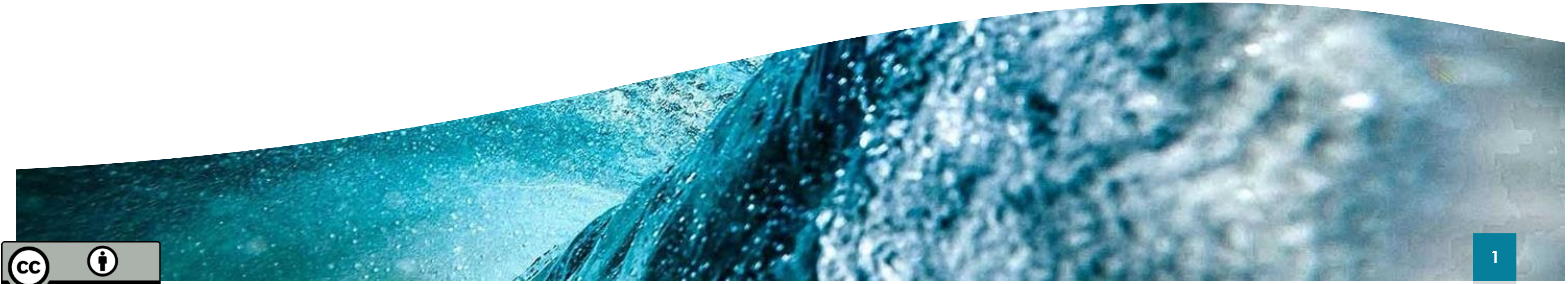
From small-scale ripples to large-scale sand transport

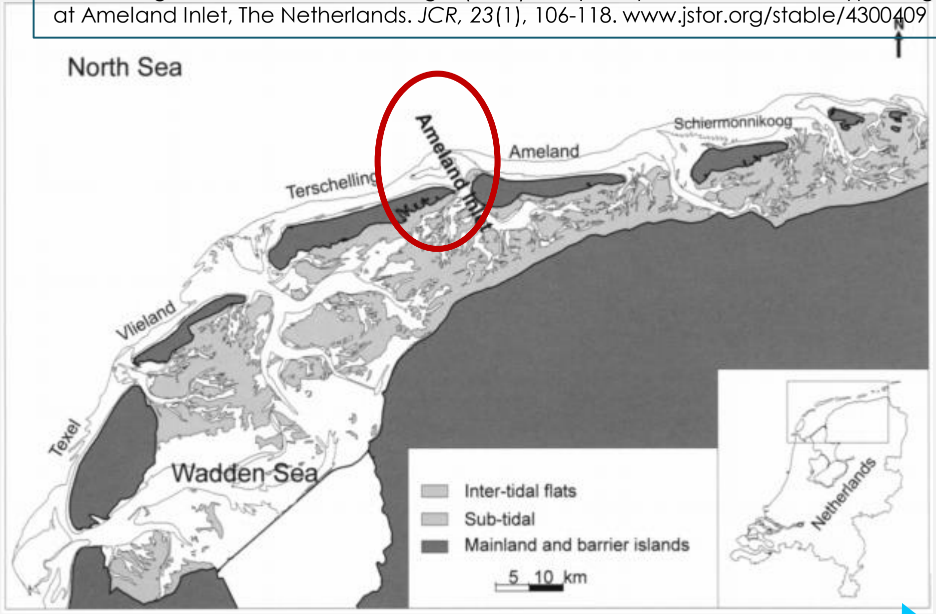
The effects of bedform-related roughness on hydrodynamics and sediment transport patterns in Delft3D

Laura Brakenhoff, Jebbe van der Werf, Bart Grasmeijer, Reinier Schrijvershof, Gerben Ruessink and Maarten van der Vegt



Introduction

KF Cheung, F Gerritsen, & J Cleveringa. (2007). Morphodynamics and Sand Bypassing at Ameland Inlet, The Netherlands. *JCR*, *23*(1), 106-118. www.jstor.org/stable/4300409

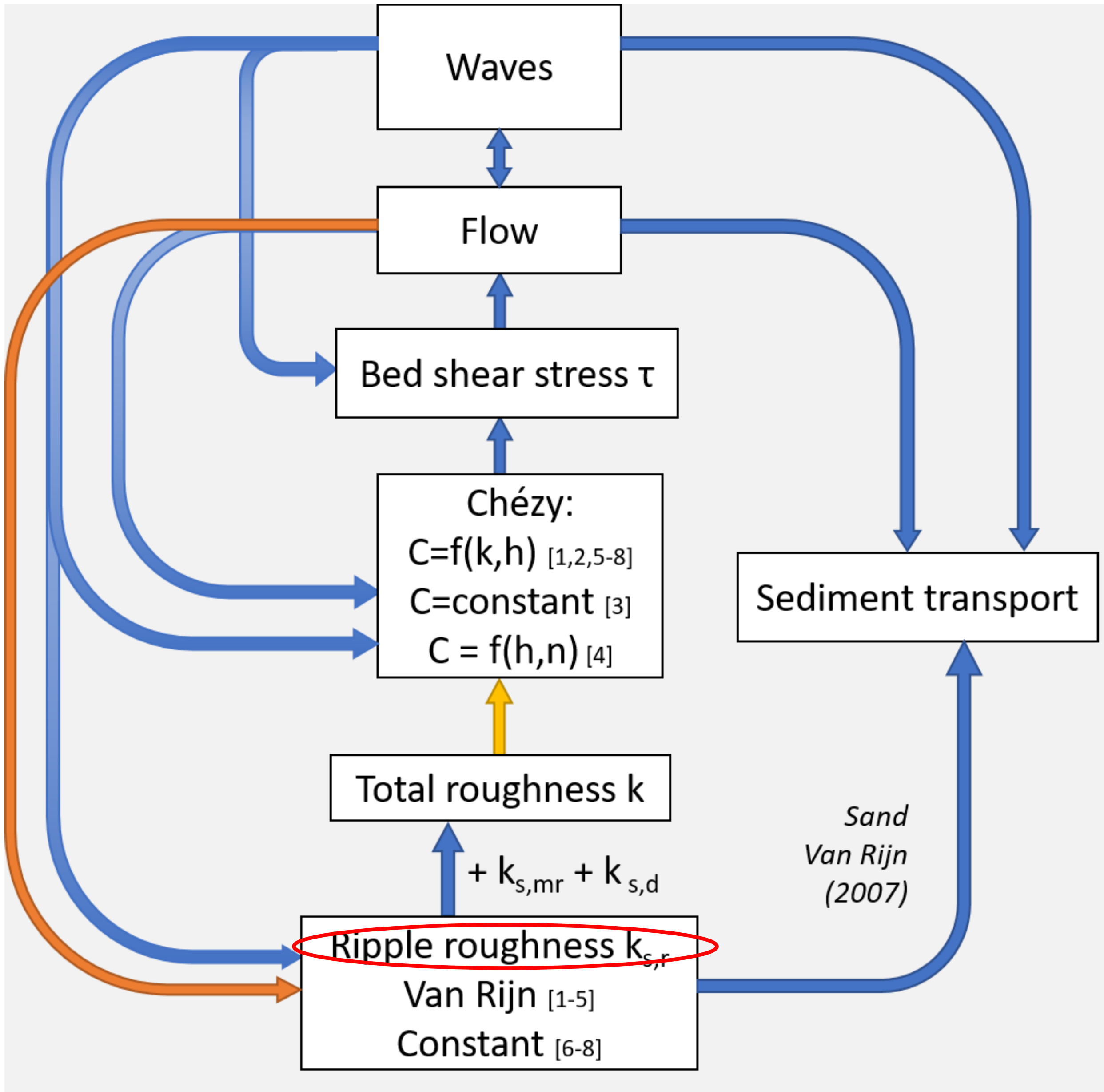


- Problem:
  Bedforms (ripples, mega ripples, dunes) cause roughness
  This roughness cannot be measured, so in models it is often parameterized
  Parameterization can be done with a spatio-temporally constant value, or with a roughness height depending on wave- and current velocity
  Ebb-tidal deltas are wave-current dominated environments, for which roughness height predictors are not thoroughly tested: uncertainty in modelled transport predictions unknown
  We now have measurements of bedform heights and hydrodynamics for the Ameland ebb-tidal delta (NL) in September 2017, for both calm and storm conditions

- Aim: find the importance of the ripple-related bedform roughness component for the calculation of hydrodynamics and sediment transport

- Approach: test sensitivity of modeled hydrodynamics and sediment transport to roughness parameterization in Delft3D.

Interaction of roughness, hydrodynamics and sediment transport in Delft3D



Model scenarios

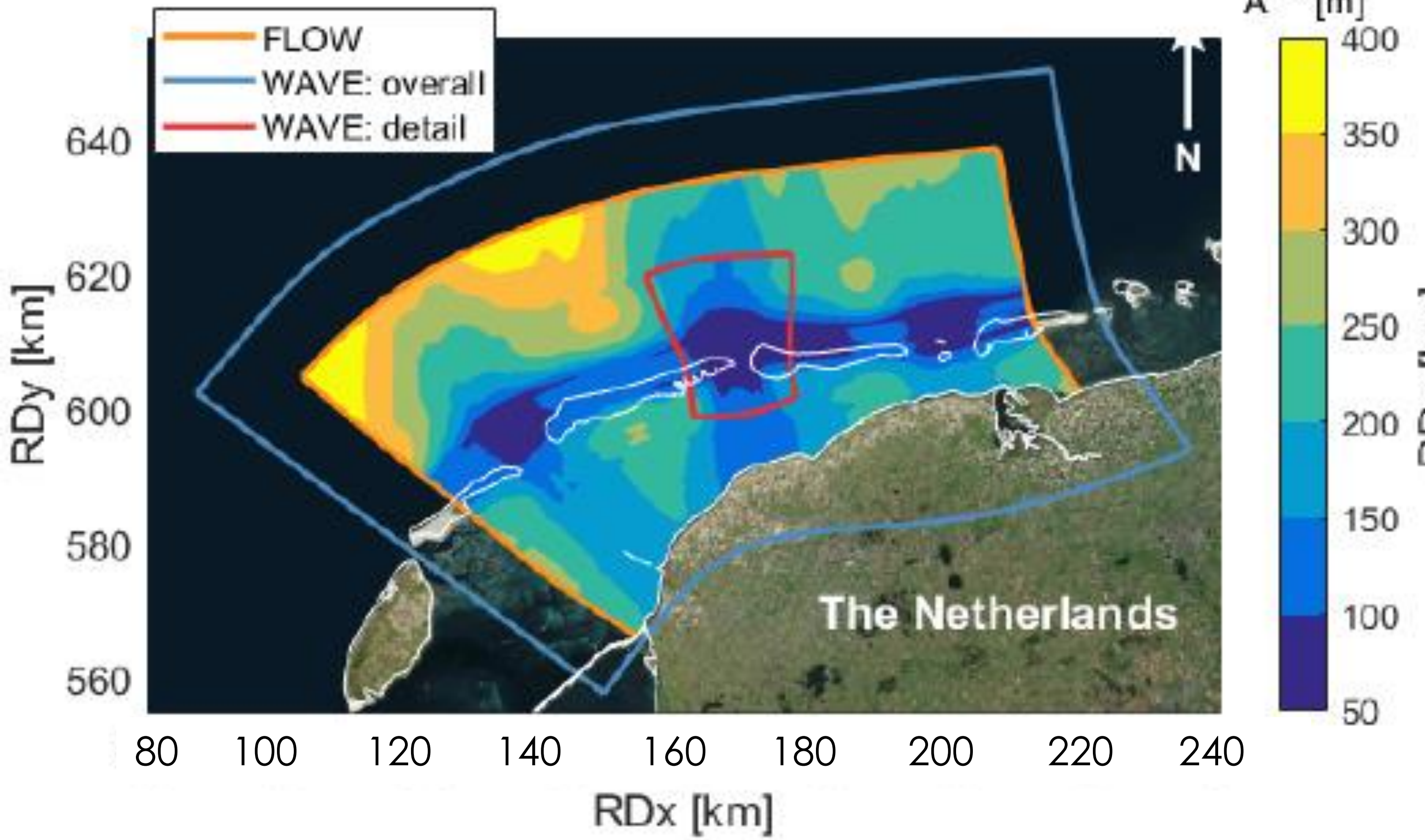
- Roughness calculated with Van Rijn (2007) x0.5 (="1. base")
- Roughness calculated with Van Rijn (2007) x1 (="2. high")
- Spatio-temporally constant Chézy value → removes interaction indicated by yellow arrow (="3. chezy")
- Spatio-temporally constant ripple height → removes interaction indicated by orange arrow (="4. constant")
- More in paper (to be submitted soon)…
- Ripples and megaripples are used, no dunes

Study site: The Ameland ebb-tidal delta

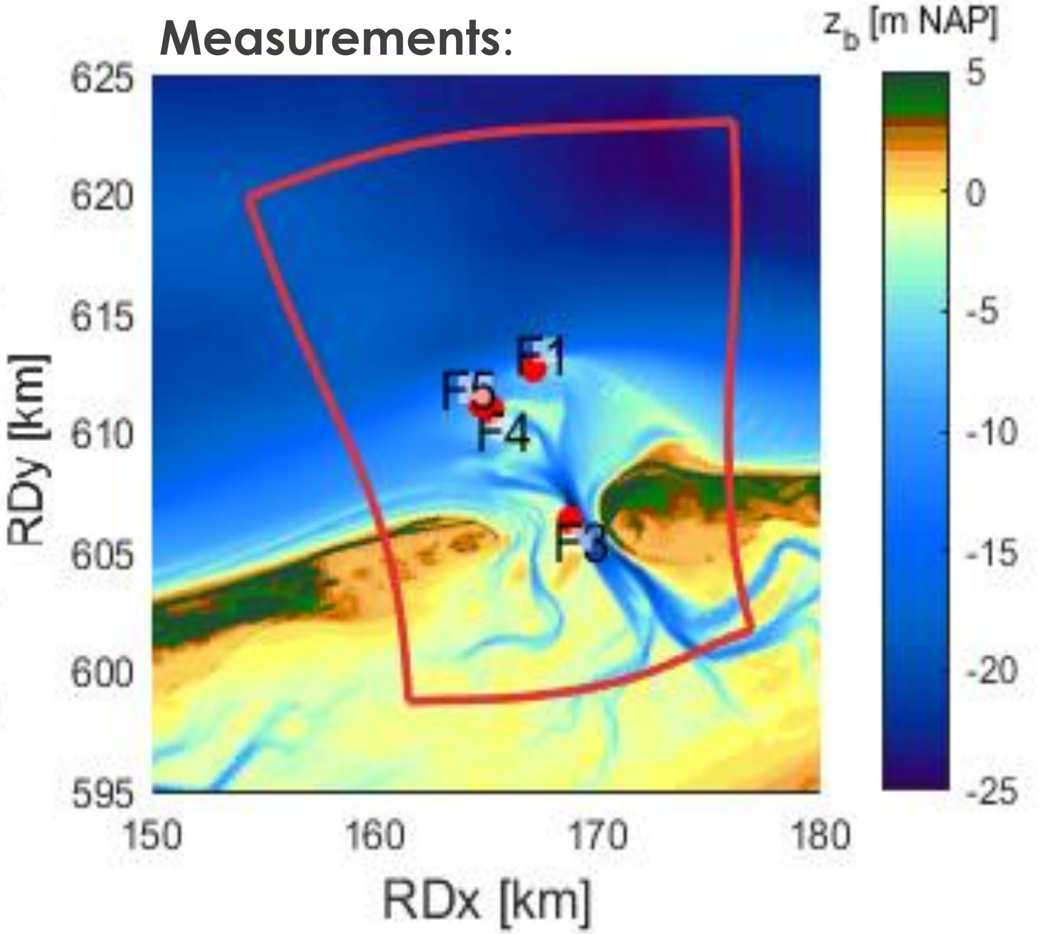
Brakenhoff et al., *ESPL*, 2020

Site	Depth [m]	Wave-current (wc) or current (c)-dominated
F1	8.6	wc
F3	15.1	c
F4	6.5	wc
F5	8.9	wc

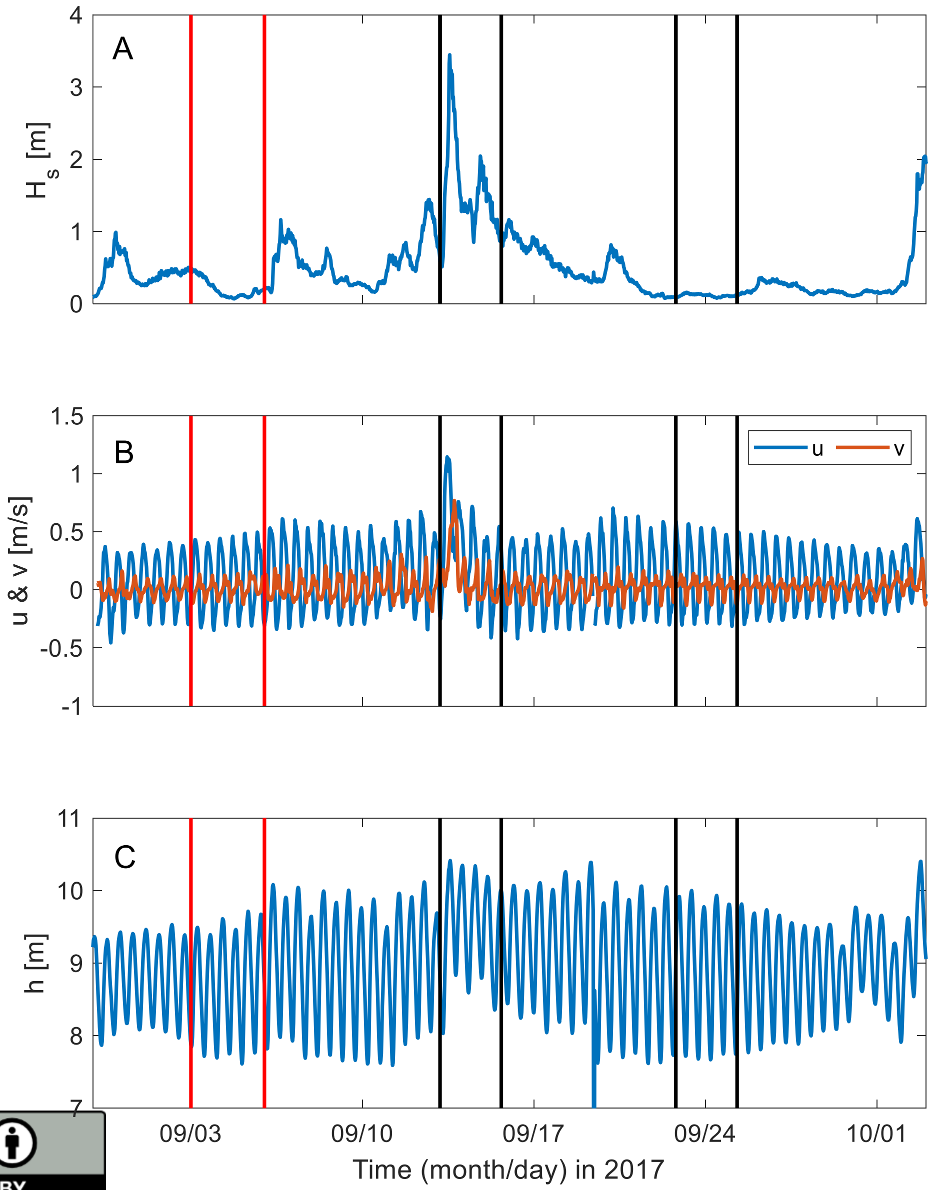
Model:

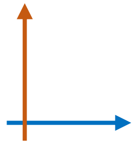


Measurements:



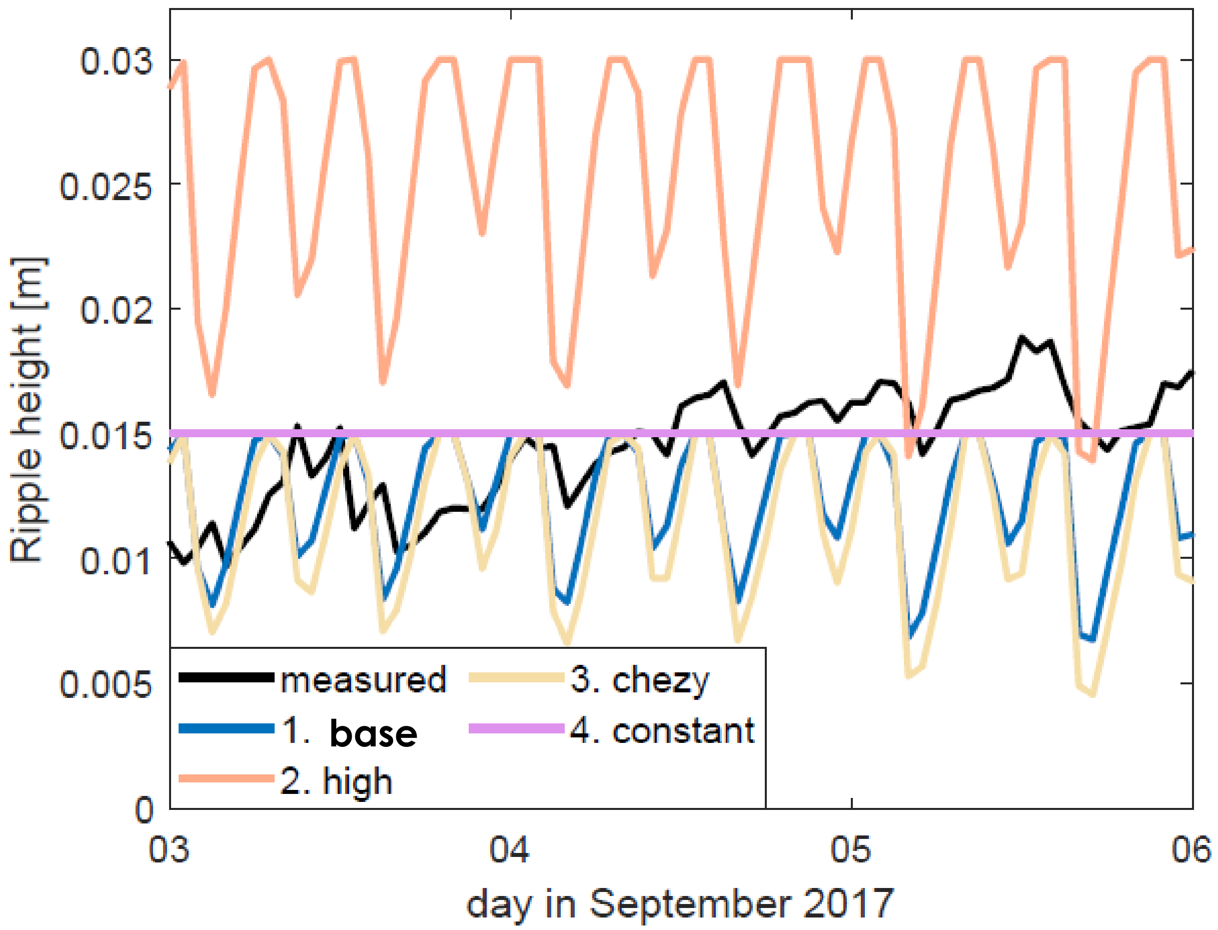
Calm and storm conditions





- Figure shows hydrodynamics at Frame 4
- A = significant wave height
- B = depth-averaged current velocity
- C = water depth
- Storm and calm period, both 36 hours, are indicated by black lines
- Red lines indicate period shown in next slide

Ripple related roughness height - scenarios

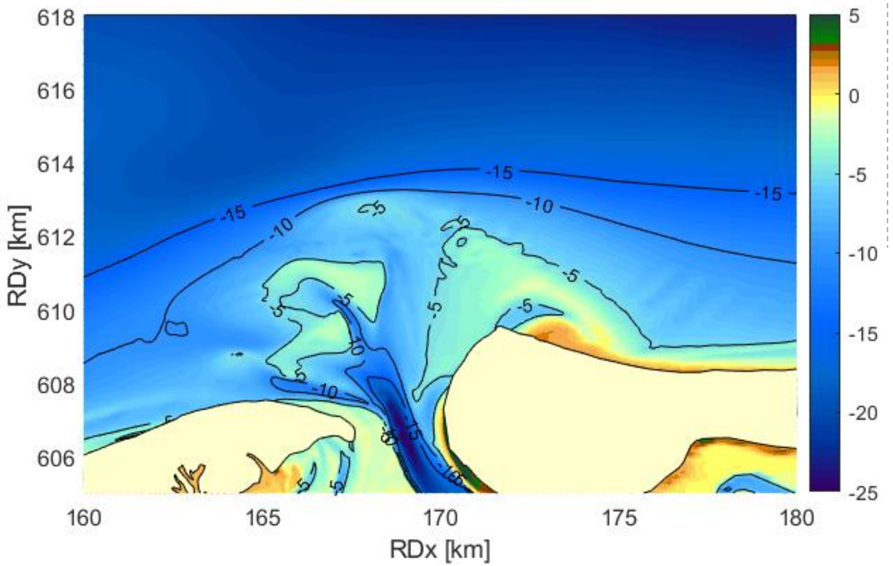


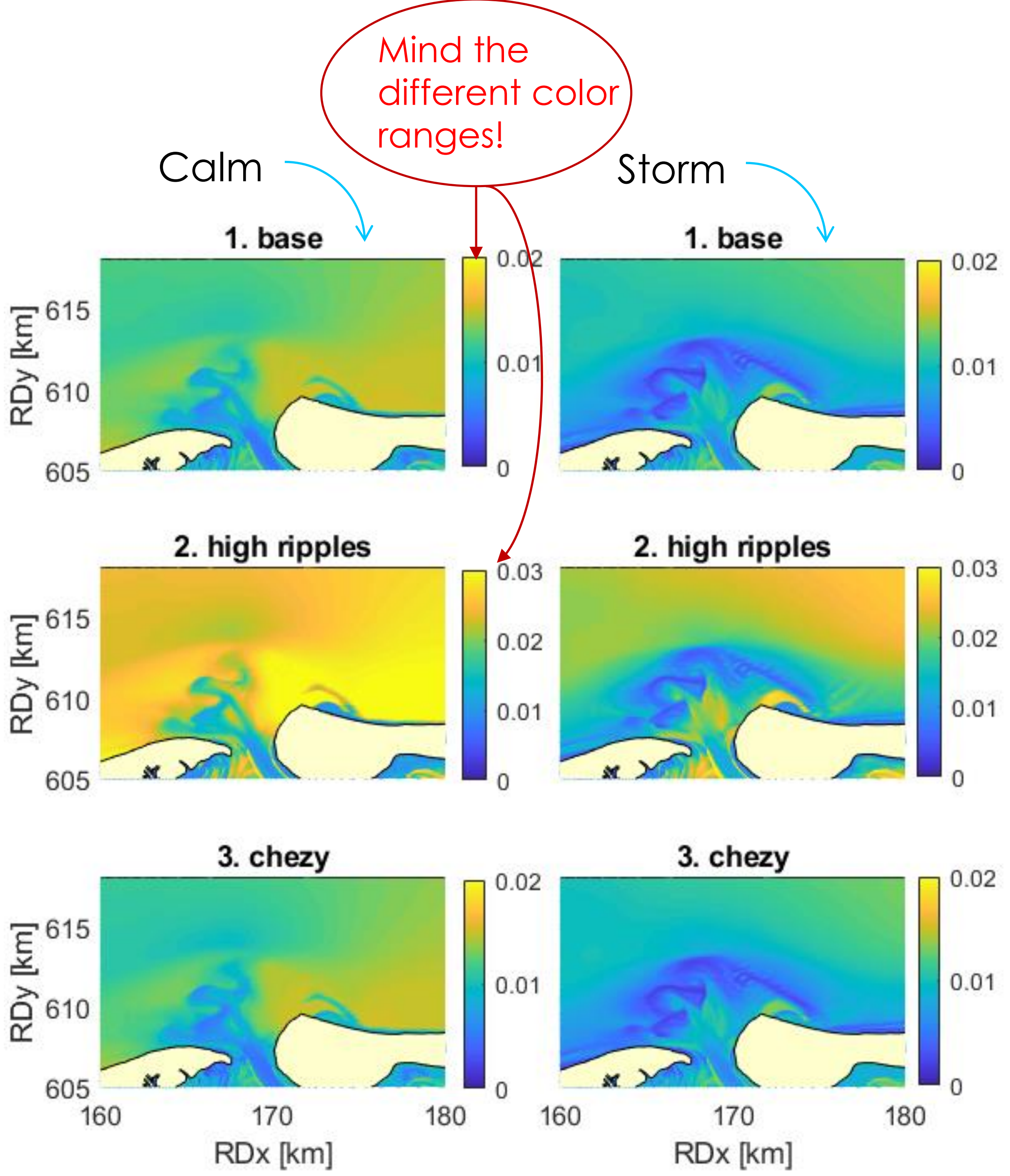
- Figure shows ripple height at Frame 1 for three days in September
- All scenarios are in the range of actual ripple heights
- Scenarios 1-3 use the Van Rijn ripple roughness height predictor, which clearly depends on the current velocity
- Measured ripple height (black line) is much less dependent on current velocity (see also Brakenhoff et al., *ESPL*, 2020)
- Scenario 3 is highly similar to scenario 1, because it is still calculated based on hydrodynamics, only the coupling between roughness and hydrodynamics is removed (see slide 3)

Calm and storm conditions

- Figure shows mean ripple height during calm and storm period
- Ripples are higher during calm weather
- Highest ripples on the shoals
- Calm weather: lowest ripples in the channel
- Storm: lowest ripples at the edges of the delta
- [In scen. 4 the ripples were always forced to be 0.015 m, so no effect of hydrodynamics]

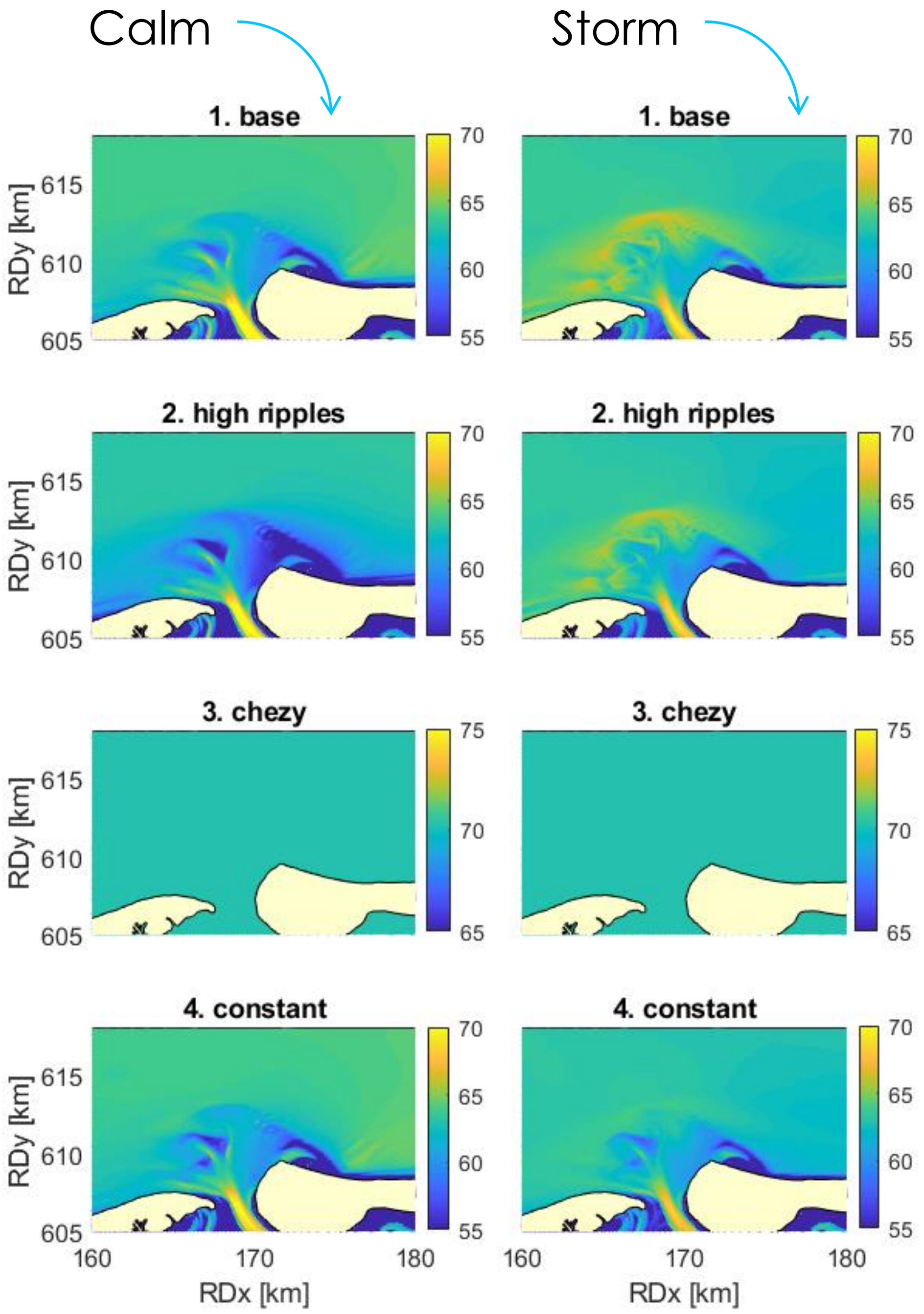
Bathymetry:





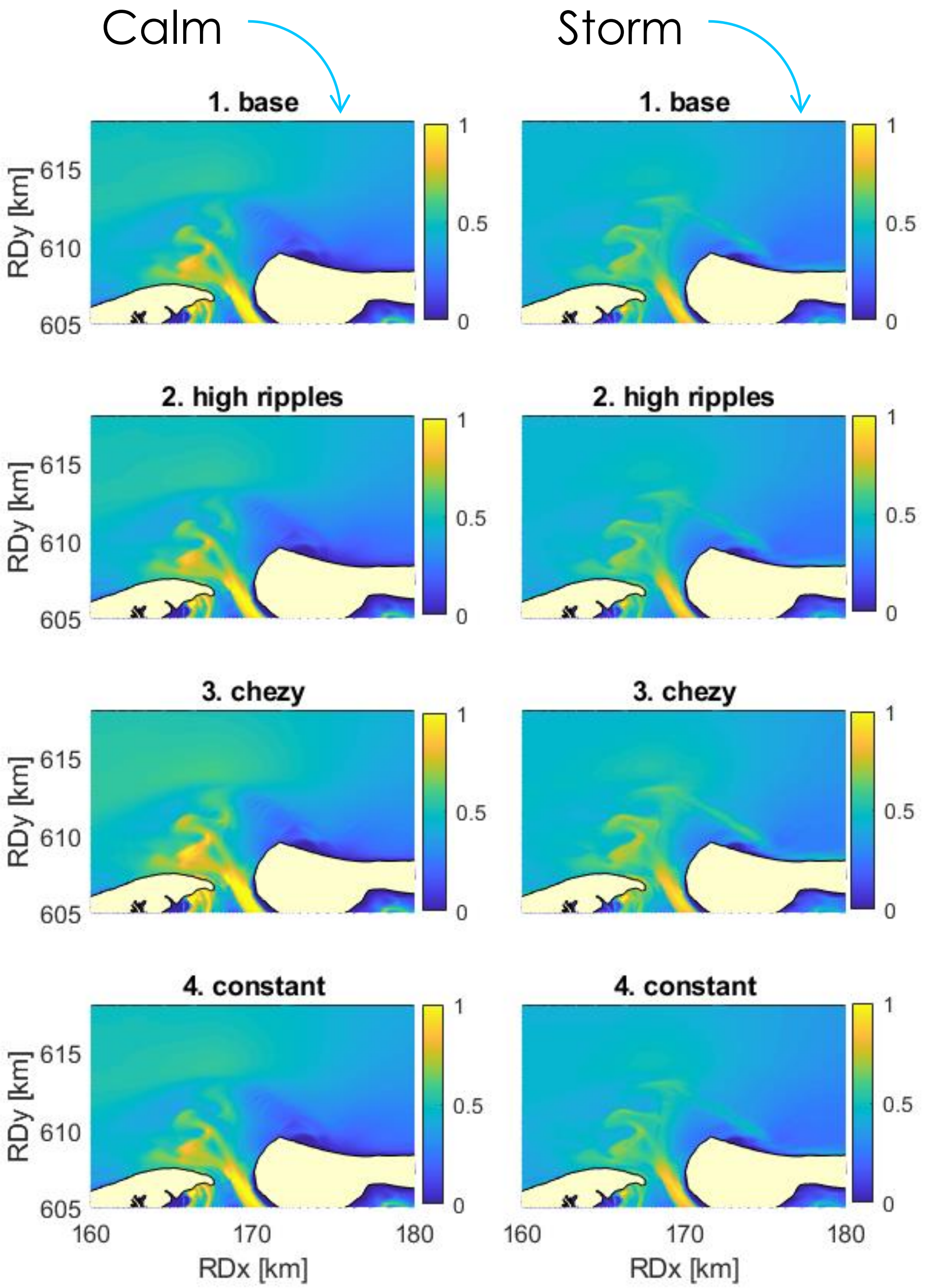
Chézy values

- Figure shows mean Chézy value during calm and storm period
- Chézy values are higher during storms
- Highest Chézy in the channel
- Scenario 2: higher ripples → lower Chézy, mainly during calm weather and in the shallow areas
- Scenario 3: forced constant Chézy, so no effect of hydrodynamics
- Scenario 4: main difference with scenario 1 is found during storm, Chézy factor is lower at the shoals



Current velocity

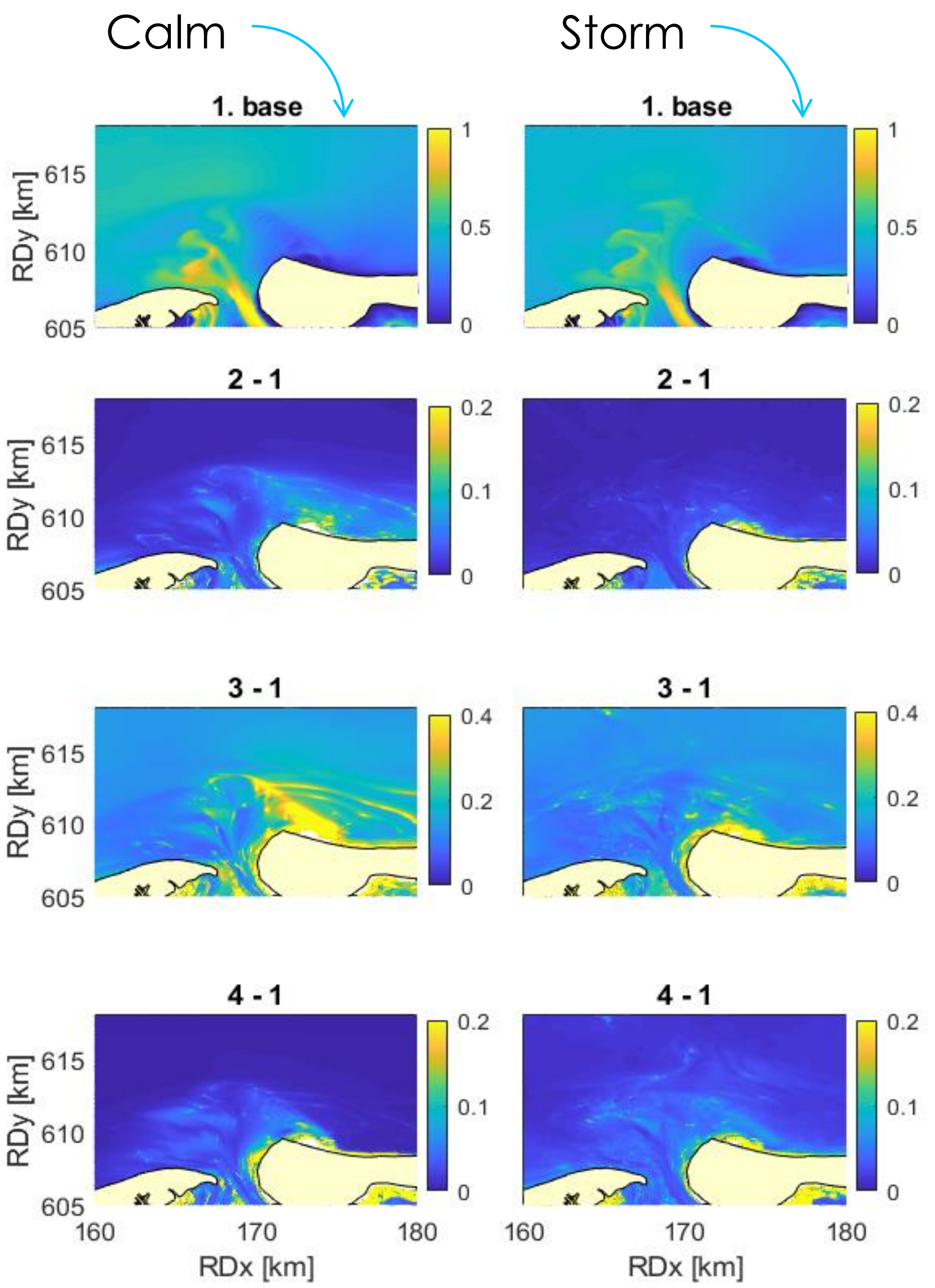
- Figure shows mean depth-averaged current velocity during calm and storm period
- Difficult to see any differences between the scenarios, right?
- Therefore, we calculated the difference between all scenarios and the base scenario....



Current velocity

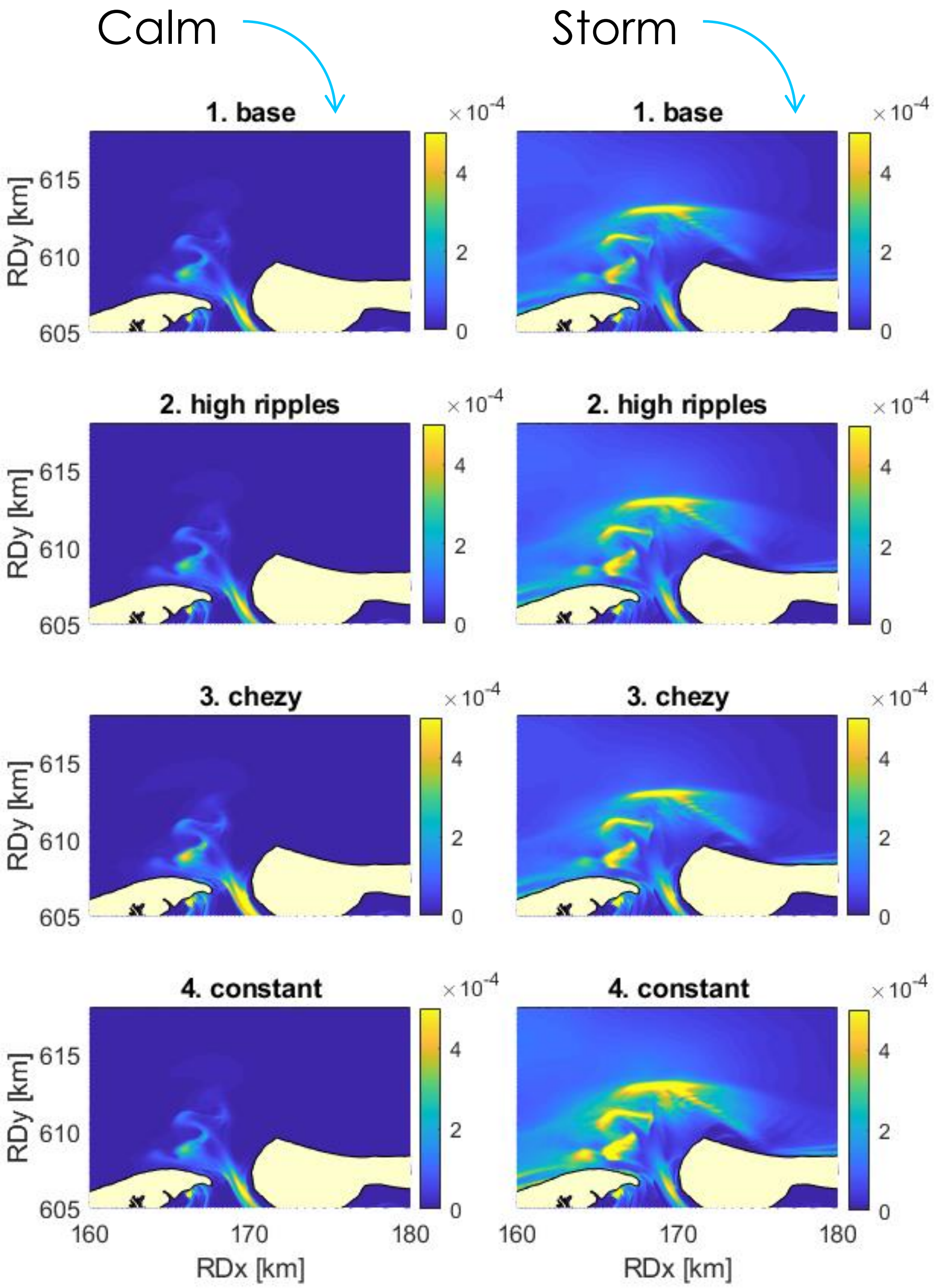
- Figure: top panels are the same as last slide, other 6 panels show mean absolute relative difference in velocity with base scenario during calm and storm period
- Differences are 0-40% of the original velocity (=max. several cm/s)
- Largest differences for the shallow areas in calm weather at scenario 3
- Scenarios 2 and 4: differences at the ebb-tidal delta in the order of 5-10%, with the smallest differences for scenario 4
- Differences in direction are smaller, and are therefore not shown

$$mard(x,y) = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{runx - run1}{run1}\right|$$



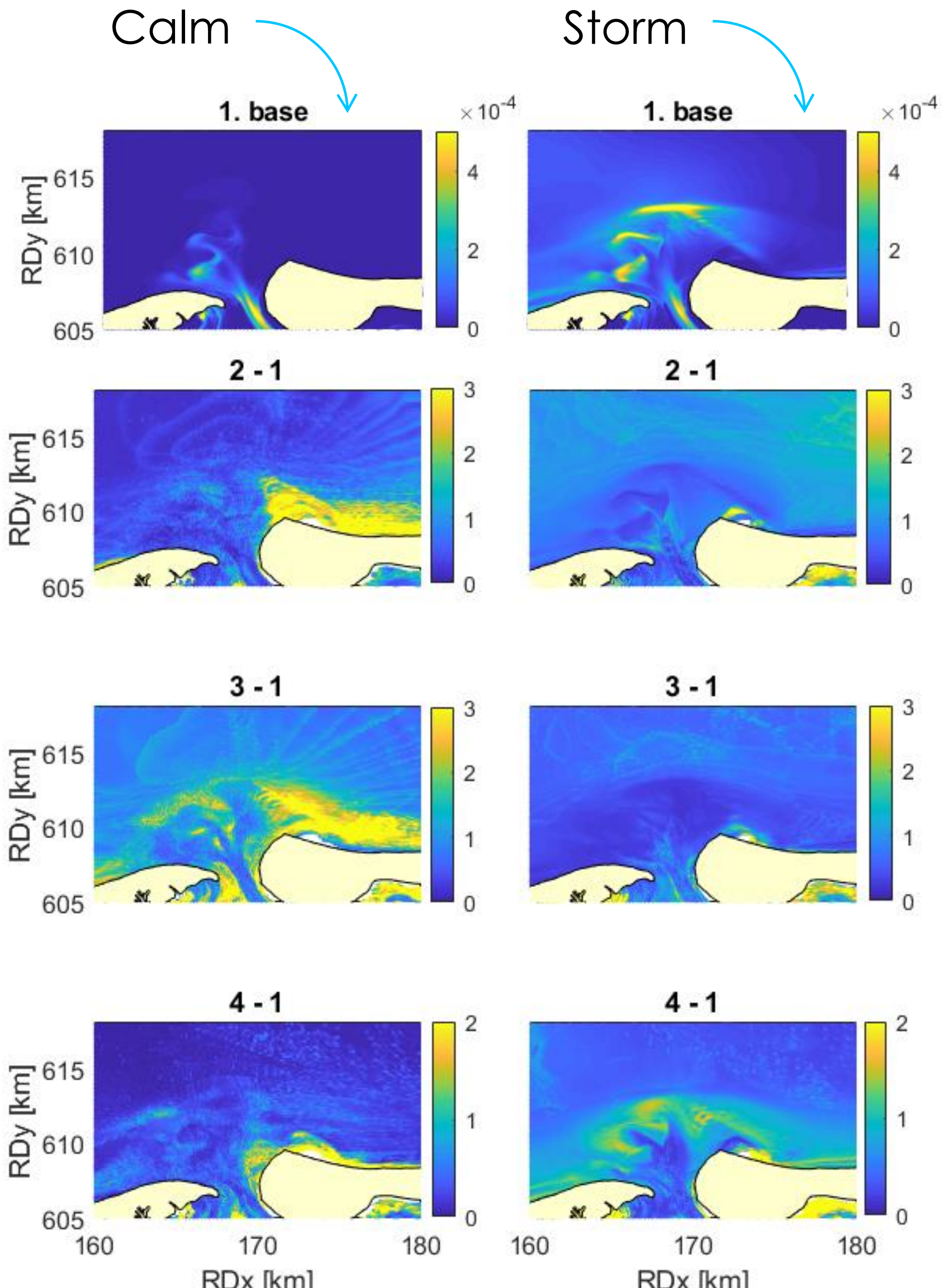
Sediment transport

- Figure shows mean suspended load transport during calm and storm period
- Suspended load transport is ~10x higher than bed load transport, so suspended load transport is shown
- Clearly, most transport takes place during the storm, on the shoals and in the channel
- Again, difficult to see differences between scenarios



Sediment transport

- Figure: top panels are same as last slide, other 6 panels show mean absolute relative difference in suspended load transport with base scenario
- Scenario 2: main differences found at the shallowest areas during calm weather
- Scenario 3: largest differences of all scenarios, mainly at shallow locations during calm weather
- Scenario 4: largest differences found during storm at the shoals



Discussion & Conclusion

- Various types of realistic ripple roughness heights cause differences in current velocity of max 40% and differences in suspended load transport of up to 300%.
- Thus, **small-scale ripple roughness is important for hydrodynamics and sediment transport**.
- The largest mean absolute relative differences are found during calm weather at small depths, which is mainly caused by the small actual values here.
- Seaward of the ebb-tidal delta, there is little to no effect if ripple roughness is calculated differently.