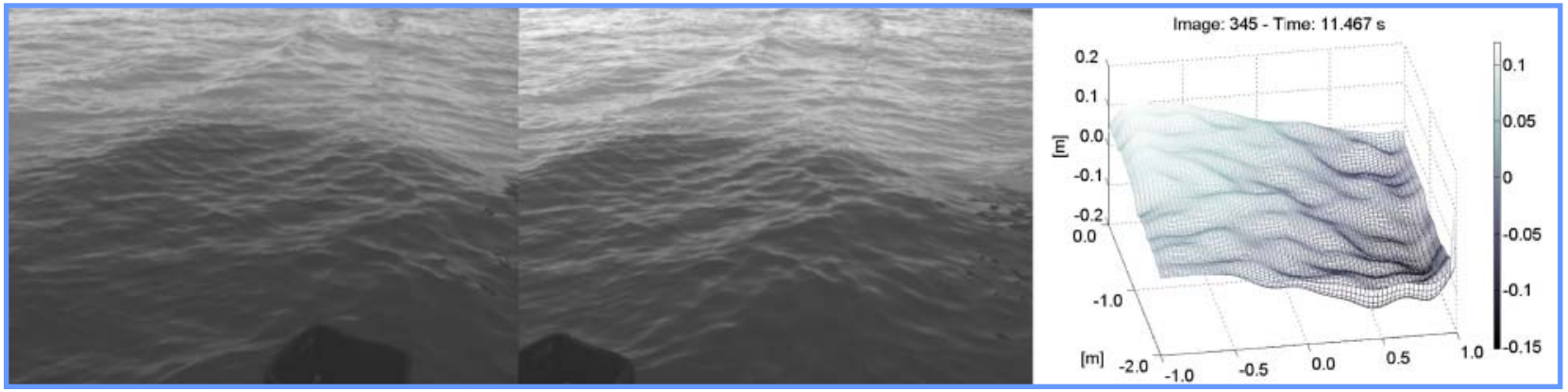
WAVE STATISTICS AND SPECTRA VIA A WAVE ACQUISITION and ANALYSIS STEREO SYSTEM



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Georgia Tech

PROTECNO

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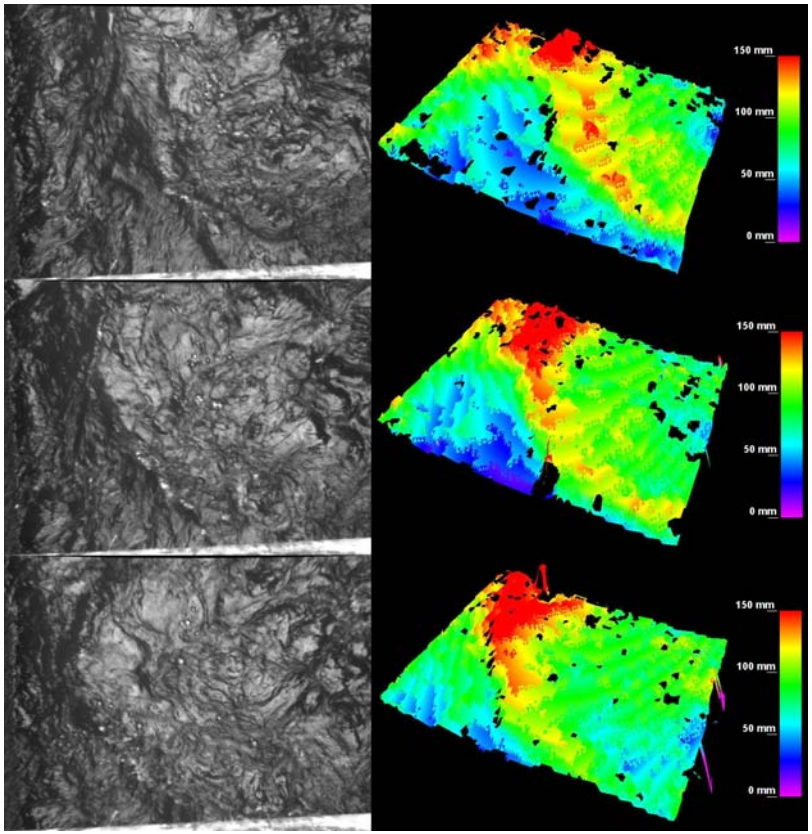
Stereo Video Imagery



Stereo reconstruction of water surface in time

GLOBAL TEAM

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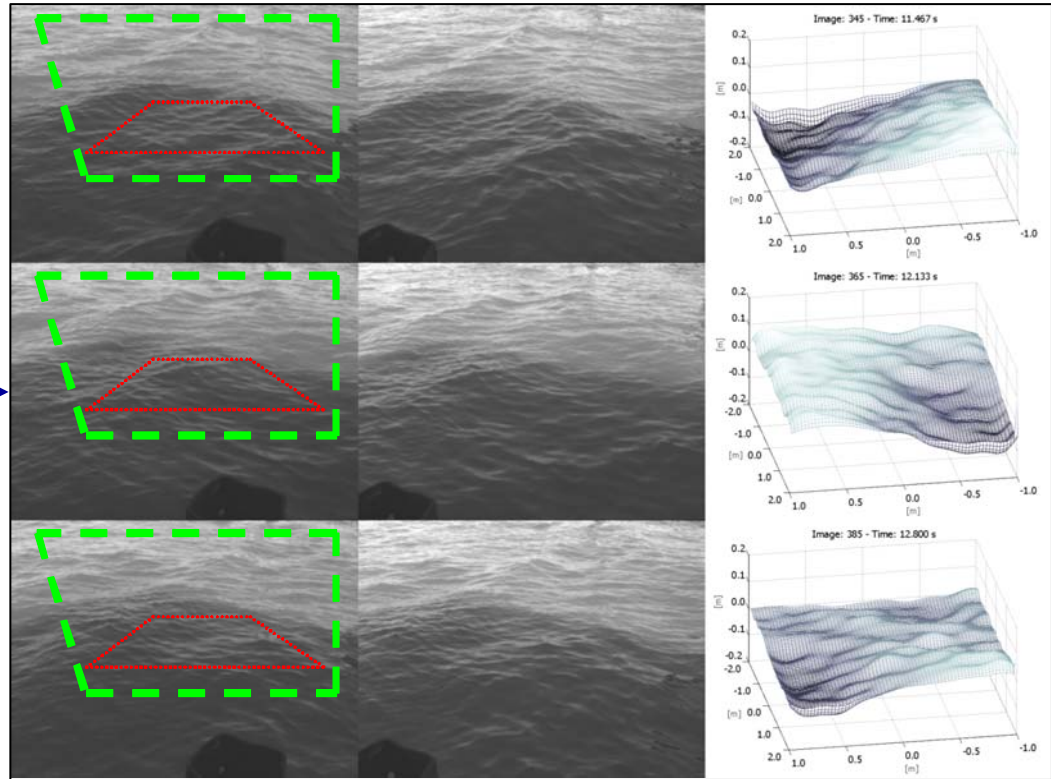
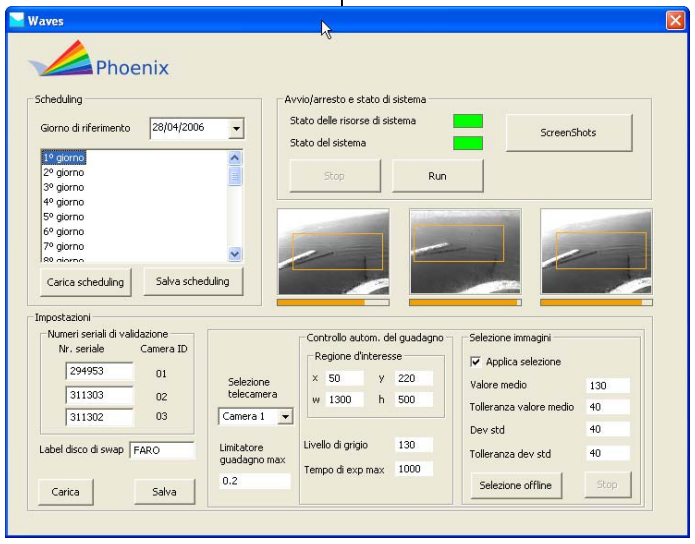


WAVE ACQUISITION and ANALYSIS STEREO SYSTEM (WASS)



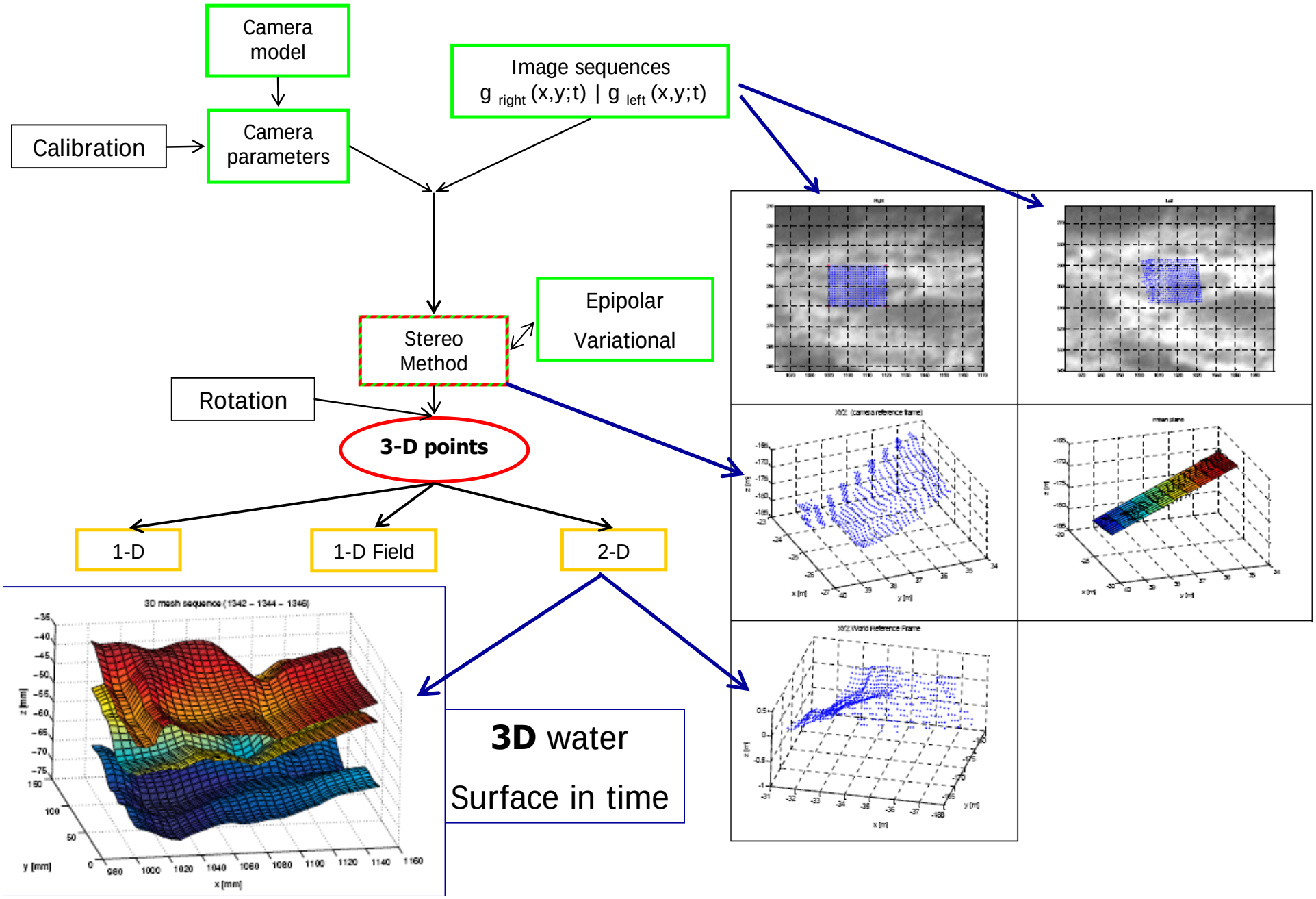
- Image acquisition

(Bi/Trinocular Synchronized digital cameras)

- Image processing

(Epipolar /Variational Stereo method)

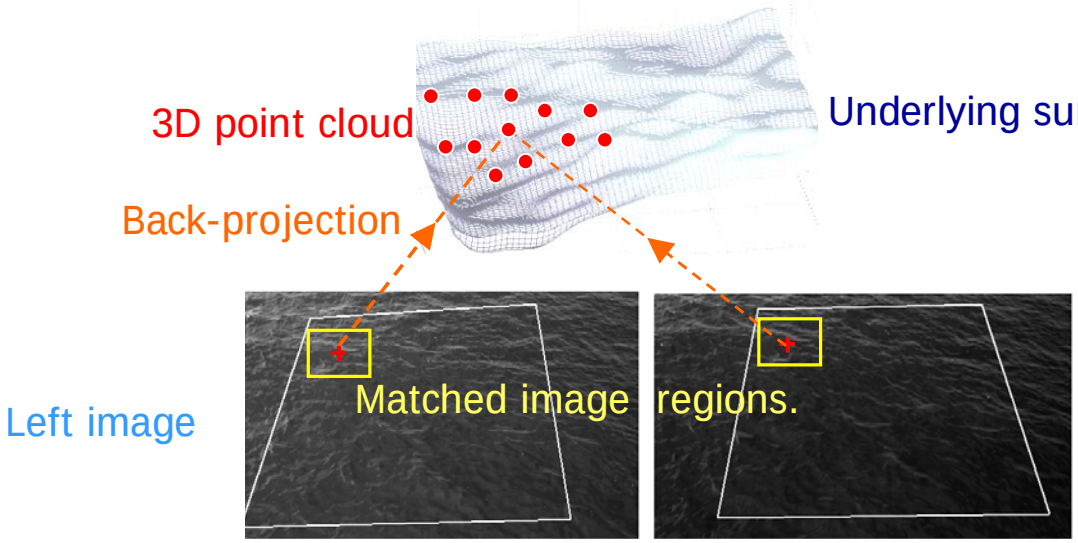
WAVE ACQUISITION and ANALYSIS STEREO SYSTEM

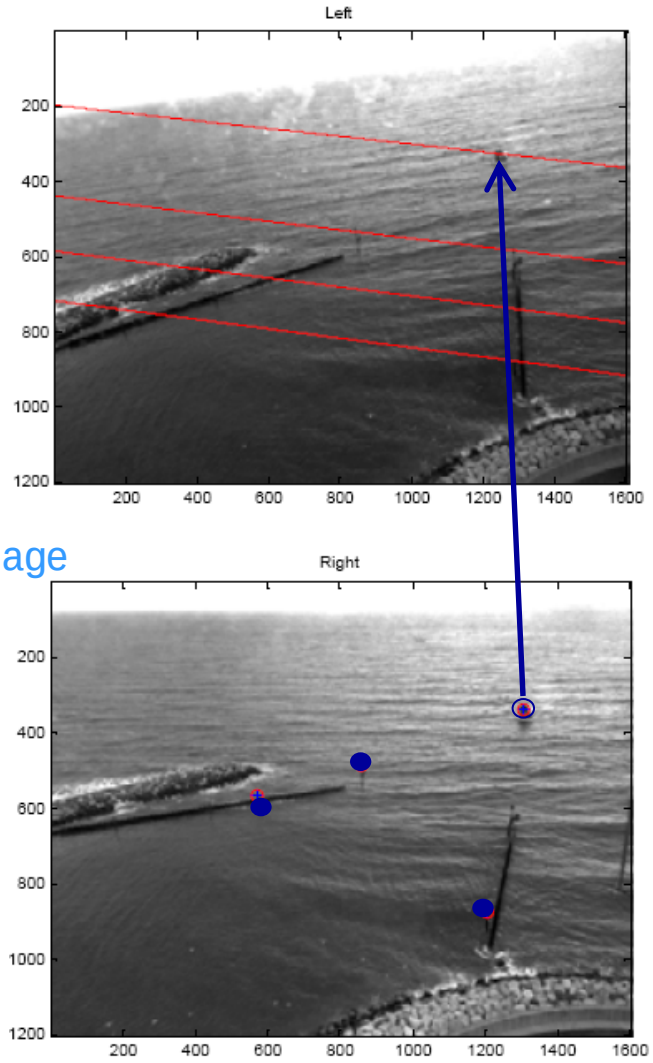


RECONSTRUCTION OF THE WATER 2D SURFACE FROM IMAGES

Epipolar stereo solution

Philosophy: separate the matching/correspondence problem from the reconstruction problem



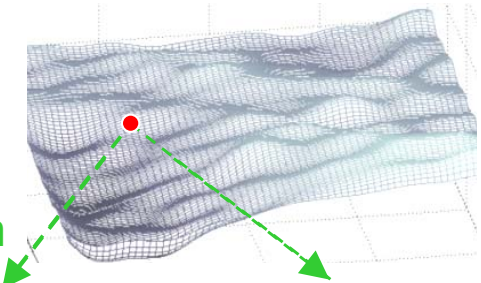


RECONSTRUCTION OF THE WATER 2D SURFACE FROM IMAGES

Variational stereo solution

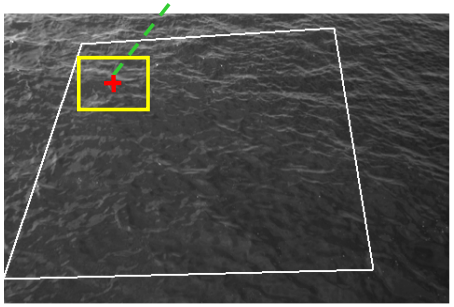
Philosophy: adjust the 3D model to the 3D world represented by the data (images) so that an energy is minimized.

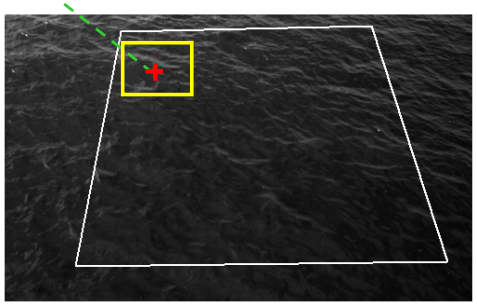
Explicit & deformable 3D model of surfaces



Deform surface until "best match" is achieved by energy minimization.

Forward projection

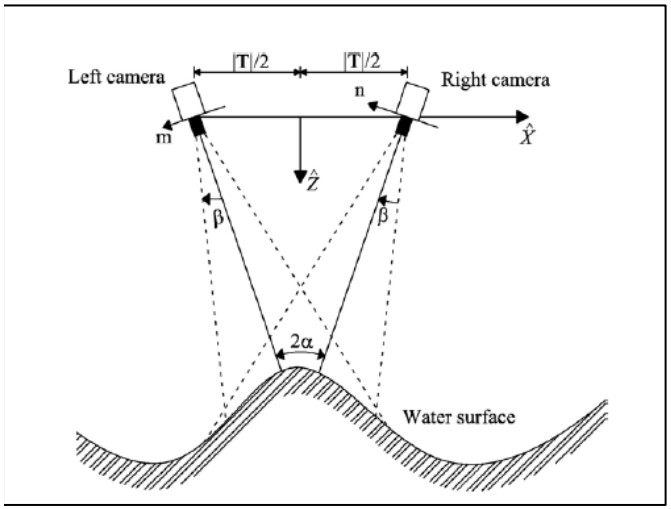


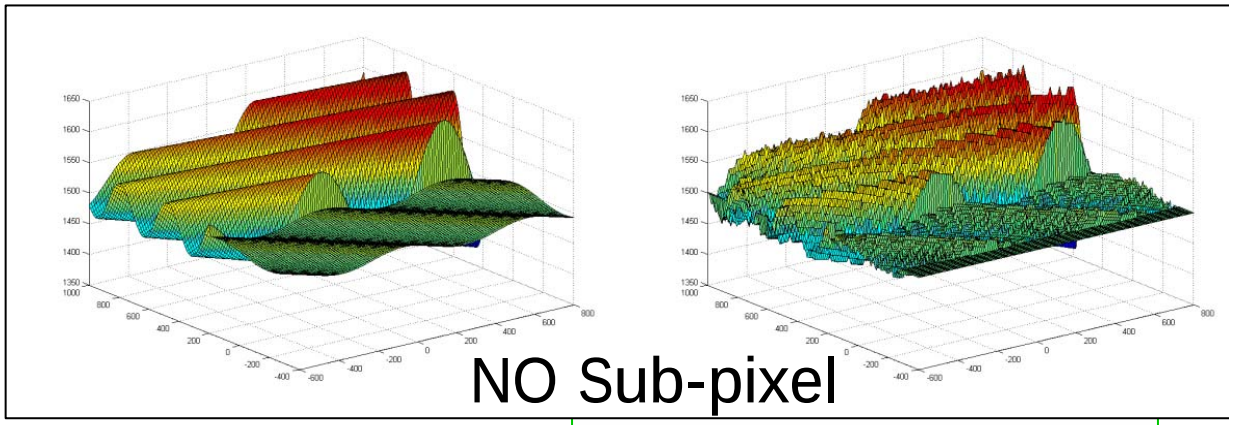


Left image

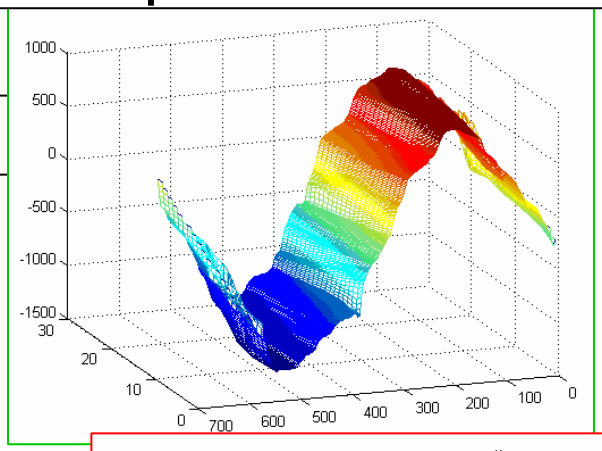
Right image

QUANTIZATION ERROR



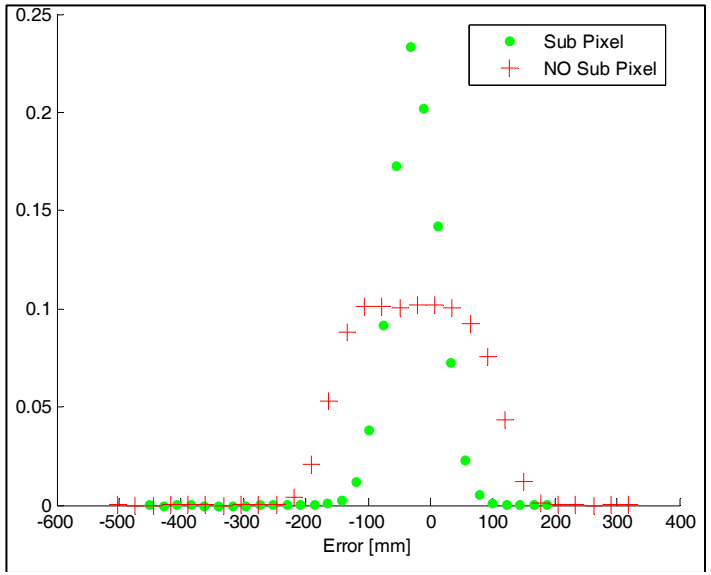


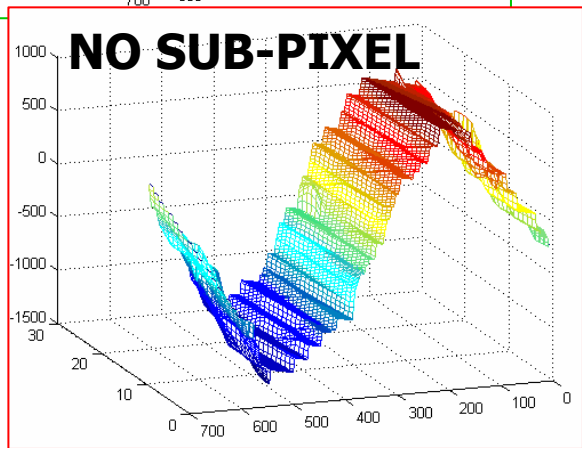
SUB-PIXEL



<u>Errors</u> depend on:

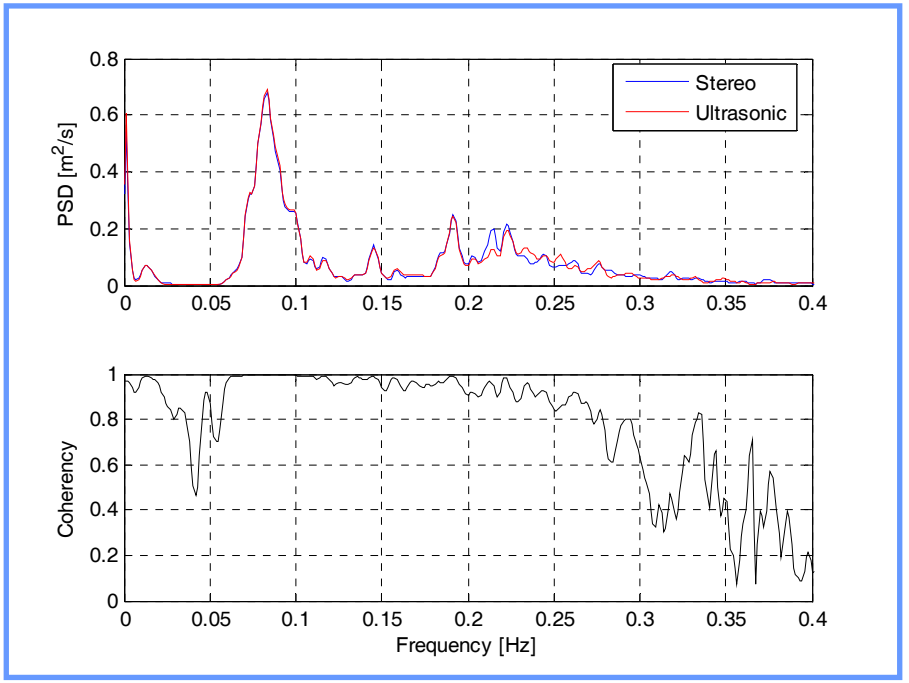
1. Camera specifics (e.g. pixel number *N*)
2. Focal length (through β)
3. Baseline distance (T)
4. Water-baseline distance (z)
5. Angle of converging axes (α)
6. Number of cameras
7. <u>Sub-pixel</u> detection

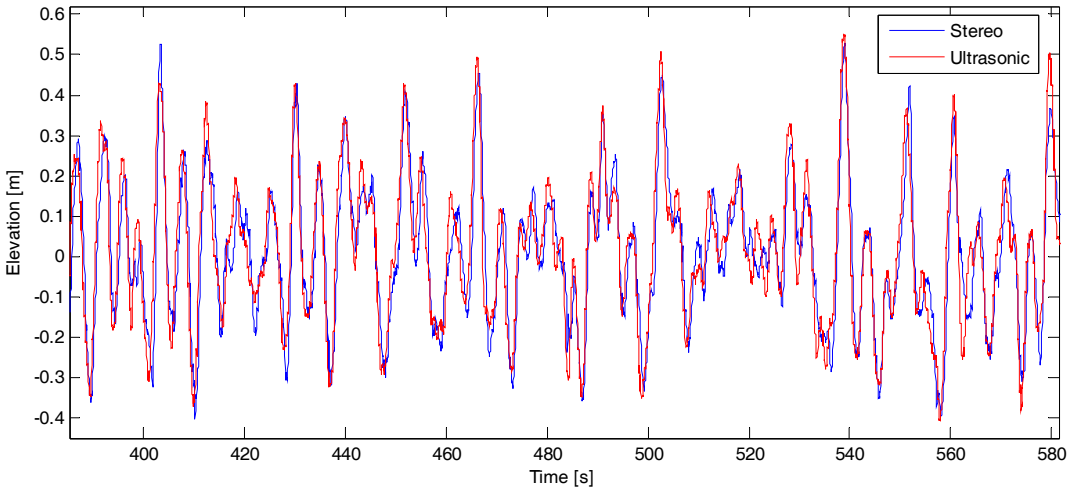




Stereo method: VALIDATION

- Z_0 ~ 11 m, b = 1.88 m
- Matched Area : 0.15 x 0.15 m²
- e_{rx} = e_{ry}= 0.4 cm, e_{rz} = 2.3 cm
- 100 % of points matched
- 1008 x 1008 pixel camera
- F = 13 mm, f4, ss = 1 / 250 s
- fr = 20 Hz, T = 24000 s





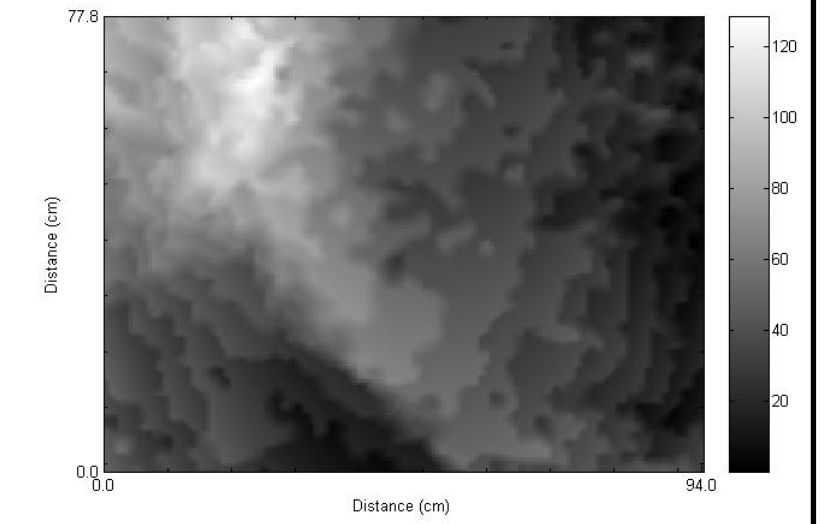
Benetazzo, A. 2006.

Measurements of short water waves using stereo matched image sequences

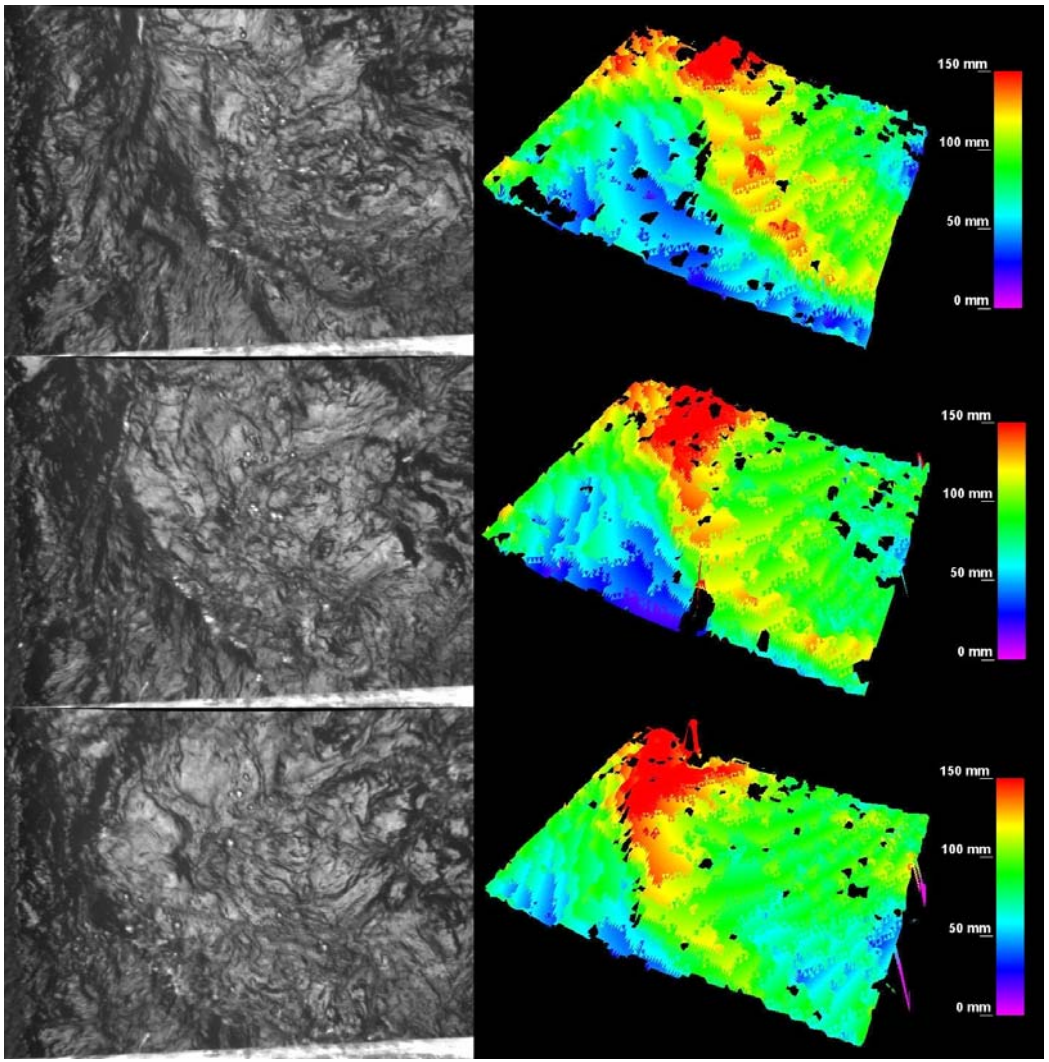
Coastal Engineering, 53:1013-1032

Water surface elevation in time: example

- Z_0 ~ 1.70 m, b = 0.22 m
- Matched Area : 0.94 x 0.78 m^2
- e_{rx} = e_{ry}= 0.15 cm, e_{rz} = 0.69 cm
- 90 % of points matched
- 480 x 640 pixel camera
- F = 6.3 mm, ss=1/200 s



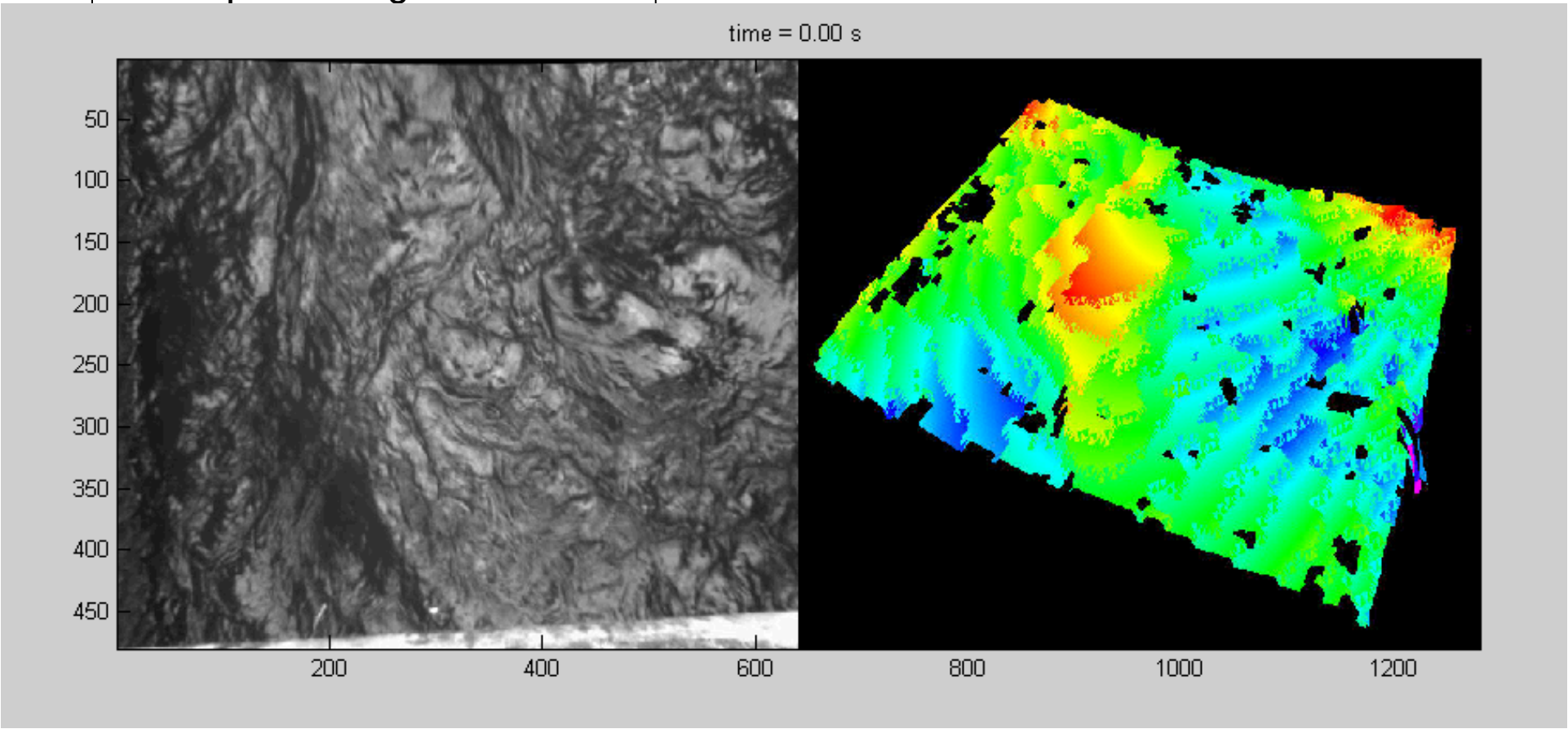
Map of the Surface elevation



Water surface elevation in time: example (epipolar method)

- No sub-pixel
- Post-processing to be done

B<0 m **G**=0 m **R**>0 m

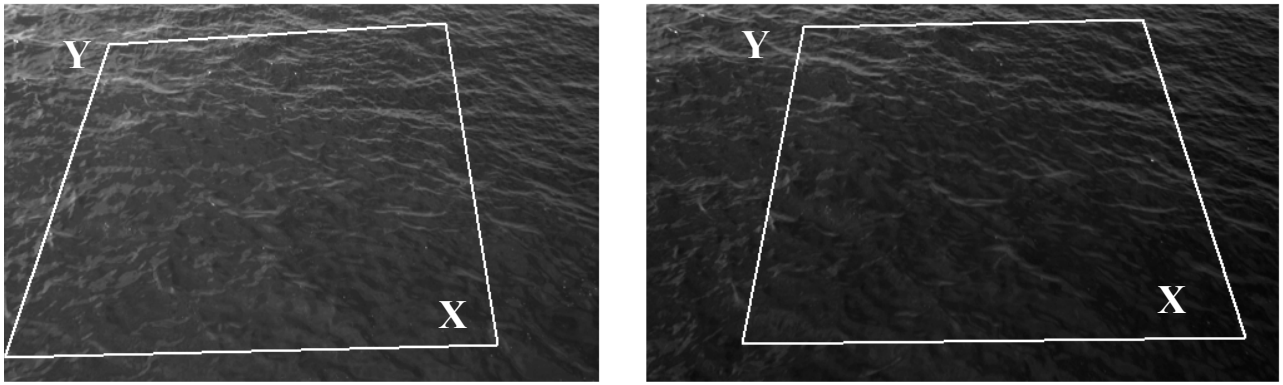


Right camera

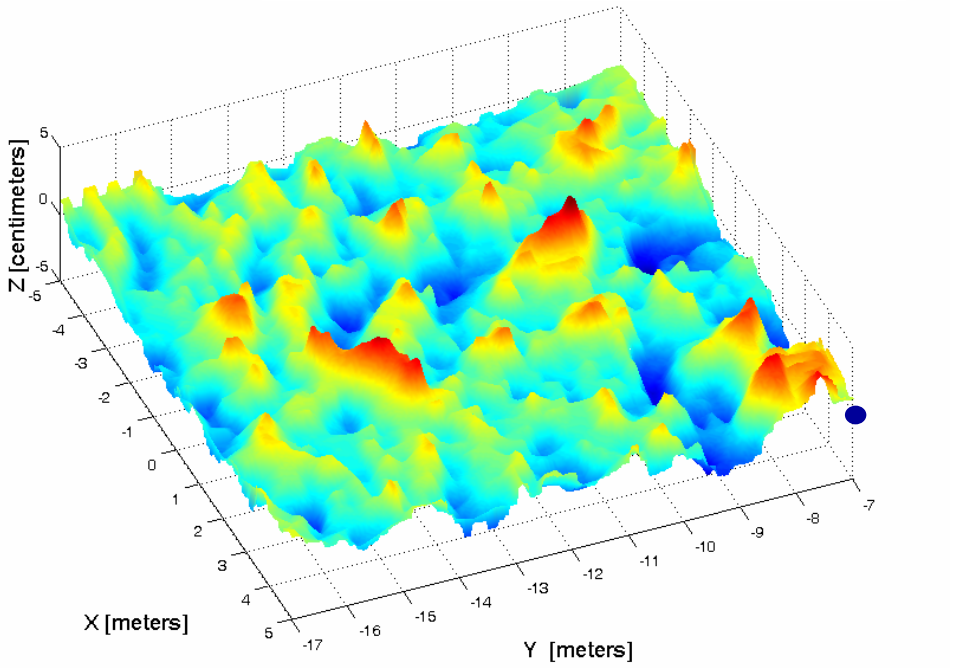
3-D Surface

VARIATIONAL WAVE ACQUISITION STEREO SYSTEM (VWASS)

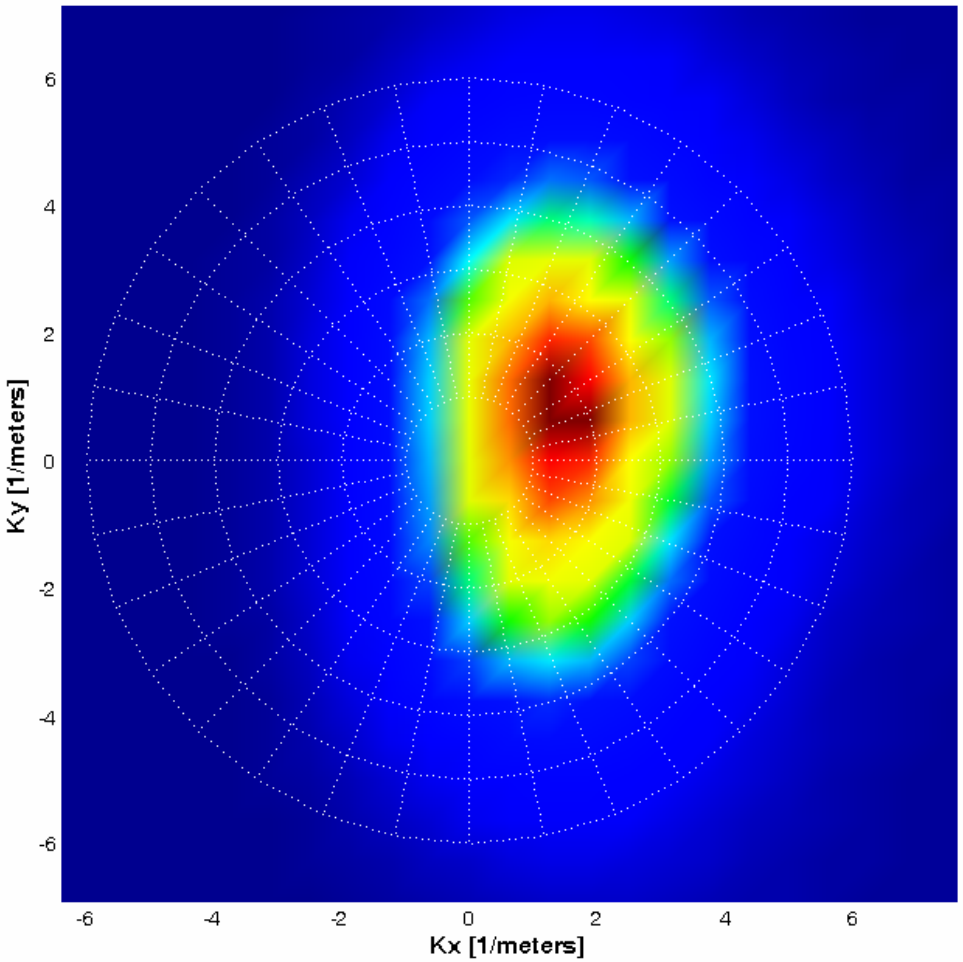
Input stereo pair images. The rectangular domain (8 m x 8.7 m).
The height of the waves is in the range ±0.2 cm.

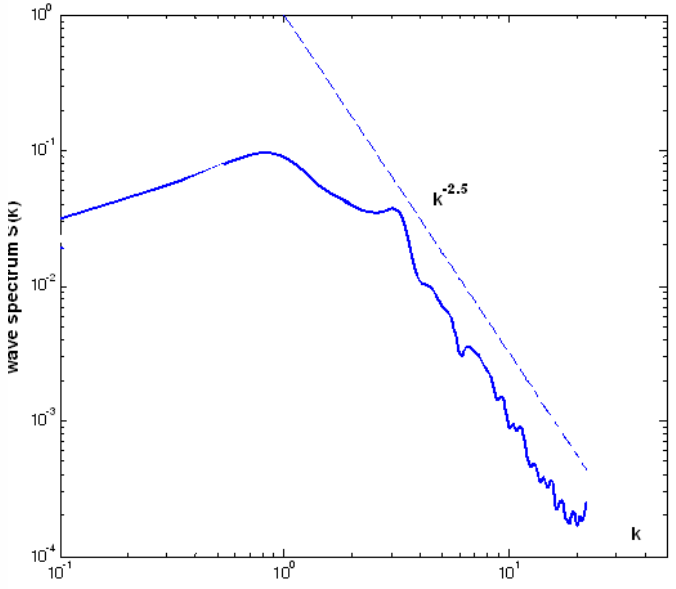


Reconstructed wave surface

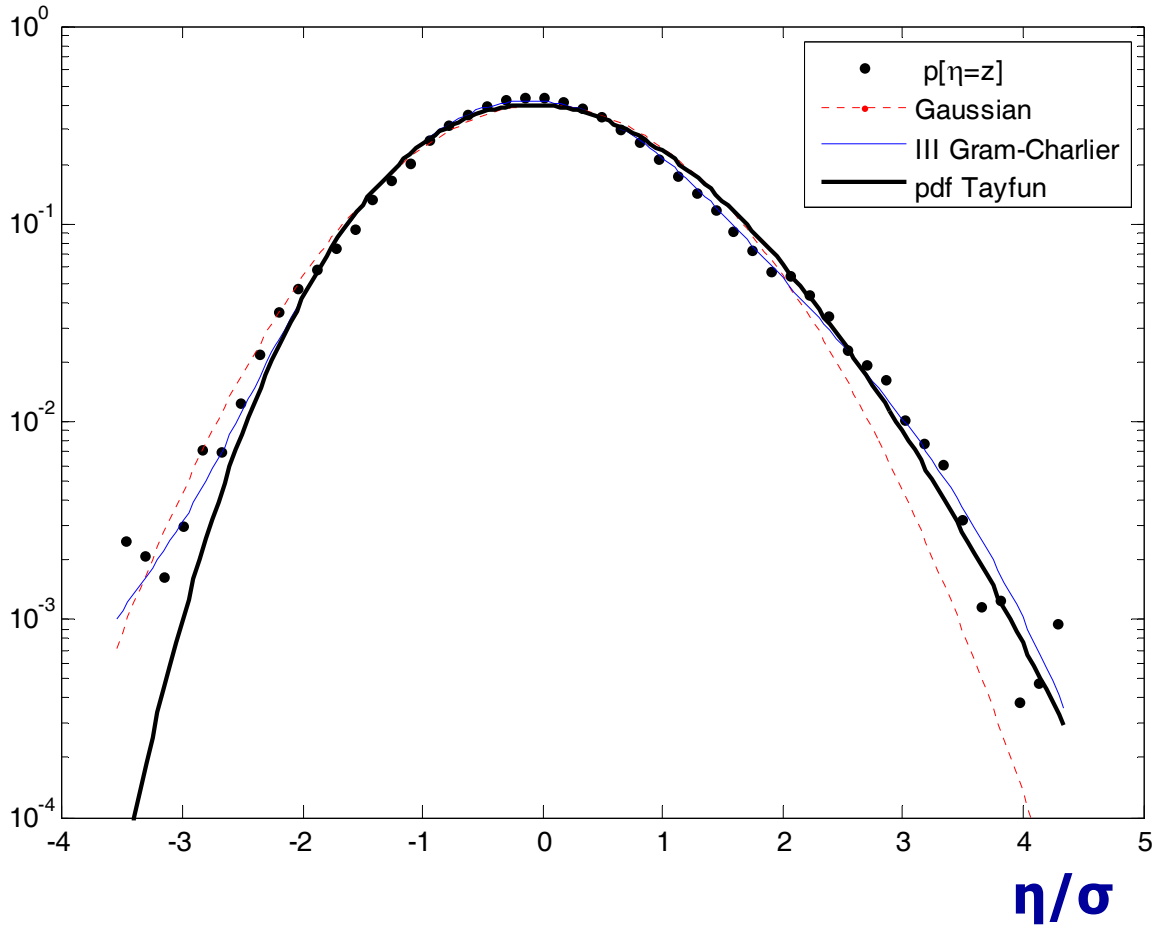


PRELIMINARY RESULTS : wave statistics and spectra





PRELIMINARY RESULTS :Probability density function of wave surface



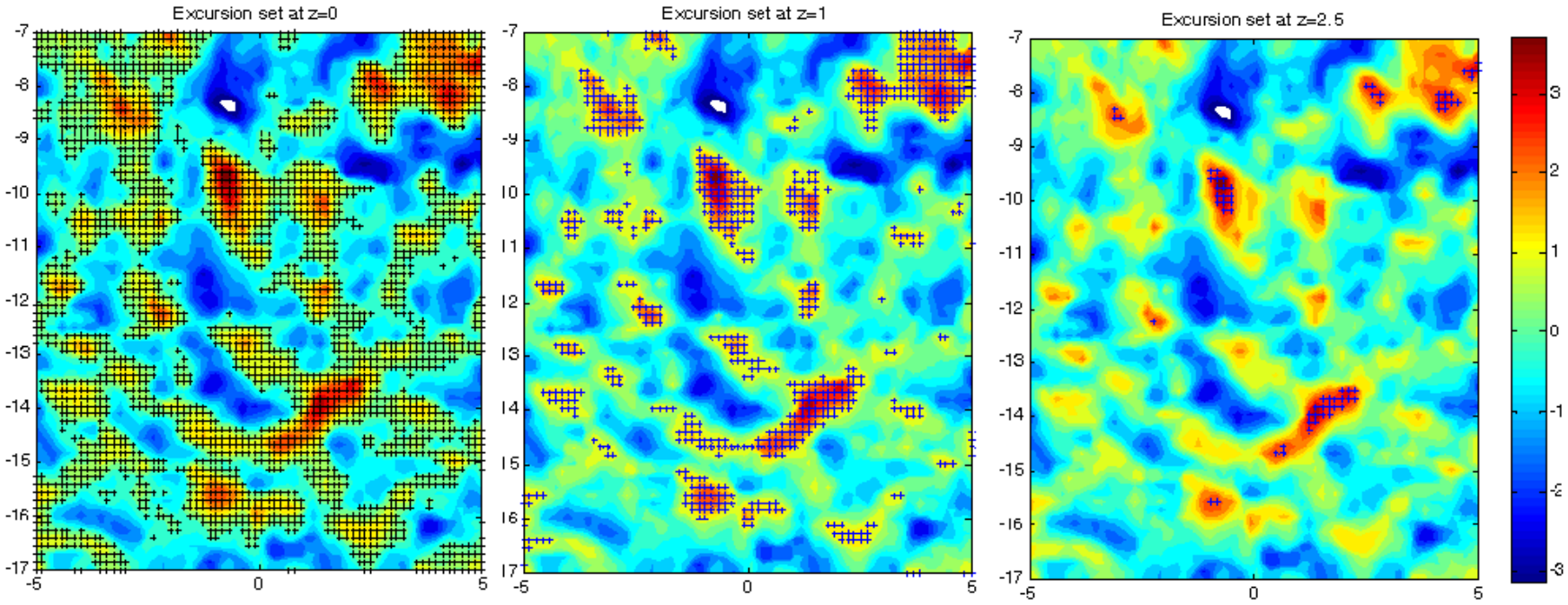
SECOND ORDER EFFECTS DOMINANT !! (Tayfun model)

BEYOND WAVES & SPECTRA: Euler Characteristic of excursion sets

The geometry of random fields

Adler (1981), Adler, Taylor & Worsley (2007)

EC = #connected components - # holes

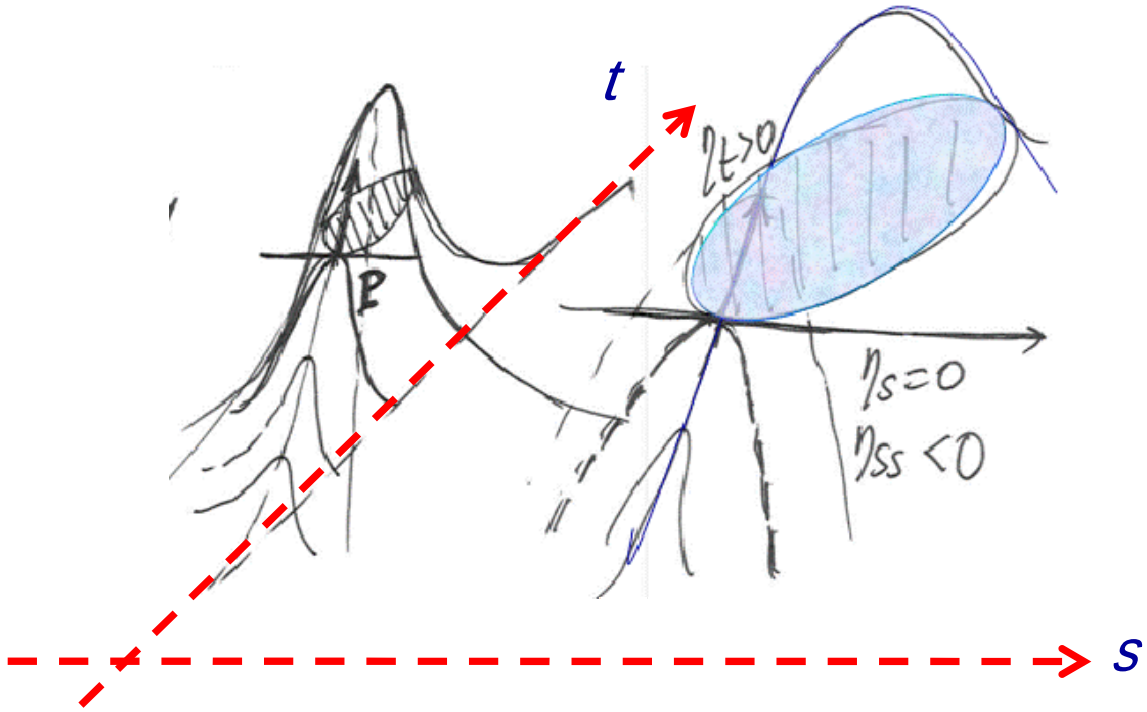


EC counts number of large maxima

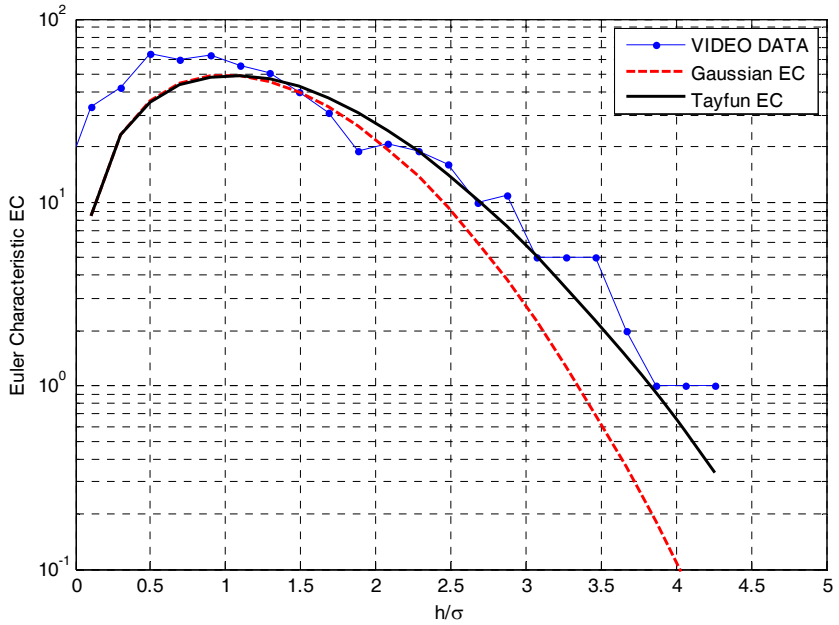
EC counts also large 3D Upcrossings

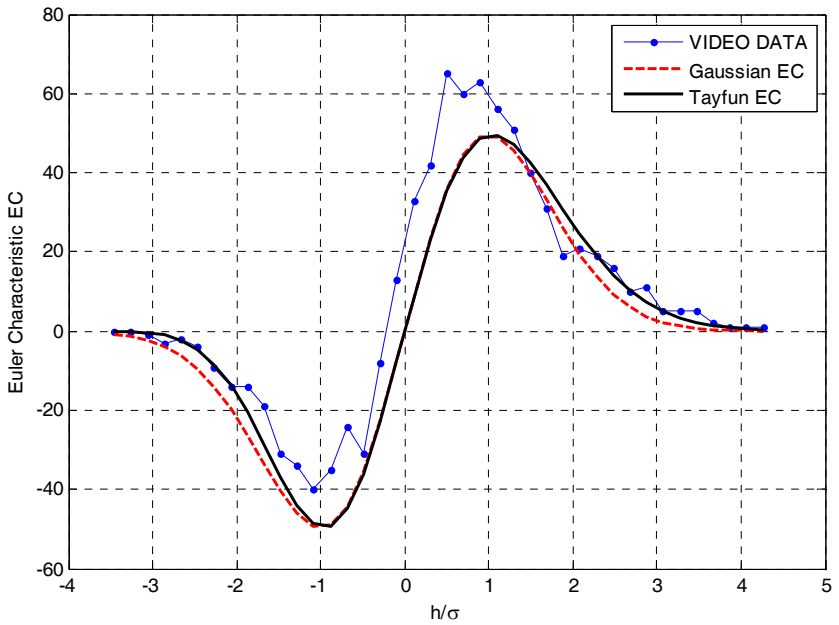
One-to-one correspondence between large maxima & 3D upcrossings

as in one dimensional stochastic processes



Euler characteristic EC of nonlinear wave fields (Piterbarg-Tayfun model)





$$EC(h) = Area\,(2\pi)^{-3/2}\left|\Lambda\right|^{1/2}\frac{-1+\sqrt{1+2\mu h}}{\mu}\exp\left[-\frac{\left(-1+\sqrt{1+2\mu h}\right)^2}{2\mu^2}\right]$$

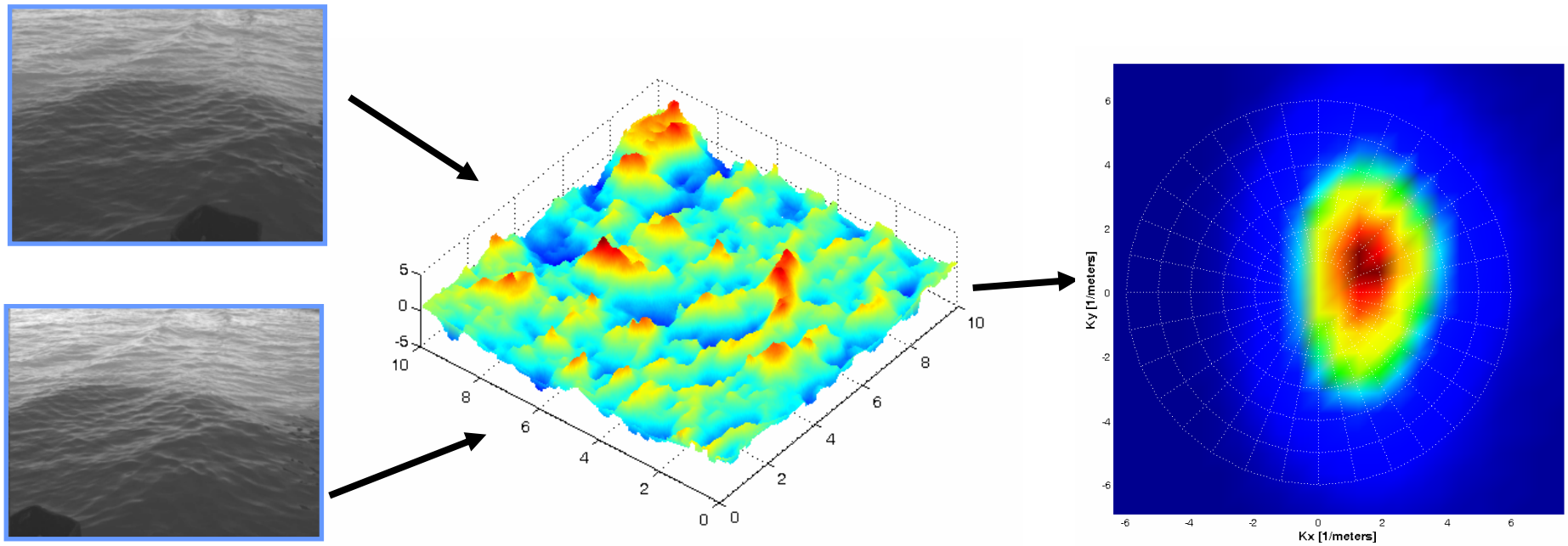
$$\Pr\left[\max_{P\in S}\eta(P) > h\right] \approx EC(h)$$

CONCLUSIONS

- Stereo reconstruction methods have more advantages than classical wave measurements

- Our method provides reliable statistics and accurate predictions of ocean waves due to the rich information content of video data

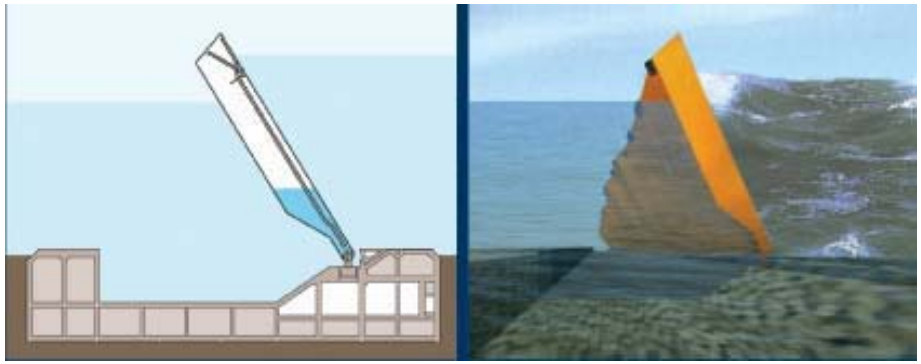
- WASS technology is beneficial to offshore design



WHAT'S NEXT?

MOSE mobile flood barriers for the defence of Venice

Analysis of wave 2D pattern ➔ water level and hydrodynamic forces



Northern Adriatic Sea

Stereo analysis of waves propagation

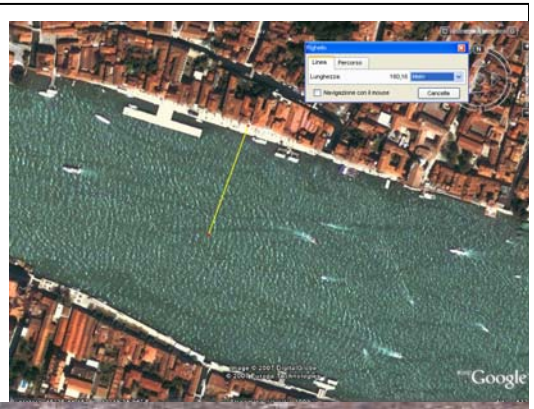
Deep waters

Italian National Research Council

Navy towers off Georgia coast USA

Venice harbour Authority

Analysis of ship generated waves on Venice hystorical buildings



ACKNOWLEDGMENTS

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We also thank both M. Aziz Tayfun & Harald Krogstad for useful discussions and suggestions.

ANY QUESTIONS ?