Spatiotemporal variability of two North Pacific fronts and their effects on micronekton

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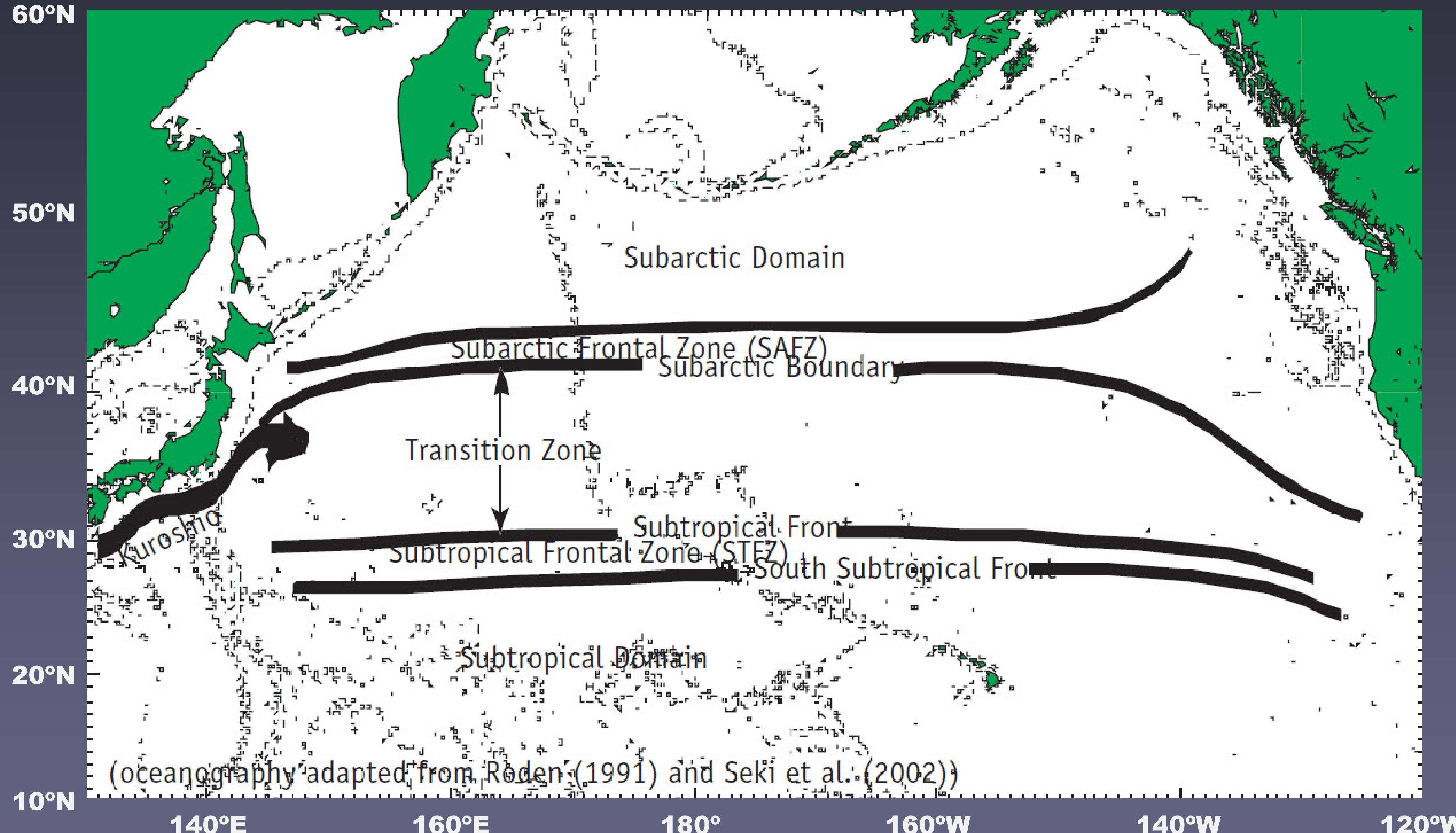
North Pacific Transition Zone



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**Seki et al., 2002*

North Pacific Transition Zone

- Importance of North Pacific Transition Zone
  - "Nutrition Highway" for top predators
    - Economically important fishing grounds (e.g., tunas, swordfish)
    - Protected species - concerns over by-catch (e.g., leatherback turtle, Hawaiian monk seal)
- Drivers and variability
  - Physical fronts
    - shear due to wind stress (convergence), thermohaline stratification
    - scales: meso-, seasonal, interannual, decadal
  - Chlorophyll front
    - horizontal Ekman flow (not vertical mixing)
    - scales: seasonal and larger
    - mesoscale ?? - vertical mixing due to storms, eddies ??
  - Forage - micronekton: "missing link" ??

Observational Study

- 3 Surveys conducted in spring 2009, 2011, 2015

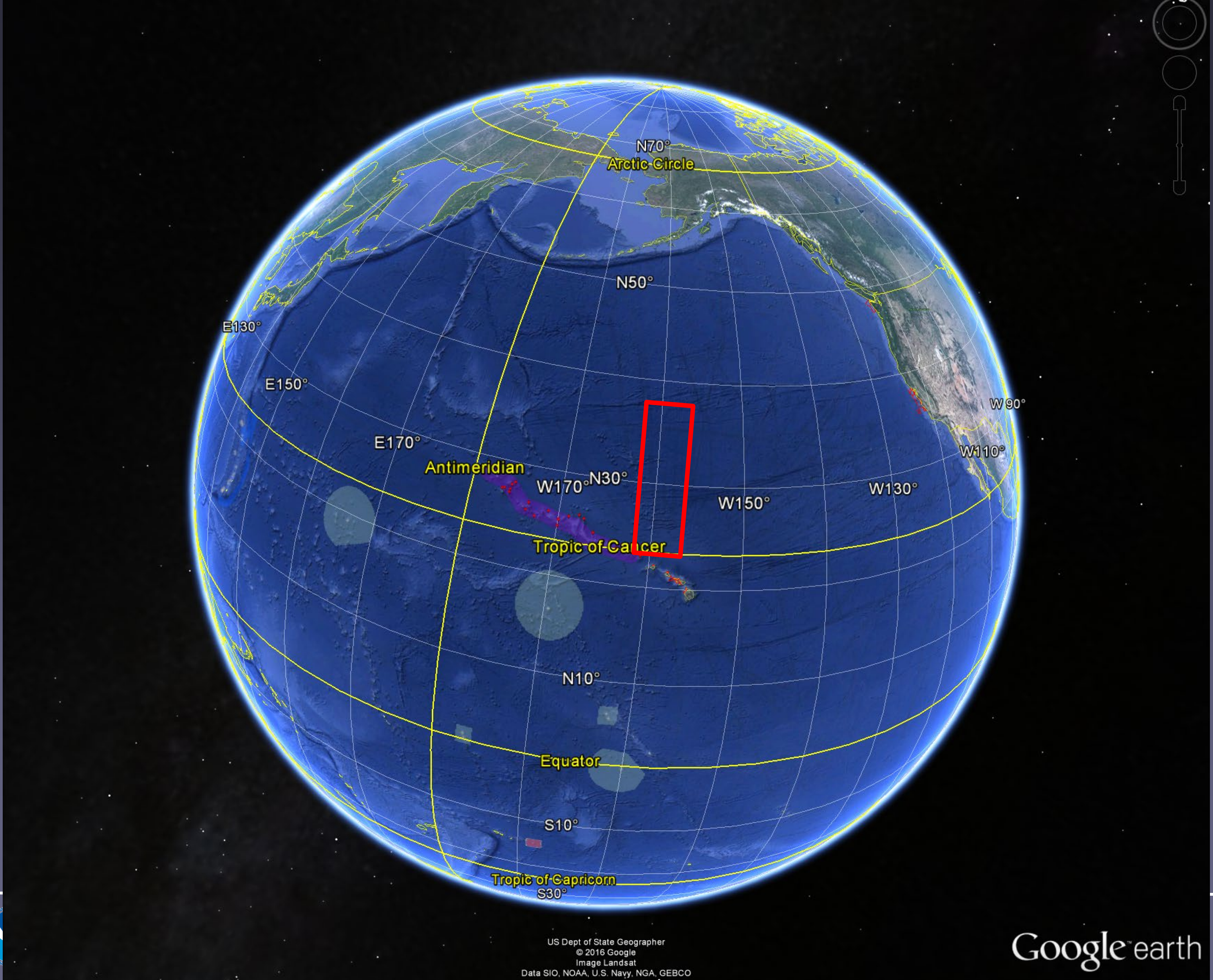
N70°
Arctic Circle
N50°
E130°
E150°
E170°
Antimeridian
W170°
N30°
W150°
W130°
W110°
W 90°
Tropic of Cancer
N10°
Equator
S10°
Tropic of Capricorn
S30°
US Dept of State Geographer
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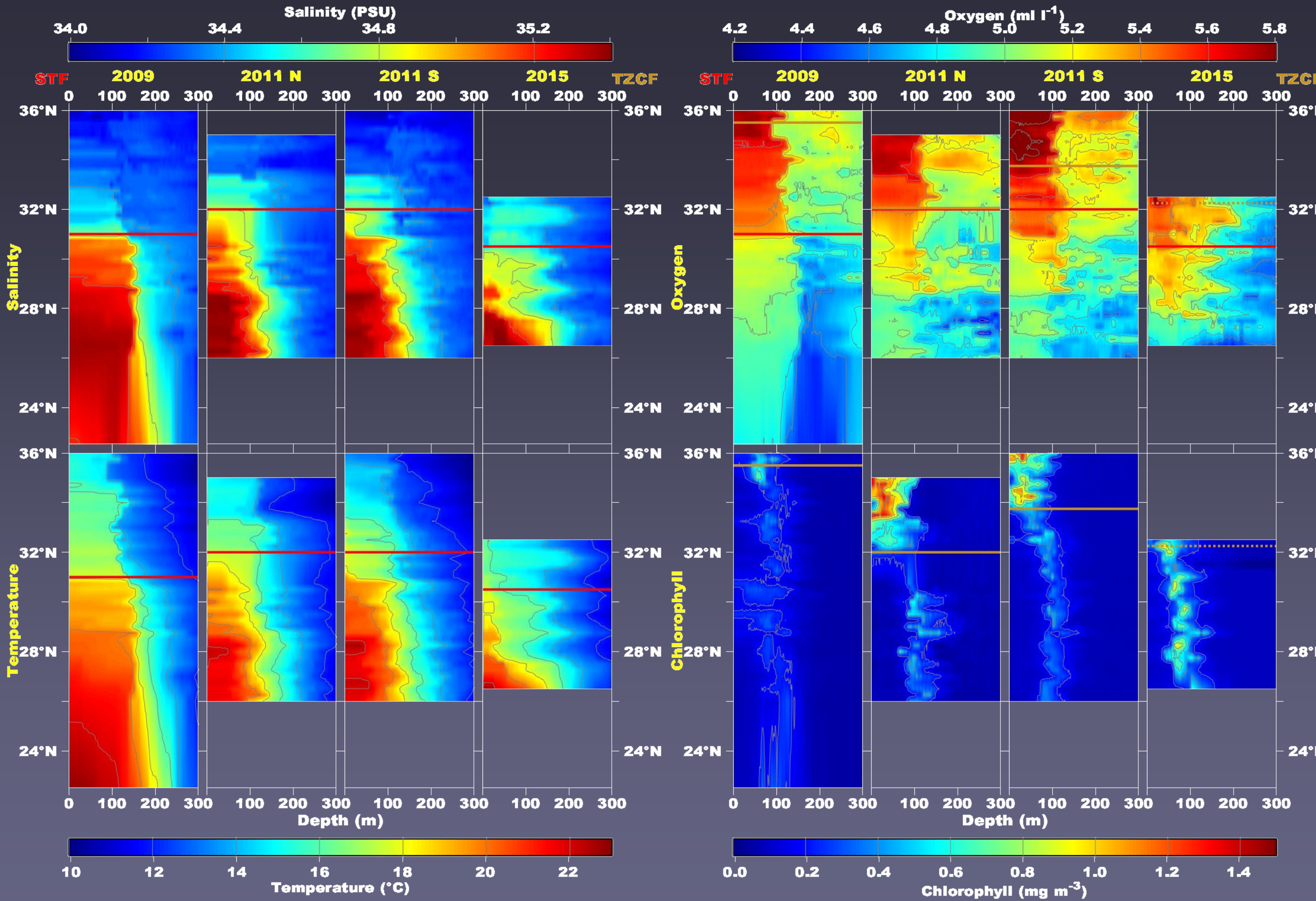
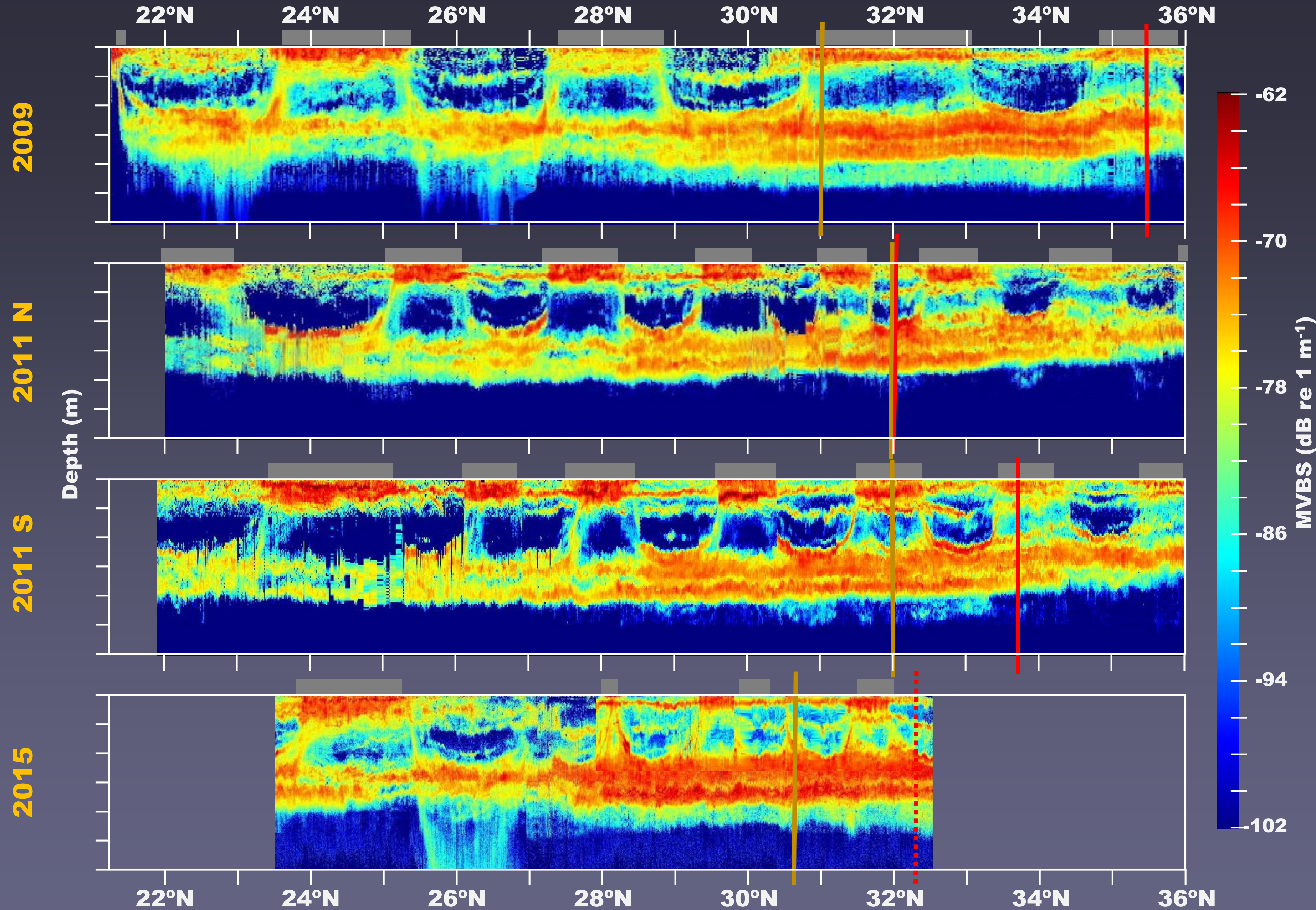
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

Observational Study

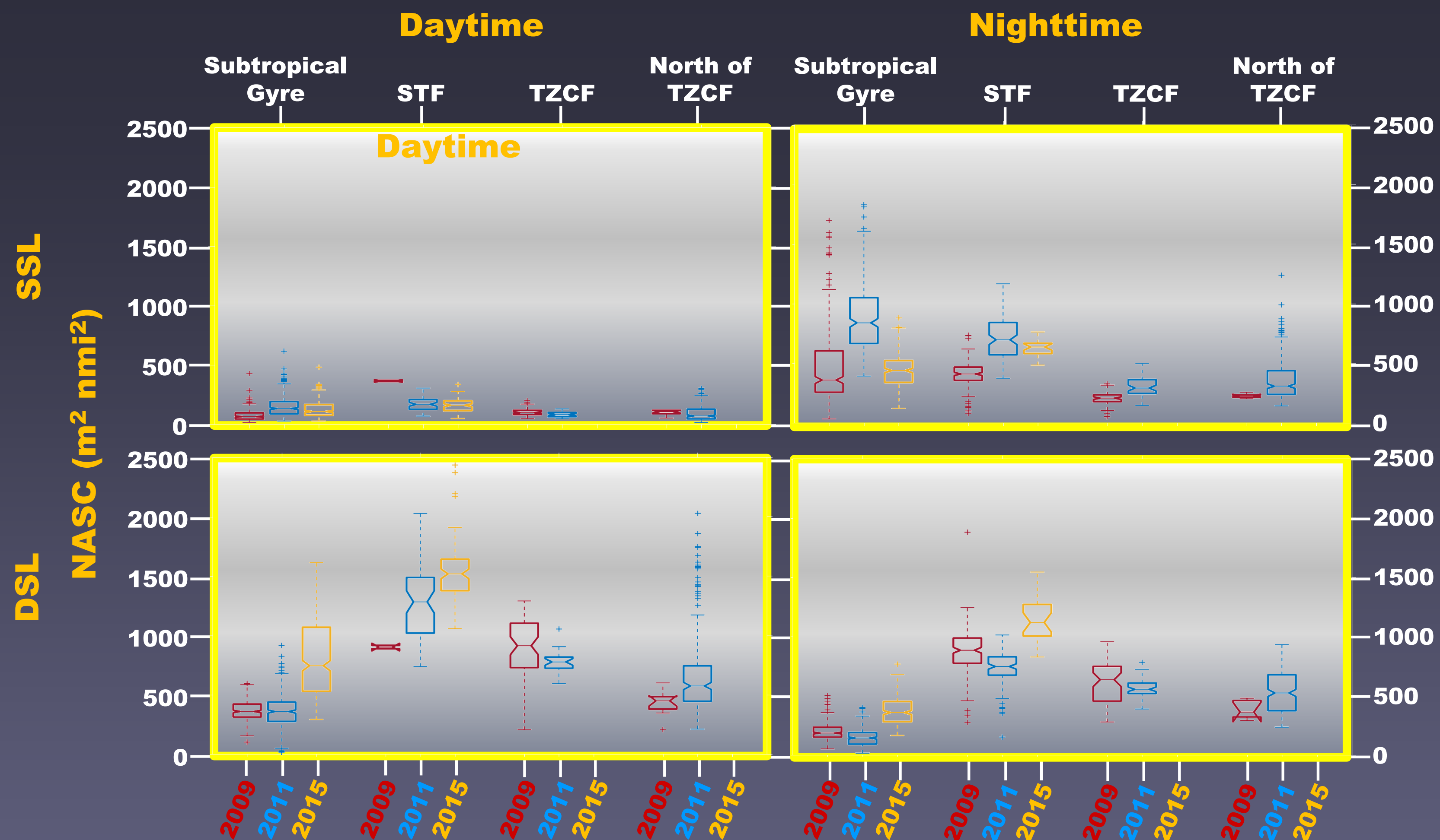
- **3 Surveys conducted in spring 2009, 2011, 2015**
  - **Platform: NOAA vessel Oscar Elton Sette**
  - **Active acoustics (38, 70, 120 kHz)**
  - **Hull mounted ADCP (75 kHz)**
  - **CTD casts (T, S, Chla, O)**
- **Satellite data**
  - **Aviso seal level anomaly & geostrophic currents**
  - **MODIS ocean color**
  - **Pathfinder Sea surface temperature and anomaly**
  - **WindSat Surface winds**



Salinity (PSU)
34.0
34.4
34.8
35.2
Oxygen (ml l-1)
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
STF
2009
2011 N
2011 S
2015
TZCF
36°N
32°N
28°N
24°N
Salinity
Oxygen
Temperature
Chlorophyll
0
100
200
300
Depth (m)
10
12
14
16
18
20
22
Temperature (°C)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Chlorophyll (mg m-3)
NOAA



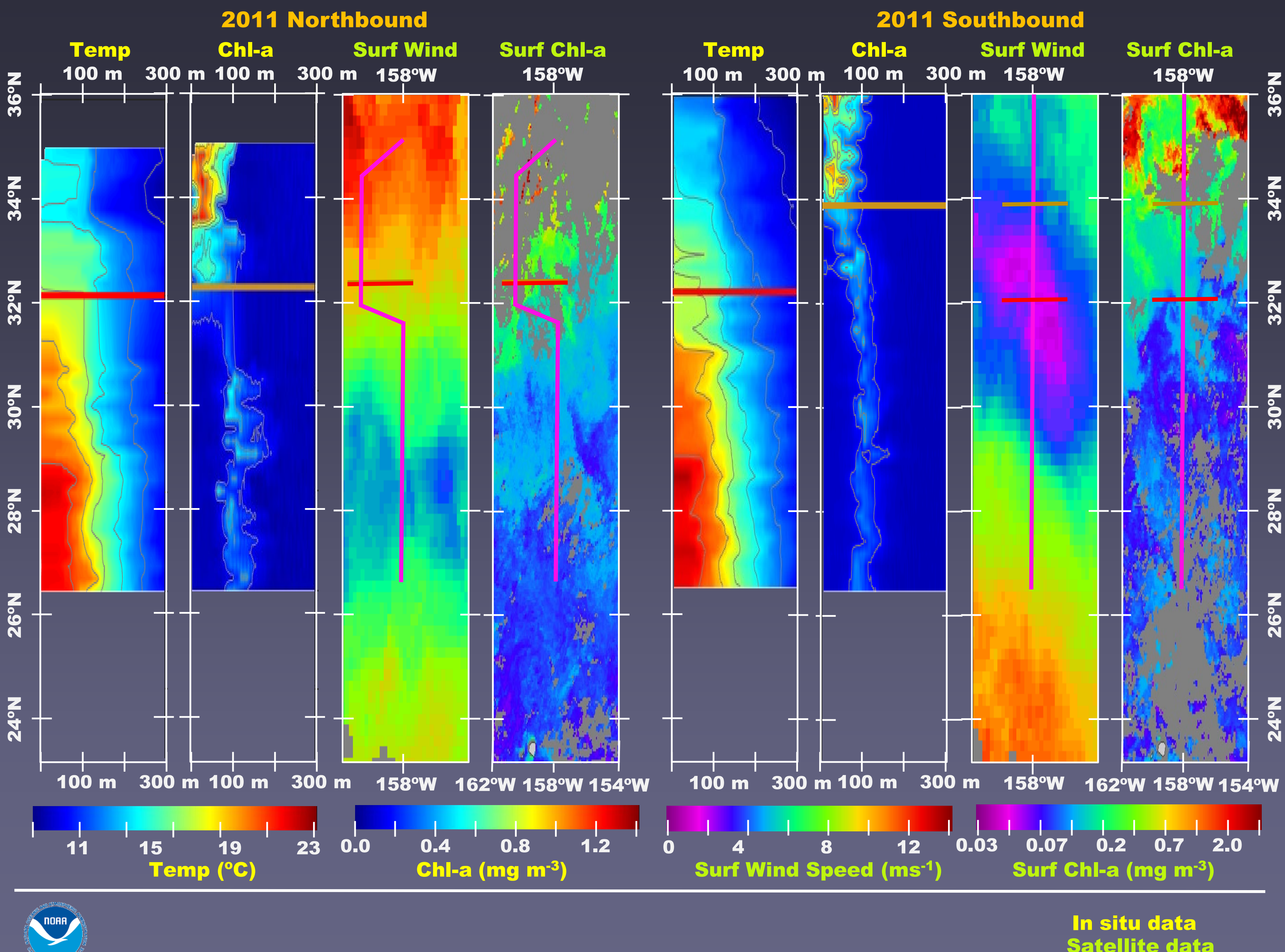
22ºN
24ºN
26ºN
28ºN
30ºN
32ºN
34ºN
36ºN
2009
2011 N
2011 S
2015
Depth (m)
MVBS (dB re 1 m-1)
-62
-70
-78
-86
-94
-102



		NASC vs Front Position	
		STF	TZCF
NASC	DSL	$r = .68; p < .01$	$r = .54; p < .01$
	Water column	$r = .49; p < .01$	$r = .36; p < .01$

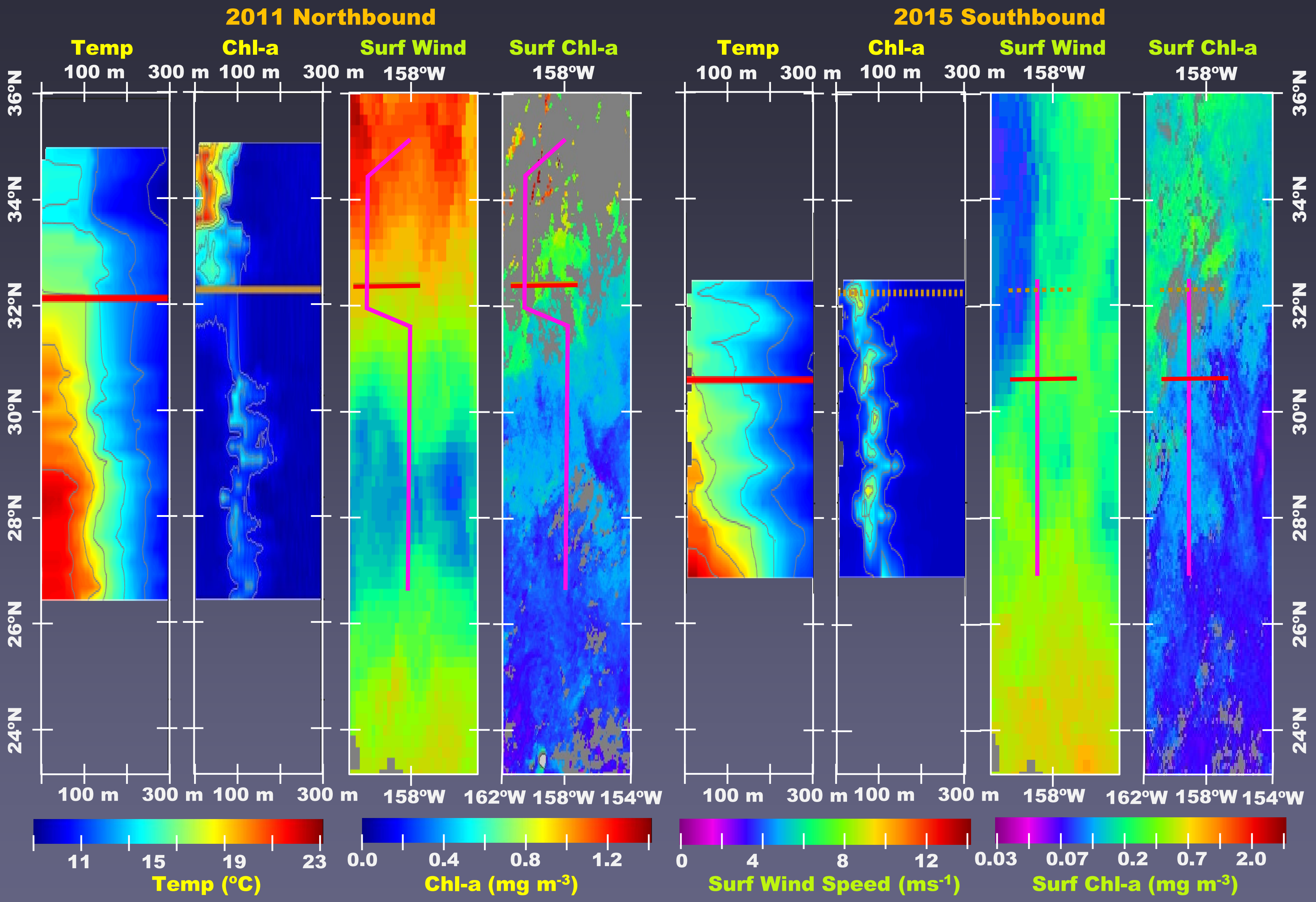
		2009				2011				2015			
Layer		DSL	SSL	SSL	SSL	DSL	SSL	SSL	SSL	DSL	SSL	SSL	SSL
δdB (kHz)		70-38	70-38	120-38	120-70	70-38	70-38	120-38	120-70	70-38	70-38	120-38	120-70
Day	SubG	-1.93±0.06	-2.10±0.05	-6.88±0.04	-6.93±0.03	-2.52±0.04	-2.69±0.03	-6.32±0.04	-4.37±0.03	2.74±0.02	0.35±0.03	-0.23±0.03	-1.61±0.02
	STF	-4.84±1.32	-5.79±0.98	-9.08±4.09	-4.27±2.91	-4.75±0.21	-4.96±0.16	-6.98±0.21	-3.60±0.17	0.96±0.05	-2.19±0.06	0.43±0.10	2.20±0.08
	TZCF	-4.90±0.21	-7.35±0.21	-10.22±0.20	-4.31±0.16	-4.62±0.52	-2.70±0.44	-4.20±0.35	-2.30±0.20	NaN	NaN	NaN	NaN
	N CF	-4.67±0.83	-6.20±1.00	-9.91±0.87	-4.16±0.71	-3.62±0.05	-3.78±0.04	-5.87±0.05	-2.25±0.03	NaN	NaN	NaN	NaN
Night	SubG	-1.05±0.05	-2.10±0.02	-6.46±0.03	-4.71±0.02	-1.03±0.05	-2.68±0.02	-6.44±0.03	-4.20±0.02	4.69±0.05	0.65±0.02	-0.94±0.02	-1.43±0.02
	STF	-4.79±0.11	-5.00±0.05	-8.16±0.04	-3.92±0.04	-4.45±0.13	-3.98±0.05	-8.12±0.08	-4.01±0.07	-0.02±0.25	-1.80±0.13	-1.92±0.18	-0.38±0.14
	TZCF	-4.78±0.19	-4.33±0.13	-7.55±0.17	-2.92±0.16	-4.38±0.25	-3.19±0.08	-7.20±0.16	-3.99±0.14	NaN	NaN	NaN	NaN
	N CF	-3.98±1.69	-4.50±1.02	-9.15±1.35	-4.15±1.47	-3.50±0.05	-3.28±0.02	-6.83±0.03	-3.65±0.03	NaN	NaN	NaN	NaN

		In situ Environmental Variables				
		Temp	SST	Oxy	Chl	SS Chl
NASC	DSL	*r* = .30; *p* < .01	*r* = -.19; *p* = .02	*r* = .42; *p* < .01	--	--
	SSL	--	--	*r* = .39; *p* < .01	*r* =.30; *p* < .01	--



2011 Northbound
2011 Southbound
Temp
Chl-a
Surf Wind
Surf Chl-a
100 m
300 m
158°W
162°W
154°W
36°N
34°N
32°N
30°N
28°N
26°N
24°N
11
15
19
23
Temp (°C)
0.0
0.4
0.8
1.2
Chl-a (mg m^{-3})
0
4
8
12
Surf Wind Speed (ms^{-1})
0.03
0.07
0.2
0.7
2.0
Surf Chl-a (mg m^{-3})
In situ data
Satellite data

		2011 NASC	
		Northbound	Southbound
Layer		Watercolumn	Watercolumn
Day	Subtropical Gyre	464±22	583±25
	North of TZCF	830±67	595±20
Night	Subtropical Gyre	863±37	1112±41
	North of TZCF	988±63	780±25



2011 Northbound
2015 Southbound
Temp
Chl-a
Surf Wind
Surf Chl-a
100 m
300 m
158ºW
162ºW
154ºW
36ºN
34ºN
32ºN
30ºN
28ºN
26ºN
24ºN
11
15
19
23
Temp (ºC)
0.0
0.4
0.8
1.2
Chl-a (mg m-3)
0
4
8
12
Surf Wind Speed (ms-1)
0.03
0.07
0.2
0.7
2.0
Surf Chl-a (mg m-3)
In situ data
Satellite data

		2009				2011				2015			
Layer		DSL	SSL	SSL	SSL	DSL	SSL	SSL	SSL	DSL	SSL	SSL	SSL
δdB (kHz)		70-38	70-38	120-38	120-70	70-38	70-38	120-38	120-70	70-38	70-38	120-38	120-70
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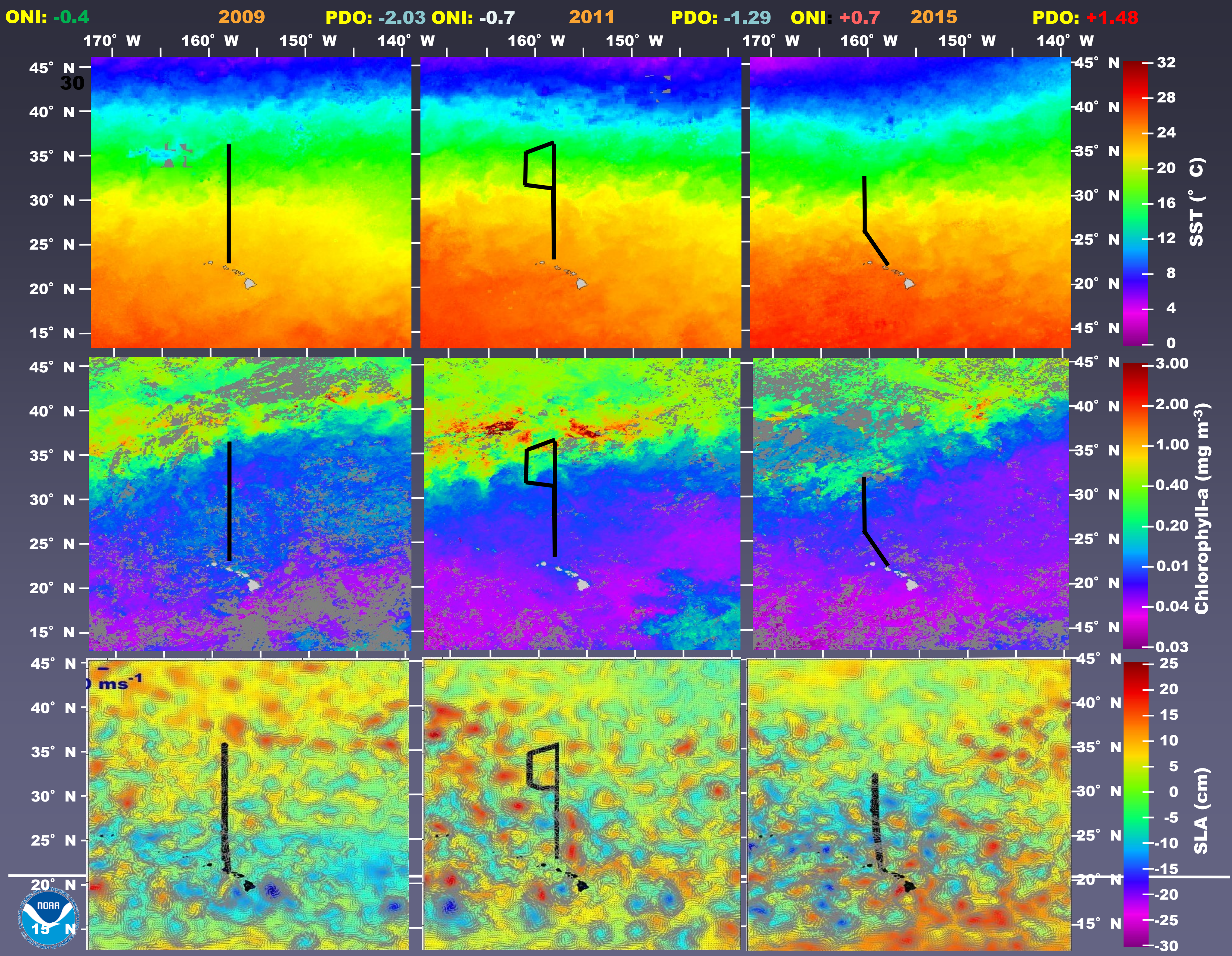
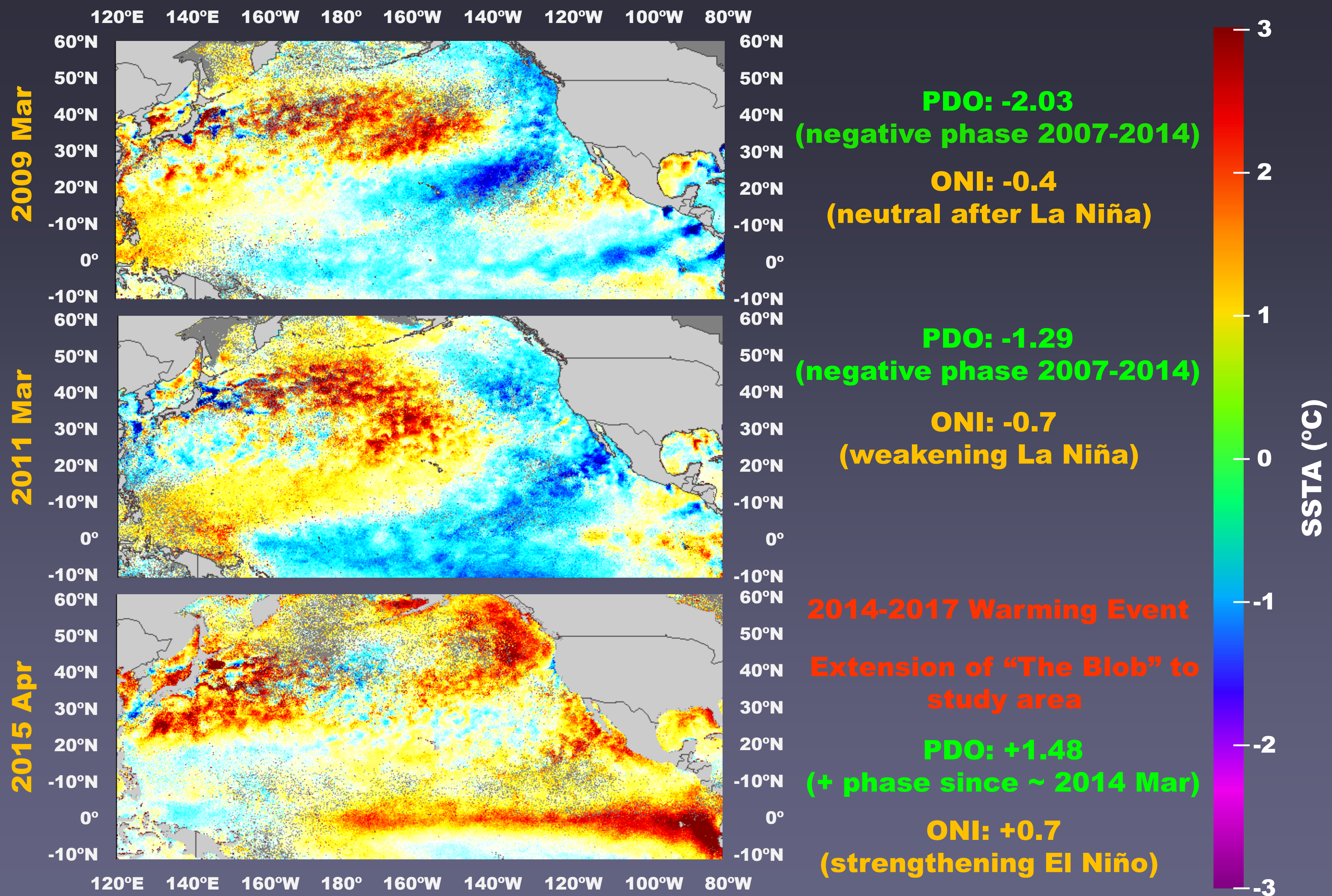


ONI: -0.4
2009
PDO: -2.03
ONI: -0.7
2011
PDO: -1.29
ONI: +0.7
2015
PDO: +1.48
170° W
160° W
150° W
140° W
45° N
40° N
35° N
30° N
25° N
20° N
15° N
30
SST (° C)
32
28
24
20
16
12
8
4
0
Chlorophyll-a (mg m⁻³)
3.00
2.00
1.00
0.40
0.20
0.01
0.04
0.03
ms⁻¹
SLA (cm)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30



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Conclusions

- **Micronekton NASC primarily correlated to position of STF**
  - highest correlation in DSL, then Watercolumn
  - SSL NASC is not correlated with position of STF
  - secondary correlation with position of TZCF (meridional extent)
  - composition differs north & south of STF
- **Satellite color (surface Chl-a)**
  - did not correlate with in situ surface Chl-a, subsurface Chl-a, nor micronekton NASC
  - is it a valid proxy for TZCF (mesoscale effects?) nor indicative of subsurface conditions
- **Effects of mesoscale forcing seems to affect position of fronts and micronekton biomass**
  - southward displacement of TZCF and increased micronekton biomass due wind stress (vertical mixing)
  - some indication of southward displacement of STF due to cyclonic eddy activity (shallow mixed layer depth)
  - shallower MLD due to cyclonic eddy activity corresponds with increased subsurface Chl-a which correlated to SSL NASC (but not to DSL or watercolumn)
- **2015 – very unusual year relative to 2009 & 2011**
  - largescale effects: 2014-17 warming, proximity of blob, positive PDO and ONI
  - backscatter significantly higher than during the two other years
  - composition of scattering layers significantly different then other years (suggesting mesoscale effects not significant)

Acknowledgements

- Amy Comer and Aimee Hoover for their meticulous cleaning of noisy 2009 and 2011 backscatter data in Echoview
- Audrey Rollo for providing assistance with some of the figures
- Jeffrey Polovina and Evan Howell providing useful information on their prior work regarding the TZCF
- The crew and scientists of the Oscar Elton Sette without whose help this project would not been possible

Questions?