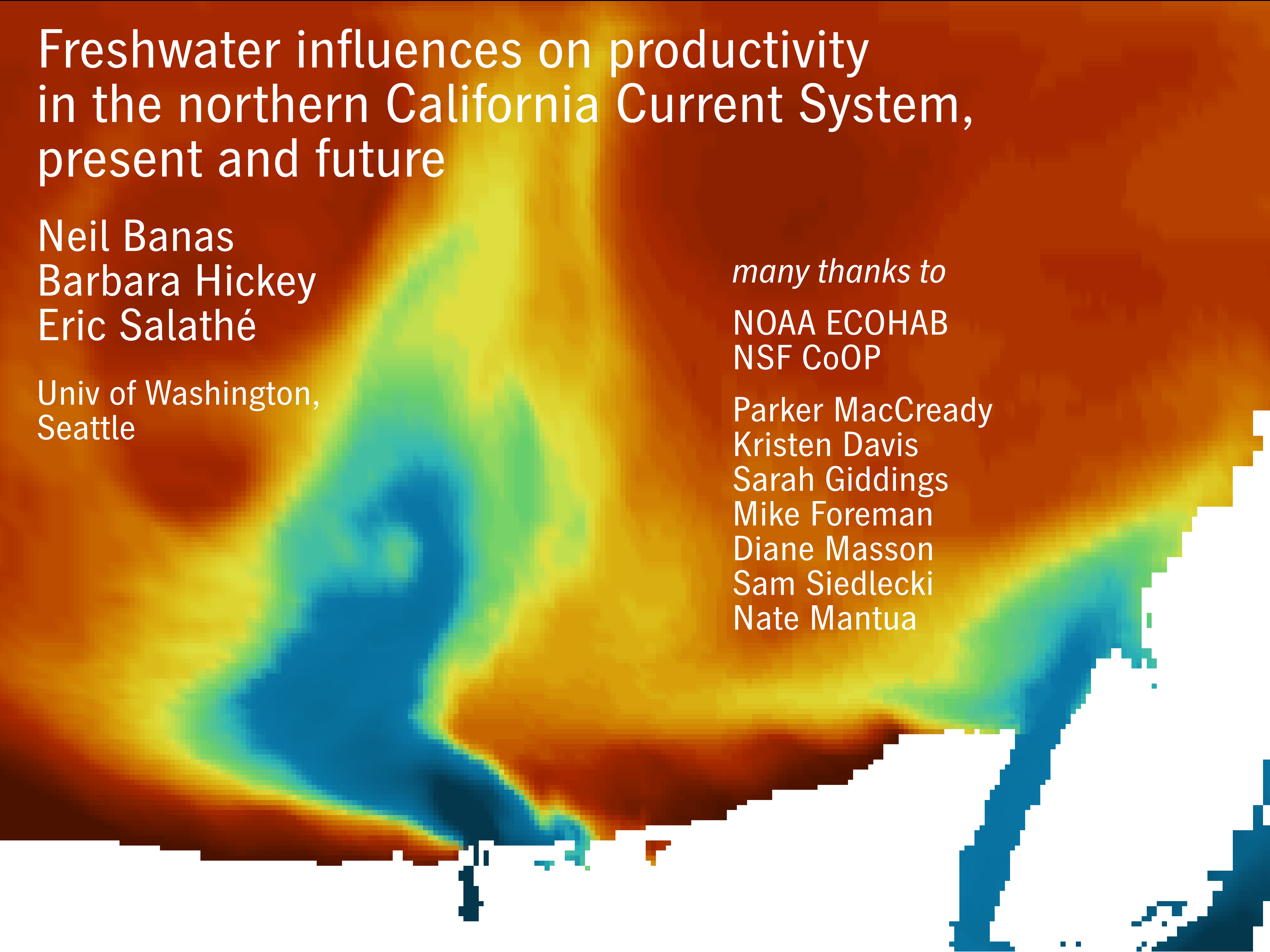


Freshwater influences on productivity in the northern California Current System, present and future

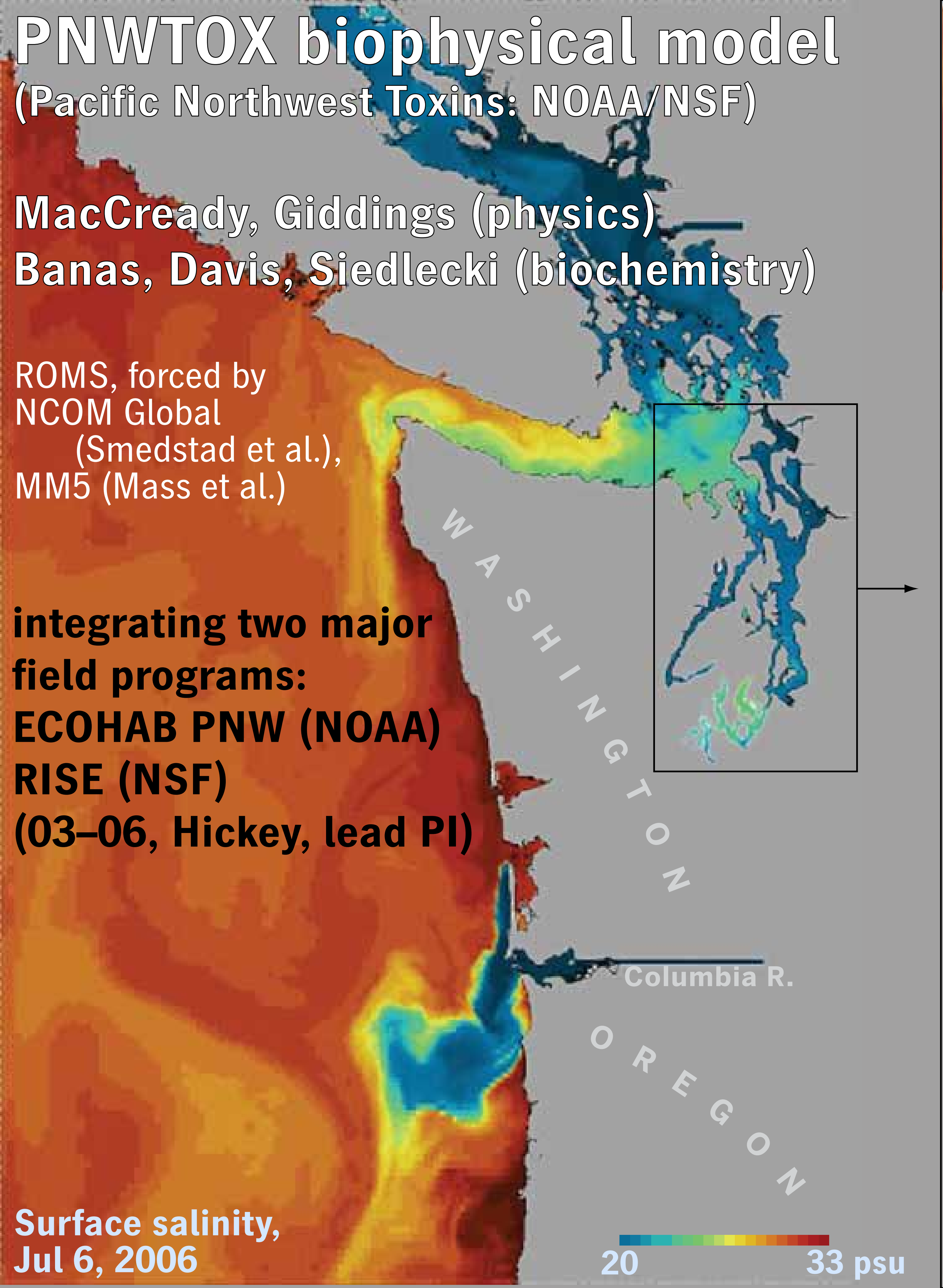
Neil Banas
Barbara Hickey
Eric Salathé

Univ of Washington,
Seattle

many thanks to

NOAA ECOHAB
NSF CoOP

Parker MacCready
Kristen Davis
Sarah Giddings
Mike Foreman
Diane Masson
Sam Siedlecki
Nate Mantua



PNWTOX biophysical model

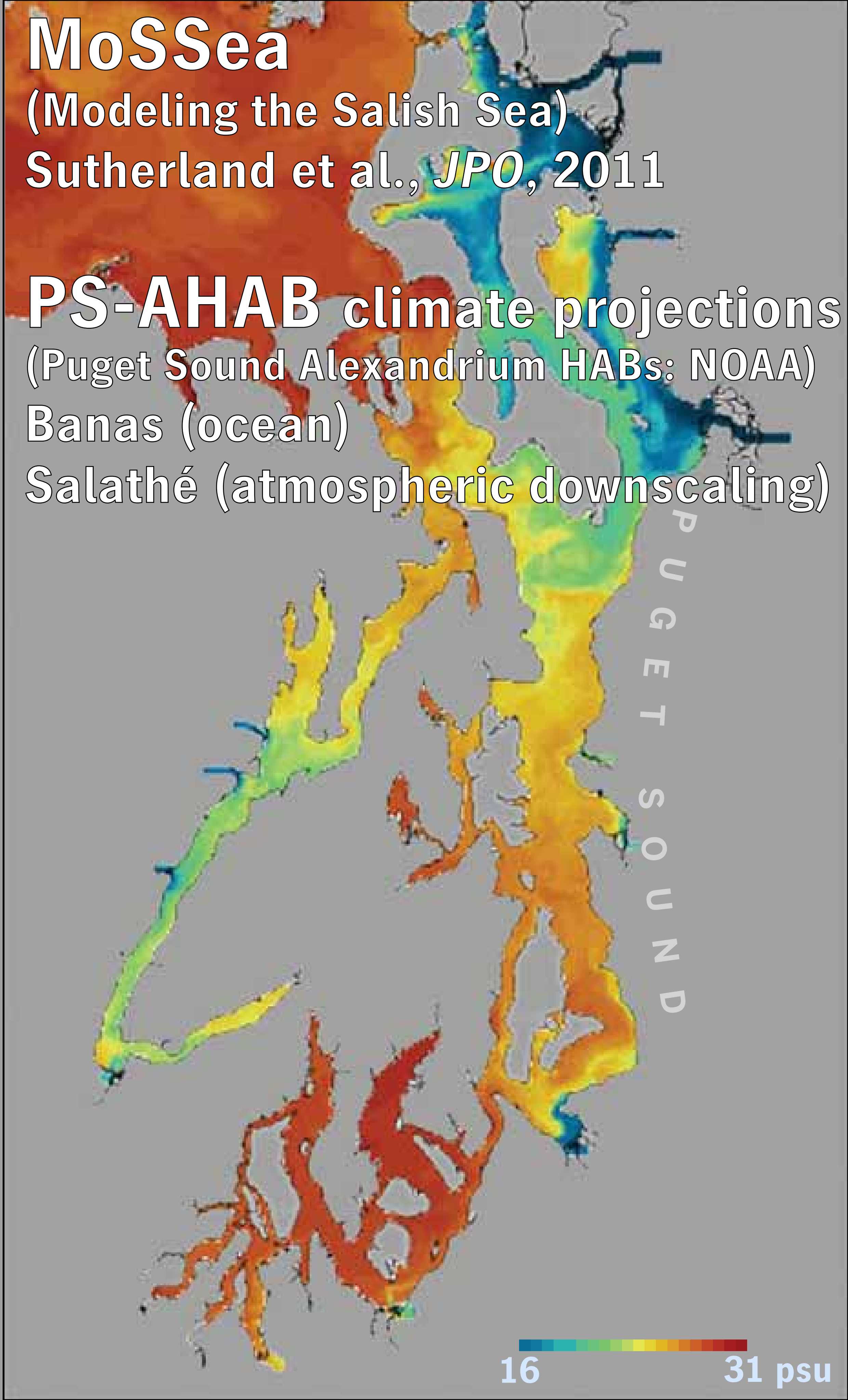
(Pacific Northwest Toxins: NOAA/NSF)

MacCready, Giddings (physics)
Banas, Davis, Siedlecki (biochemistry)

ROMS, forced by
NCOM Global
(Smedstad et al.),
MM5 (Mass et al.)

integrating two major field programs:
ECOHAB PNW (NOAA)
RISE (NSF)
(03–06, Hickey, lead PI)

Surface salinity,
Jul 6, 2006



MoSSea

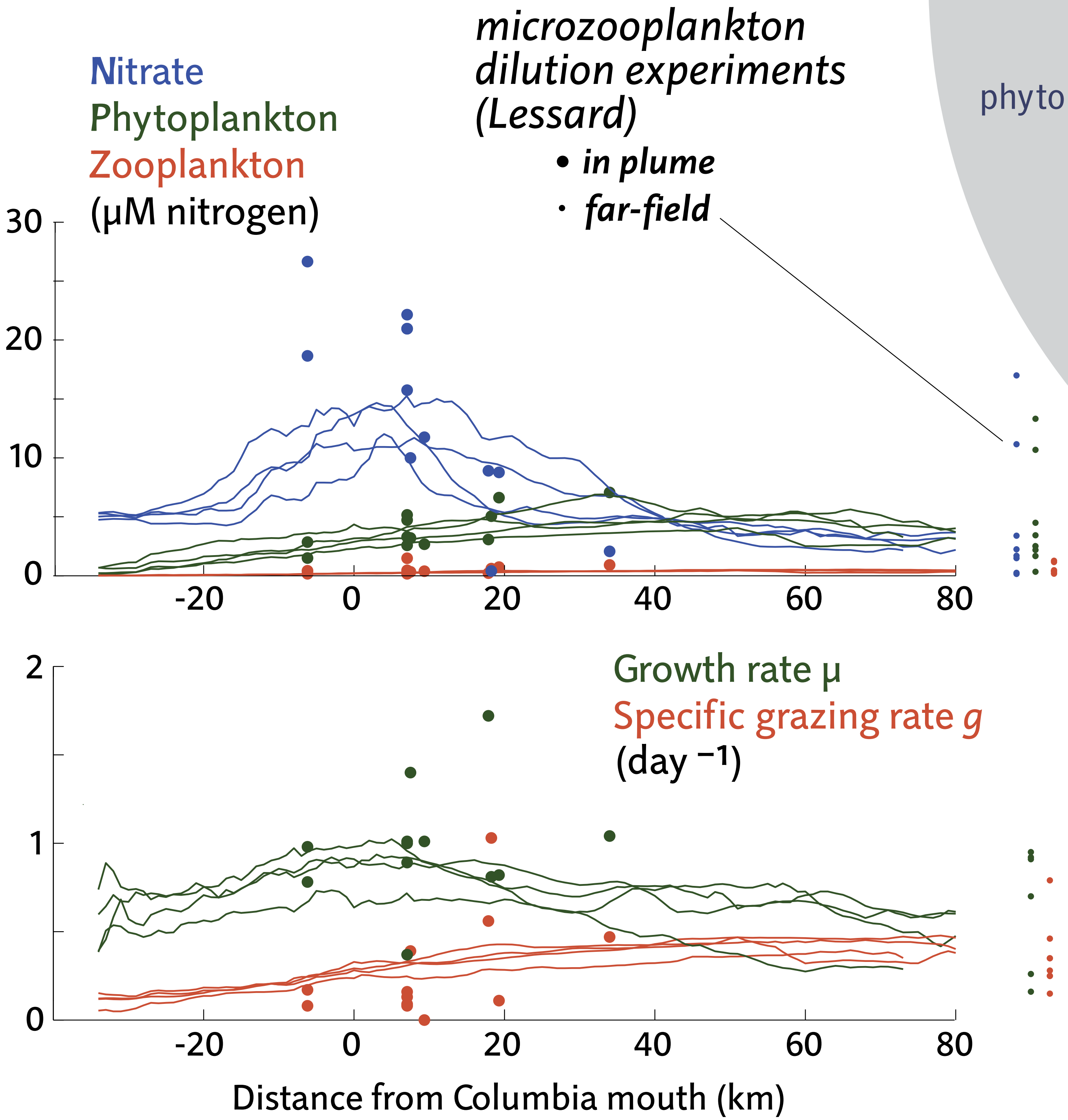
(Modeling the Salish Sea)
Sutherland et al., *JPO*, 2011

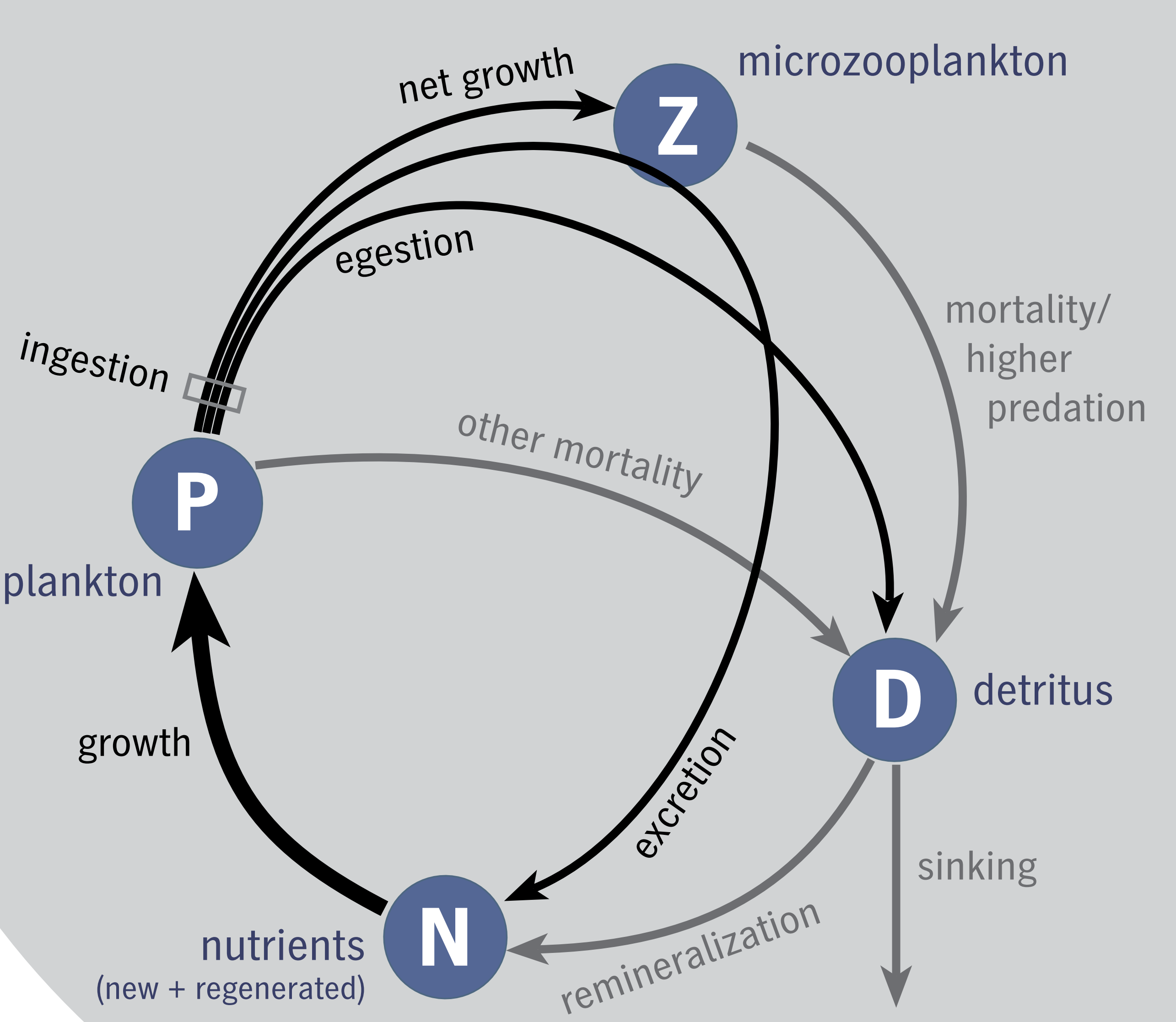
PS-AHAB climate projections

(Puget Sound Alexandrium HABs: NOAA)
Banas (ocean)
Salathé (atmospheric downscaling)

RISE ecosystem modeling (Banas et al, JGR, 2009)

improvements to P growth and detrital processes underway (K Davis and S Siedlecki)





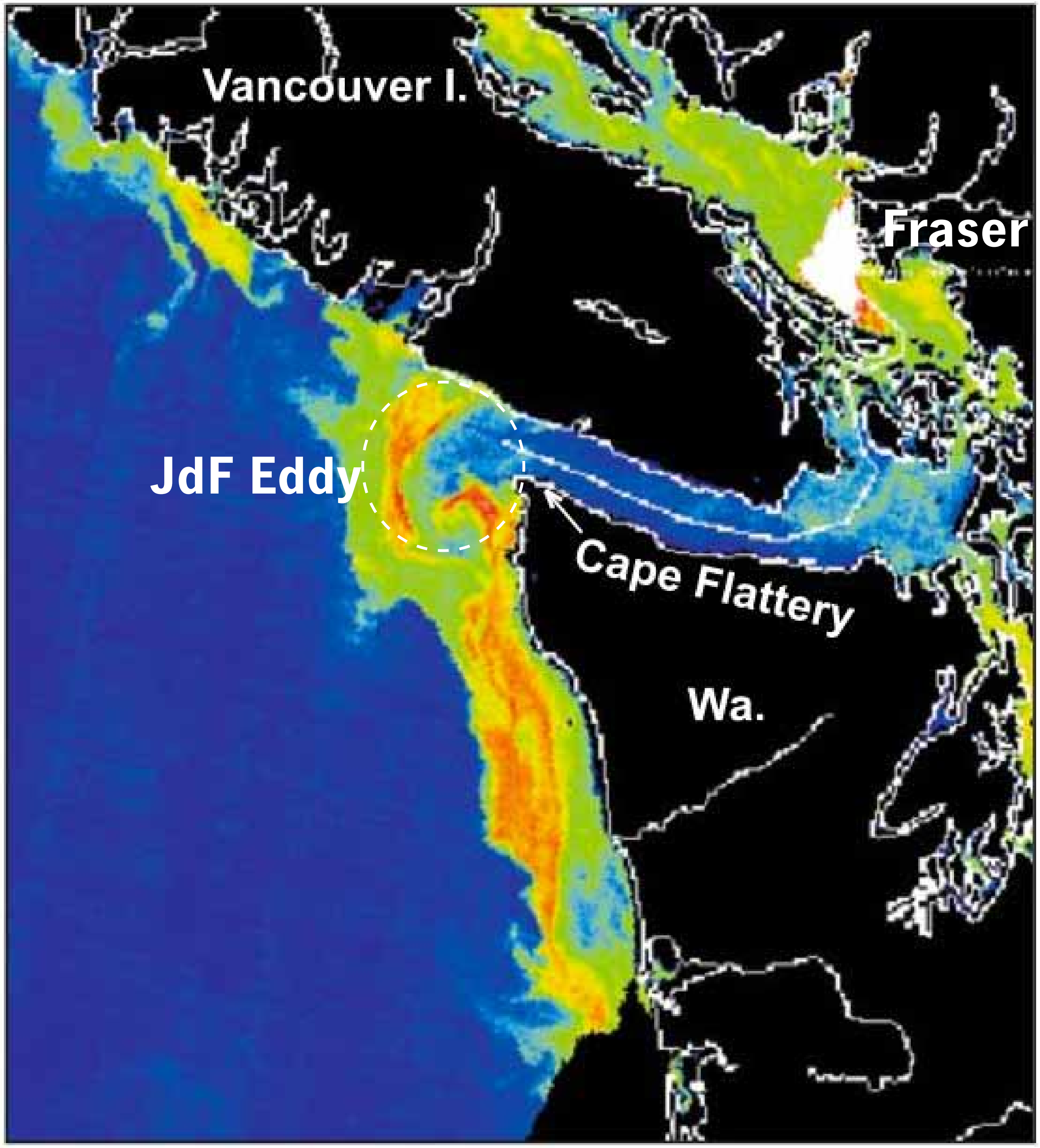


Figure 2. MERIS satellite fluorescence for 6 June 2003 (courtesy of the European Space Agency and provided by J. Gower and S. King). Offshore black regions are clouds.

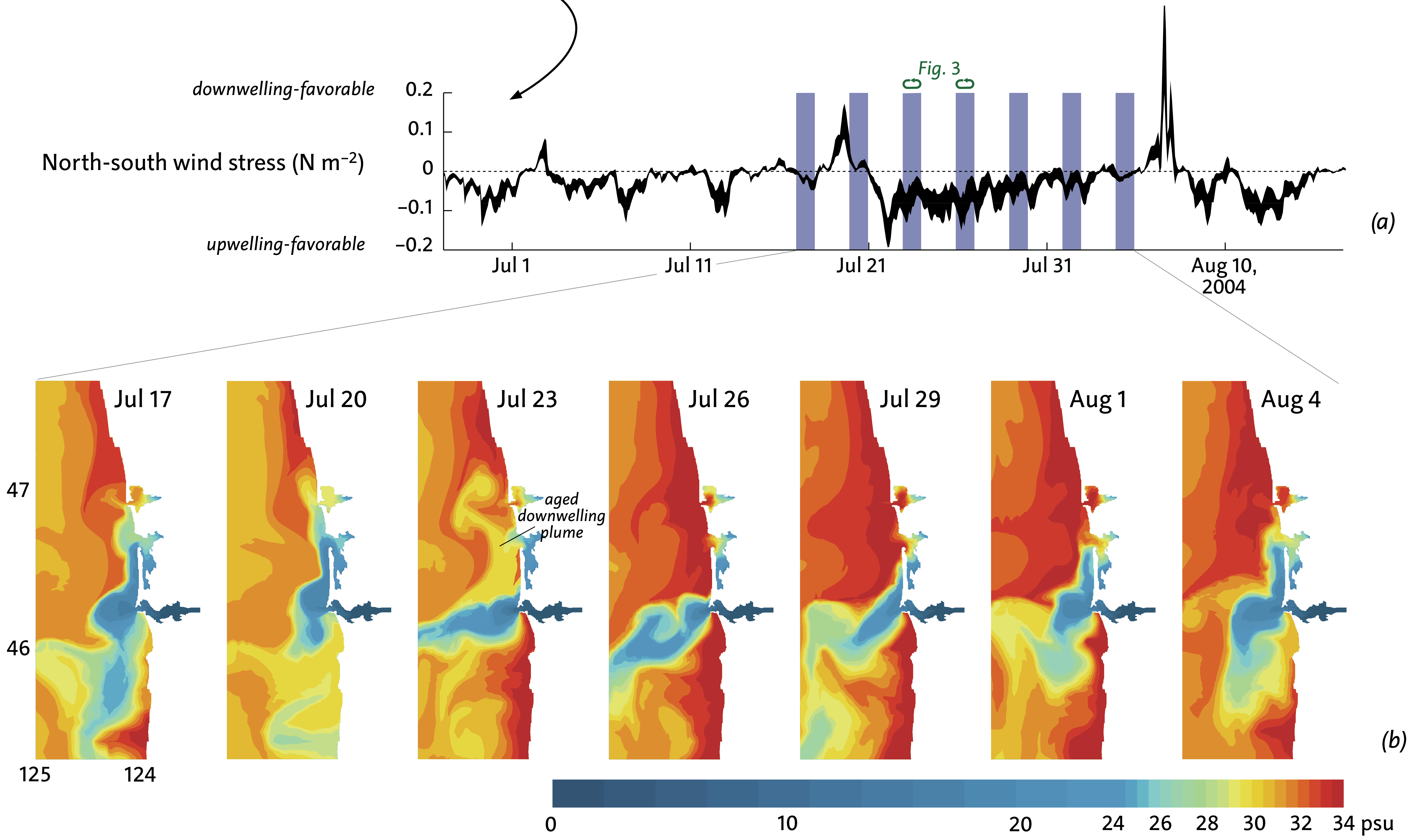
Juan de Fuca Eddy generated by the combination of

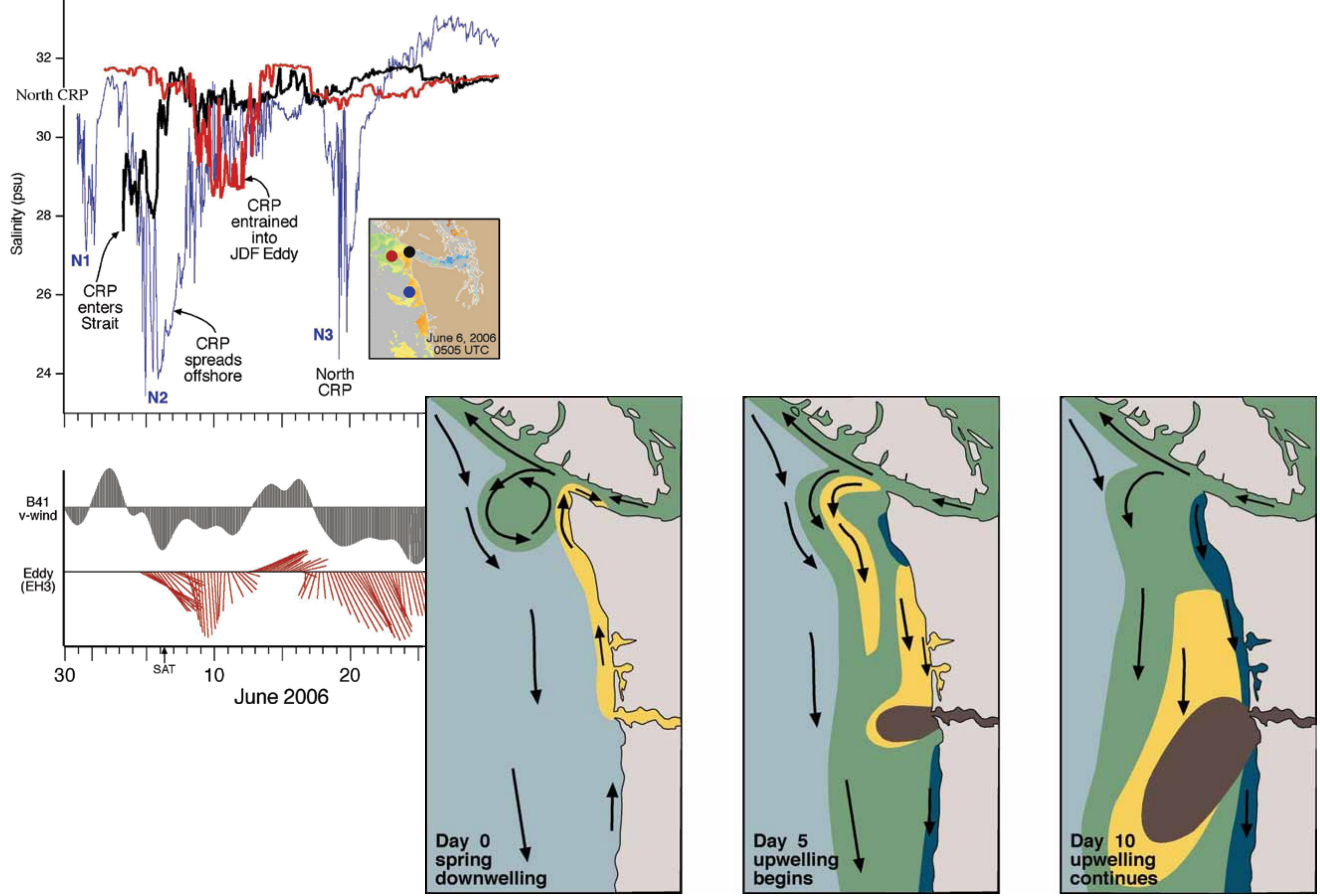
- Salish Sea estuarine circulation (80% Fraser River-driven)
- tides
- summer winds

(Foreman et al., *JGR*, 2008)

Bi-directional Columbia River plume

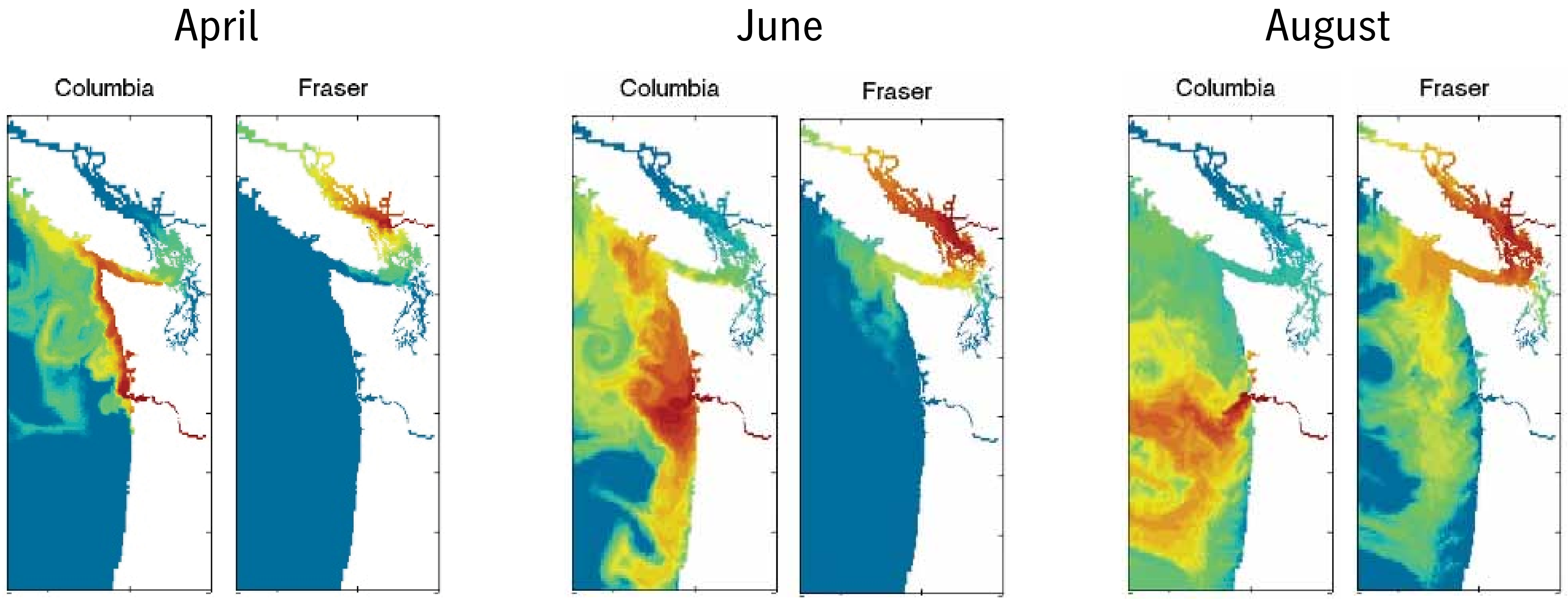
(Hickey et al., CSR, 2005;
Banas et al., CSR, 2009)





Three interacting freshwater plumes
(Hickey et al., *JGR*, 2009)

model dye experiments: interacting river plumes



Columbia R intrusions
into the Salish Sea
(S Giddings)

Pacific Northwest freshwater plumes and coastal productivity, part 1:

effects on supply and retention

NO_3 supply, Apr–Sep, southern Vancouver I – WA coast (10^8 kg)

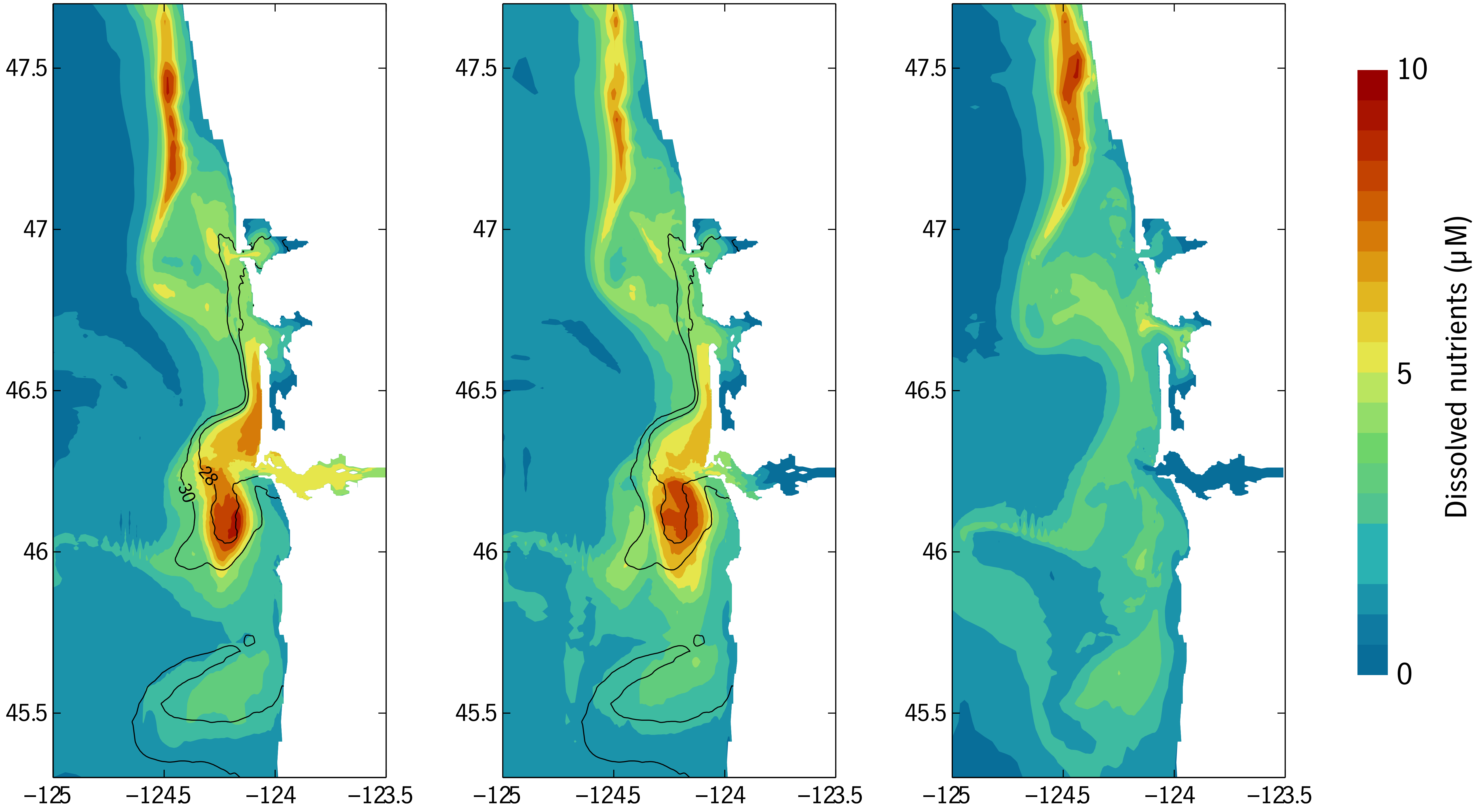
(Hickey and Banas,
Oceanography, 2008;
K Davis)

Wind-driven upwelling (WA)	4
Canyon enhancement	2–5
Watershed-derived	
Fraser	0.3 minus estuarine trapping
Columbia	0.6 minus estuarine trapping
Estuarine dynamics	
Fraser / Juan de Fuca	**5** = exchange flow + doming in eddy
Columbia	0.4

note: winter/early spring picture very different!
(Wetz et al. 2006)

Nutrient retention in the Columbia near-field (“bulge region”)

(Kudela et al., *GRL*, 2010)

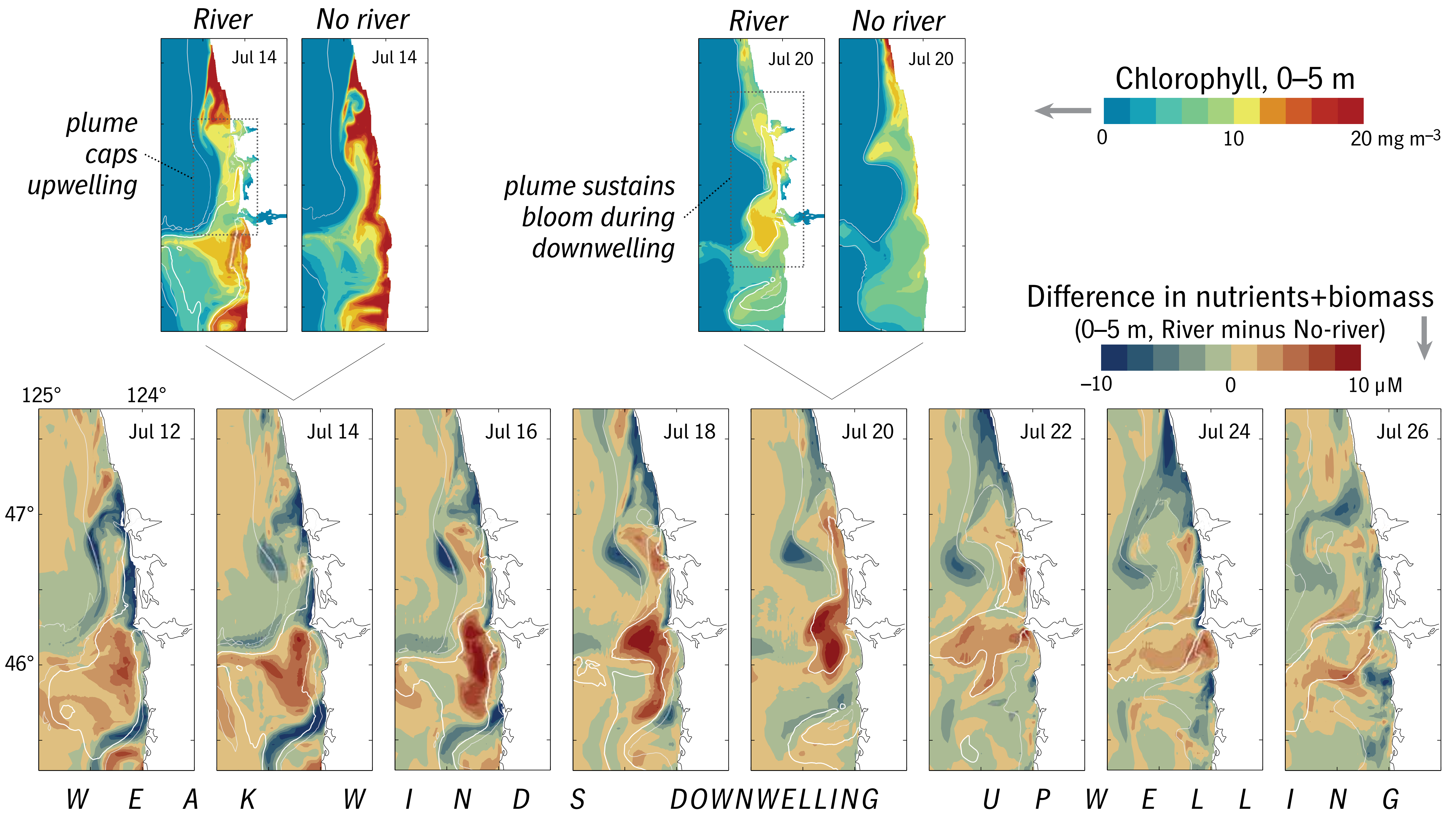


River on,
carrying 5 µM nitrogen

River on,
no terrestrial N supply

River off

Near-surface nutrients (0–5 m),
July 20, 2005



plume caps upwelling

plume sustains bloom during downwelling

Chlorophyll, 0–5 m

Difference in nutrients+biomass (0–5 m, River minus No-river)

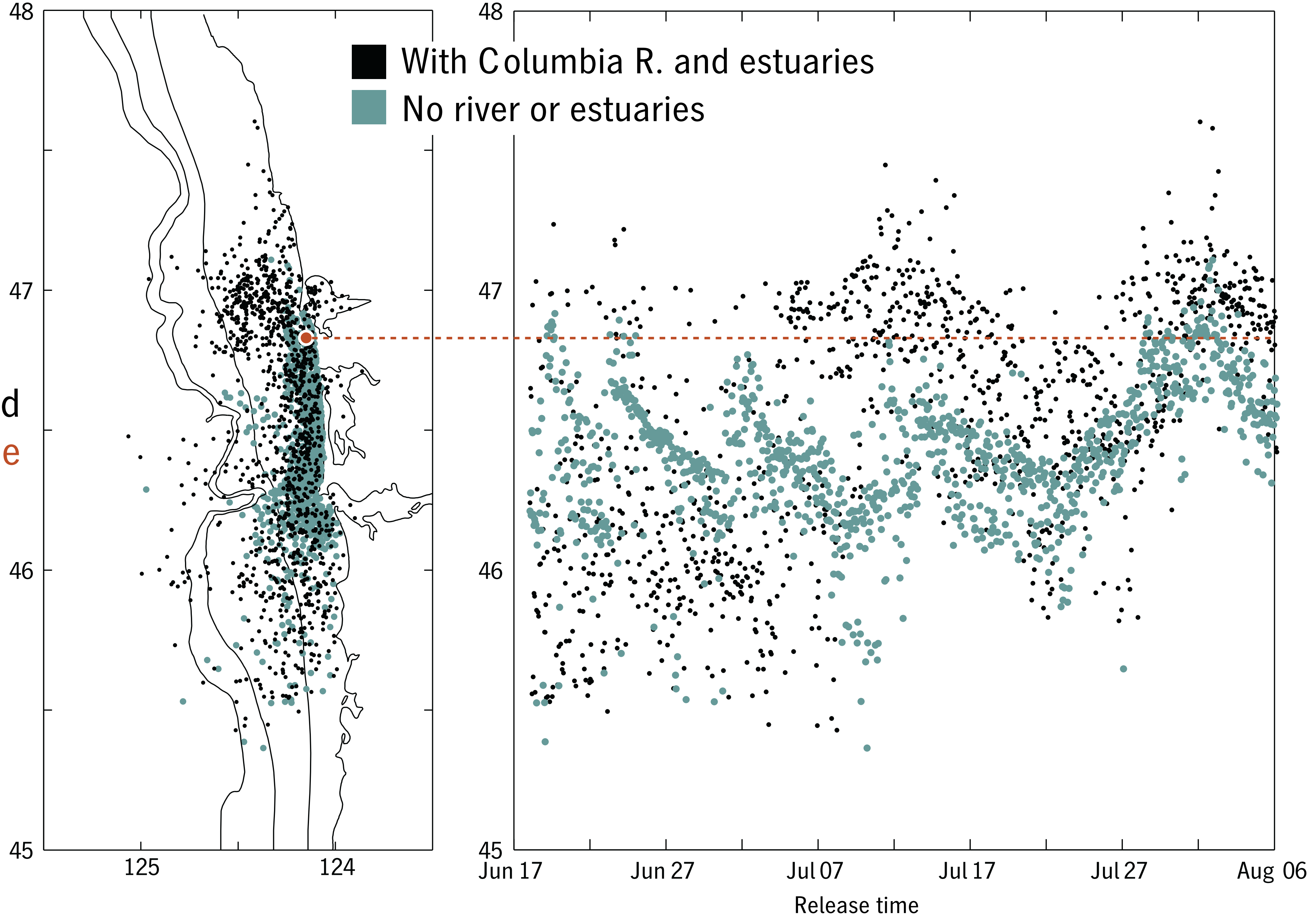
WEAK WINDS DOWNWELLING UPWELLING

(Hickey and Banas, *Oceanography*, 2008; Banas et al., *JGR*, 2009)

Along-coast retention

The Columbia River plume **disperses** water both north and south, through eddy entrainment and increased response to intervals of downwelling winds, but the net effect is **retention** in the along-coast direction.

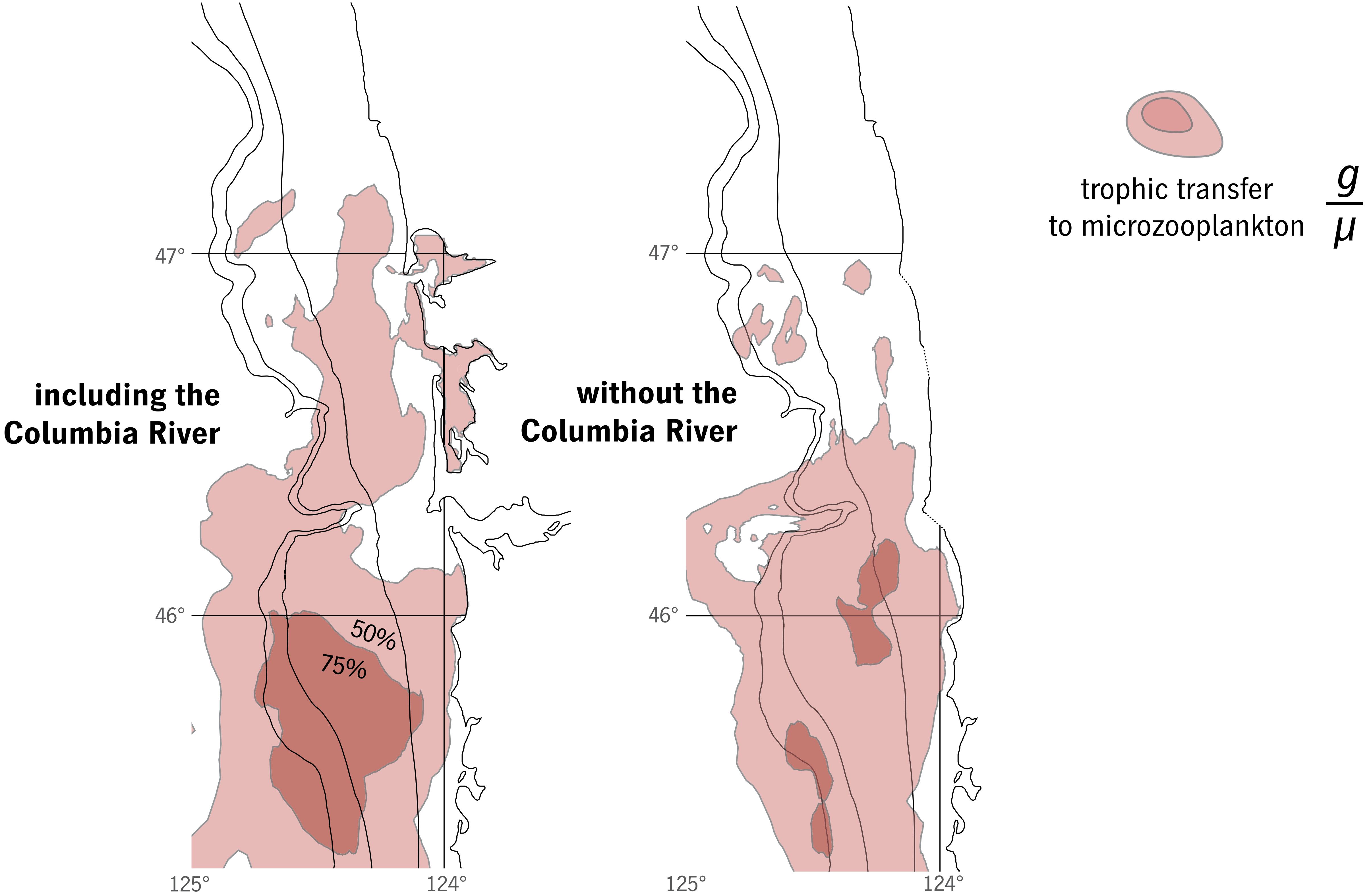
Latitude 10 d after release

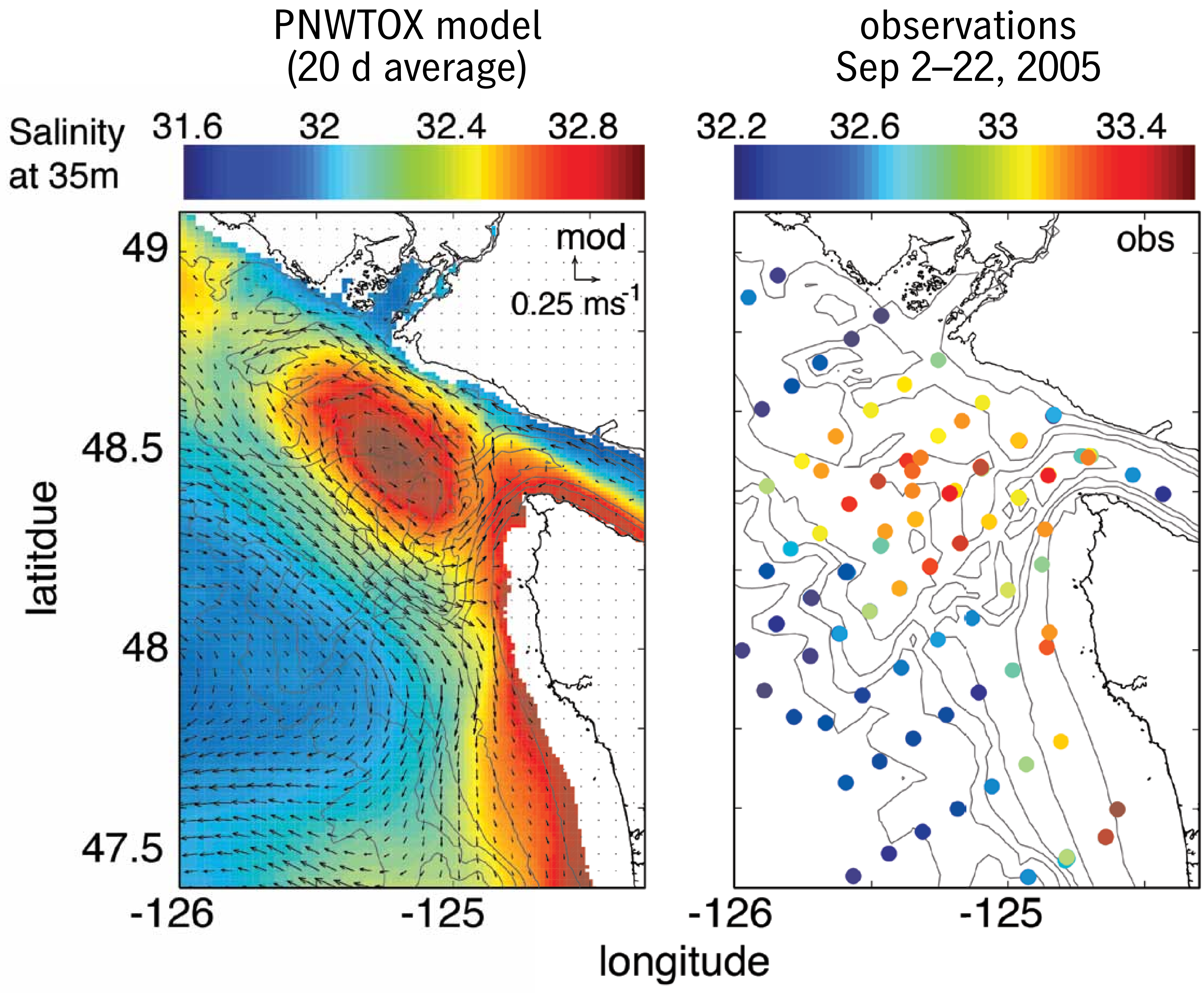


(Banas et al, CSR, 2009)

Along-coast retention

Increased retention leads to older plankton communities in which **grazers** have more time to develop (most likely increasing the efficiency of C export).





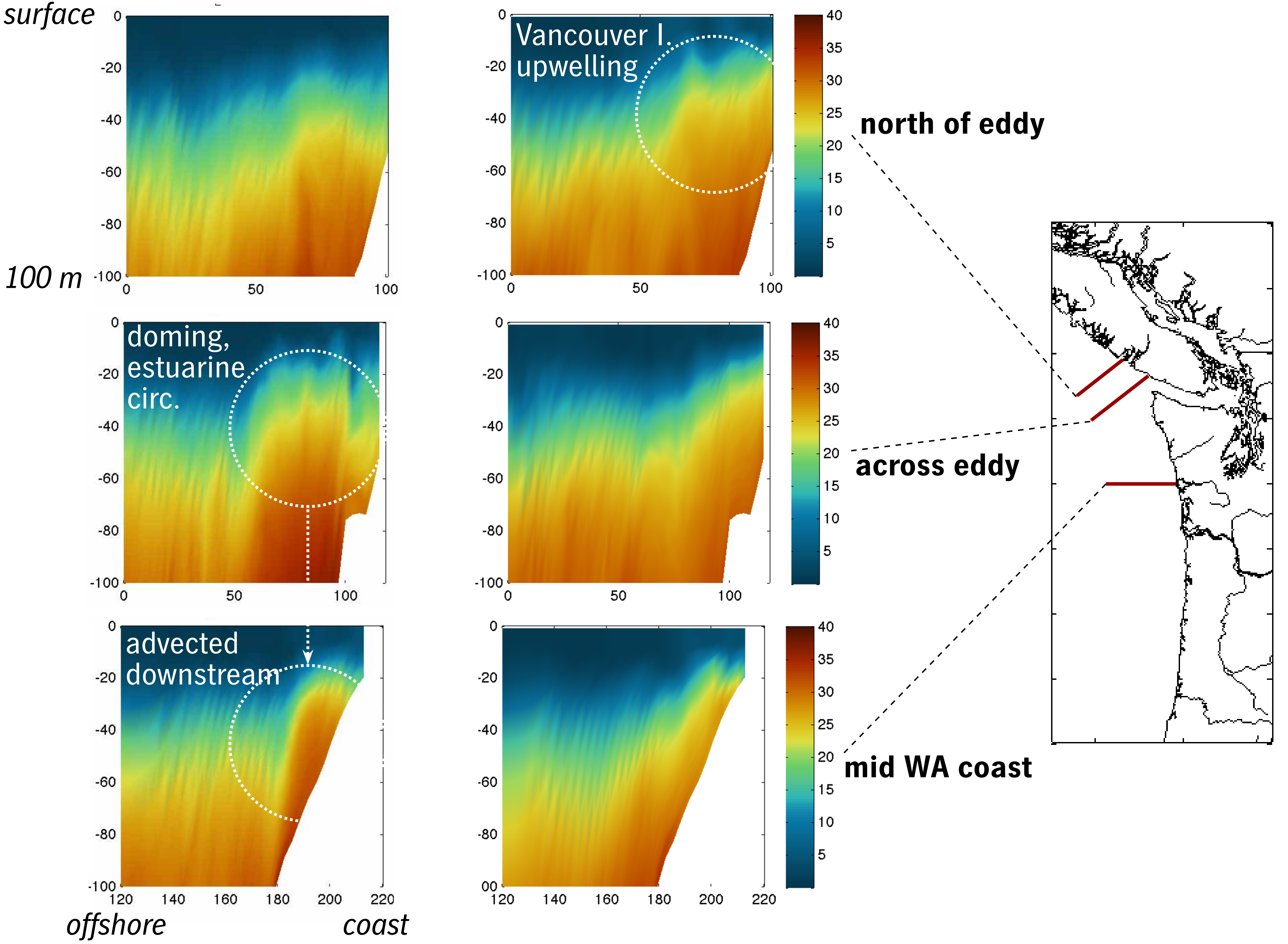
*retention time **10 d** on average,*
***30 d** during relaxation/downwelling*
events (cf. MacFadyen et al. 2008)

(S Giddings)

Nitrate, Jul 1, 2005

(K Davis)

(cf. Foreman et al., *JGR*, 2008,
Hickey and Banas, *Oceanogr.*, 2008)



base case

no Fraser,
no Salish Sea

Vancouver I. upwelling

doming, estuarine circ.

advected downstream

north of eddy

across eddy

mid WA coast

surface

100 m

offshore

coast

In each case:

· partial *suppression* of wind-driven nutrient supply

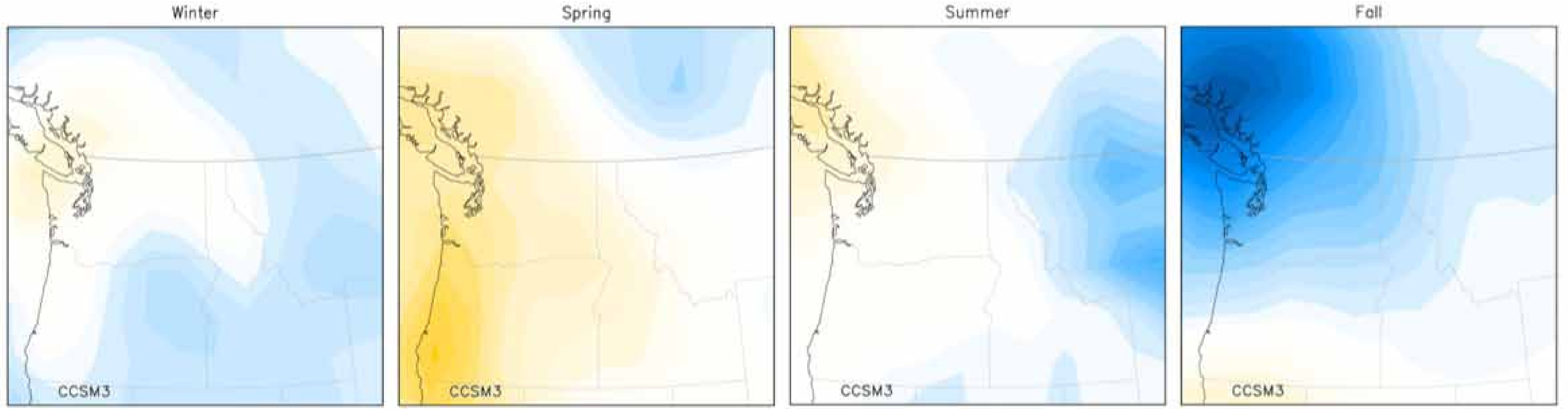
· *addition* of buoyancy-driven supply/retention

thus making total nutrient availability *steadier*, though not necessarily higher.

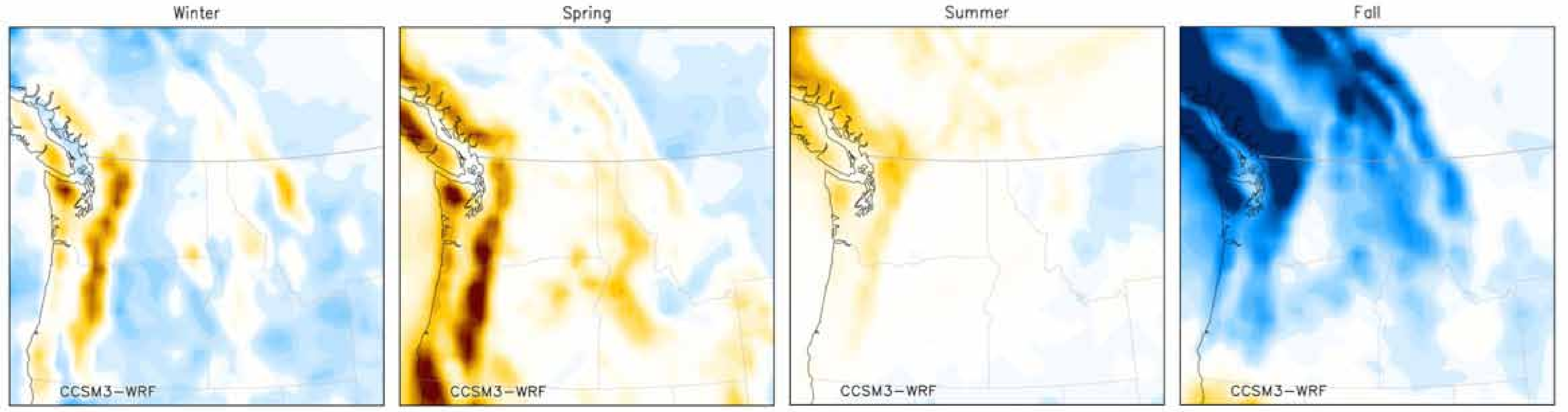
Pacific Northwest freshwater plumes and coastal productivity, part 2:

interaction with climate change

CCSM3-A1B

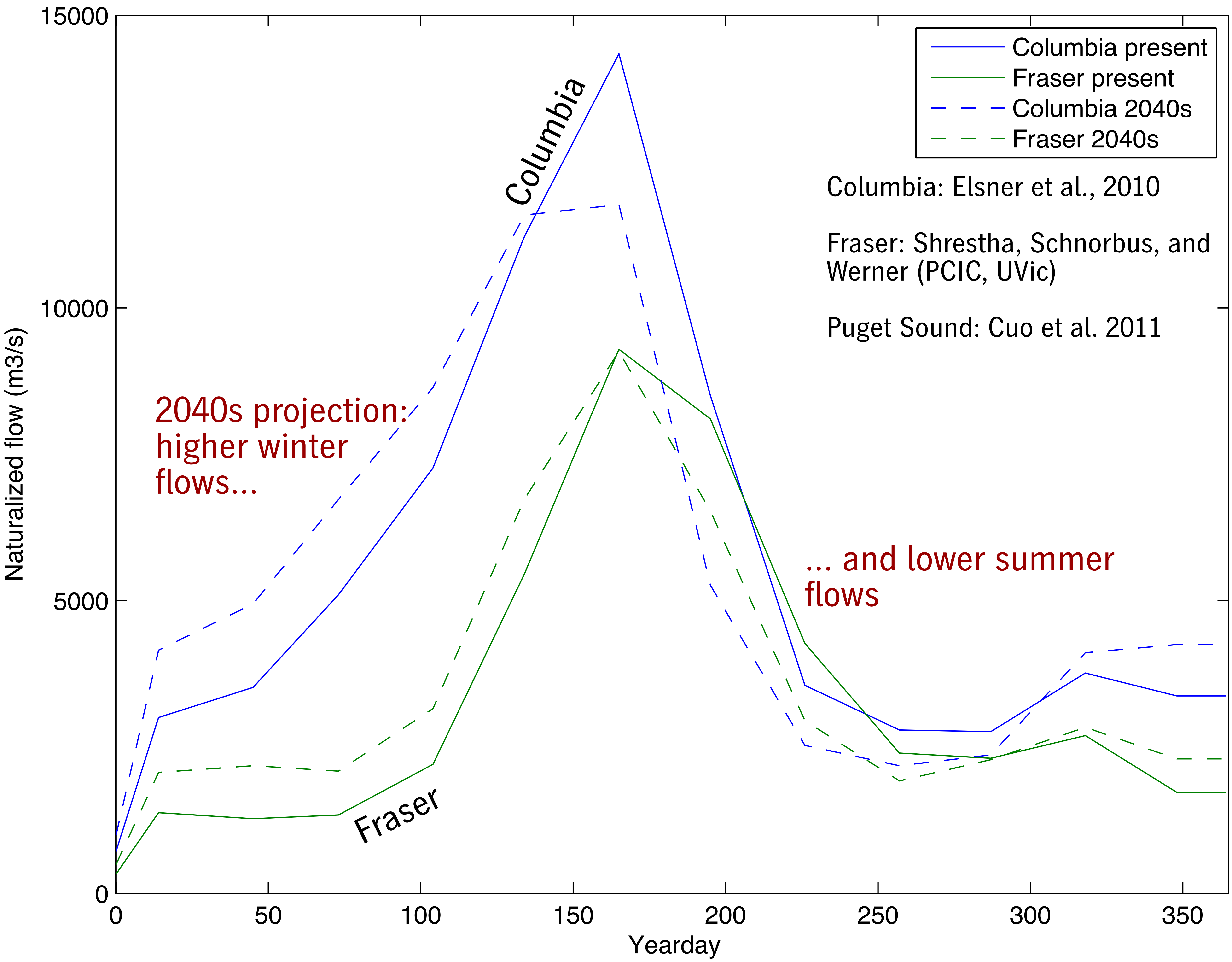


downscaled using WRF (Salathé et al. *Climatic Change*, 2010)



seasonal precip anomalies,
1980s – 2040s

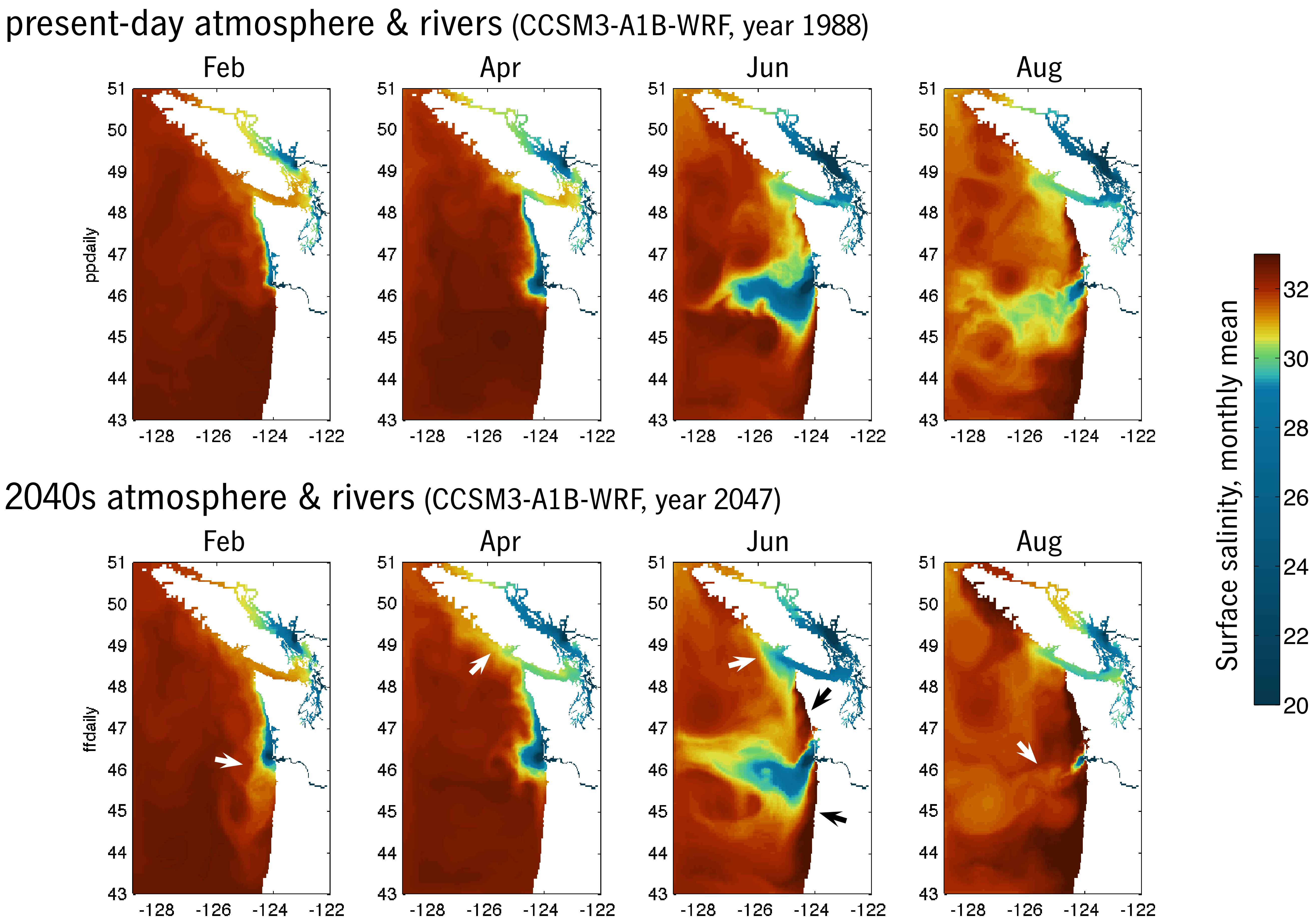
2040s projection:
20% stronger summer
upwelling wind stress



Columbia: Elsner et al., 2010

Fraser: Shrestha, Schnorbus, and Werner (PCIC, UVic)

Puget Sound: Cuo et al. 2011



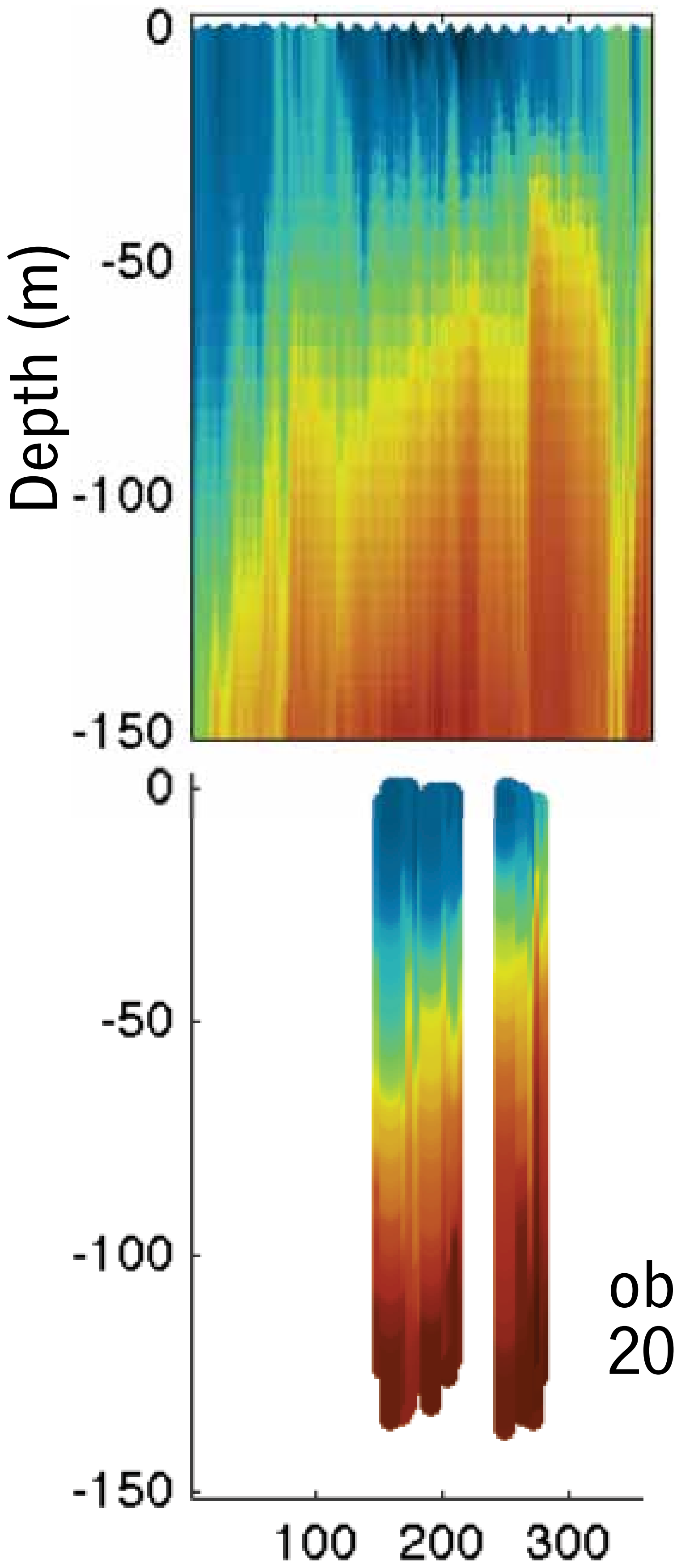
present-day atmosphere & rivers (CCSM3-A1B-WRF, year 1988)

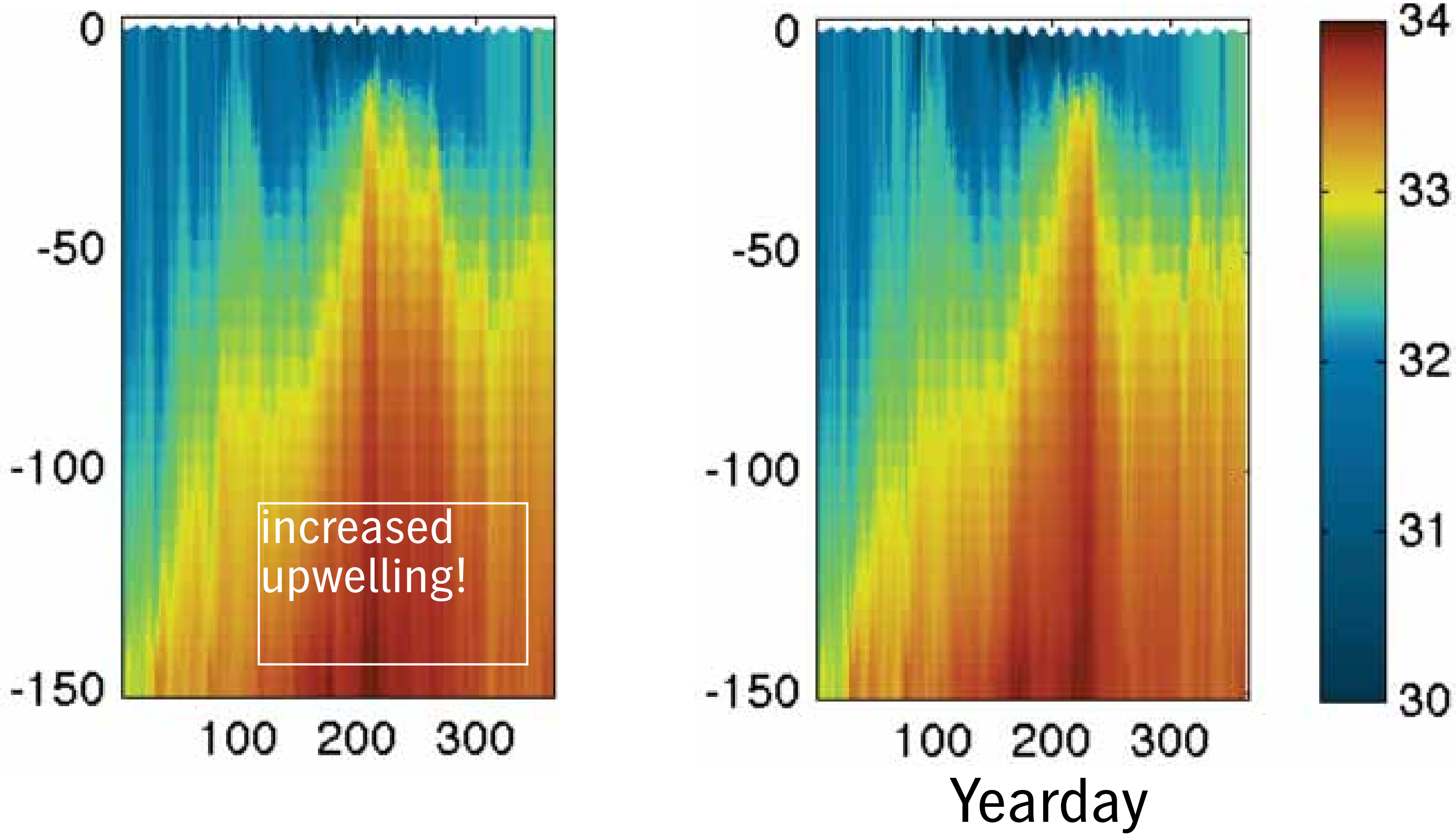
2040s atmosphere & rivers (CCSM3-A1B-WRF, year 2047)

present-day atmosphere
present-day rivers

2040s atmosphere

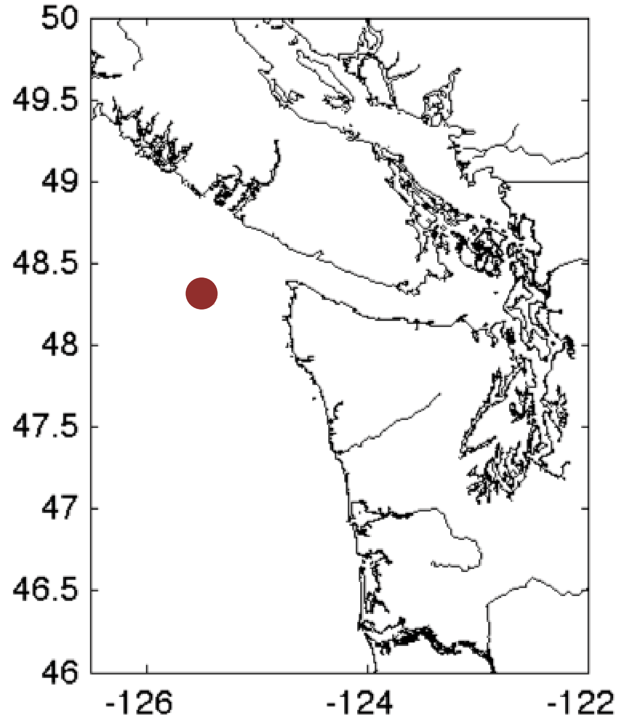
2040s rivers





observations
2003–06

**salinity at EH3
(center of eddy)**



$$Q_{exchange\ flow} \sim Q_{river}^{1/3}$$

(MacCready and Geyer, 2010)

Hypothesis:

River influences buffer upwelling zones against climate change impacts on productivity.

(In a similar way, PNW rivers buffer against event- to seasonal-scale variability in wind-driven nutrient supply, through both retention and supply.)

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