

# The Biophysical Oceanography of the Leeuwin Current, a Poleward-Flowing Eastern Boundary Current off the West Coast of Australia



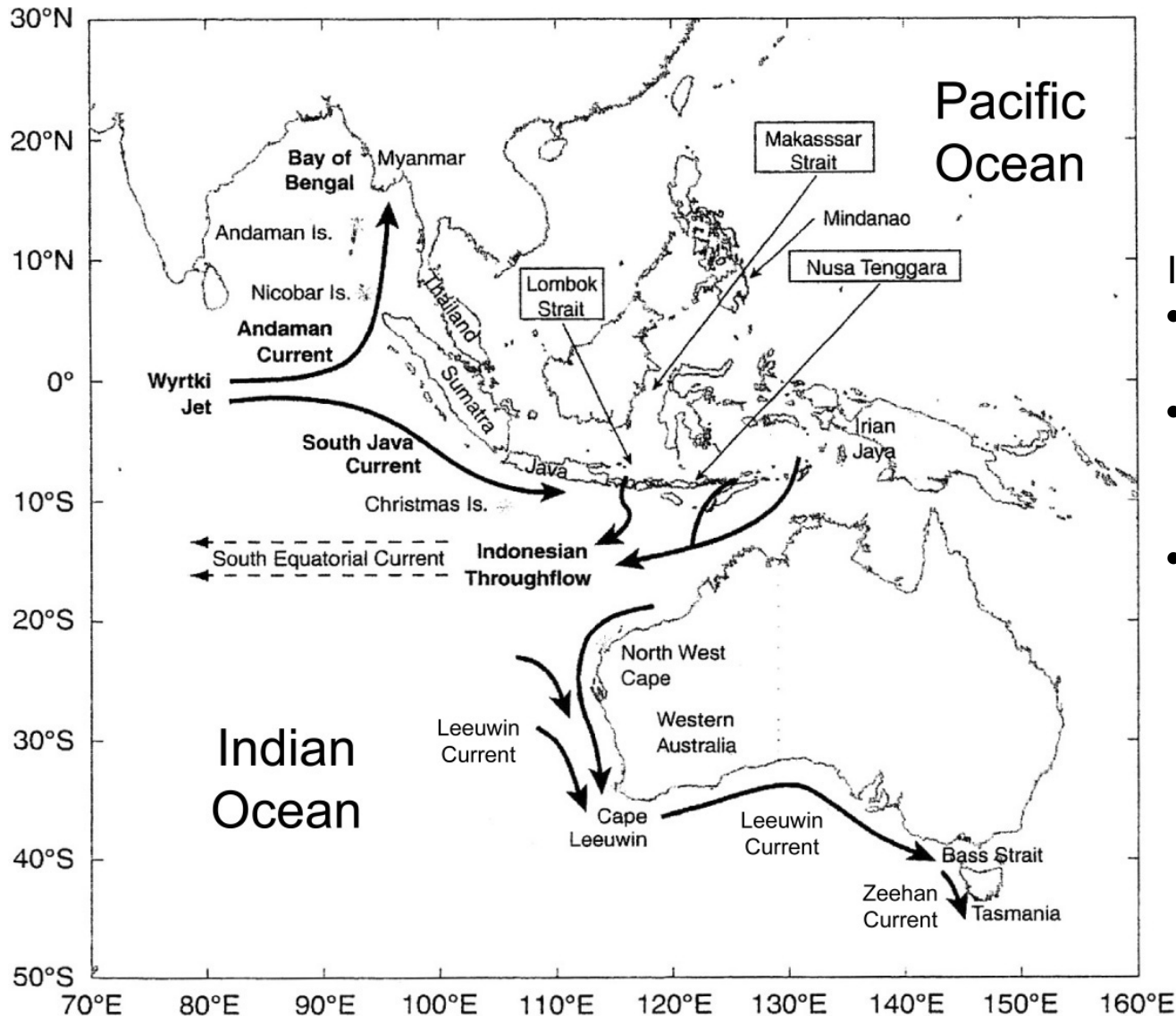
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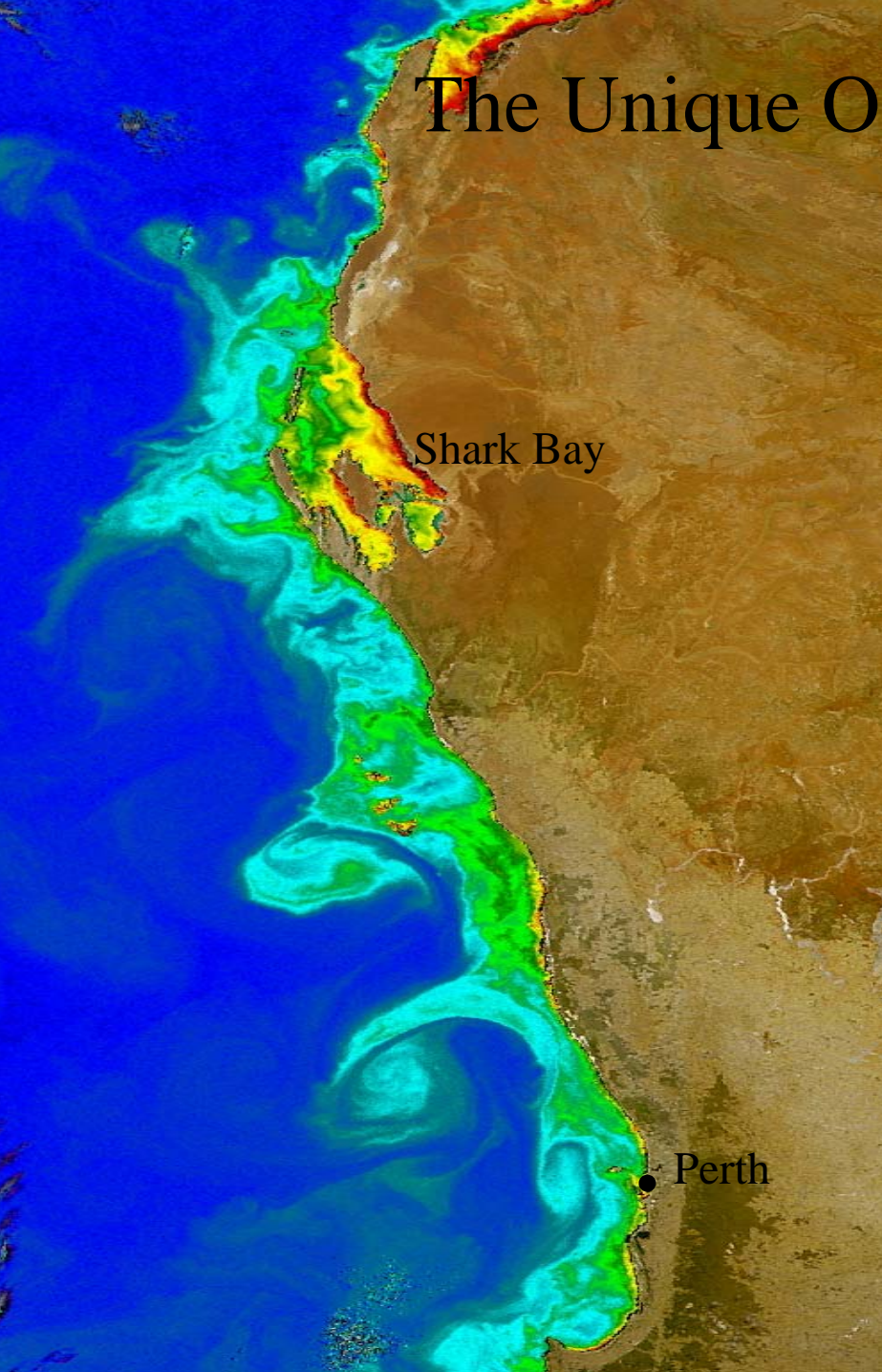
# Surface circulation of E Indian Ocean



## Indonesian Throughflow:

- Key link between Pacific & Indian Oceans
- Transport varies with ENSO
  - 5 - 10 Sv (Meyers 1996)
- Helps set up pressure gradient that drives the Leeuwin Current

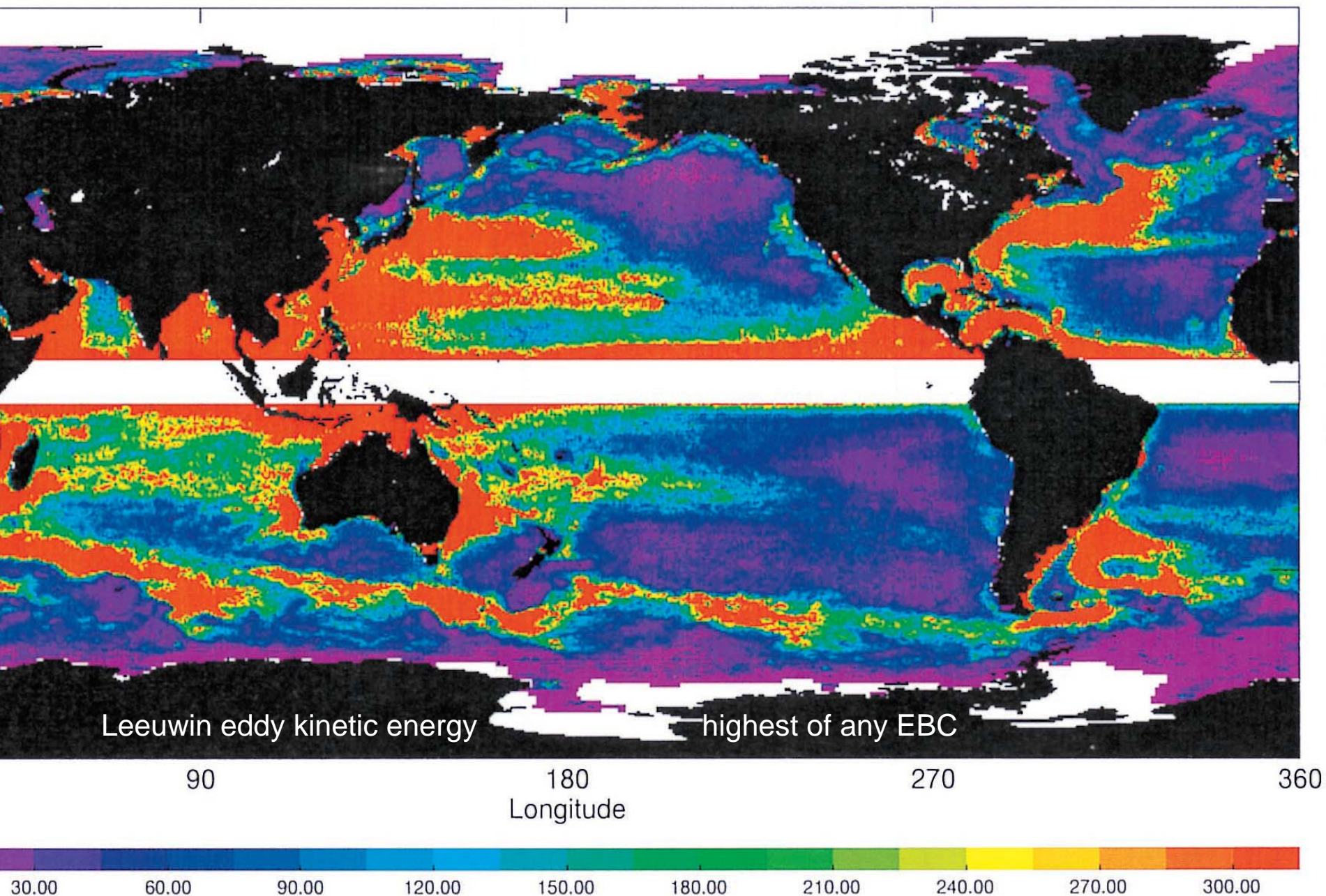
# The Unique Oceanography off WA



- Leeuwin Current: *Poleward* flowing E boundary current
- Flow ~1 kt, 300 m deep, *counter* to prevailing southerlies (summer monsoon)
- Warm, tropical, low nutrient water, *downwelling*
- Major fishery benthic: western rock lobster; pilchard population <  $10^4$  t

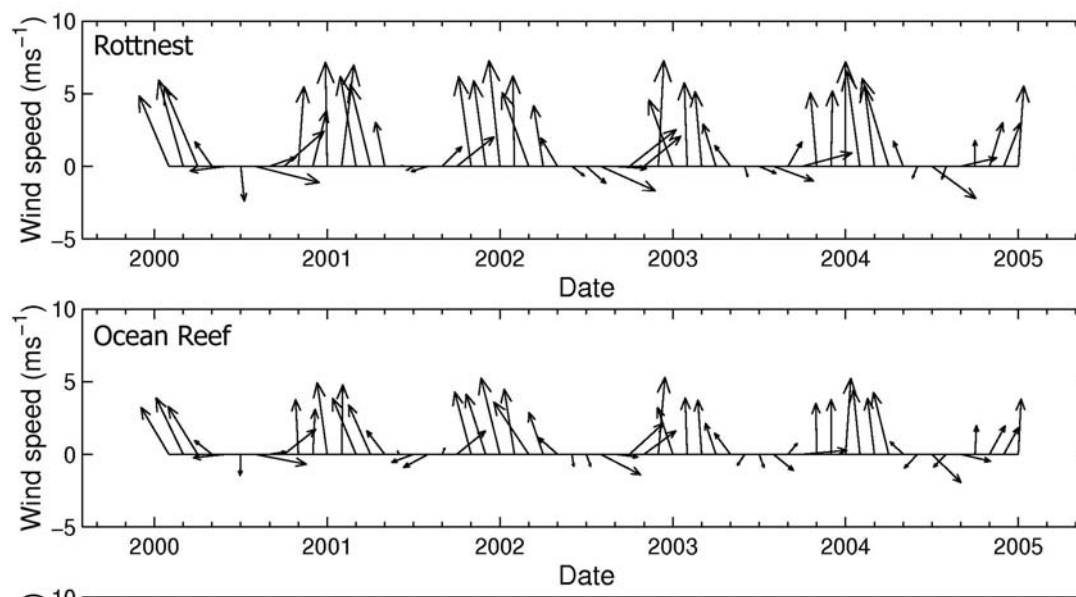


# Eddy kinetic energy in $\text{cm}^2/\text{sec}$ . (From Ducet et al 2000)



# Seasonal forcing: the wind field

- Strong summer southerlies
  - Mean winds strongest in summer!
- Variable nor'westerly winter storms
- Consistent pattern on coast & offshore

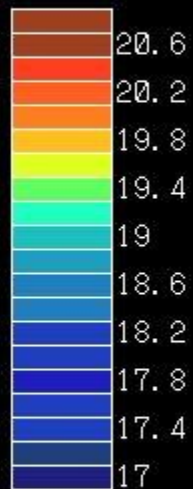
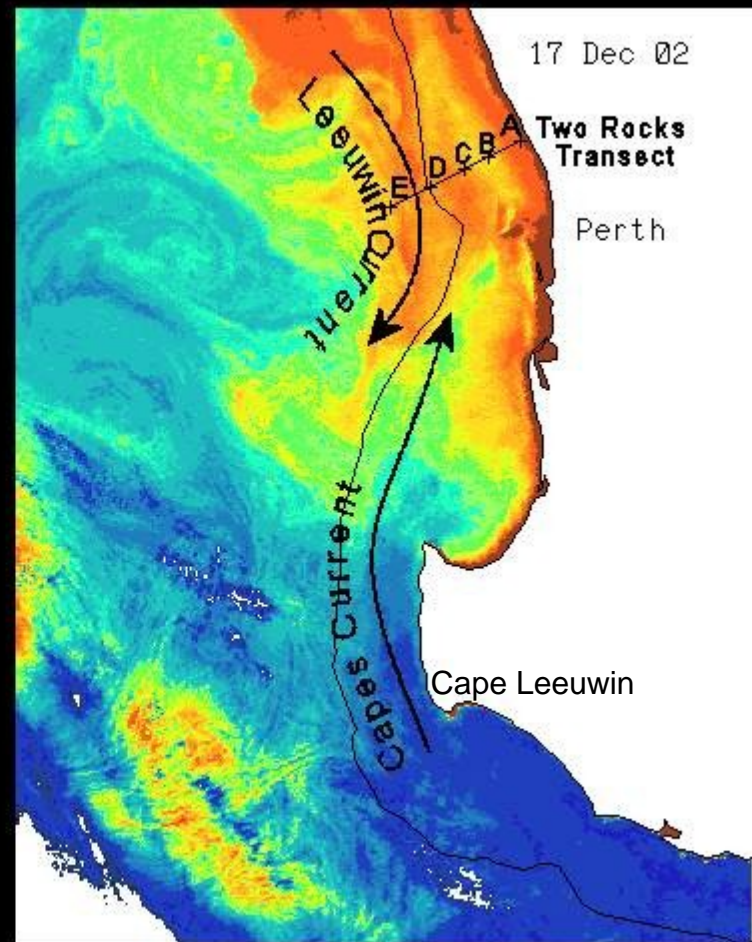
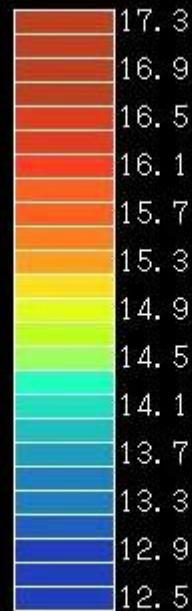
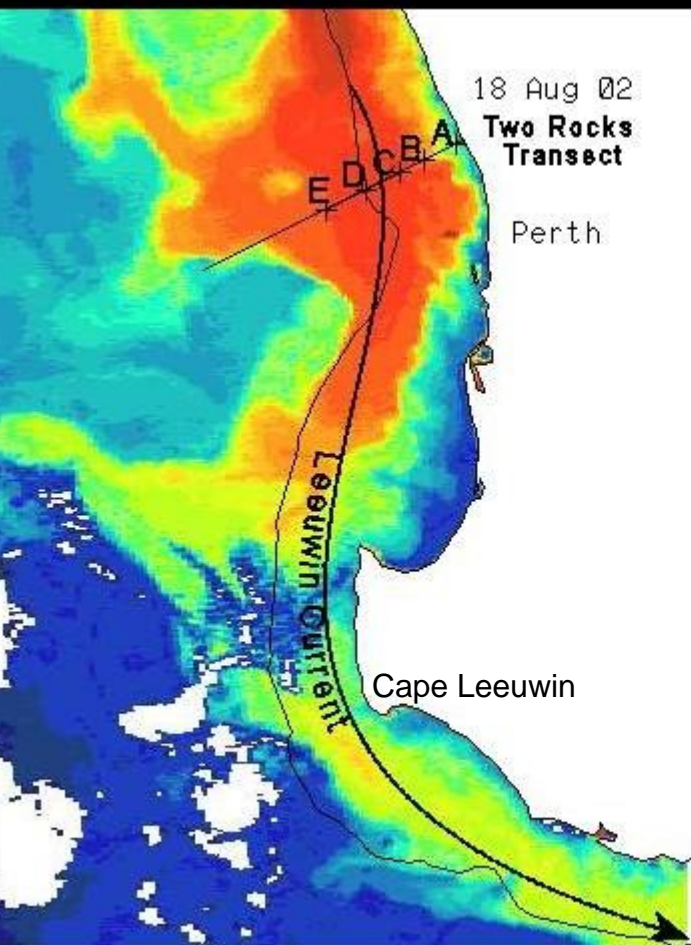




# Leeuwin Current seasonality

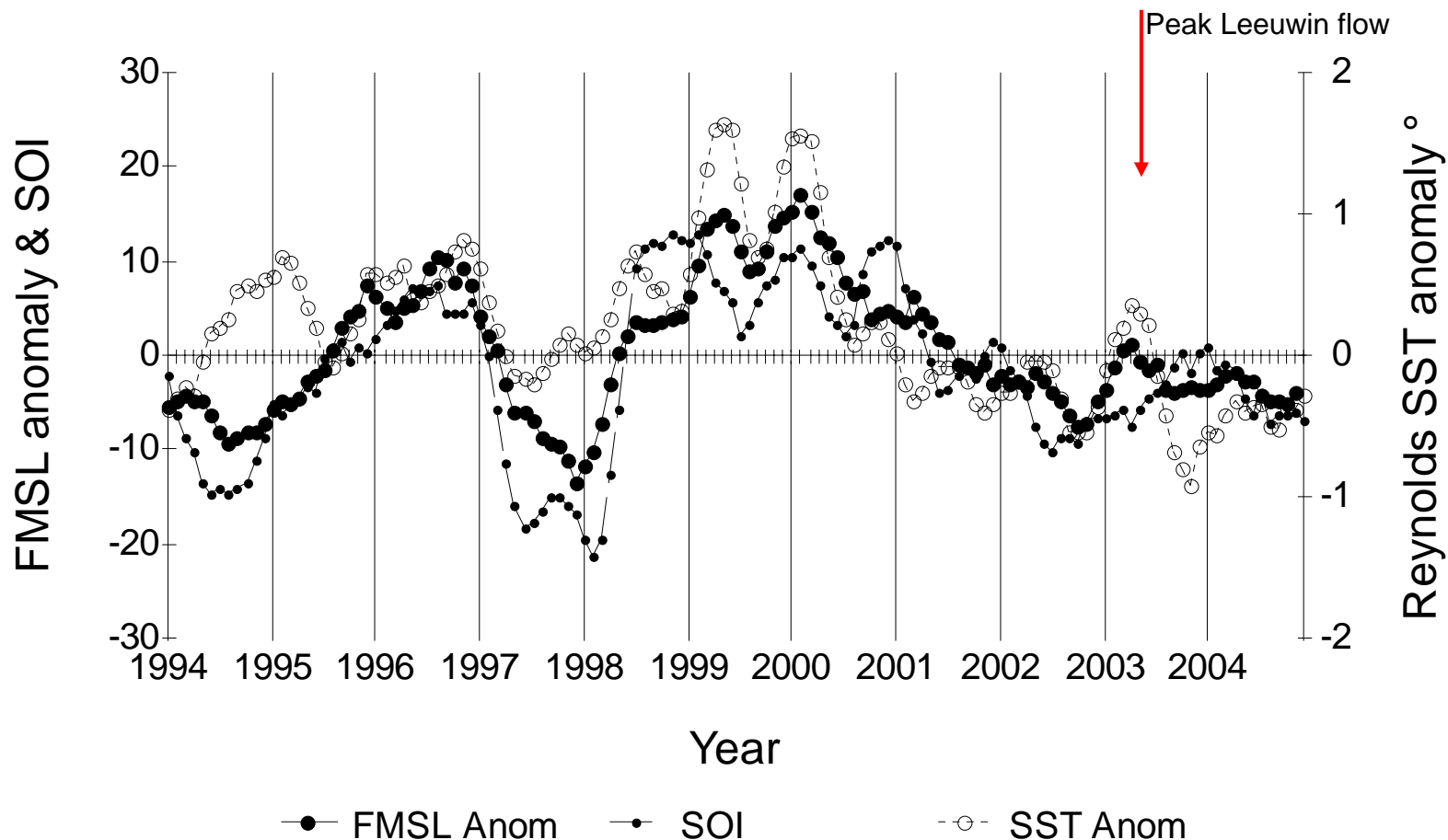
Flow strongest in late autumn/winter when unopposed by S winds

Capes Current: summer wind-driven shelf counter-current



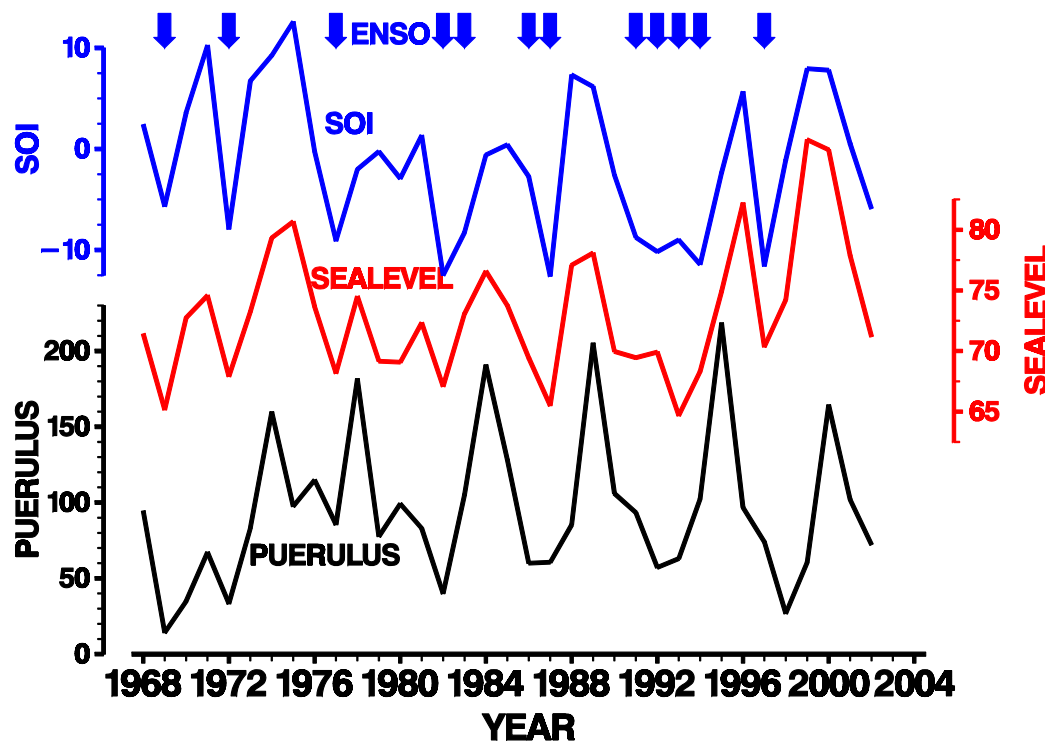
## Monthly smoothed sealevel, SOI, SST

1994 to 2004



- Fremantle sea level a good index of Leeuwin
- Leeuwin Current linked to ENSO
- Field study during period of weak El Nino – average conditions

# ENSO, the Leeuwin & WA fisheries



- ENSO linked with Leeuwin (Fremantle sea level) & western rock lobster fishery, Australia's most valuable single-species fishery (also pilchards, scallops, Australian salmon)
- But what is the link from the physics . . . -> . . . fish?
  - Griffin et al 2001: The link is not via advection. Productivity?



# Seasonal dynamics off SW Western Australia: Hypotheses

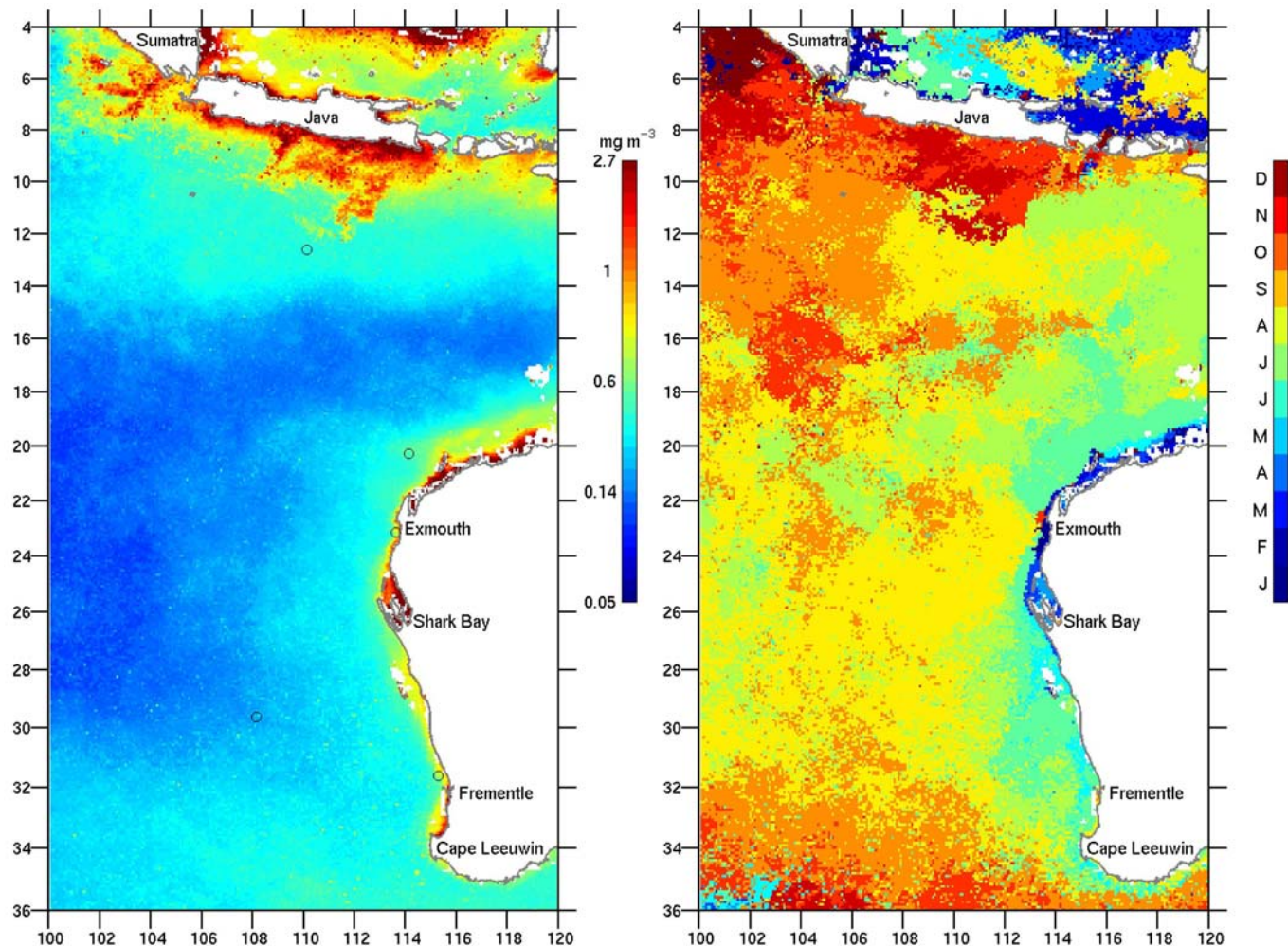
## H1: Temperate shelf cycle (Longhurst, 1995)

- Summer: stratified
- Winter:  $MLD > D_{cr}$
- Spring bloom:  $MLD < D_{cr}$

## H2: Subtropical cycle

- Light not limiting
- Summer production in DCM
- Winter/spring bloom: deep ML  $\rightarrow$  nutrient input

# SEAWIFS Chlorophyll *a* Climatology in the SE Indian Ocean



Maximum chl

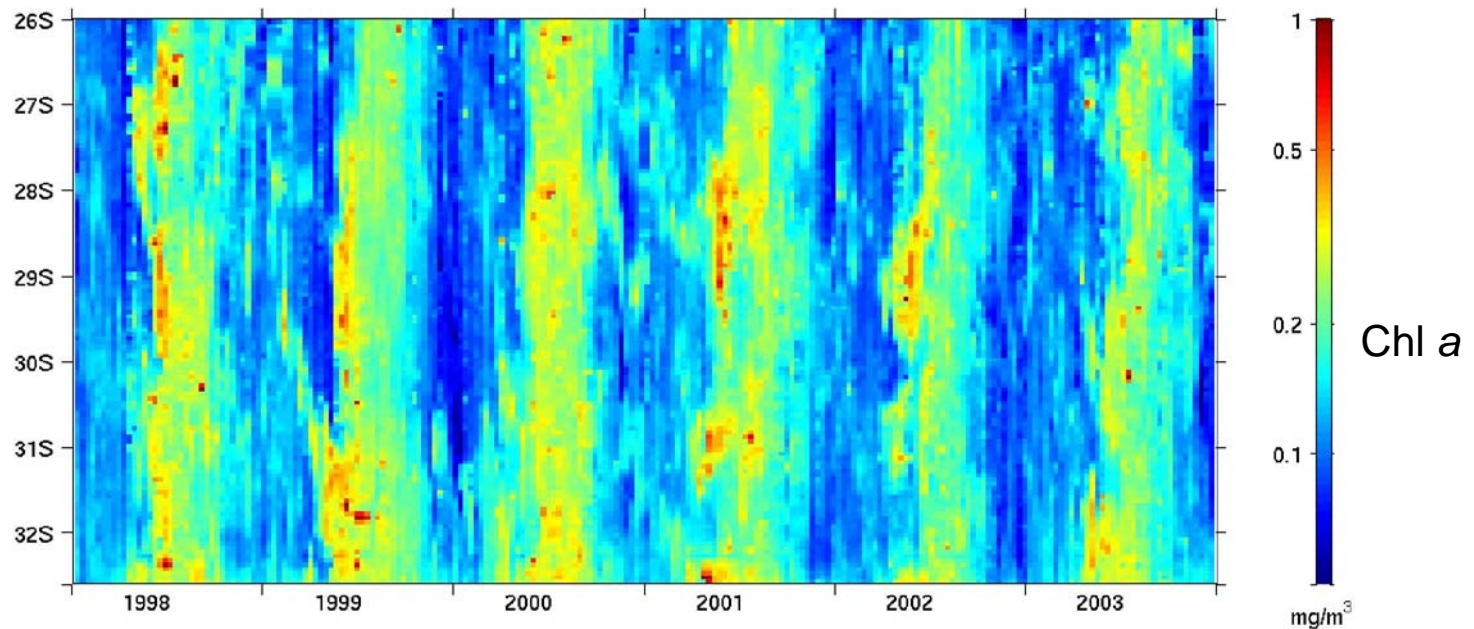
Timing of peak chl

Region from S  
of Shark Bay –  
Capes linked:  
amplitude &  
timing of chl  
climatology

# SeaWiFS ocean color off WA

(Shark Bay – Perth, 1998 – 2003)

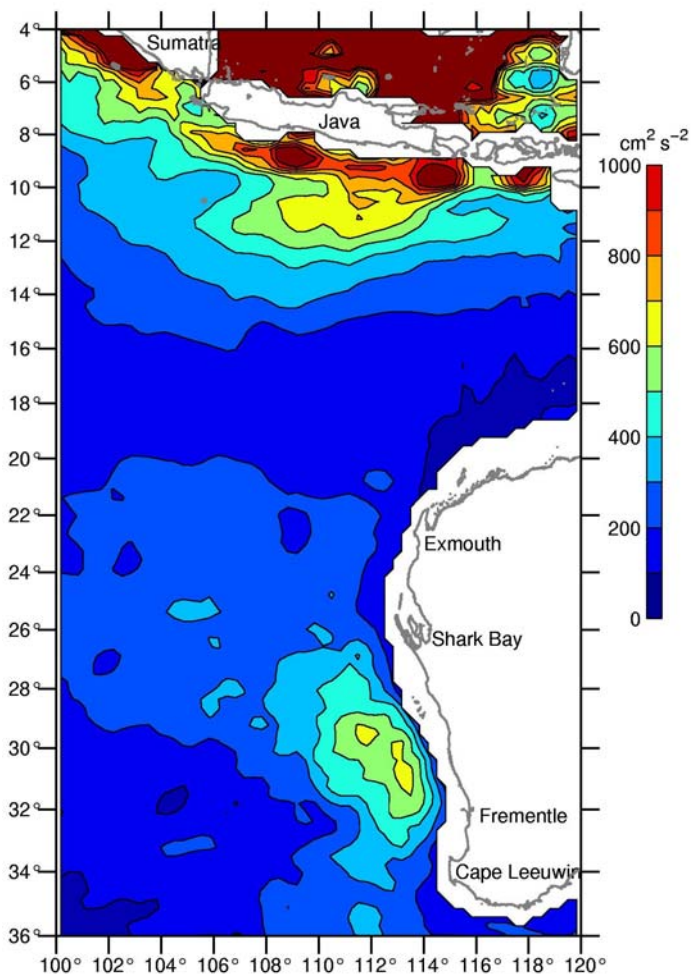
Coherent seasonal cycle beyond the shelf edge, ~ 700 km



What underlies the late autumn/early winter bloom off SW WA?

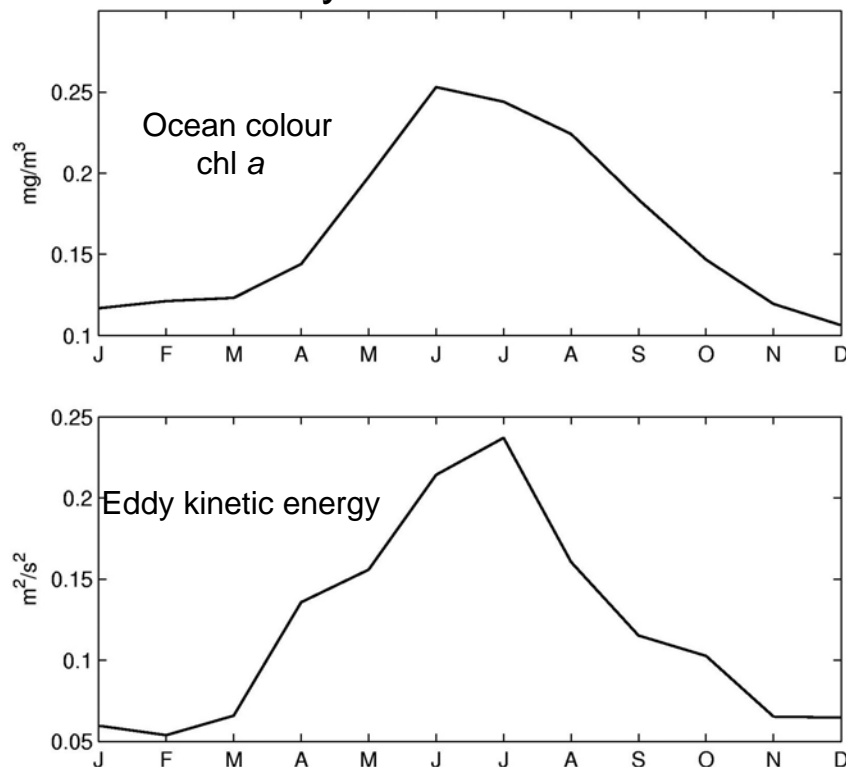


# Eddy kinetic energy and chl off SW WA



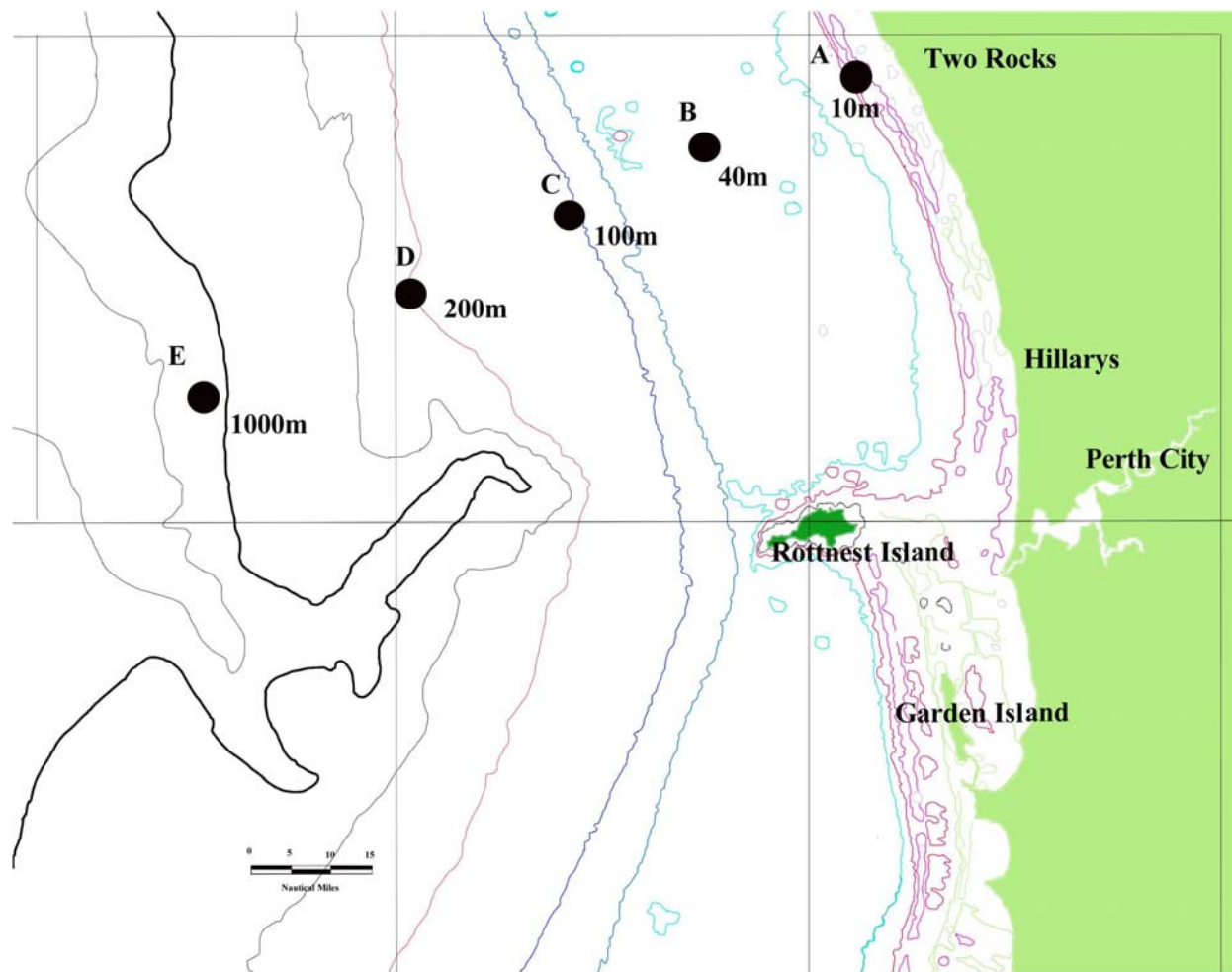
Eddy kinetic energy

Region of peak eddy kinetic energy corresponds with the region of coherent late autumn/early winter bloom



Timing also coincides  
Coincidence?

# Field sampling, 2002 - 2004



Monthly (A – C)/  
Qtr-ly (D – E) sampling

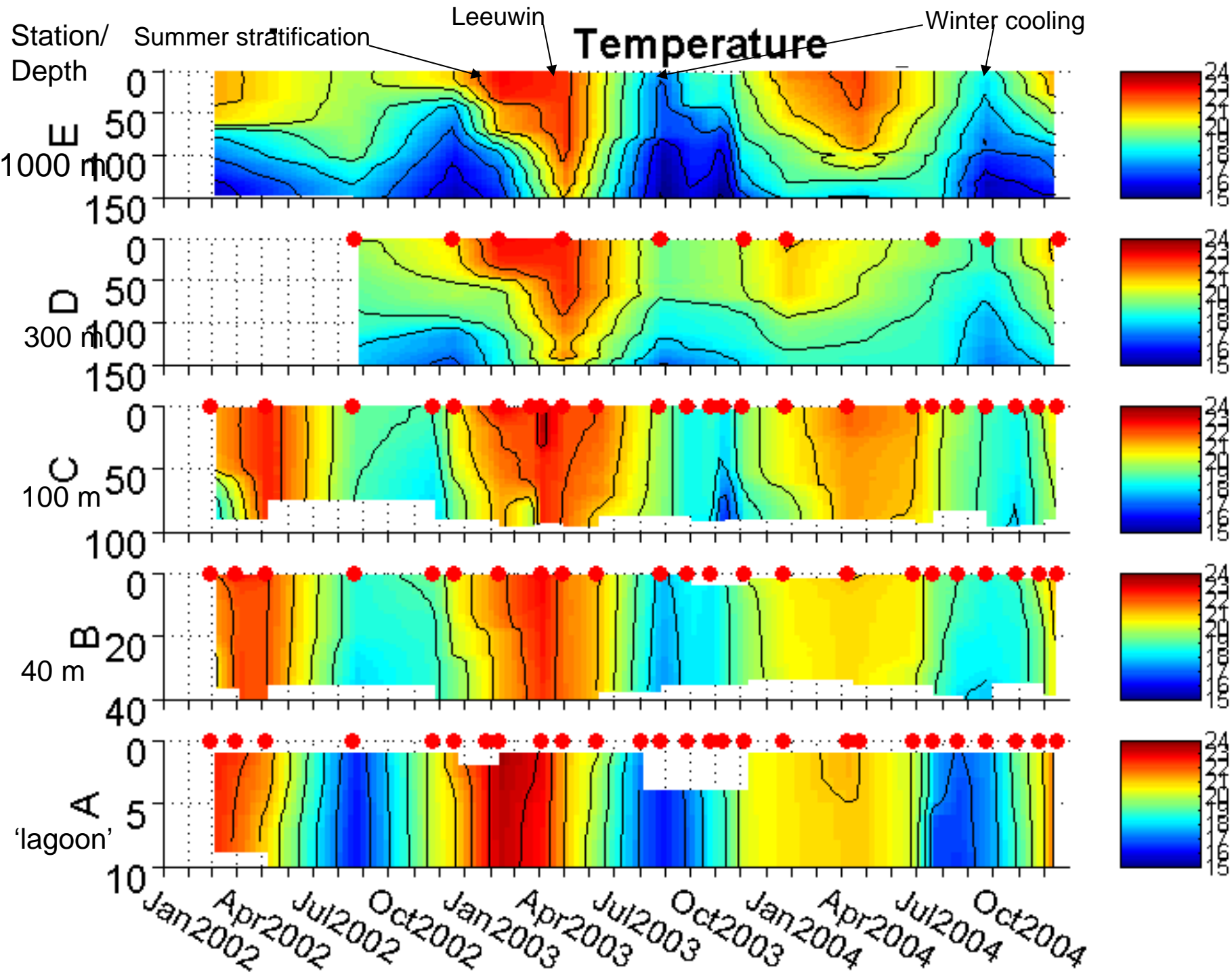
- CTD: T, S, chl
- Nutrients
- Phytoplankton, primary productivity
- Micro-, mesozooplankton, ichthyoplankton (Bongos)
- Acoustics (3 freq + TAPS)

Supplemented by

- Current meter moorings

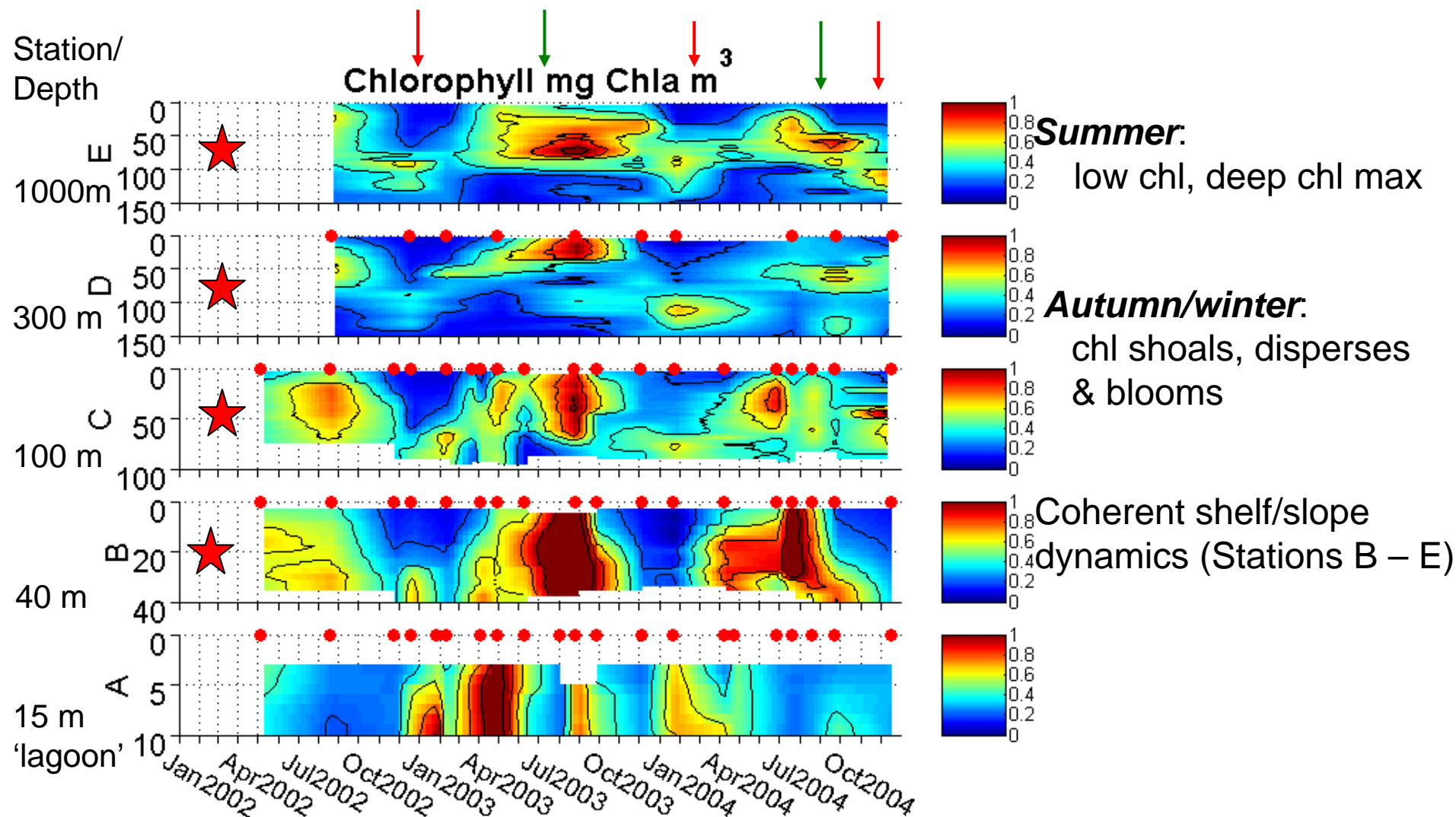
- (A – C) (1 yr)
- Satellite obs

Transect N of Perth avoids influence of outfalls, island wake/canyon effects

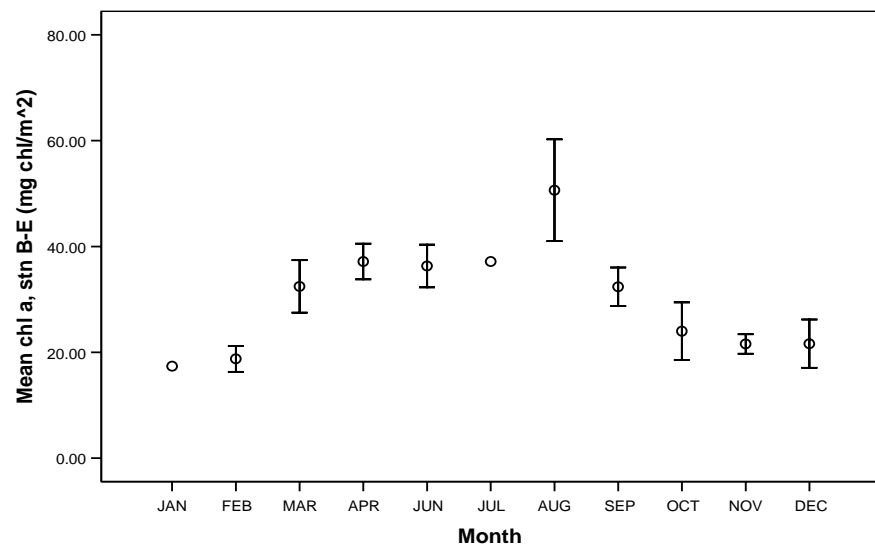




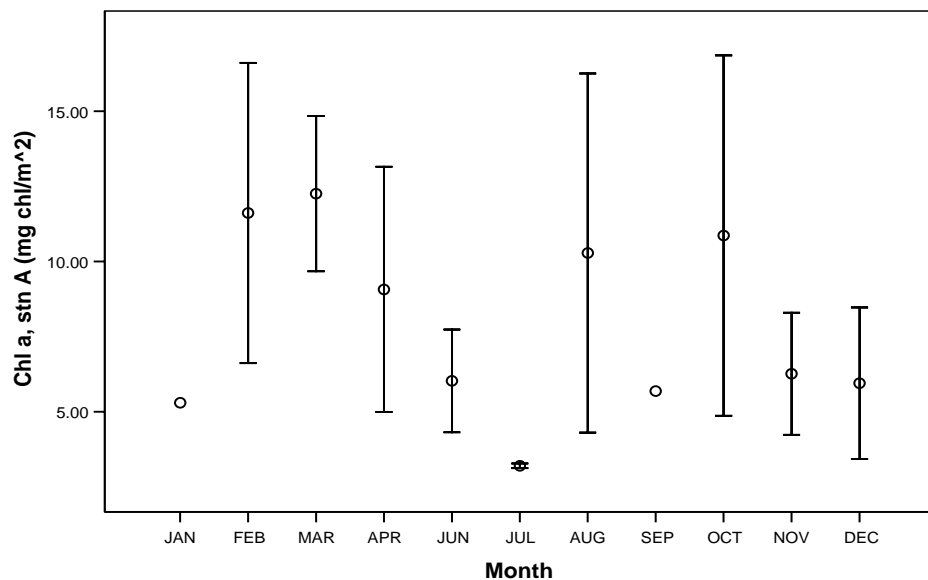
# Seasonal chlorophyll dynamics



# Annual chlorophyll *a* cycle, 2002 - 2204



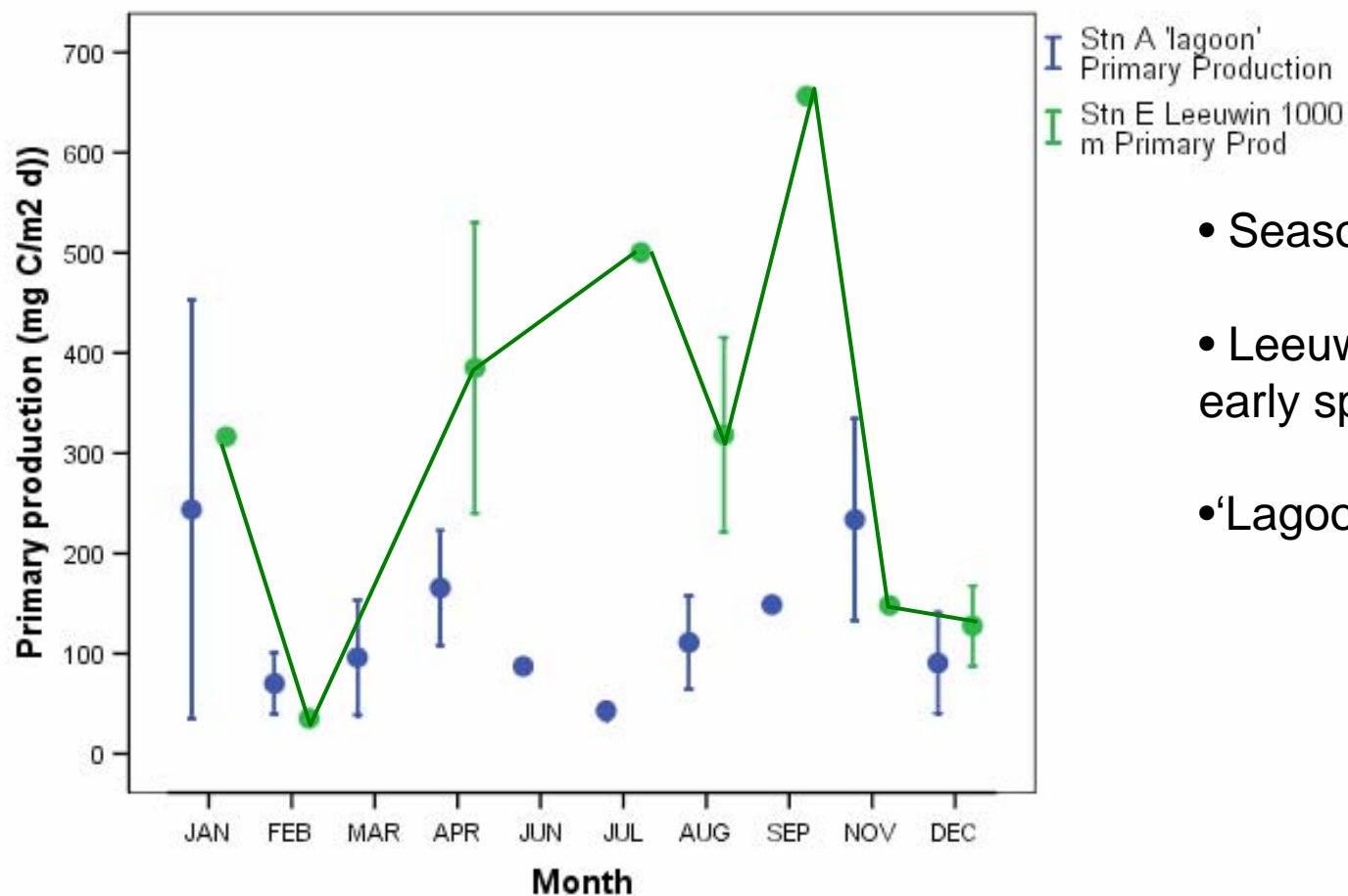
Shelf/slope:  
autumn/winter bloom



Inshore: high variability

# Annual cycle of primary production (C-14 incubations)

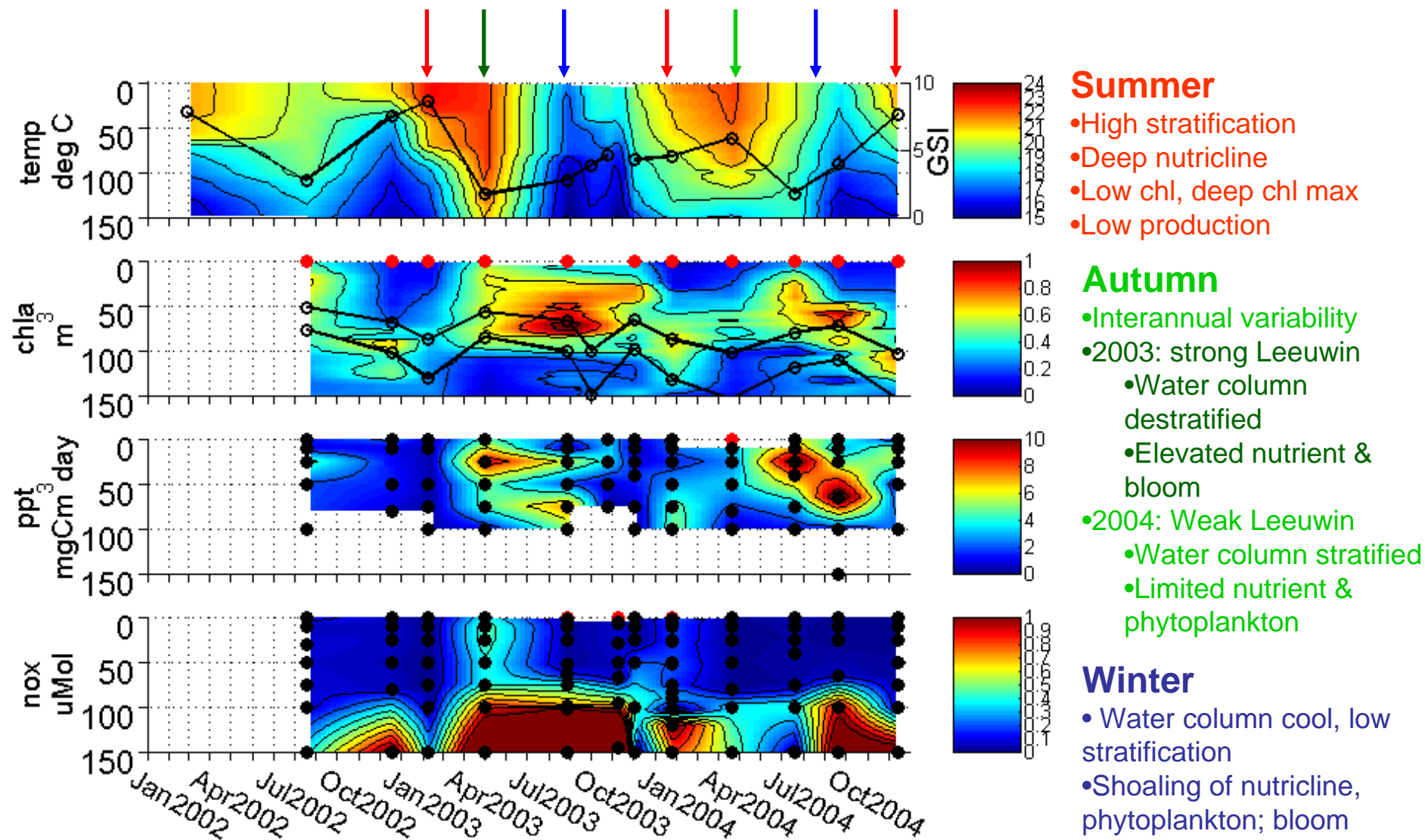
Mean integrated primary production



- Seasonal pattern less clear
- Leeuwin: Late autumn to early spring
- 'Lagoon': No pattern

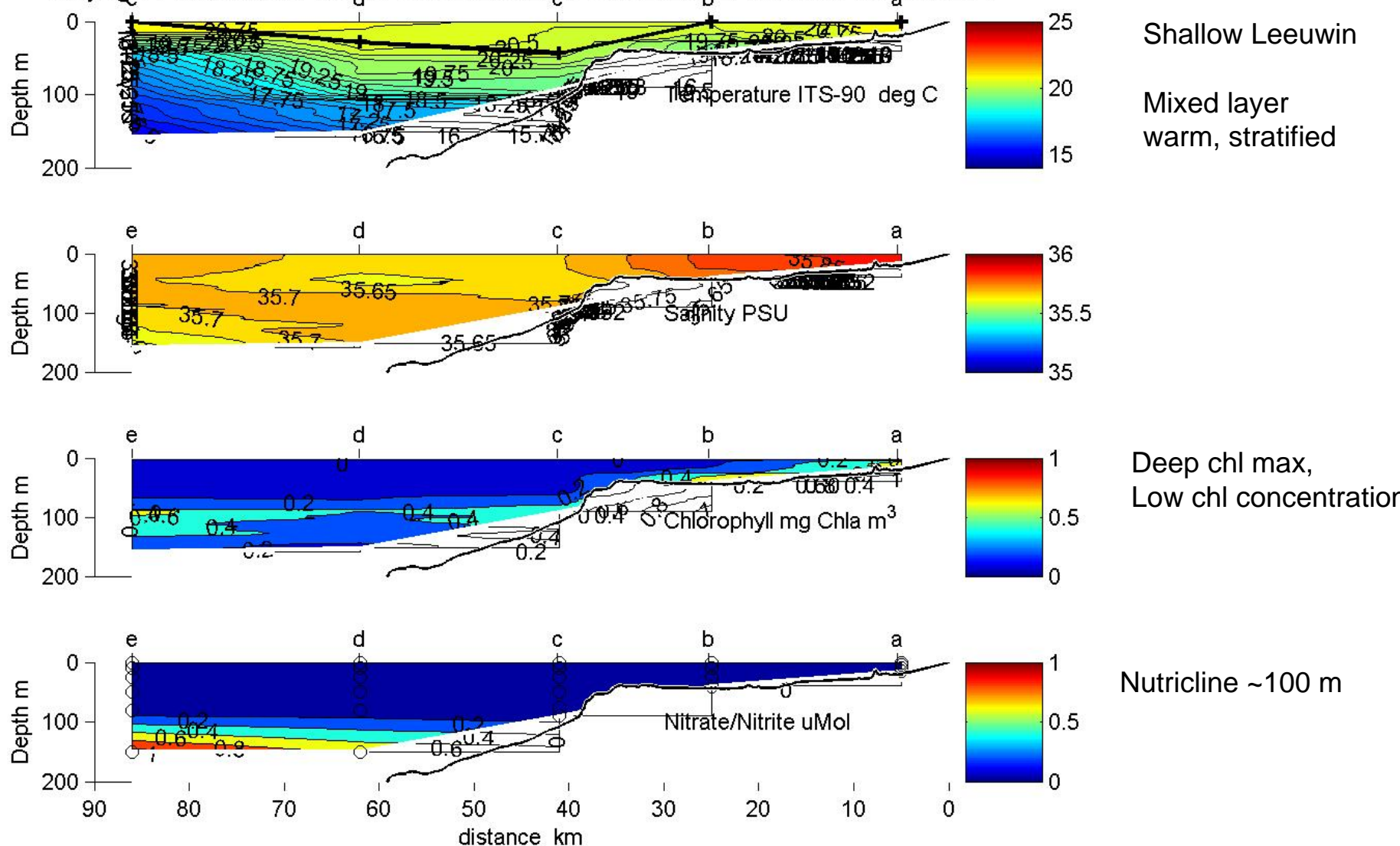


# Temperature, chl, primary production & nitrate/nitrite at Station E (Leeuwin, 1000 m depth), 0 – 150 m, 2002 - 2004



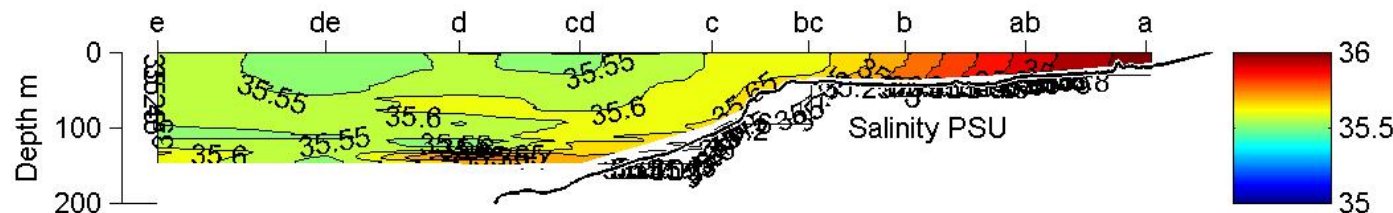
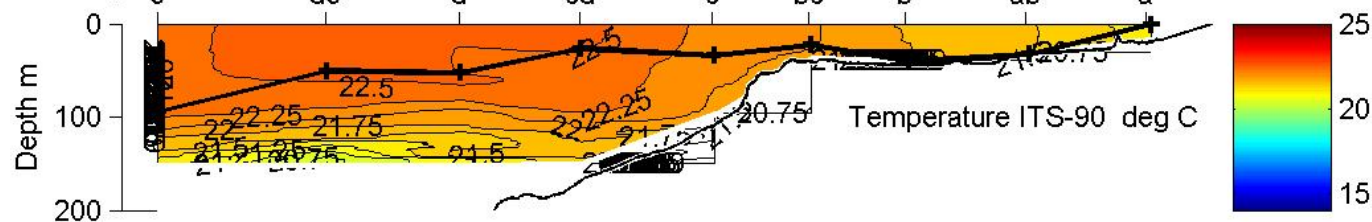
# Seasonal dynamics cross-shelf: summer

Voyage : mi200206 Date: 17/12/2002 to 18/12/2002 Season :SUMMER

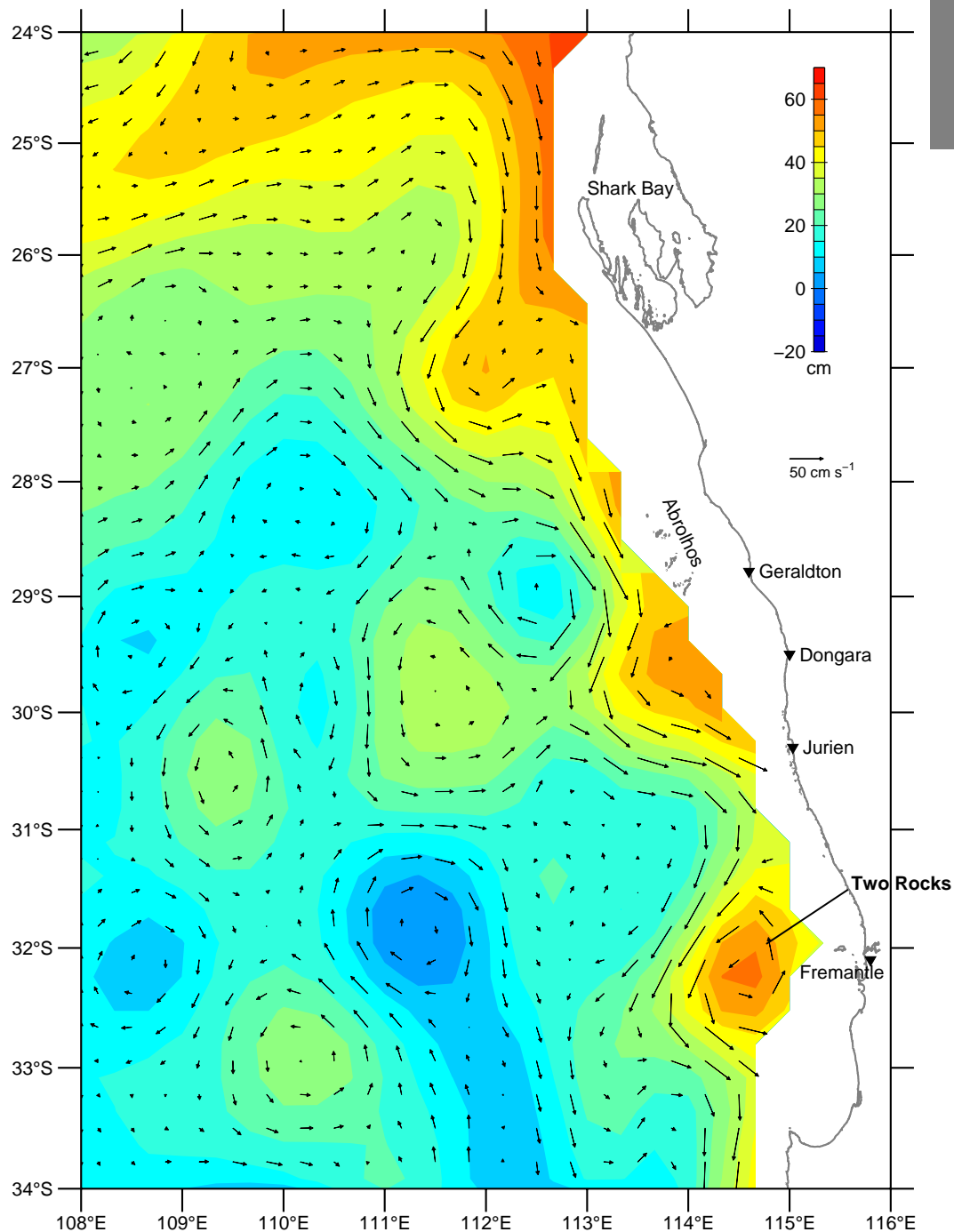


# Seasonal cross-shelf dynamics: autumn

Voyage : na200304 Date: 28/04/2003 to 30/04/2003 Season :AUTUMN







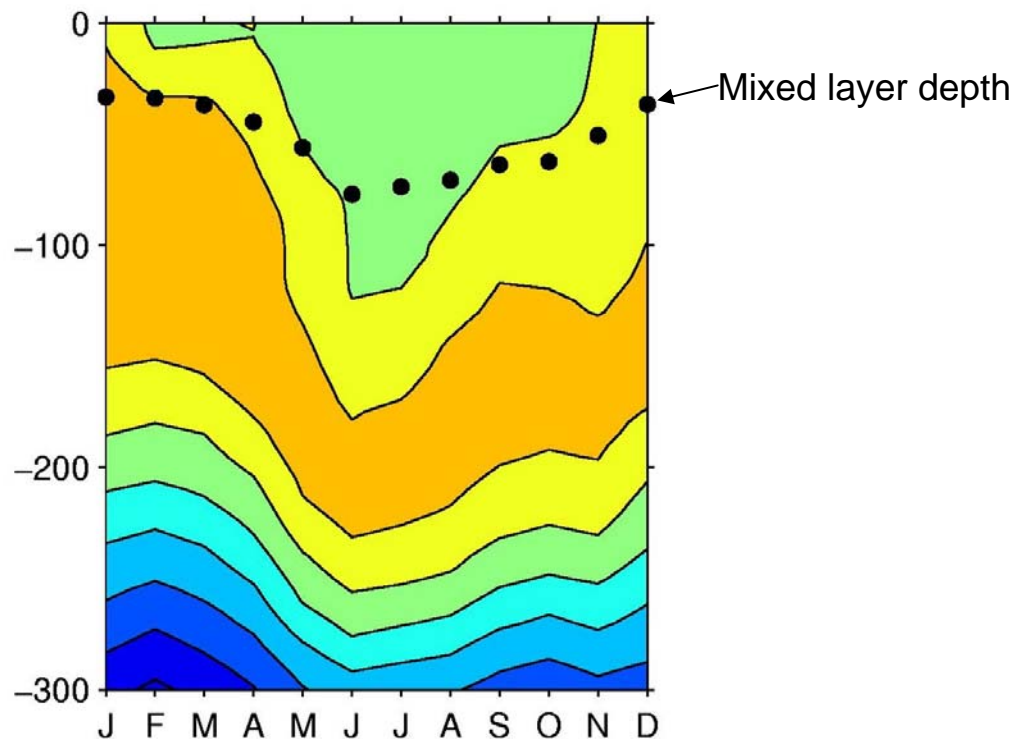
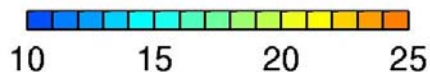
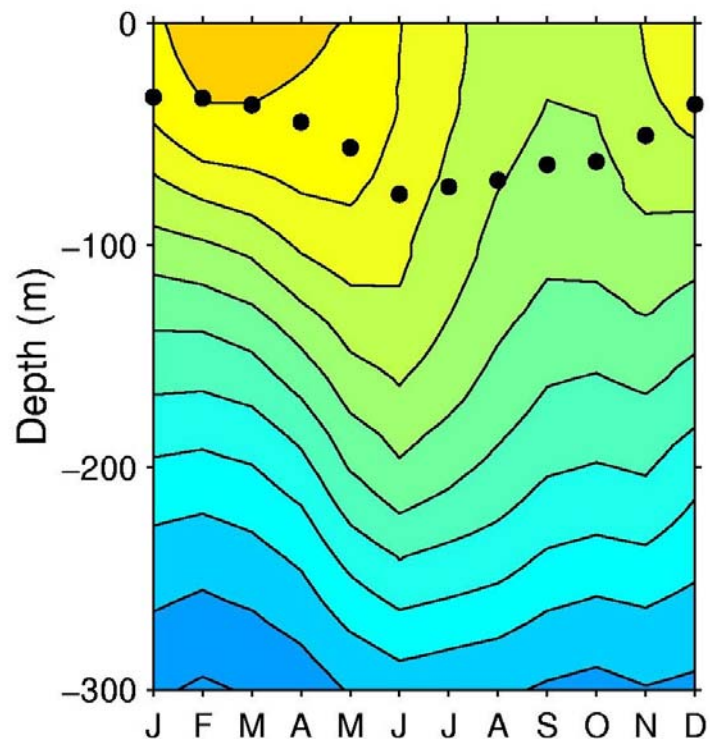
Eddy offshore of Two Rocks  
transect, meander north

Nutrient enrichment offshore  
in Leeuwin and across shelf:  
• Upwelling induced by eddy-  
meander pair and 'pumped'  
across the shelf

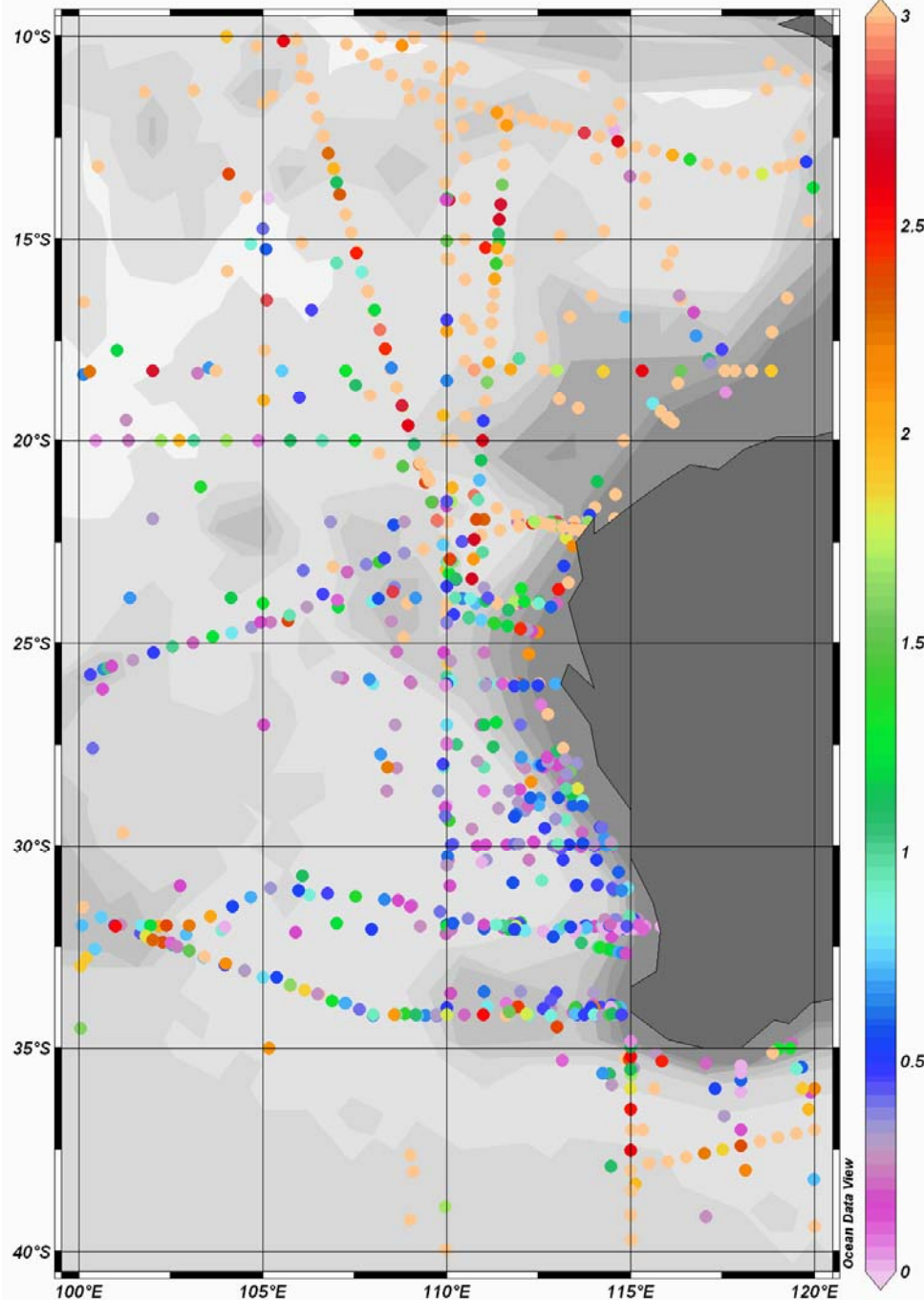
- Similar eddy  
enrichment of shelf  
noted in wbc off SE  
USA, Brazil, Kuroshio;  
also inshore of  
poleward-flowing  
Bering Slope Current  
(Stabeno and Meurs 1999;  
Mizobata and Saitoh 2004)

## Temperature

## Salinity



Stratification breakdown & deepening of mixed layer with arrival of low-salinity Leeuwin in late autumn/early winter



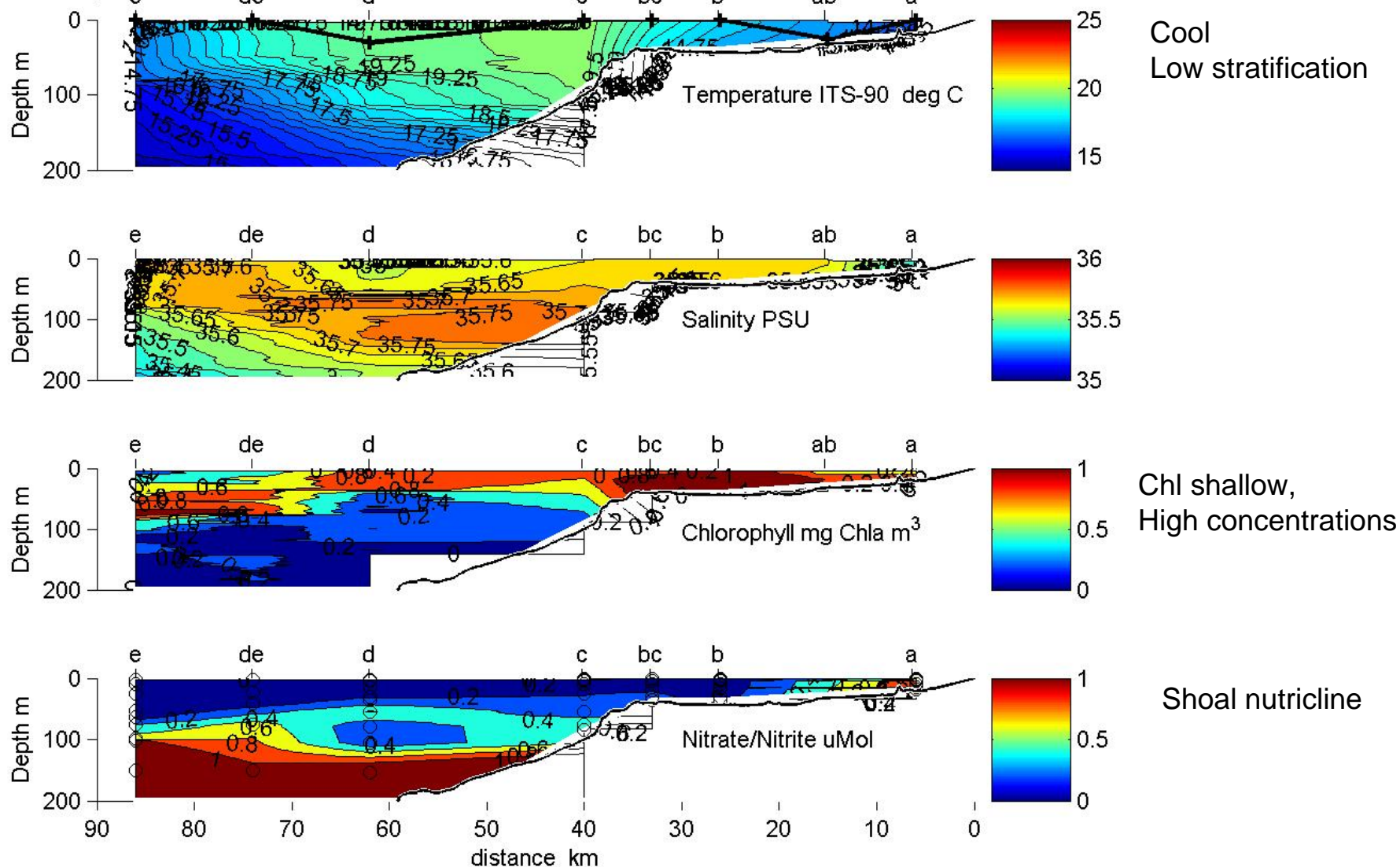
Another possible mechanism:

Nutrient entrainment in North,  
where nutricline is shallower, by  
stronger deeper Leeuwin in late  
autumn

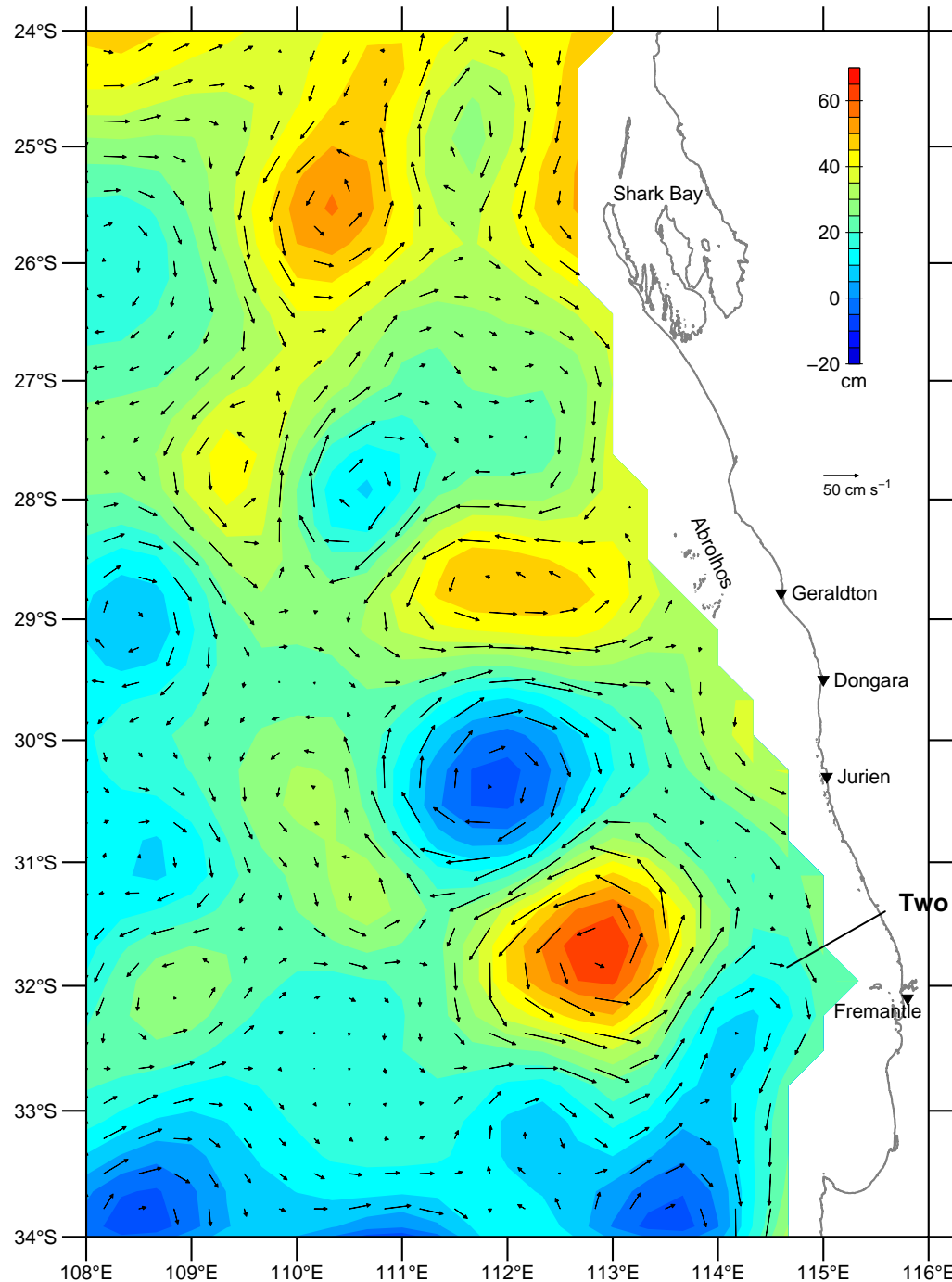
Advection southward

# Seasonal dynamics: winter

Voyage : ss200307 Date: 23/08/2003 to 27/08/2003 Season : WINTER







Eddies drift offshore in winter

Water column cooled

Nutrient flux into upper mixed layer driven by convective cooling, mixing by winter storms

# What drives the production cycle?

## •Inshore:

- Groundwater
- Winter runoff
- Sediment/benthic diatom re-suspension
- Wrack re-mineralization in winter

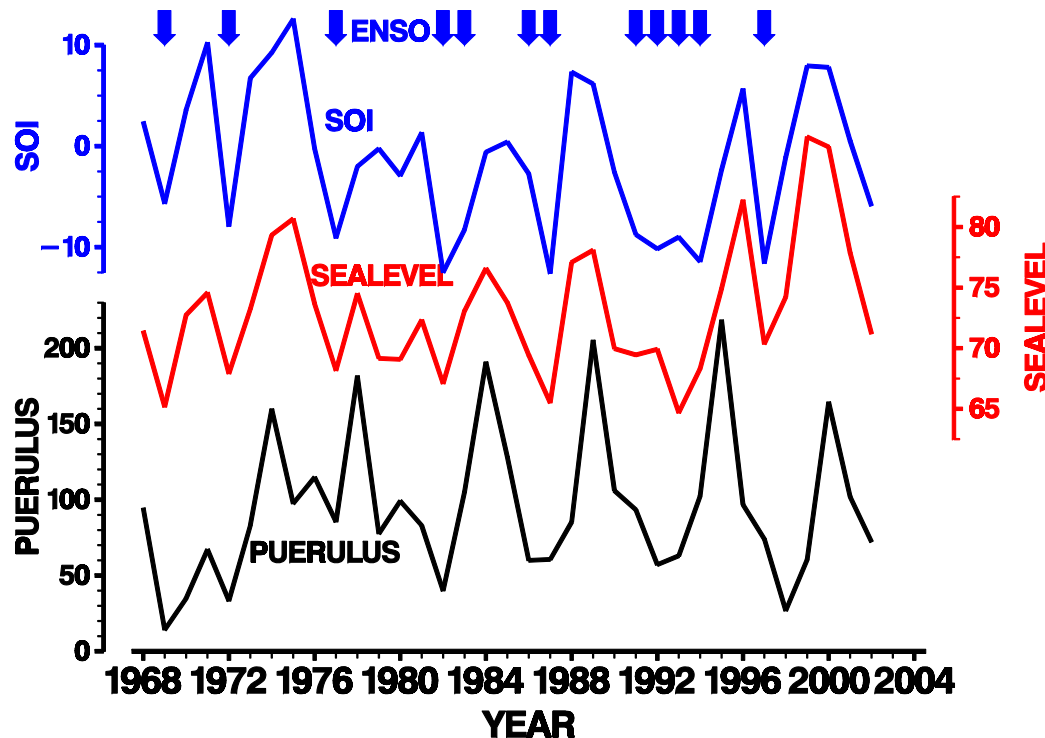
## •Shelf & slope (Leeuwin)

- Eddy pumping of nutrients across the shelf (observed for western boundary currents off SE USA, Brazil, Japan; also Bering Sea)
  - Upwelling in eddies & cross-shelf transport?
  - Advection of nutrients from north?
  - Breakdown of stratification/convective overturning?

# Interannual variability

Low-nutrient Leeuwin sets the region's low productivity, but, a strong Leeuwin promotes *higher* production!

Explanation for the + Leeuwin-lobster correlation?



# Acknowledgements

## The Team

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