C-HARRIER
Calibration, Validation, and Research of Water Quality in Coastal and Inland Waters

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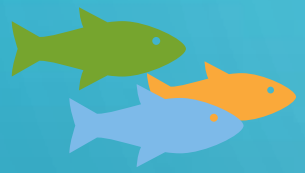
Anthony Bucholtz, Haf Jonsson, Roy Woods, Greg Cooper, Naval Postgraduate School Twin Otter

And the pilots and staff at NPS, and all the San Jose State and UCSC students!

Introducing Jeremy Kravitz, NASA Postdoc at NASA ARC

NASA Funding:
HOPE 2010, SIF 2013, RSWQ 2013, SIF 2015, AITT 2016
Coastal High Acquisition Rate Radiometers for Innovative Environmental Research (C-HARRIER)

OUTLINE



Challenges for remote sensing of aquatic targets

Concept of operations for airborne/field campaigns

Airborne and ship-based instrumentation

California test sites

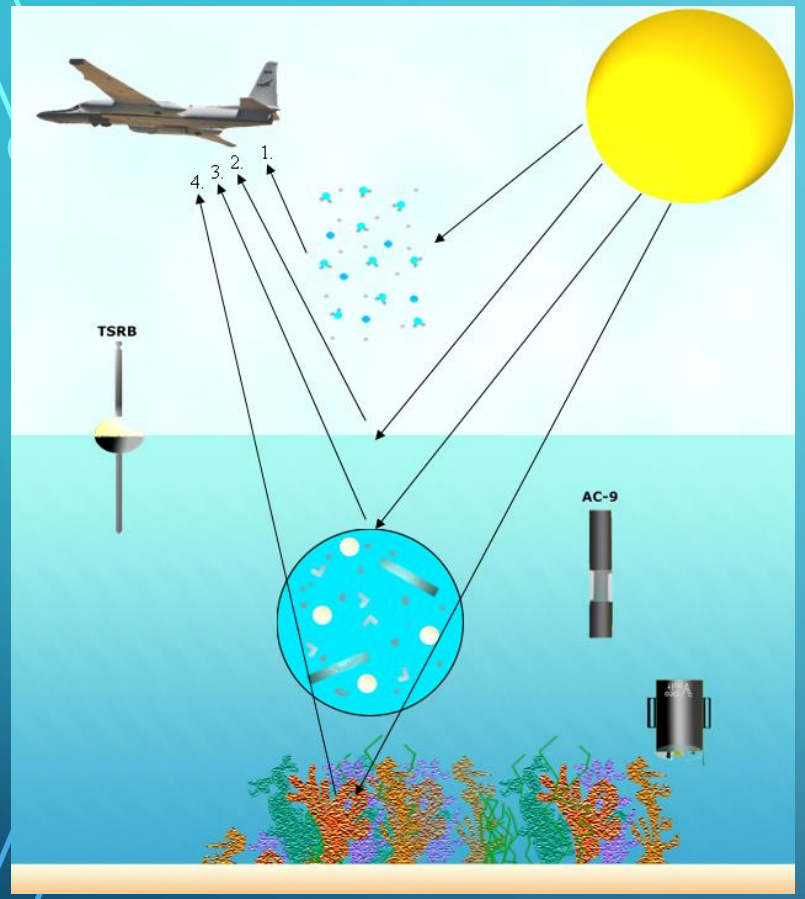
Campaigns 2011, 2013, 2017-2019

&

Results

….What's next!

CHALLENGES AND OPPORTUNITIES



This represents <20% of the signal reaching the remote sensing instrument!

- Accurate retrieval of aquatic reflectance
  - Highly variable radiance signals (deep water to the coast).
  - ~20% of the signal reaches the sensor due to light attenuation/scattering by the atmospheric constituents, water surface, or within the water column. Higher signal (SNR) requirement over water than for land targets.

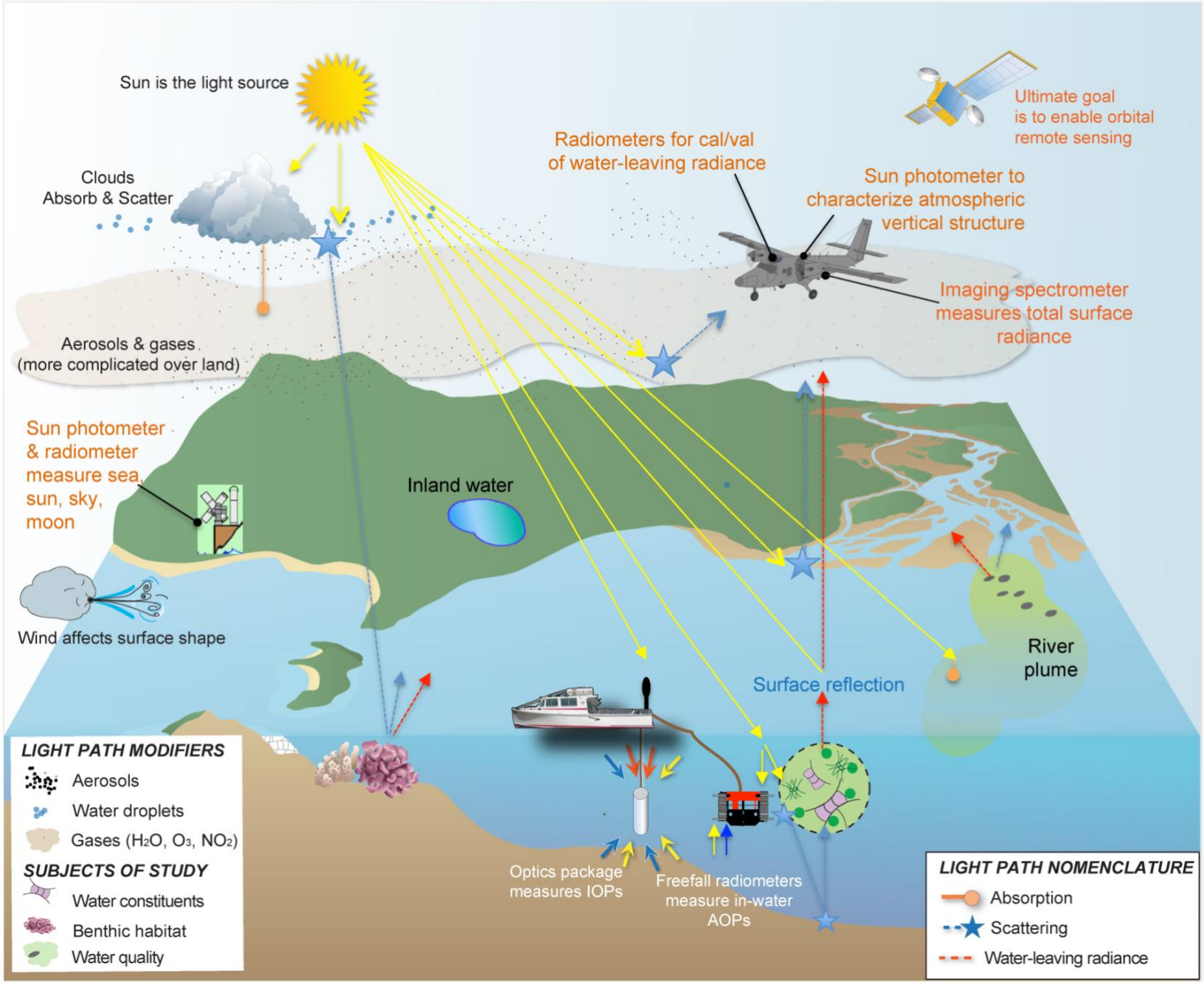
  → **High dynamic range radiometers.**
- Atmospheric correction
  - Aerosol and trace gas plumes from continental sources complicate the task of atmospheric correction.

  → **Flying at lowest safe altitude (~100 ft!)**

  → **flying radiometers as sun photometers.**

CONCEPT OF OPERATIONS FOR AIRBORNE/FIELD CAMPAIGNS

A sensor network approach enables simultaneous measurements in support of calibration, validation, and research exercises for satellite inland waters and coastal ocean (aquatic) color products.

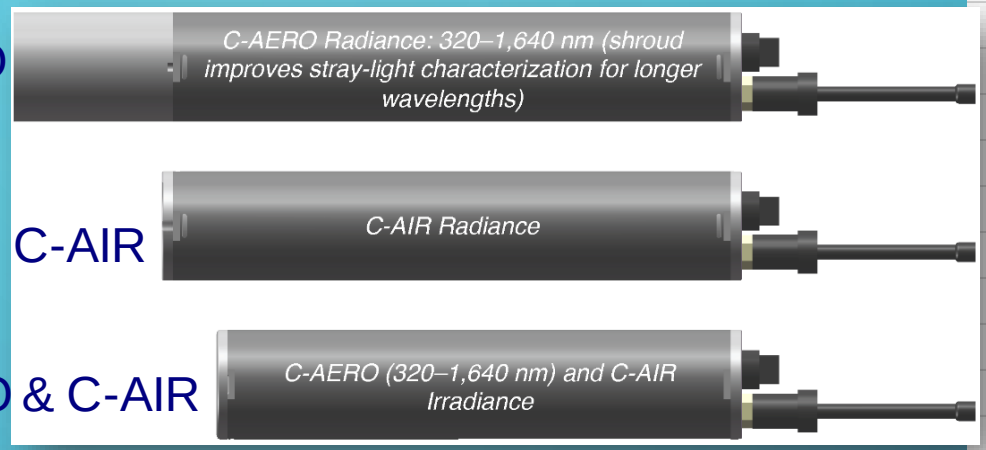


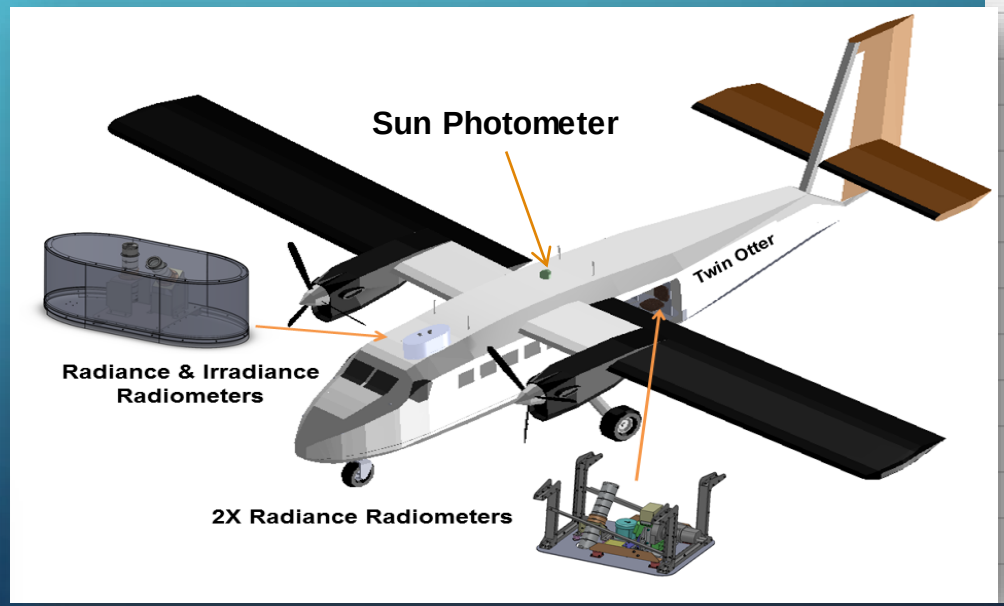
PORTABLE MICRO RADIOMETERS BIOSPHERICAL INSTRUMENTS

19-channel micro radiometers:
1. Cosine collector for measuring global solar irradiance (E_s)
2. Sky radiance (L_i) and
3. Total radiance (L_T)

Expansive spectral range: 320-1640 nm and matching satellite (NASA MODIS) ocean color bands.

Derived water-leaving radiance in VIS and NIR for satellite match-ups for algorithm validation or for use in discrimination of absorbing and scattering constituents.



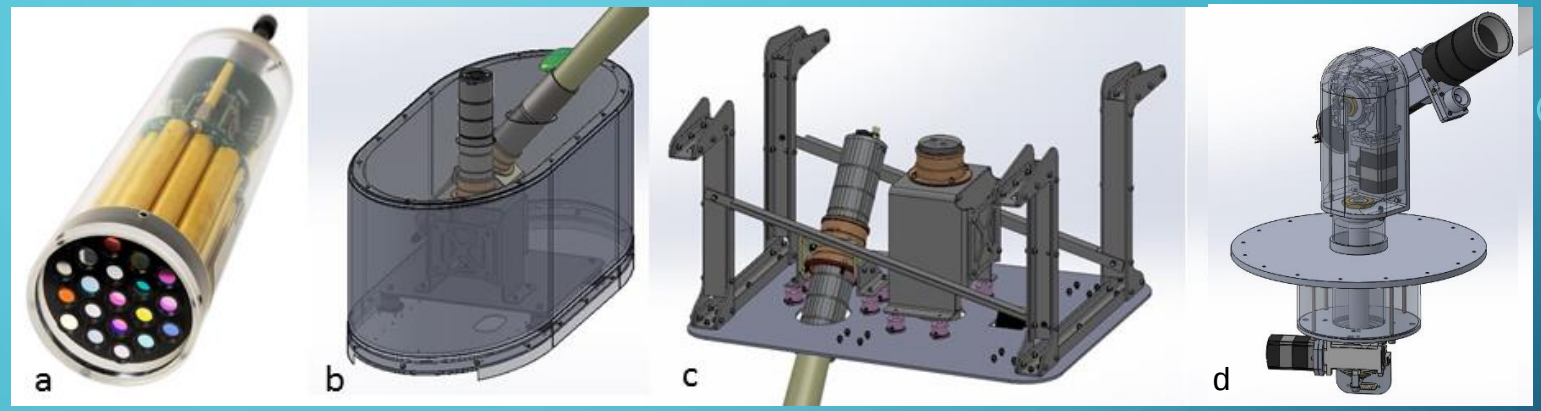


Channel Number	C-AERO/C-AIR Wave-lengths
1	320
2	340
3	380
4	412
5	443
6	490
7	510
8	532
9	555
10	589
11	625
12	670
13	683
14	710
15	780
16	875
17	1020
18	1245
19	1640

Biospherical Instruments Inc.

AIRBORNE SENSOR SUITE

a. BSI microradiometer,
b. Zenith mount of upward looking radiometers,
c. Nadir mount of downward looking radiometers, and
d. New 3STAR design on sun tracking mount.



MONTEREY BAY, CALIFORNIA

Monterey Bay has both open ocean and optically complex water masses (Case 1 and 2 waters), so the full dynamic range of the sensor suite and protocols being used in the field can be evaluated

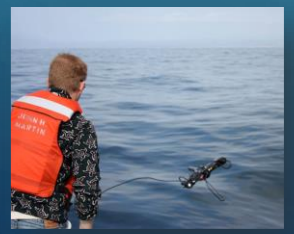
Ongoing time-series by UCSC, MLML, MBARI, with moorings and shore stations

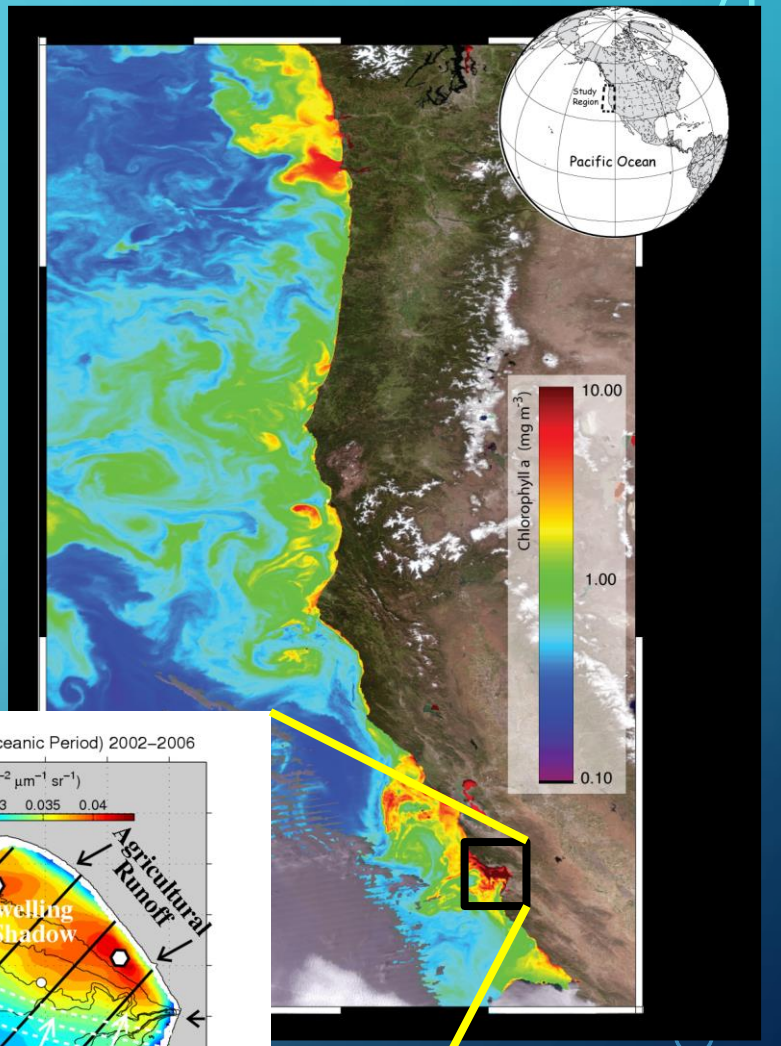
Features include Elkhorn Slough, red tides, kelp beds, river plumes

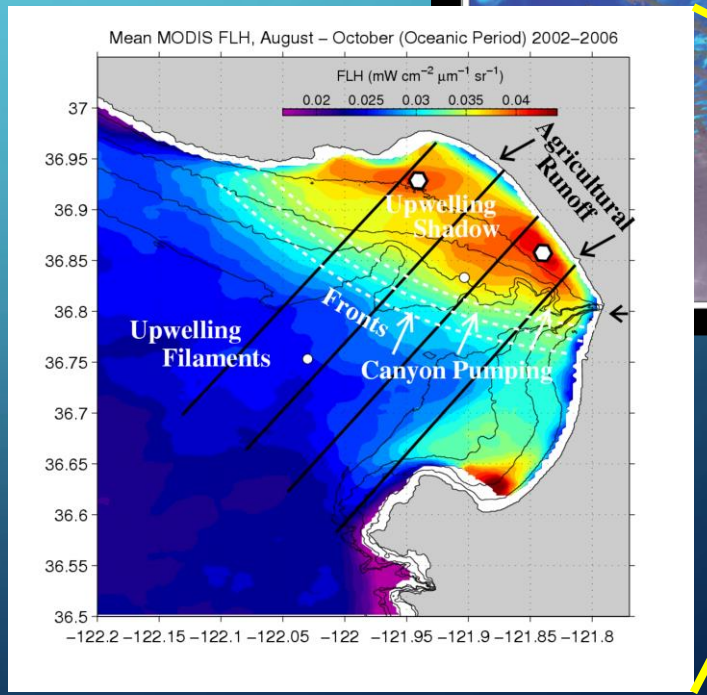
Seasonality: fall transition, upwelling versus warm stratified conditions, and seasonal “first flush” rain events for riverine plumes

At each station (T, S, Chl-a, Fluorescence):

- Water samples for size fractionated chlorophyll, cell enumeration, HPLC Pigments, CDOM, phyto absorption
- Surface and profile AOPs (water-leaving radiance)
  - Sea-Bird Scientific HyperPro II and BSI C-OPS
- Surface and profile IOPs (backscattering and absorption)
  - HS6 and Sea-Bird Scientific ac-s
- Surface reflectance - ASD
- AOD spectra – Microtops sun photometer

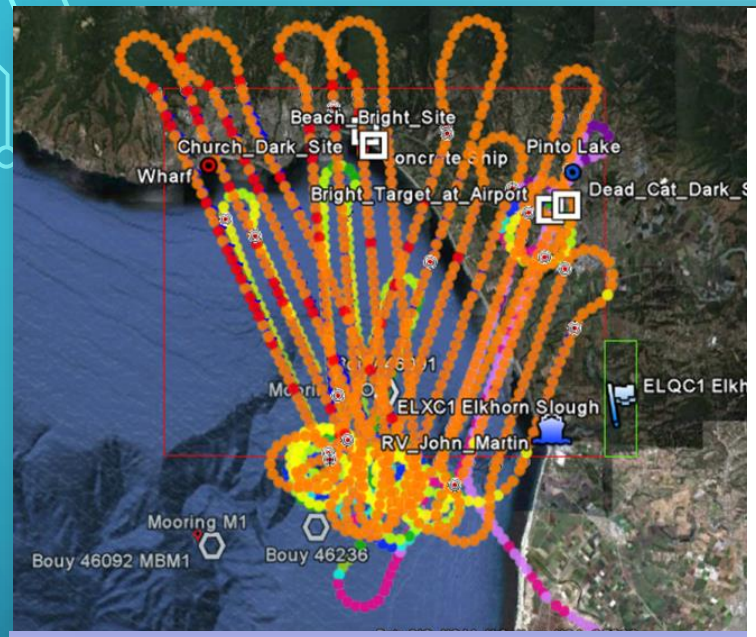


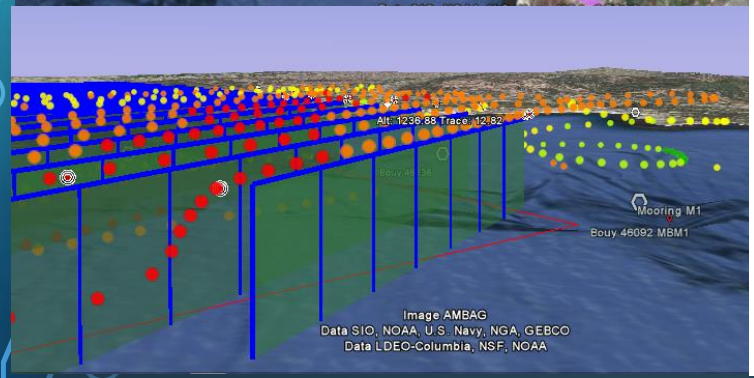


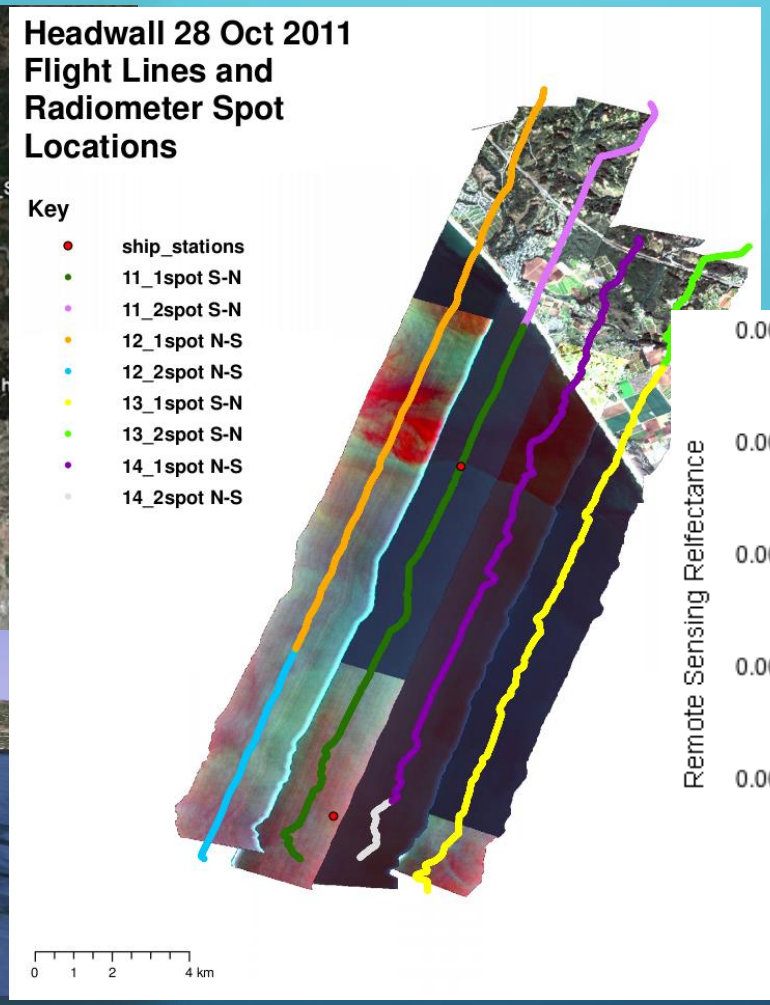


Monterey Bay

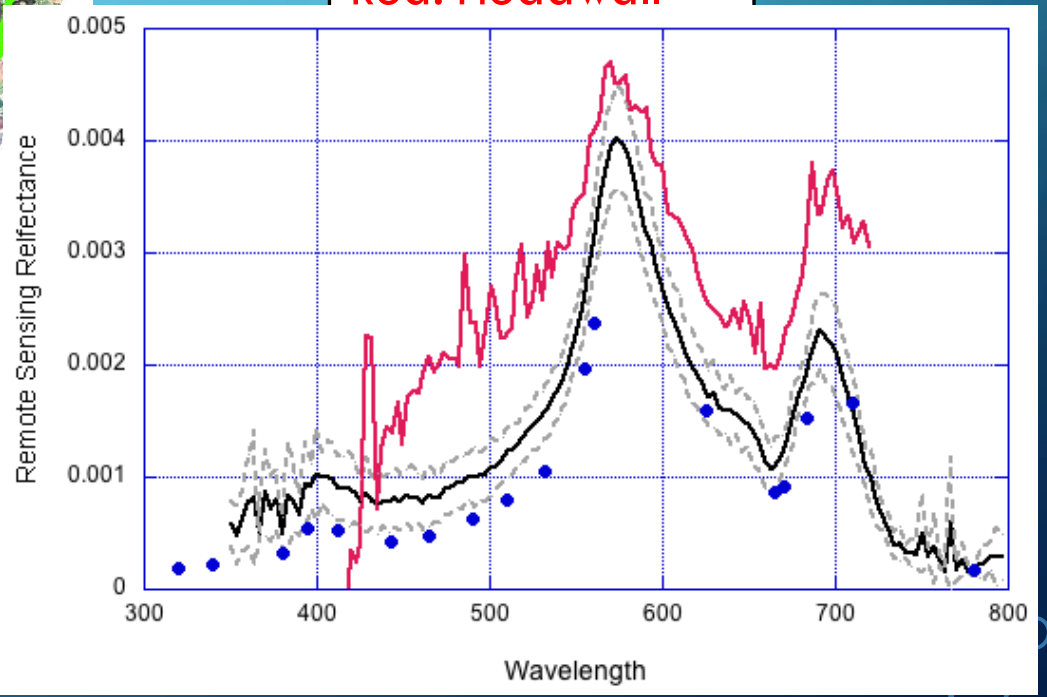
AIRBORNE CAMPAIGN – COAST 2011





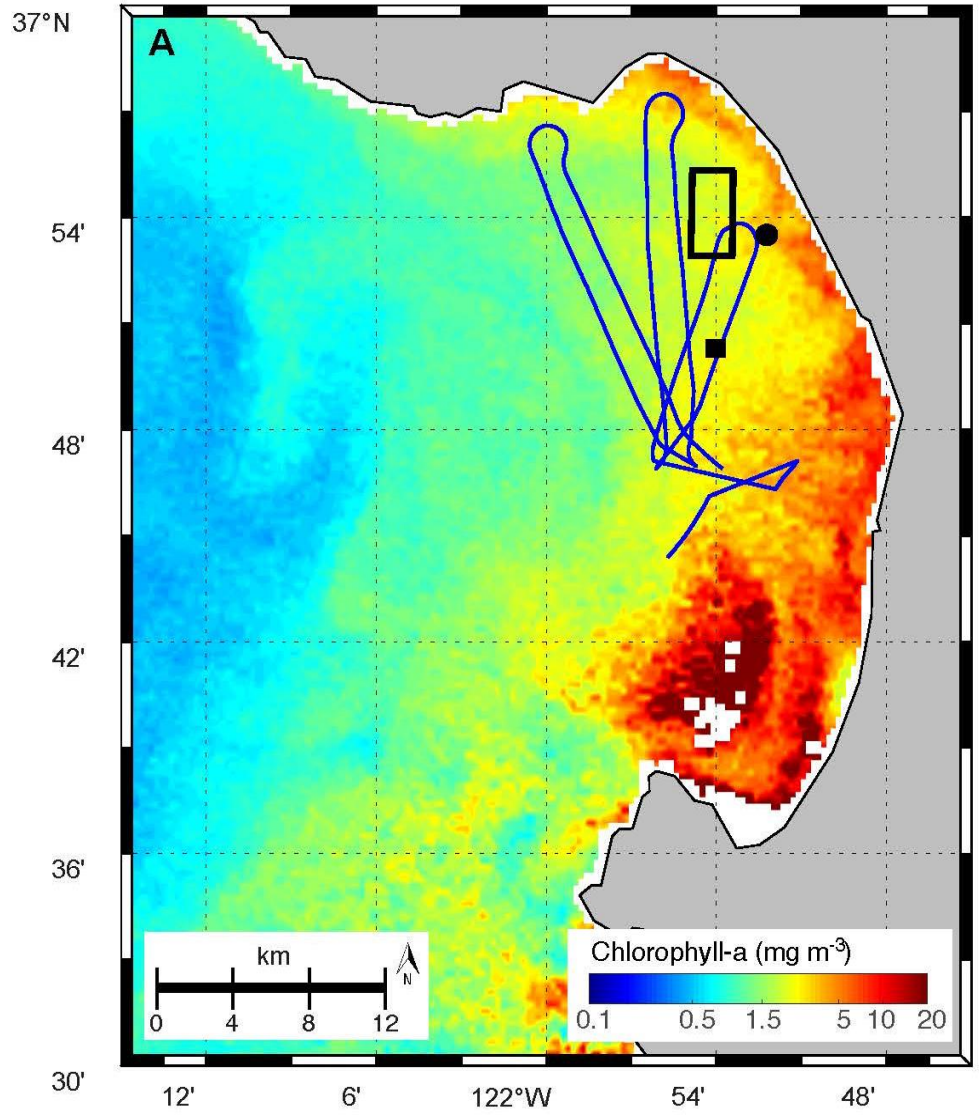


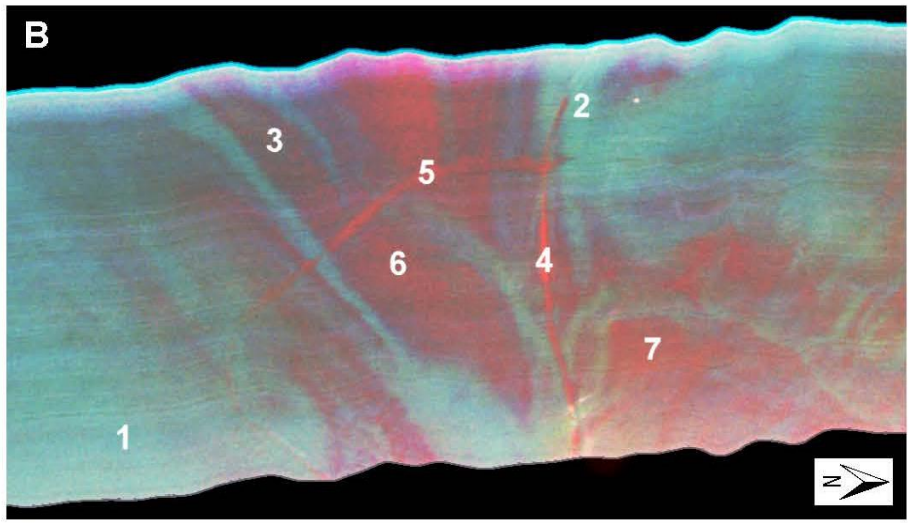
Blue: C-OPS
Black: HyperPro II
Red: Headwall

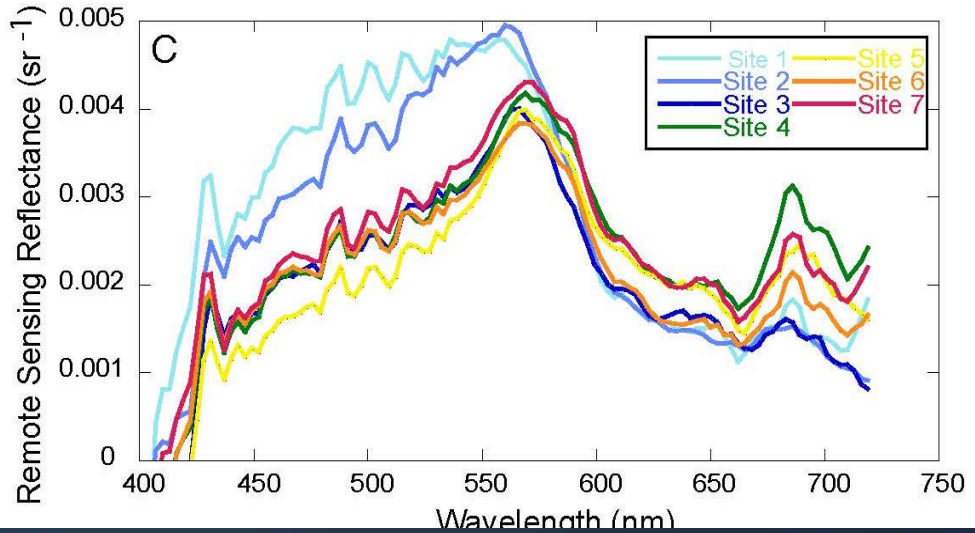


Left: Low (100 ft yellow lines) and high-altitude (orange lines) flight lines. Middle: Headwall imaging spectrometer and C-AIR data alignment. Right: Comparison of C-OPS, HyperPro II and Headwall data over a red tide.

COAST 2011 VALIDATION OF AIRBORNE AND SATELLITE DATA

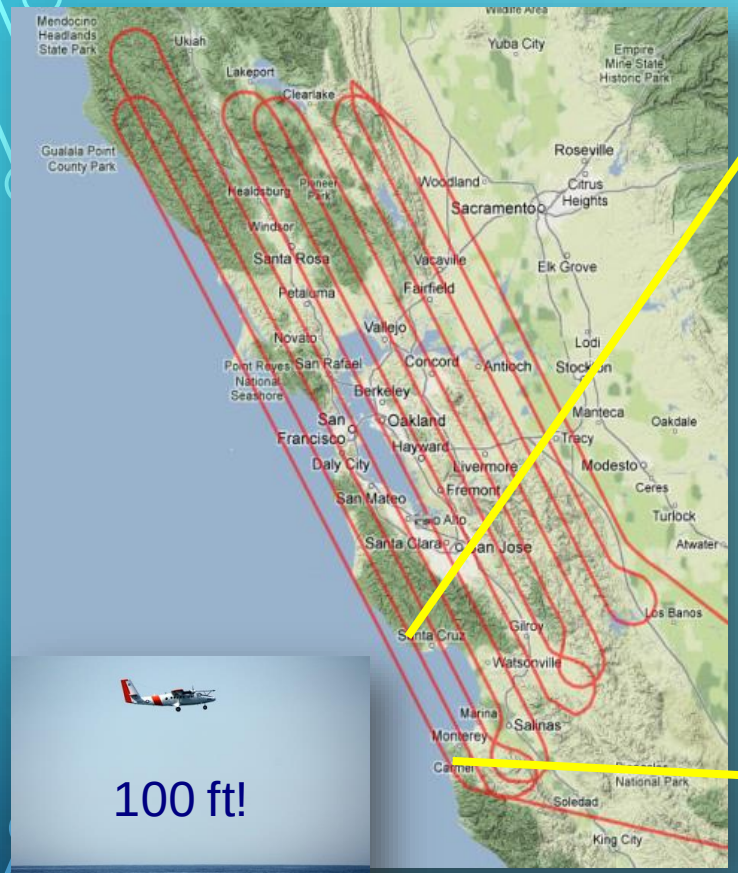


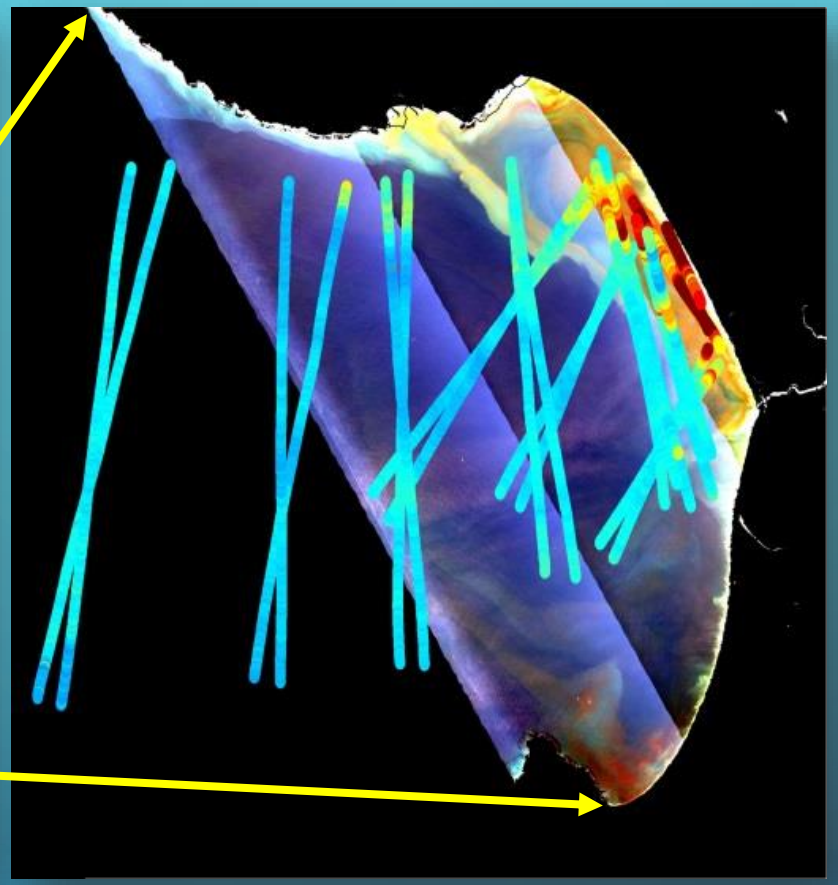


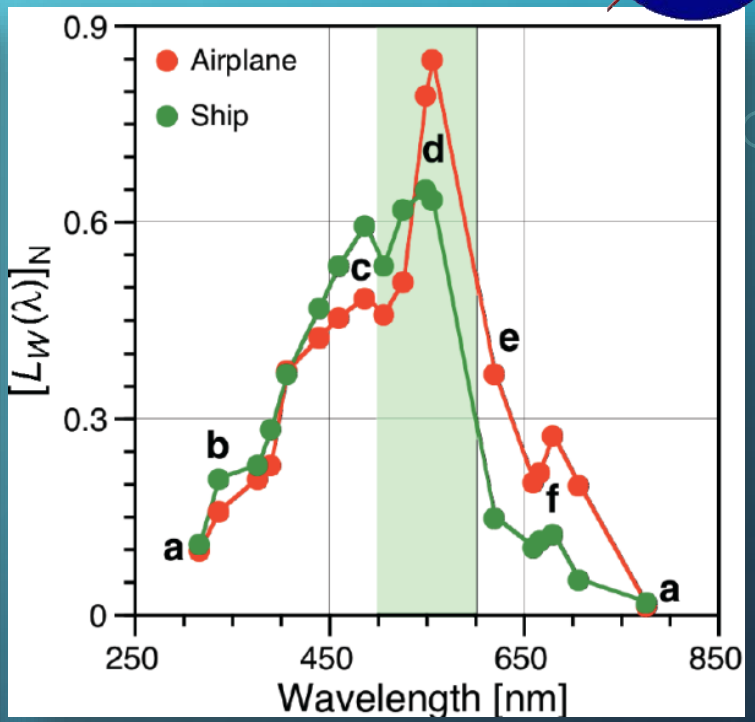


Guild et al., FES 2020

AIRBORNE CAMPAIGN – OCEANIA & HYSPIRI 2013







Left: High altitude airborne flight (NASA ER-2 at 65,000 ft)) with imaging spectrometer (AVIRIS). Inset: Navy Twin Otter flying at 100 ft
Middle: Airborne Visible Infrared Imaging Spectrometer (AVIRIS) images with Coastal Airborne In-situ Radiometers (C-AIR) lines.
Right: Comparison of C-AIR (airborne, red symbols) in more intense bloom conditions and C-OPS (ship, green symbols) measurements in a red-tide in Monterey Bay. There is good agreement for a) the UV and NIR end members, b) the UV "shoulder" for the type of coastal water sampled is seen in both spectra, c) the blue "shoulder" for higher productivity coastal waters, d) the expected peak in the green domain, e) the elevation of the red domain, and f) the fluorescence peak.

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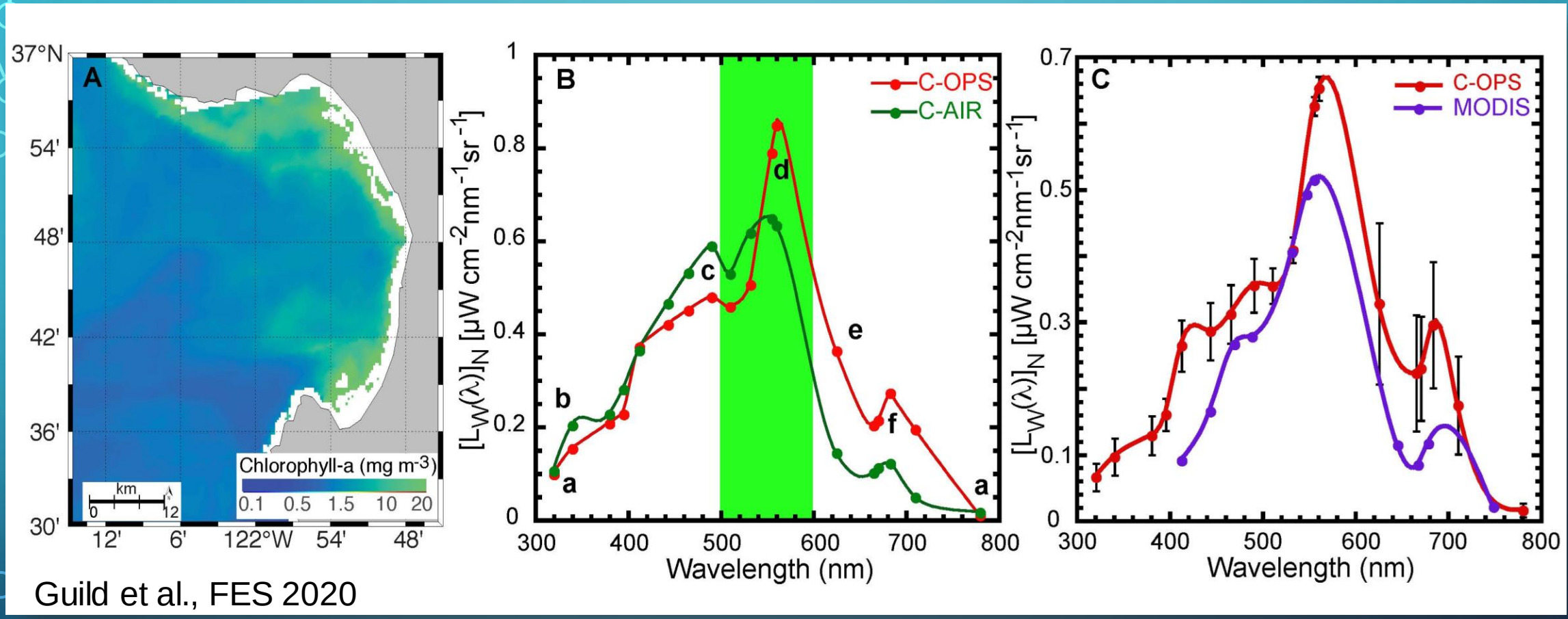
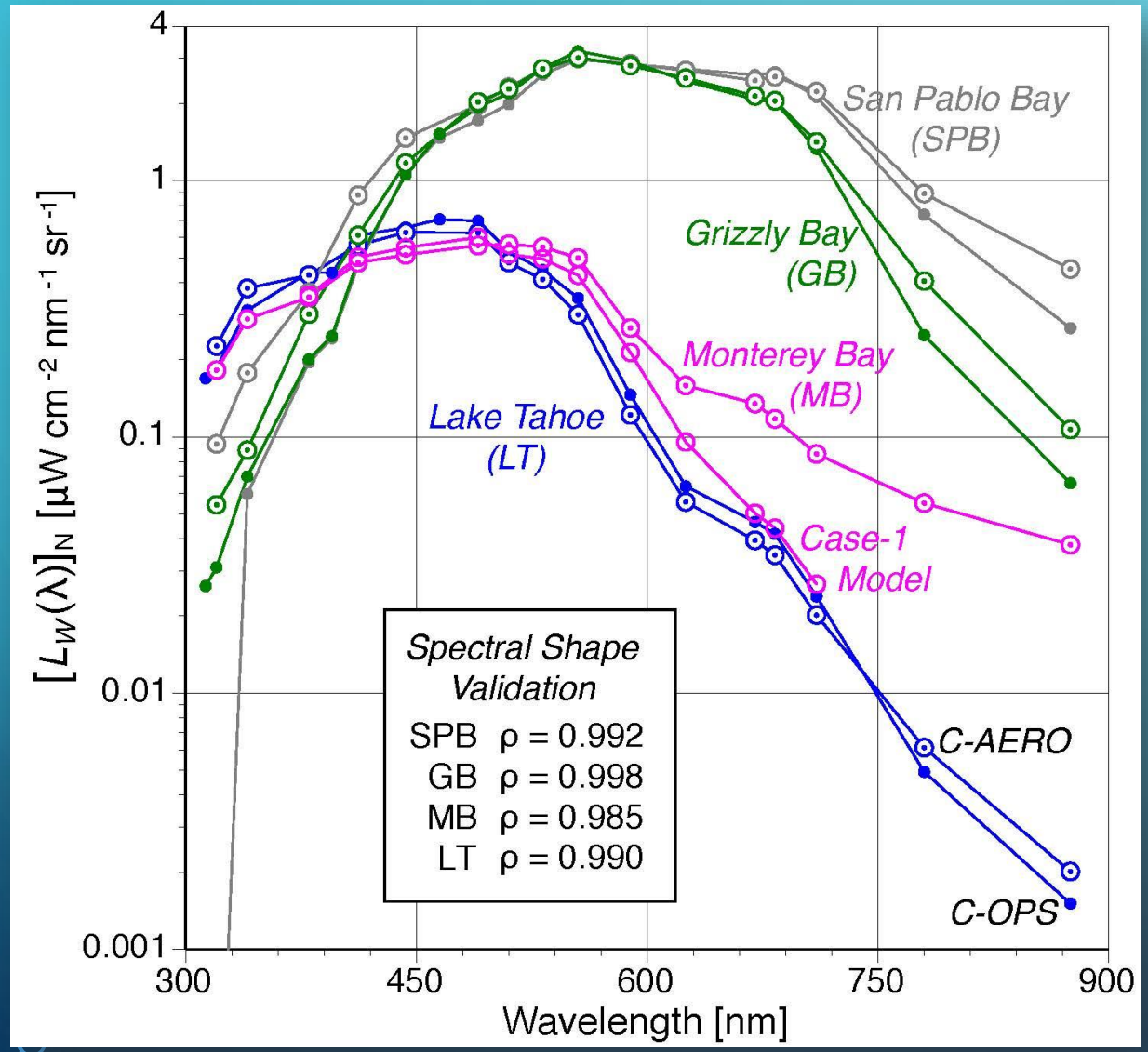
VALIDATION OF AIRBORNE AND SATELLITE DATA 2013

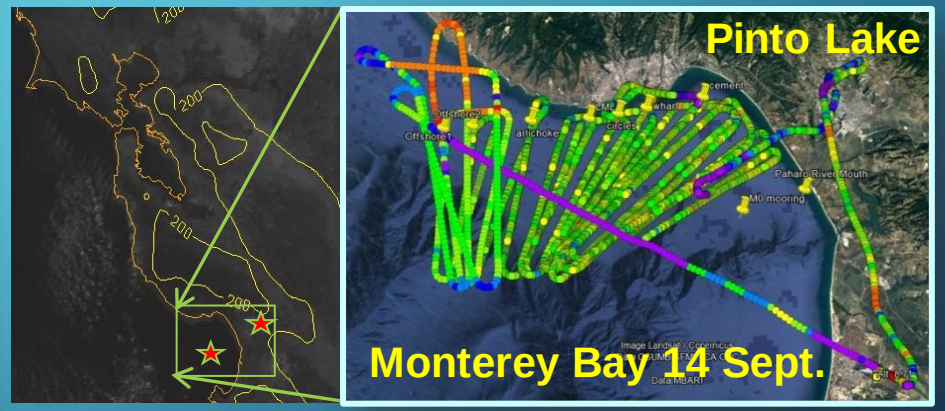


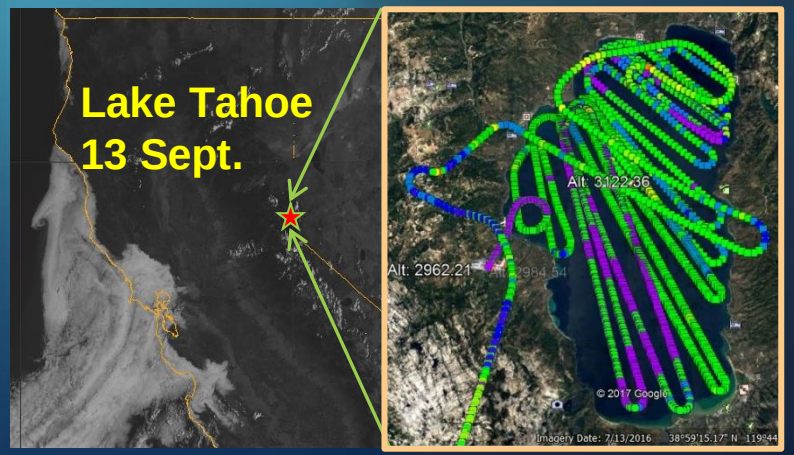
Guild et al., FES 2020

A. MODIS AQUA Chl *a* (250 m resolution) 5 November 2013,
B. Comparison of C-OPS (in-water) and C-AIR (airborne) within the red tide, and
C. The corresponding C-OPS vs MODIS data processed at 1km resolution. Error bars in Panel C represent the standard deviation of three consecutive C-OPS profiles.

C-HARRIER 2017
C-AERO AND C-OPS





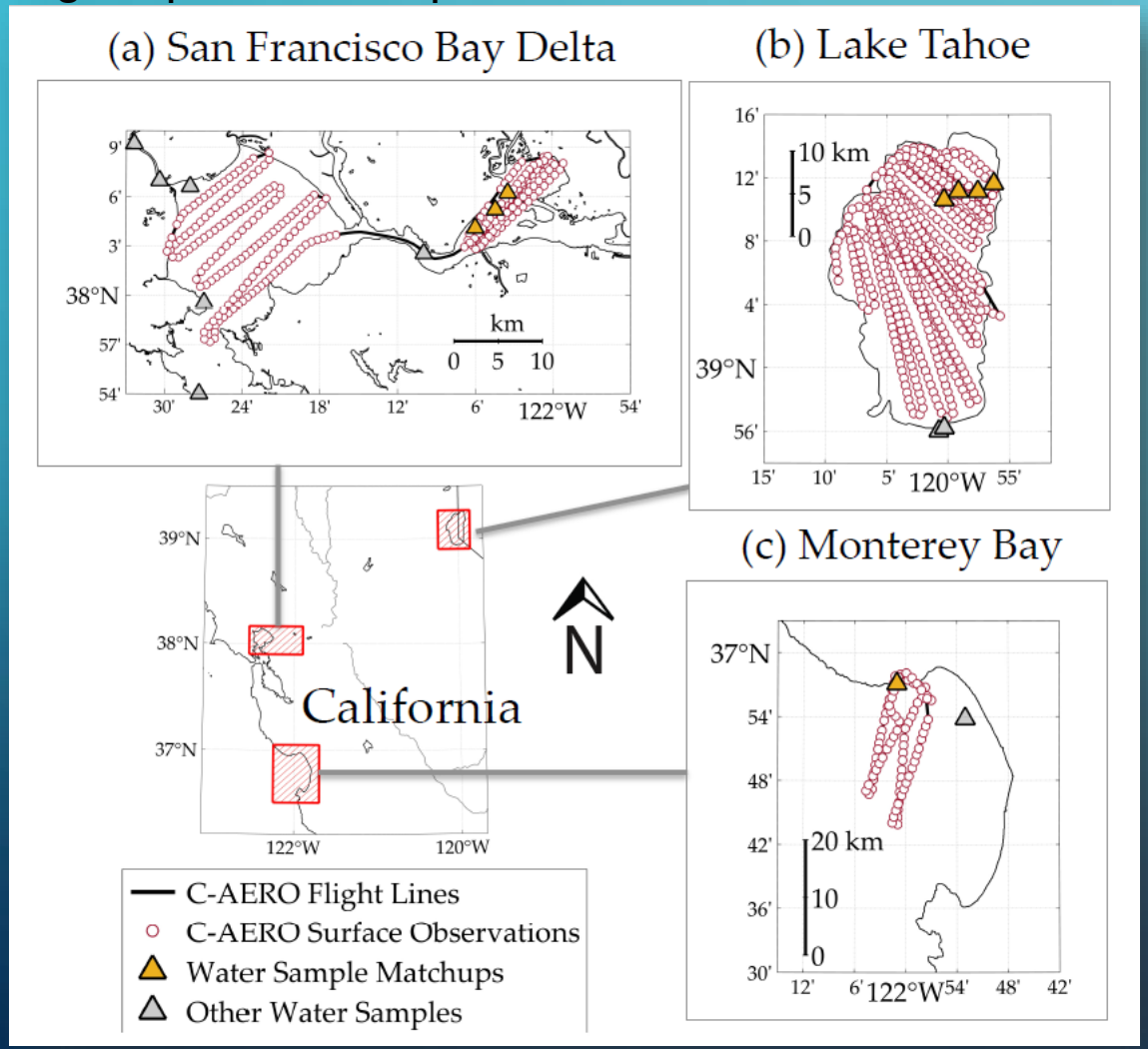


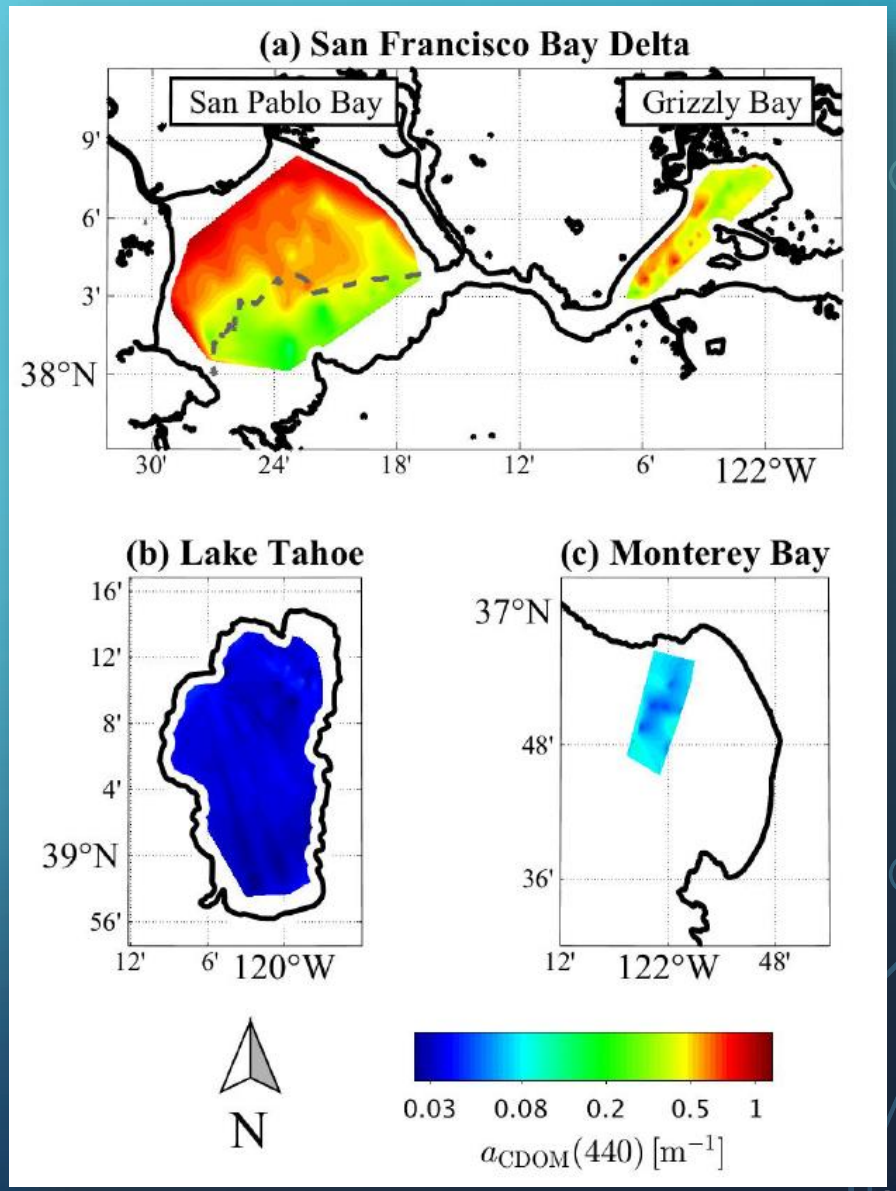
Guild et al., FES 2020

C-AERO RESULTS 2017: REMOTE ESTIMATION OF CDOM

End-member analyses were used to create $a_{CDOM}(440)$ maps using a spatial interpolation method.

All data satisfy 20% log uncertainty in waters spanning oligotrophic to eutrophic and sediment laden waters.





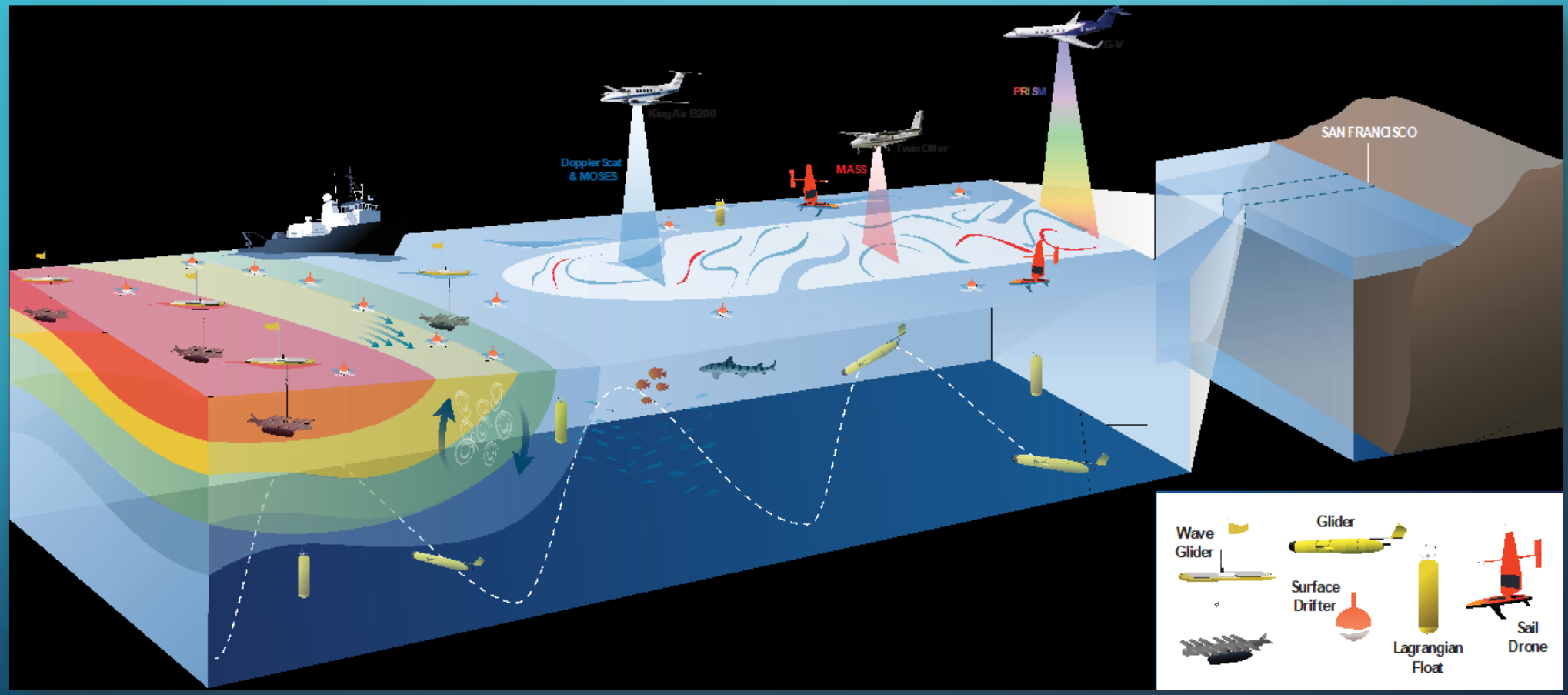
Houskeeper et al., RSE 2021

WHAT'S NEXT: CAL/VAL & RESEARCH

- Earth Venture Project: Sub-Mesoscale Ocean Dynamics Experiment (S-MODE)

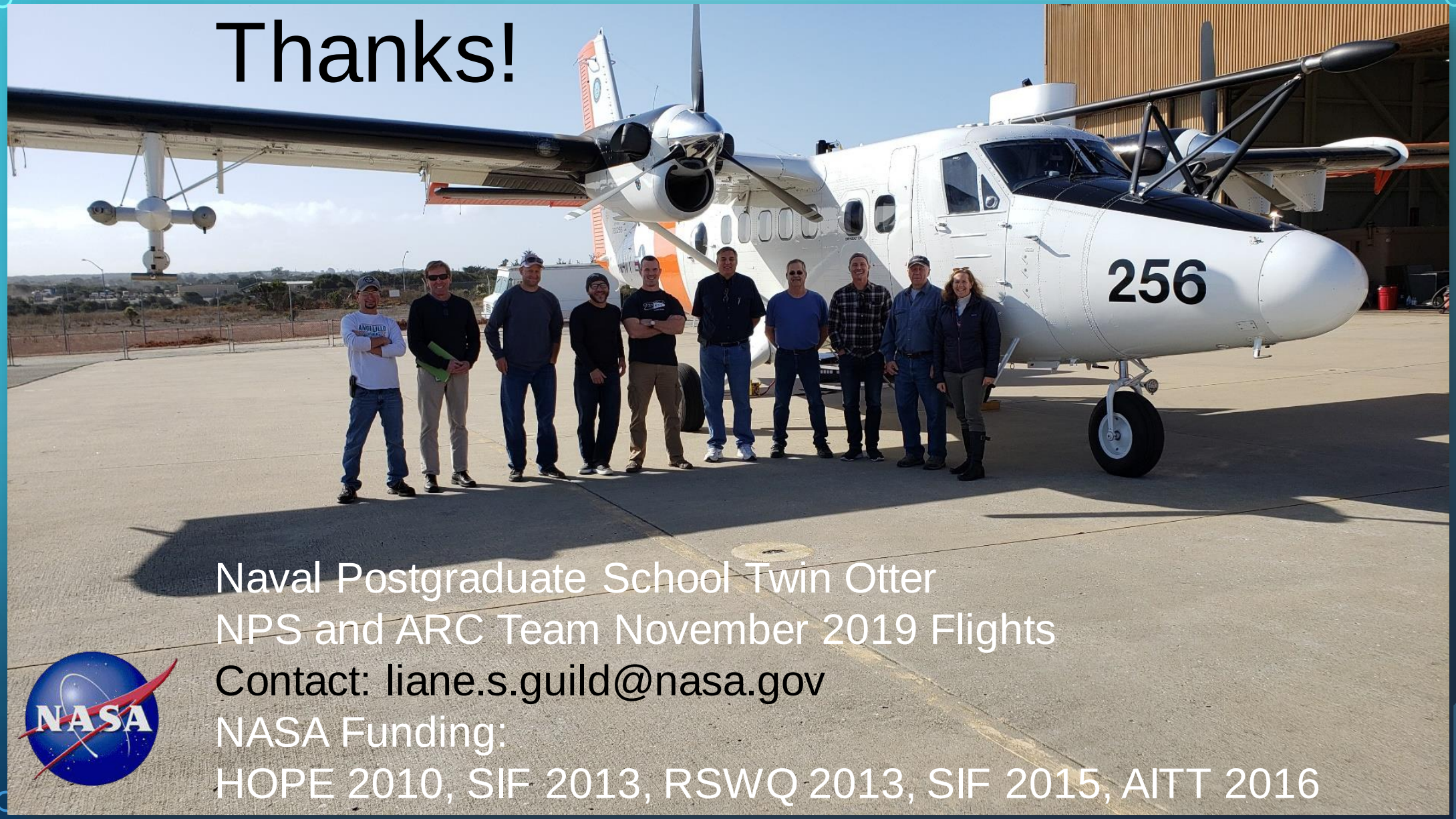
- Align with airborne cal/val opportunities for PACE, GLIMR, and SBG!

WHAT'S NEXT: SUB-MESOSCALE OCEAN DYNAMICS EXPERIMENT (S-MODE) – OCT/NOV 2021 SF CA



S-MODE Hypothesis: Submesoscale ocean dynamics make important contributions to **vertical exchange** in the upper ocean.
C-HARRIER returns to SF Bay Delta, Monterey Bay, and Pinto Lake sites for water quality.

Thanks!



Naval Postgraduate School Twin Otter
NPS and ARC Team November 2019 Flights
Contact: liane.s.guild@nasa.gov
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