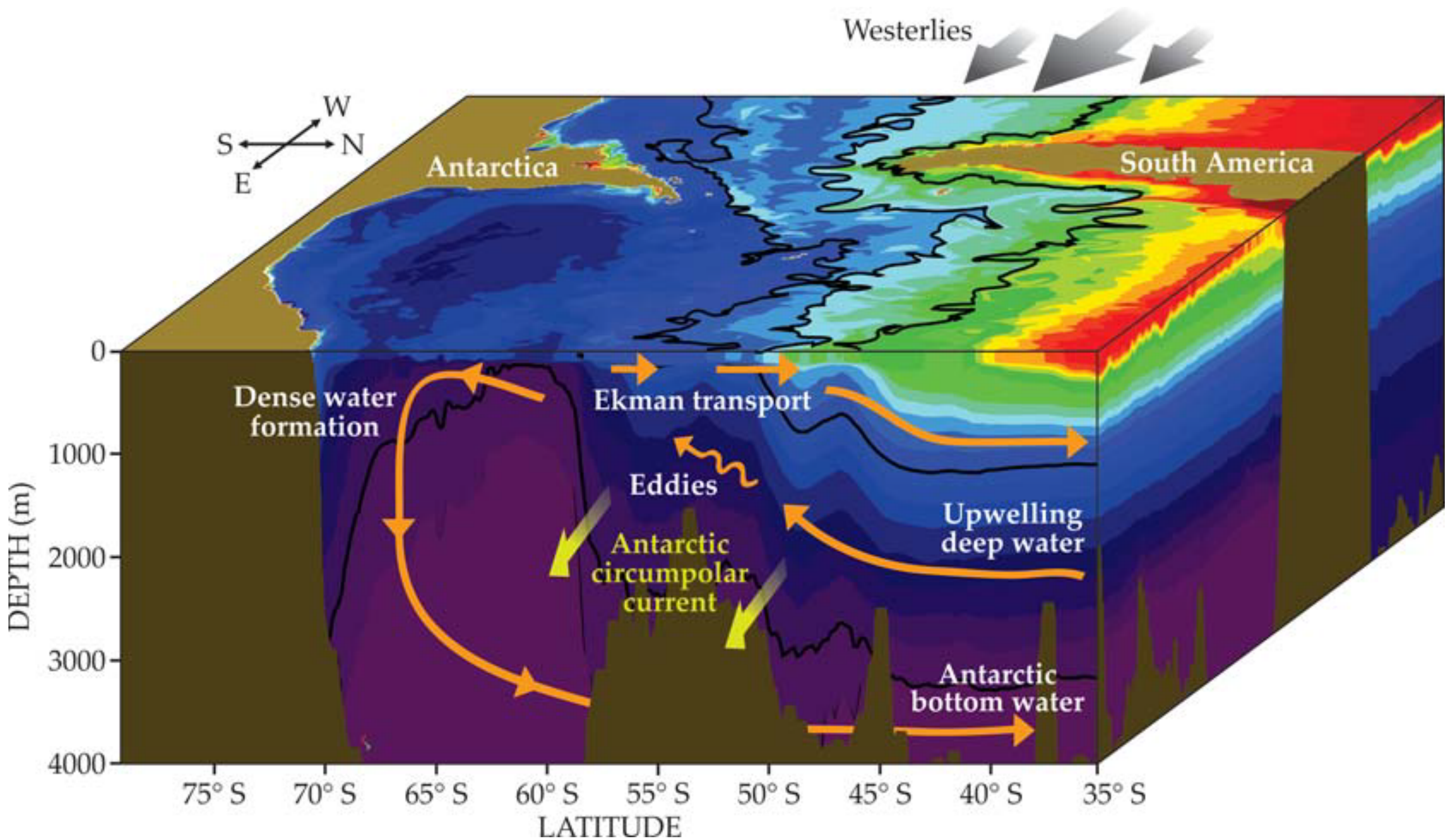
SOCCOM

Southern Ocean Carbon and Climate Observations and Modeling

The challenge

Deep ocean outflow: about 80% occurs in the Southern Ocean



Morrison et al. (Physics Today, 2015)

Consequences for the role of the Southern Ocean in carbon and climate

The ocean south of 30°S accounts for

- Nutrient supply supporting three-quarters of biological production north of 30°S
- Half of the current anthropogenic carbon dioxide uptake by the oceans (43 ± 3% in CMIP5 models)
- About 75% ± 22% of excess heat uptake by the oceans (in CMIP5 models)

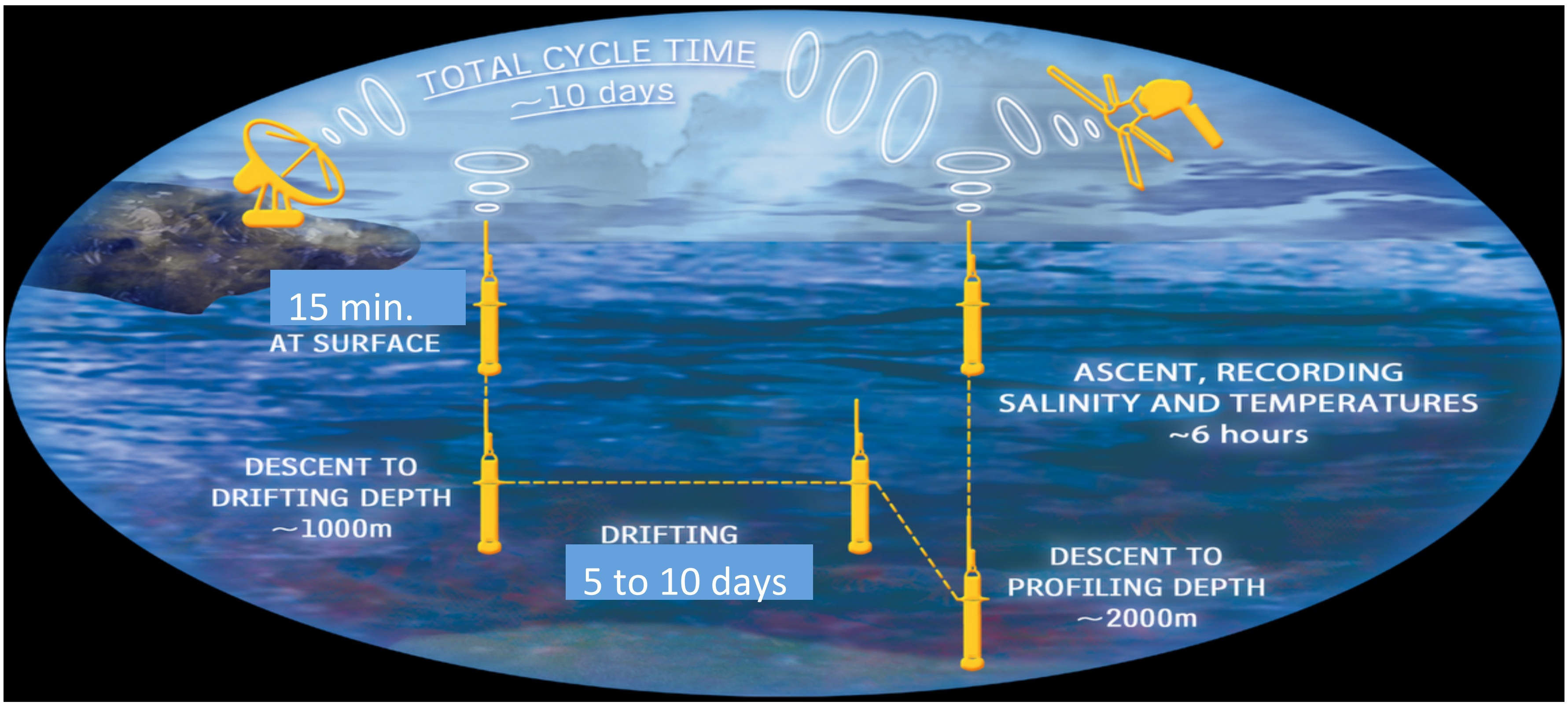
The grand challenge

- Despite its critical importance, the Southern Ocean is the least understood region of the world ocean.
  - The meridional overturning circulation and its response to climate change are highly uncertain
  - Biogeochemical and carbon cycling are poorly constrained
  - Current climate models are unable to resolve the crucial contribution of eddies
- And yet
  - It is the least observed region of the world ocean
  - The public is largely unaware of the importance of this region
  - We are sorely lacking in experts on the Southern Ocean

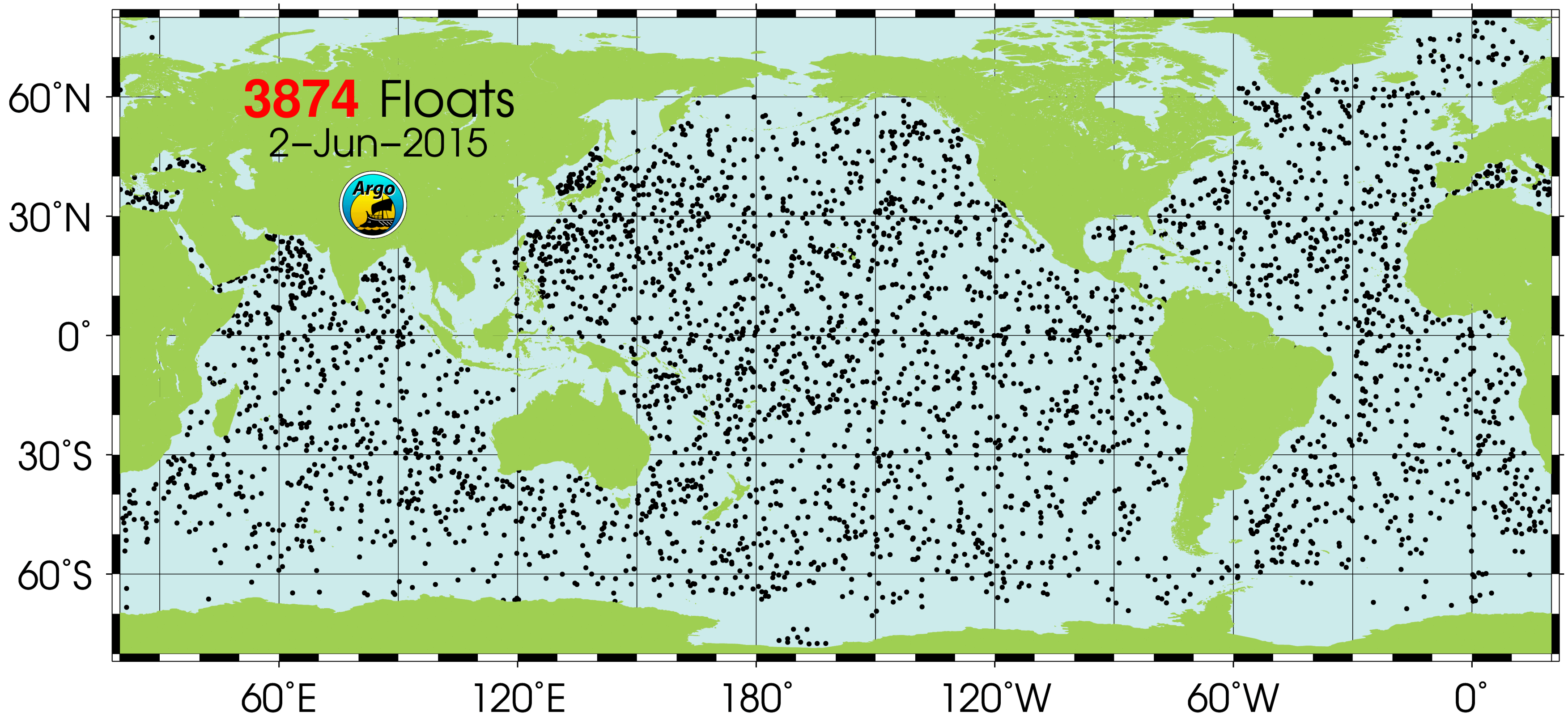
The opportunity

(1) Transformative observing system

- Argo profiling floats
  - have a 4 to 7 year lifetime,
  - Measure T & S from ~2000 m to the surface each 5 to 10 days.
  - data direct to Internet.



Current Argo float distribution



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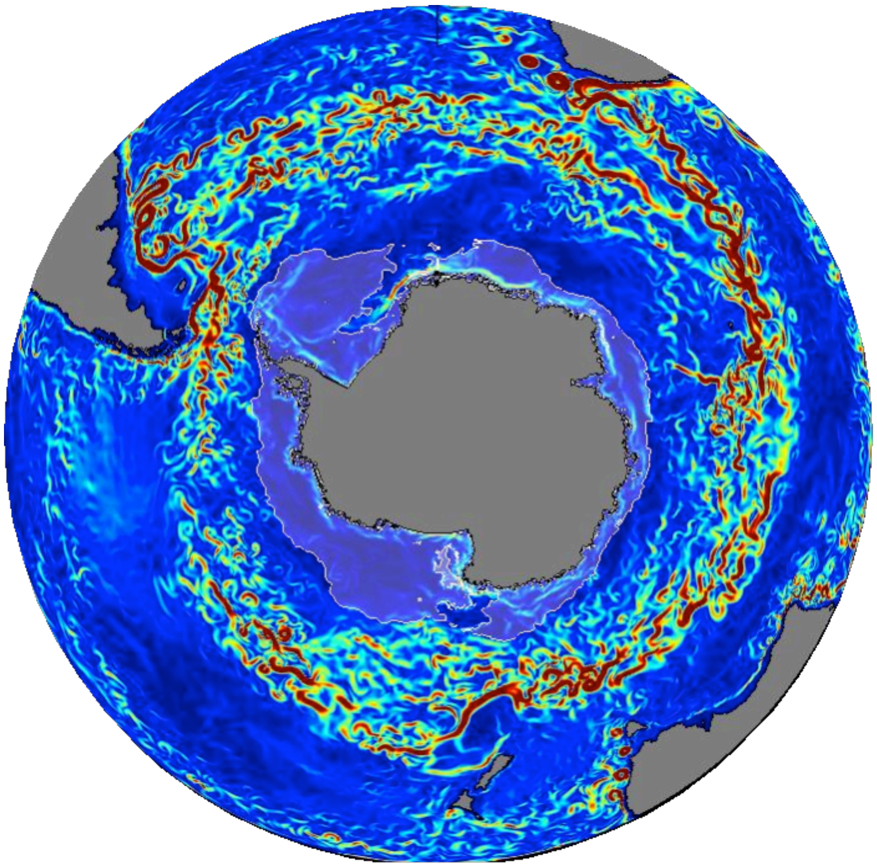
Southern Ocean: a paradigm shift
Transformative biogeochemical sensors

- Field developing rapidly:
  - Körtzinger, et al. (2005) – O_2
  - Tengberg et al. (2006) – O_2
  - Riser and Johnson (2008) – O_2
  - Johnson et al. (2010) – ISUS nitrate
  - Johnson et al. (2013) – ISUS nitrate
  - Martz et al. (2010) – Durafet pH
  - Ongoing work
  - E. Boss et al. (2008) – FLBB optics
  - Whitmire et al. (2009) – FLBB optics
  - Boss and Behrenfeld (2010) – FLBB optics

(2) Transformative observational analysis methods



- Southern Ocean State Estimation (SOSE) using data assimilation to produce full 4D estimates of ocean properties

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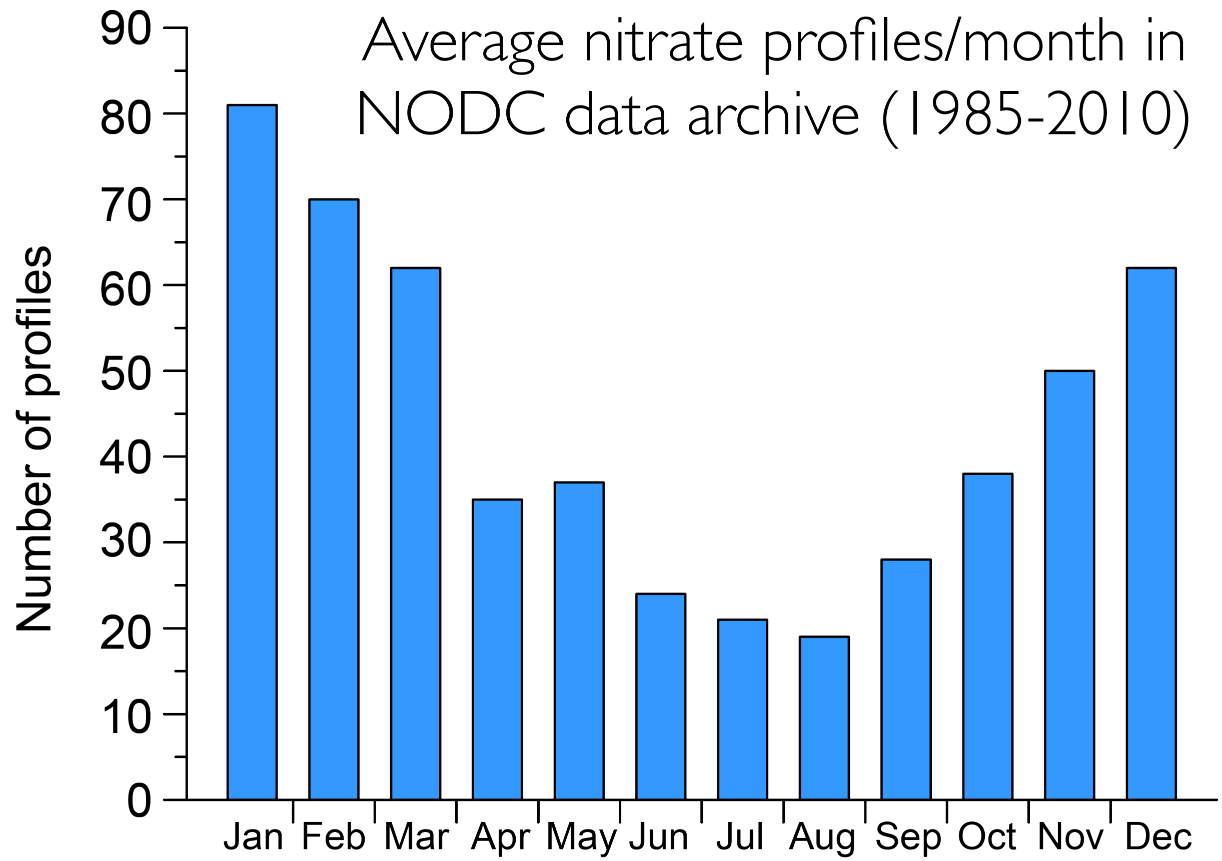
The plan

Specific Objectives

- **Objective 1:** To develop a new observing system for carbon, nutrients, and oxygen based on ~200 biogeochem floats
- **Objective 2:** To produce an unprecedented 3-dimensional space and time resolved estimate of Southern Ocean biogeochemistry based on SOSE.

Nutrient profiles south of 30°S

The goal of SOCCOM is to measure ~500 profiles per month every month of the year



Proposed deployment cruises (6 yrs):

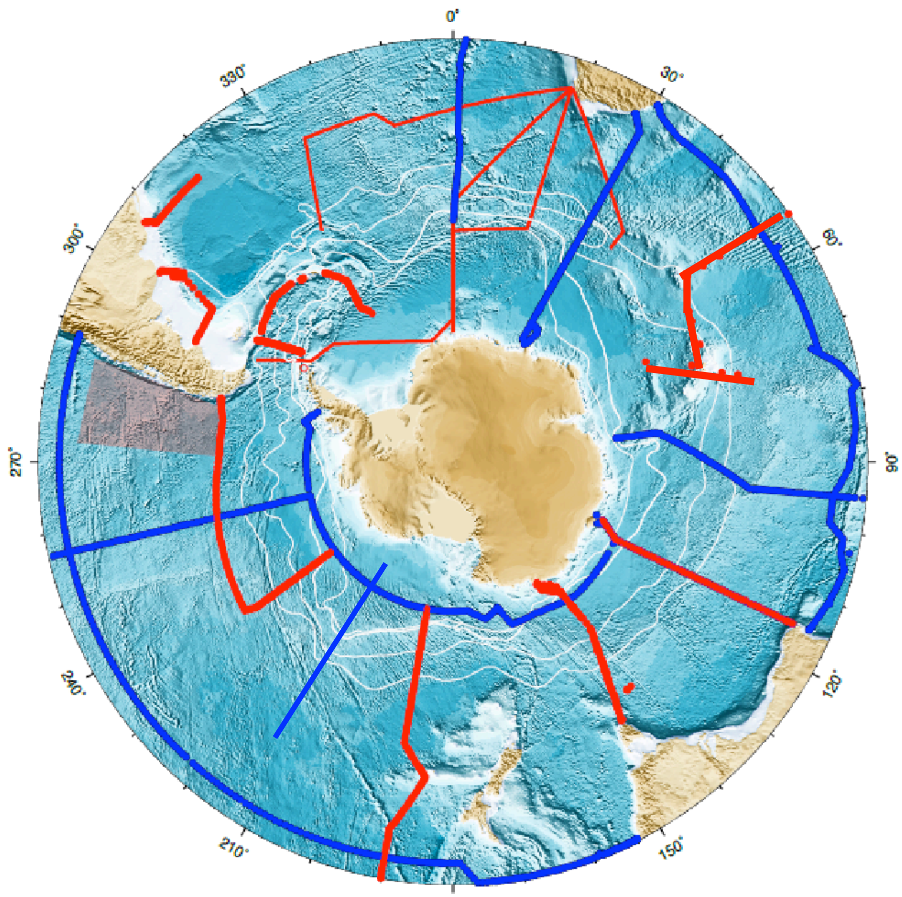


Table 2. Proposed float production and research ship deployment, with source of calibration costs. *Full chemistry/CTD provided (no cost to SOCOM):* (a) U.S. GO-SHIP cruises (ushydro.ucsd.edu) and (b) other, mostly international, cruise collaborations. *Some SOCOM calibration costs required:* (c) international cruise collaborations with partial SOCOM support (chemistry only), and (d) requested UNOLS cruises requiring full support (chemistry and CTD).

Year	Floats Totals		In situ calibration at **no cost** to SOCOM		In situ calibration costs paid partially or in full by SOCOM	
	Build	Deploy	a. US GO-SHIP b. Other	Deploy	c. Chemistry only d. SOCOM UNOLS cruises	Deploy
2014/2015	39	17	(none)		Polarstern (Ger.)	15
			SOTS (Aust.)	2		
2015/2016	23	43	P18 (US)	4	Malvinas (Arg.)	4
			I08S (US)	4	Pacific/Ross Sea (SOCOM)	25
			P15S (Aust.)	6		
2016/2017	35	26	P6 (US)	6	SR1/A23 (UK)	7
			SR3 (Aust.)	5		
			P17E/P19C (Japan)	2		
			OISO (Fr.)	4		
			LTER (US)	2		
2017/2018	27	38	I5 (US)	7	Indian Antarctic (SOCOM)	25
			I9S (Aust.)	6		
2018/2019	31	31	I6S (US)	8	SE Pac. (Chile)	4
			A13.5 (US)	7	SE Atl. (S. Africa)	6
			OISO (Fr.)	6		
2019/2020	30	30	S4P (US)	16	Good Hope (S. Africa)	6
			LTER (US)	2	SAMOC (Arg./Brazil)	6
Totals	185	185	15 cruises	87	9 cruises	98

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Sources of support

Agency	Program manager	Contribution
NSF/PLR	Peter Milne	Core support ($3.5M/yr x 6 yr; PI: J. Sarmiento)
NOAA/CPO	Stephen Piotrowicz	50% of Argo equivalent floats
NOAA/GFDL	V. Ramaswamy	Mesoscale eddying coupled climate model simulations
NASA	Paula Bontempi	Optical sensors for Argo floats (PI: E. Boss & O. Schofield)

Accomplishments

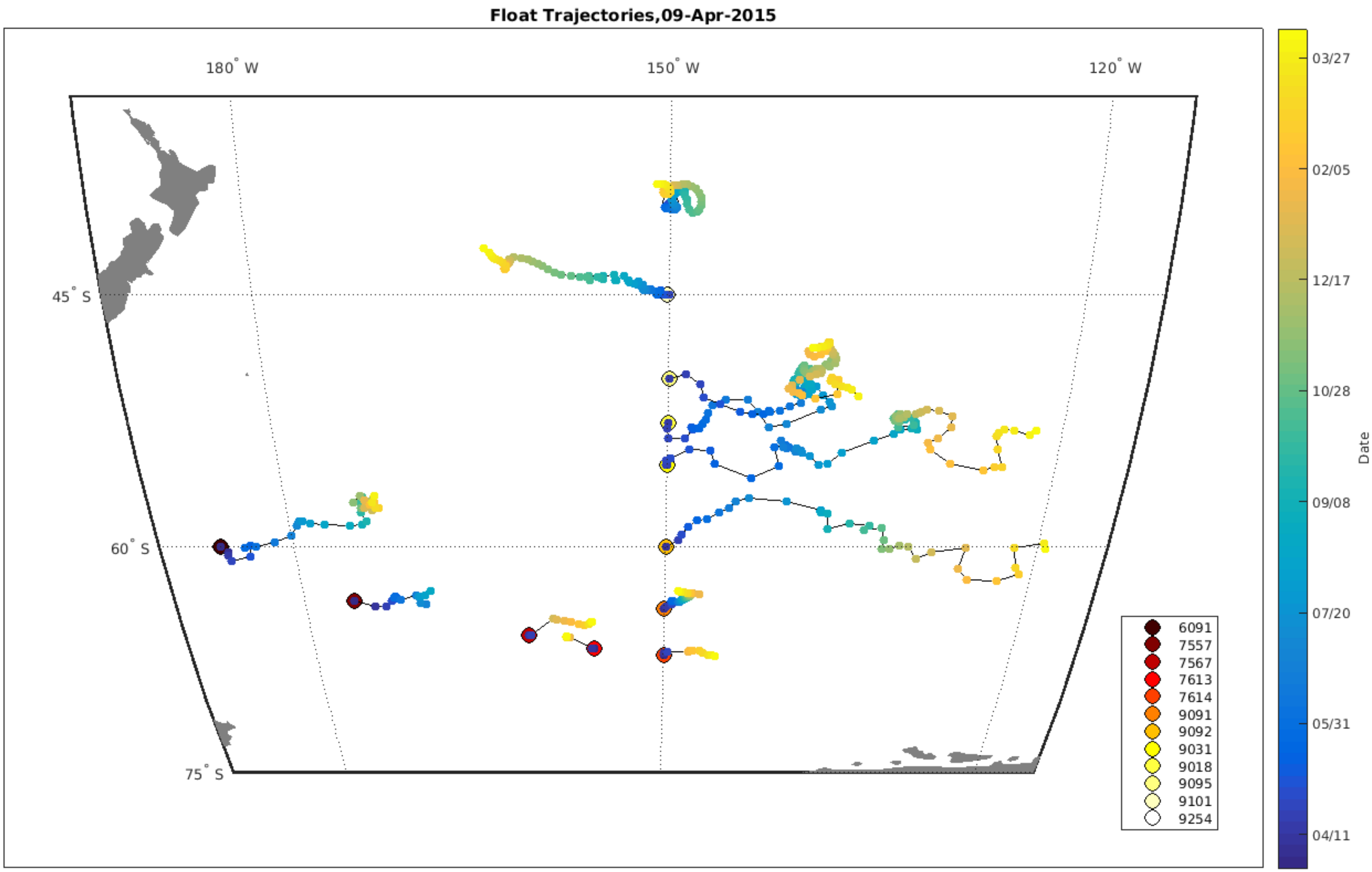
SOCCOM started Sept. 1, 2014

SOCCOM Year 1 accomplishments

Theme	Topic	Significant results
Observa-tional	Floats	• 12 in pre-SOCCOM (EAGER) • 13 in Year 1
	Cruises	• P16S Pre-SOCCOM (EAGER) (Pacific) • Polarstern (Atlantic) • SOTS (Pacific)
	Data availability	• Available in real time from SOCCOMViz • pH sensor analysis in progress
	State Estimation	• Biogeochemical models setup and being tested

Some early results from Alison Gray & Ken Johson analysis of pre-SOCCOM P16S cruise

Float trajectories (pre-SOCCOM P16S)



Different regimes

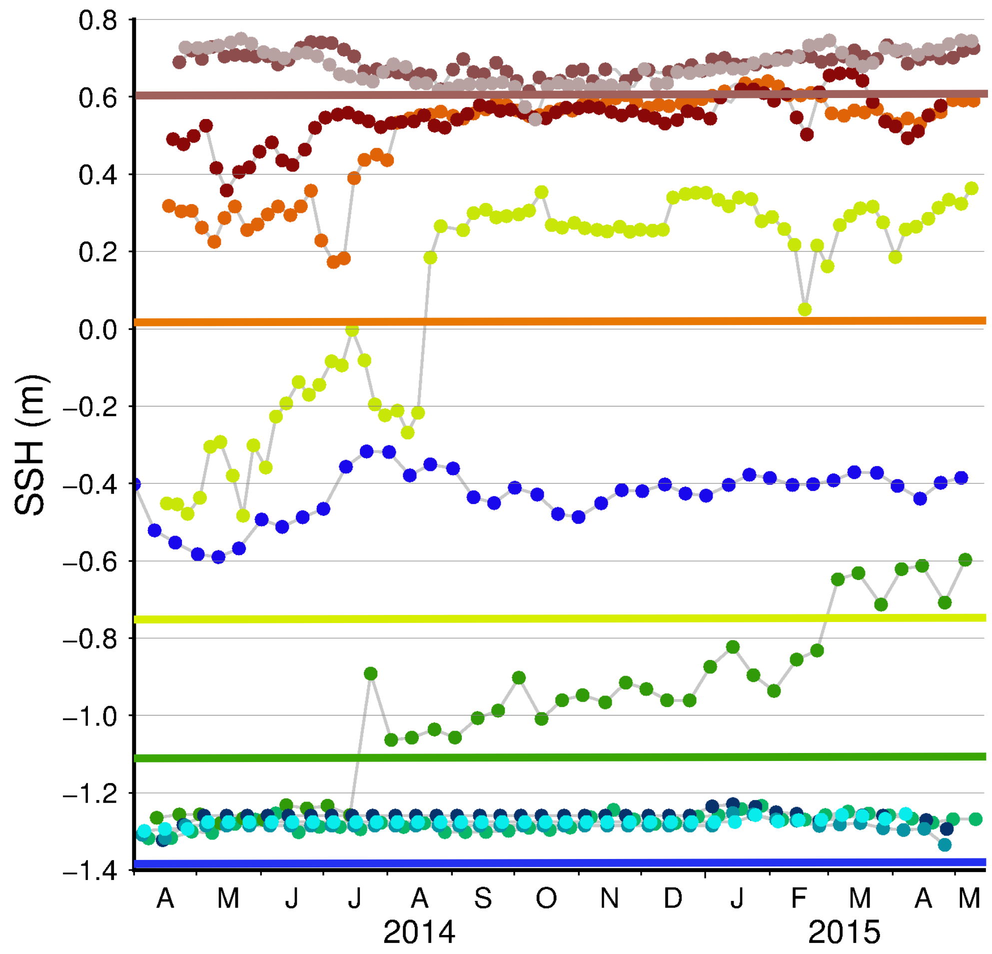
Subtropical Front Zone

Subantarctic Front Zone

Polar Front Zone

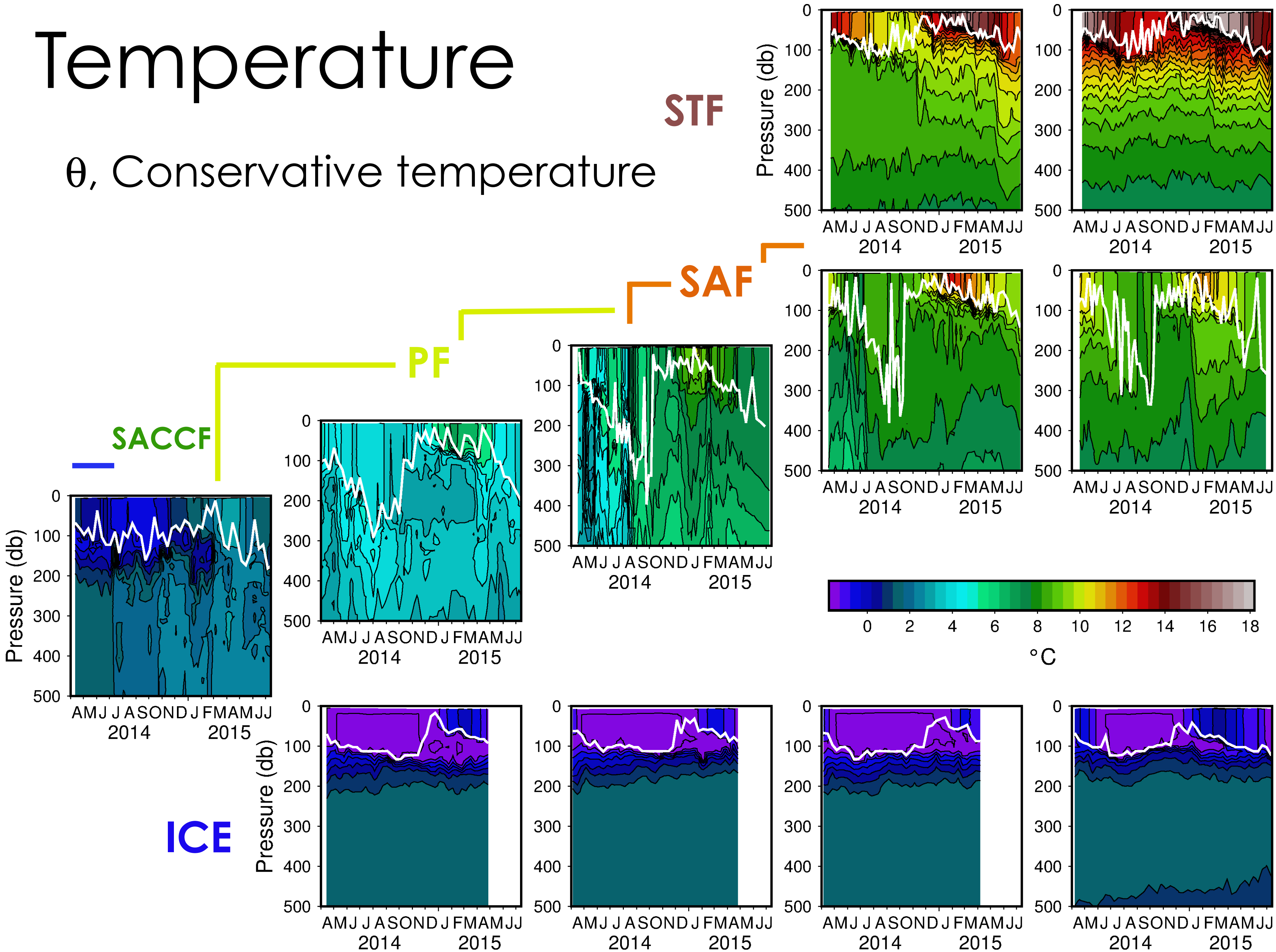
South ACC Front Zone

Seasonal Ice Zone



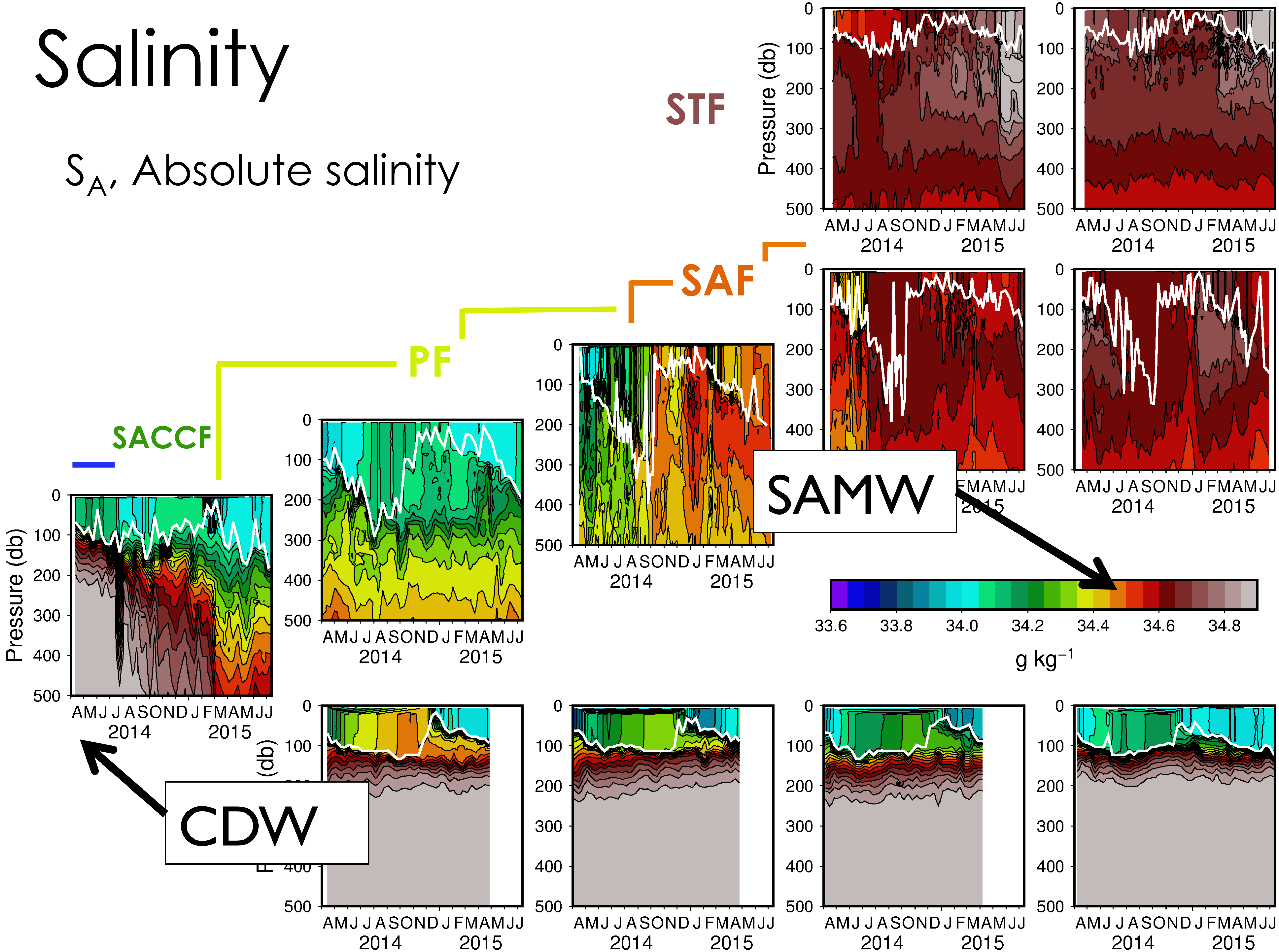
Temperature

θ, Conservative temperature



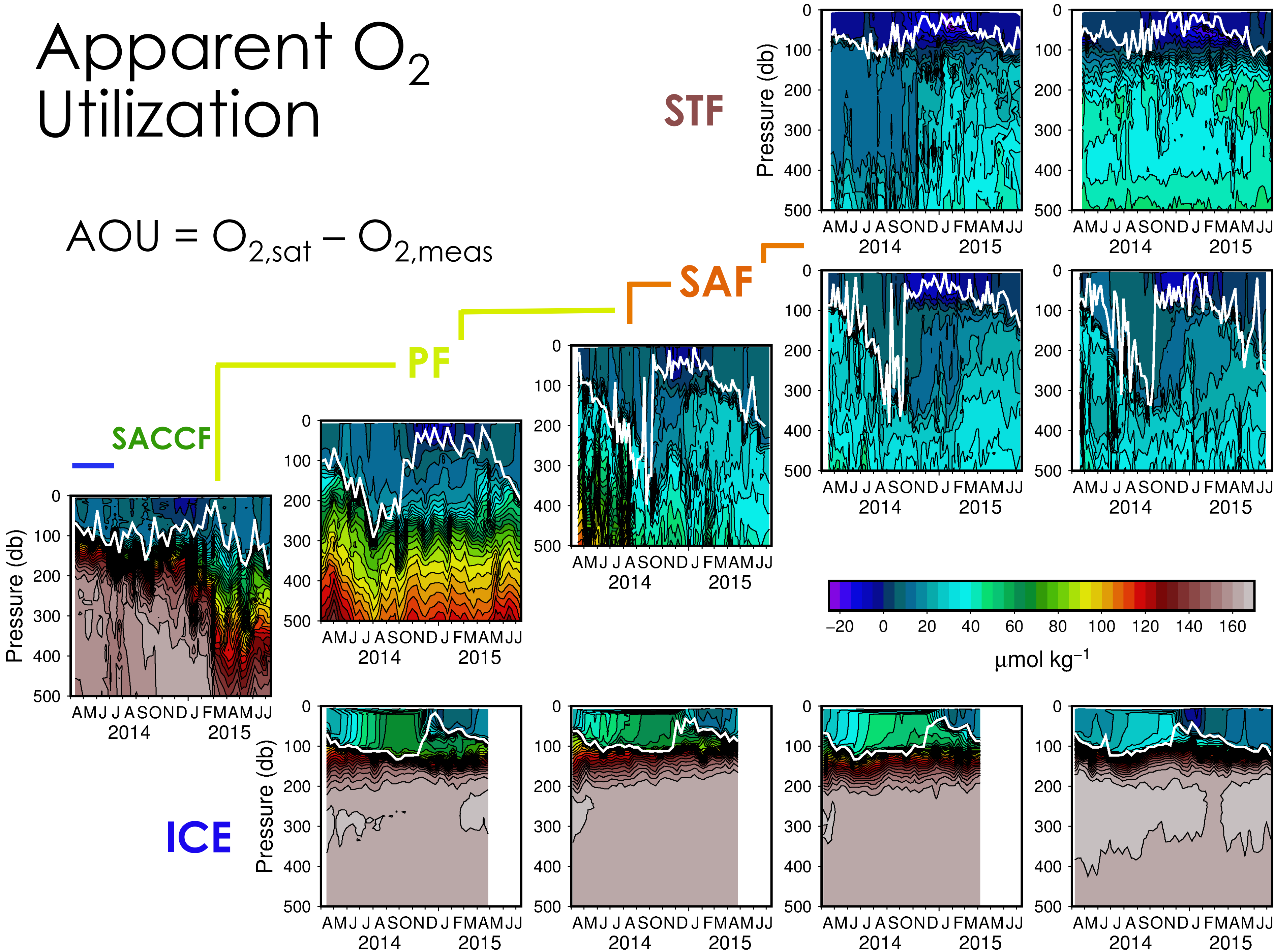
Salinity

S_A, Absolute salinity

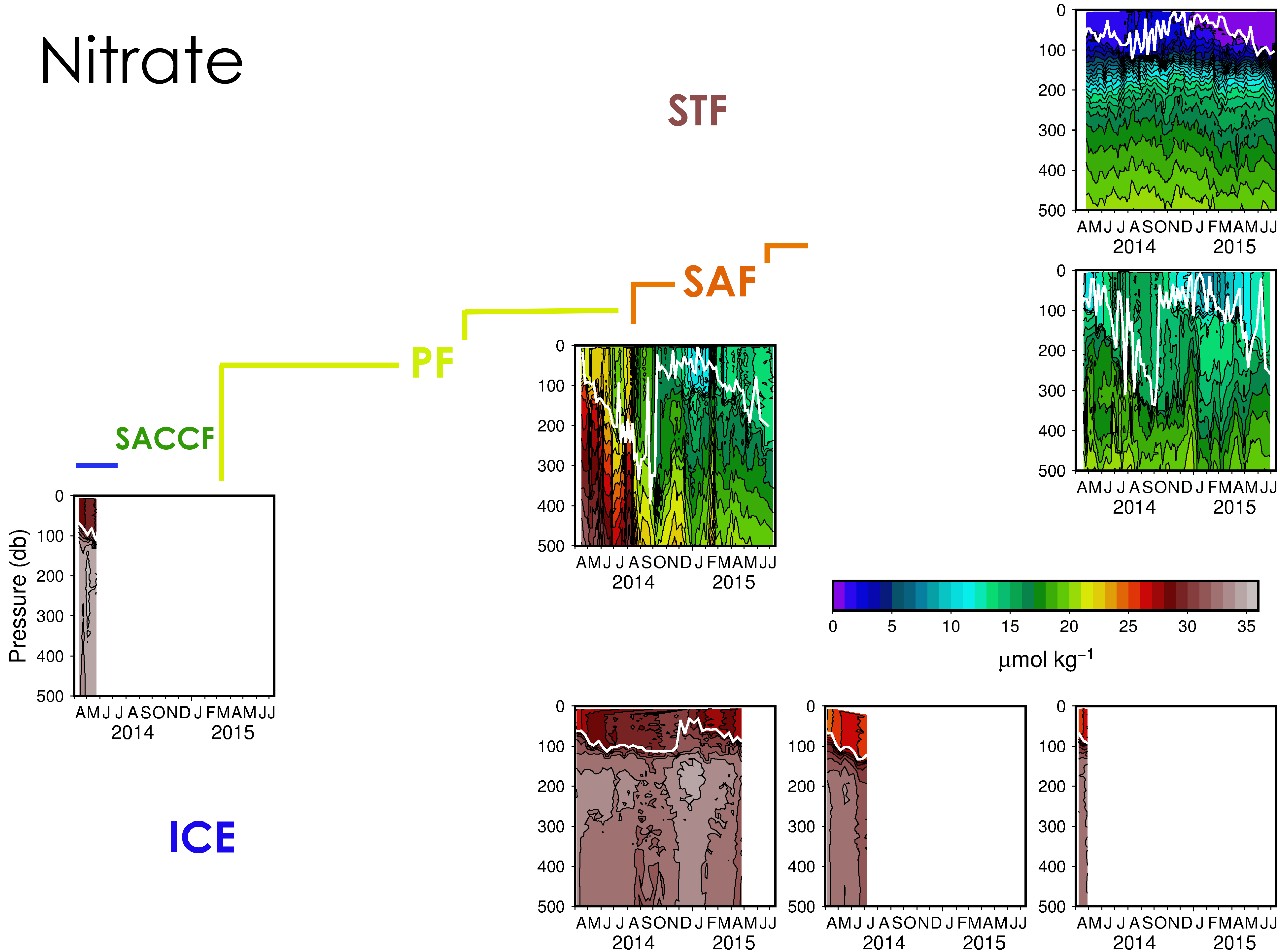


Apparent O_2 Utilization

$$AOU = O_{2,sat} - O_{2,meas}$$



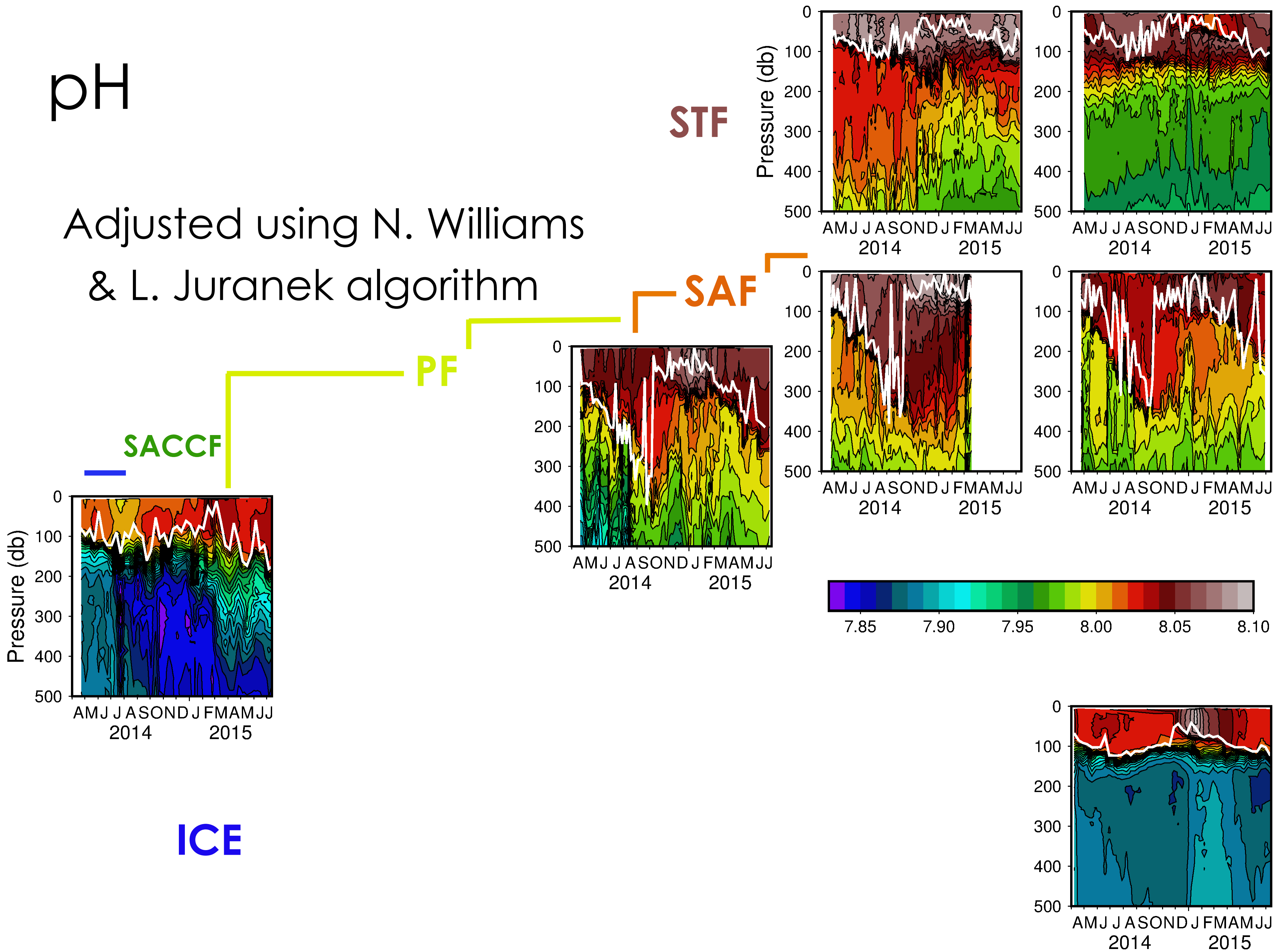
Nitrate



STF
SAF
PF
SACCF
ICE
Pressure (db)
0
100
200
300
400
500
AMJ J ASOND J FMAMJJ
2014
2015
0
5
10
15
20
25
30
35
µmol kg⁻¹

pH

Adjusted using N. Williams & L. Juranek algorithm



Alkalinity

Estimated using 3D-window multiple linear regression algorithm, developed by B. Carter based on Velo et al. 2013 (cf. ongoing work by N. Williams, L. Juranek, & R. Feely)

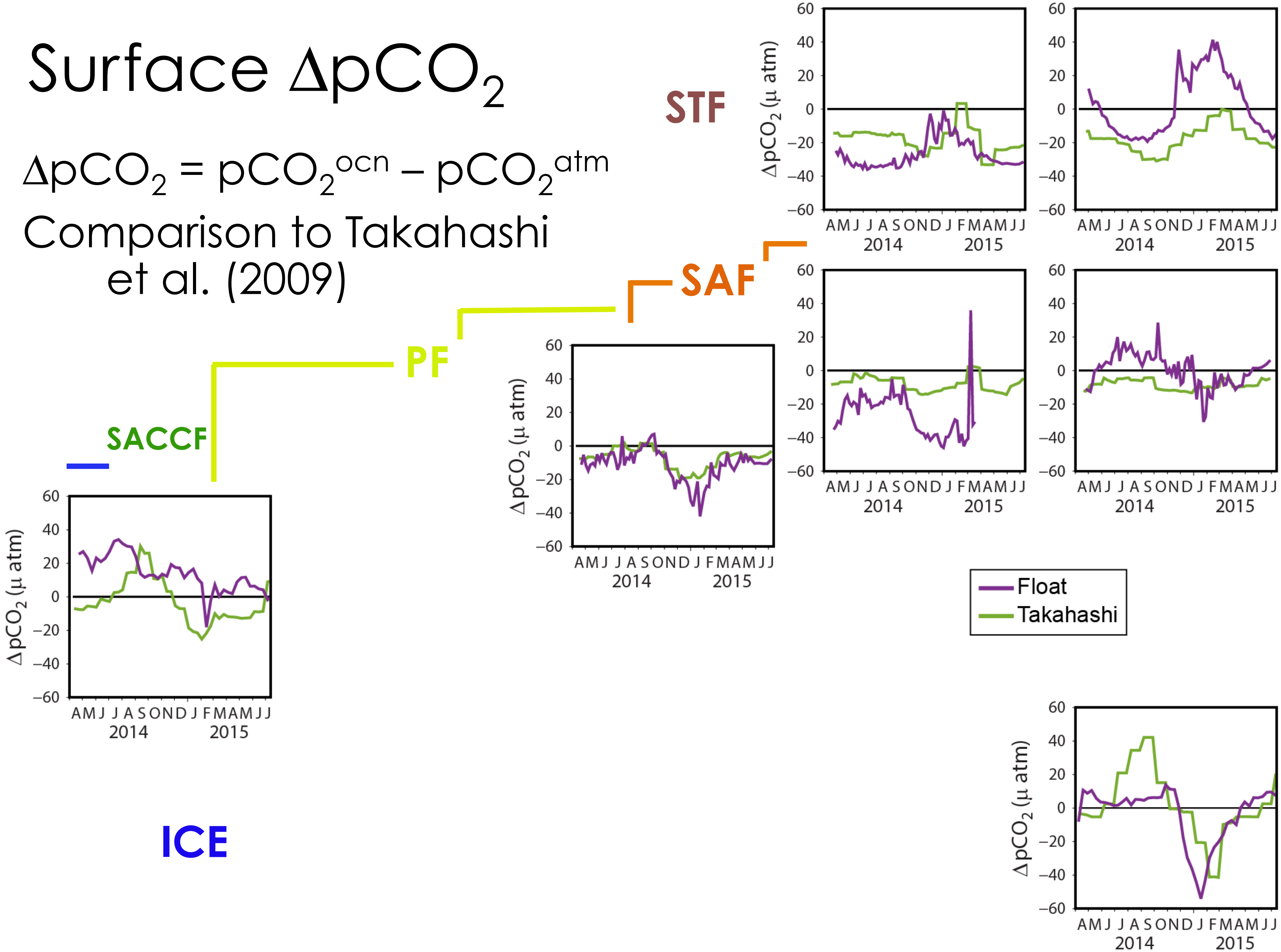
Algorithm is trained using bottle data (GLODAPv1 + PACIFICA + CARINA)

$Alk_{est} = f(S, \theta, NO_3, O_2)$ for 3 floats
$Alk_{est} = f(S, \theta, O_2)$ for 4 floats

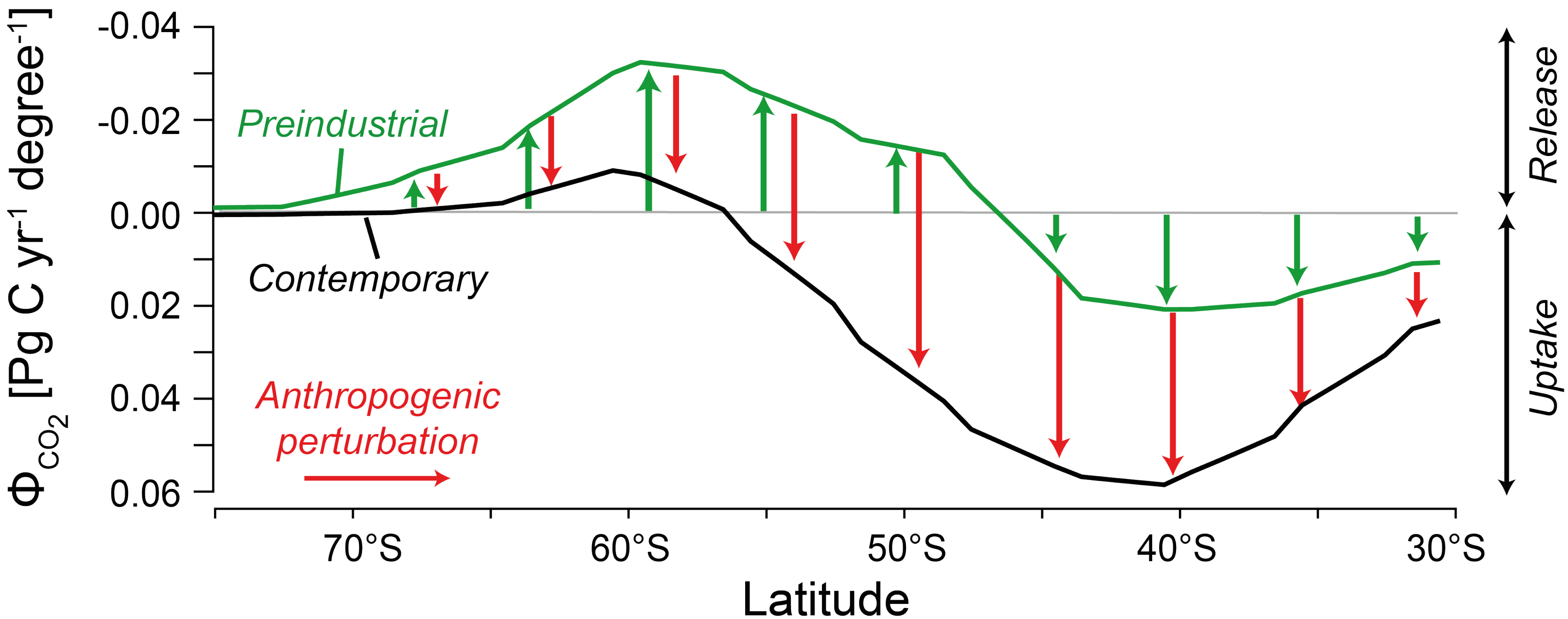
Surface ΔpCO_2

$\Delta pCO_2 = pCO_2^{ocn} - pCO_2^{atm}$

Comparison to Takahashi et al. (2009)



Air-sea CO_2 fluxes in the Southern Ocean south of 30°S



Pre-industrial from Mikaloff-Fletcher et al. (2006); Contemporary from Takahashi et al. (2009)

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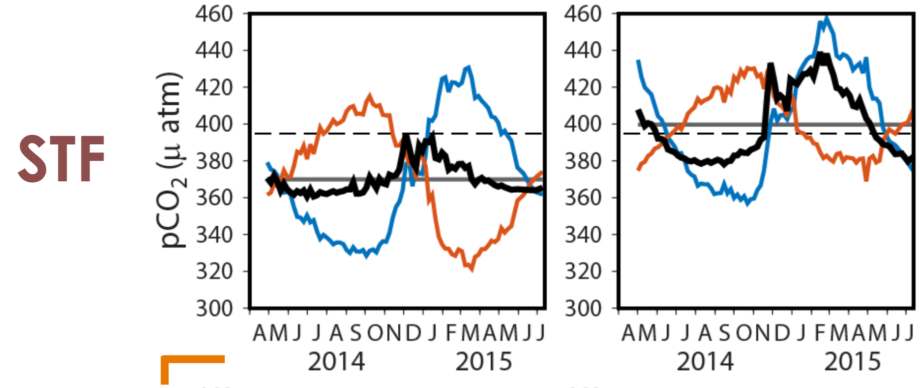
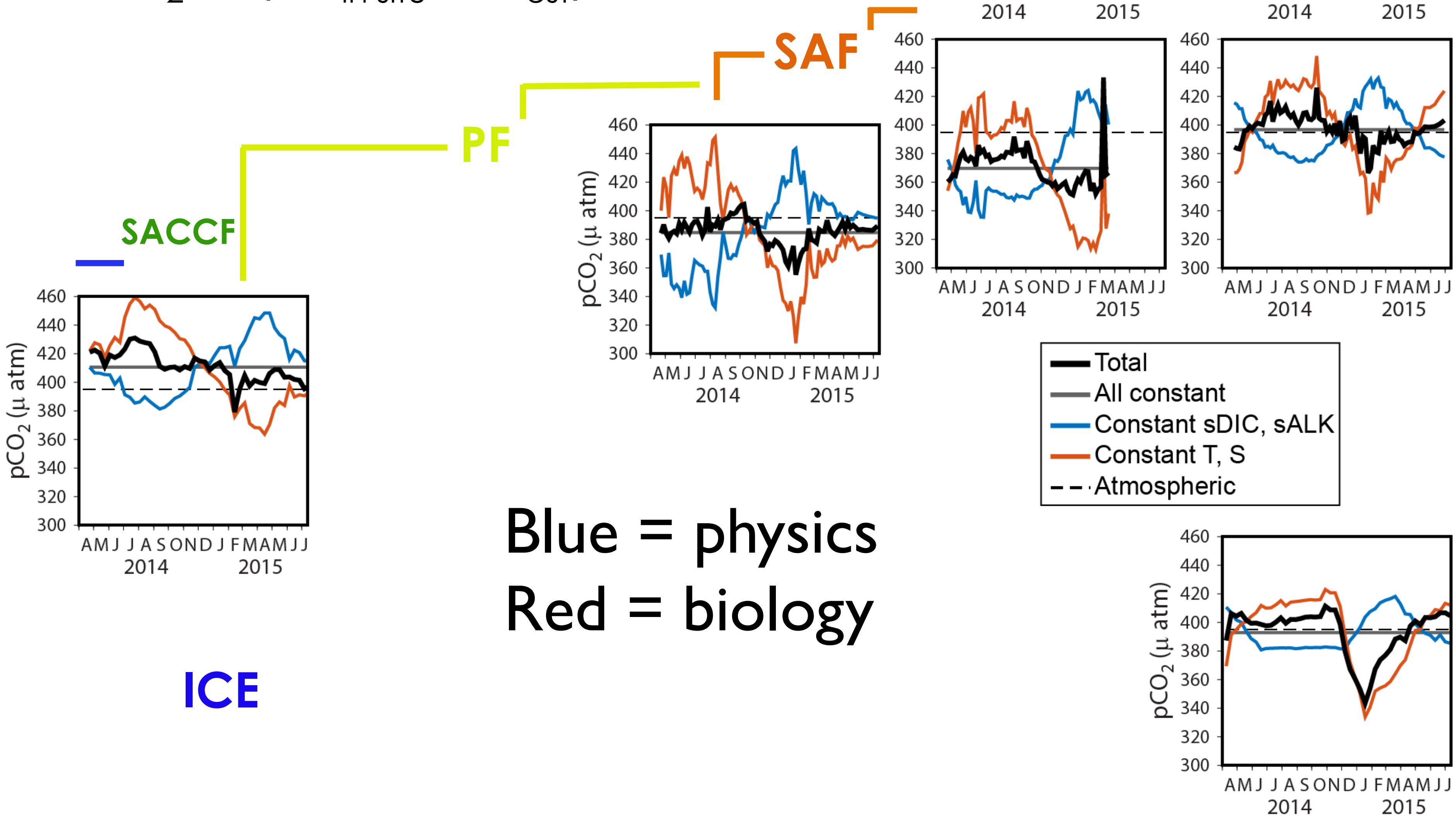
Froelicher et al. (pers. comm.)

Surface pCO_2

$pCO_2 = f(pH_{in\ situ}, Alk_{est})$





Blue = physics

Red = biology

What's next?

- Mixed layer budgets
  - Carbon processes
  - Stoichiometric ratios
  - Chl:C ratio
- SOSE (Southern Ocean State Estimate)
- OSSEs (Observation System Simulation Experiments)
- BGC Argo global coverage

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