CANON
June Experiment
Overview

Research focus

Pelagic ecosystem dynamics across frontal boundaries

Goals:

❖ Study contrasting plankton communities in different types of water and in the frontal zone(s) between them. We began to pursue this goal with Dorado / TREX in 2009. Lessons learned from that effort included: *Experiment design should maximize the probability of encountering strong signal (contrast, gradients) – of value to science and autonomy algorithm development.*

❖ Apply existing and emergent capabilities from the growing "AUV toolbox" to effectively survey and sample dynamic boundary zones. These capabilities included autonomy algorithms tested on Tethys and Dorado individually, coordinated multi-AUV operations successfully applied in previous CANON experiments, and a recently developed algorithm for allocation of Gulpers among multiple water types detected in situ.

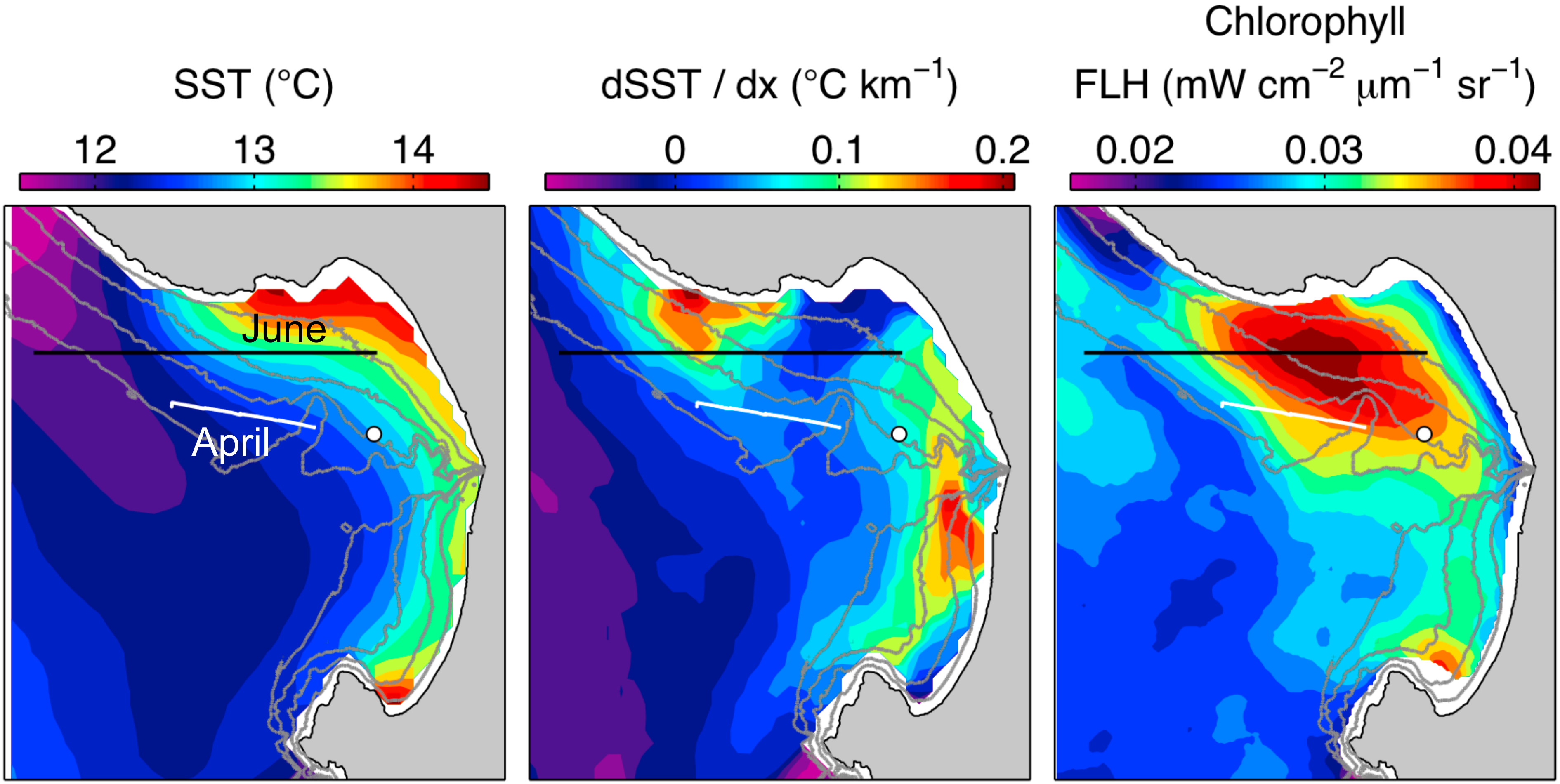
Some experiment design considerations

- ❖ We aimed to coordinate AUV and boat operations more effectively than we did in April, with the intention that more "dense" observations will allow us to detect and understand patterns and processes with greater clarity.

- ❖ We had no ESP in June as we did in April, so we were not focused on understanding what was flowing into or away from a mooring location.

- ❖ We needed to weigh and balance goals, e.g.
  - ❖ "freeing" Tethys to exercise a valuable capability – patch tracking – versus maintaining coordinated observations along a common slice of ocean (including AUV-AUV interaction)
  - ❖ testing of novel adaptive Gulper sampling versus "predictable" geographically prescribed sample acquisition
  - ❖ spatial coverage versus temporal resolution (AUVs)

Choosing a location for effective coordination of assets

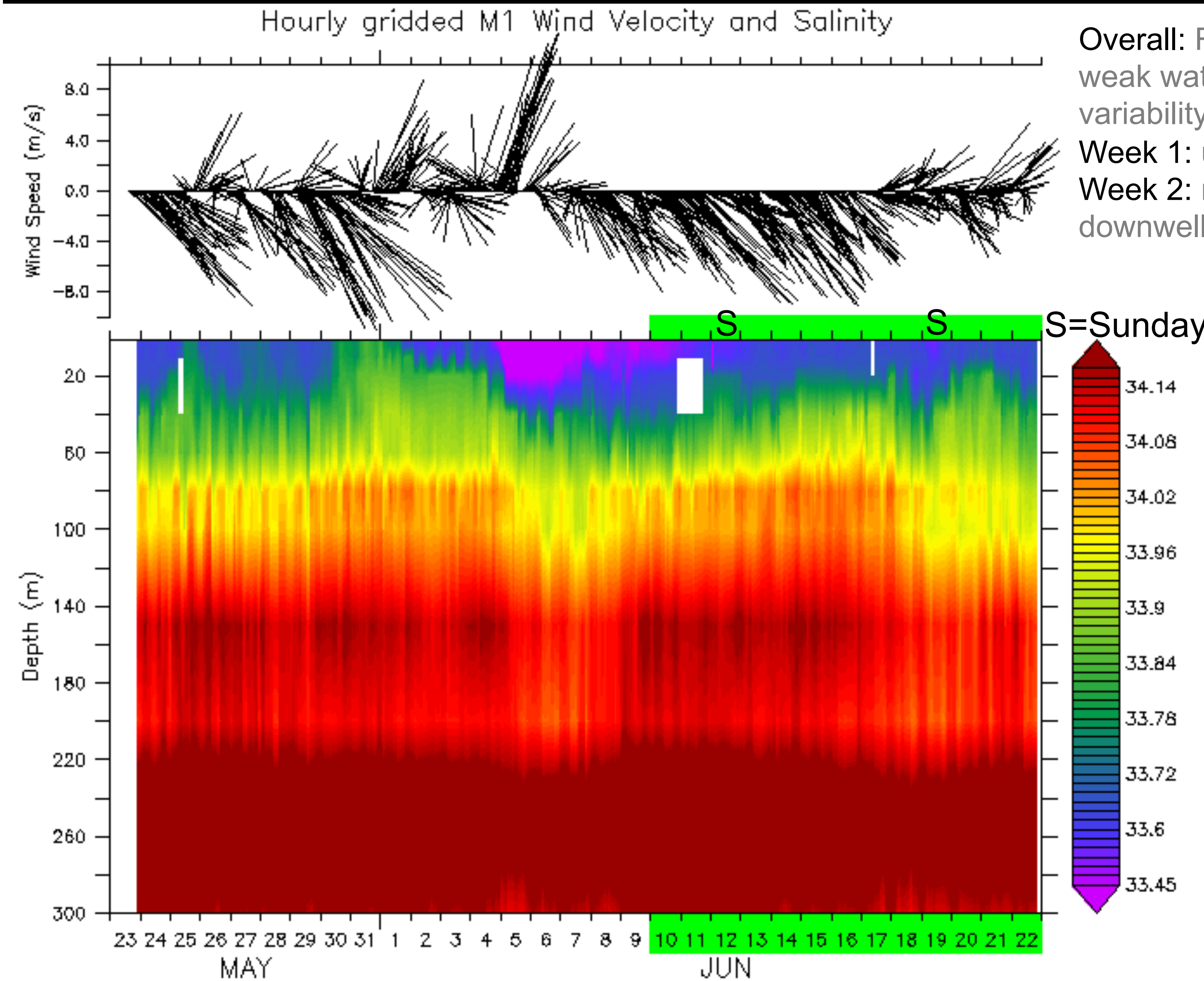


Far northern bay:

✧ Relatively high probability of encountering strong contrast in water types and thus strong frontal (boundary) gradients

✧ Potential for a meaningful and logistically favorable patch tracking

Winds and water column at M1

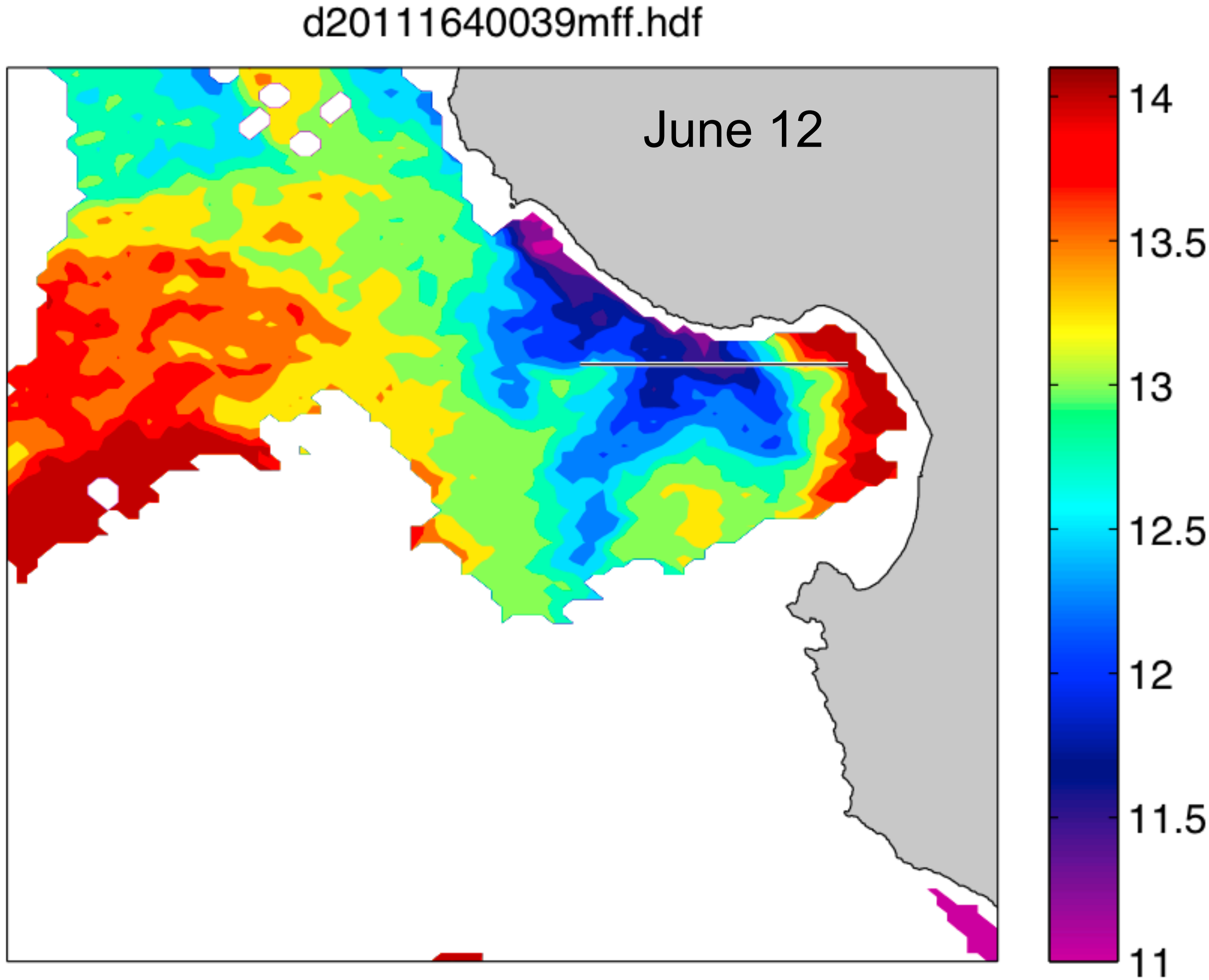


Overall: Relatively weak water-column variability

Week 1: upwelling

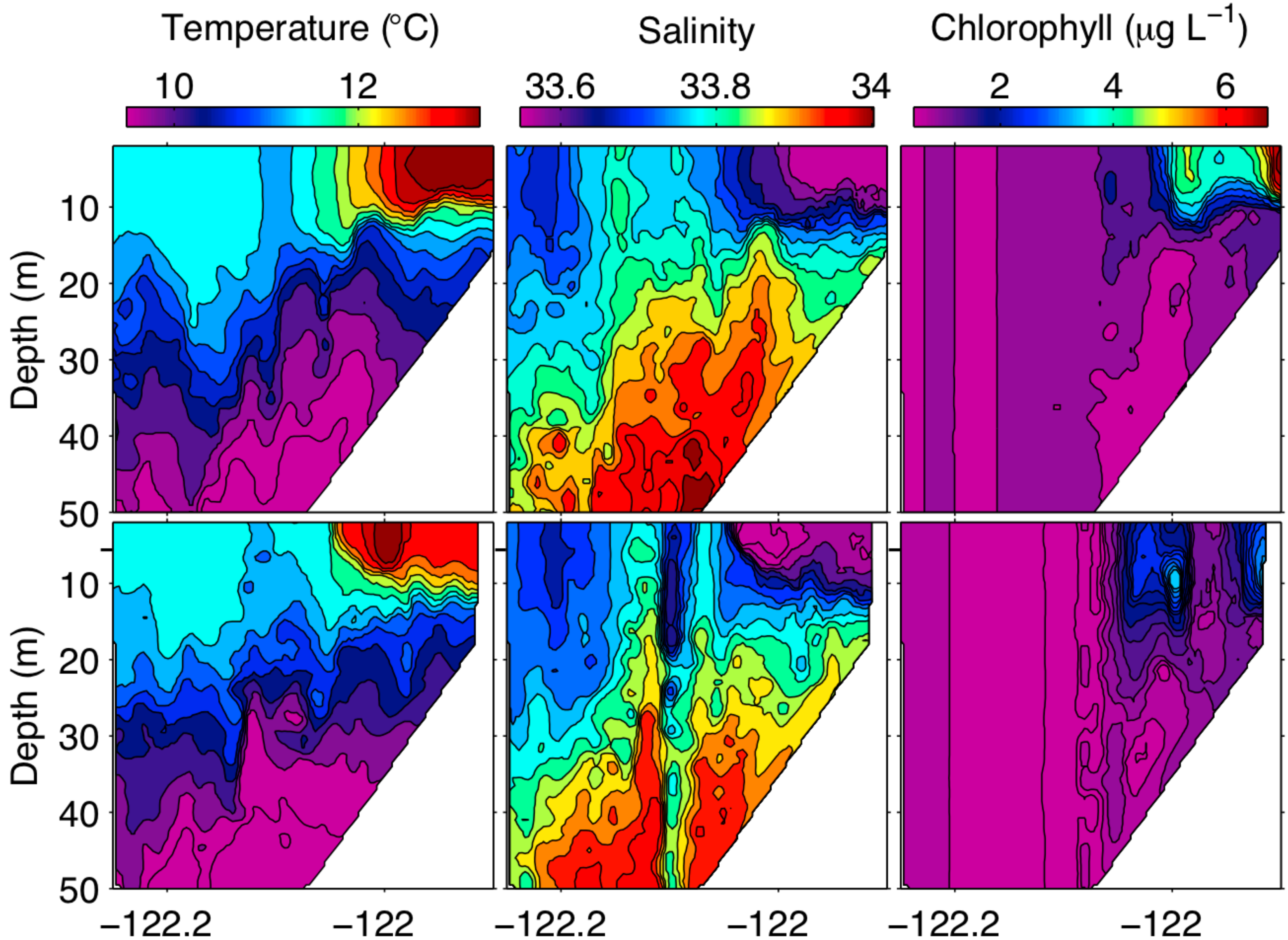
Week 2: relaxation / downwelling

Early conditions: strong contrast along 36.9N



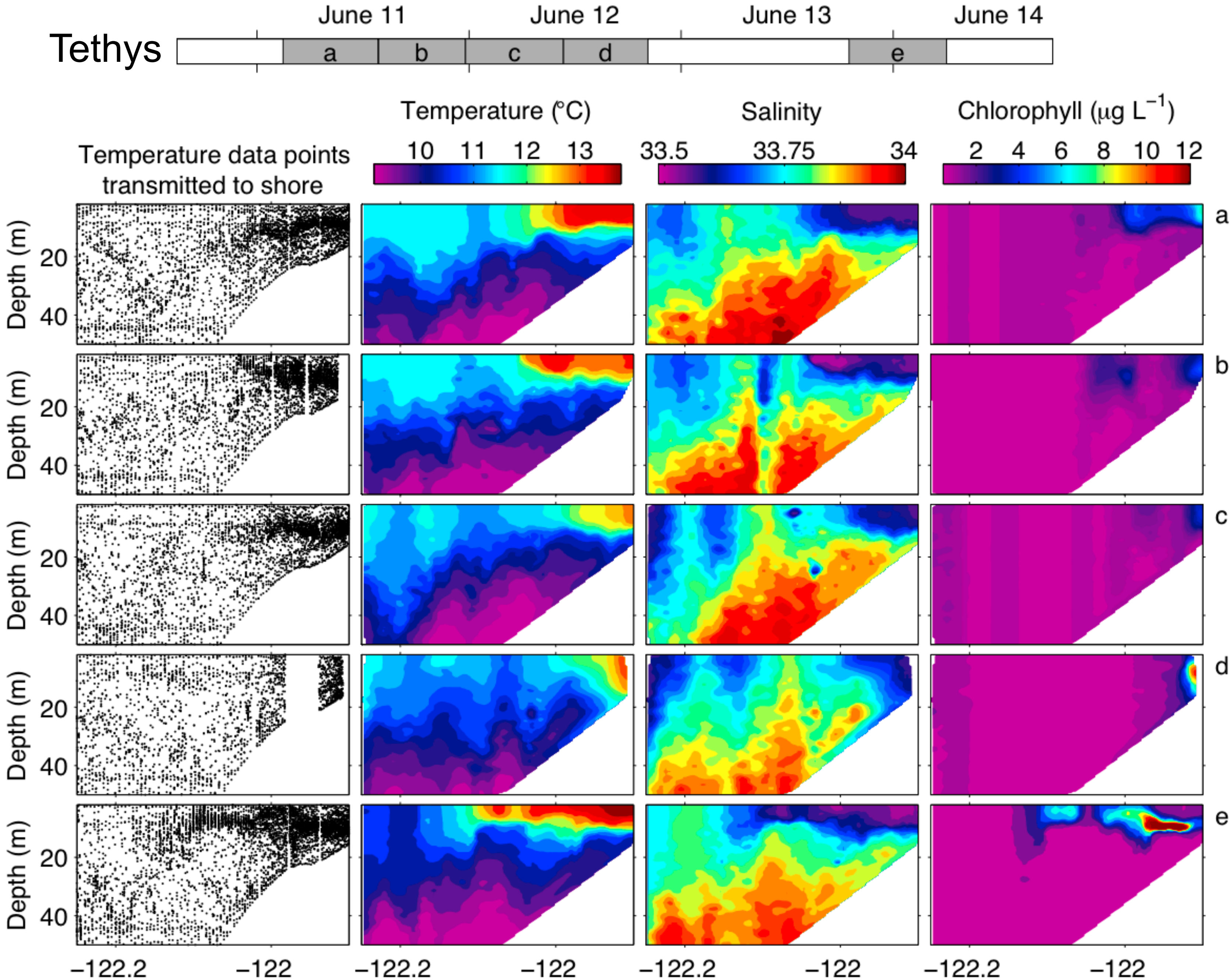
AVHRR data courtesy of Kudela Lab (UCSC) and NOAA CoastWatch

Early conditions: clearly defined water types and front

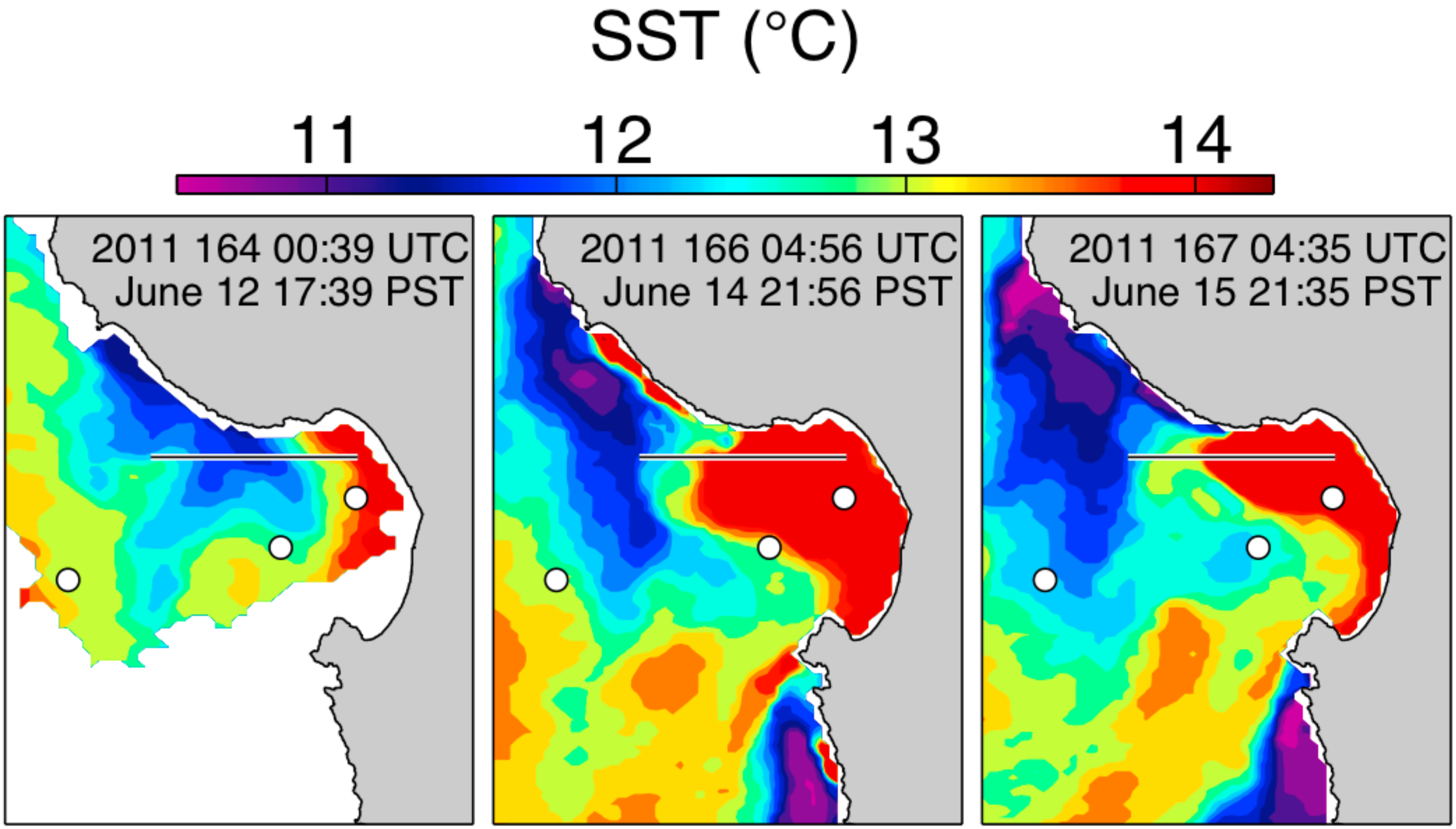


Tethys, June 10 - 11

Week 1: westward expansion of the upwelling shadow



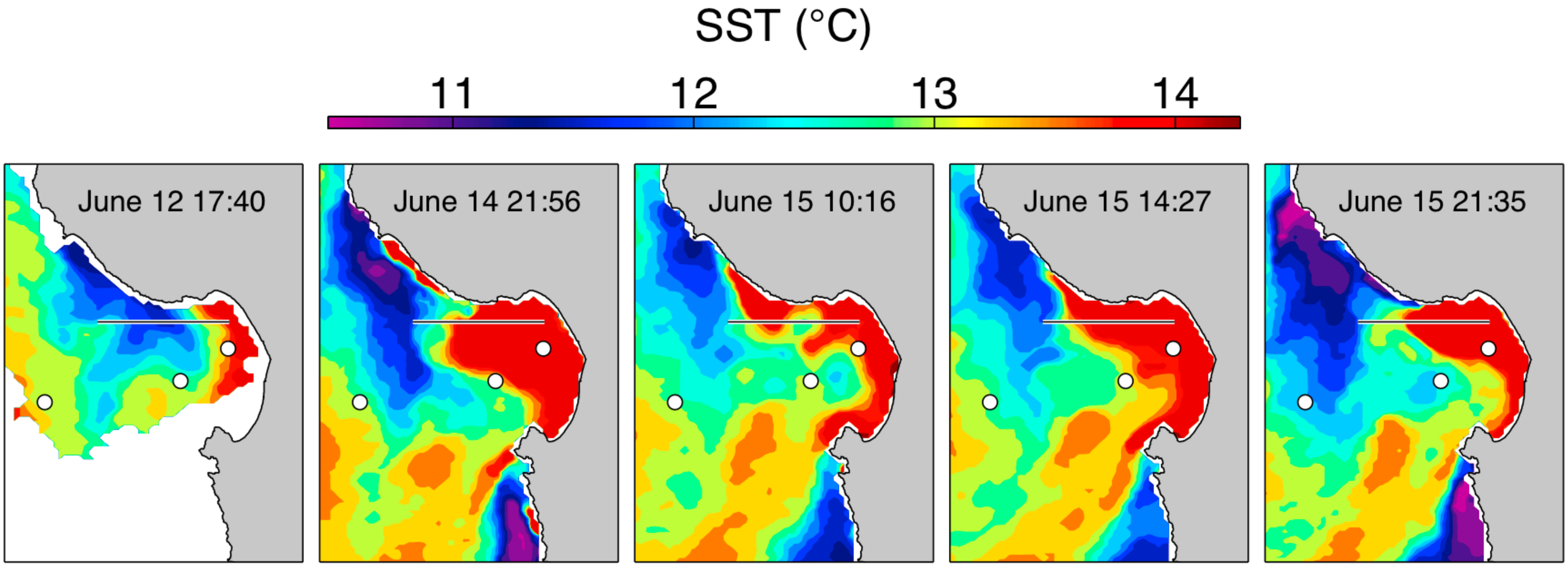
Week 1: westward expansion of the upwelling shadow



Expansion of the upwelling shadow:

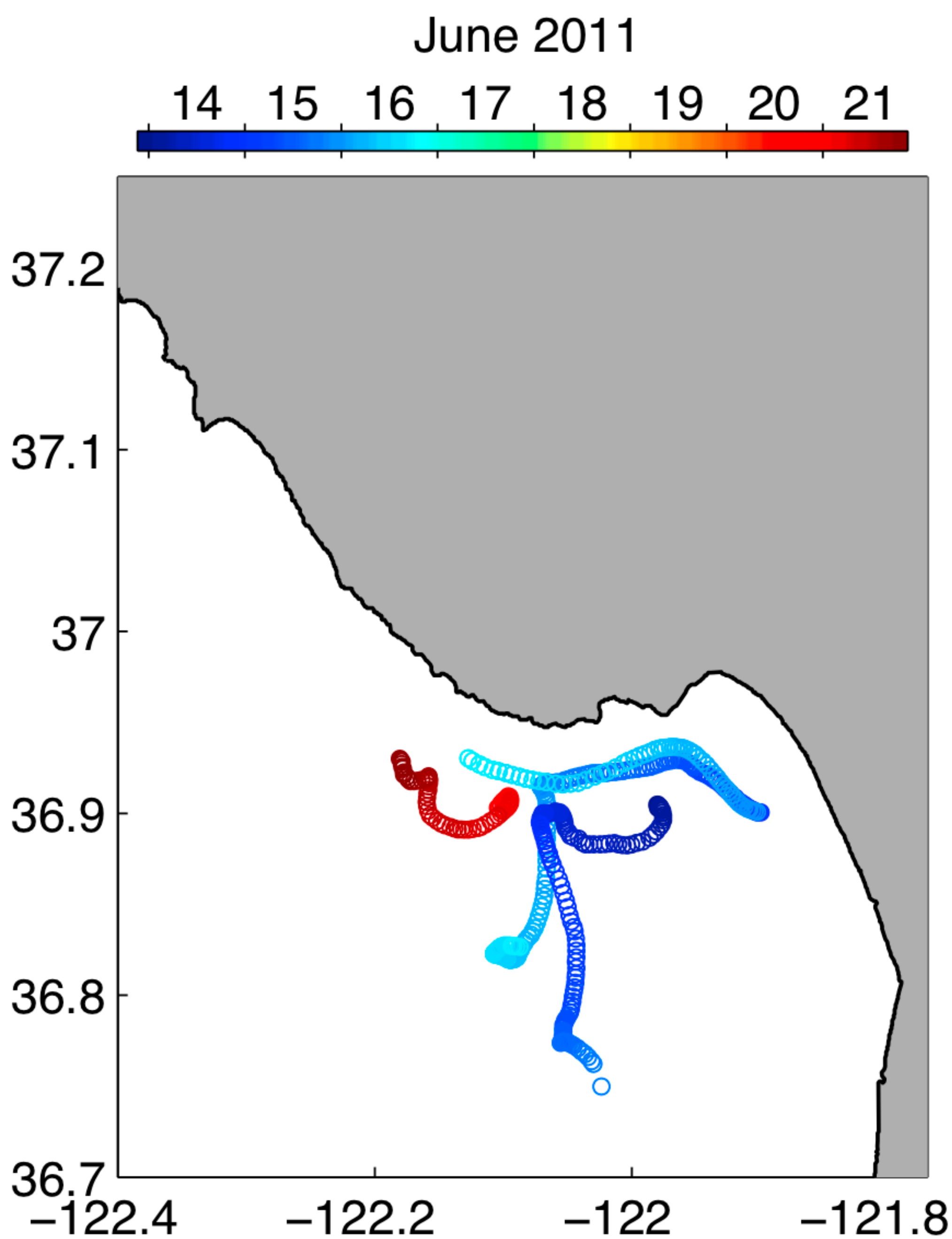
- was associated with response to steady upwelling winds
- moved the key front nearly "out of range".

“Amoeboid” boundary deformation of the upwelling shadow

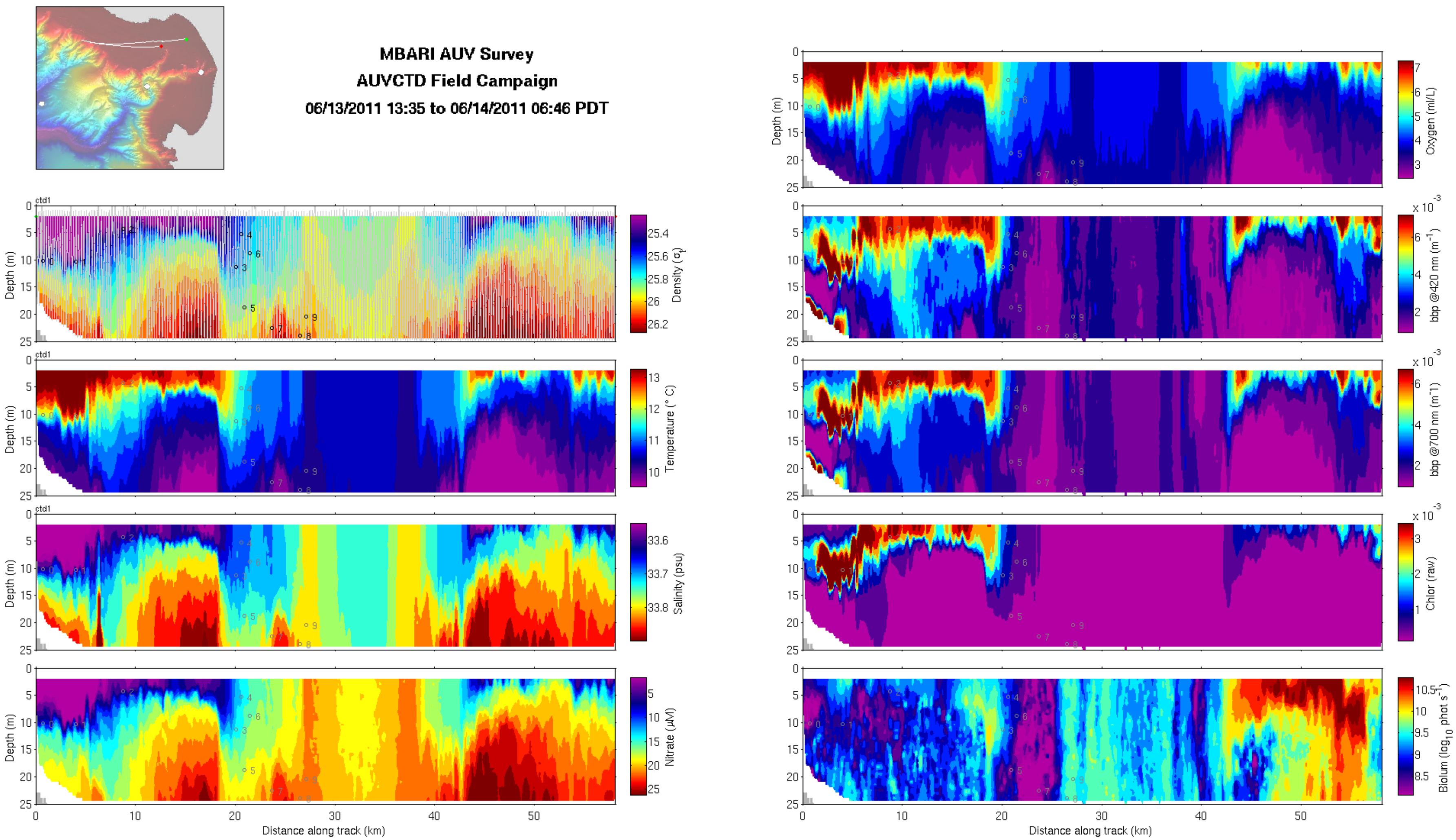


Observed at high temporal resolution with remote sensing, the upwelling shadow was seen to evolve with surprising high-frequency variation, including “amoeboid” extension and retraction.

Stella 103 & 105

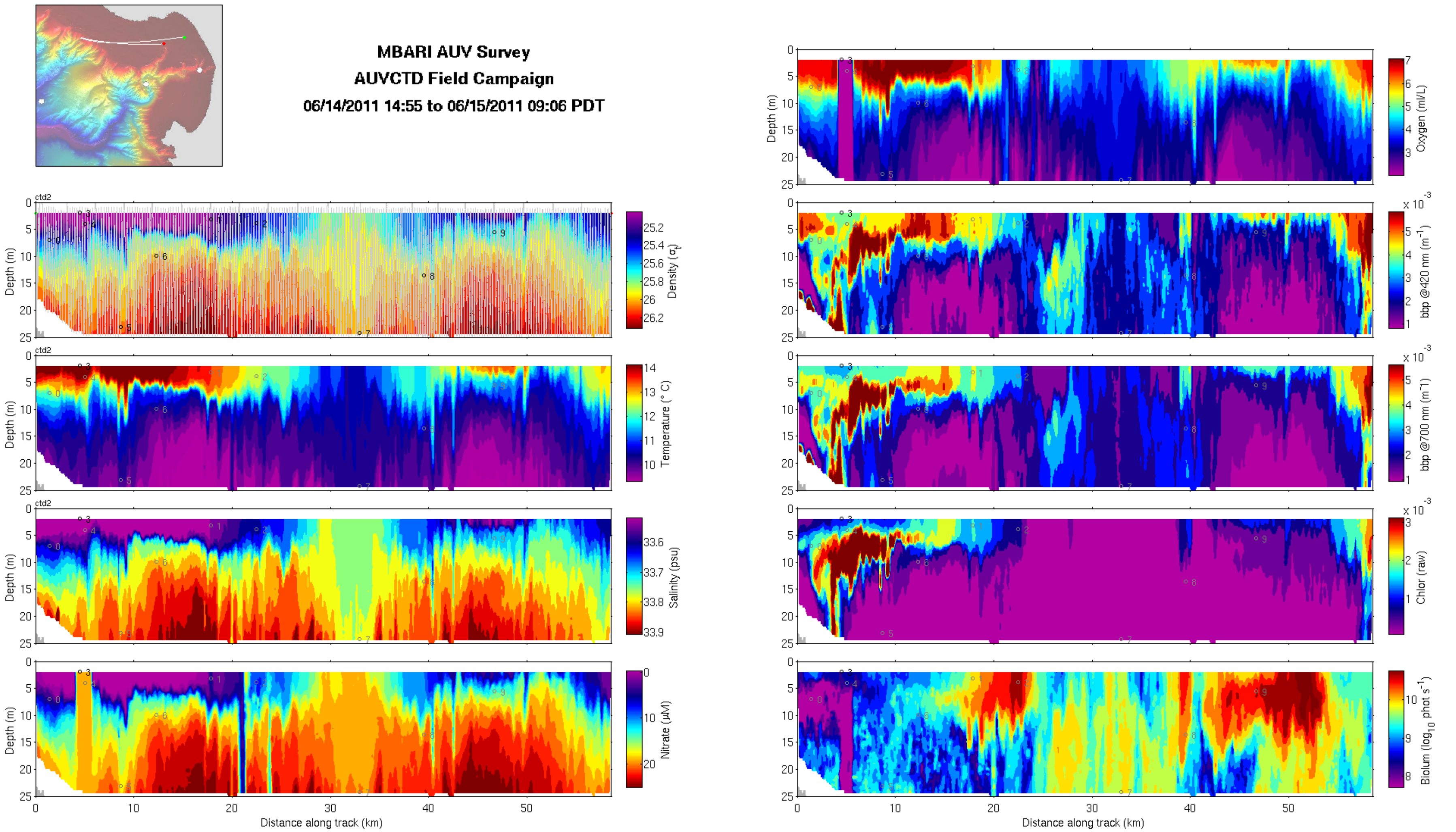


Dorado: taking over the line, June 13-14



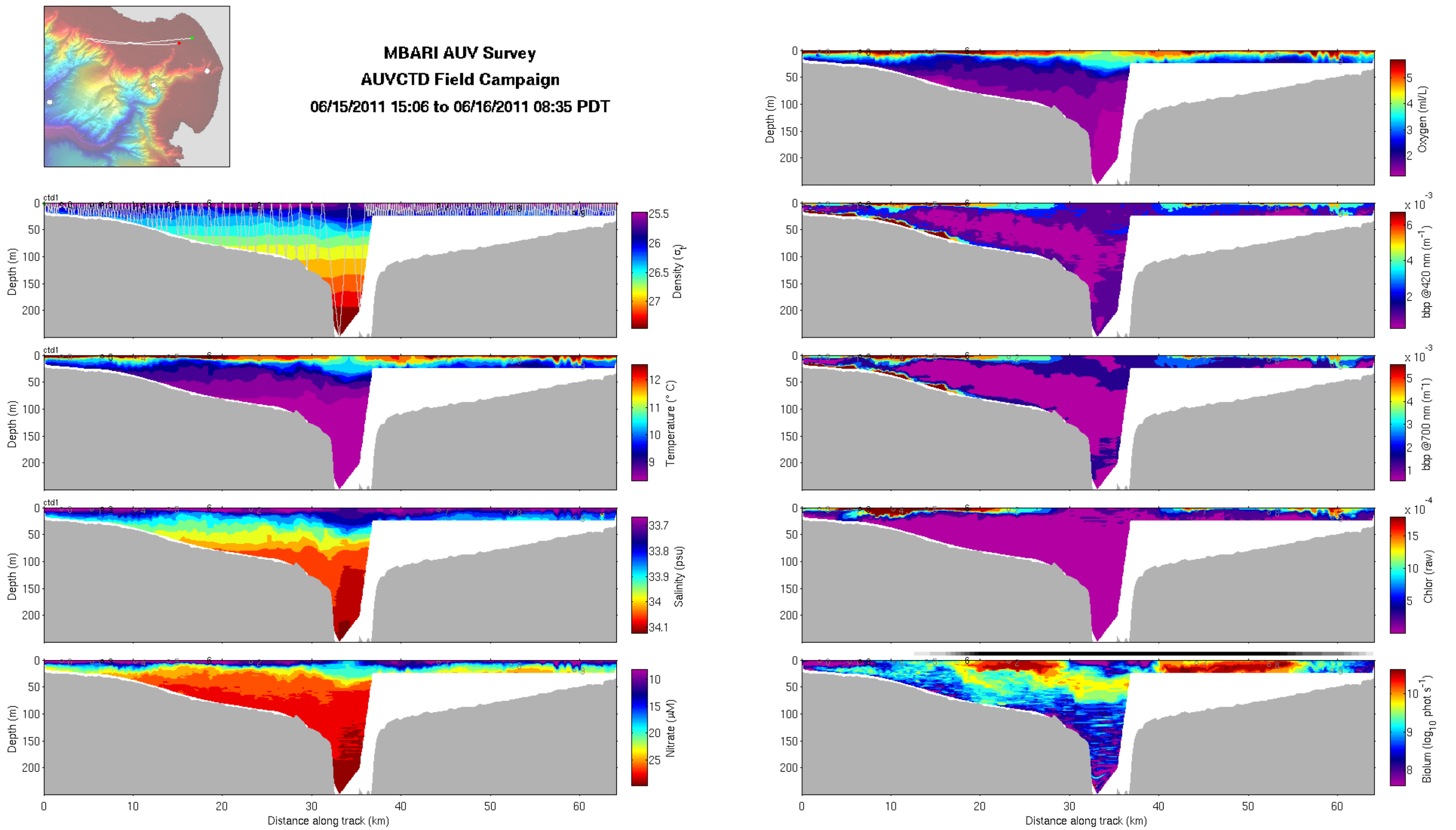
First autonomous detection and sampling of 3 specified categories: (1) biological patches in the upwelling shadow, (2) within the front between the upwelling shadow and the upwelling filament, and (3) within the upwelling filament (Y. Zhang).

Dorado: towing the line, June 14-15



Homogenization of the upwelling shadow water type, yet retention of depth variation in phytoplankton populations within the upwelling shadow (deeper inshore). Phytoplankton population “outcrop” moved offshore, to shadow / filament front.

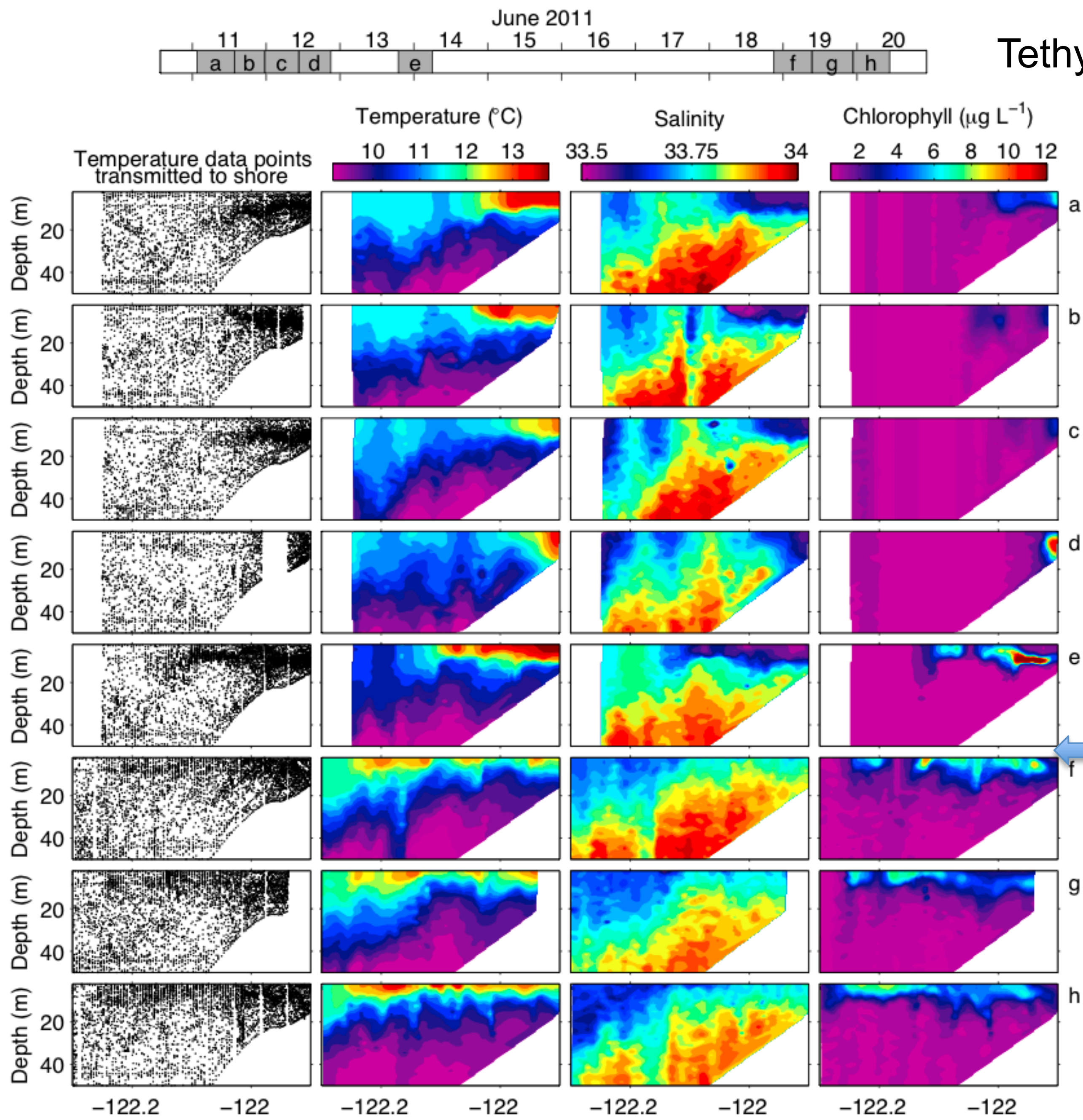
Dorado: going deeper June 15-16



Pennington et al.: Humpback whales (20-40) observed at the outer reaches of the 36.9N line, evidently feeding on a zooplankton layer at ~ 70 m depth ➔ examine LOPC and ADCP data.

Week 2: further westward expansion of the upwelling shadow

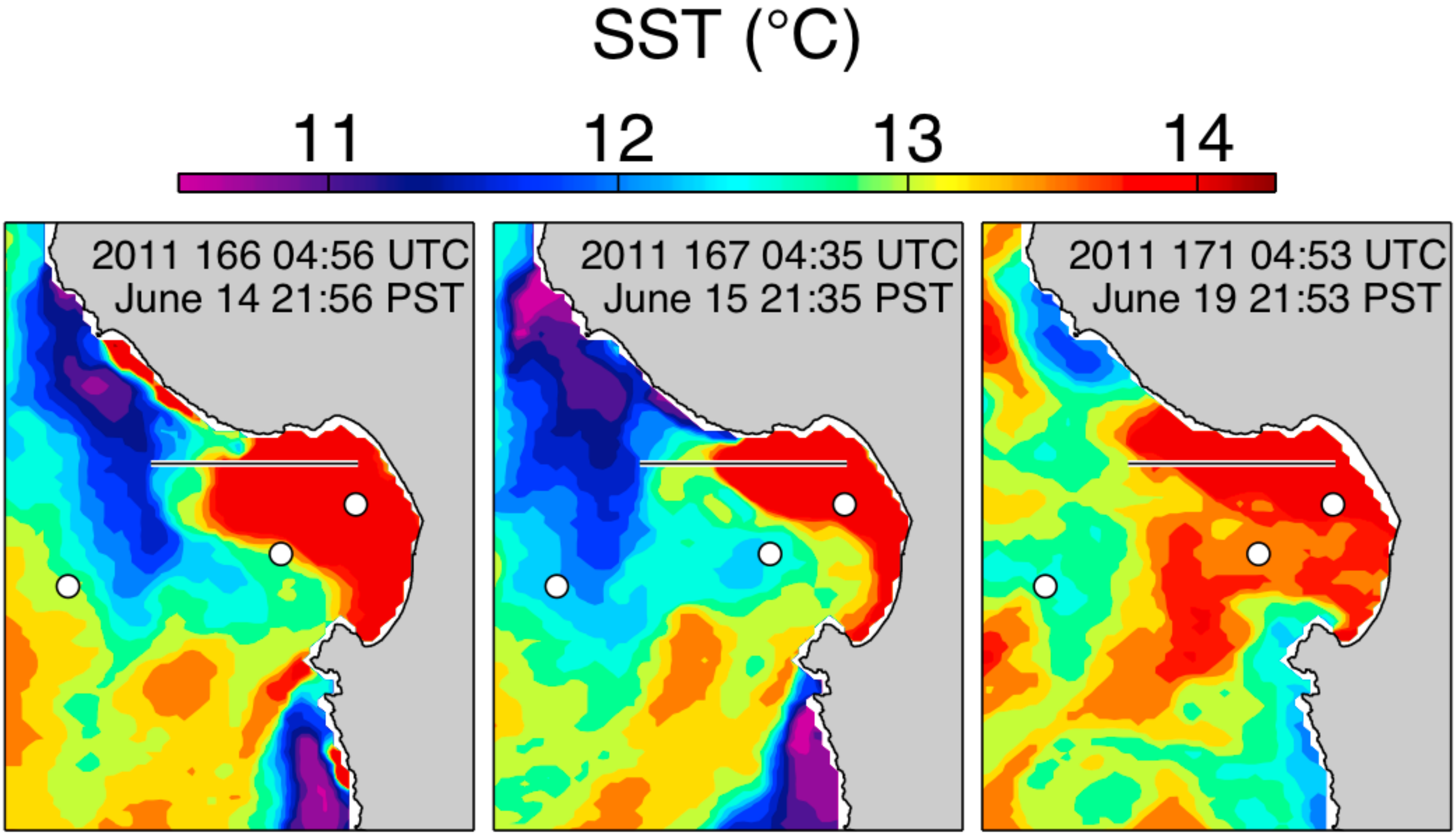
Tethys, 11-20 June



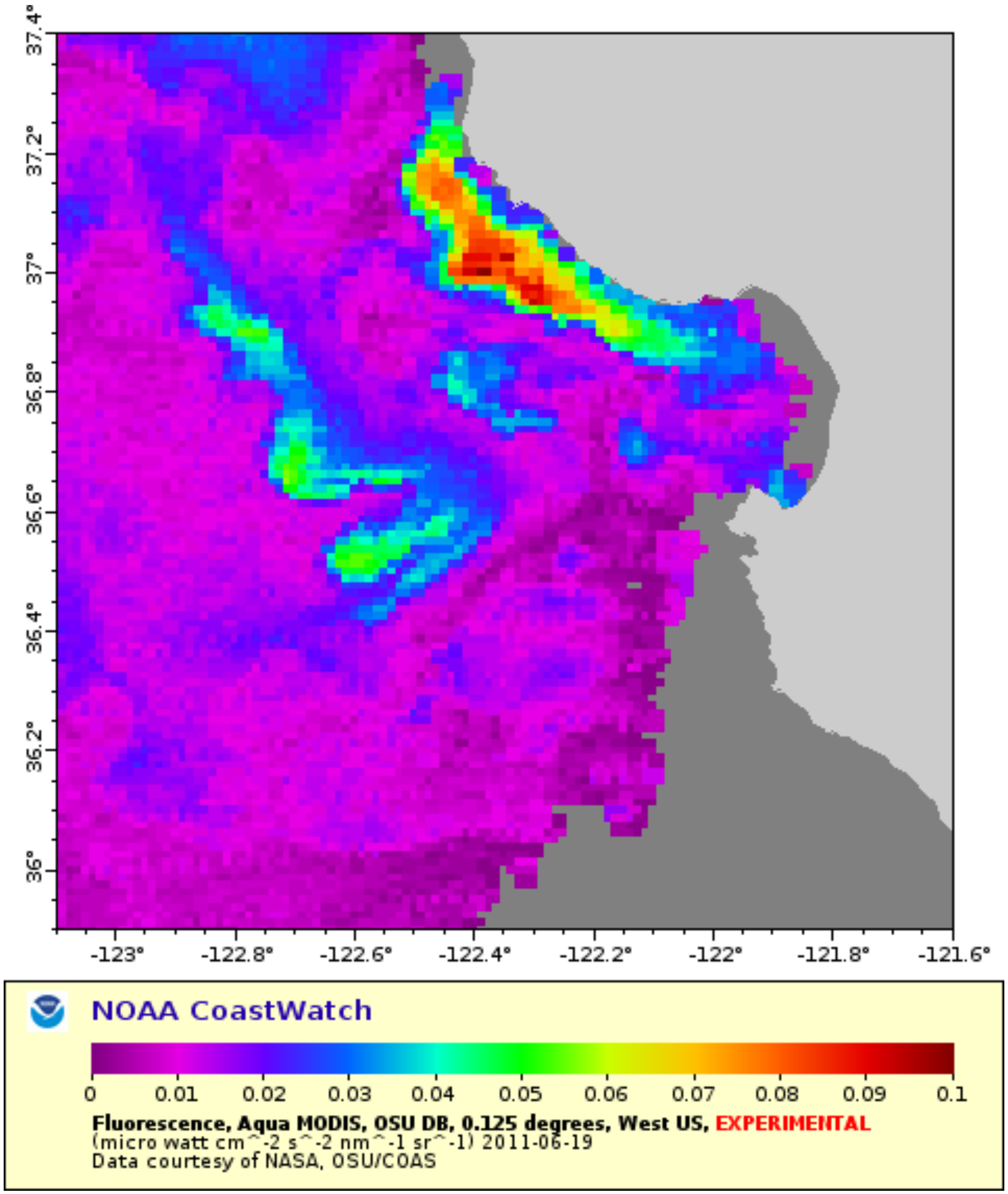
Changes:

- ◆ Nature of front
- ◆ Preparing to "zoom-in" with coordination of two AUVs (trading spatial coverage for temporal resolution)

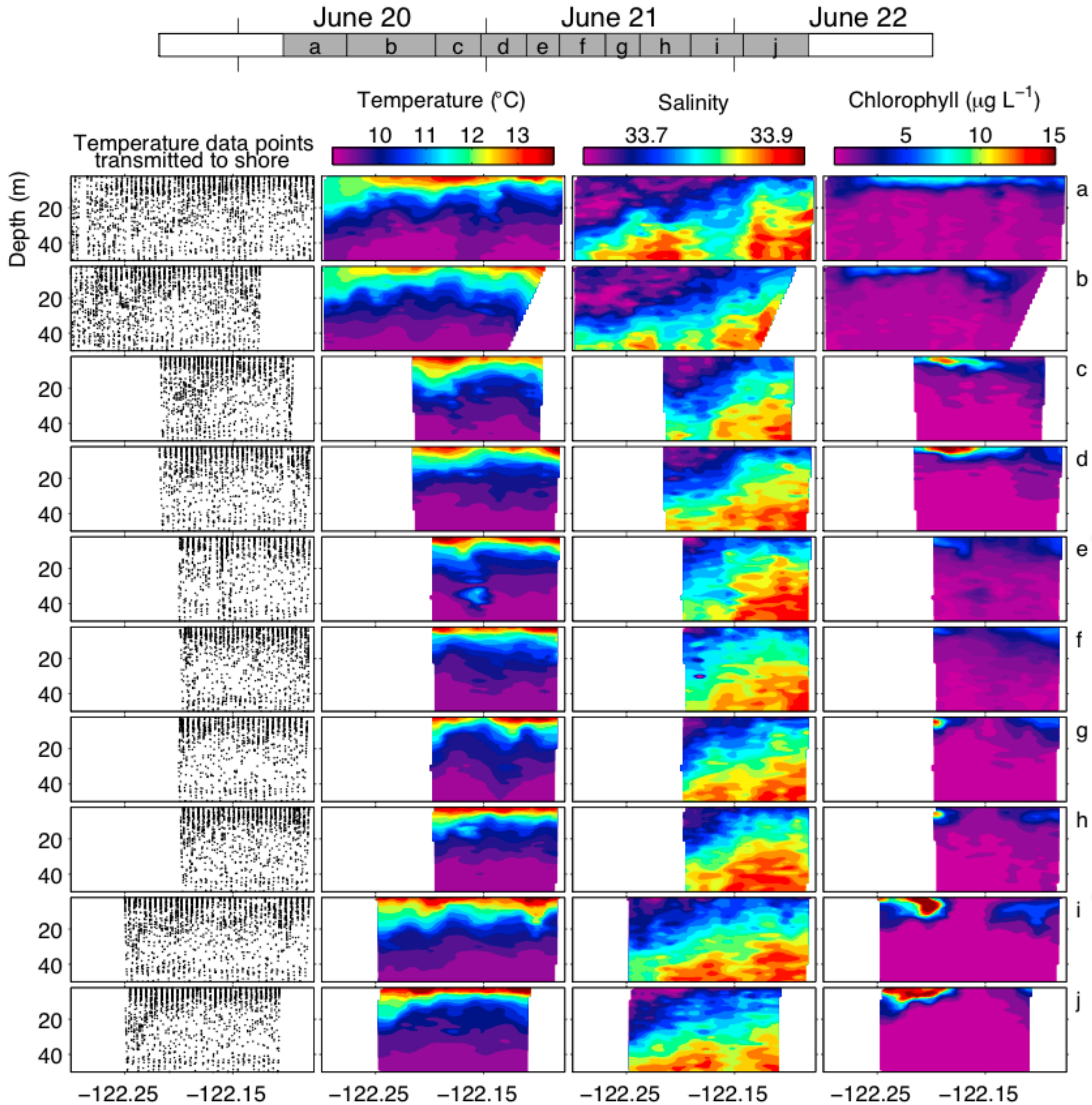
Week 2: further westward expansion of the upwelling shadow



"Bio-optical front"



Tethys & Dorado: zooming-in on a bio-optical / salinity front



Algorithm to autonomously track an upwelling front?

- Check.

Adapt for a different type of front?

- Seeds planted.

Meanwhile…

Human in the loop

Human in the loop

Summary

Although wind-driven variability was not “strong”, the first week of the experiment was dominated by upwelling and brought conditions quite consistent with the experiment plan and goals for studying the “classic” upwelling filament / shadow system. We watched the upwelling shadow expand (and behave somewhat like an amoeba) in association with persistent upwelling favorable winds, and we successfully tested a novel intelligent Gulper allocation algorithm across 3 water types. Large changes in water column structure in the upwelling shadow were observed by the AUVs, yet some patterns remained consistent, e.g. subsurface layers (phytoplankton “hot spots”) in the upwelling shadow transitioned to surface biomass maxima at fronts within or at the outer boundary of the upwelling shadow.

Week 2, dominated by relaxation and downwelling, brought conditions that were not as simply delineated as the classic upwelling filament / shadow system. Near-surface salinity gradients reversed, and a salinity / bio-optical front at the outer boundary of the upwelling shadow became the focus to which we applied dual-AUV “zooming-in”. This different type of front was nonetheless the proximate boundary of bay waters and exhibited the maximum bio-optical signal (evident in AUV and remote sensing data), so it was the natural focus for coordinated AUV operations.

Tethys real-time data was the first data source to alert us to changes occurring during both weeks of the experiment.