Simulating Saltstraumen, the strongest tidal current in the world (?)

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Saltstraumen

- Most famous tidal current in Norway (and outside?)
- Large tidal currents
- Located in northern Norway

- Gjevik (2009)

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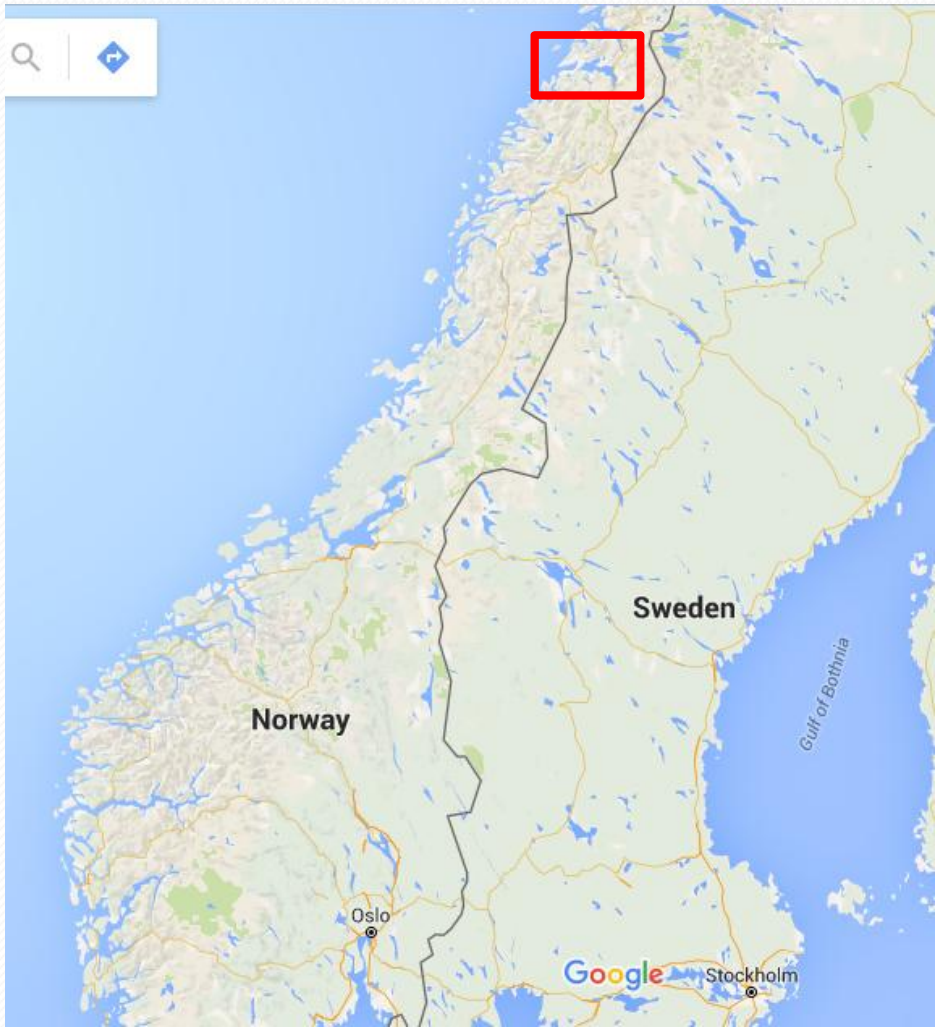
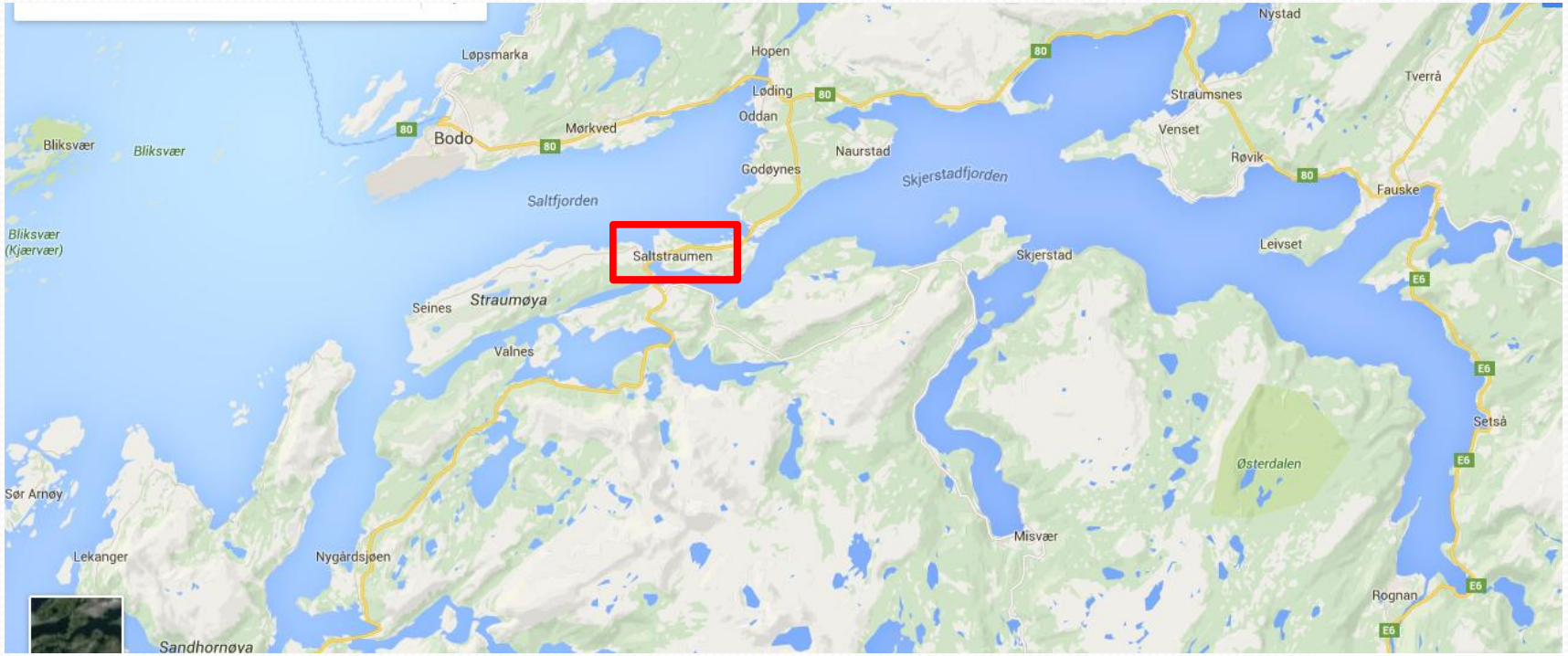
Saltstraumen

- Located in northern Norway



Saltstraumen

- Located in northern Norway near Bodø.



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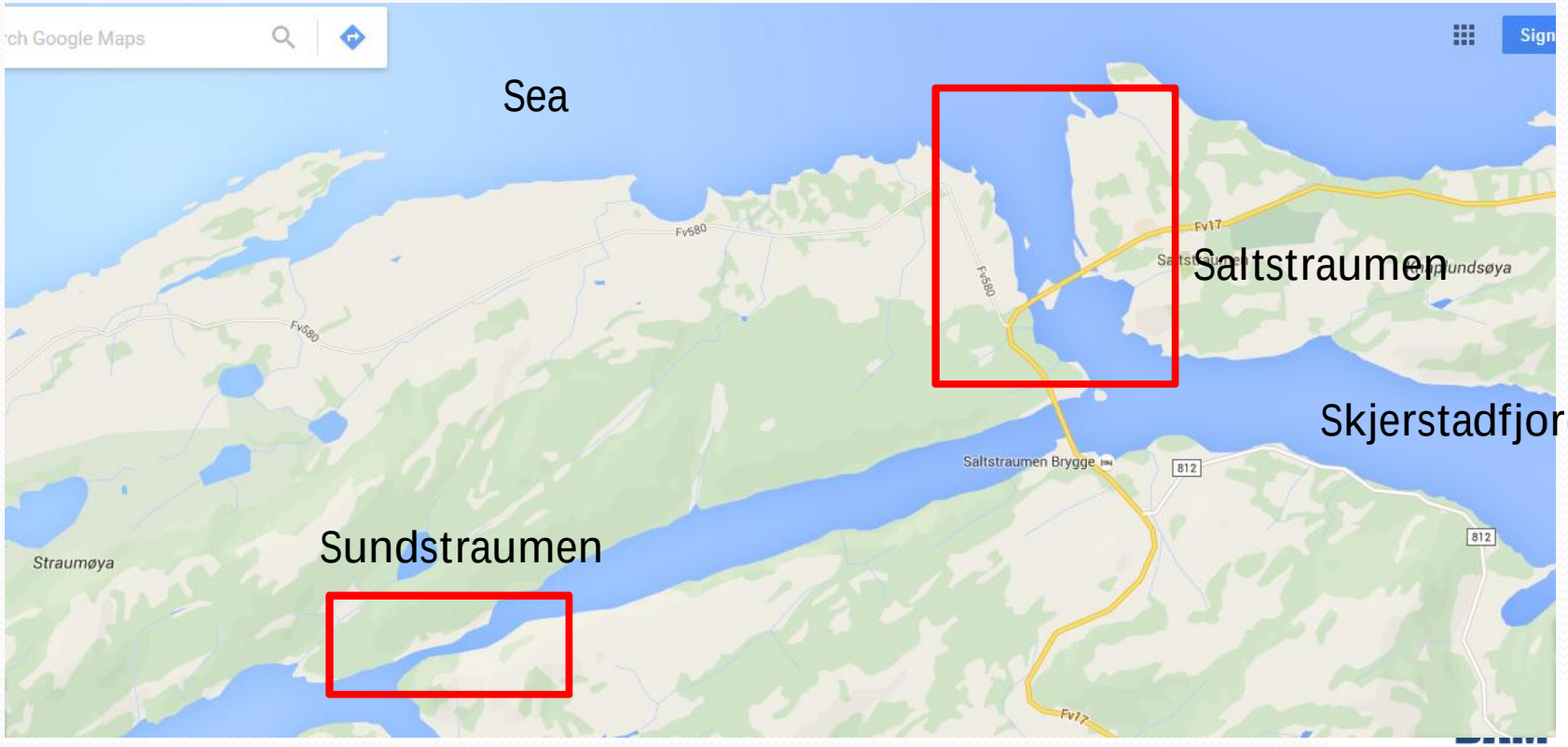
- Saltstraumen is 125m wide at narrowst.
- 235km^2 Skjerstadfjorden needs to be filled through Saltstraumen and Sundstaumen: ~470 million m^3/tide at large springtide (Gjevik, 2009)



- Skjerstadfjorden does not get filled during a tide (Tidal choking)
- The tide inside is 61 % of the tide outside and has a time delay of 100 min (kartverket.no)

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Ingoing flow

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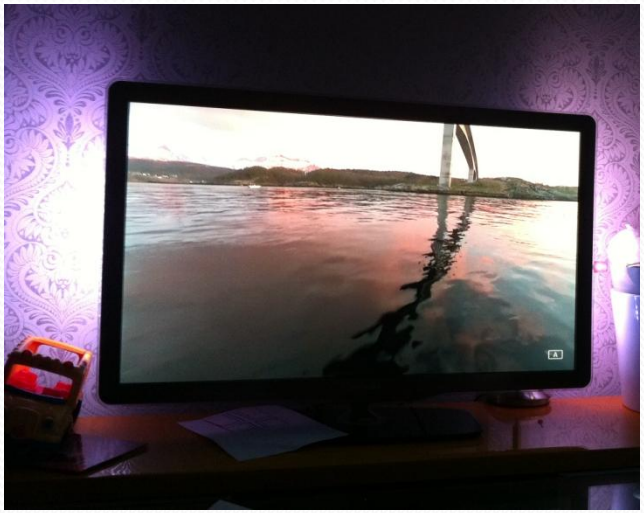
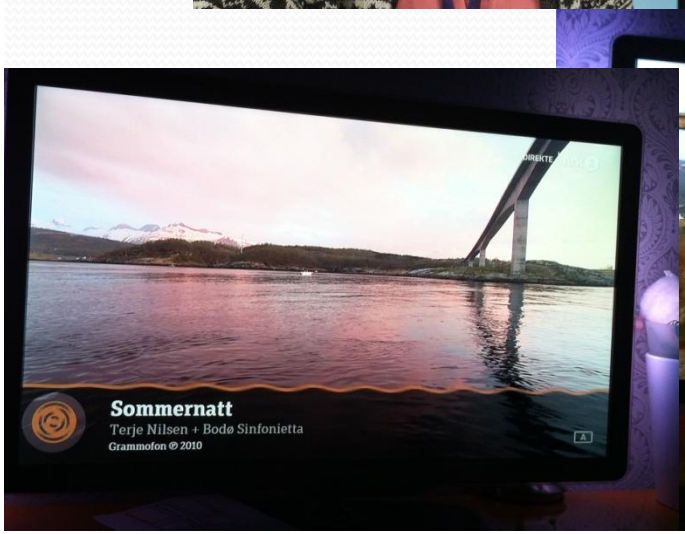
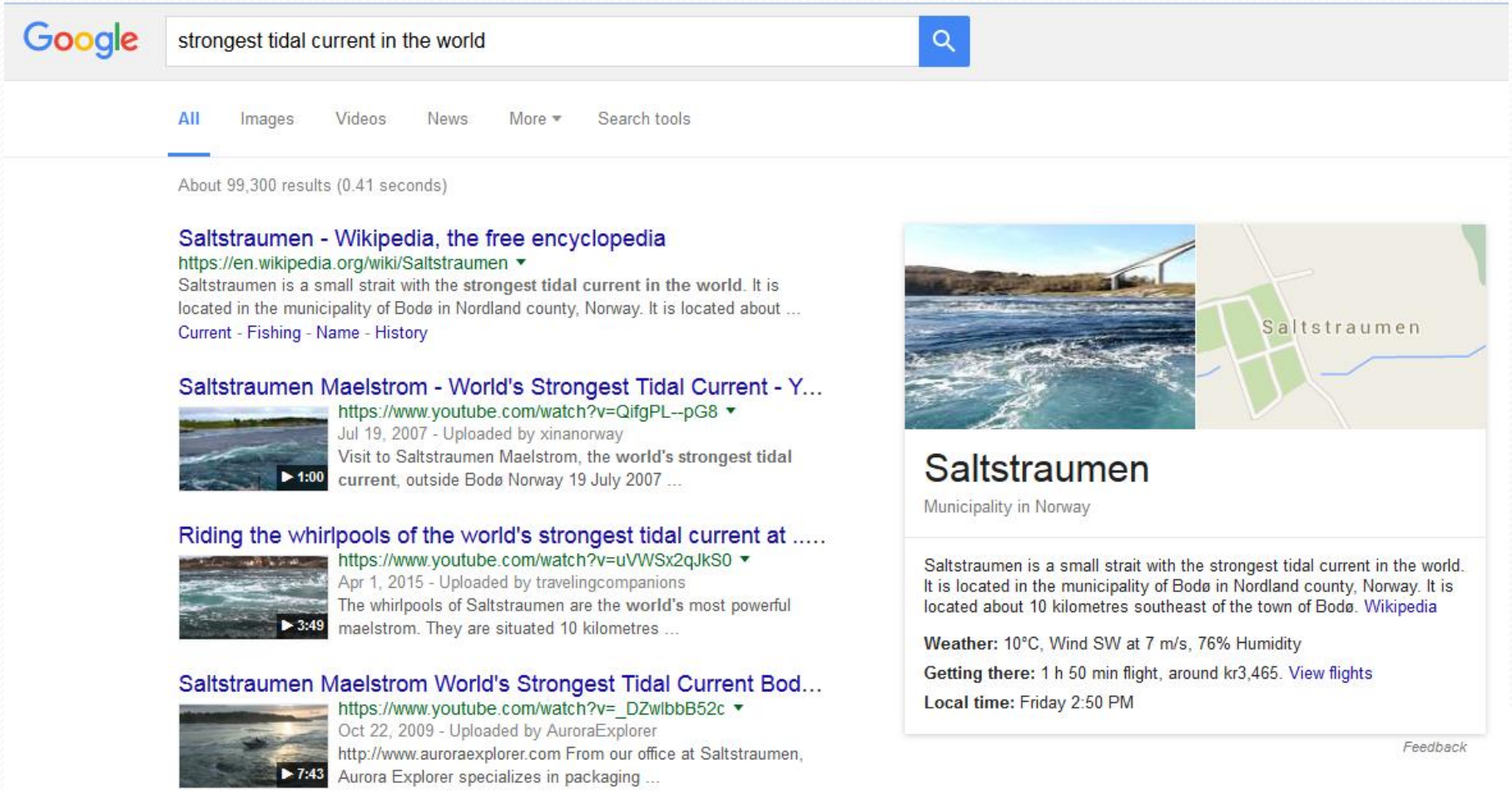
Last Saturday NRK broadcasted 12hrs life from Saltstraumen





- Saltstraumen claimed to be the strongest tidal velocity in the world!



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- Saltstraumen claimed to be the strongest tidal velocity in the world!
- Tourist brochure: 10 or 11 (up to 13) m/s!
- However: no current measurements (old German measurements)
- Pilot guide (den Norske Los): 8,5 knt (4.3 m/s) springtide
- Gjevik (2009): average 6m/s, but can get up to 10 m/s.

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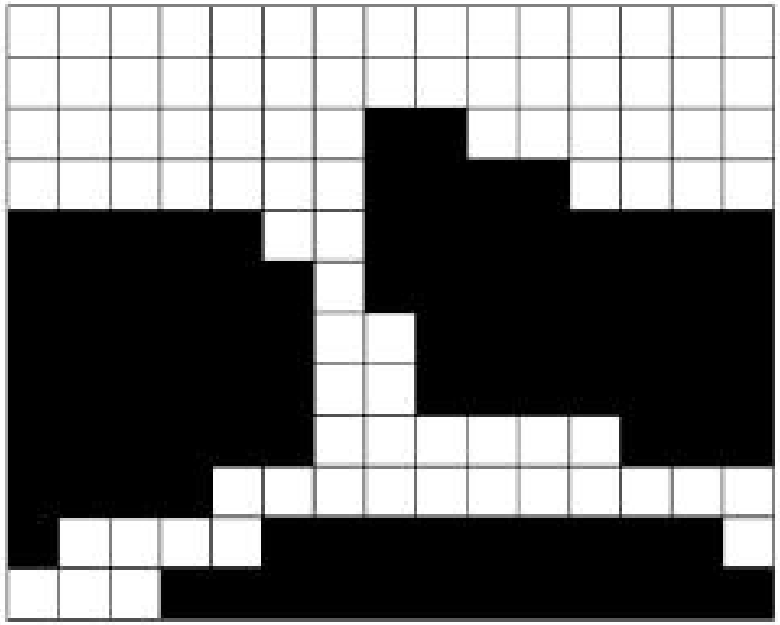
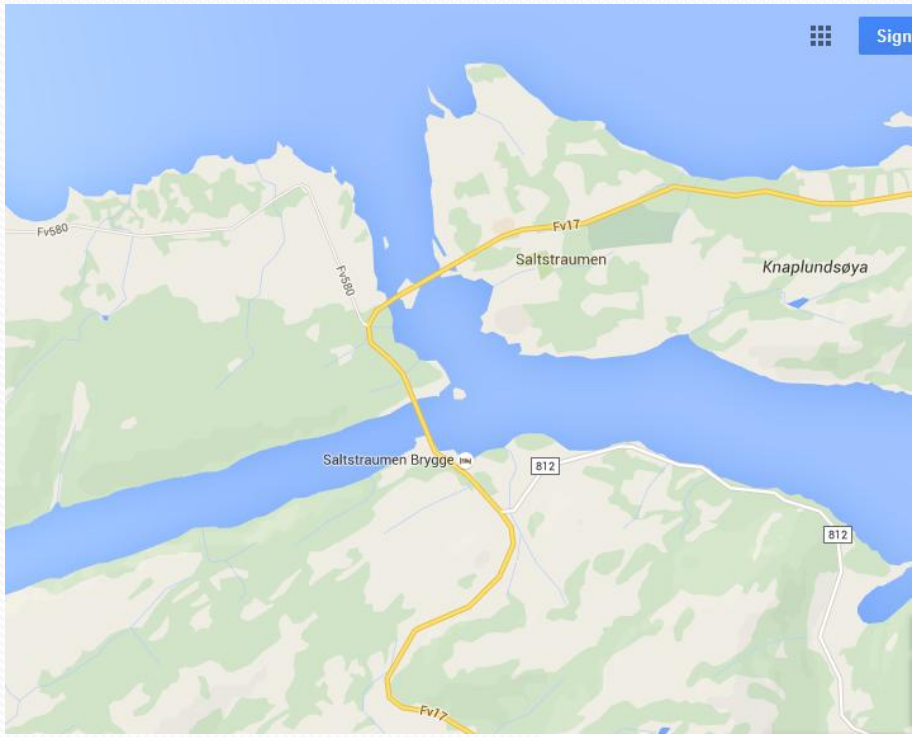
Modelling efforts (1/2)

- Eliassen et al., 2001 (CSR); no flow velocities mentioded





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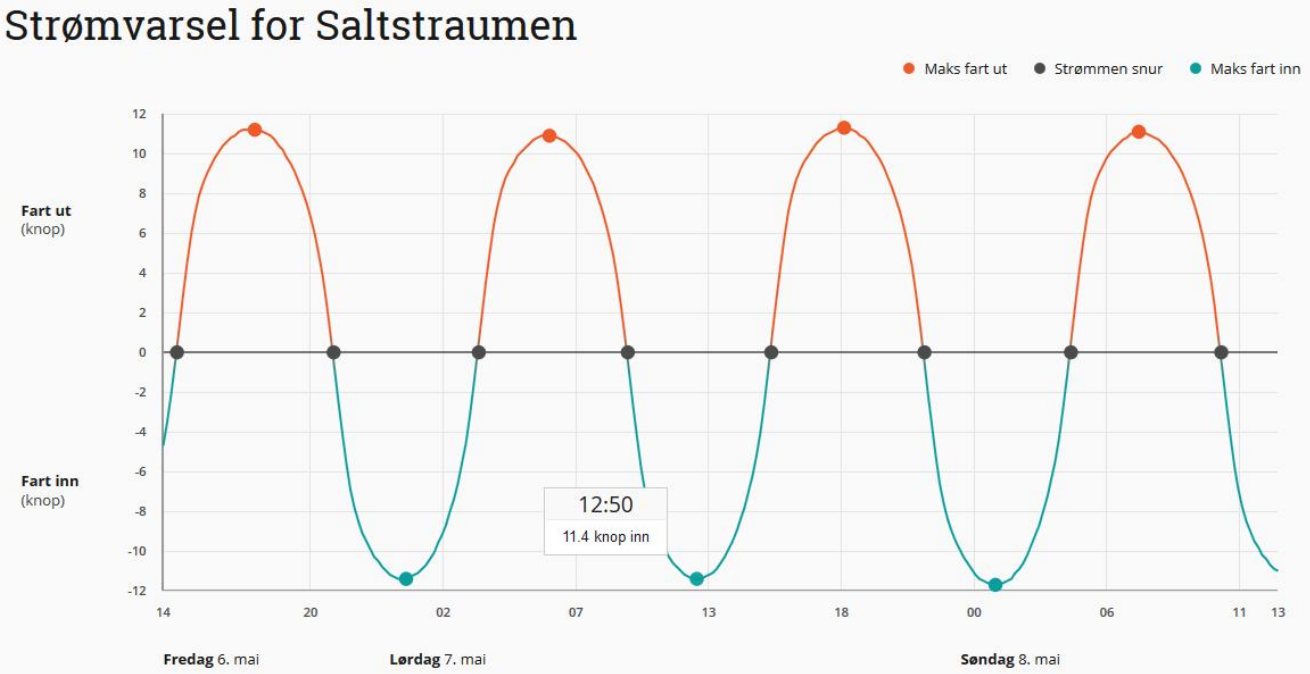
Modelling efforts (2/2)

- Barentswatch.no/saltstraumen
- Operational model (Polytec): 100 m resolution
- Max 12 knots (6 m/s)



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Conclusion so far:

- Uncertainty about these high velocites (>10 m/s)
- -measurements not available
- -modelling efforts so far cannot reproduce these high velocities (resolution?)

- -> Buid high-resolution model of Saltstraumen and check these high velocities can be reached

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FINEL model

- Finite element model
- Use in 2Dh now (works fine to predict velocities in Gimsøystraumen, Lofoten)
- Explicit solver
- Automatic time stepping (this case: 0.014 sec)
- Robust
- Fast (parallel on 16 CPU's)

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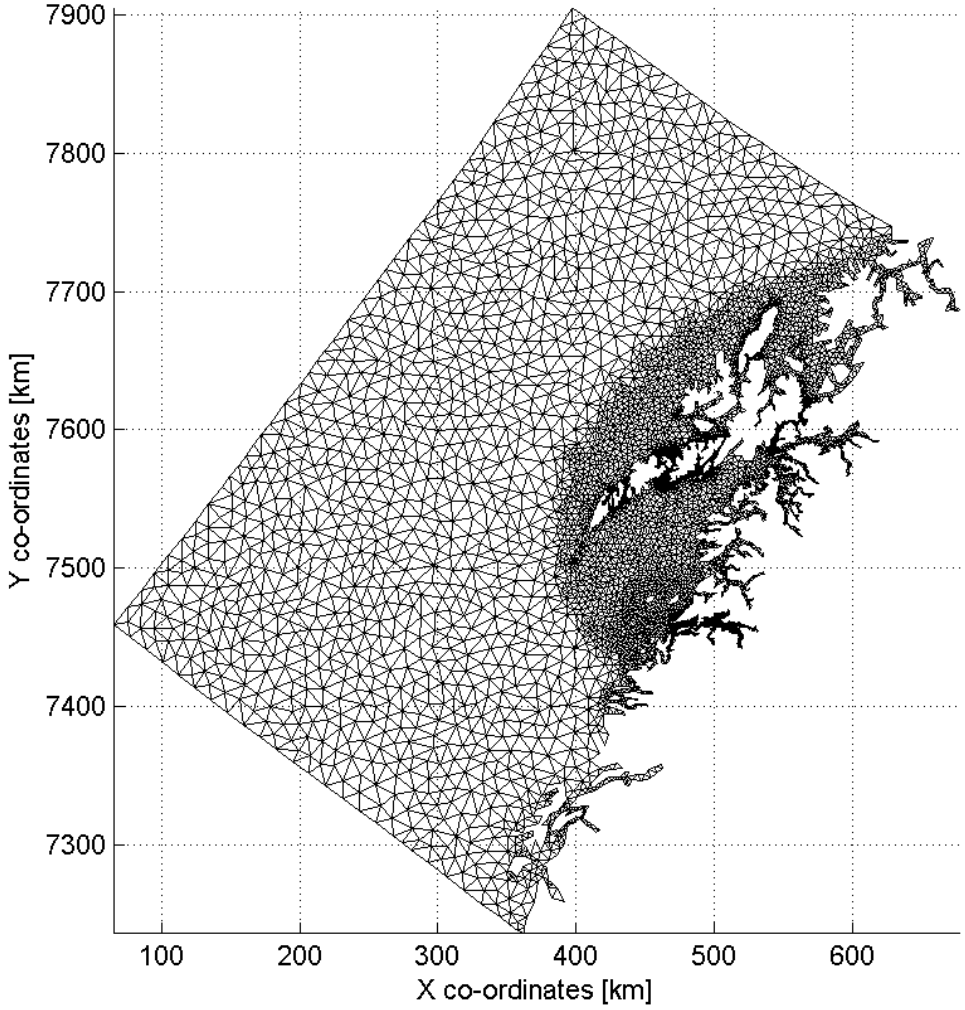
FINEL grid: 10km resolution on boundary



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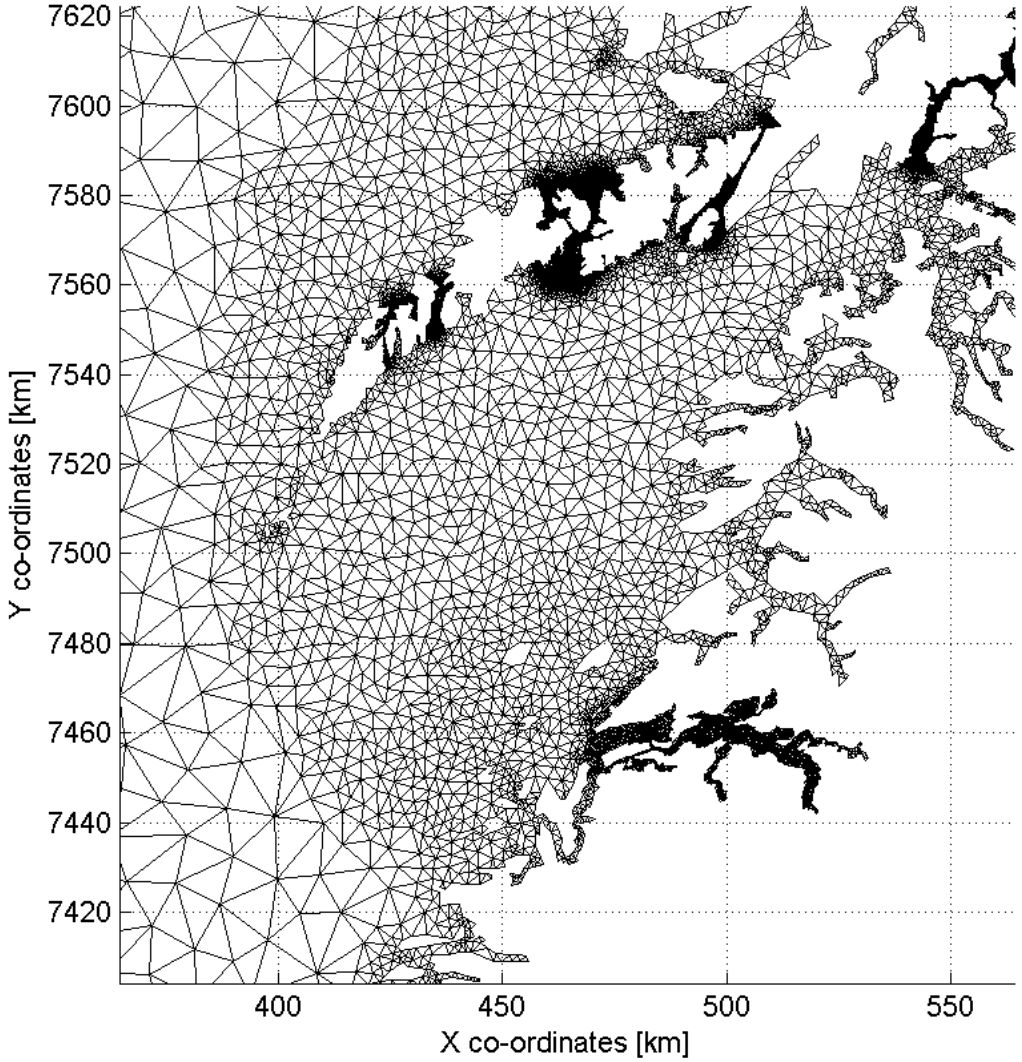

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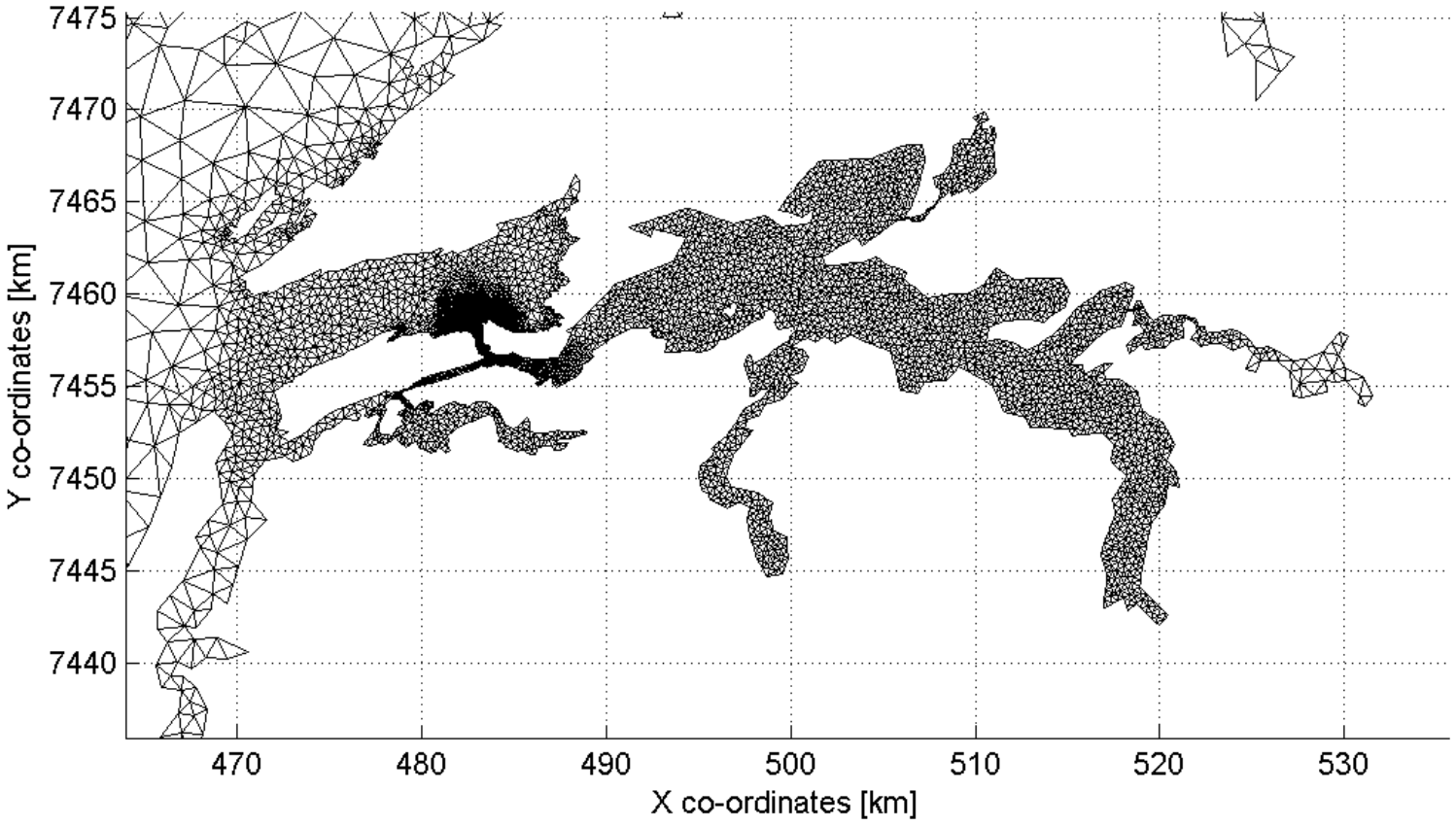

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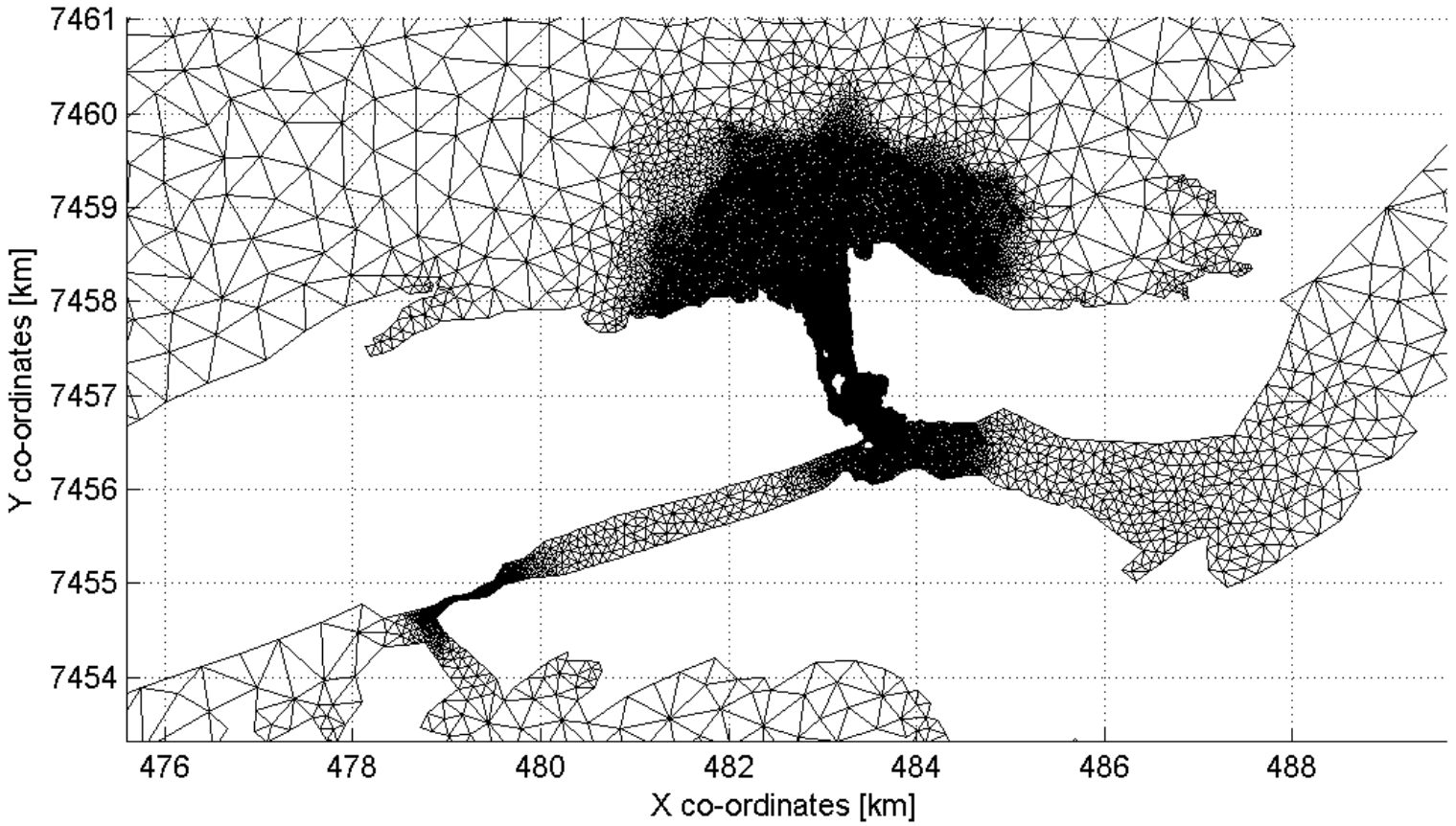

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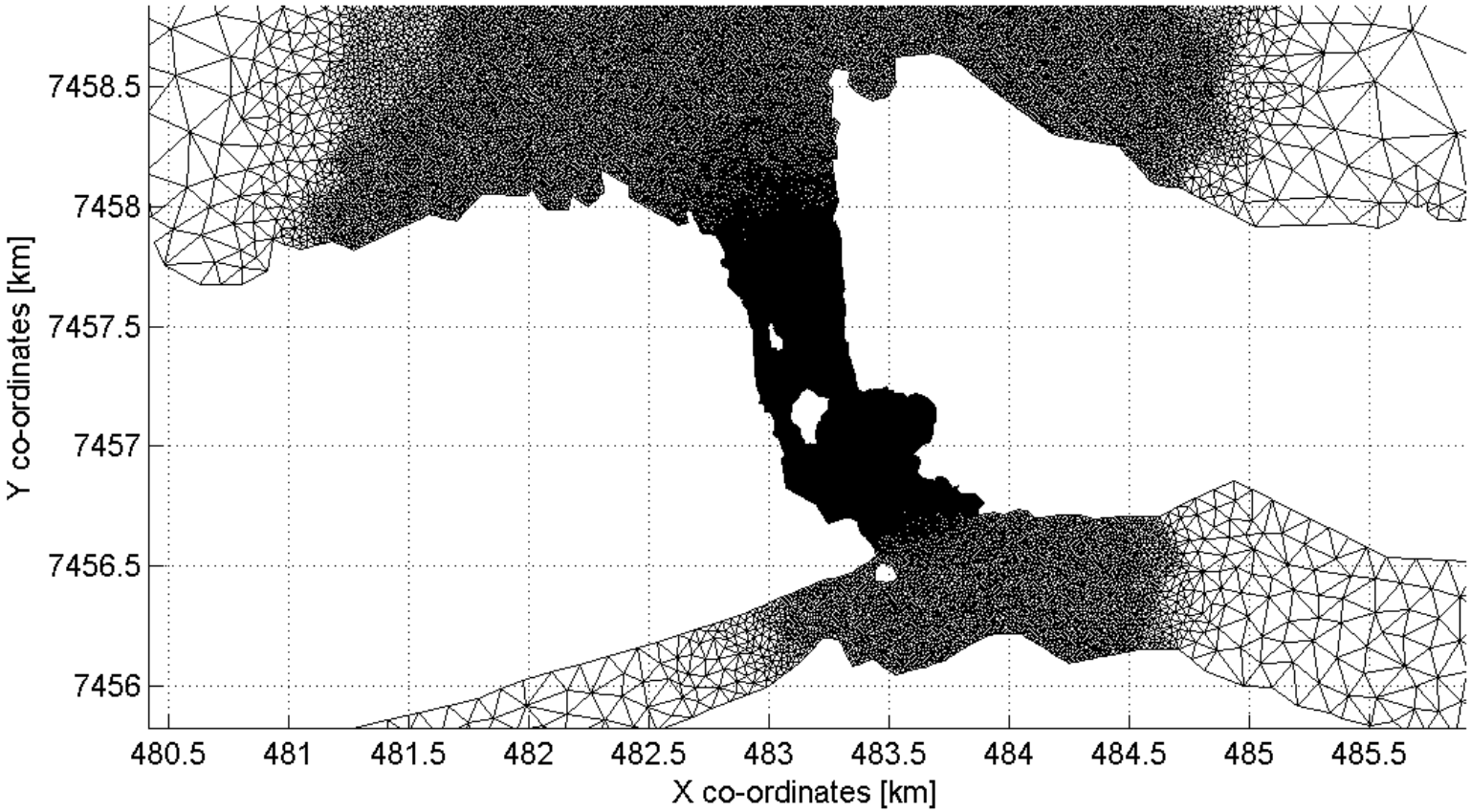

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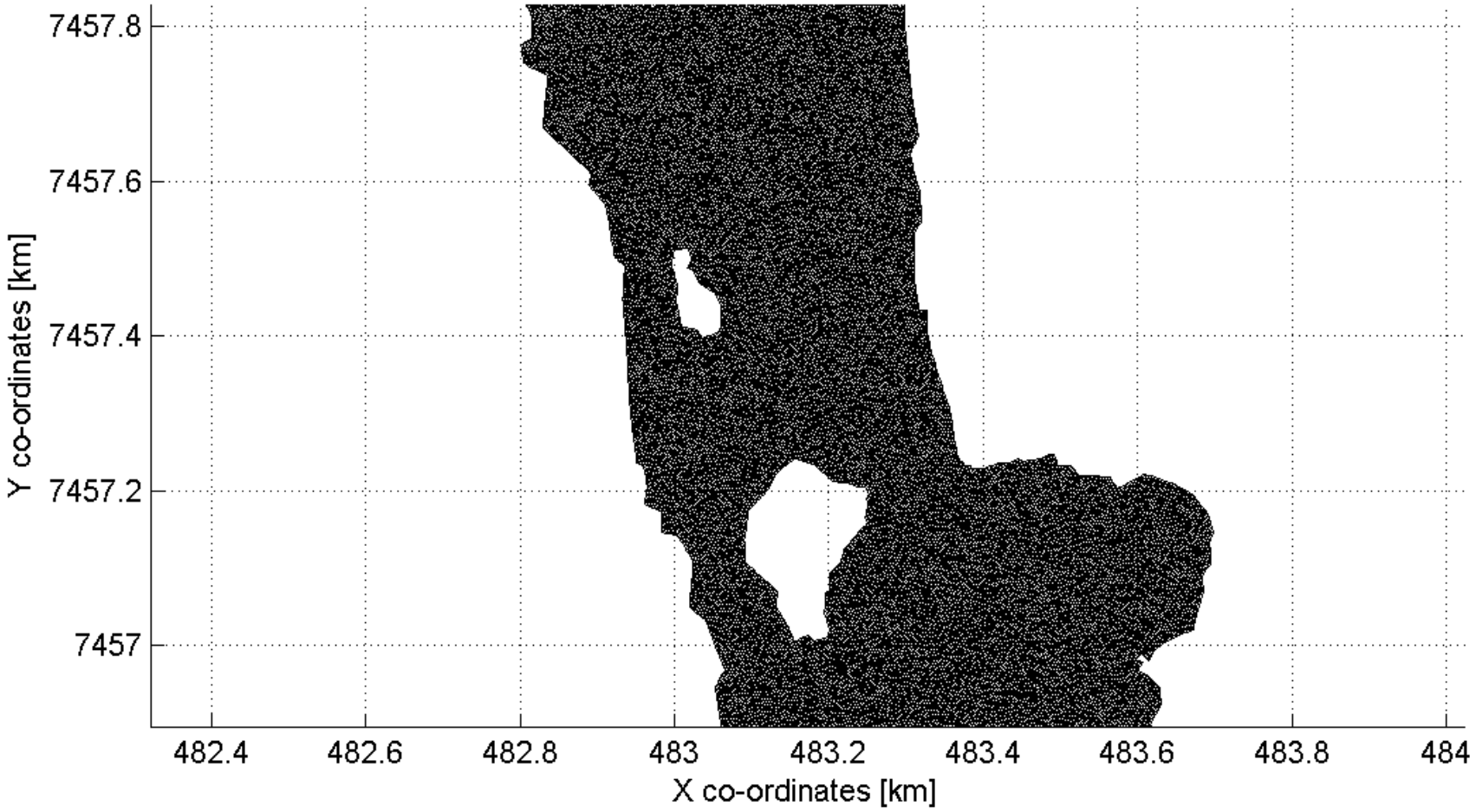

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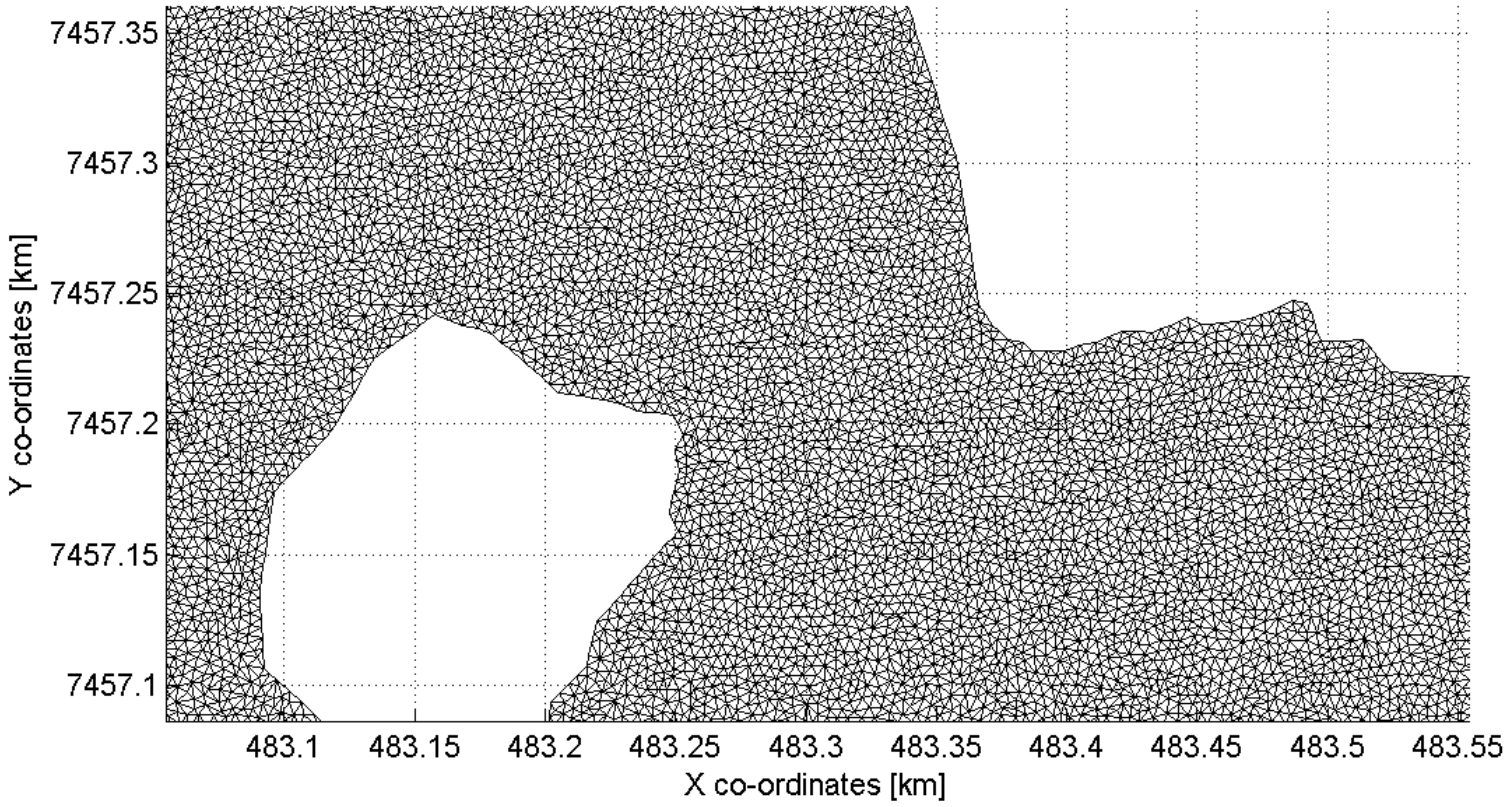
FINEL grid: 3m resolution in Saltstraumen (5m in Sundstraumen)



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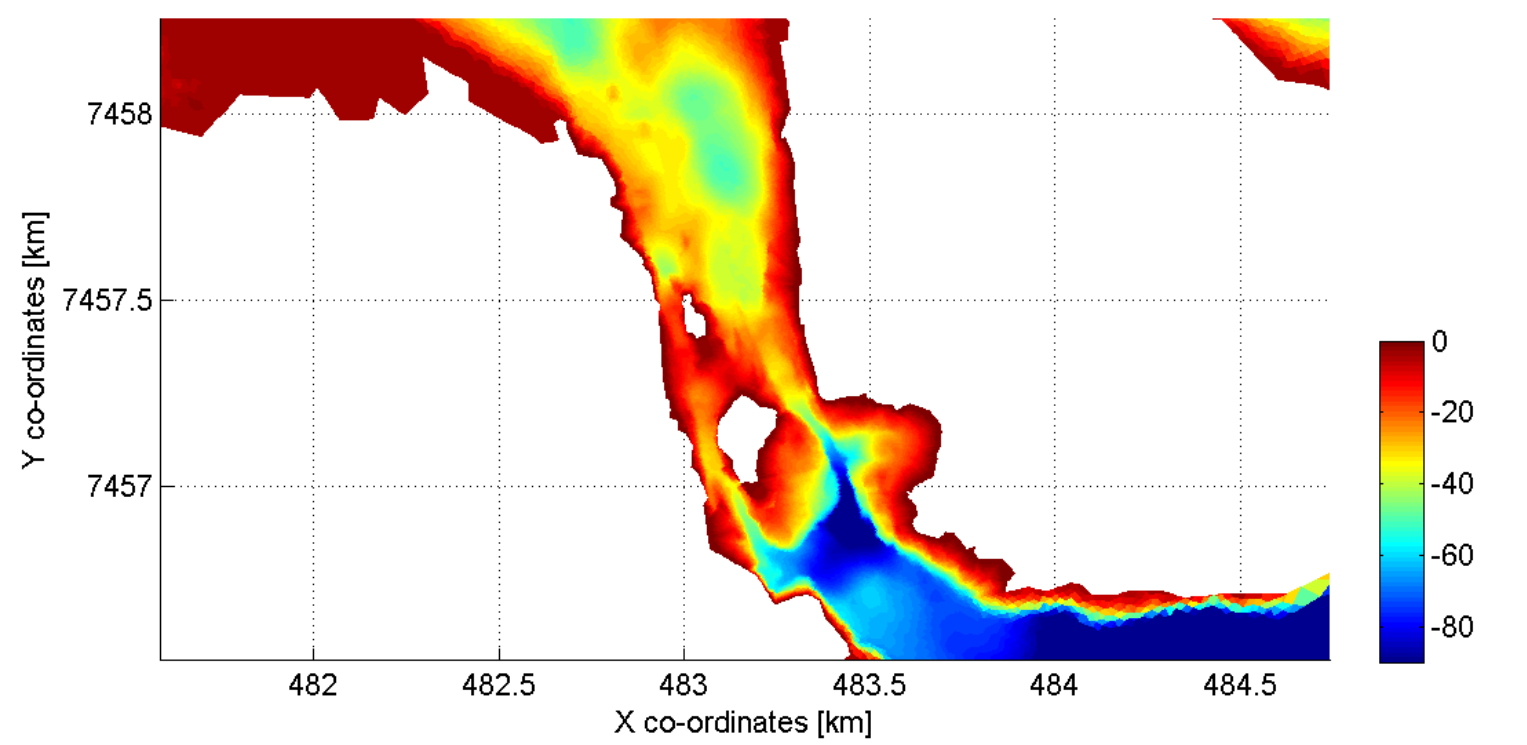
1m bed level resolution (NGU/kartverket)



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Test period:

- 8 october 2006:
- large springtide
- 3.15 m astronomical tidal difference Bodø (3.3 max possible astronomical (HAT-LAT))

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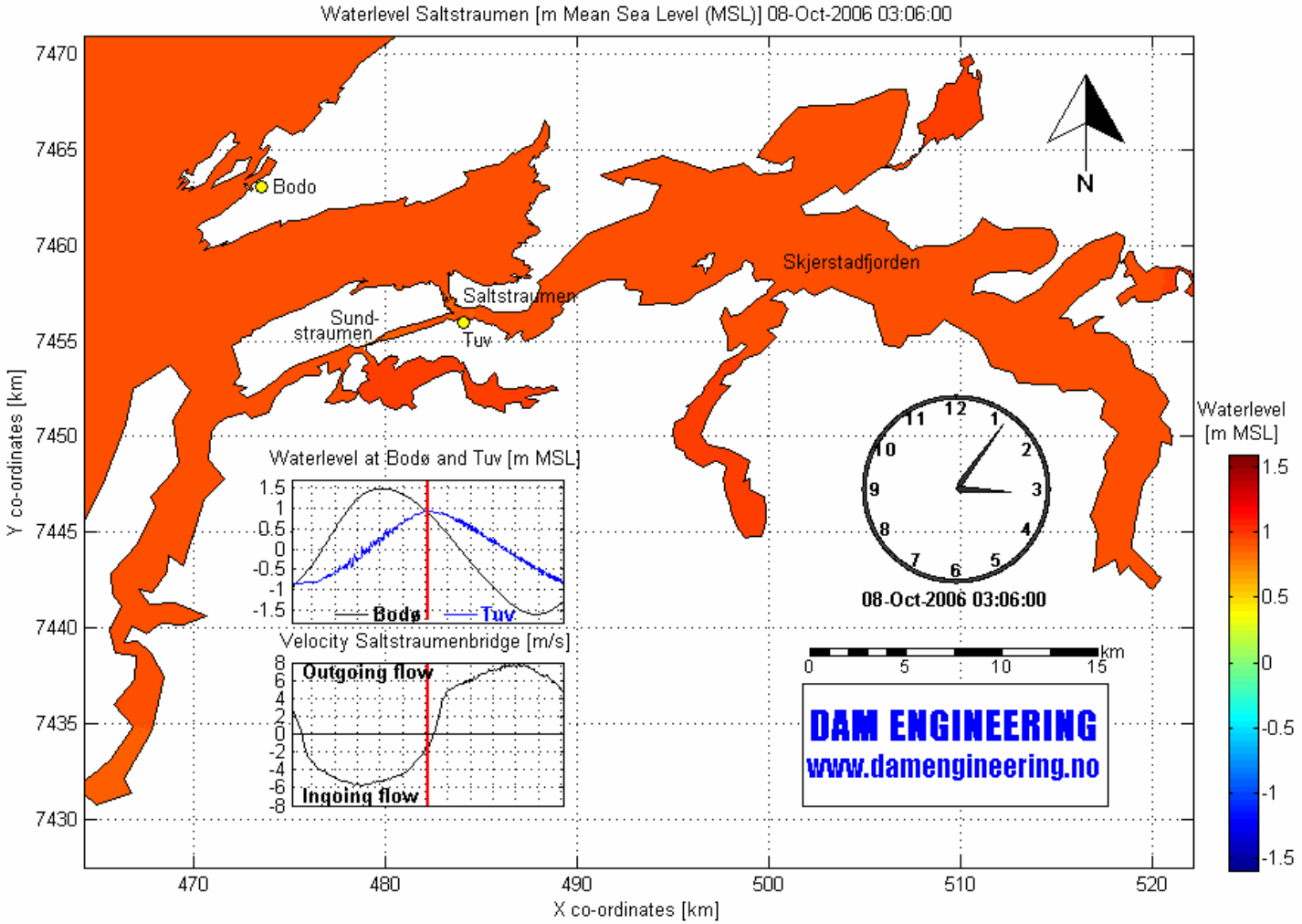
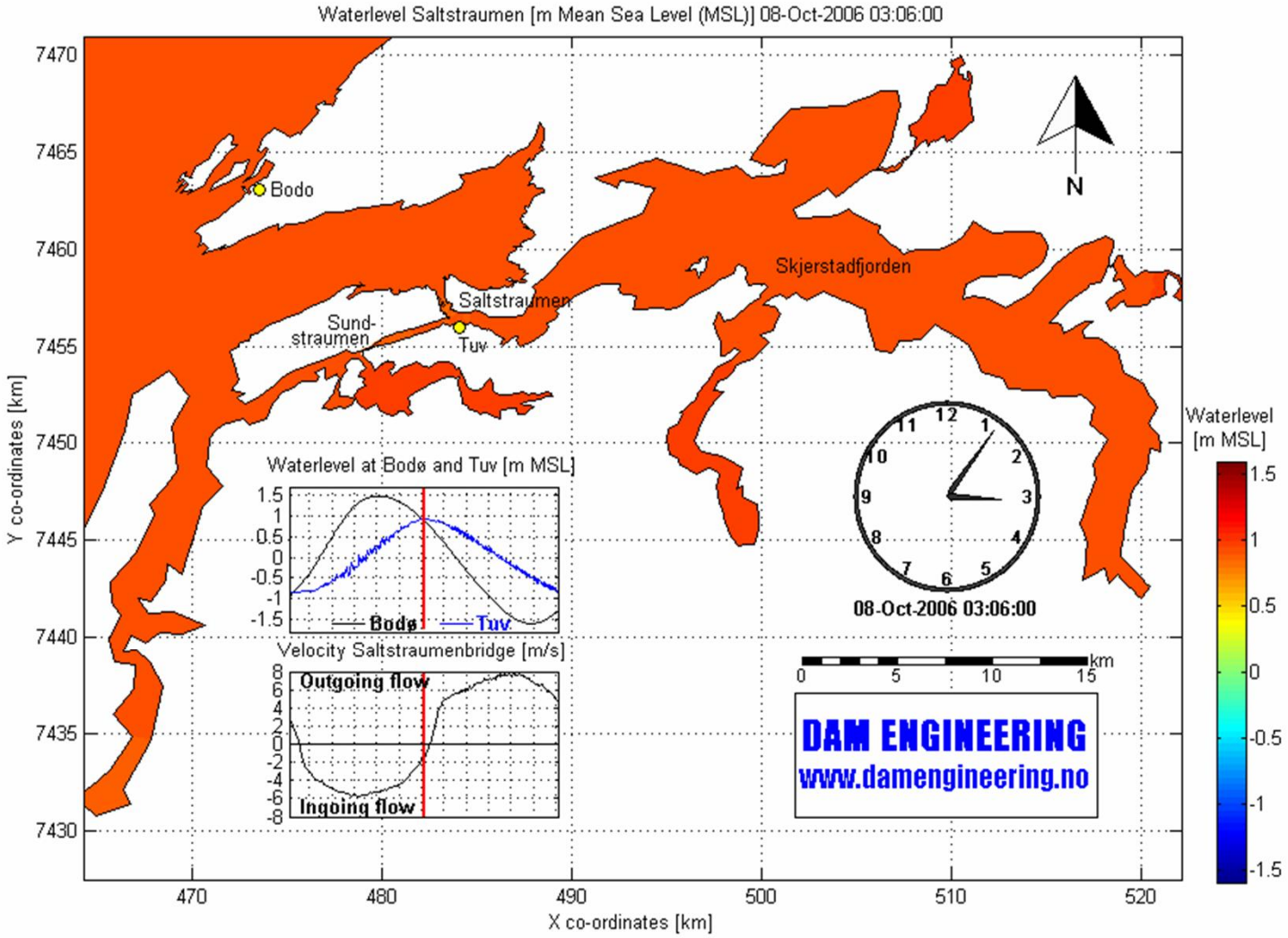
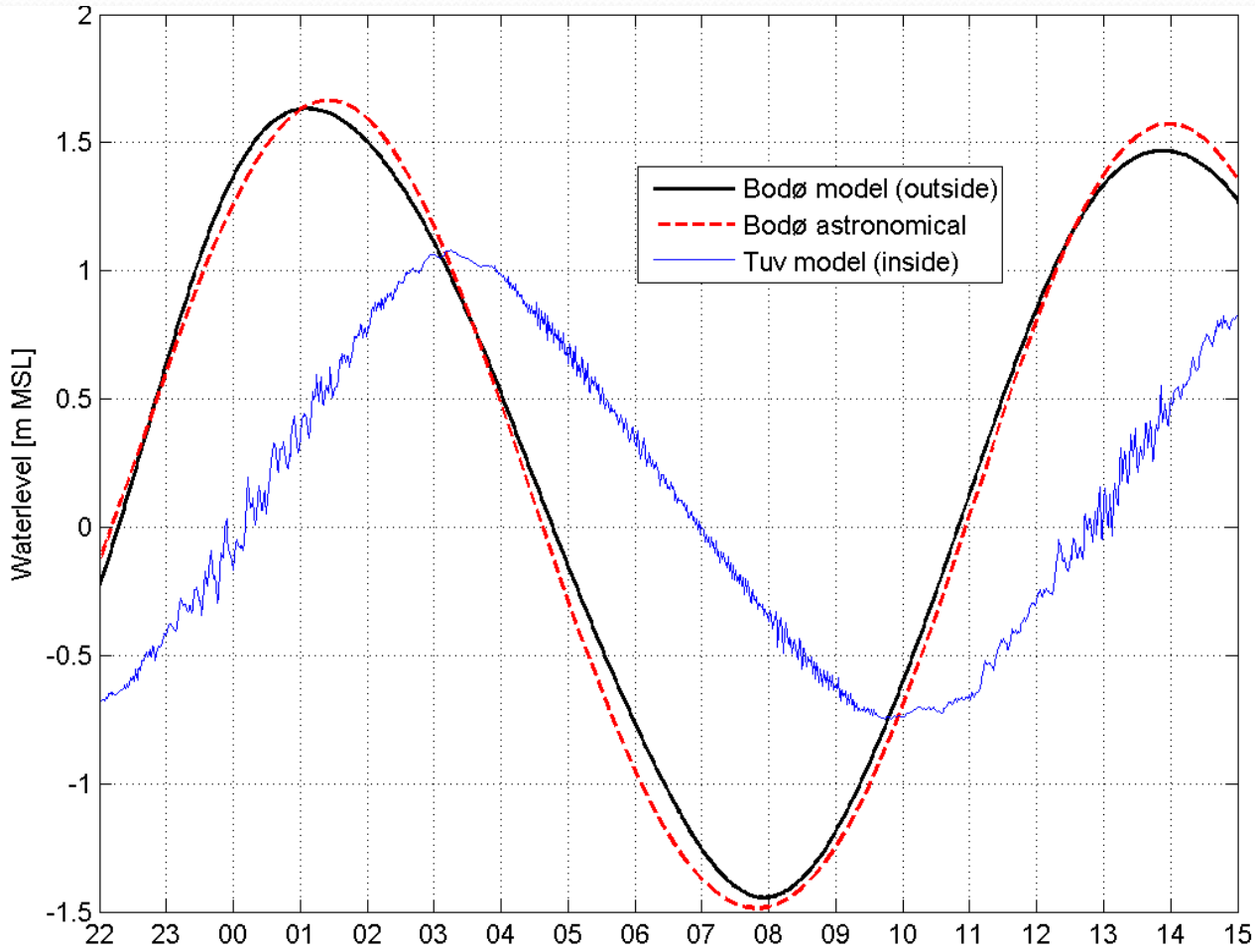
Water level inside/outside



Water level inside/outside



Water level check



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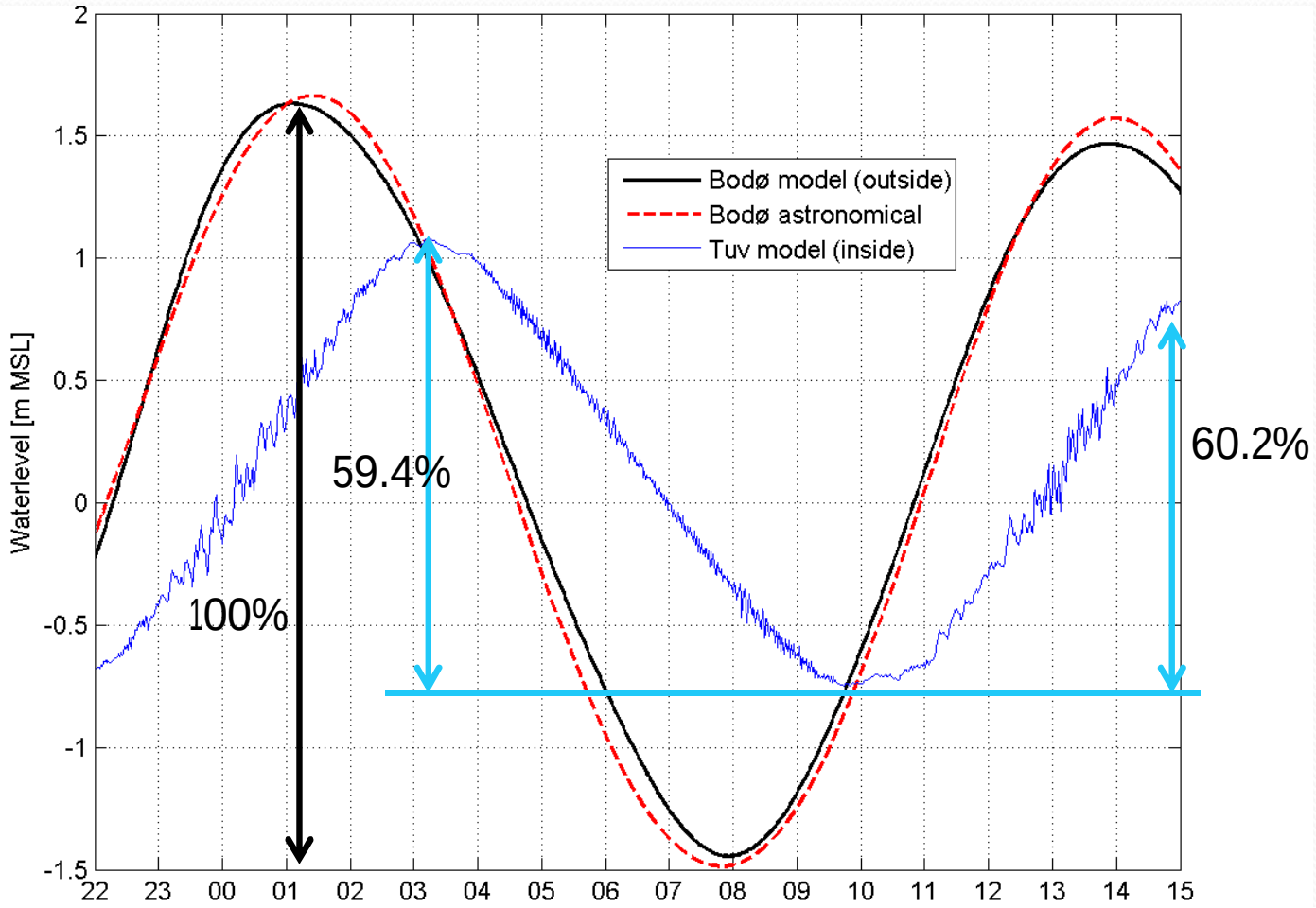
Tidal range (Tuv: 61% of Bodø)



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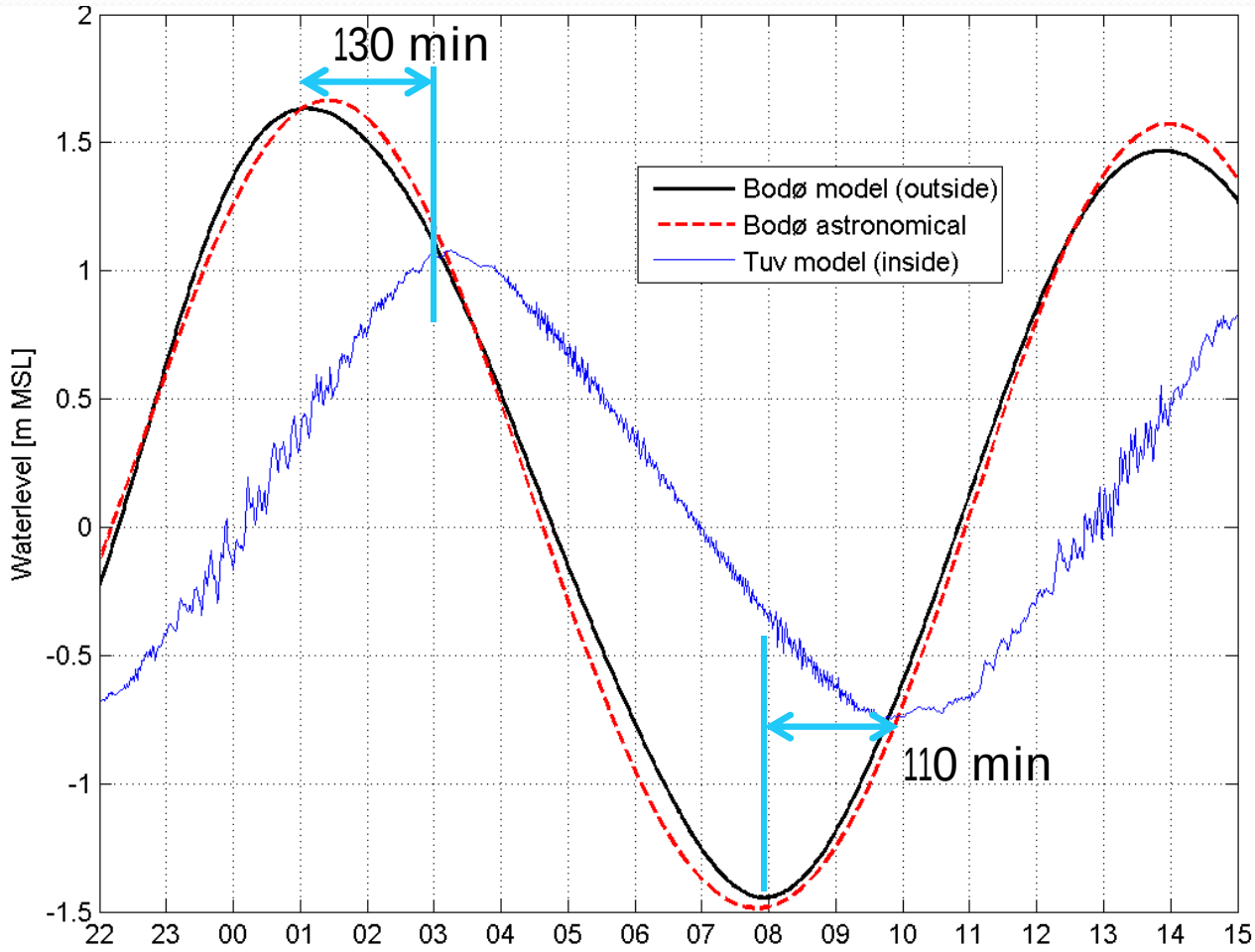
Tidal phase (Tuv: 100 min behind Bodø (kartverket))
Gjevik (2009): observed 130 min behind Bodø



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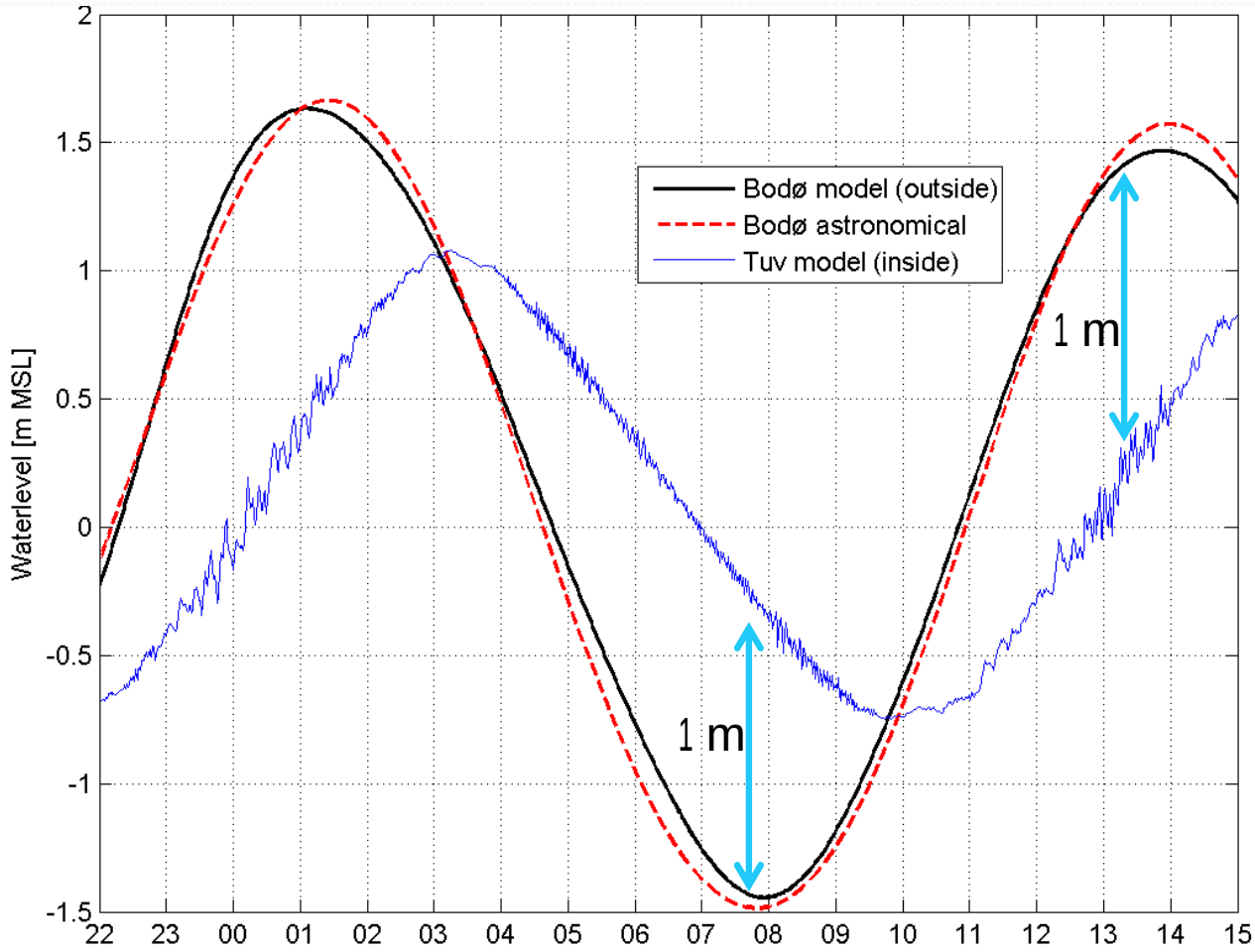
Up to 1m water level difference between in- and outside reported



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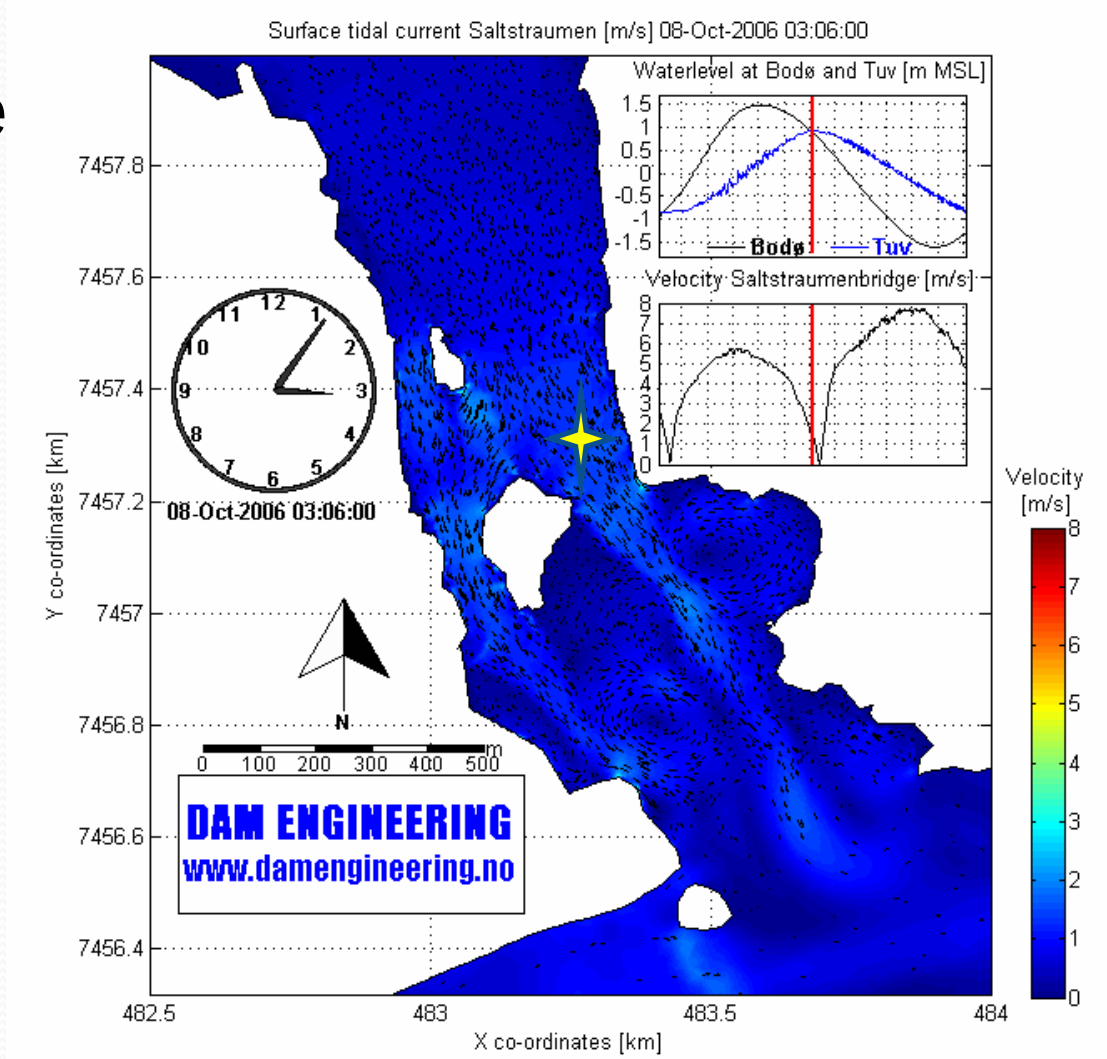
Velocties:

- Animation over one tide (8 oct 2006)
- One minute interval
- Using a log-profile to calculate the surface velocity from depth averaged flow (~10% larger)



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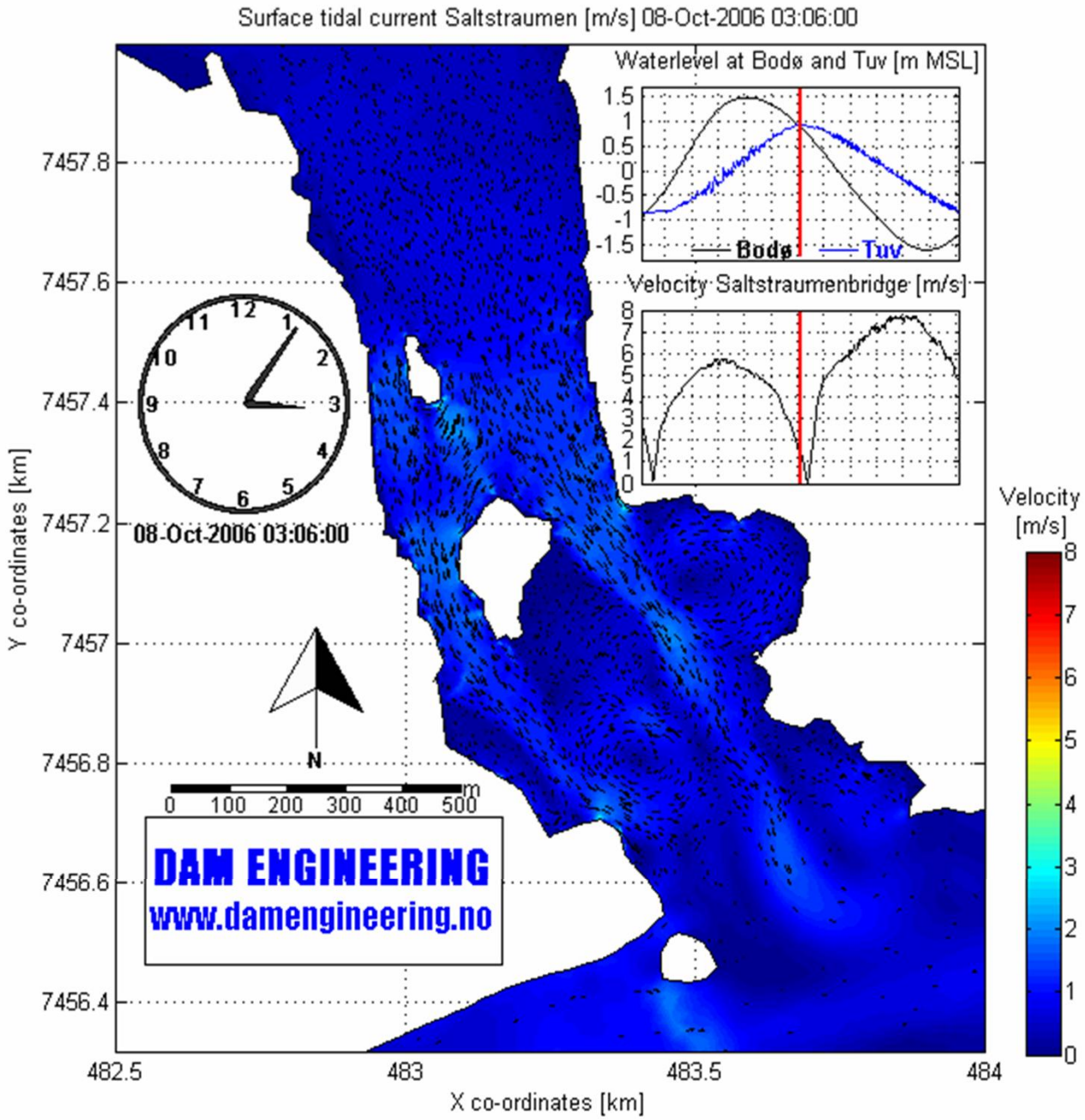
Surface tidal current Saltstraumen [m/s] 08-Oct-2006 03:06:00
Waterlevel at Bodø and Tuv [m MSL]
1.5
1
0.5
0
-0.5
-1
-1.5
Bodø
Tuv
Velocity Saltstraumenbridge [m/s]
8
7
6
5
4
3
2
1
0
08-Oct-2006 03:06:00
N
0 100 200 300 400 500 m
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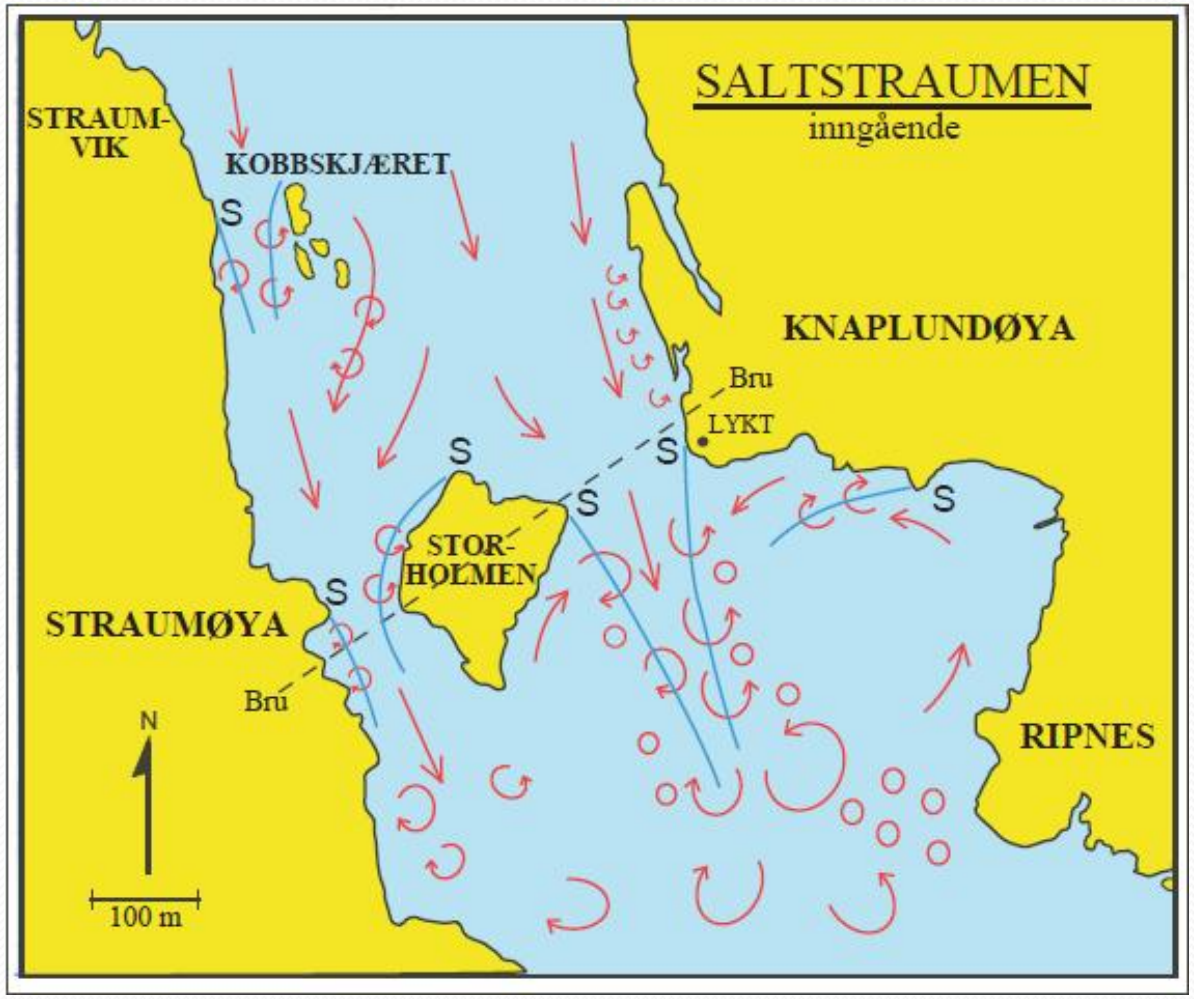
Velocity [m/s]
8
7
6
5
4
3
2
1
0
Y co-ordinates [km]
7457.8
7457.6
7457.4
7457.2
7457
7456.8
7456.6
7456.4
482.5
483
483.5
484
X co-ordinates [km]

Ingoing flow



- Source: Gjevik (2009): Flo og fjære

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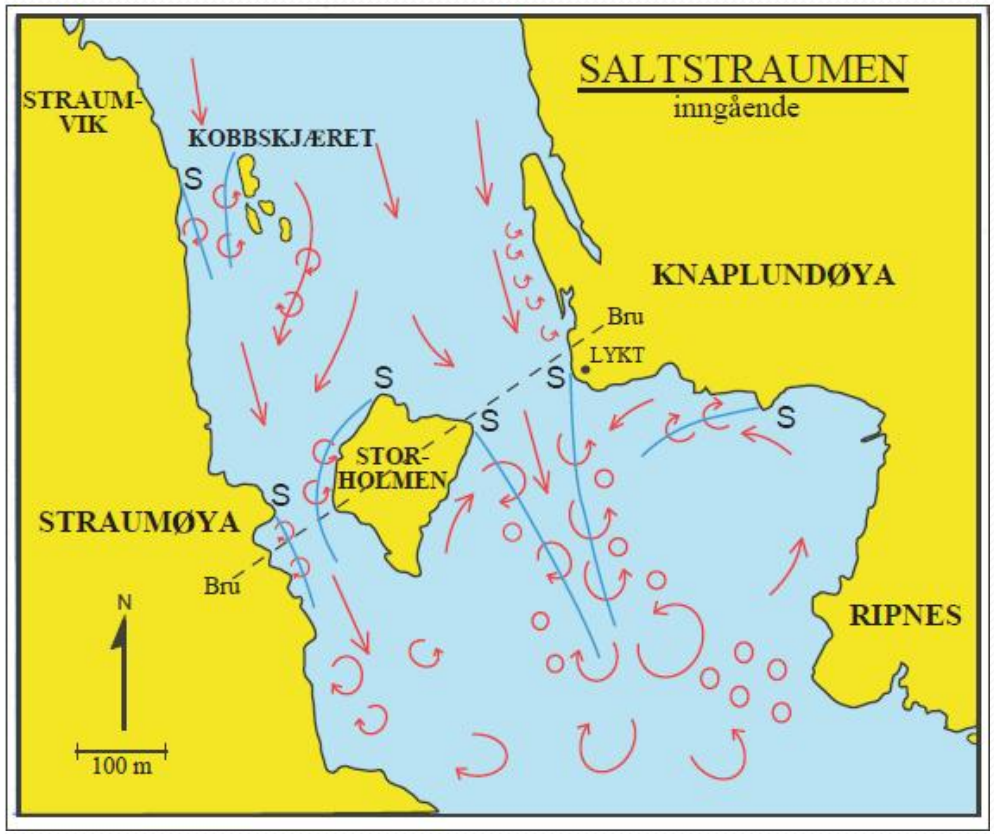
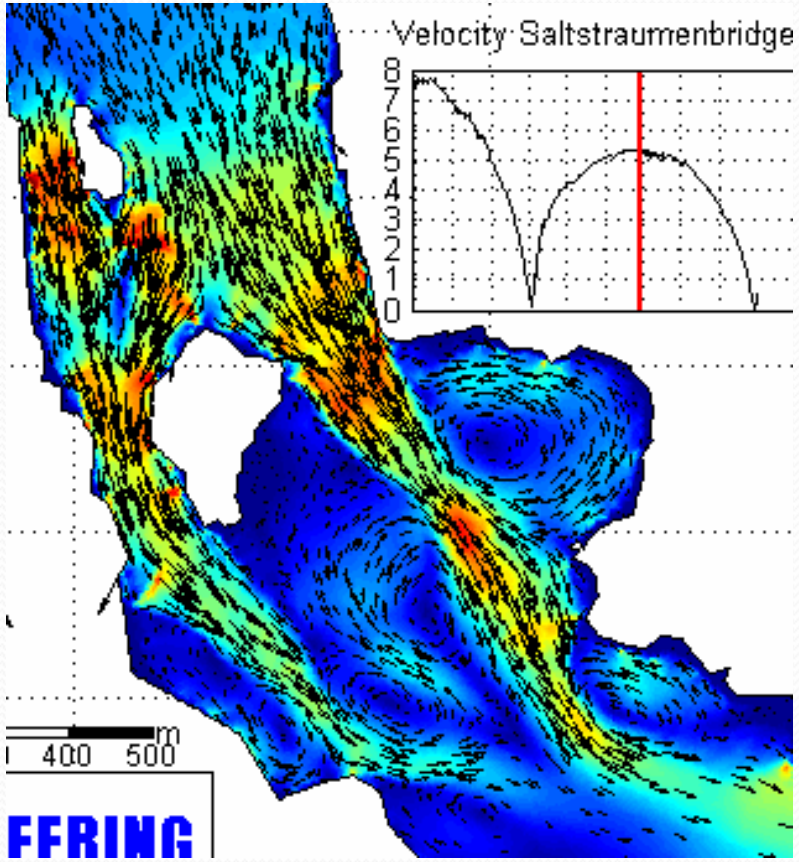
Ingoing flow comparison





- Source: Gjevik (2009): Flo og fjære

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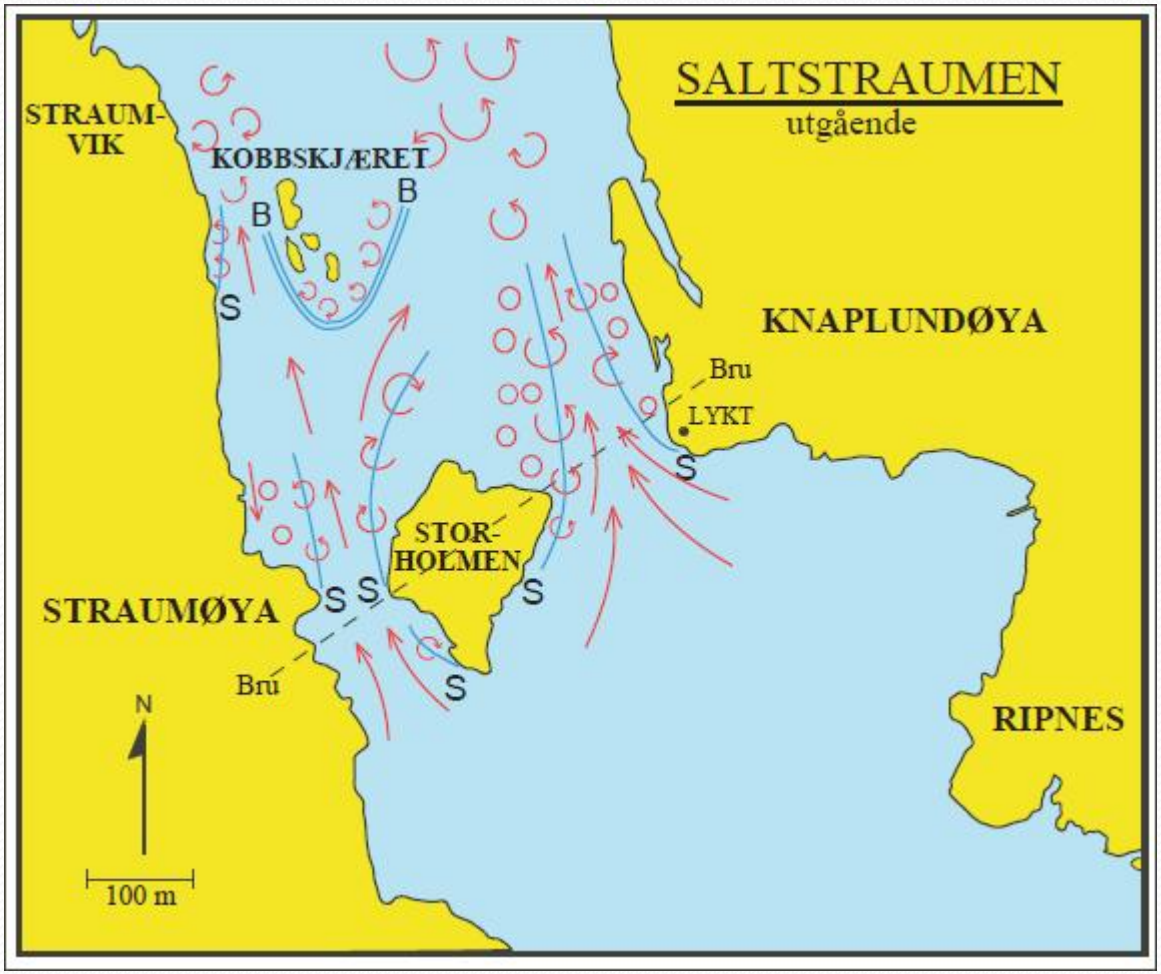
Outgoing flow



- Source: Gjevik (2009): Flo og fjære

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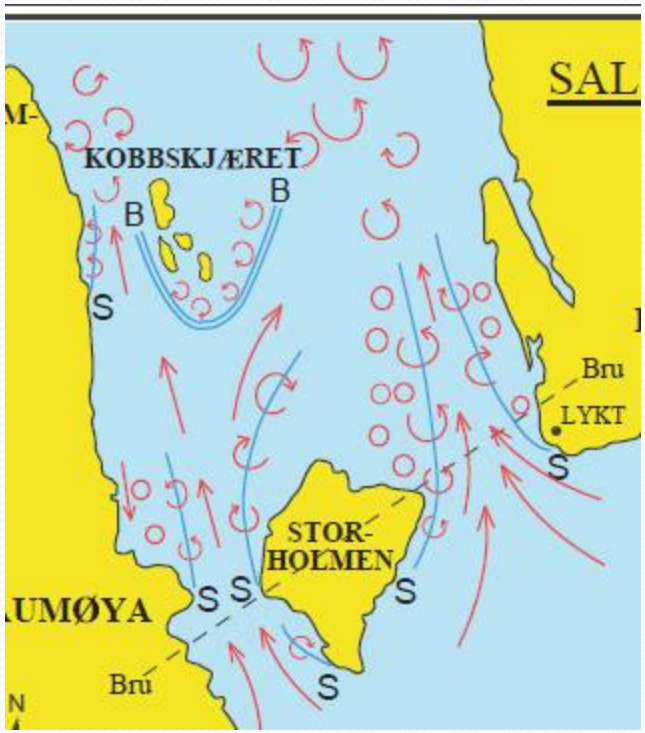
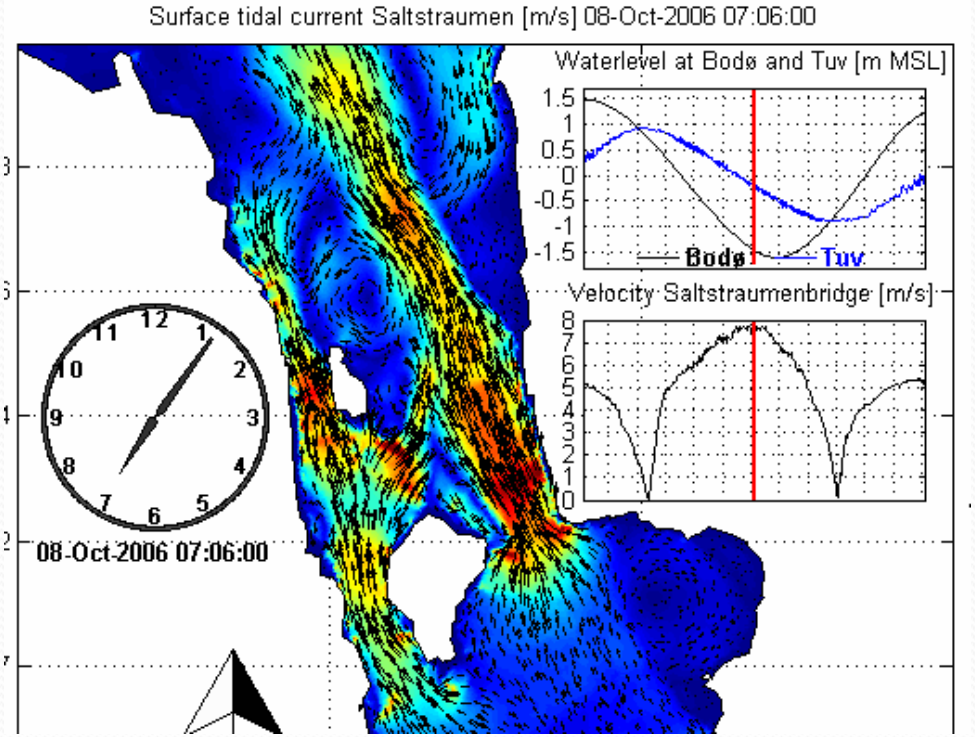
Outgoing maximum flow comparison





- Source: Gjevik (2009): Flo og fjære

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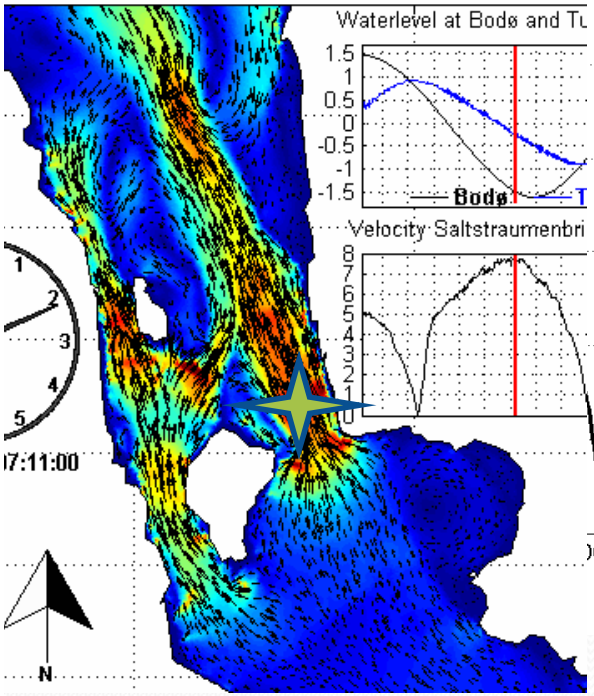
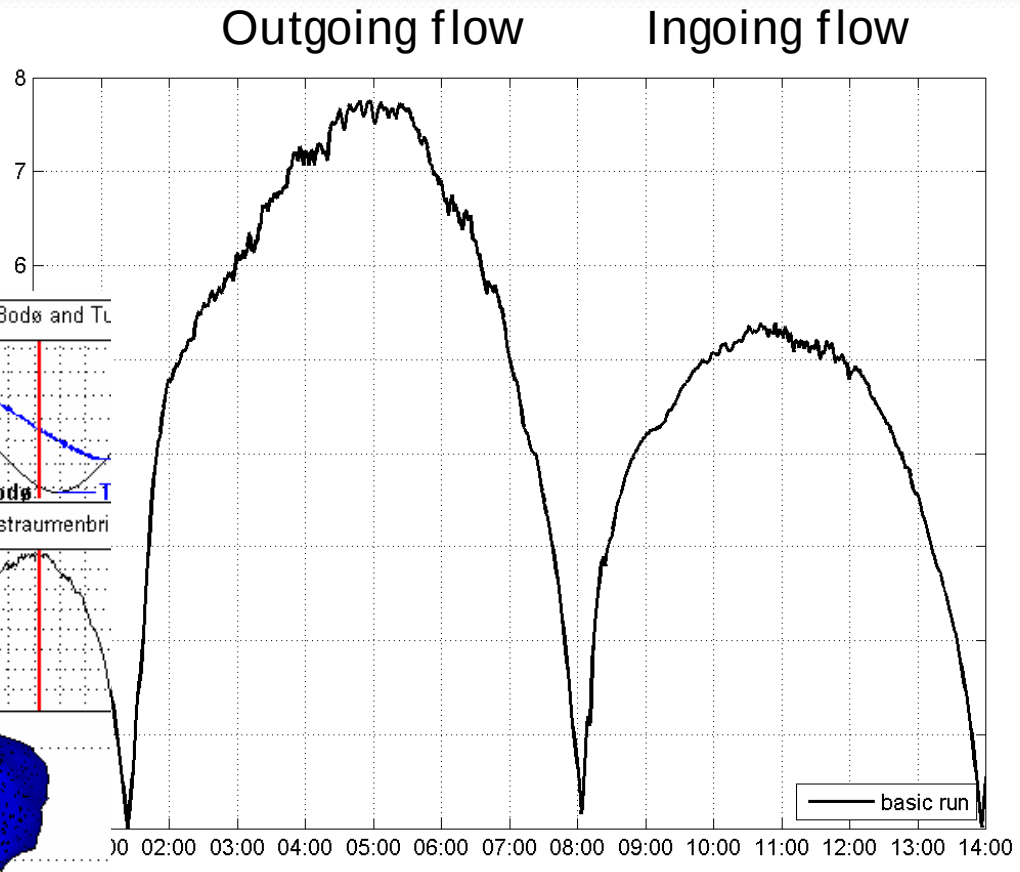
Sensitivity checks, default run:





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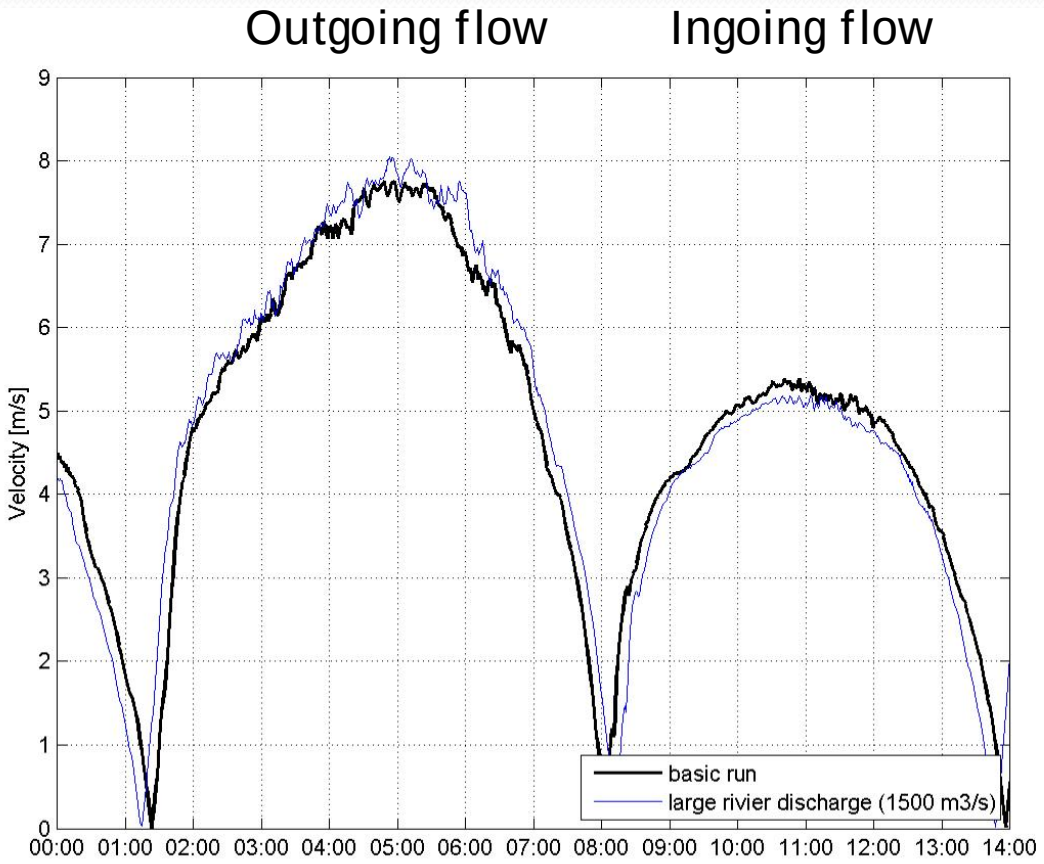
Sensitivity: large river discharge: 1500 m^3/s; ~1/30 year event; (Arctic-hype model - SMHI)



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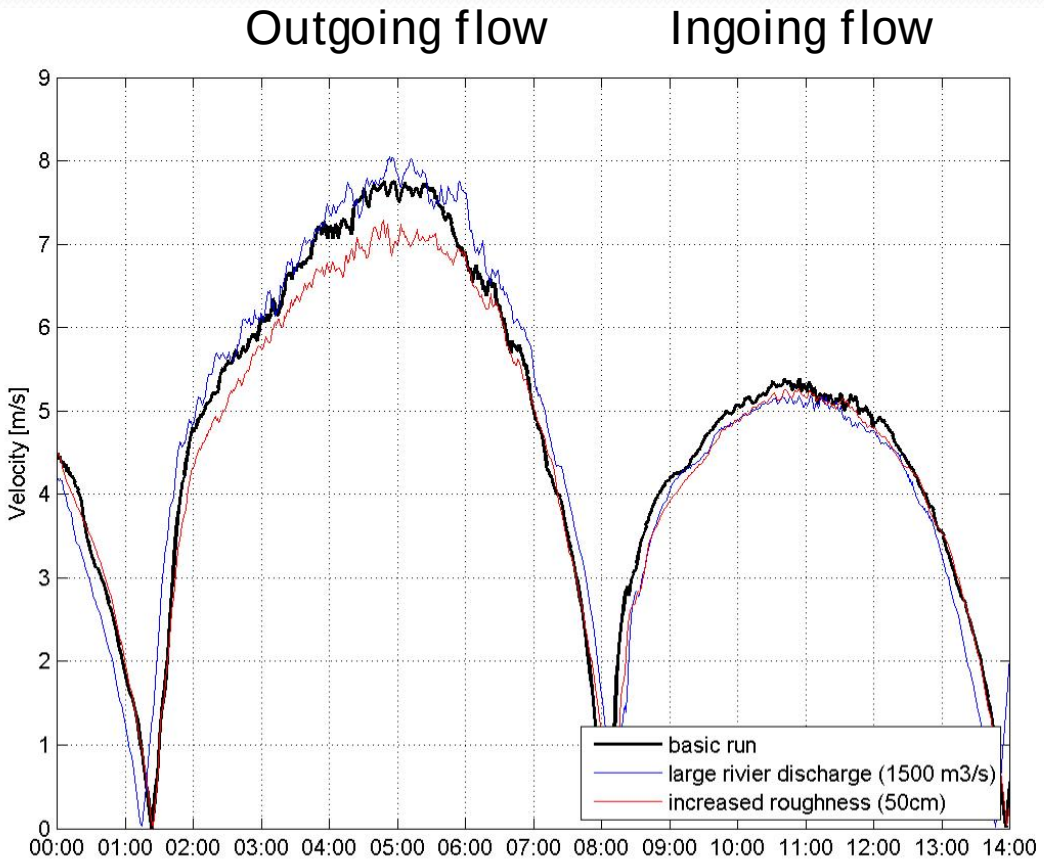
Sensitivity: increased roughness (default=1cm roughness; now 50cm)



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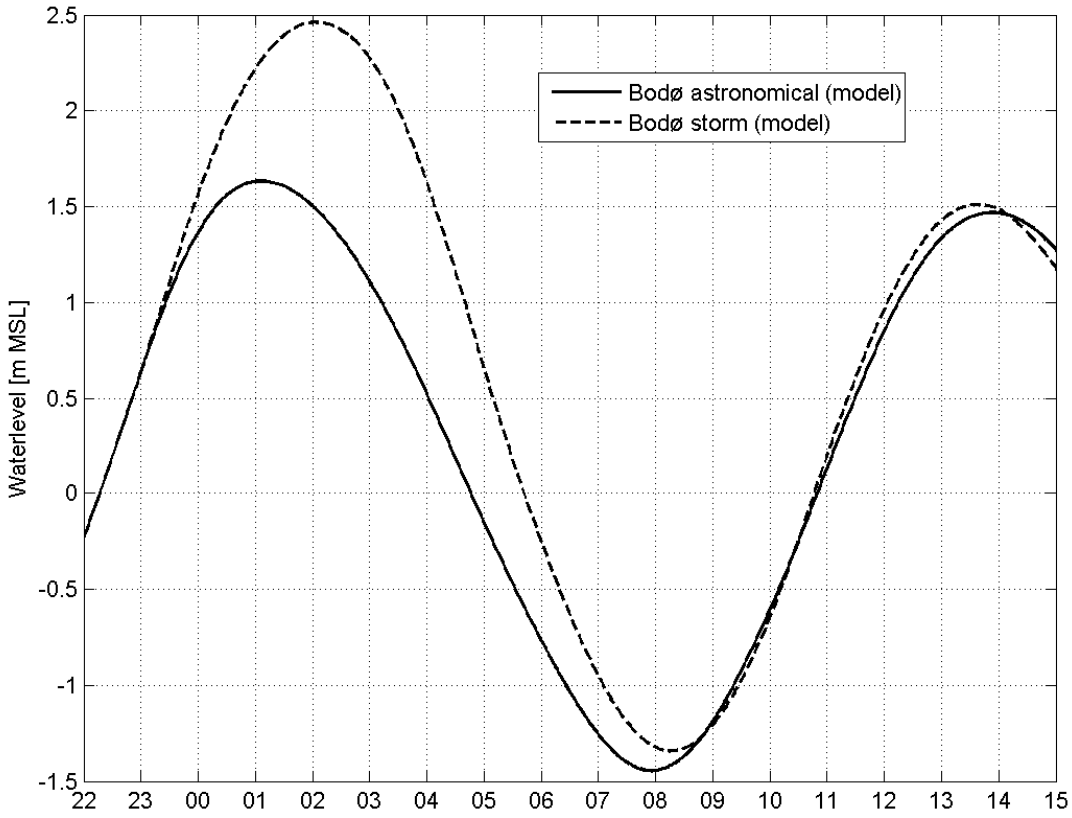
Sensitivity: large storm surge: 62 cm extra tidal range in Bodø (in total 3.8m tidal range)



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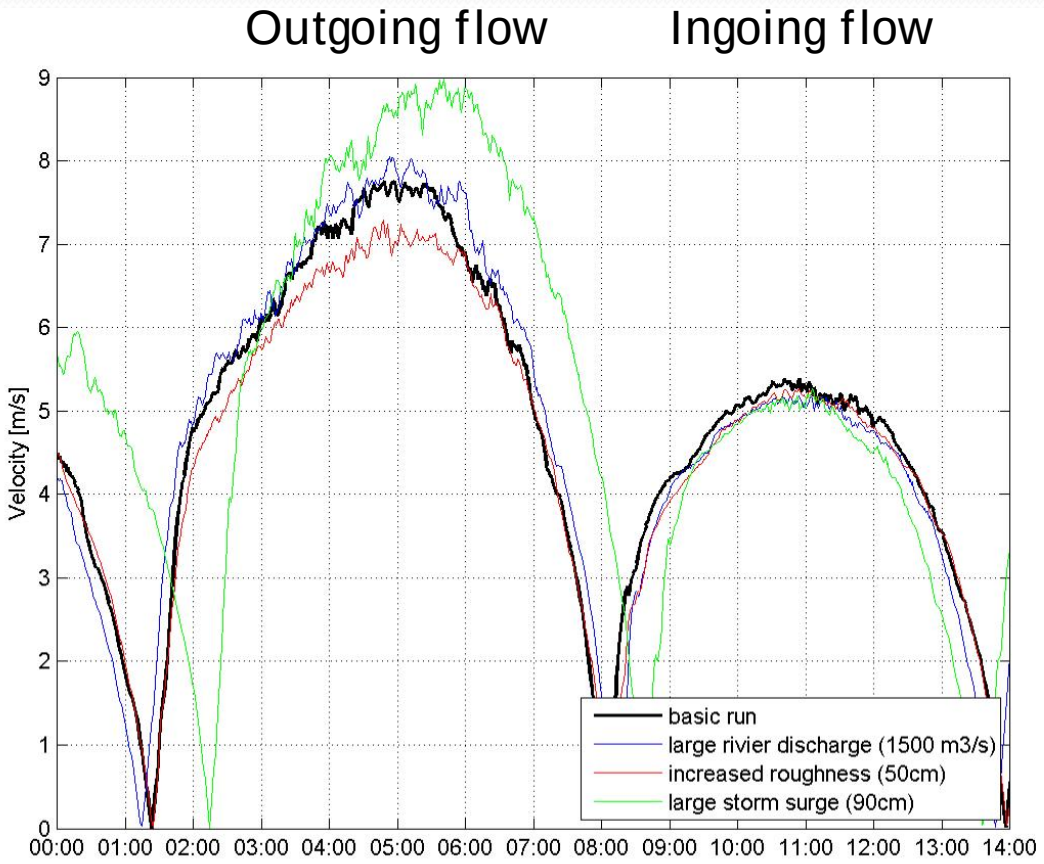

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What now?

- Still no velocities >10 m/s

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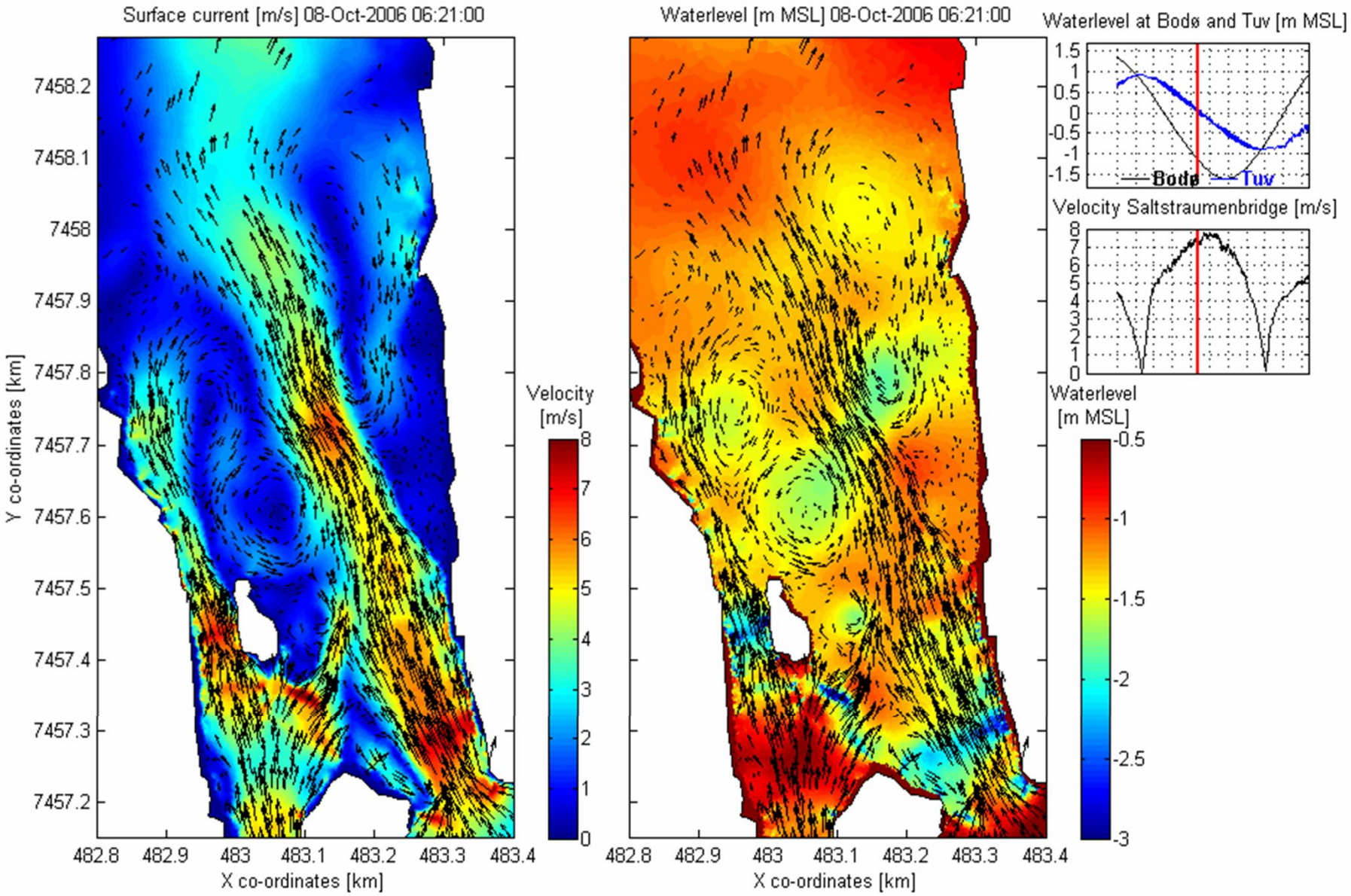
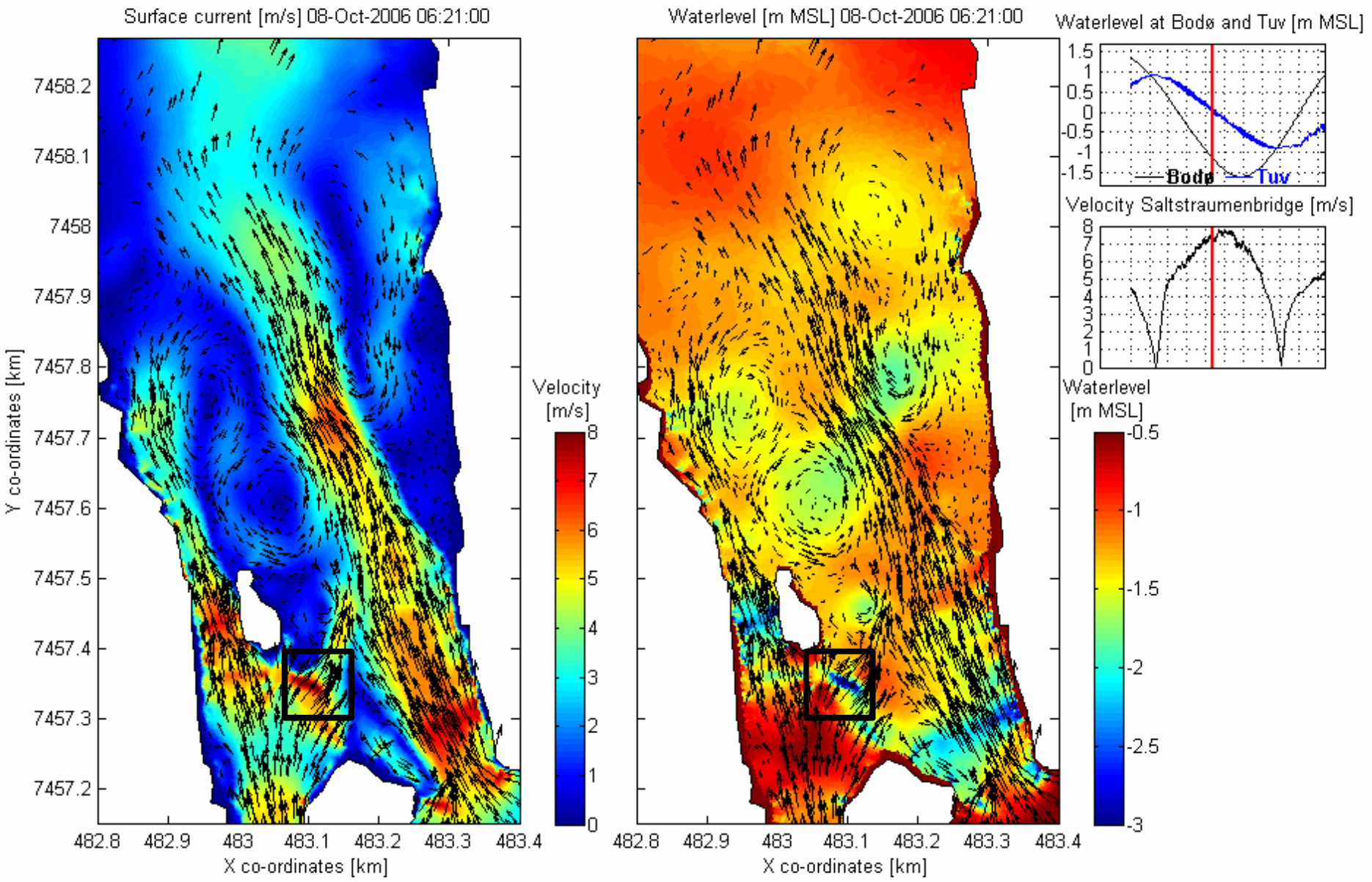
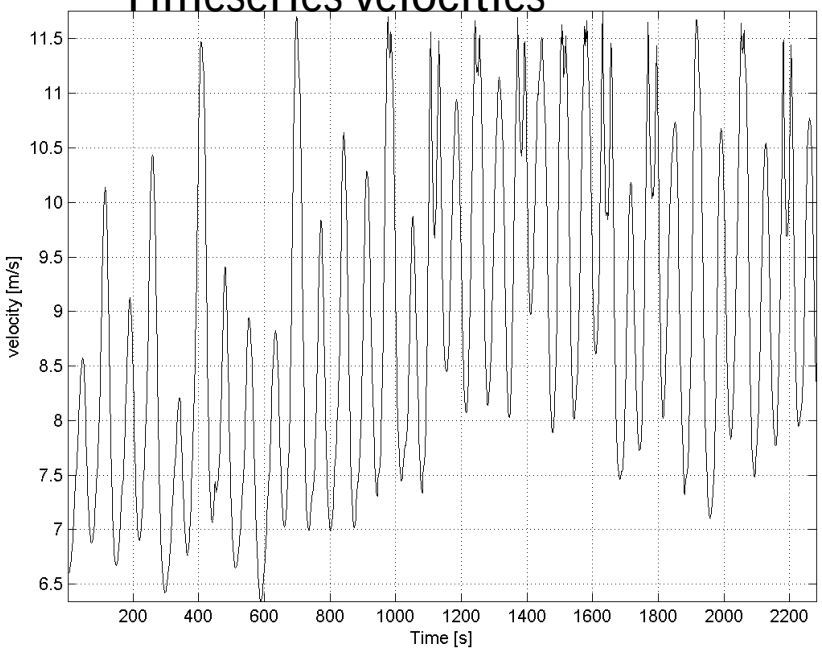

Surface current [m/s] 08-Oct-2006 06:21:00
Waterlevel [m MSL] 08-Oct-2006 06:21:00
Waterlevel at Bodø and Tuv [m MSL]
Bodø
Tuv
Velocity Saltstraumenbridge [m/s]
Velocity [m/s]
Waterlevel [m MSL]
Y co-ordinates [km]
X co-ordinates [km]
X co-ordinates [km]

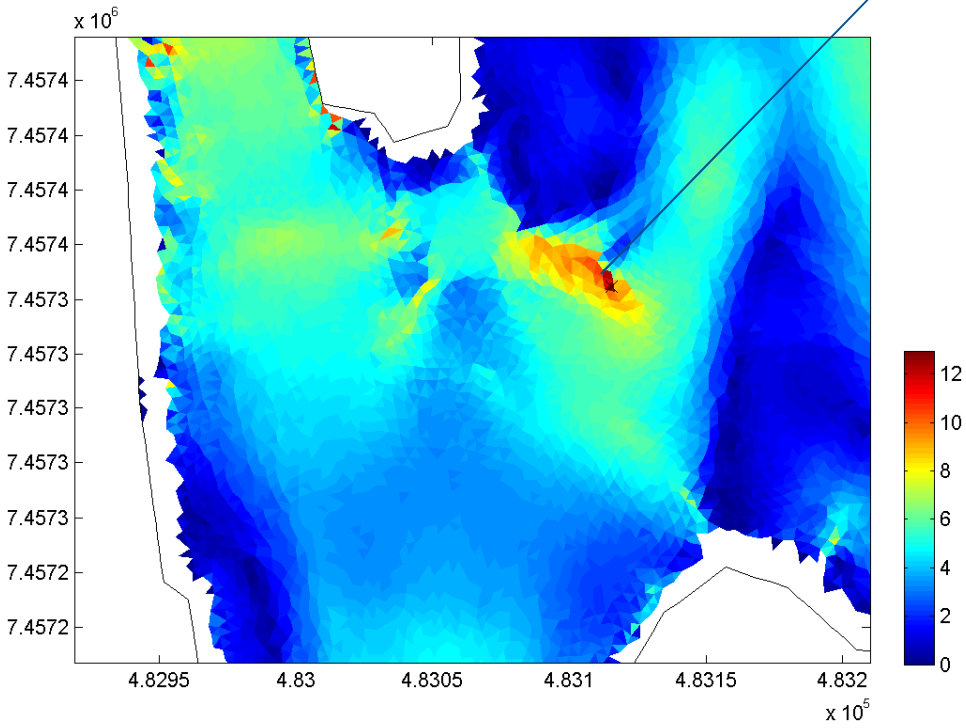

Surface current [m/s] 08-Oct-2006 06:21:00
Waterlevel [m MSL] 08-Oct-2006 06:21:00
Waterlevel at Bodø and Tuv [m MSL]
Bodø
Tuv
Velocity Saltstraumenbridge [m/s]
Velocity [m/s]
Waterlevel [m MSL]
Y co-ordinates [km]
X co-ordinates [km]
X co-ordinates [km]
7458.2
7458.1
7458
7457.9
7457.8
7457.7
7457.6
7457.5
7457.4
7457.3
7457.2
482.8
482.9
483
483.1
483.2
483.3
483.4

Cross-channel

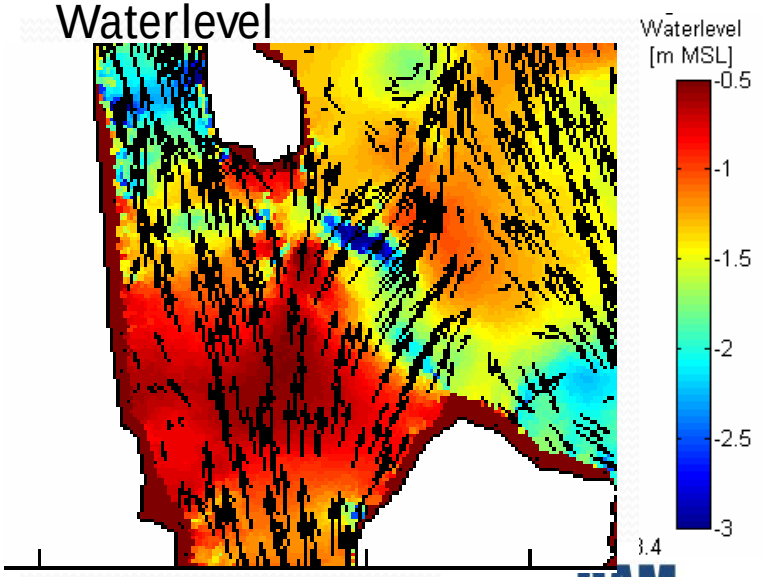
Timeseries velocities



Velocities maximum outflow



Waterlevel



Shallow area (~8m deep); Supercritical flow and hydraulic jump reported here by Gjevik (2009) with lots of turbulence!

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Conclusions so far:

- You get a long way with this 2Dh approach
- In main channel velocities up to 8m/s can be reached by model during high springtides
- In storm conditions/ high river discharge this can be higher, but unlikely to be higher than 10 m/s
- In cross-channel super critical flow occurs in model with spots >10 m/s.
- Overall conclusion: do we get >10 m/s?
- Plausible

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Future outlook:

- Extent the model in 3D to see if main channel velocities become higher

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www.damengineering.no/saltstraumen.html

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