Subsurface Fluxes Beneath Large-Scale Convective Centers in the Indian Ocean

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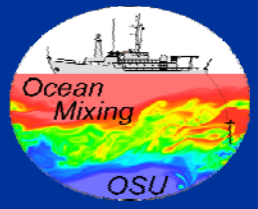
Jim Moum (Oregon State University)



- intensive & detailed shipboard profiling
- mixing meters on moorings

Ren-Chieh Lien (APL / University of Washington)

- Dynamo moorings (3) + *mixing meters*

Mike McPhaden (NOAA / PMEL)

- RAMA moorings + *mixing meters*

DYNAMO / NSF-related objectives

measure T(z), S(z), density(z), currents(z), *esp. SST*

$\partial SST/\partial t$ = surface flux + advection (?) - ∂(turbulent flux)/ ∂z + I(z)

ONR DRI-related objectives

• quantify the detailed vertical and time-varying structure in both velocity and stratification of the Wyrtki jets. This measurement leads to estimation of *Ri* and potential parameterization of mixing;

assess negative feedbacks to atmospheric convection → $dSST/dt < 0$

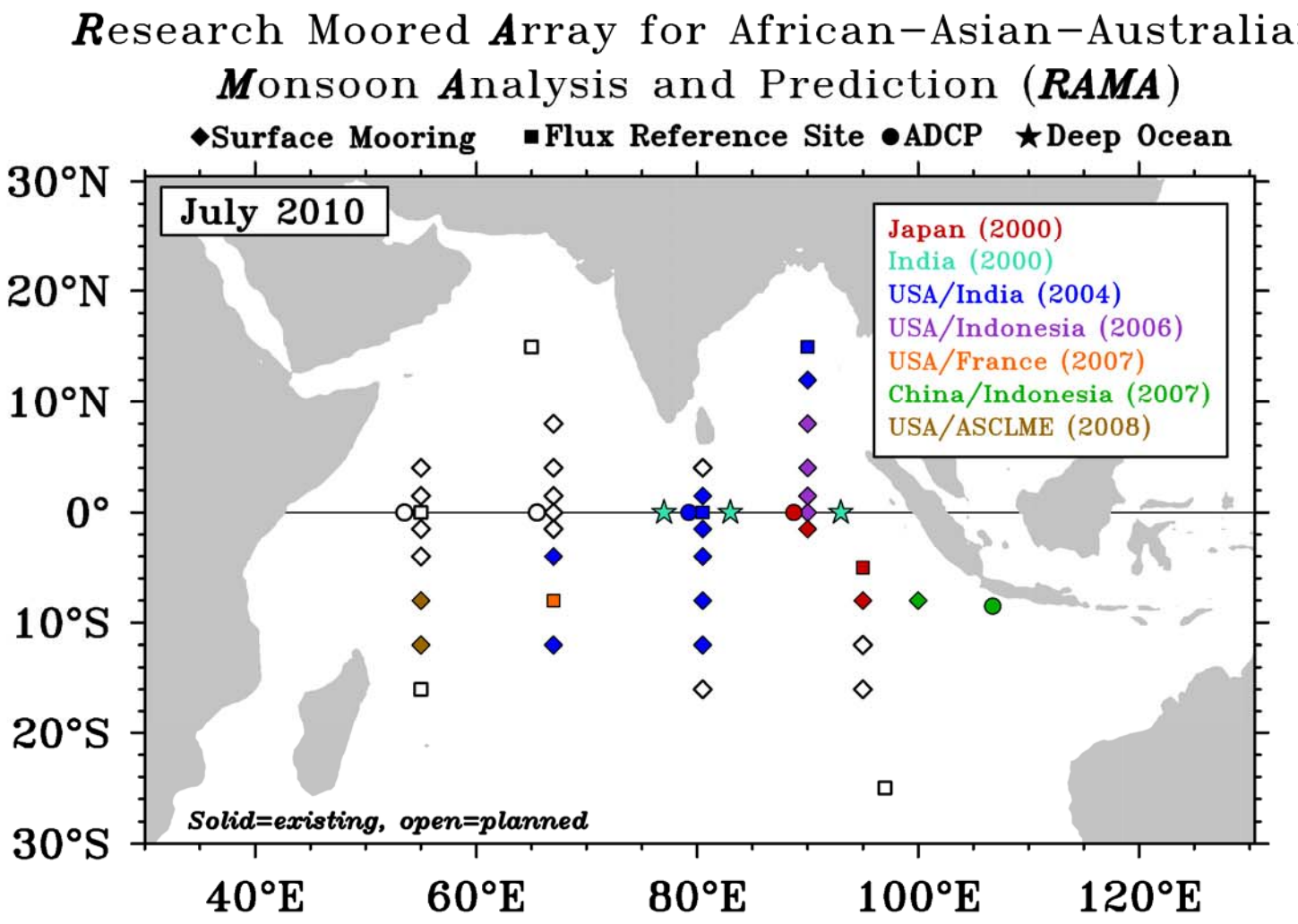
• quantify sea surface cooling rates due to wind mixing and diurnal cooling;

• quantify sea surface cooling rates due to shear instability created by the highly-sheared currents, particularly the Wyrtki jets; and

assess positive feedbacks to atmospheric convection → $dSST/dt > 0$

• quantify sea surface heating rates (from both above and below) in thin near-surface fresh layers deposited by convective precipitation.

RAMA

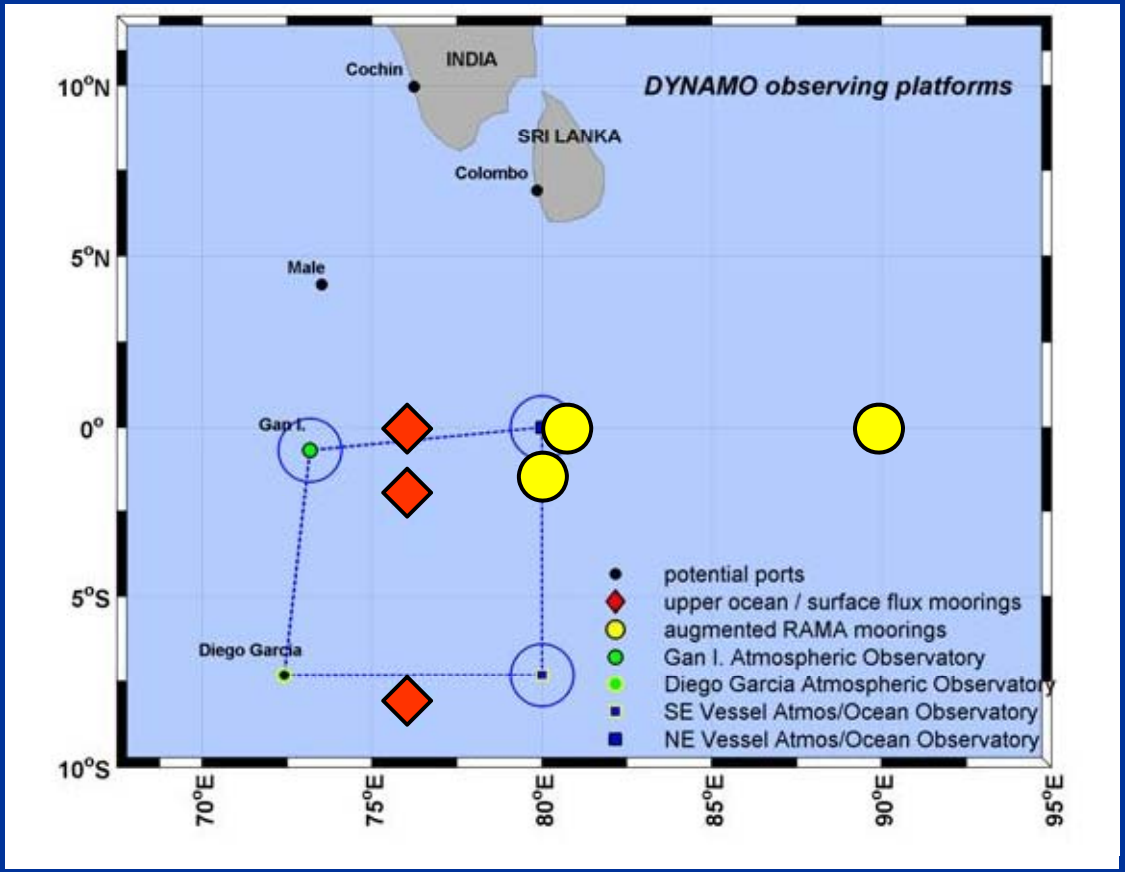

Research Moored Array for African–Asian–Australian
Monsoon Analysis and Prediction (RAMA)
◆Surface Mooring ■Flux Reference Site ●ADCP ★Deep Ocean
July 2010
Japan (2000)
India (2000)
USA/India (2004)
USA/Indonesia (2006)
USA/France (2007)
China/Indonesia (2007)
USA/ASCLME (2008)
Solid=existing, open=planned
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°E
60°E
80°E
100°E
120°E

DYNAMO Moorings

equatorial mooring 0 76E
- Wyrtki Jet
- shear-driven, low *Ri* mixing

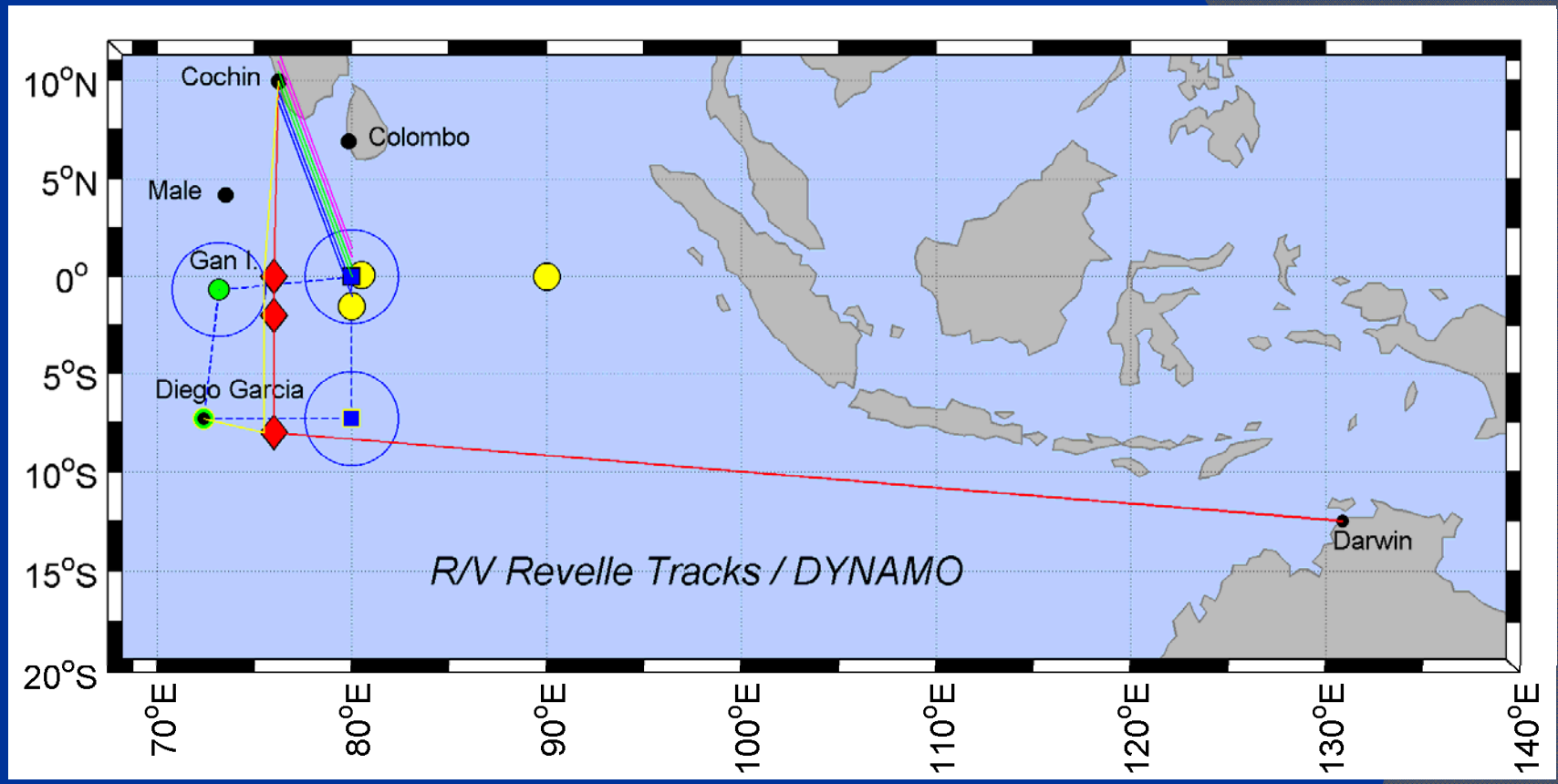
array central mooring 2S 76E
- meridional extent of Wyrtki jet?

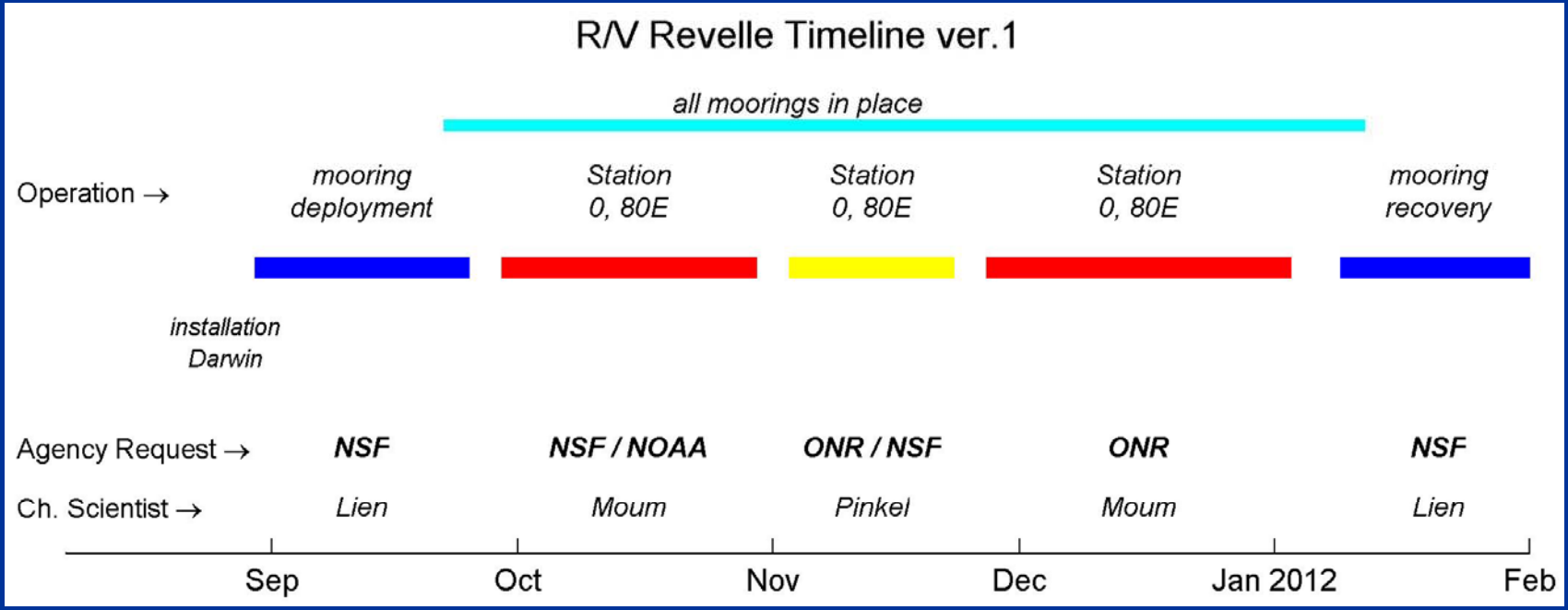
SCTR mooring 8S 76E
- mixing in SCTR where large SST variability has been observed



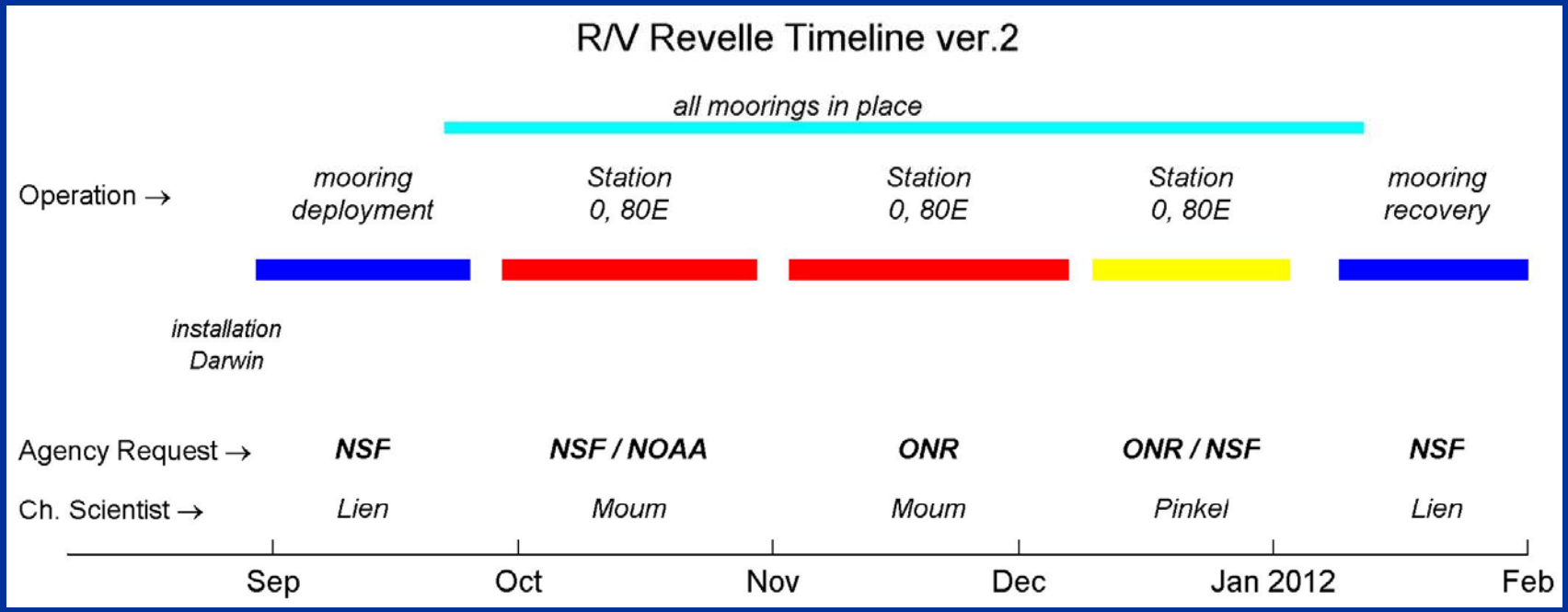
RAMA moorings

augmented with χpods


Cochin
Colombo
Male
Gan I.
Diego Garcia
Darwin
R/V Revelle Tracks / DYNAMO
10°N
5°N
0°
5°S
10°S
15°S
20°S
70°E
80°E
90°E
100°E
110°E
120°E
130°E
140°E



Installation	23 Aug – 30 Aug
Deployment	30 Aug – 25 Sep
Moum Leg 1	28 Sep – 30 Oct
Pinkel Leg 2	03 Nov – 23 Nov
Moum Leg 3	27 Nov – 03 Jan
Recovery	09 Jan – 03 Feb



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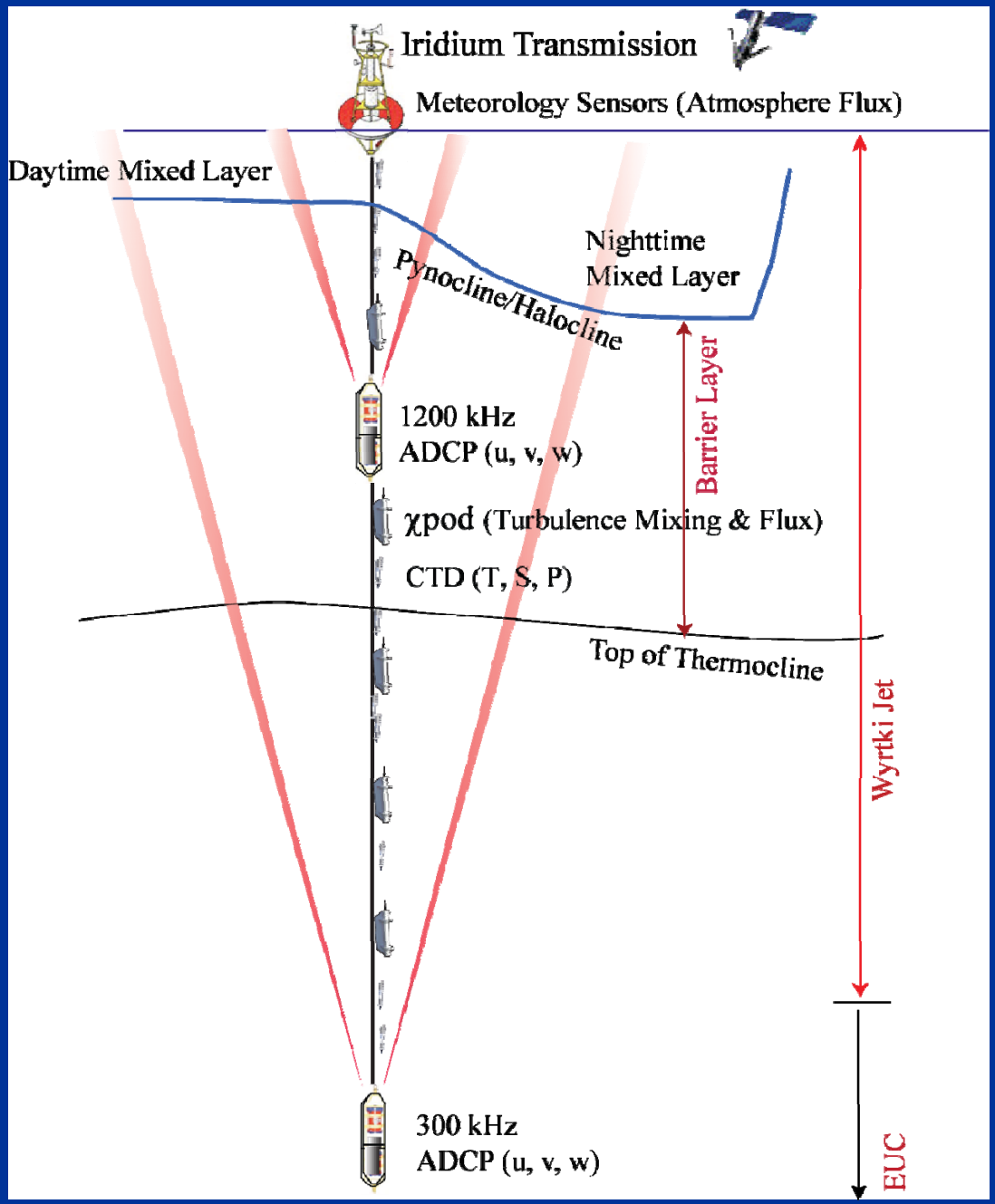
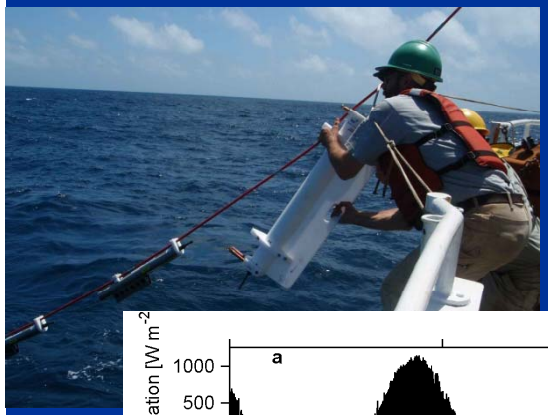
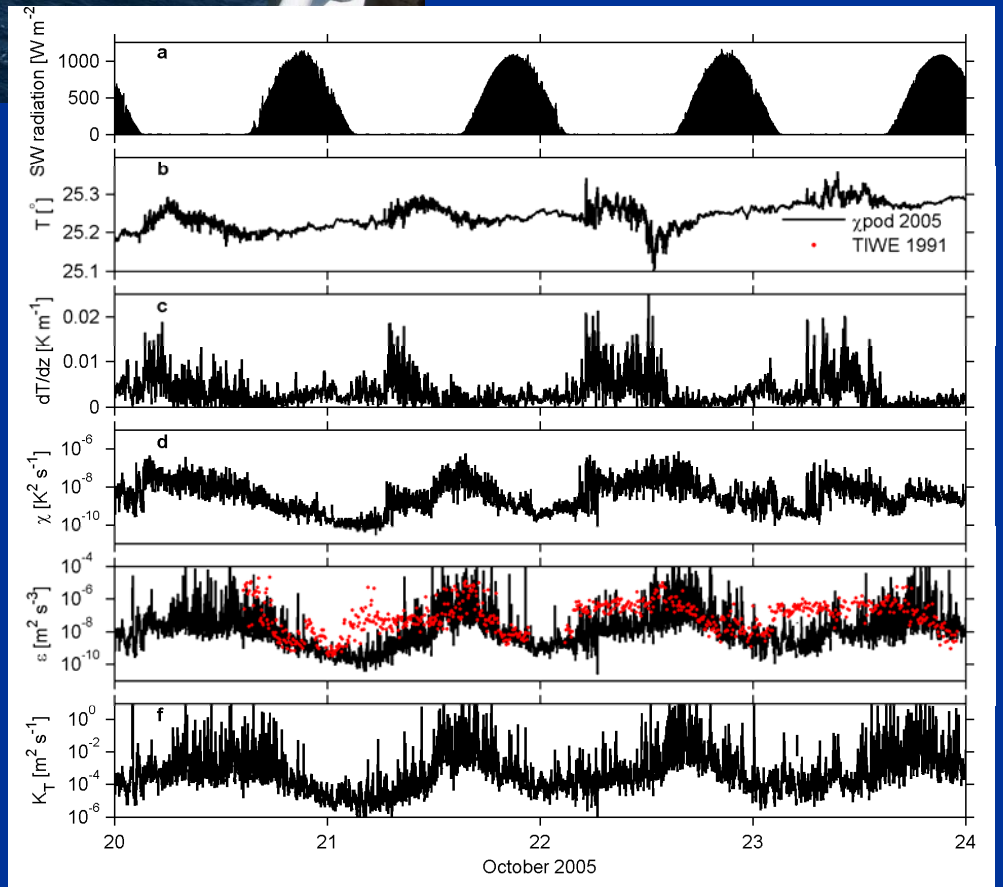
DYNAMO moorings subsurface expression

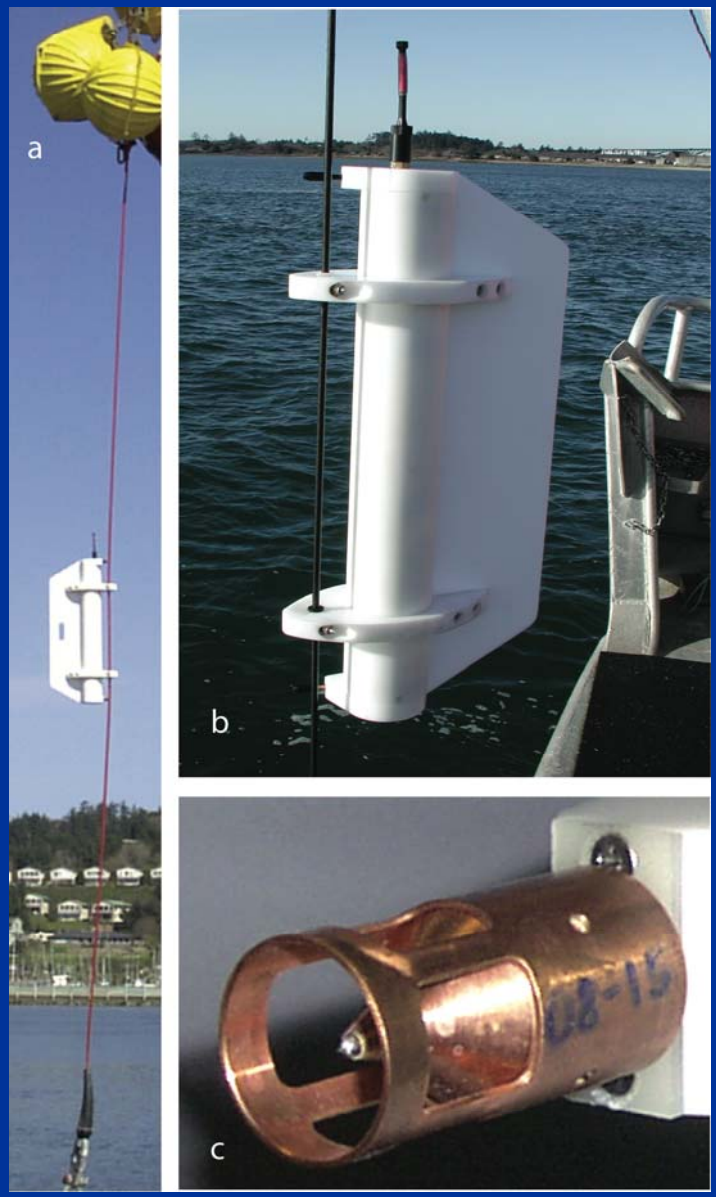


χpods on DYNAMO / RAMA moorings

- moored subsurface flux measurement
- analogous to a surface flux tower







Moum & Nash 2009

shipboard profiling 24h ops / fixed station

subsurface flux measurements coordinated with surface fluxes Doppler radar

Chameleon turbulence profiler

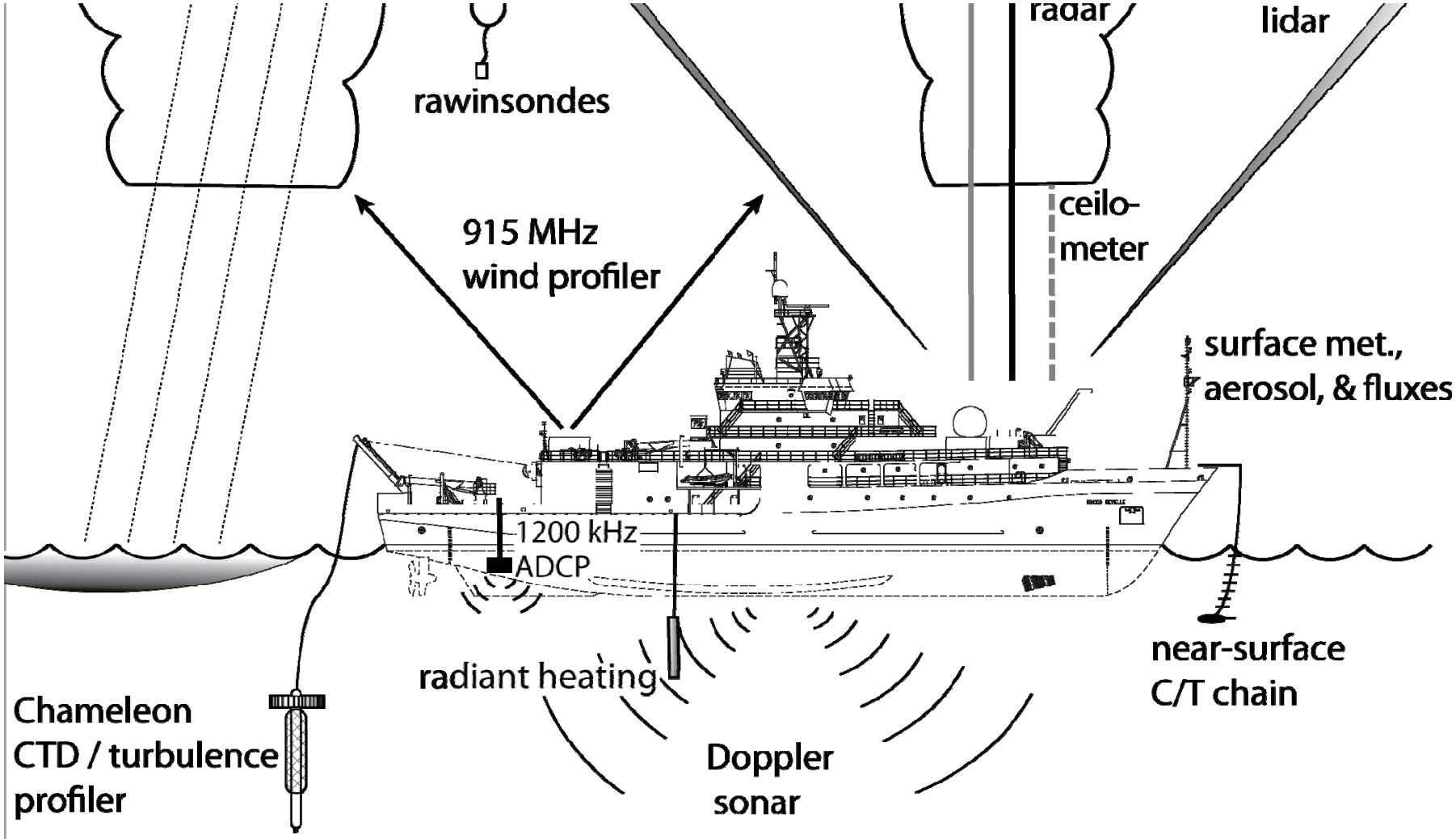
multiple high-res modern ***ADCP***s sampled rapidly

Hull 50 kHz

140 kHz

Over-the-side

150 kHz


radar
lidar
rawinsondes
915 MHz
wind profiler
ceilo-
meter
surface met.,
aerosol, & fluxes
1200 kHz
ADCP
radiant heating
near-surface
C/T chain
Chameleon
CTD / turbulence
profiler
Doppler
sonar

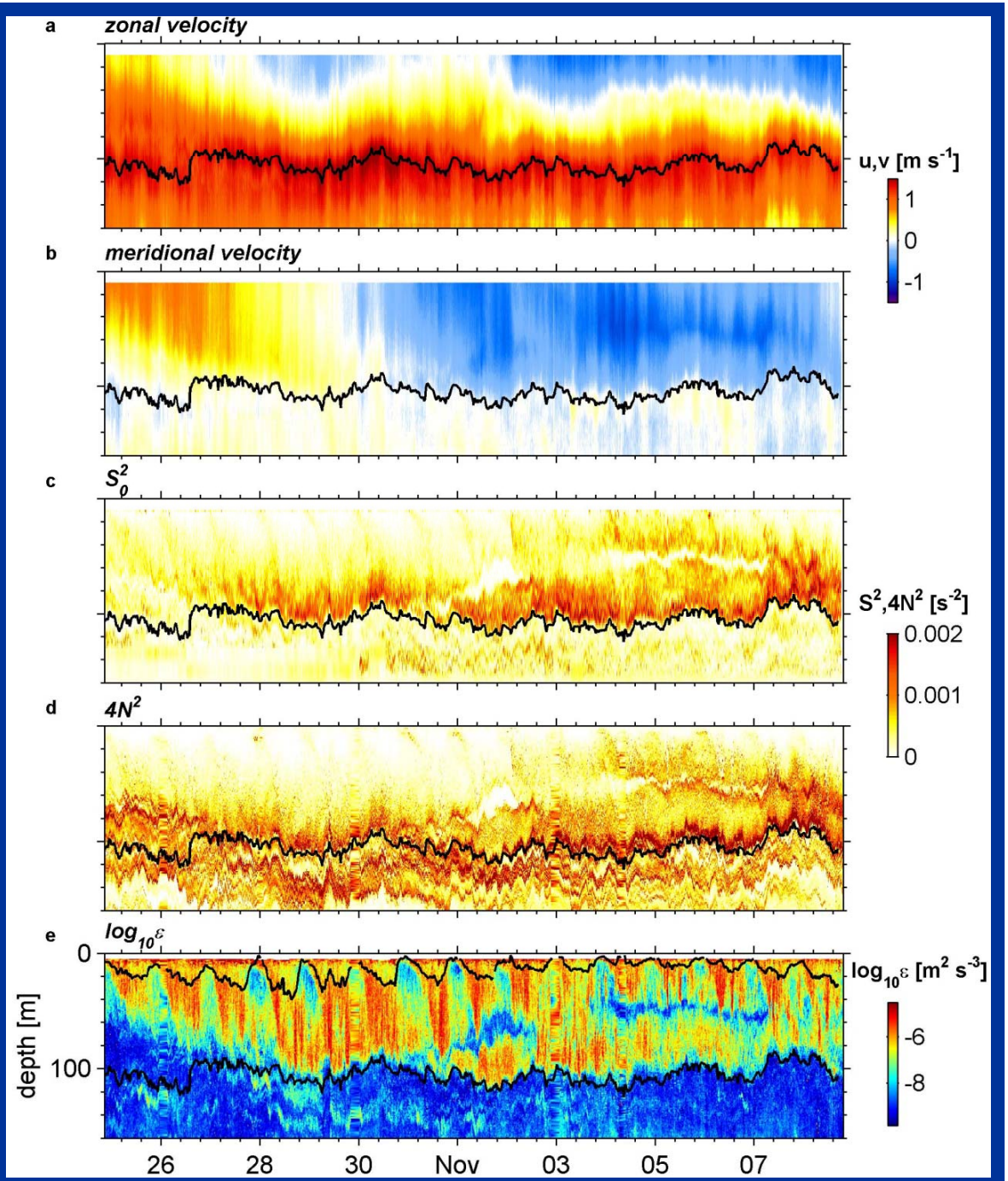
An example of how the Ocean *does not* care what the Atmosphere does but the Atmosphere has to care what the Ocean does!

TIWs cool the sea surface independently of surface forcing!

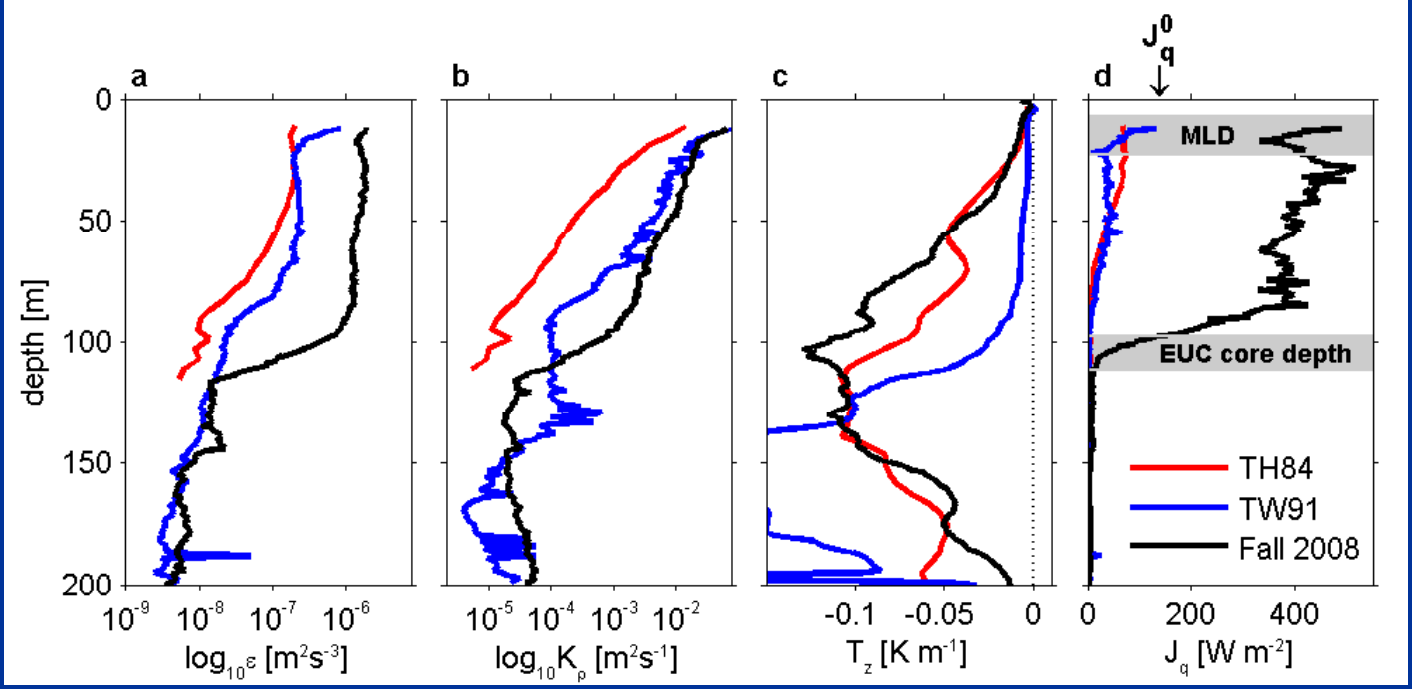
Nature Geophysics, 2009

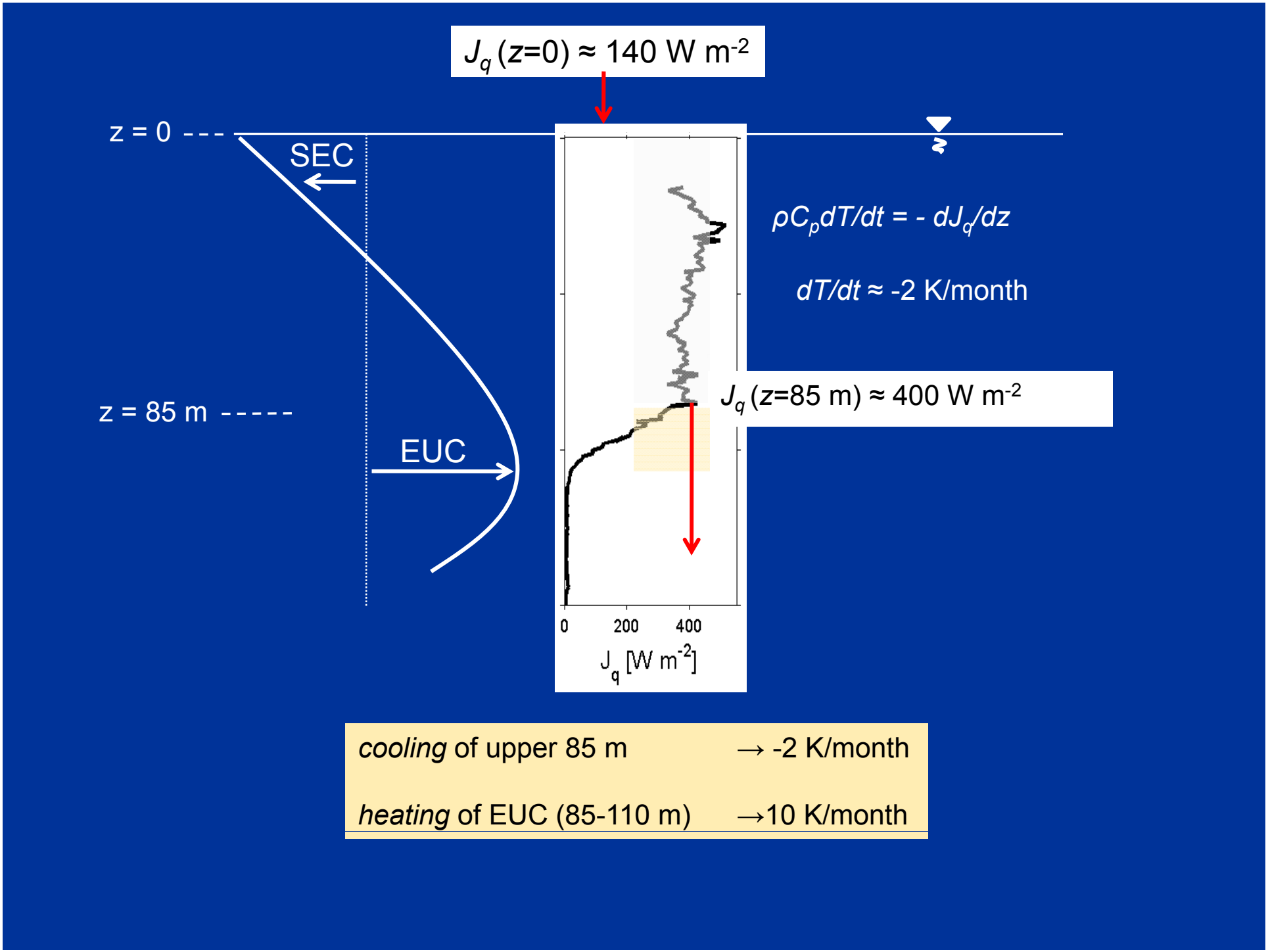
upper ocean structure
0 140W
boreal fall 2008

TIW – enhanced subsurface mixing

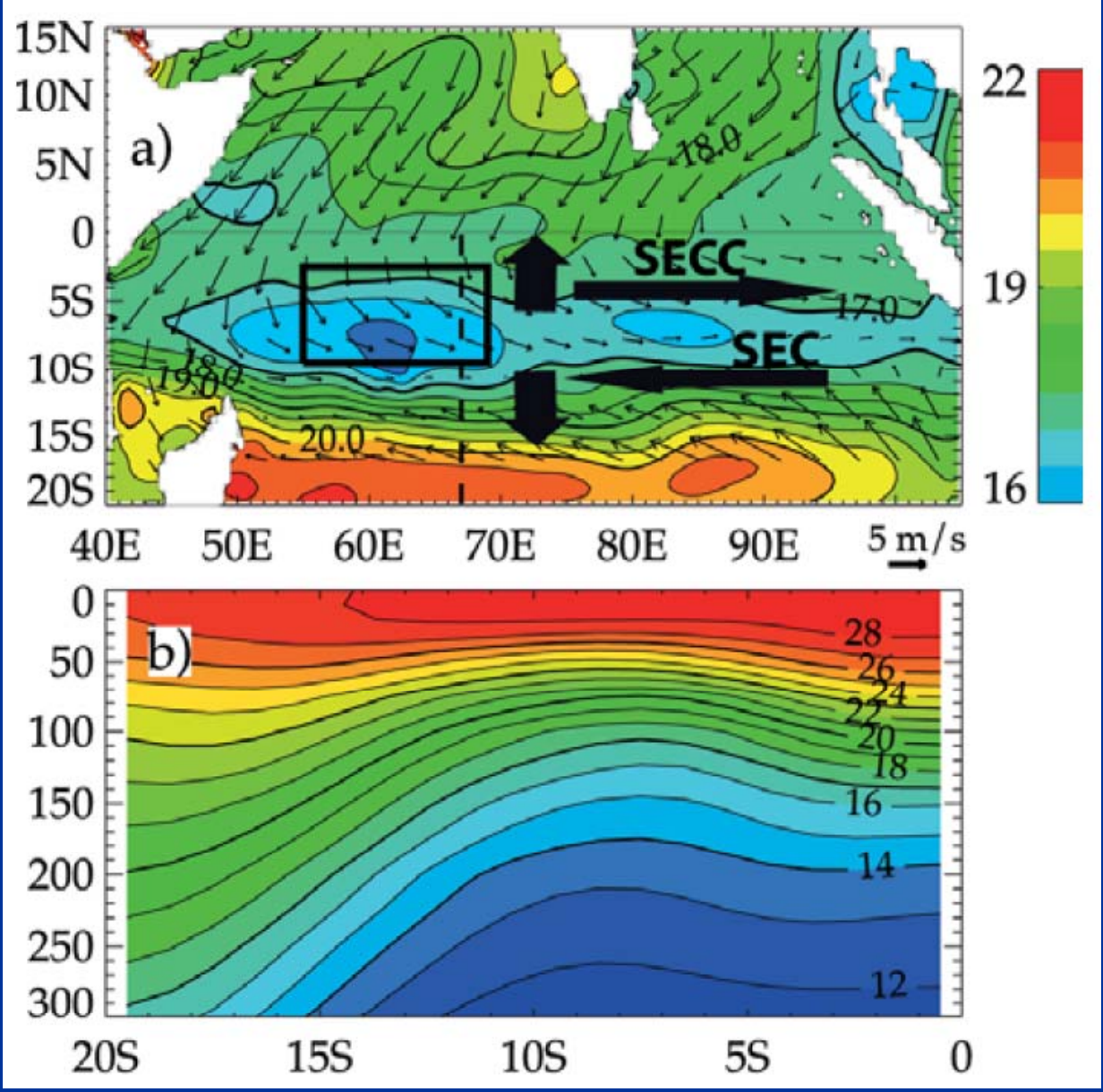


subsurface fluxes in TIW (black)
SST cooling rate > 2 K/month




J_q (z=0) ≈ 140 W m^{-2}
z = 0
SEC
z = 85 m
EUC
$\rho C_p dT/dt = - dJ_q/dz$
dT/dt ≈ -2 K/month
J_q (z=85 m) ≈ 400 W m^{-2}
0
200
400
J_q [W m^{-2}]
cooling of upper 85 m → -2 K/month
heating of EUC (85-110 m) →10 K/month

Seychelles-Chagos Thermocline Ridge south of equator

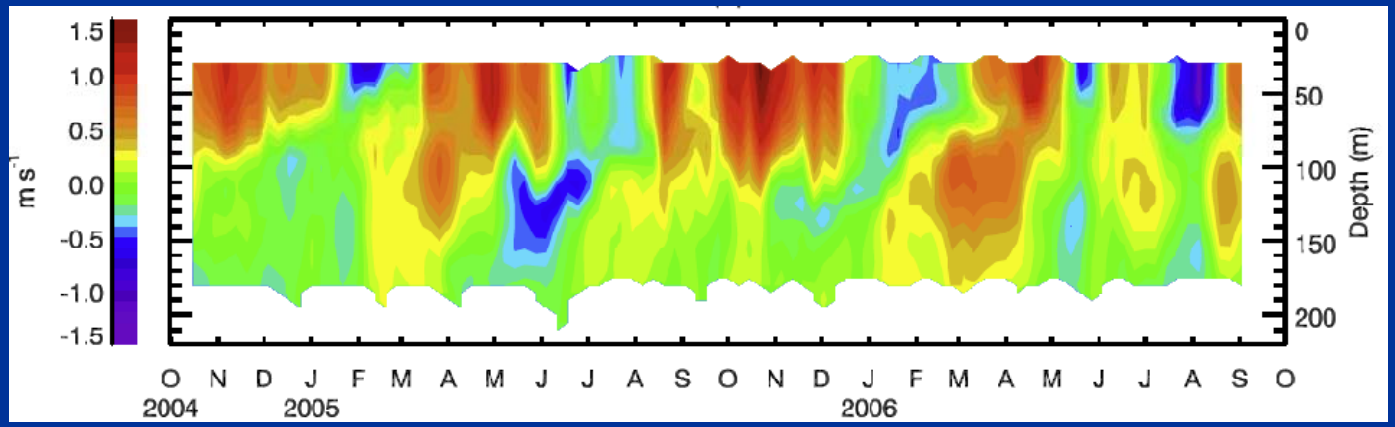


winds
avg T / 0-300 m

climatology
Jan-Feb

Vialard etal, 2008 BAMS

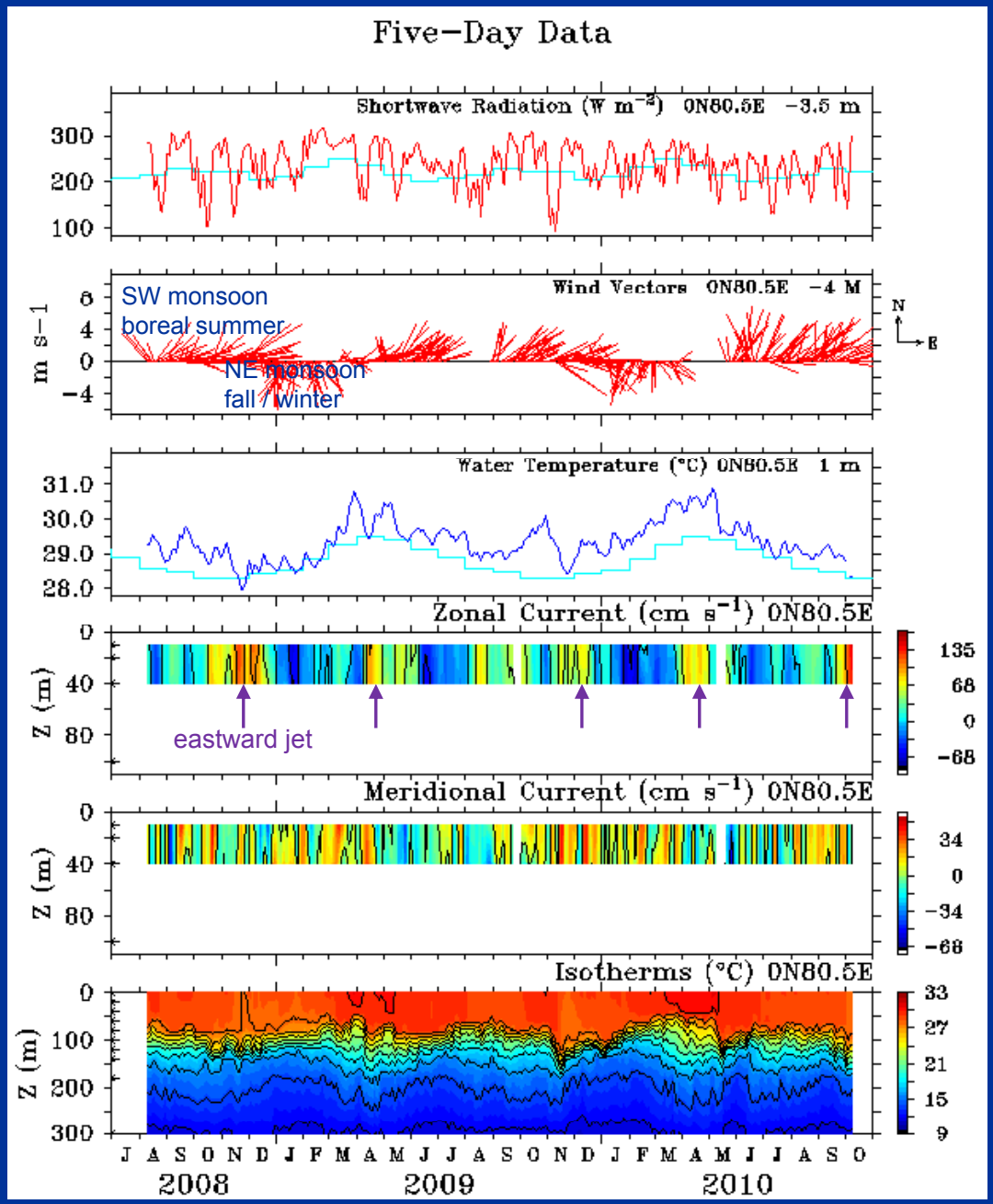
Wyrtki Jets at the equator



Zonal currents in the equatorial Indian ocean at 0 80.5E. Intense eastward currents in boreal spring and fall are the Wyrtki jets. These measurements from subsurface ADCPs indicate strong vertical shear but which we know to be attenuated. (Nagura & McPhaden, 2008)

RAMA data
0, 80E

easy to get from website



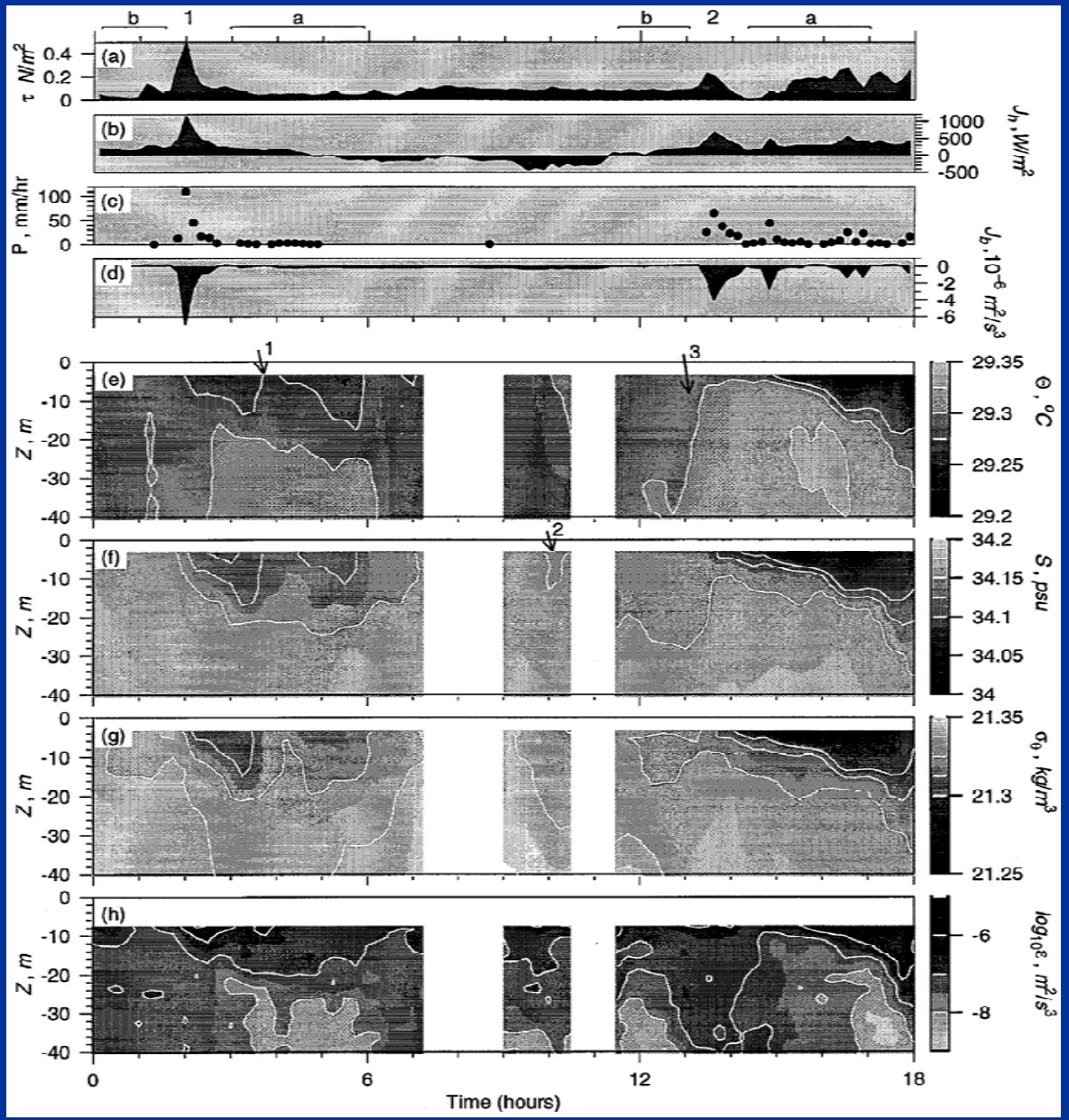
18 h time series
from COARE

squalls excite near-surface mixing

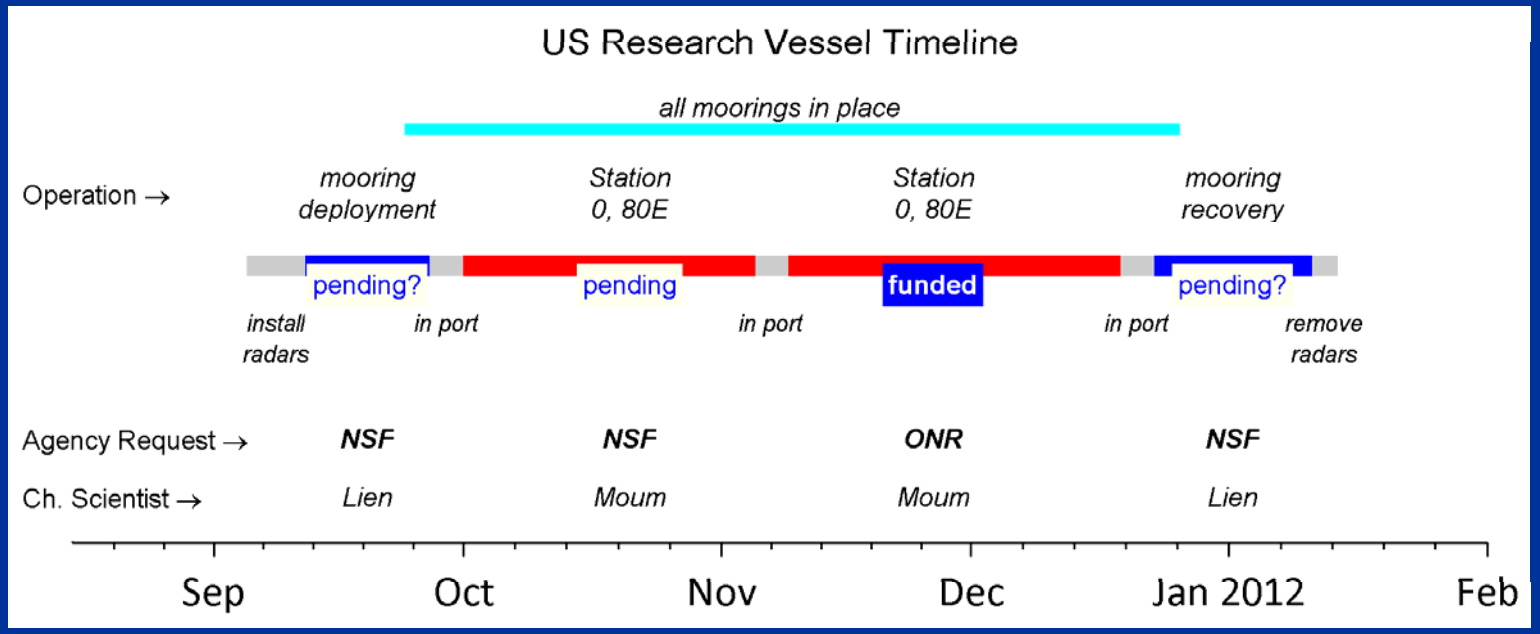
cool precip. isolates near-surface from subsurface reducing susbsurface mixing

fresh, cool puddles spread like gravity currents

puddles heat from above and below



Smyth etal 1996



from Ren-Chien Lien:

deployment cruise plan to load in Darwin, get on at Cocos Keeling, and off at Cochin.
I would like to bring Scripps' Seasoar for surveys around mooring array. No extra shiptime requested. Will use built-in weather days. Objective – map out barrier layer.

On the recovery cruise, we will get on at Cochin, and off at either Diego Garcia or Port Louis. We need to find out the shipping cost too. The latter seems simpler.

Indian Ocean SST anomaly

http://wn.com/Indian_Ocean_SST_Anomaly_Animation_1996_to_2009