17th Annual CCSM Workshop, Breckenridge, CO
June, 2012

ESTUARY-SHELF FRESHWATER EXCHANGE PARAMETERIZATIONS FOR THE CESM

Yu-heng Tseng (NCAR), Frank Bryan (NCAR), John Dennis (NCAR), Allison Baker (NCAR), Parker MacCready (U Washington), Michael Whitney (U Connecticut)

SciDAC project: Collaborative project: Improving the Representation of Coastal and Estuarine Processes in Earth System Models

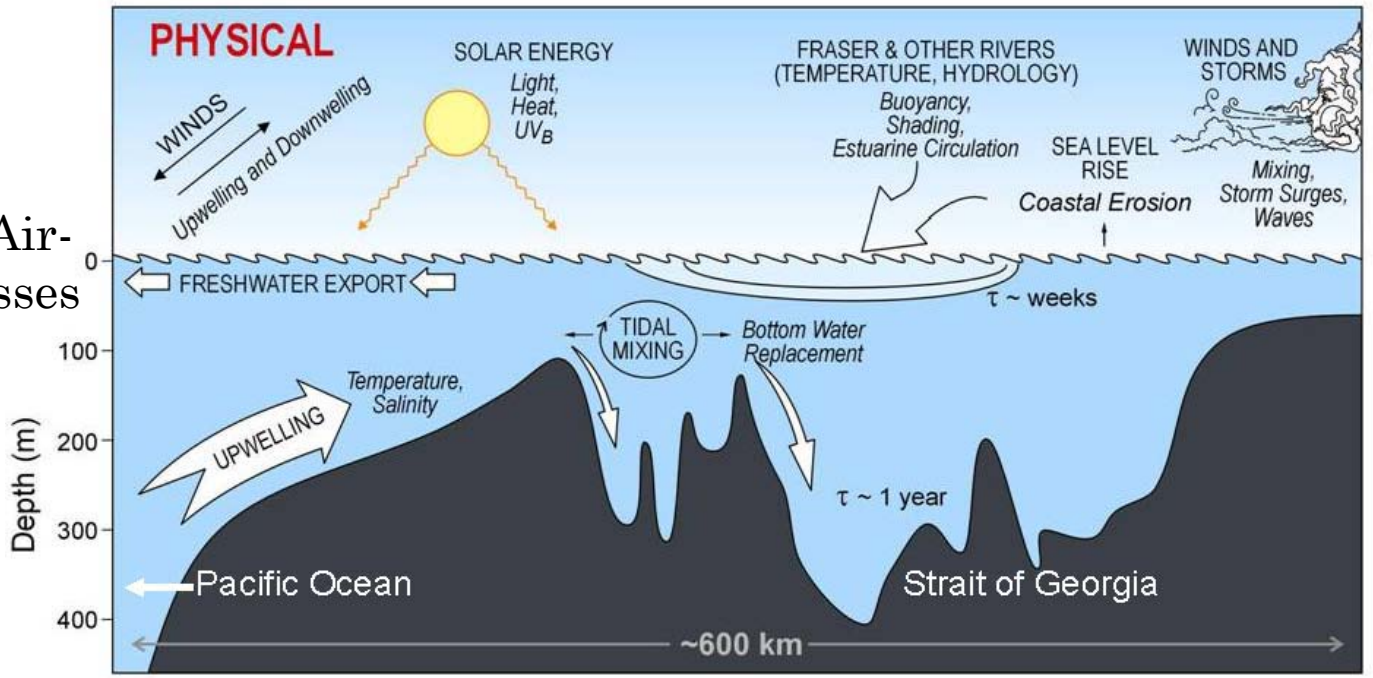
OUTLINE

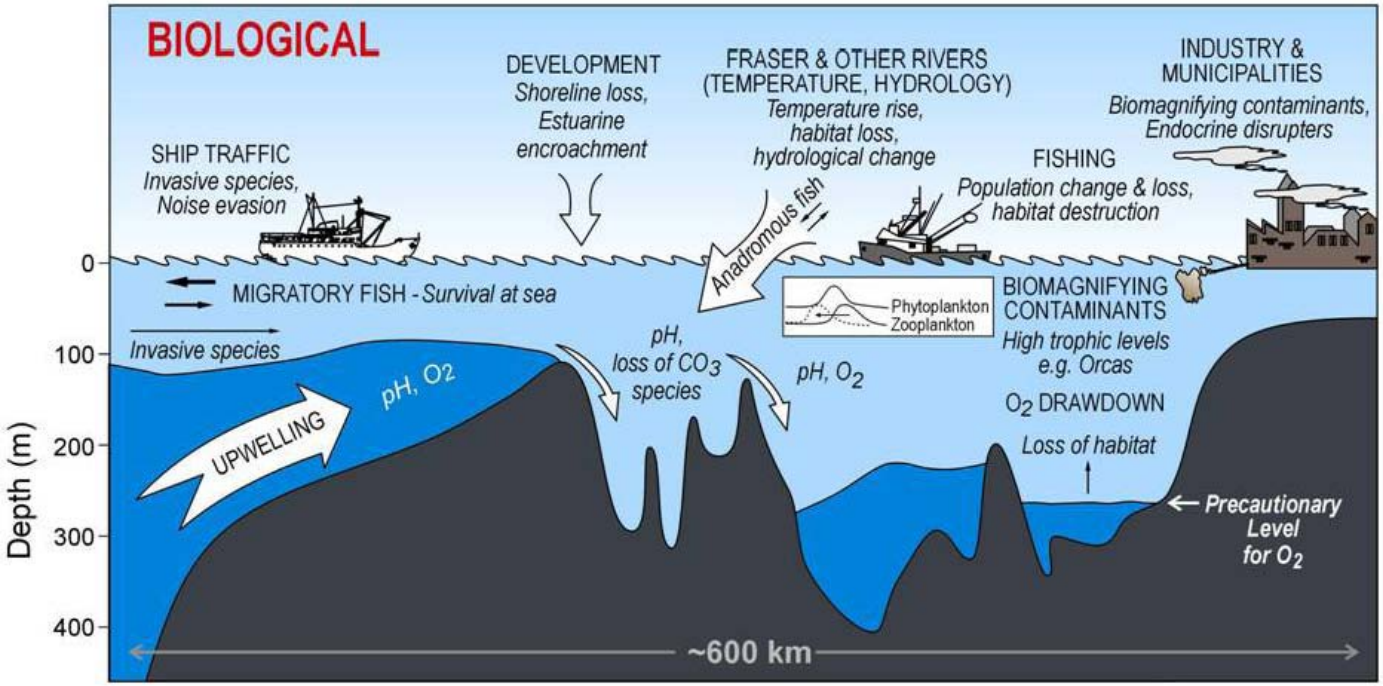
- Why?
- What's the current status?
- What are and will be done?
- How?
- Future……

Why?

Coastal zone: coupled Air-land-ocean-BGC processes

Multi-scale dynamics





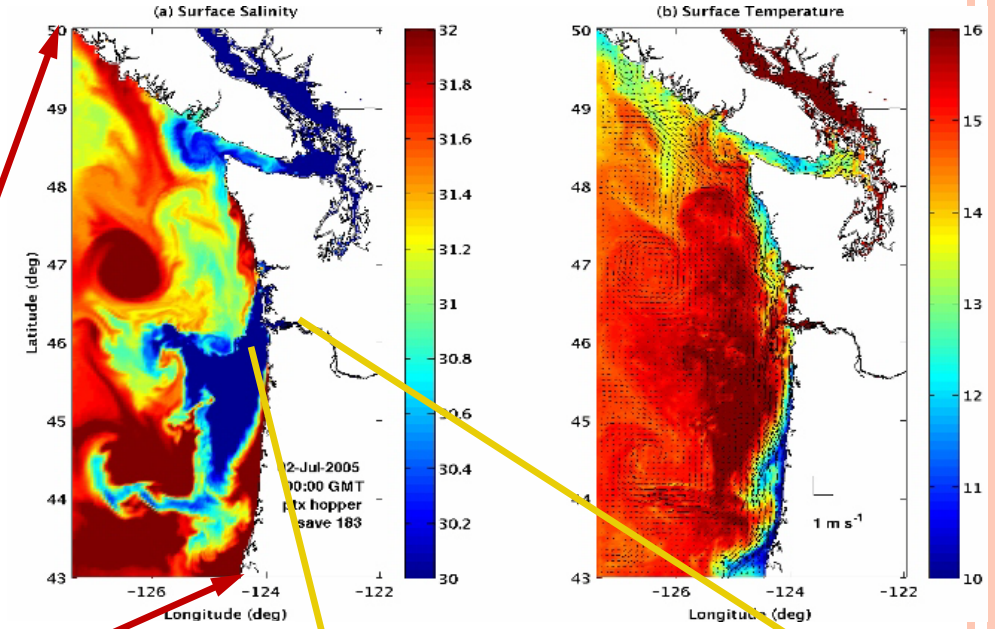
Johannessen & Macdonald (2009)

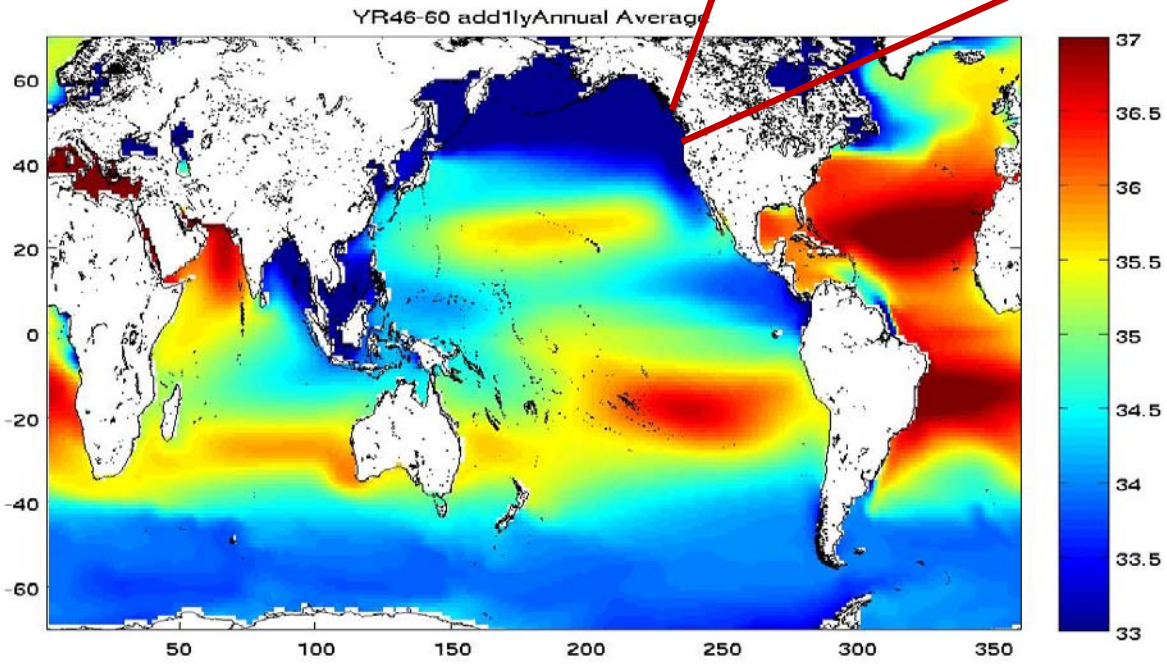
Why?

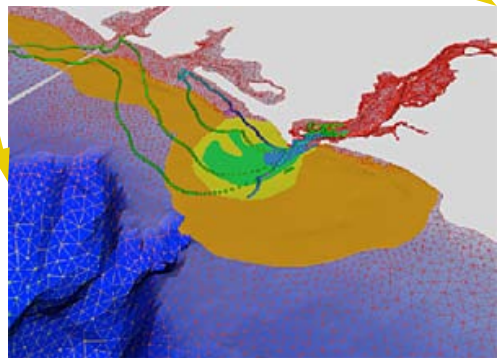
How are these features affected by climate?

Impacts of the nutrients and carbon from the river mouth

Require better representation of transport and mixing processes along the coast





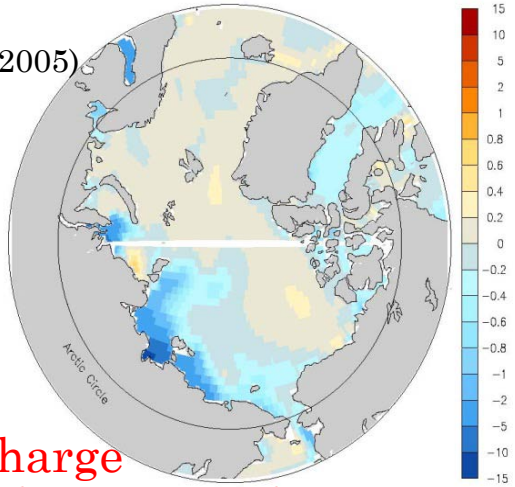


Human impacts: 40% population lives along the coast

Why?

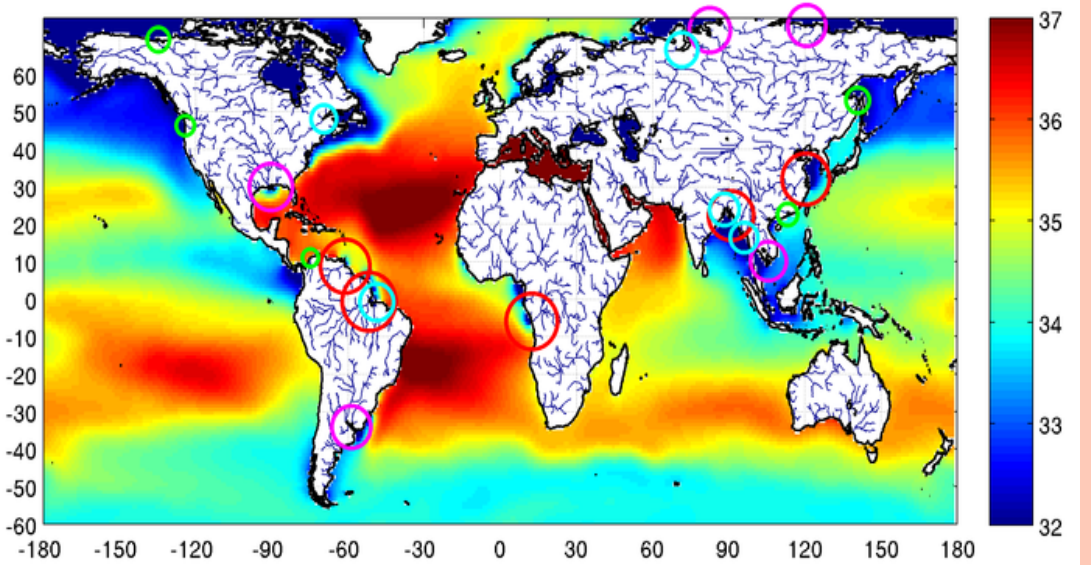
SALINITY BIAS

Griffies et al. (2005)

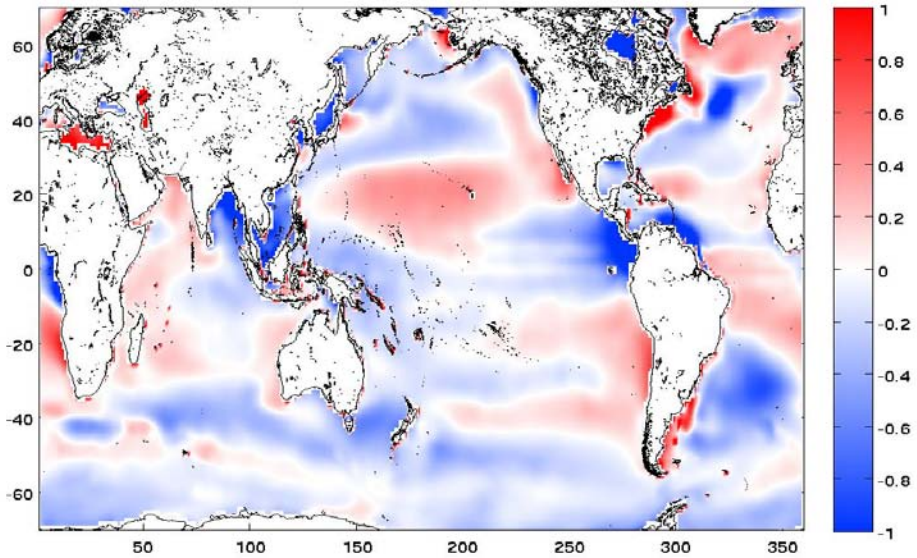


river discharge thickness h_r=40 m -> h_r=10m

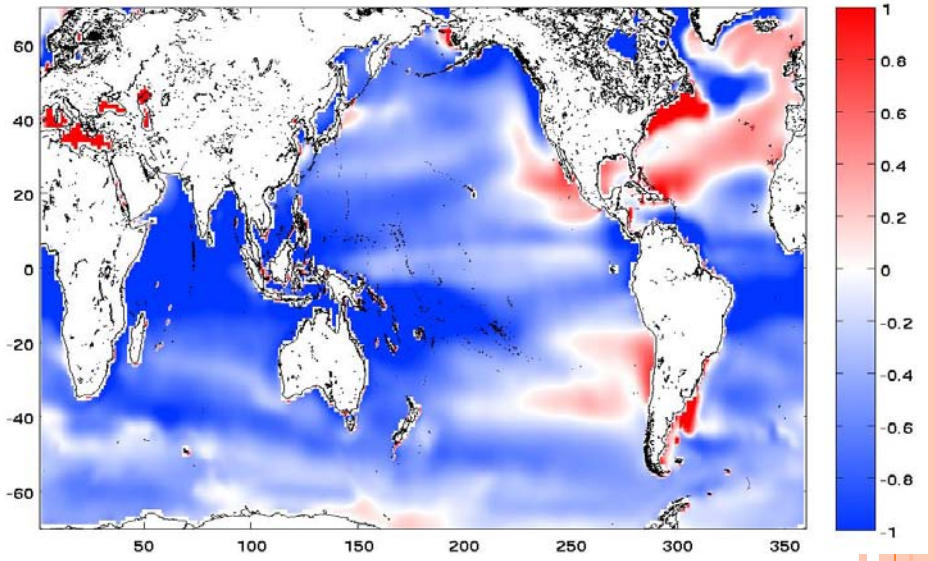
Salinity (WOA09 annual mean)



Larger bias in CCSM4



CORE forc. 1˚ POP (1993-2007)



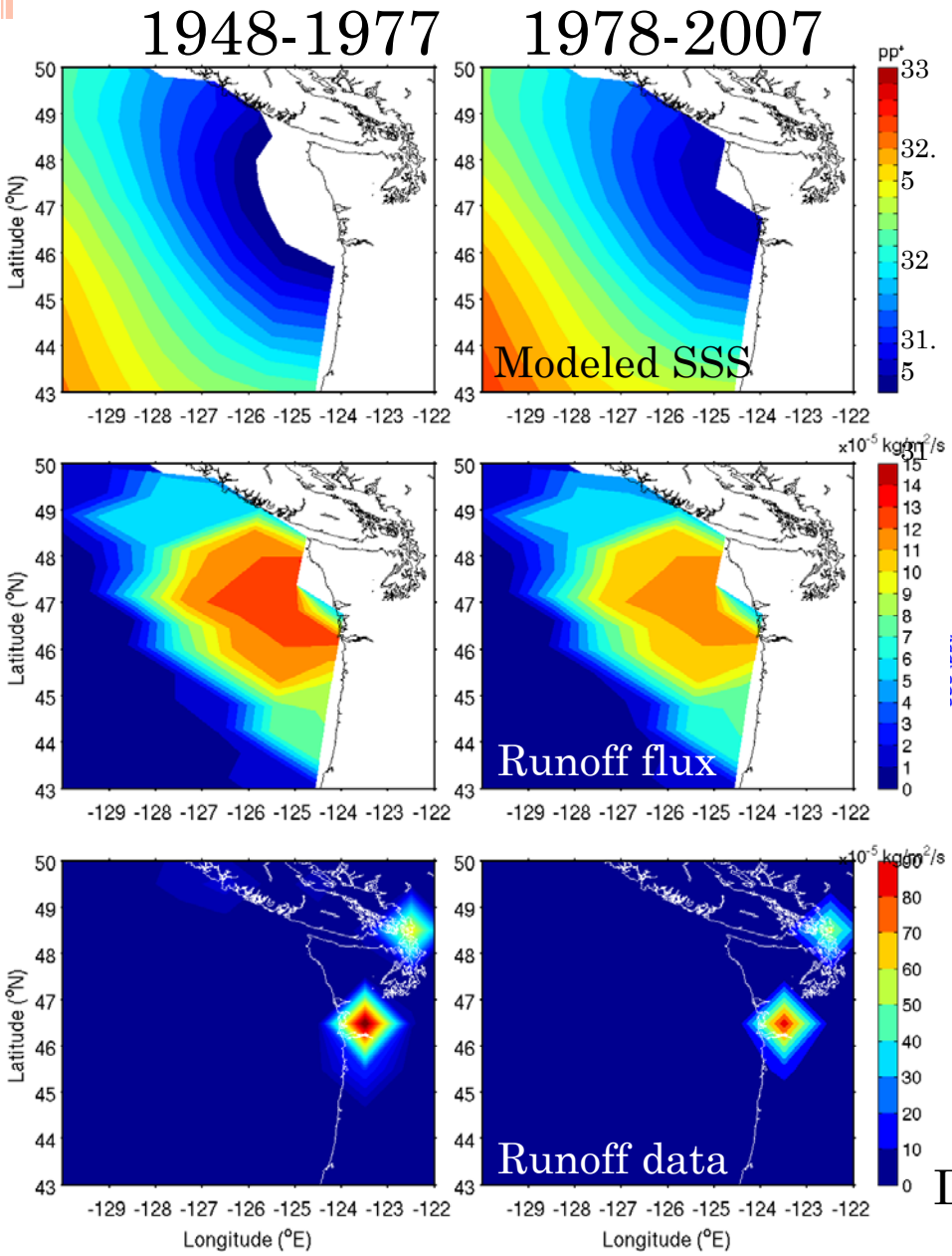
CCSM4 1˚ 20th Century Ens. #1 (1990-2005)

World's largest 20 rivers

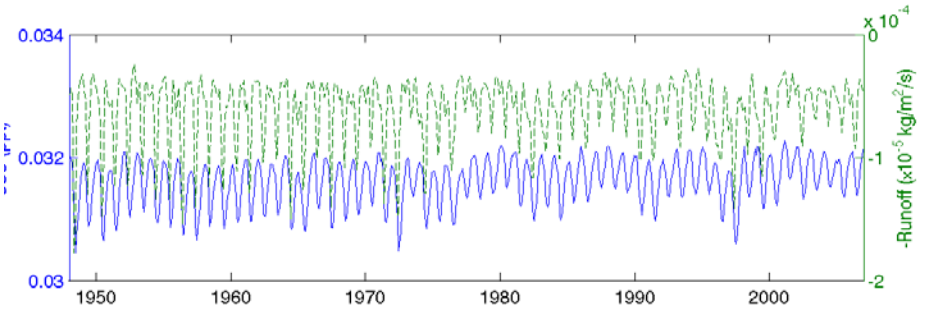
[Dai et al. 2002; 2008]

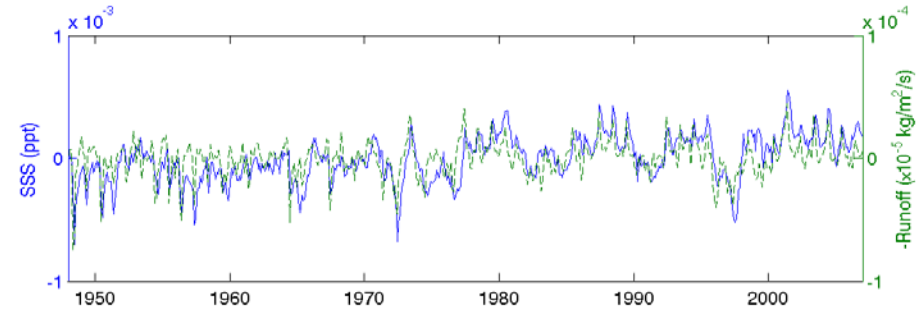
River (Station, country)	Lon _s(°)	Lat_s (°)	Lon_m (°)	Lat _m(°)	V_{obs} (km^3 yr^{-1})	V_{clm} (km^3 yr^{-1})	H(m)
Amazon(Obidos, Brazil)	-55.5	-2.0	-51.75	-0.667	5444	3228	-1.2
Congo(Kinshasa, Congo)	15.3	-4.3	12.5	-5.96	1270	1089	-48.4
Orinoco(Pte Angostu, Venezuela)	-63.6	8.1	-61.085	8.71	996	814	-16.0
Changjiang(Datong, China)	117.6	30.8	120.5	32.08	907	838	-8.0
Brahmaputra(Bahadurabad, Bangladesh)	89.7	25.2	91	22.25	643	399	-9.9
Mississippi(Vicksburg, MS, U.S.)	-90.9	32.3	-90.4	29.92	552	651	-2.7
Yenisey(Igarka, Russia)	86.5	67.4	82.5	71.8	588	493	-2.1
Parana(Timbues, Argentina)	-60.7	-32.7	-58.6	-34.1	517	692	-3.2
Lena(Kusur, Russia)	127.4	70.7	120.85	73	532	396	-55.0
Mekong(Pakse, Laos)	105.8	15.1	105.75	10.08	312	187	-56.9
Tocantins(Tucurui, Brazil)	-49.7	-3.8	-48.6	-0.84	347	486	-2.2
Ob(Salekhard, Russia)	66.6	66.6	71.5	66.6	402	533	-2.5
Ganges(Farakka, India)	88.1	24.5	88.25	24	371	465	-10.1
Irrawaddy(Sagaing, Myanmar (Burma))	96.0	21.9	96	16.42	272	243	-9.1
St. Lawrence(Cornwall, ON, Canada)	-74.7	45.0	-69.5	48.1	230	400	-63.0
Amur(Komsomolsk, Russia)	137.0	50.5	140.917	53.083	307	367	-4.9
Mackenzie(Arctic Red, Canada)	-133.7	67.5	-134.65	69.165	286	259	-3.0
Xijiang(Wuzhou, China)	111.3	23.5	113.3	22.6	207	172	-18.5
Columbia(The Dalles, OR, U.S.)	-121.2	45.6	-124	46.24	167	226	-95.4
Magdalena(Calamar, Colombia)	-74.9	10.2	-74.9	11.1	224	193	-692.6

What's the Current Status?



- CESM 1degree sea-ice global model –GIAF
- CORE experiment (Large and Yeager, 2009)
- 1948-2007 (after 5 cycles)





Dai, A., and K. E. Trenberth, 2002

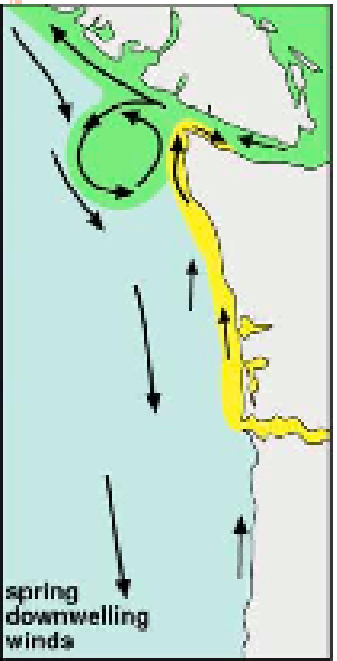
What are and will be done?

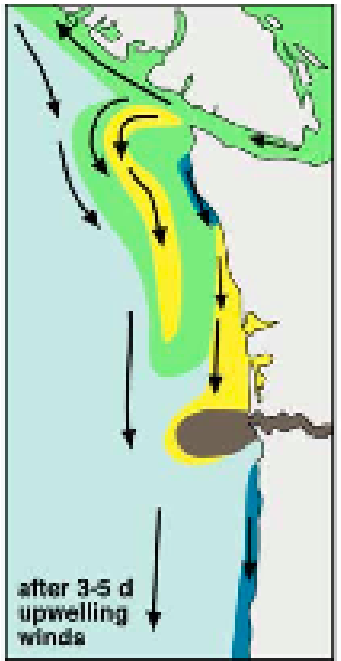
- Global scale:
  - Estuary-shelf freshwater exchange parameterizations
    - Improved “augmented precipitation” scheme
    - Estuary and shelf box models
- Regional scale:
  - Nested coupled Ocean Model Development

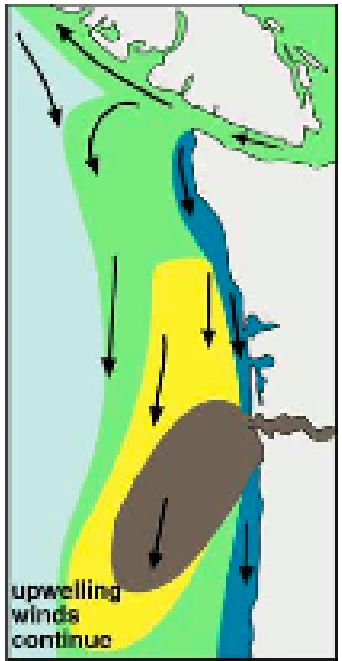
How?

➢ Improved "augmented precipitation" scheme

- Actual river PE inputs often form slender coastal currents/plumes.
- Redistribute the runoff flux as a source term vertically by considering the change of available potential energy (APE)=$\Delta\rho gz$
- Available potential energy flux (APE flux)=$\Delta\rho_f g h_p Q_R$



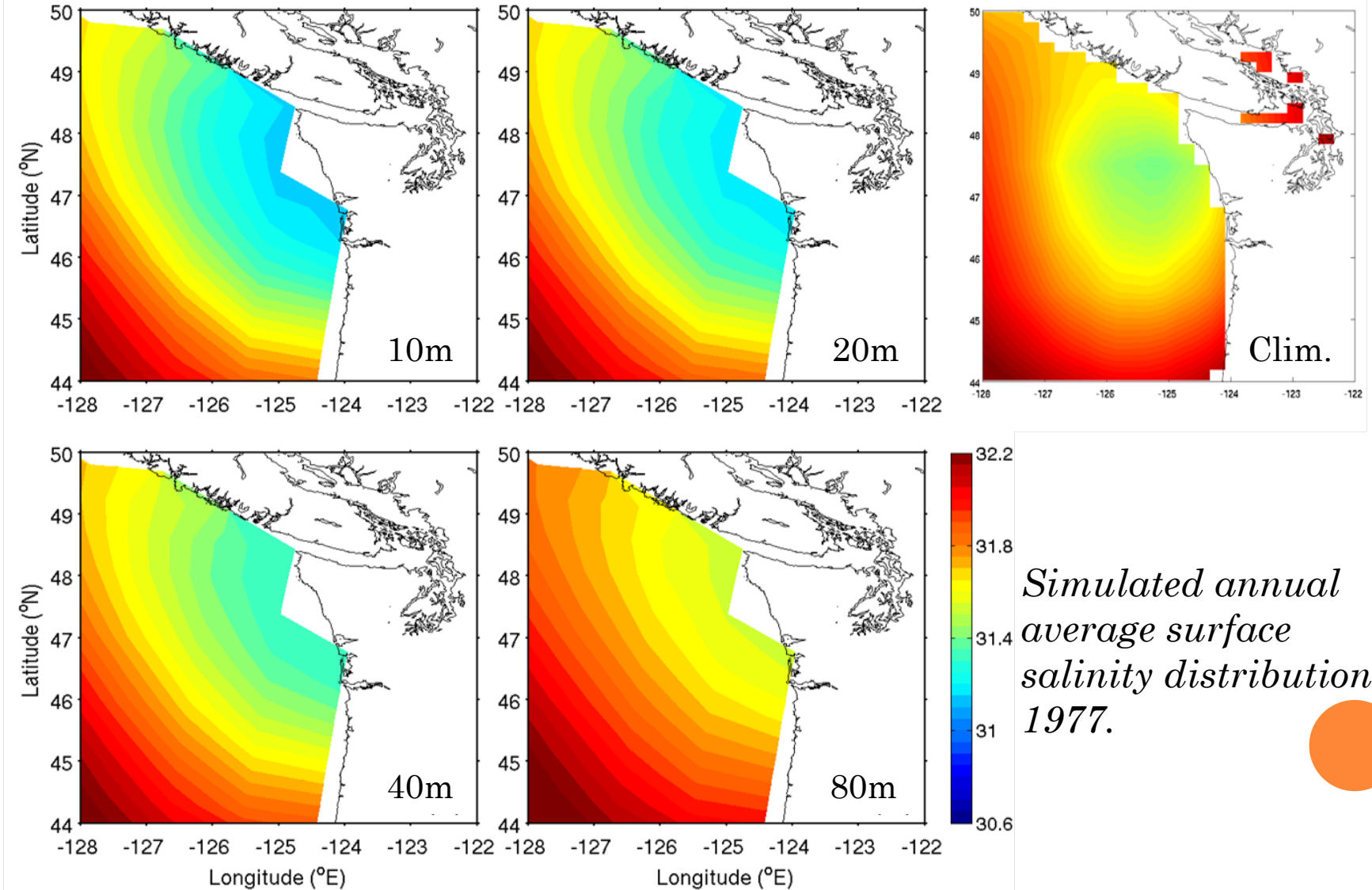




h_p can be determined by (a) observation or (b) river discharge rate (Yankovsky and Chapman, 1997).

How?

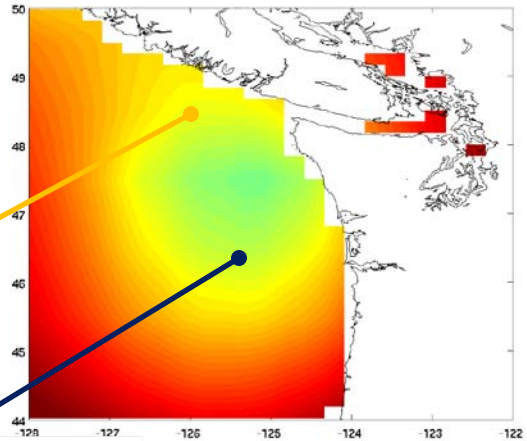
Sensitivity of different plume's vertical distribution on the surface salinity



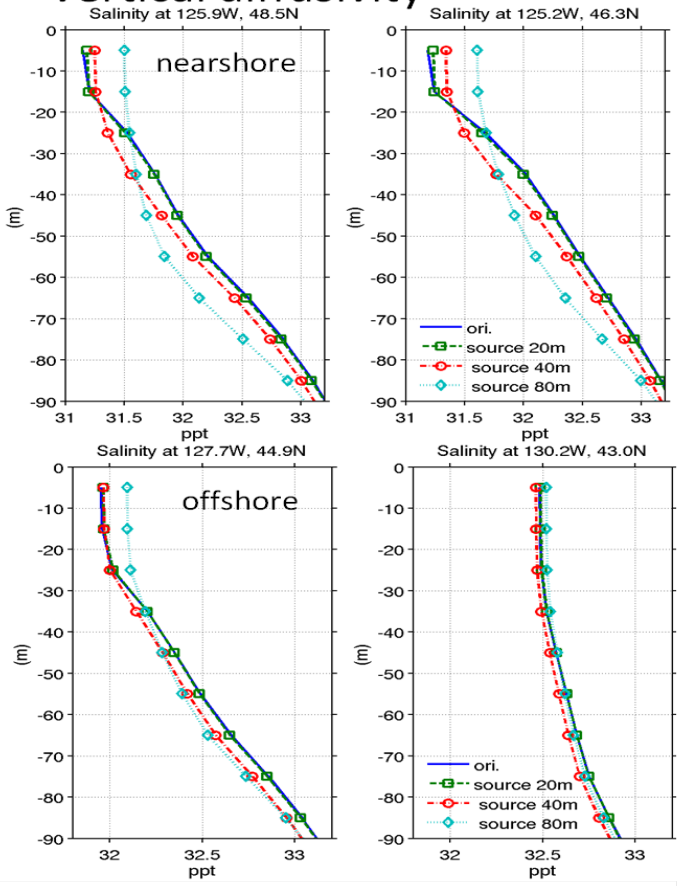
Simulated annual average surface salinity distribution in 1977.

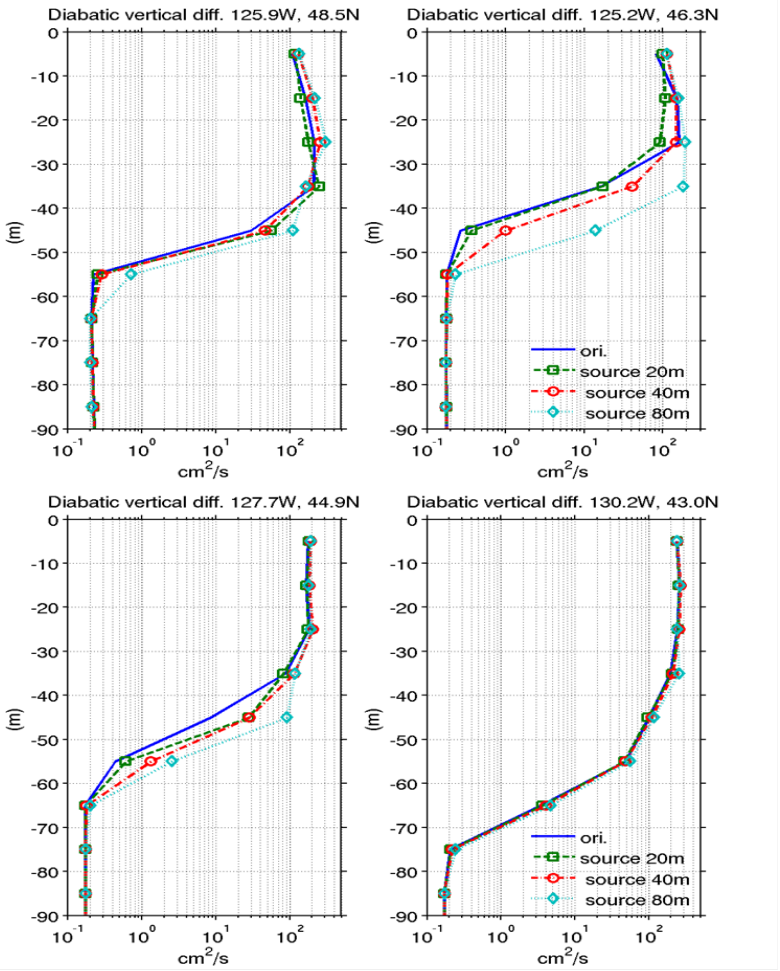
How?

Sensitivity of the one-year averaged vertical profiles of salinity and vertical eddy diffusivity in 1977



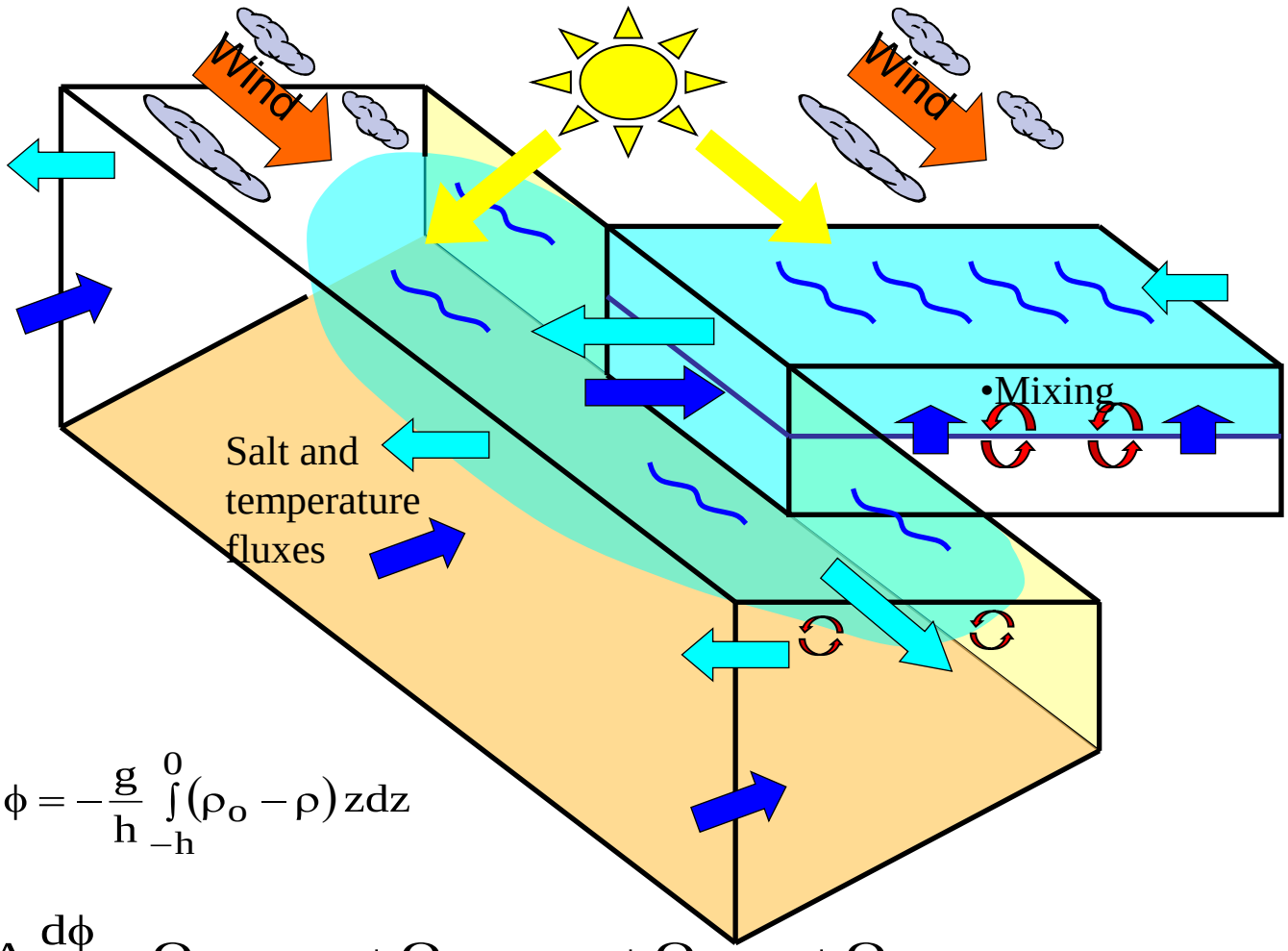
Vertical profile of salinity and vertical diffusivity





How?

- Estuary and shelf box model



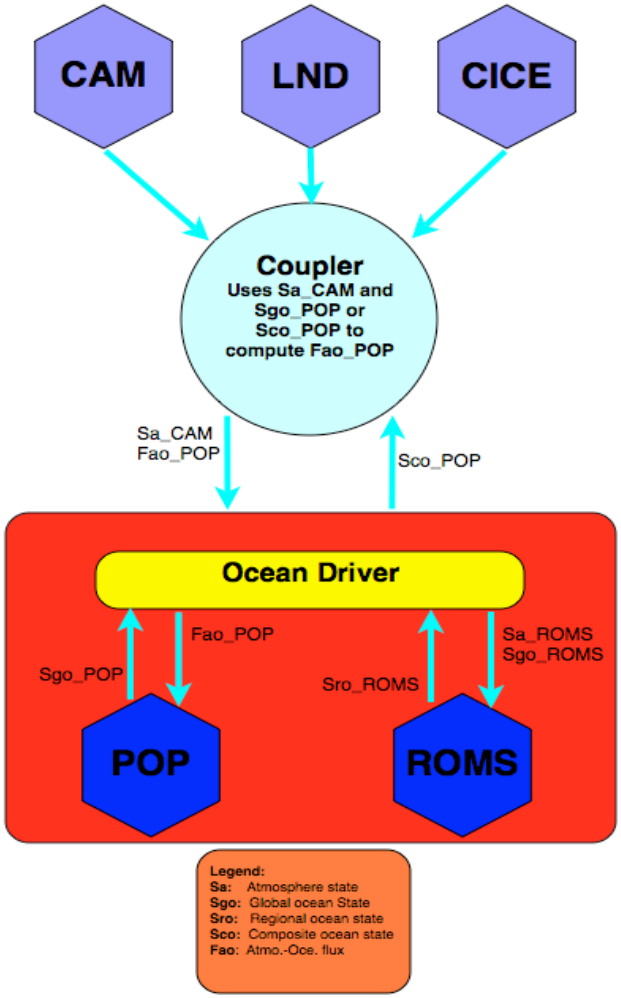
$$\phi = -\frac{g}{h}\int_{-h}^{0}(\rho_o - \rho)\,z\,dz$$

$$A\frac{d\phi}{dt} = \Omega_{Buoyant} + \Omega_{Heatflux} + \Omega_{Tidal} + \Omega_{Wind}$$

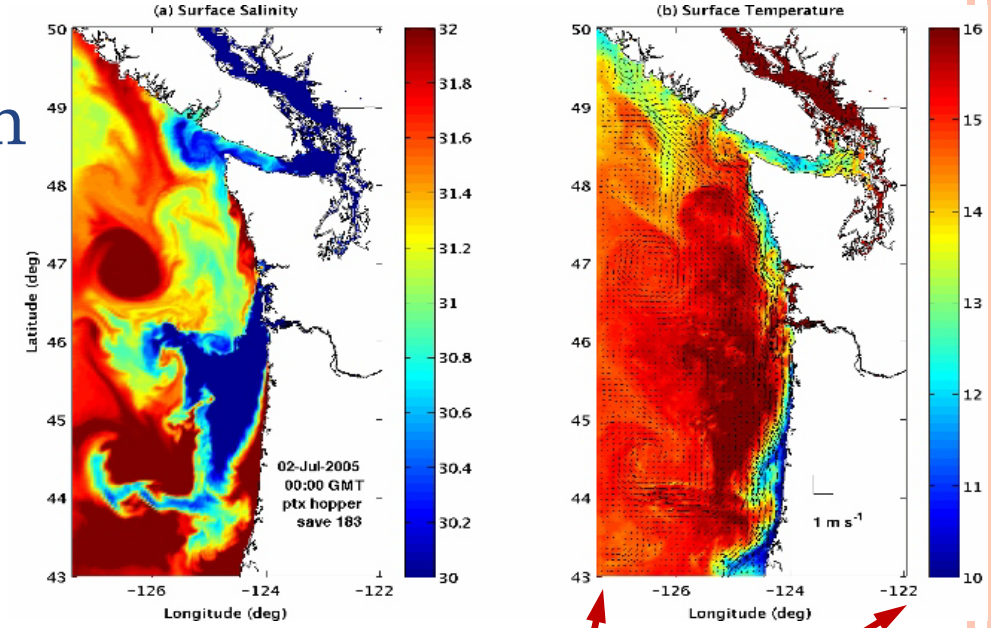
Approach by Garvine and Whitney (2006), Hordoir et al. (2008)

How?

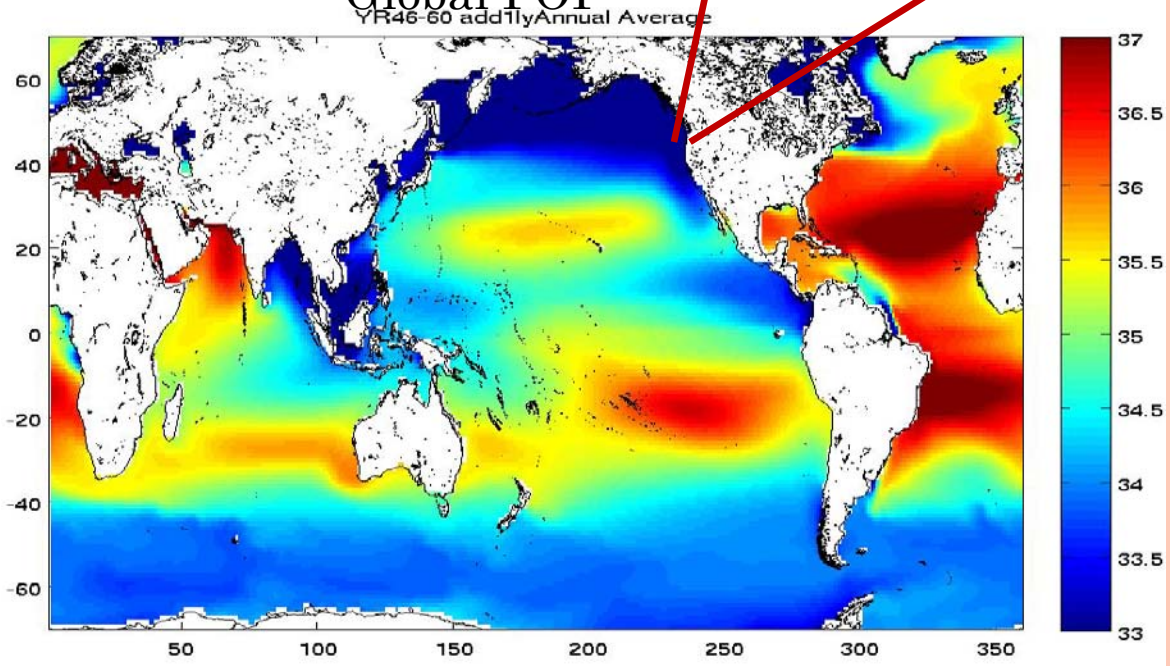
- Nested coupled ocean model development



0.3-3km resolution regional ROMS



Global POP



Future……

- Modification of KPP for model consistency
- Full package of Estuary-shelf freshwater exchange parameterizations
  - Useful for other exchange between the ocean and other climate system components (e.g., carbon, nutrient and any tracer)
- “data models”: ingest observations or output from a different modeling system.
- Two-way nested CESM-ROMS