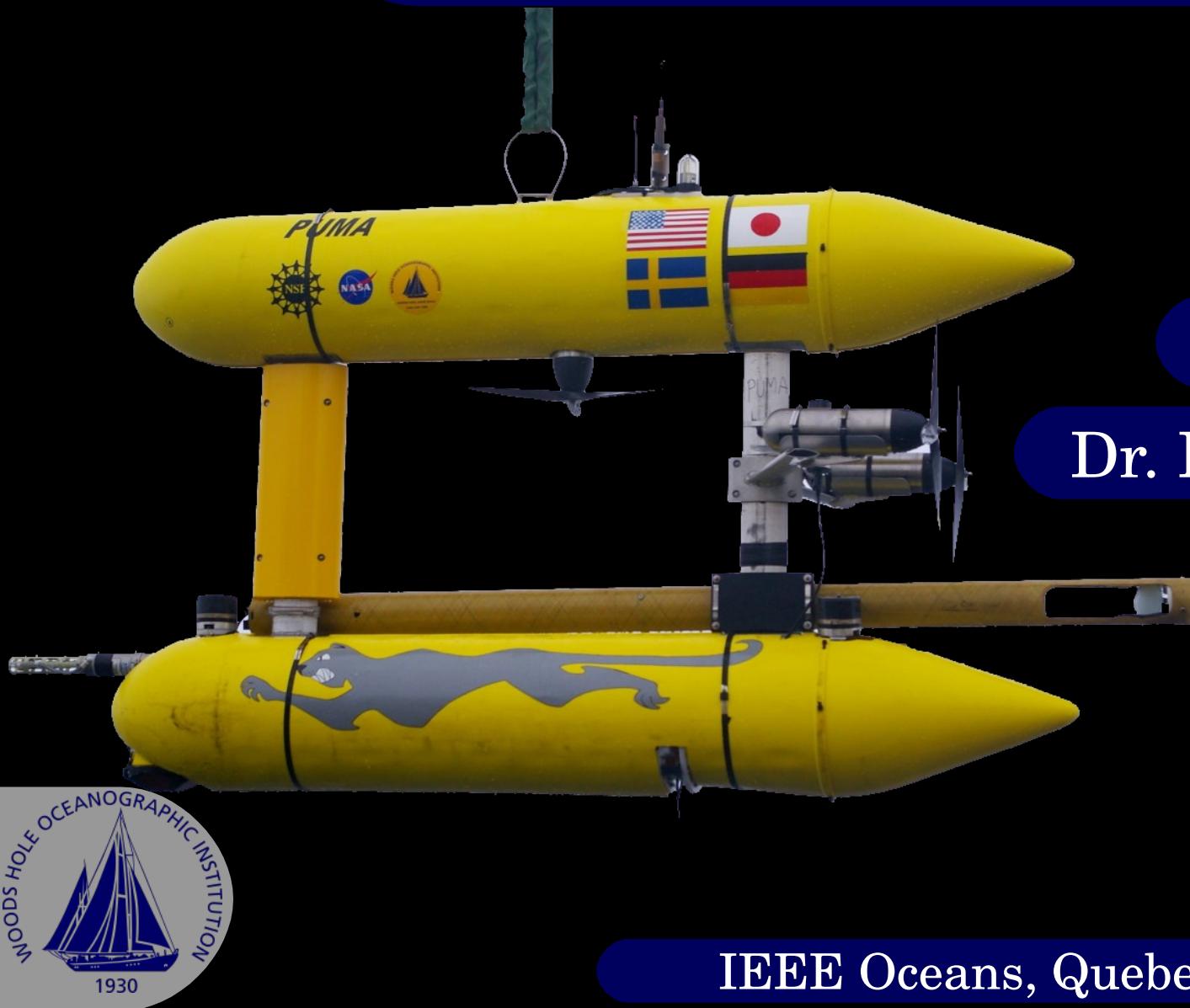


Human-Guided Autonomy for Acoustically Tethered Underwater Vehicles



Chris Murphy

Dr. Hanumant Singh

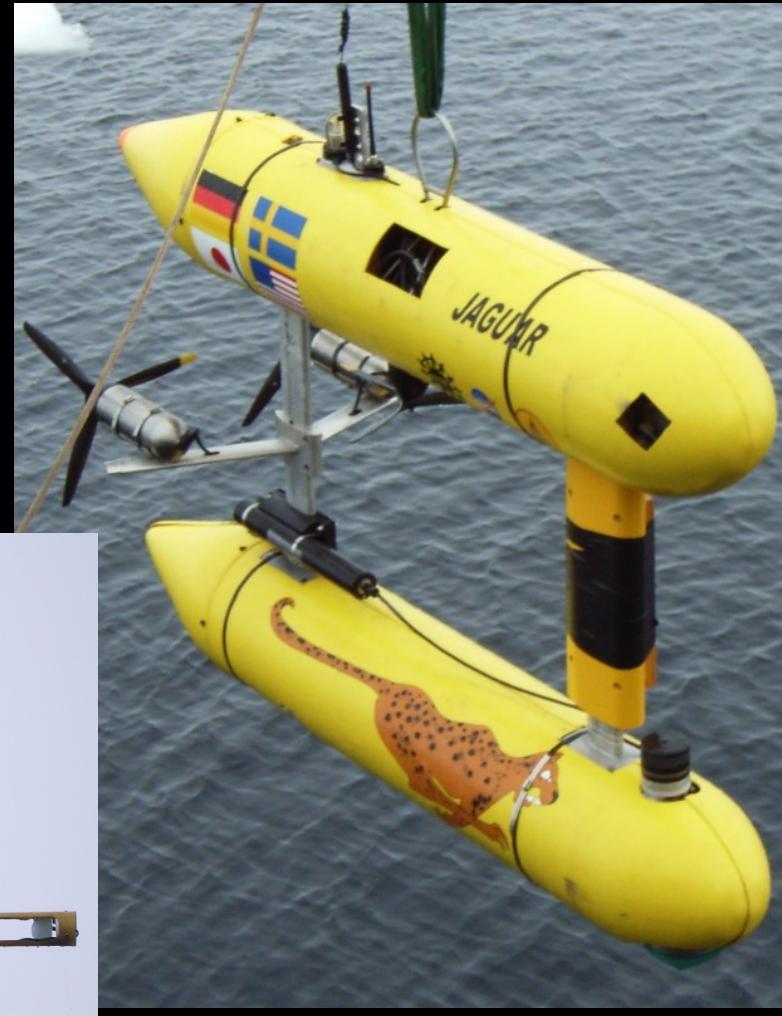
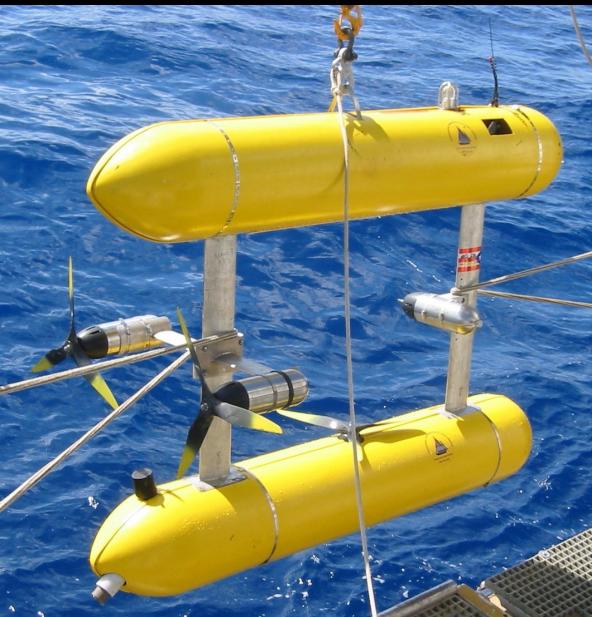
*Thanks to NSF
CenSSIS ERC
EEC-99868321*

IEEE Oceans, Quebec, 16 September 2008

Seabed, Puma and Jaguar

Seabed Family

- Low Cost AUV
- WHOI MicroModem
- FH/FSK @ ~80 bps
- 933MHz x86 CPU
- Linux + custom code



AGAVE 2007

Vehicle Dives

9 to >200m

6 to > 2000m

~50 Days at Sea

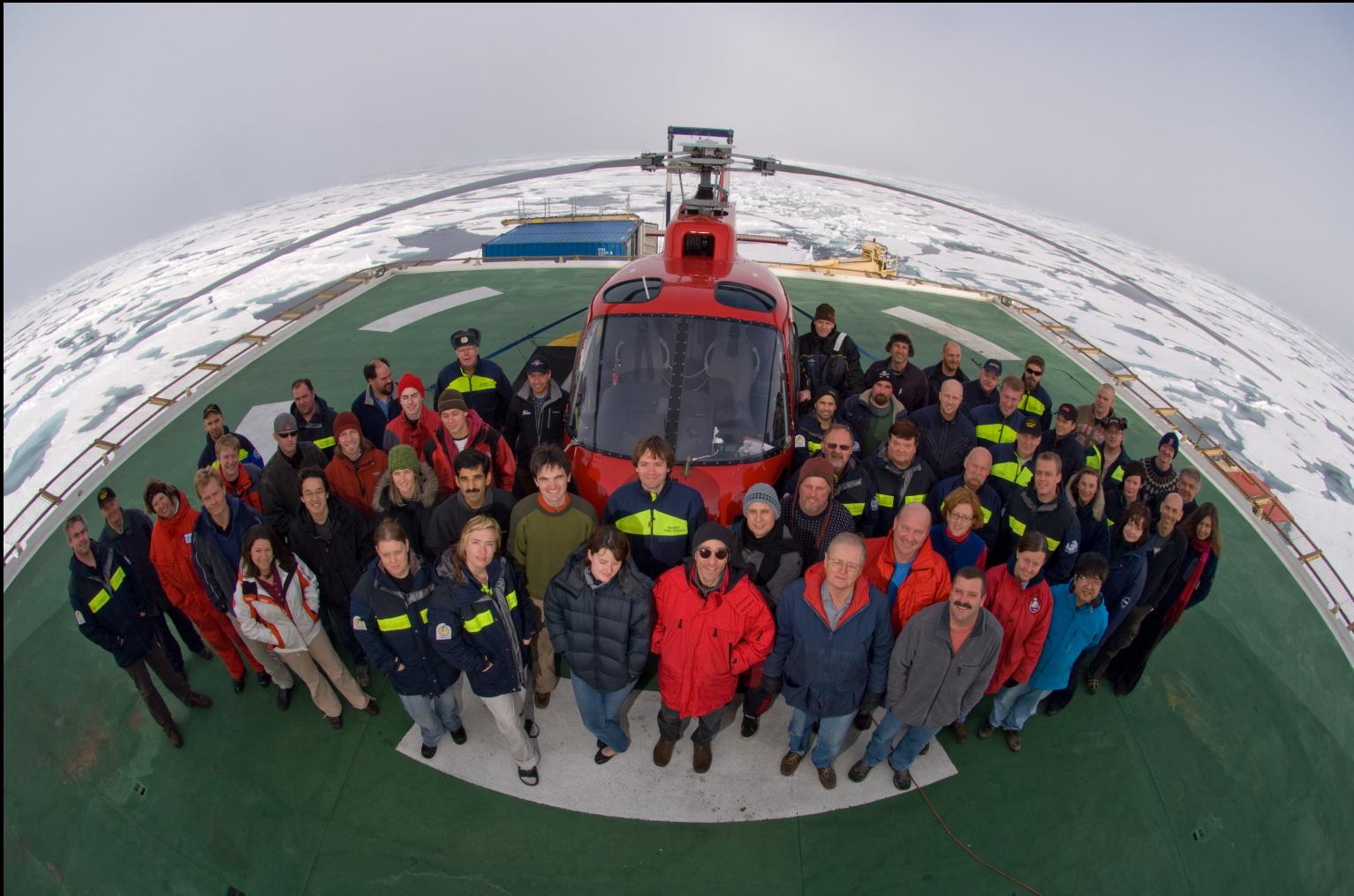
~50 People

9 scientists

8 engineers

8 grad students

25 crew

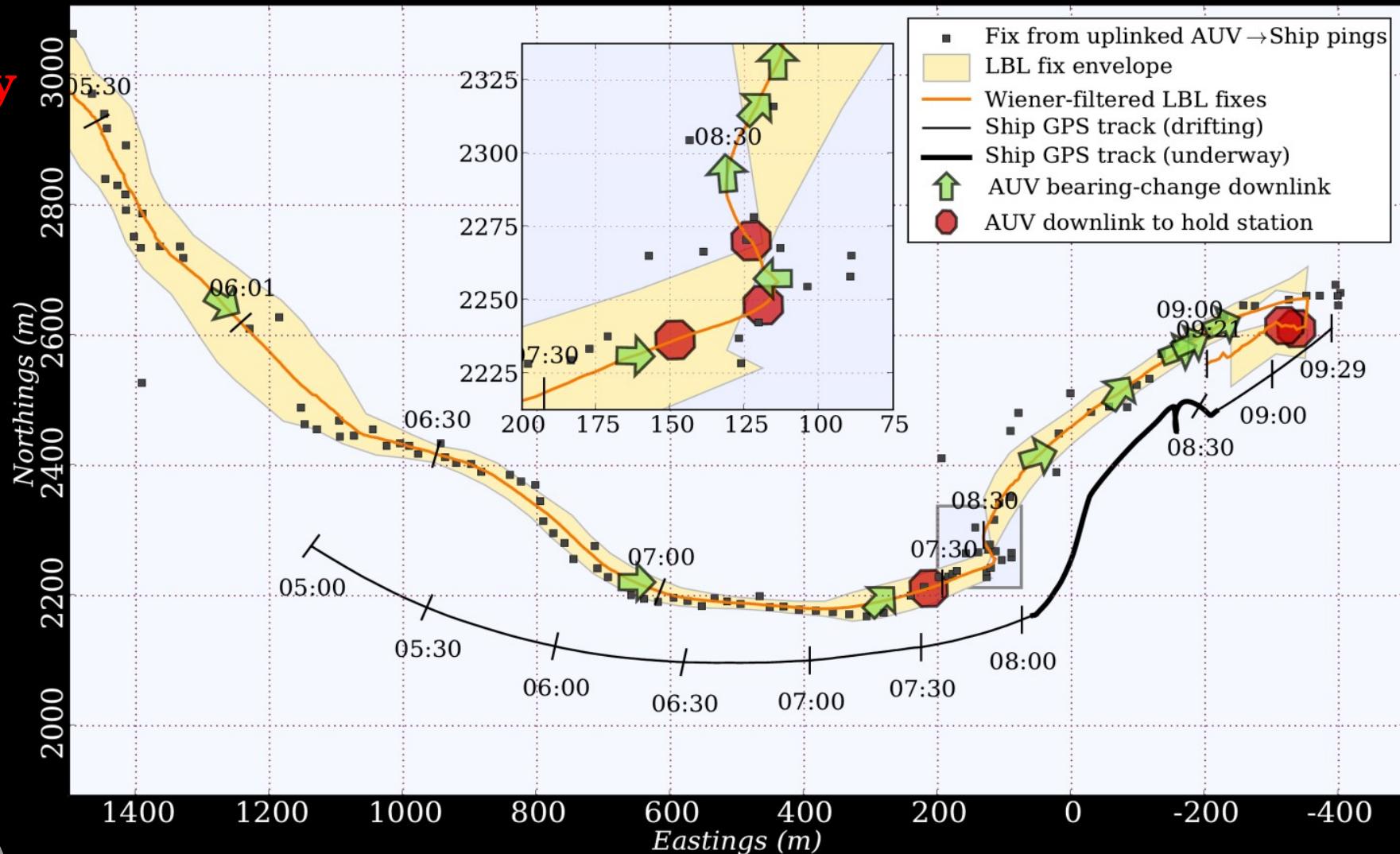


AGAVE Recovery

Recovery
Is
HARD

Toward
Extraplanetary
Under-Ice
Exploration:
Robotic Steps in
the Arctic

Submitted,
Journal of Field
Robotics



AUV Missions

Historically, AUV's navigate through the ocean under the assumption that the ocean is large and contains few obstacles ...

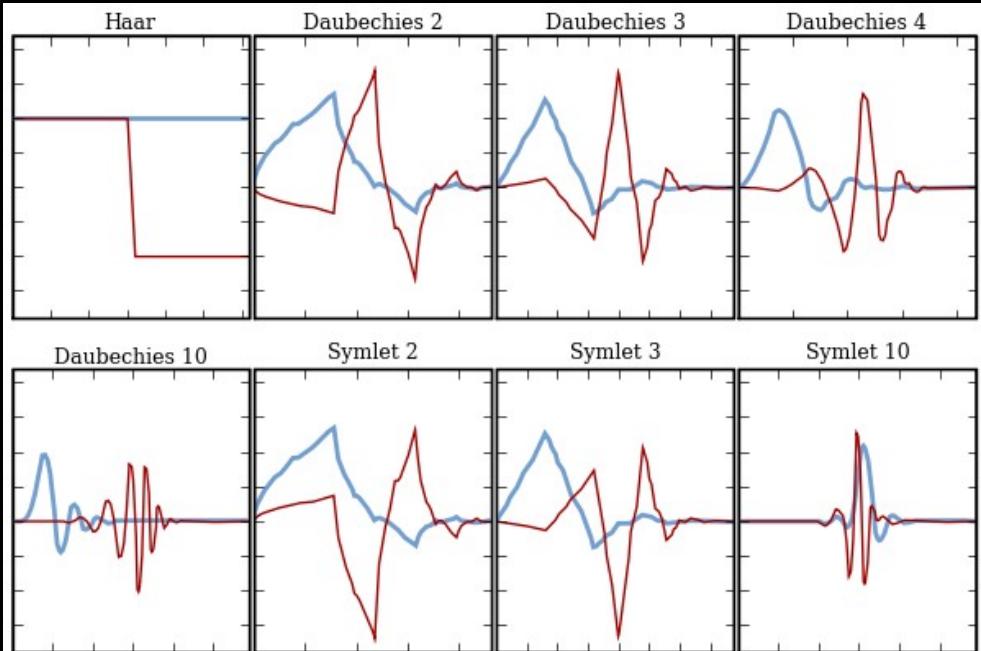
Sensor information is ... [not] used to provide the vehicle with the ability to adapt ... it is simply recorded for future analysis.

— 2003, Christopher von Alt (CEO, Hydroid Robotics)



Wavelet Compressed Scalar Telemetry

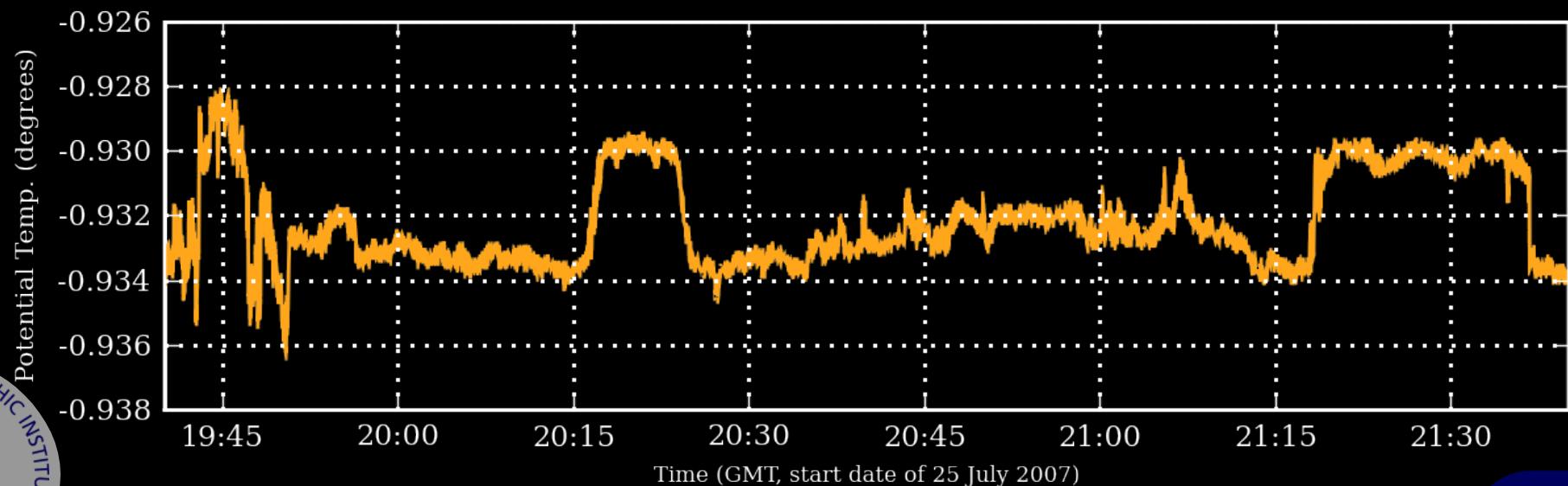
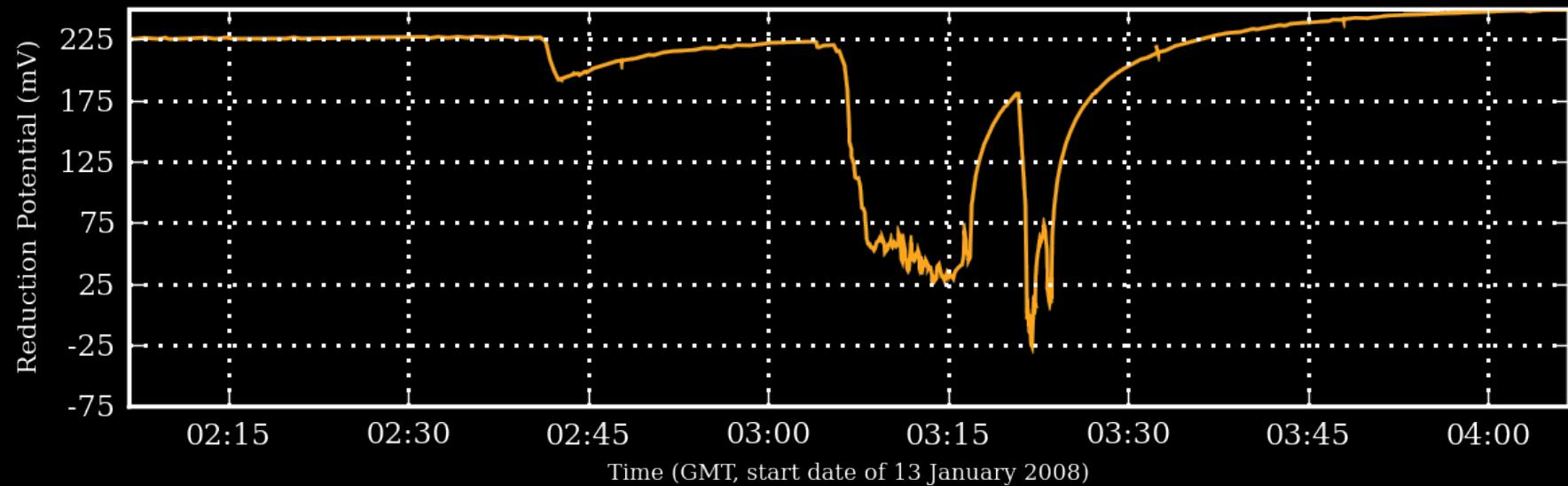
Google Earth Topside Visualization



Telemetry



Environmental Sensors

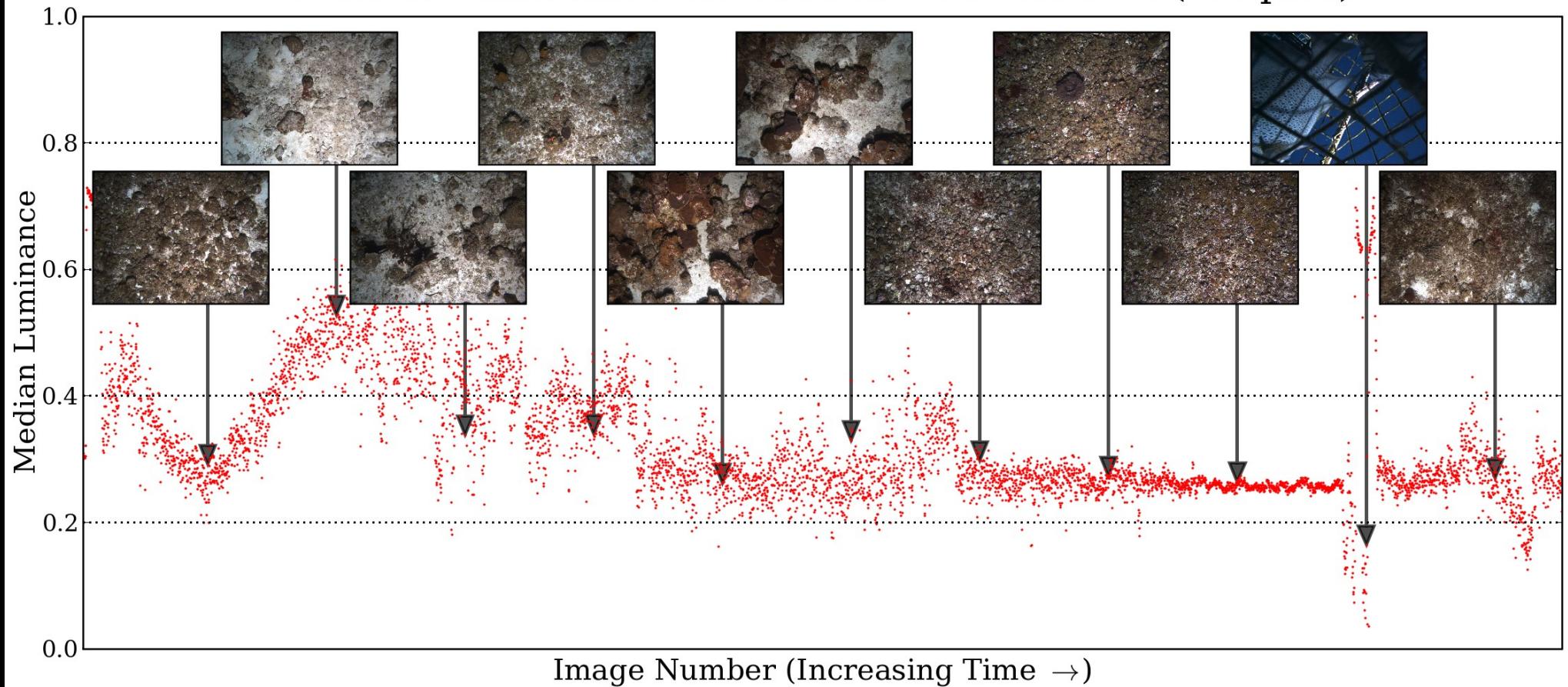


Cameras

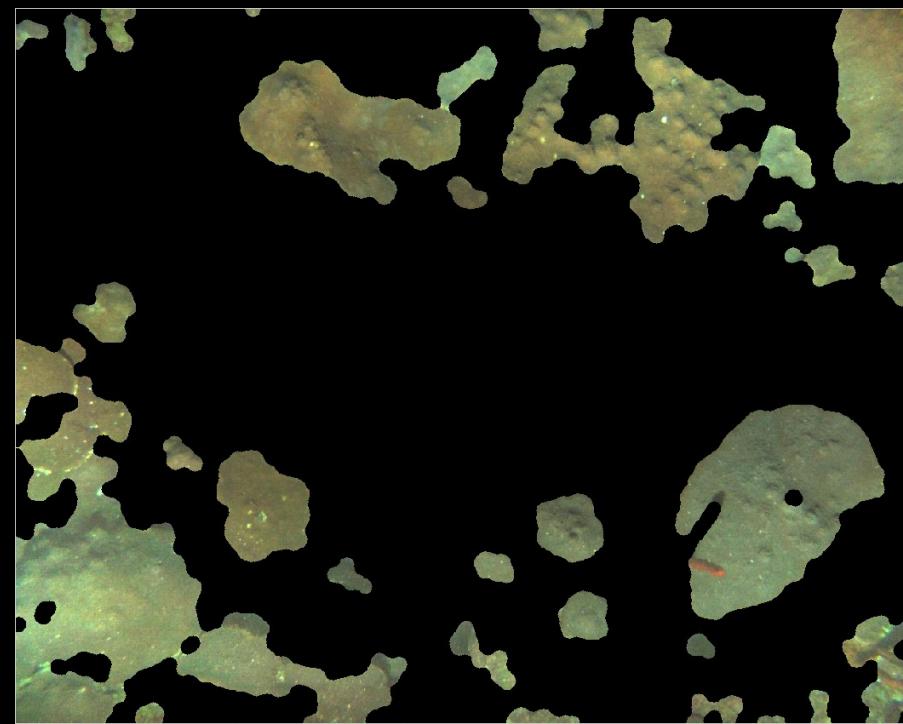
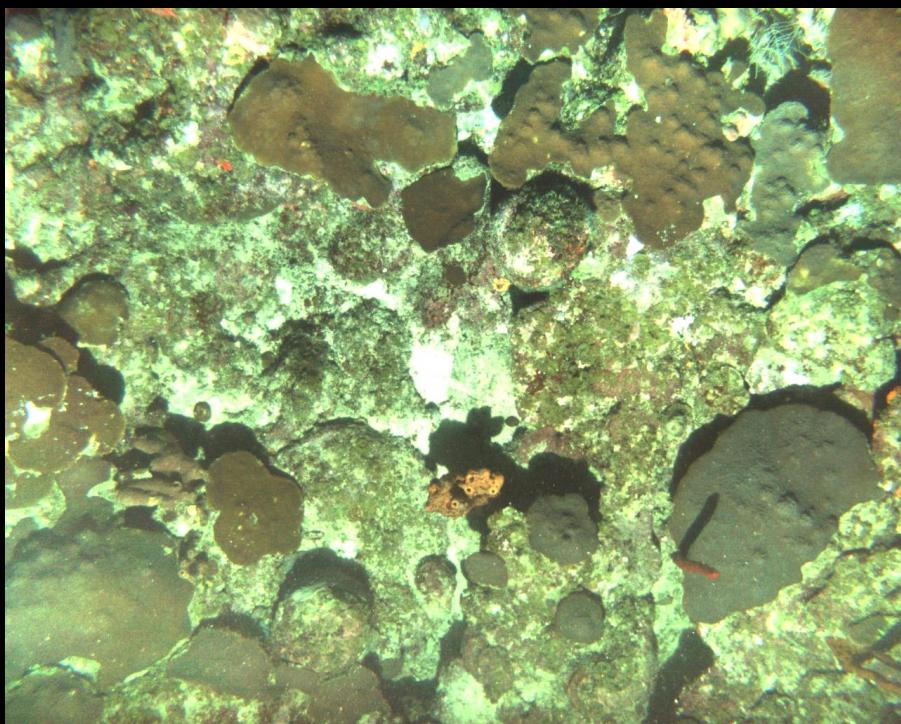


Visual Telemetry

Median Luminance for Seabed Dive PR08-06 (Vieques)



Visual Telemetry Sources



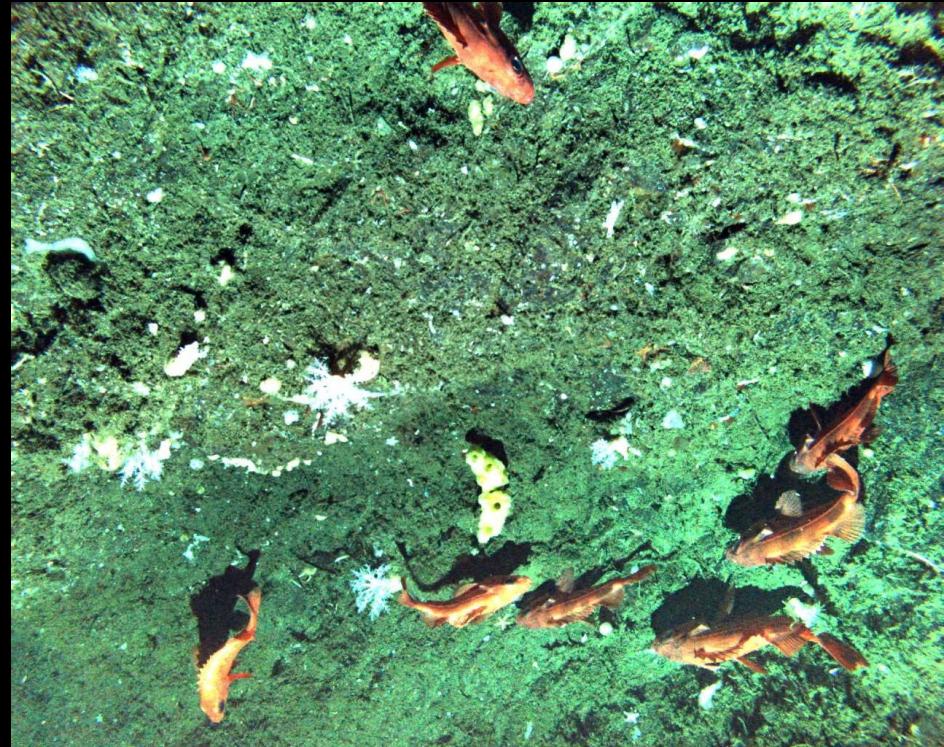
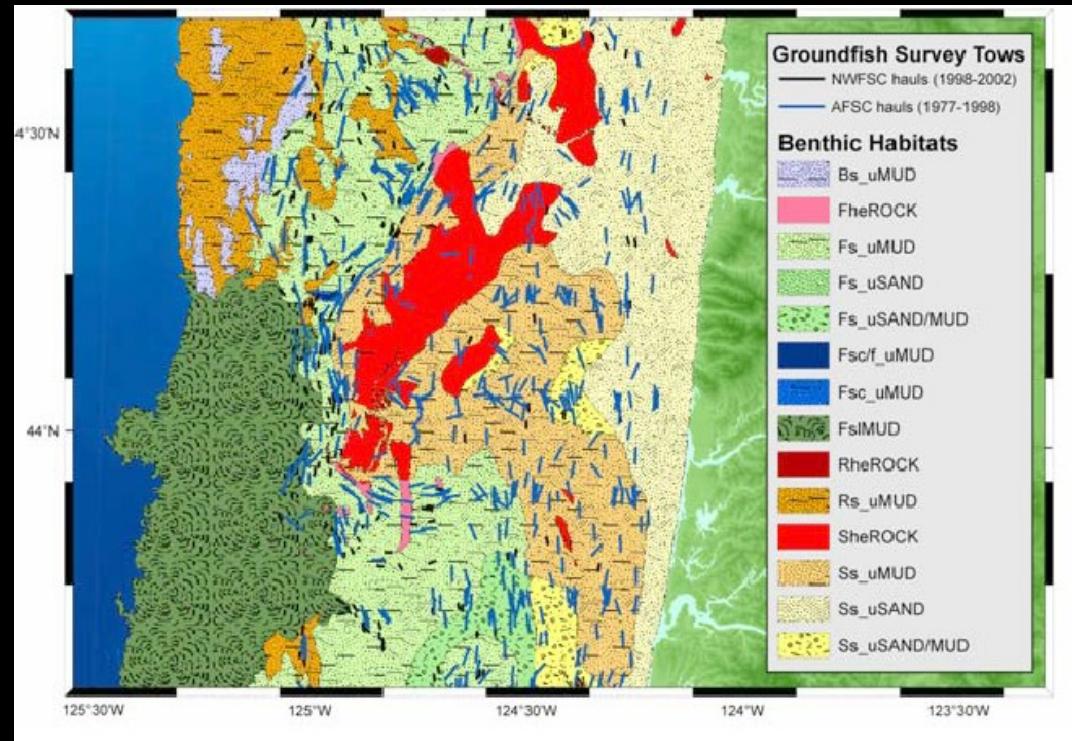
**Percentage of coral cover, or coral health metrics
*Texture ID, Morphological processing?***



Kaeli, Singh and Armstrong, "An Automated Morphological Image Processing Based Methodology for Quantifying Coral Cover in Deeper-Reef Zones", 2006

IEEE Oceans, Quebec, 16 September 2008

Visual Telemetry Sources



**Seafloor Makeup / Rugosity
Texture Identification?**

**Wildlife Density
Object ID? Segmentation?**



Wavelet Compression



Step 1

Calculate Discrete Wavelet Transform (DWT) of data.

Result: A few approximation coefficients, many detail coefficients.

Step 2

Threshold detail coefficients, leaving only N largest.

Result: Sparse list of detail coefficients.

Step 3

Quantize approximation and detail coefficients.

Result: Combined with step 4, data ready for transmission.

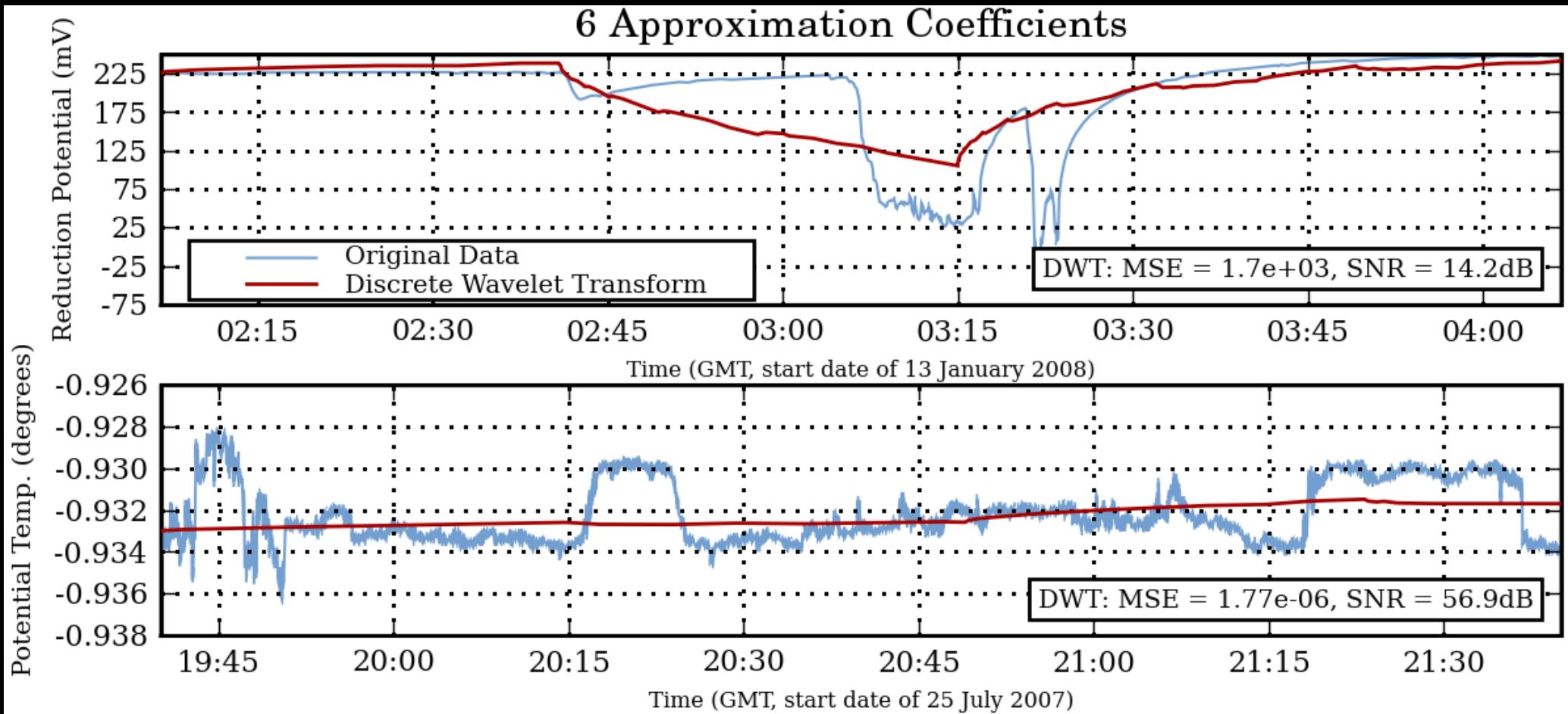
Step 4

Entropy encode (now sparse) detail coefficients

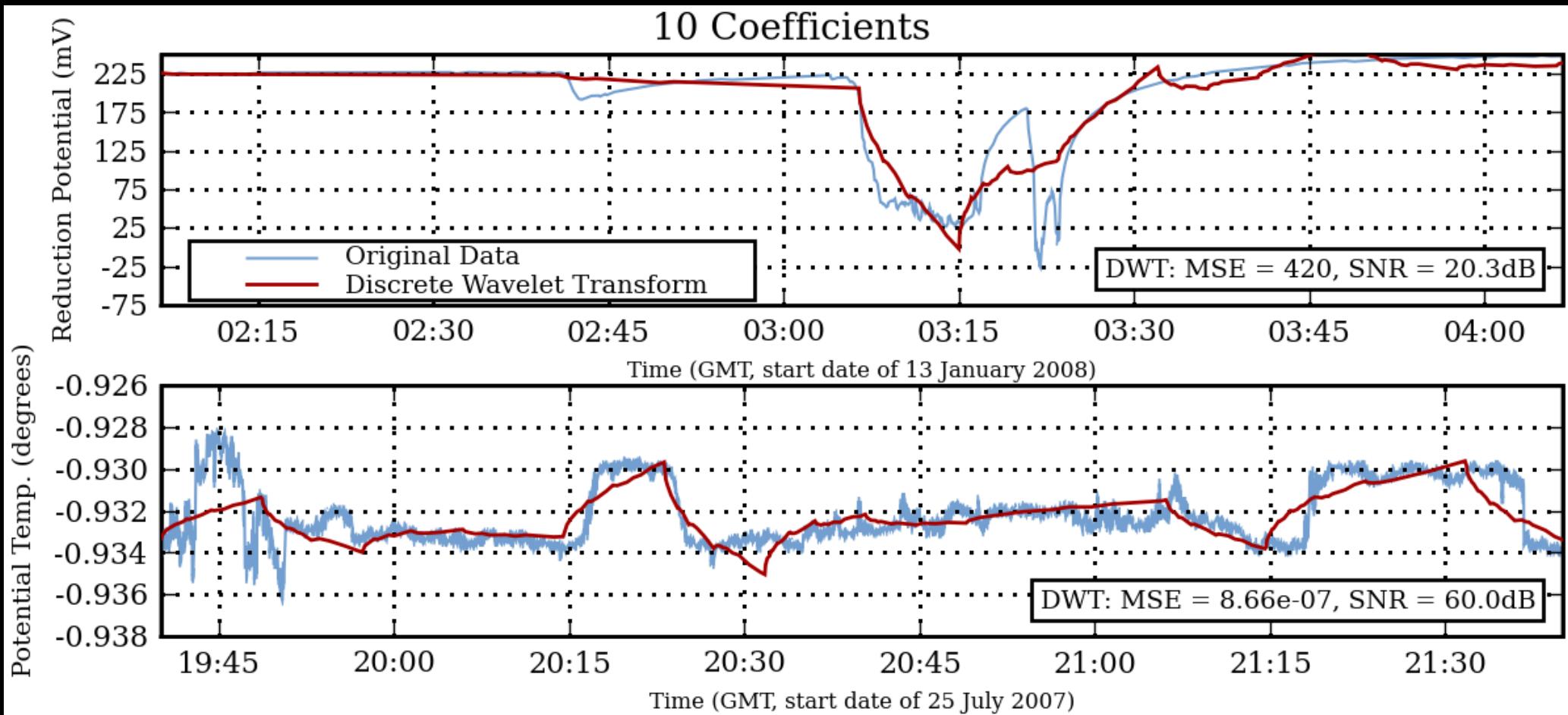
Result: condensed representation of detail coefficient positions.



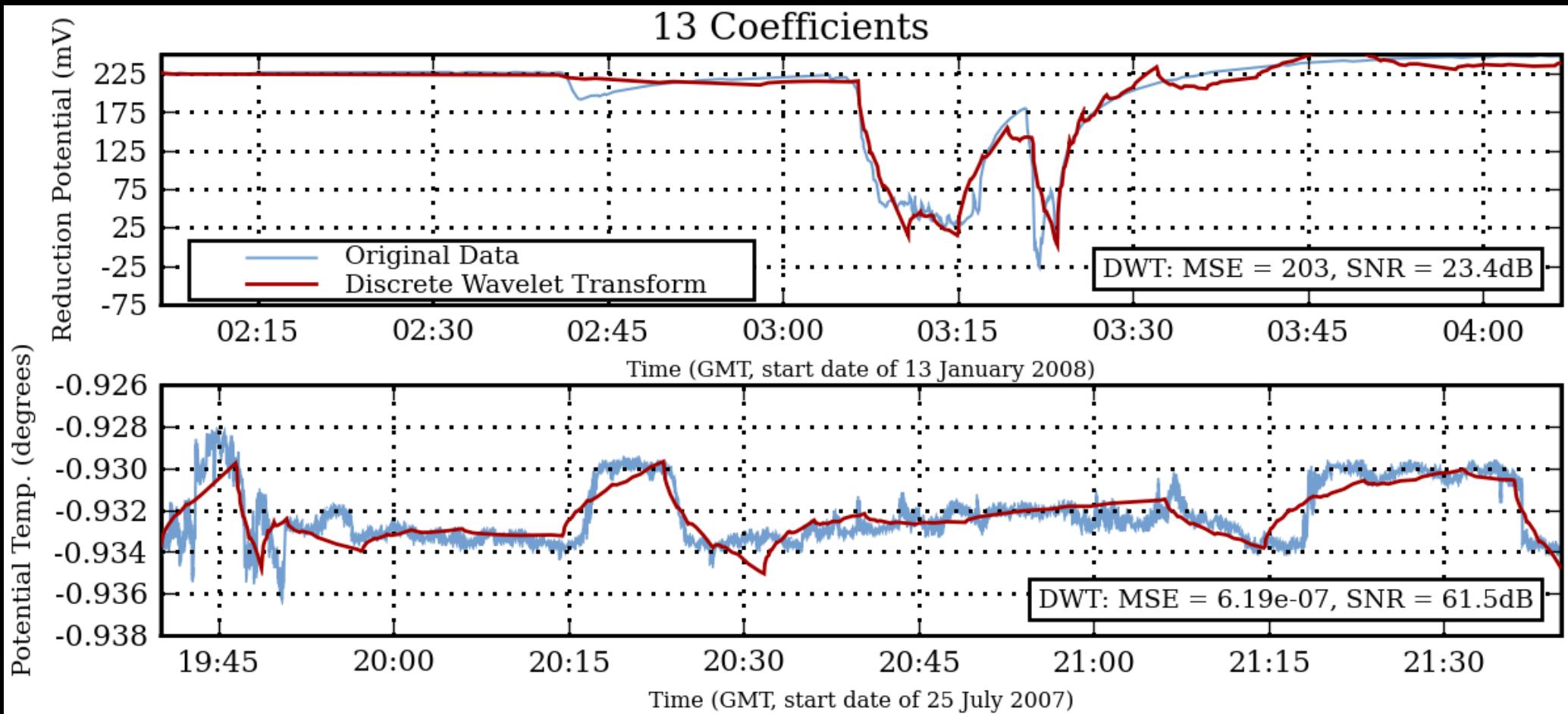
Wavelet Approximation



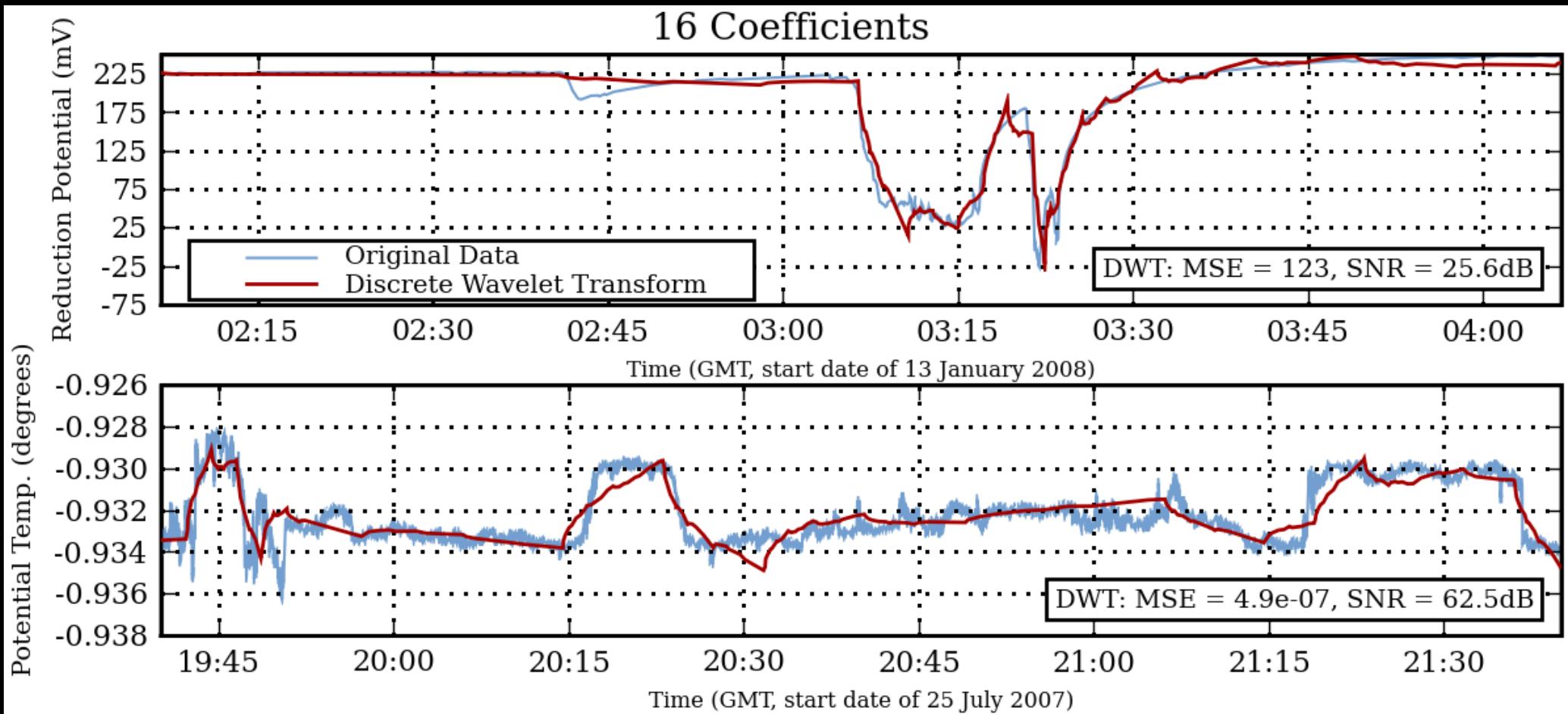
Wavelet Approximation



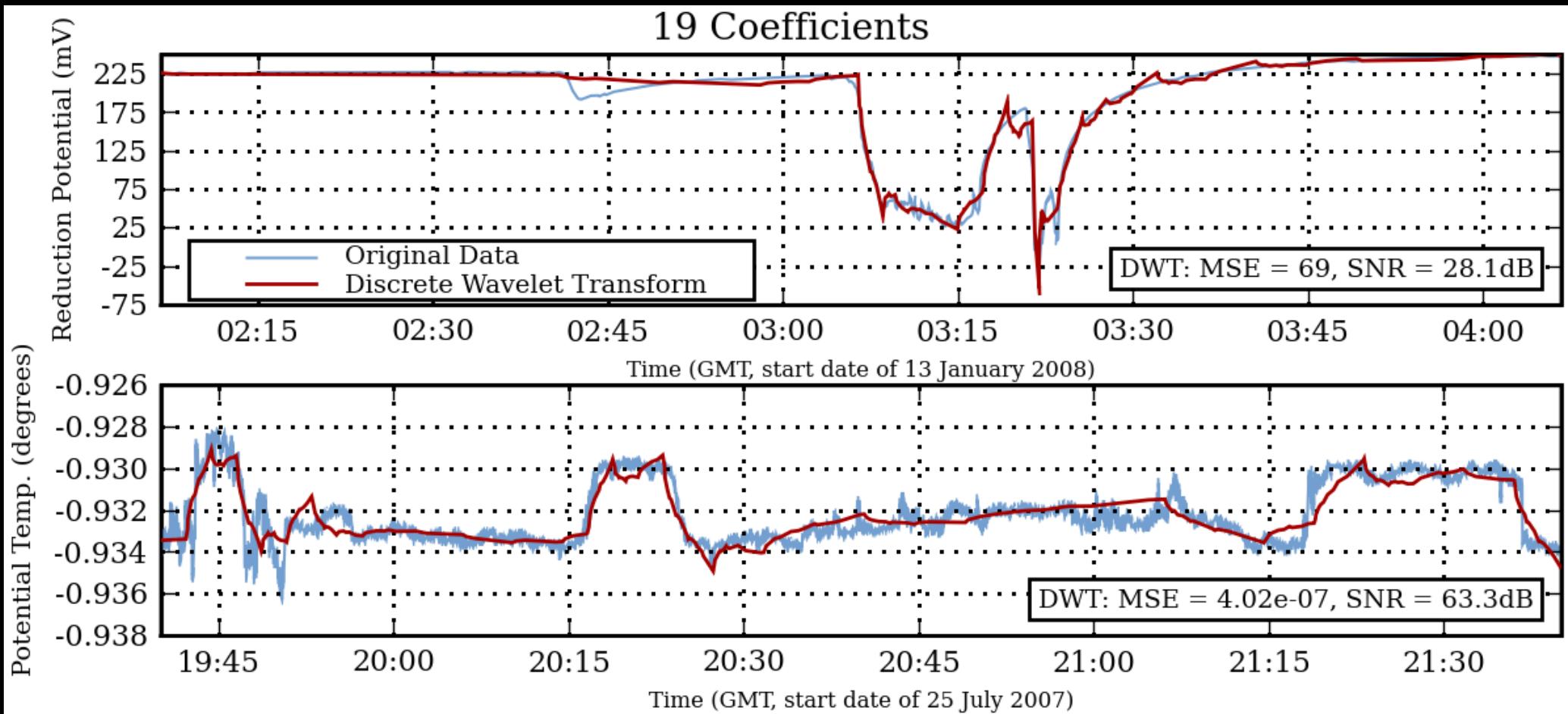
Wavelet Approximation



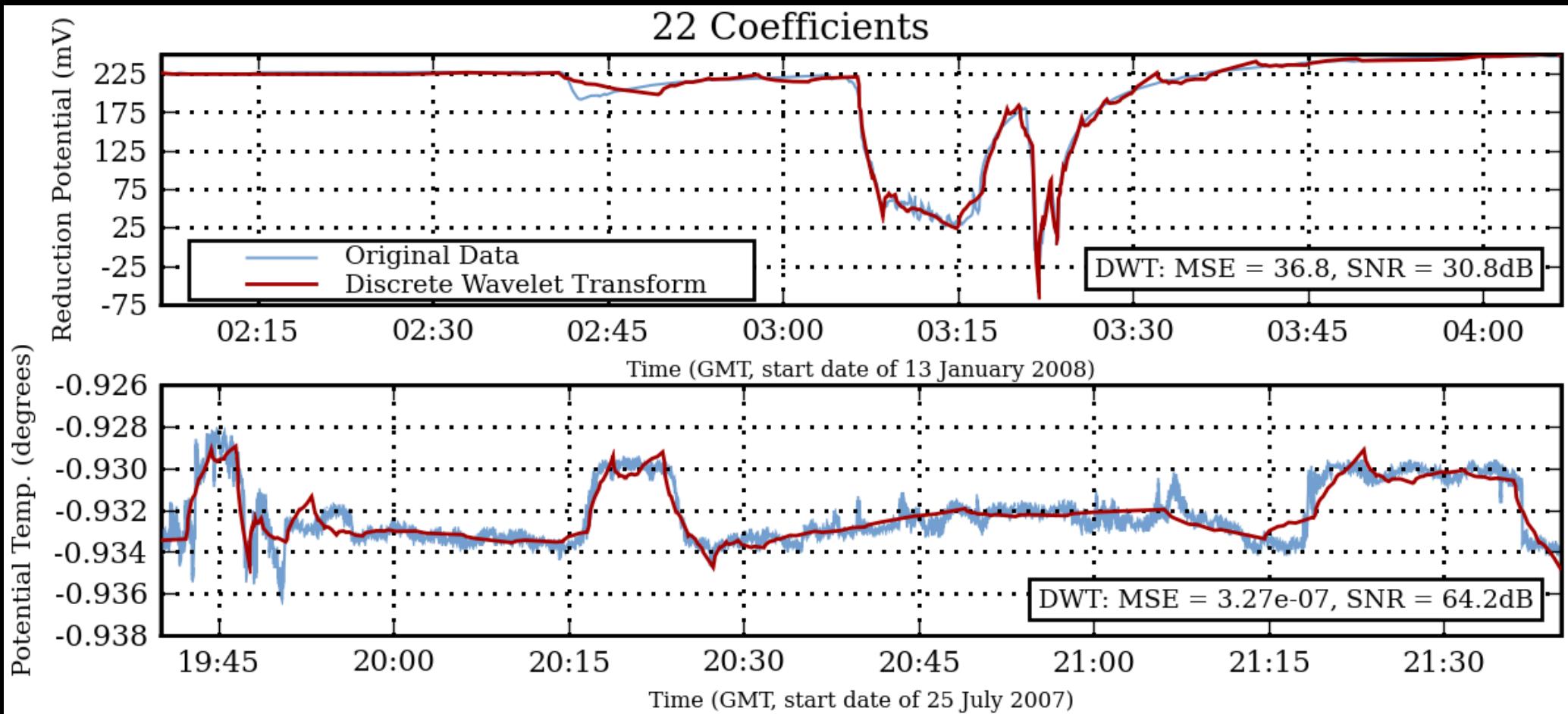
Wavelet Approximation



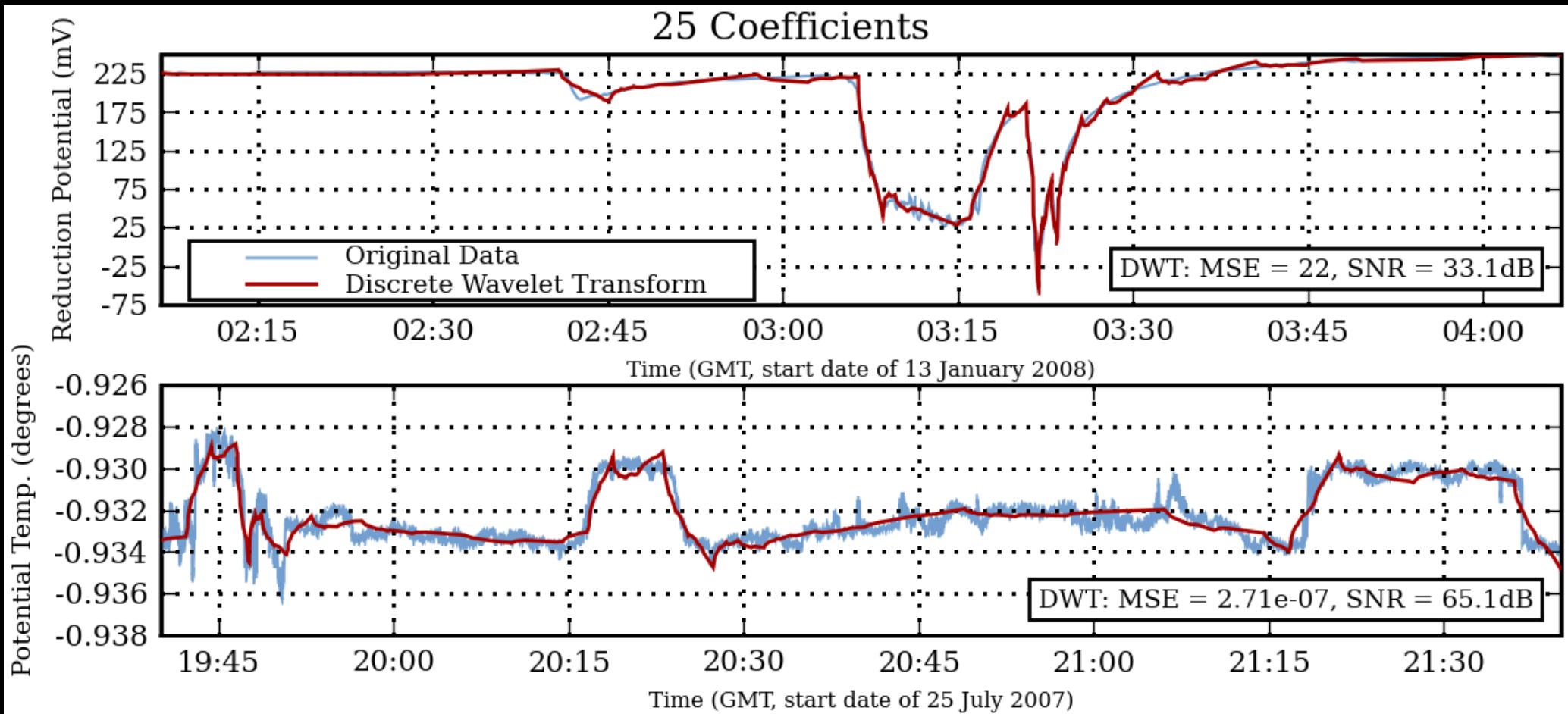
Wavelet Approximation



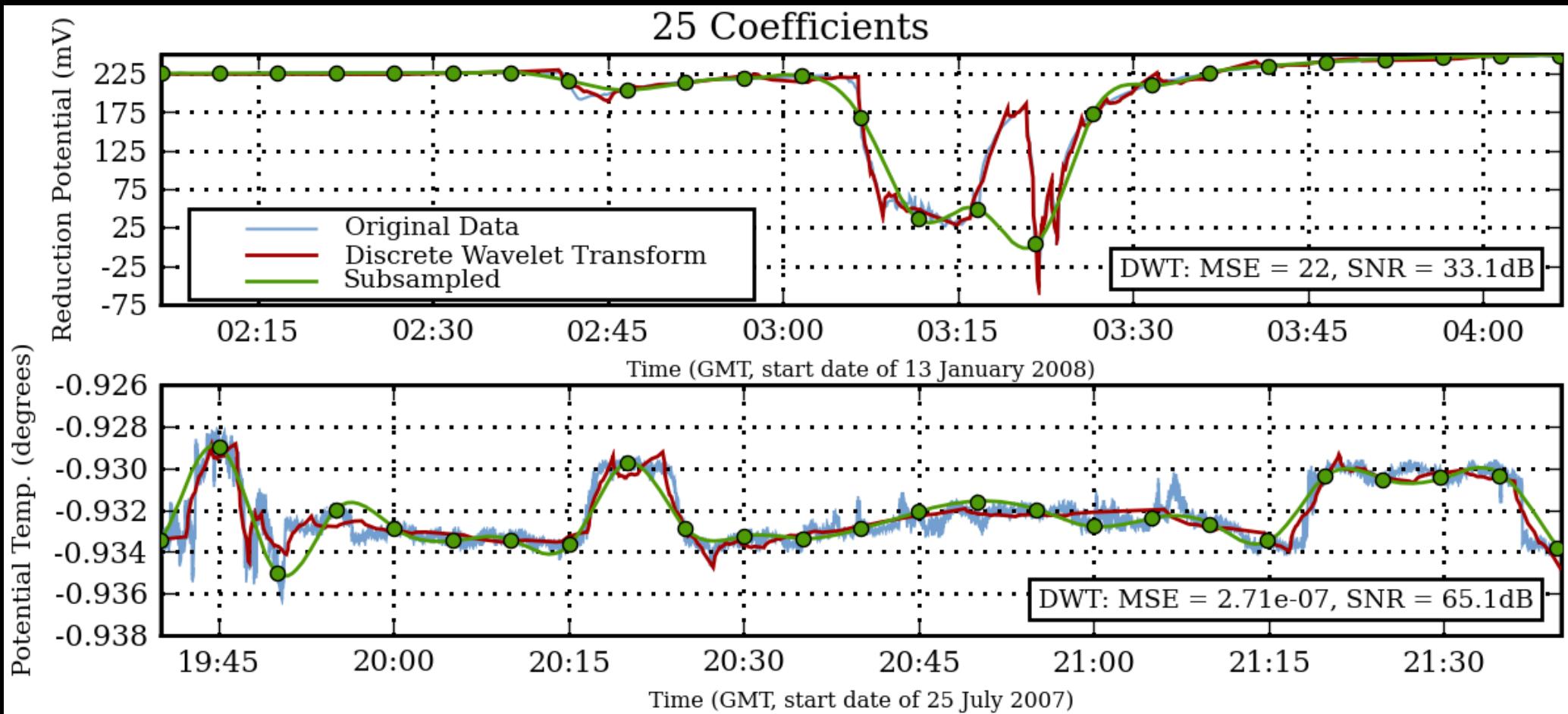
Wavelet Approximation



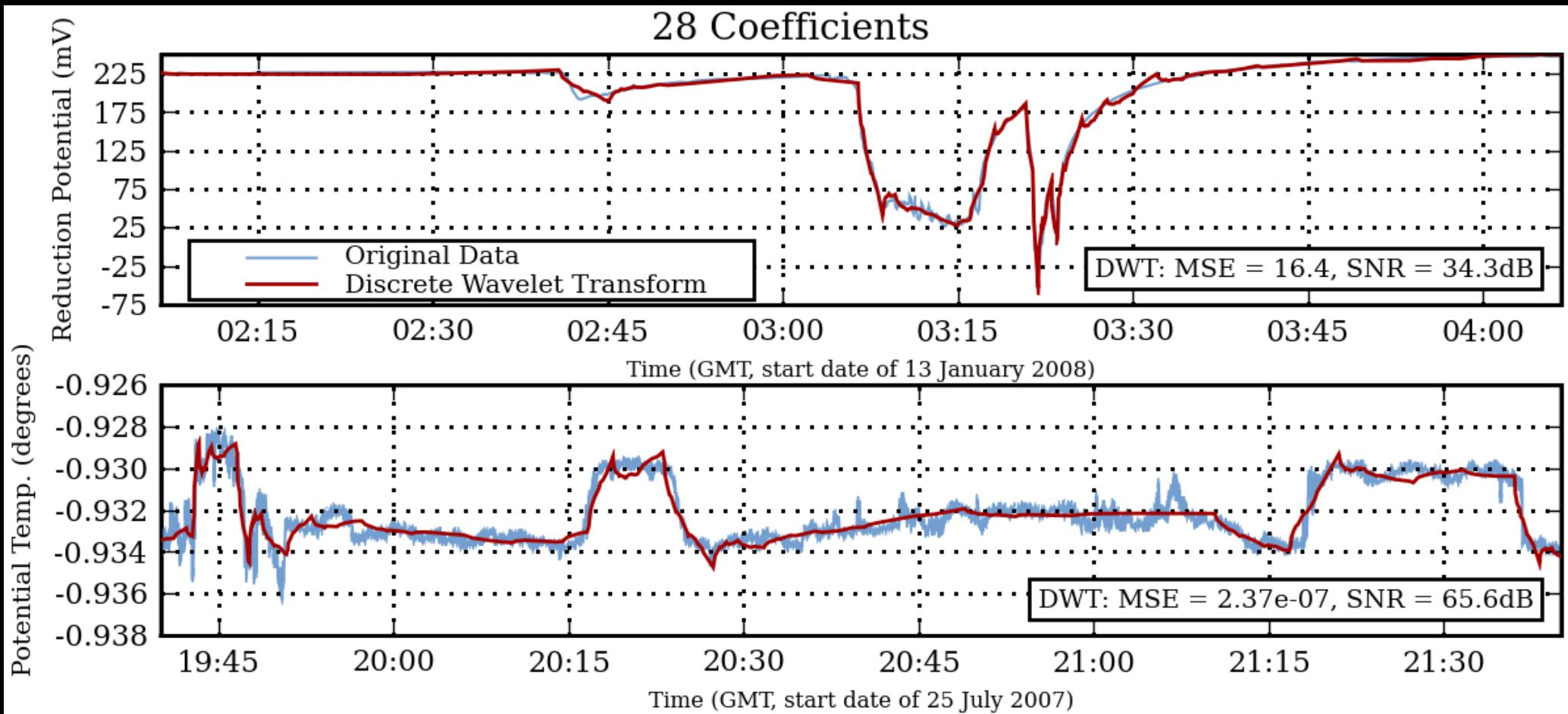
Wavelet Approximation



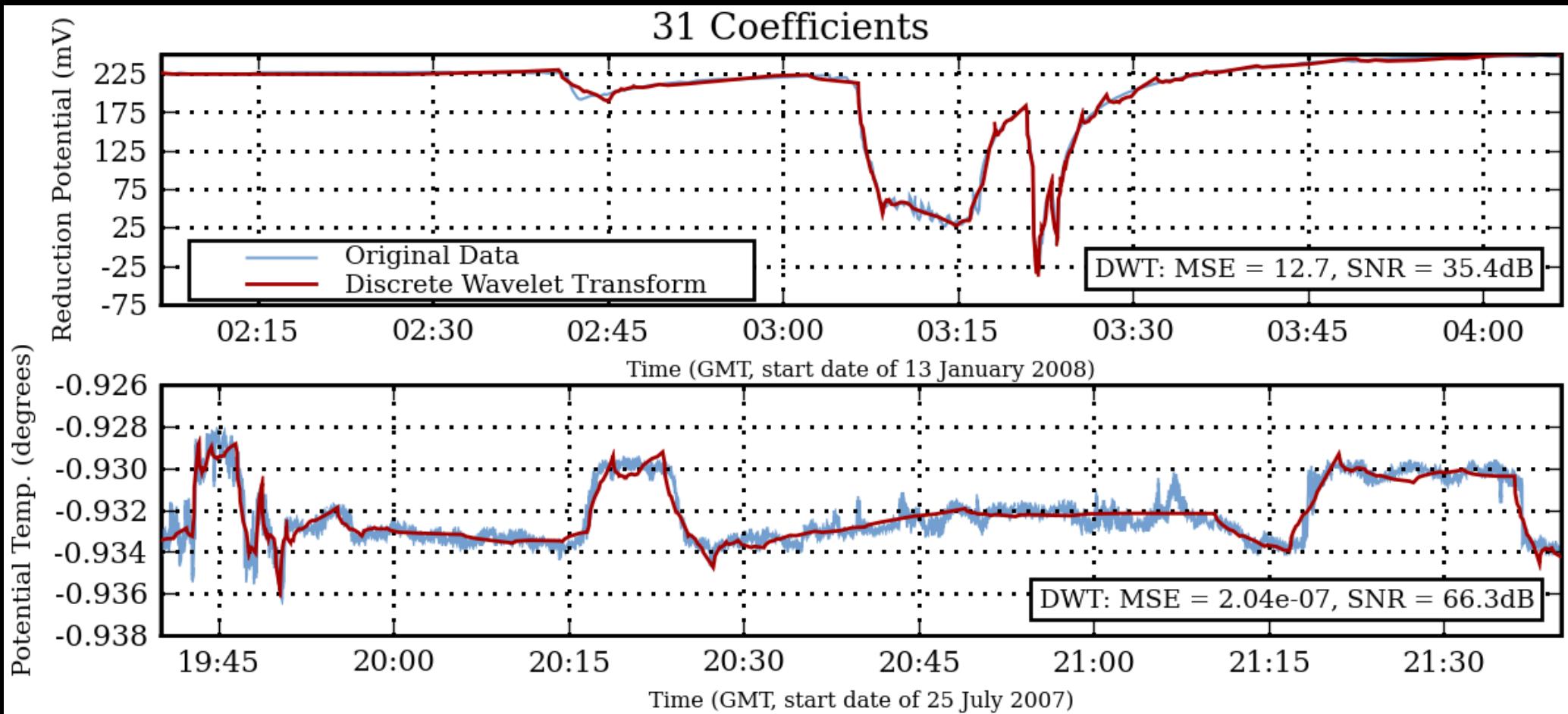
Wavelet Approximation



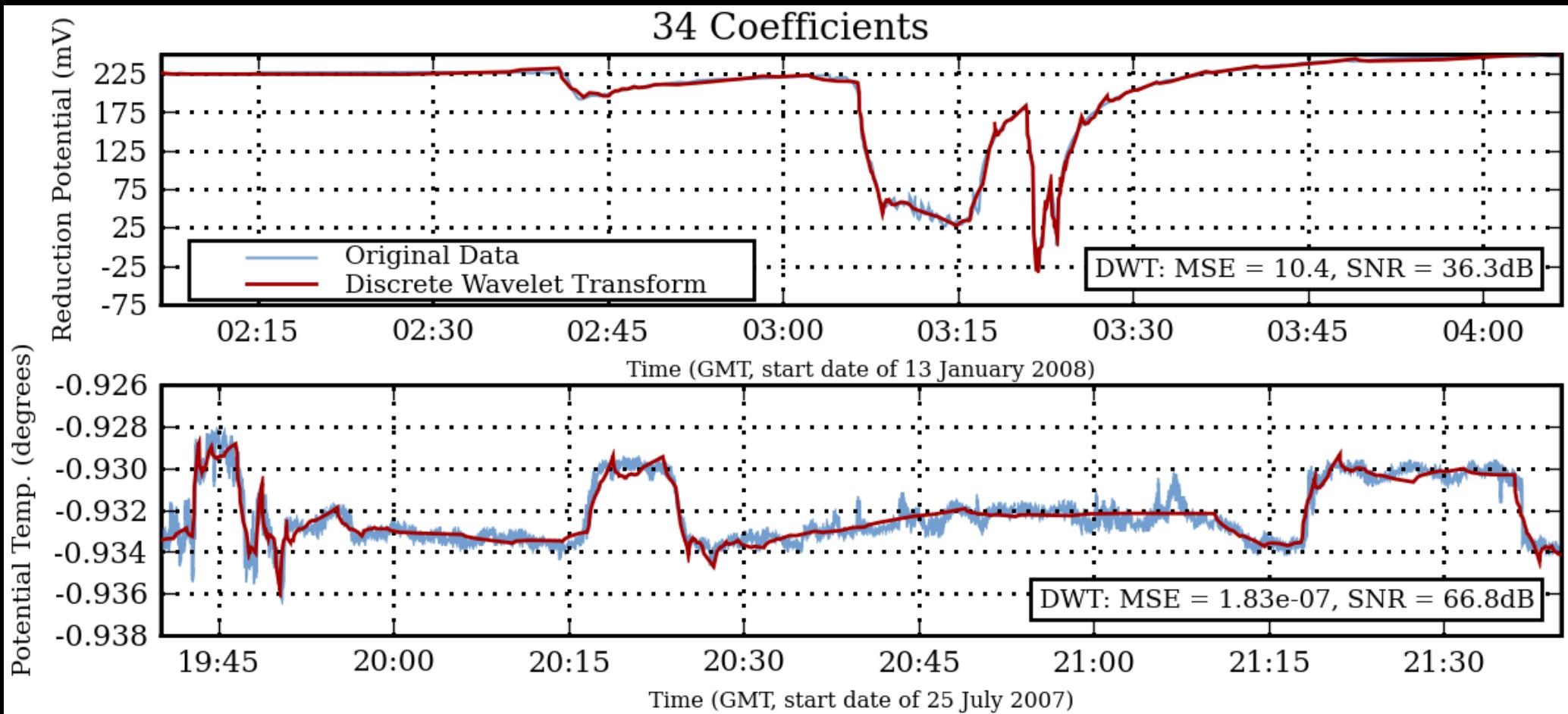
Wavelet Approximation



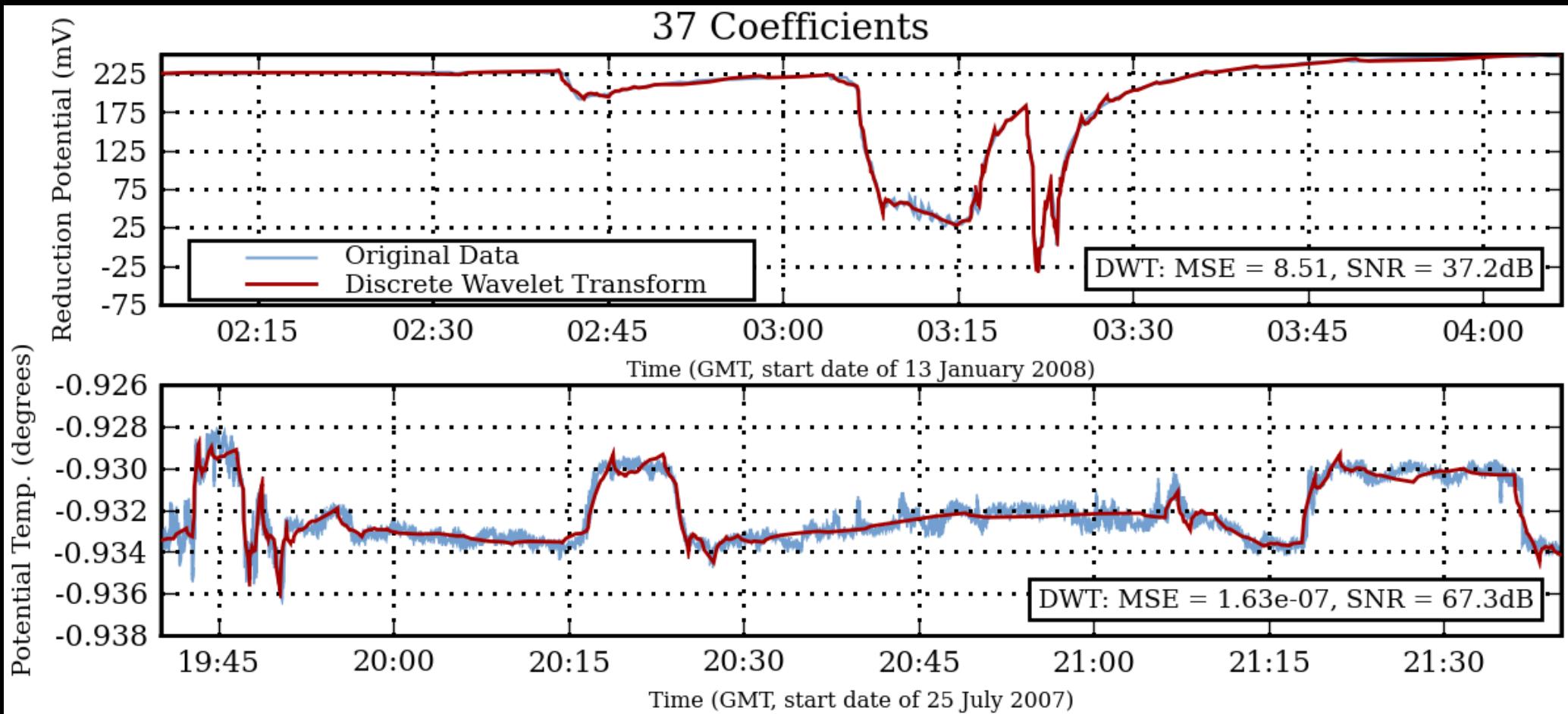
Wavelet Approximation



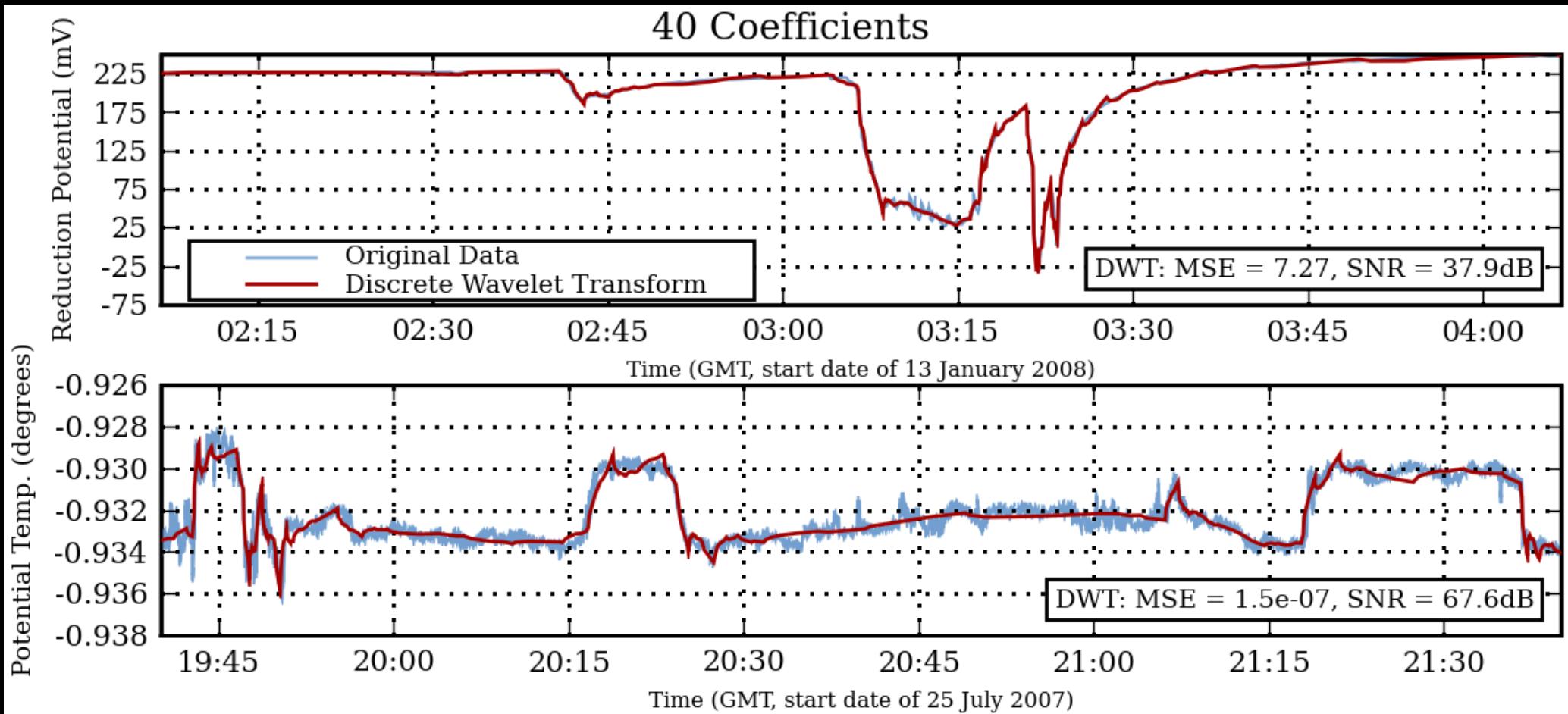
Wavelet Approximation



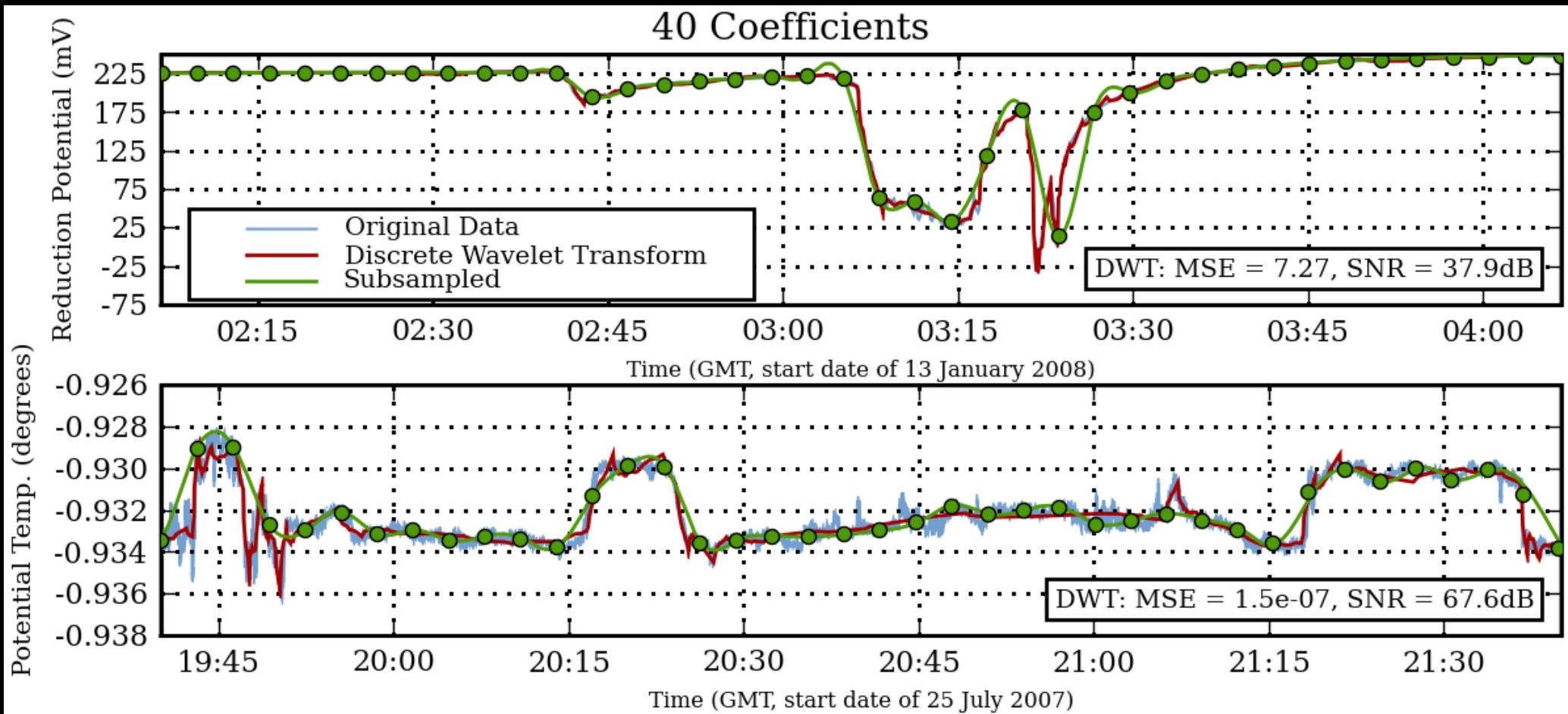
Wavelet Approximation



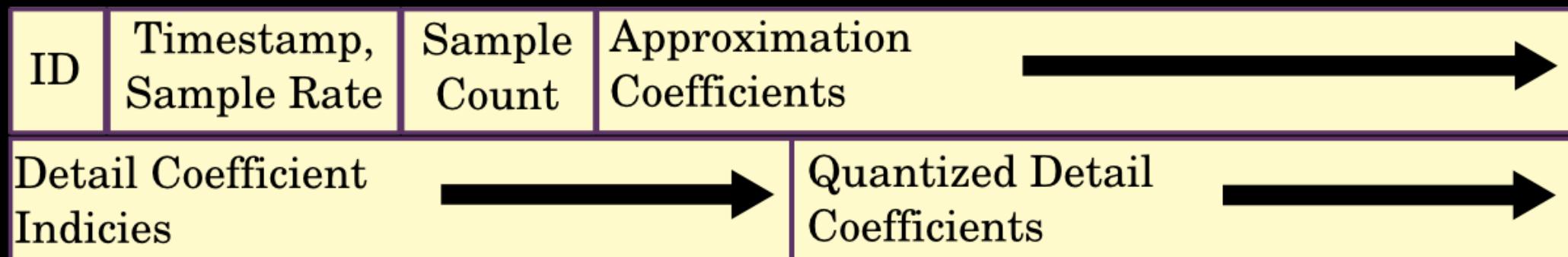
Wavelet Approximation



Wavelet Approximation



Packet Usage

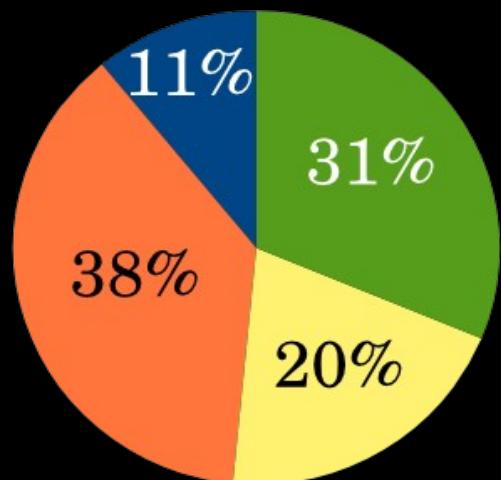


Metadata

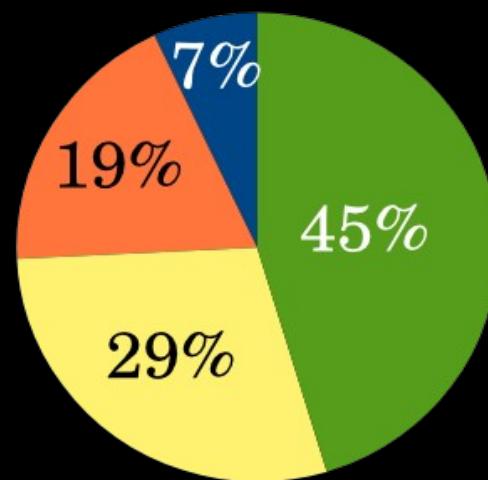
Detail Indices

Approx. Coeff's

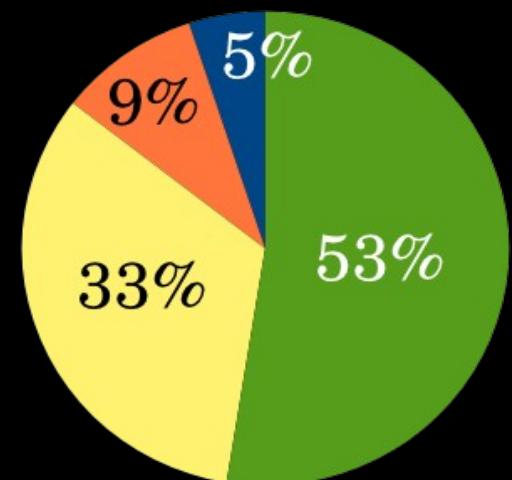
Detail Coeff's



64 Bytes



128 Bytes



256 Bytes



Embedded Coding

Currently developing new method for encoding packets based on:

Embedded coding – A high quality version of encoded data shares first N bits *identically* with a poor quality encoding of length N.

Low Quality Preview

Medium Quality Representation

High Quality Representation

If preview is interesting, users request additional packets to obtain high quality sections of signals.



Topside Display

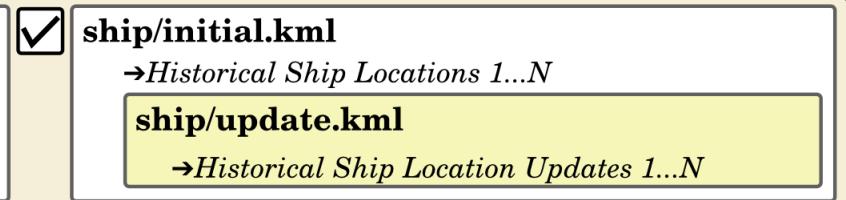
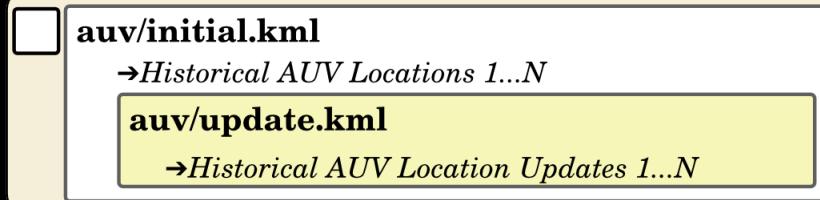


KML

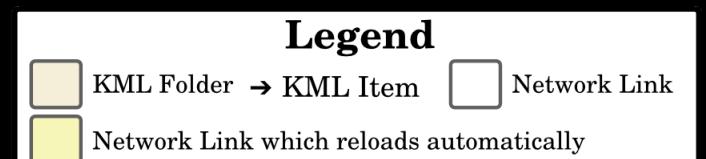
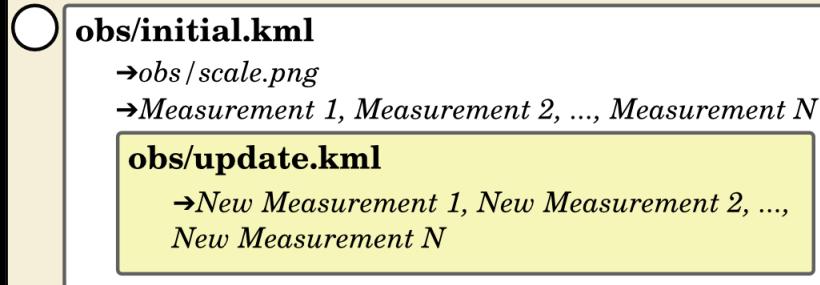
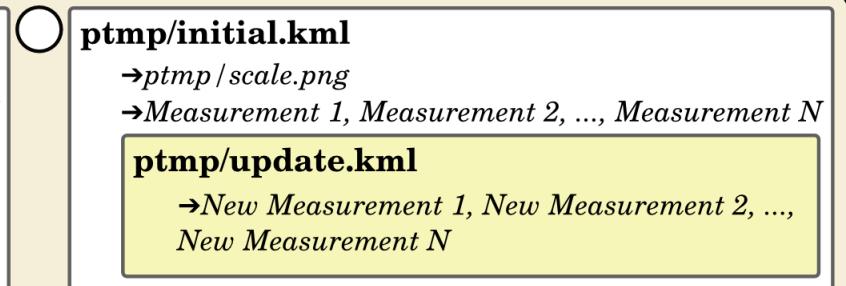
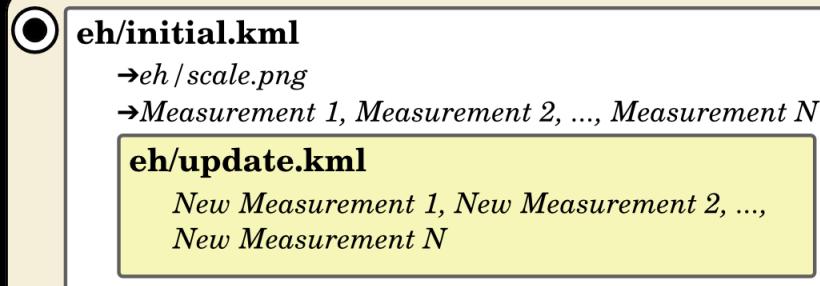
main.kml

- Bathymetry → Points of Interest
- Logos → LBL Beacons
- Mission Plans
- Other Science Data

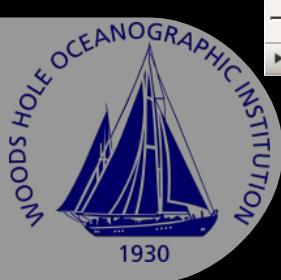
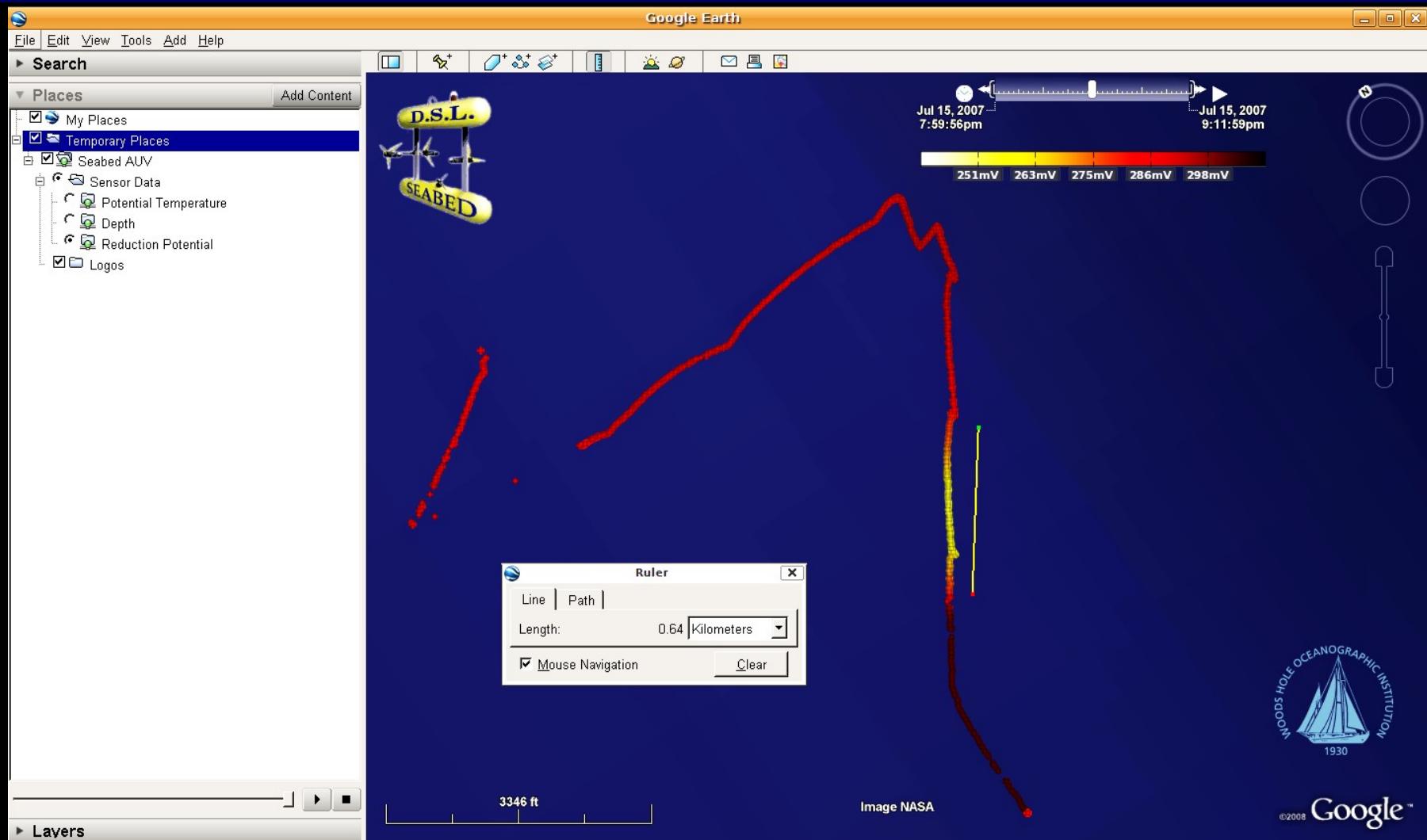
Vehicles



Sensors

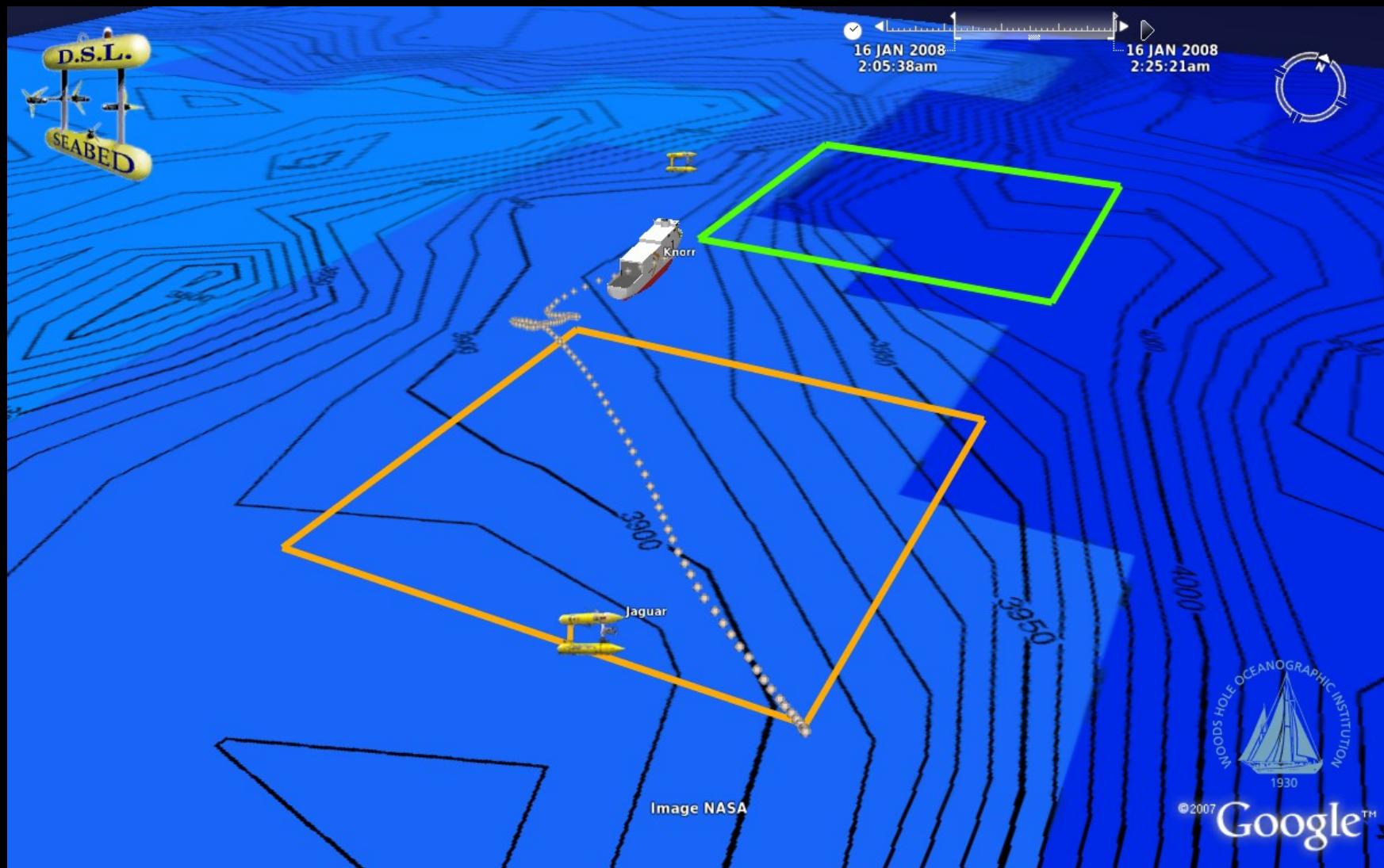


Google Earth



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Google Earth



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Google Earth

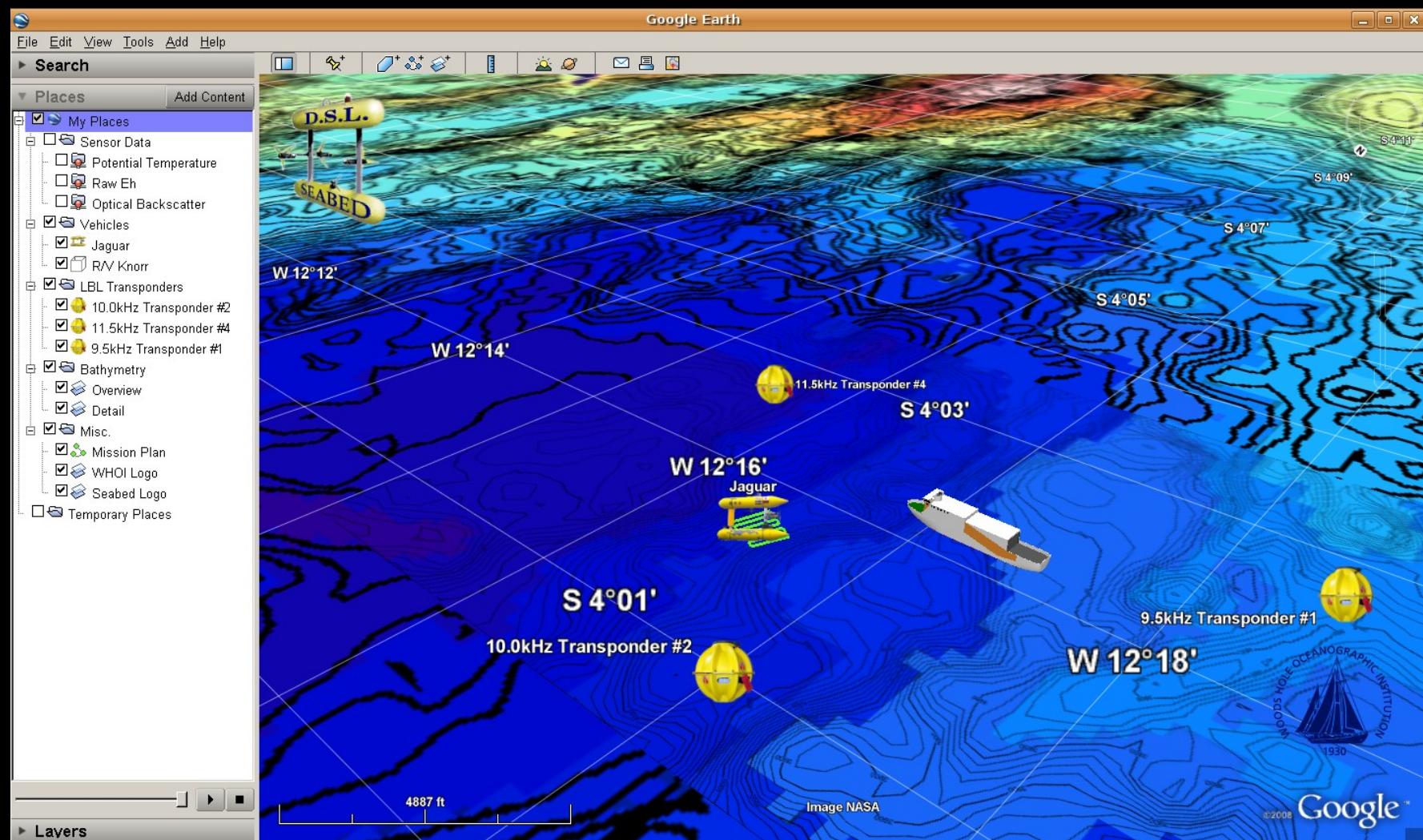
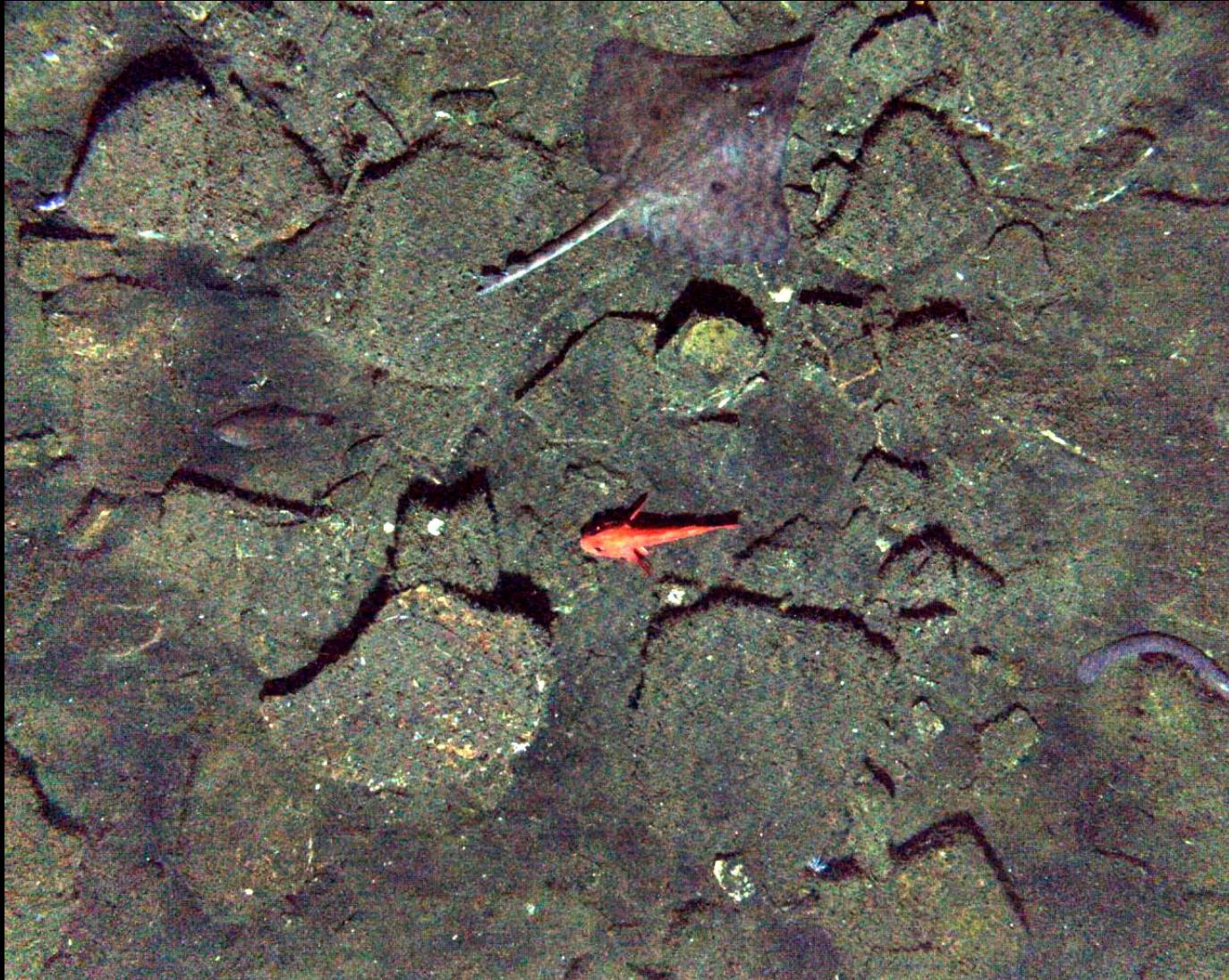


Photo Telemetry



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Vector Quantized Encoding

16x16



24x24



32x32



Step 1

Generate tile library
from previously
captured images

Step 2

Calculate feature
vector for each tile

Step 3

Provide list of
feature vectors to
AUV and receivers

Step 4

Capture image; calculate
feature vectors for each tile
in new image.

Step 5

Identify closest previously
captured tile

Step 6

Transmit list of indices of nearest
feature vector for each tile

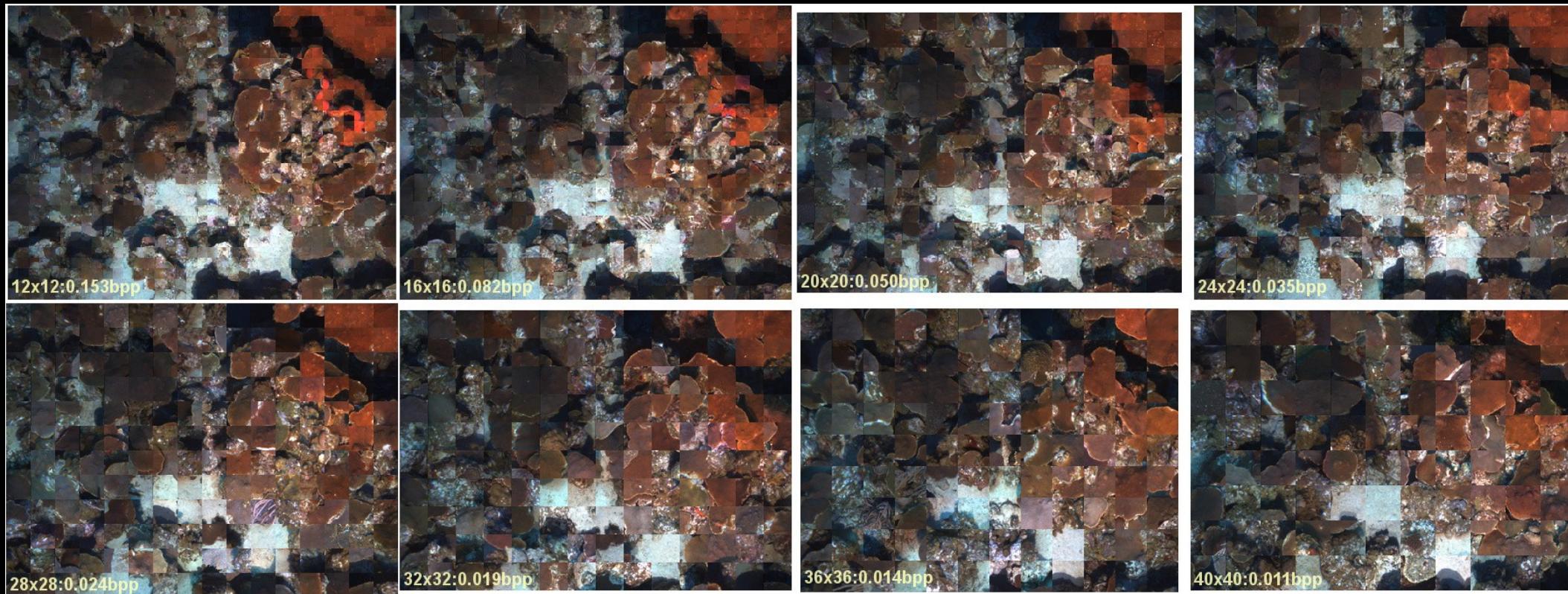


Representative Images



VQ With 5x5 YUV Features

22792bits = 2849B. 12348bits = 1544B. 7040bits = 880B. 5040bits = 630B.



3648bits = 630B.

2660bits = 333B.

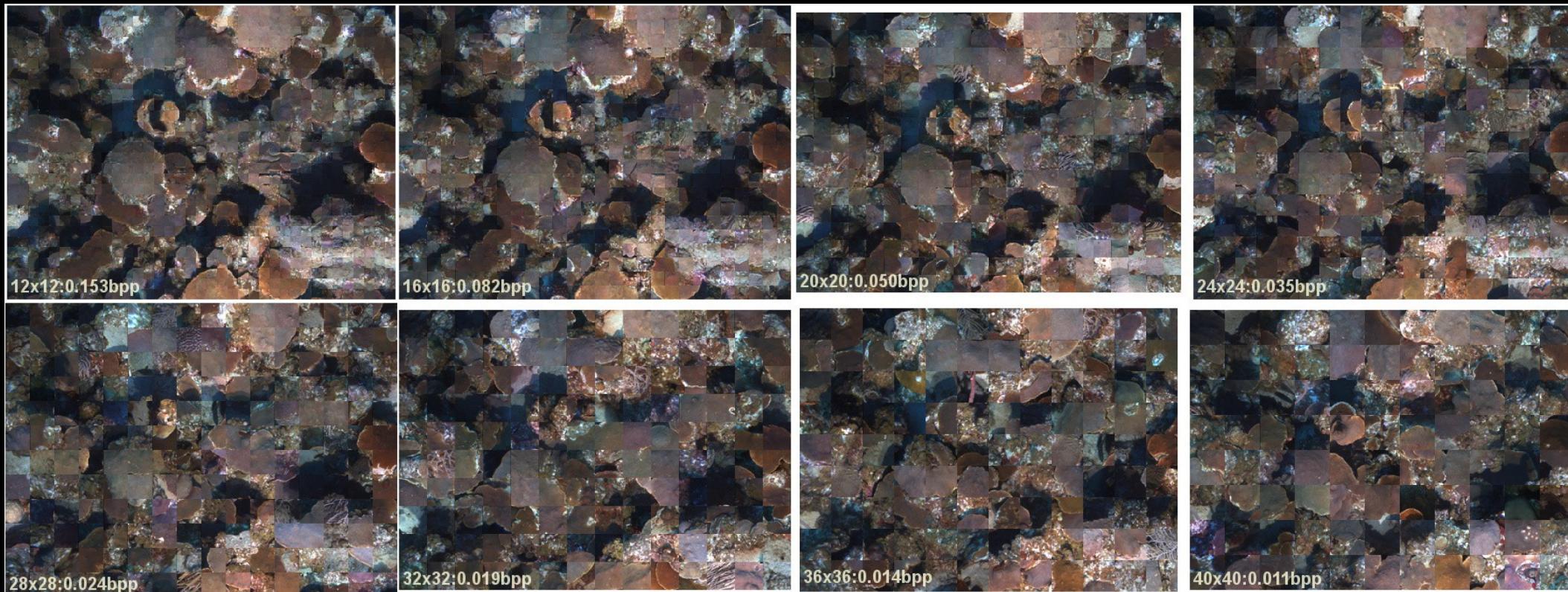
1944bits = 243B.

1584bits = 198B.



VQ With 5x5 YUV Features

22792bits = 2849B. 12348bits = 1544B. 7040bits = 880B. 5040bits = 630B.



3648bits = 630B.

2660bits = 333B.

1944bits = 243B.

1584bits = 198B.





Thank You.

chrismurf @ whoi.edu



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Partners in Vent Finding

Puma

- Optical Backscatter
- Long-range Optical Backscatter
- eH Sensor
- High-altitude DVL / ADCP
- No camera, no imaging sonar

Jaguar

- Magnetometer
- High-res camera
- Imaging Sonar



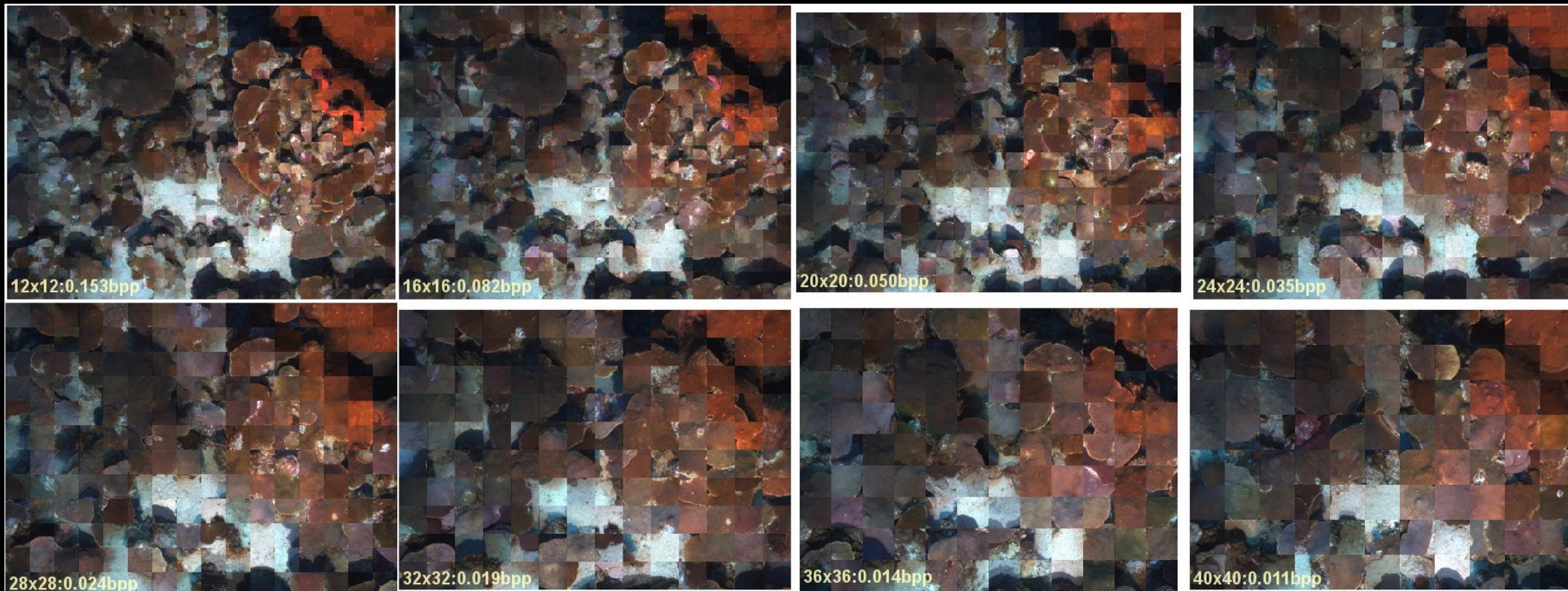
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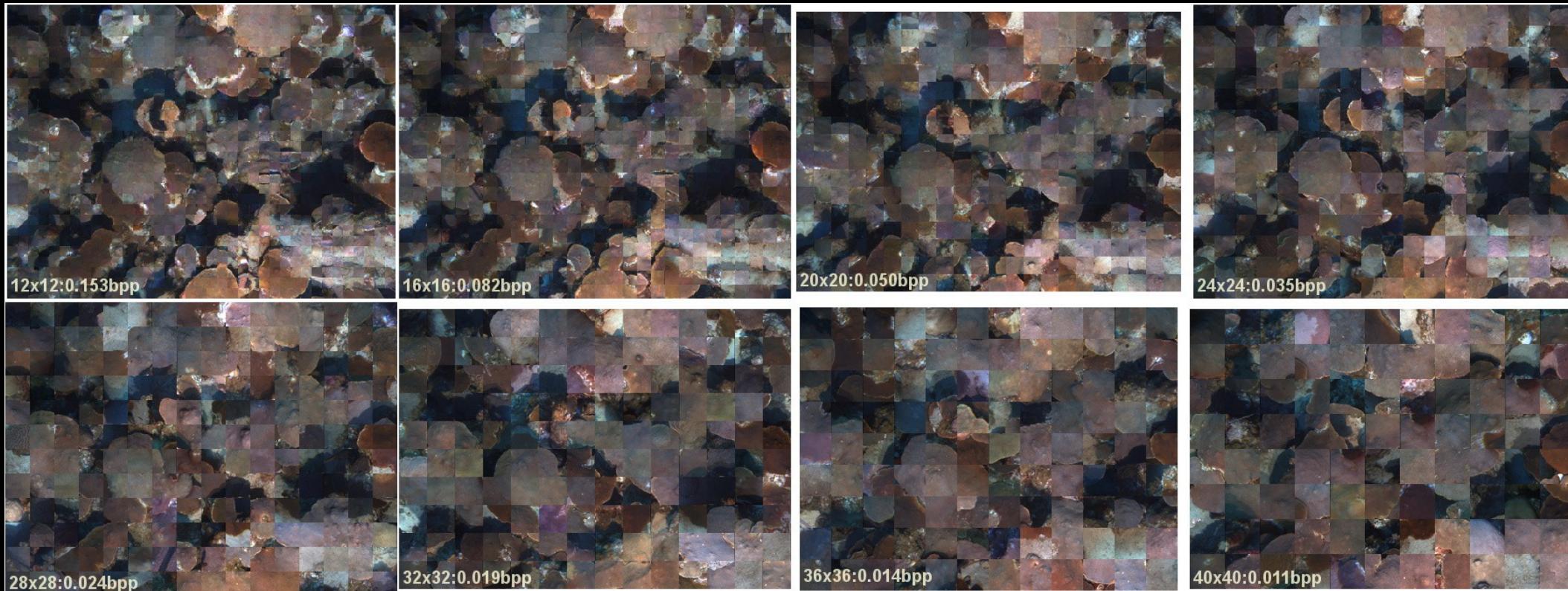
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1944bits = 243B.

1584bits = 198B.



Recent Expeditions



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SMAR 2008

Engineering focus

Navigation methods
Communication
Multiple AUV Op's

Joint work with
Johns Hopkins

20+ days at sea

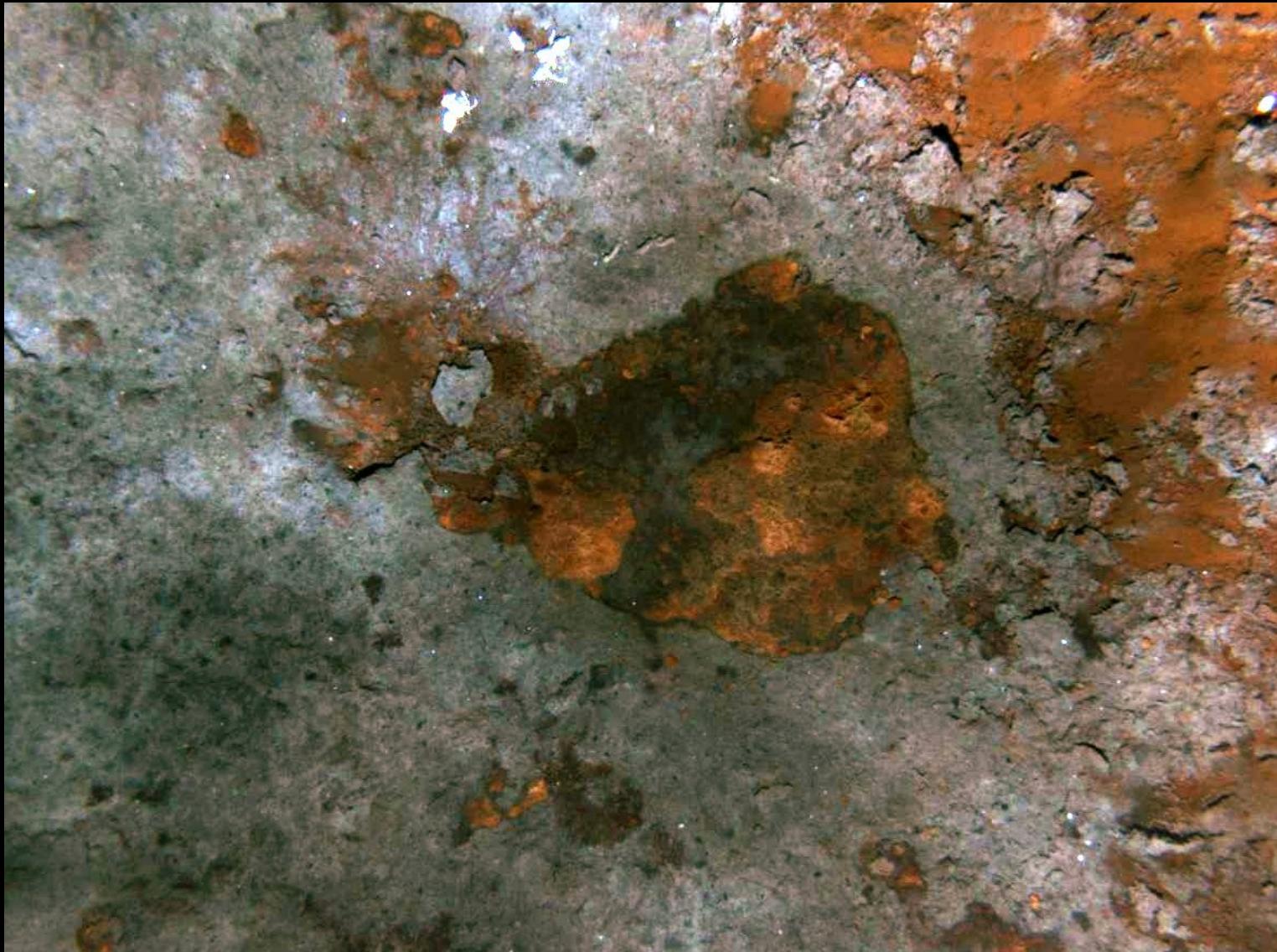


SMAR 2008



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SMAR 2008



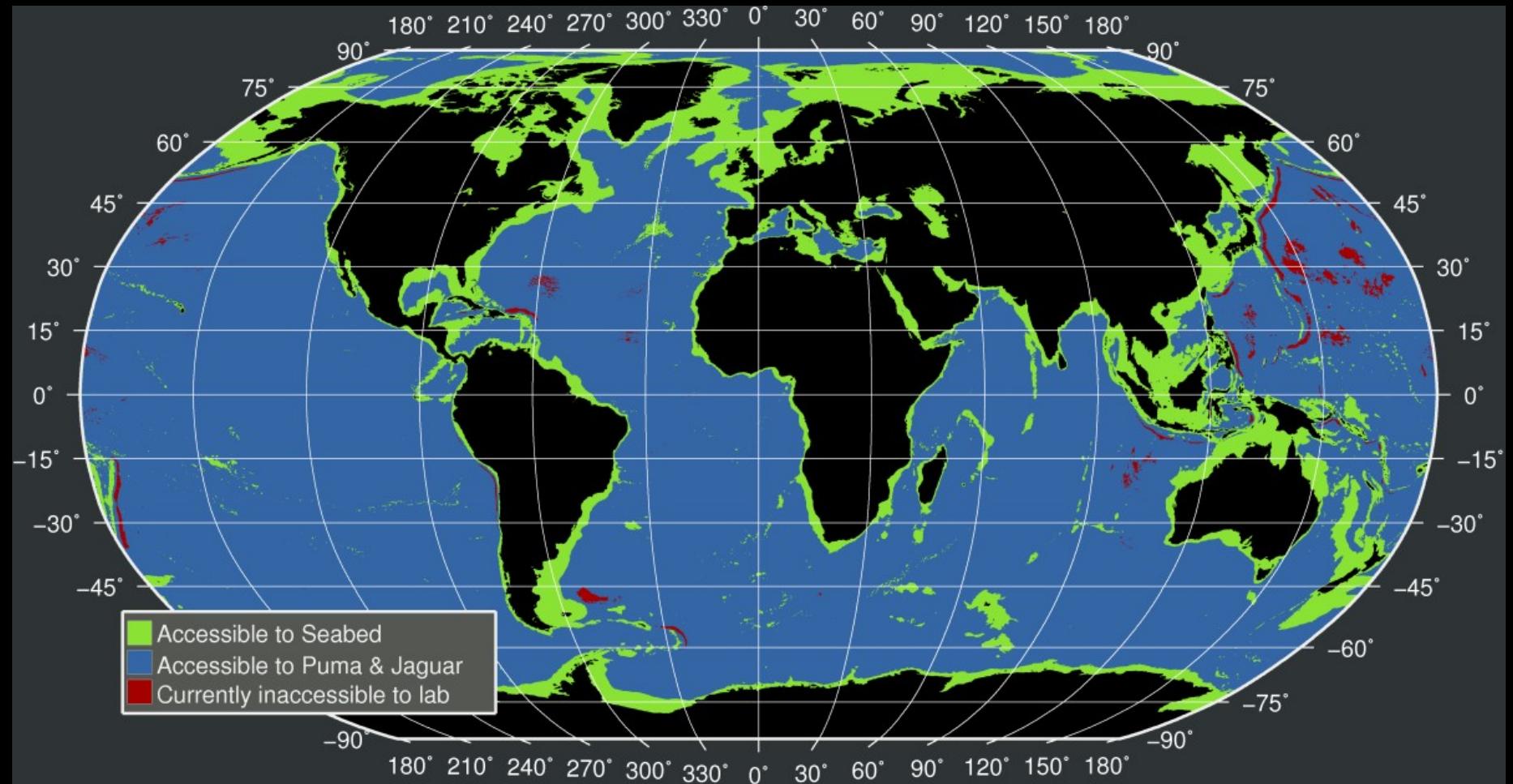
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SMAR 2008



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Ocean Coverage



AGAVE Recovery

