Tidal modulation of wave-setup and wave-induced currents on the Aboré coral reef, New Caledonia

Philippe BONNETON, Jean-Pierre LEFEBVRE, Patrice BRETEL, Sylvain OUILLON, Pascal DOUILLET

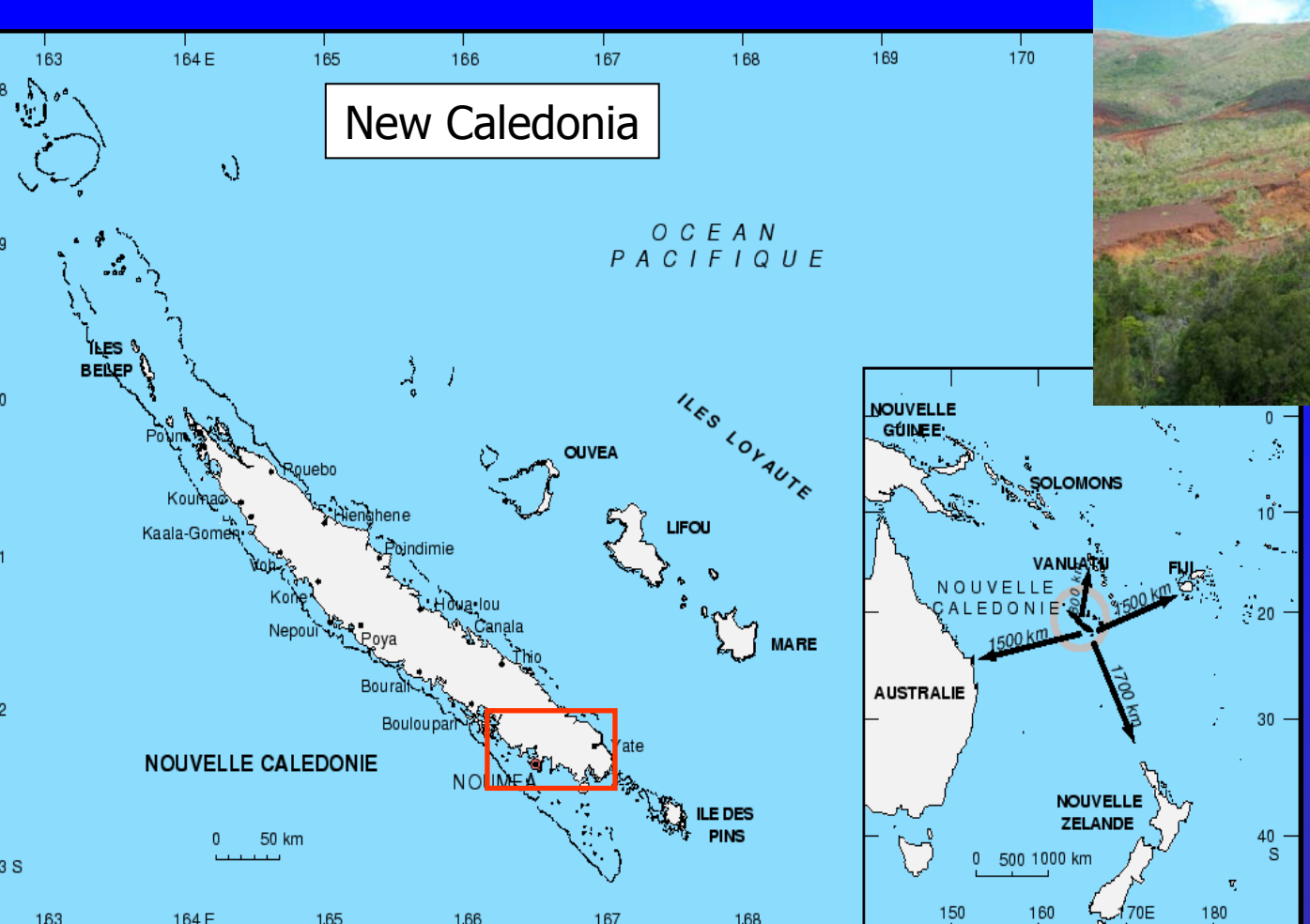
Department of Geology and Oceanography, UMR EPOC, CNRS, University of Bordeaux 1, France

Institut de Recherche pour le Développement, UR Camelia, Nouméa, New Caledonia, France

IRD Institut de recherche

18th April 2007

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE



- Nickel : Opencast mining, 30 % of global reserves (3rd global producer)
- Total lagoon area : 23 400 km²
- Nouméa (main city) : 120 000 people

Context : urbanism, mining ⇨ Focus on the Nouméa lagoon (red box : 2100 km²)

Meteorological stations

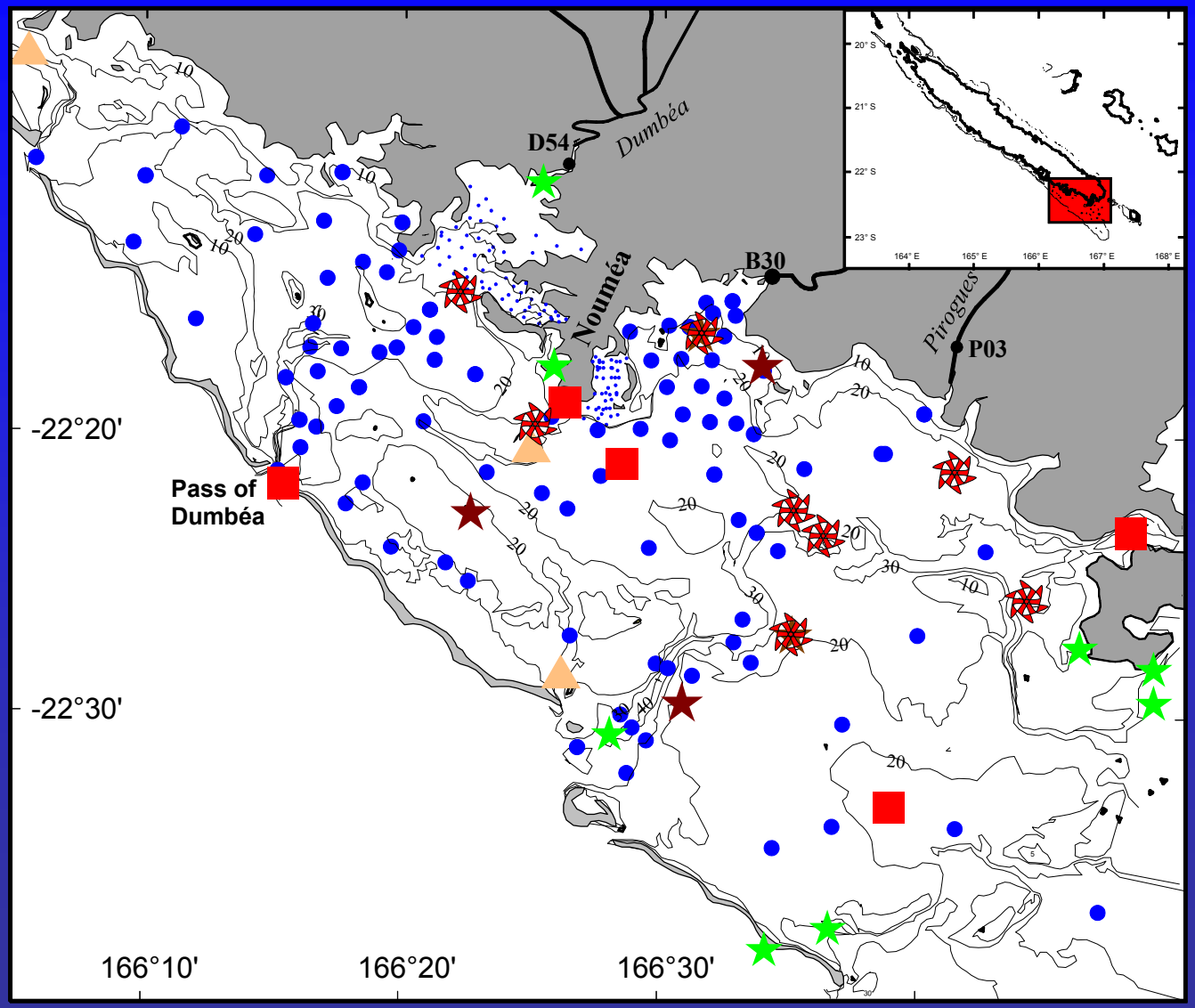
Tide recorders

Currentmeter moorings

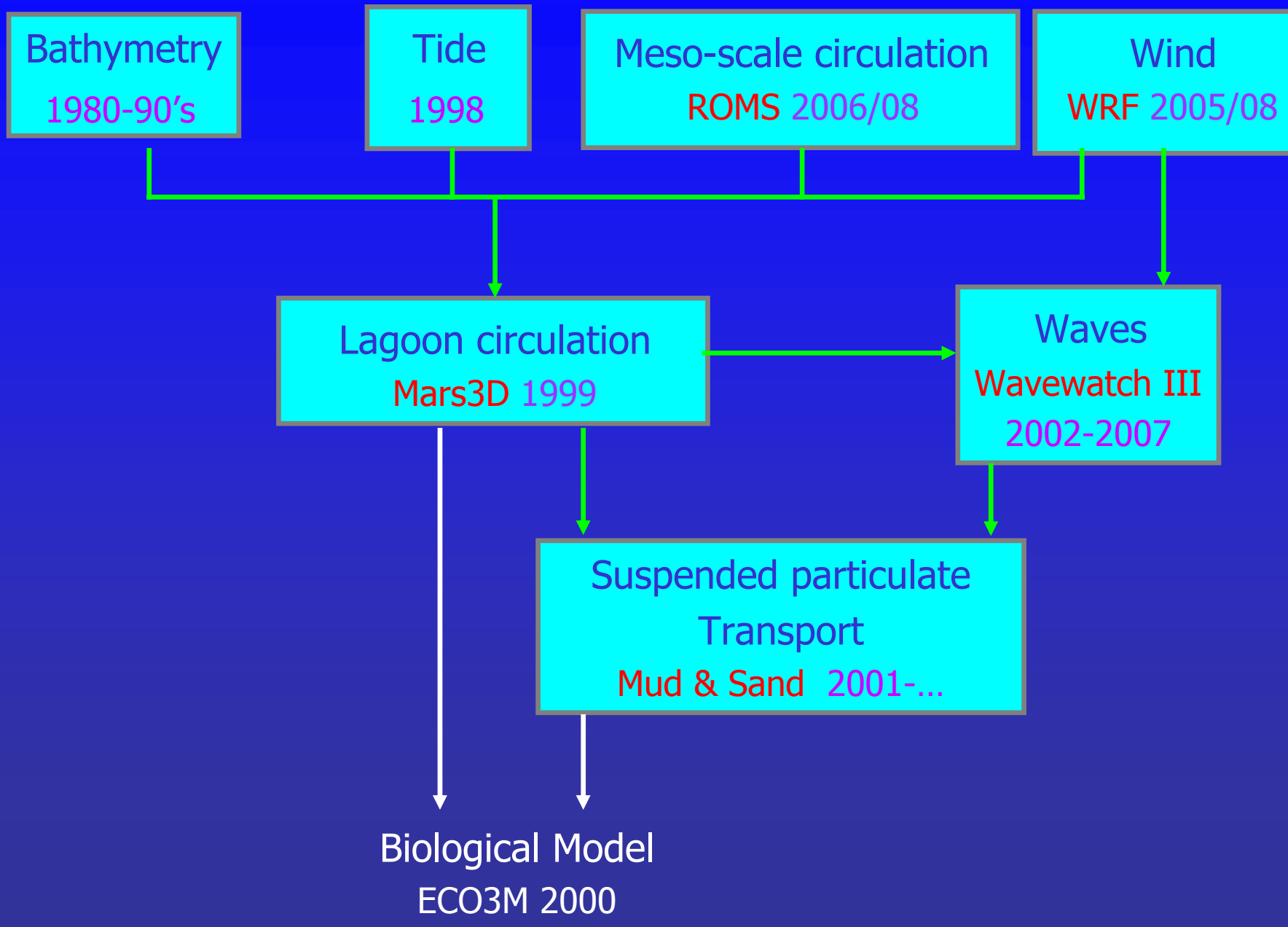
CTD profiling

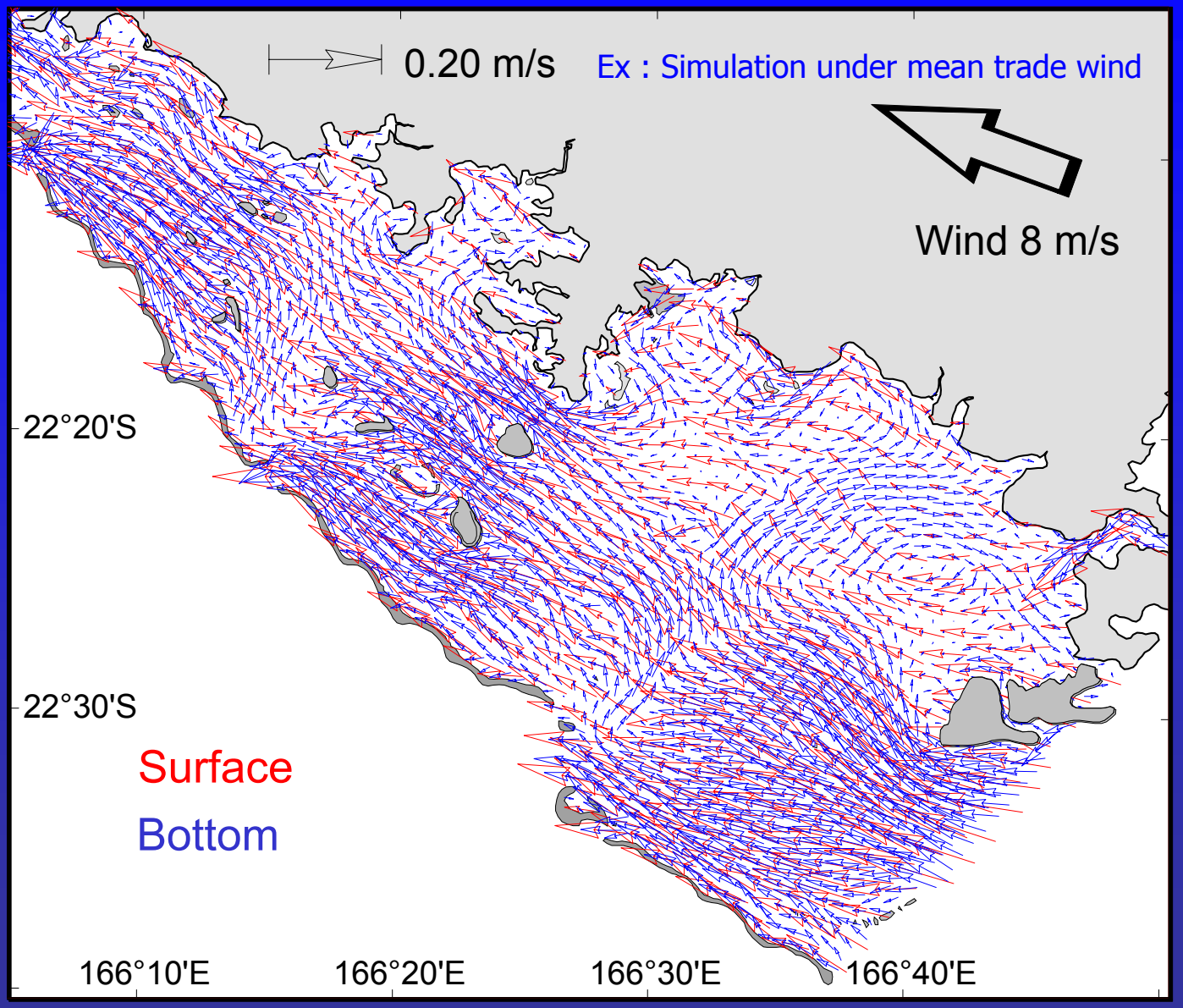
Doppler profiling

Wavemeter



Ouillon, Douillet, Fichez, Panché, 2005, *C R Geoscience*, 337 (16), 1509-0517

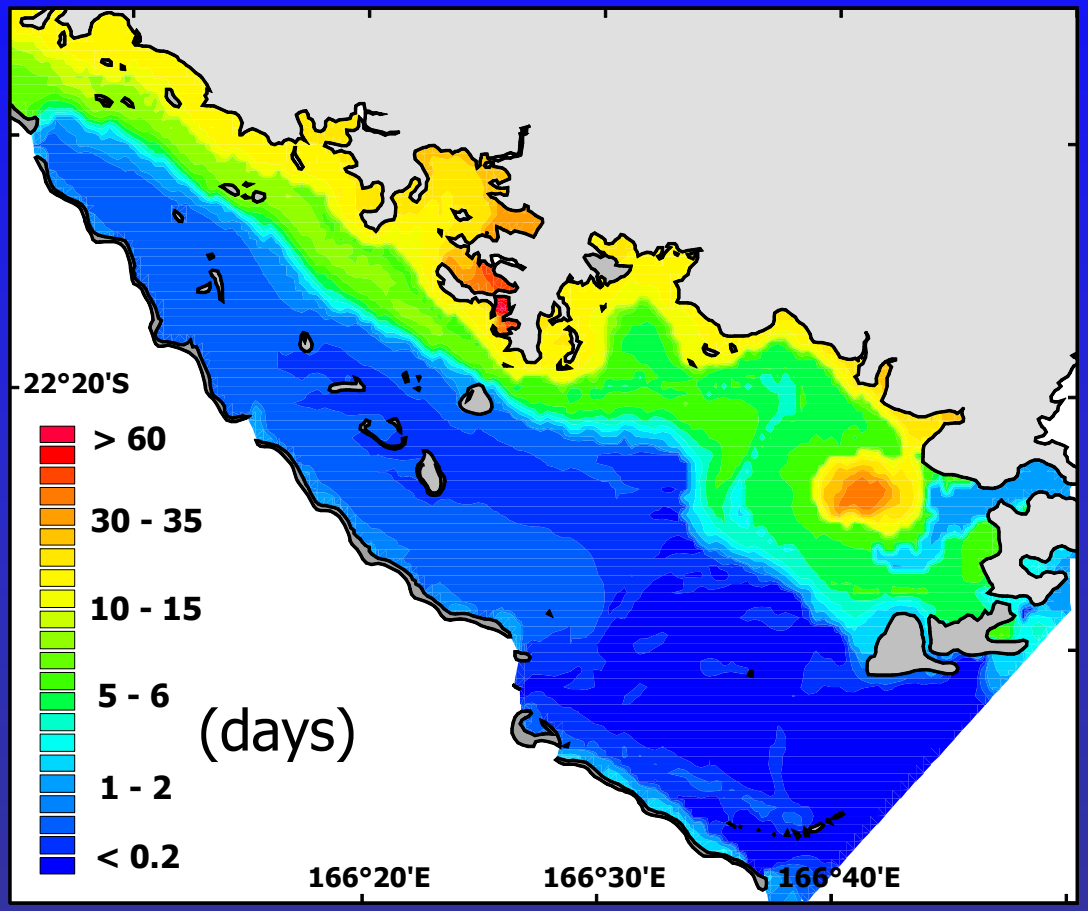

Bathymetry
1980-90's
Tide
1998
Meso-scale circulation
ROMS 2006/08
Wind
WRF 2005/08
Lagoon circulation
Mars3D 1999
Waves
Wavewatch III
2002-2007
Suspended particulate
Transport
Mud & Sand 2001-...
Biological Model
ECO3M 2000



Douillet, Ouillon, Cordier, 2001, *Coral Reefs*, 20 (4), 361-372

Local flushing time (days)

Method : tracer concentration – Case : 8 m/s trade wind + Tide



Jouon, Douillet, Ouillon & Fraunié, 2006, *Continental Shelf Research*, 26, 1395-1415

What about the reef influence on the lagoon ?

- **Input and output fluxes across the barrier reef**
- **Transformation processes of waves propagating across the reef**

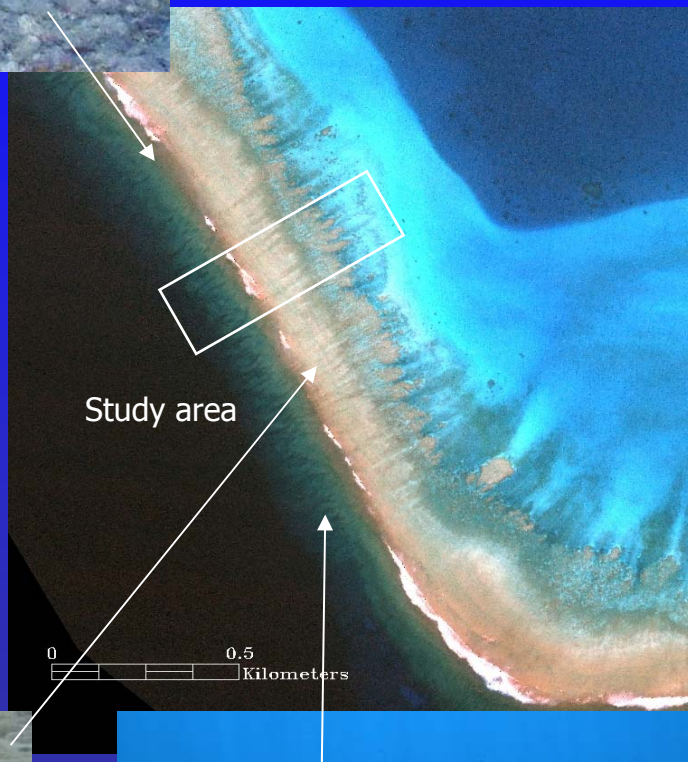
Caracterisation of energy transfert across the coral reef

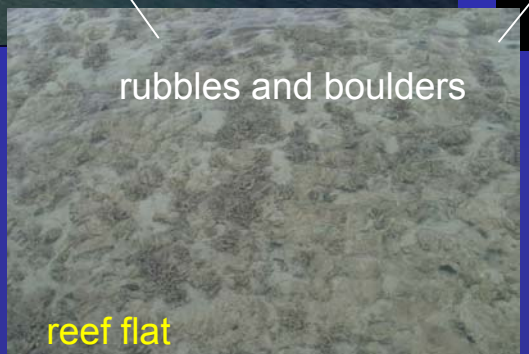
Field campaign : oct-nov 2005

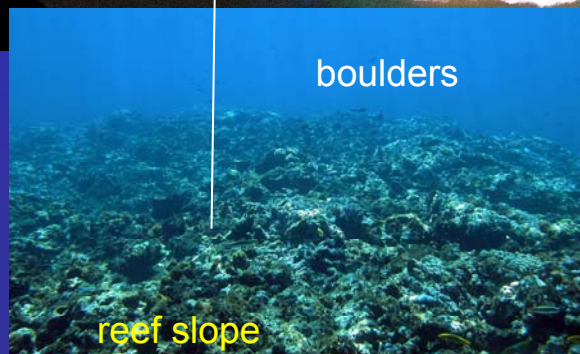
- Estimation of the wave setup
- Estimation of the cross reef-wave induced current

Study area

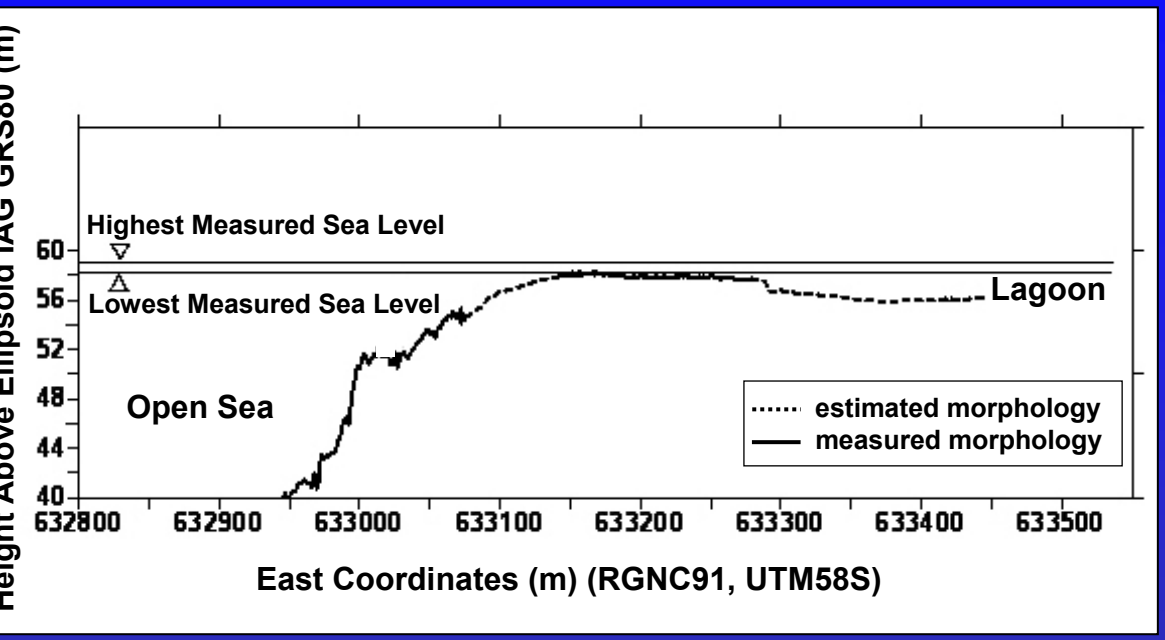

outer rim
Living corals


Study area
0
0.5
Kilometers


rubbles and boulders
reef flat

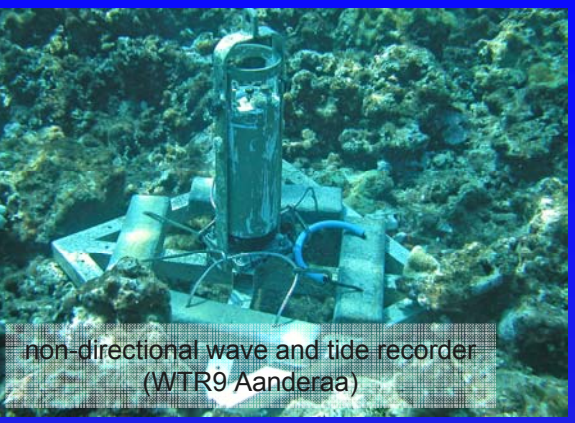

boulders
reef slope

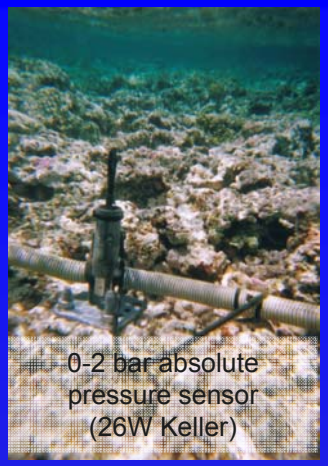
Reef profile



DGPS Trimble 5700
(vertical accuracy 5 cm)

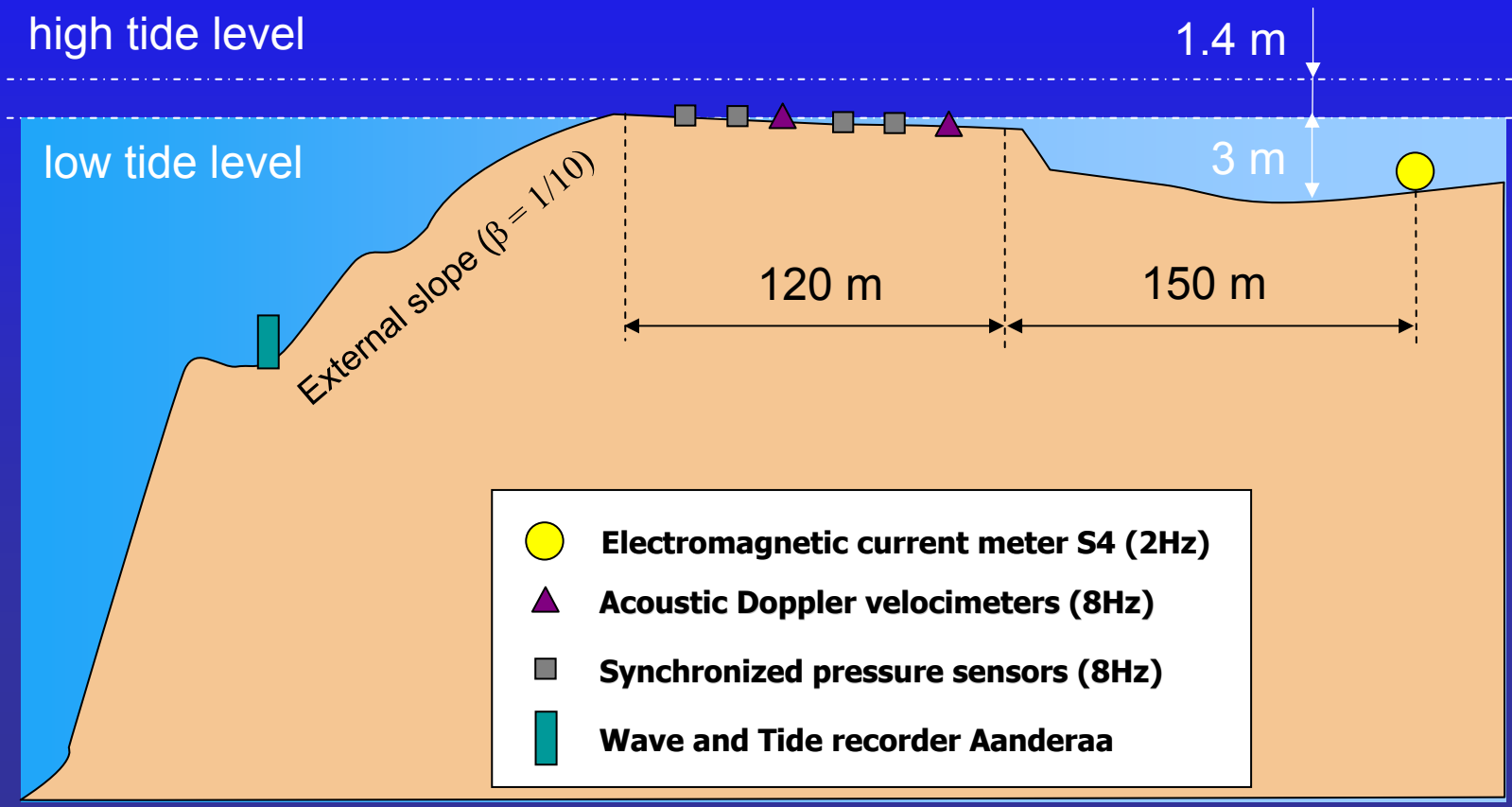
Instruments deployment


non-directional wave and tide recorder (WTR9 Aanderaa)


0-2 bar absolute pressure sensor (26W Keller)

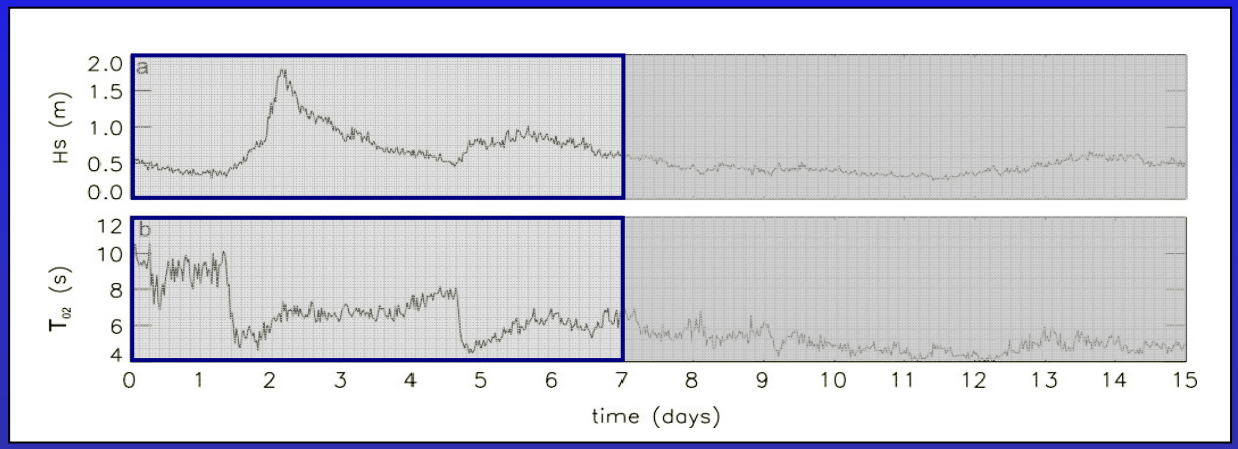

acoustic Doppler velocimeter (ADV Vector Nortek)


electromagnetic current meter (S4 InterOcean)



Wave conditions

	October, 18th to 25th (days 0 to 7)	October, 19th to November,2nd (days 8 to 15)
Wind speed ($m.s^{-1}$)	5	10
Wind direction	NW	SE
H_s (m)	0.3 to 1.8	0.25 to 0.65
$T0_2$ (s)	5 to 10	4 to 6



(a) incident significant wave height in a 6.5 m mean water depth
(b) incident wave period

Caracterisation of energy transfert across the coral reef

Field campaign : oct-nov 2005

- Estimation of the wave setup
- Estimation of the cross reef-wave induced current

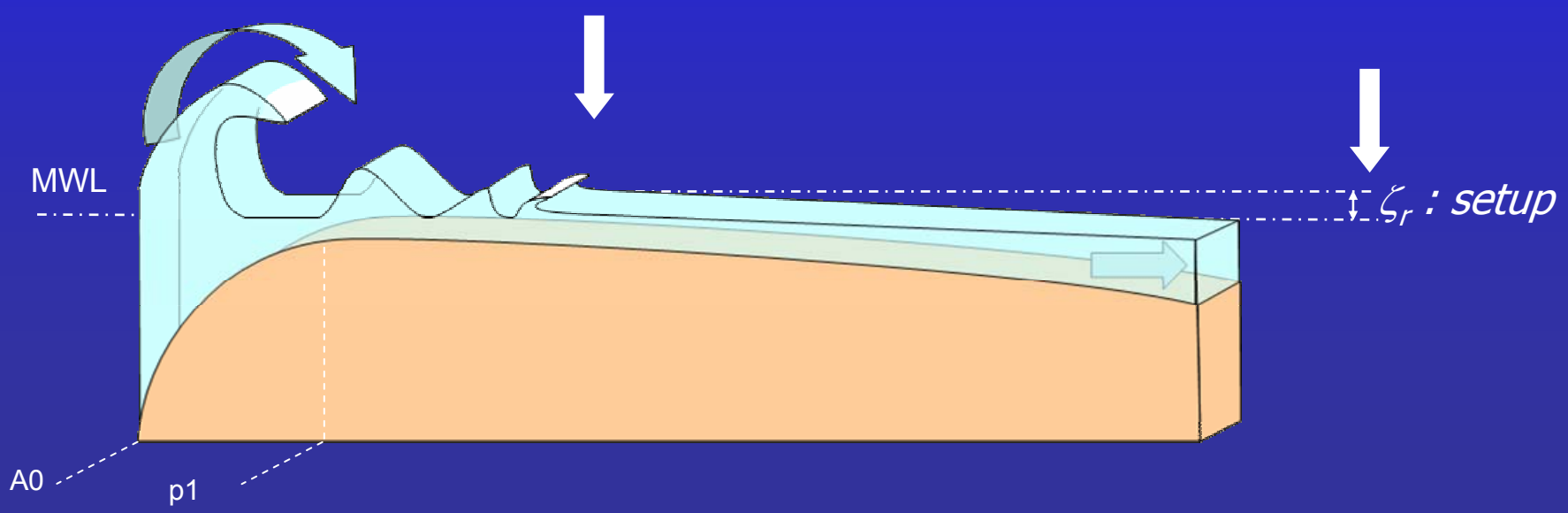
Reef-top wave setup - Measurements

$$\zeta_r = \overline{\zeta_{p1}} - \overline{\zeta_{A0}}$$

$\overline{\zeta}$: 30 minutes averaged elevation mesurements at the reef-top (p1) and offshore (A0)

h_b : *depth at the breaking point*

d_r : *mean water level over the reef (with no setup)*



Reef-top wave setup – Estimation (Symonds *et al.*, 1995)

$$d_r = \overline{\zeta_{A0}} - z_r$$

d_r : mean water level over the reef-top (with no setup)

$\overline{\zeta_{A0}}$: 30 minutes averaged elevation measurements offshore (A0)

z_r : reef-top elevation

With the conditions :

$\beta\, x_L / d_r >> 1$

$h_b \equiv Hs_b/\gamma_b$

$$\zeta_r = \alpha(h_b - d_r)$$

ζ_r : wave setup at the reef-top

h_b : water height at the breaking point

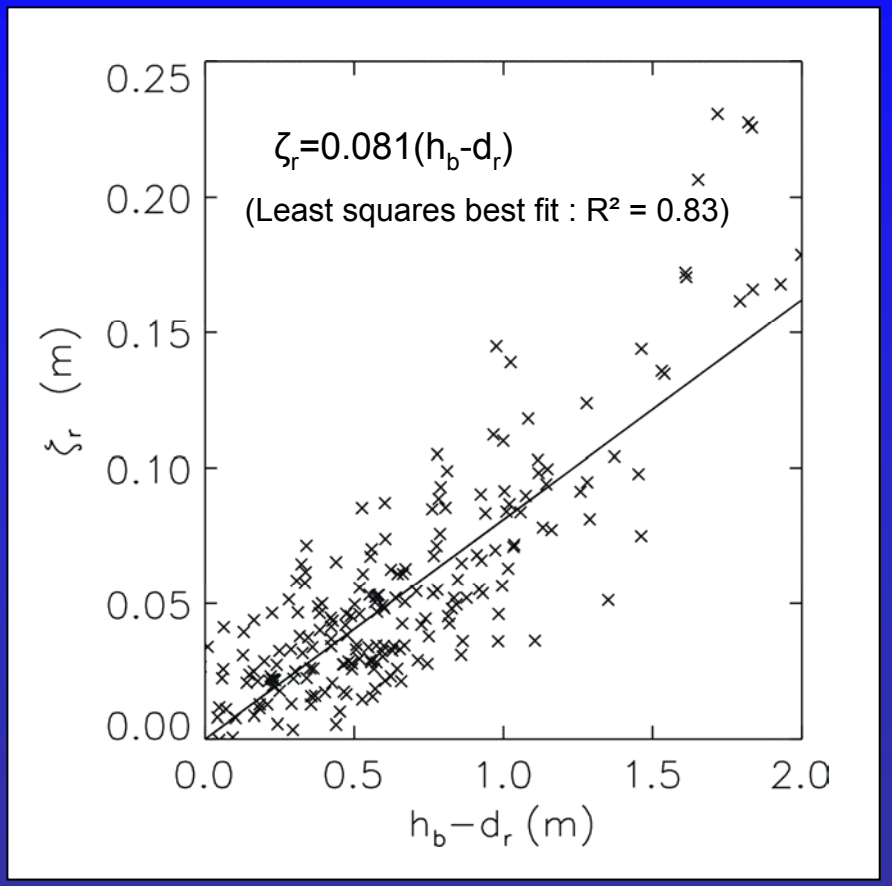
x_L : reef flat width

β : reef slope

H_0 : incident wave height

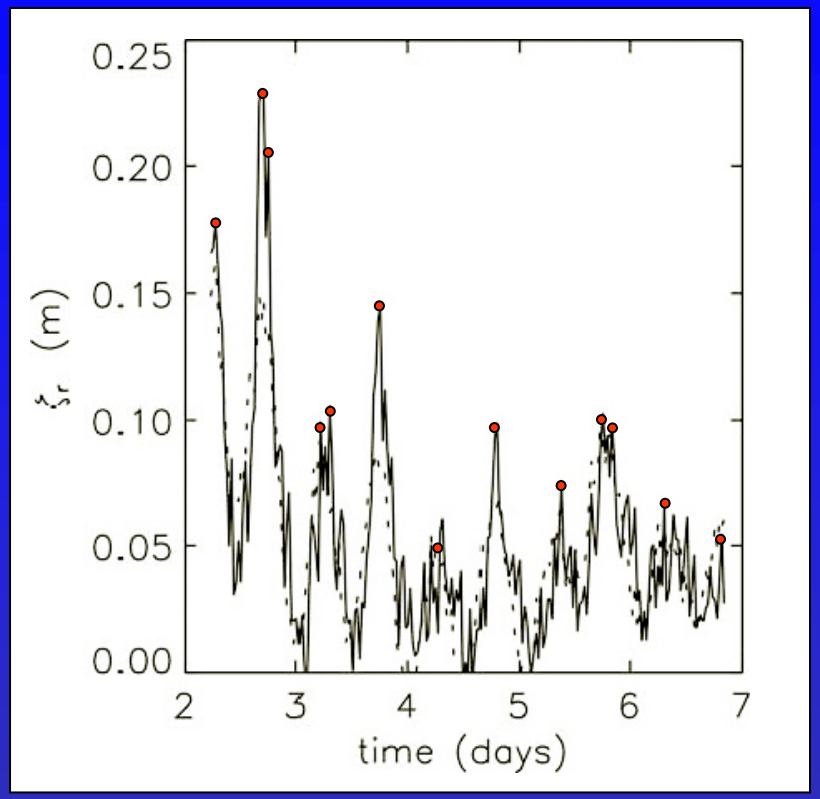
Hs_b : Hs at the breaking point

γ_b : constant breaking coefficient = 0.7 (Symonds et al., 1995)



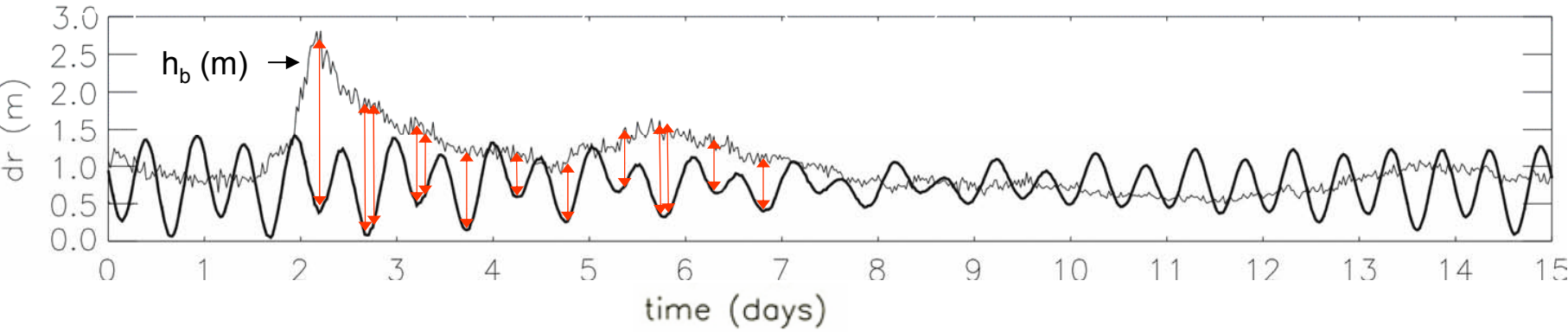
Wave setup on the reef-top, ζ_r, as a function of h_b-d_r from data acquired between day 2 and day 7.

Reef-top wave setup - Results



from $\zeta_r = \alpha (h_b - d_r)$

$\zeta_r$max is reached for $(h_b - d_r)$max

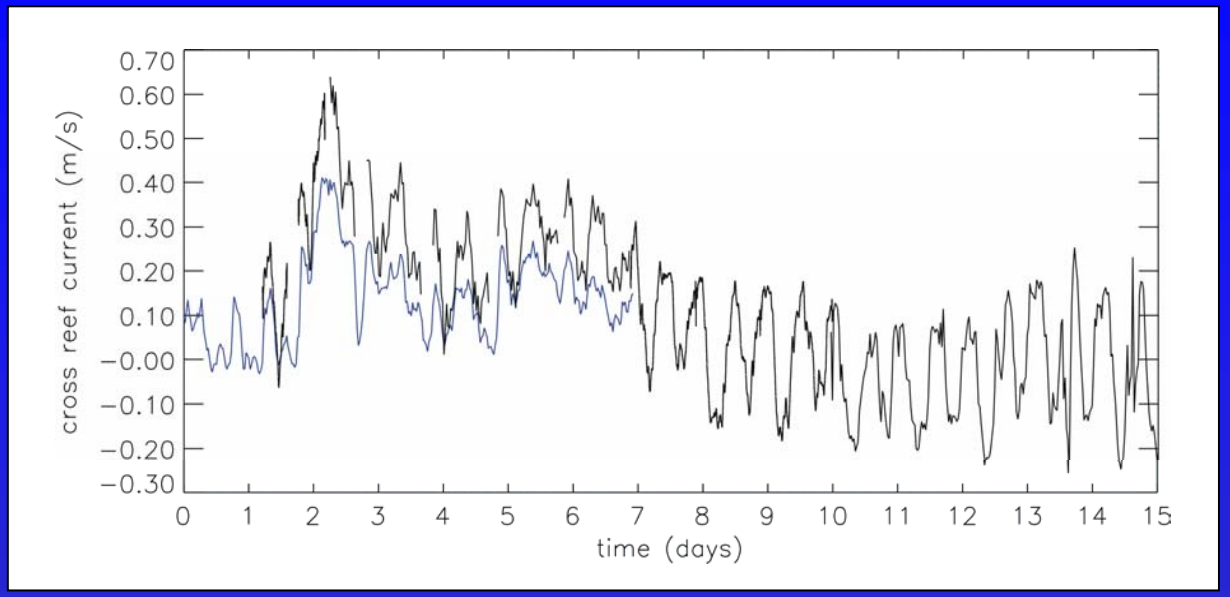


Caracterisation of energy transfert across the coral reef

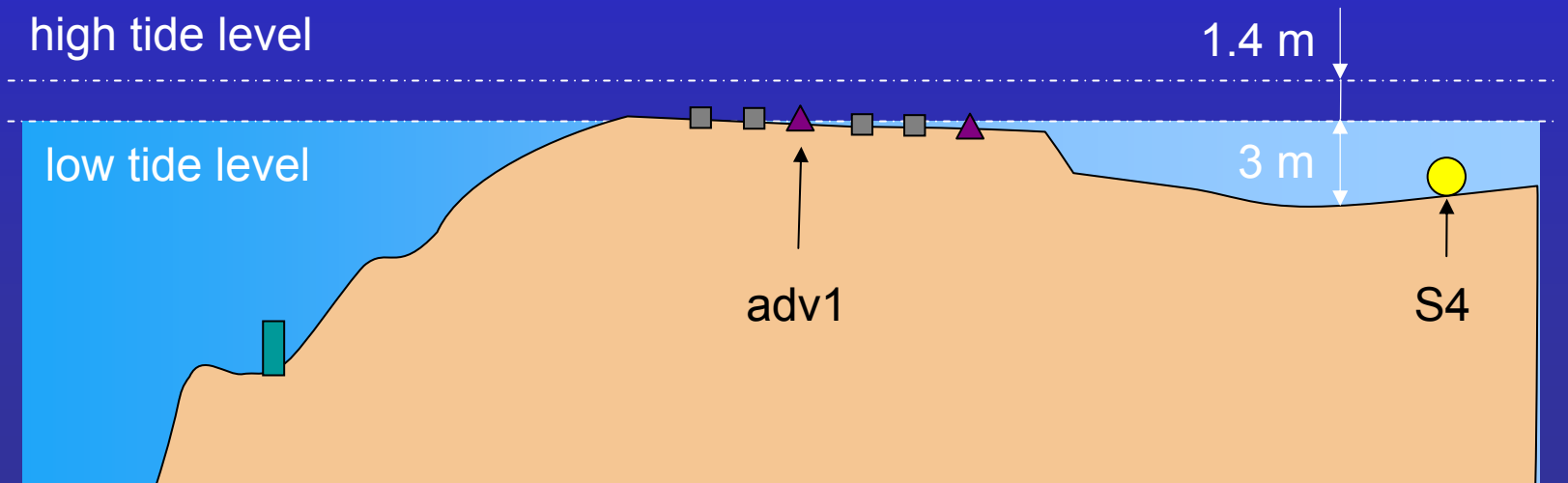
Field campaign : oct-nov 2005

- Estimation of the wave setup
- Estimation of the cross reef-wave induced current

Cross reef current - Measurements



Thirty minute averaged cross reef currents measured on the reef-top at site adv1 (black line) and in the lagoon at site S4 (blue line)

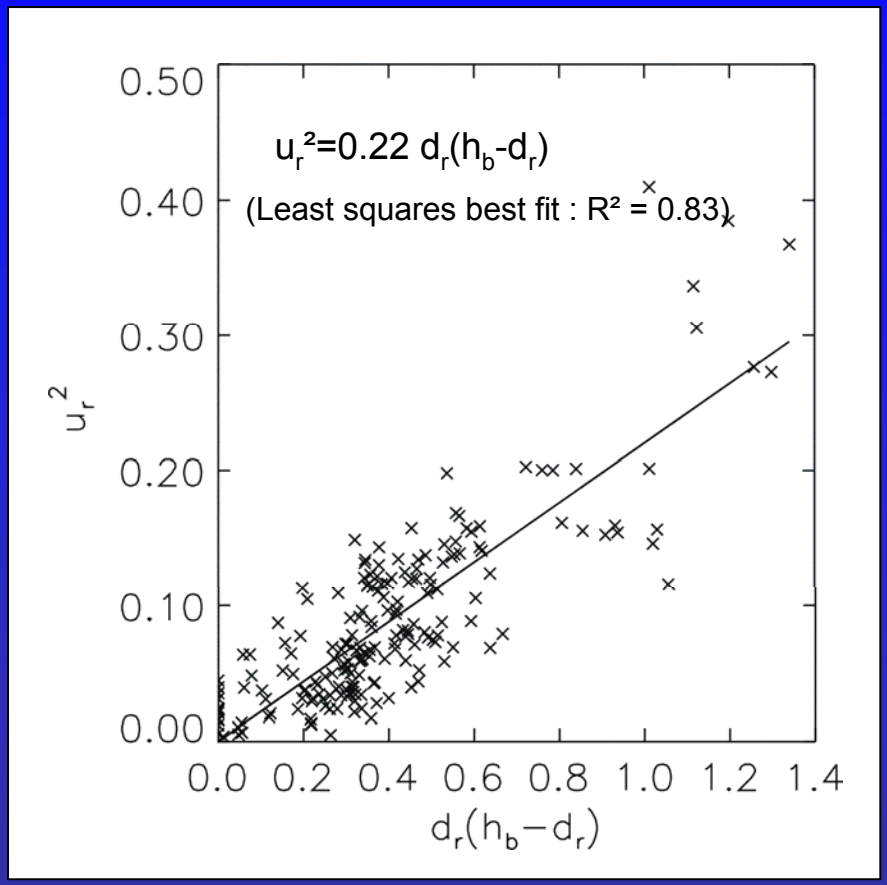


Cross-reef current – Estimation (Hearn, 1999)

With the condition : $\zeta_r/d_r << 1$

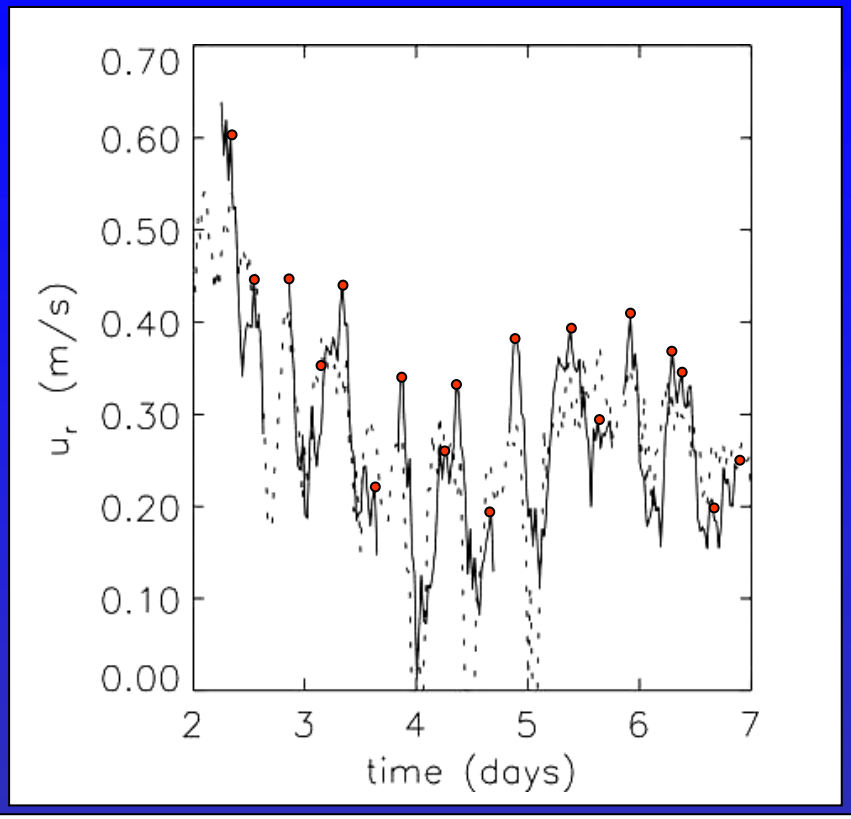
$$u_r{}^2 = K_H d_r (h_b - d_r)$$

u_r : cross-reef current
h_b : water height at the breaking
d_r : mean water level over the reef-top
K_H : Hearn's coefficient
γ_b : constant breaking coefficient = 0.7



Square of the reef-top current u_r as a function of $d_r(h_b-d_r)$ from data acquired between day 2 and day 7

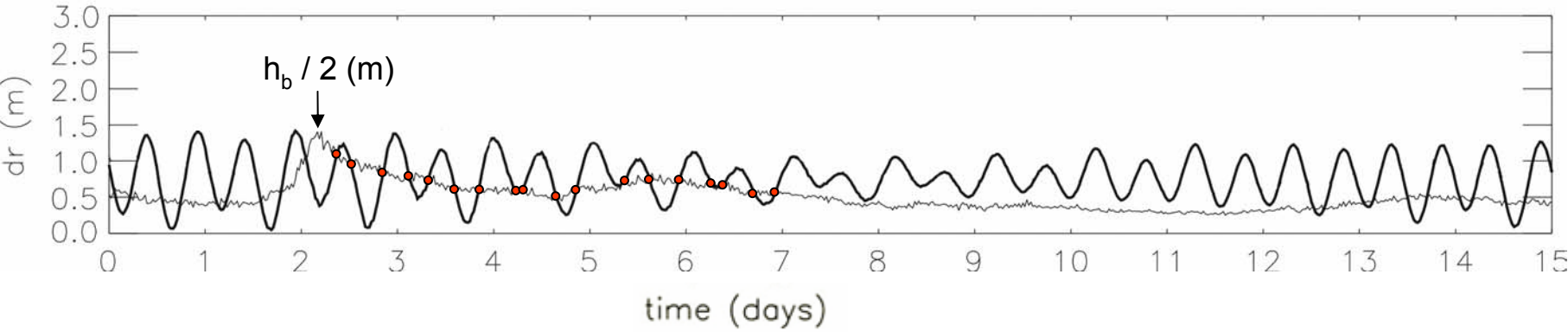
Cross-reef current – Results



from $u_r^2 = K_H\, d_r(h_b - d_r)$

- if $d_r min > h_b/2$

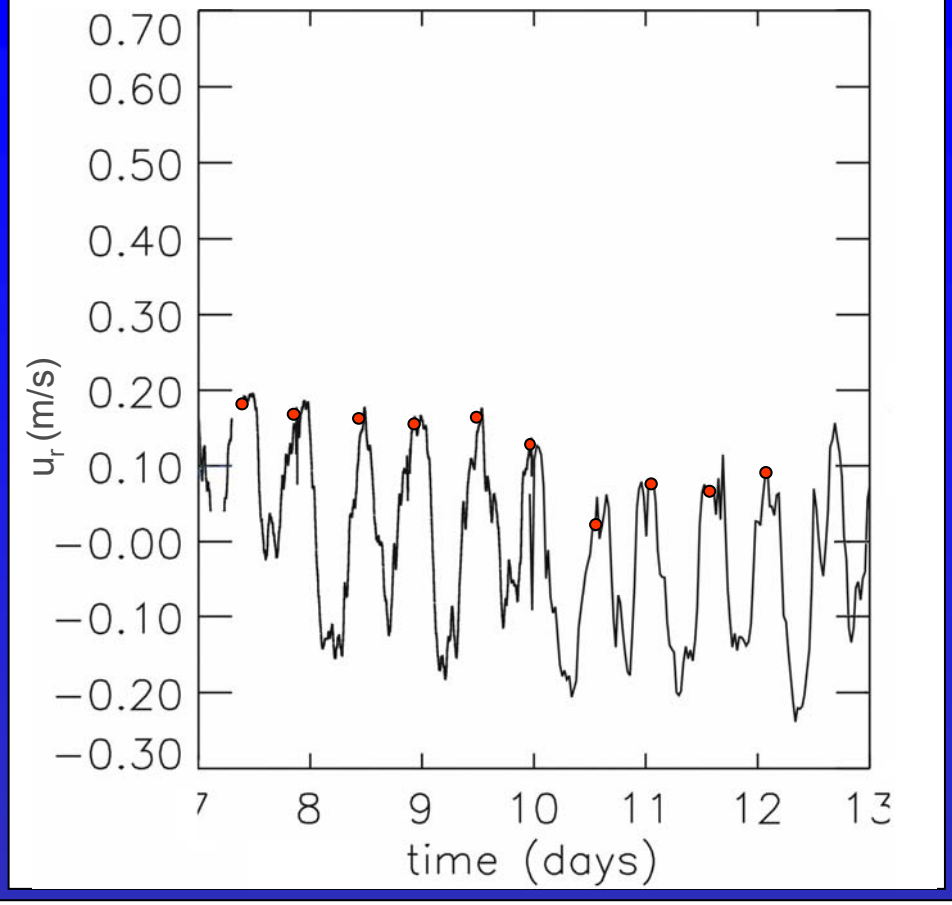
$u_r max$ is reached for $d_r = h_b/2$

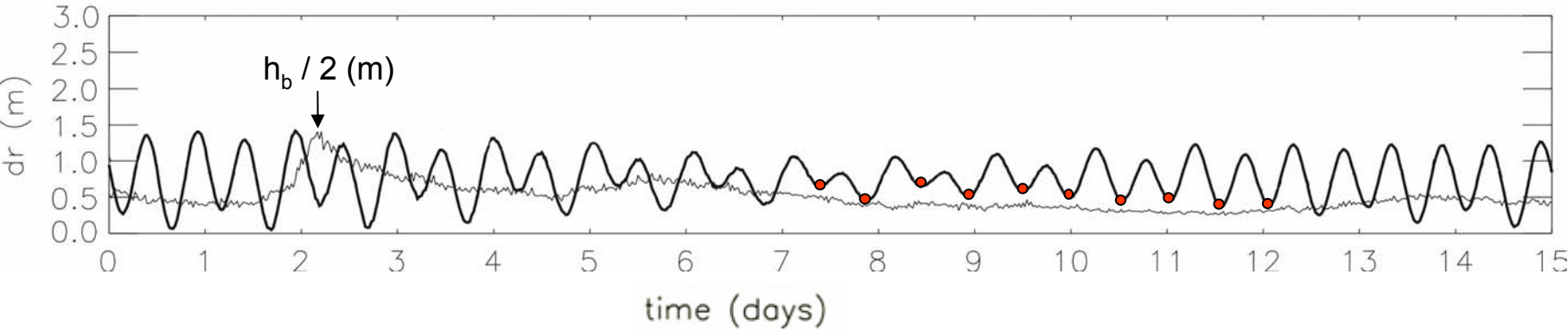


Cross-reef current – Results

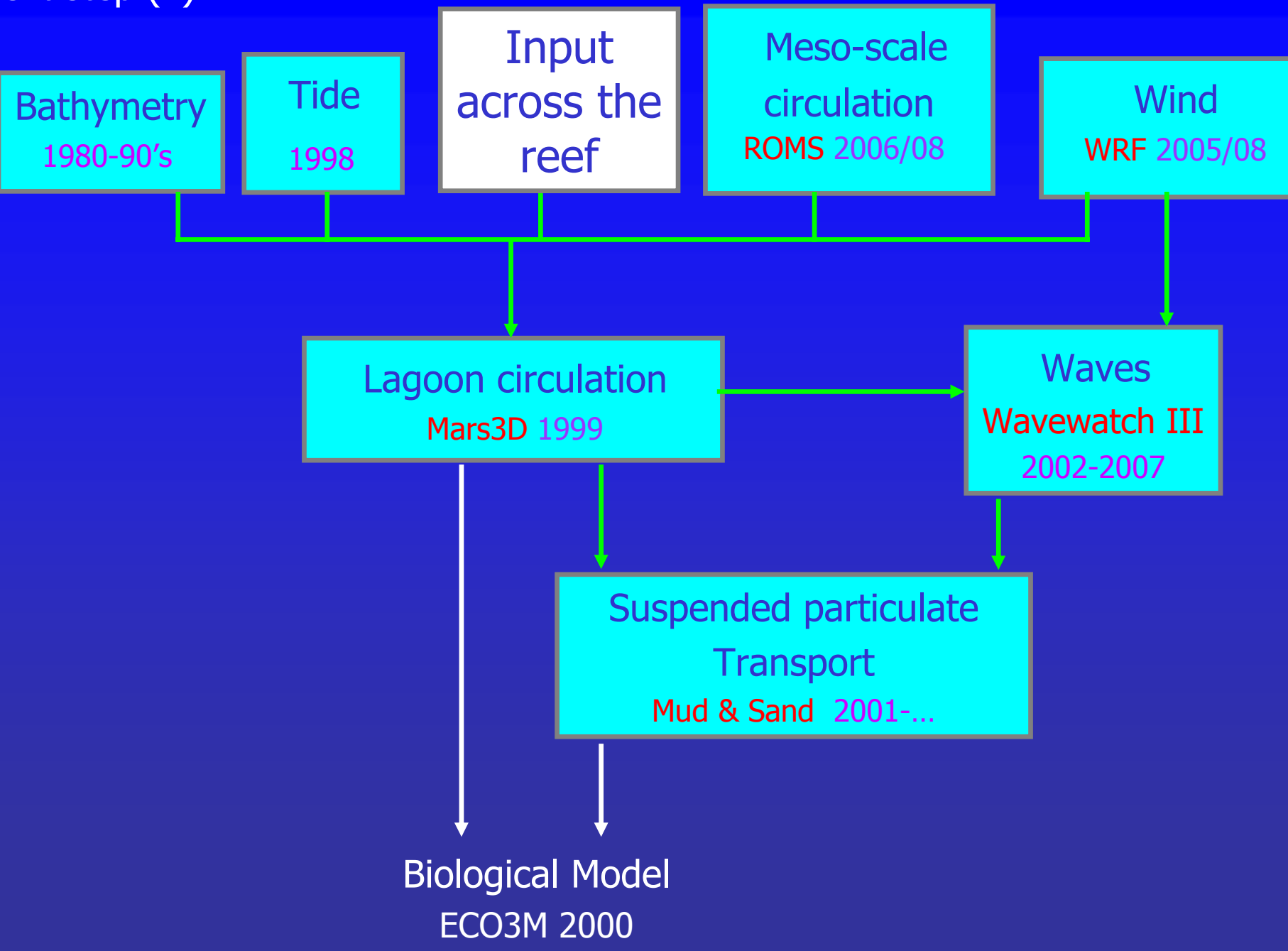
- if $d_r min > h_b/2$

$u_r max$ is reached for $d_r min$





ext step (1)

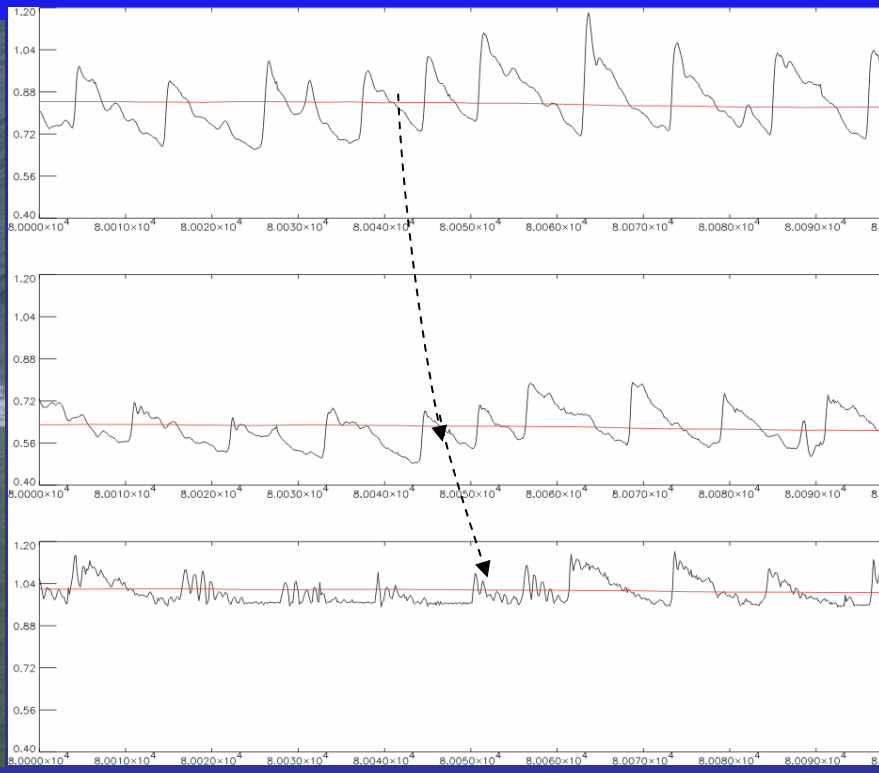

Bathymetry
1980-90's
Tide
1998
Input across the reef
Meso-scale circulation
ROMS 2006/08
Wind
WRF 2005/08
Lagoon circulation
Mars3D 1999
Waves
Wavewatch III
2002-2007
Suspended particulate Transport
Mud & Sand 2001-…
Biological Model
ECO3M 2000

Next step (2)

Transformation processes of waves propagating across the reef

Harmonic generation (triads)

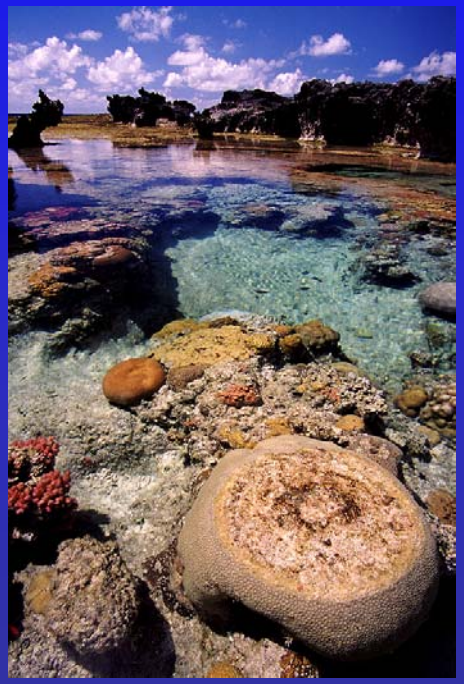
« Boussinesq type » approach to model harmonic generation



CONCLUSION

Strong correlation between wave induced setup and tidal level oscillations:

- ζ_r is maximum when d_r is minimum
- when $h_b > 2d_r$: u_r oscillated with a maximum twice a tide, out of phase with d_r
- when $h_b < 2d_r$: u_r oscillated with a maximum at low tide, 180° out of phase with d_r



Further details in the proceedings :

Bonneton, Lefebvre, Bretel, Ouillon & Douillet, 2007, *J Coastal Research*, in press