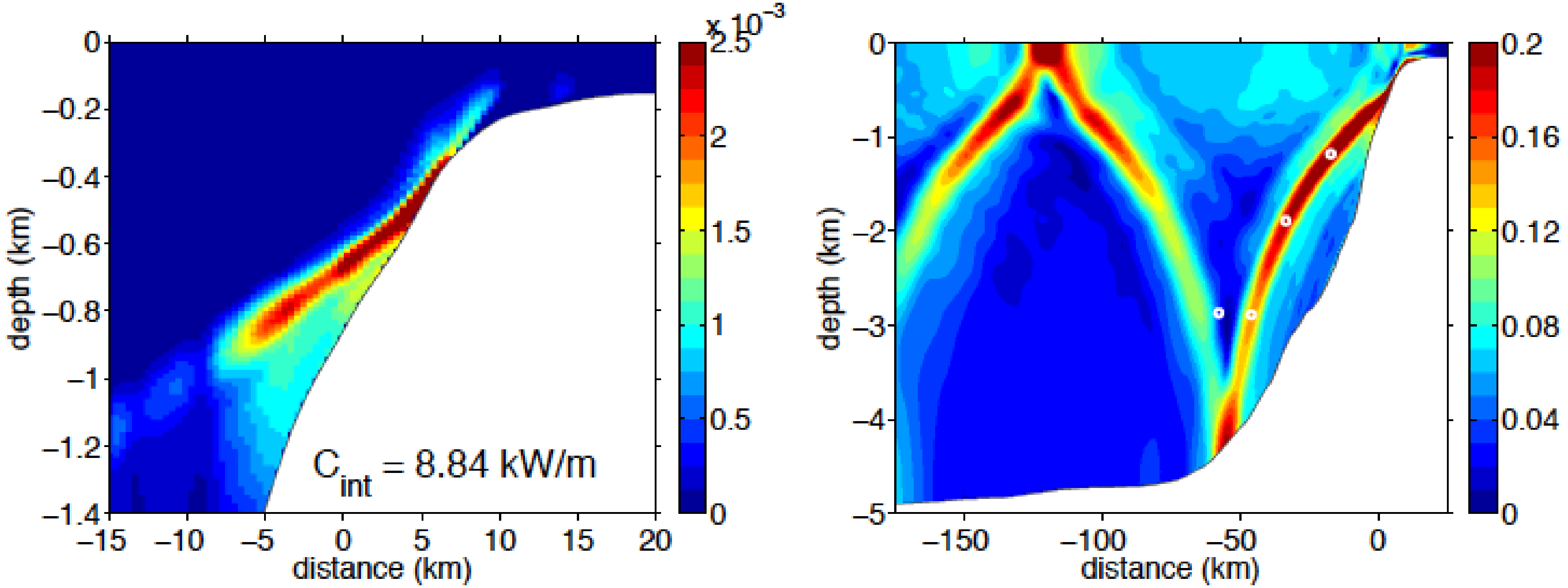
Observation of internal tides and solitary waves during Mouton2008

Xiaohui Xie, Pascale Bouruet Aubertot, Yannis Cuypers, Antonio Lourenço
Locean-ipsl UPMC
Annick Pichon (SHOM)
Bruno Ferron (LPO)

Internal tide and nonlinear solitary internal waves generation in the Bay of Biscay

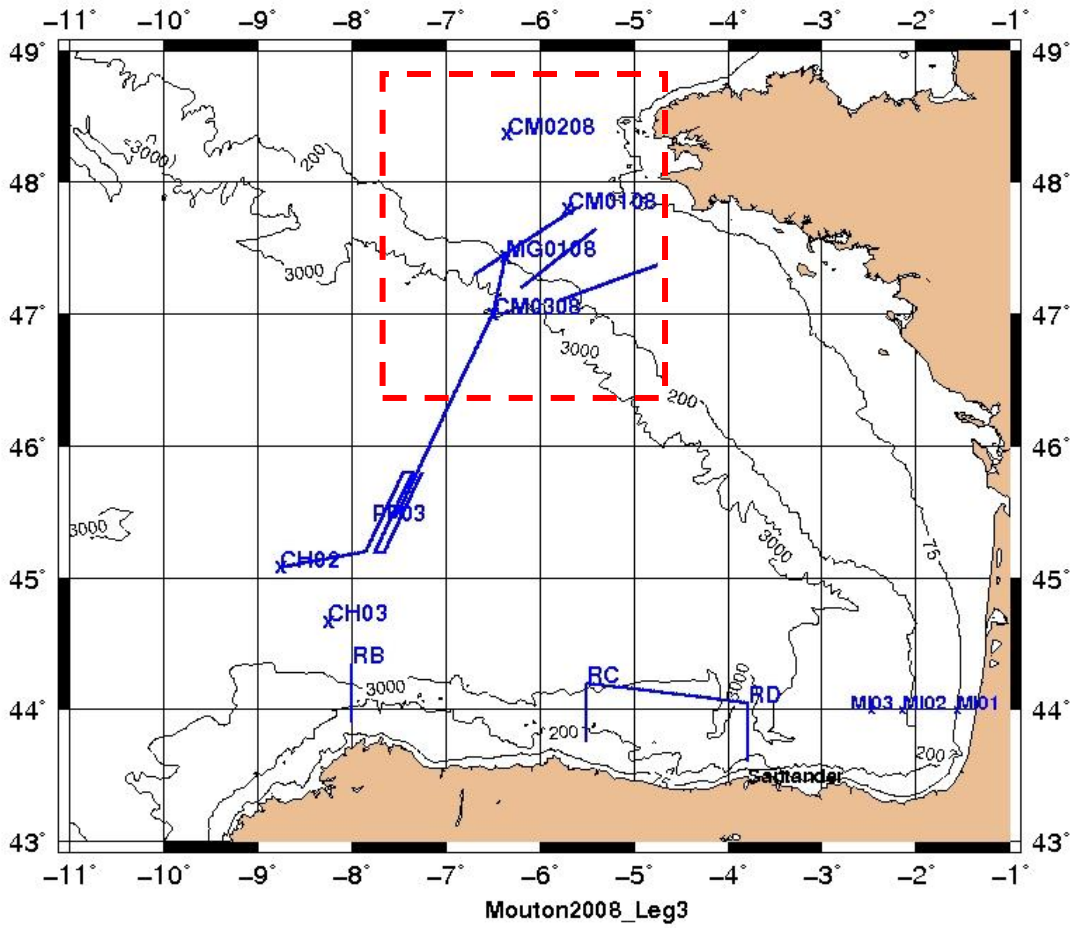
Numerical simulations from Gerkema (2008)

- Internal tides in Bay of Biscay are mainly generated at the continental slope
- After generating, internal tides propagate their energy to deep sea and coast. In this course, they can gradually evolve into a series of high-frequency nonlinear solitary waves due to the nonlinear steepening.



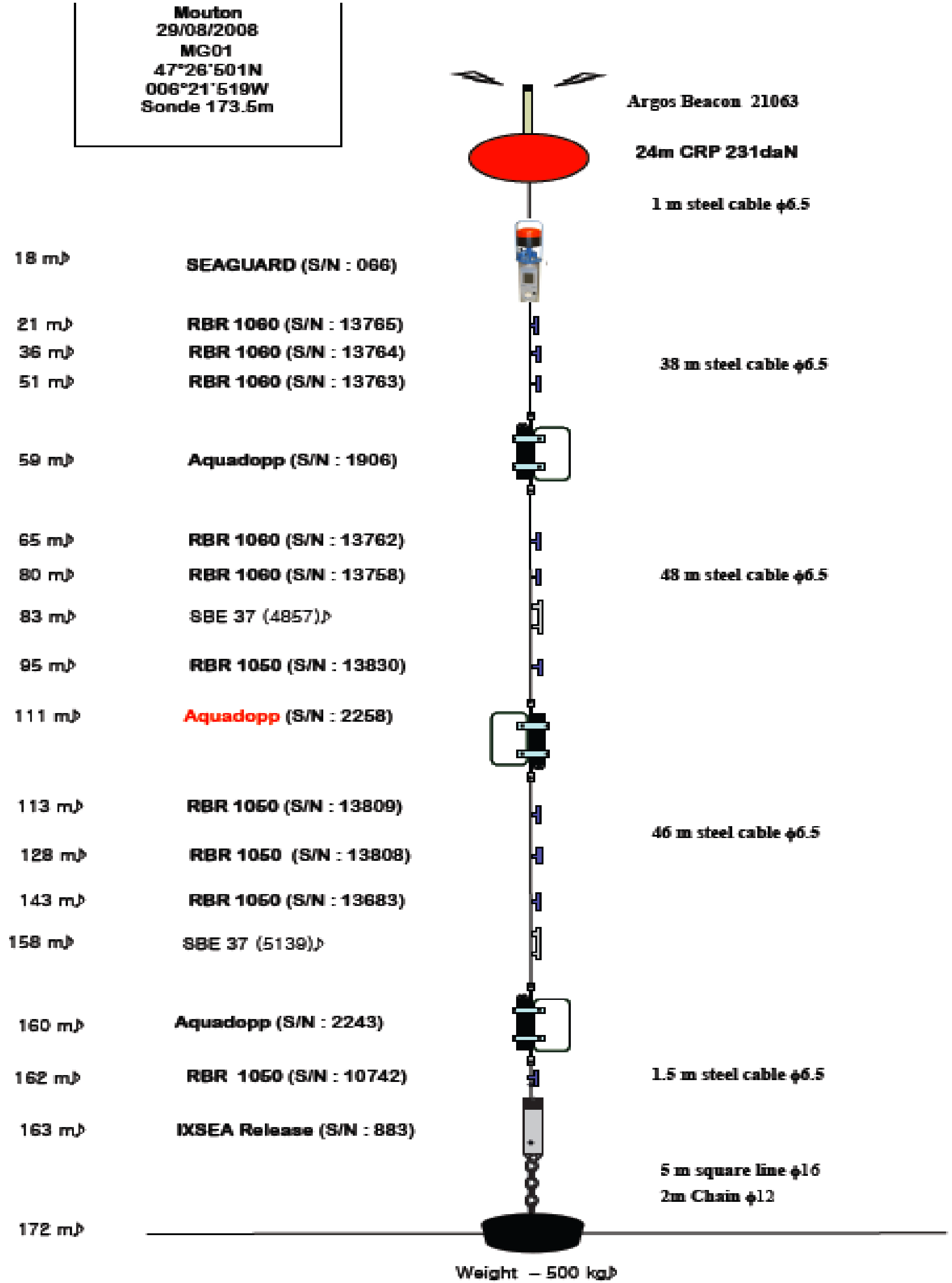
Mouton2008

- Four moorings with temperature chain and current meter were deployed in the northern Bay of Biscay. Its main object is to study generation and evolution of internal tides and solitons.
- Four moorings are located in CM01, CM02, CM03, and MG01. Amongst, MG01 is in the shelf break, where there is the strongest internal tide. Data obtained at this site have higher sampling in both time and space.



MG01 mooring (174 m depth)

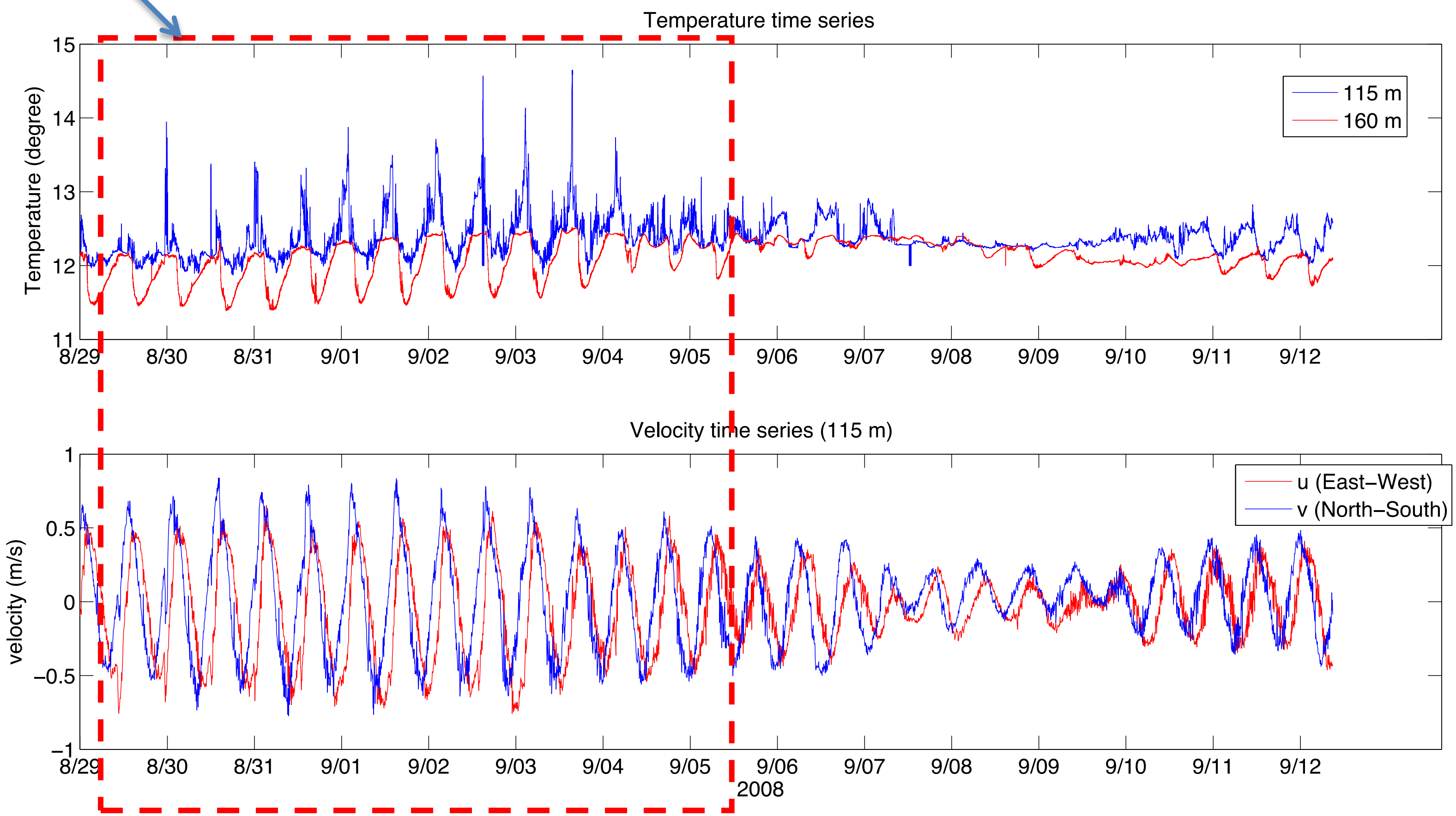
- 10 RBR high frequency temperature sensors (from 18 to 162 m, Δz=15 m), with time sampling of 5 seconds
- 2 SBE sensors, with Δt=5 s
- 4 current meters at depths of 20, 59, 115 and 160 m, Δt=5 mins



Time series

Spring tide
(8/29~9/05)

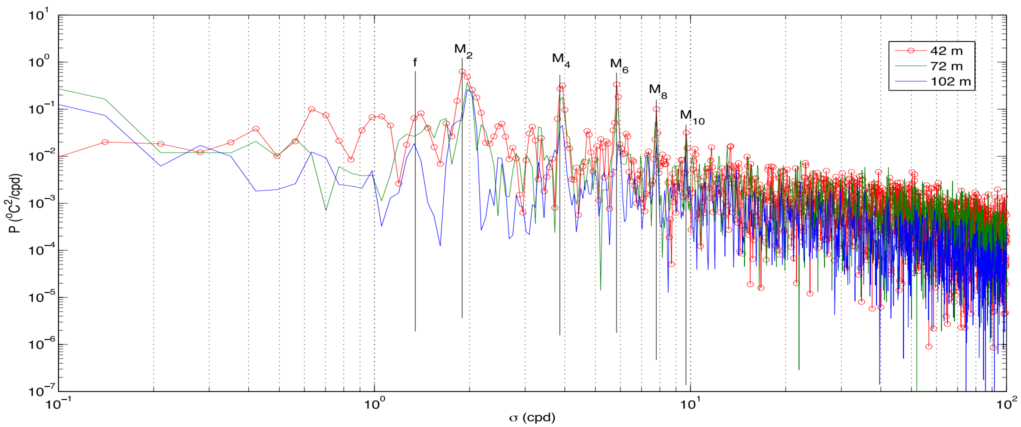
Time series of temperature at 115 and 160 m (top) and current velocity at 115 m (bottom)



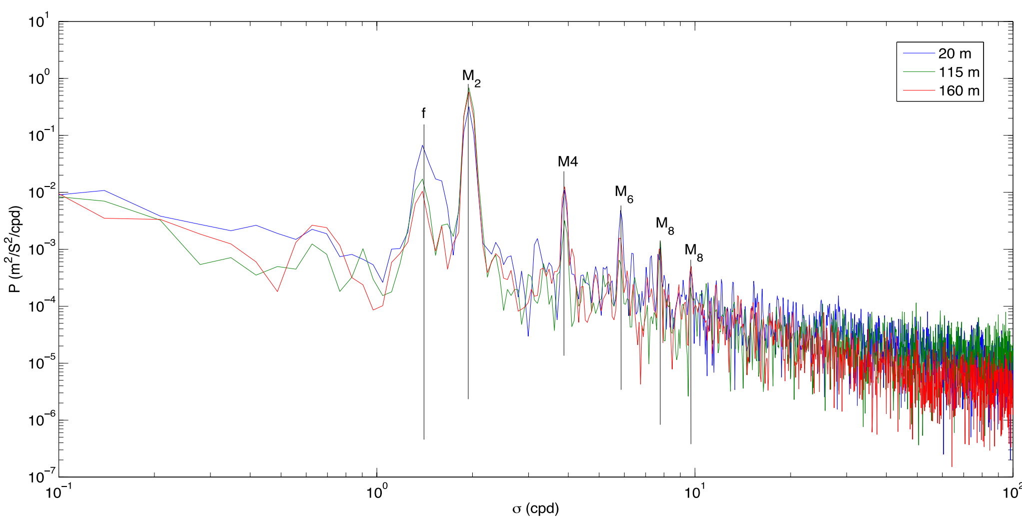
Dominant semidiurnal tidal period (12hours)

Frequency components of internal wave field

Temperature fluctuation spectra at 42, 72 and 102 m.



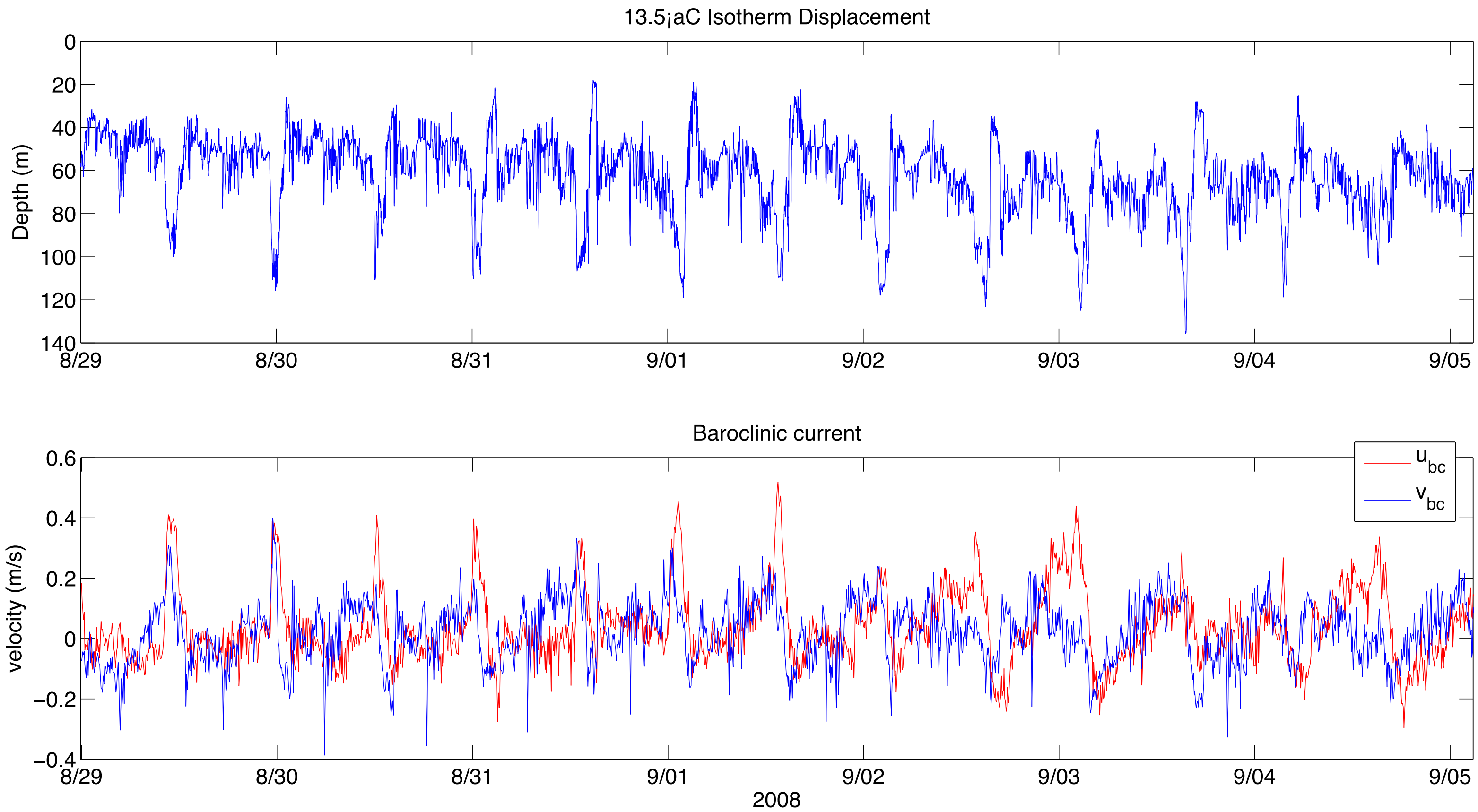
Kinetic energy spectra at 20, 115 and 160 m



- Signal variation in the internal wave field are dominated by M2 and its higher harmonics (such M4, M6)
- Also, inertial peak (*f*) is significant.

Isotherm displacement and baroclinic velocity

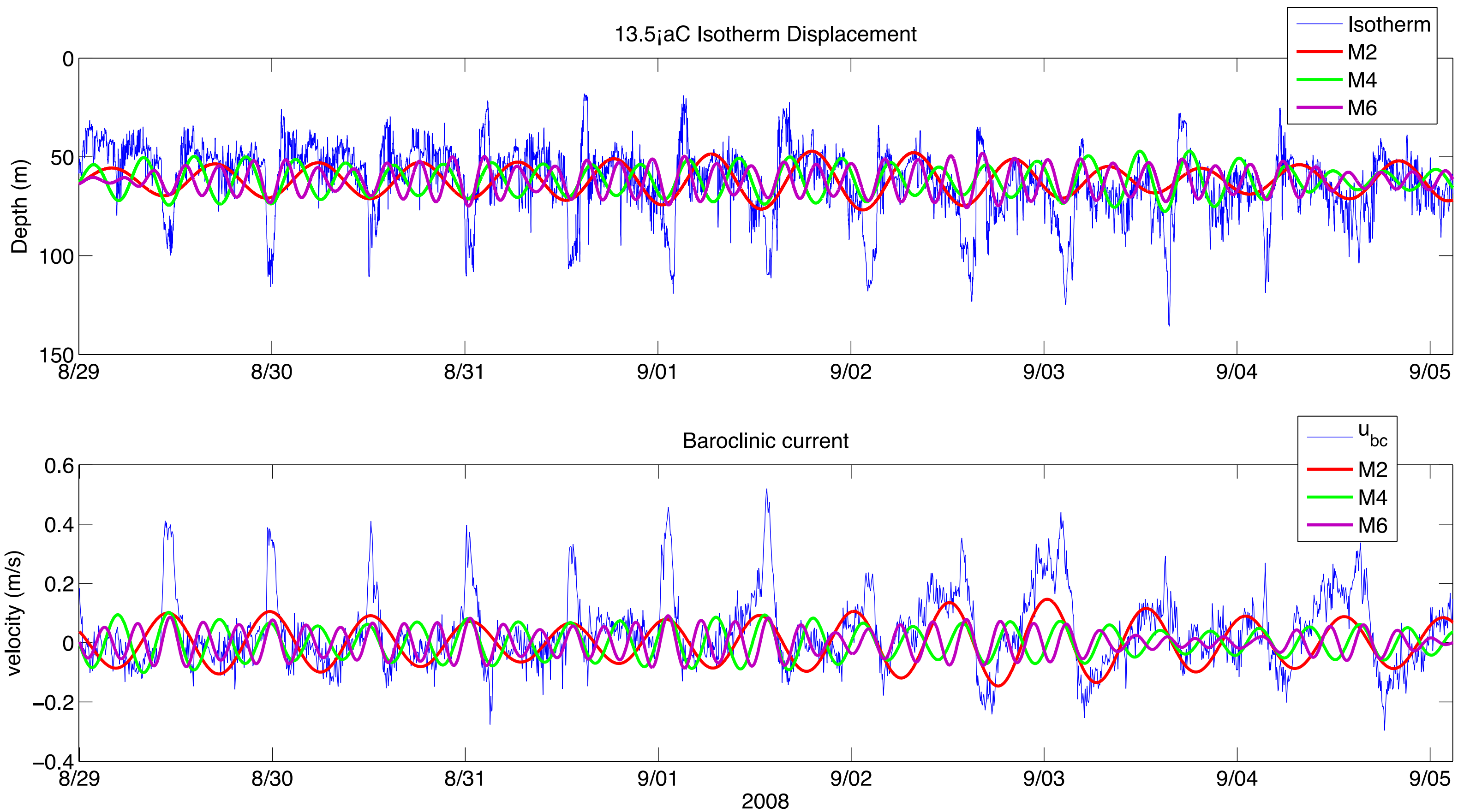
The 13.5 C isotherm displacement (top) and
baroclinic velocity (bottom) during spring tide



The largest displacement caused by internal waves is more than 50 m, generating strong north-east currents

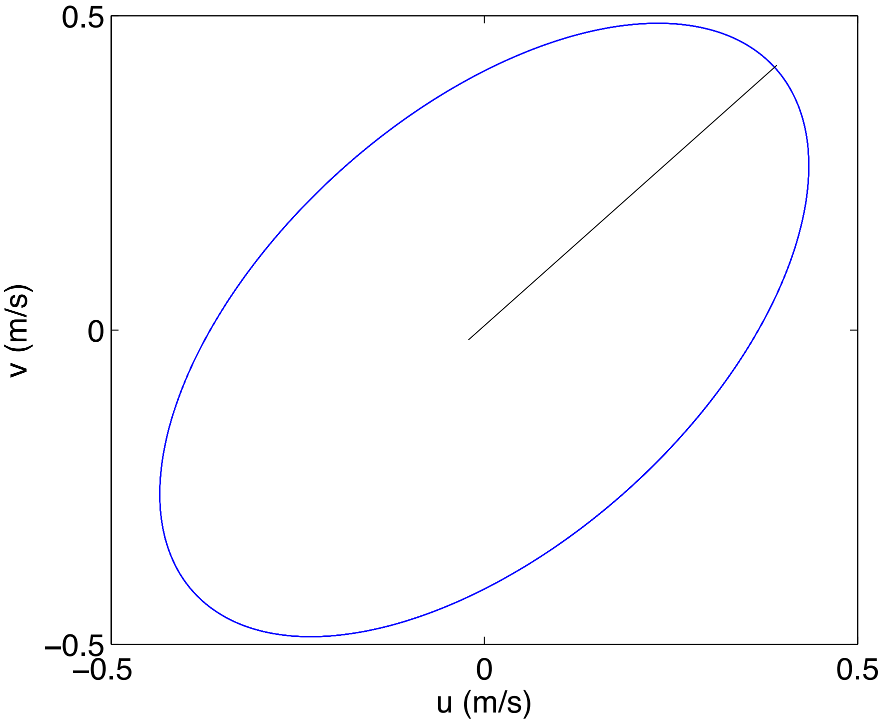
Internal tides

Time series of Band-pass filtered M2 (red), M4 (green) and M6 (pink) internal tidal signals

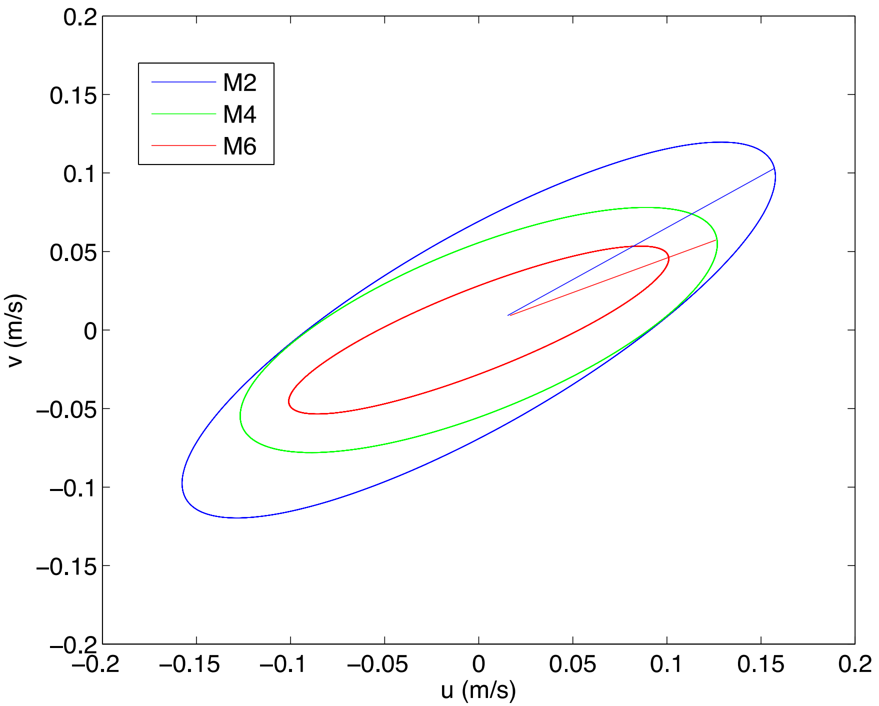


Phase coupling between M2 internal tides and its higher harmonics (M4, M6) causes the largest amplitudes

Velocity ellipse of internal tides



Barotropic tides

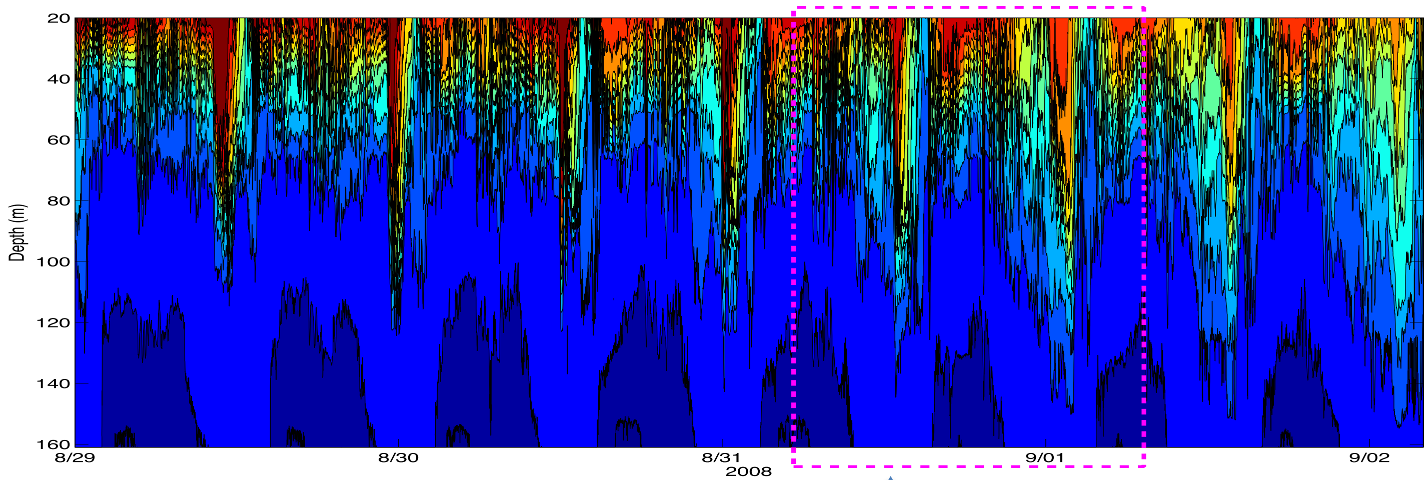


Internal tides

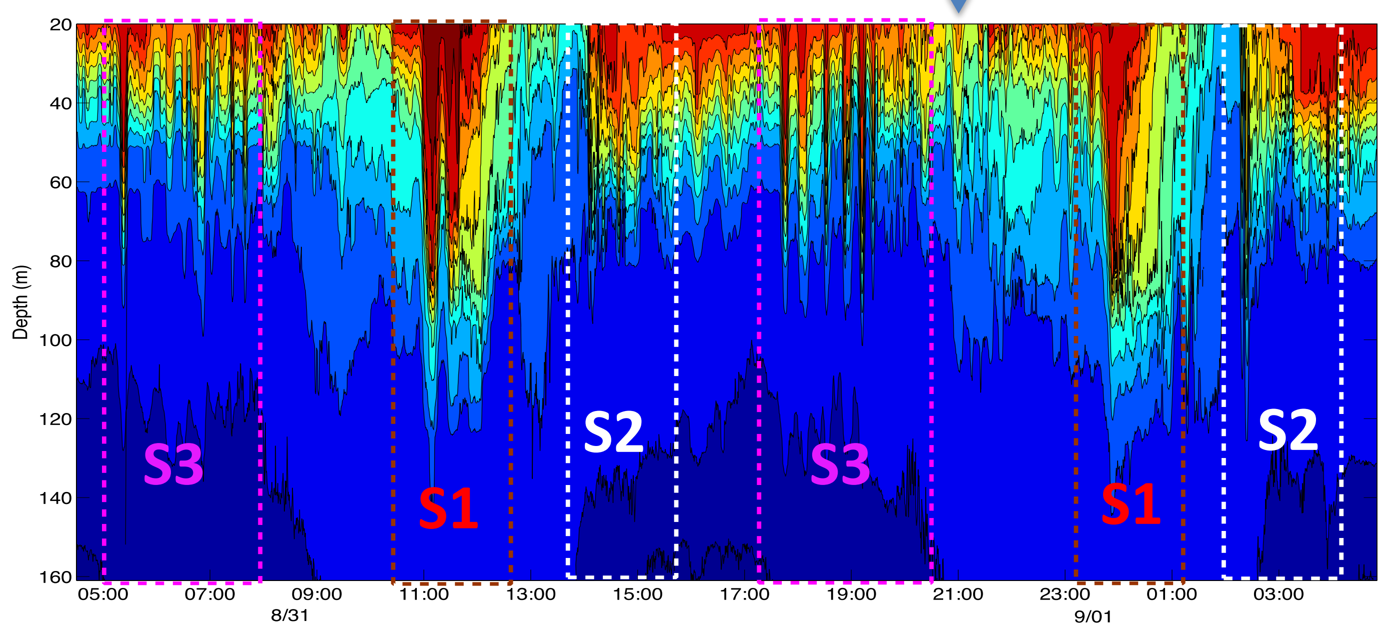
Barotropic tides (for M2) and internal tides (M2, M4 and M6) propagate northeastward

Nonlinear solitary waves

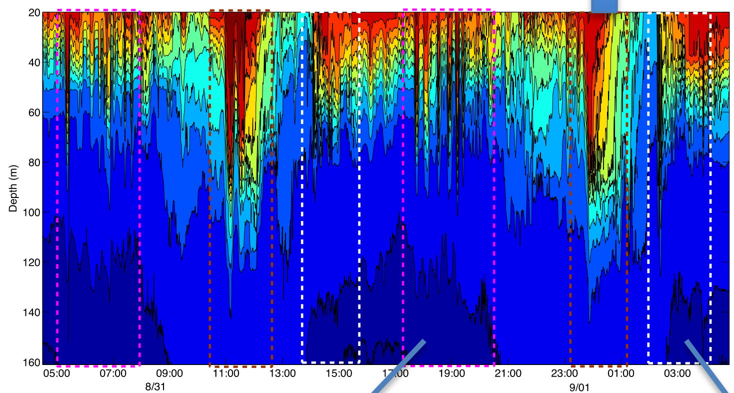
Depth-time map of temperature data



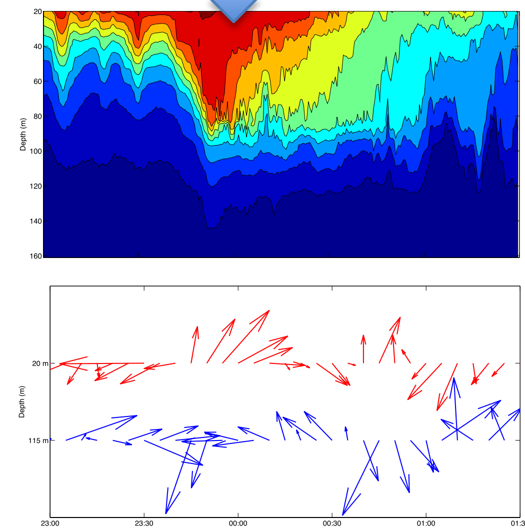
Solitons occur irregularly in a M2 cycle (12 hours), but they still can be roughly classified as three types: S1, S2 and S3. Time interval for all there types of solitons is 12 hours

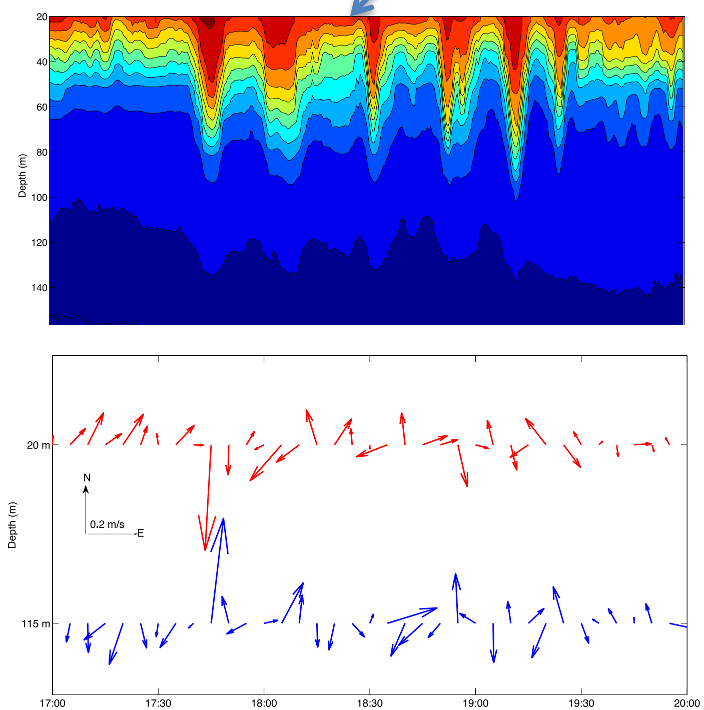


Nonlinear solitary waves

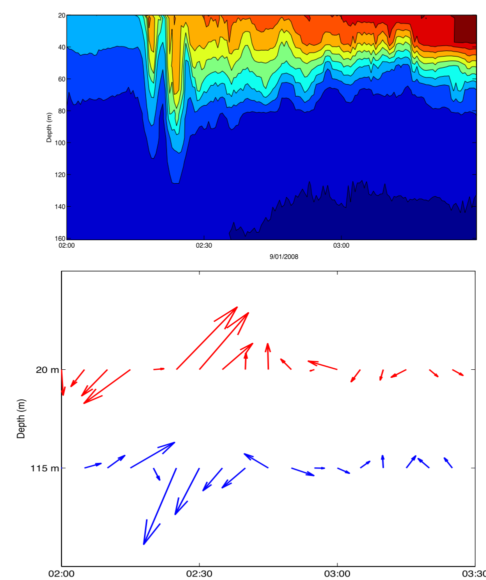


Type-S1 has the largest amplitude, with north-eastward velocity vector





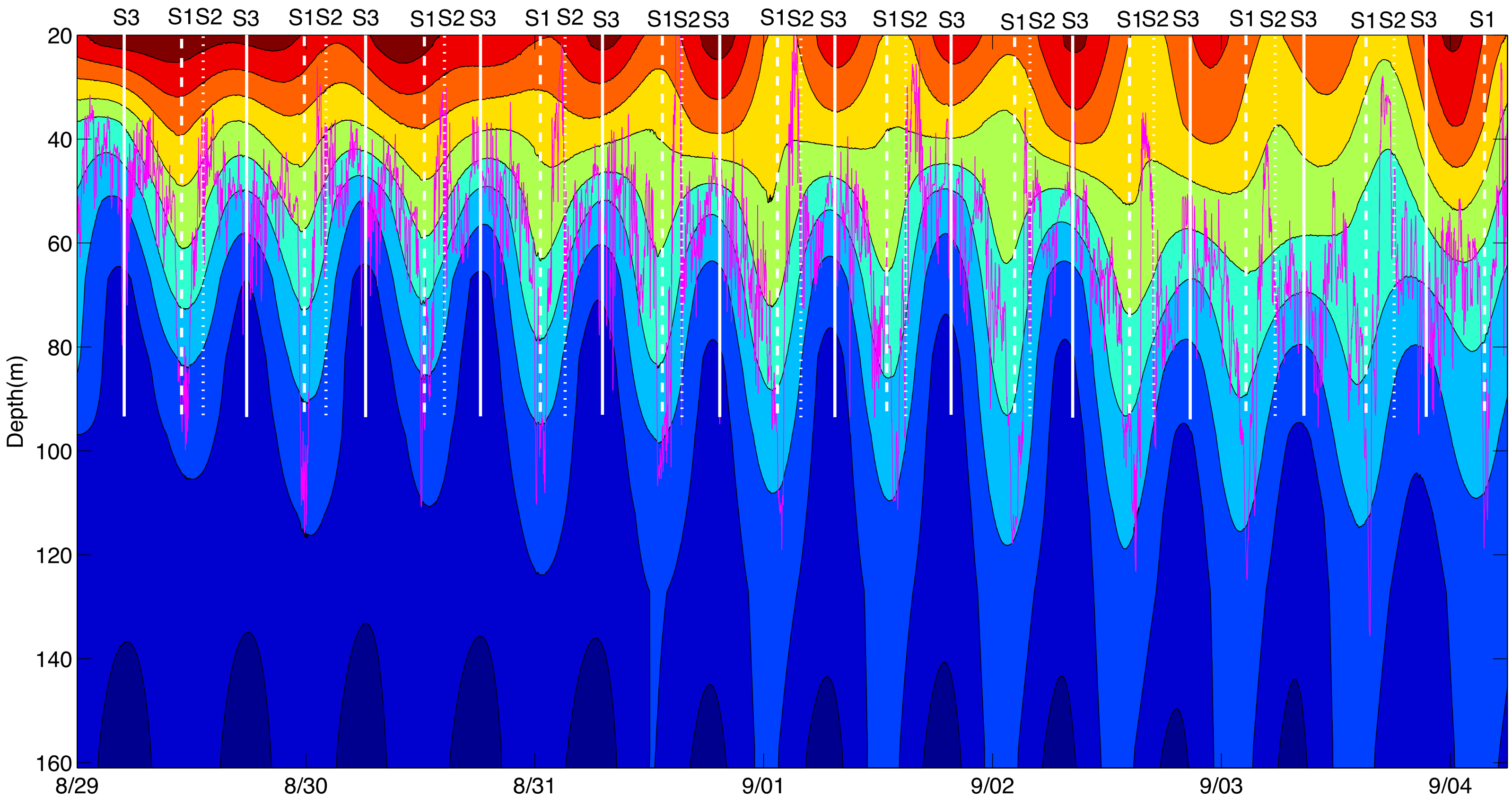
Type-S3: relatively small amplitude, with nearly southward velocity vector



Type-S2: relatively small amplitude, with north-eastward velocity vector

Distribution of solitary waves

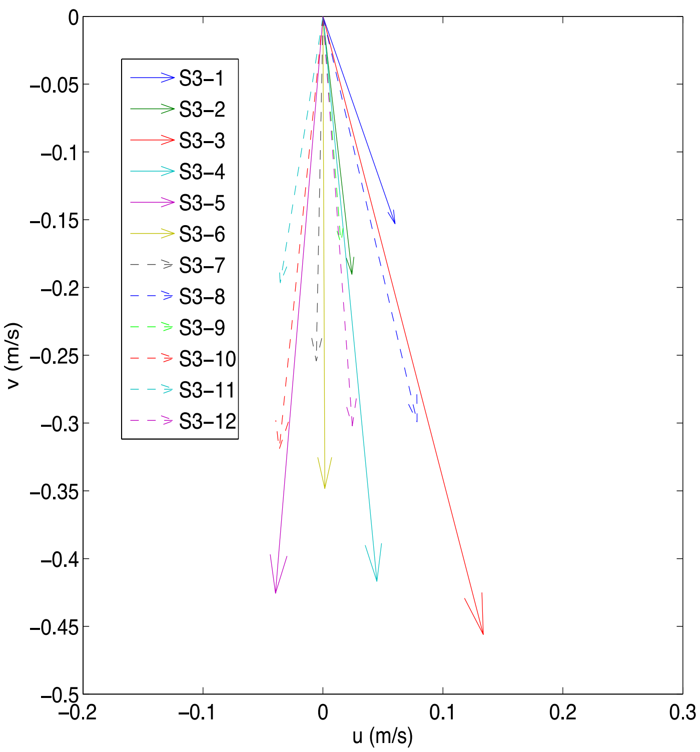
Depth-time map of low-pass filtered temperature data. Isotherm of 13.5°C is covered in the map. Dash, dot and solid vertical lines indicate type-S1, S2 and S3 wave packets, respectively.



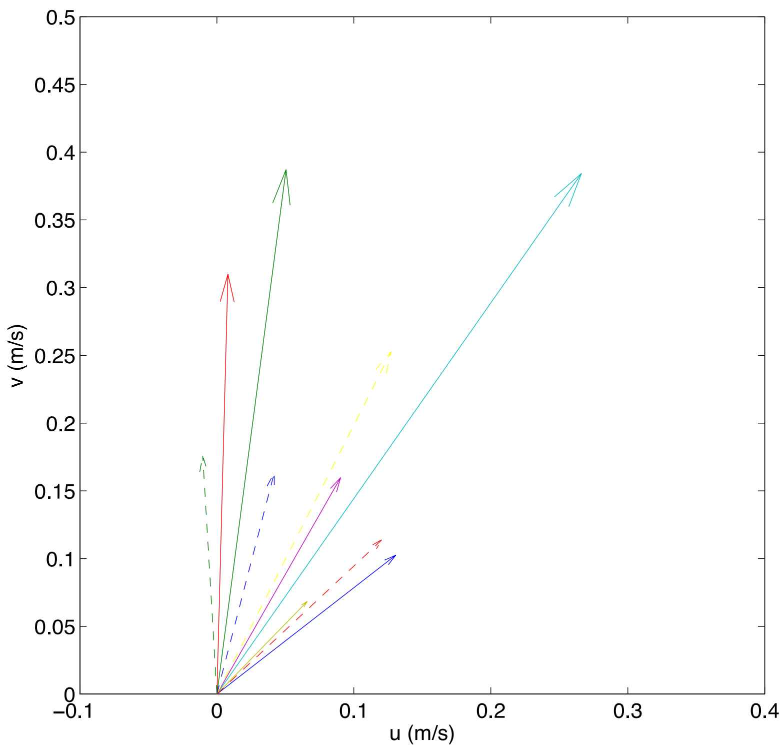
S1 and S3 wave packets are located in the trough and ridge of M2, respectively . S2 is between them.

Propagation of solitary waves

Velocity vectors of S3 waves



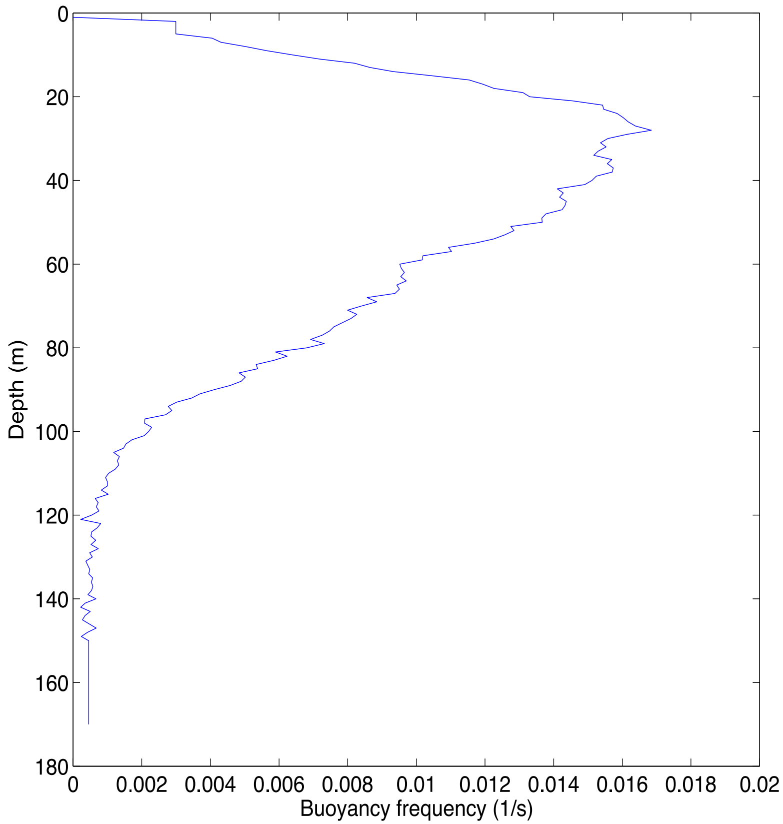
Velocity vectors of S1 and S2 waves



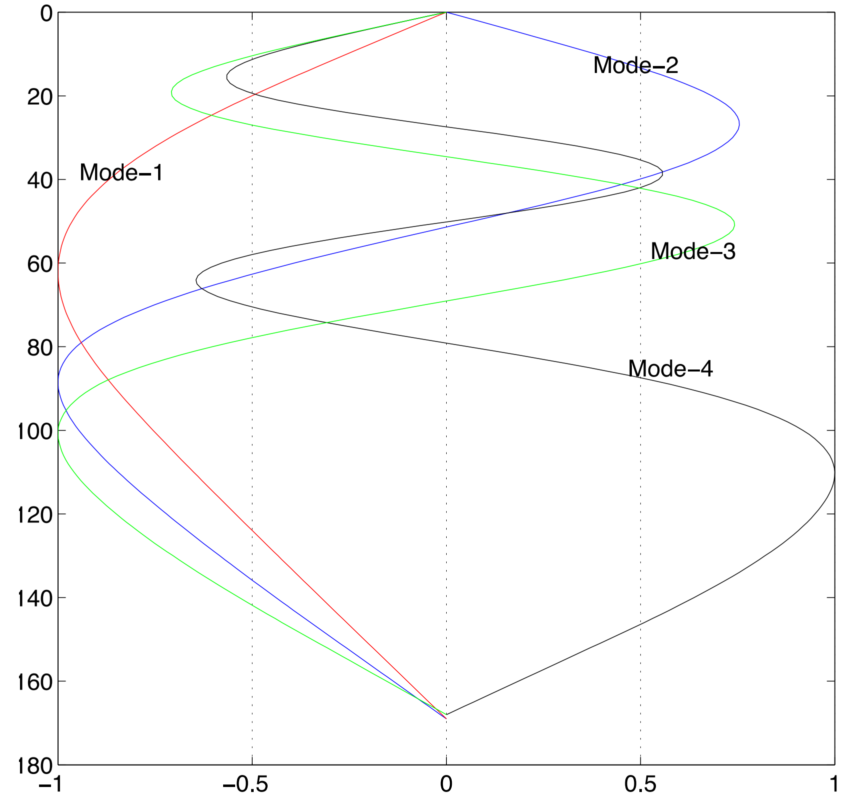
S3 and S1/S2 waves propagate quasi-southward and northeastward, respectively.
They have nearly opposite propagating direction

Decomposition of internal wave mode

Vertical profile of buoyancy frequency

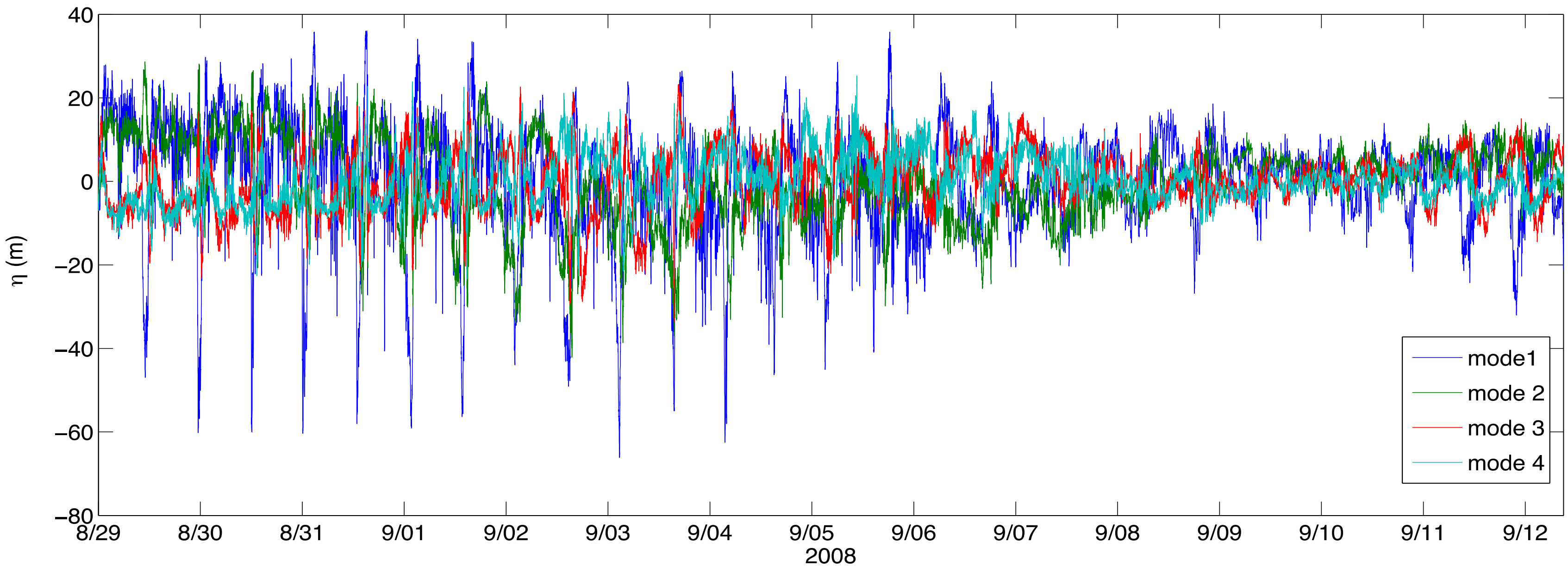


Normalized vertical structure of the first four baroclinic mode for vertical displacement



Decomposition of internal wave mode

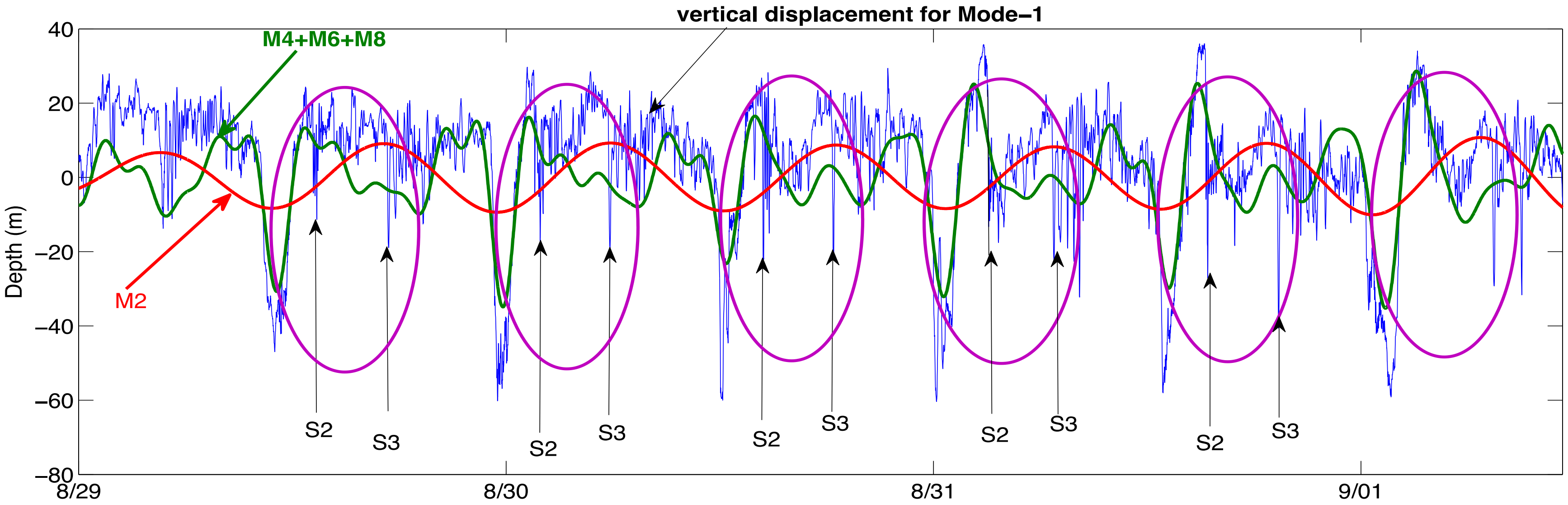
Time series of vertical displacement for mode-1 (blue), mode-2 (green), mode-3 (red) and mode-4 (cyan)



Mode-1 is dominant in the internal wave field

Nonlinear steepening of internal tides

Vertical displacement of mode-1 M2 and higher harmonics



- Sum of higher harmonics generates a nonlinear front with the vertical displacement of an abrupt rise and gradual fall, after which a series of high-frequency waves emerge. So , generation of solitons may be associated with higher tidal harmonics.

Preliminary conclusions

- During observation period, internal tides and nonlinear solitary waves are visibly evident.
- Apart from semidiurnal internal tides (M2), large energy also appears at some higher tidal harmonics (e.g. M4, M6). There is a clear phase coupling between them.
- More than one soliton wave packet is observed per M2 tidal period. Furthermore, solitary waves have different direction of propagation in a M2 tidal cycle.
- Solitons are not only associated with semidiurnal internal tides, but also linked to higher tidal harmonics.

Perspectives

- Confirming the generation mechanism of different types of solitary waves.
- Identifying the relationship among semidiurnal internal tides, higher tidal harmonics and solitary internal waves.
- Using KDV or eKDV equation to model nonliear solitary waves evolution.

Thank You !