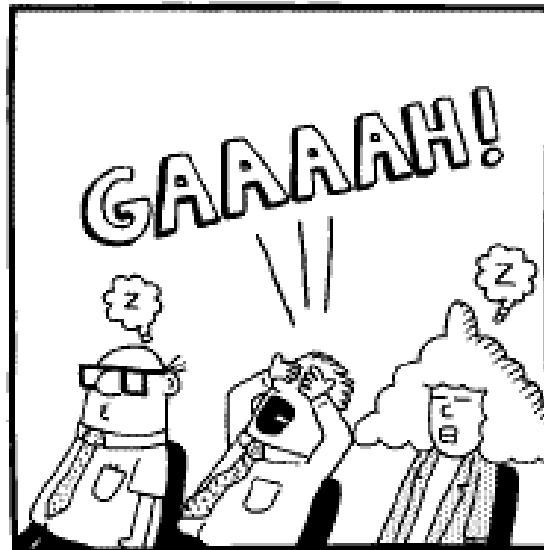


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www.dilbert.com



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# Bluelink>: Large-Scale Operational Oceanography in the Southern Hemisphere

GODAE Summer School 2004  
La Londe Les Maures

Andreas Schiller  
CSIRO Marine Research  
Hobart, Australia



With thanks to the  
Teams at BoM and  
CSIRO

  
BLUelink> *Ocean Forecasting Australia*  
<http://www.marine.csiro.au/bluelink/>

# Contents\*

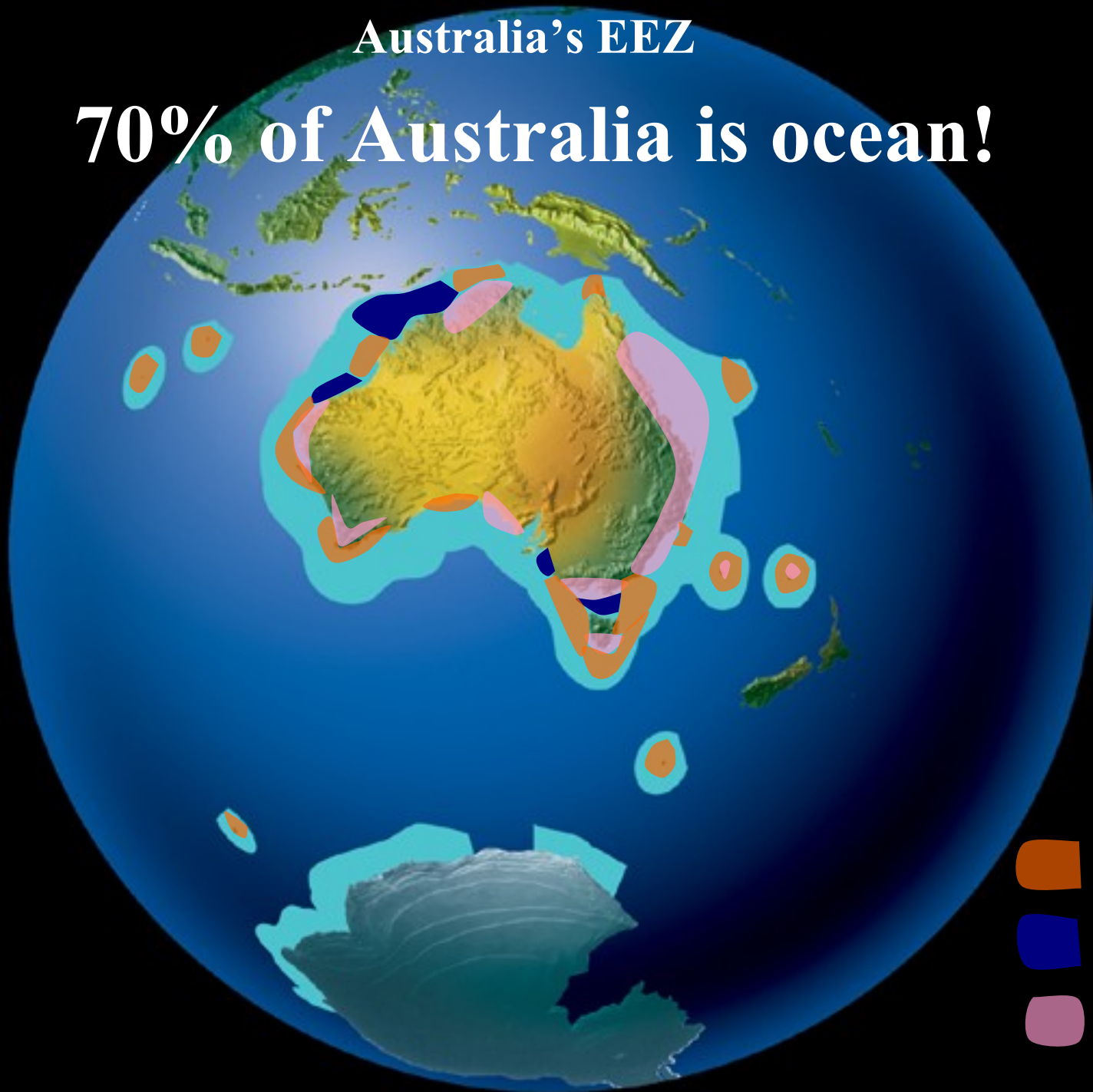
\* with special emphasis on regional oceanography



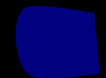
- **Background**
- **Ocean Analysis System:**
  - **CSIRO Atlas of Regional Seas (CARS)**
  - **High-Res. SST, SSH, wind products**
  - **Cal/val of satellite data / QC of in-situ data**
- **Ocean Modelling System**
  - **Ocean Forecasting Australia Model (OFAM)**
  - **Bluelink Data Assimilation System (BODAS)**
  - **Nested Relocatable Ocean-Atmosphere Model**
- **Operational Forecasting System**
  - **Input Data/Observations**
  - **Output Data/Products/Access**
  - **Reanalysis, GODAE metrics**

# Australia's EEZ

## 70% of Australia is ocean!



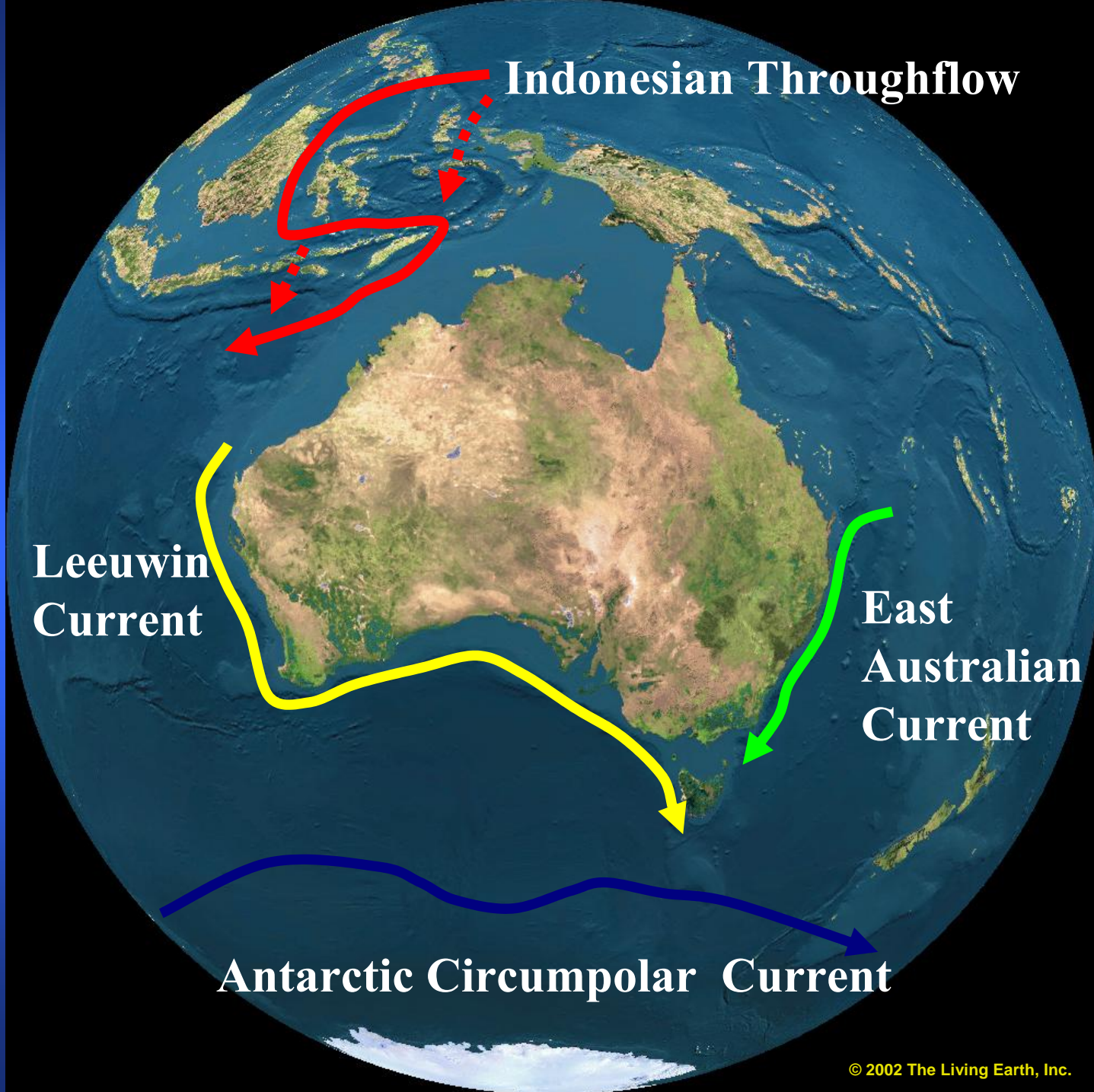
Fisheries



Oil & Gas



Tourism



**Indonesian Throughflow**

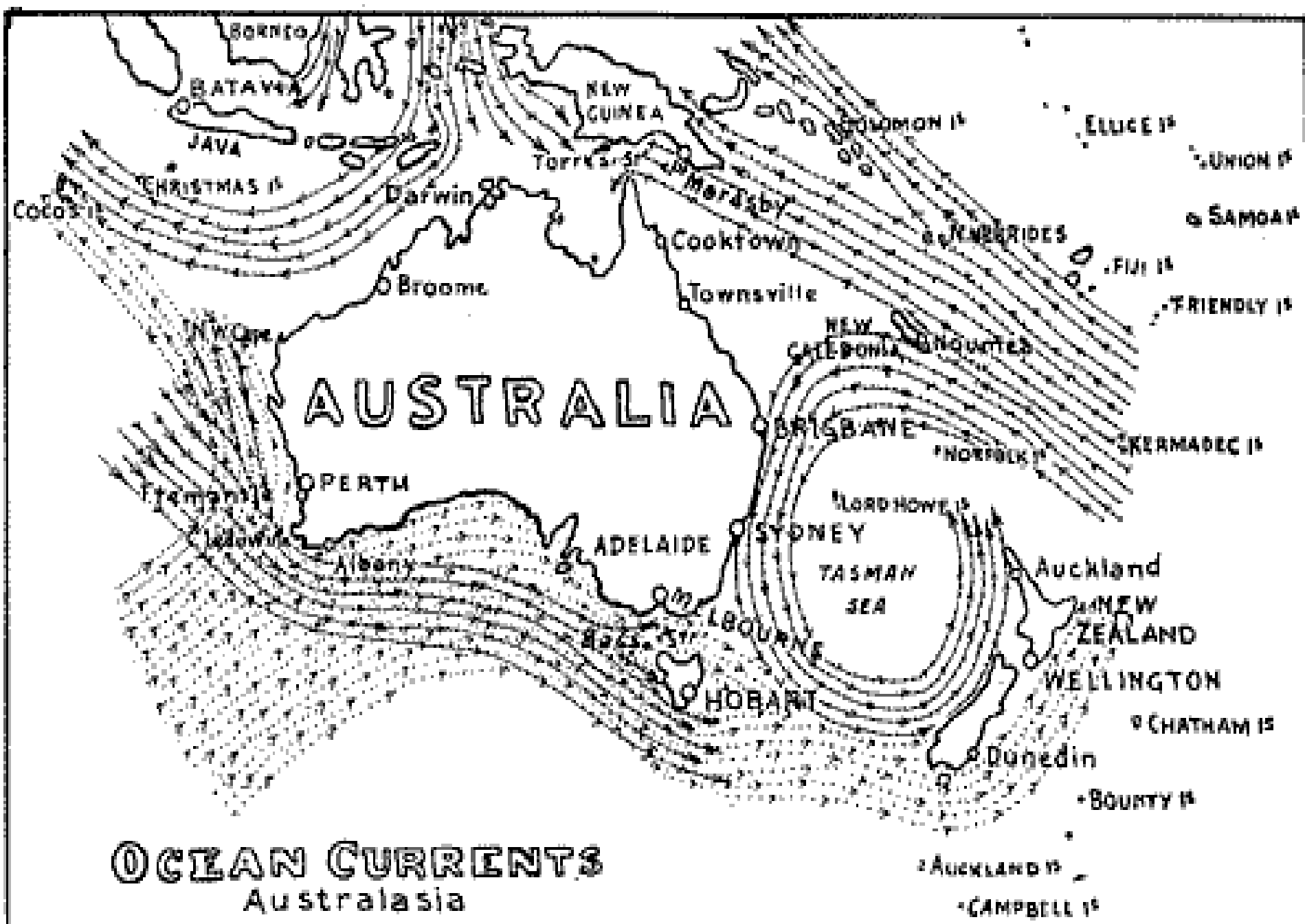
**Leeuwin  
Current**

**East  
Australian  
Current**

**Antarctic Circumpolar Current**



**Black's Atlas of the World**  
(~1853)

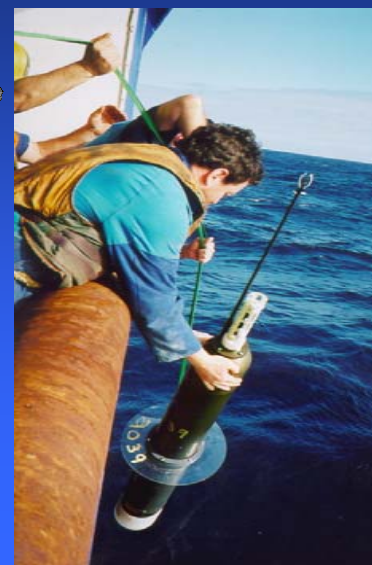
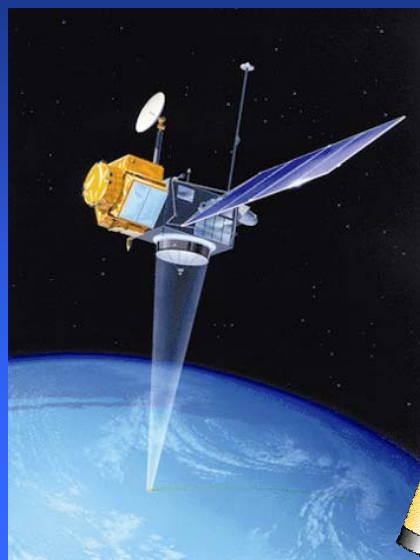


Cold Currents are shown by dotted lines  
 Warm do do do full lines

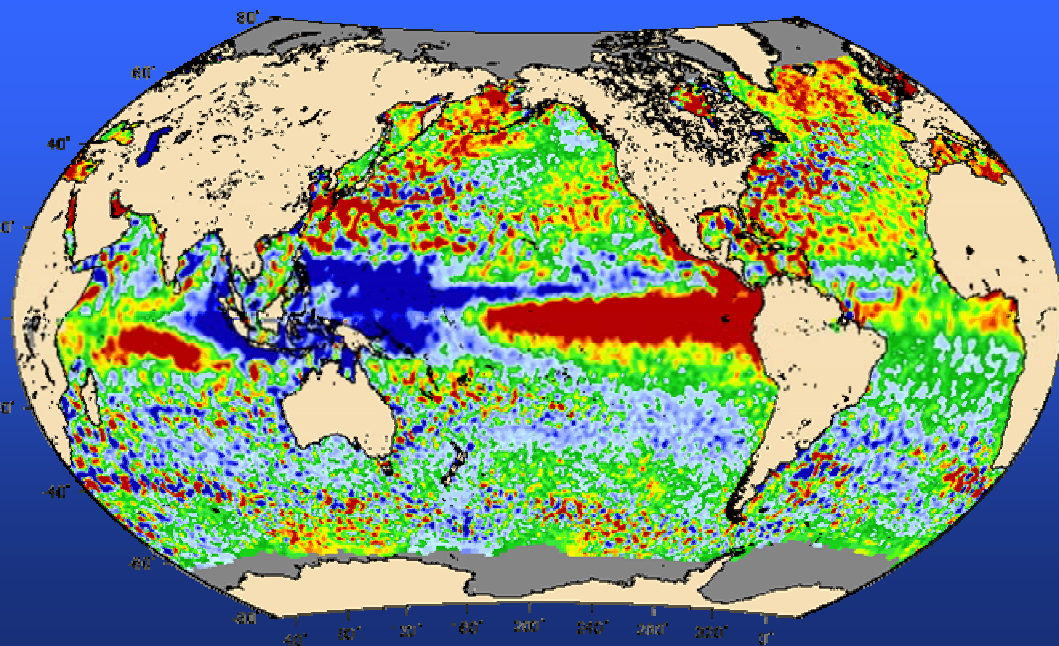
MACQUARIE IS Halligan (1921)

# Ocean Prediction – A Revolution in Ocean Science

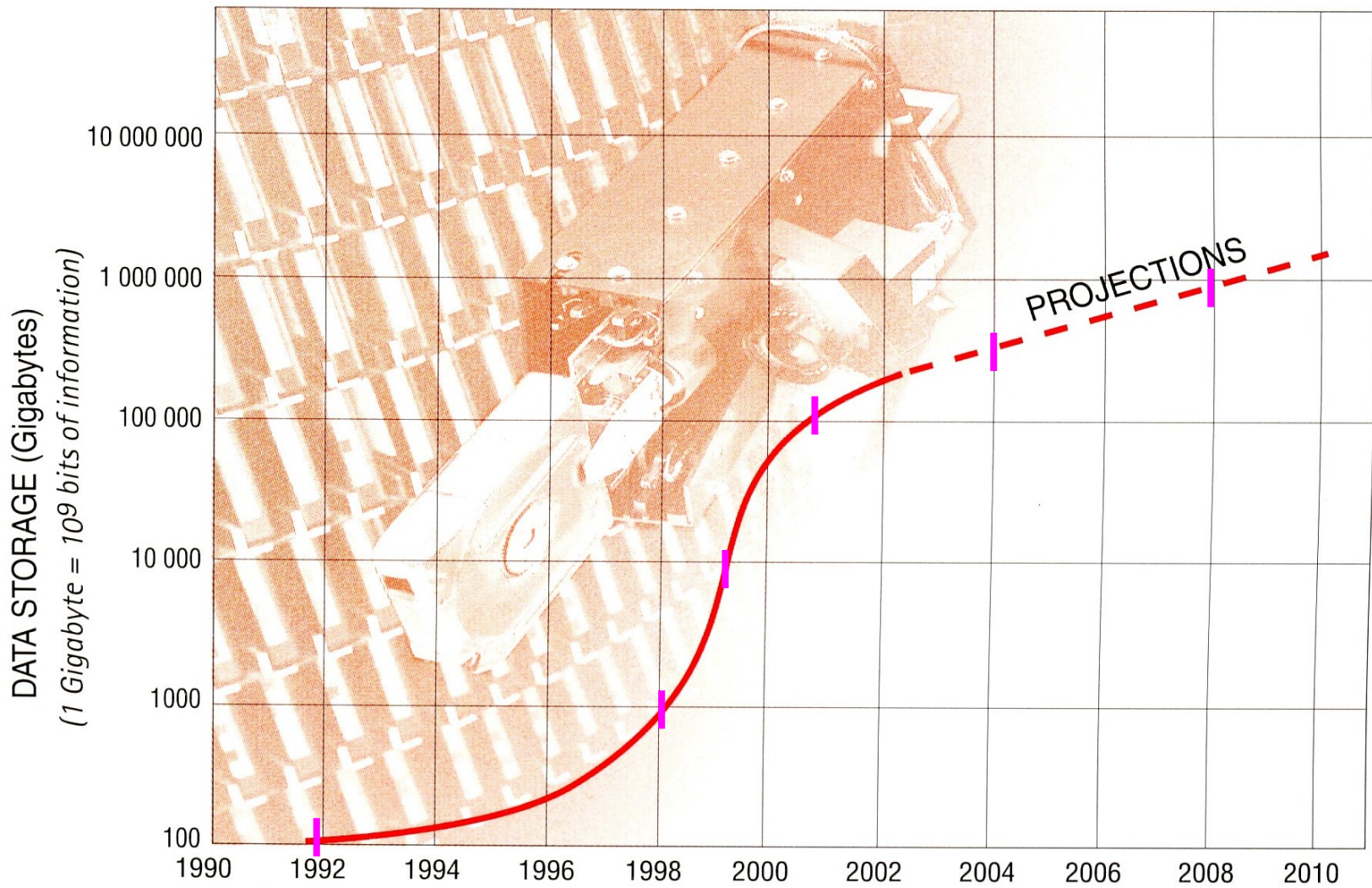
Satellites (SST, altimetry, surface winds, ocean colour) and in-situ observations



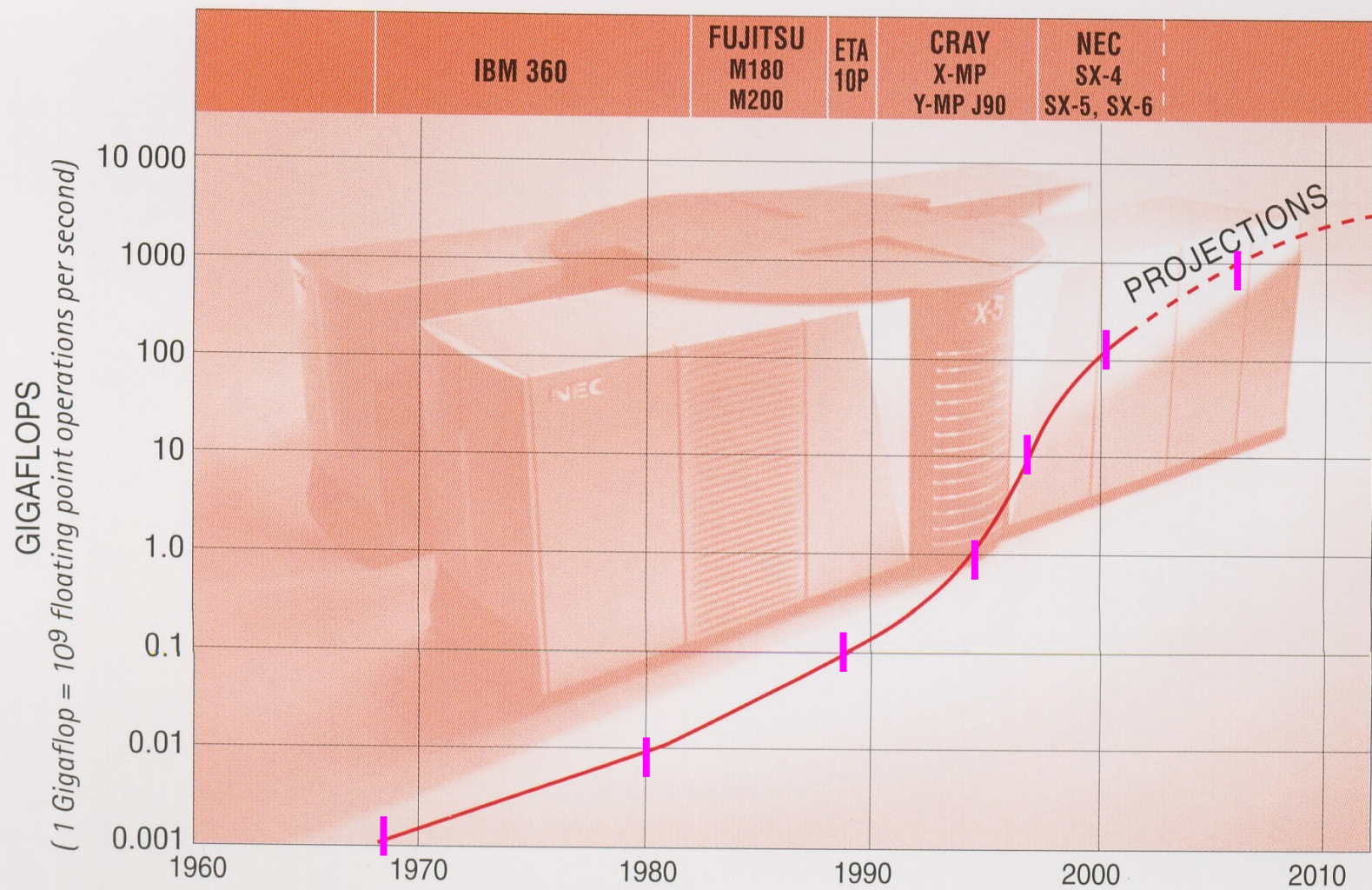
Supercomputing and high-resolution ocean circulation models







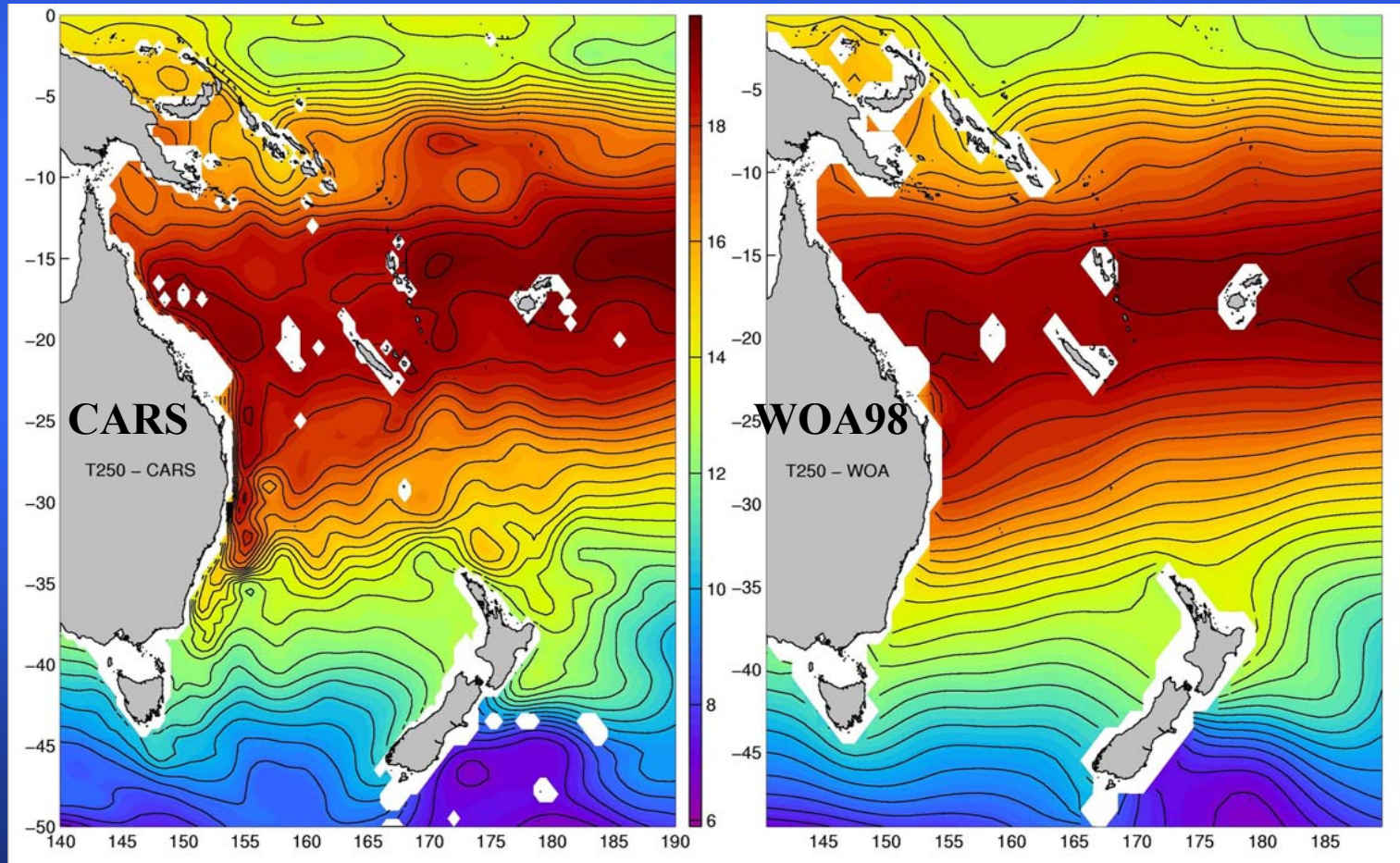
*History of data storage available to the Bureau of Meteorology (1992–2003) and projections.*



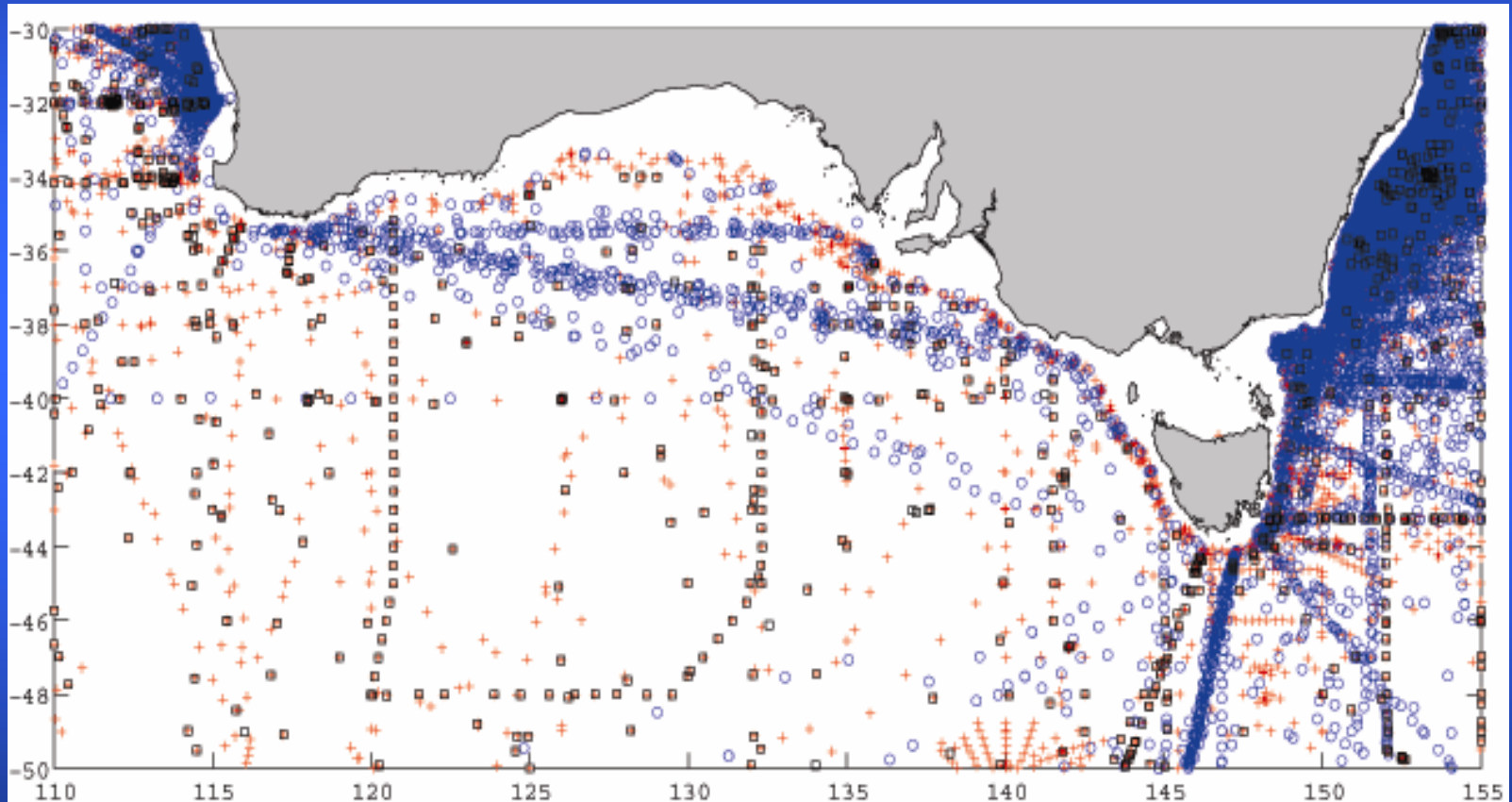
*History of computer power available to the Bureau of Meteorology.*

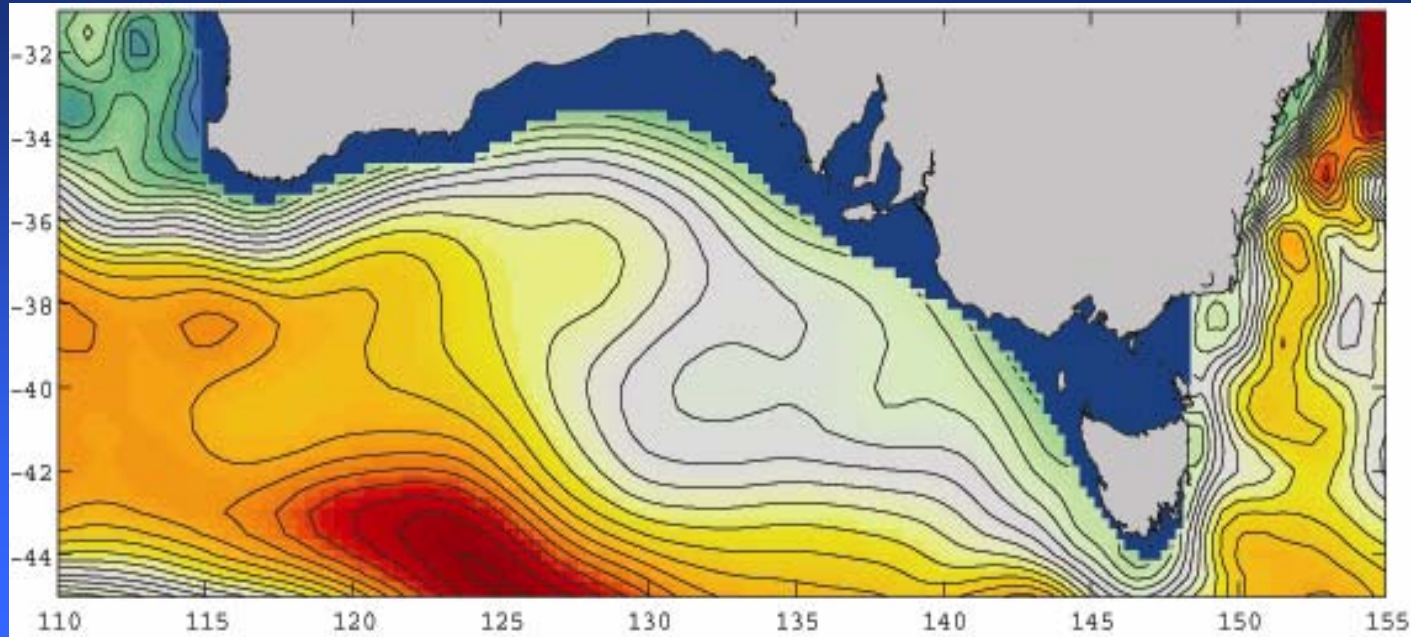
# Regional Climatology

A regional ( $10^{\circ}\text{N}$ - $60^{\circ}\text{S}$ ;  $90^{\circ}\text{E}$ - $180^{\circ}\text{E}$ ) high-resolution ocean climatology of mean and monthly fields of temperature and salinity ( $0.5^{\circ}\times 0.5^{\circ}$  to  $1/8^{\circ}$  resolution at coastal boundaries)

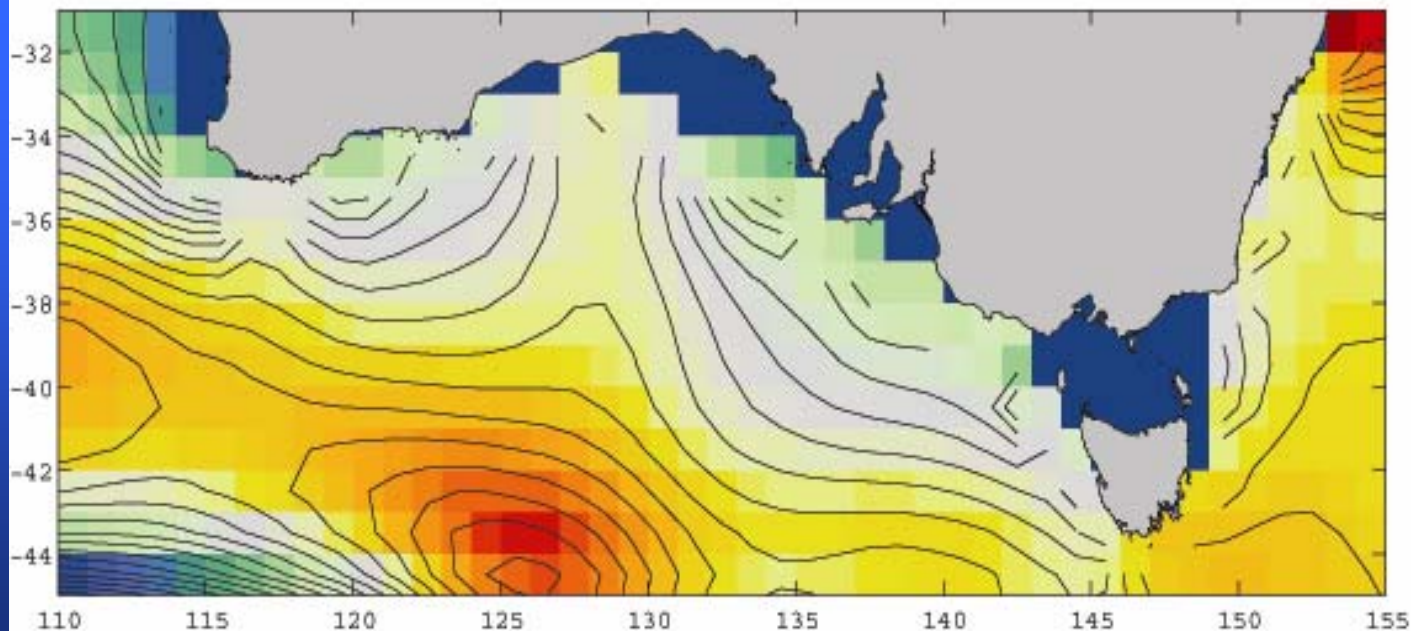


# All stations > 2000-m (Bottle, CDT and XBT casts)



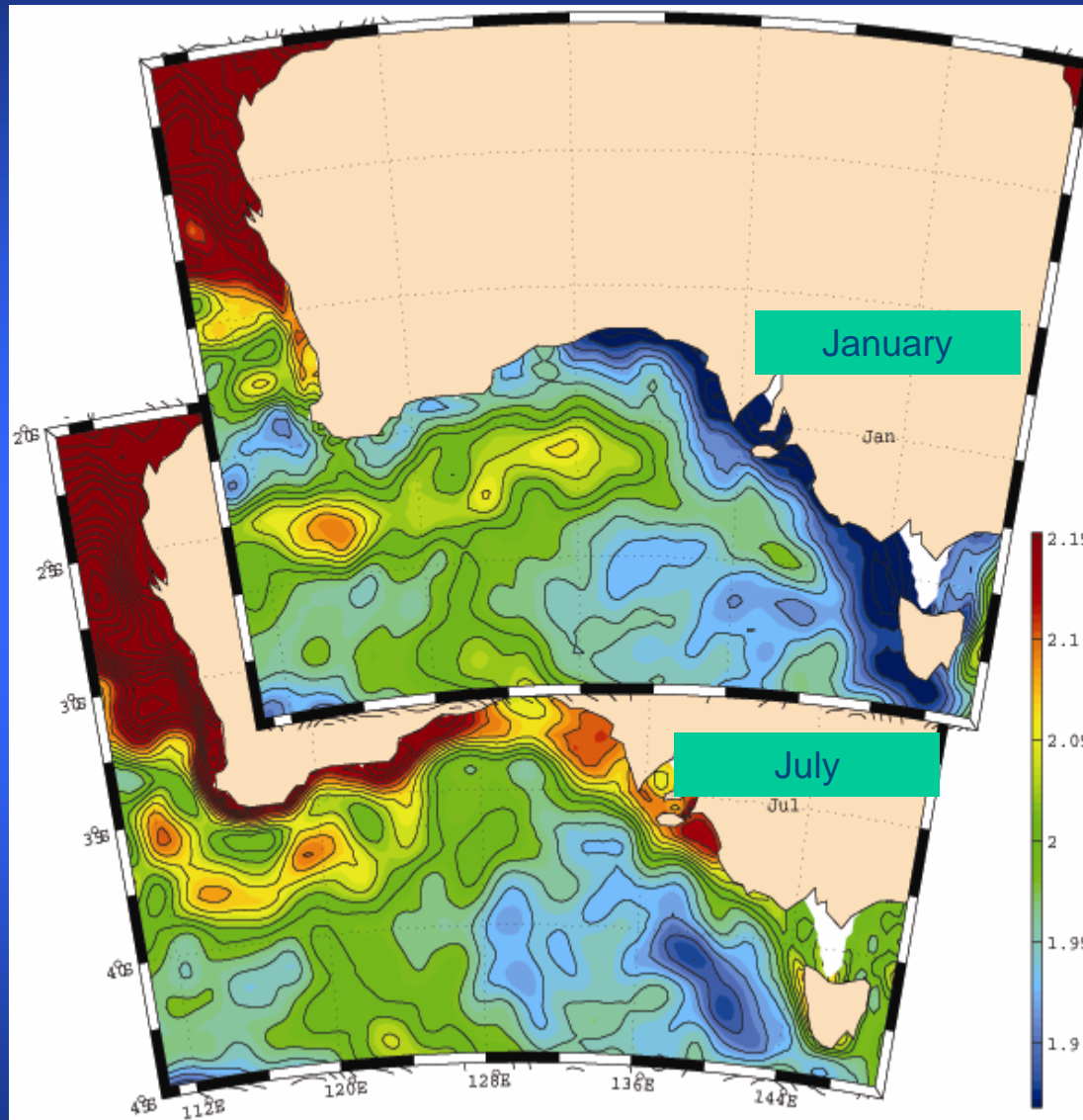


CARS  
H400/2000



WOA  
(Levitus)  
H400/2000

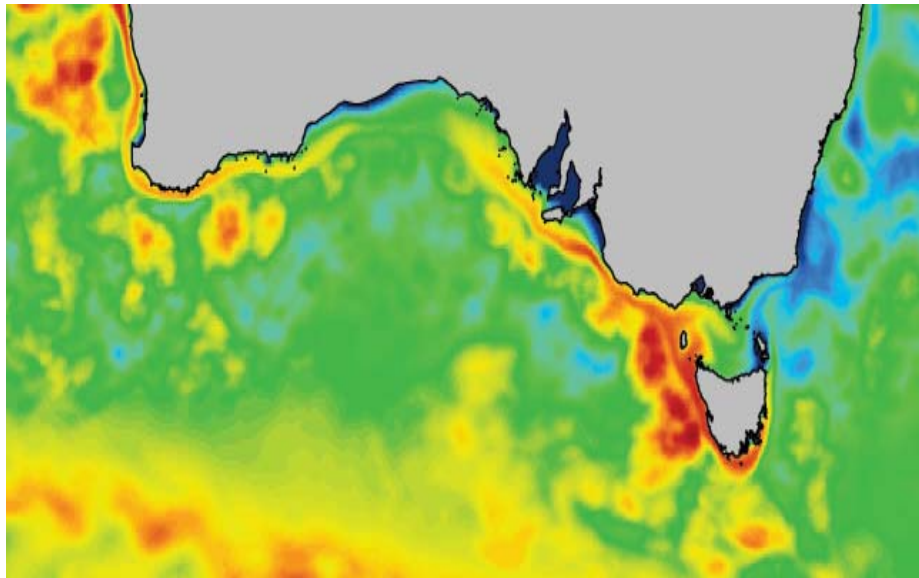
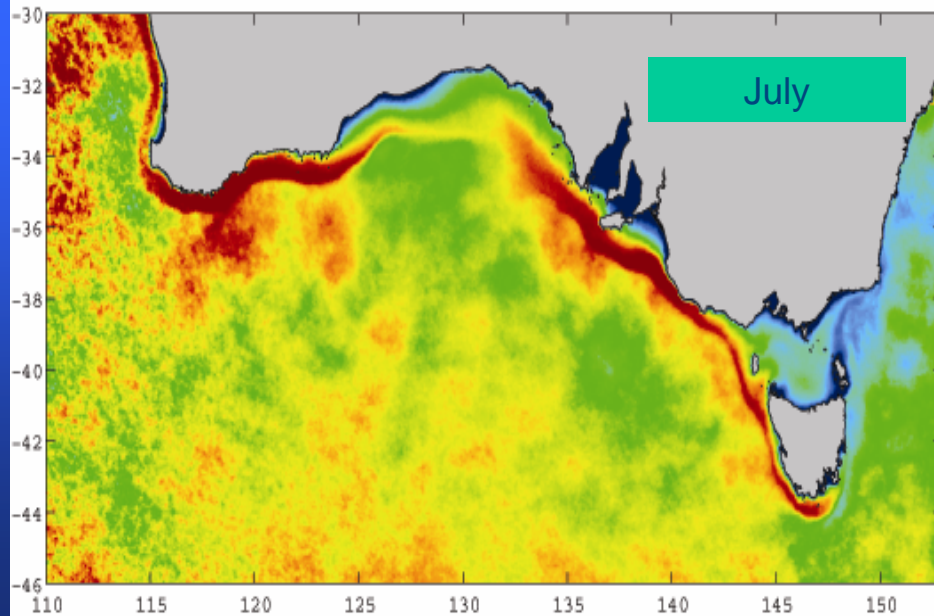
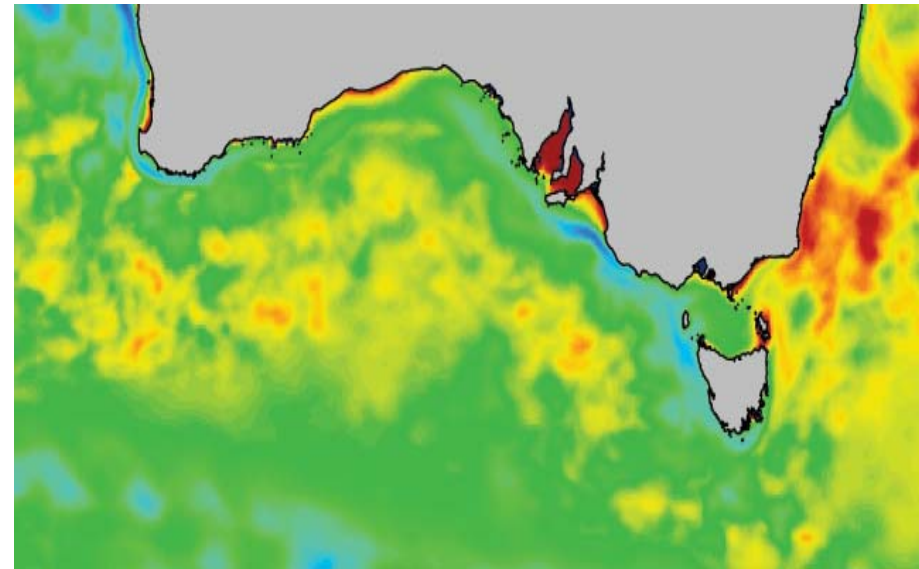
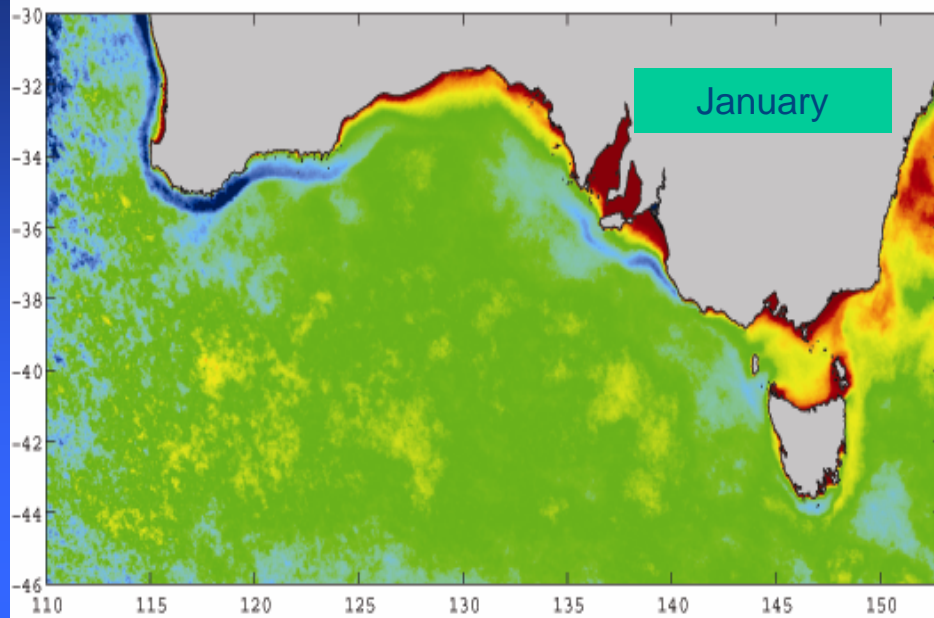
# Altimetry + CARS: Mean Surface Height



# SST Anomaly

Obs

Model



# Near Real-Time Regional Analysis



## ➤ Regional sea level analysis:

- Gridded fields of sea level ( $0.2^\circ \times 0.2^\circ$  at 4-day intervals) from October 1992 to August 2002 using delayed-mode quality altimetric sea level data from the ERS-1, ERS-2, Topex/Poseidon and Jason-1 altimeters, and most Australian tide gauges.

## ➤ High-resolution regional SST analysis:

Archive of all Australian AVHRR data: ~4km resolution, 1-, 3-, 6-, 10- and 15-day composite images for October 1993 – June 2003, 80E-190E, 10N-65S.

## ➤ Daily-updated images of ocean surface temperature, sea level and currents – available through the CSIRO CMR website at

<http://www.marine.csiro.au/remotesensing/oceancurrents/>



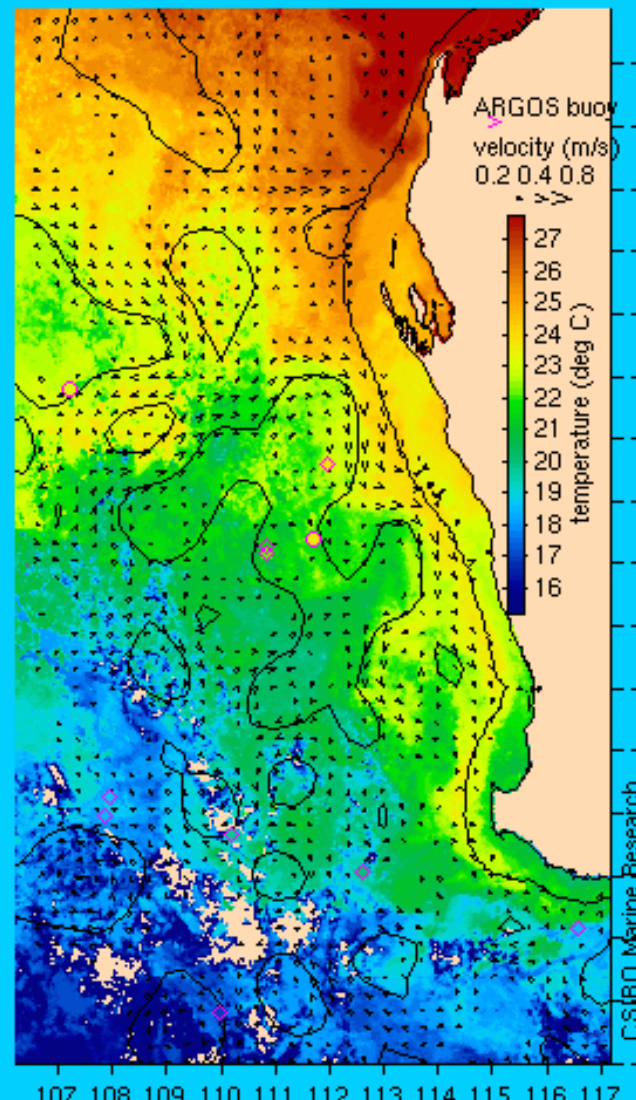
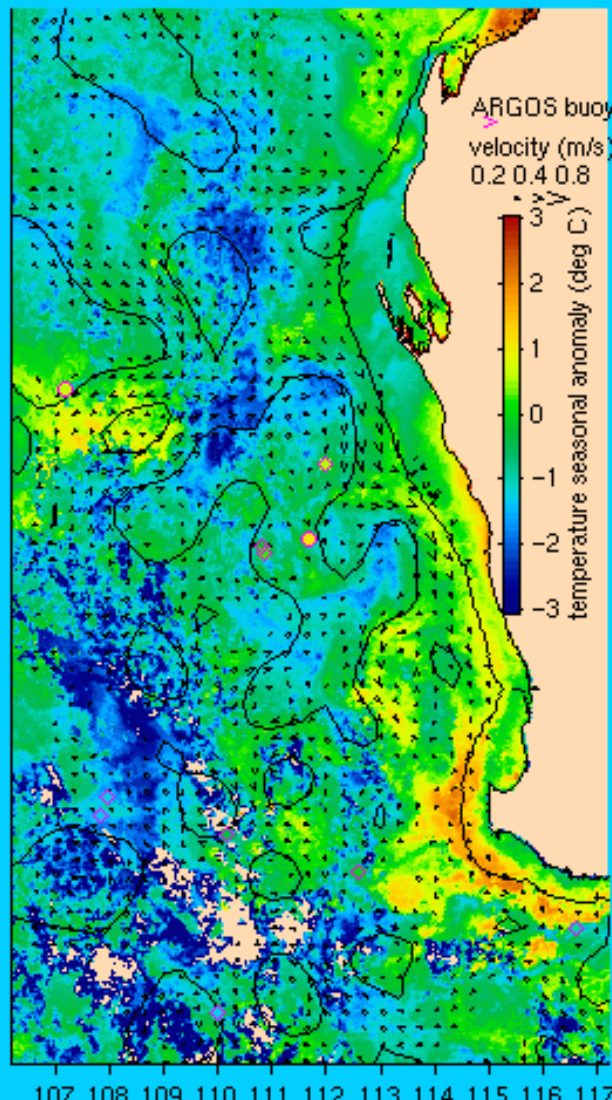
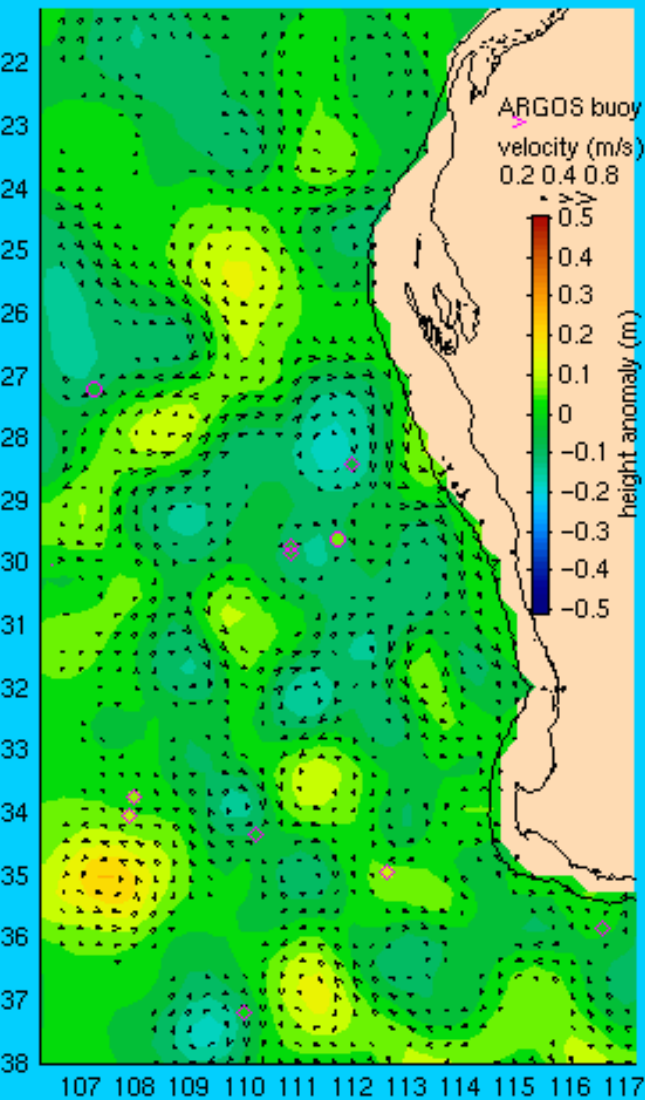
# Ocean Nowcasting

SSH Anomaly (AVISO DUACS)  
&  
Geostrophic Velocity

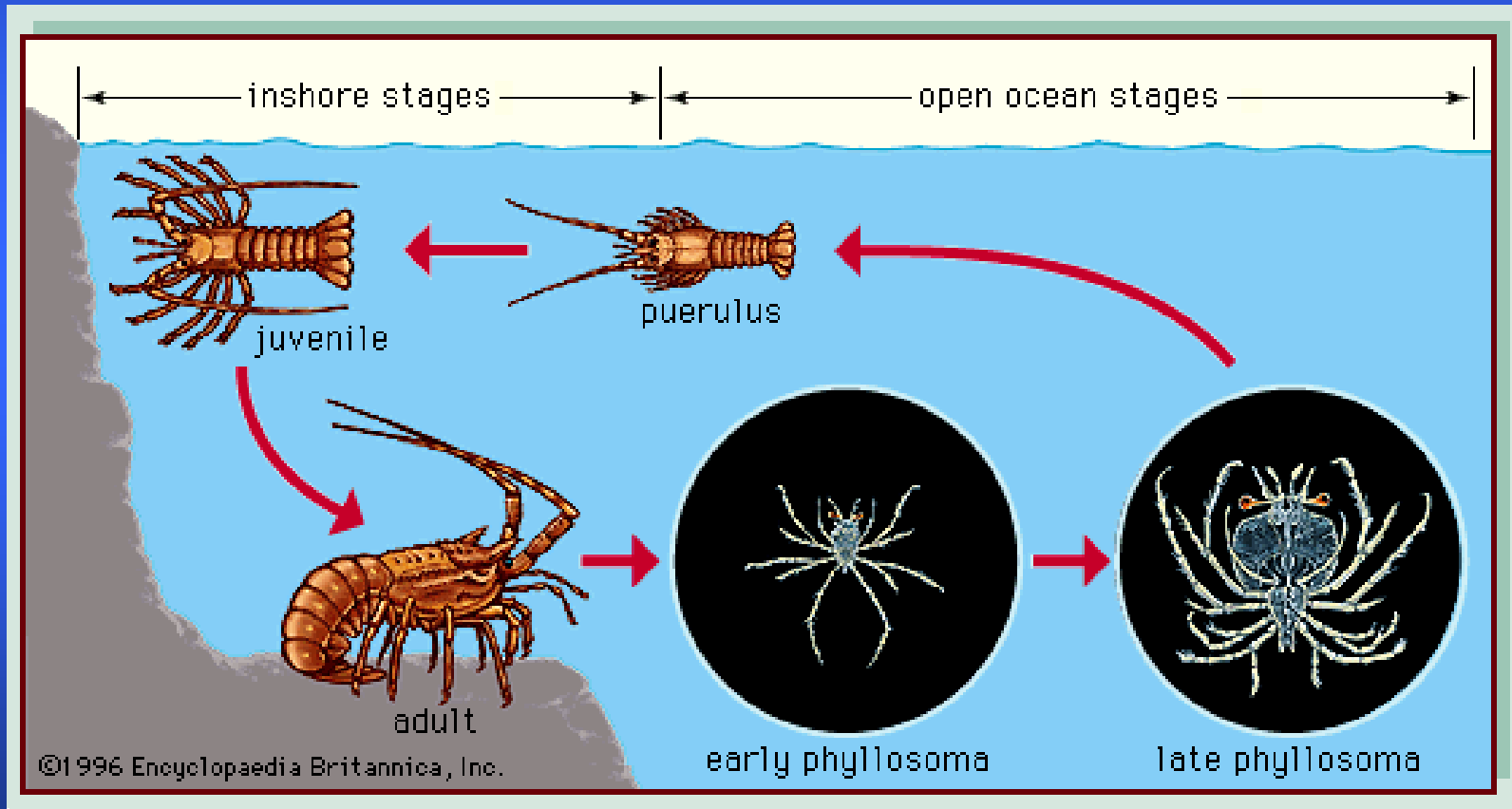
SST Anomaly (AVHRR)  
&  
Geostrophic Velocity

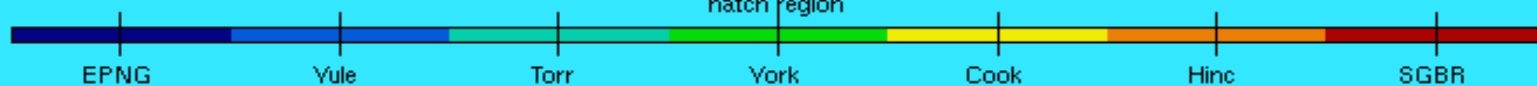
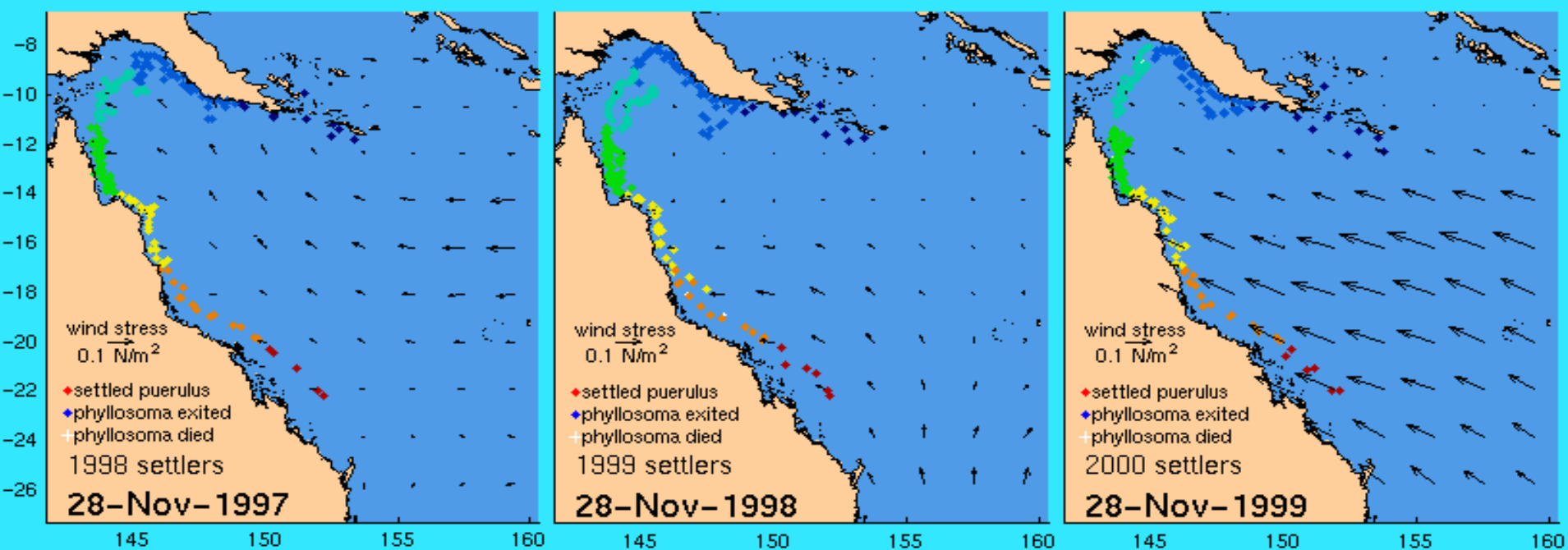
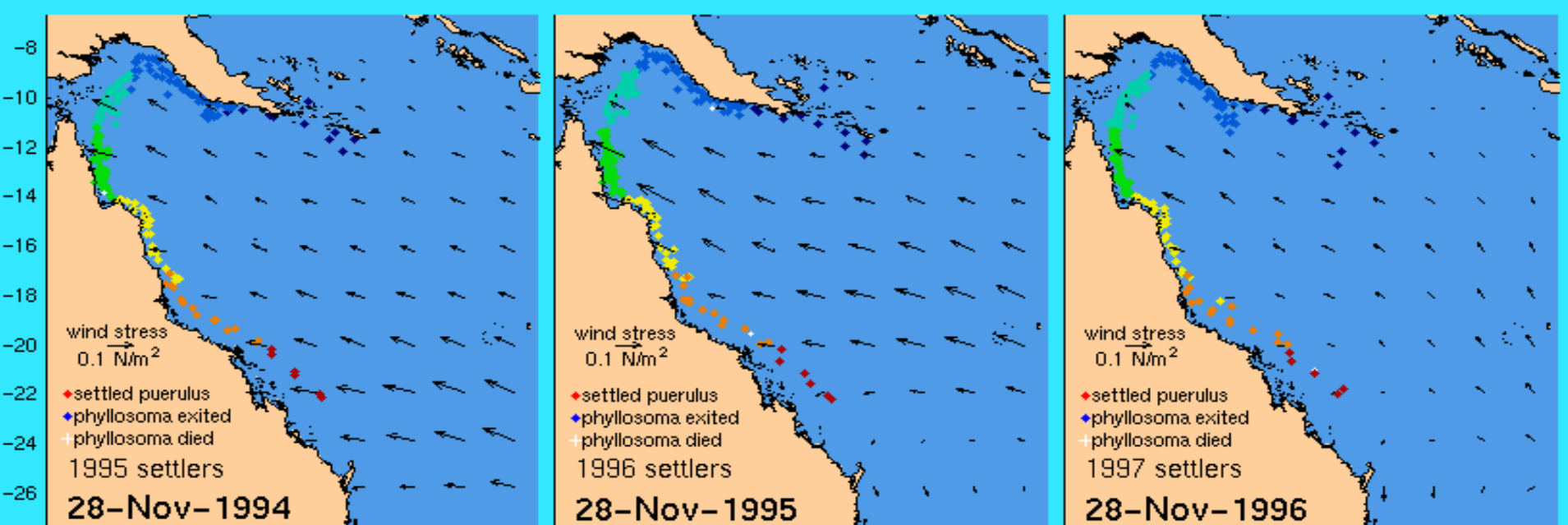
SST (AVHRR)  
&  
Geostrophic Velocity

msla-oer-merged-h-19449.nc Altimetry for 02-Apr-2003  
msla-oer-merged-h-19449.nc Altimetry for 02-Apr-2003  
comp3dAu SST seasonal anomaly for 01-Apr-2003  
comp3dAu SST for 01-Apr-2003

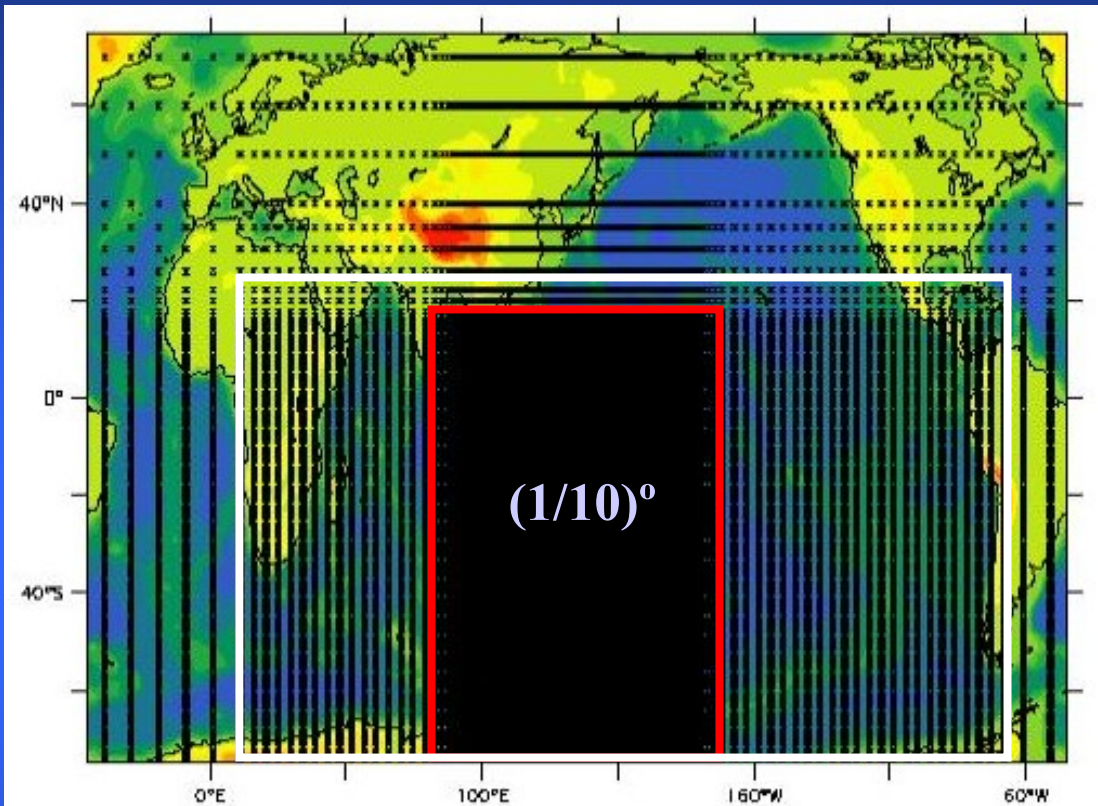


# Rock Lobster & Oceanography



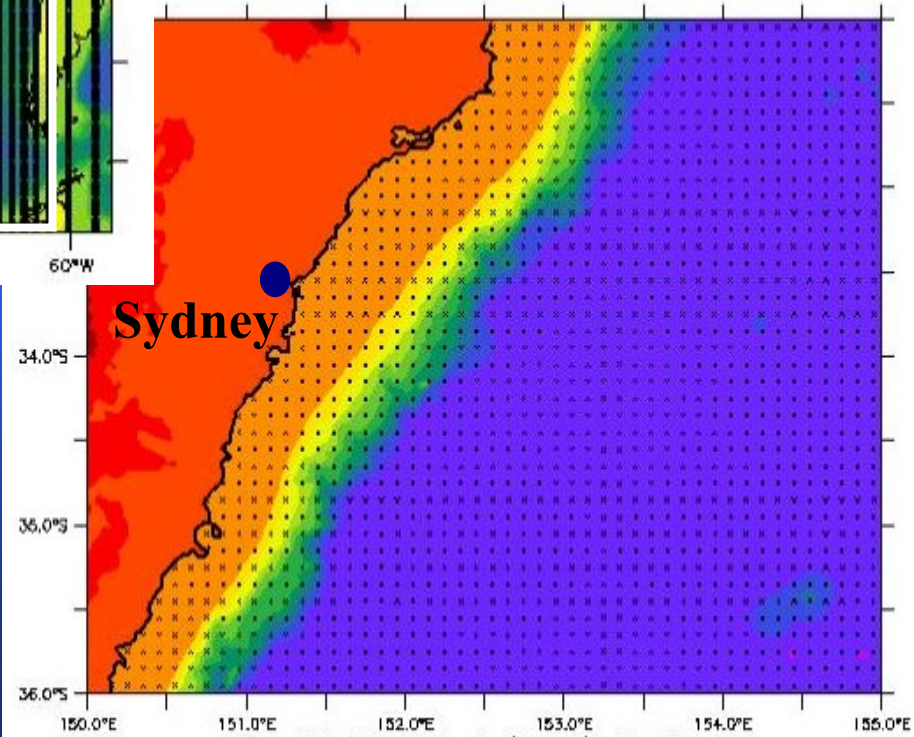


# OFAM Grid Structure

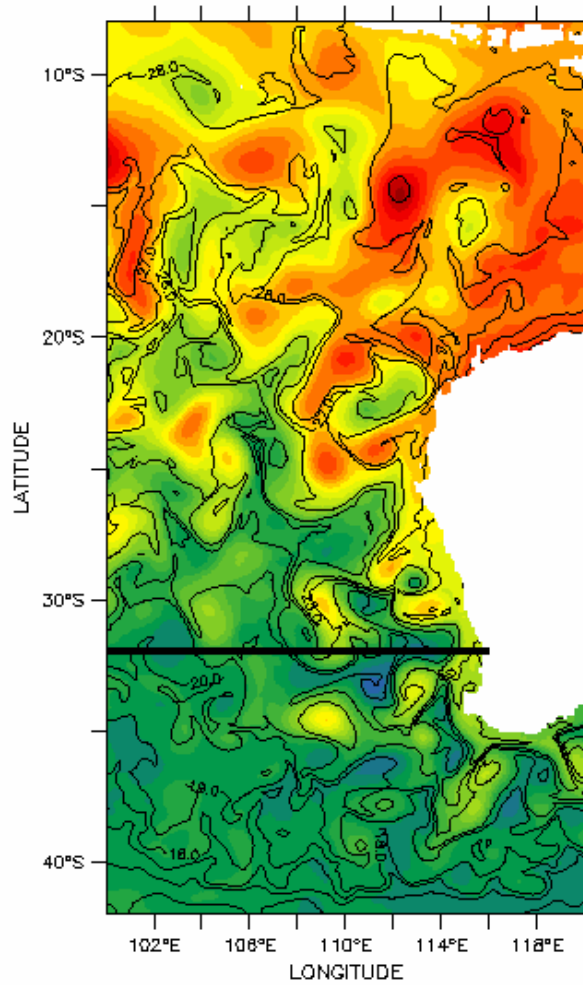


MOM4.0 (Jan 2004)  
GFDL code with  
enhancements

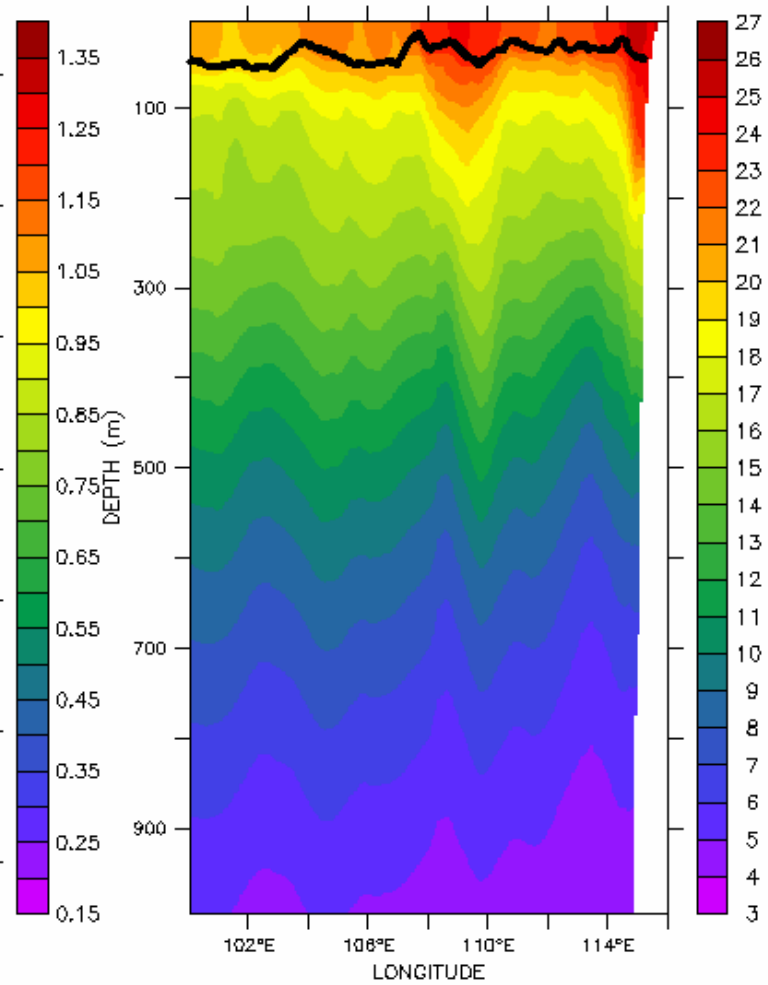
- 1191 x 968 grid points, 47 vertical levels (35 in top 1000m)
- Hybrid mixed-layer model [Chen et al., 1994]
- Isopycnal mixing and GM parameter.
- SGS viscosity is function of grid-scale (Smagorinski)



TIME : 02-JAN-2000 12:00



surface height on T cells (meter)



Potential temperature

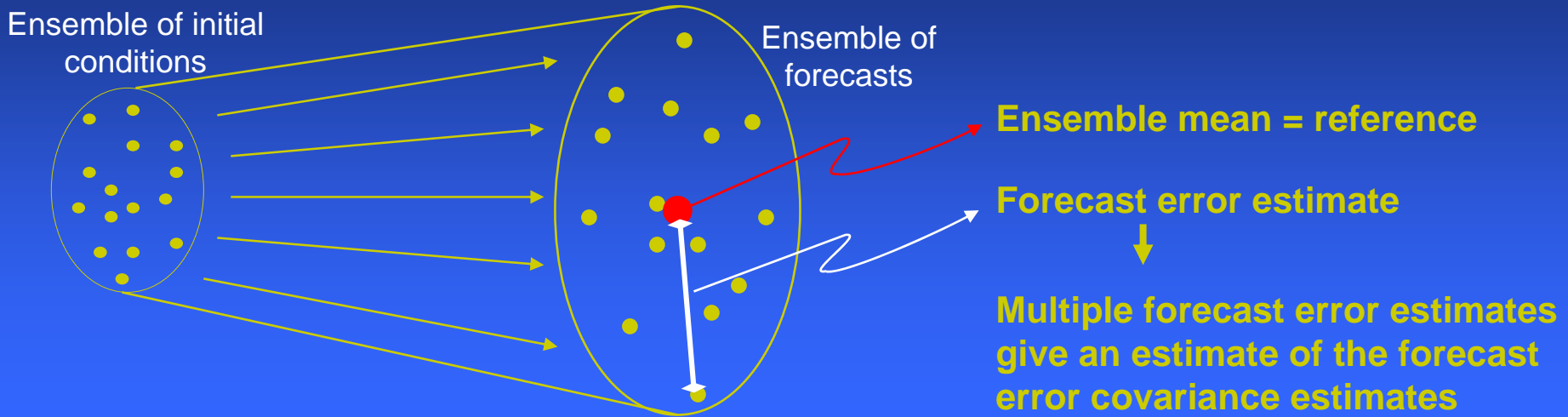
# **BLUElink Ocean Data Assimilation System (BODAS)**

**A data assimilation system that combines a model forecast with available in situ and satellite derived observations to provide improved initial conditions for short-range model predictions.**

## **Assimilation Method**

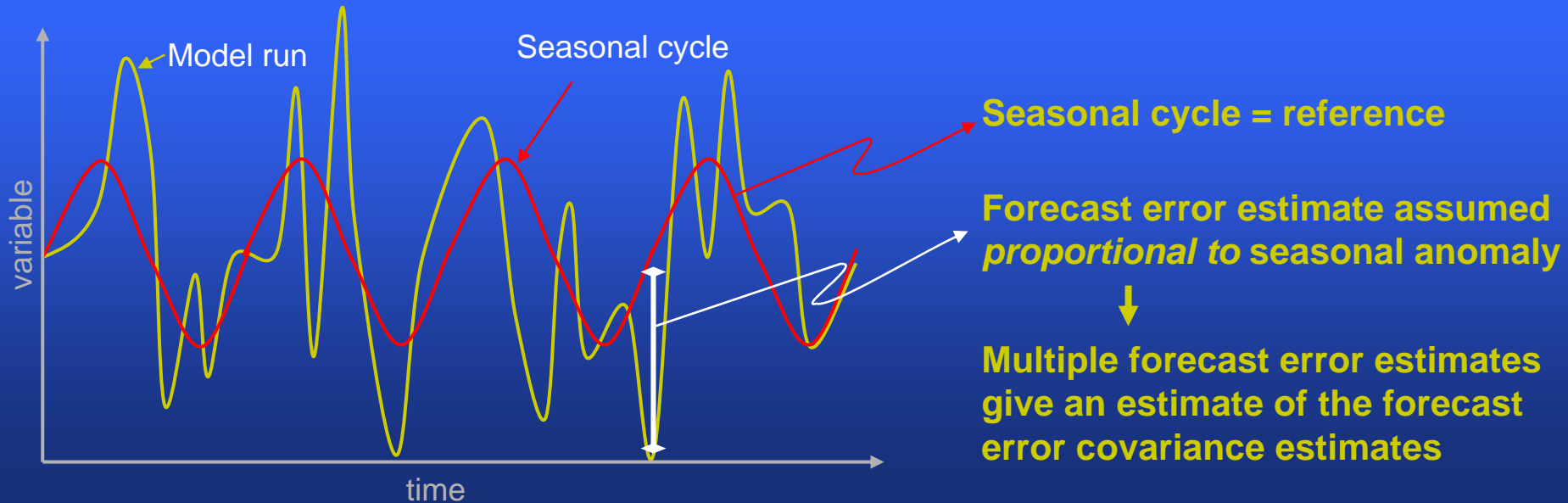
- **Multivariate Optimum Interpolation (long-term goal: EnKF)**
  - ... described by Evensen (2003) as Ensemble Optimal Interpolation (EnOI): Error co-variances are assumed proportional to modeled co-variances in a multi-year simulation**
- **Direct assimilation of observations into OGCM**
- **Observation types**
  - **Along-track sea-level anomalies altimetry**
  - **T-S profiles from ARGO**
  - **Coastal sea-level**
  - **XBT profiles**
  - **SST**

# Ensemble Kalman Filter



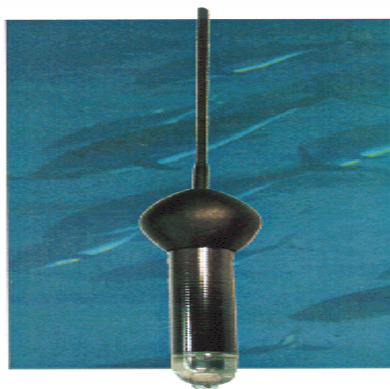
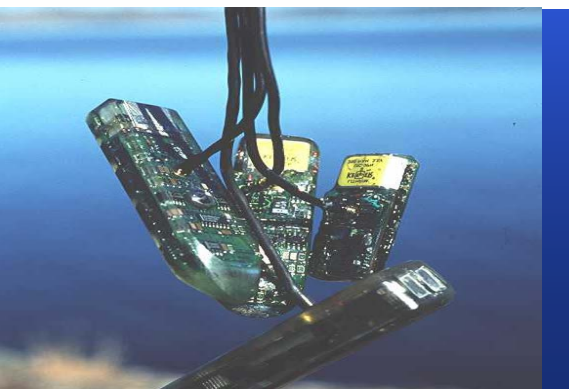
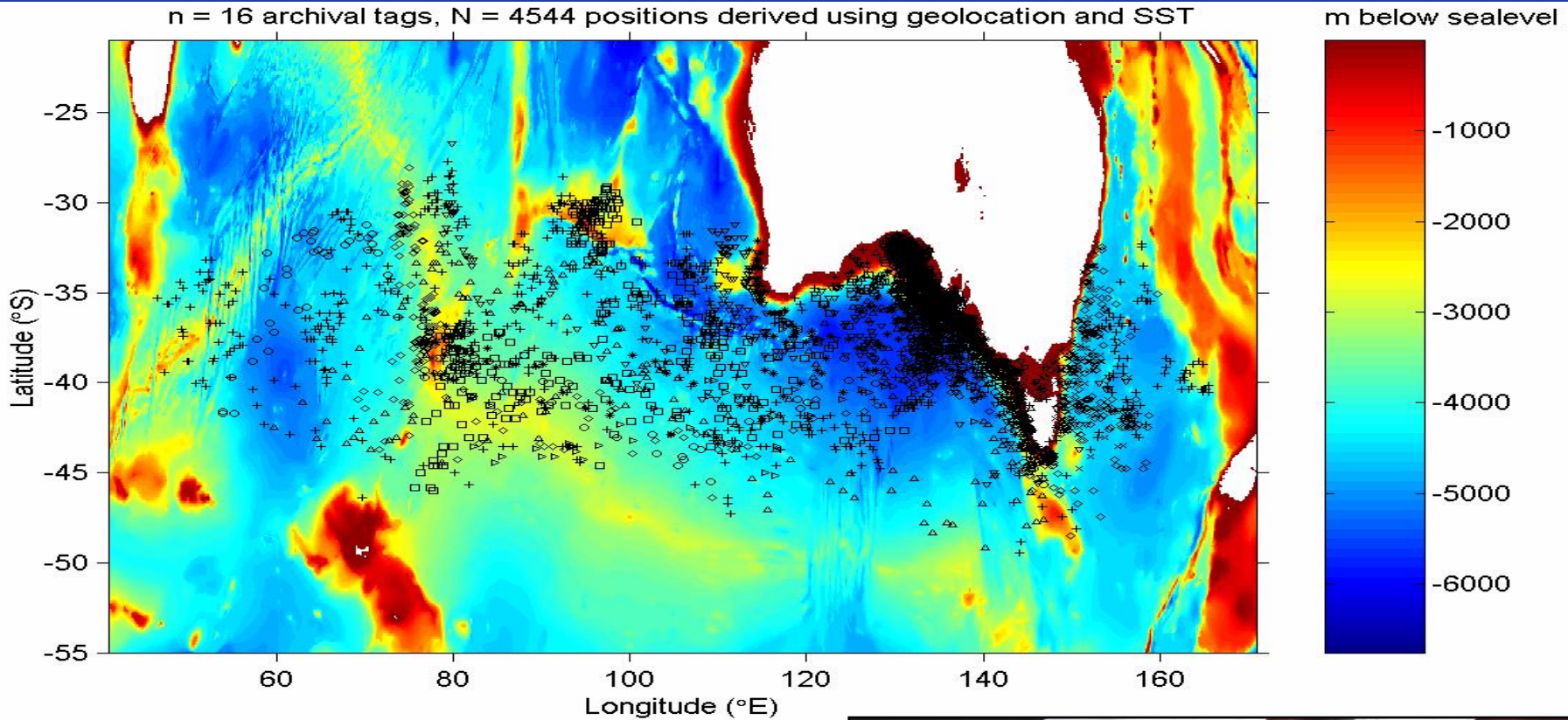
---

# Ensemble-based Optimal Interpolation

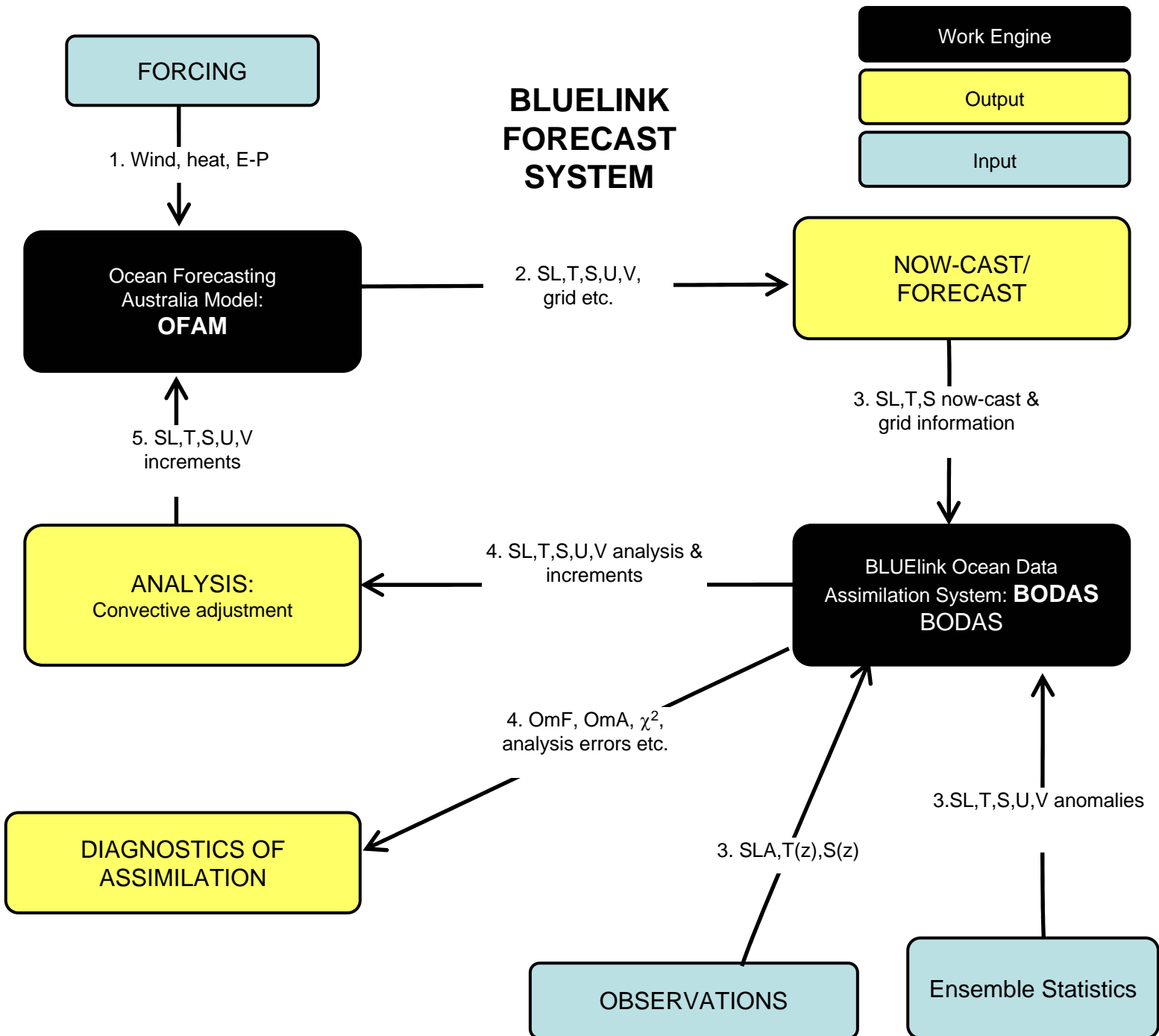


# Smart sensors on fish simultaneously monitor fish behavior and T, (S)

n = 16 archival tags, N = 4544 positions derived using geolocation and SST





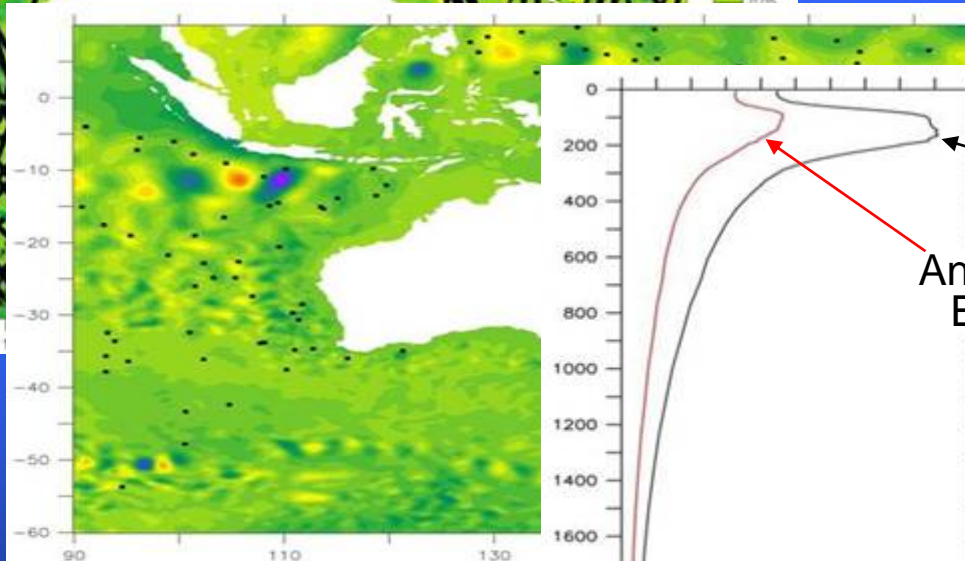


# Identical Twin Experiment

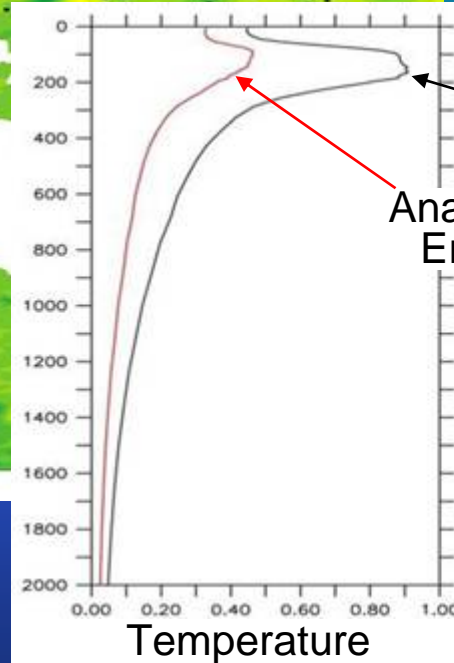
Satellite Altimetry



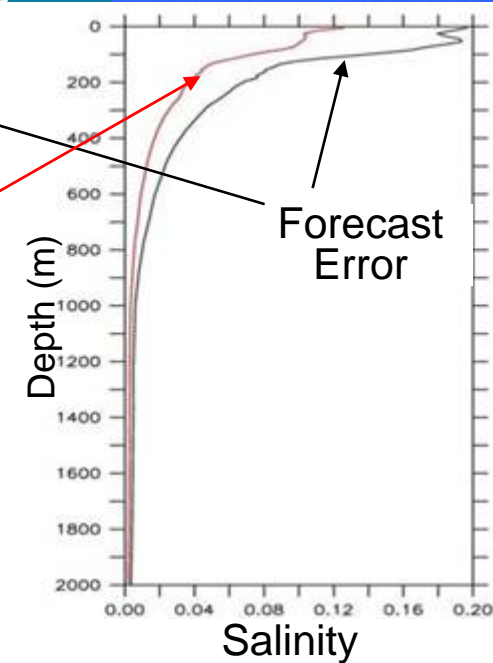
ARGO profiles



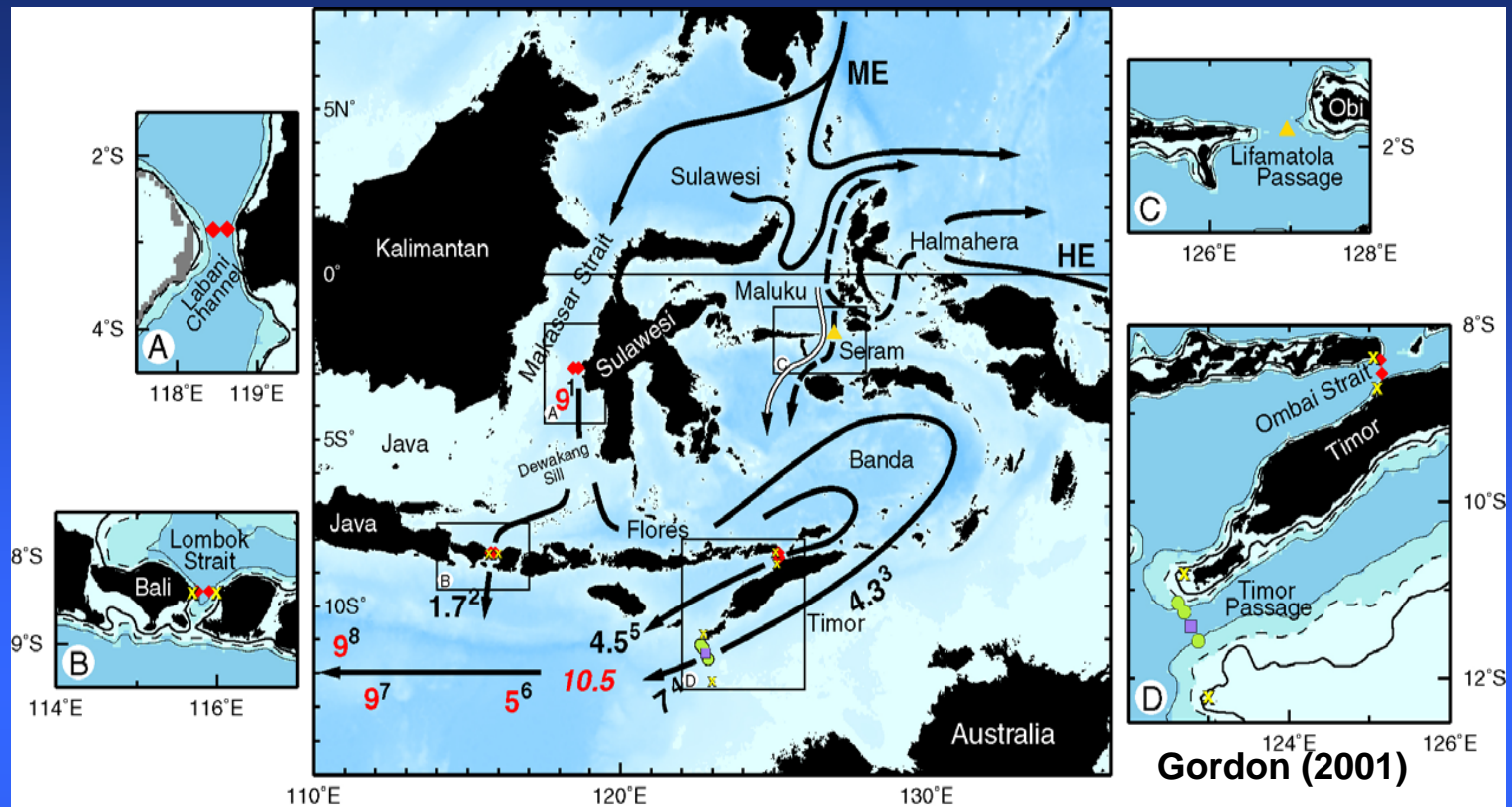
Analysis



Analysis Error



Forecast Error

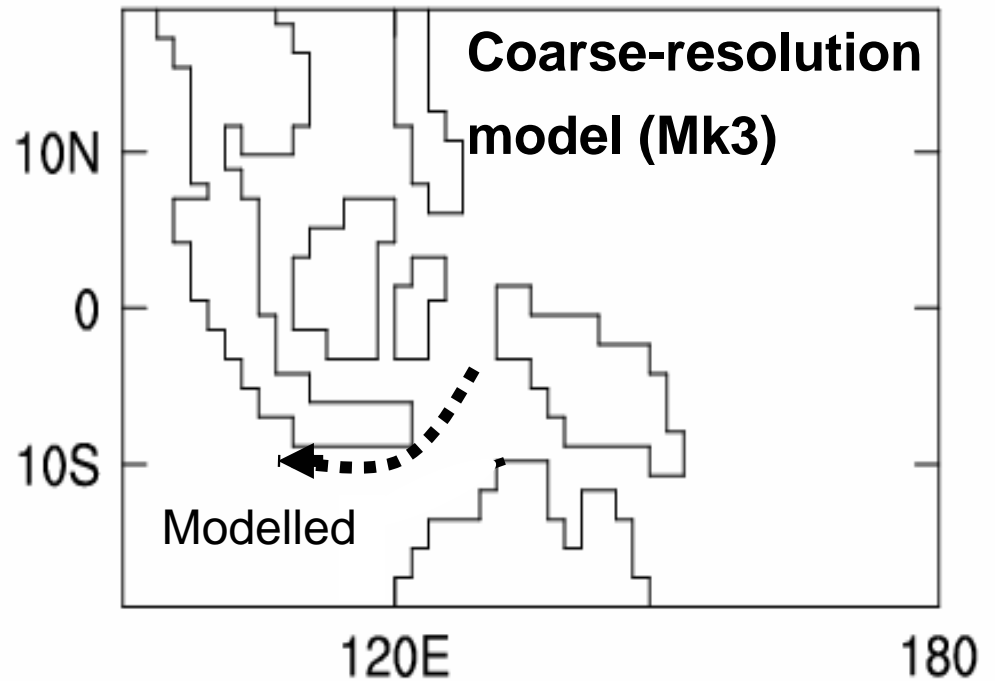
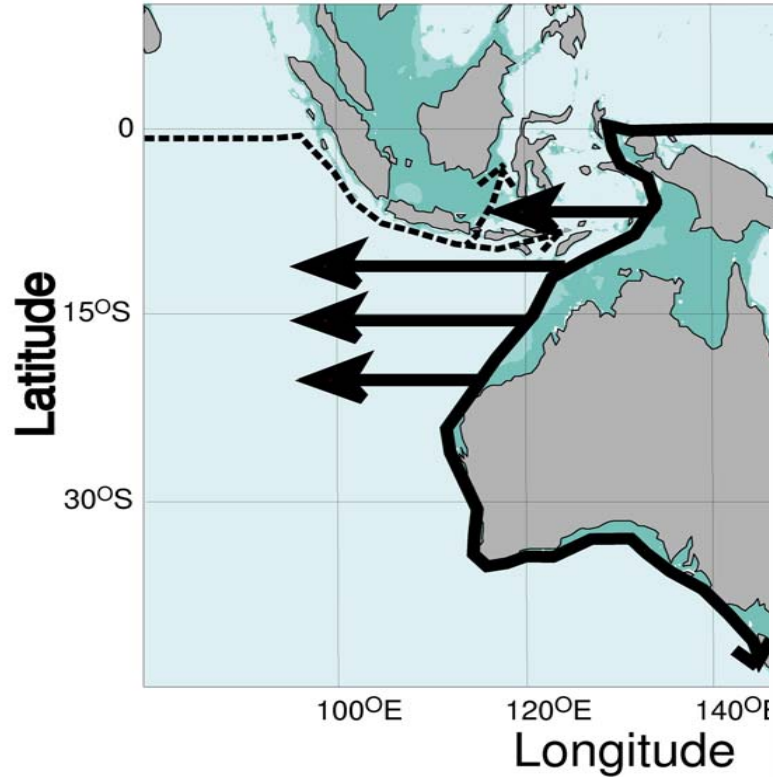


INSTANT 2003-2006 (Indonesia, USA, France, Netherlands, Australia)

# Indo-Pacific Throughflow

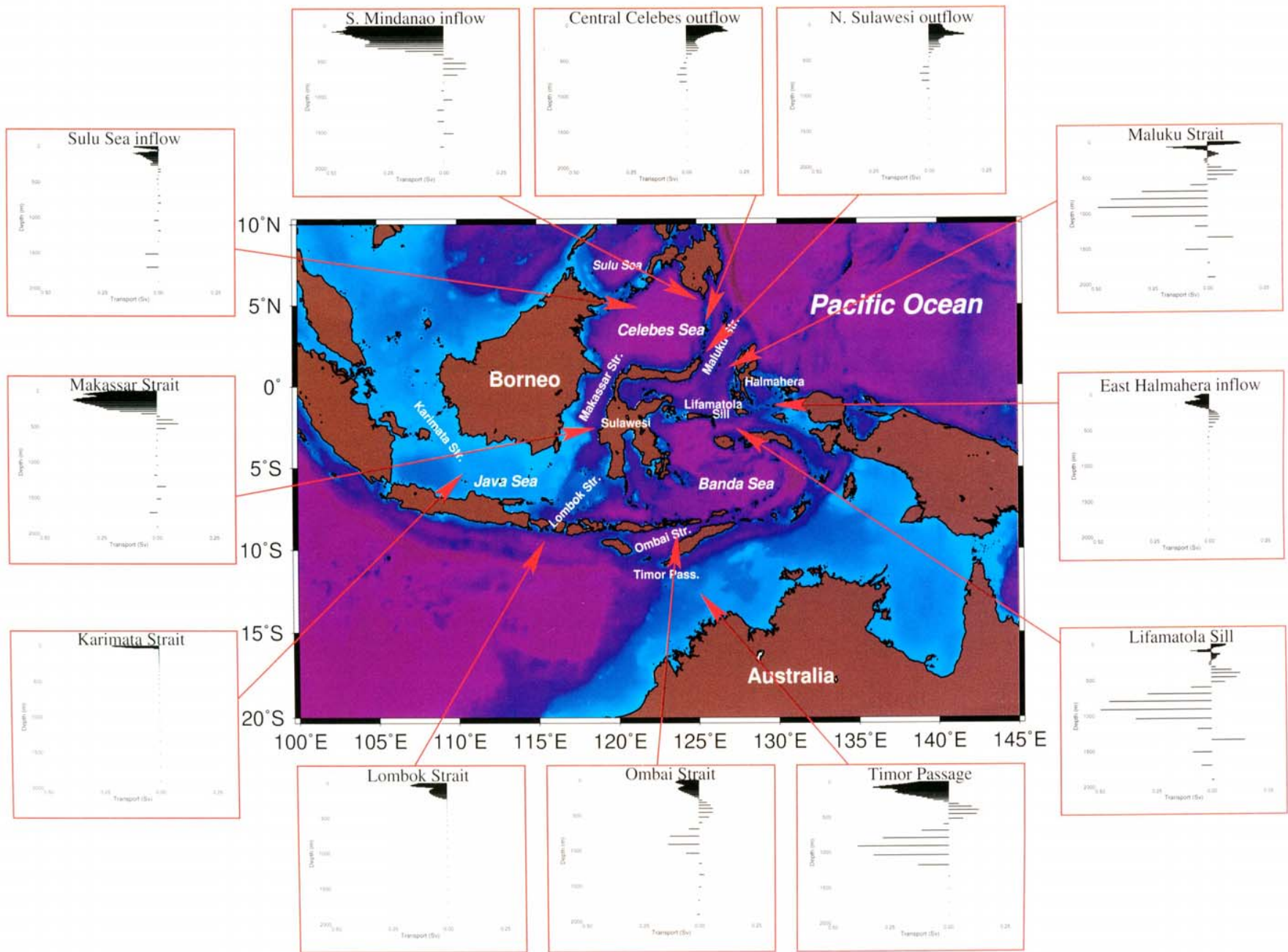
- important branch of global oceanic thermohaline circulation (near-surface return flow from Pacific to Atlantic)
- both inter-seasonal and inter-annual variability play role in transport variability (5-15 Sv)
- interactions with tropical climate phenomena, e.g. ENSO, IOZM/DM (heat and freshwater transports)

# The Indonesian Throughflow: An Intersection of Oceanic Wave Guides



# ITF Modelling Issues

- **Resolution and Bathymetry:**
  - **Latitude of ITF gap in West Pacific and relative position to equatorial current system affect core water-masses and wave guide through ITF**
  - **Sill depths and deep channels influence total transport**
  - **Lower Sunda Straits: need to resolve main gaps ( $\leq 50\text{km}$ )**
    - ➔ **how much transport flows through narrow straits?**
    - ➔ **if unresolved (too wide) can create artificial “stationary eddies”**
- **Tidal Mixing: impact on water-mass structure**

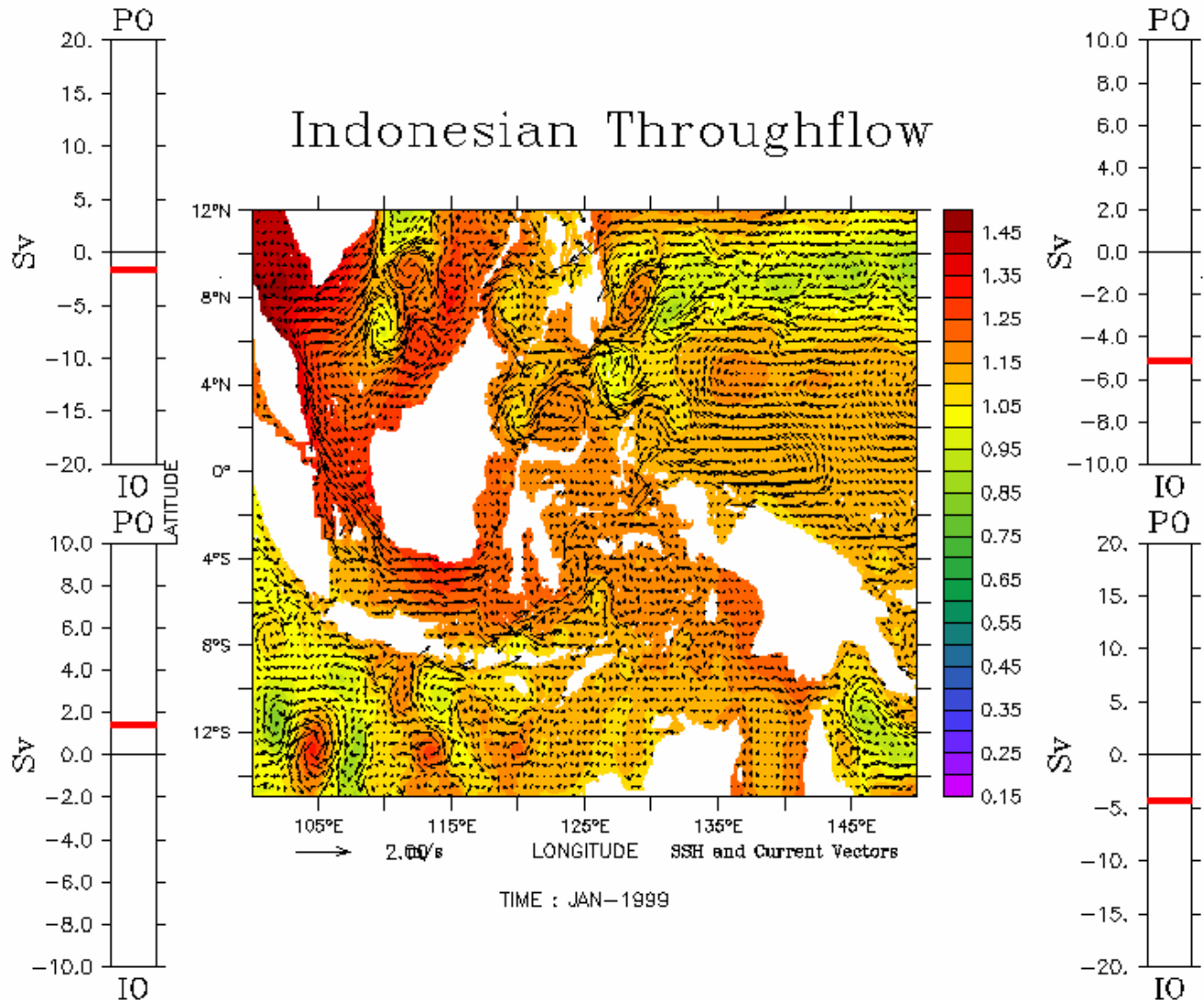


**Ocean Model for the Earth Simulator (OFES), Masumoto et al.(2004)**

Makassar Strait

Ombai Strait

# Indonesian Throughflow



Lombok Strait

Timor Strait

TIME : JAN-1999

# Relocatable Ocean Atmosphere Model (ROAM)



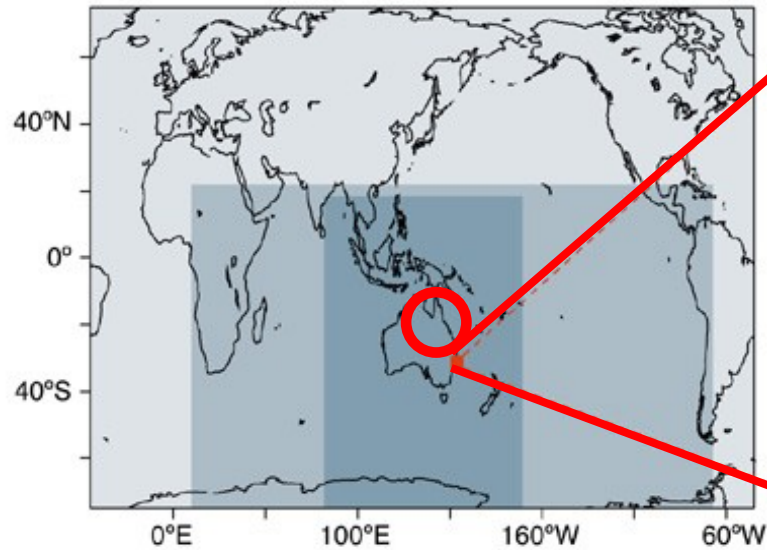
control system



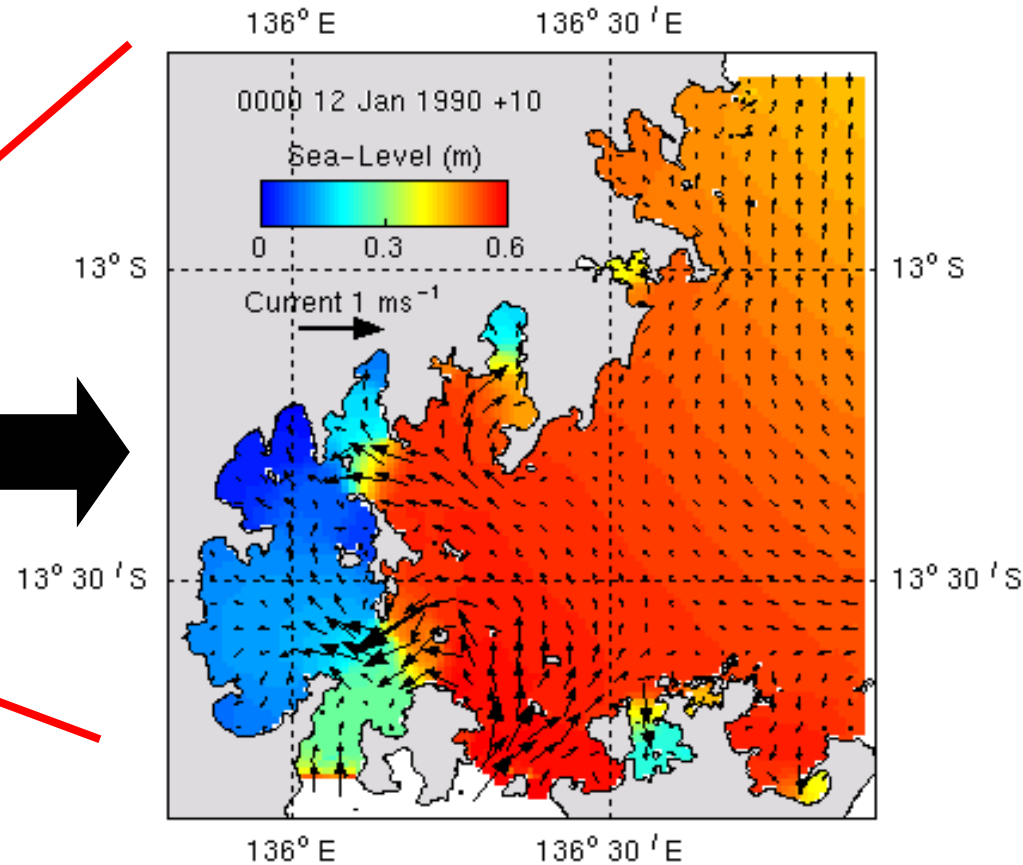
# Zoom: Nested Relocatable Model

## OFAM

Grid structure of the global ocean forecasting model called OFAM



High resolution (1/10°) around Australia





region name	run date	start time	status	priority	% complete	time to completi...	forecast period
Perth	2004-7-8	15:18	<b>in-progress</b>	critical	0	5 - 6 hours	3 days
Perth	2004-7-7	13:28	finished	critical	100		3 days
Perth	2004-7-6	13:28	finished	critical	100		3 days
Perth	2004-7-5	13:28	finished	critical	100		3 days
Perth	2004-7-4	13:28	<b>aborted</b>	critical			3 days
Perth	2004-7-3	13:28	finished	critical	100		3 days
Perth	2004-7-1	13:28	finished	critical	100		3 days
Perth	2004-6-30	13:28	finished	critical	100		3 days
Perth	2004-6-29	13:28	<b>aborted</b>	critical			3 days
NSW South Co...	2004-7-8	15:29	<b>in-progress</b>	medium	0	6 - 7 hours	7 days
NSW South Co...	2004-7-7	15:29	finished	medium	100		7 days
NSW South Co...	2004-7-6	15:29	finished	medium	100		7 days
NSW South Co...	2004-7-5	15:29	finished	medium	100		7 days
NSW South Co...	2004-7-4	15:29	finished	medium	100		7 days
NSW South Co...	2004-7-3	15:29	finished	medium	100		7 days
NSW South Co...	2004-7-2	15:29	finished	medium	100		7 days
Bass St	2004-7-8	15:19	<b>in-progress</b>	low	0	6 - 7 hours	3 days
Bass St	2004-7-7	15:19	finished	low	100		3 days
Bass St	2004-7-6	15:19	finished	low	100		3 days
Bass St	2004-7-5	15:19	finished	low	100		3 days
Bass St	2004-7-4	15:19	finished	low	100		3 days
Bass St	2004-7-3	15:19	finished	low	100		3 days

run settings | execution state

**run details**

run name: 2004-7-8  
 run group: Perth

**scheduling**

scheduled start: 15:16  
 run priority: critical  
 auto repeat: false

**forecasting**

forecast period: 3 days  
 forecast models: atmospheric and ocean

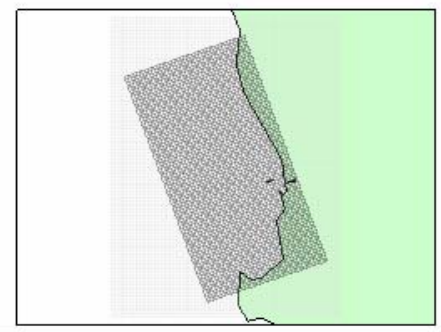
**grid**

**atmospheric model**

origin: 112.92576, -34.276  
 dimensions: 75 x 101  
 resolution: 0.05, 0.05

**ocean model**

origin: 114.47734, -34.0268  
 dimensions: 42 x 81  
 resolution: 0.05, 0.05  
 rotation: 19.5838

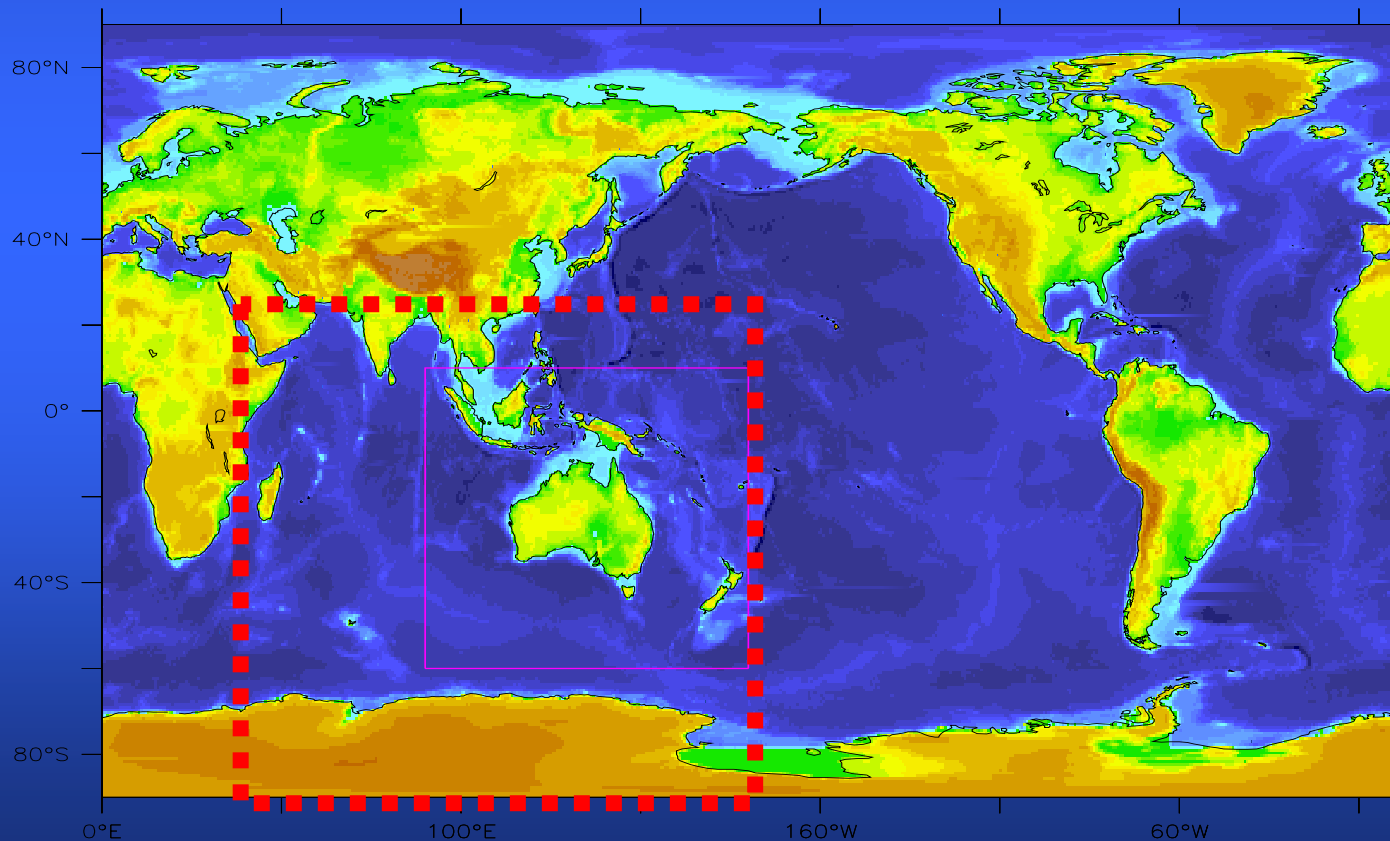


Recent messages

run data acquired from data-source

# What's happening right now?

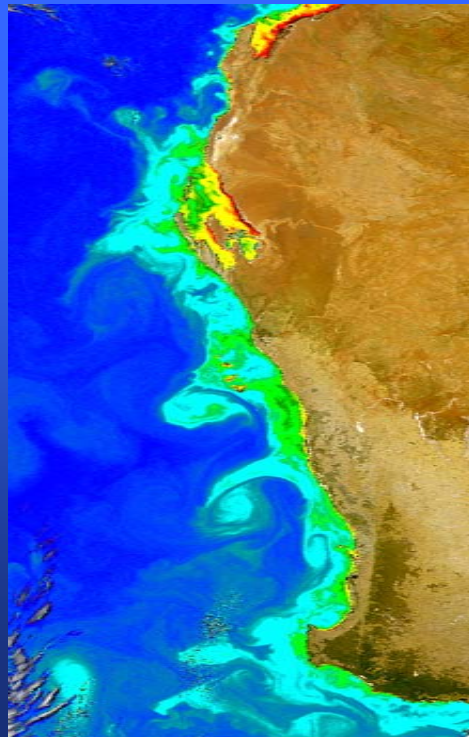
- Testing of the forecast system (model, obs, data assimilation)
- Reanalysis over the last decade (first results in second quarter of 2005) with metrics adopted from MERSEA/MERCATOR



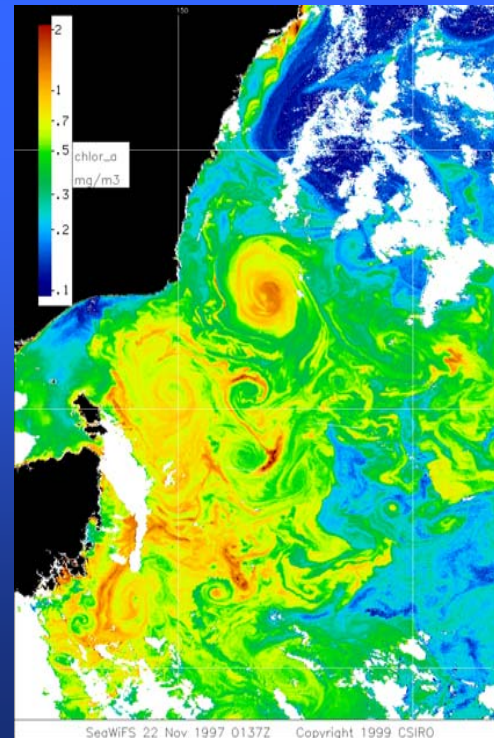
# Future R&D ?



- Improved global analysis and prediction system (e.g. Ensemble Kalman Filter)
- Downscaling: Fully coupled relocatable nested regional eddy-resolving model with data assimilation?
- Include biology and chemistry, e.g. biomass prediction:



Chl-a



# Thank You!

