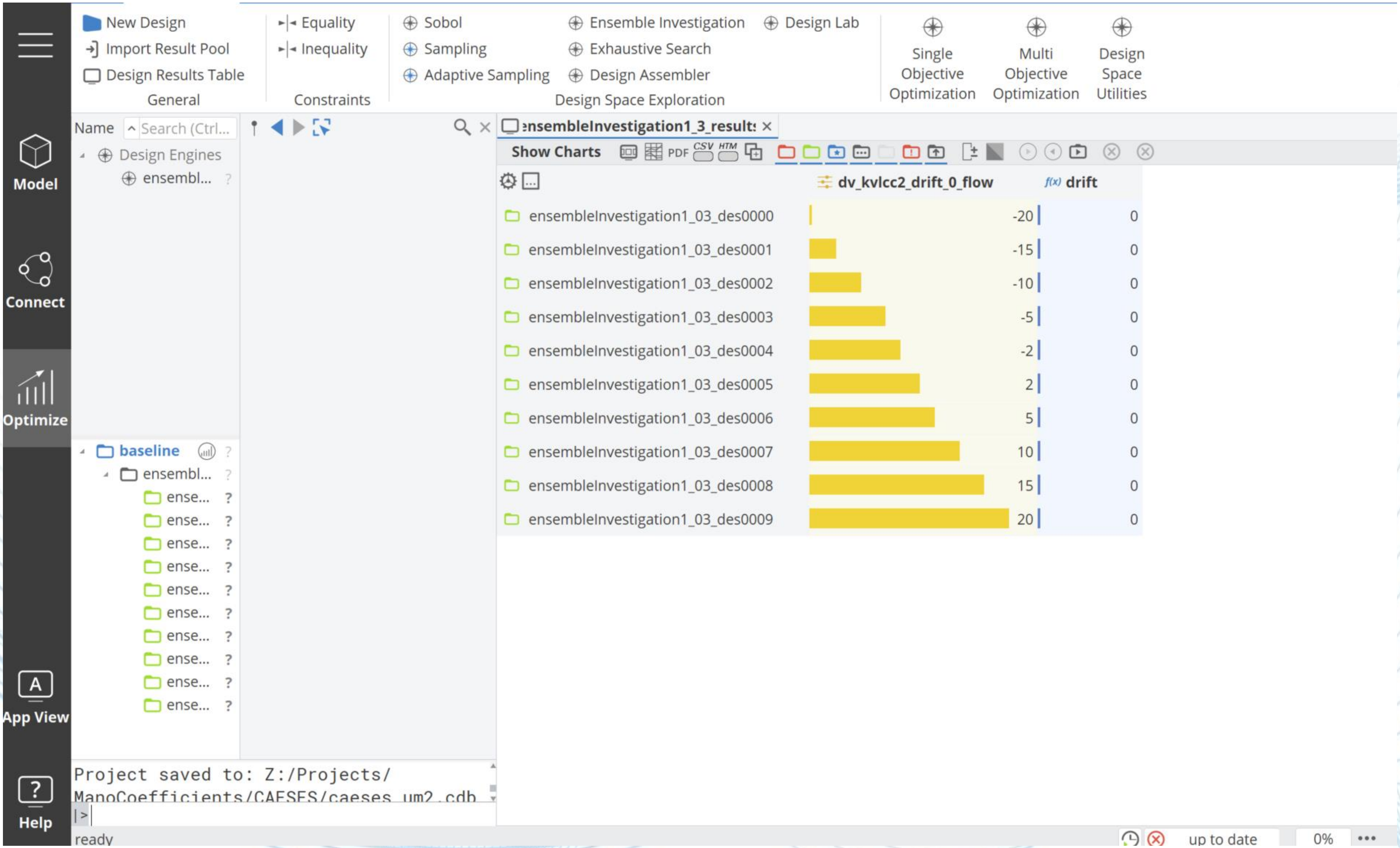
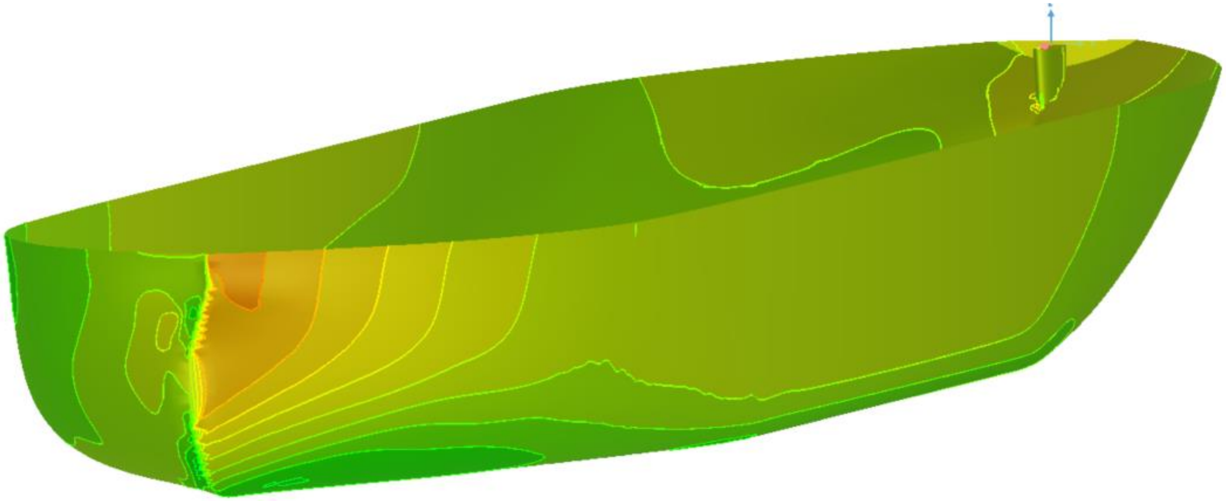
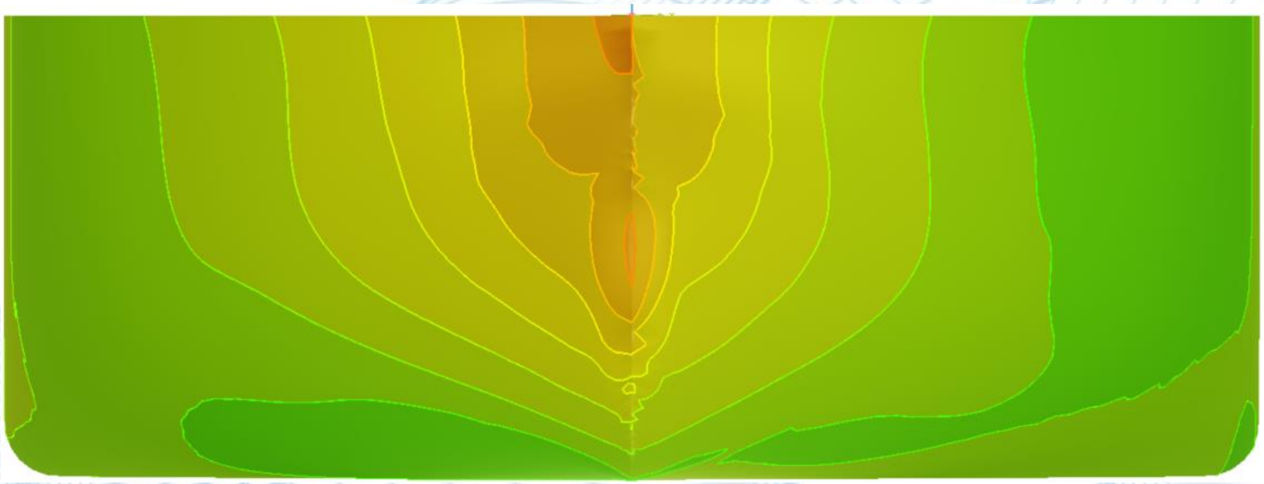
ENSEMBLE INVESTIGATION



FLOW SOLUTION FOR DRIFT CASES





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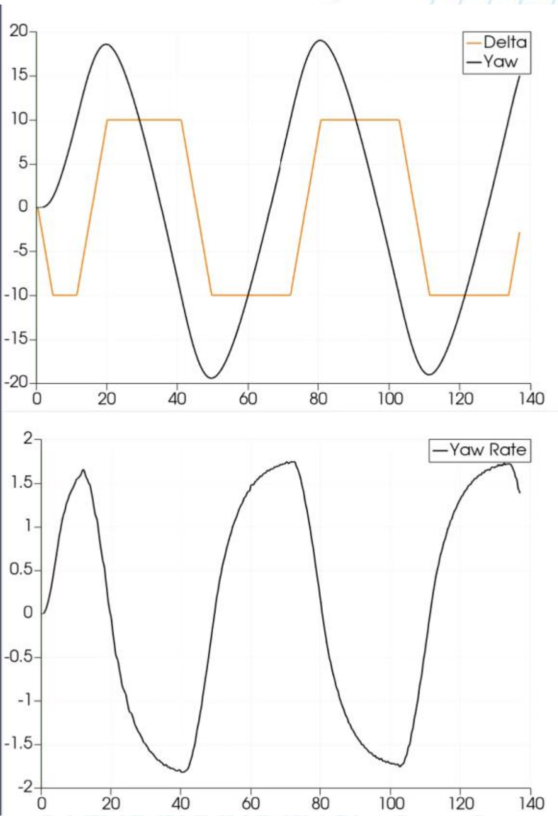
MANOEUVRING SIMULATIONS – SUB BODIES

- To model self propelled models, it is necessary to add rudders, propellers and engines.
- The forces produced by the sub-bodies are obtained with simplified models, ie they are not meshed and included in the flow solutions
- The sub-bodies are controlled with PID controllers:
  - Target heading or course for rudders
  - Target rps for engine and propeller

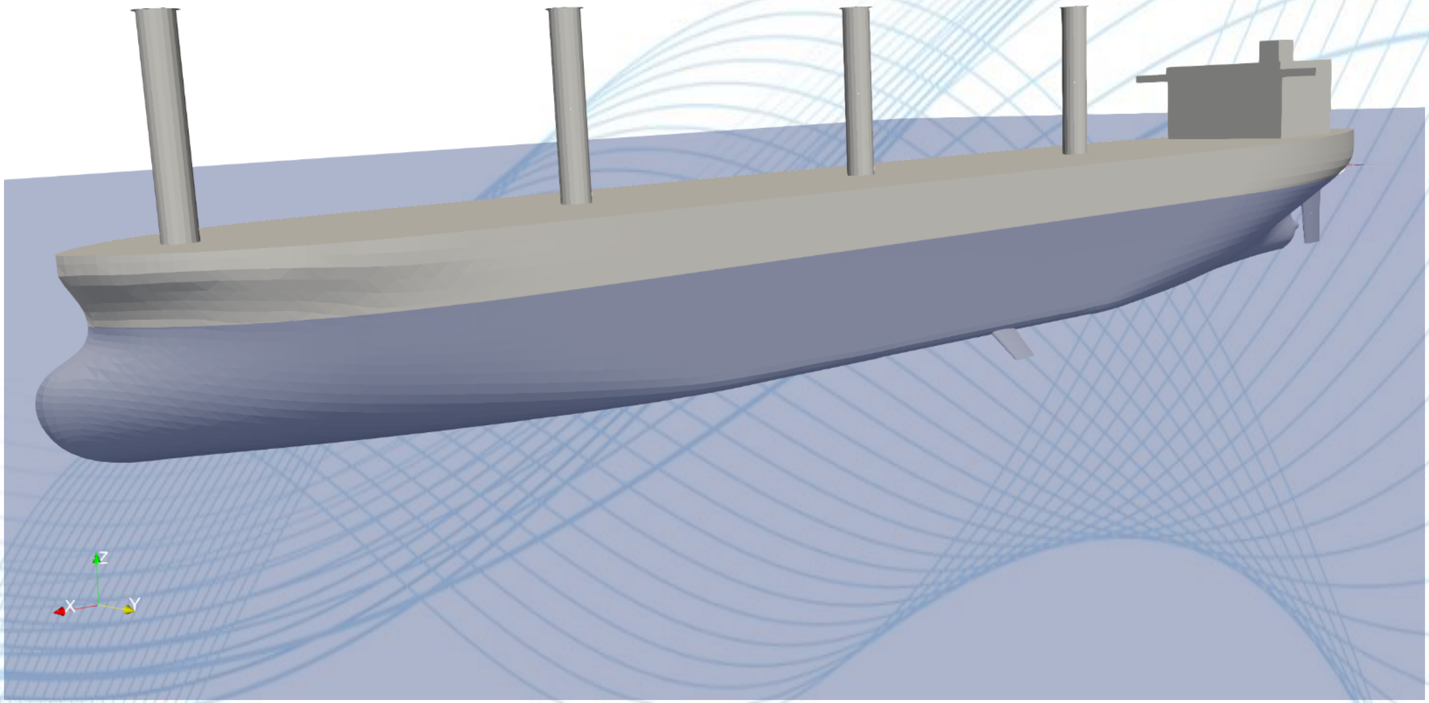
```
xflow
  …
  subb( rudder | prop | engine | thrusters, … )
end
```

MANOEUVRING SIMULATIONS – ZZ



SETUP FOR CASES WITH FLETTNERS

- KVLCC2 in full scale
- Wind speed 10 m/s and 15 m/s
- Wind directions between 30 and 150 degrees
- 4 flettner rotors:
  - 34 meters high
  - 5 meters diameter
  - End plate 6.5 meters
  - 3 rps



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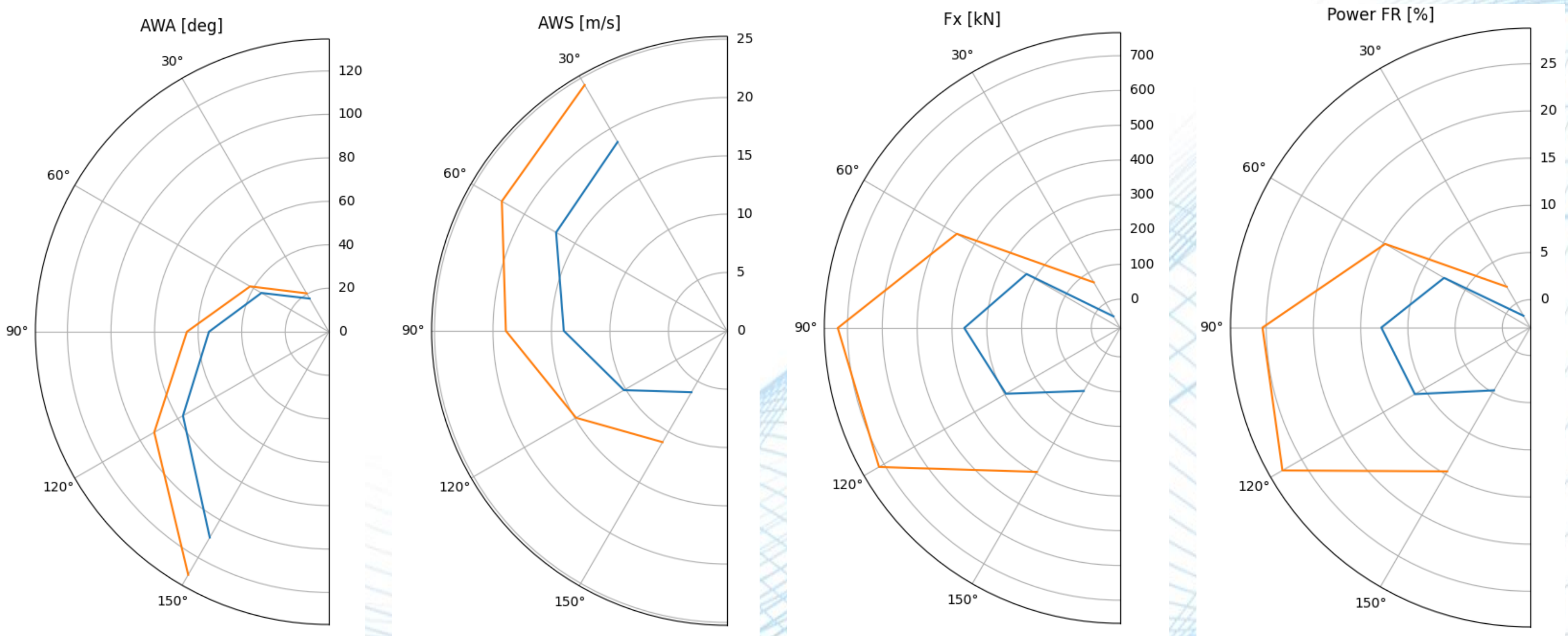
FLETTNER ROTORS – CALM WATER

Power saved up to 25% in best case scenario

5 hrs for 8 cases on a 48 cores machine for 10’ of real time full scale

10 m/s wind

15 m/s wind



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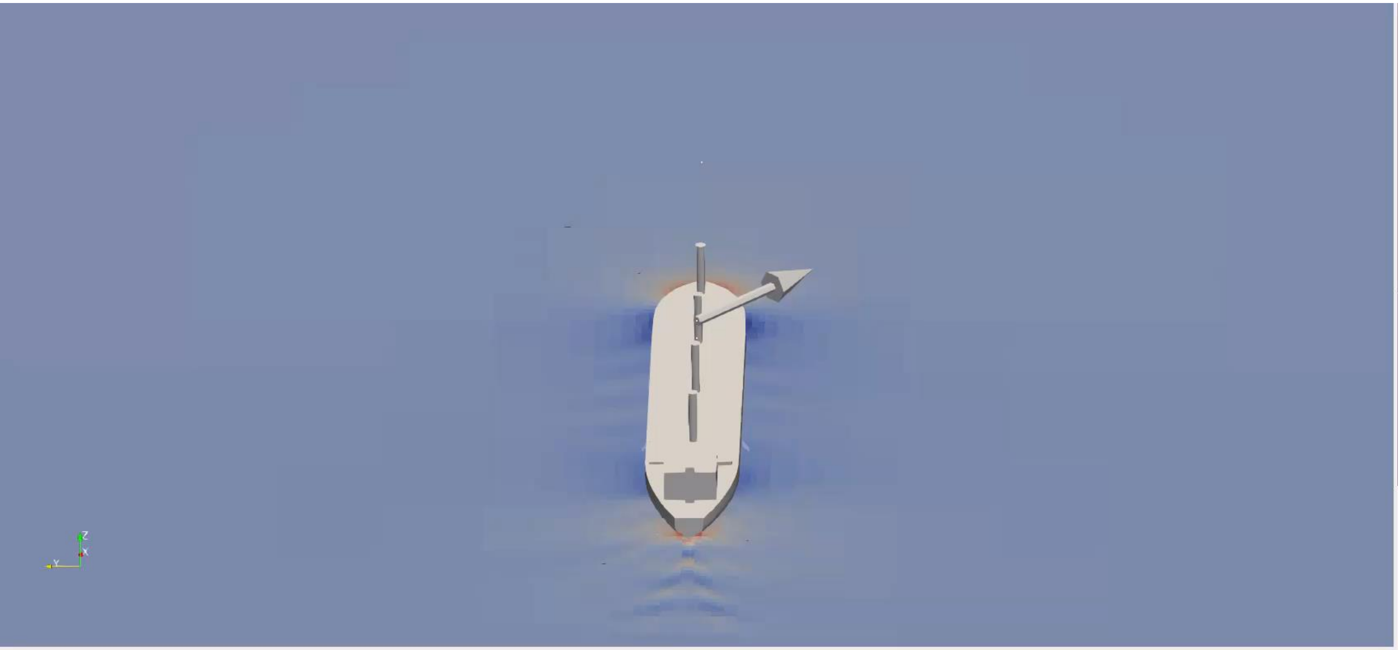
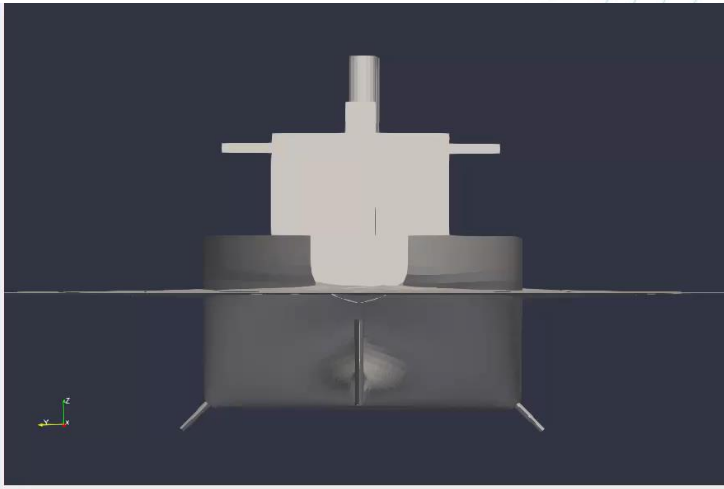
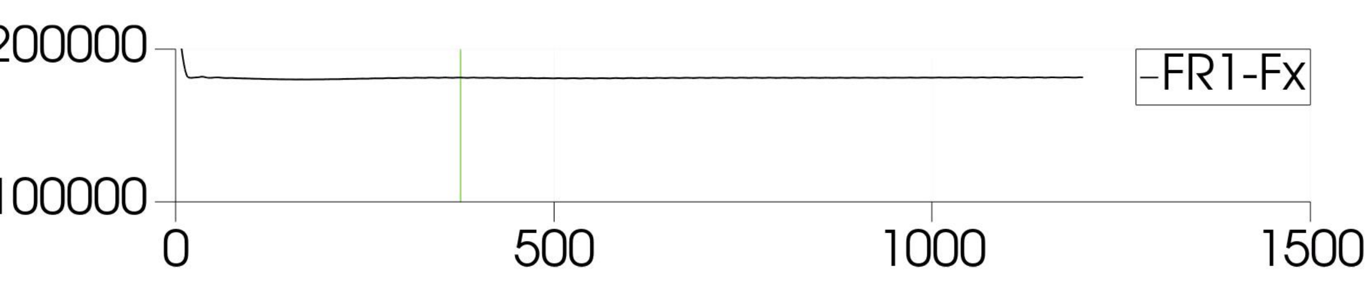
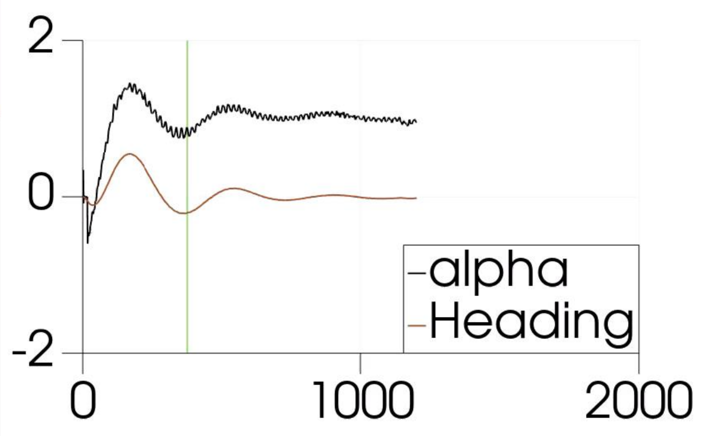
FLETTNER ROTORS – CALM WATER

Self propelled KVLCC2 with Flettner rotors in constant wind









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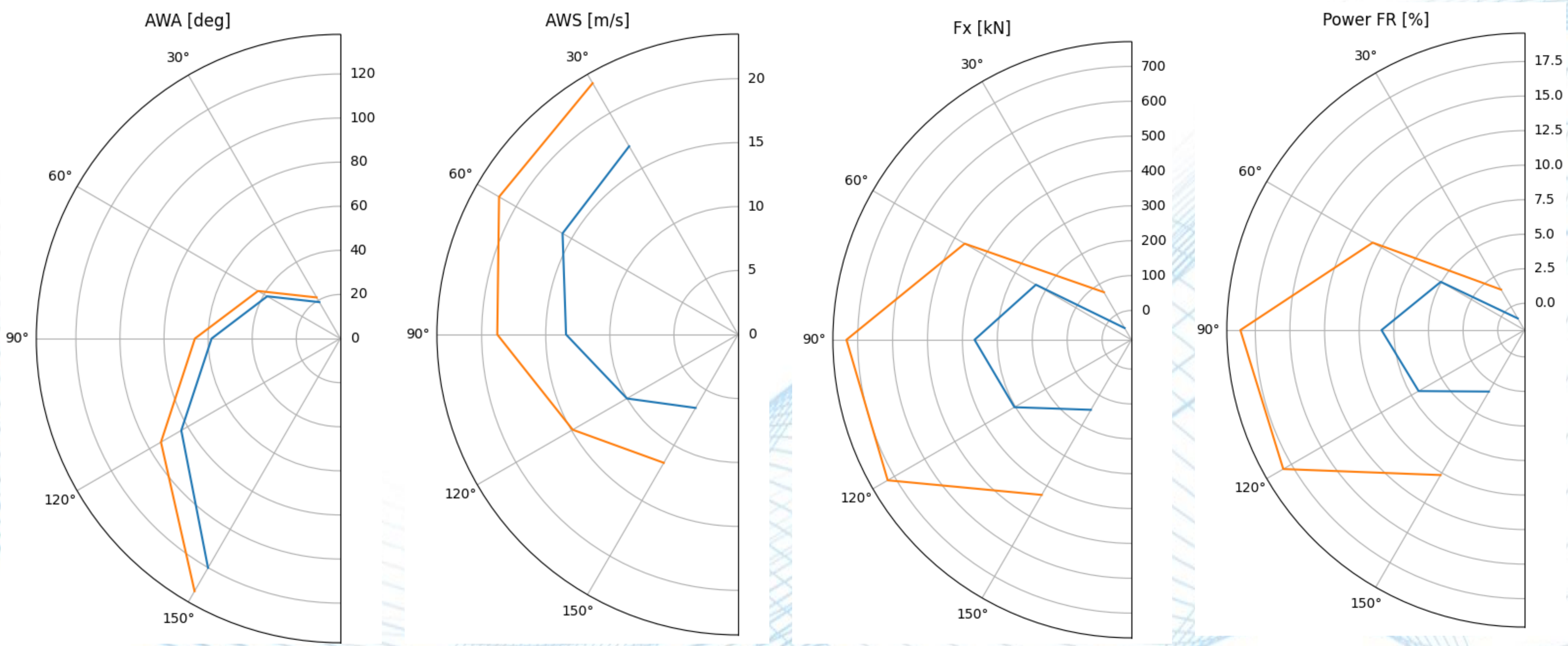
FLETTNER ROTORS – HEAD WAVES

Power saved up to 17% in best case scenario

1.25 m/s wind
2.50 m/s wind



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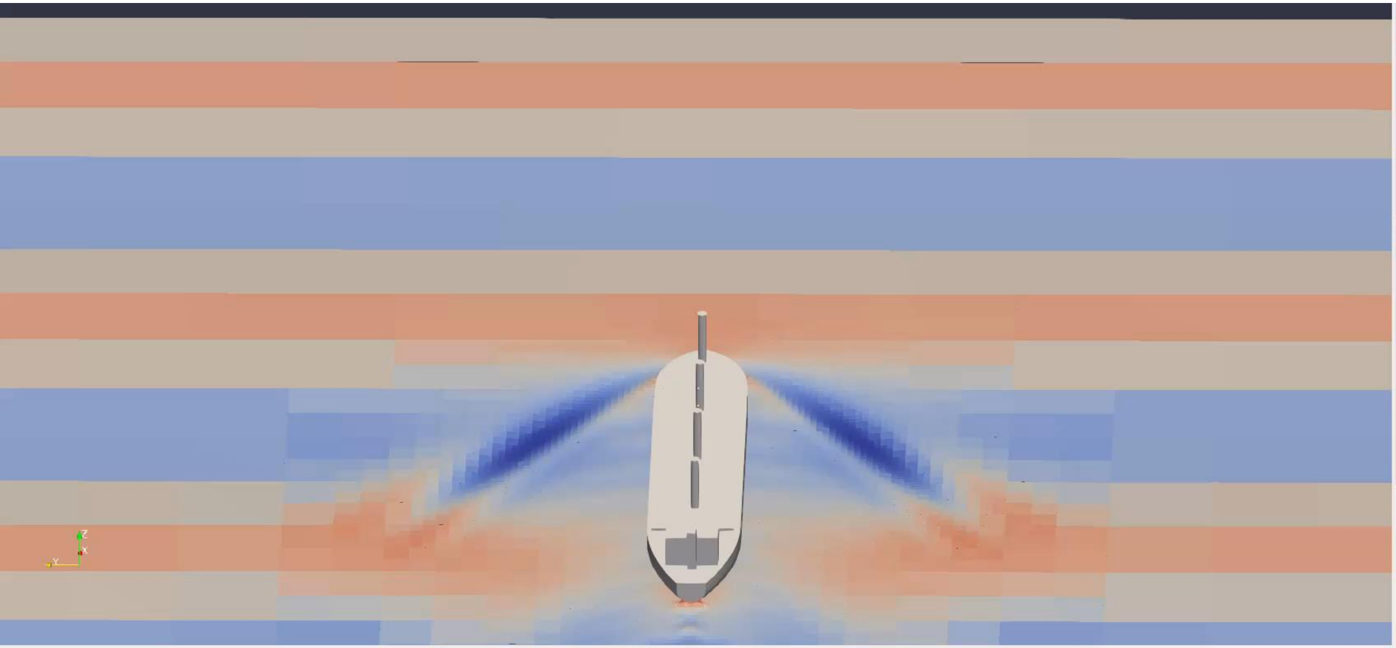
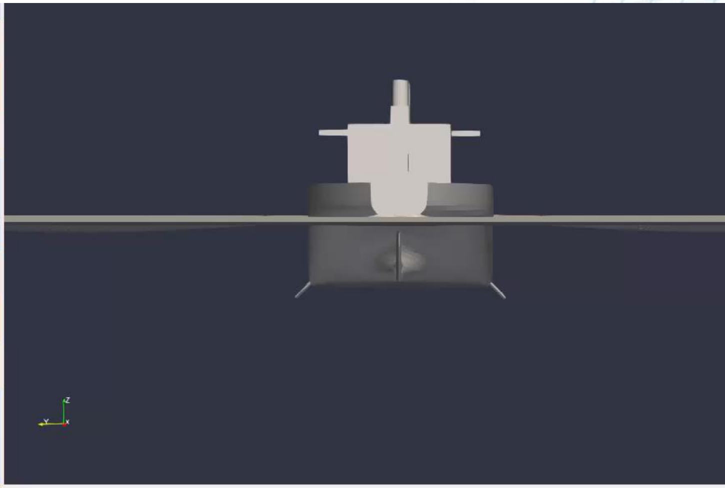
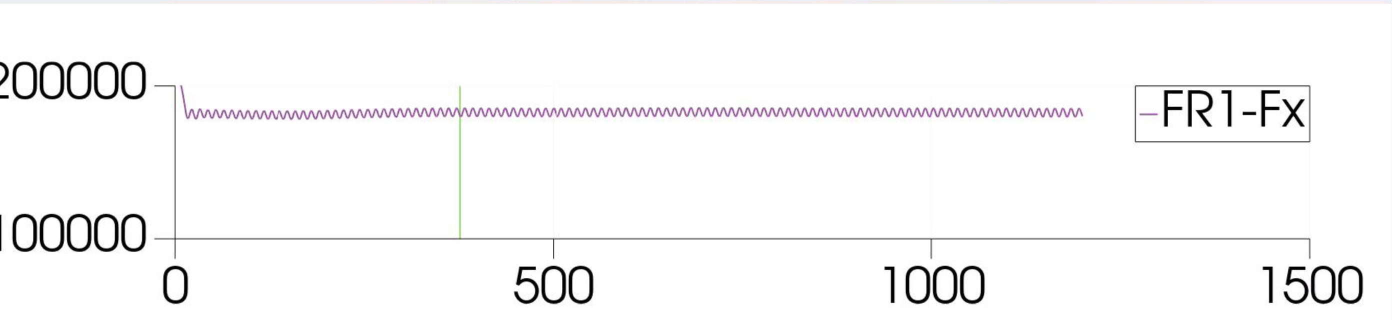
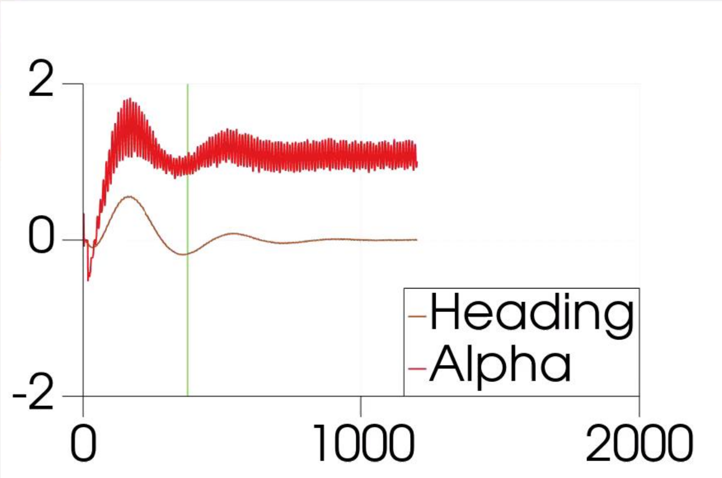
FLETTNER ROTORS – HEAD WAVES

Self propelled KVLCC2 with Flettner rotors in constant wind









Thank You

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