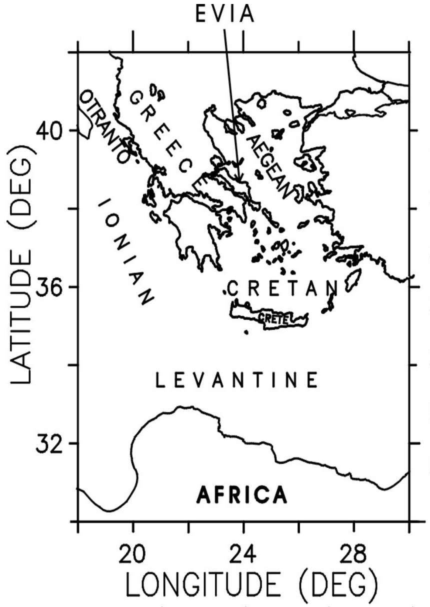
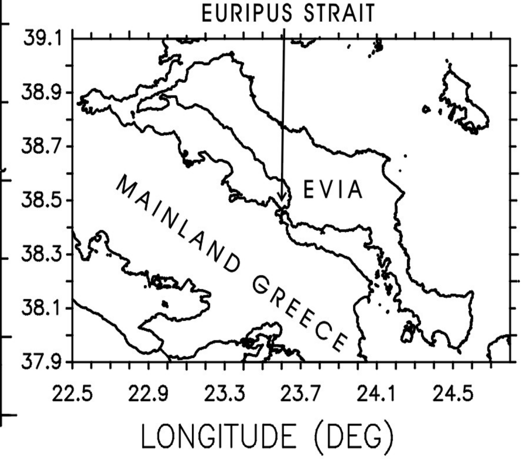
The Euripus Tidal Stream at Halkida/Greece: A practical, inexpensive approach in assessing the hydrokinetic renewable energy from field measurements in a tidal channel

(accepted by JOEME / Ocean Eng. Mar. Ene.)



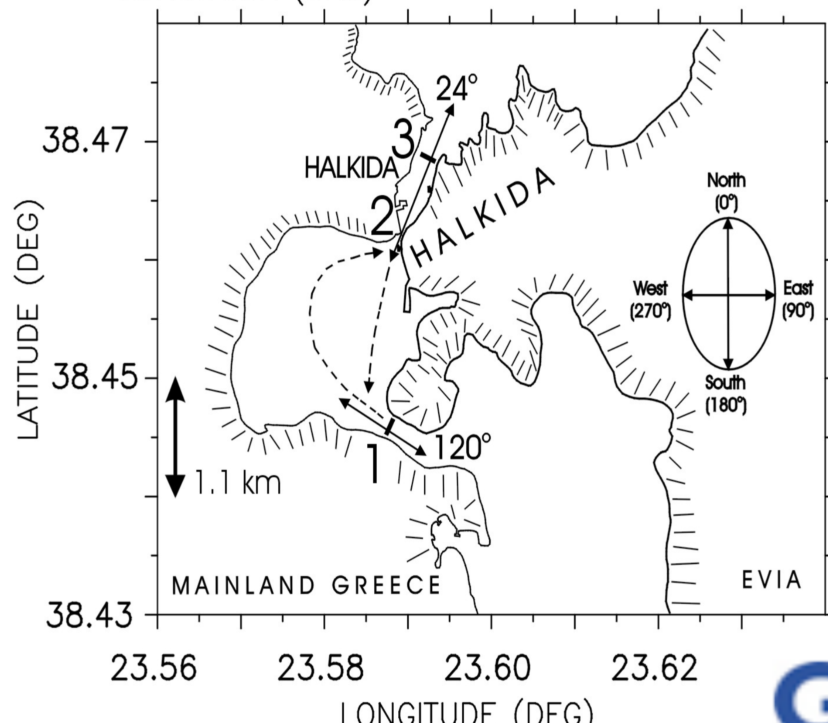


…. ARISTOTLE ….

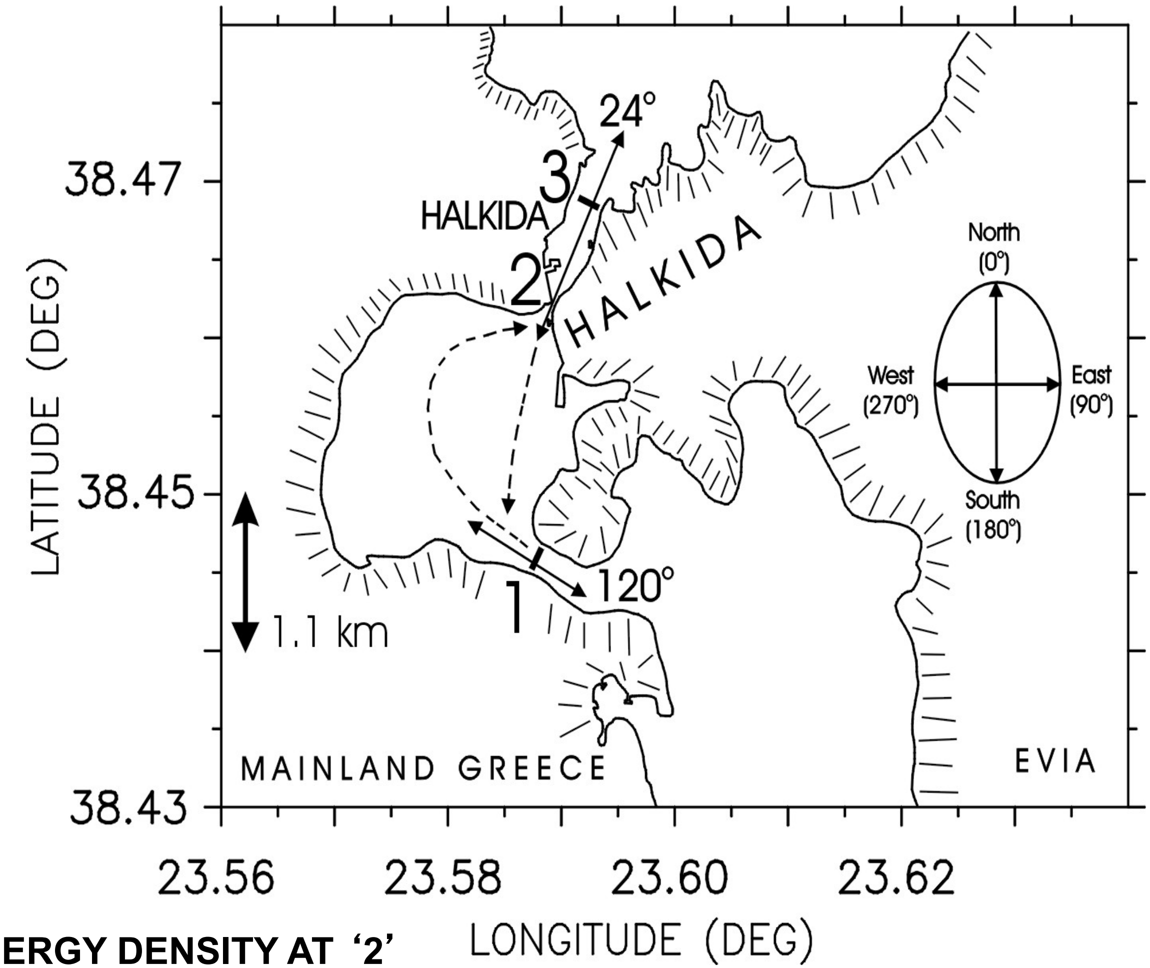
… 'Walter, Aristotle and the Tides of Euripus' by Adrian Gill

SIO Reference Series 84-5, March 1984, Library of Congress, No 84-181943

… A celebration in honor of Walter Munk for his 65th birthday (October 1982)



1: New Bridge , 2: Old Bridge, 3: North Lights



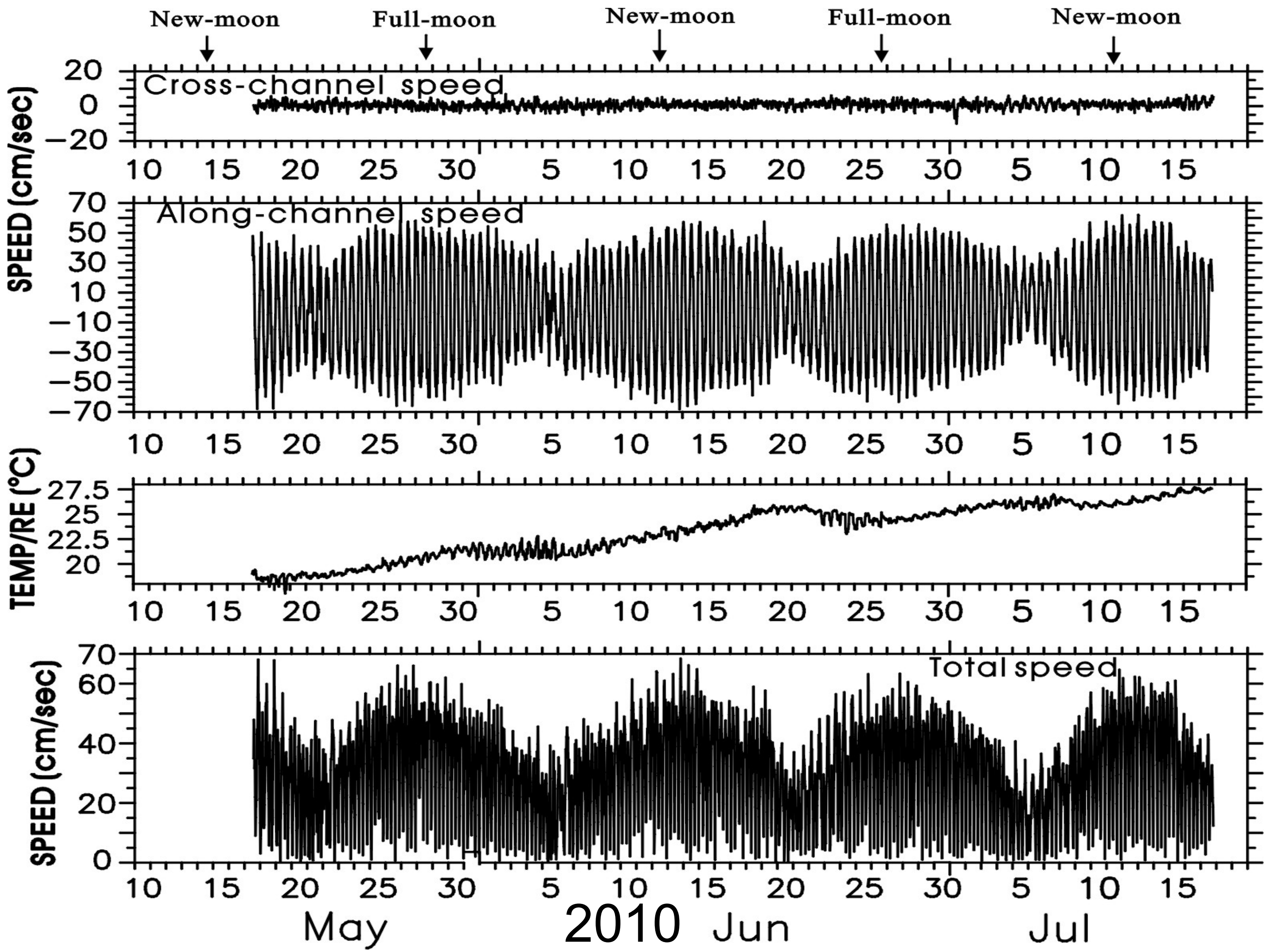
1: New Bridge
2: Old Bridge
3: North Lights

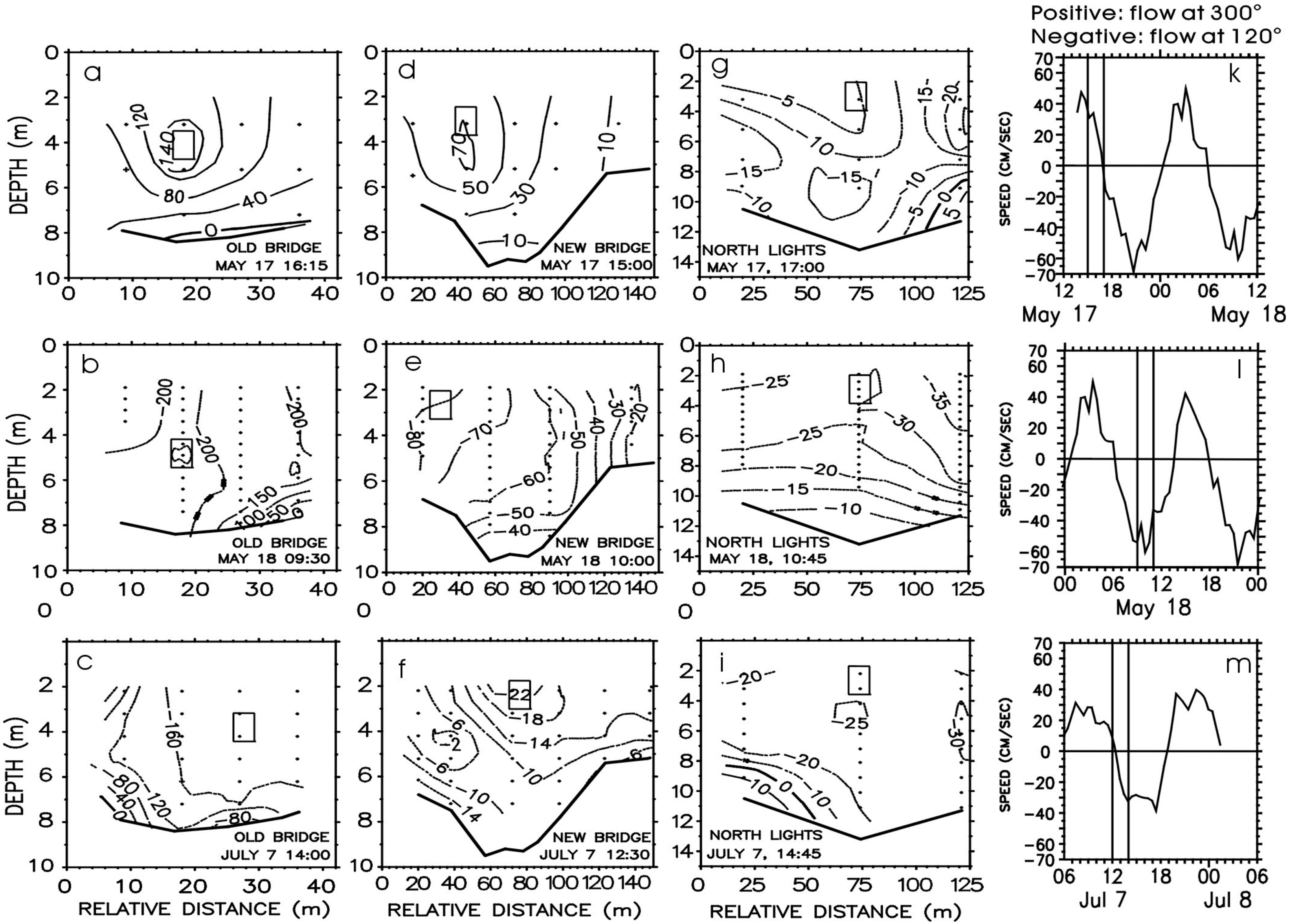
→ **HIGHEST ENERGY DENSITY AT '2'**

→ **Deploy current-meter** (CM) at **'1'** and **do ADCP snapshot-transects** at **'2'** → **Observational linear relationship** between the CM along-channel velocity and the maximum along-channel velocity of the ADCP transect at **'2'** → **normalization** of the along-channel velocities at each transect at **'2'** relative to the transect velocity maximum (produce several non-dimensional current structures that can be averaged) …
so we get time series of ADCP transects at '2'

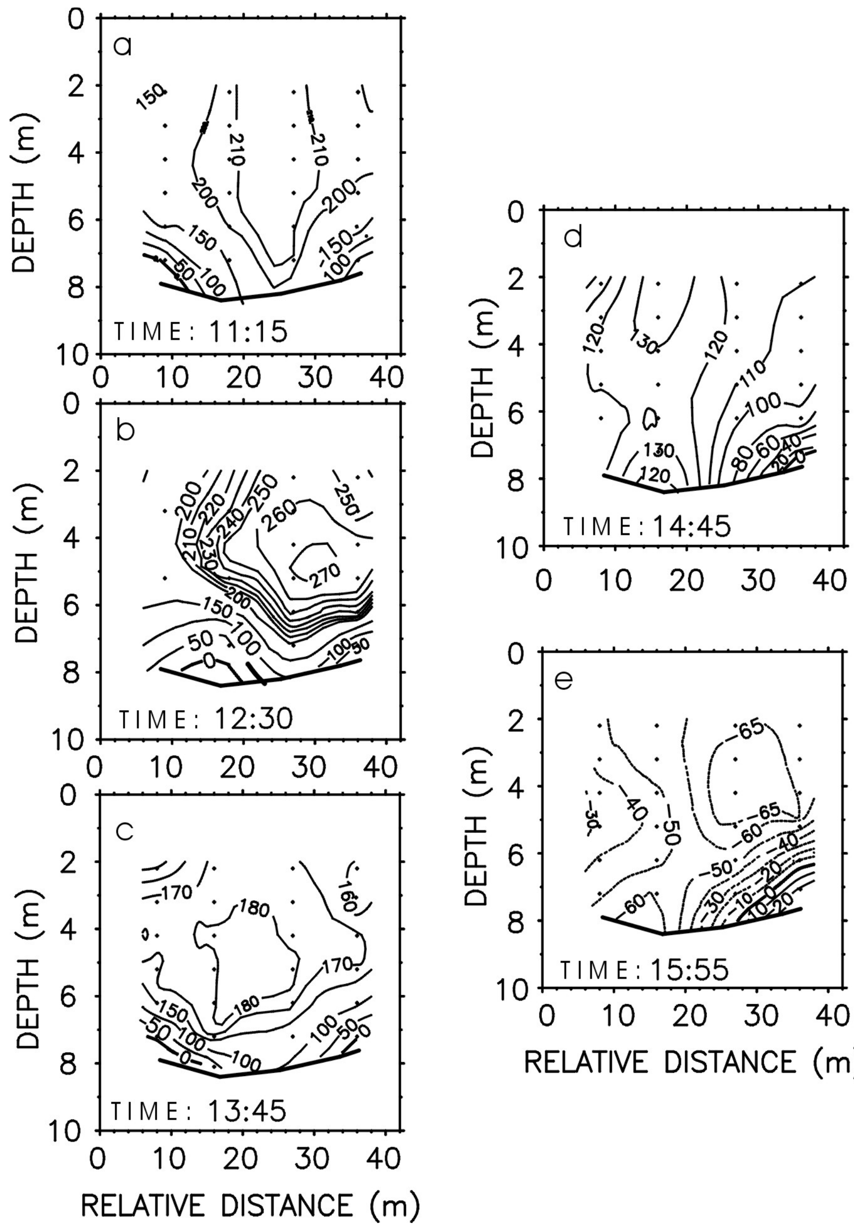
Current and temperature timeseries at the edge of the New-Bridge section

(1.5 m off the bottom)

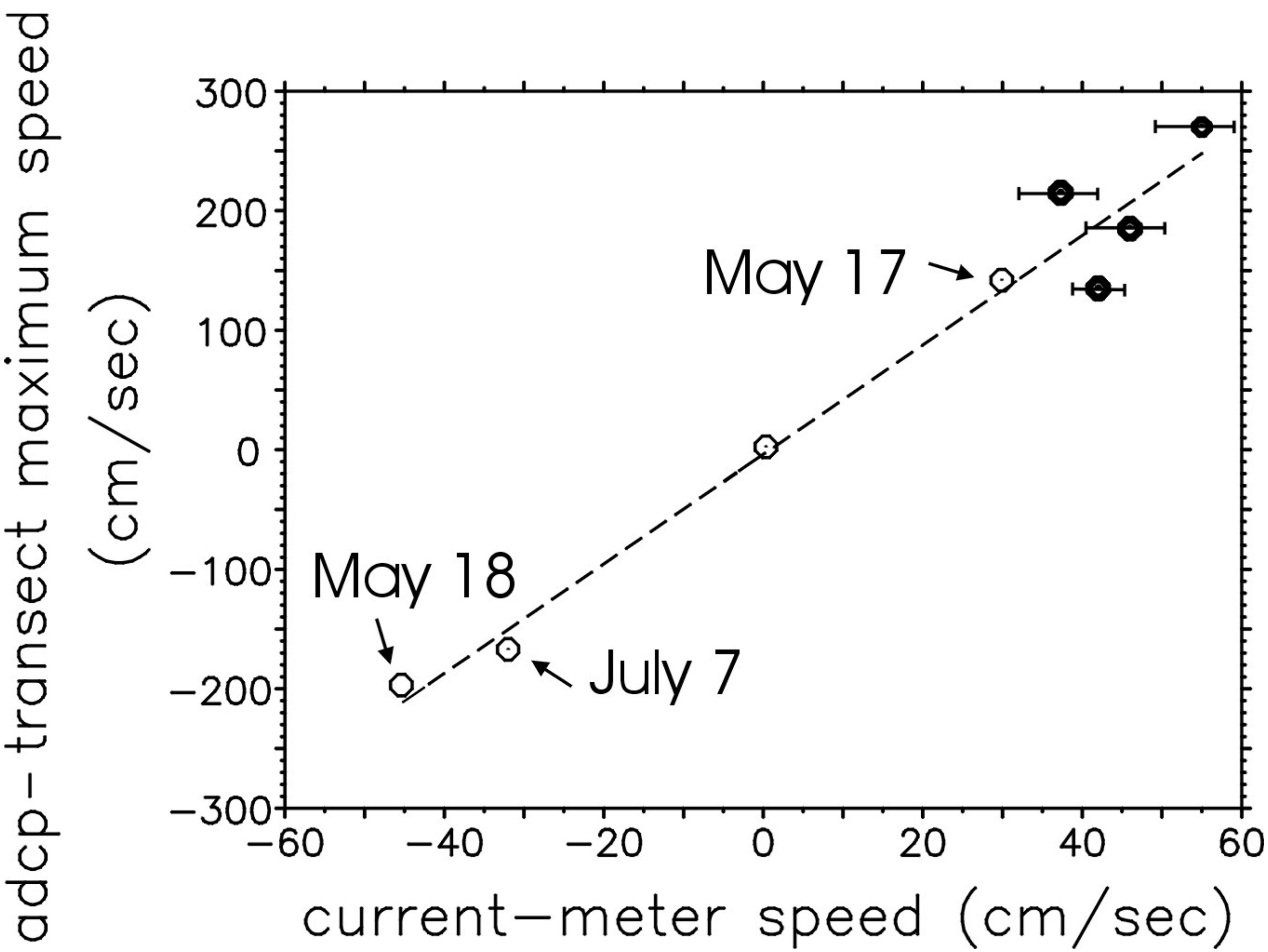




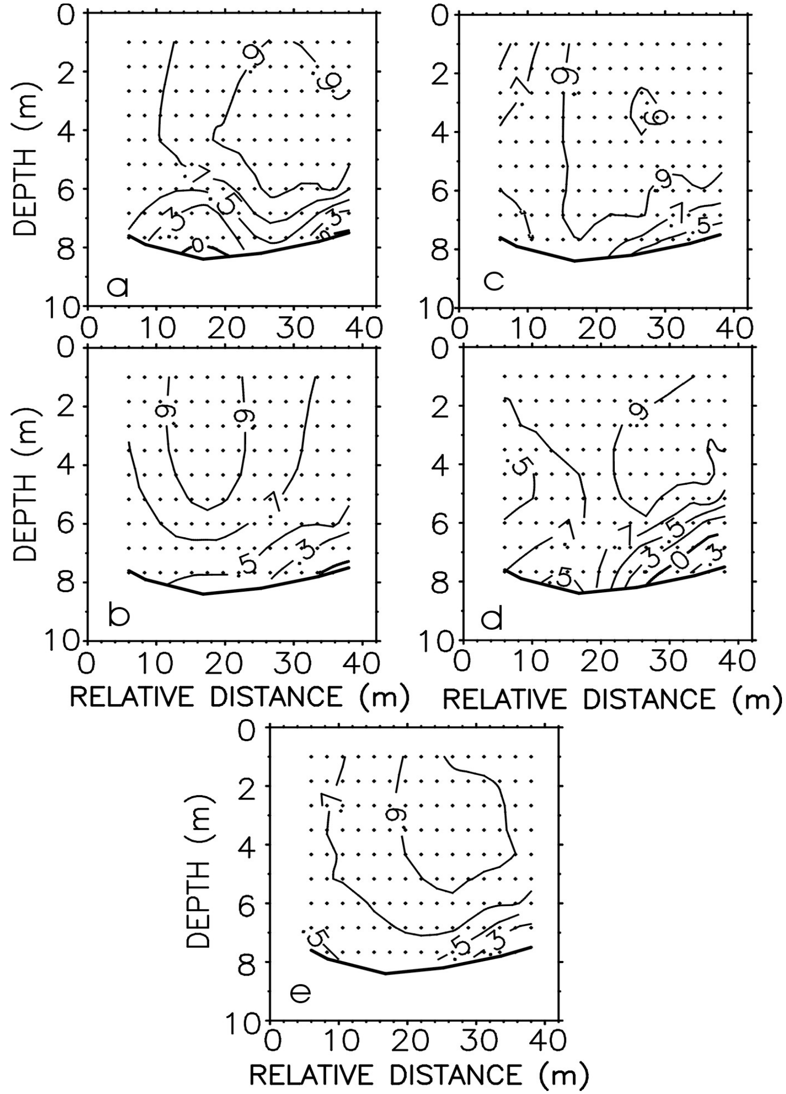
ADCP along-channel velocity distributions at the three sections and the corresponding part of the velocity current-meter record at the New Bridge



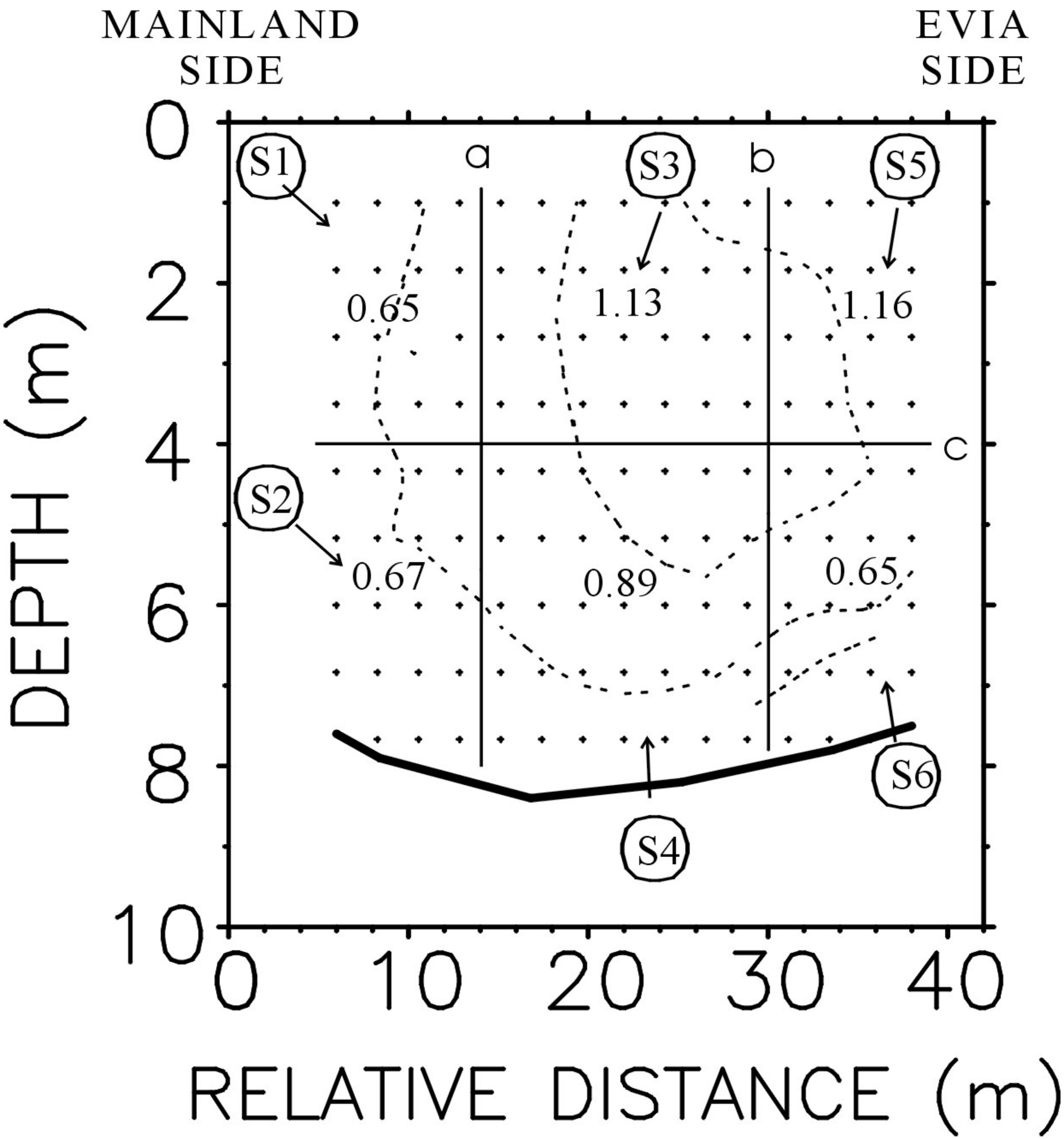
ADCP sections at the Old Bridge on September 23rd 2010 (full-moon)



A linear relationship exists between the along-channel current-meter velocity at the New-Bridge and the maximum of the along-channel velocity at the Old-Bridge ADCP transect



Four basic along-channel velocity structures at the Old Bridge (α,b,c,b) (normalized values relative to the section-maximum velocity) and their overall mean (e).



Available hydrokinetic power flux per unit cross-sectional area (in kWatts/m^2)

((8/27) ρ V^3)

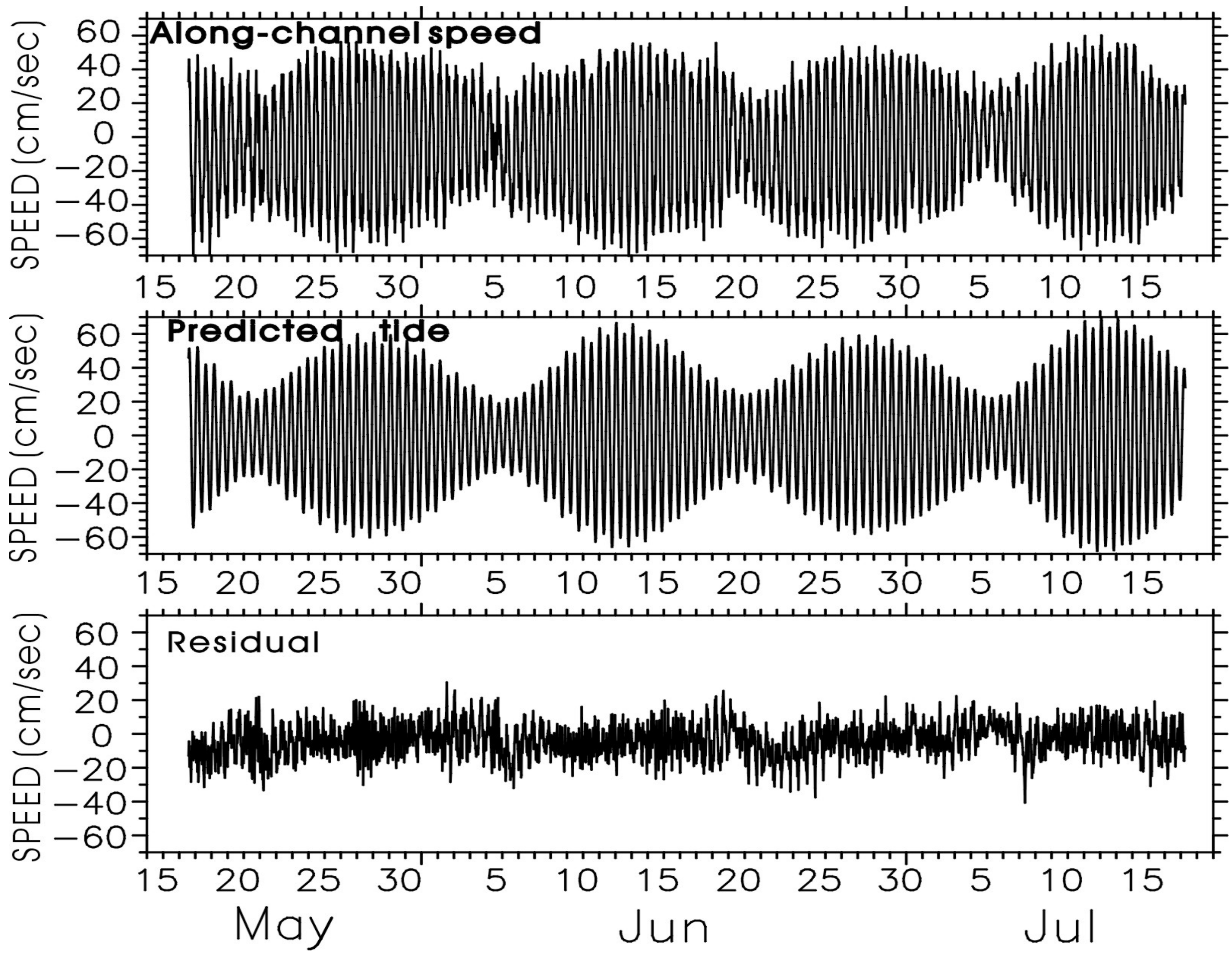
In different subsections at the Old-Bridge

(assuming a hydroturbine with 100% efficiency)

(these are two-month mean values)

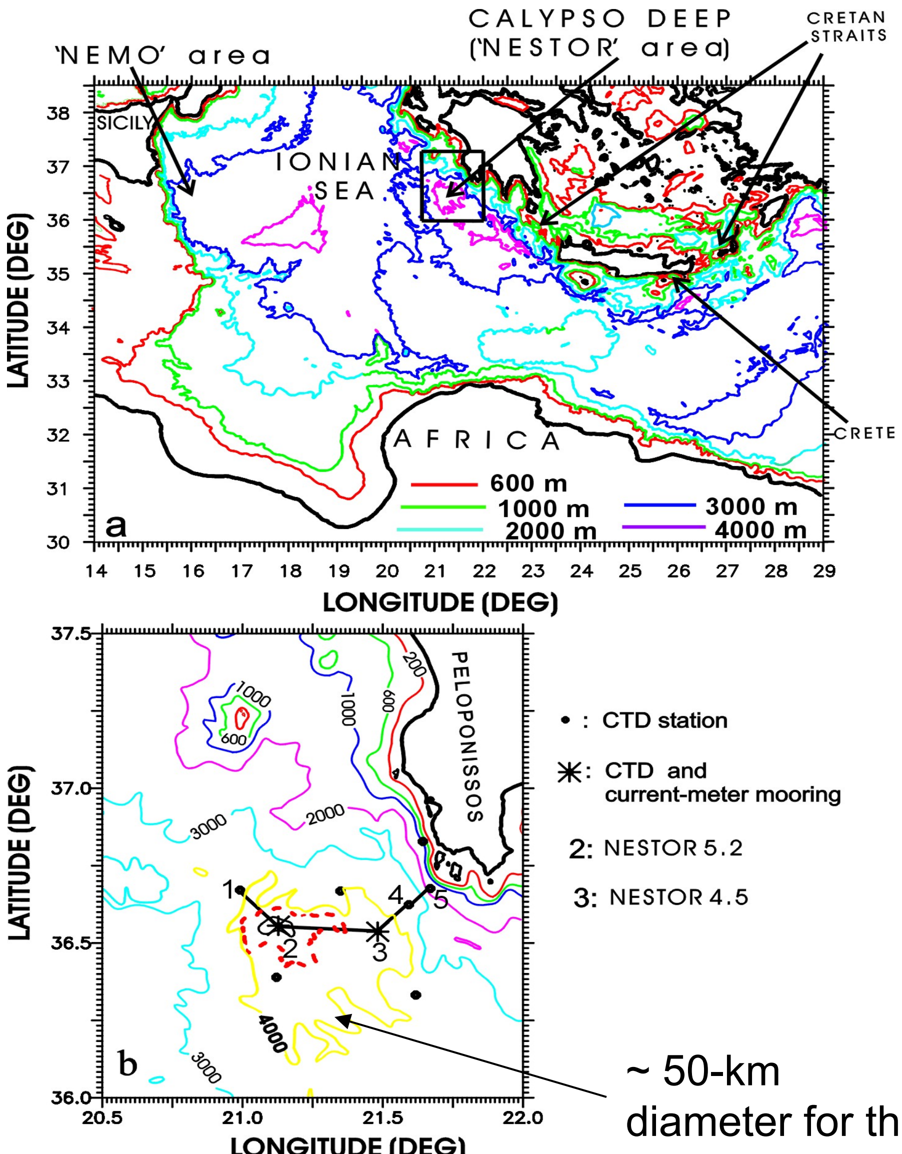
Dotted lines show the mean along-stream velocity structure

TIDAL RESPONSE ANALYSIS



Is it safe to extrapolate the two-month results to a year mean? i.e., what's the comparison between the predicted tide and the residual

Deep-mixing at the CALYPSO DEEP (East Mediterranean)



~ 50-km diameter for the 4-km depth contour

- **N**eutrino **E**xtended **S**ubmarine **T**elescope and **O**ceanographic **R**esearch

(**H**ellenic **C**enter for **M**arine **R**esearch)
PO involvement was to:

Investigate physical properties and deep current regime

- CTD surveys and CM/ sediment trap tall-mooring recycling/renewal:

June 2006

October 2006

May 2007

October 2007

April 2008

October 2008

May 2009

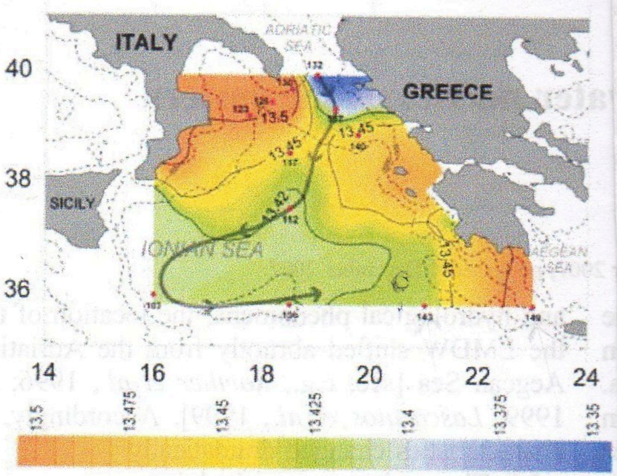
Some more background relative to the E. Med Deep Thermohaline Circulation (and deep spreading routes)

By 2001, i.e., 8 years after the dominating Aegean dense-water influx of 1993, the EMT-inversions in the Levantine deep waters below about 1000 m depth were still prominent, a

L23607 RUBINO AND HAINBUCHER: CHAN

JRL 2007

W. ROETHER et al. PIO, 2007



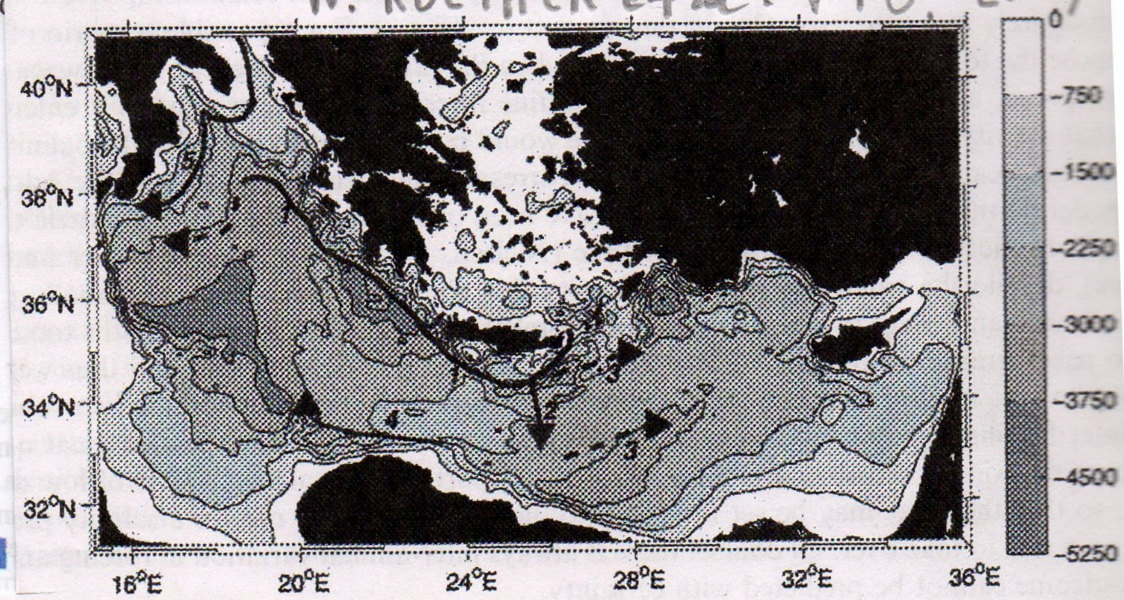


Fig. 14. Schematic of EMT-induced flow in the EMed deep waters, deduced as described in the text (bathymetry of Fig. indicate head of a streamline; dashed lines indicate less steady flow or 'spreading'. Thinner streamlines indicate relatively lo (1) Main route of waters carrying Aegean outflow, fed through the Kasos and Antikithira Straits; later in the EMT, there bottom counter-flow in the Hellenic Trench. (2) Overflow of EMR during EMT (after 1991). (3) Eastward spreading nort the EMR. (4) Flow westward through the Herodotus Trough. (5) Adriatic outflow.

Salinity (n

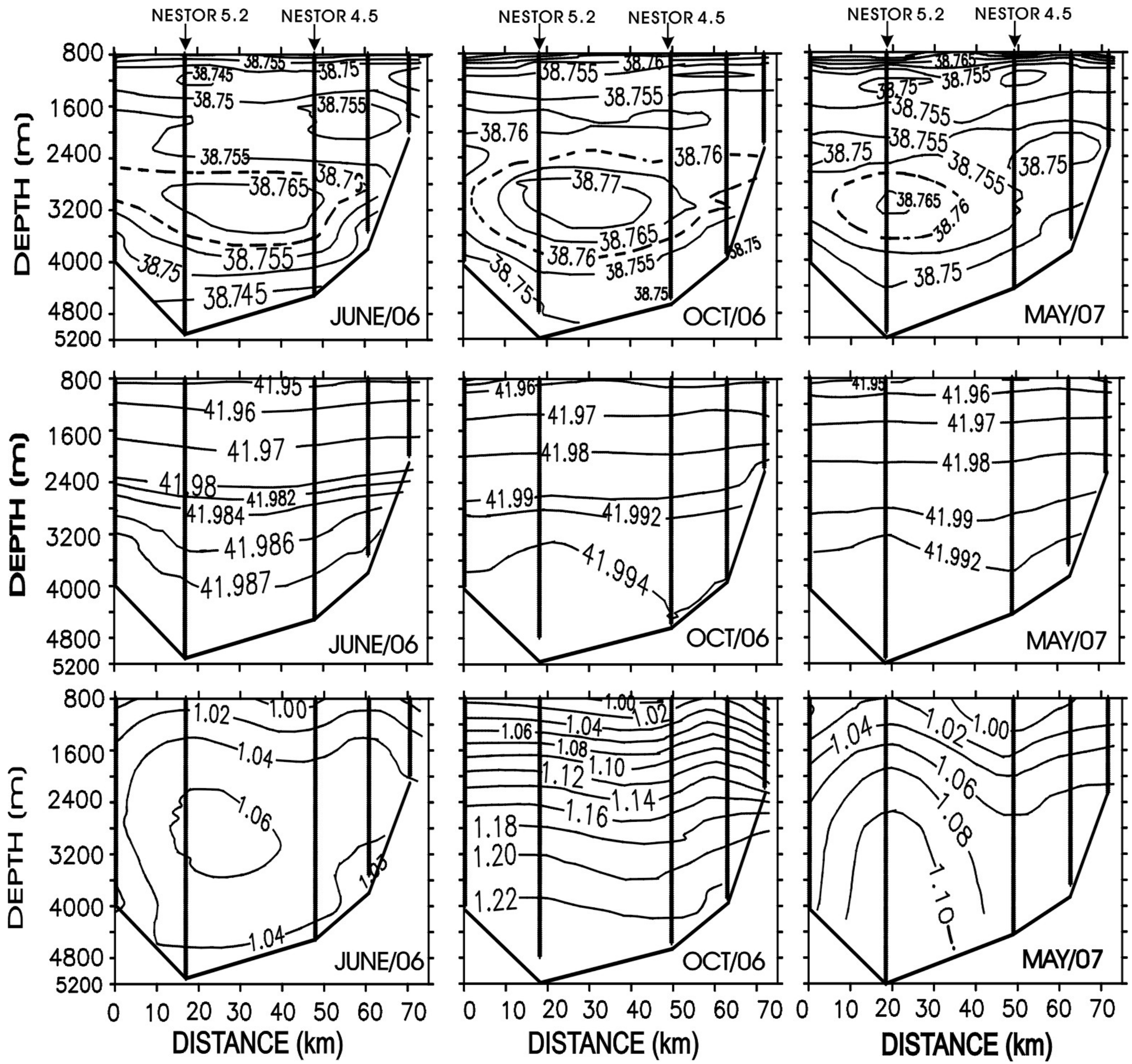
…after the early 2000s (2002-2003…) … Adriatic Water occupies the E. Med bottom layers again and Cretan Water spreads deep (2km +) but not on the bottom

hcmr ΕΛΚΕΘΕ

GSO

… we indentified a deep (from ~2400-to-3600 m) warm (+0.020^{o} C) and saline (+0.012) lens of predominantly Cretan Water – locked over the trough bottom topography - fading after October 2006 due to lateral mixing - … estimation of horizontal eddy mixing coefficients

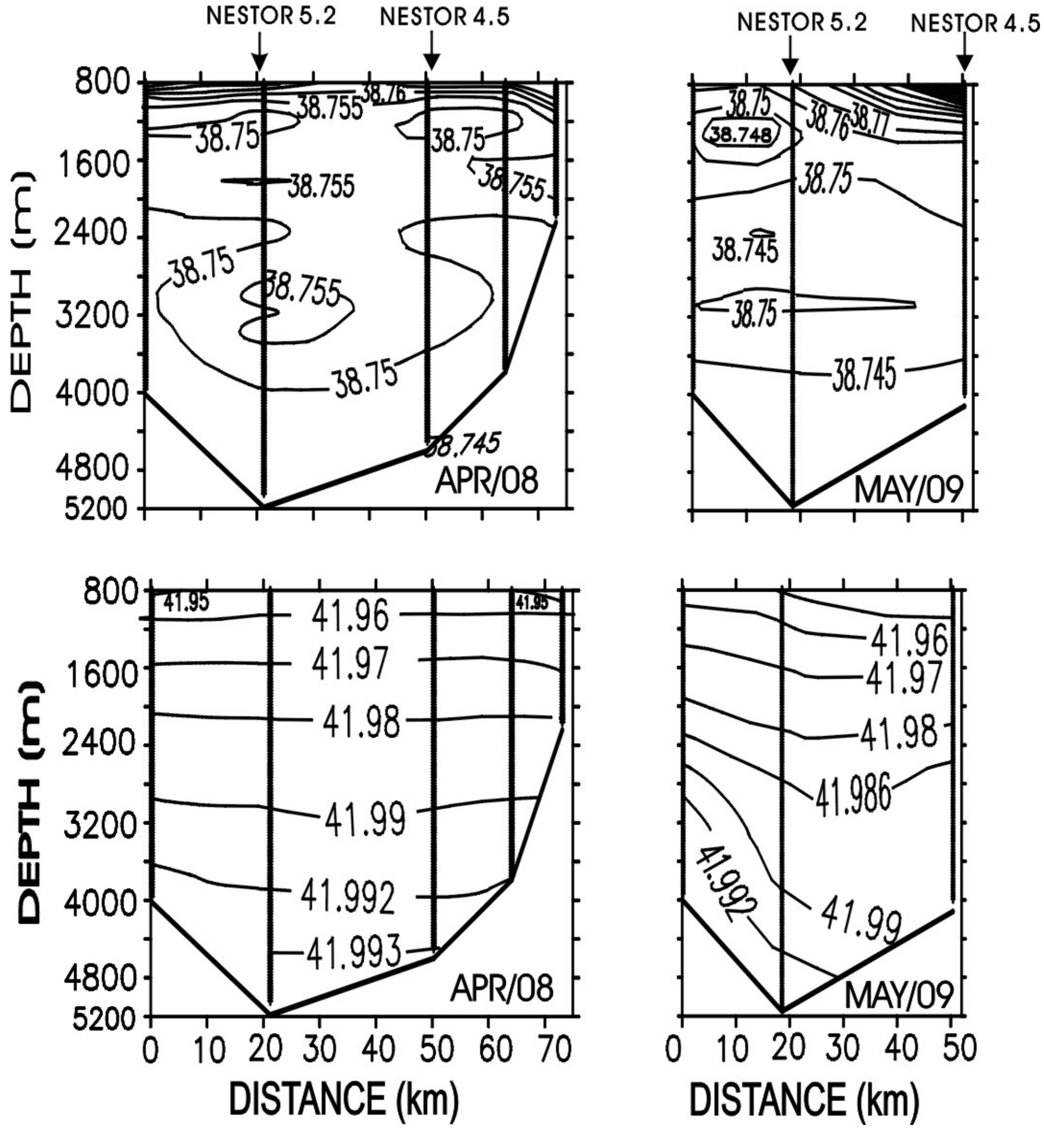
… so we have CTDs on the transect



It appears as if we cut through a Cretan (saline) vein … however it's a lens

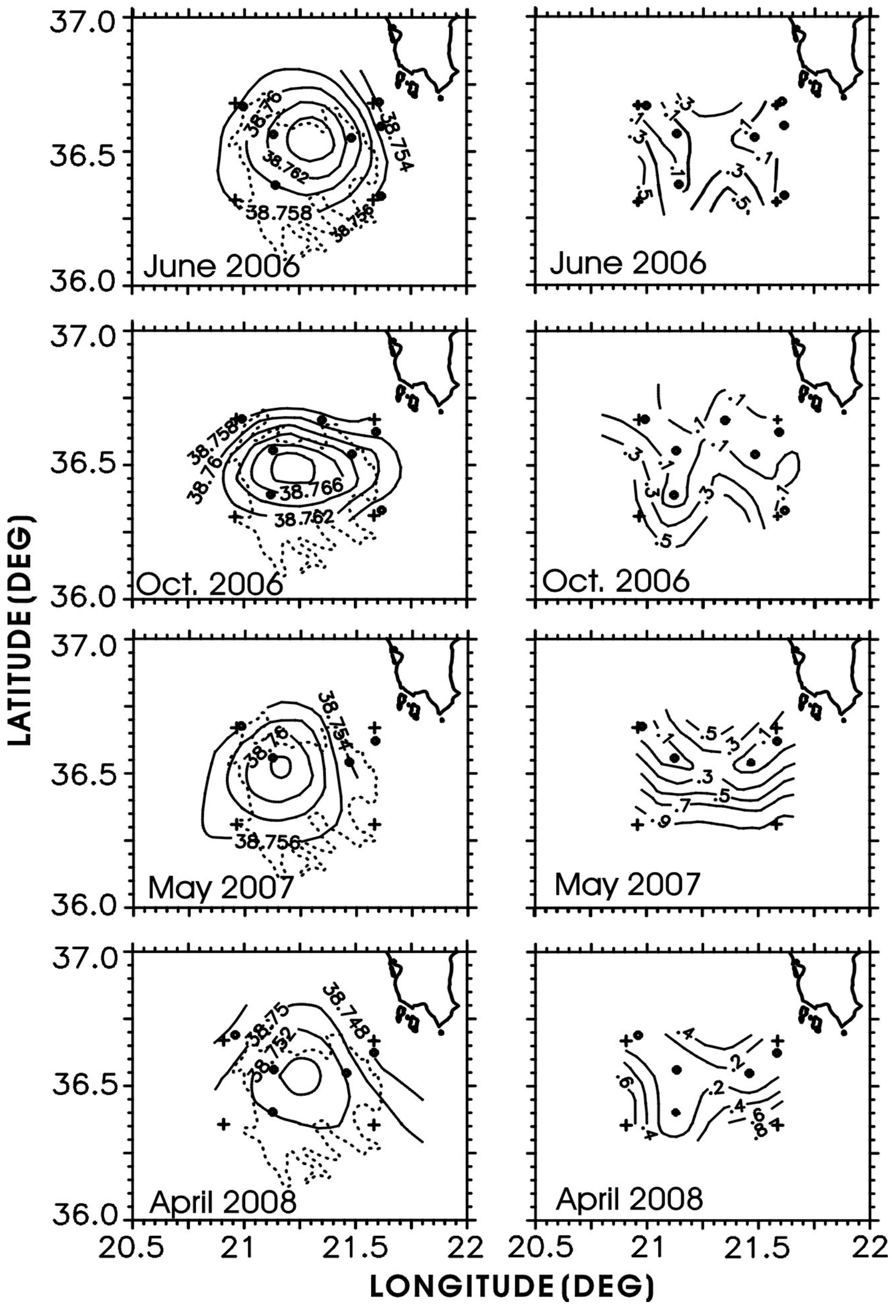
Intrusion of a dense ventilated bottom mass in October 2006

West-to-East section through the Calypso Deep (Salinity/σ_3/ normalized O_2 relative to the water-column O_2 minimum occurring at ~800 m)



…continuation through Apr/08 and May/09 of west-to-east section through the Calypso Deep (Salinity and σ_3) … deep (3200 m) salinity blob weakens more

WHY THIS IS A LENS AND NOT A VEIN ??? (…given that from the literature we expected to see a vein)



Left: OA maps of depth-averaged salinities in the depth range (2400-to-3600 m) of the deep salinity water blob (seen in the CTD transects). (dotted line is the 4-km bottom contour)

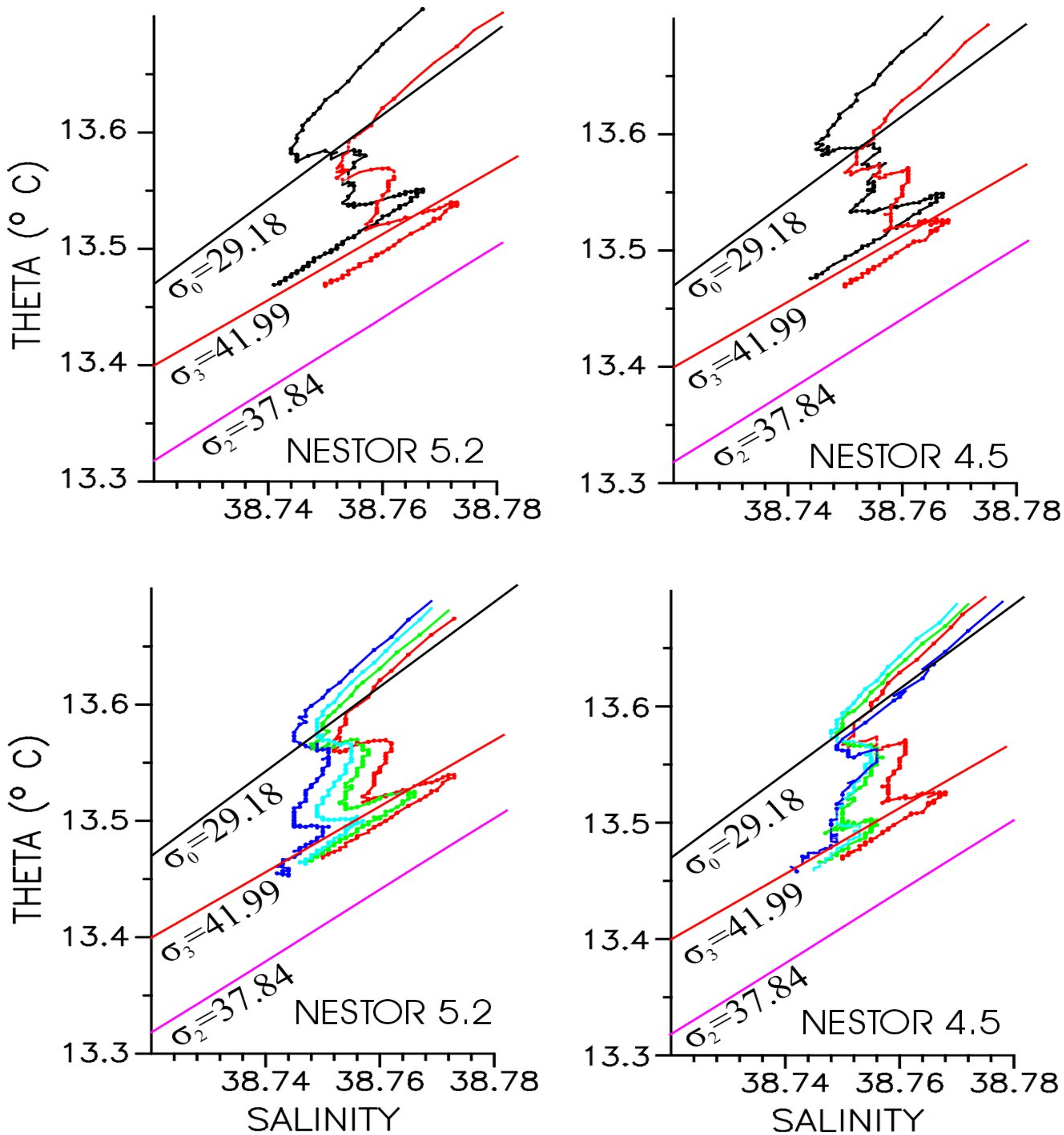
Contour Int/val = 0.002

Right: Mapping error (that also includes the measurement uncertainty)

… so it's a deep salinity lens locked/trapped over the deep topography of the Calypso Deep!!!

…that fades with time after Oct/2006 due to mixing …

(what kind of mixing??)



Black: June 2006

Red: October 2006

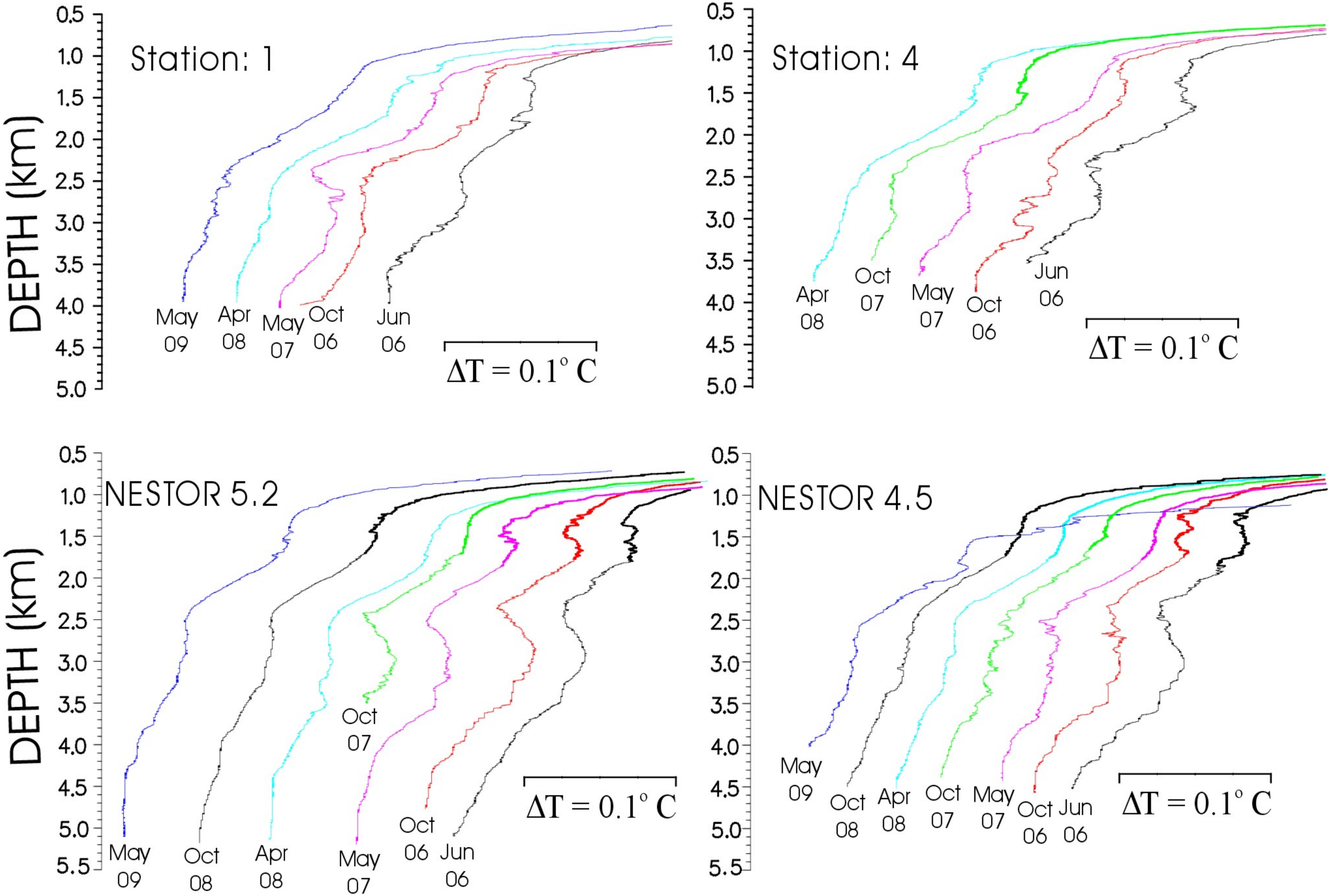
Red: October 2006

Green: May 2007

Cyan: April 2008

Blue: May 2009

Properties sliding very nearly along an isopycnal … predominance of lateral mixing … fine-structure lateral intrusions ….



Magnitude of lateral intrusions larger at the peripheral stations of the lens … mixing works from the outside towards the inside (same also was for the Meddy Sharon (JPO 1998 Armi, Hebert, Oakey,Richardson, Price, Rossby, Ruddick))

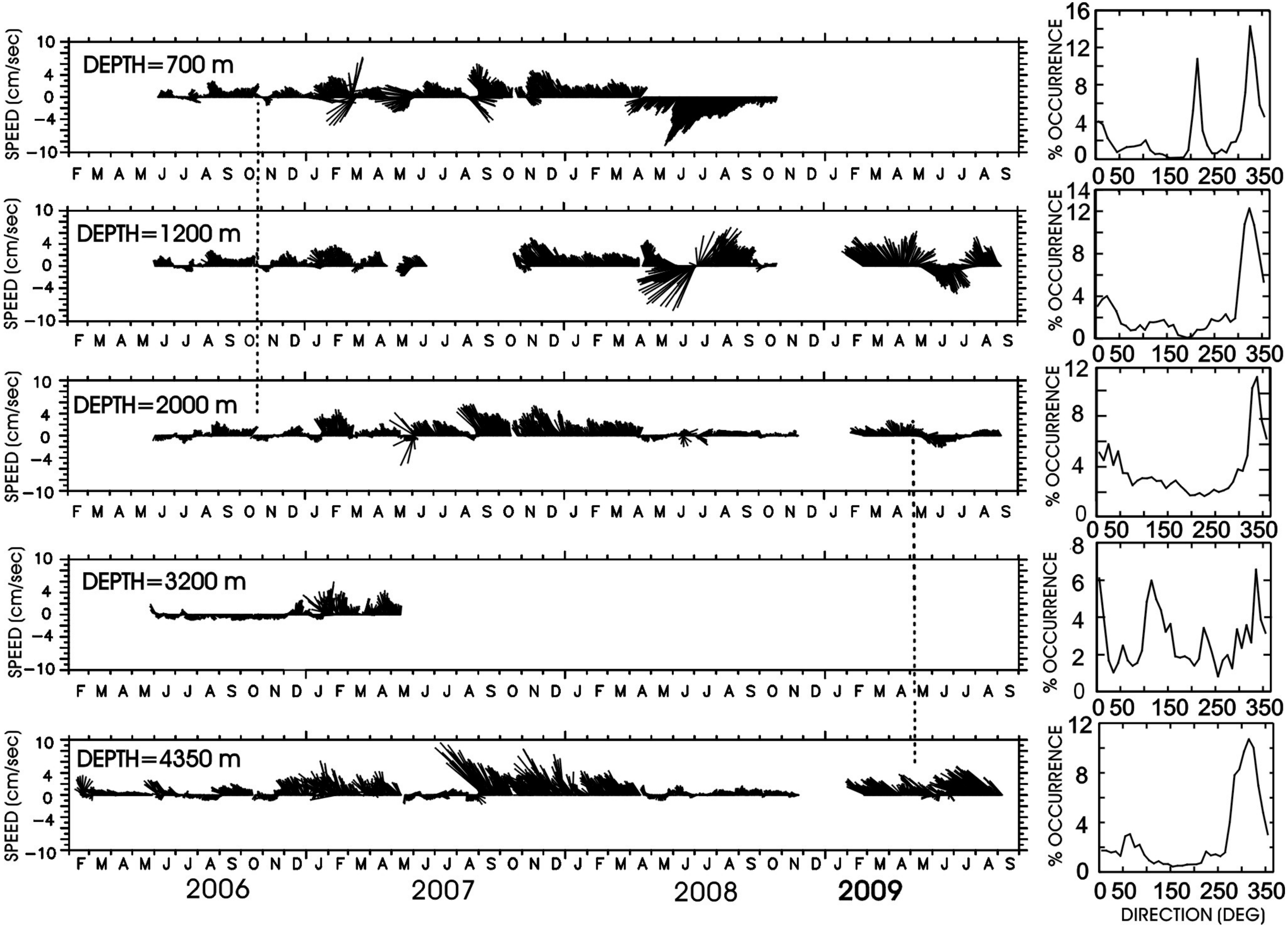
Predominance of lateral mixing, … i.e., Ignore terms responsible for vertical mixing, i.e., … go to horizontal advection - diffusion

$$\partial T/\partial t + u\, \partial T/\partial x + v\, \partial T/\partial y \sim K_H\, (\partial^2 T/\partial x^2 + \partial^2 T/\partial y^2),$$

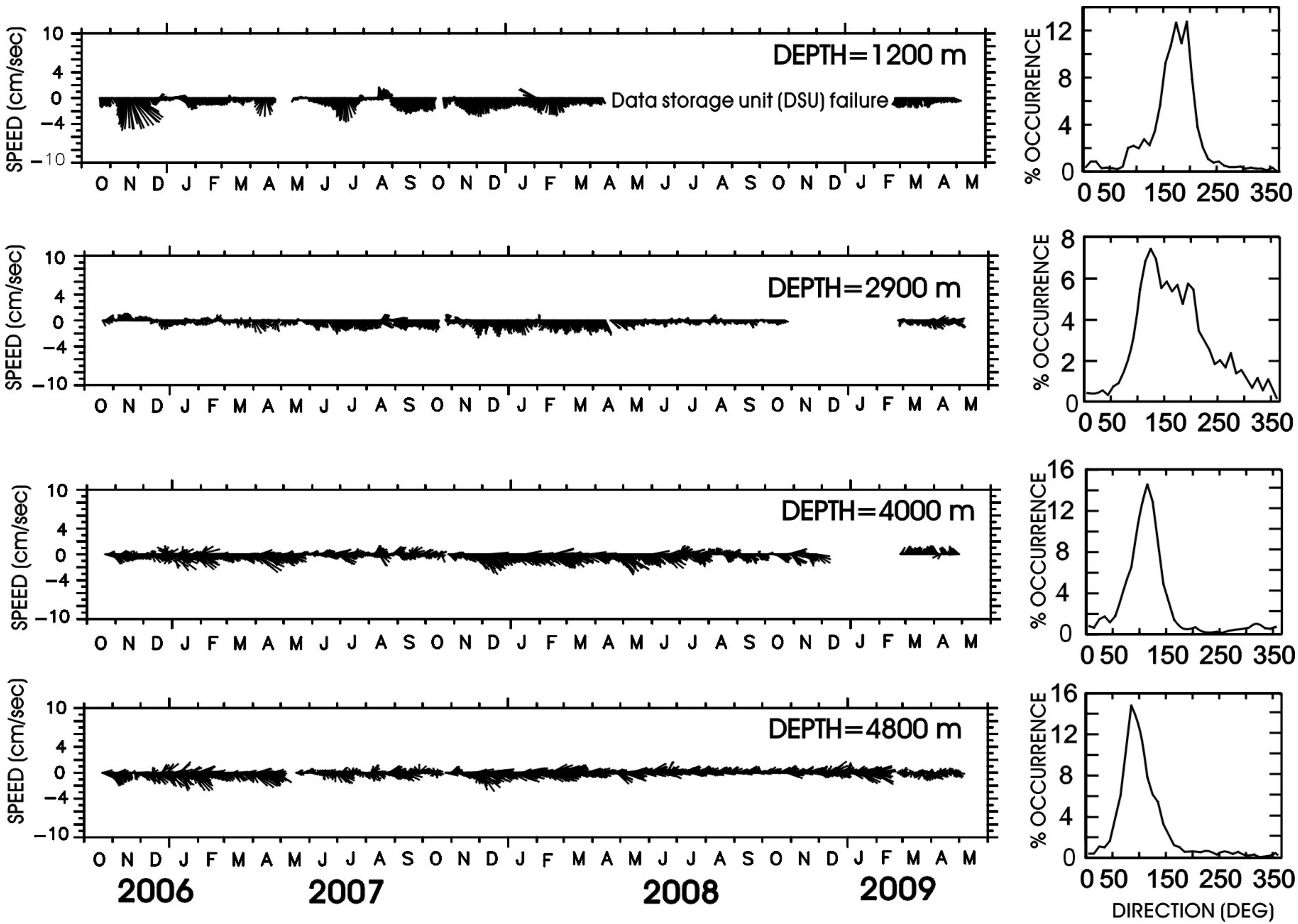
In order to get $K_{H,}$ I need T(x,y), S(x,y), $\partial T/\partial t$, $\partial S/\partial t$ and u, v, at some depth(s) within the saline lens.

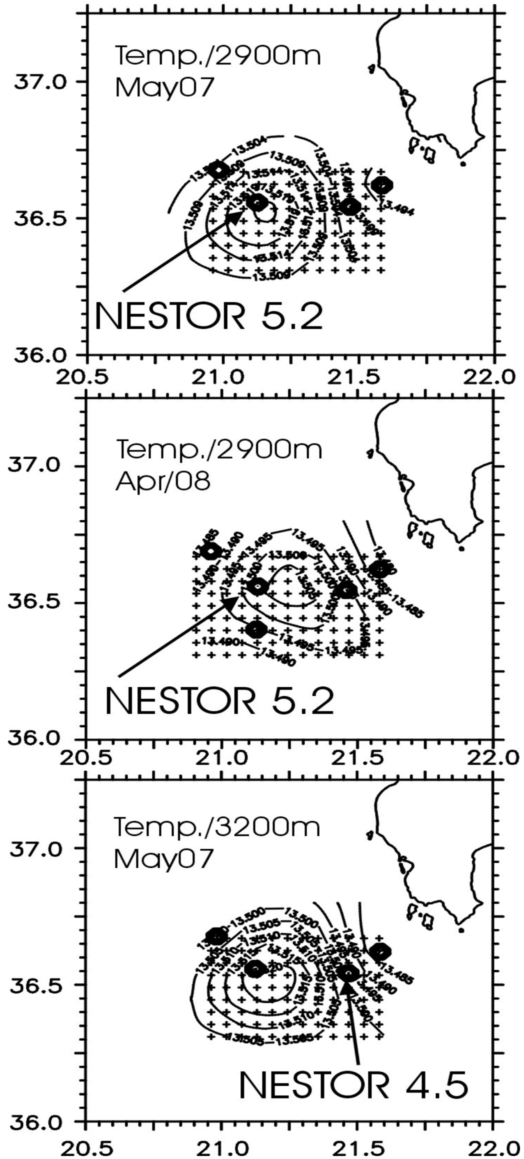
… let' s see what we have wrt u, v at NESTOR 4.5 and NESTOR 5.2 …

LOW-PASSED CURRENTS AT NESTOR 4.5 and distribution of current directions



LOW-PASSED CURRENTS AT NESTOR 5.2 and distribution of current directions





Temperature OA maps at depths and months indicated in the inset labels. Arrows indicate positions where horizontal eddy coefficients can be determined (OA grid points at 5x5 km)

NESTOR 5.2 (at depth 2900m) / MAY 2007

K_H for heat : ~9 (± 27) $m^2 s^{-1}$
K_H for salt : ~8 (± 64) $m^2 s^{-1}$

NESTOR 5.2 (at depth 2900m) / APR. 2008

K_H for heat : ~11 (± 100) $m^2 s^{-1}$
K_H for salt : ~24 (± 600) $m^2 s^{-1}$

NESTOR 4.5 (at depth 3200 m) / MAY 2007

K_H for heat : ~890 (±11000) $m^2 s^{-1}$
K_H for salt : ~550 (± 13000) $m^2 s^{-1}$

Circulation and mixing of Med. Water west of the Iberian Peninsula (Daniault et al., Deep Sea Res. I, 1994) (salt advection-diffusion along the Med. vein) … found K_H ~ 70-to-800 $m^2 s^{-1}$ (+ a single estimate of ~1500 $m^2 s^{-1}$ / No error bars)

THANK YOU FOR YOUR ATTENTION

Cape **Oktonia**

(East coast of **Evia Isl.** / Aegean Sea / Greece)

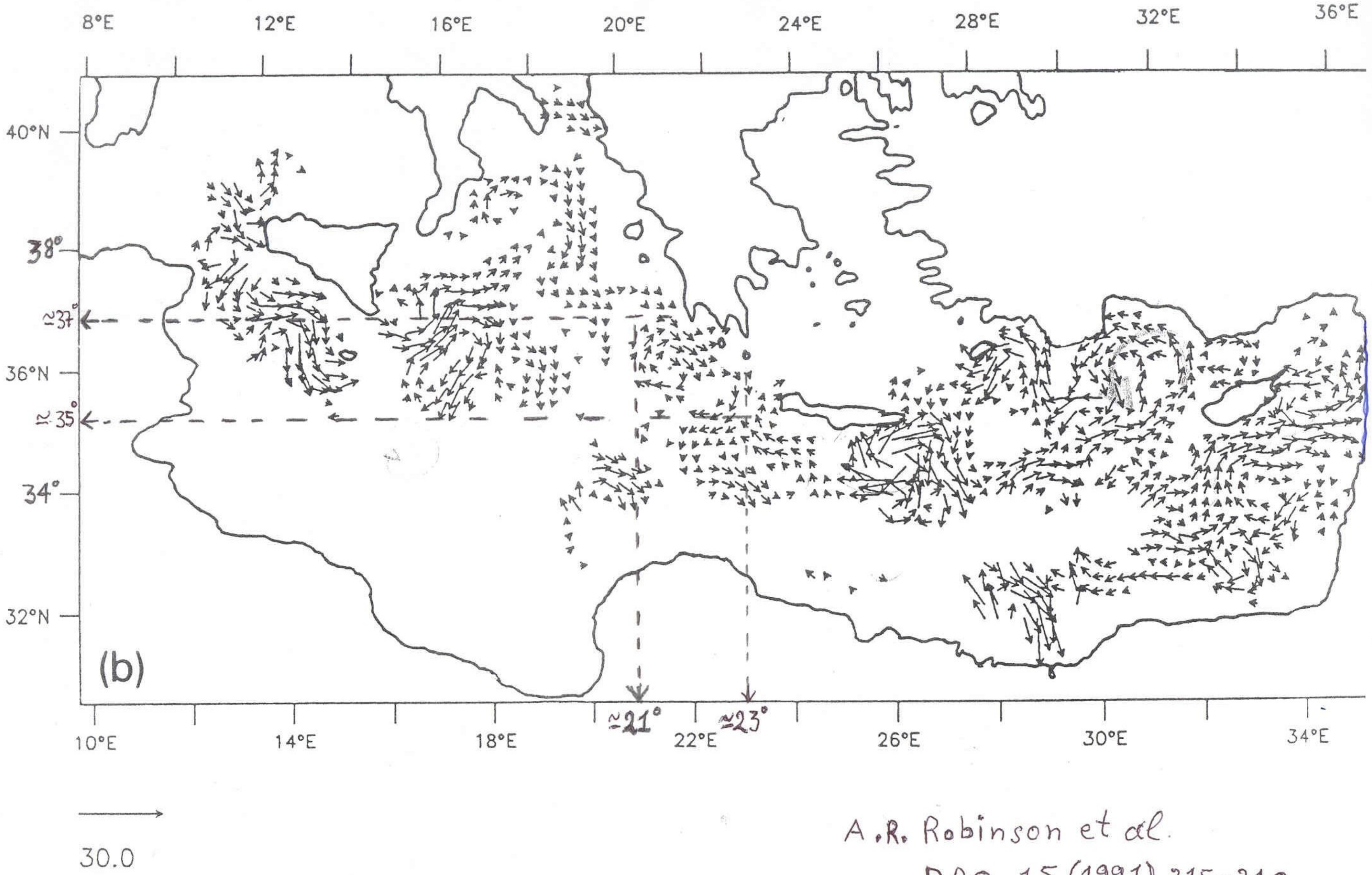


Fig. 7 (continued).

A.R. Robinson et al.
DAO 15 (1991) 215-240