Land-ocean conductivity in the carbon cycle of the Pacific Northwest margin

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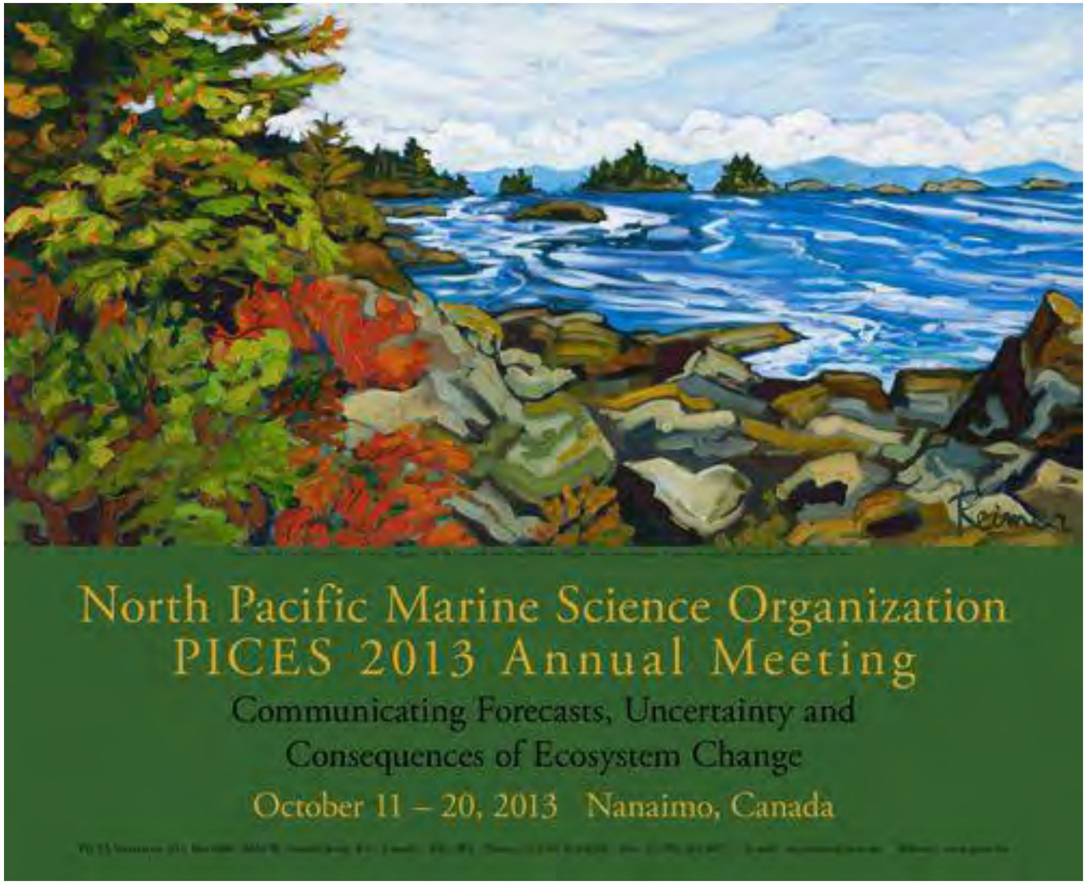


Main points of the talk:

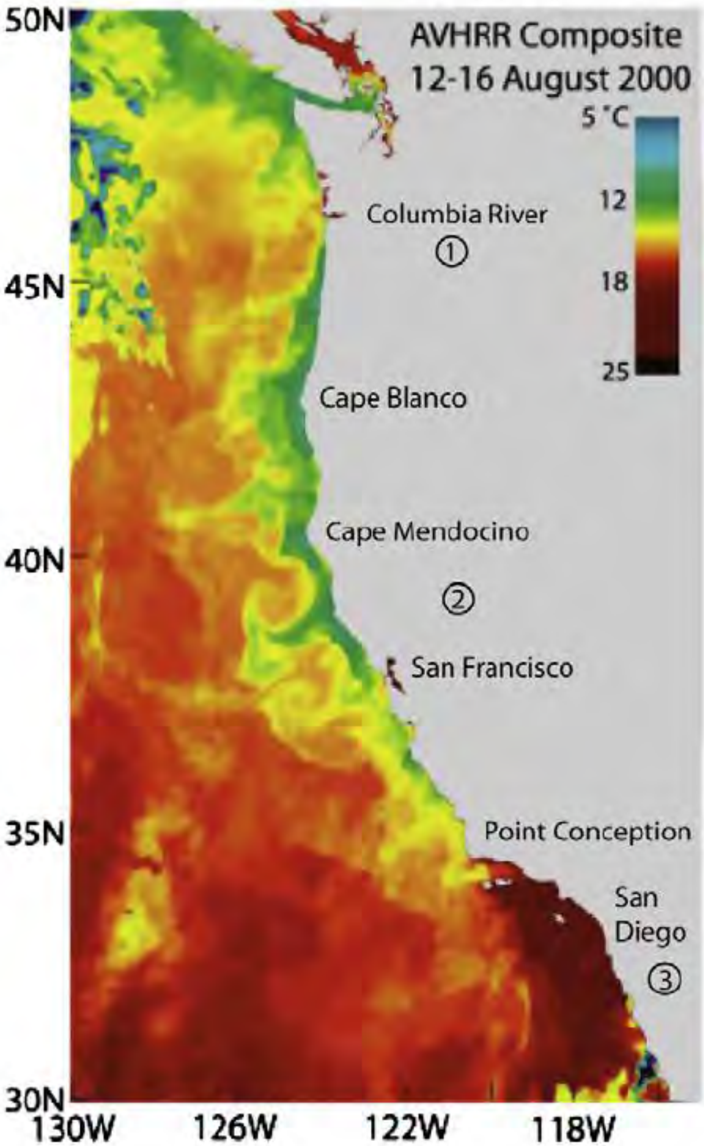
- There is significant carbon connectivity between land-ocean along PNW margin
- Coastal rivers represent a line source of carbon-relevant materials
- Winter-time (flooding) conditions are key
- Working towards understanding spatial and temporal interactions and feedbacks

Atmospheric forcings along PNW Margin

Summer vs. Winter Conditions

Checkley Jr., D.M., Barth, J.A. Prog. Oceanogr. (2009)

b



Summertime Conditions:

- Sustained northerly winds
- Upwelling due to Ekman transport
- Upwelling of cold, nutrient rich waters
- High levels of primary productivity
- Subject of intense research efforts (modeling, hypoxia, etc.)

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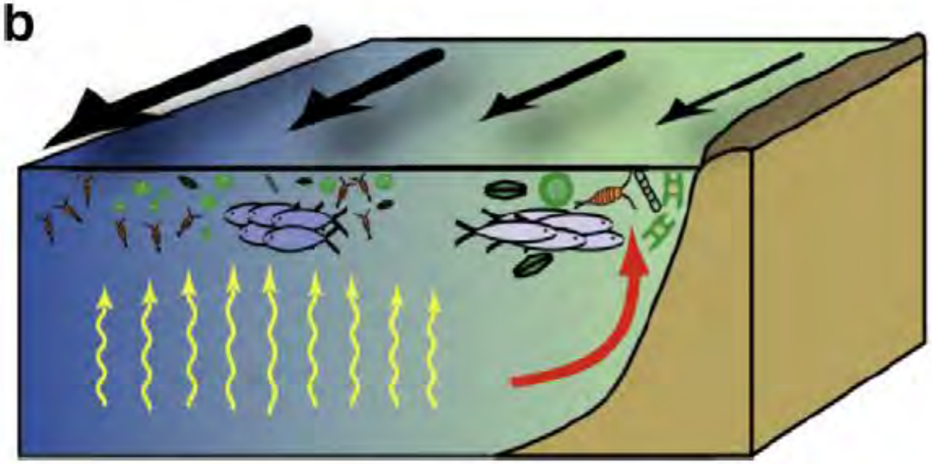
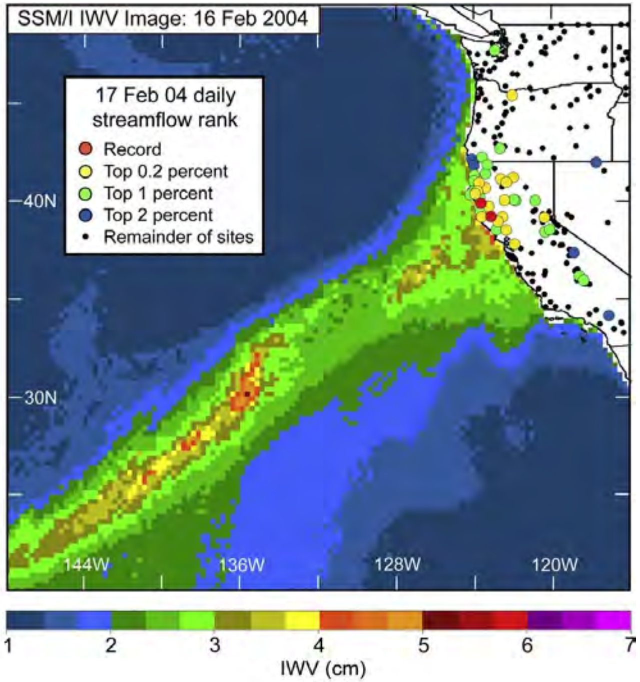


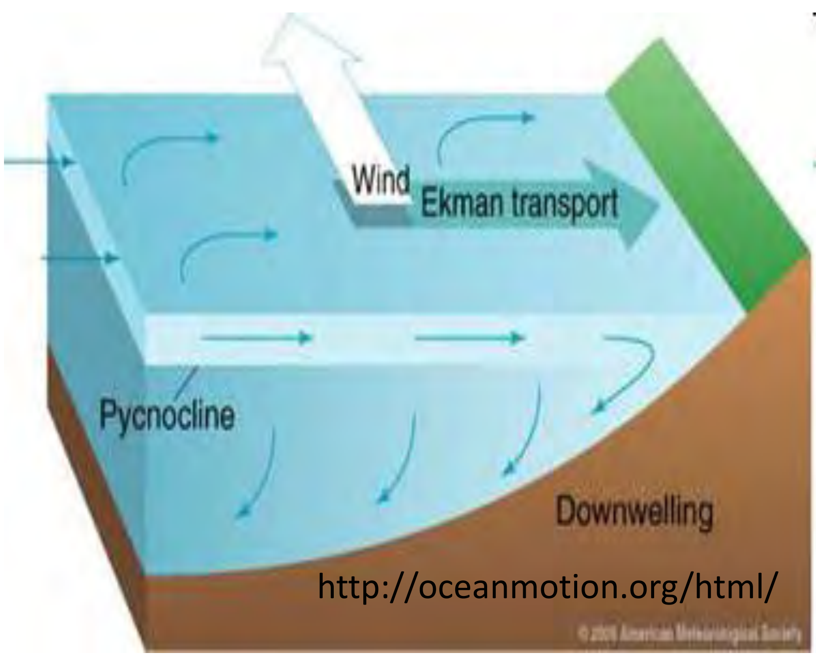
Fig. 4. Biological responses to upwelling in the CCS. (a) *Calanus marhallae* life cycle



Less-Studied Wintertime Conditions:

- Prevailing southerly winds
- Storms systems from the southwest
- Interaction with coastal topography results in high precipitation and flooding by coastal rivers

*"**Atmospheric rivers**": narrow bands of enhanced water vapor and low-level winds*



http://oceanmotion.org/html/

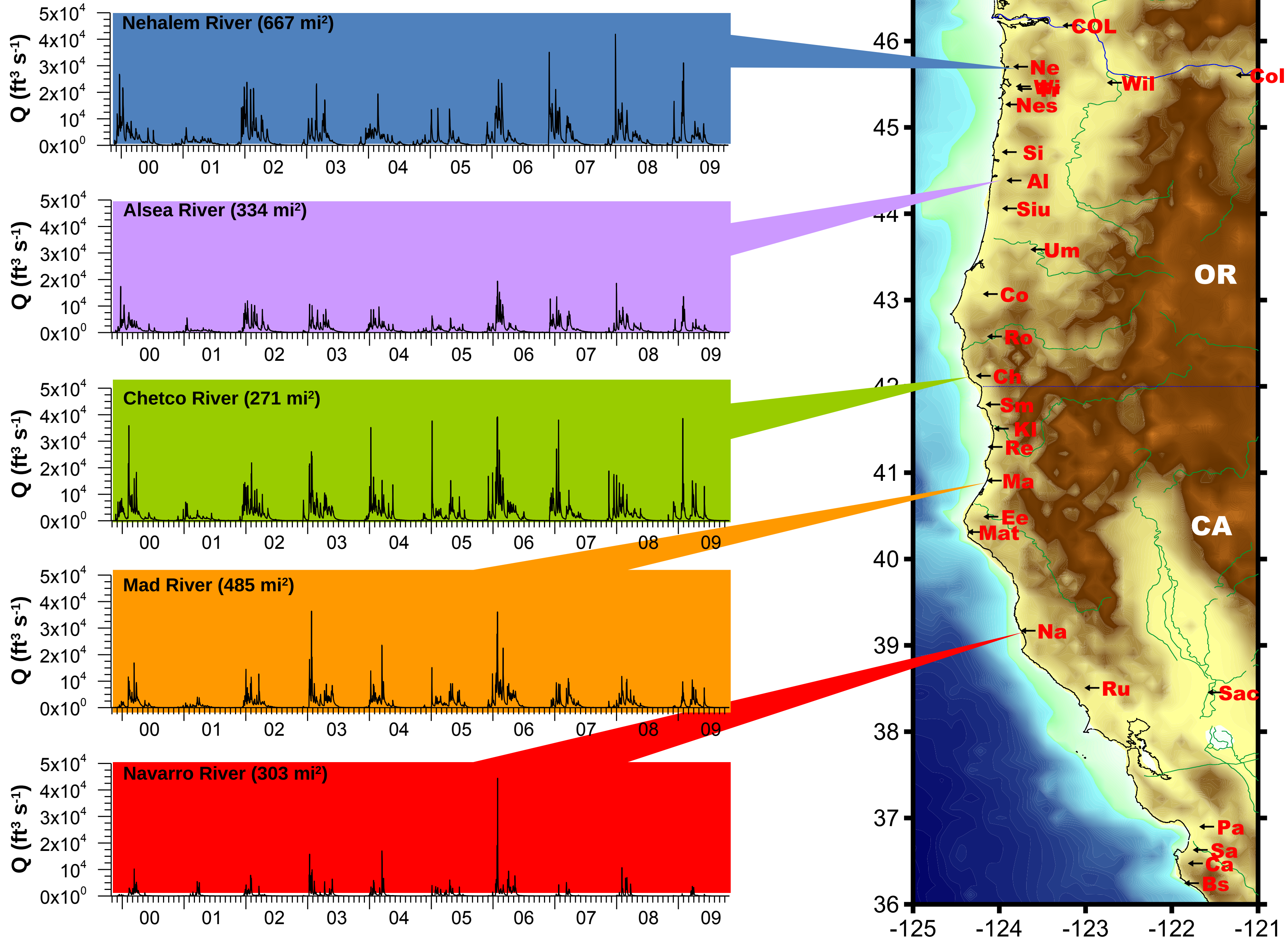
Downwelling-favorable winds and high waves facilitate

- trapping of freshwater inshore and
- offshore particle transport along benthic boundary layer

http://damp.coas.oregonstate.edu/coast/summary.shtml

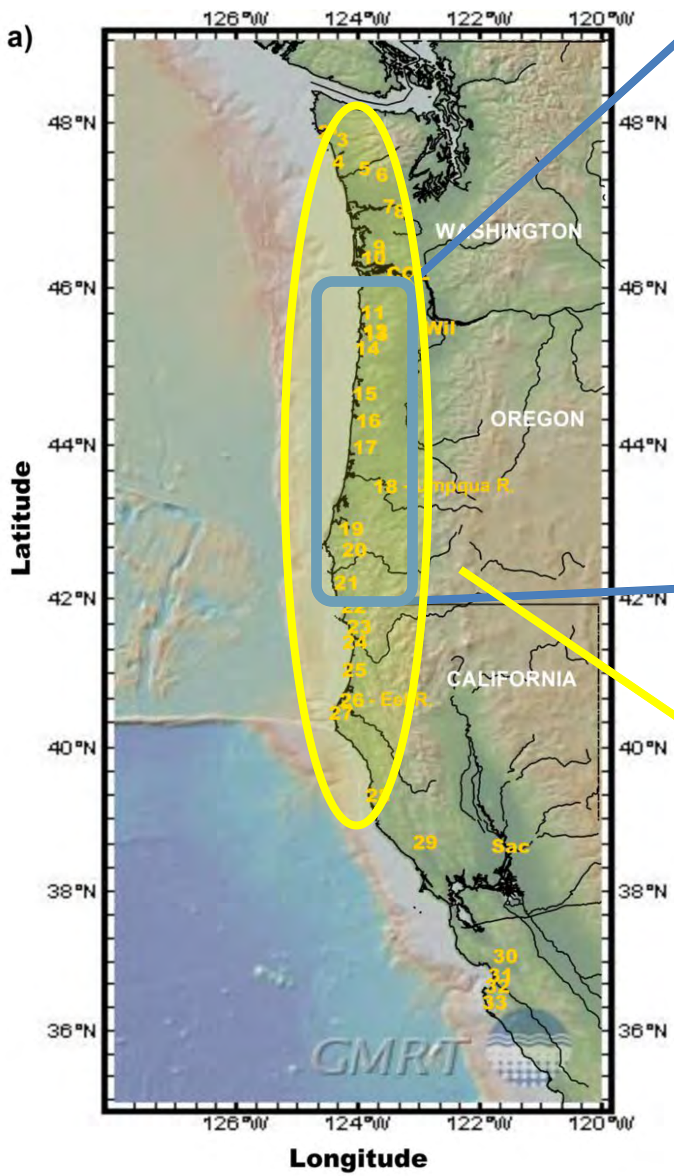
PNW Coastal Rivers: Peak flows in Winter

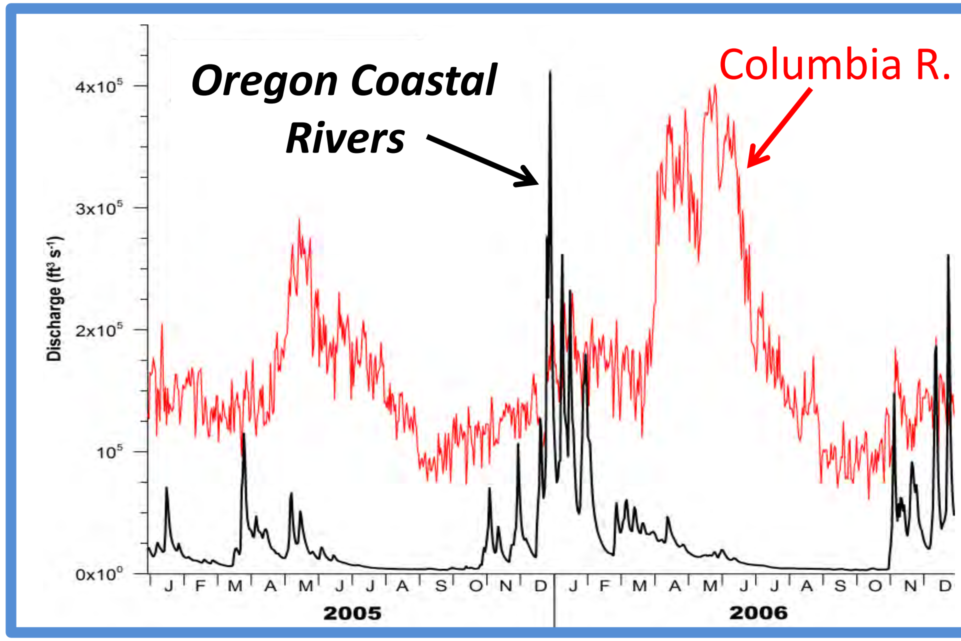
Latitudinal coherence in discharge



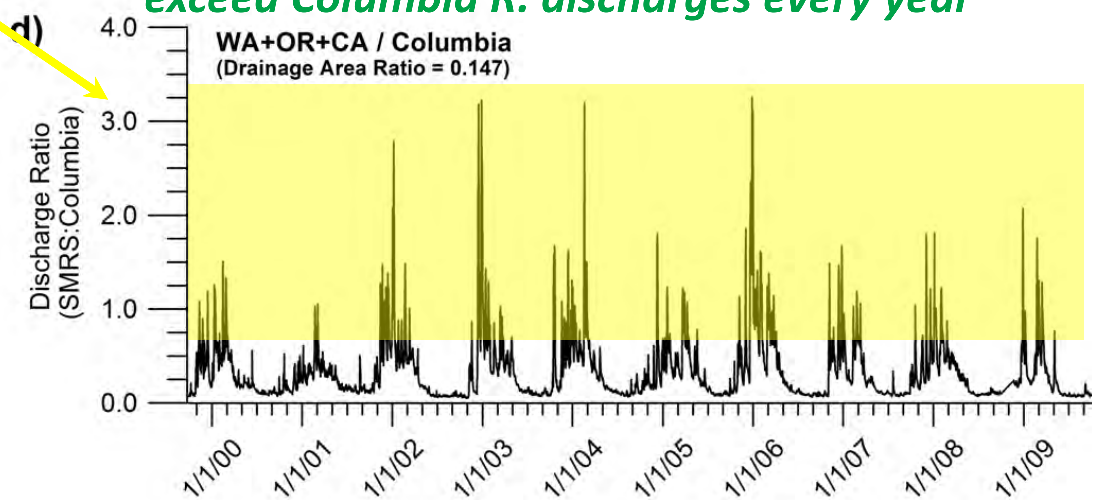
Regional Impacts:

- *Combined discharge of Oregon coastal rivers can exceed that of Columbia during winter months*

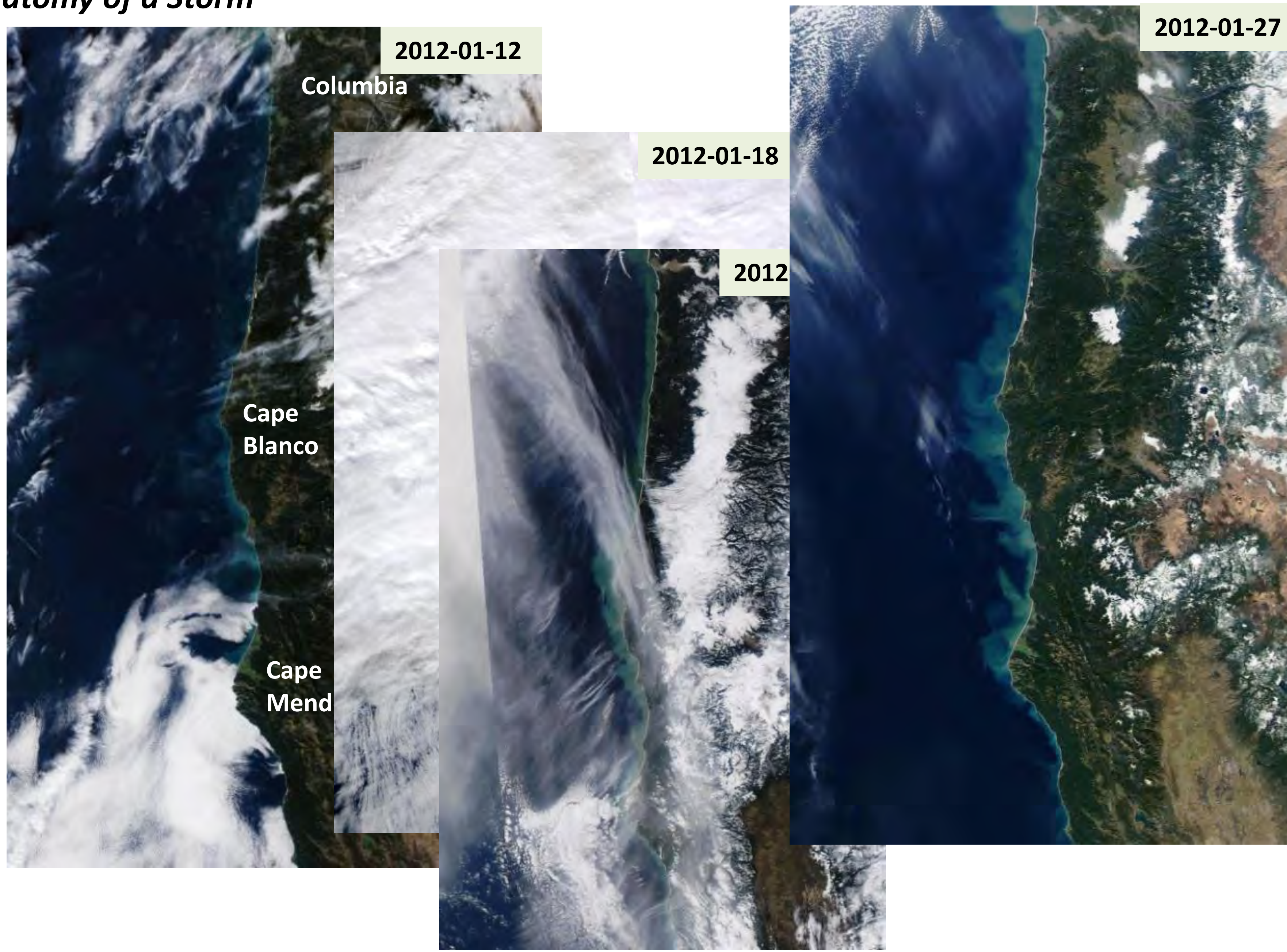




- *Regional winter discharges punctuated by floods exceed Columbia R. discharges every year*



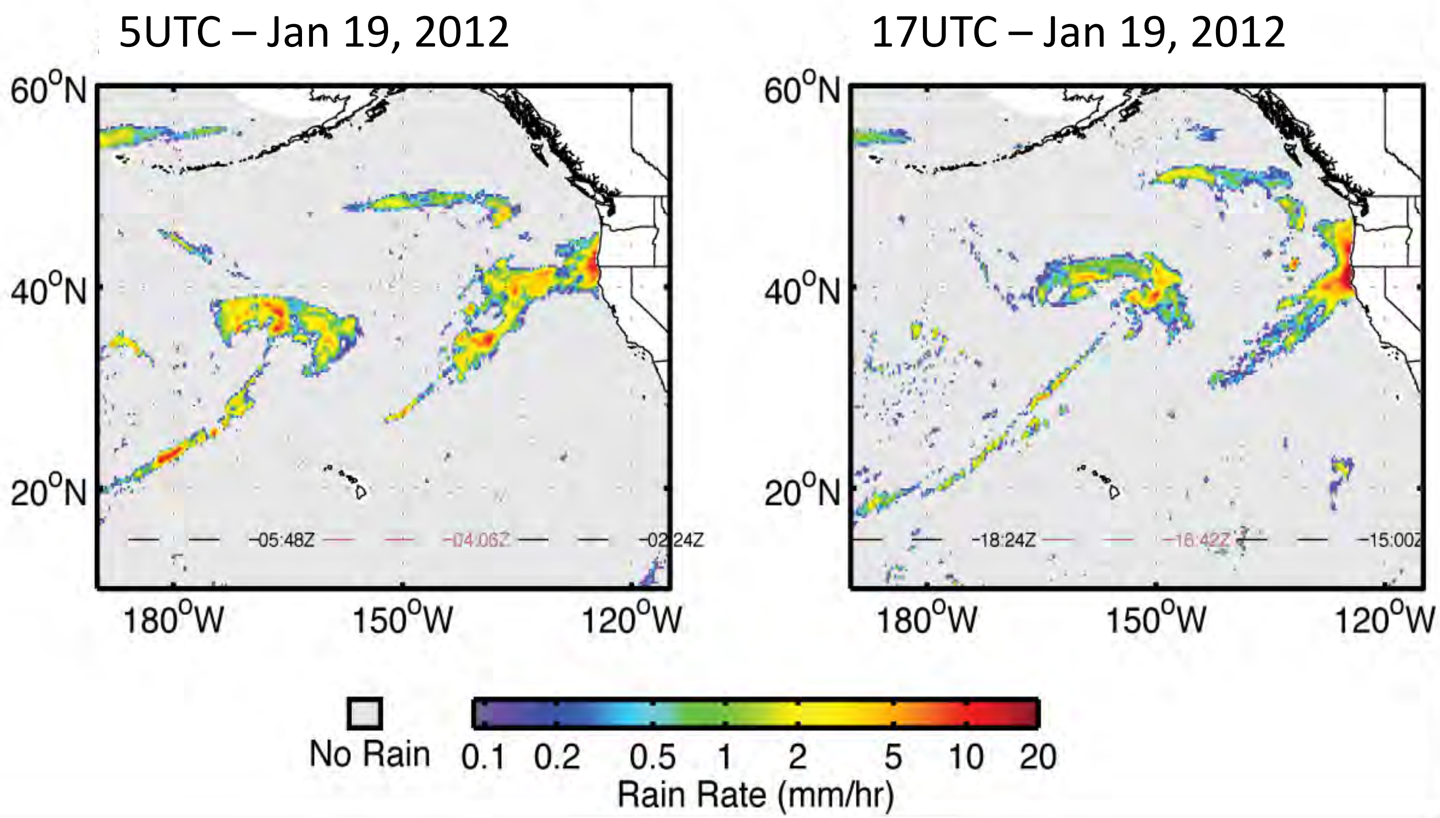
Anatomy of a Storm



Atmospheric – Land Interaction:

- Coastal mountain ranges intercept atmospheric moisture transport
- Lead to high rates of precipitation
- Efficient conduit for freshwater transfer to coastal ocean

Satellite estimates of Rainfall rate during January 2012 storm



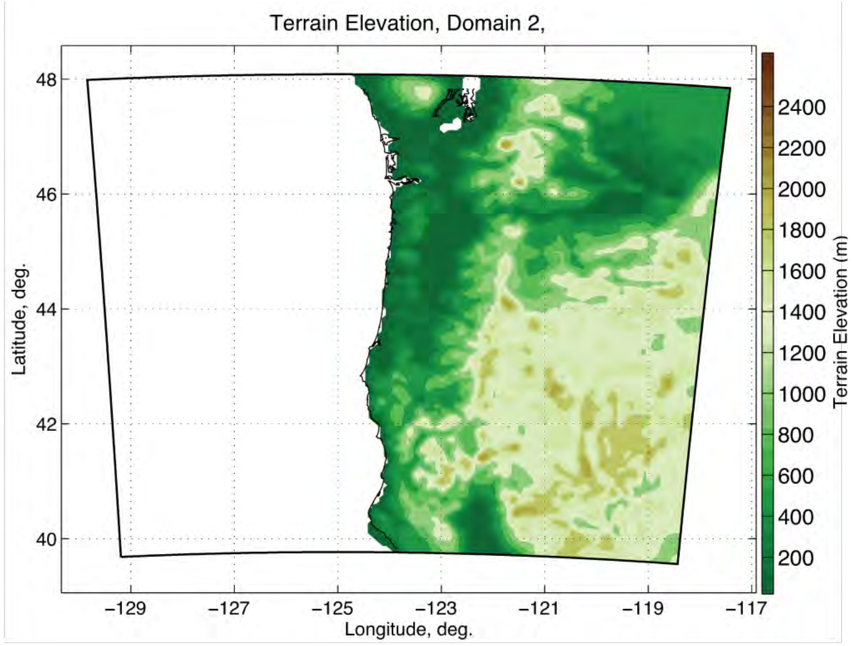
(Skyllingstad et al., in prep)

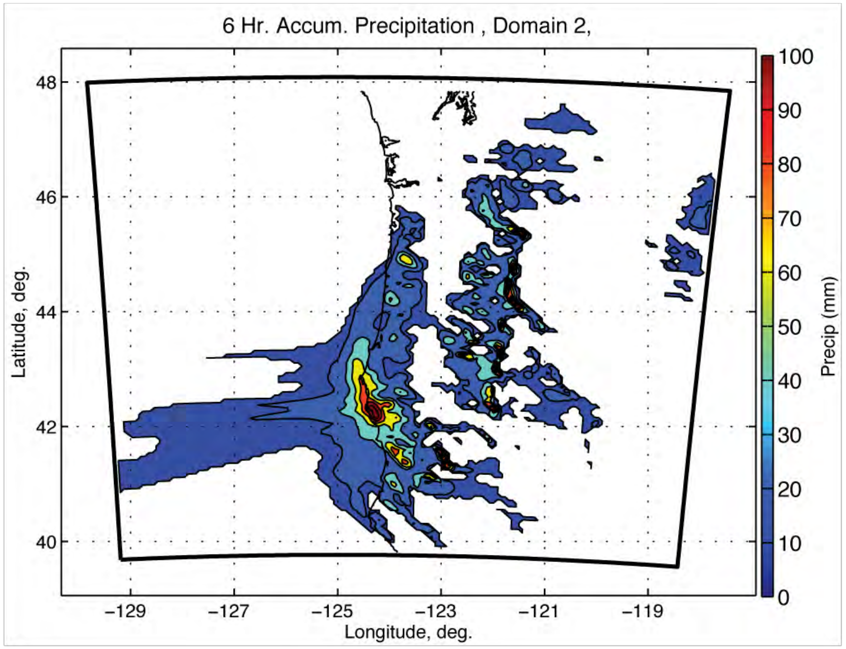
Atmospheric – Land Interaction (continued):

- Model topography and simulation of surface precipitation for January 19, 2012
- Precipitation on coastal ranges can be extremely high (relative to higher Cascades)

  ➔ **Efficient moisture barrier**

  ➔ **Verification of precipitation/runoff relationships planned**





Simulation Details (Skyllingstad et al., in prep):

WRF ARW (v3.4.1), 6 km nested domain of 150x150 points,

45 vertical levels, Thompson cloud microphysics, time-dependent RTGSST lower boundary conditions over the oceans and the Mellor –Yamada-Janjic boundary layer scheme.

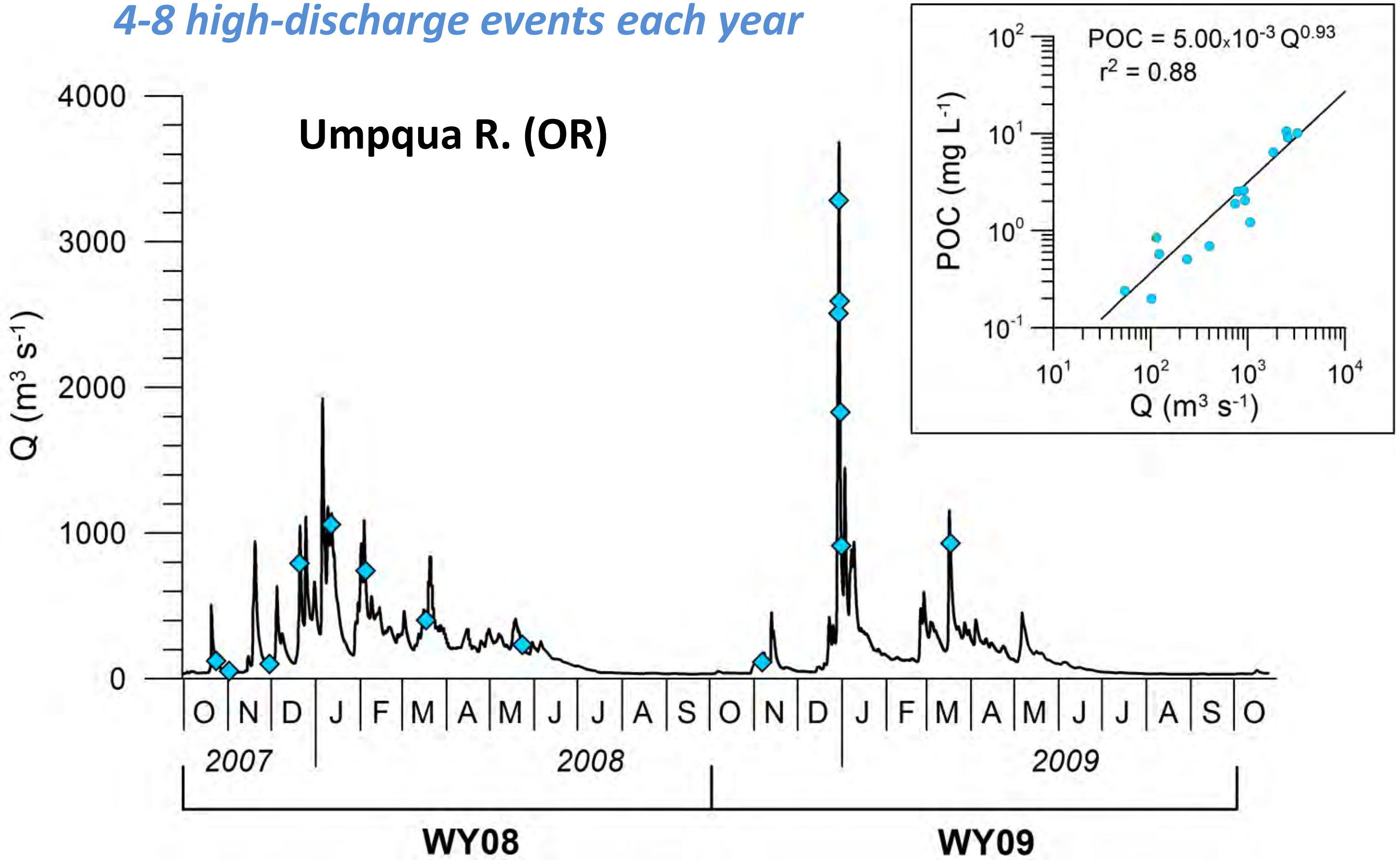
Lower Alsea River in Flood

Alsea Bay (Waldport) in Flood

Impacts on Carbon Export from Land:

- Rivers are effective transporters of biogenic relevant materials in winter
- Sediment, organic matter, nutrient loads increase with discharge
- Seasonal floods (intermediate magnitude/frequency) are responsible for the bulk of the transport

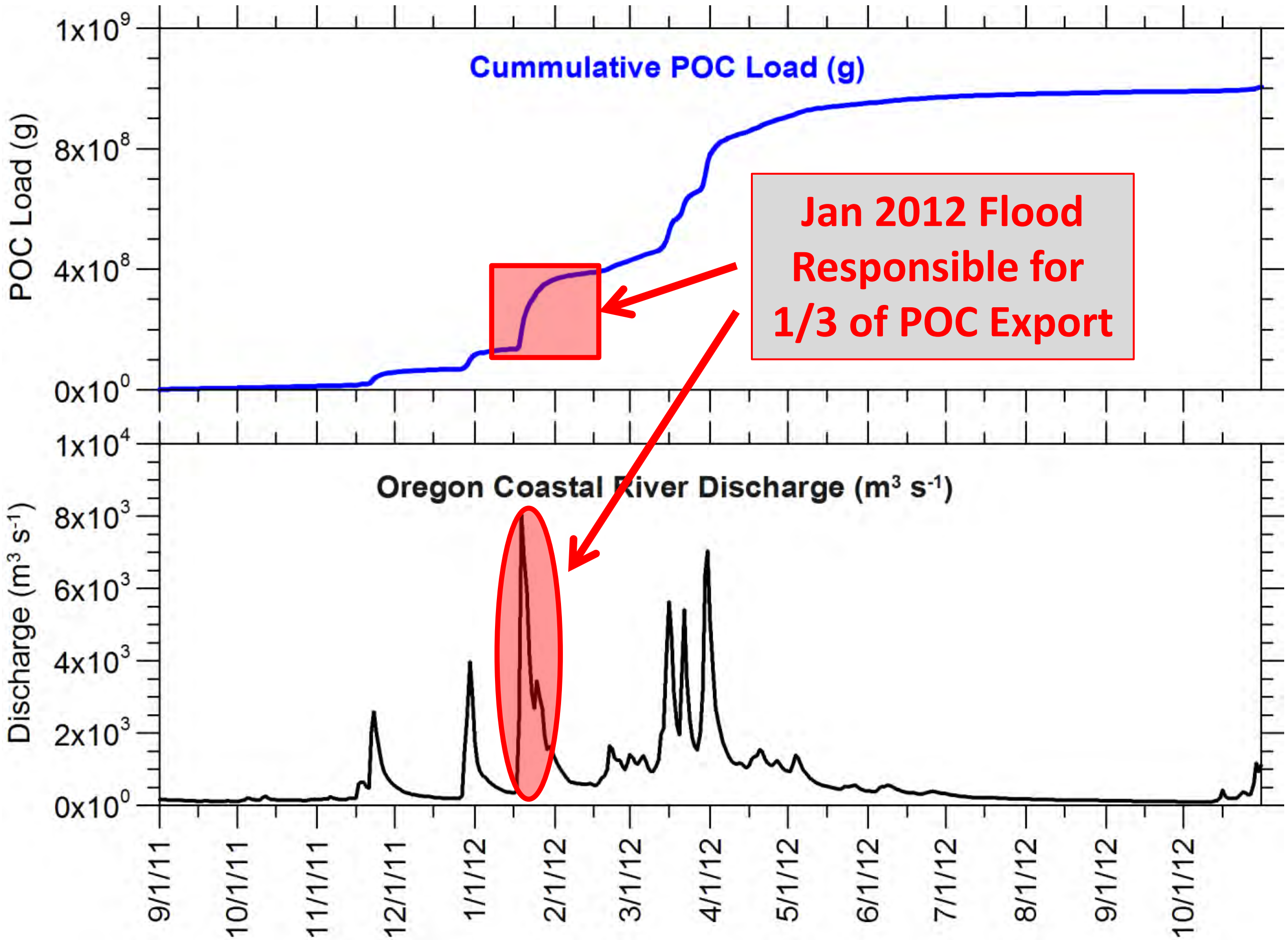
> 90% of annual Particulate Organic Carbon (POC) loads delivered during 4-8 high-discharge events each year



Goni et al., 2013; Hatten et al., 2012

Impacts on Carbon Export from Land (continued):

- Winter storms as flood-producing agents of transport
- Export is highly seasonal/episodic and coherent with ocean conditions



Annual POC load delivered by PNW coastal rivers:

~ 0.4 Tg C y^{-1}

Same order of magnitude as other carbon flux terms:

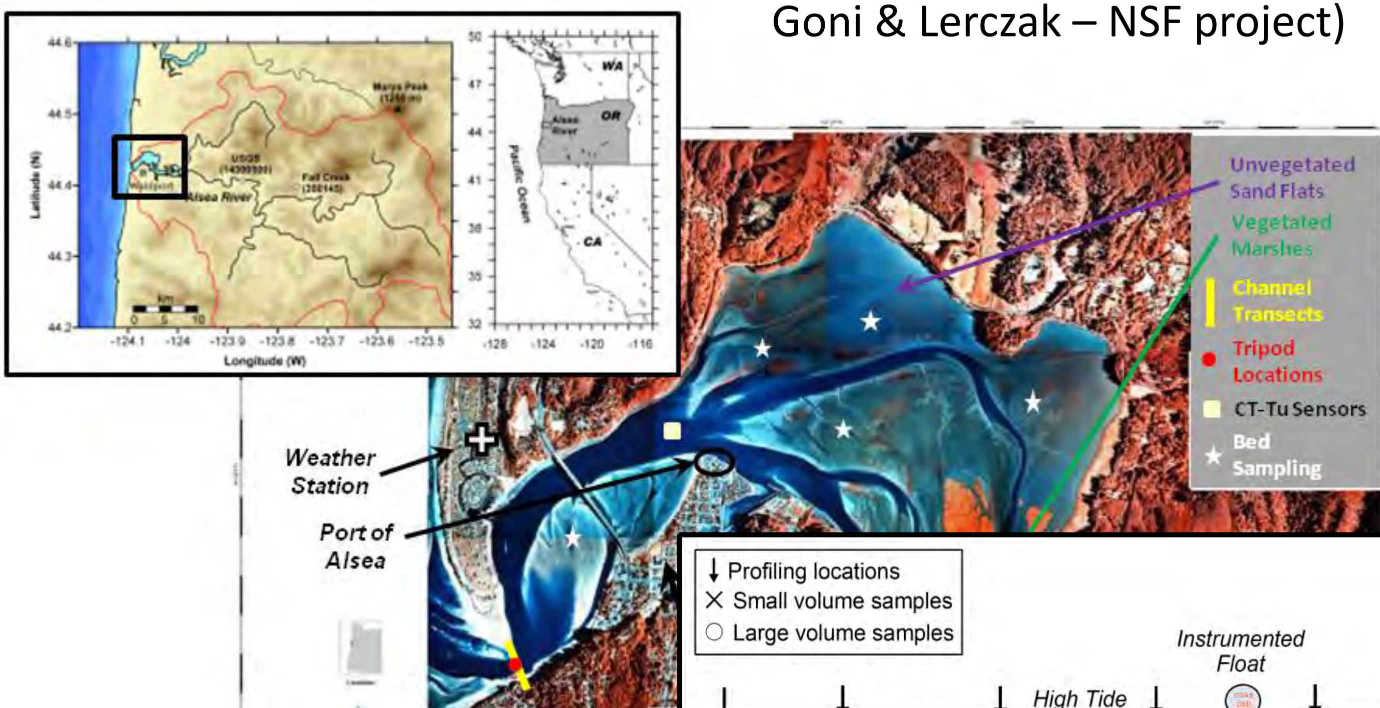
- **Carbon export by large rivers (Columbia/Fraser)**
- **Total CO_2 flux across air-sea interface in PNW coastal region**

Goni et al., 2013; Goni et al., in prep.

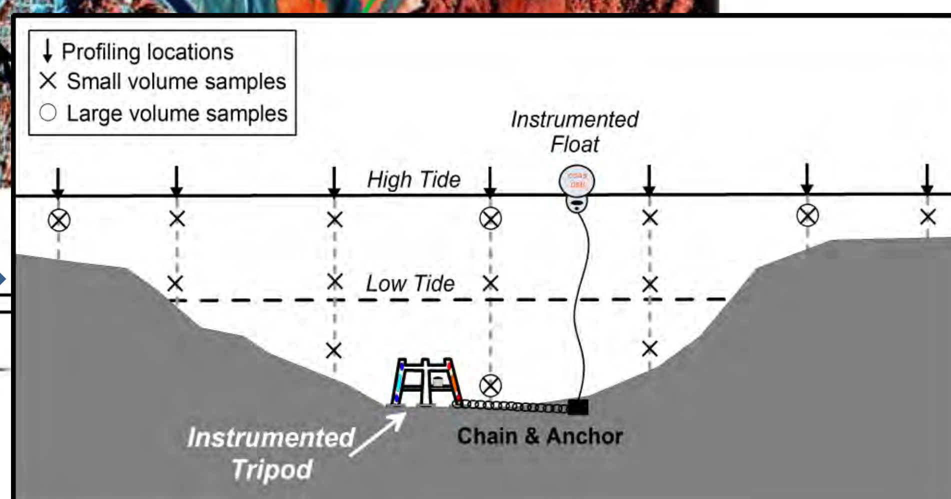
Impacts in coastal environments: Estuaries

- Coastal floods as sources of extreme variability
- Episodic exposure to fresh water, high sediment/POM loads
- Physics/biogeochemical interactions in estuaries during floods
  – key questions being addressed by on-going research

(Study Site ➔ ***Alsea Bay***
Goni & Lerczak – NSF project)

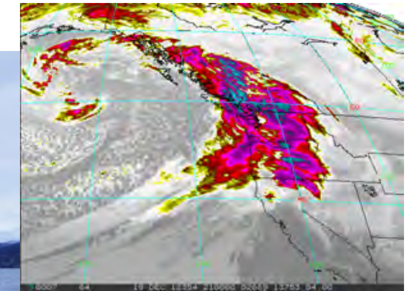


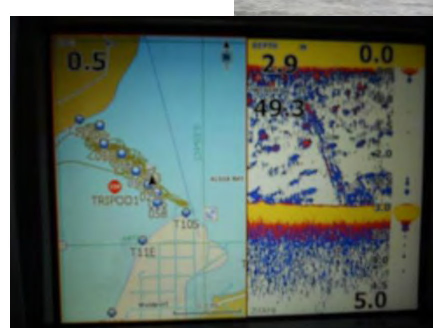
Measurements being currently conducted in Oregon Estuaries



Instrumented Tripods

Event-Response Sampling





Flood impacts in Estuaries:

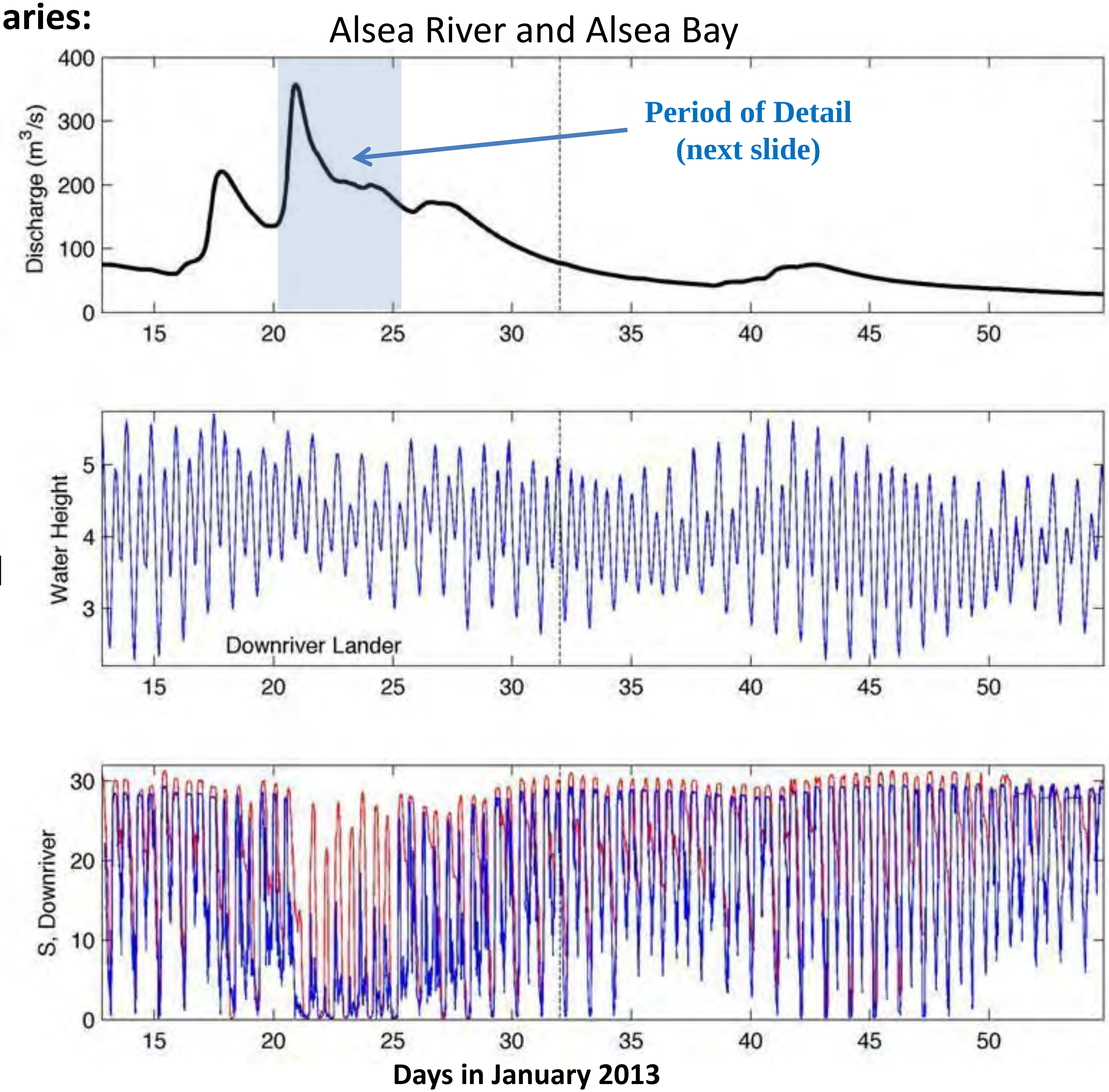
Example of a seasonal flood:

High discharge during neap tides

Effect on local sea level

Impacts on surface (Blue) and bottom (Red) salinity for days prior and post peak discharge

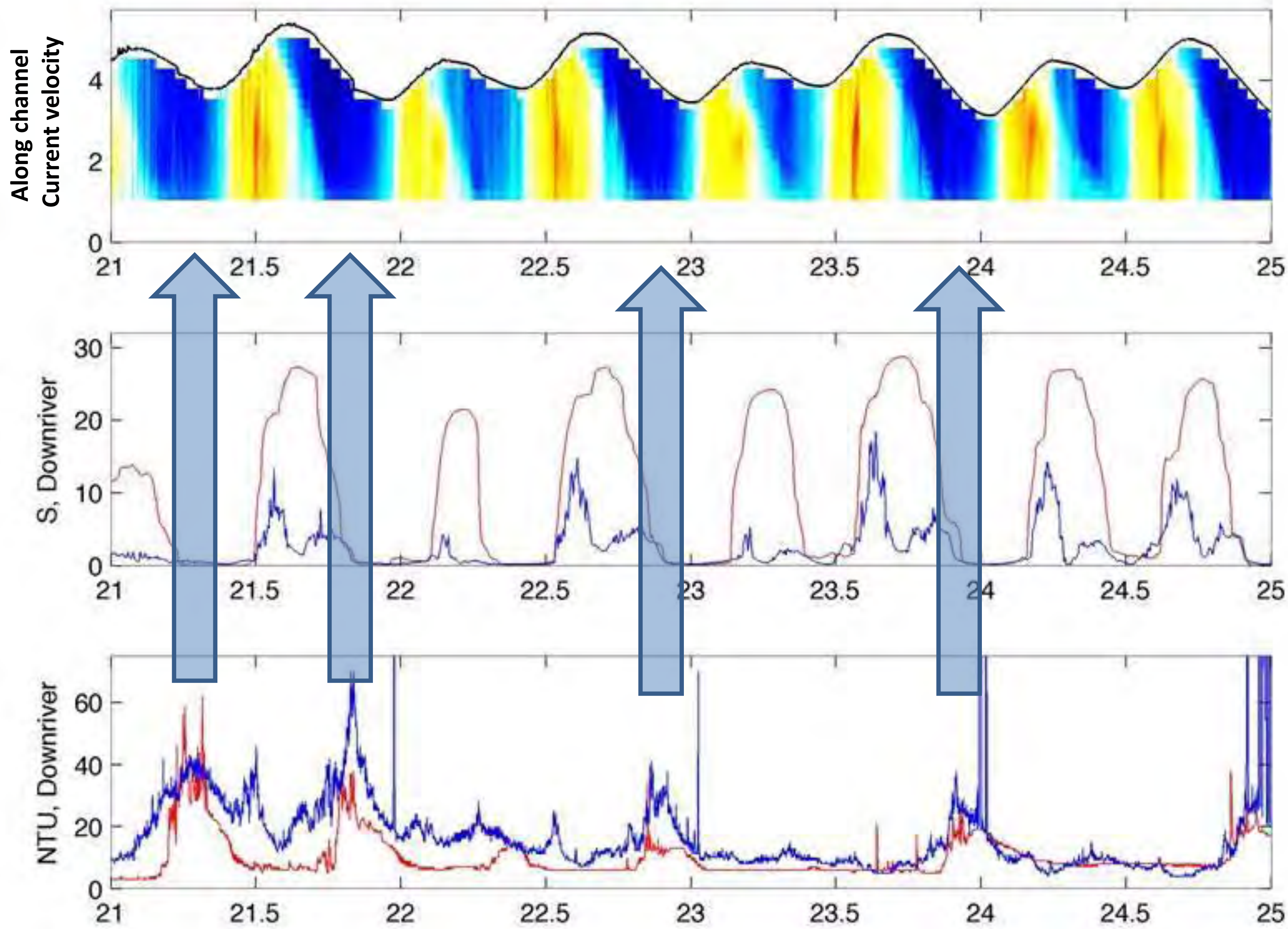
Salinity variability a function of discharge and tidal conditions



Flood impacts in Estuaries (continued):

Hydrodynamic relationships between flood/ebb currents and salinity

(**effects of residual circulation at the surface**)



Tidal control on turbidity signals in both surface and bottom waters

➔ **Ebb dominated transport**

Goni and Lerczak (ASLO 2014)

Flood impacts in Estuaries (continued):

Samples analyzed for:

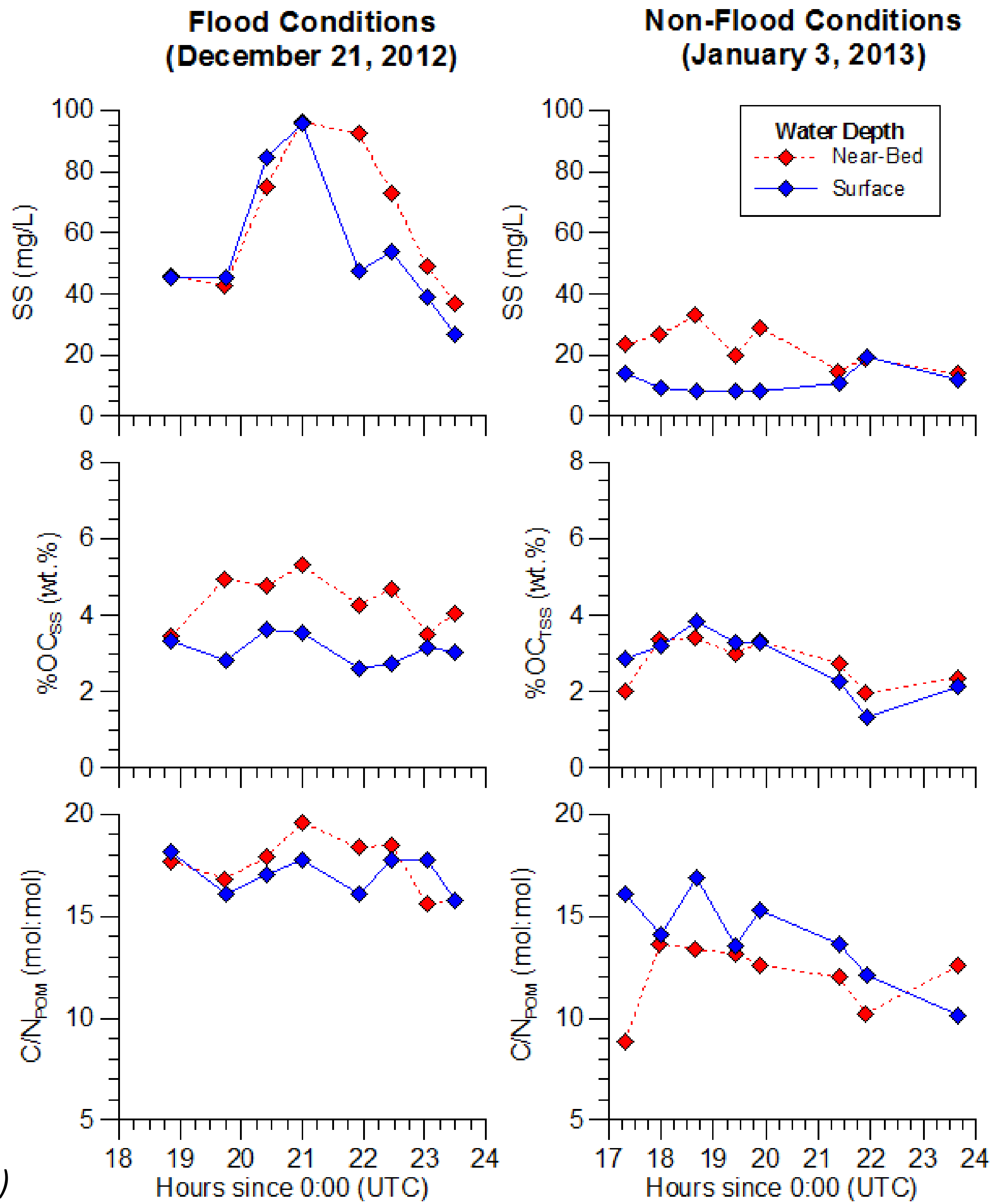
- Suspended sediment (SS)
- Organic carbon content (%OC_{SS})
- Carbon/nitrogen ratios of POM (C/N_{POM})

surface (blue) vs. bottom (red) waters

Large contrasts in the concentration (SS) and composition (%OC, C/N) of suspended particles in the estuary

- **Flood vs. non-flood conditions**
- **Ebb vs. flood current**

➔ ***Effective transport of terrestrial carbon during floods***



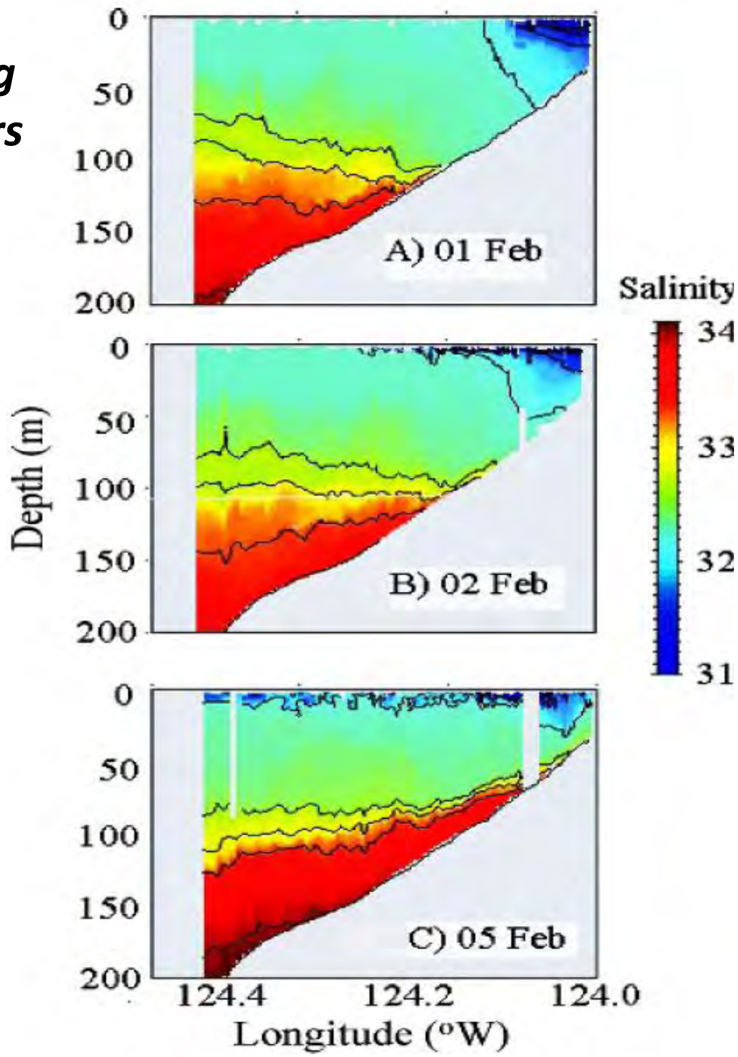
Goni and Lerczak (ASLO 2014)

Flood impacts in Coastal Zone:

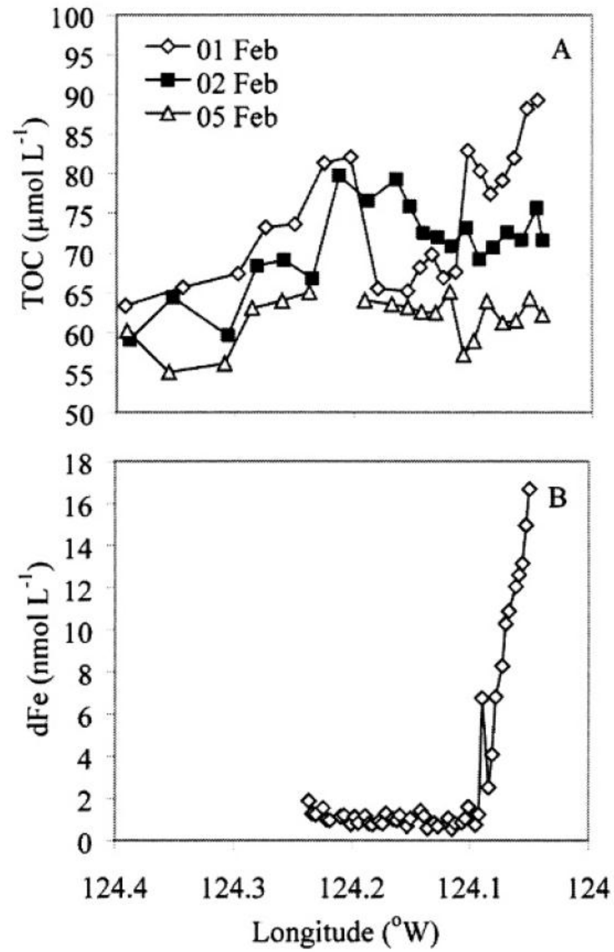
Wetz et al. *Limnol. Oceanogr. 2006*

Cross-shelf transects off Oregon in Feb-03
Coincident with flooding of Coast Range rivers

Low salinity river-influenced water near the coast
➔ Downwelling relaxation



Elevated diss. Fe in freshwater plume near the coast
Elevated OC in flood-influenced waters
➔ Runoff-derived productivity

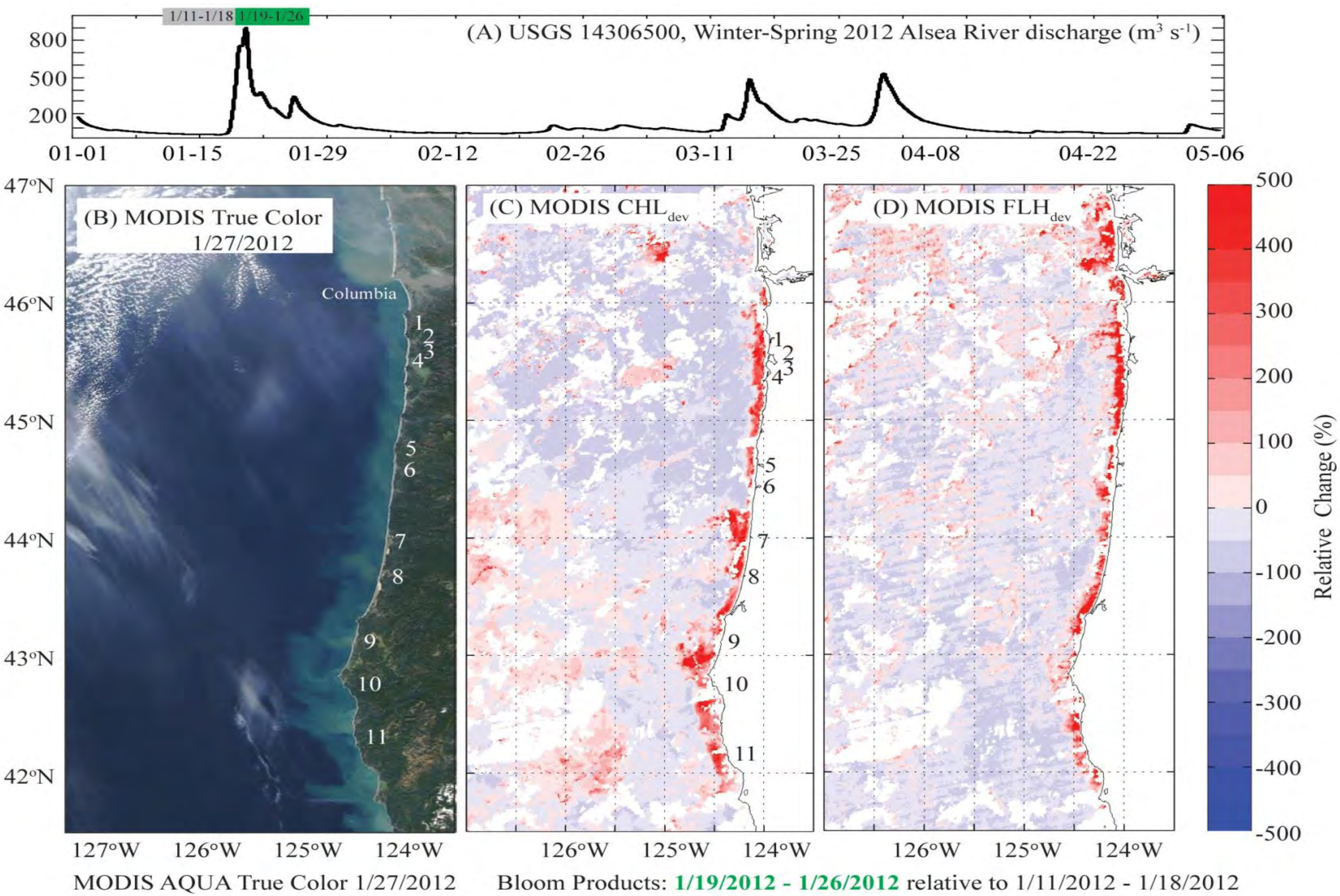


Key Conclusion:

Nutrients supplied by the rivers could result in winter carbon fixation equating to ~20% of the summer upwelling carbon fixation

Flood impacts in Coastal Zone (continued): ***The January 2012 Storm***

- Phytoplankton bloom products→ MODIS chlorophyll (CHL_{dev}) and fluorescence line height (FLH_{dev}) indicate widespread impact in coastal ocean following peak flows.
- Enhanced buoyancy and nutrient loads triggers for winter plankton blooms
  (White et al., in preparation; McKibben et al., 2013)

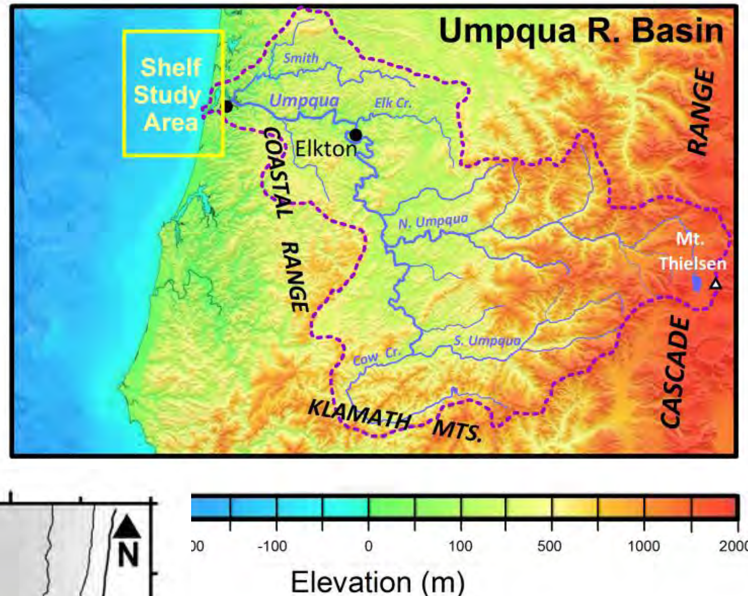


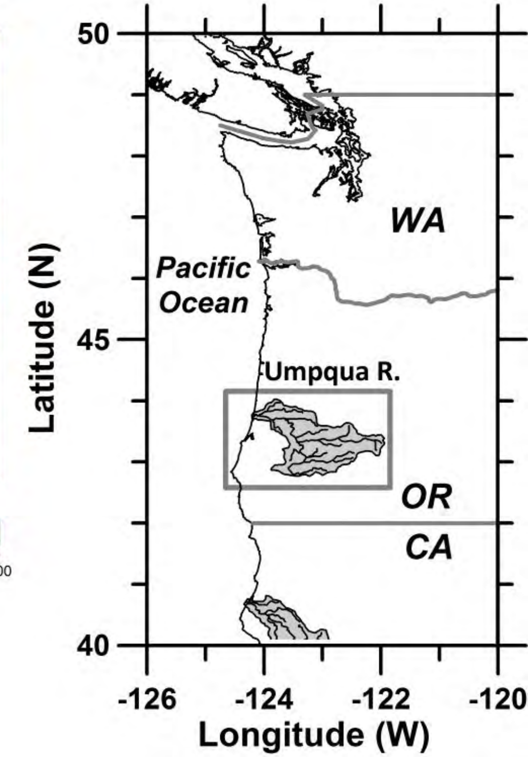
Flood Impacts in Coastal Zone (III):

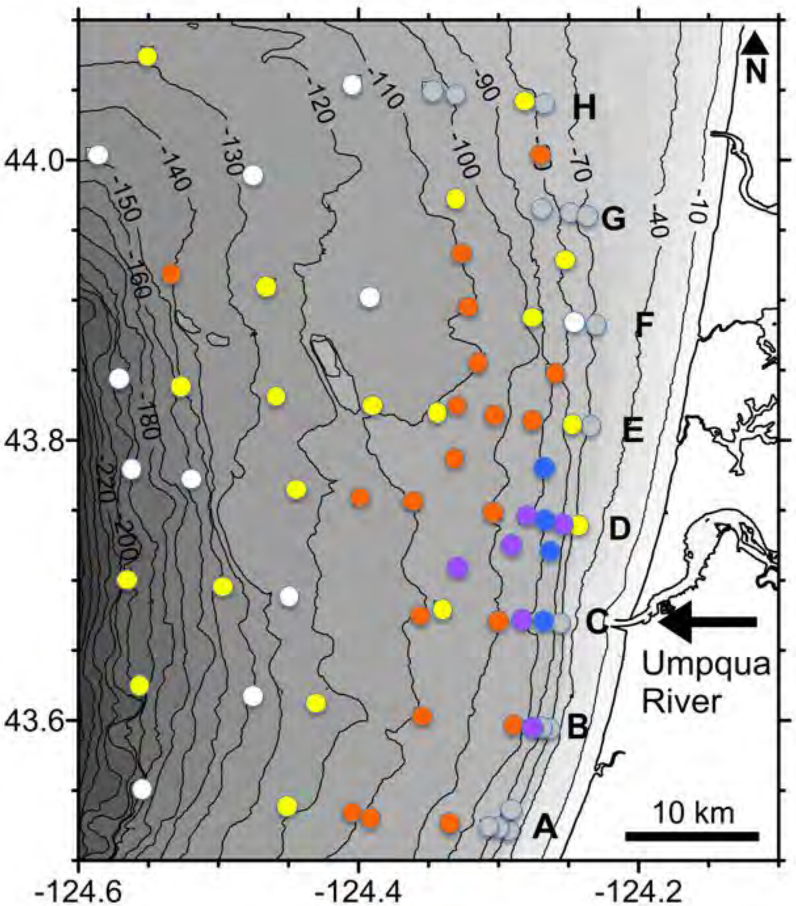
Benthic habitats

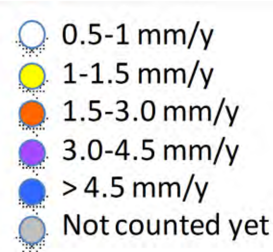
e.g. Umpqua R. Depocenter

(*Hastings et al., 2012; Wheatcroft et al., 2013*)









Recent Studies:

Characterization of ***shelf-depocenters*** associated with coastal rivers (such as Umpqua R)

Areas of higher accumulation rates found along inner to mid-shelf

➔ Result of sediment delivery during floods and wave climate.

(Kniskern et al., 2011)

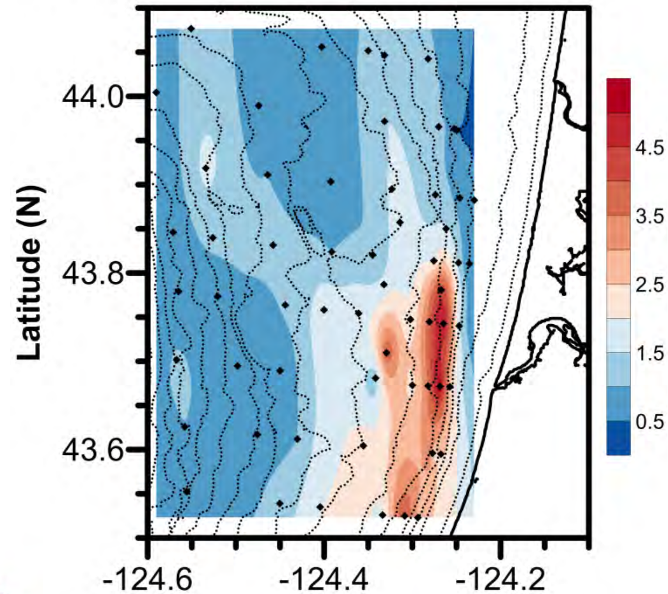
Flood Impacts in Coastal Zone:

Sediment Depocenters with High Sed. Accum. Rates

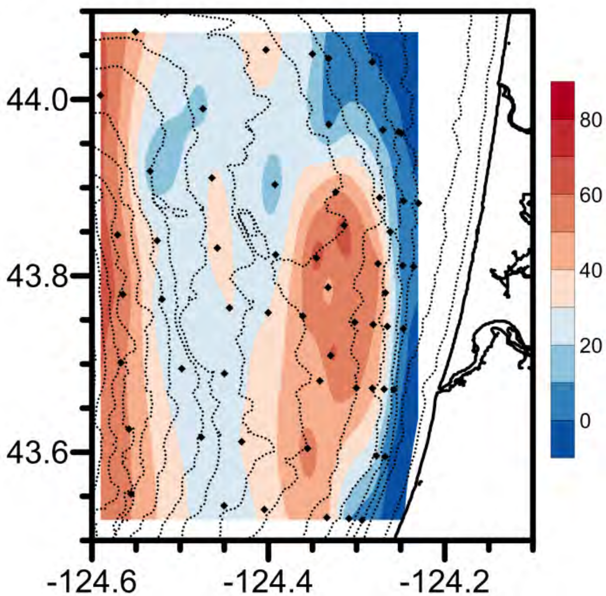
- Well defined silty-mud deposit
  - Sediments enriched in organic carbon,
  - Elevated contributions from terrestrial materials

➔ **Contrast in benthic habitats within the shelf**

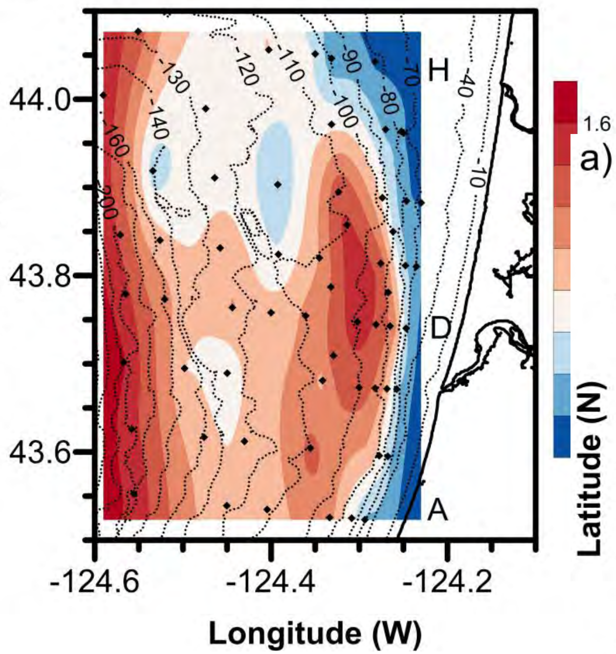
a) SAR (mm/y)



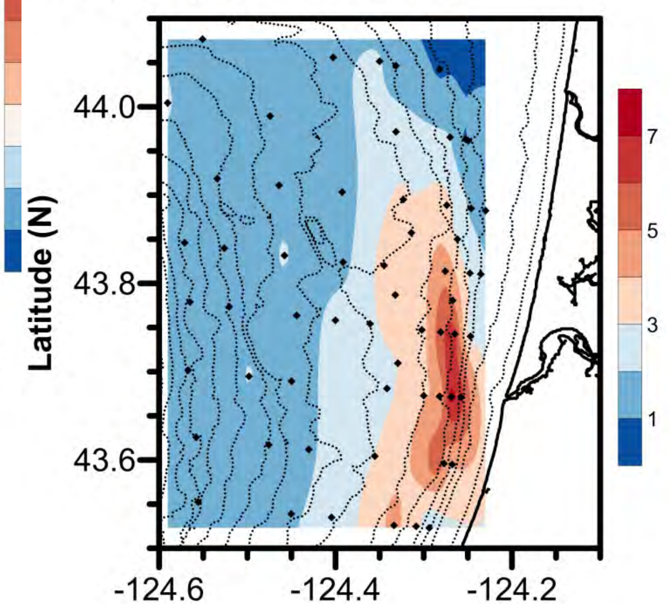
b) %Silt (wt.%)



%OC (wt.%)



a) Lignin (mg/100 mg OC)



Flood Impacts in Coastal Zone (IV):

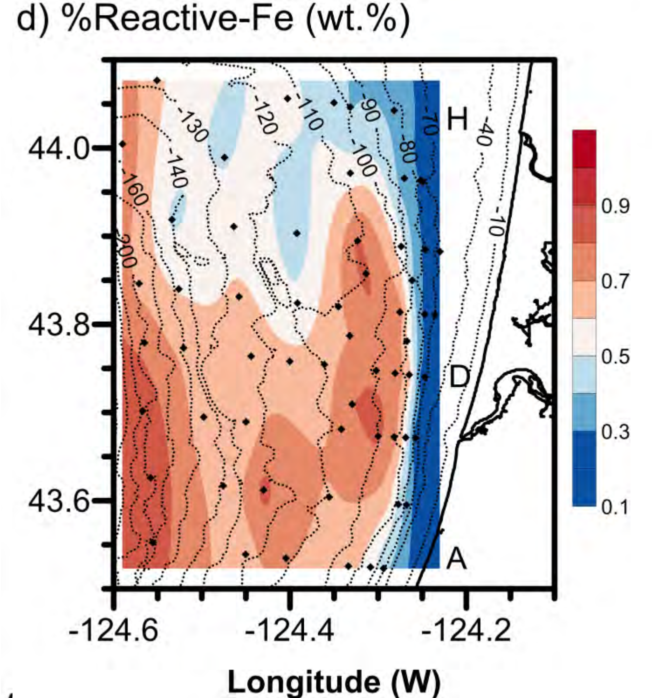
Sediment Depocenters

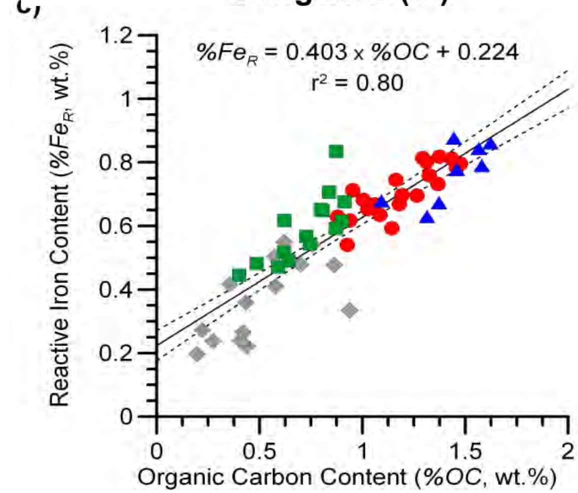
Sources of limiting micronutrients such as reactive Iron (Roy et al., 2013)

➔ ***Distribution of reactive-Fe in shallow shelf coincides with fresh fluvial deposits***

➔ ***Close correlation between OC and reactive-Fe:*** carbon/iron cycle feedback (McManus et al., in prep).

➔ Depocenters sediments as reservoirs of reactive iron – ***limiting nutrient*** during summer, upwelling season.



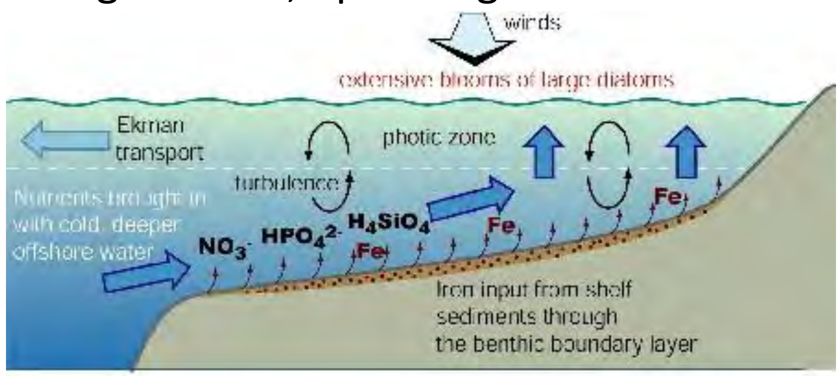


Rethinking of shelf-iron limitation hypothesis:

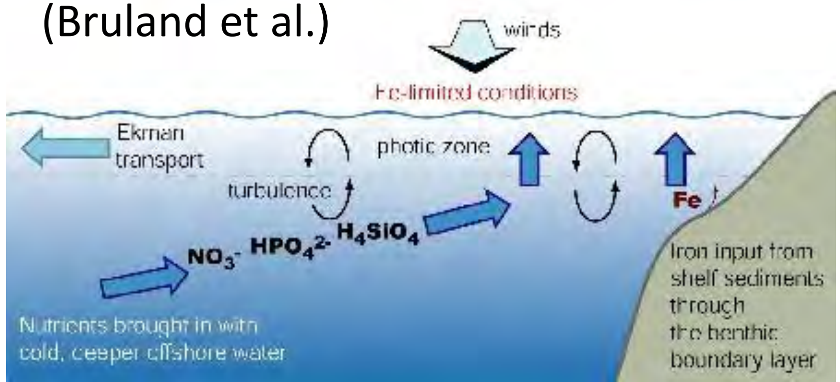
Wide/Narrow shelves

vs.

Location/Extent of Flood Depocenters



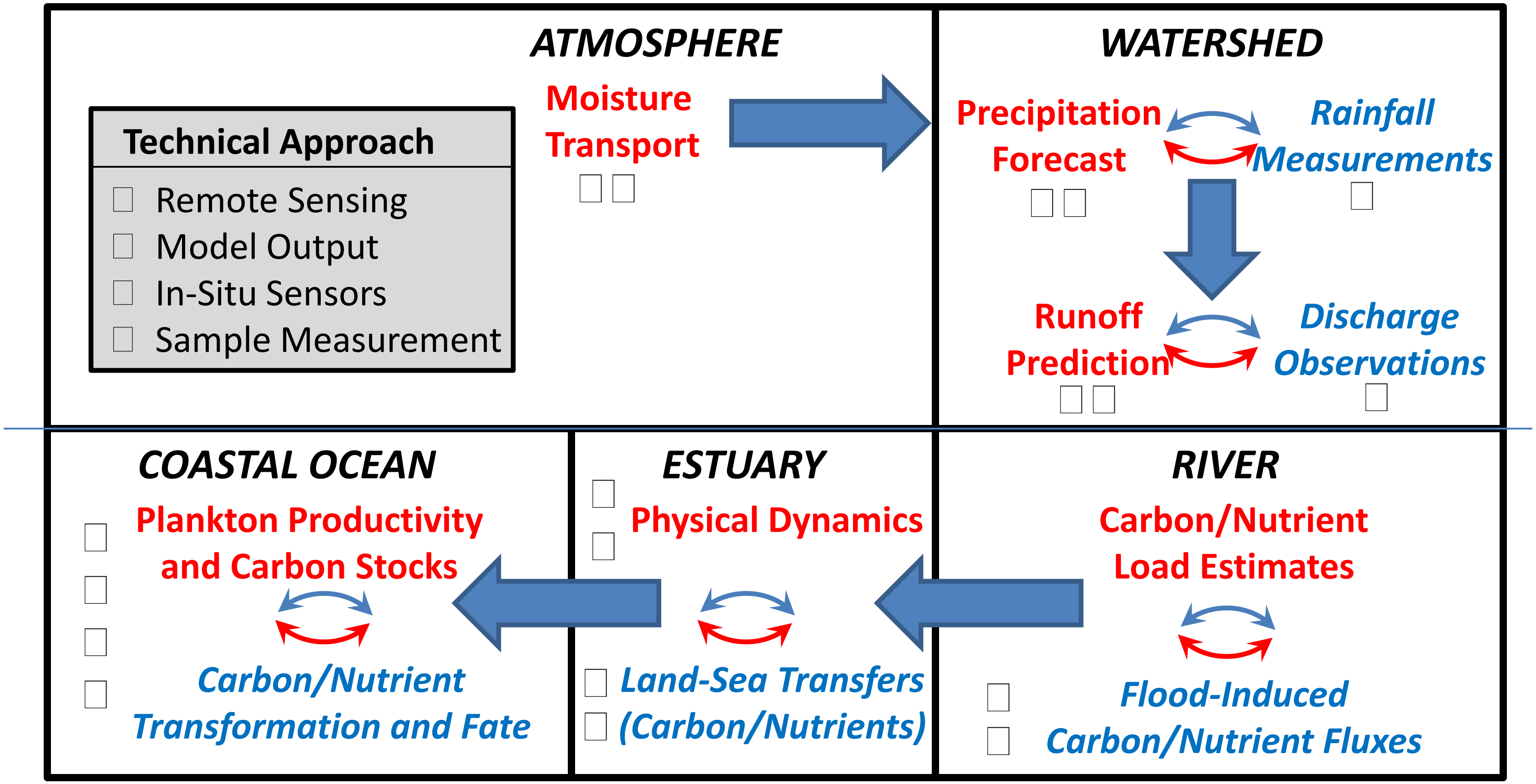
(Bruland et al.)



Summary

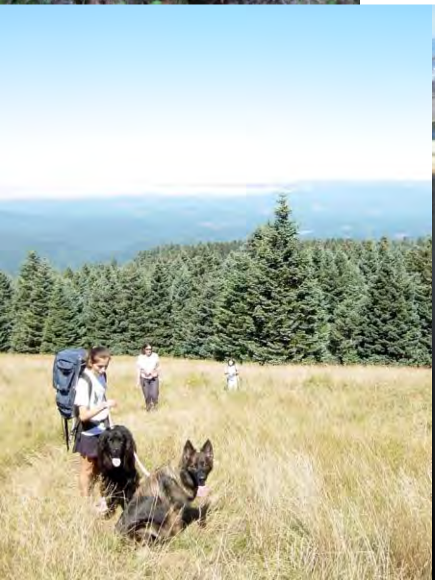
- There is significant carbon connectivity between land-ocean along PNW margin
- We are just starting to fully understand the spatial and temporal interactions and feedbacks among different components of the margin

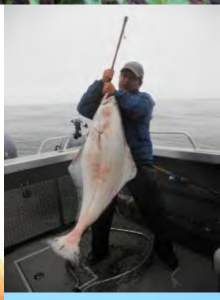
Carbon Connectivity along Atmosphere-Watershed-Coastal Ocean



Questions?

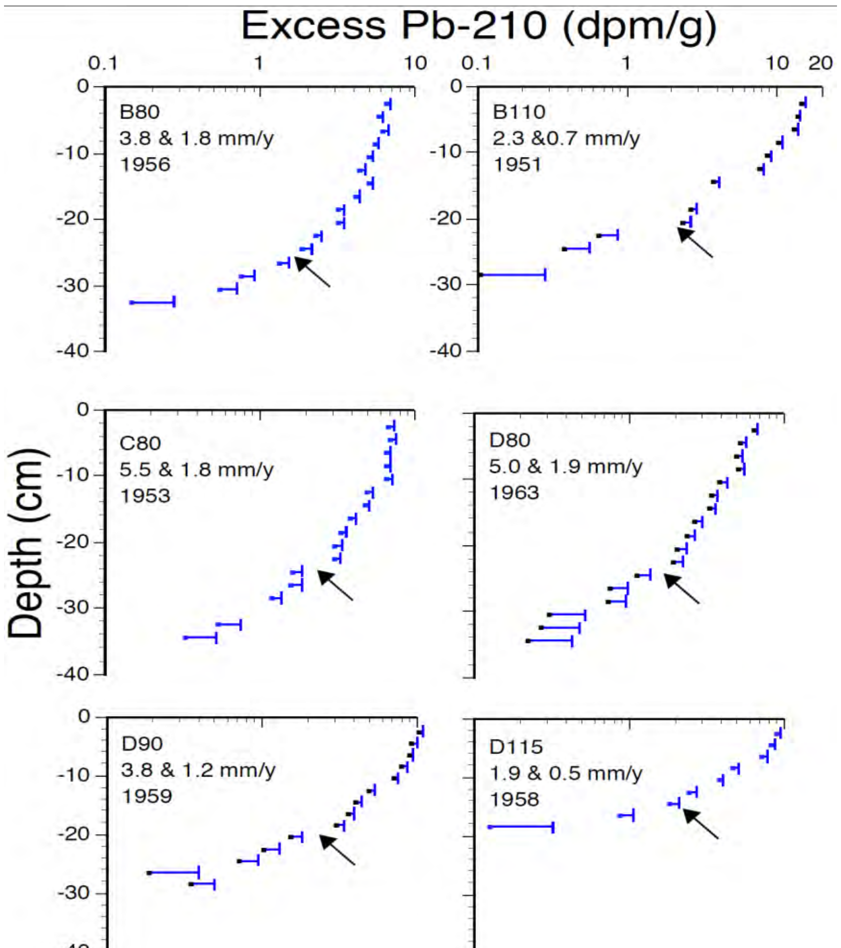
Family and friends are part of Oregon's linked Coastal Ecosystems

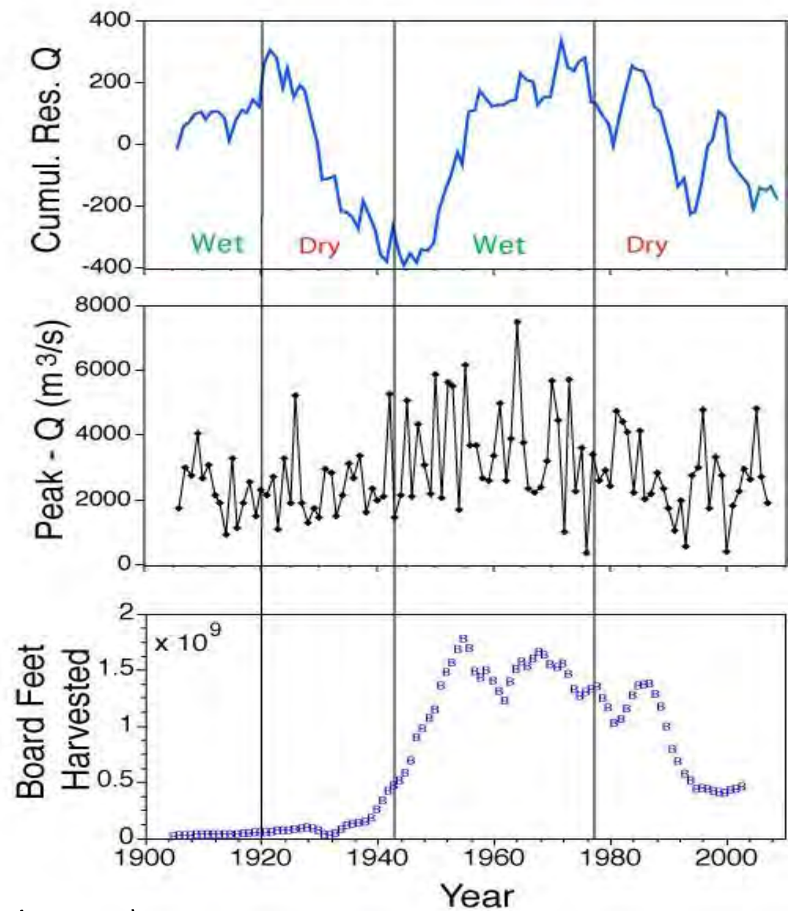




Flood Impacts in Coastal Zone (V): Human/climate effects and non-steady state

- Connectivity with watershed: historical changes in sediment (and carbon) accumulation rates ➔ ***Kinks in Pb-210 profiles ~1950's-1960's***
- Relationship between sediment accumulation rates, climate and land-use
  ➔ ***effects of onset of industrial logging and cold PDO***

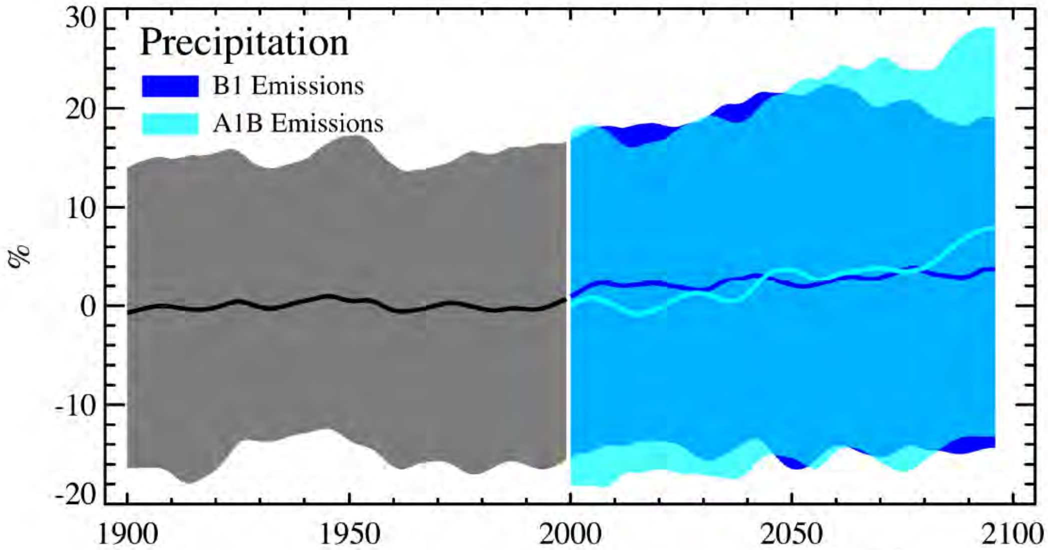




(Wheatcroft et al., 2013)

Connectivity with watershed: future changes as a function of climate change

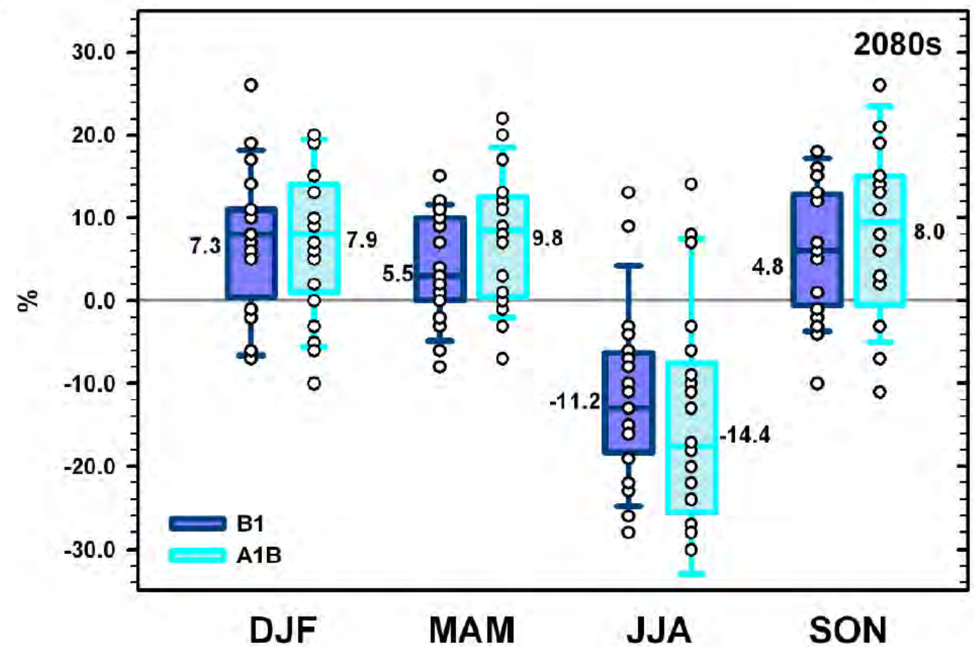
Effects of climate on flood frequency/intensity



Projected changes in annual precipitation, averaged over all models, are small (+1 to +2%)

Models project an enhanced seasonal cycle with changes toward

➔ **Wetter autumns and winters and drier summers.**



http://cses.washington.edu/cig/fpt/ccscenarios.shtml

Connectivity with watershed: future changes as a function of land use changes

Effects of future land use changes

➔ expected increases in timber harvest in the 21st century

➔ watershed development

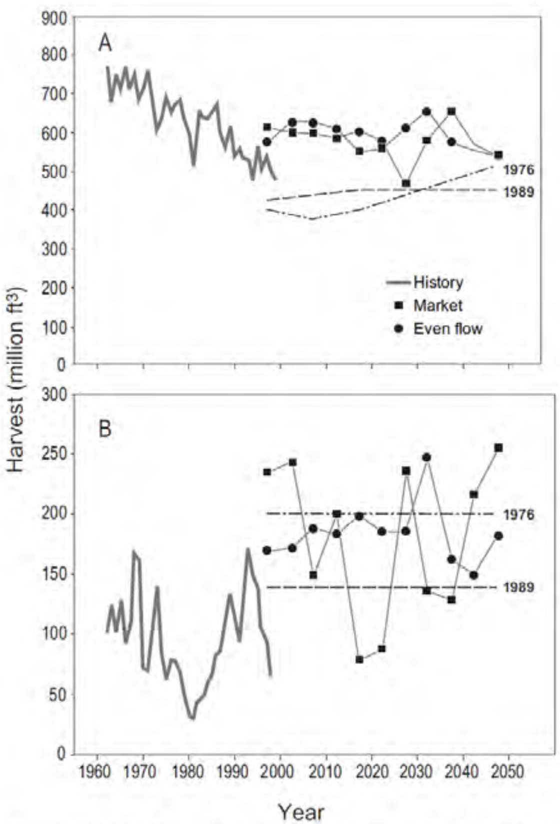


Figure 18. (A) Forest industry and (B) nonindustrial private harvest projections from current and earlier studies of western Oregon.

Adams et al., 2002

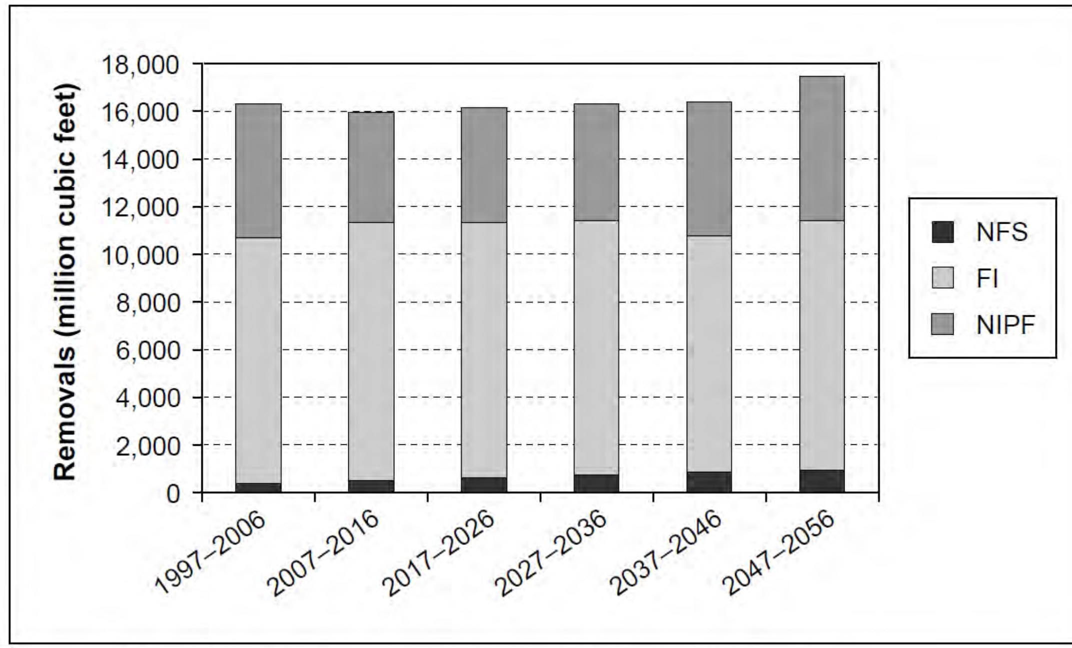
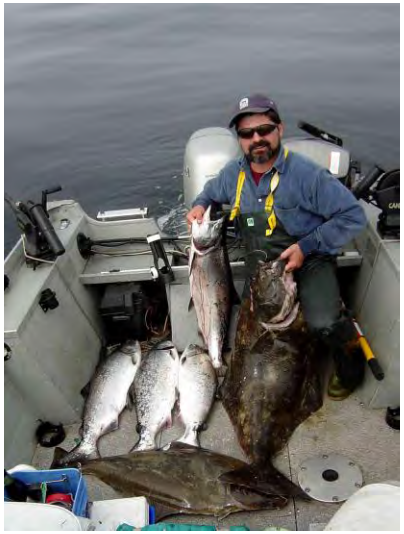


Figure 4—Projected removals by decade and ownership in west-side counties.
NFS = national forest system, FI = forest industry, NIPF = nonindustrial private forest.

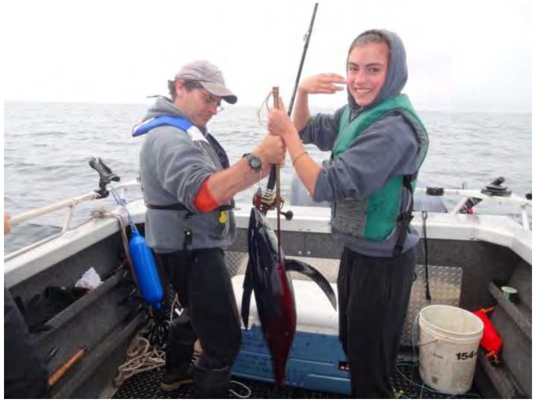
Zhou et al., 2005

Questions?









Local impacts of January 2012 storm