

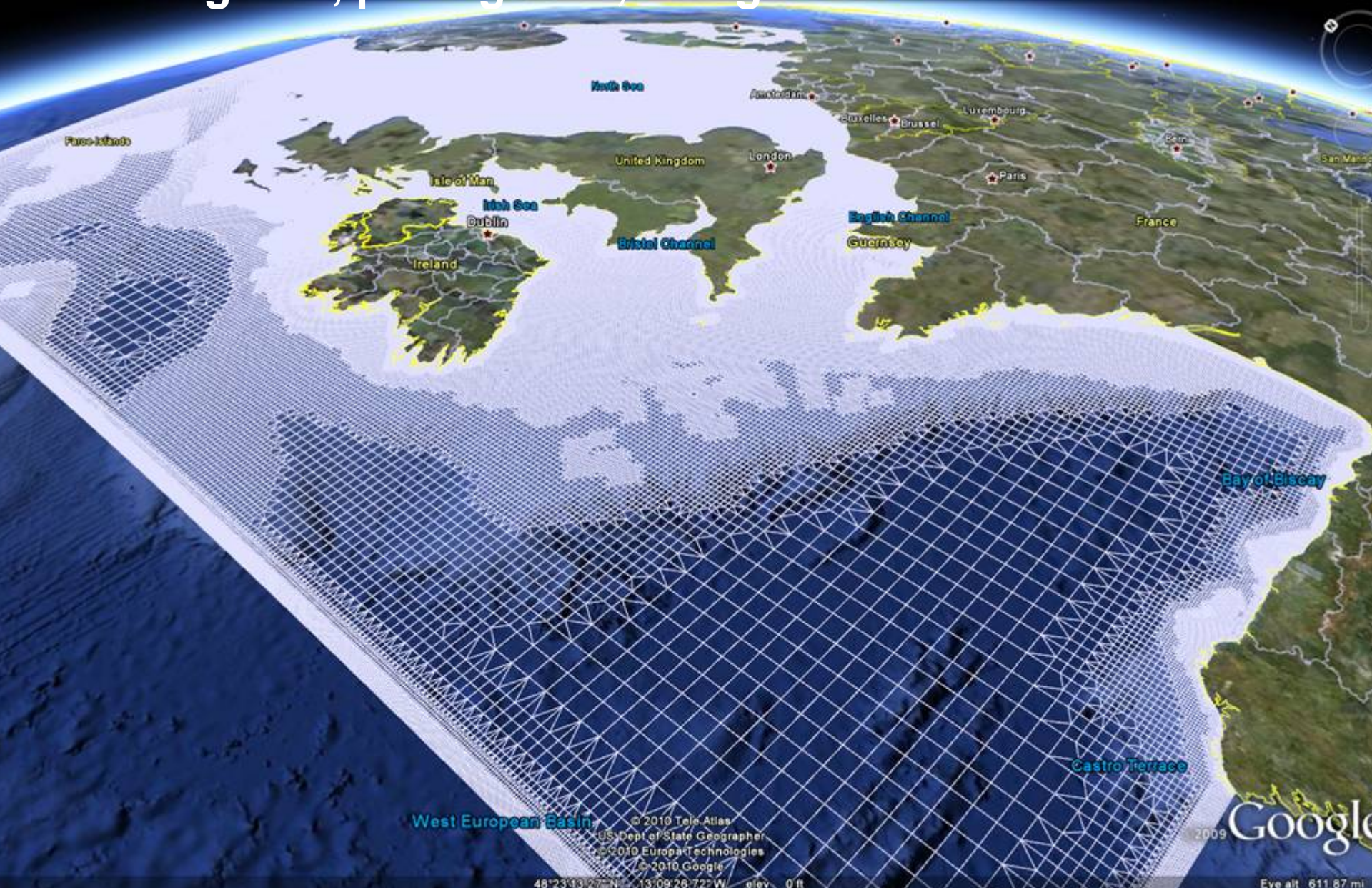


D-Flow Flexible Mesh: a showcase of hydrodynamic applications on flexible unstructured grids

Arthur van Dam, Herman Kernkamp, Sander van der Pijl and [Erik de Goede](#)

JONSMOD 2012
May 22, 2012

D-Flow Flexible Mesh: flow computations on curvilinear, triangular-, pentagonal-, etc.-grids.



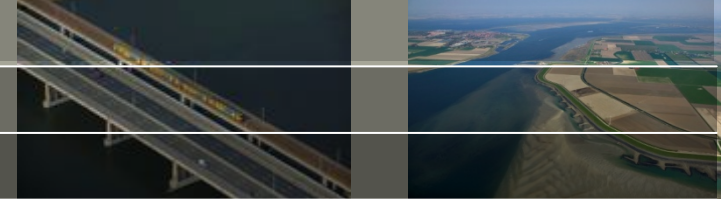
1D-2D-3D modelling suite for integral water solutions

D-Flow Flexible Mesh



Hydrodynamics

User Manual



D-Flow Flexible Mesh (FM)

New hydrodynamical engine.

Combines techniques from
Delft3D-FLOW and SOBEK

2009-2011: 1D+2D(+3D)

2012-2013: 3D+morphology,
parallellization,
misc. couplings.

Flexible Meshes:

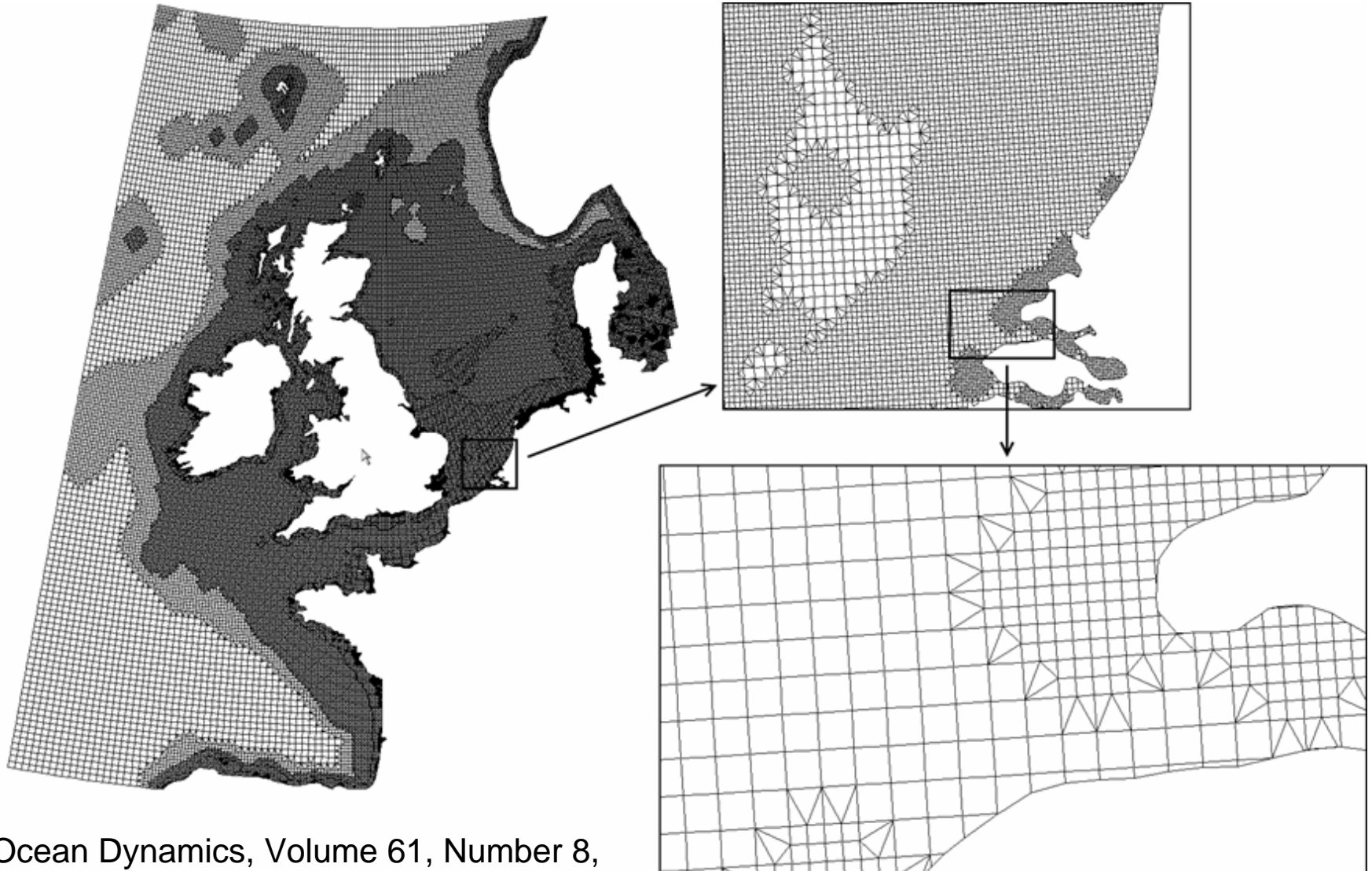
- Curvilinear grids
- Extended with triangles
- Integral coupling with 1D

Deltares

An aerial photograph showing a coastal region. On the left, a large body of water (likely a bay or estuary) meets a dike. The dike runs along the coast, separating the water from a large area of agricultural fields. The fields are divided into various colored plots, including green, brown, and tan. In the background, a small town or village is visible. The sky is clear and blue.

D-Flow Flexible Mesh applications

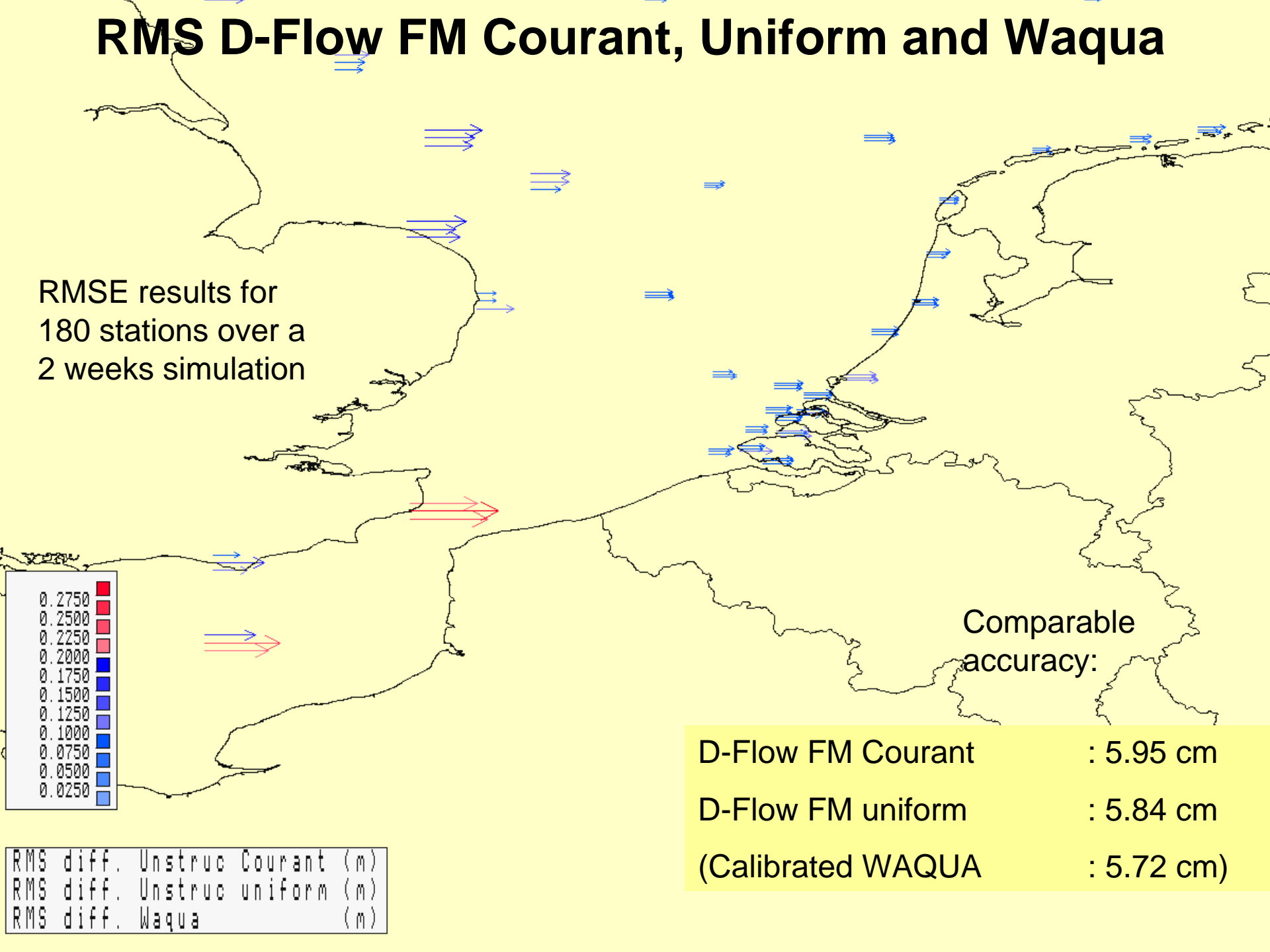
CSM model Courant grid (coarse in deeper parts) (JONSMOD 2010)



Ocean Dynamics, Volume 61, Number 8,
pp. 1175-1188, 2011. DOI: [10.1007/s10236-011-0423-6](https://doi.org/10.1007/s10236-011-0423-6)

RMS D-Flow FM Courant, Uniform and Waqua

RMSE results for 180 stations over a 2 weeks simulation



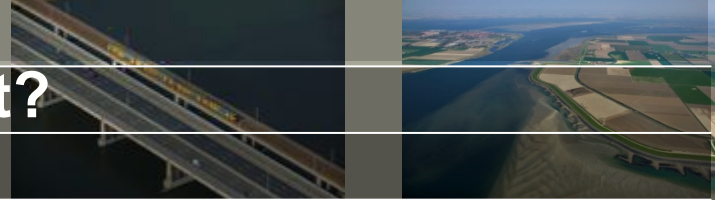
Comparable accuracy:

D-Flow FM Courant	: 5.95 cm
D-Flow FM uniform	: 5.84 cm
(Calibrated WAQUA	: 5.72 cm)

- 0.2750
- 0.2500
- 0.2250
- 0.2000
- 0.1750
- 0.1500
- 0.1250
- 0.1000
- 0.0750
- 0.0500
- 0.0250

RMS diff. Unstruc Courant (m)	
RMS diff. Unstruc uniform (m)	
RMS diff. Waqua (m)	

Comparable accuracy, at what cost? Comparison of computation times



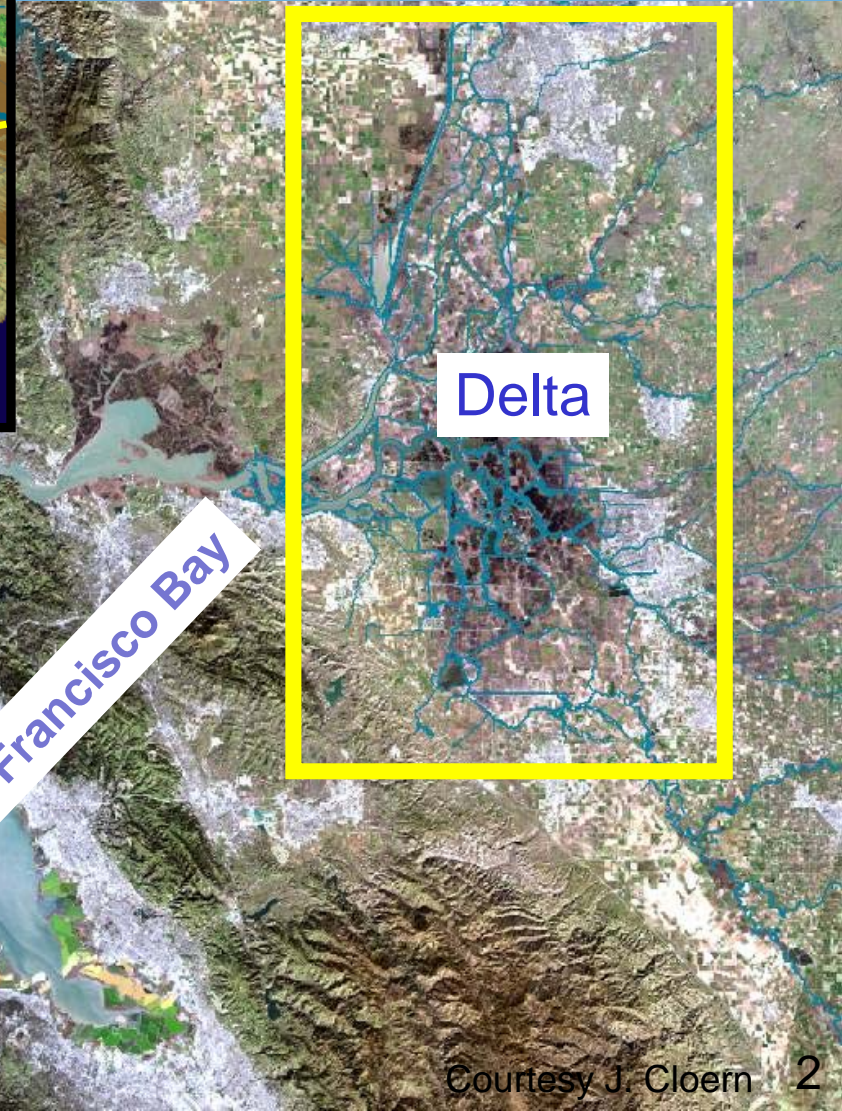
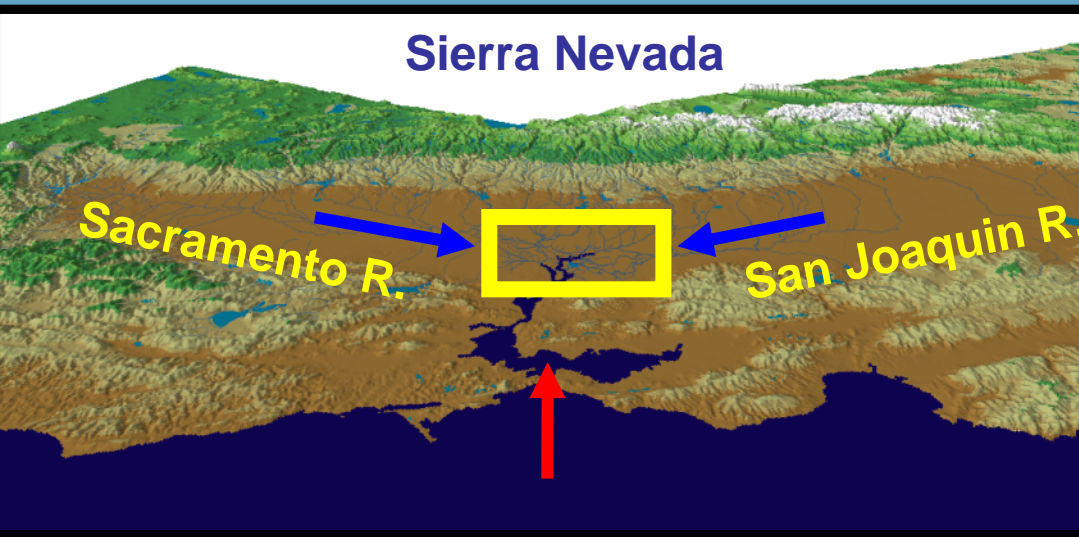
Computation time one week of simulation DCMv5 (~9,3 km) in seconds

WAQUA	31s (Dutch Rijkswaterstaat)
TRIWAQ	34s
Delft3D-FLOW	60s (Delft3D curvilinear)
D-Flow FM (single thread)	84s
D-Flow FM (eight thread OpenMP)	35s
D-Flow FM (eight thread, Saad ILUd BiCG-STAB)	24s (D-Flow FM, same grid)

D-Flow FM competes in computation time with established packages (in spite of possibly expected data structure overhead).

CASCade II:

“[...] extend modeling capabilities to assess Delta ecosystem response to changes in climate and physical configuration”



Pacific Ocean

Courtesy:
Mick van der Wegen
(UNESCO-IHE)

UNESCO-IHE
Institute for Water Education



Bays + Sacramento-delta behind San Francisco



Deltas: numerous curvilinear rivers, triangles for coupling and for lakes



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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

38°03'46.80" N 121°30'24.46" W elev -9 ft

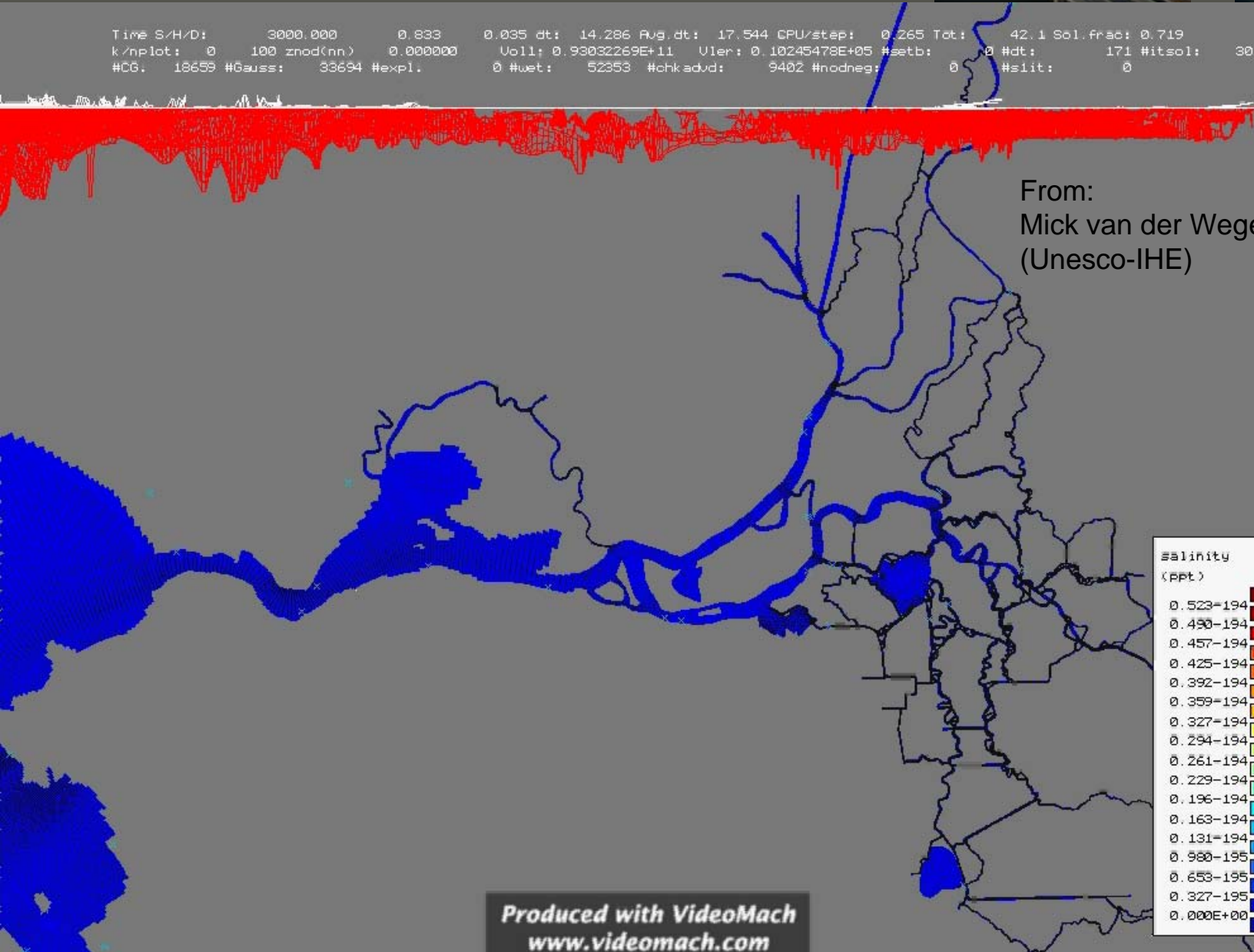
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Imagery Dates: Sep 24, 2009 - Jun 14, 2010

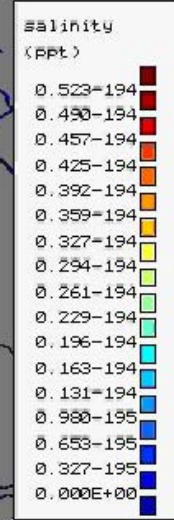
Eye alt 12058 ft

Intrusion of salt water and contaminants.

Time S/H/D: 3000.000 0.833 0.035 dt: 14.286 Avg.dt: 17.544 CPU/step: 0.265 Tot: 42.1 Sol.frac: 0.719
k/nplot: 0 100 znod(nn) 0.000000 Uoll: 0.93032269E+11 Uler: 0.10245478E+05 #setb: 0 #dt: 171 #itsol: 30
#CG: 18659 #Gauss: 33694 #expl: 0 #wet: 52353 #chkadvd: 9402 #nodneg: 0 #slit: 0



From:
Mick van der Wegen
(Unesco-IHE)



Produced with VideoMach
www.videomach.com

tares

A finer-scale model: the Kam Tin Drainage channel

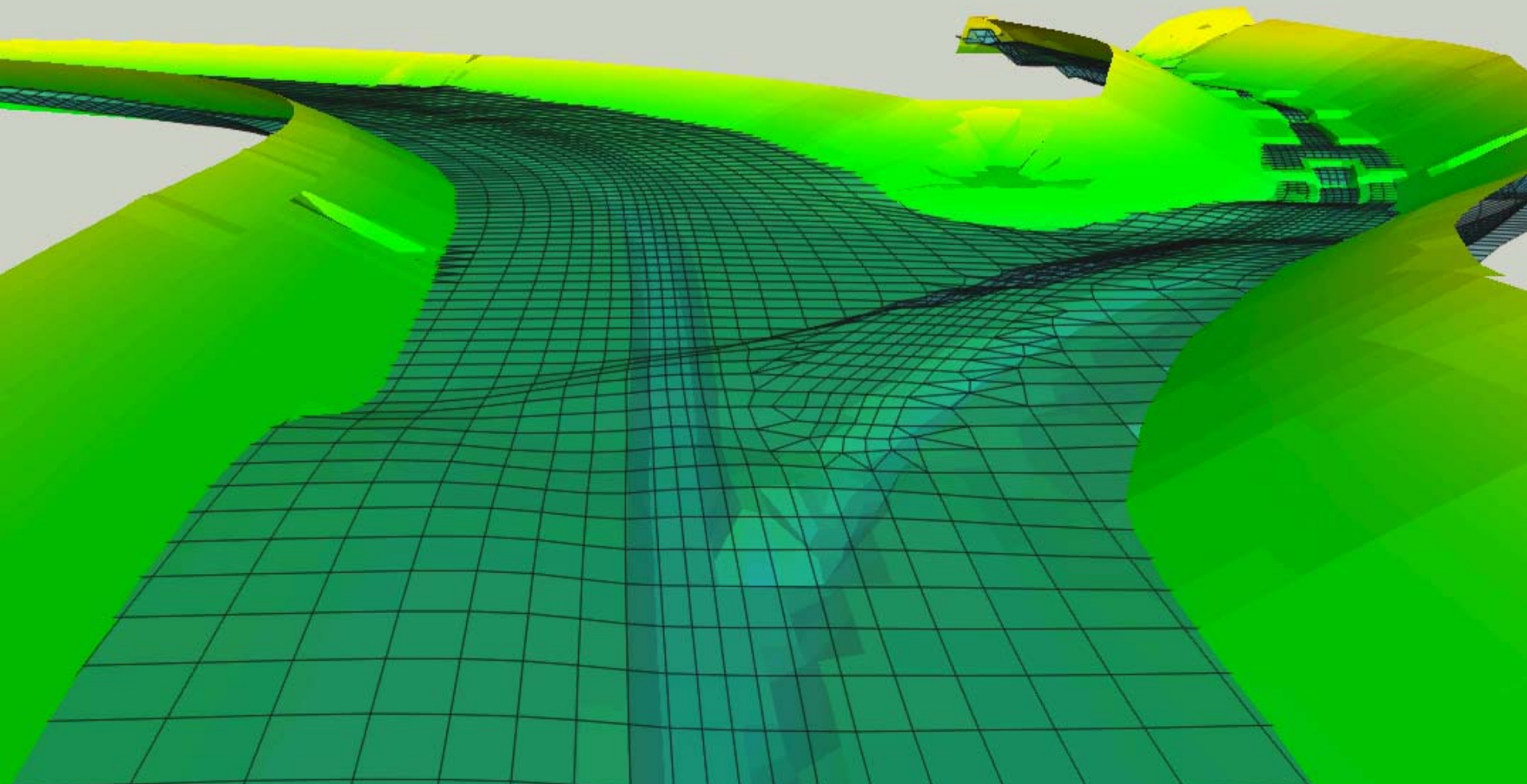
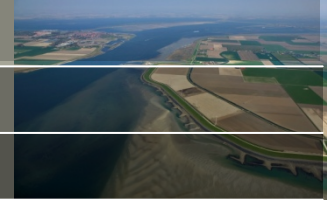


May 22, 2012

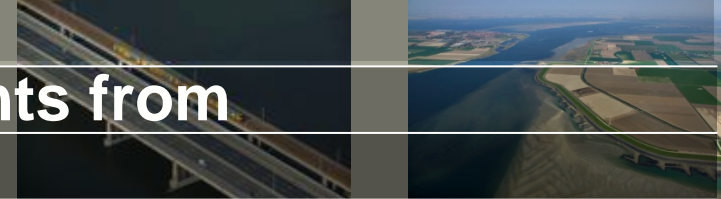
peak flows ~ 6 m/s



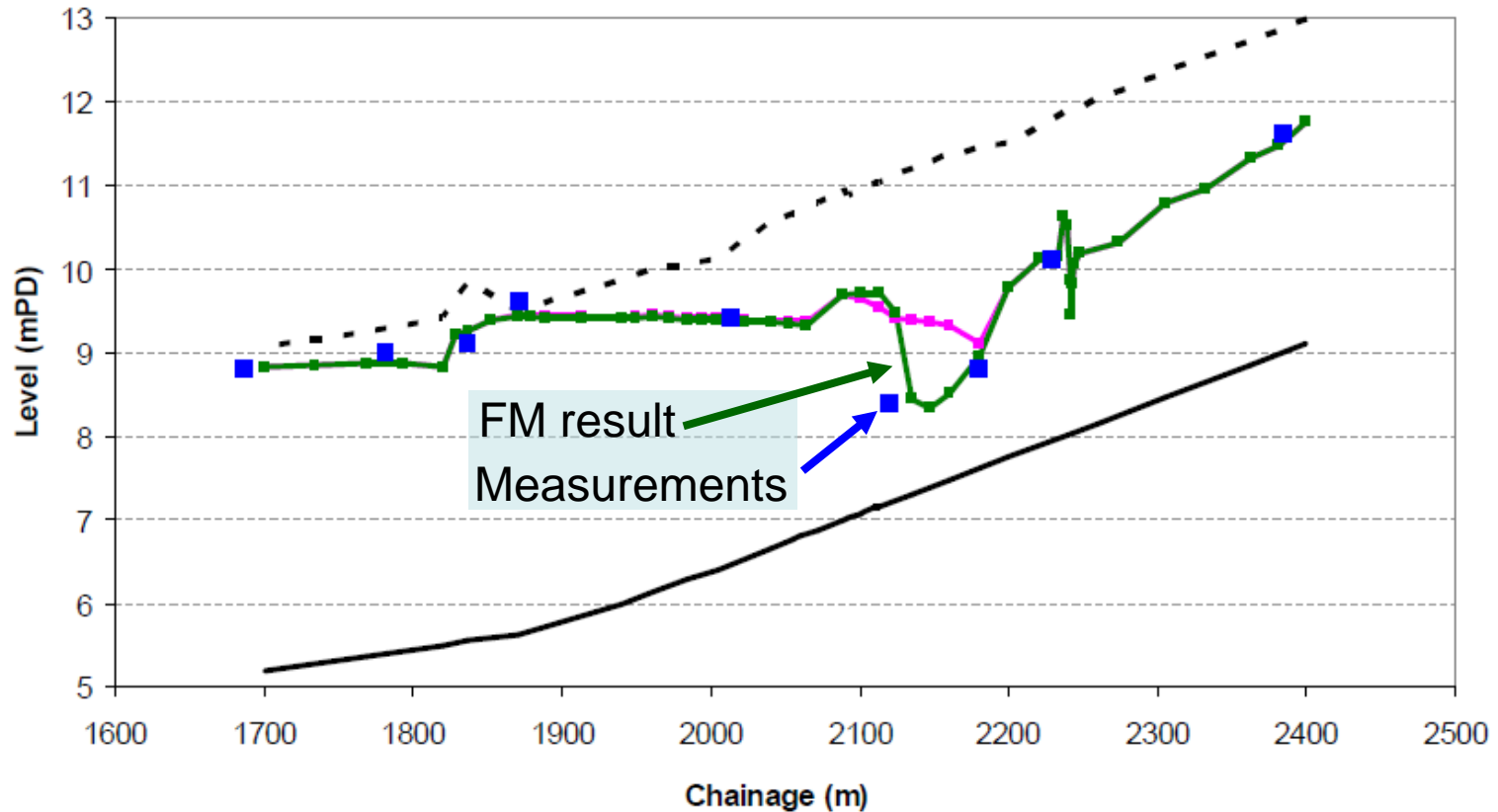
3D visualization of D-Flow FM results



Good agreement with measurements from laboratory/scale model

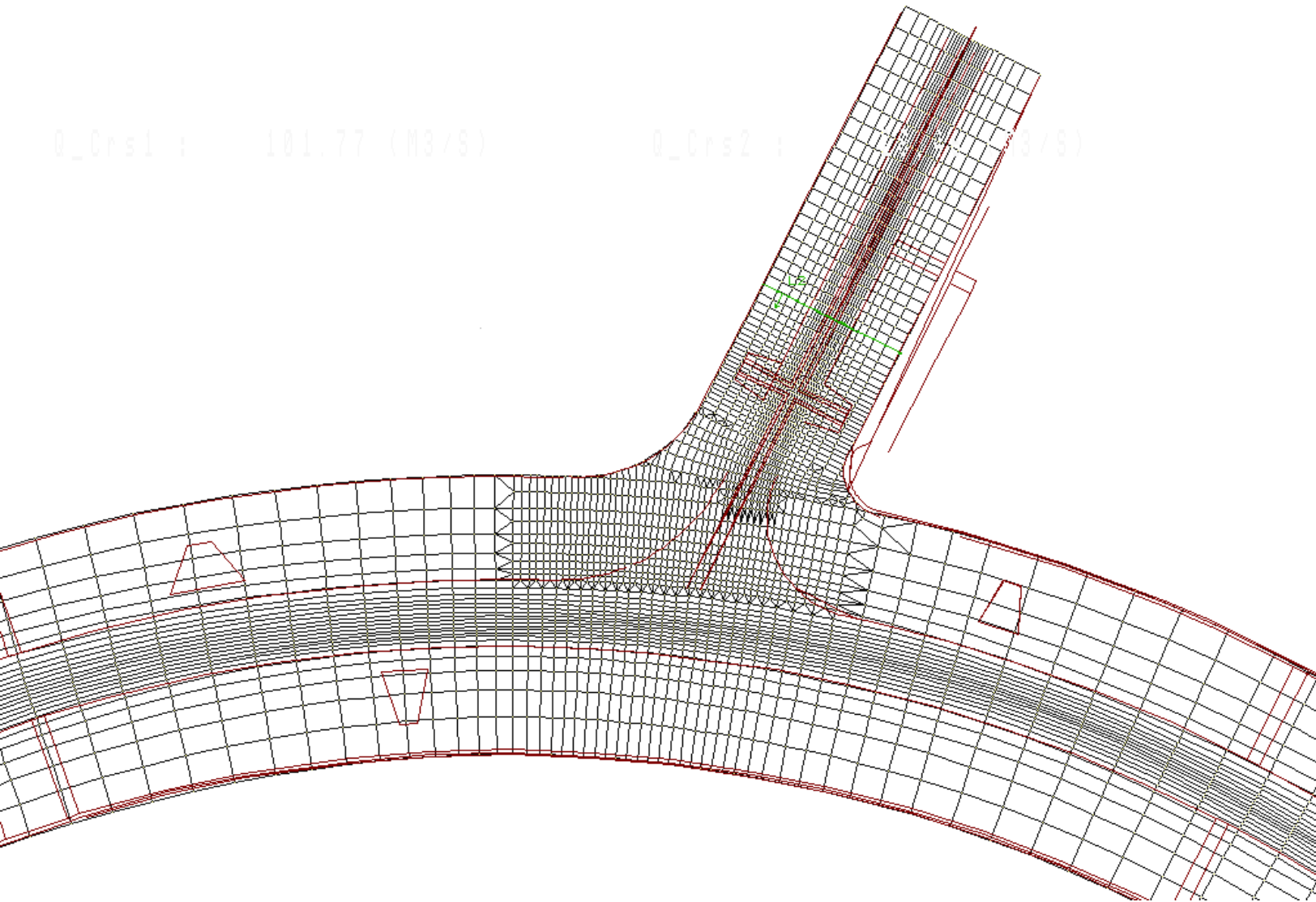


Result Comparison of the Hydraulic Scale Model with 2D-Unstructured Grid Model for Q200

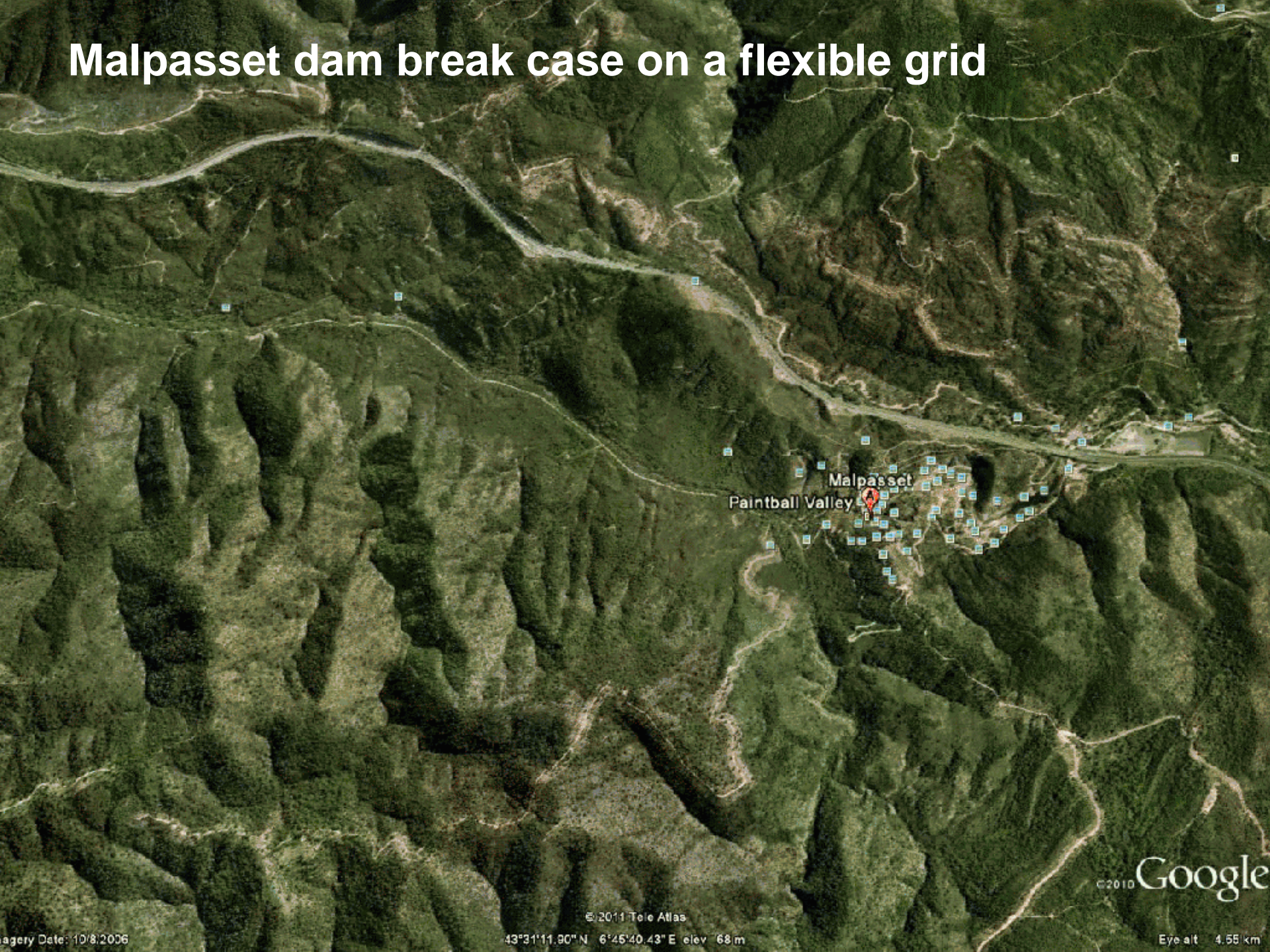


- Bed Level
- - - Coping Level
- Unstructured Grid Model (n=0.024)
- Unstructured Grid Model (n=0.01 for Plexiglass in Channel Segment 3)
- Unsteady-state Fixed Gauge (Fig 4.7, Scott's Report 1998)

Drainage channel Hong Kong: locally fine resolution



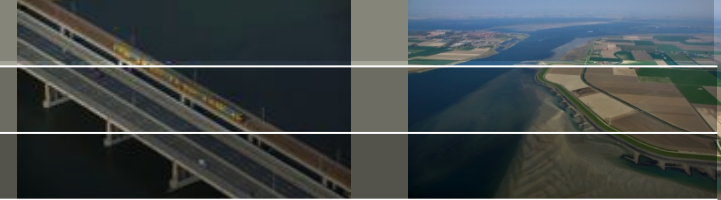
Malpasset dam break case on a flexible grid



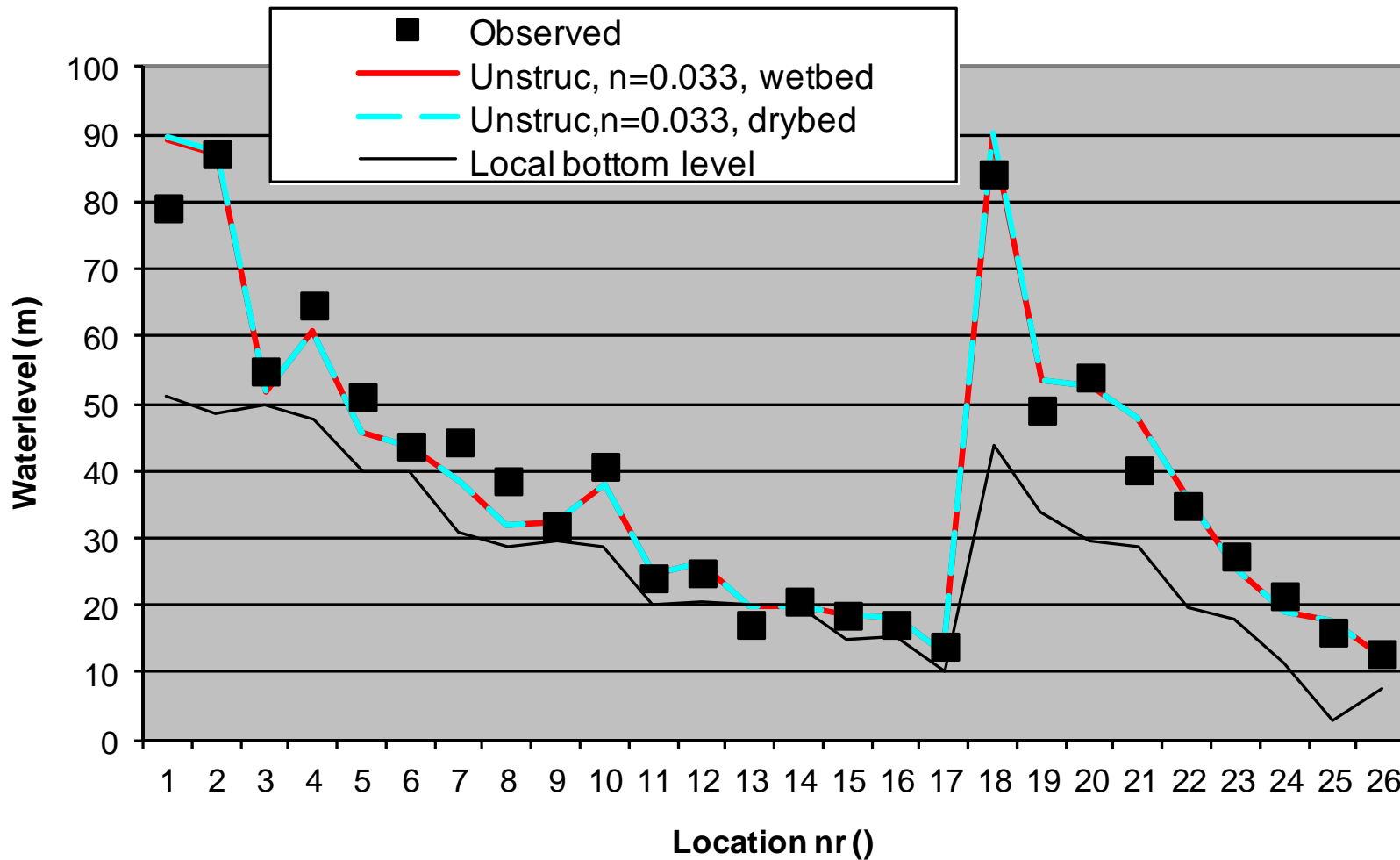
Malpasset
Paintball Valley

©2010 Google

Malpasset Dambreak

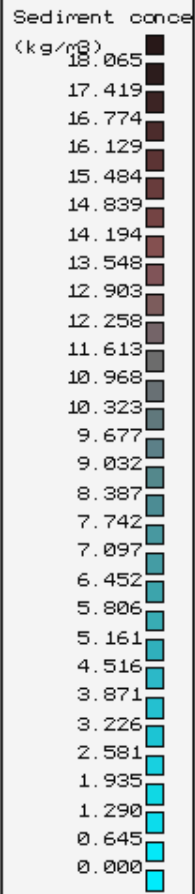
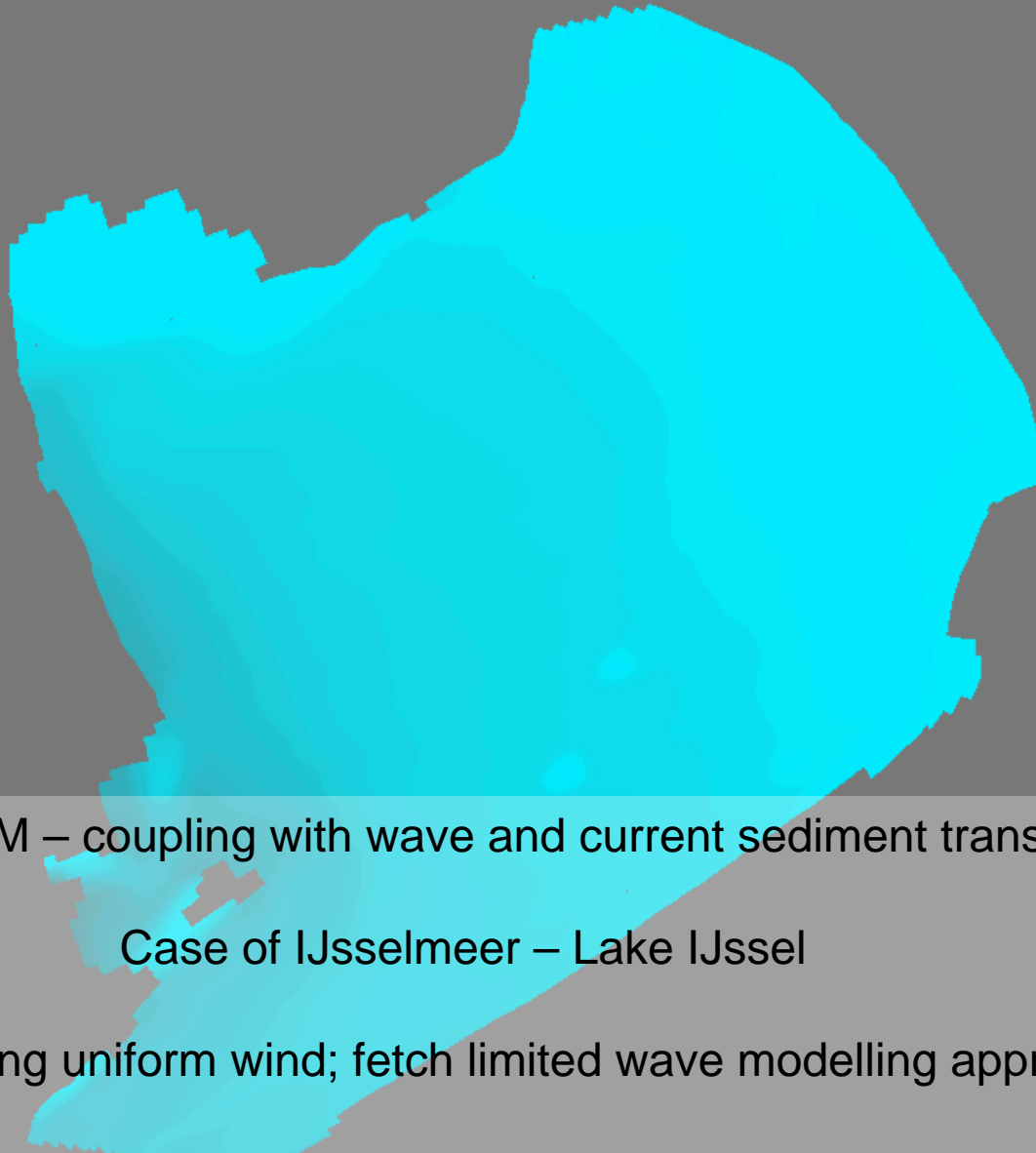


Malpasset Dambreak maximum waterlevels
Location nrs 1-17: prototype, location nrs 18-26: physical scale model



Time S/H/D: 9000.000 2.500 0.104 dt: 120.000 Avg.dt: 78.261 CPU/step: 0.031 Tot: 1.8 Sol/Rest: 0.358
k/nplot: 1 100 znod(nn) 0.009599 Uo11: 0.24834033E+10 U1er: 0.95367432E-06 #setb: 0 #dt: 115 #itsol: 49
#CG: 3569 #Gauss: 3654 #expl: 0 #wet: 7223 #chkadvd: 0 #nodneg: 0 #slit: 0

8.000



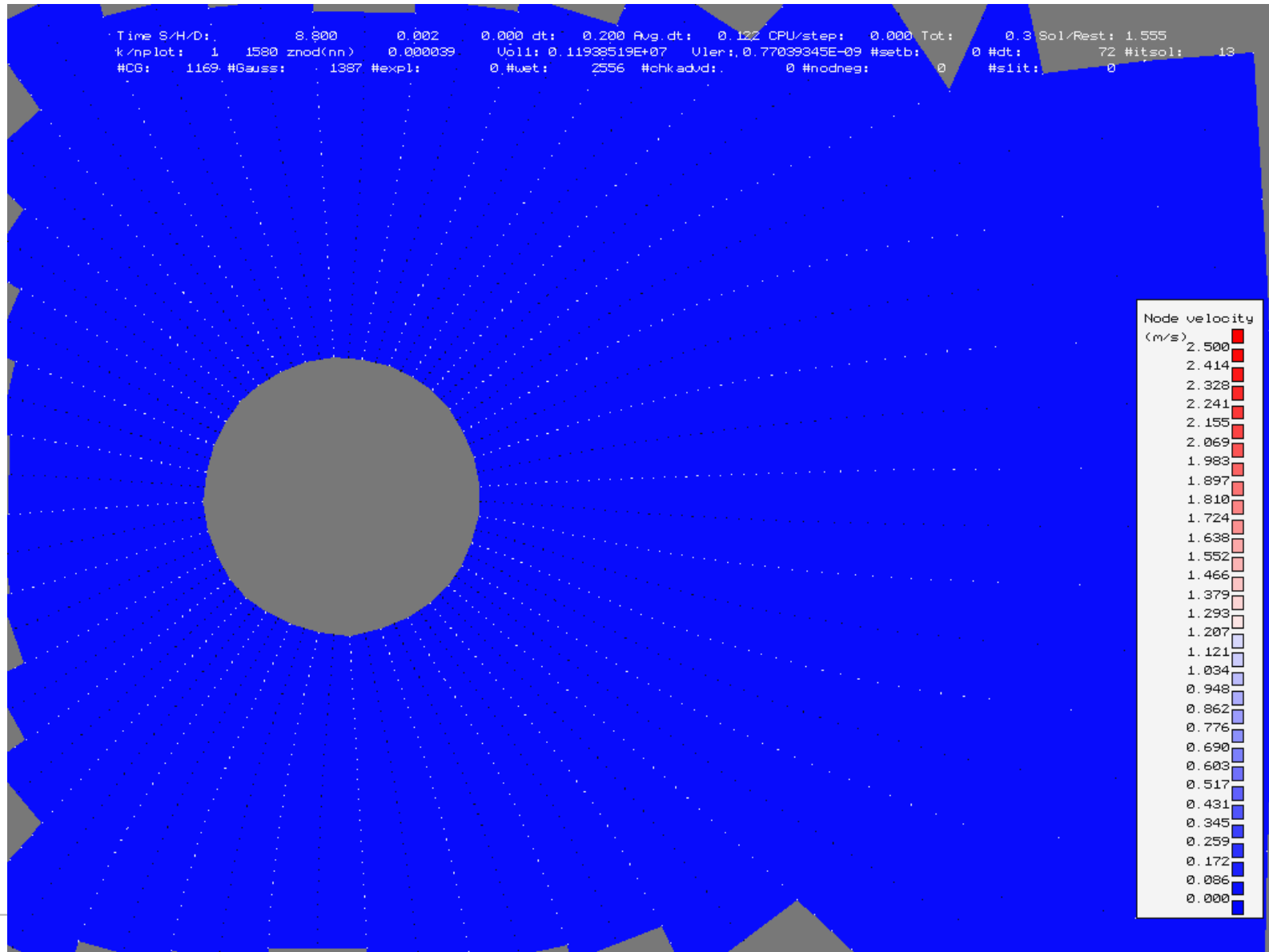
D-Flow FM – coupling with wave and current sediment transport

Case of IJsselmeer – Lake IJssel

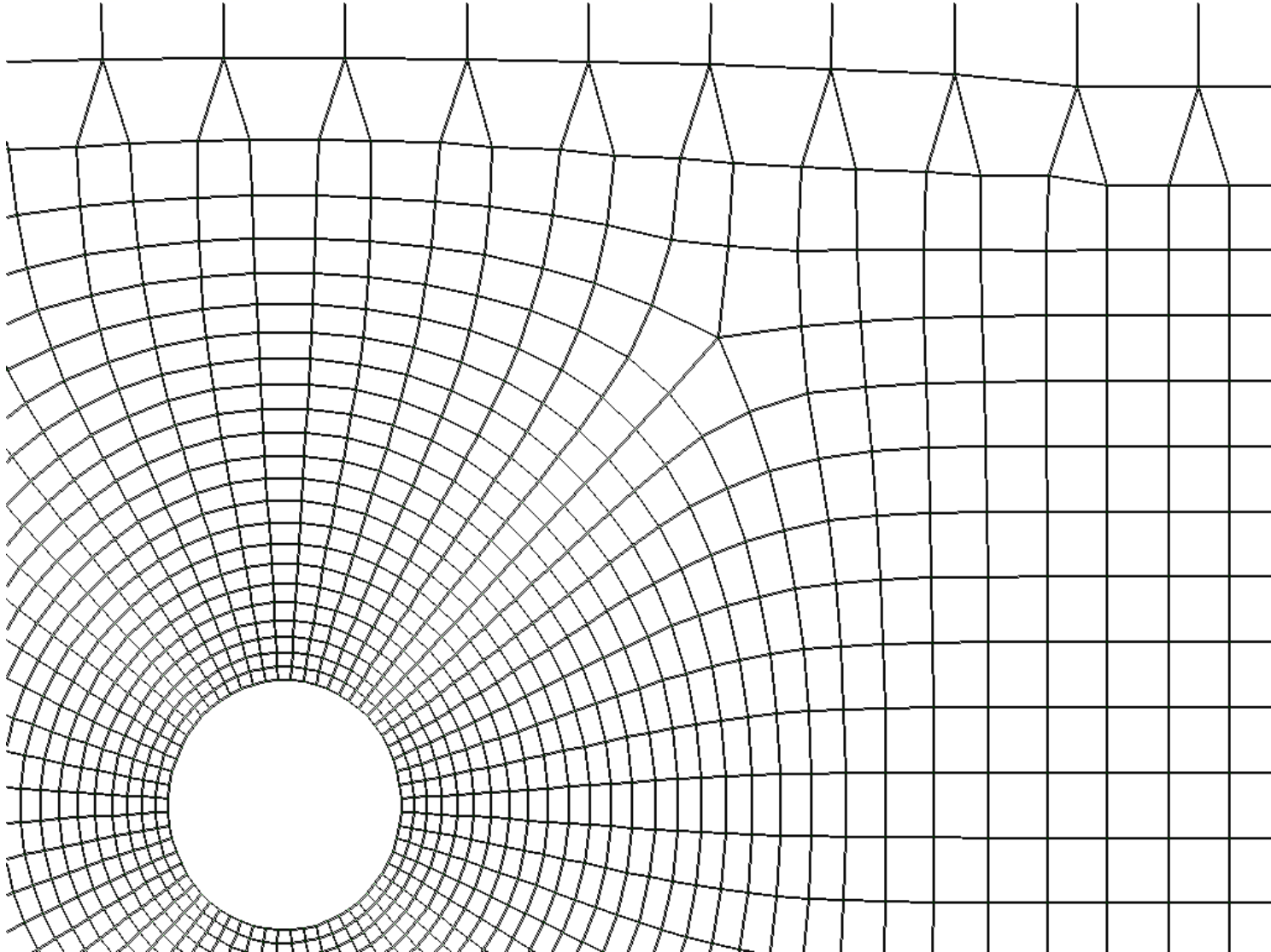
Time varying uniform wind; fetch limited wave modelling approach

Hurdle and Stive (1989) / Monbaliu et al. (1995)

Viscous flow around a cylinder (vortex shedding)



Flexible grid: horizontal in main channel, circular to support pillar's boundary layer.



Mahakam-delta: 1D-2D(-3D) modelling



3.80 mi

Image © 2012 TerraMetrics
Data SIC, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 DigitalGlobe

Google earth