

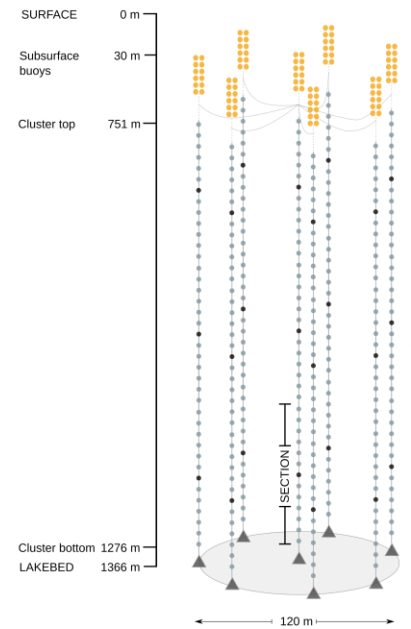
Spatial positioning of underwater components for Baikal-GVD

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INR RAS

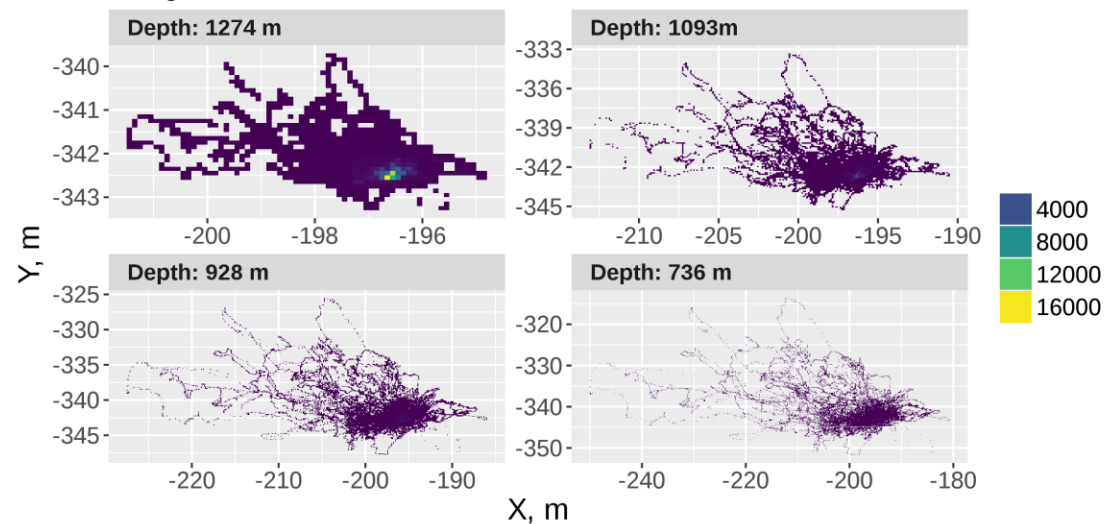


OVERVIEW

- GVD components are mounted on flexible strings strung between an anchor and subsurface buoys.
- Acoustic measurements show that coordinate deviations can reach several meters for depth and 10s of meters for XY plane over the course of the season.
- Strings can also twist and rotate OMs up to 360 degrees.
- 1 m error in positioning OM is equivalent to ~ 4.4 ns error in time calibration.
- We need to know OM coordinates and spatial orientation at any given time. That's what the spatial positioning system is for.

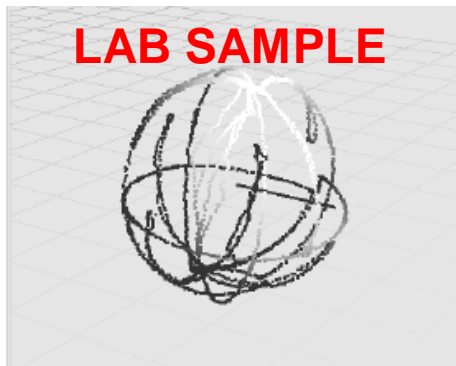
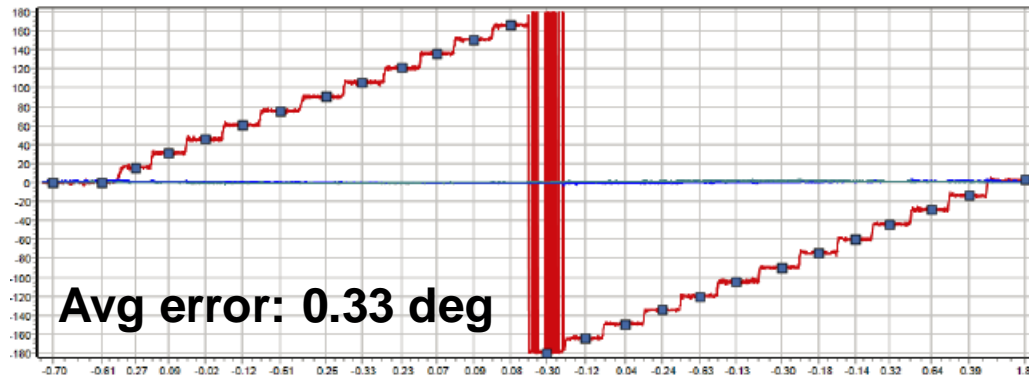


Acoustic modem coordinate measurements
String #1, Cluster #2, Season 2017

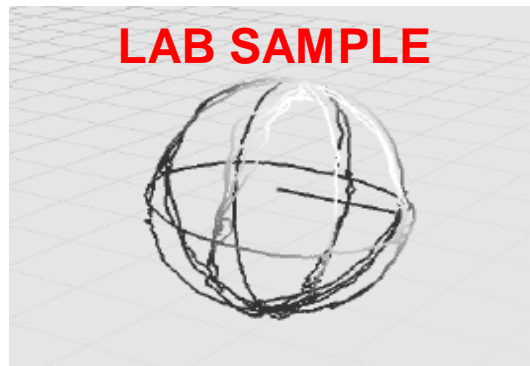


SPATIAL ORIENTATION

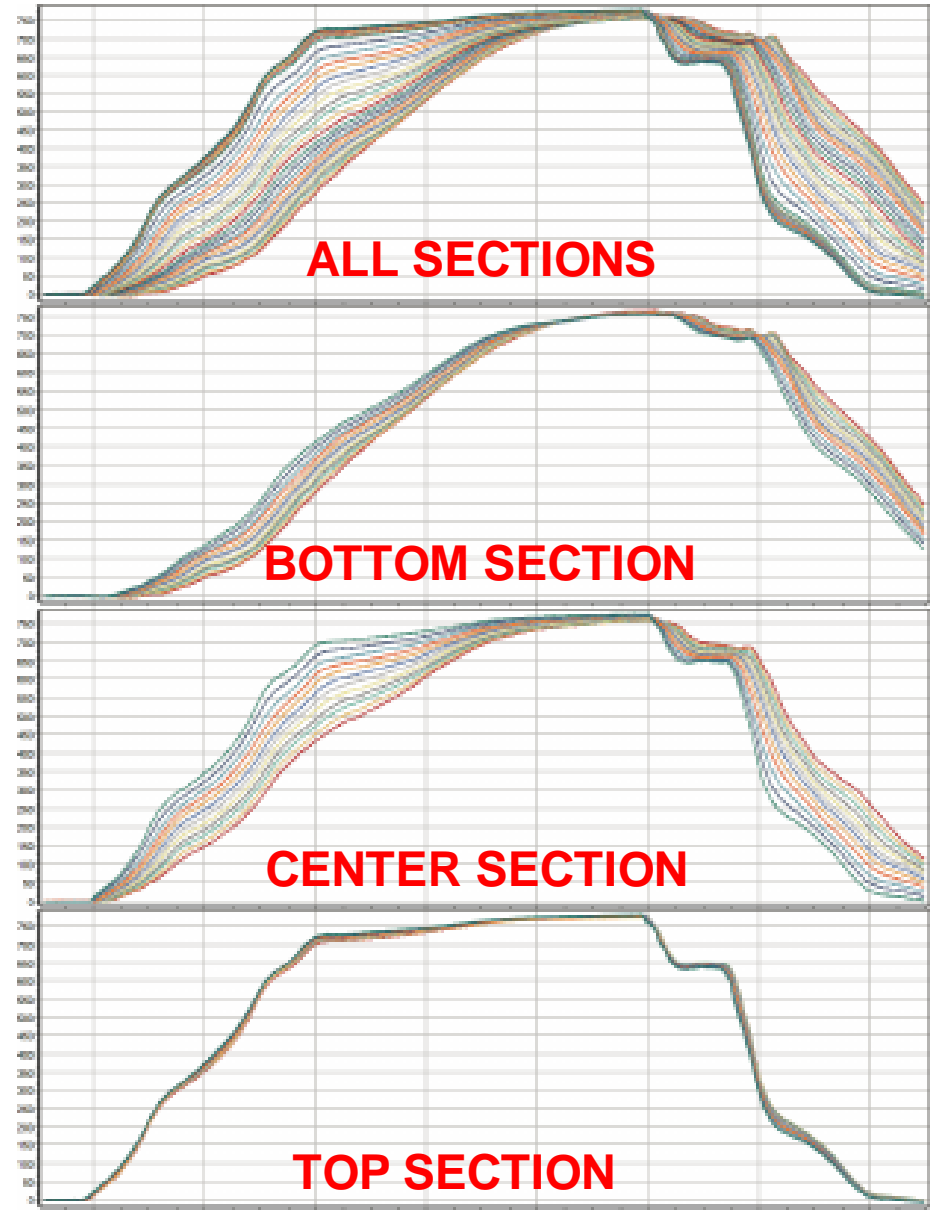
- Each new OM is equipped with an array of sensors.
- These sensors include, among others, an accelerometer and a compass.
- Their data is used to reconstruct OM direction.



Compass data



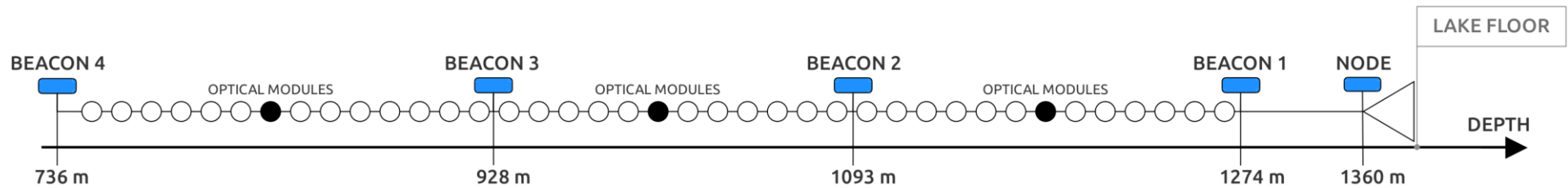
Accelerometer data



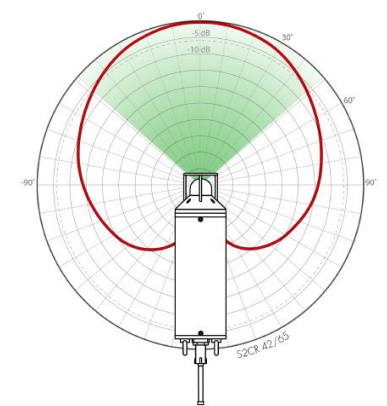
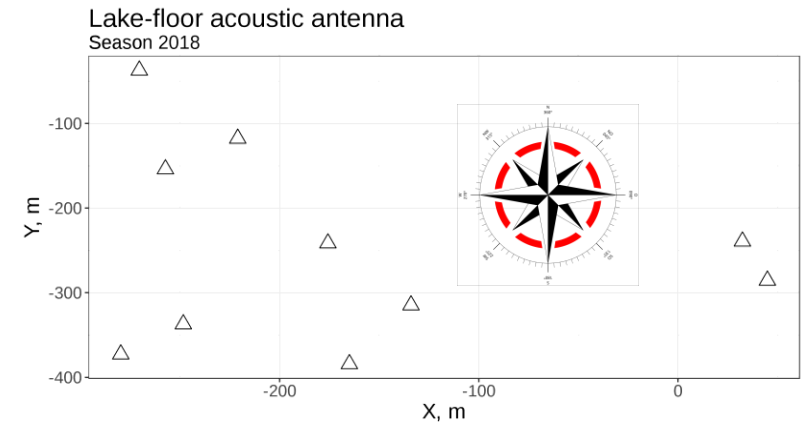
On-site calibration (2017)

COORDINATES

APS LAYOUT FOR A BAIKAL-GVD STRING



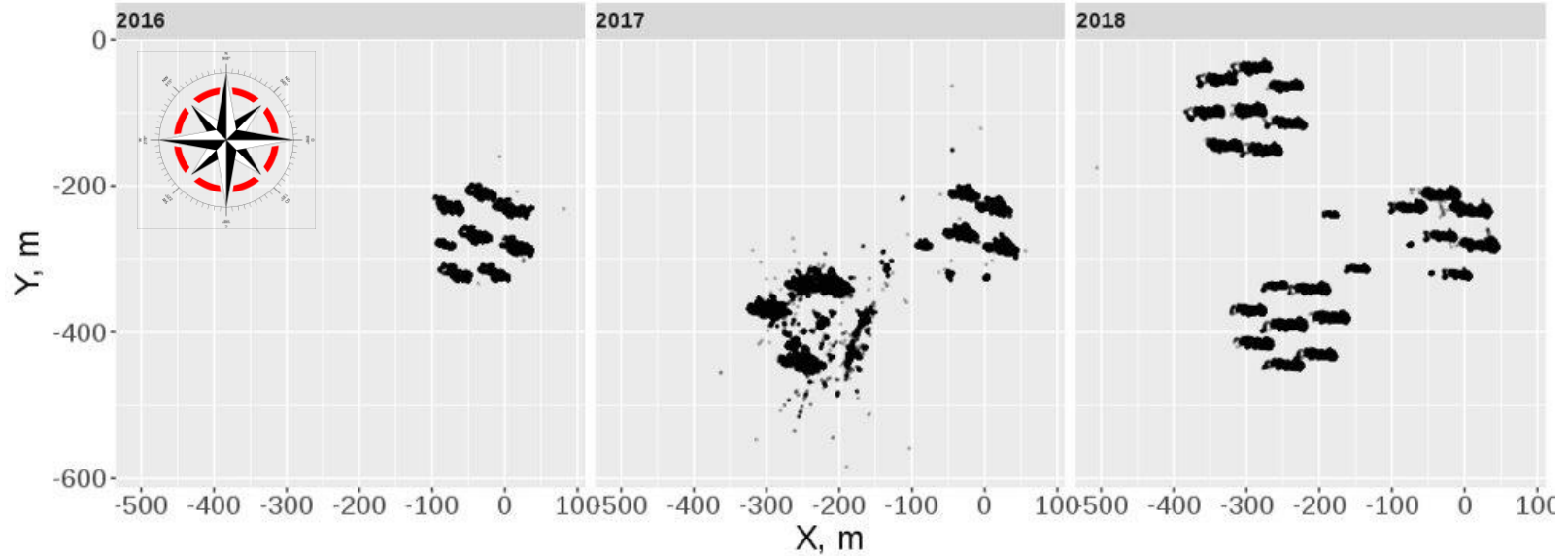
- Coordinate measurements are performed with the **hydro-acoustic positioning system (APS)**
- 4 acoustic modems (AMs) on each string (default).
- 1 AM (node) is fixed to the anchor, the rest (beacons) are mobile.
- Anchor coordinates are measured once, during winter expedition.
- Beacons measure acoustic distances to the nodes, regularly send data to the shore.
- Beacon coordinates are then trilaterated, online.
- OM and calibration light source coordinates are linearly interpolated from beacon positions.



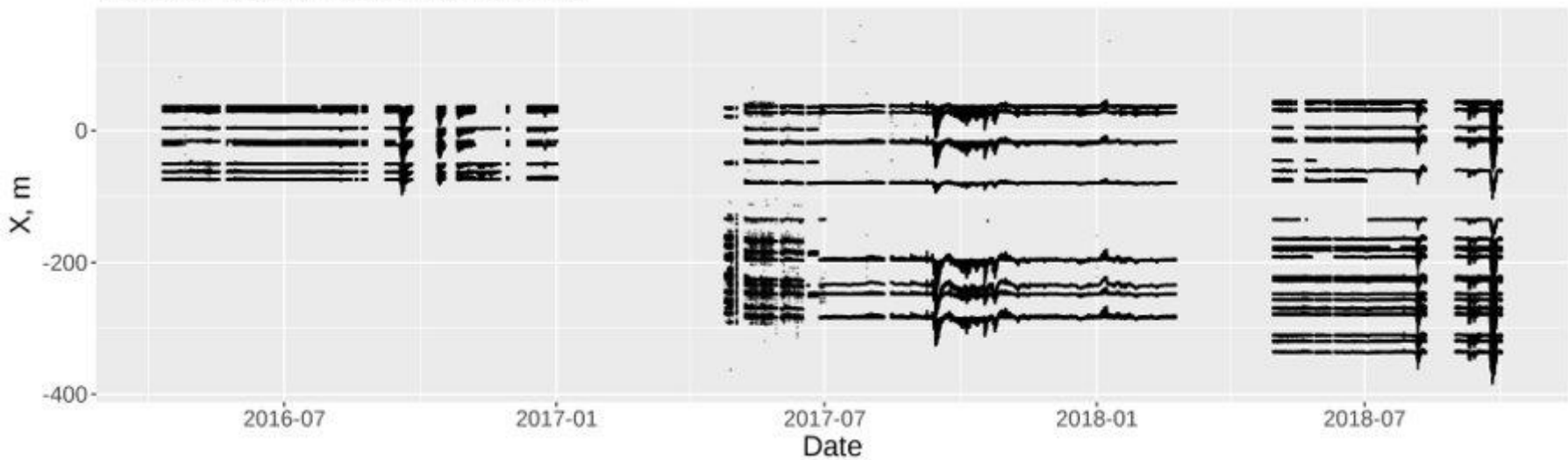
EvoLogics S2C R42/65 acoustic modem

APS PERFORMANCE

Beacon coordinates, 2016-2017

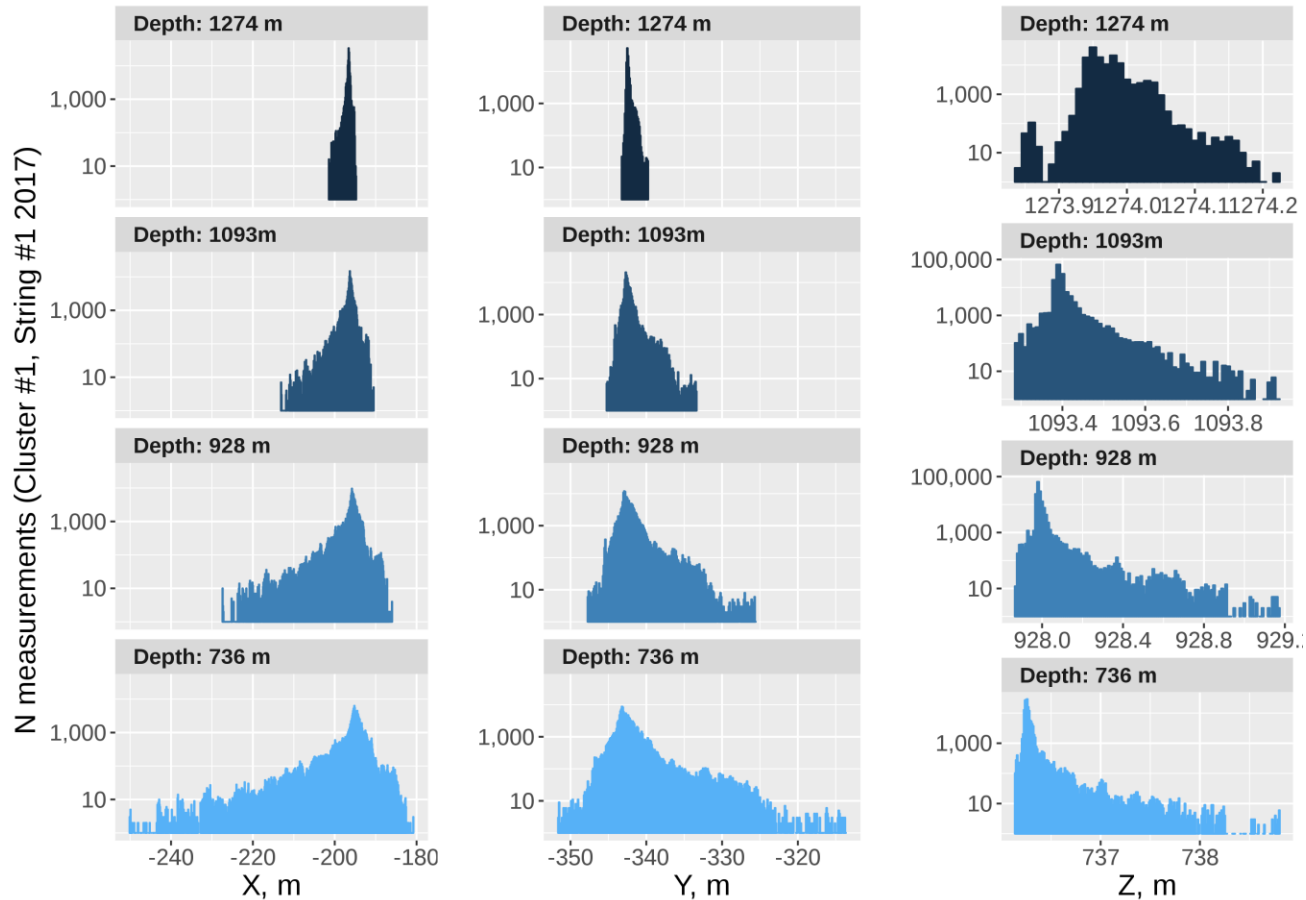


Beacon coordinates, 2016-2018

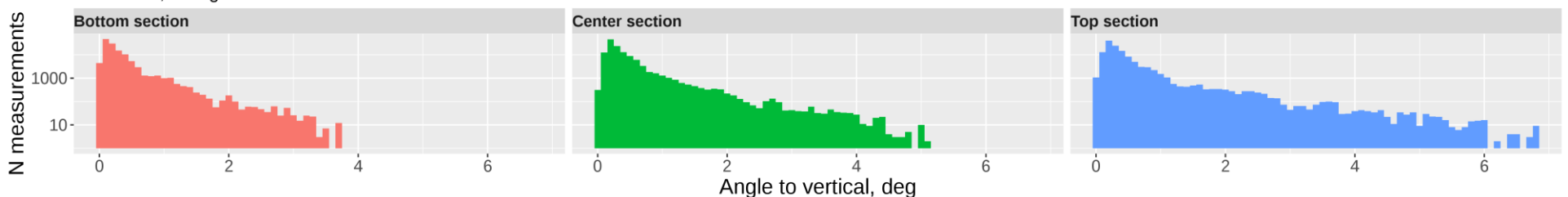


BEACON BEHAVIOR

- Z-coordinate variation is ~several cm (except autumn).
- X, Y – 10s of meters.
- Coordinate variation decreases with depth.
- Z variation gives a good estimate of trilateration error
- Strings are near-vertical.

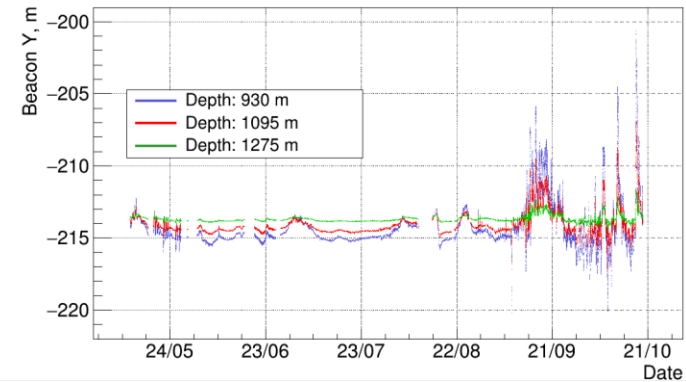


Section inclination, 2017
Cluster #2, String #1

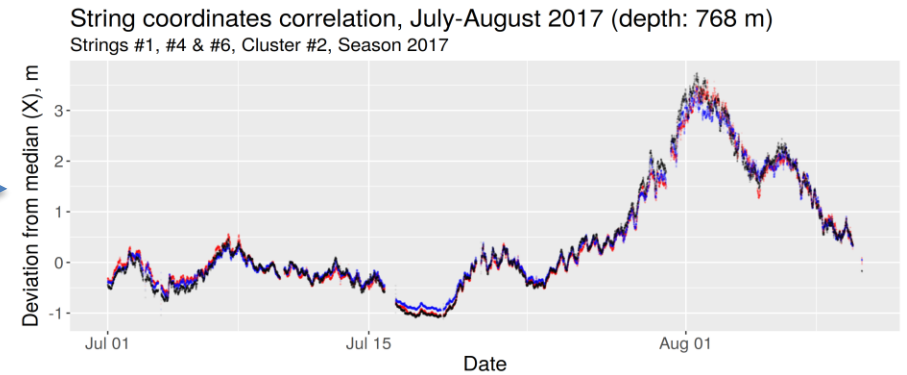


STRING BEHAVIOR

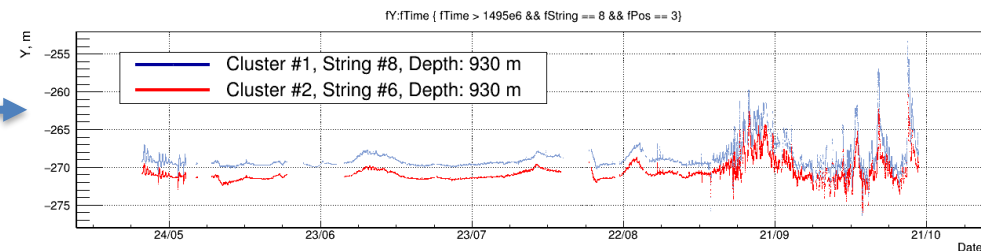
Beacon coordinates correlate within one string



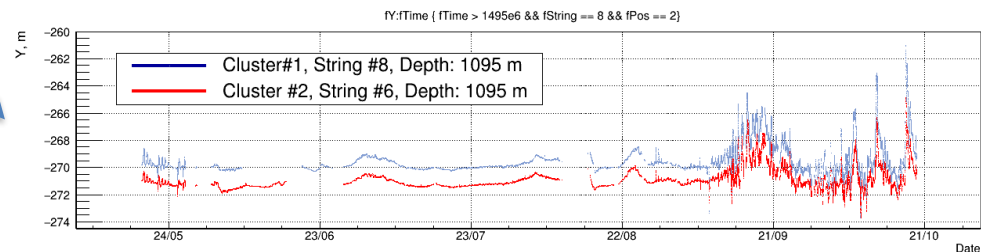
Beacon coordinates correlate within one cluster (on the same depth)



Beacon coordinates correlate between clusters



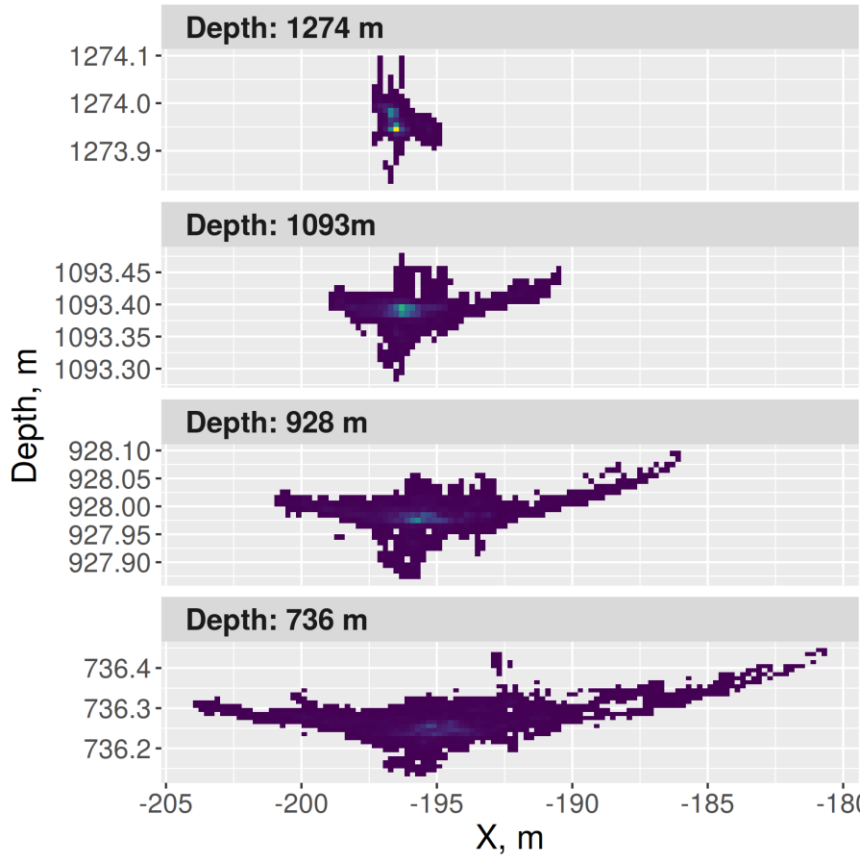
Strings tend to move in sync, and so do clusters



SEASONAL VARIATION

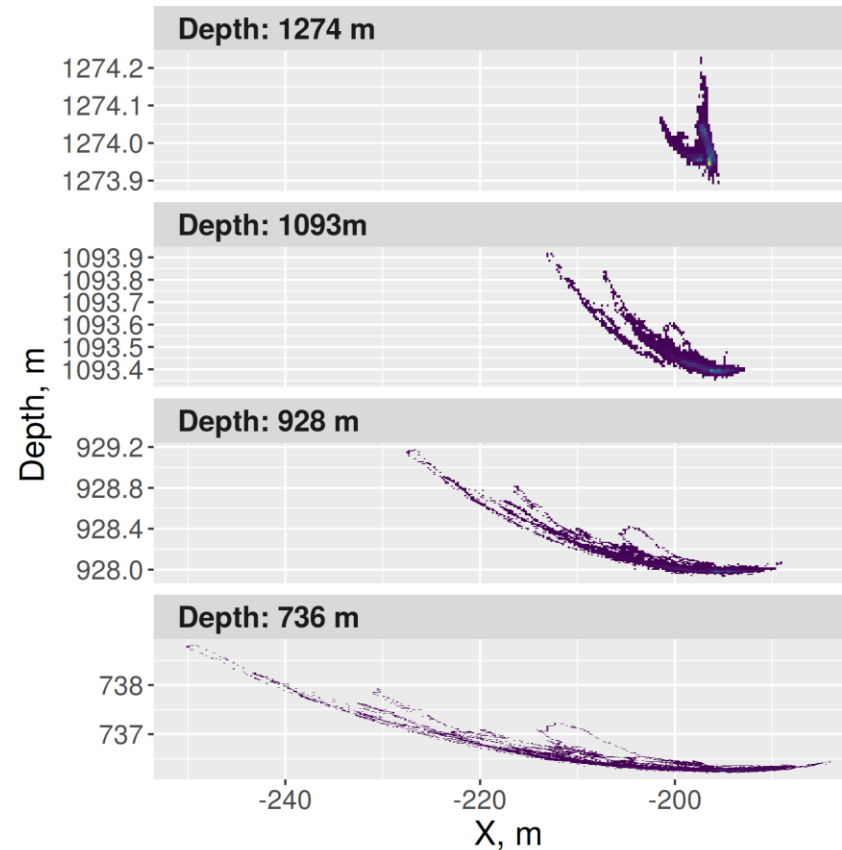
Regular beacon behavior

Beacon coordinate variation with depth
String #1, Cluster #2, Season 2017



Active period (September-October)

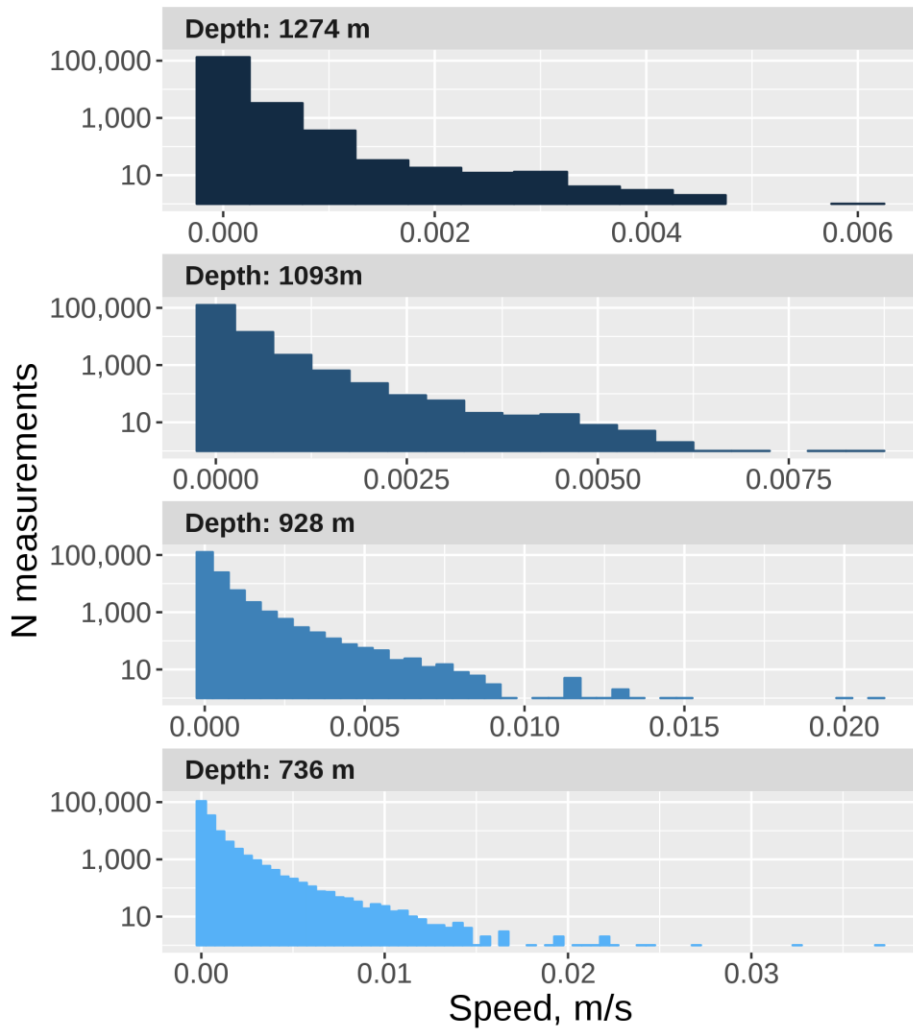
Beacon coordinate variation with depth
String #1, Cluster #2, Season 2017



Dynamics

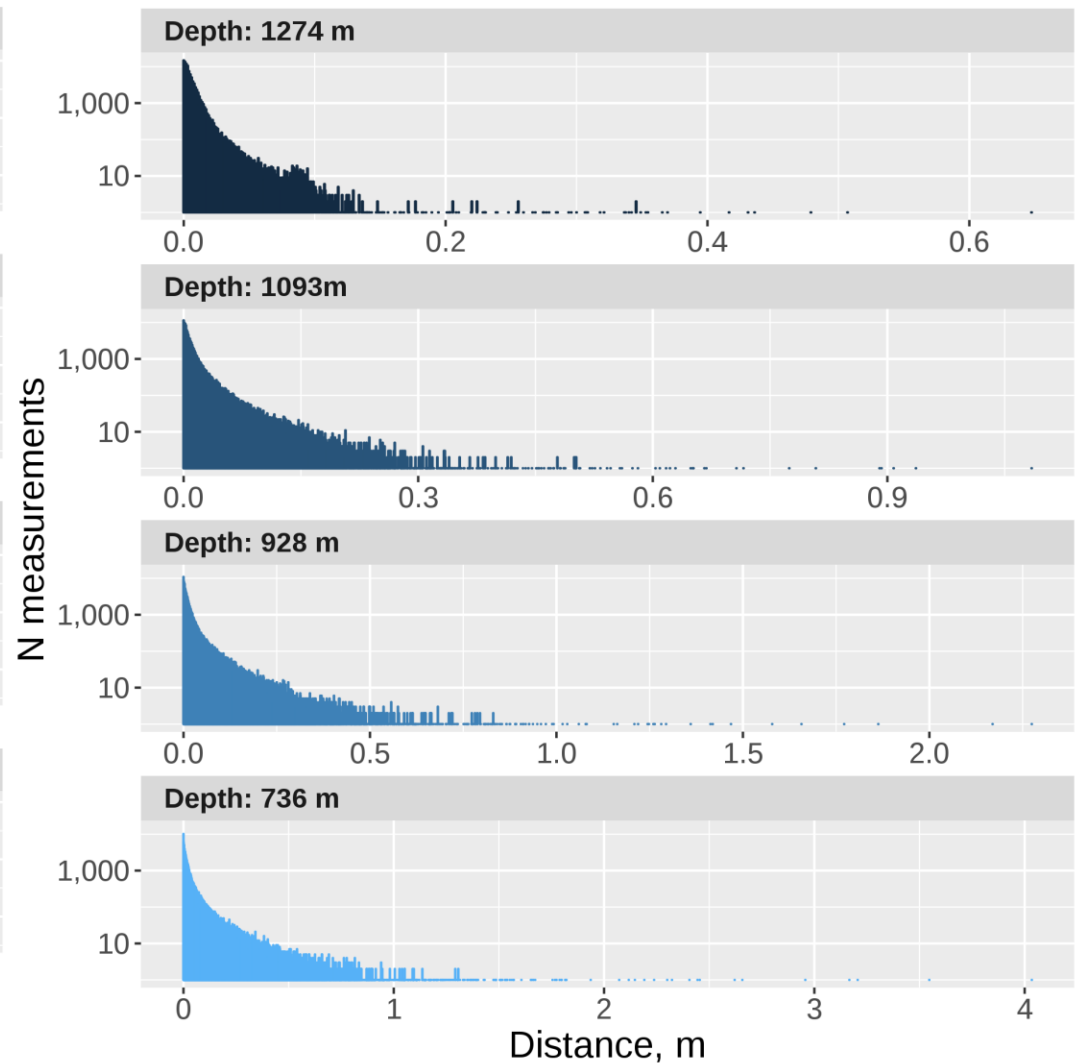
AM speed, 2017

Cluster #2, String #1



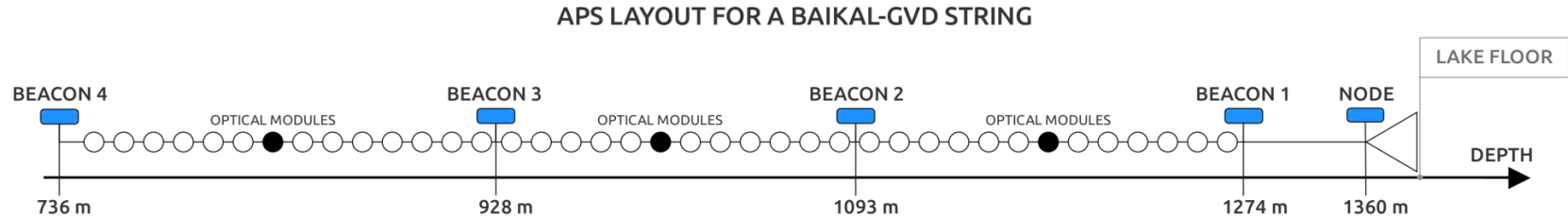
Distance between AM measurements, 2017

Cluster #2, String #1

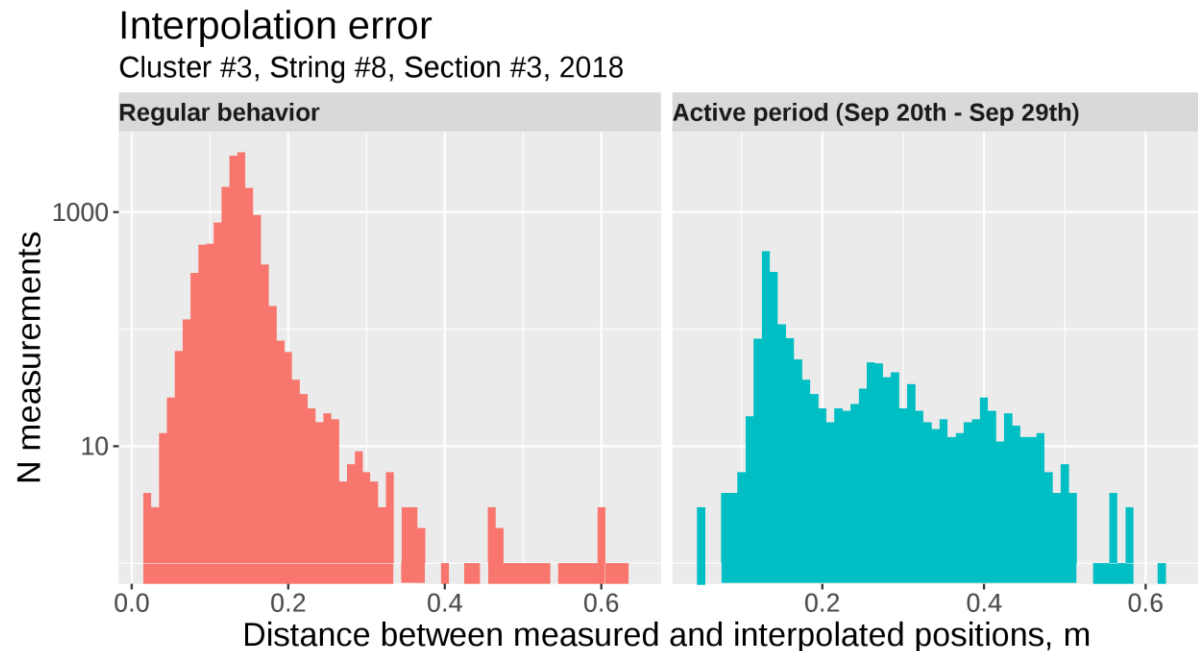


COORDINATE ERROR ESTIMATION

- Coordinate error for each OM depends on its distance to the nearest beacons and beacon speed (varies with time and depth).

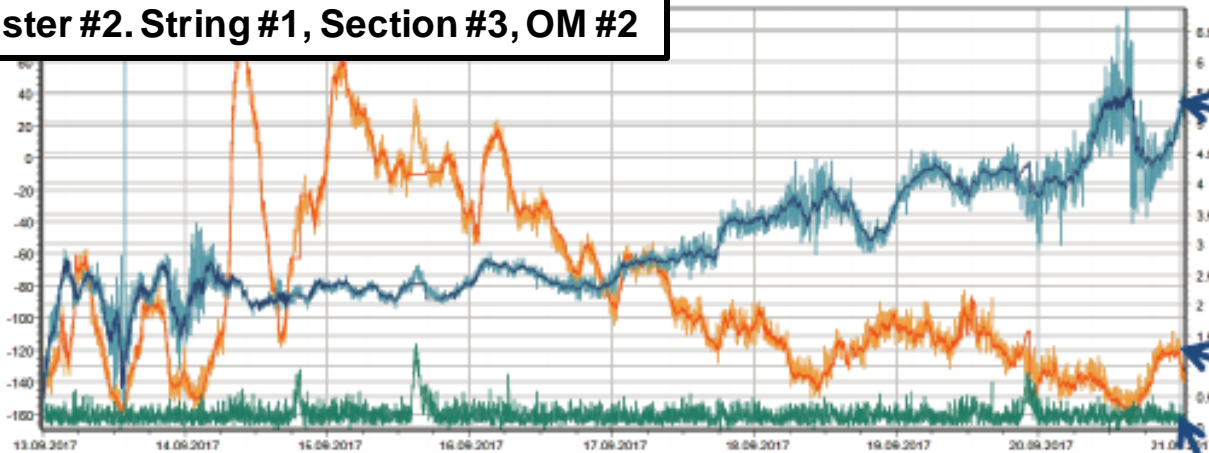


- We have installed an additional AM at the center of top section, then compared interpolated coordinates with acoustic measurements.
- Mean XY error is ~ 13 cm (20 cm for active period)



Acoustics/OM sensors crosscheck

2017, Cluster #2. String #1, Section #3, OM #2

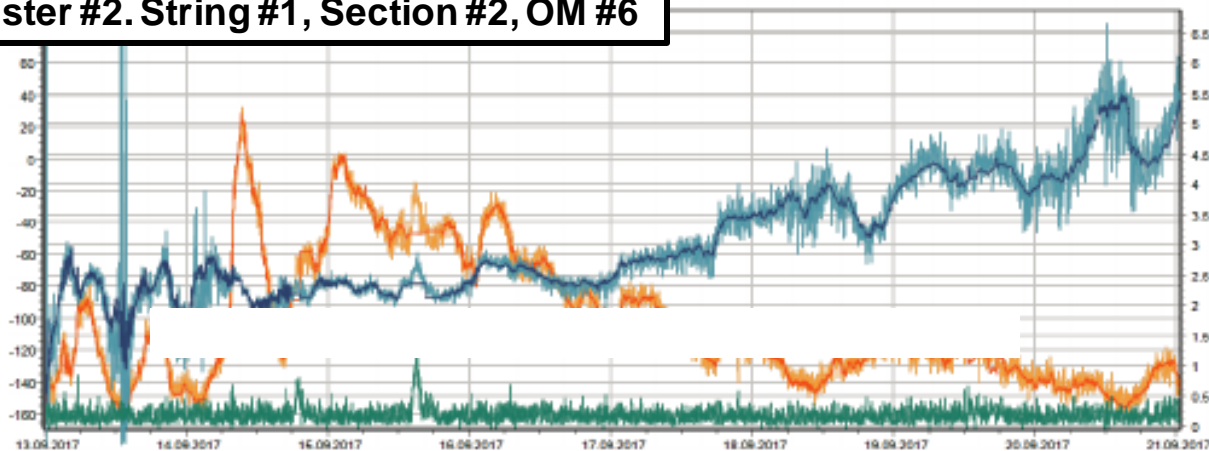


Section azimuth

Section inclination

Difference between estimates

2017, Cluster #2. String #1, Section #2, OM #6



- Both APS and OM sensors can be used to estimate section inclination.
- APS and OM sensors are fully independent systems.
- Comparing section inclination estimates allows us to crosscheck both systems.
- **Work done by S. Koligaev**

Summary

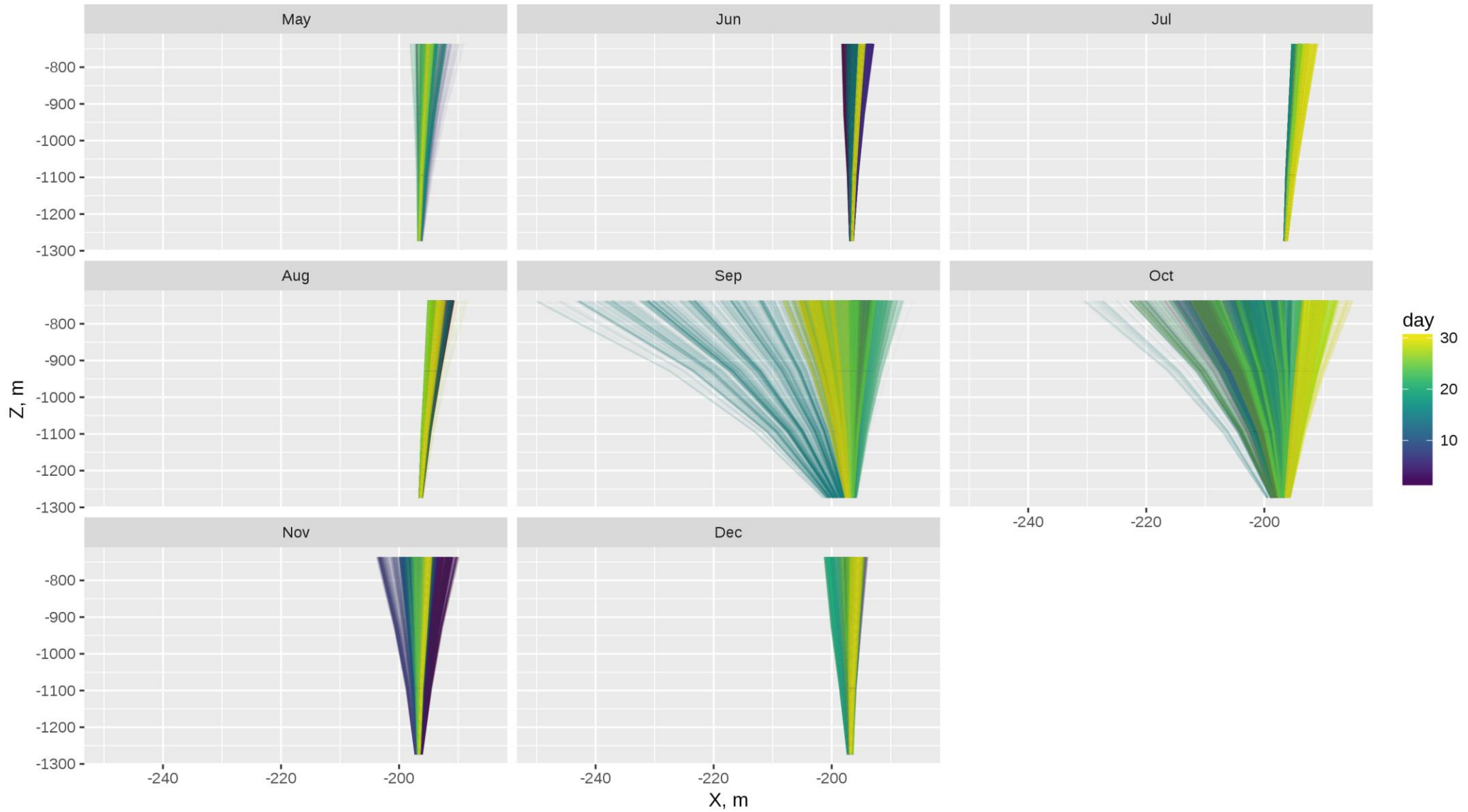
- Coordinates of GVD components are determined via a hydro-acoustic positioning system. OM positioning error varies, but our baseline estimate is 10 cm.
- OM orientation is estimated from inclinometer and compass mounted inside OMs. Average error – 0.33 deg.
- Acoustic modem coordinates correlate with each other heavily, both within a string, a cluster or between clusters, providing positioning redundancy.
- Top-most (and most spatially volatile) components move at a speed < 3 cm/s.
- Crosscheck between acoustic and orientation data shows commendable consistency.

THANK YOU

String profiles

String profiles 2017

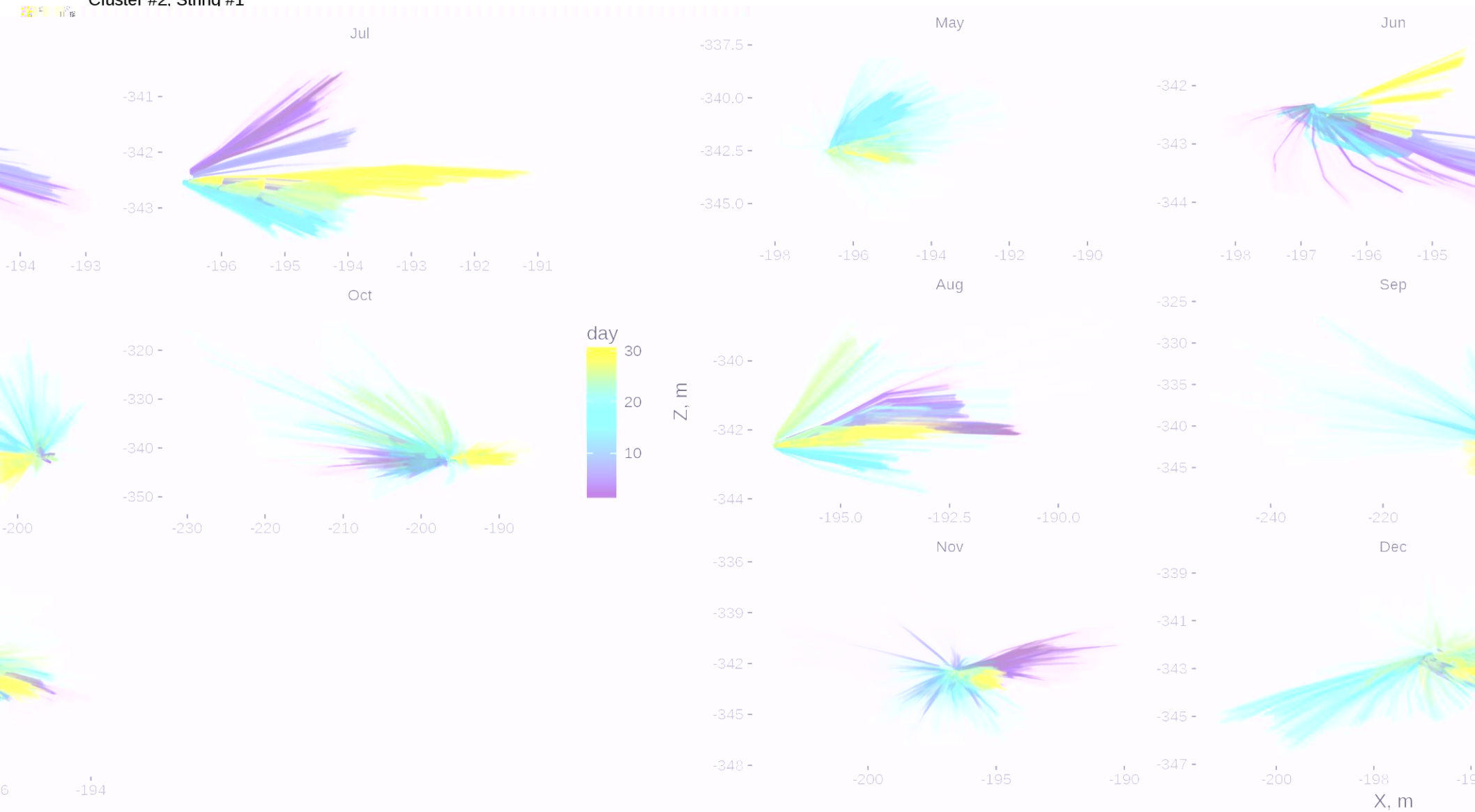
Cluster #2, String #2



String behavior

String profiles 2017

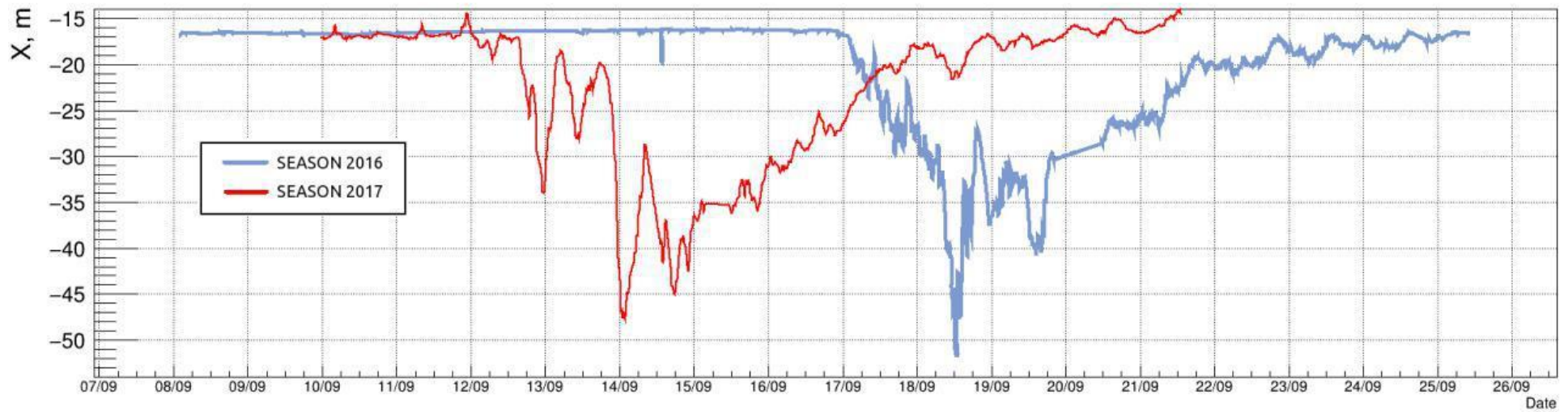
Cluster #2, String #1



Extreme string displacement 2016-2017

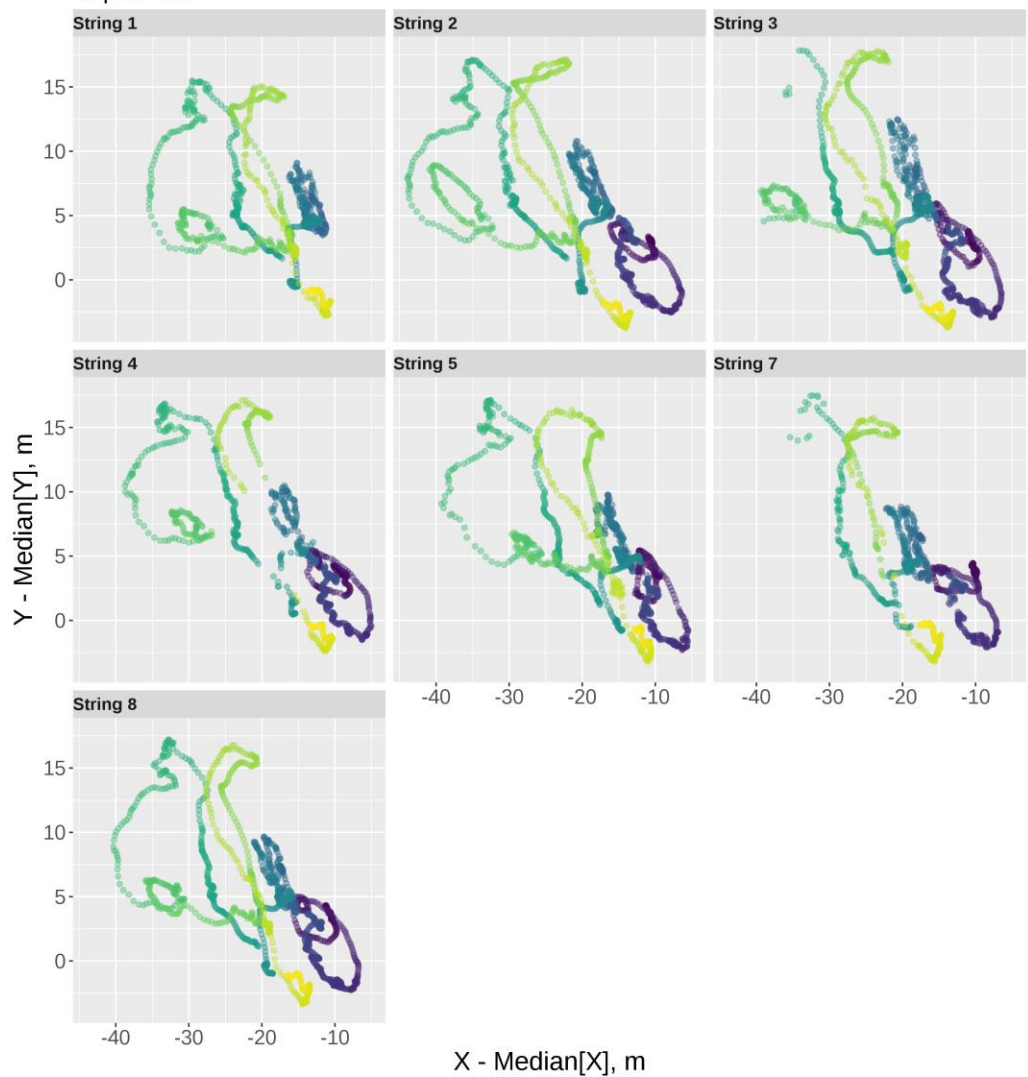
AM #48 [DEPTH: 930 m]

CLUSTER #1 STRING #1



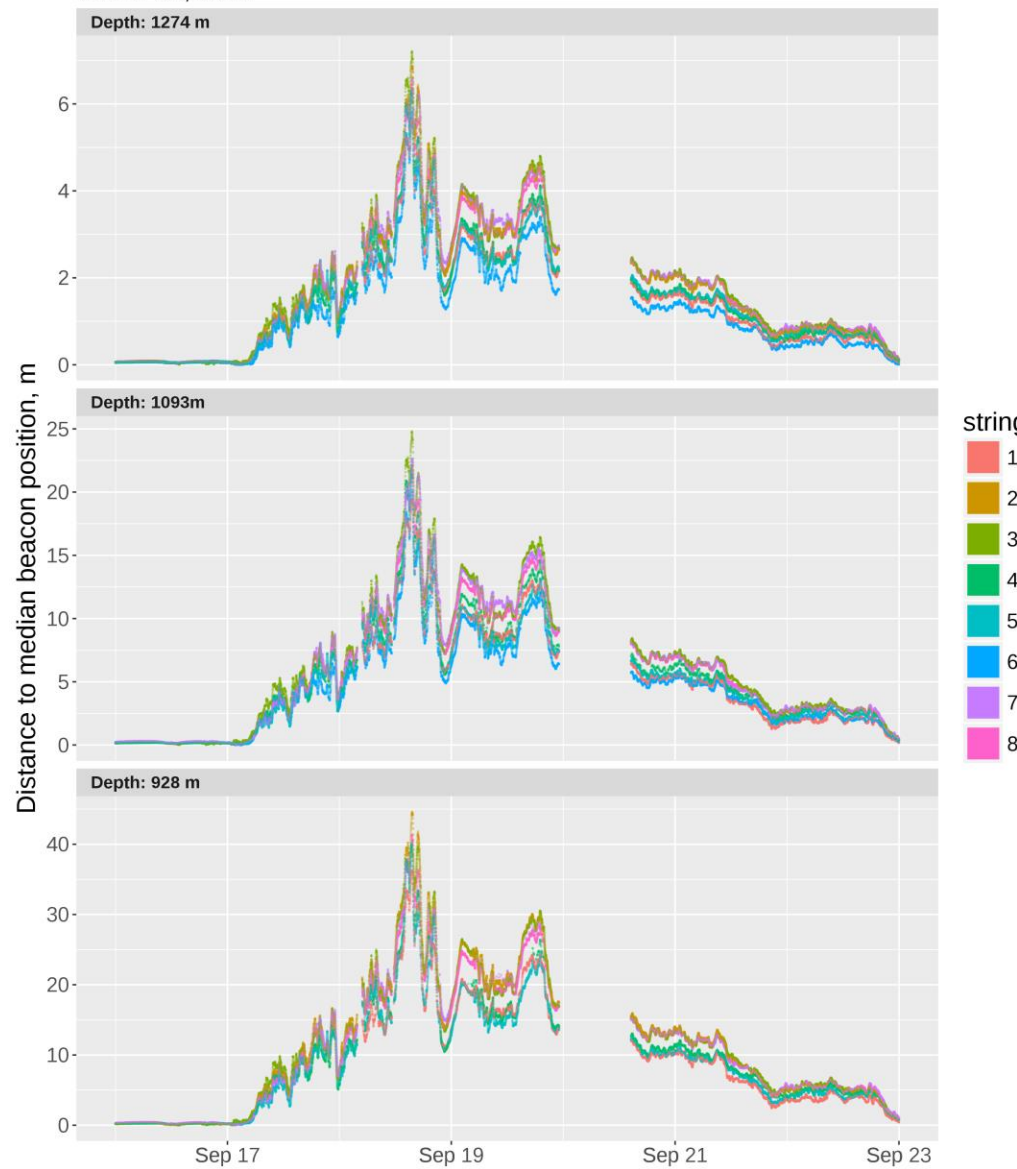
Active period deviations, 2016

Depth: 923 m



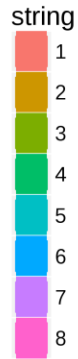
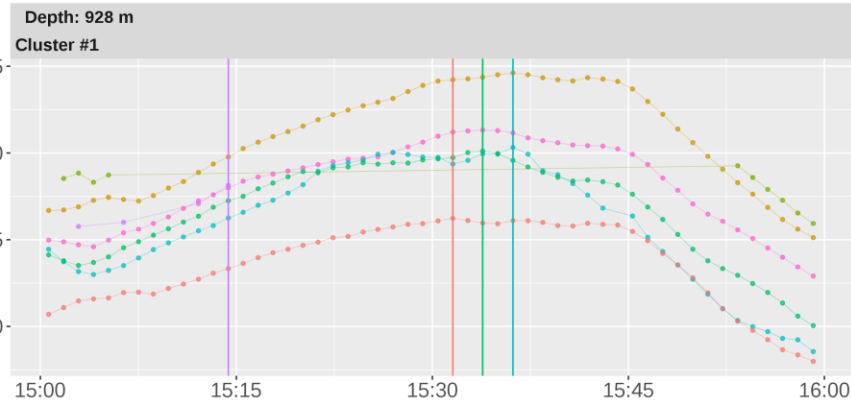
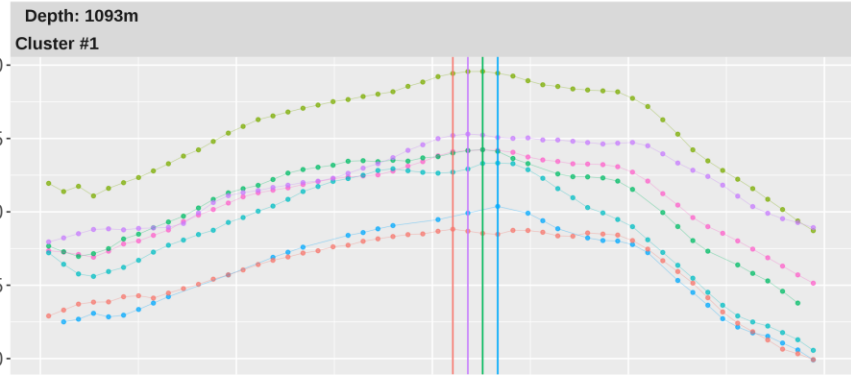
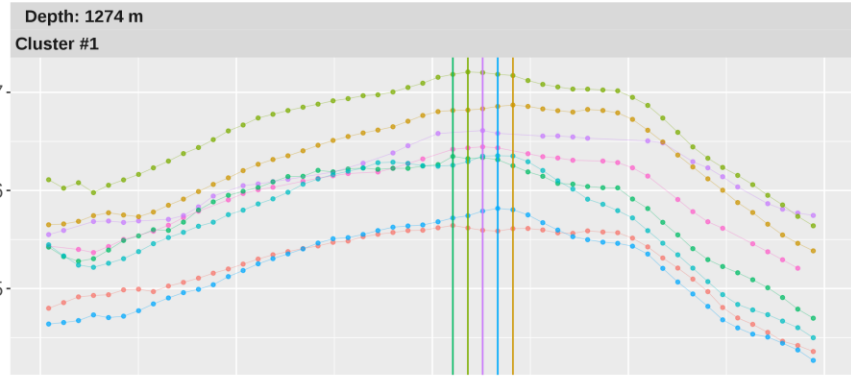
Active period deviations

Cluster #1, 2016



Peak active period deviations

September 14th, 2016



Peak active period deviations

September 14th, 2016

