Carbon fluxes in the coastal zone of the North Pacific

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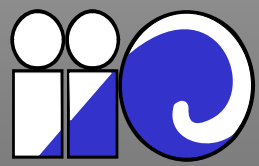

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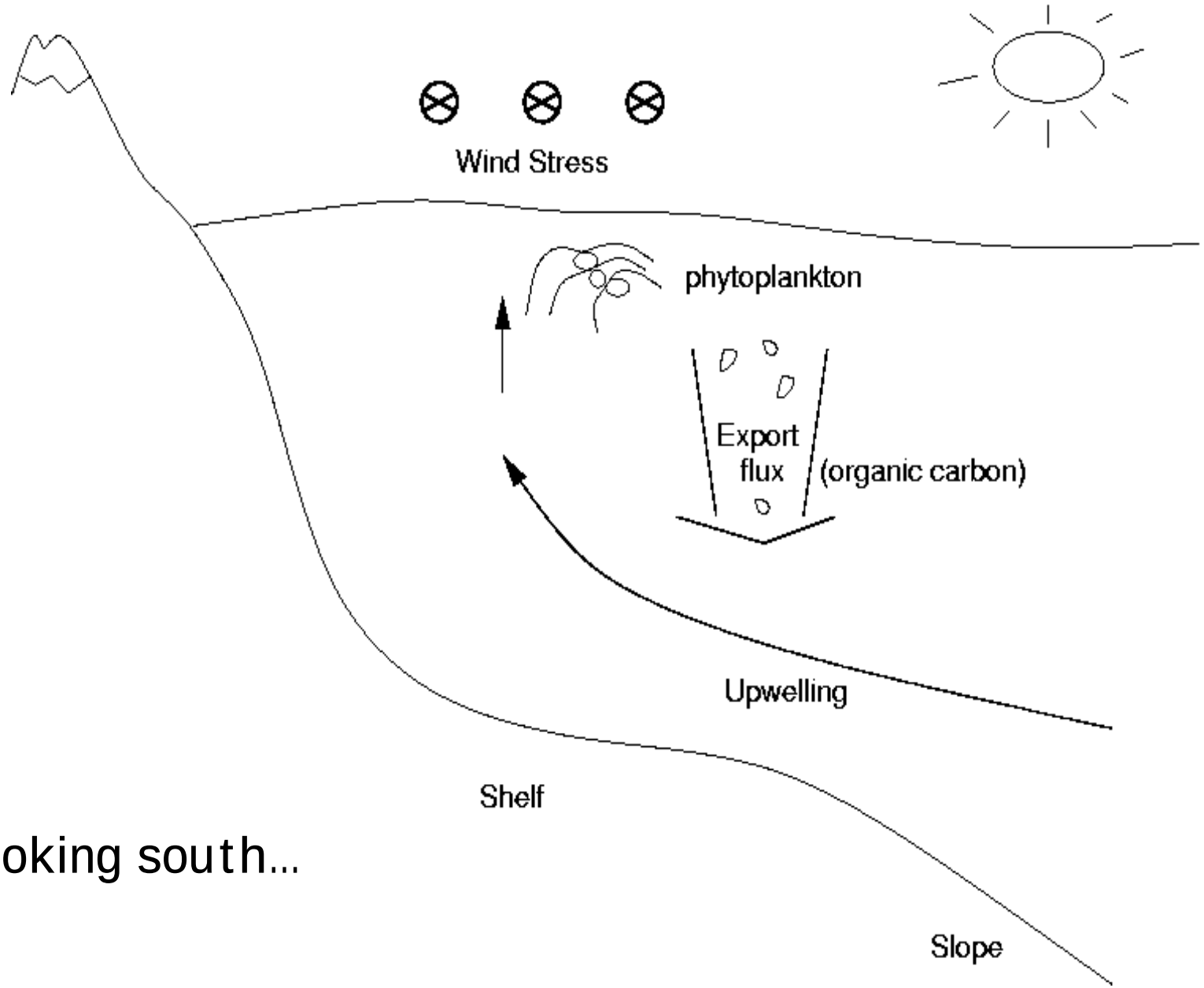
studying carbon in coastal regions:

- carbon fluxes are disproportionately large on the coast (e.g. Borges et al. 2005)
- the range in TCO2 and pH is extreme in coastal upwelling regions (e.g. Ianson et al. 2003, Hales et al. 2005)
- NACP -- understanding and estimating carbon fluxes on the coast

contrasting regions

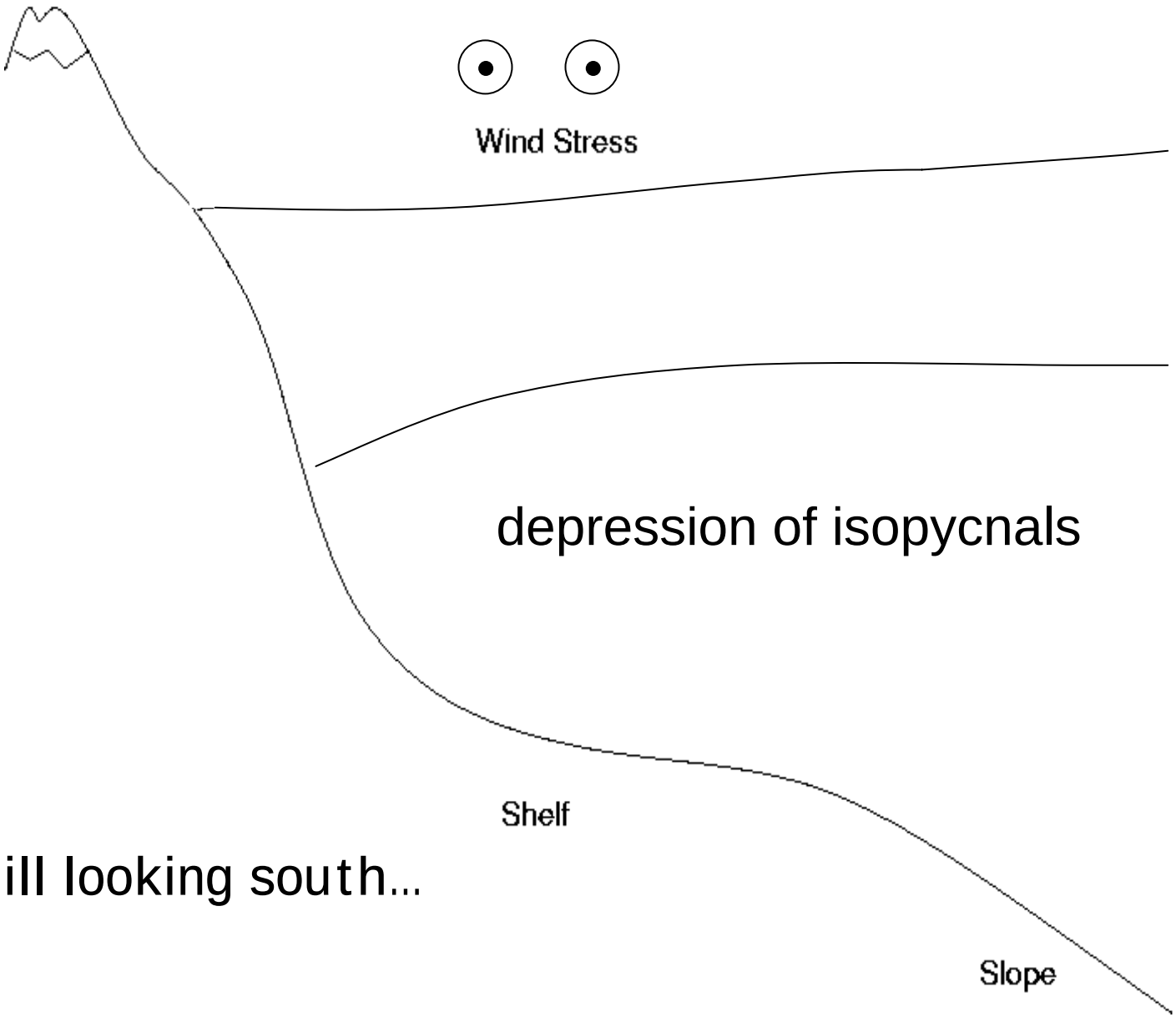
- results of a simple model -- annual cycles in carbon inventories and net carbon exchange with the atmosphere and open ocean
- snapshots in time from one cruise, spring 2007 -- present 4 transects of carbon (and oxygen) profiles in 3 distinct regions

Coastal Upwelling



looking south…

downwelling

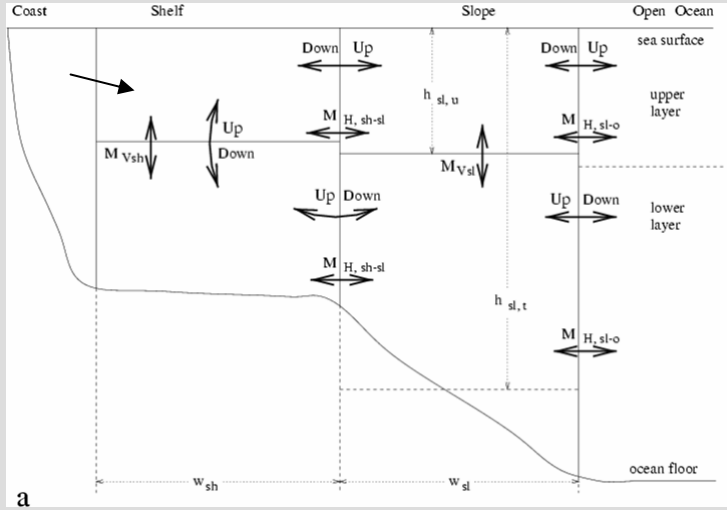


still looking south…

simple model

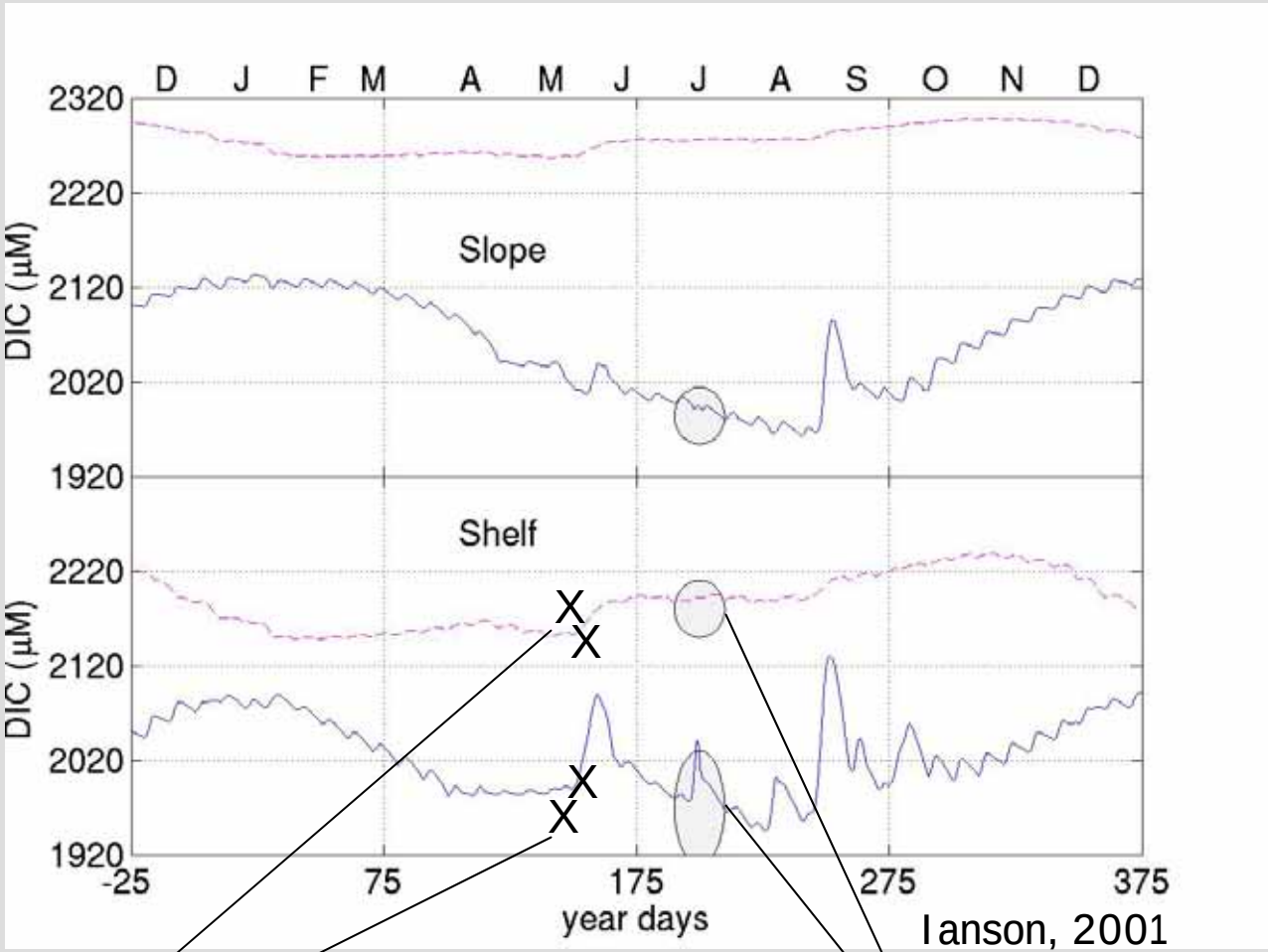
- 7 physical boxes with 2-D circulation
- biochemical model embedded, prognostic over mid-shelf and slope in surface and lower layer
- time--scales weeks to decades
- west coast of Vancouver Island

physical model



Ianson and Allen, **GBC**, 2002

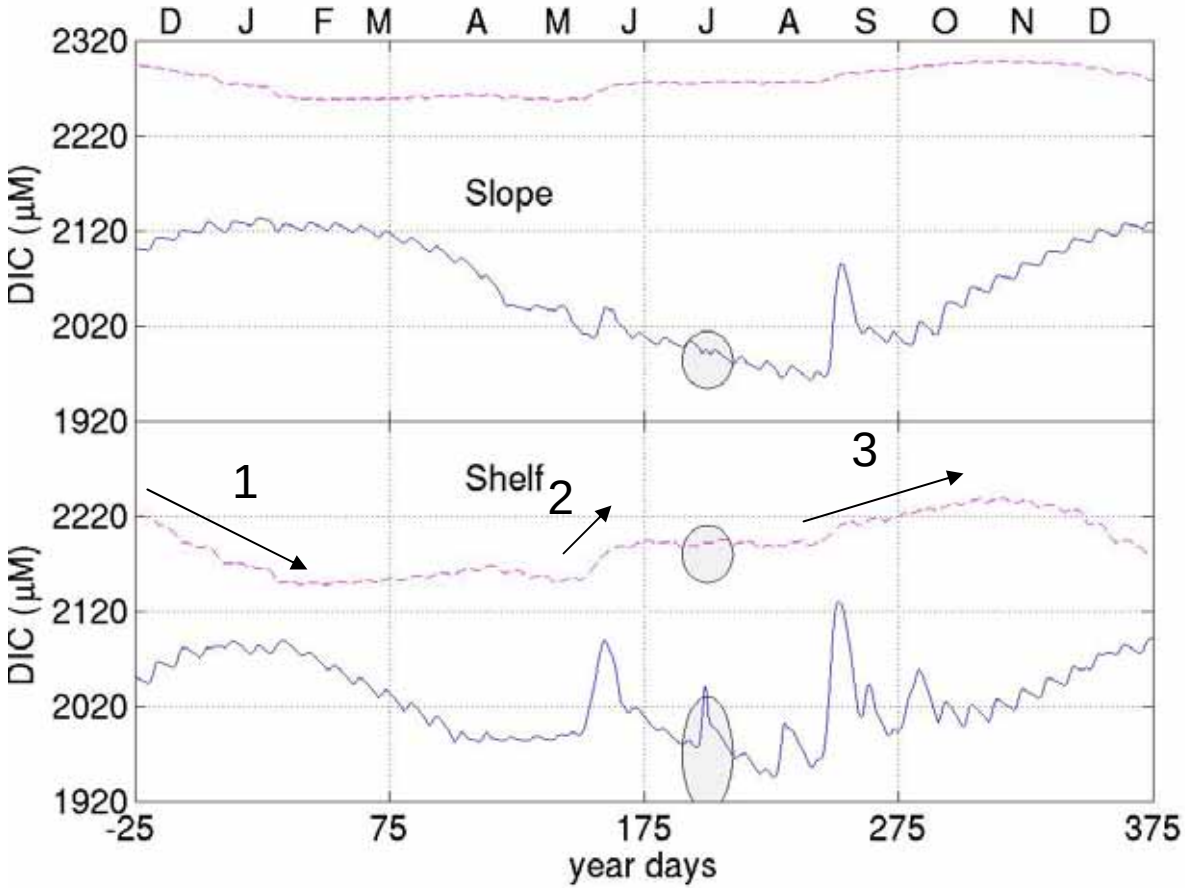
model annual cycle



Ianson, 2001

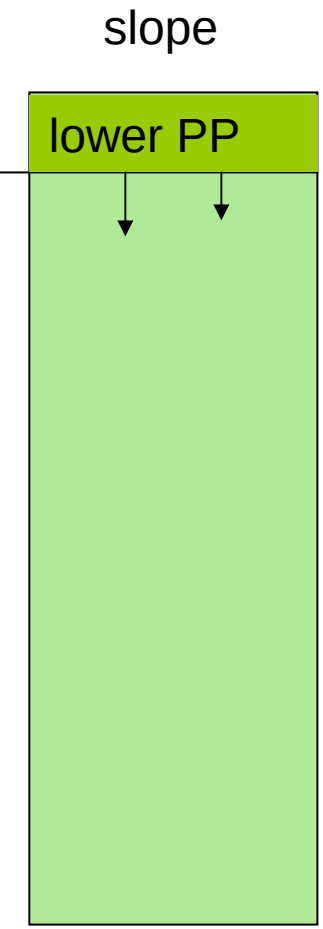
X – data from NACP 2007 cruise

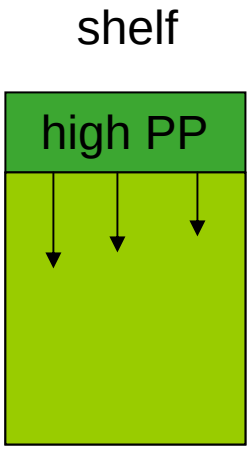
data from 1998, Ianson et al. 2003



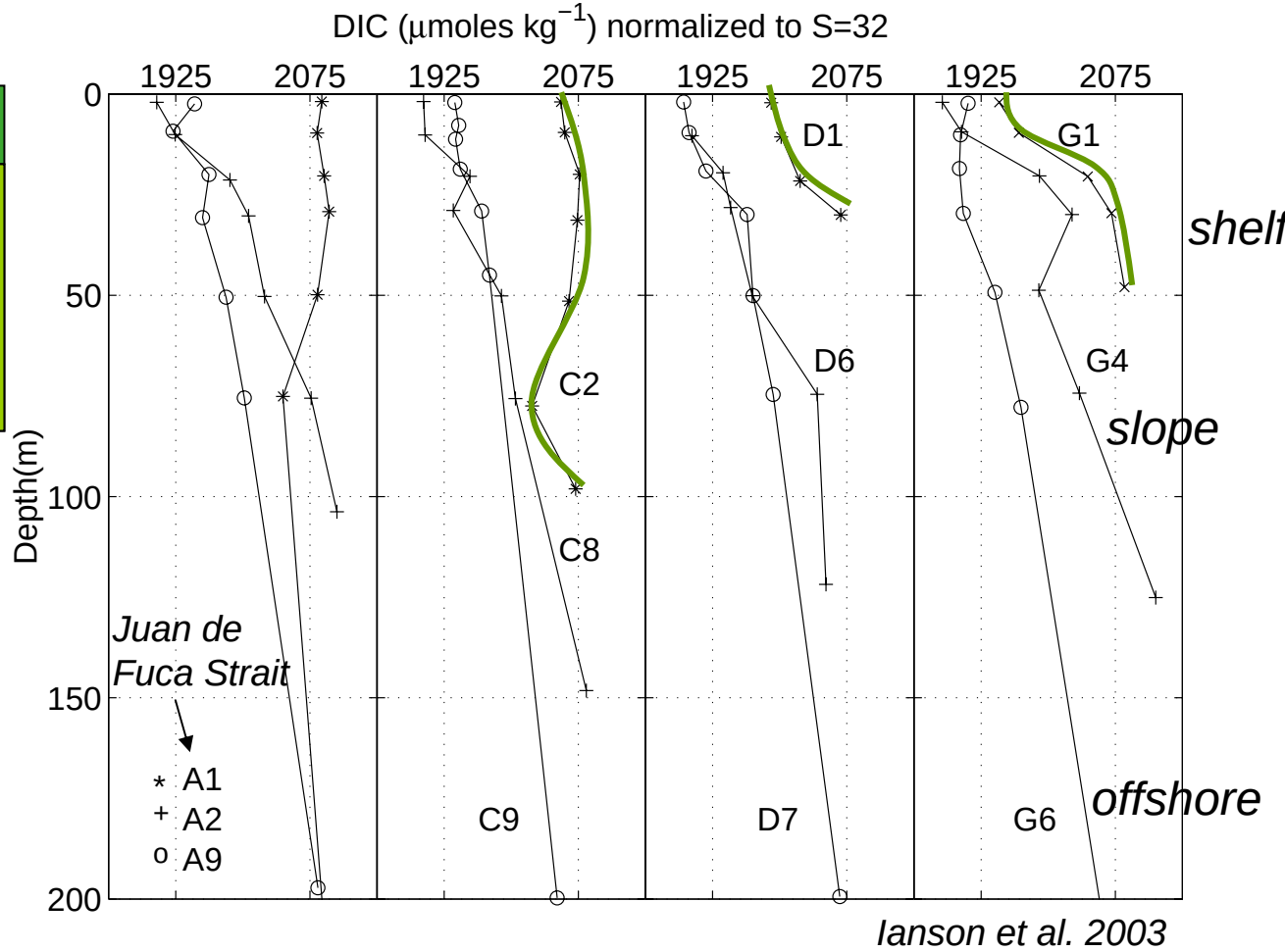
1. mixing and downwelling
2. upwelling
3. remineralization

across-shelf DIC transects



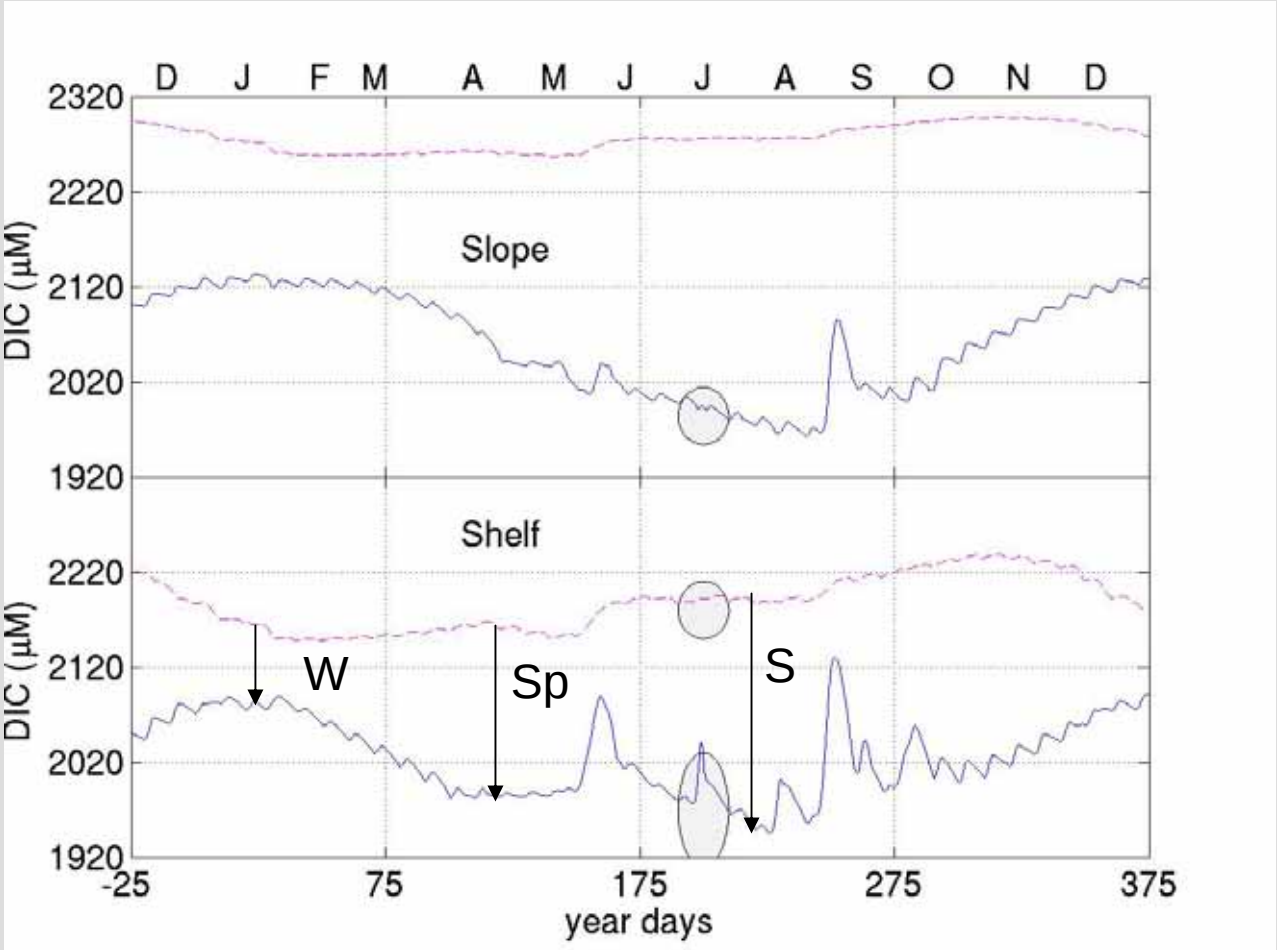


high CO2
low O2
low pH



Ianson et al. 2003

more carbon over the **shelf**
high organic matter supply remineralized in a smaller volume of water **"nutrient trapping"**



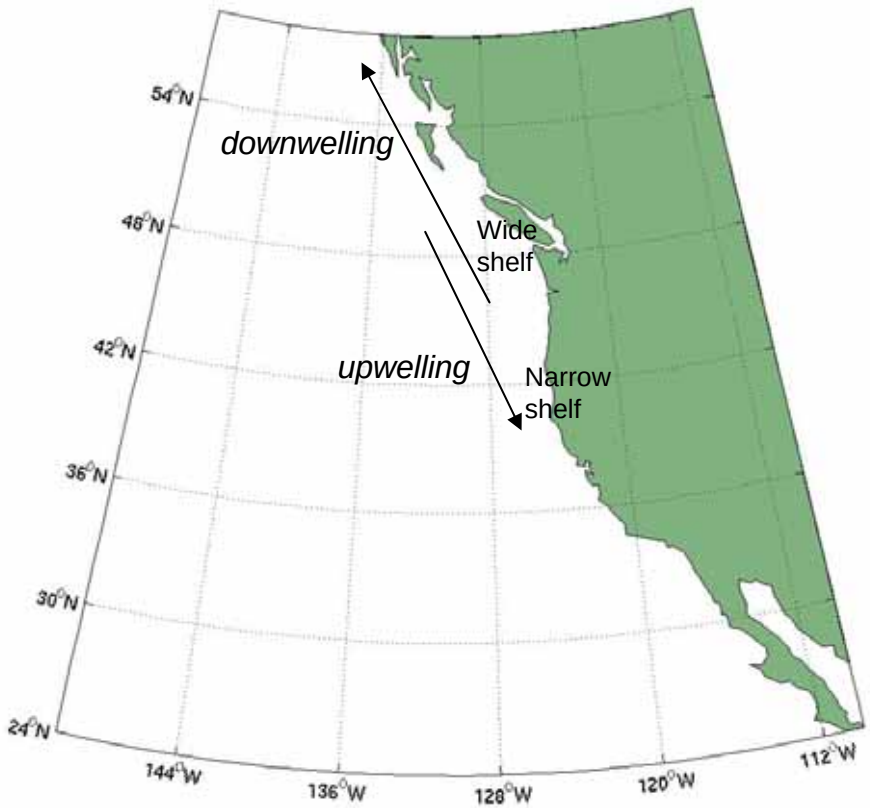
In winter carbon (and nutrients) from below are mixed into the surface and surface Temperature is at a minimum – also a time when pH could be low and aragonite saturation horizons could shoal

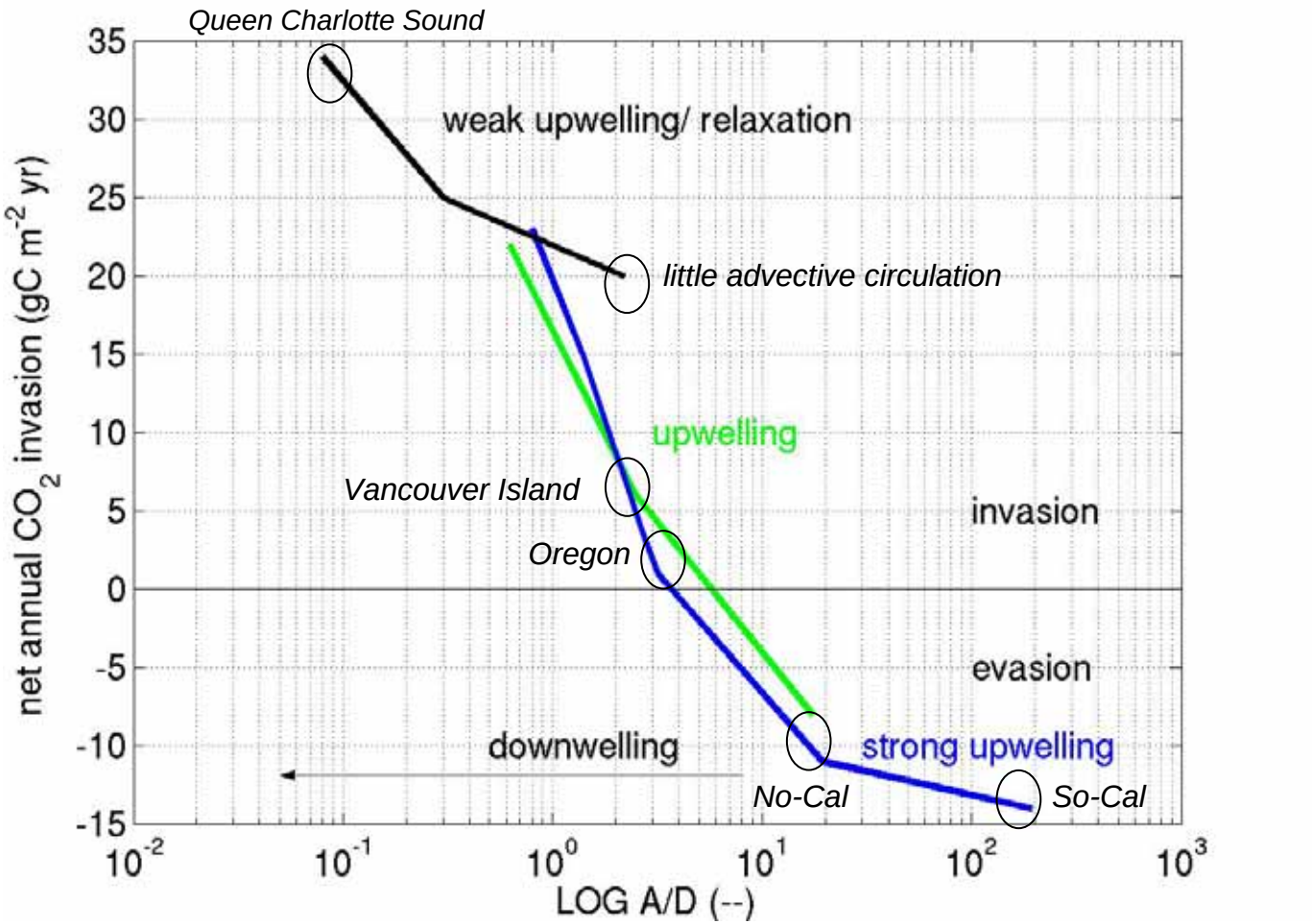
Shutting off upwelling – lower total carbon and smaller surface-lower layer gradients

contrasting regions on the west coast of North America

Important features

- **physical circulation, upwelling and downwelling strength**
- **shelf width**
- light limitation
- terrestrial water sources (e.g. Columbia)





In general increasing downwelling flushes the trapped carbon off of the shelf so that there is less gas evasion during winter (non, or reduced upwelling) – continual upwelling with no relaxation season can have a similar flushing effect

The northern lines of the NACP cruise, 2007

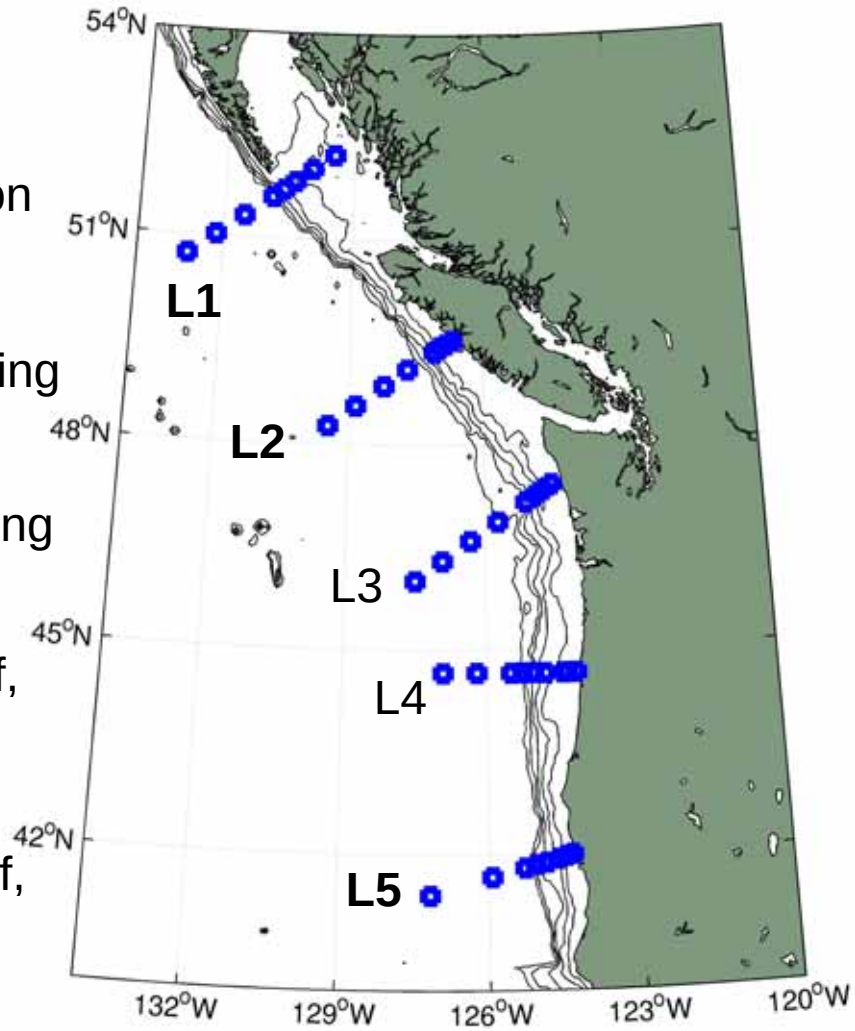
L1 – wide shelf, summer relaxation

L2 – med. shelf, moderate upwelling

L3 – med. shelf, moderate upwelling

L4 – narrow shelf, Columbia River

L5 – narrow shelf, strong upwelling

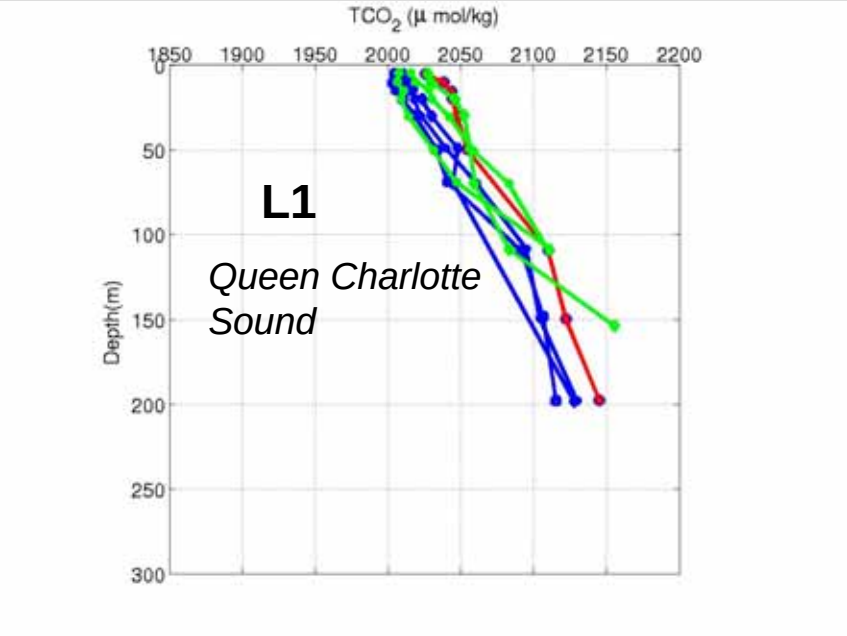


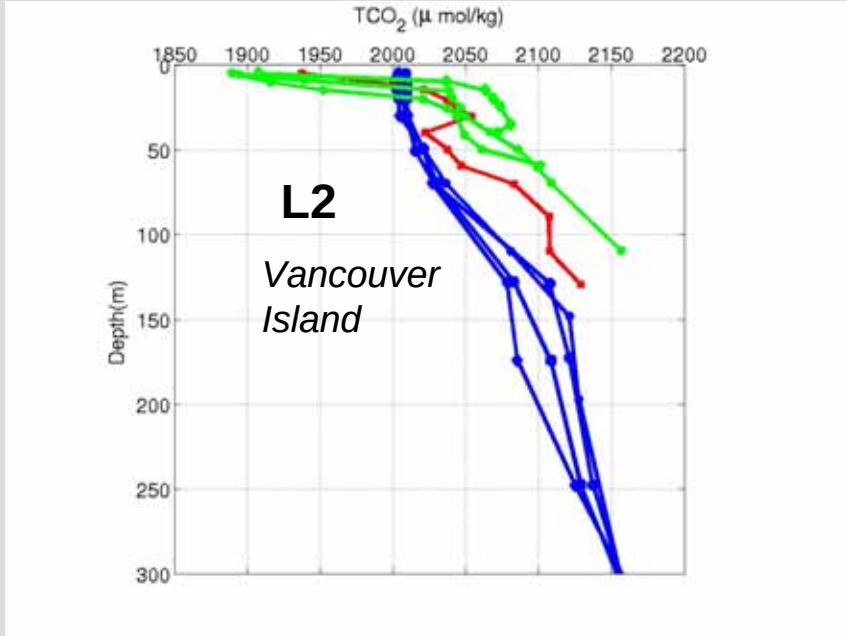
bathymetry – 200m isobath to 1800m isobath

2007 May/June data (CDN)

shelf — shelf break — offshore

normalized to a salinity of 32.5



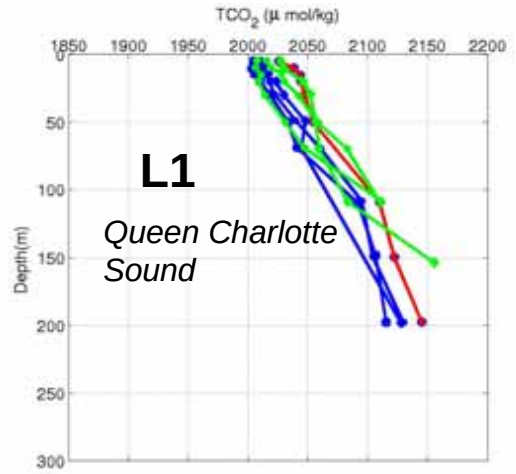


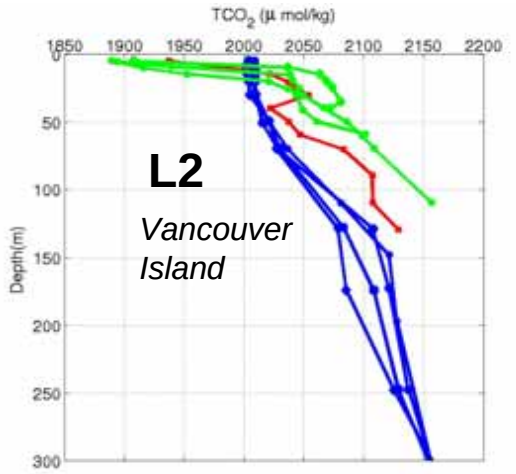
- surface-lower layer gradient small
- shelf profiles and offshore similar
- weak upwelling or relaxation, less primary productivity, less total carbon
- note that shelf is wide and cut with troughs

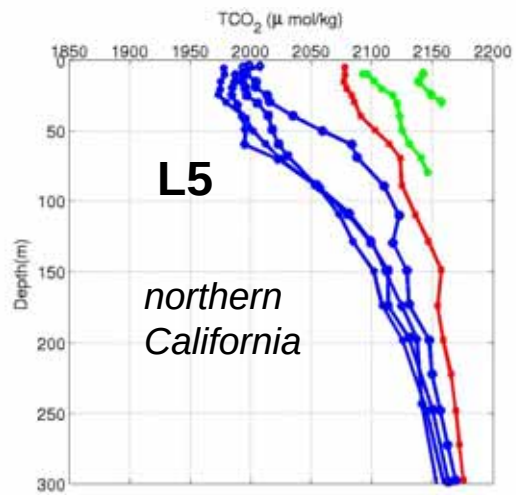
- surface-lower layer gradient large
- more carbon over the shelf in lower layer
- note that structure around 50 m is seen in the O_2 profiles as well
- L3 similar but less surface lower gradient

shelf shelf break offshore

normalized to a salinity of 32.5







L5 – strong upwelling and narrow shelf

- the whole shelf is flushed with an event
- carbon is much higher over the shelf than further north

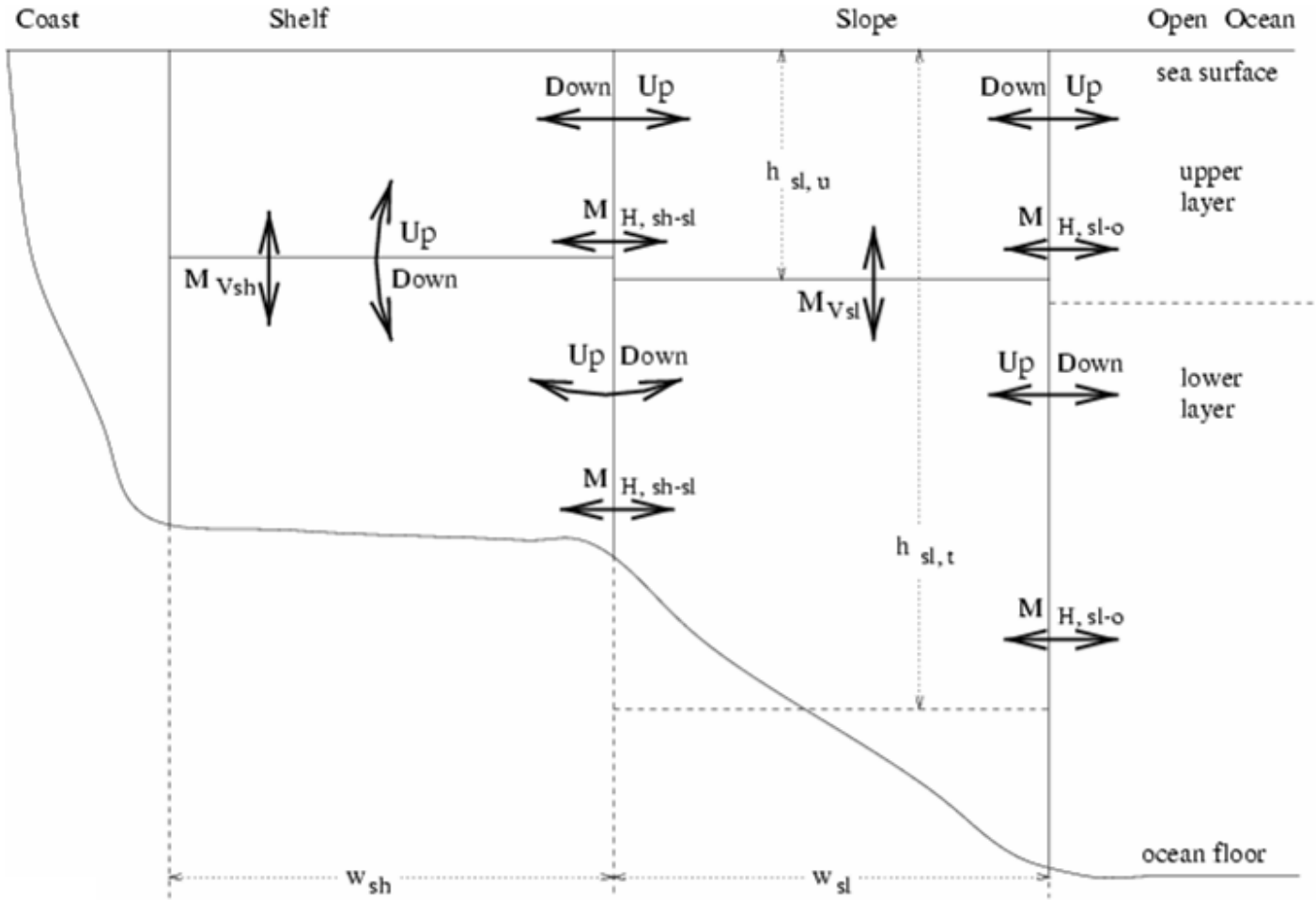
conclusions:

- there are distinct regions within the coastal upwelling region
- upwelling and downwelling strength control carbon inventories (and productivity) over shelf: upwelling - “nutrient trapping” and large surface-lower layer gradients in spring/summer
- in the north surface waters in winter could have low pH (especially where upwelling occurs)
- shelf width is important – narrow shelves get flushed

Acknowledgements

- Susan Allen, UBC
- Ken Denman, DFO, CCMA
- Dana Greeley, Paul Covert, Kristy McTaggert, PMEL, NOAA
- Officers and crew of the *RV Wecoma*

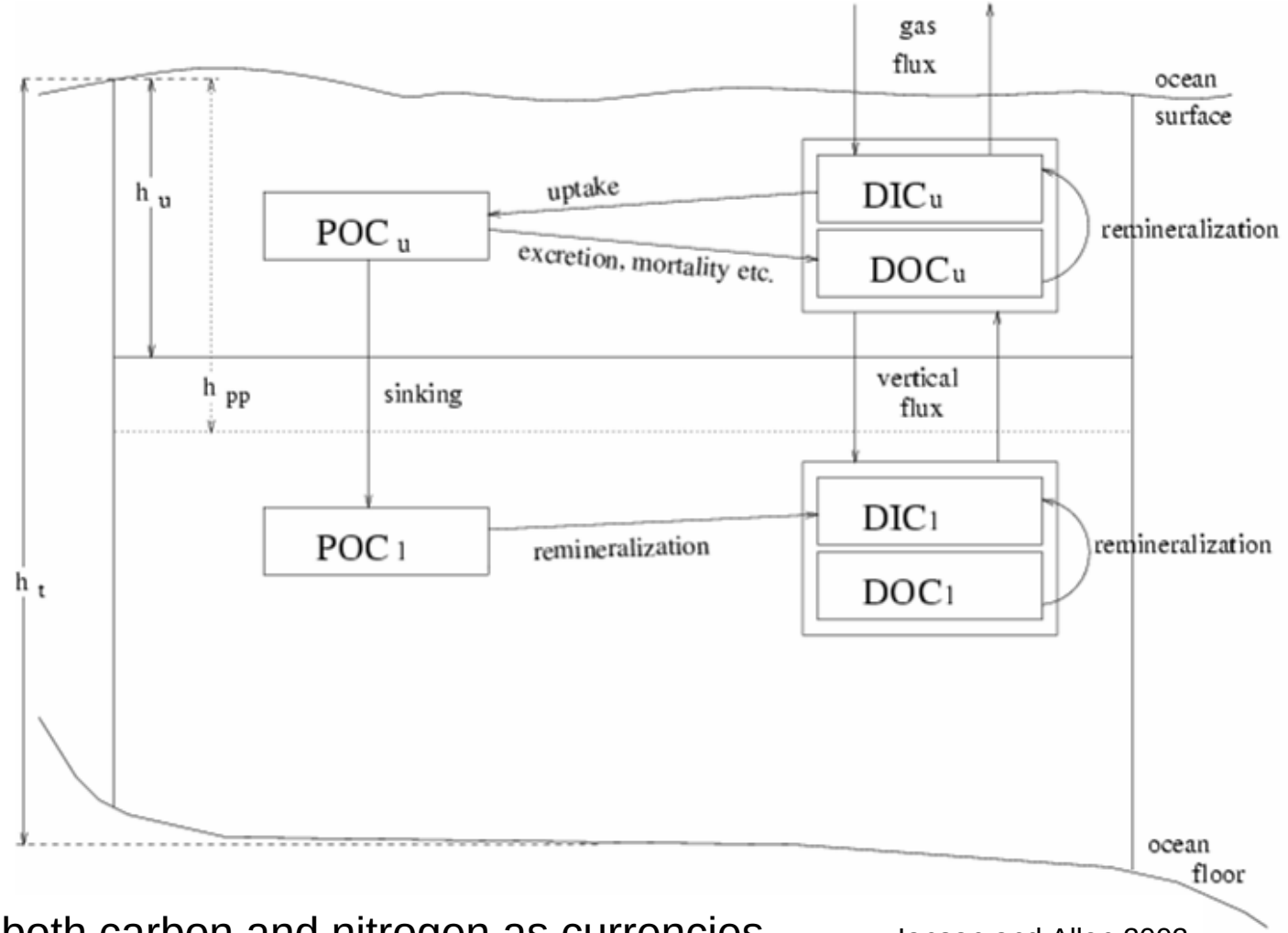
Physical model



Ianson and Allen 2002

- mixing at all interfaces
- advection forced with sharp upwelling (and downwelling in winter)
- buoyancy fluxes included (including mixing with the inner shelf VICC)
- vertical gradient between layers

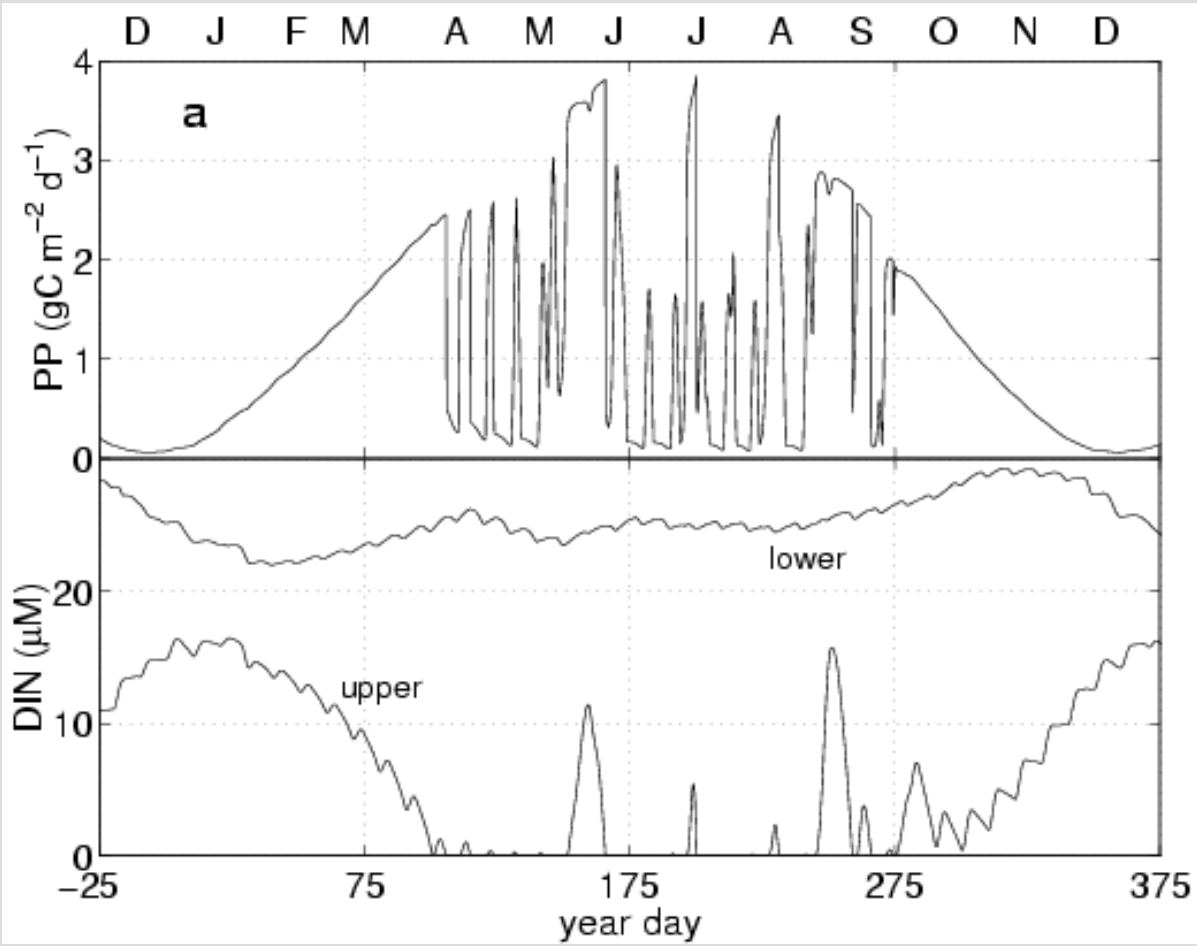
Biological – chemical model



- both carbon and nitrogen as currencies
- large blooms and sinking fluxes (diatoms)
- ‘sinking’ depends on health of phytoplankton
- C and N uptake are decoupled, excess C goes to the DOC

Ianson and Allen 2002

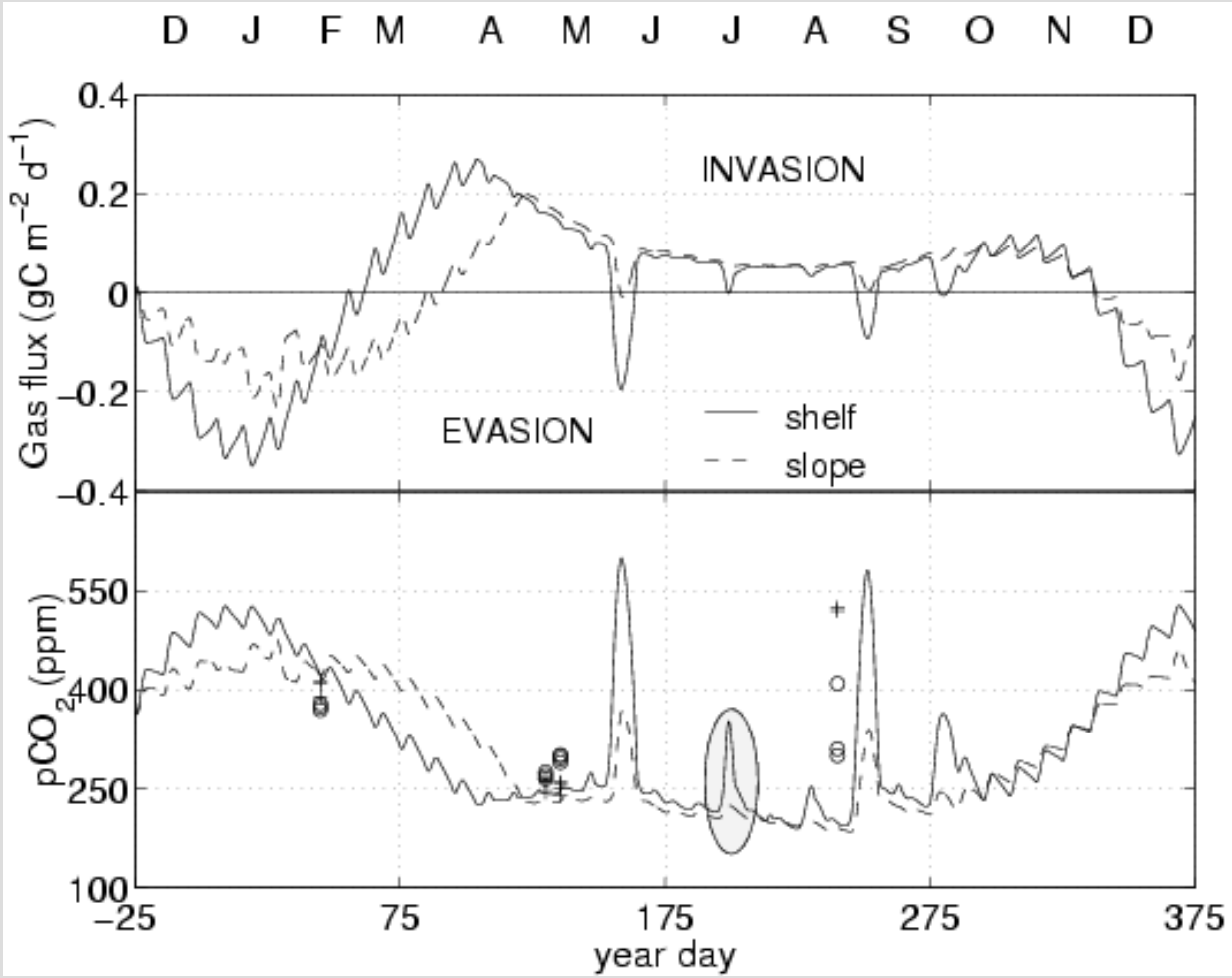
Primary production and inorganic nitrogen



Ianson and Allen 2002

Primary production and nutrients change sharply with upwelling events. Sharp forcing allows nutrient to be advected offshore, more production over slope.

CO_2 flux and pCO_2

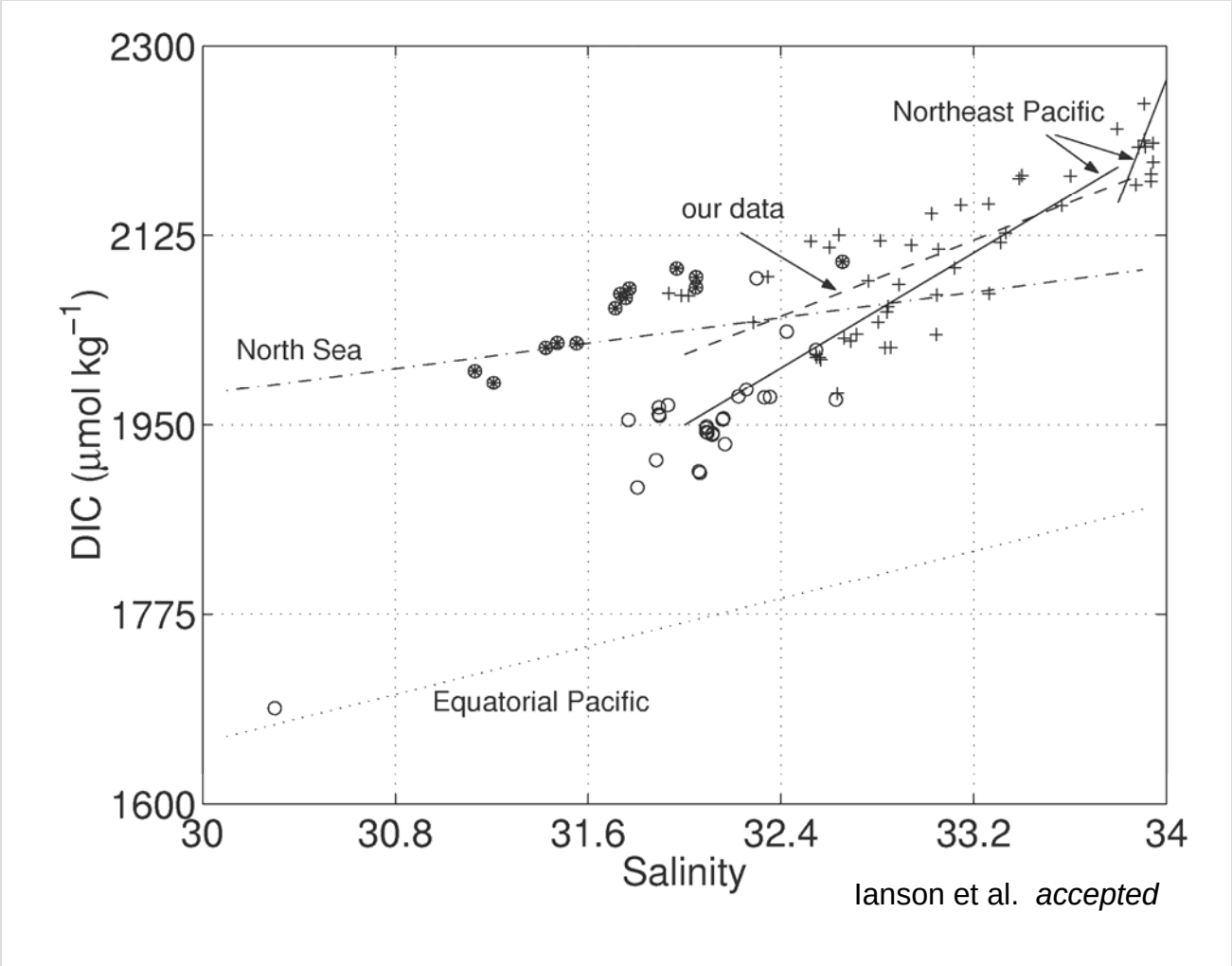


Ianson and Allen 2002

Surface pCO2 is high in winter.

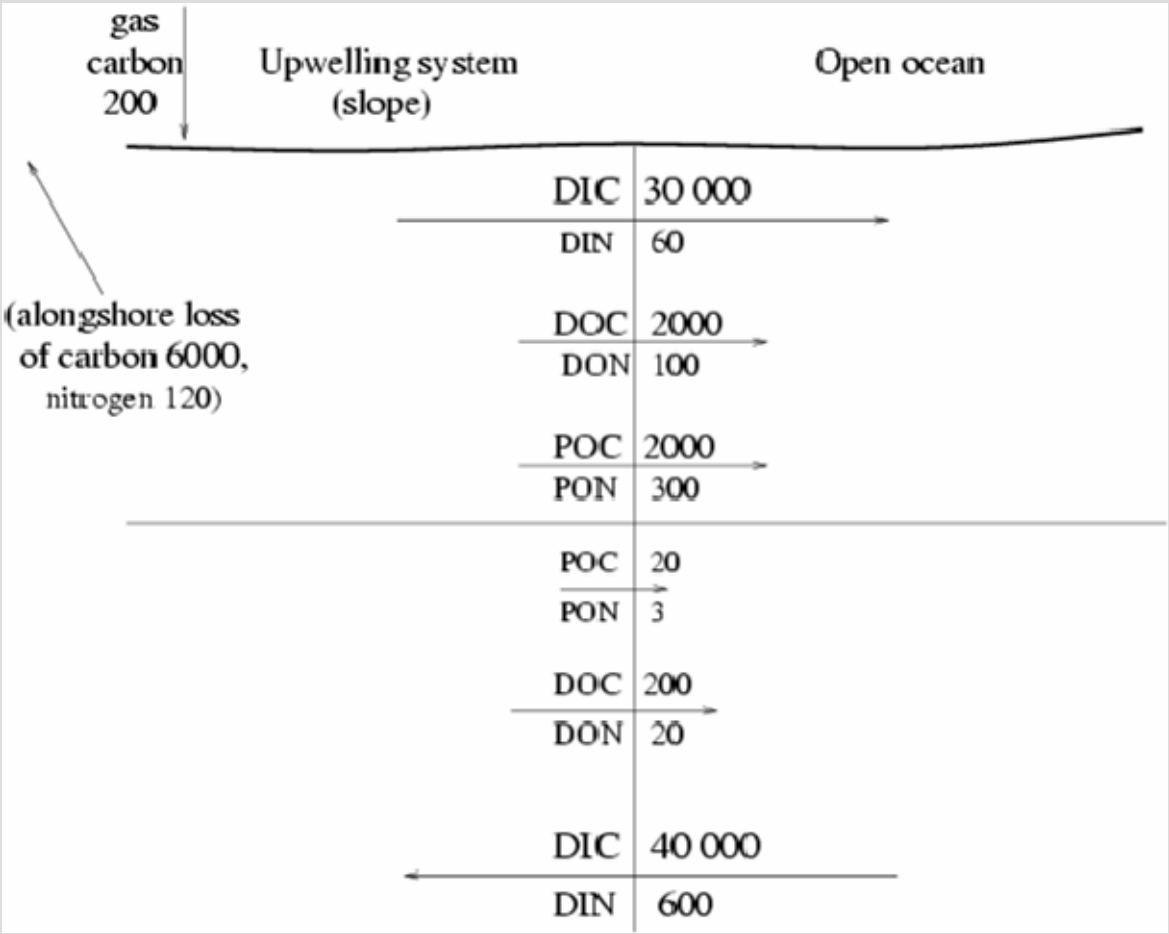
+ - shelf, o – slope, ship of opportunity: ellipse our data

DIC-Salinity data



- VICC is rich DIC (unexpected)
- DIC per S is higher closer to the coast in lower layer

Net annual exchange



Ianson and Allen 2002

The largest carbon flux is into the coastal system in the lower layer.
Most of this carbon flows back into the open ocean in the surface layer.