

3D CFD Investigations of Seabed Stresses around Subsea Pipelines

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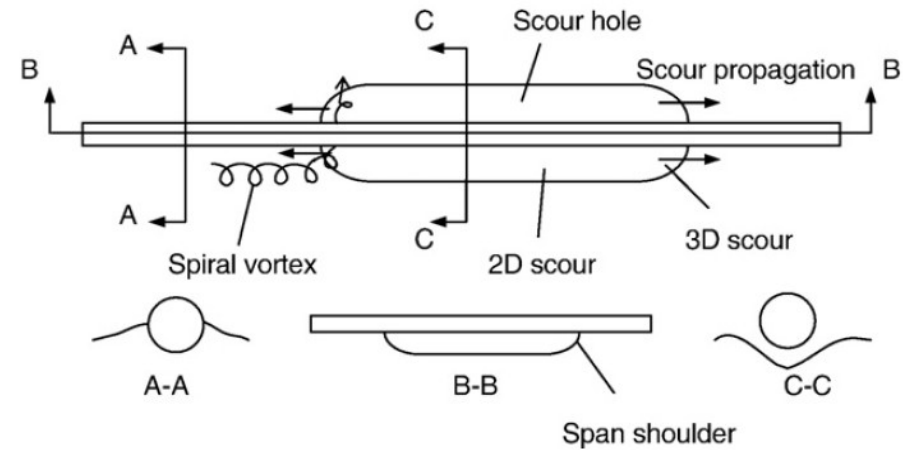
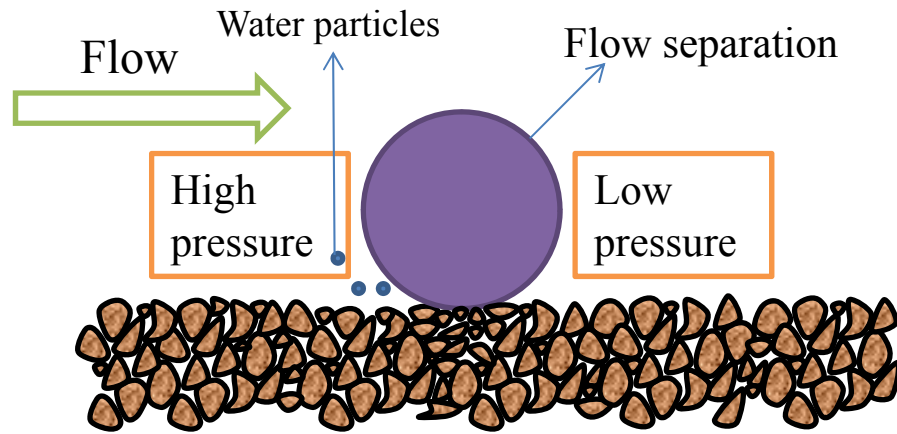
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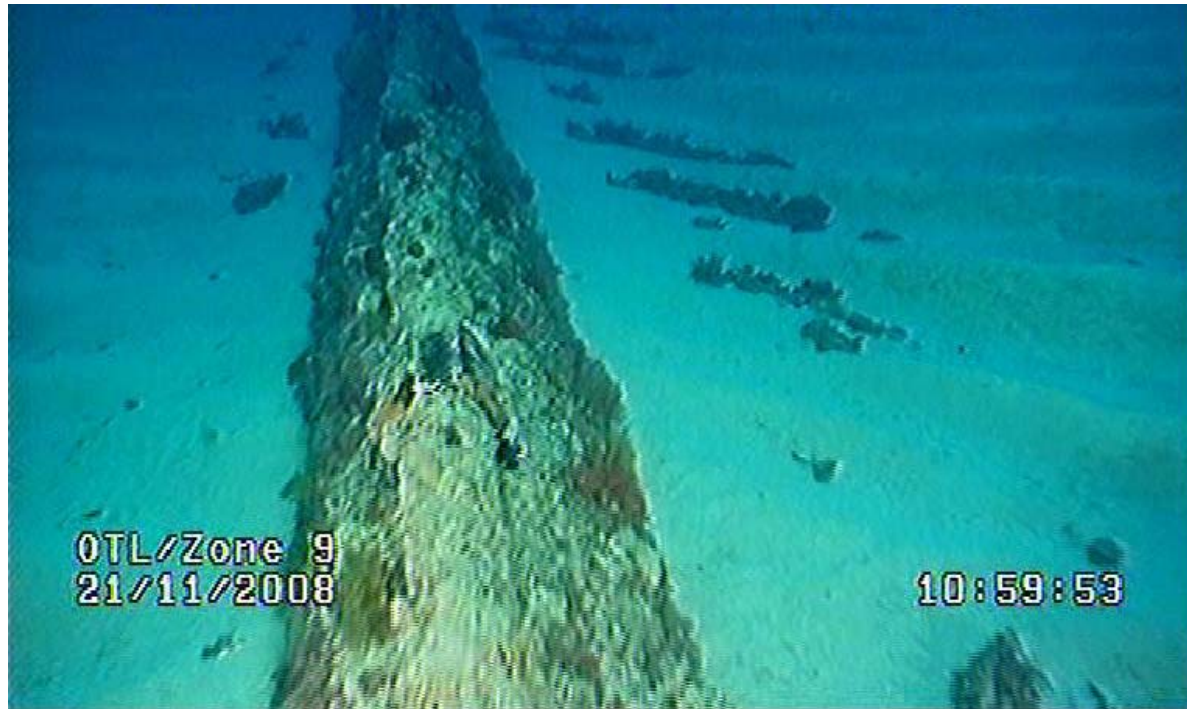
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Sediment Transport – Scour mechanisms



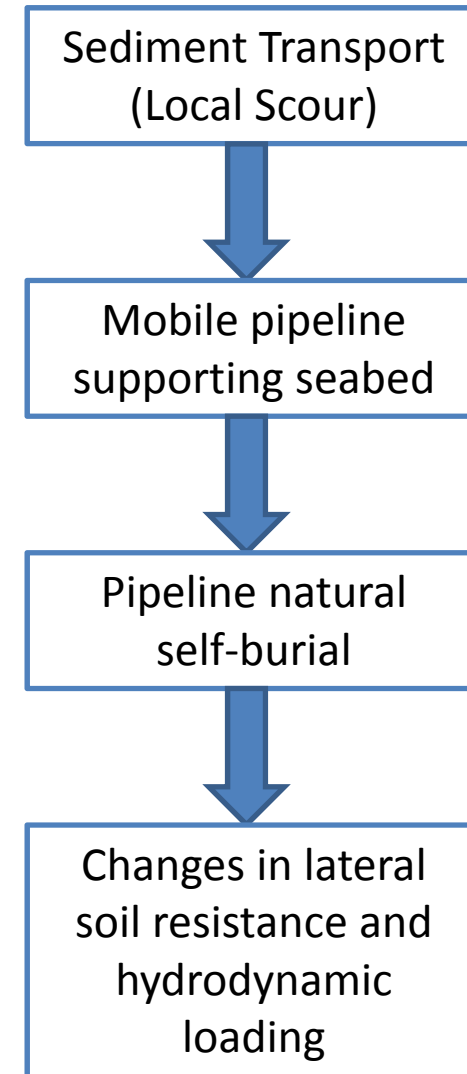
A typical scour process below a pipeline
(Cheng et al.2009)

Sediment Transport Effects on Pipeline Stability



A field picture of pipe self-burial from Client Mentor

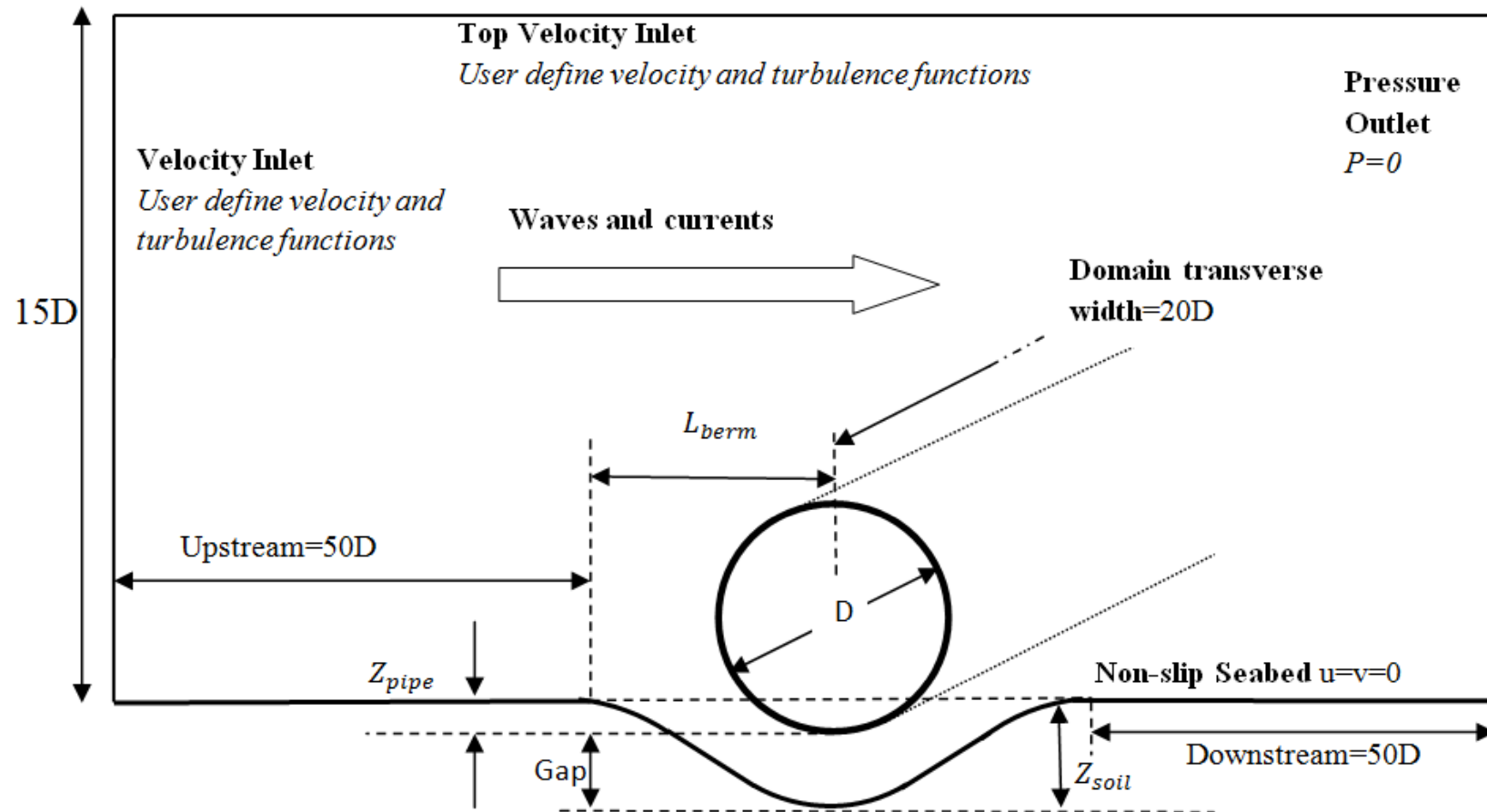
- Conventional stability analysis assume the seabed is stable
- Field observation of pipelines confirms they are typically embedded between 10-50%



CFD Numerical Modeling

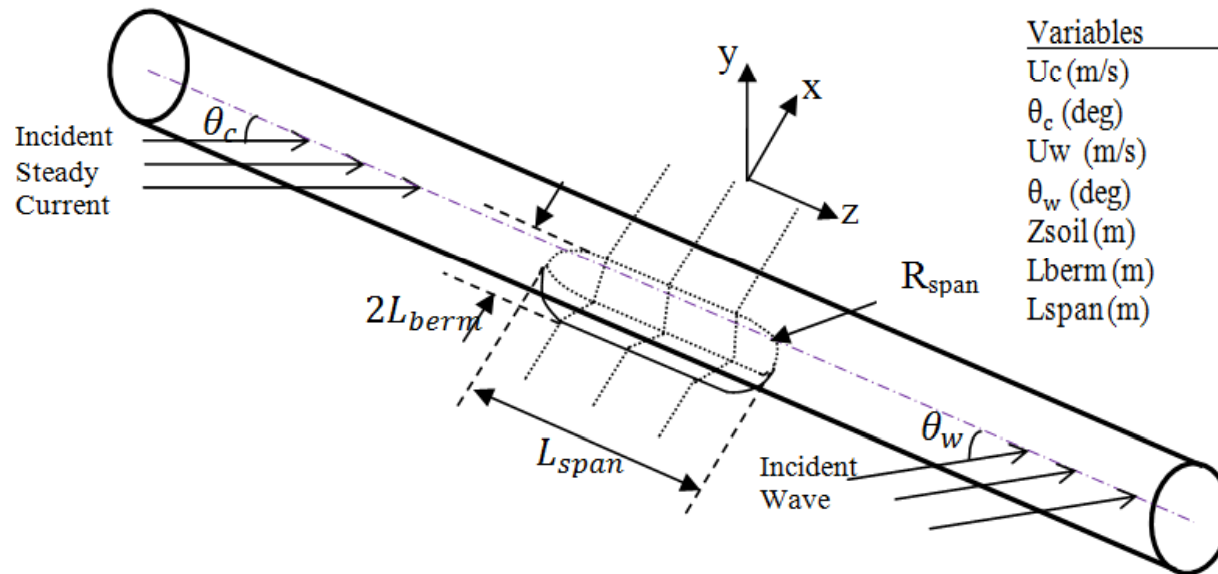
Computational Domain

- All the 3D flow simulations are carried out using commercial computational fluid dynamics (CFD) software ANSYS Fluent 12.1



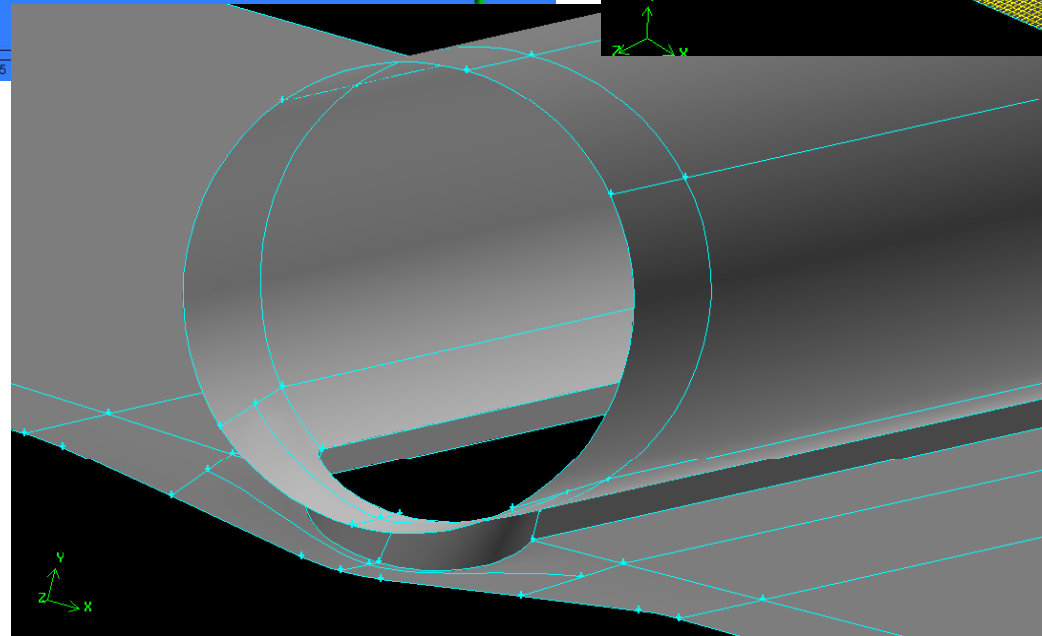
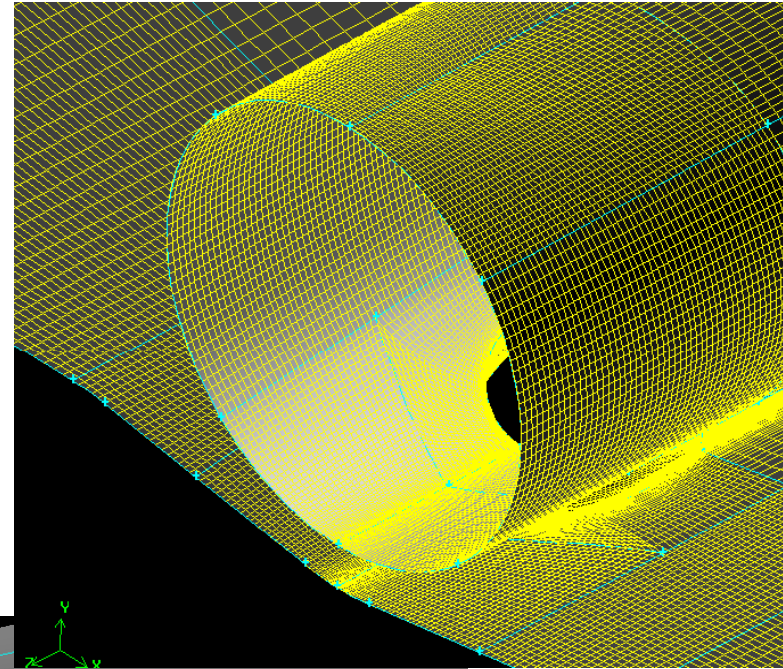
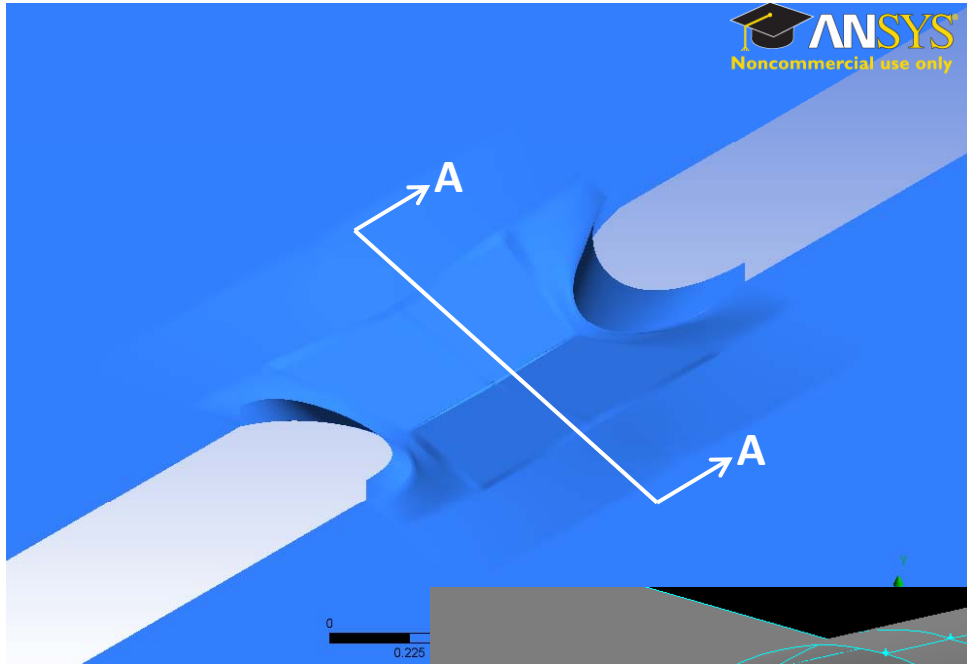
Case Matrix

Simulation Case	Geometry Case	D (m)	Zpipe (m)	Zsoil (m)	Lberm (m)	Lspan (m)	Gap (m)	Uc (m/s)	θ_c (deg)	D (m)	H (m)	L (m)	Uw (m/s)	θ_w (deg)	T (s)
1	1	1	0	0	0	0	0	1	90						
2	1	1	0	0	0	0	0	1	45						
3	1	1	0	0	0	0	0	-	-	40	5.32	261.58	1	90	15
6	1	1	0	0	0	0	0	1	90	40	5.32	261.58	1	90	15
7	2	1	0	-0.1	0.75	1	0.1	1	90						
8	3	1	0	-0.1	0.75	5	0.1	1	90						
9	2	1	0	-0.1	0.75	1	0.1	1	45						
10	2	1	0	-0.1	0.75	1	0.1	-	-	40	5.32	261.58	1	90	15
12	1	1	0	0	0	0	0	1	15						
13	2	1	0	-0.1	0.75	1	0.1	1	15						
14	3	1	0	-0.1	0.75	5	0.1	1	15						
15	4	1	0	-0.25	3	1	0.25	1	45						
16	5	1	0	-0.25	3	5	0.25	1	45						
17	4	1	0	-0.25	3	1	0.25	1	15						



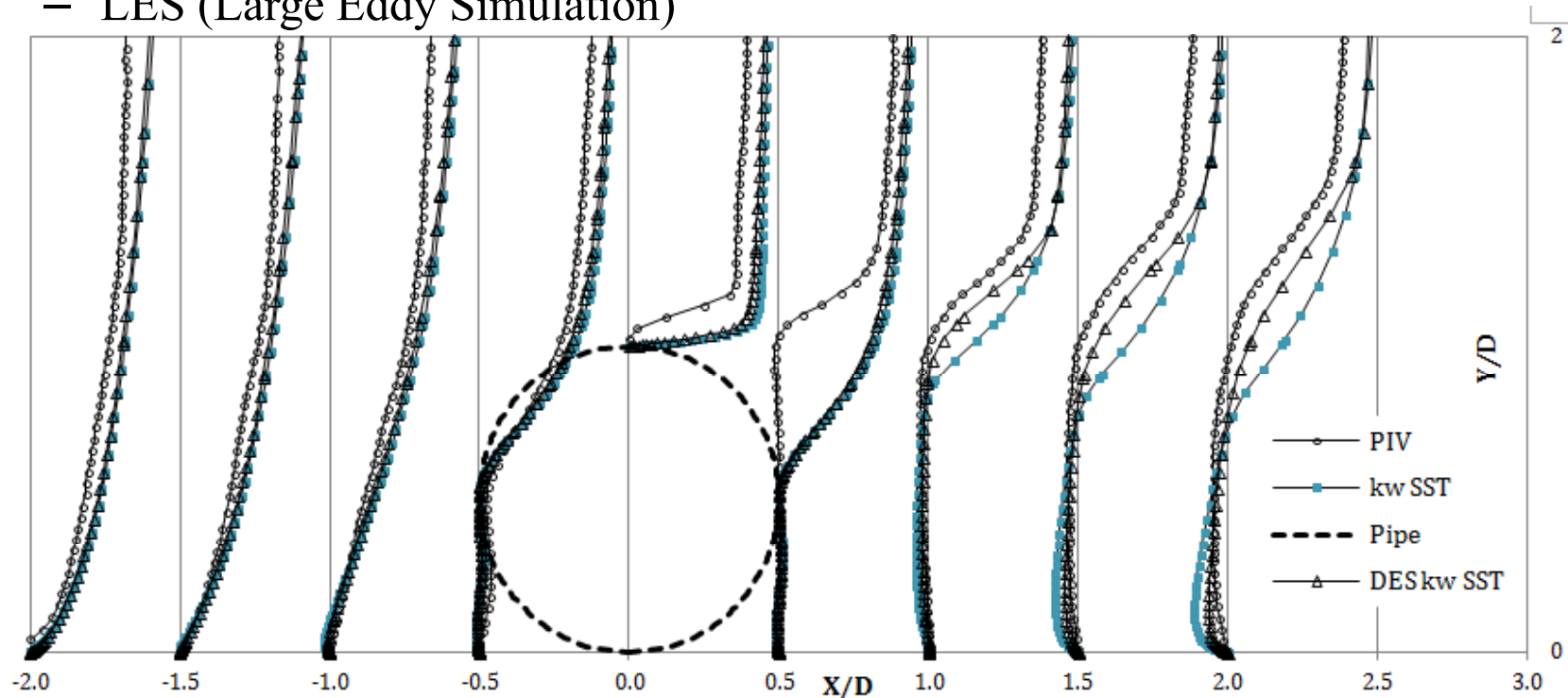
Variables	Possible Values		
Uc (m/s)	1		
θ_c (deg)	15	45	90
Uw (m/s)	1		
θ_w (deg)	45	90	
Zsoil (m)	-0.1	-0.25	
Lberm (m)	0.75	3	
Lspan (m)	1	5	

Computational Mesh



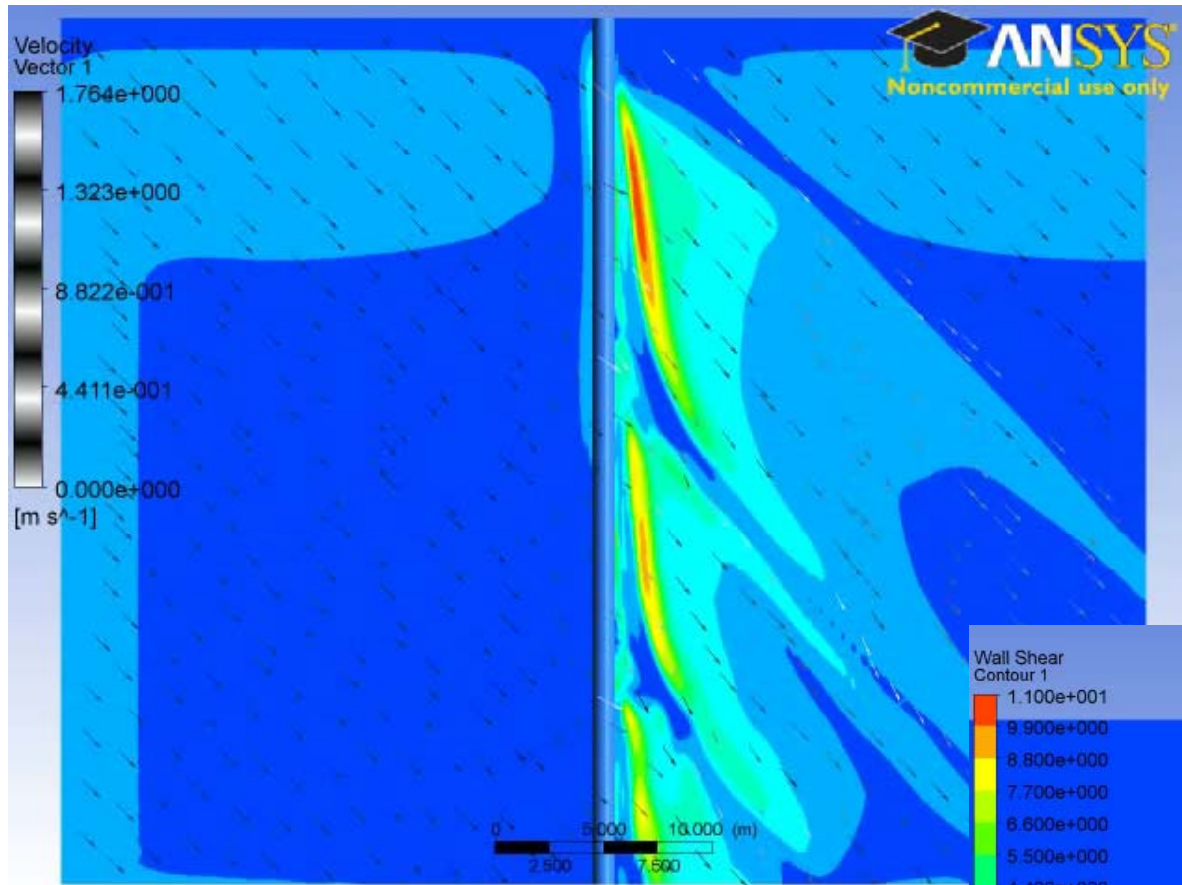
Turbulence Model Selection

- Final model selection was based on benchmarking against the particle image velocimetry (PIV) data describing the velocity field in the vicinity of a pipe from Akoz and Kirkgoz (2009)
 - $k-\epsilon$
 - **$k-\omega$ SST (Shear Stress Transport)**
 - DES (Detached Eddy Simulation) $k-\epsilon$
 - **DES $k-\omega$ SST**
 - LES (Large Eddy Simulation)



Simulation Results - Case 1 & 2

The pipe is simply sitting on a uniform flat seabed

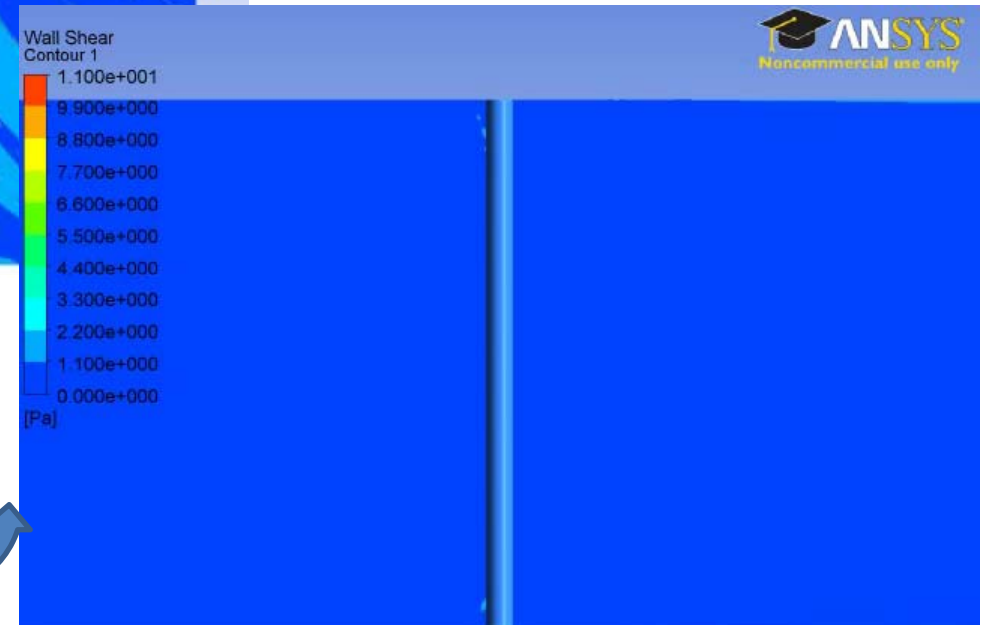


Case 2

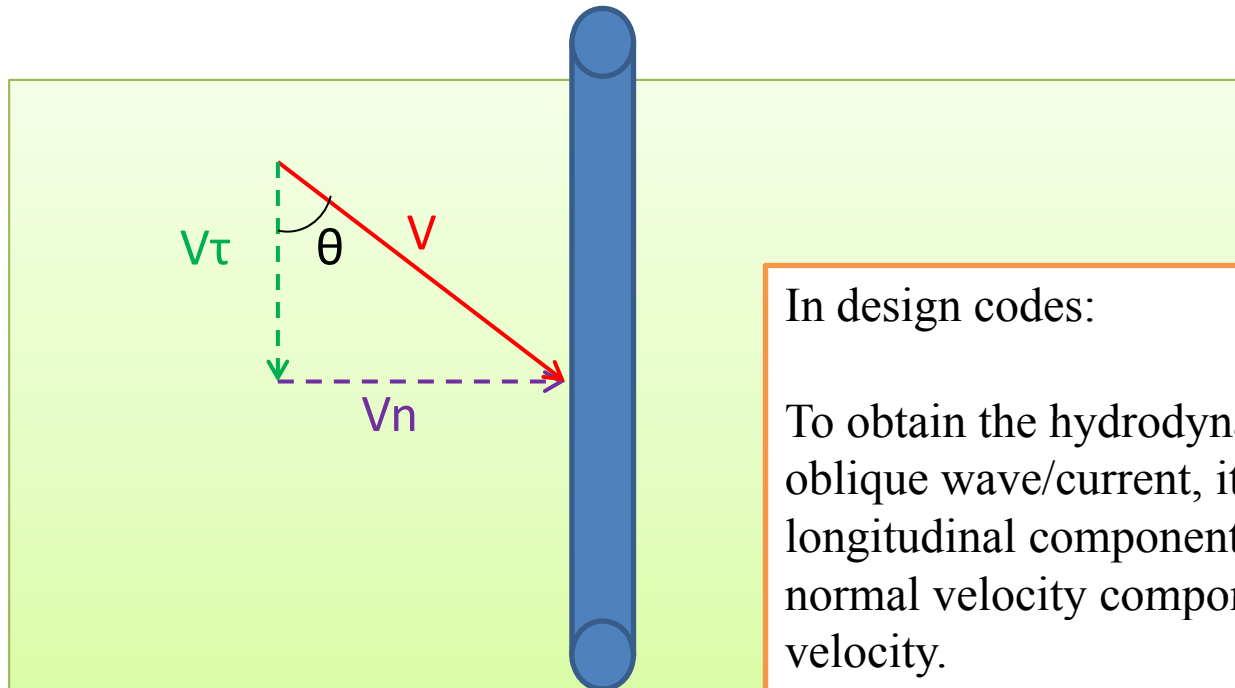
45 degrees Inclined Incident 1m/s Current

Case 1

Perpendicular Incident 1m/s Current



An application of above observation



In design codes:

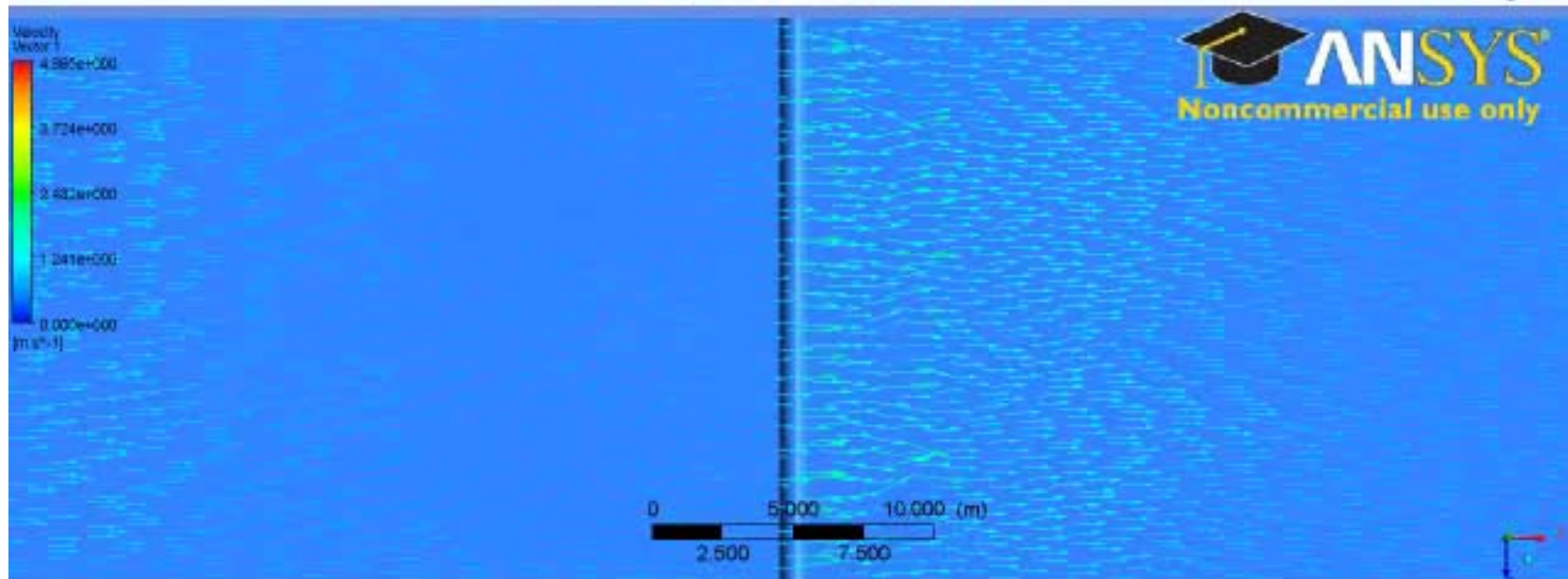
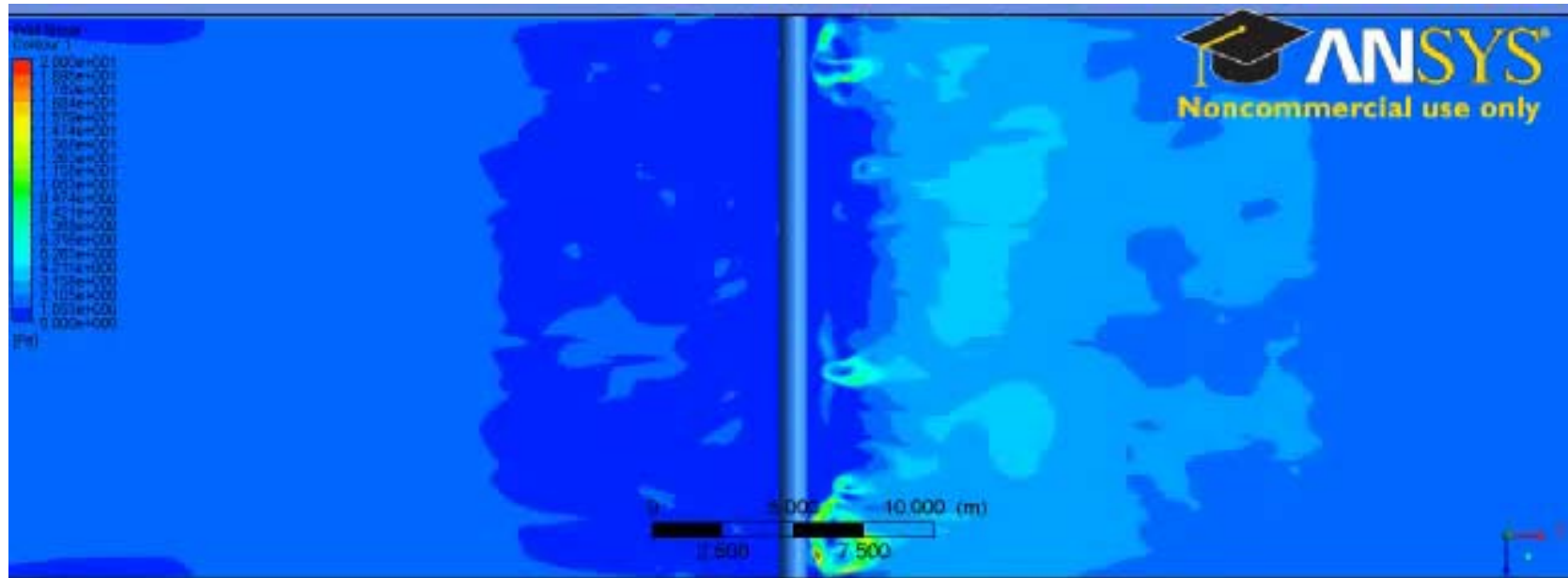
To obtain the hydrodynamic loading under oblique wave/current, it is very often that the longitudinal component is ignored; only the normal velocity component is used as design velocity.

$$V_{design} = V \sin \theta$$

However, as it is indicated by the simulation results of Case 1 and Case 2, this approach seems to bring large errors.

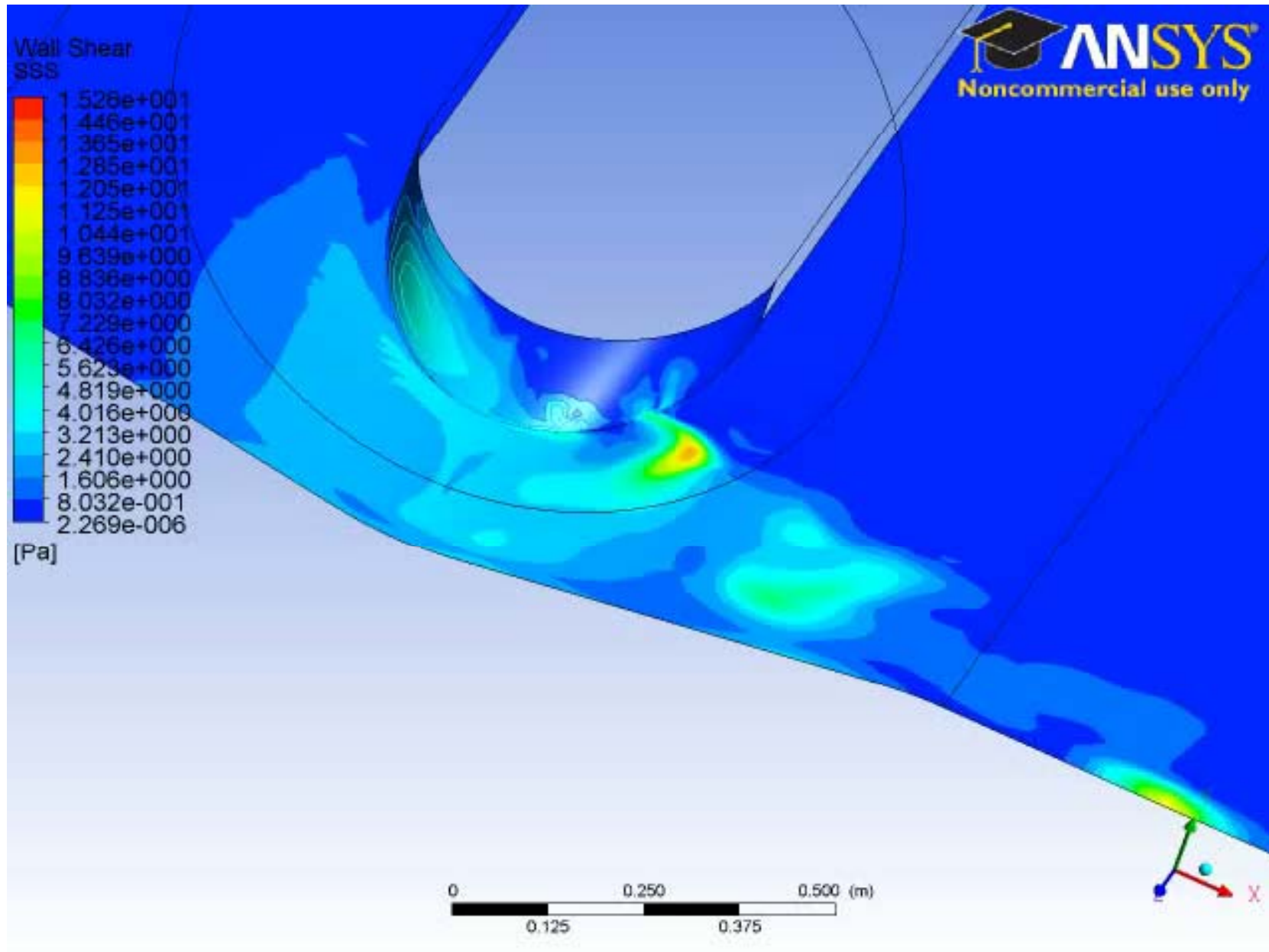
Simulation Results - Case 3

Perpendicular Incident Wave Only

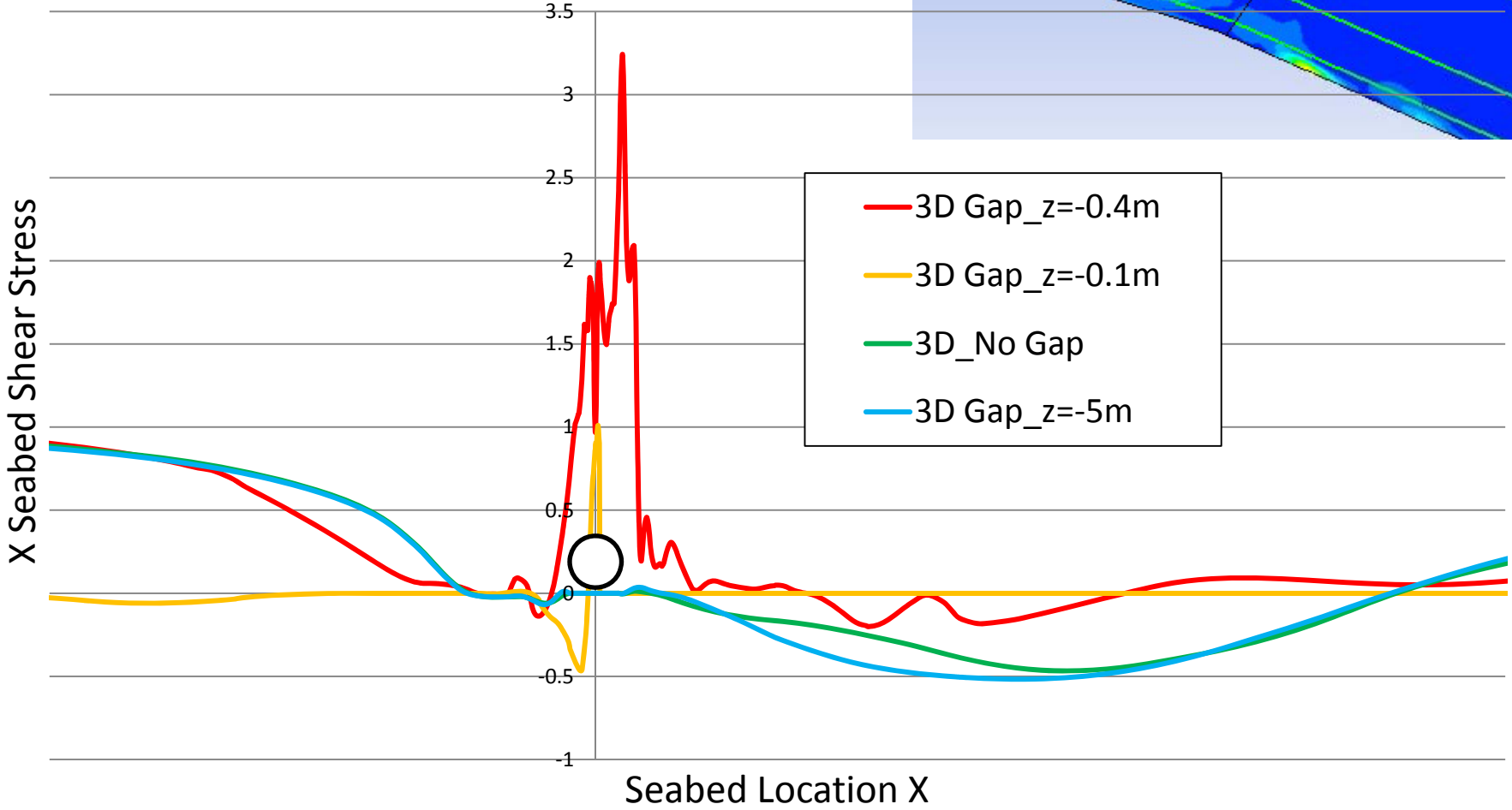
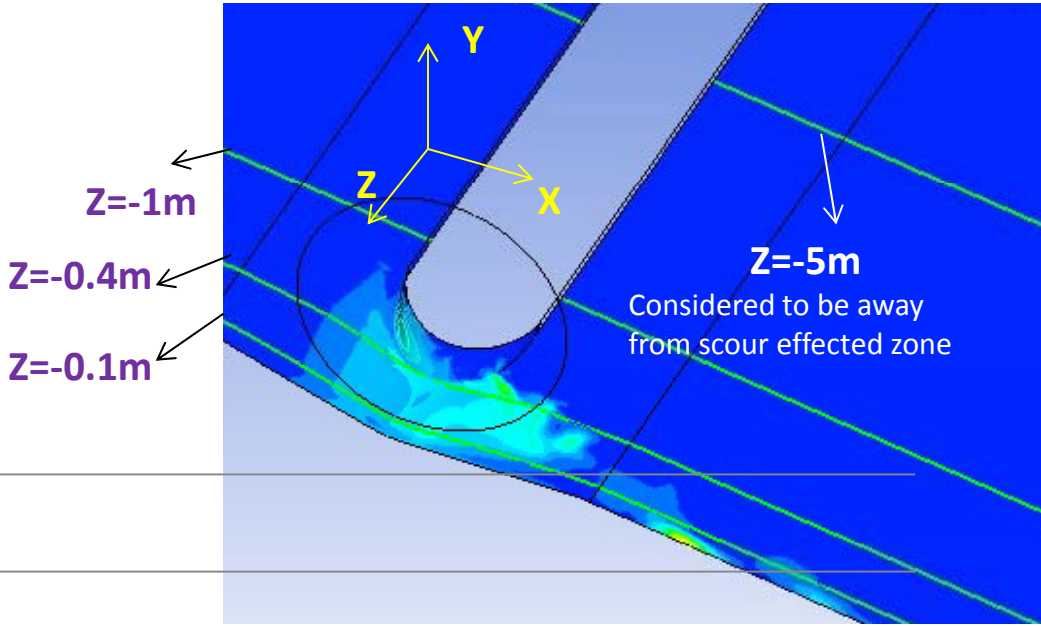


Simulation Results - Case 7

Perpendicular Incident Current



Seabed Shear Stress Comparison



Conclusion

- The meshing as well as the size of the domain is a compromise of simulation accuracy, computing resource and time
- UDF is an efficient tool to decrease the domain size
- A phase shift exists between the seabed shear stress and the velocity.
- Once a scour hole is initiated, significant shear stresses occur at the span shoulders. Strong three dimensional flow will keep washing out the sediments supporting the free spanning pipe, which leads to scour propagation along the axis of the pipe.

Questions?

Zone 9
1/2008

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