进大海探索　入无人之境

张燕武

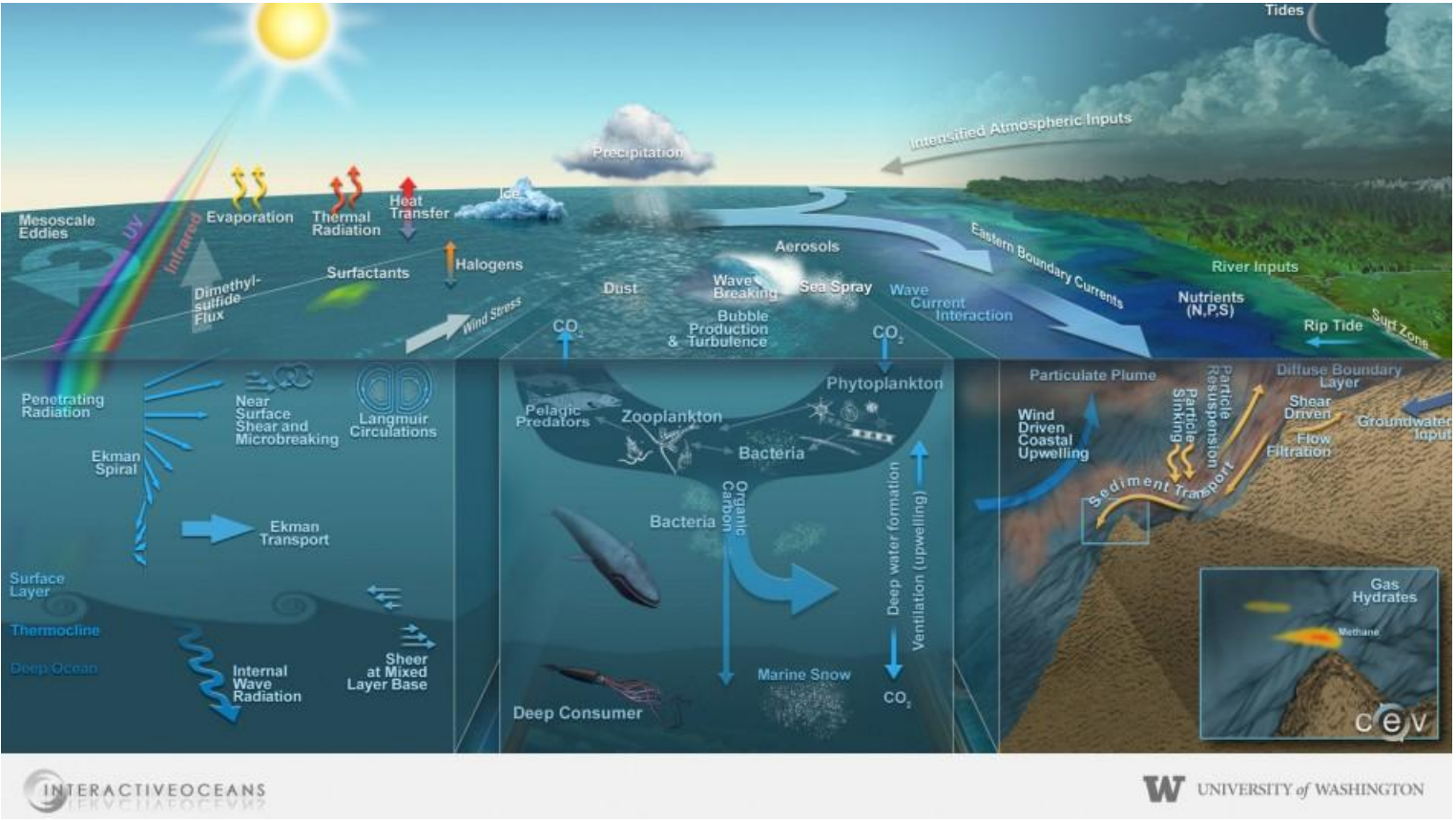
Monterey Bay Aquarium Research Institute

(蒙特瑞海洋研究所)

M B A R I

April 2013

我们的海洋



海洋生态系统及气候变化

海洋动力学

地球板块动力学

From *http://www.oceanobservatories.org/design/major-science-themes/*

惊涛骇浪

Labrador 海, 1998

冰层覆盖

南极, 1993

Photos courtesy of J. G. Bellingham

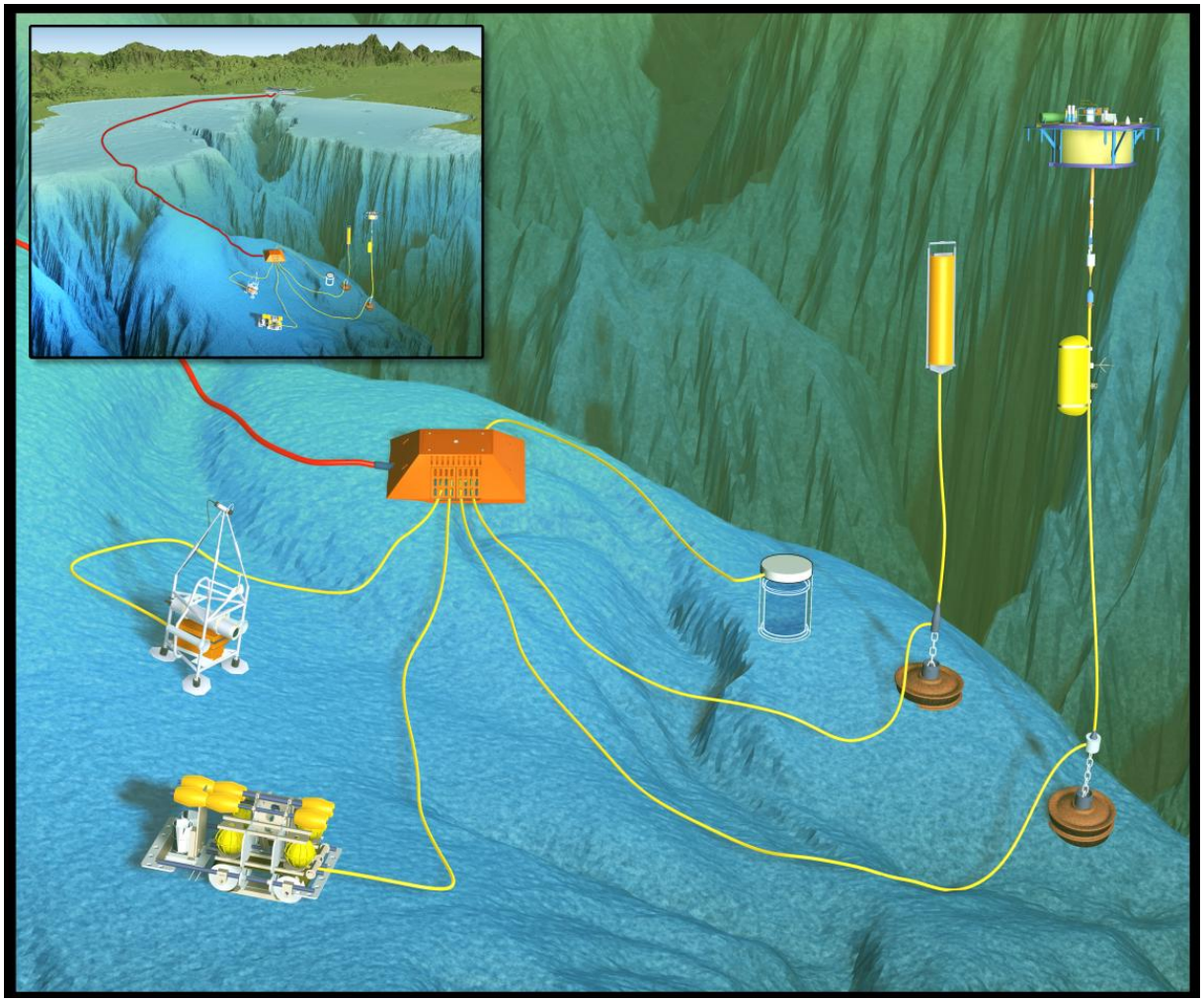
Monterey Bay Aquarium Research Institute (MBARI)

MBARI founder David Packard:

"Send instruments to sea, not people.

Return information to shore, not samples"

The Monterey Accelerated Research System (MARS)
海底观测站



- Depth: 890 m. 52-km undersea cable.
- 37 km from MBARI.
- 8 ports: 9 kW power and 100 Mbps x 8 ethernet communications.
- Development cost: 6 years (2002-2008), $13.5M.

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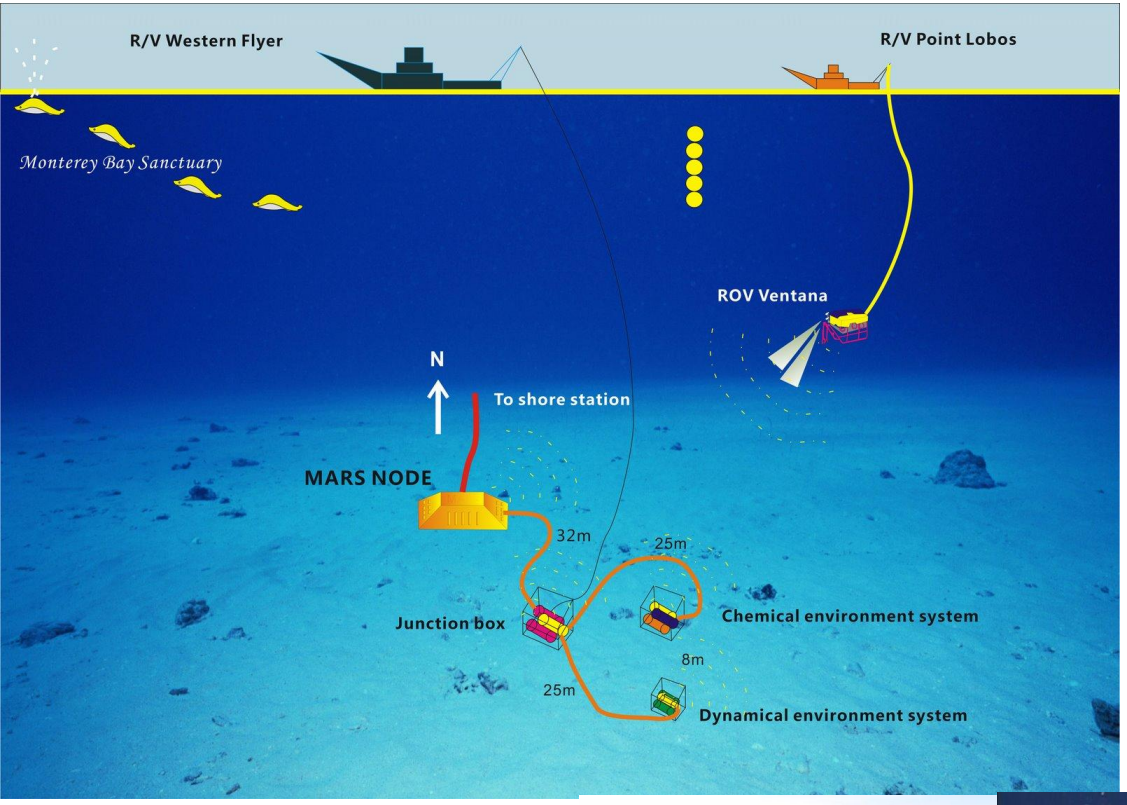
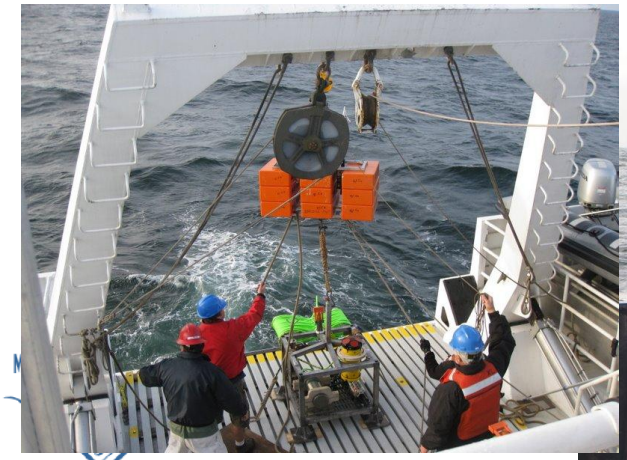
MARS 的中国节点 (2011 年)

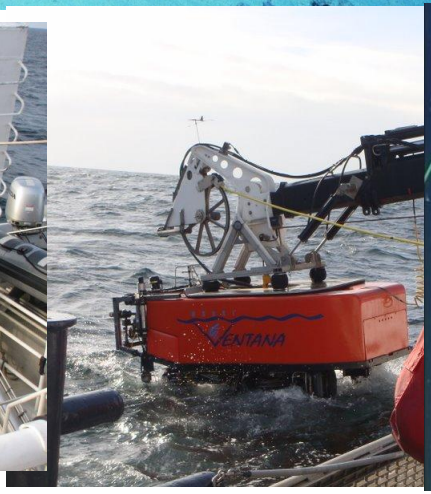


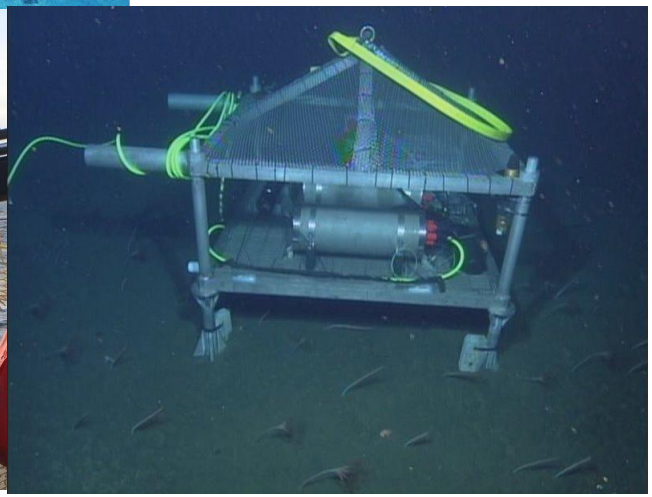
- 接驳盒
- 化学环境监测子系统
- 动力环境监测子系统
- 摄像机

(同济大学、浙江大学、中国海洋大学、上海交通大学)

彭晓彤等,《地球科学进展》, 2011



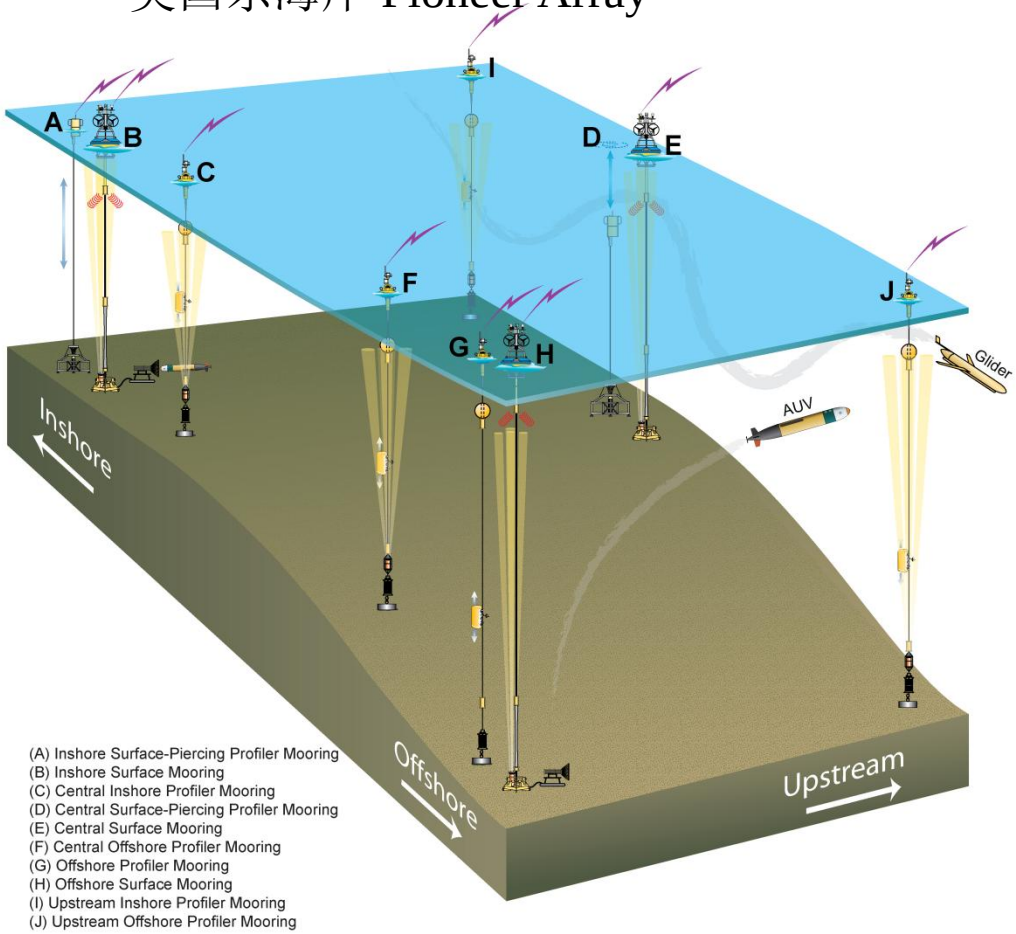




April 2013

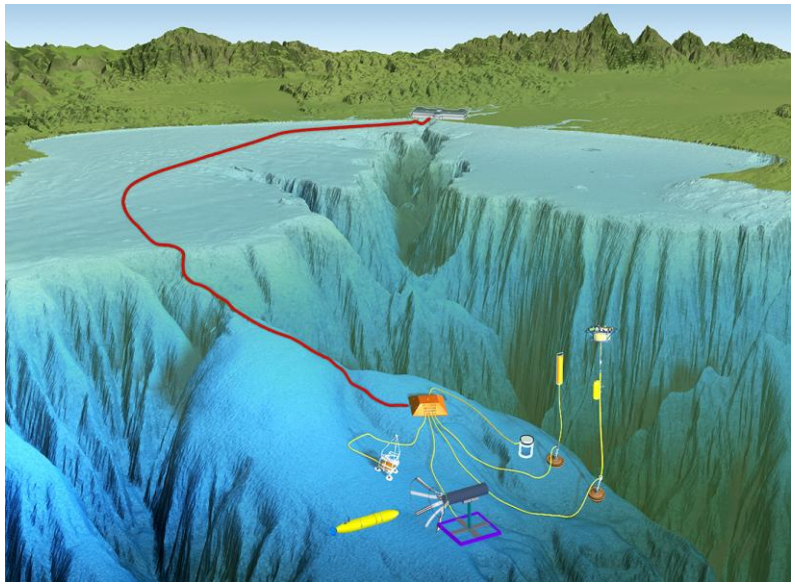
海底观测网的发展方向: 固定平台 + 移动平台

OOI 近岸网(Coastal Scale Nodes) 之一:
美国东海岸 Pioneer Array

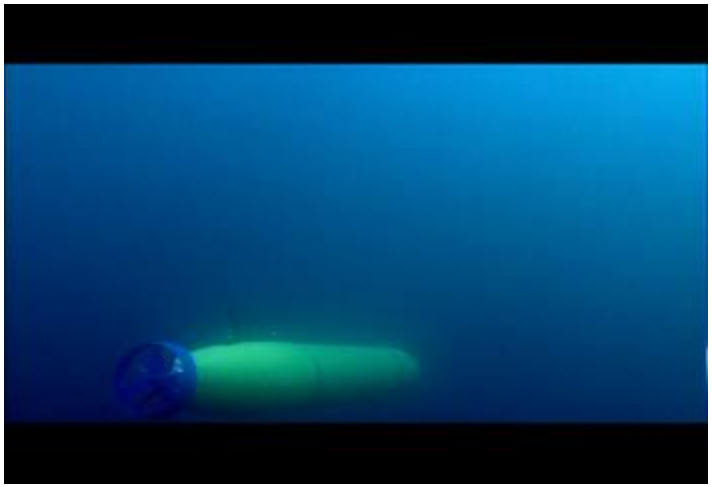


From *http://www.oceanobservatories.org/infrastructure/ooi-station-map/pioneer-array/*

MARS



MBARI Dorado AUV

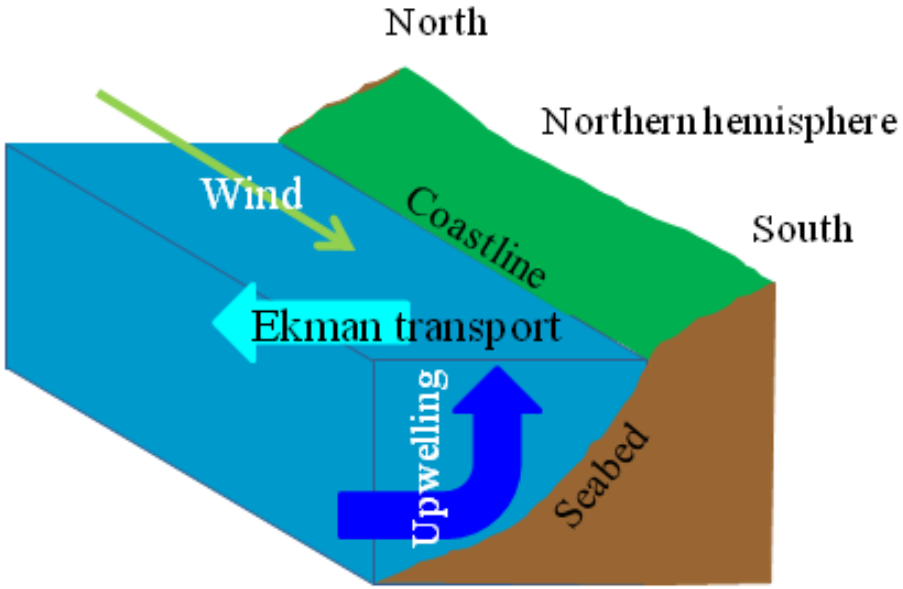


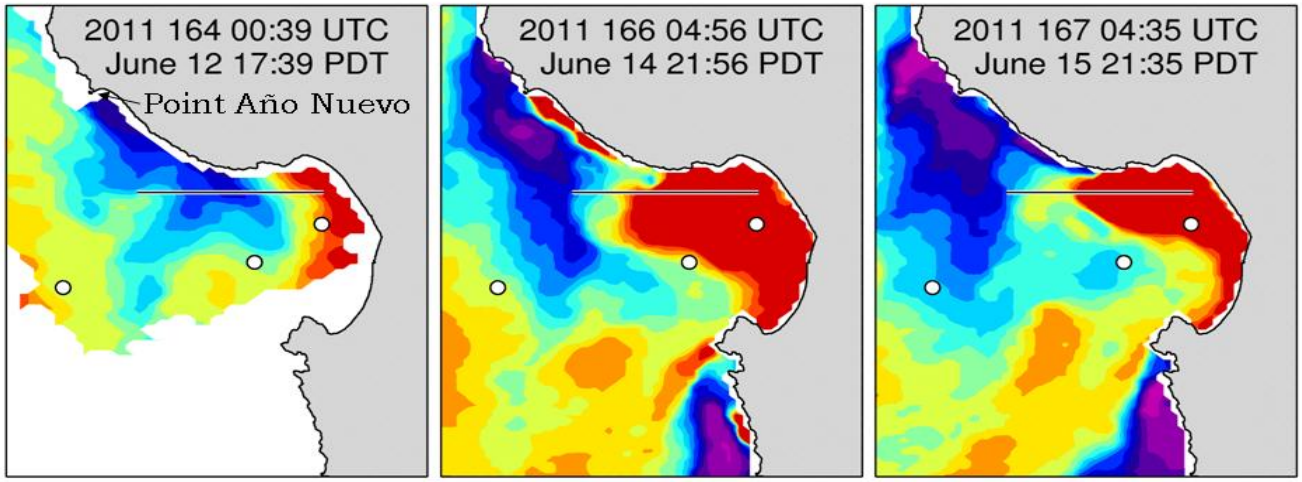
Courtesy of J. G. Bellingham

Autonomous Ocean Sampling Network (AOSN)

Courtesy of J. G. Bellingham

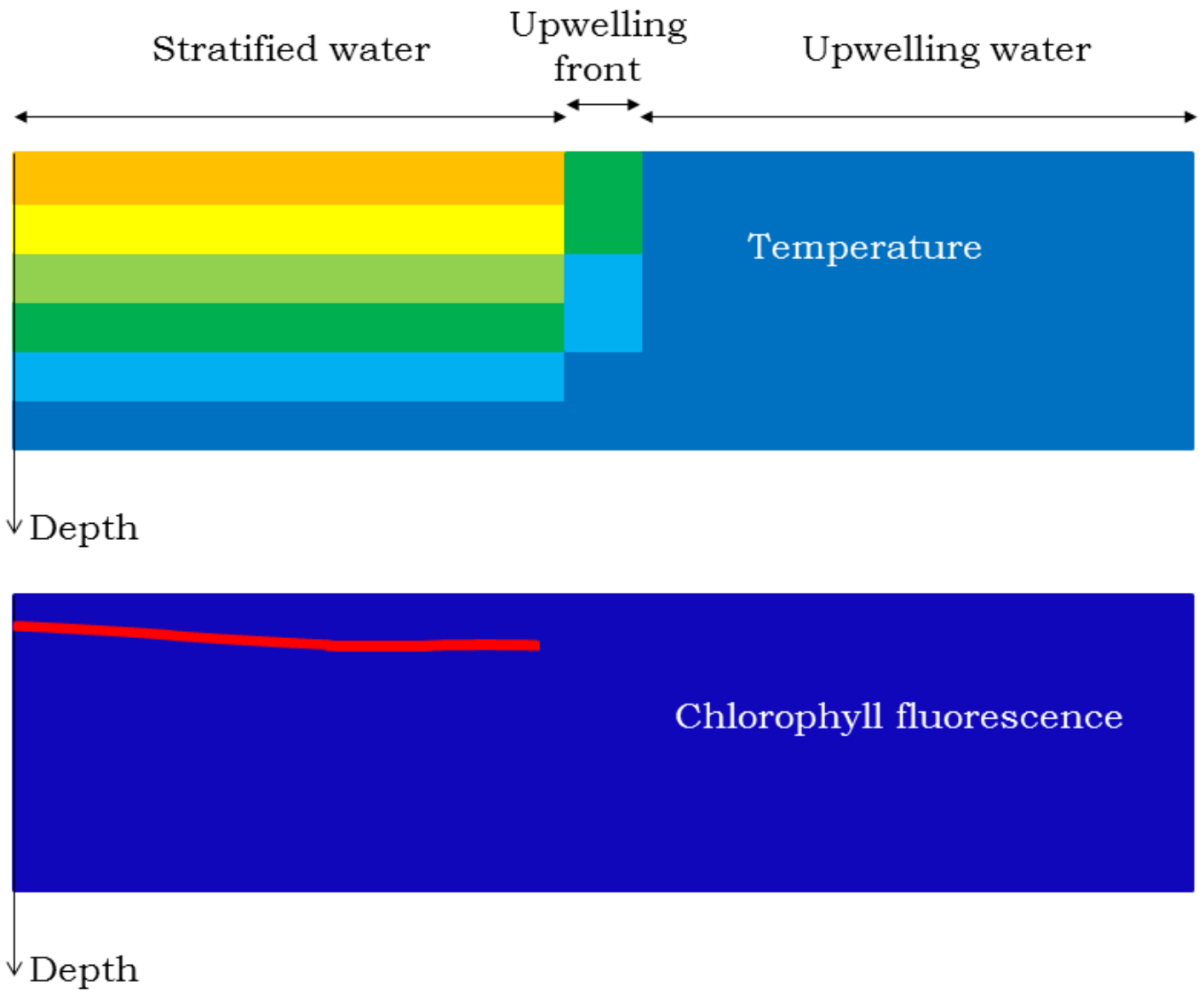
Monterey Bay Upwelling System



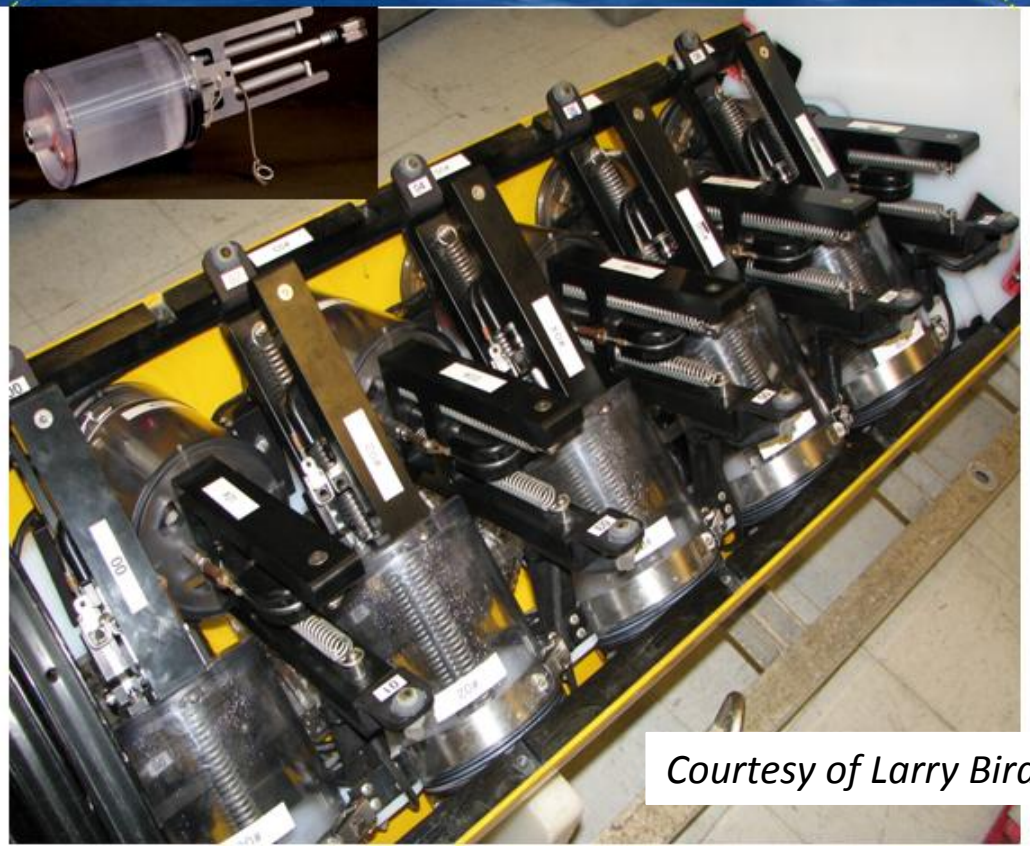


Satellite AVHRR SST data Courtesy of Kudela Lab (UCSC) and NOAA CoastWatch

Vertical Structures of Three Distinct Water Types in an Upwelling System

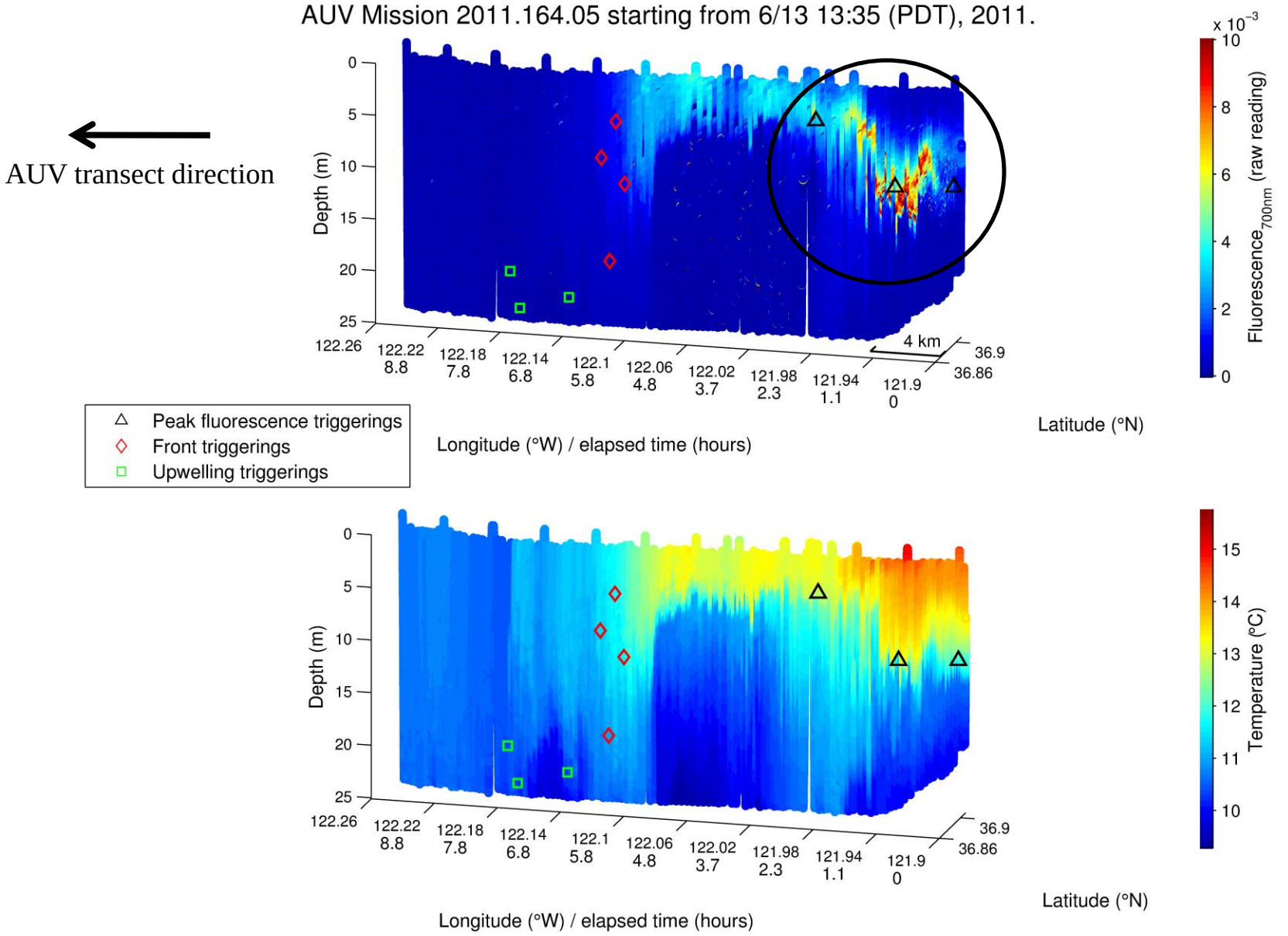


MBARI Dorado AUV and Its 10 “Gulpers”

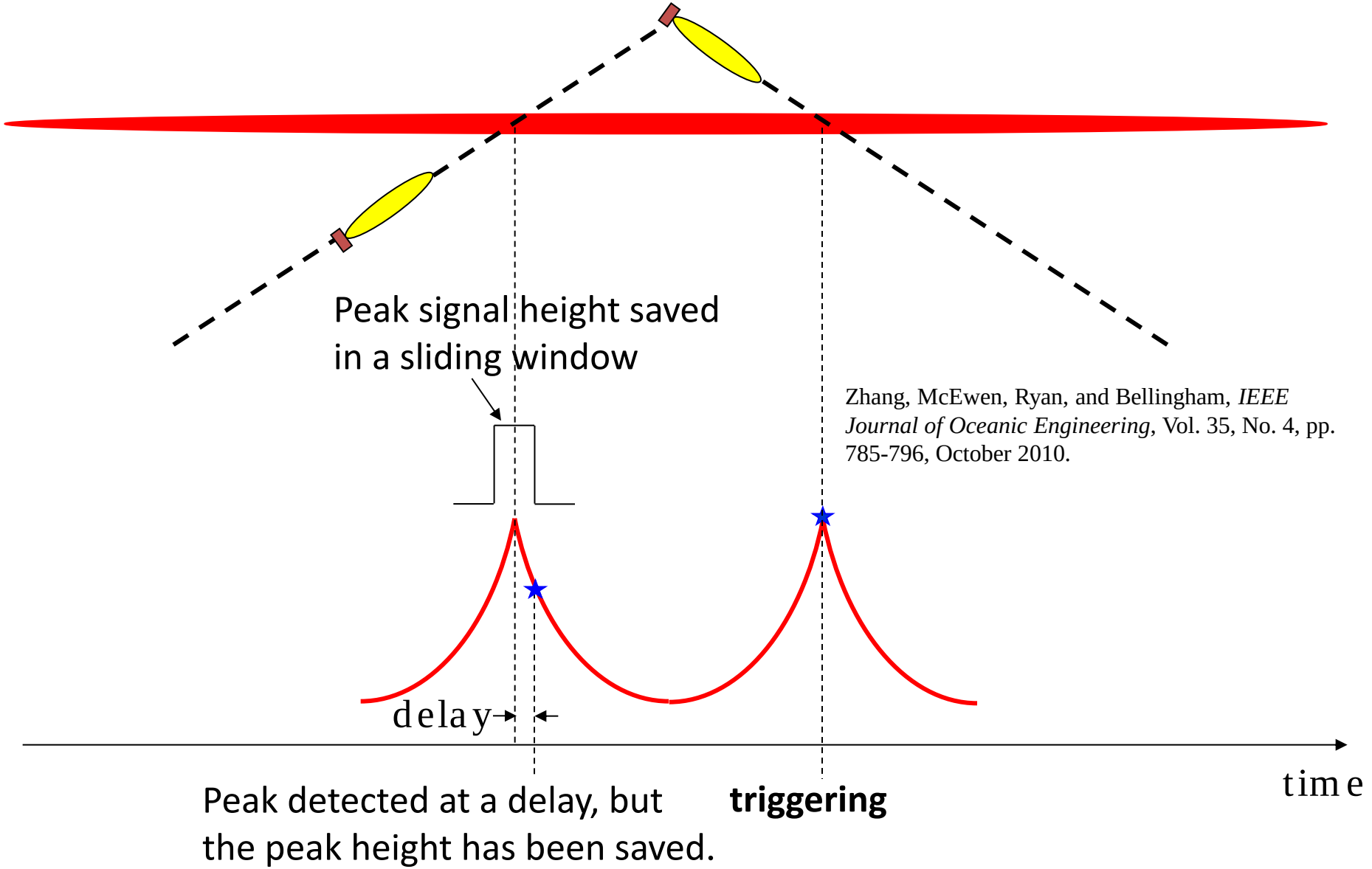


Courtesy of Larry Bird and Alana Sherman

Dorado AUV's Autonomous Detection and Targeted Sampling in the Three Water Types during the June 2011 CANON Experiment

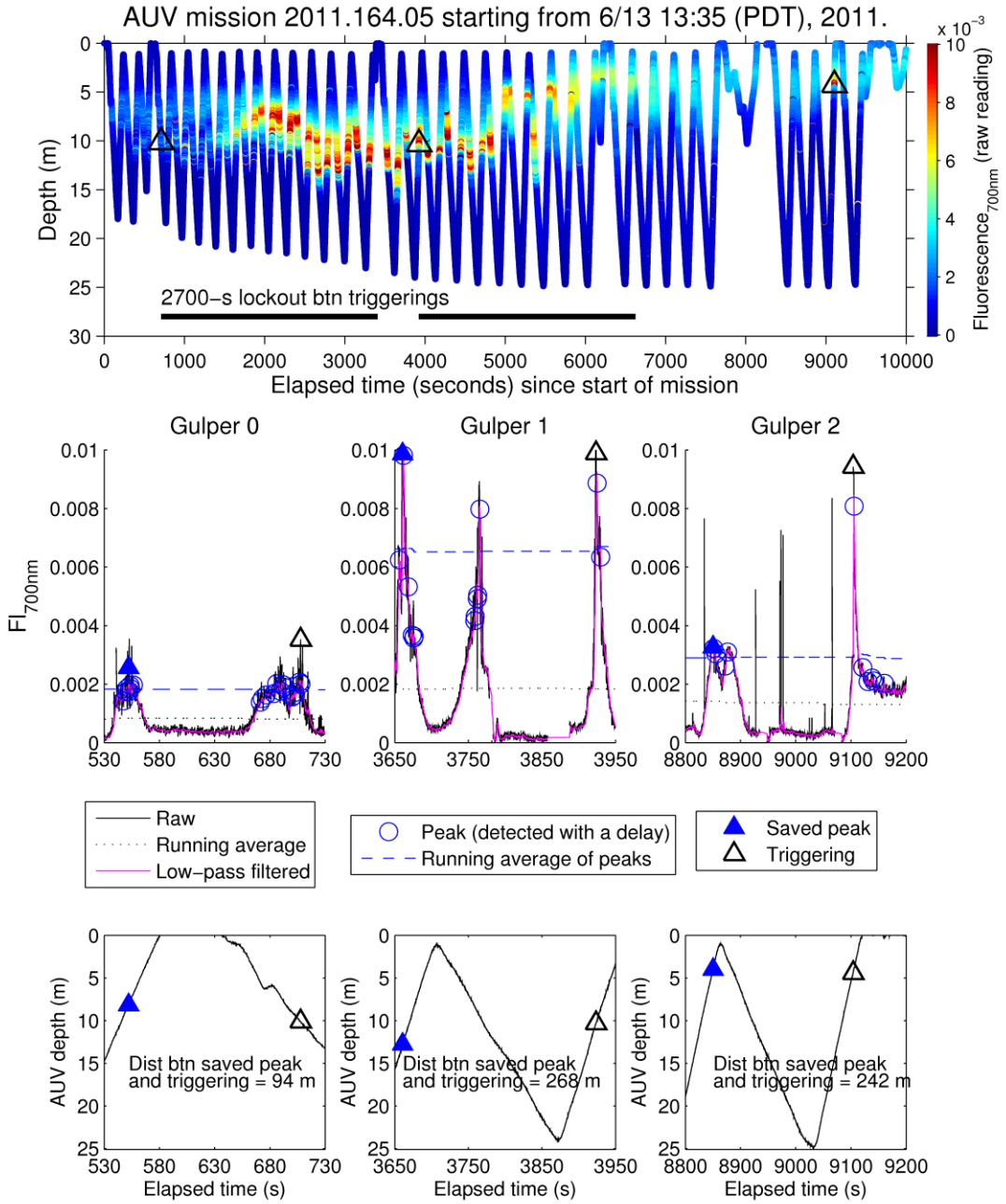


An Adaptive Triggering Method for the Dorado AUV to Capture Peak-Chlorophyll Water Samples in a Phytoplankton Thin Layer



Zhang, McEwen, Ryan, and Bellingham, *IEEE Journal of Oceanic Engineering*, Vol. 35, No. 4, pp. 785-796, October 2010.

Dorado AUV's Samplings in the Phytoplankton Thin Layer in the June 2011 Mission



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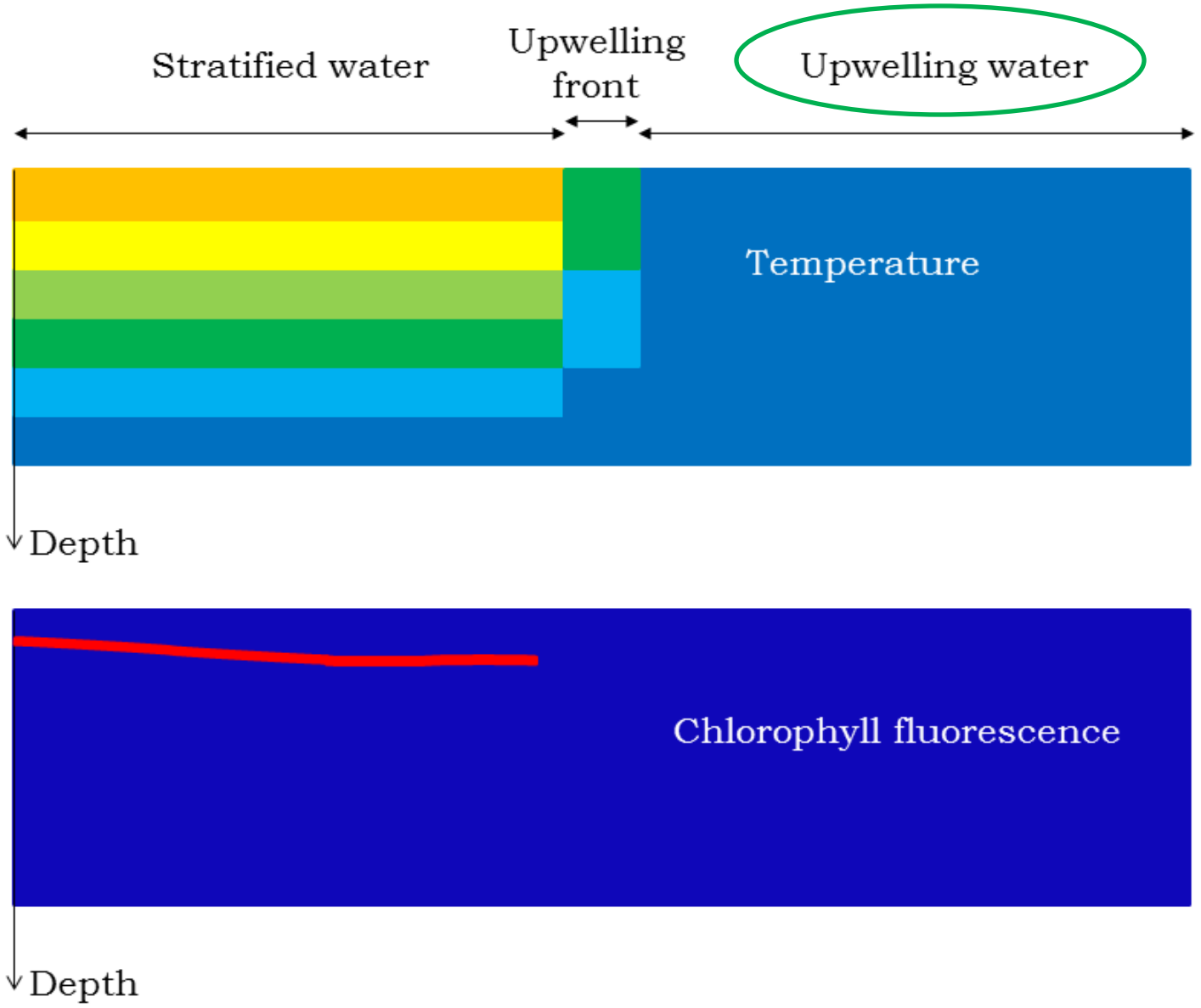
Distinguishing between Upwelling Water and Stratified Water

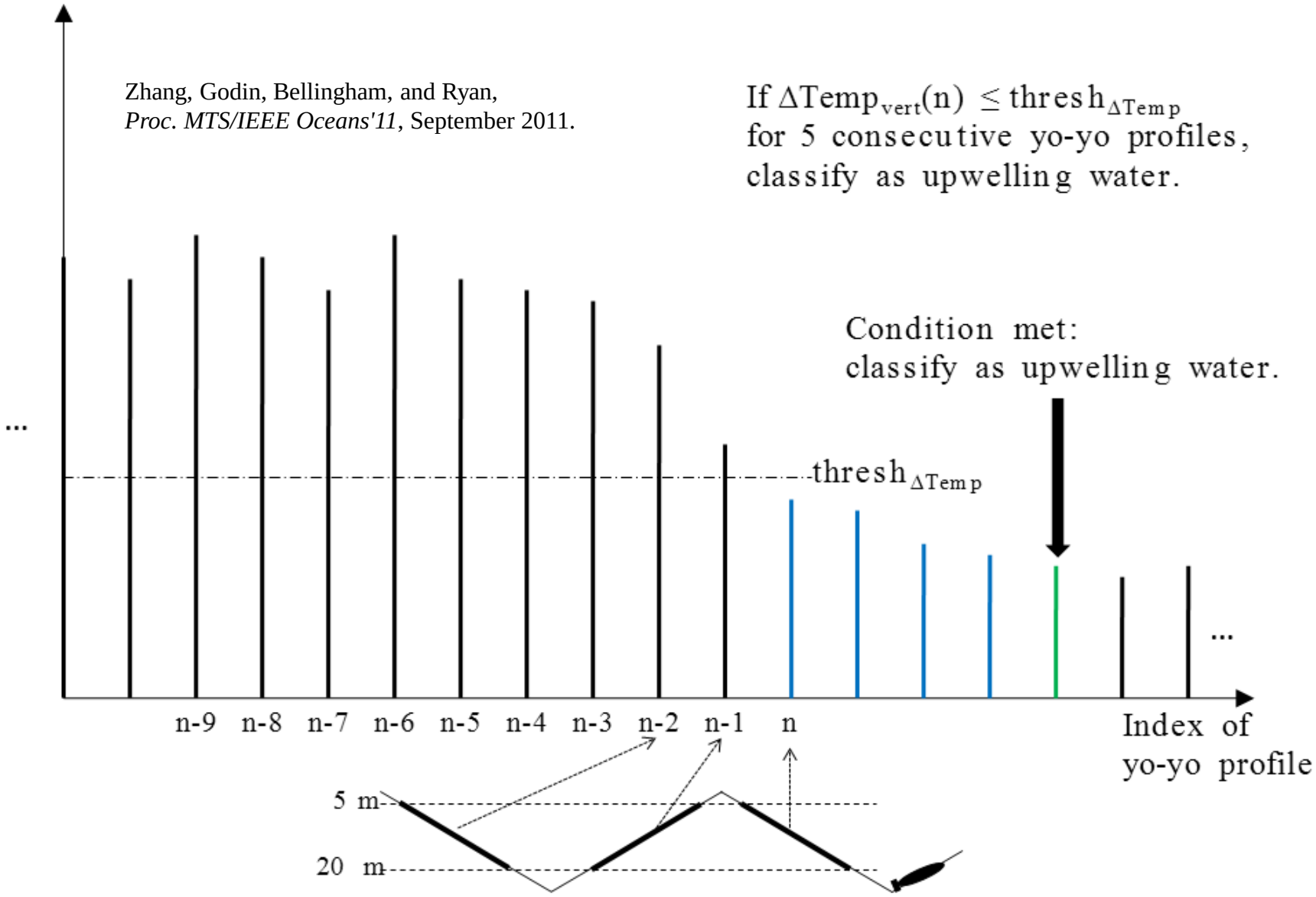


AUV Algorithm for Detecting an Upwelling Water Column

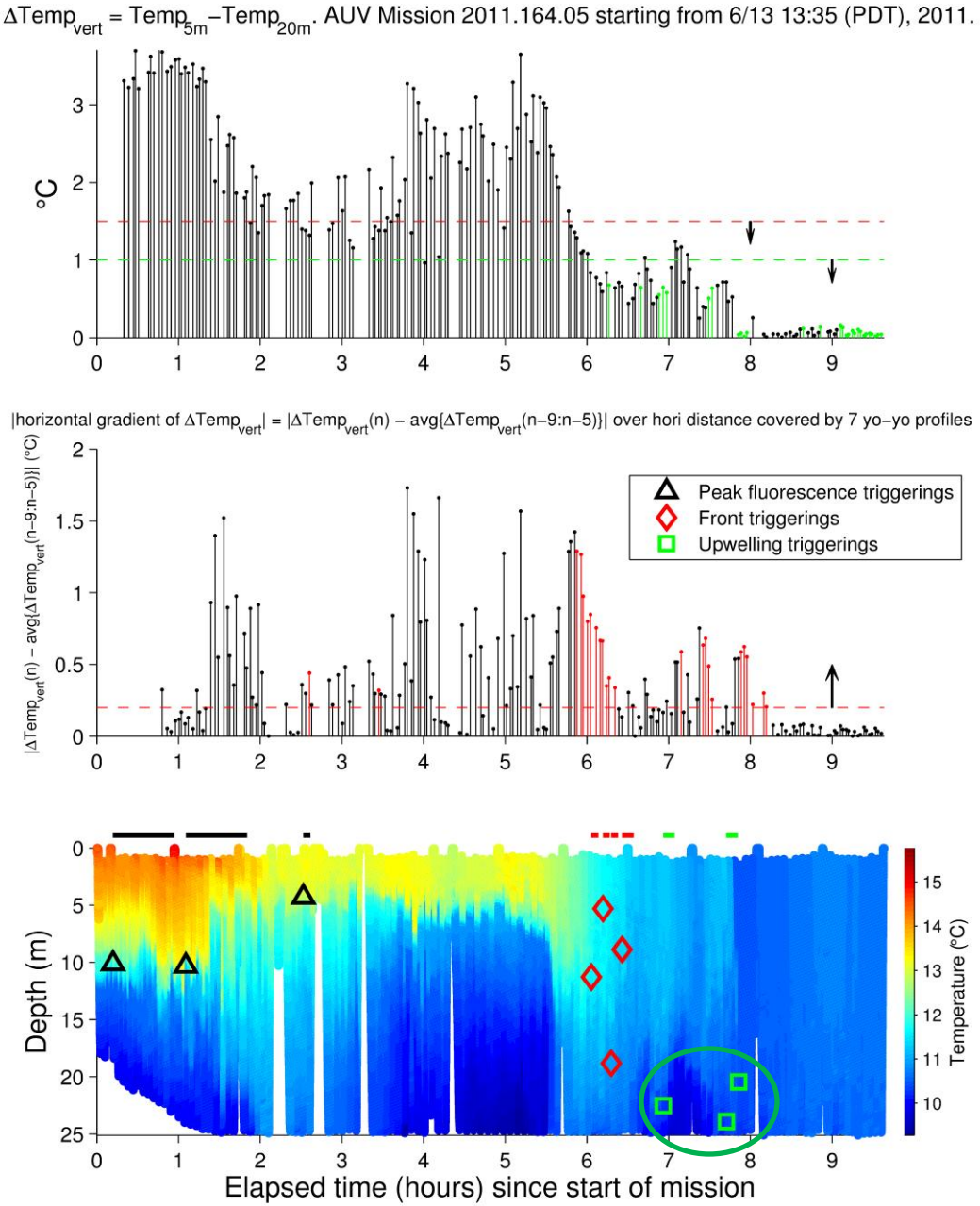
$\Delta Temp_{vert} = Temp_{5m} - Temp_{20m}$ on each yo-yo profile

Zhang, Godin, Bellingham, and Ryan,
Proc. MTS/IEEE Oceans'11, September 2011.

If $\Delta Temp_{vert}(n) \leq thresh_{\Delta Temp}$
for 5 consecutive yo-yo profiles,
classify as upwelling water.



Dorado AUV's Samplings in the Upwelling Water Column in the June 2011 Mission



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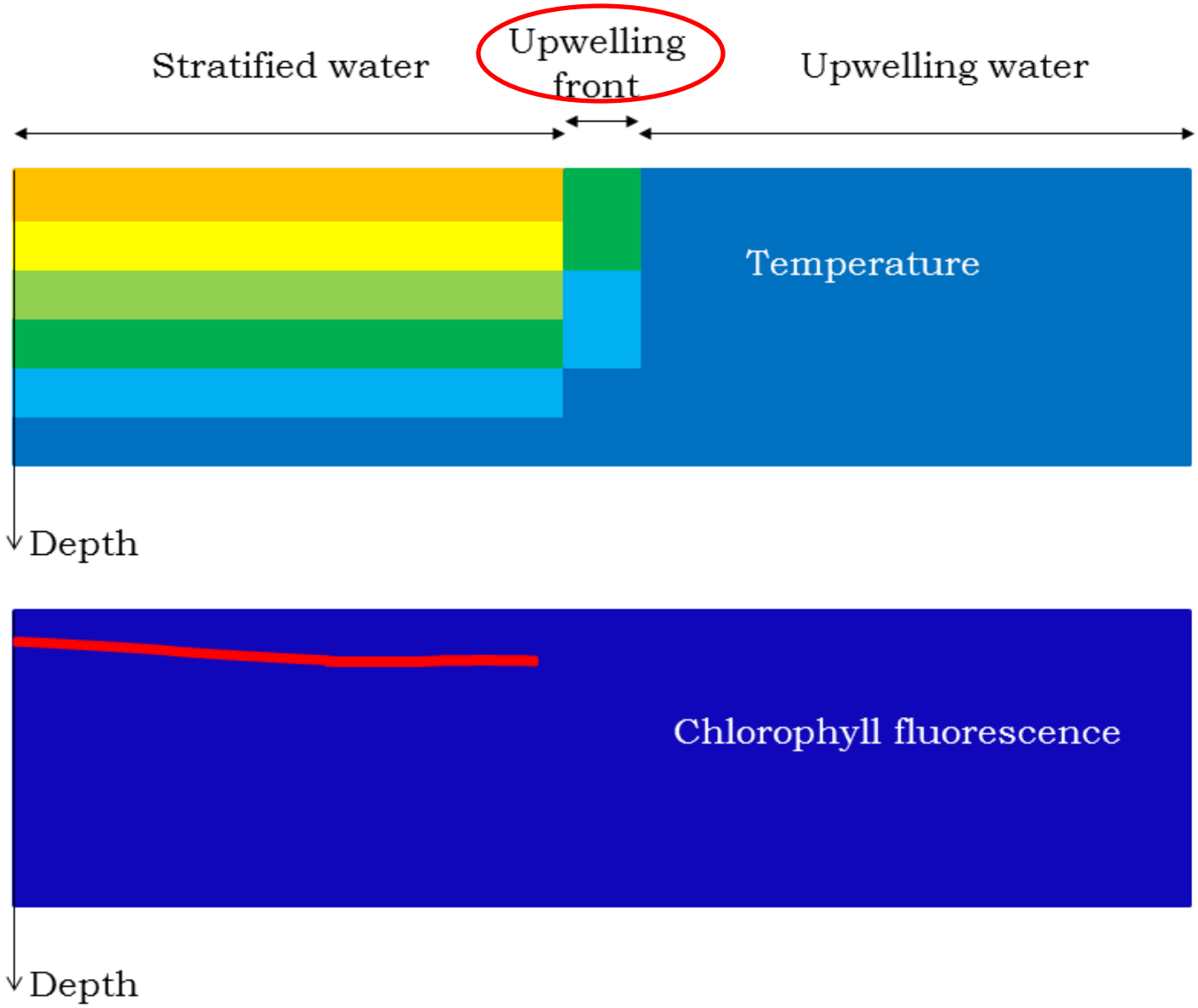
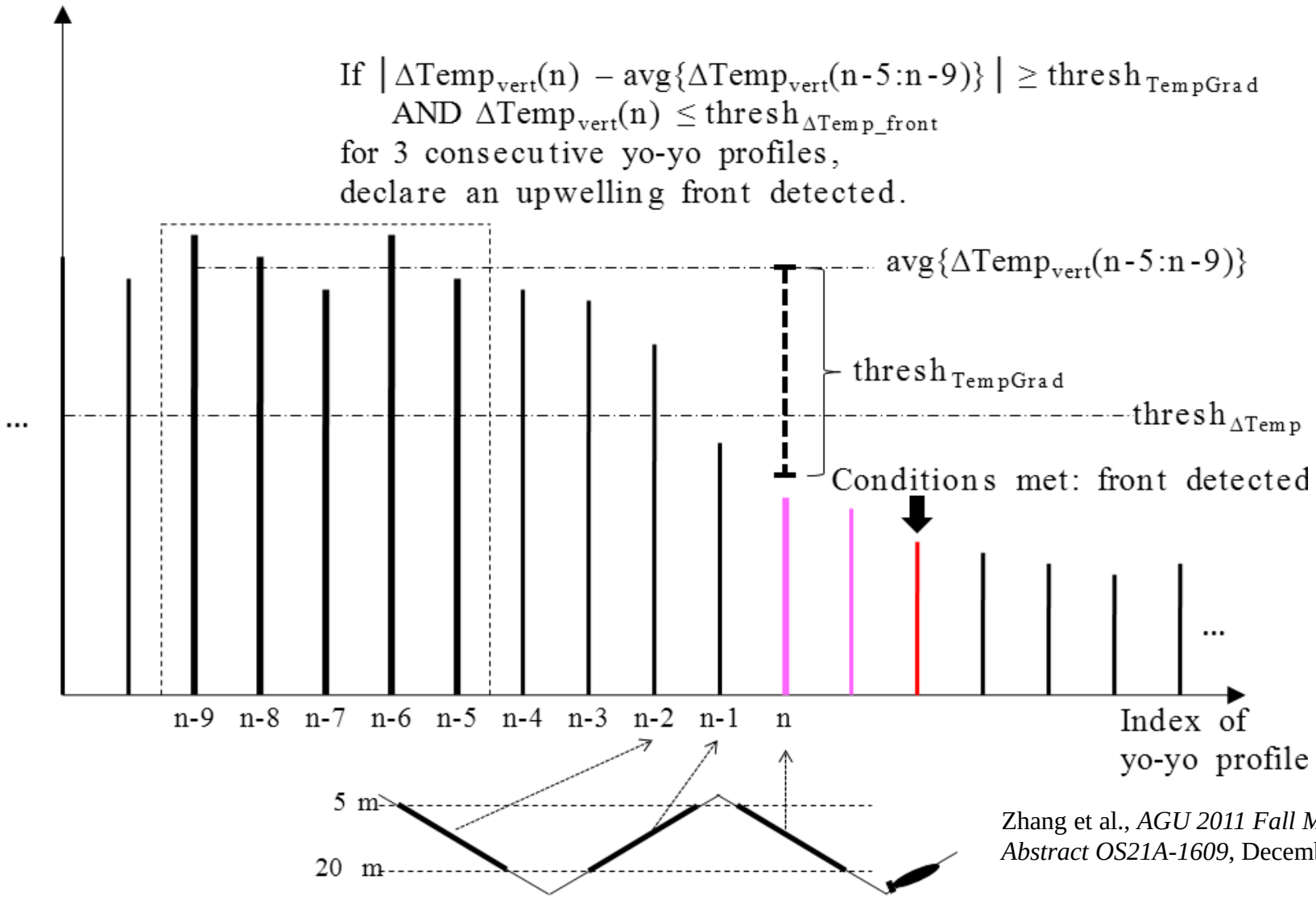
Detecting the Narrow Front between Stratified Water and Upwelling Water



AUV Algorithm for Detecting the Upwelling Front

$\Delta Temp_{vert} = Temp_{5m} - Temp_{20m}$ on each yo-yo profile

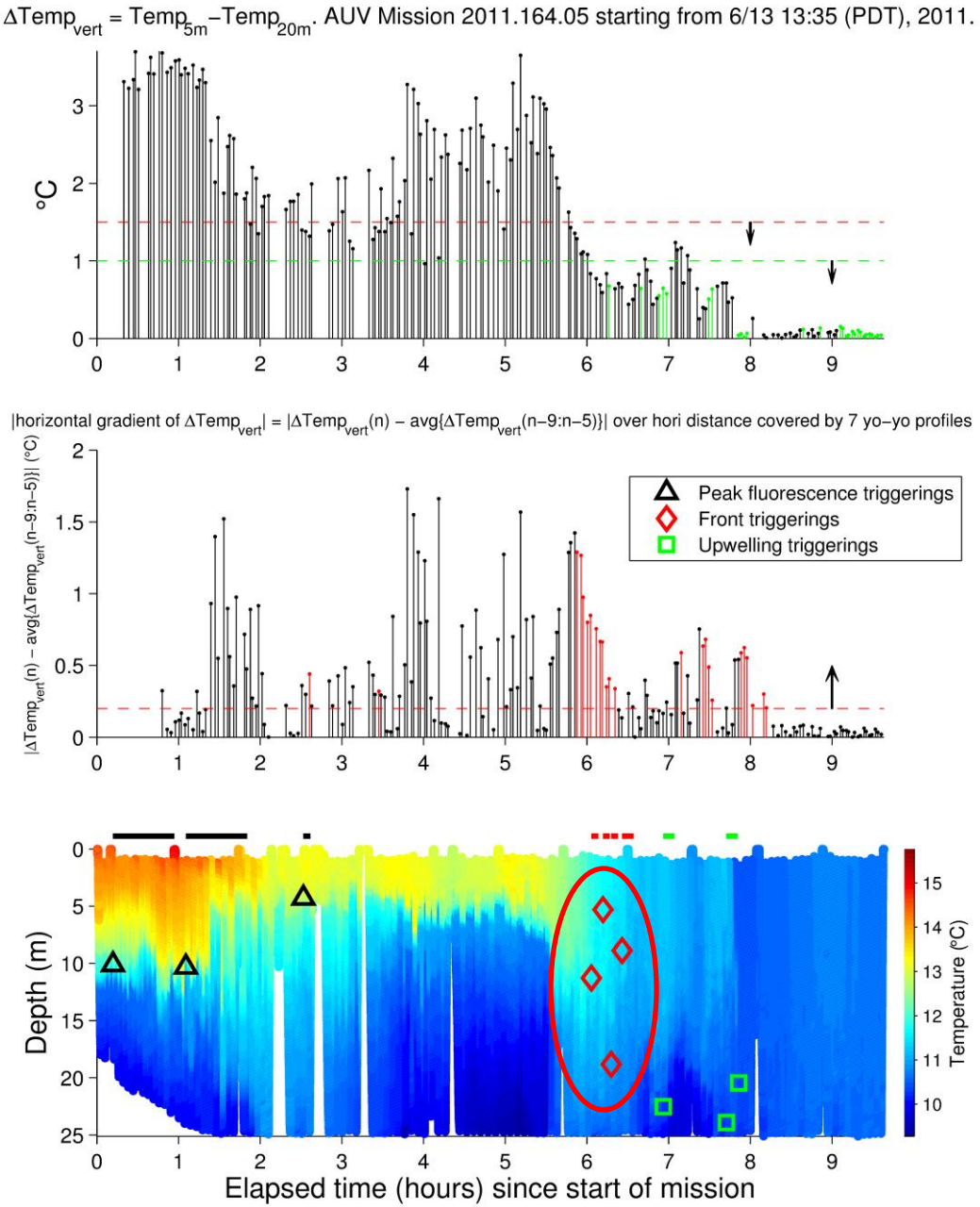
If $|\Delta Temp_{vert}(n) - avg\{\Delta Temp_{vert}(n-5:n-9)\}| \geq thresh_{TempGrad}$
AND $\Delta Temp_{vert}(n) \leq thresh_{\Delta Temp\_front}$
for 3 consecutive yo-yo profiles,
declare an upwelling front detected.



Zhang et al., *AGU 2011 Fall Meeting Abstract OS21A-1609*, December 2011.

Zhang et al., *Limnology and Oceanography: Methods*, Vol. 10, pp. 934-951, 2012.

Dorado AUV's Samplings in the Narrow Upwelling Front in the June 2011 Mission



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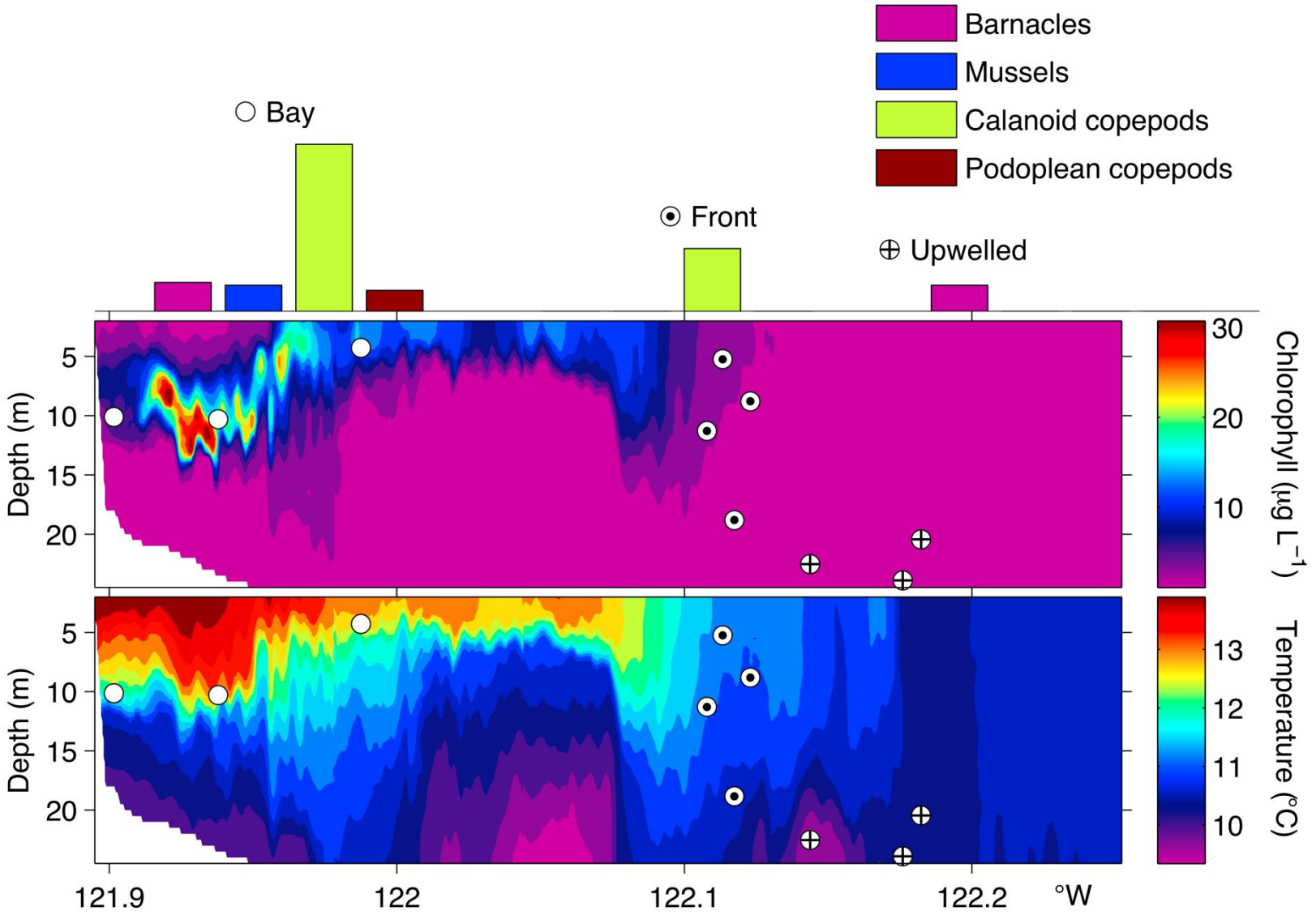
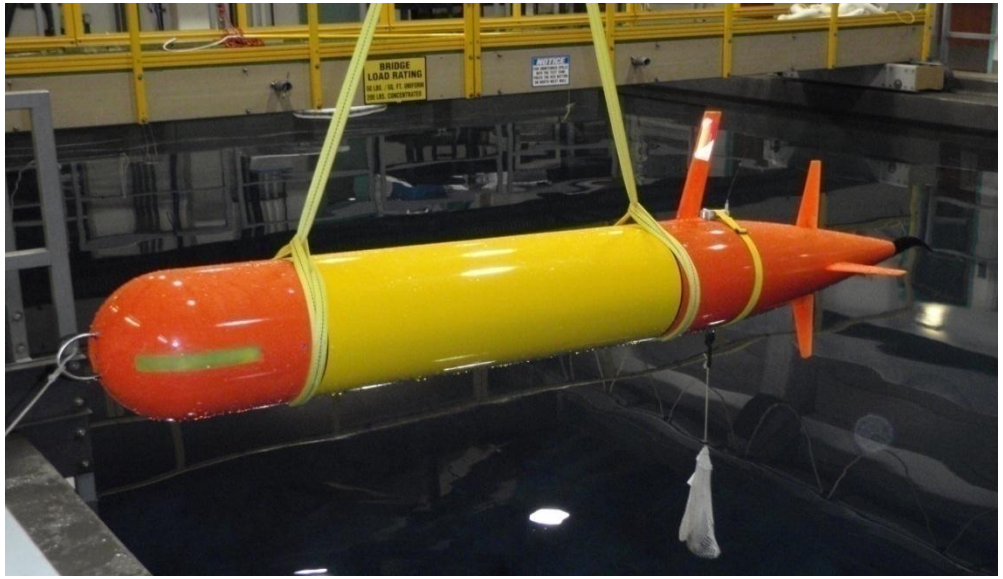
Biological Analysis Results of the 10 Gulpers' Water Samples



Tethys Long-Range AUV



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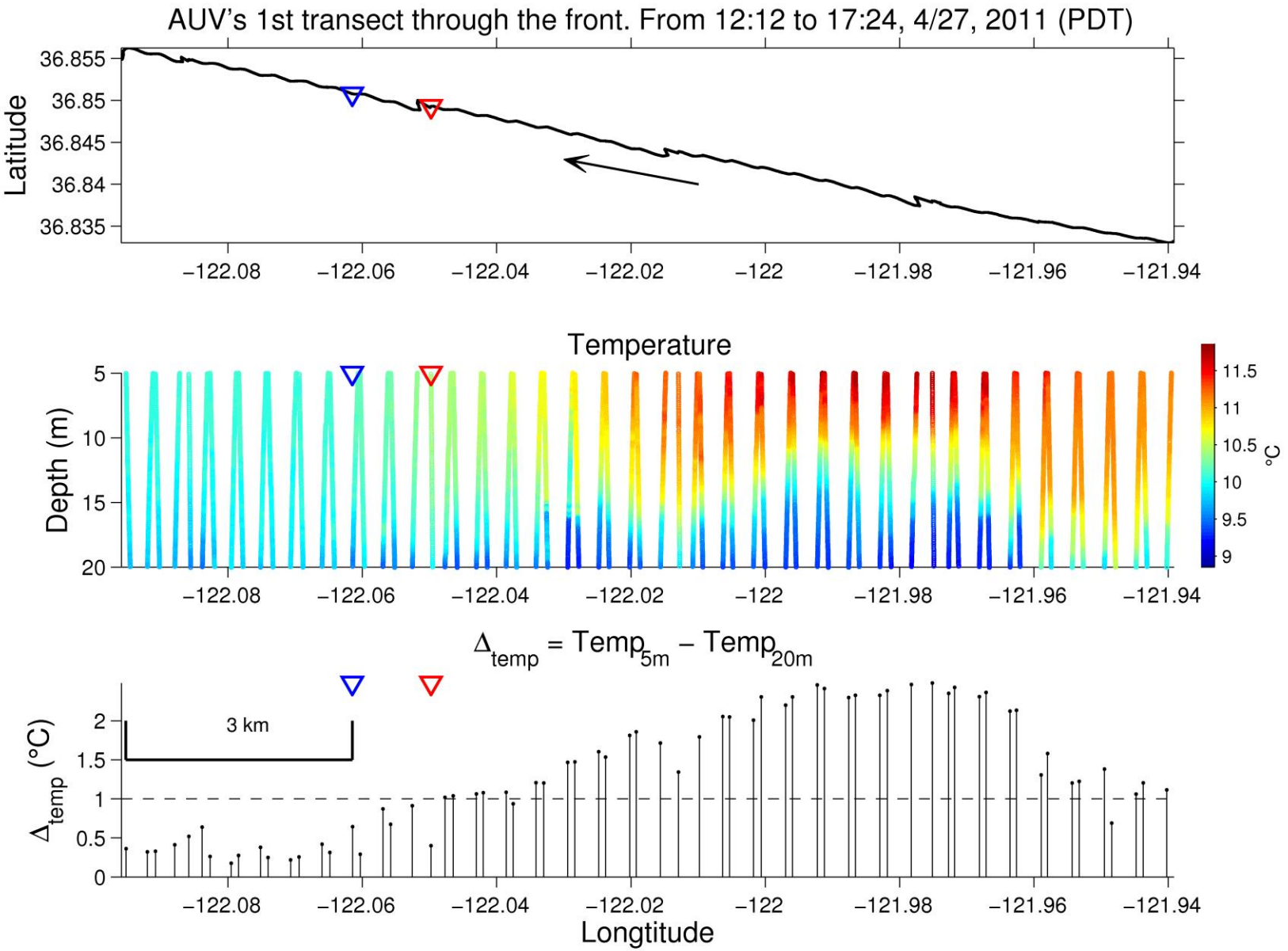
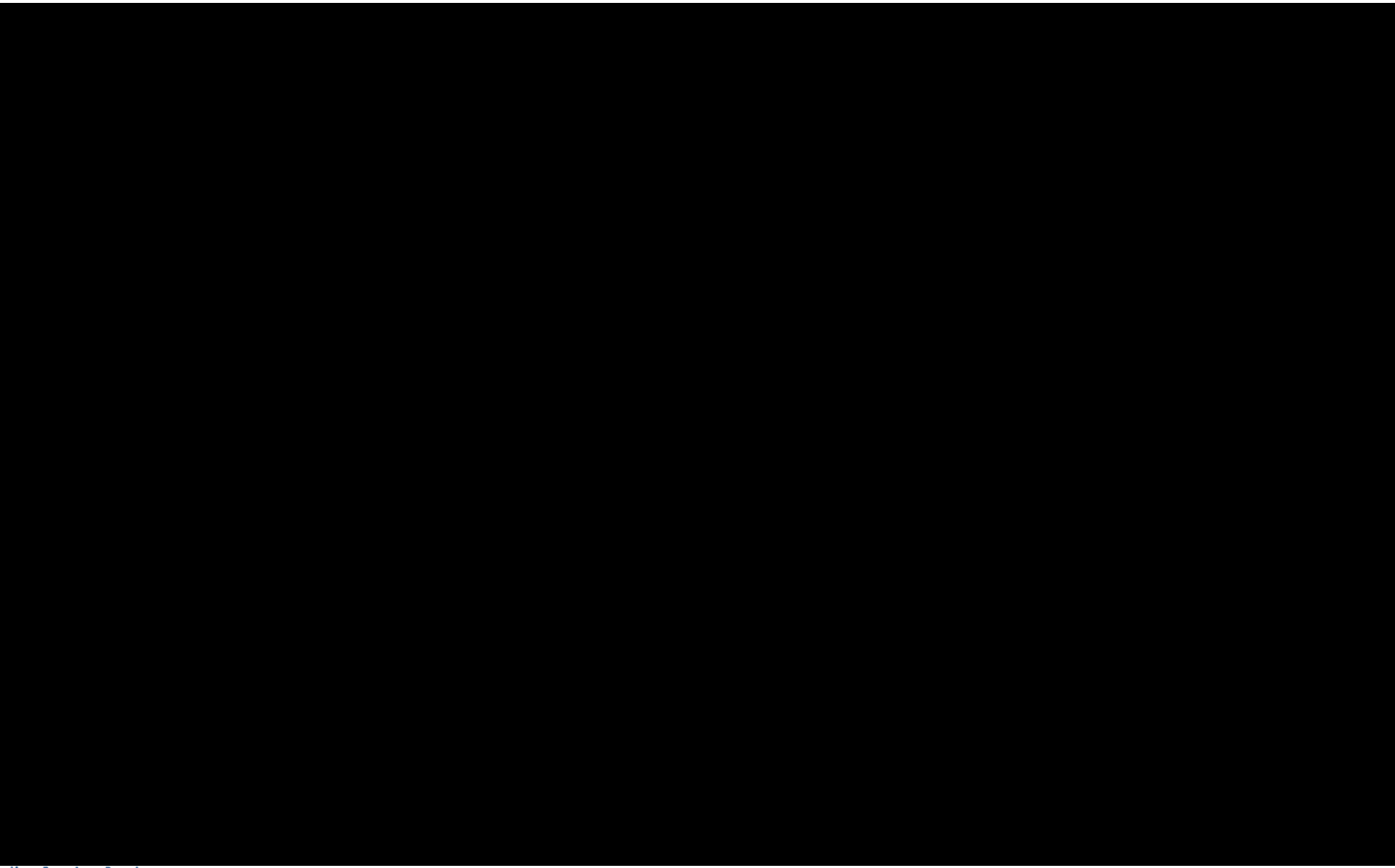
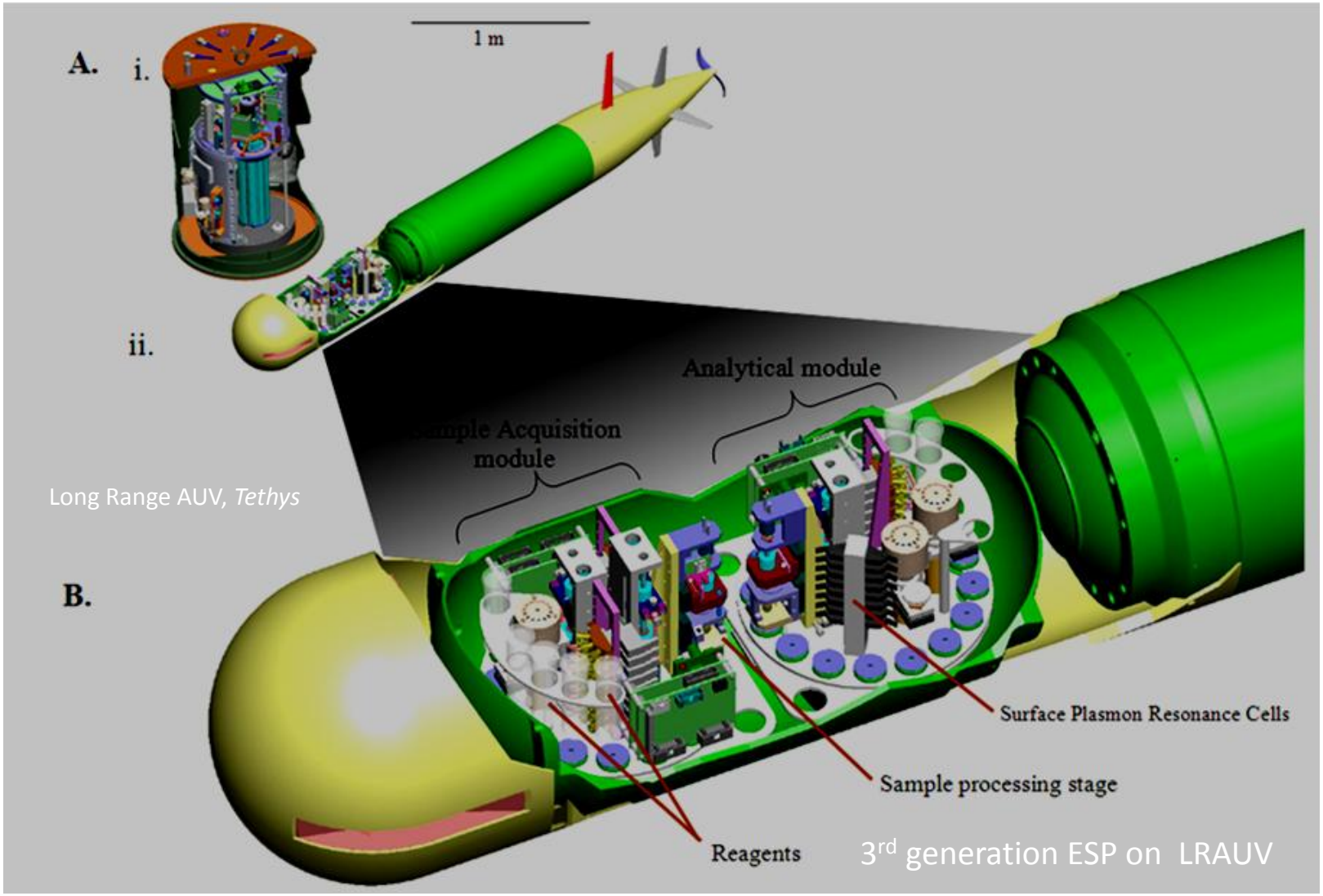
Tethys AUV's Front-Tracking on One Transect in the April 2011 Mission





Robotic Microbiology Lab (ESP) on Tethys AUV



Scholin, Birch, Bellingham, and Hobson

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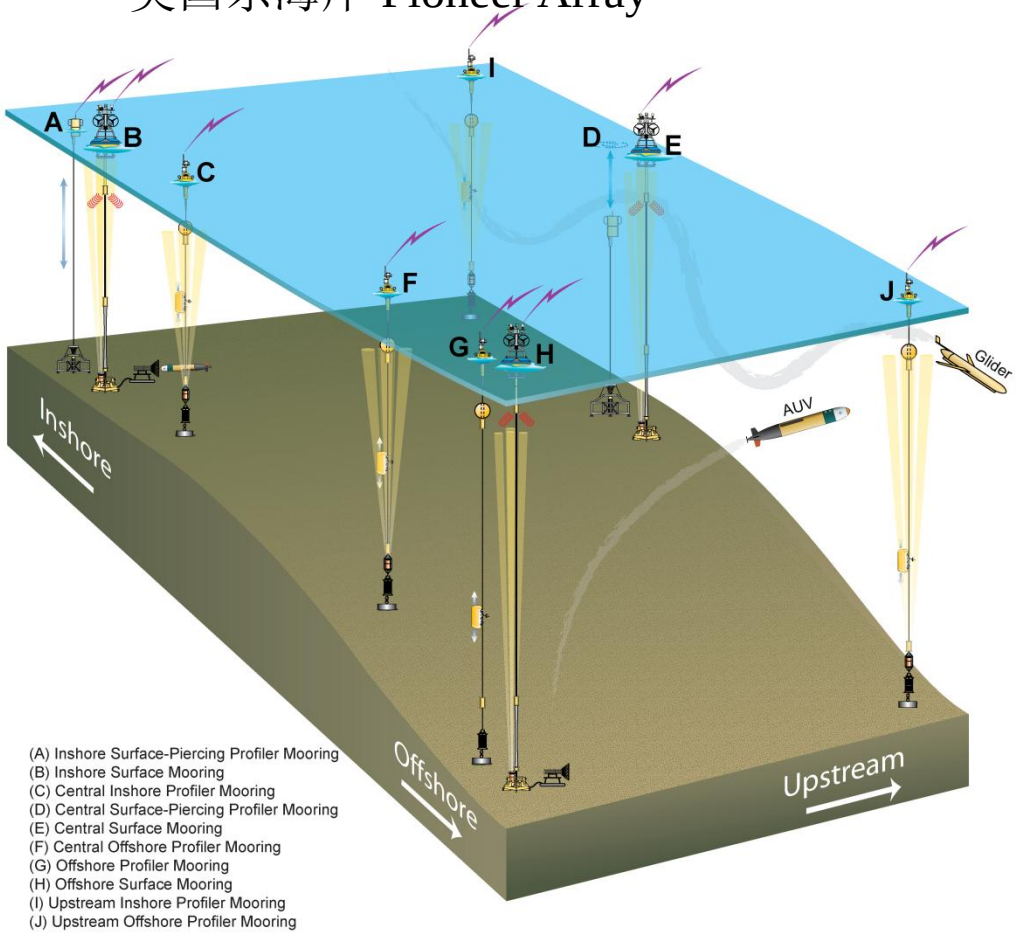
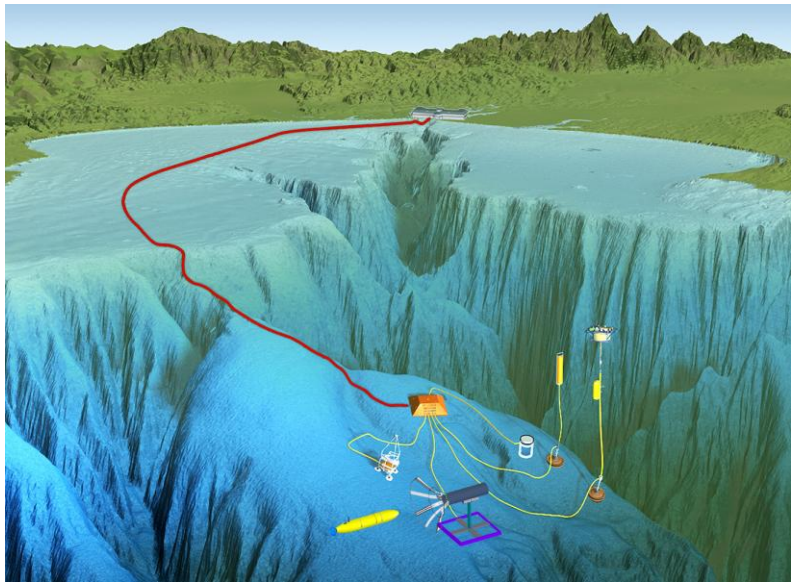
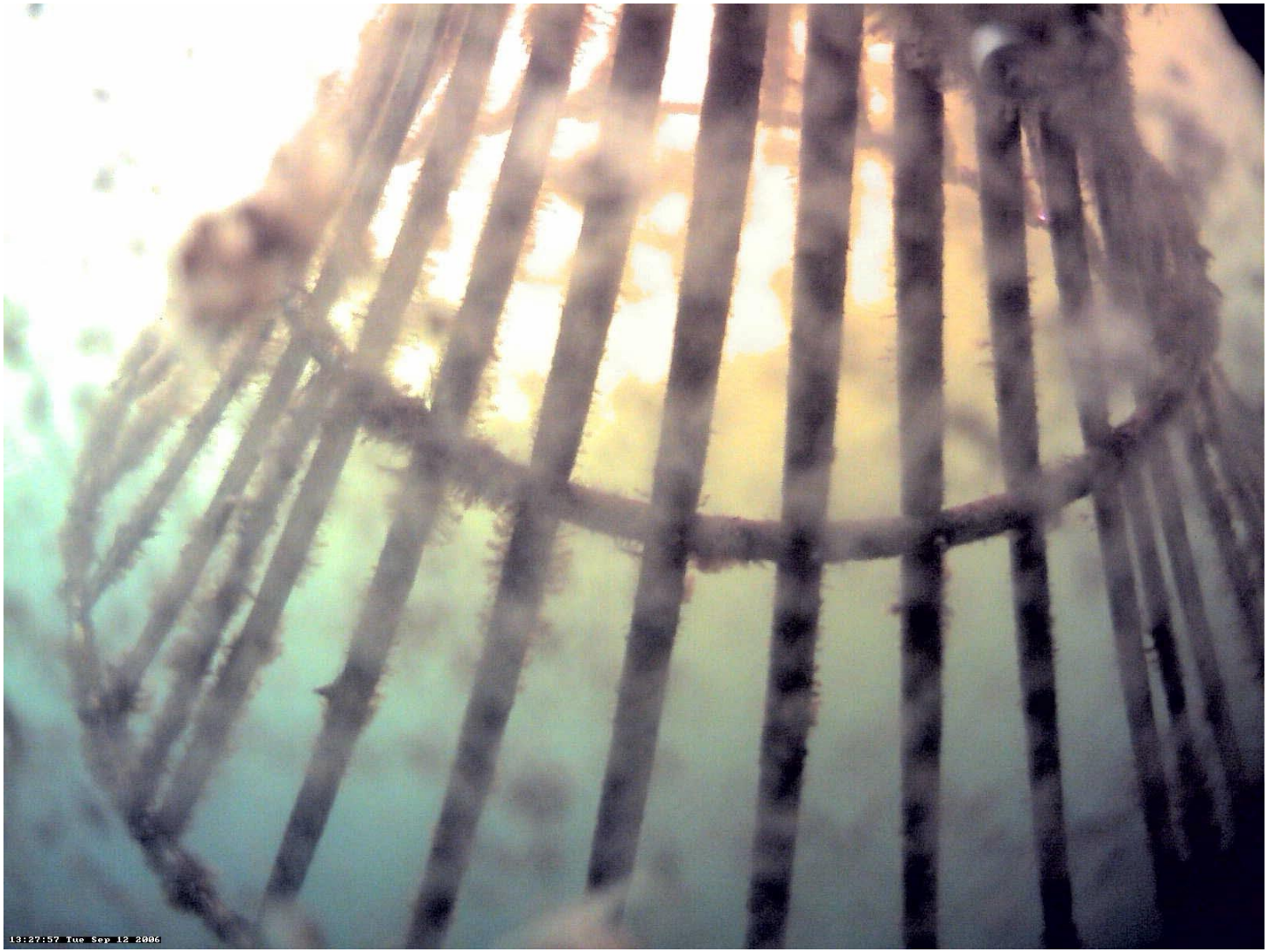


From *http://www.oceanobservatories.org/infrastructure/ooi-station-map/pioneer-array/*

MARS



AUV Docking



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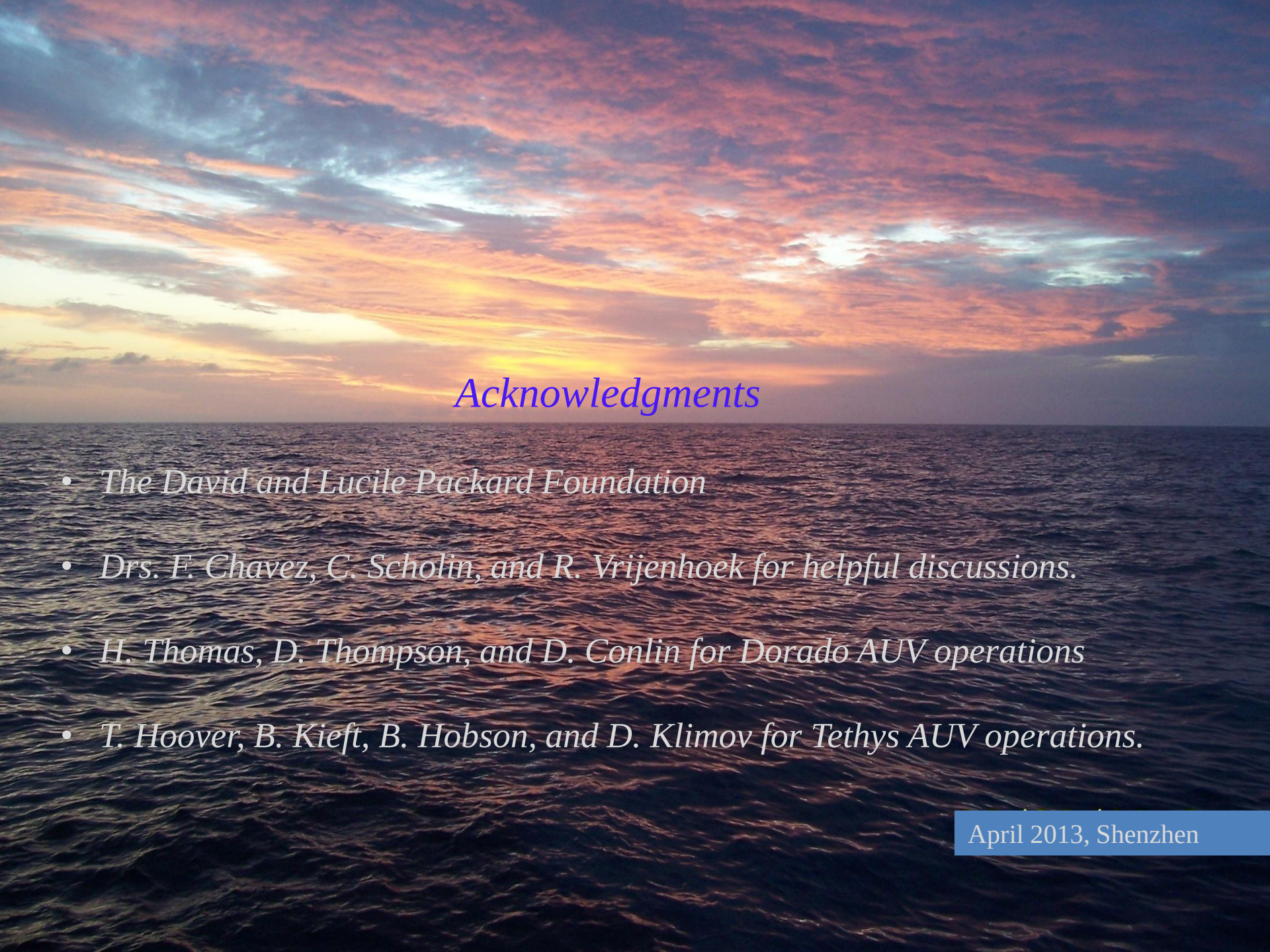

Acknowledgments

- *The David and Lucile Packard Foundation*
- *Drs. F. Chavez, C. Scholin, and R. Vrijenhoek for helpful discussions.*
- *H. Thomas, D. Thompson, and D. Conlin for Dorado AUV operations*
- *T. Hoover, B. Kieft, B. Hobson, and D. Klimov for Tethys AUV operations.*