Sea surface roughness by photogrammetry

SSUP: Sea SUrface Photogrammetry

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NATO Undersea Research Centre

Why?

Digital photogrammetry of the sea surface

- Measuring height
- Natural, time dependant environment poses problems
  - Seafloor surface
  - Sea surface
- Single point measurements *vs.* spatial measurements

Why?

Digital photogrammetry of the sea surface

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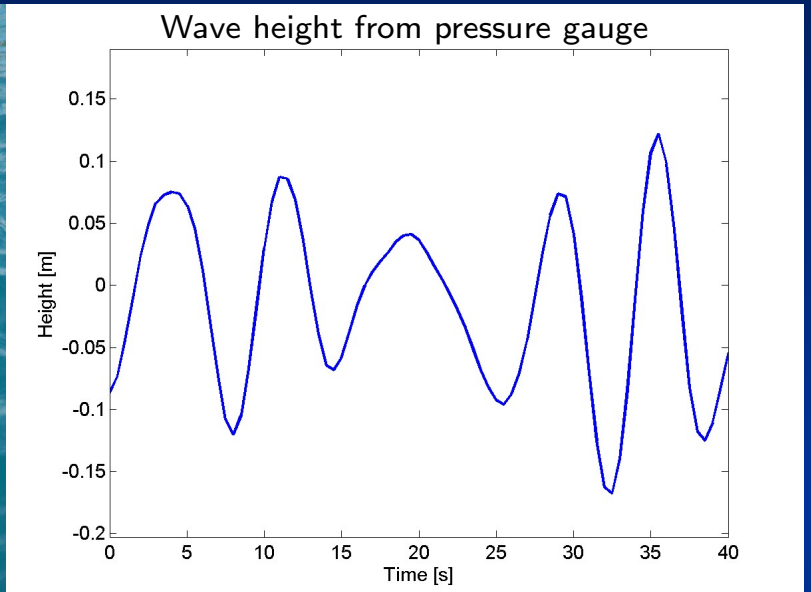
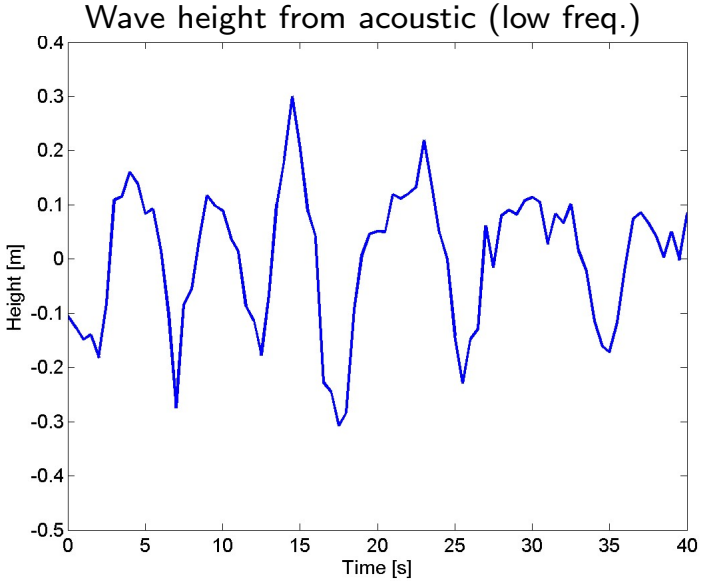
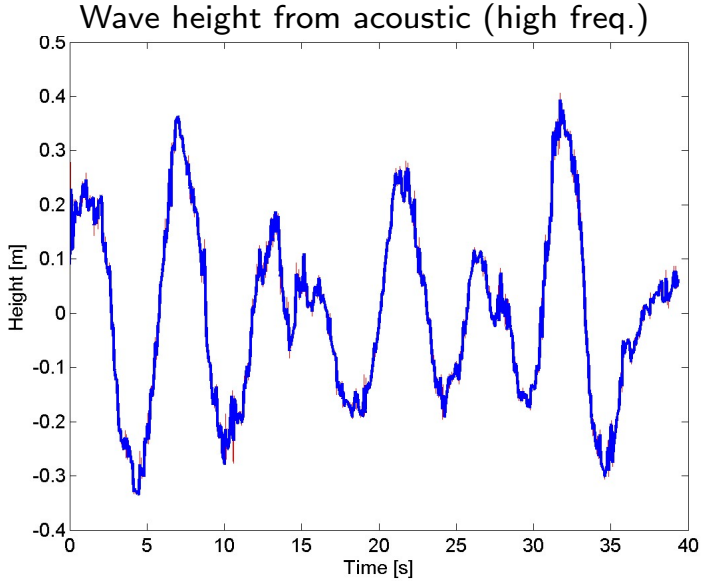
Digital photogrammetry of the sea surface







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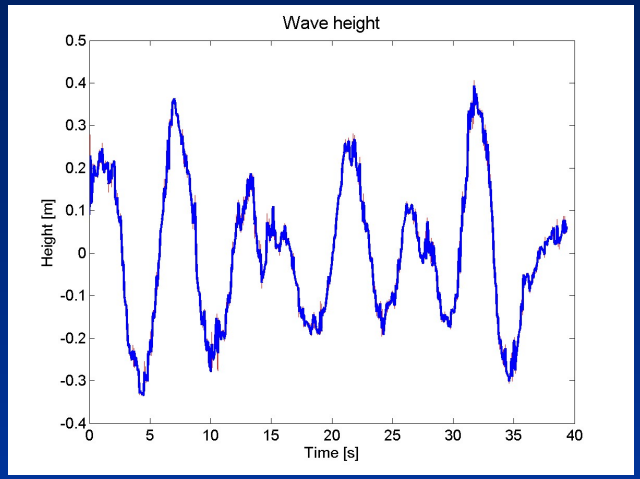

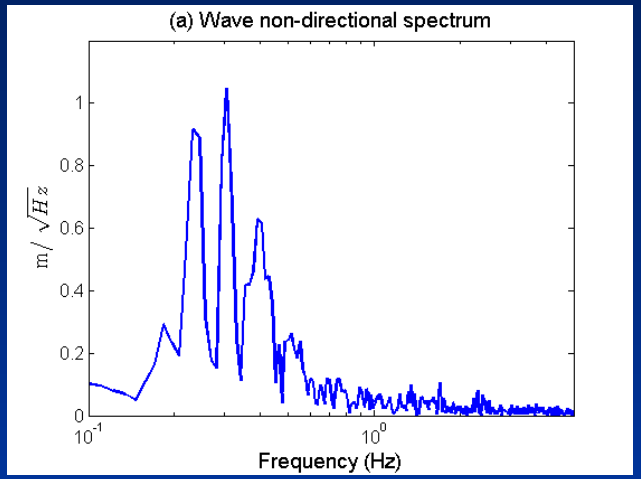

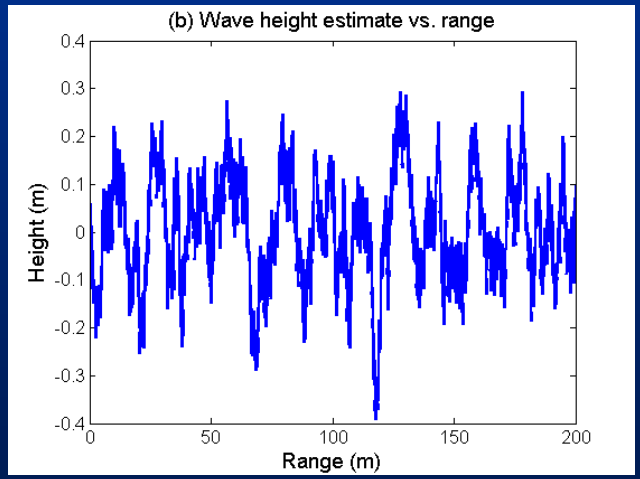

Characteristic equation

$$f = \frac{1}{2\pi}\sqrt{\frac{2\pi}{\lambda} g \tanh\left(\frac{2\pi H}{\lambda}\right)}$$

where : H the water depth

f is the temporal frequency

g is the gravity

λ the spatial wave length

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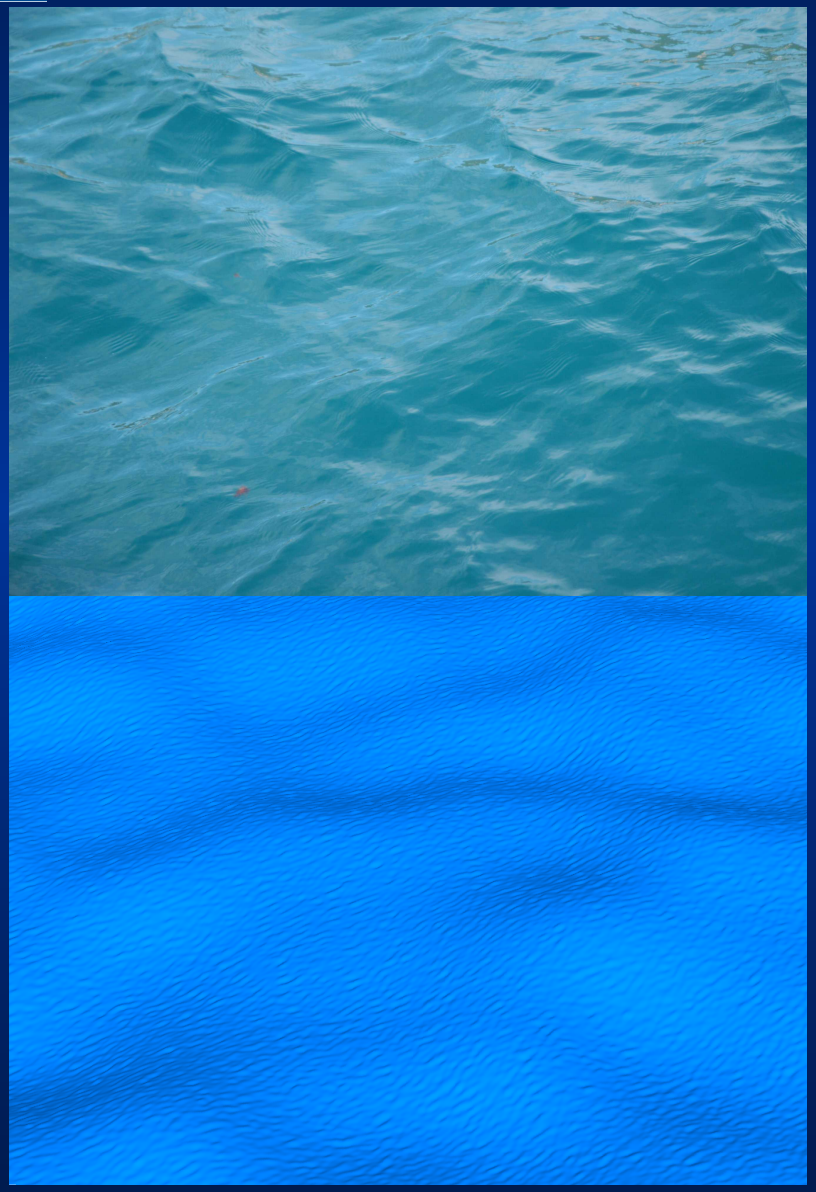
- Natural, time dependant environment poses problems
  - Seafloor surface
  - Sea surface
- Single point measurements *vs.* spatial measurements
- Importance for scattering models

Why?

Digital photogrammetry of the sea surface



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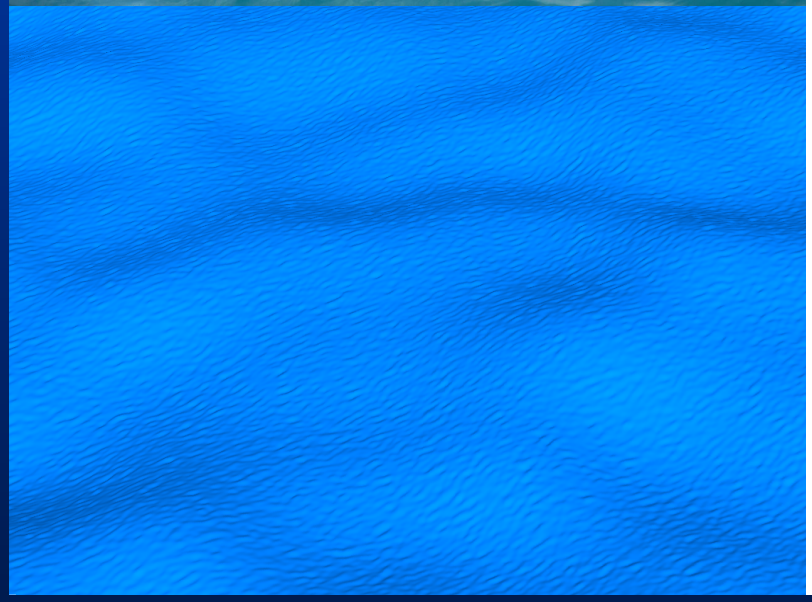

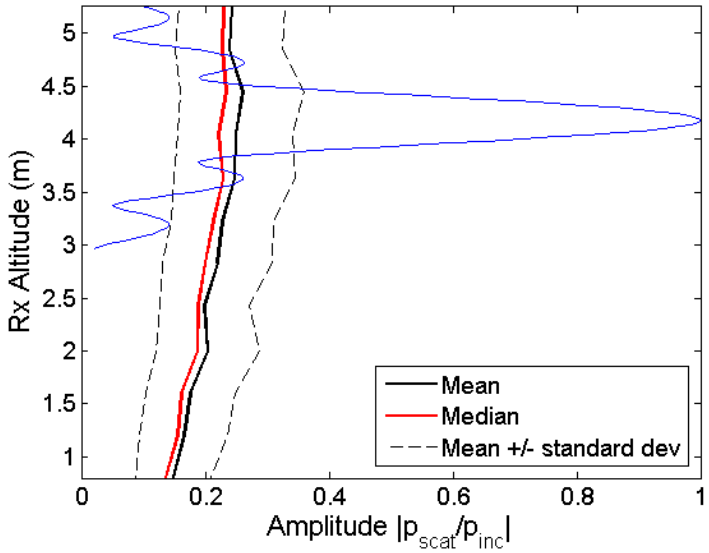

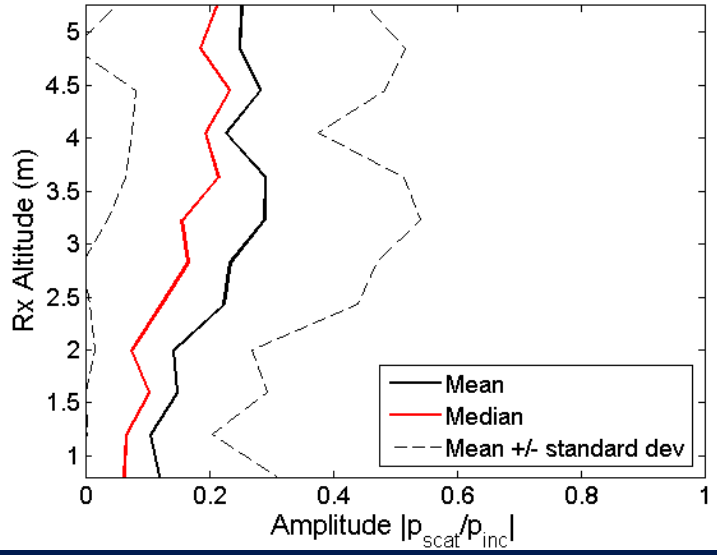

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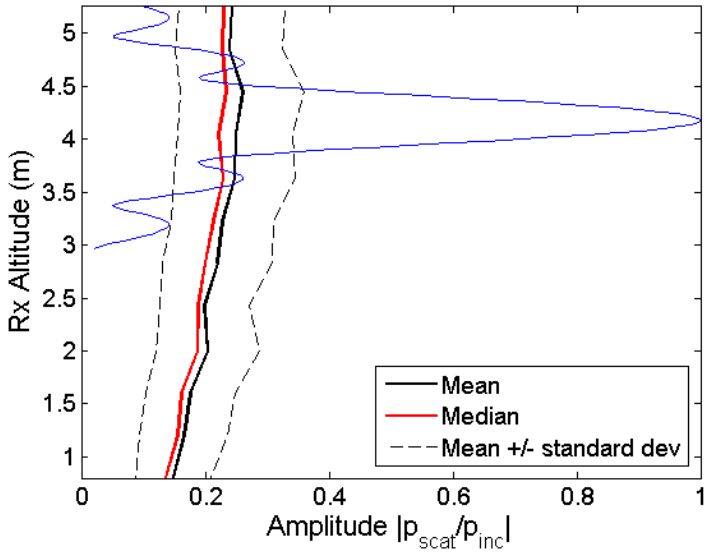
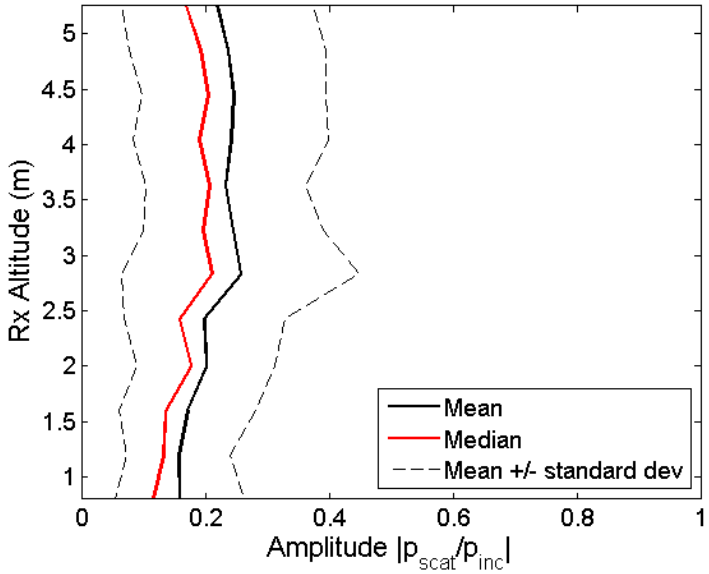
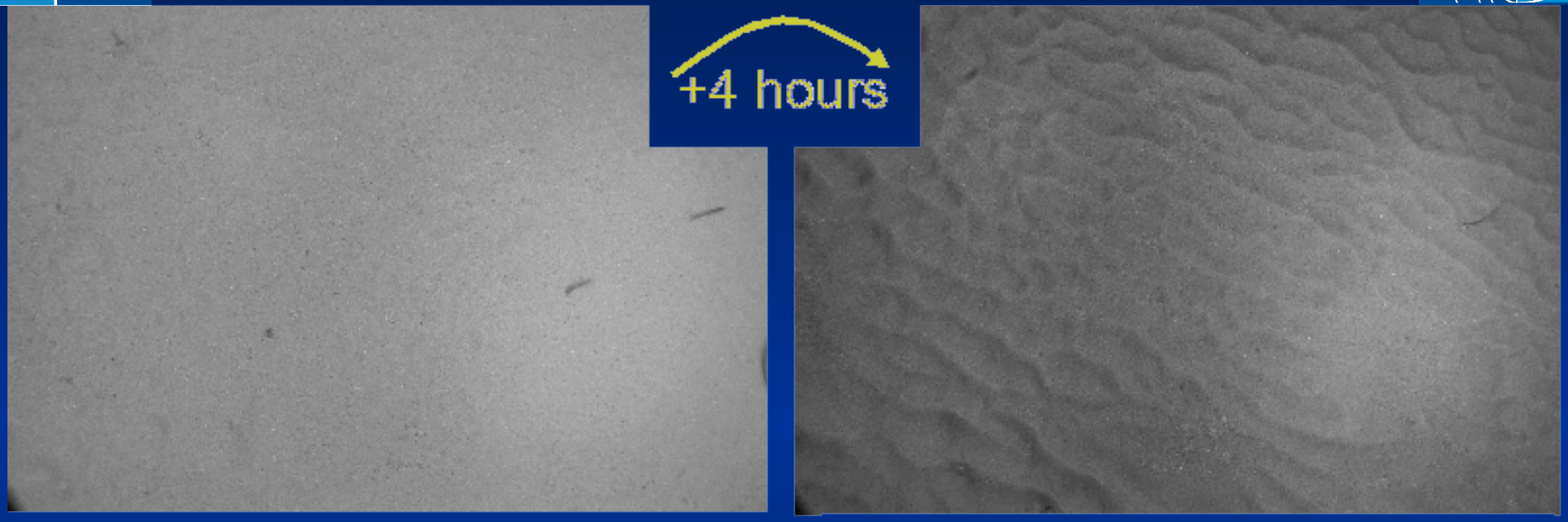


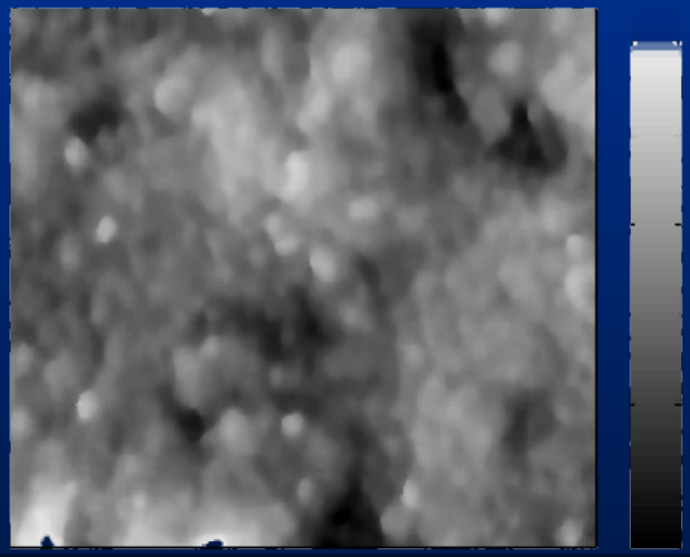


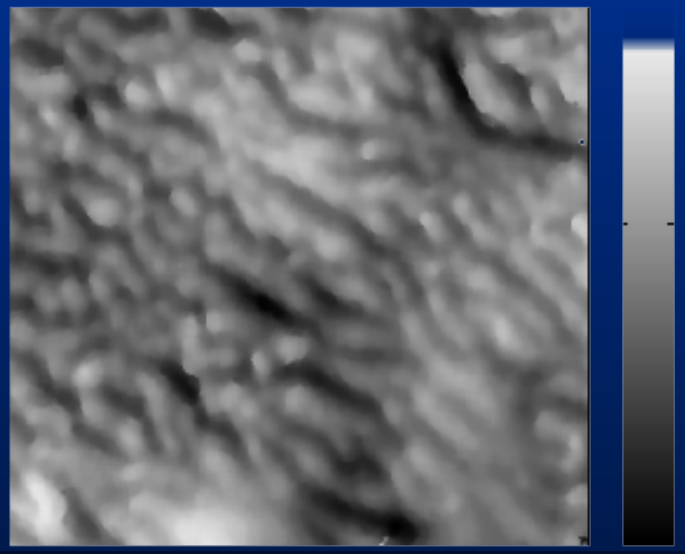
Stereo-photography

- Old technique used by:
  - Carthographer (eg. mapping)
  - Geologist (eg. location of floor features)
  - Architect (eg. building dimensions)
  - Robotics (eg. object distance)
  - Etc...
- What's new here:
  - Use for:
    - Seafloor (underwater)
    - Sea surface (moving surface)
  - Low contrast surface/object
  - Dense map (Digital Terrain Map)
  - Spatial variability
  - Temporal variability

Stereo-photography







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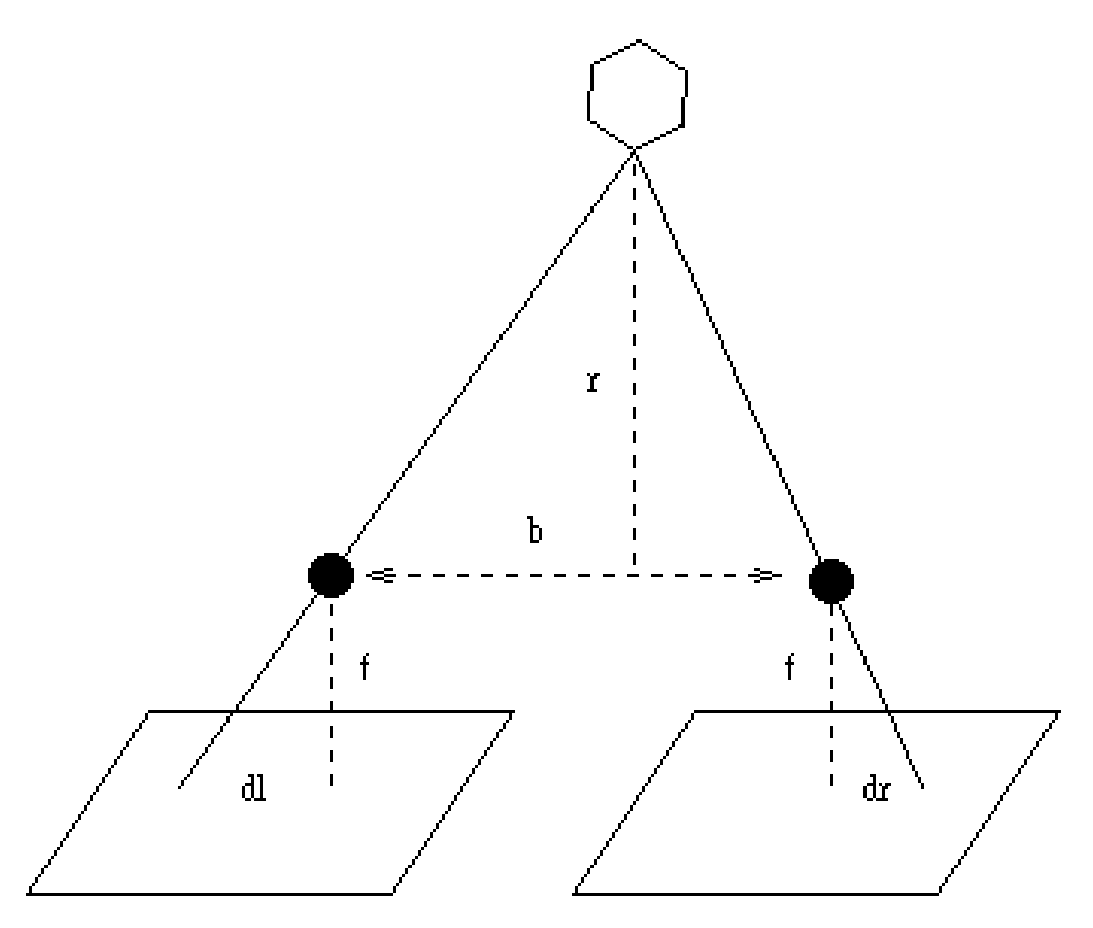
  - Temporal variability
- How does it work

Stereo-photography



$r = \frac{bf}{d}$, where the disparity d is given by $d = dl - dr$

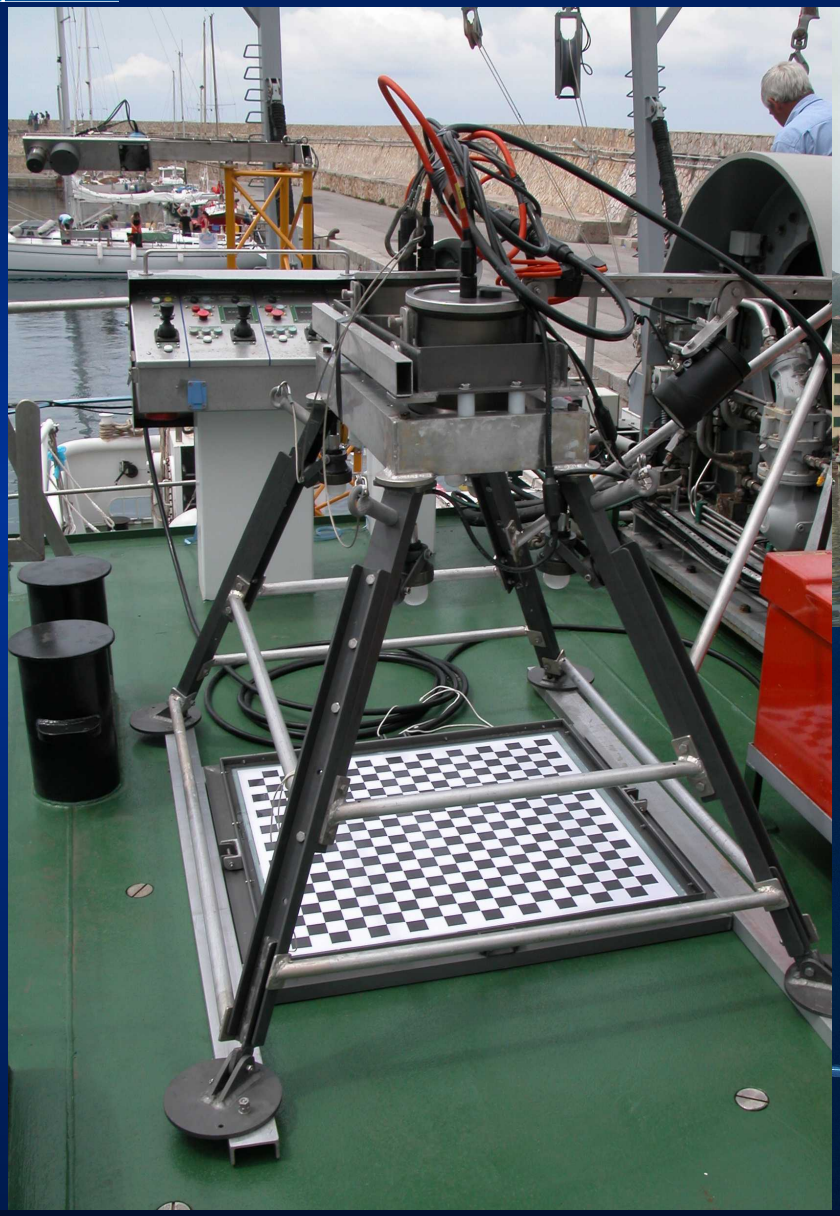
NURC previous experience

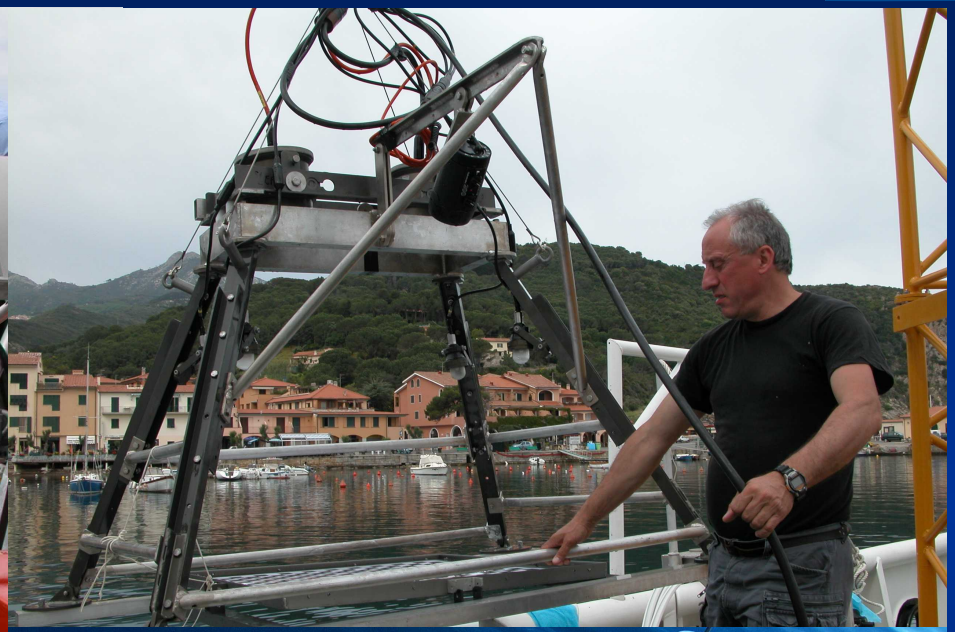
- Tony Lyons & Eric Pouliquen[1]:
  - First prototype
  - Seafloor roughness
- Gaetano Canepa, Eric Pouliquen, Alberto Figoli & Tony Lyons[2]:
  - Seafloor roughness
  - Improved:
    - Camera
    - Acquisition (usb instead of low speed serial)
    - Calibration, rectification, ...

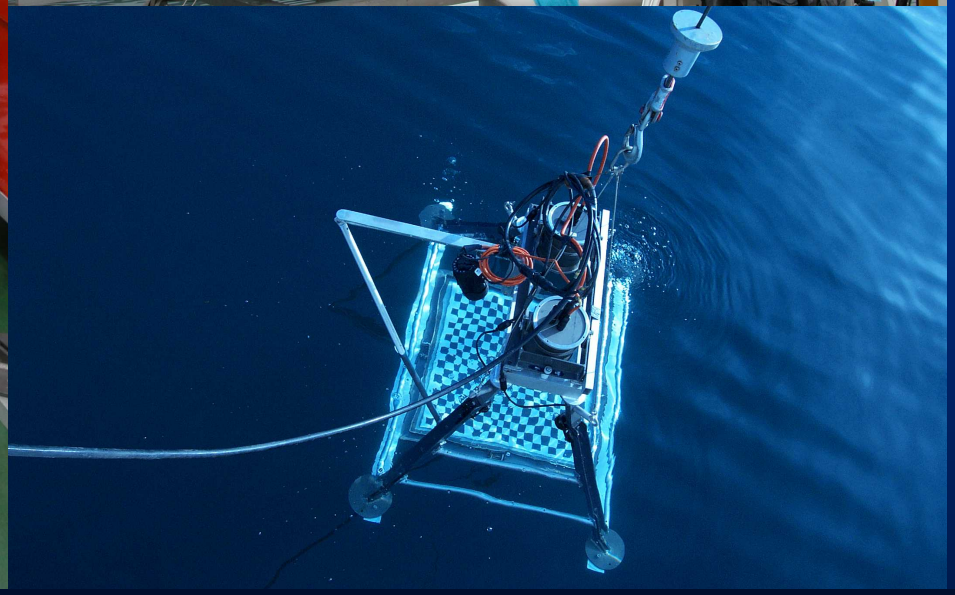
[1] Lyons A.P., *et al.*, Characterization of the Two Dimensional Roughness of Wave-Rippled Sea Floors Using Digital Photogrammetry, IEEE JOE, 27(3), pp. 515-524, 2002.

[2] Canepa G., *et al.*, Underwater stereo-photographic measurement of small scale roughness: limits to spatial correlation accuracy, JASA, 123 (5-2), p. 3085, 2009.

NURC previous experience







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  - Improved:
    - Camera
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    - Calibration, rectification, ...
- A new system to measure sea surface instantaneous height

Sea surface *vs* Seafloor

- Pros:
  - Better optics
  - Better camera (in our case)
  - System nearer to the observer
  - Better medium (no water turbidity)

Sea surface *vs* Seafloor

Sea surface *vs* Seafloor

- Pros:
  - Better optics
  - Better camera (in our case)
  - System nearer to the observer
  - Better medium (no water turbidity)
- Cons:
  - Lower contrast
  - Fast variation

SSUP system

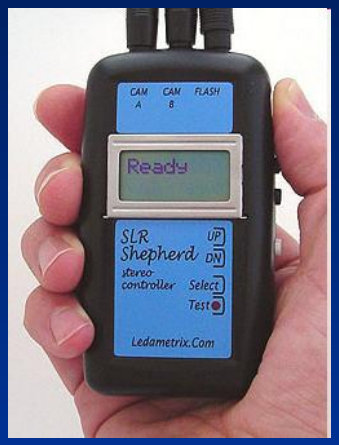
Sea SUrface Photogrammetry

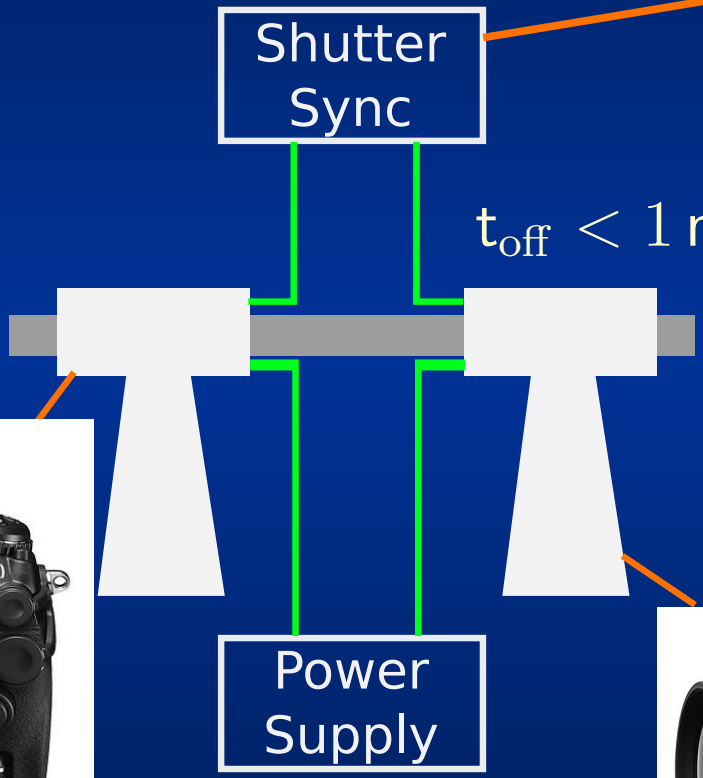
- Hardware:
  - Camera
  - Optics
  - Synchronizer

SSUP system

Sea SUrface Photogrammetry

4,256 x 2,832
Lowest noise
8 frame/s
14 bits raw images





Zoom (adaptable)
High contrast
Fast (f/2.8)

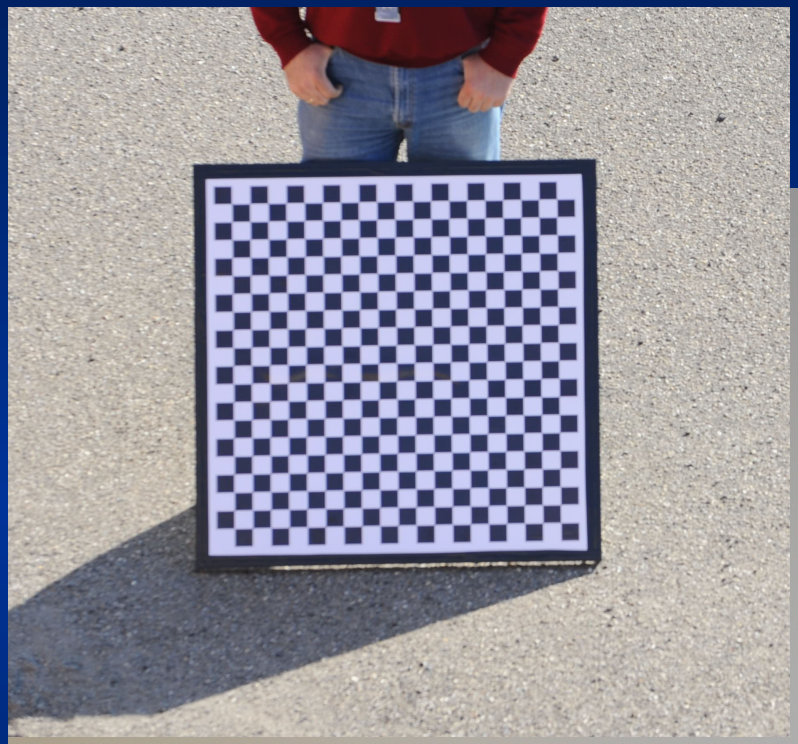
SSUP system

Sea SUrface Photogrammetry

- Hardware:
  - Camera
  - Optics
  - Synchronizer
  - Support
  - Calibration chessboard

SSUP system

Sea SUrface Photogrammetry



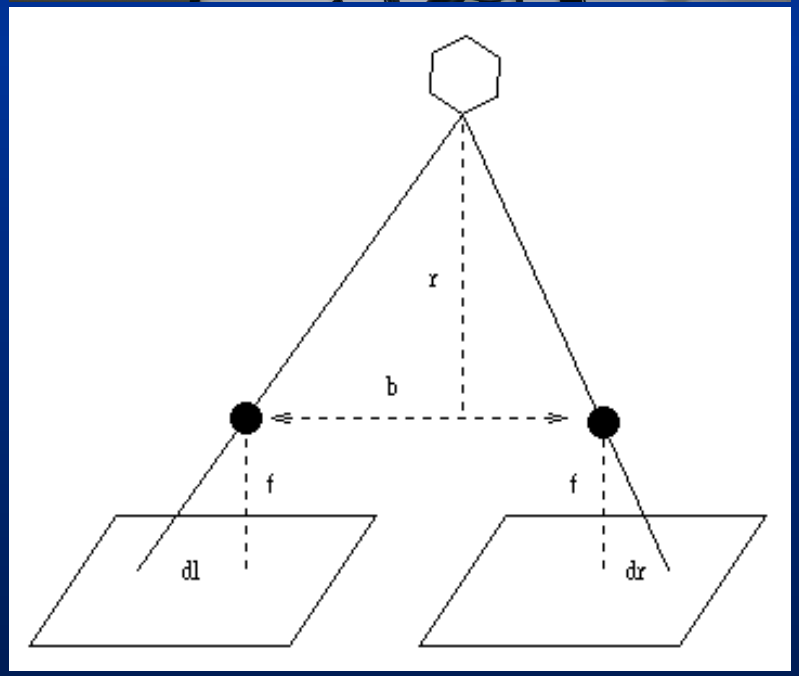
SSUP system

Sea SUrface Photogrammetry

- Hardware:
  - Camera
  - Optics
  - Synchronizer
  - Support
  - Calibration chessboard
- Software:
  - Calibration
  - Rectification
  - Disparity
  - Filtering
  - Reprojection

Calibration

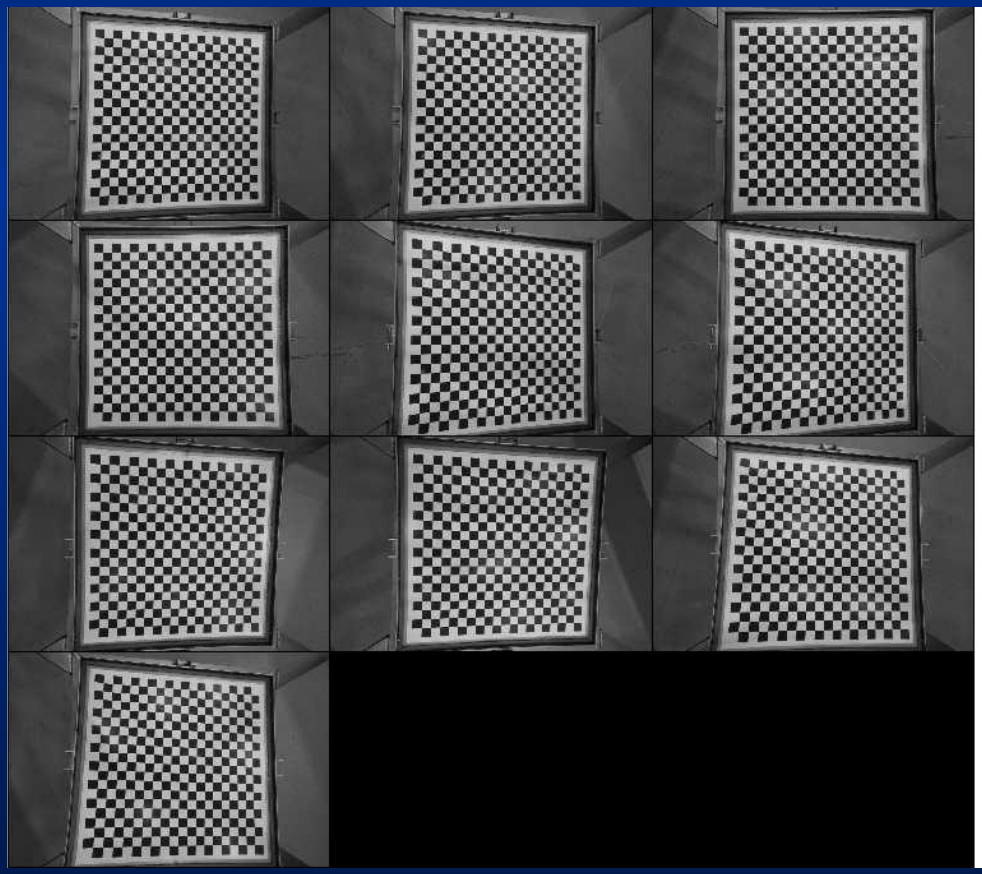
- Calibration
  - Spatial positions and orientation
  - Pin-hole camera parameters (Focal length *etc.*)
  - Spherical aberration
- Complicated by
  - Image dimensions
  - 16 bits images
  - Chromatic aberration
  - Target Distance

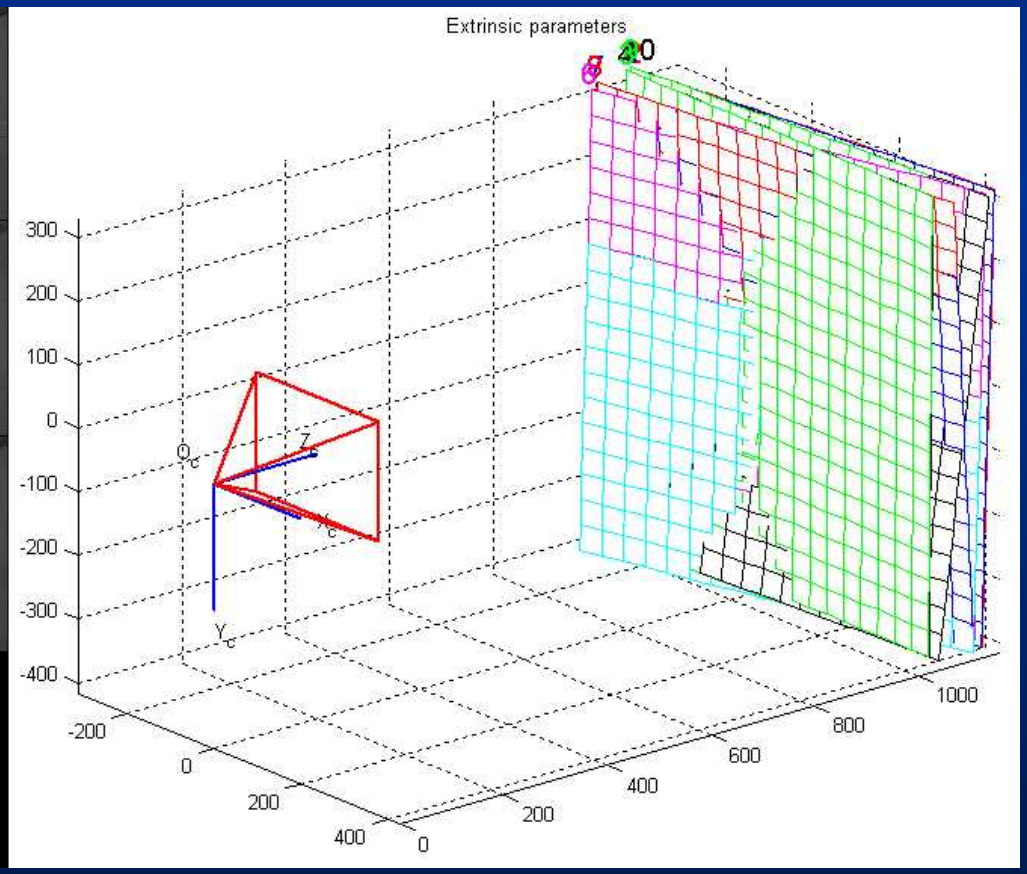


Calibration

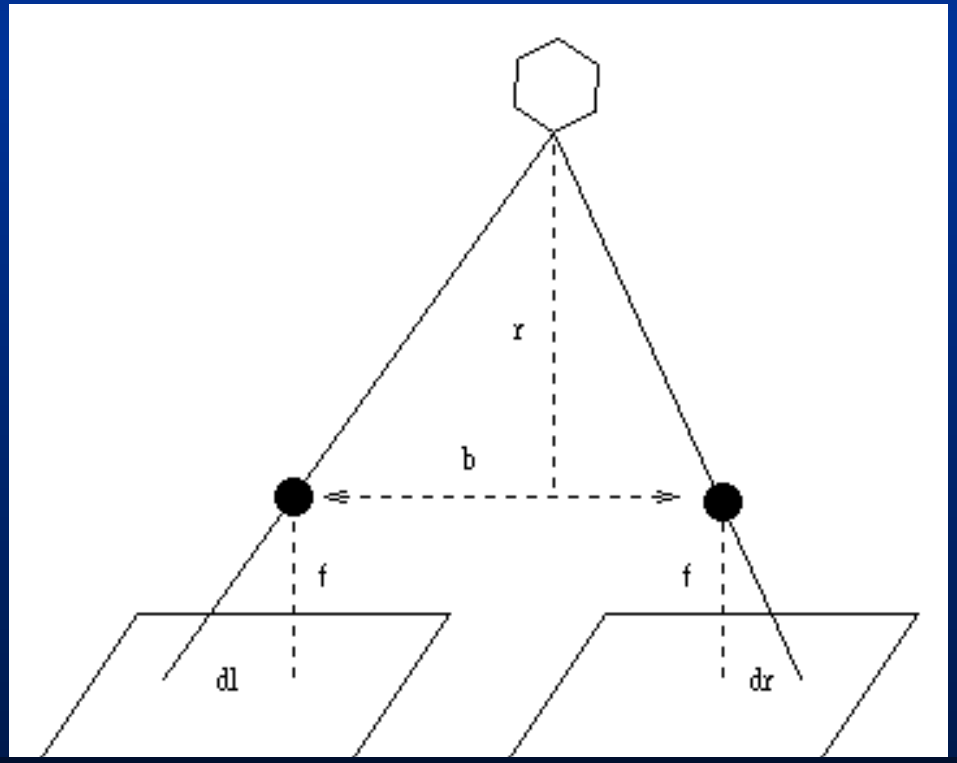
Camera Calibration Toolbox for Matlab

http://www.vision.caltech.edu/bouguetj/calib_doc/





Rectification



Rectification

Note: No gamma correction applied (images appear dark)

Thanks to Claudio Sisti

Rectification

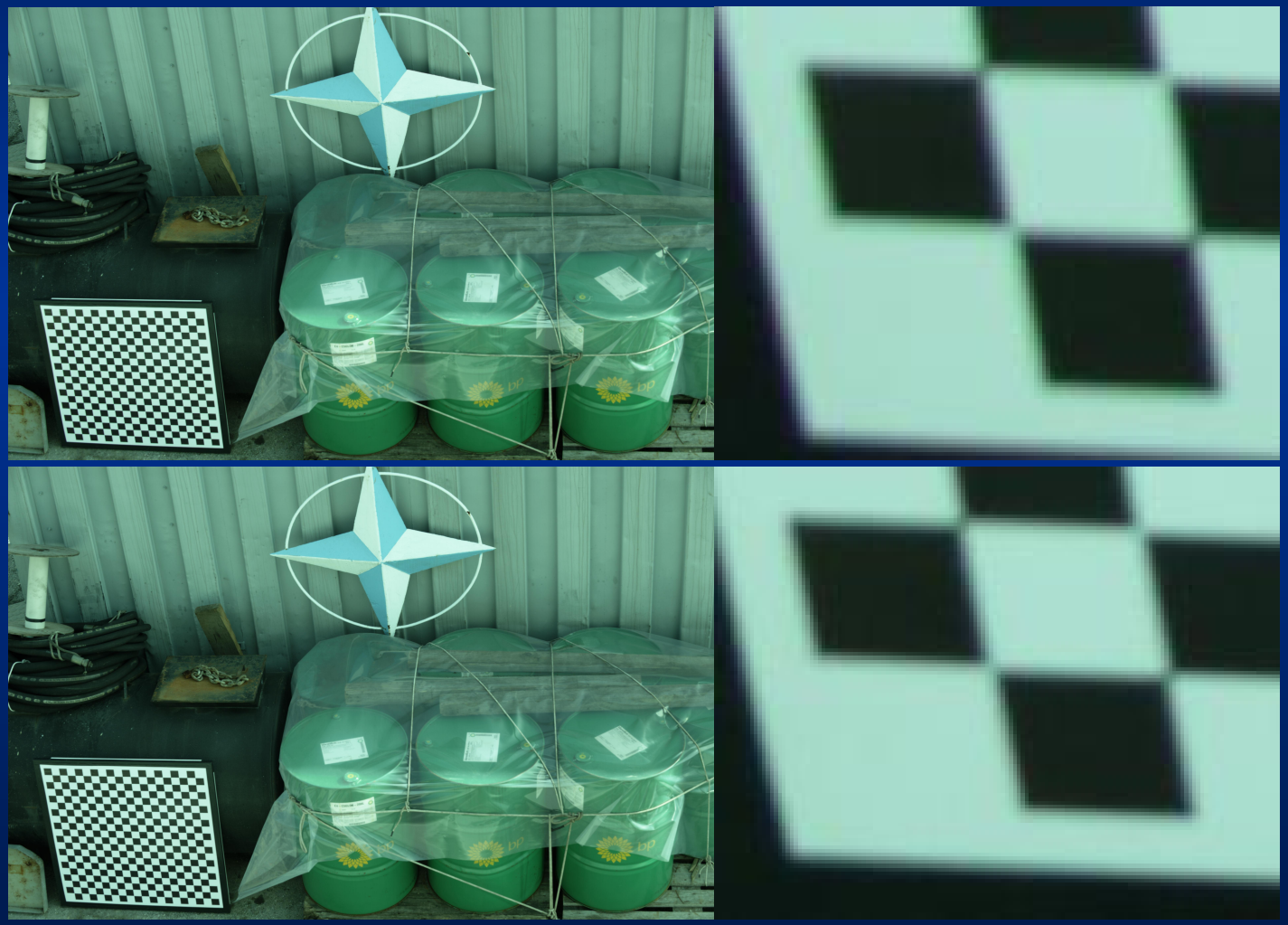
Chromatic aberration

- Never previously attempted
- Reduction of noise (correlation of three components rather than one)
- Reduction of chromatic aberration blurring
- Better rectification accuracy

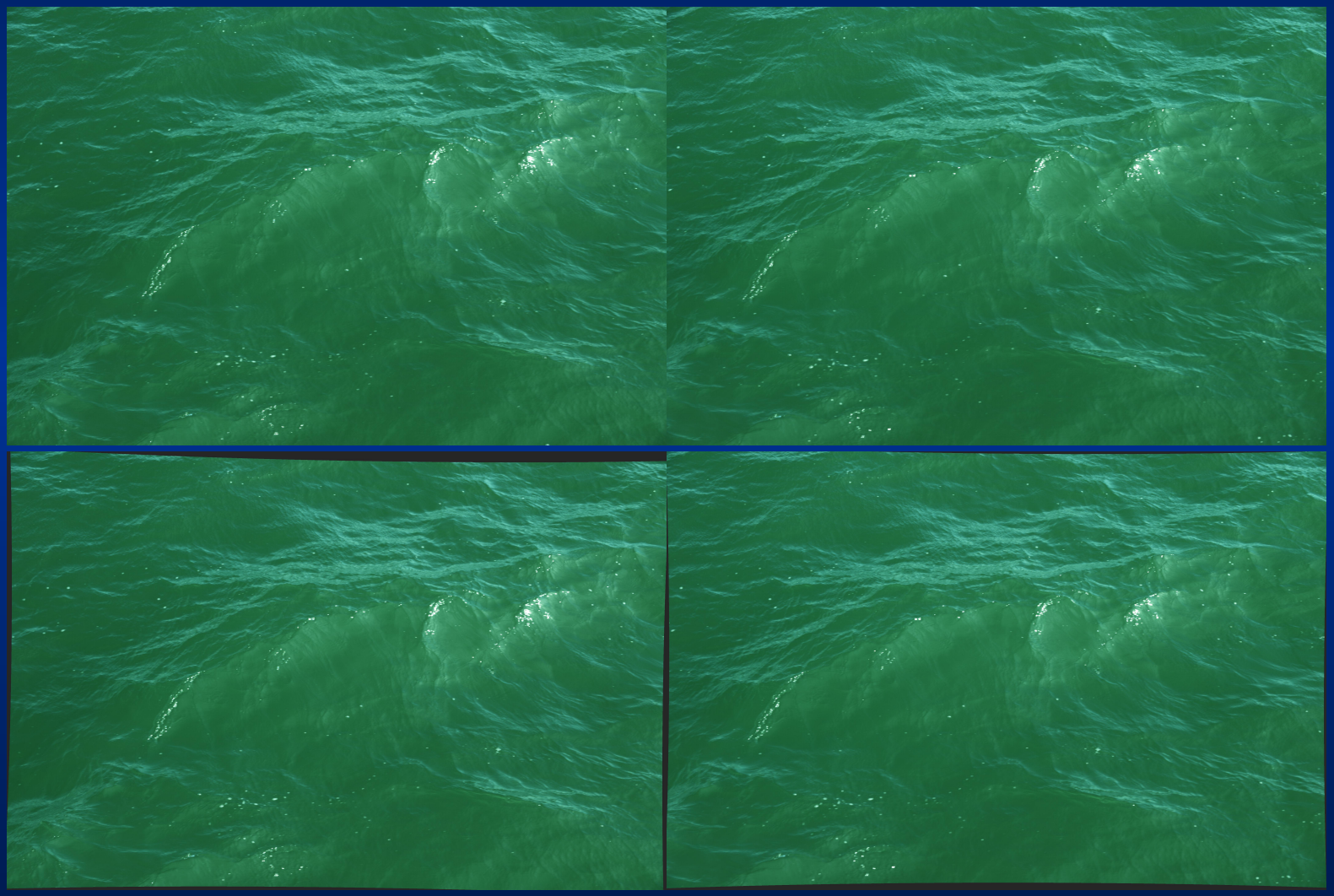
- More time-consuming

Rectification

Chromatic aberration



Disparity



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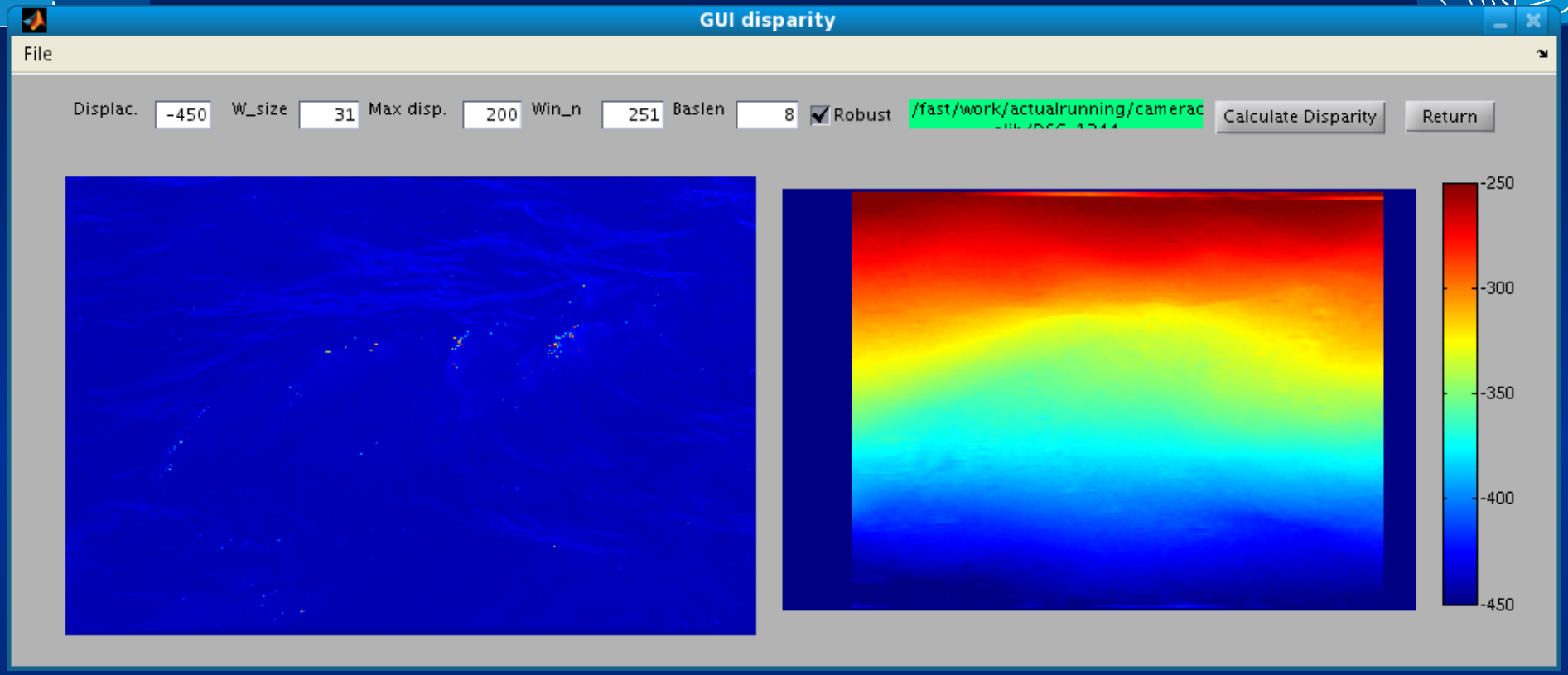
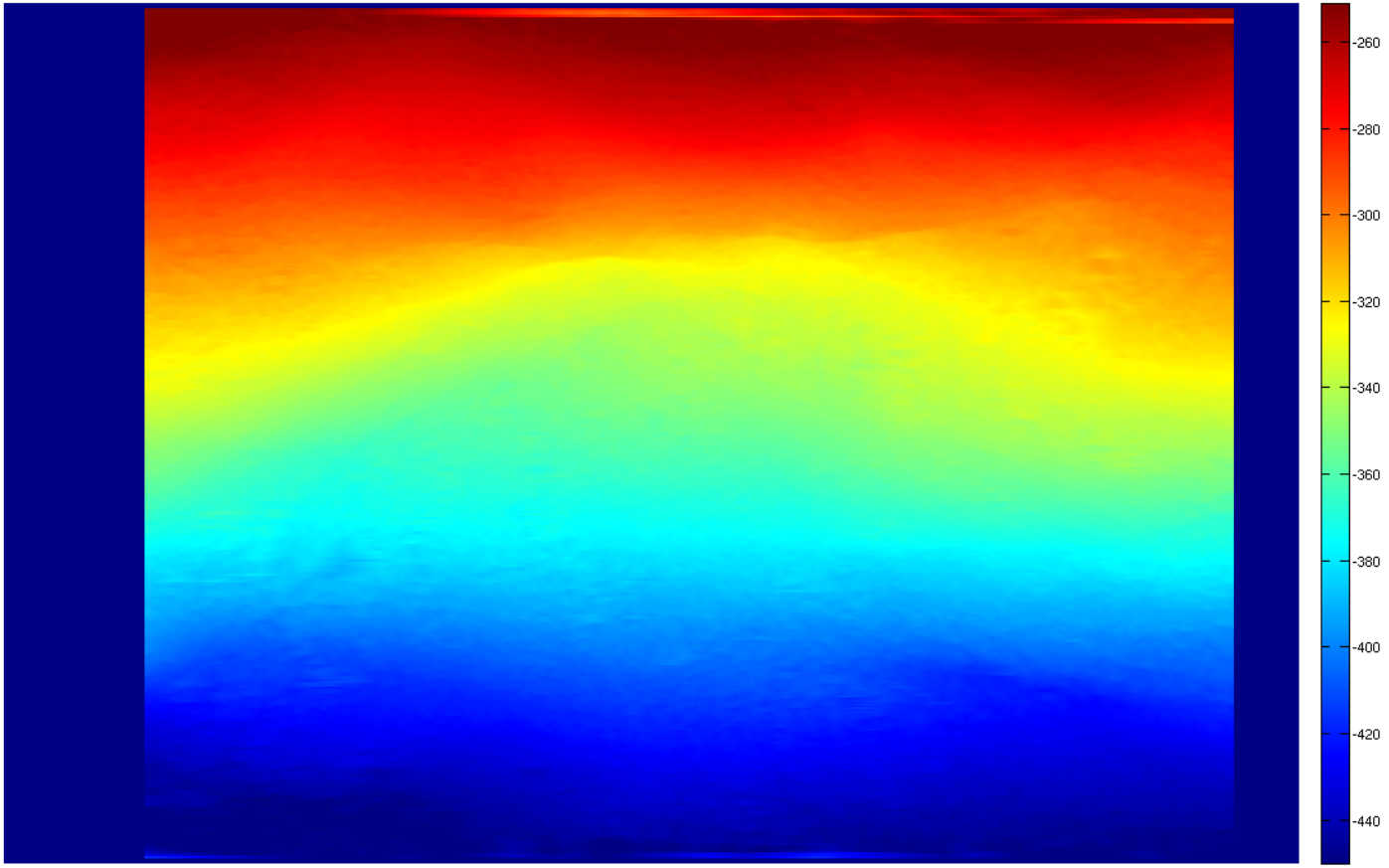


- In-house software
- High pass filtering
- Normalization
- Horizontal search
- Hanning shading
- Weighted L1 norm (three colors)
- Robust filtering
- 3D reprojection

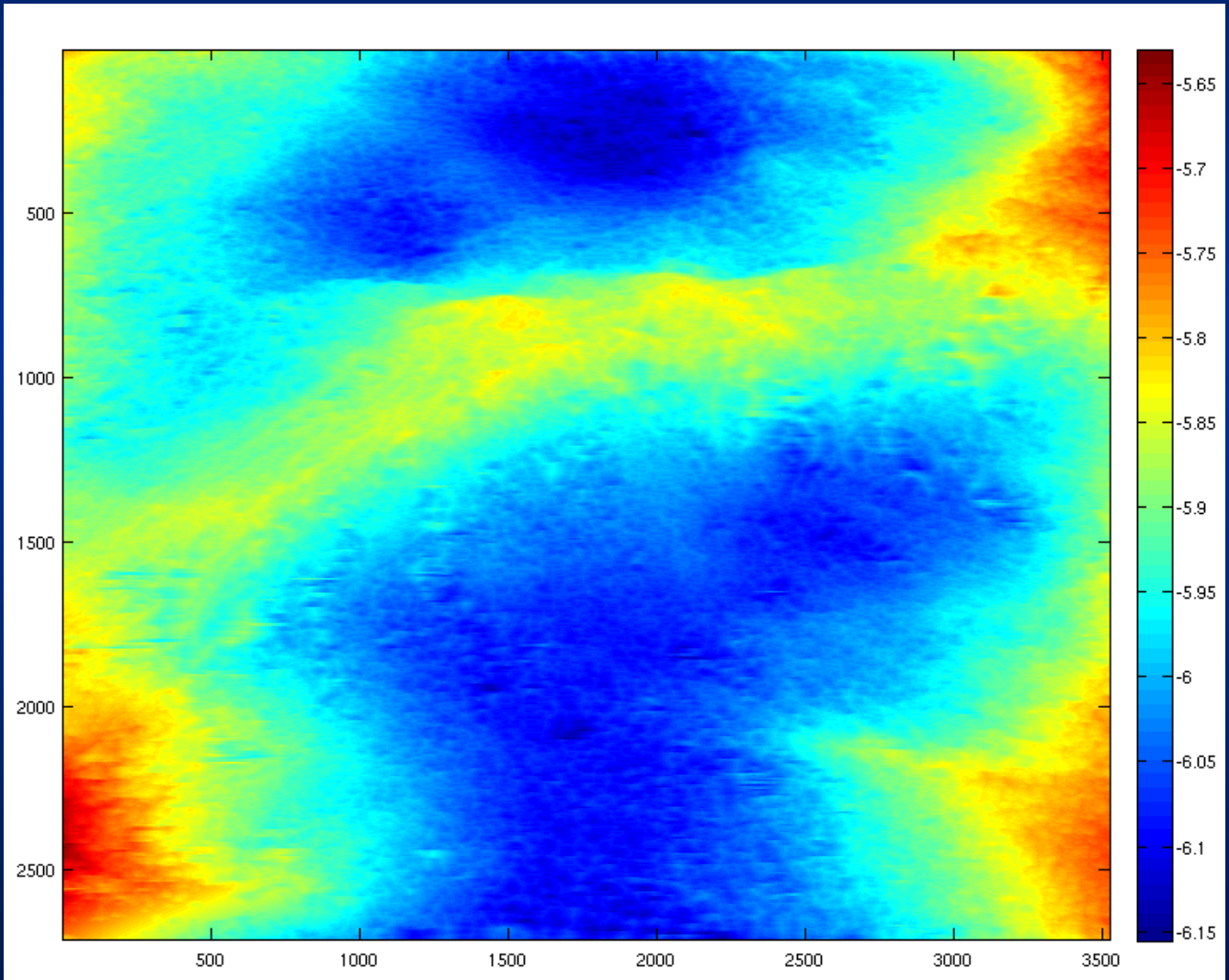
Disparity

Correlation Results



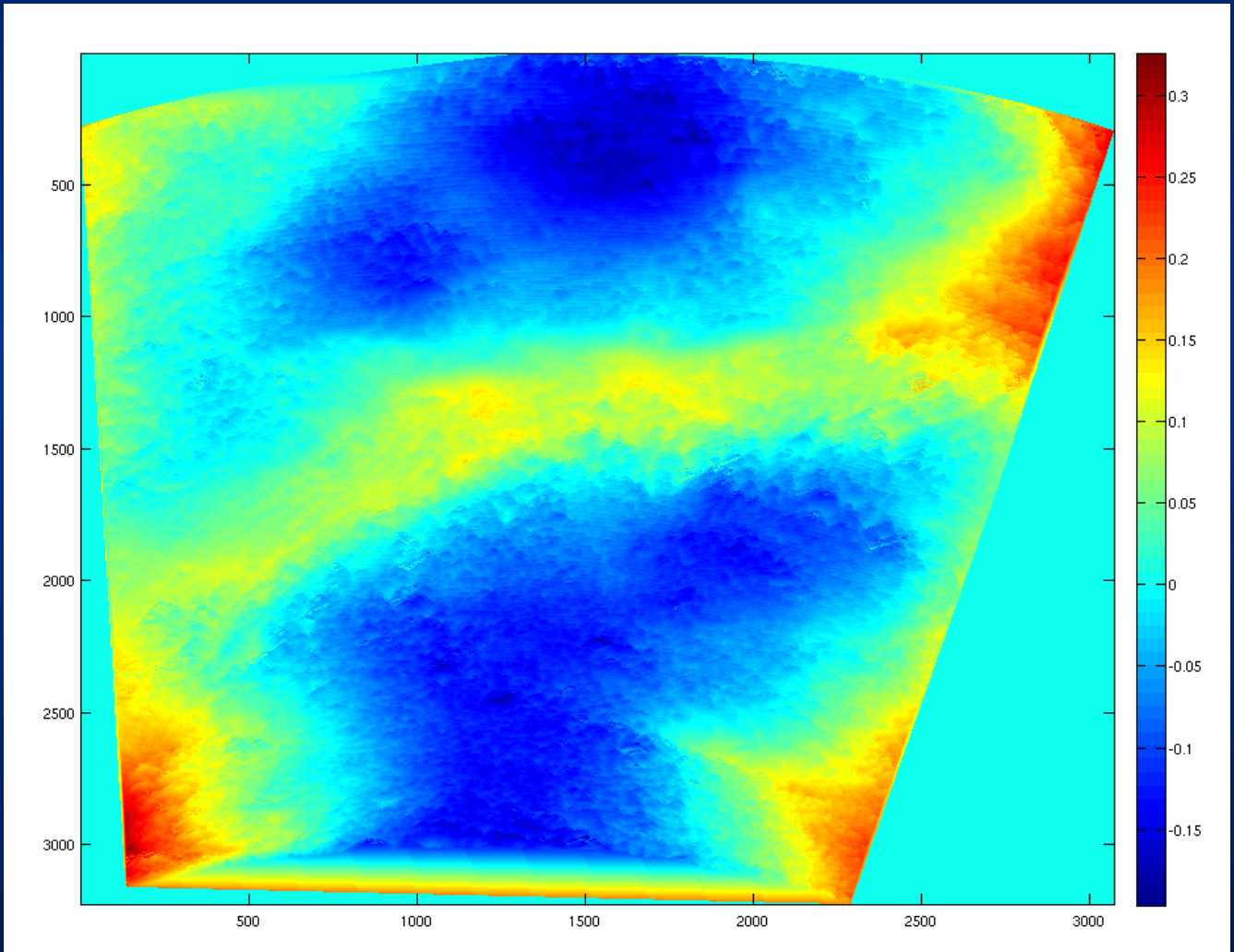
Disparity

Correlation Results (slope removed)

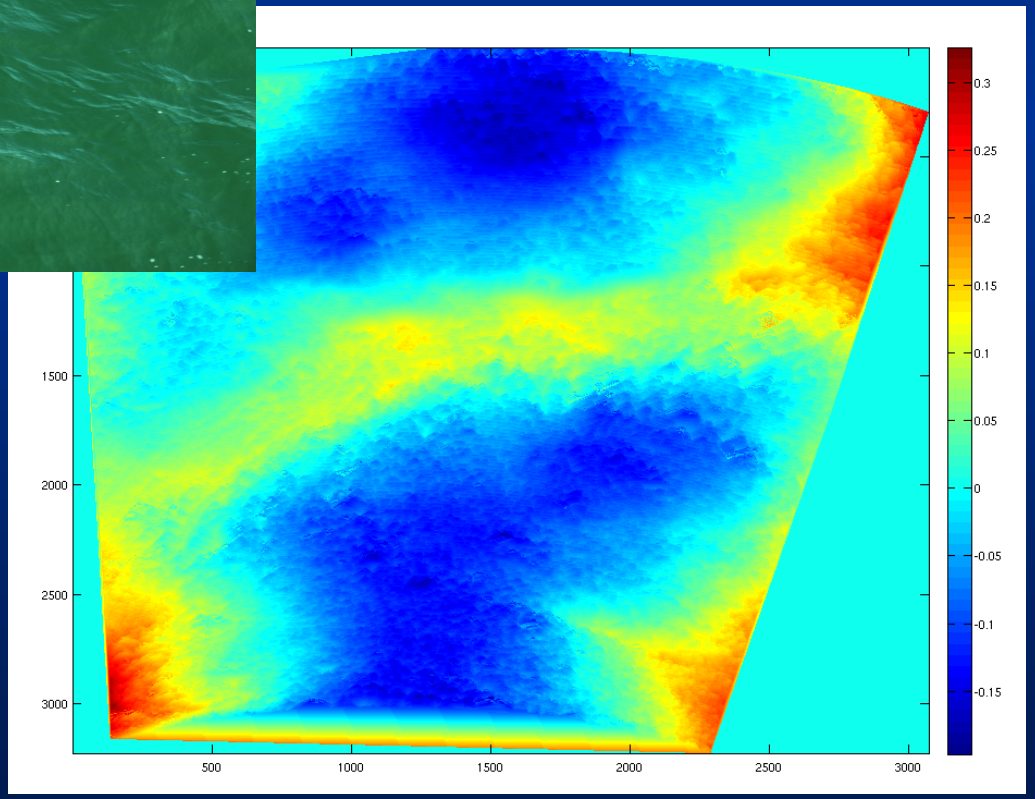


Disparity

Correlation Results (reprojected)

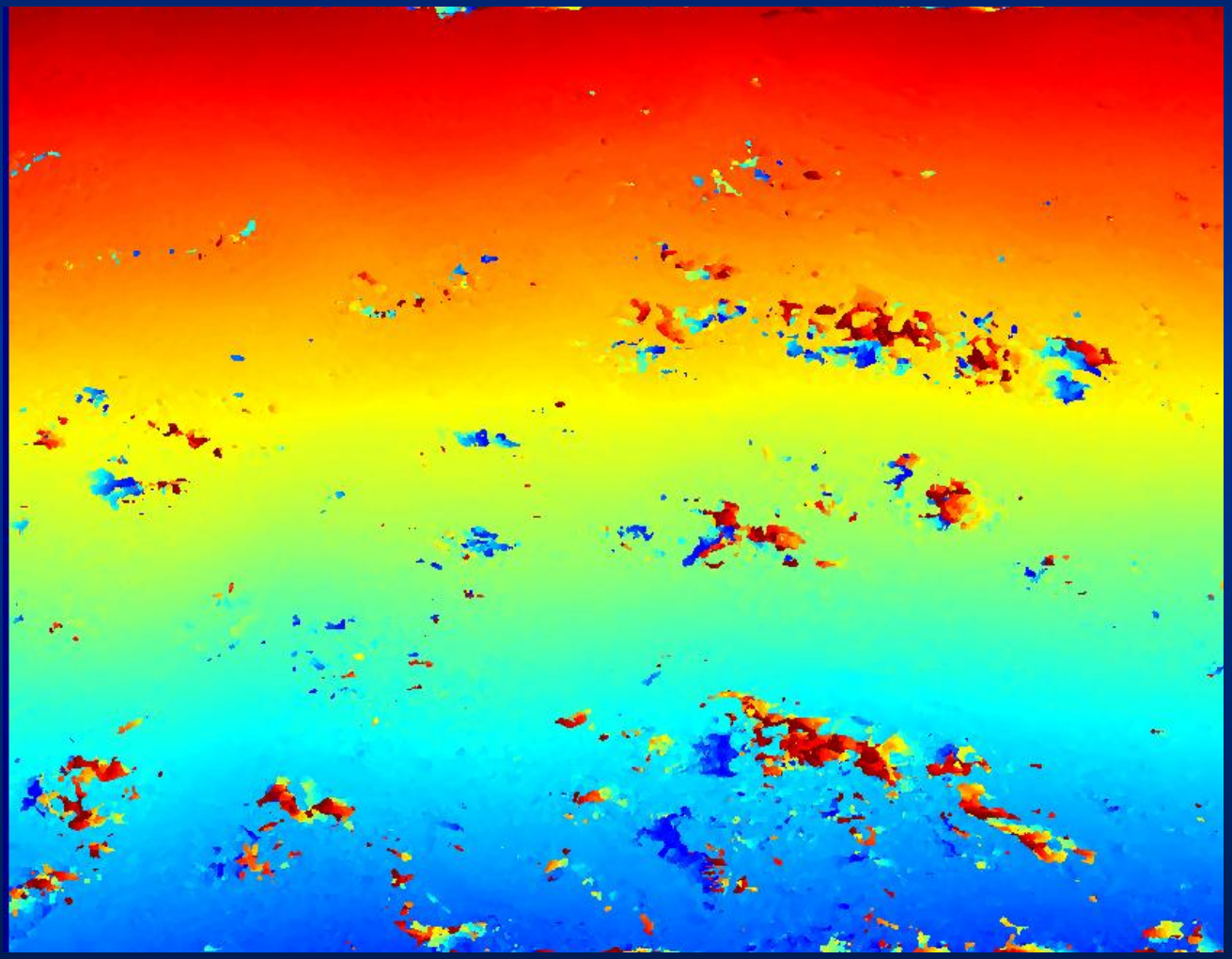


Disparity


1500
2000
2500
3000
500
1000
1500
2000
2500
3000
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15

Disparity

Robust filtering



Discussion

- Better camera for the application
- Intrinsic measurement problem:
  - Image texture/contrast
  - Camera noise
  - Occlusions
- Three color correlation
- First results are good
- More work:
  - On camera optimal separation
  - Measurement accuracy
  - Further mesurement

Questions?

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