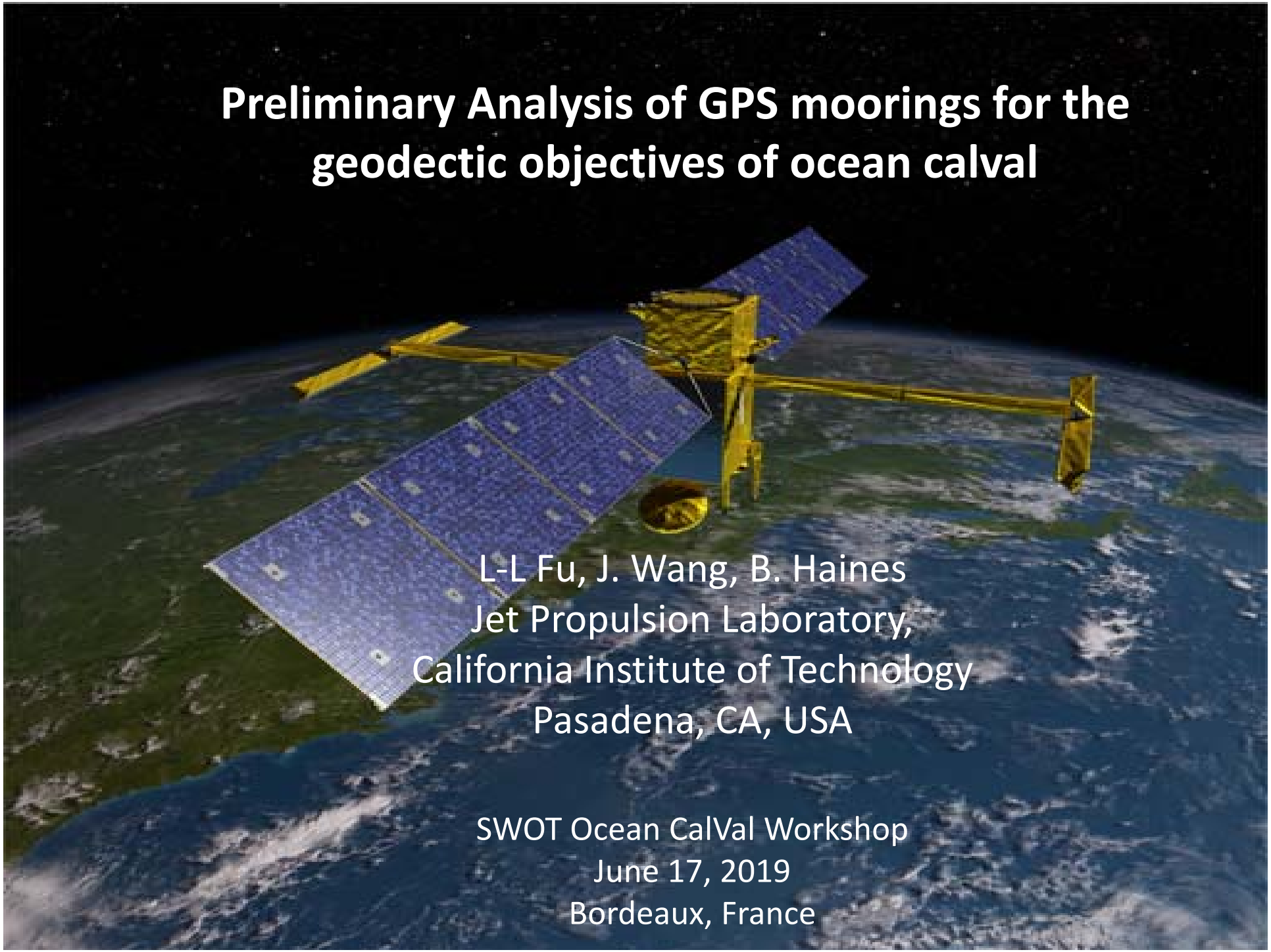
# Preliminary Analysis of GPS moorings for the geodectic objectives of ocean calval



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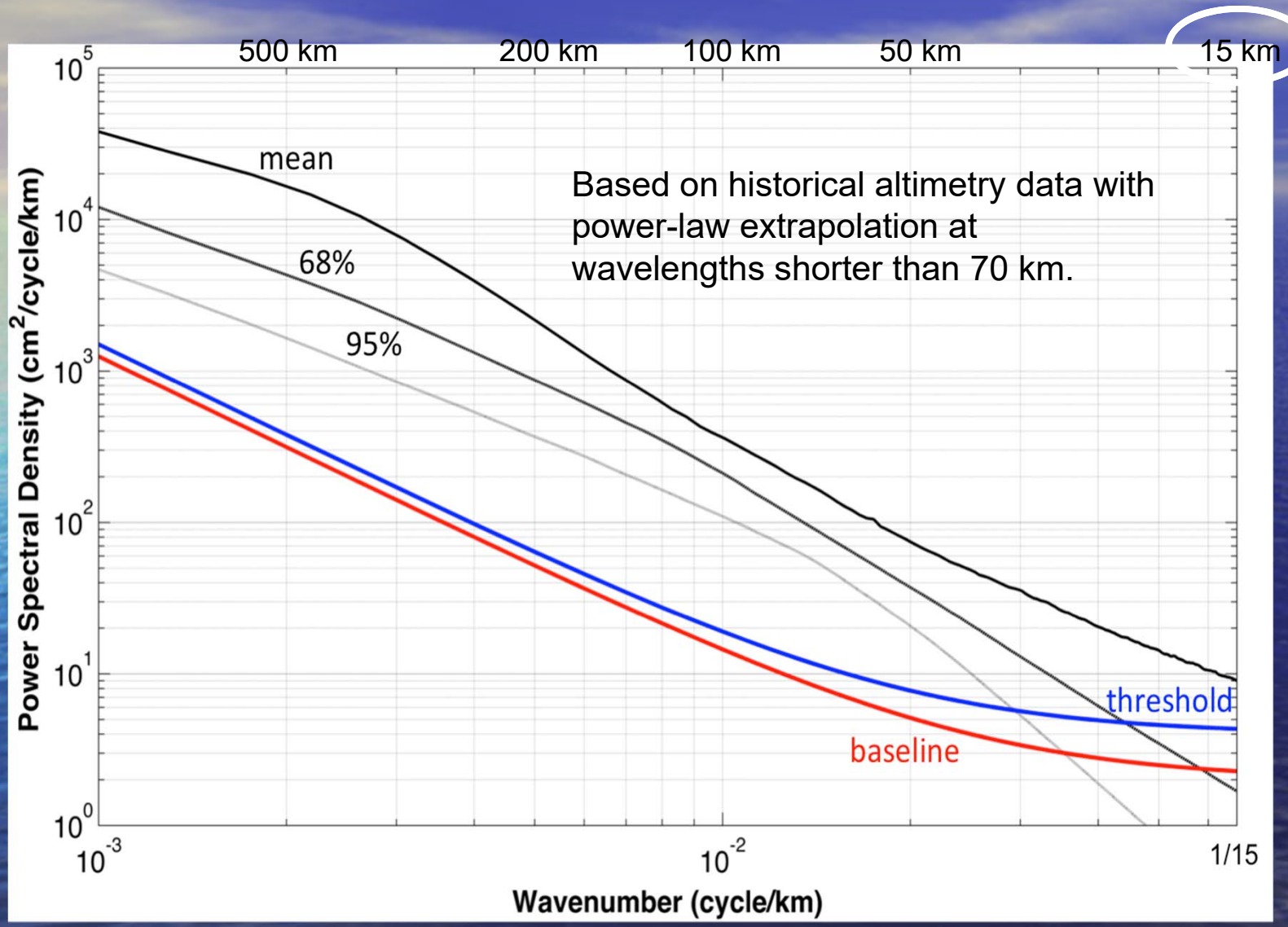
# SWOT ocean calval objectives

- Geodetic validation - validate the measurement of SSH to meet the wavenumber spectrum requirement
  - GPS buoys and airborne lidar

- Oceanographic validation – validate the utility of the SSH measurement to meet the science objectives of determining the upper ocean circulation at wavelengths down to ~ 15 km.
  - Moorings of temperature and salinity sensors
  - Station-keeping gliders
  - Upper ocean profilers (Prawler, wire-walker)

# Sea Surface Height Requirement



# Some notes on the SSH spectral requirement

- The random noise will be reduced by 2-d smoothing, an advantage of swath altimetry.
- As the spectral requirement indicates, the noise floor must be reduced below 10 $cm^2$/cyc/km to make significant progress beyond conventional altimetry.
- The rms noise of KaRIN is likely to reach below 2.7 cm (***cross-track averaging***) for SWH ~ 2m on 1 km grids.
- After smoothing over 7.5 km x 7.5 km grids, the noise floor is ~ 2 $cm^2$/cyc/km to resolve ocean signals at 15 km wavelength.
- The requirement is imposed on cross-track averaged data to accommodate the cross-track variability of the measurement errors.

# Measurement of SSH by GPS buoys

- Lack of spatial sampling to produce 7.5 km x 7.5 km smoothed data for comparison with SWOT SSH.
- Time series measurement allows temporal smoothing.
- The working assumption is that temporal smoothing over one hour is sufficient to reduce the spatial variability at wavelengths less than 7.5 km, as most of surface gravity waves have wavelengths less than 1 km, periods less than 1 hour.
- The variance of SSH requirement from integrating 2 $cm^2$/cyc/km to 15 km wavelength is 0.13 $cm^2$, or 0.37 cm for standard deviation on 7.5 km x 7.5 km grids.
- The GPS SSH requirement for random errors is therefore less than 0.37 cm after hourly averaging.

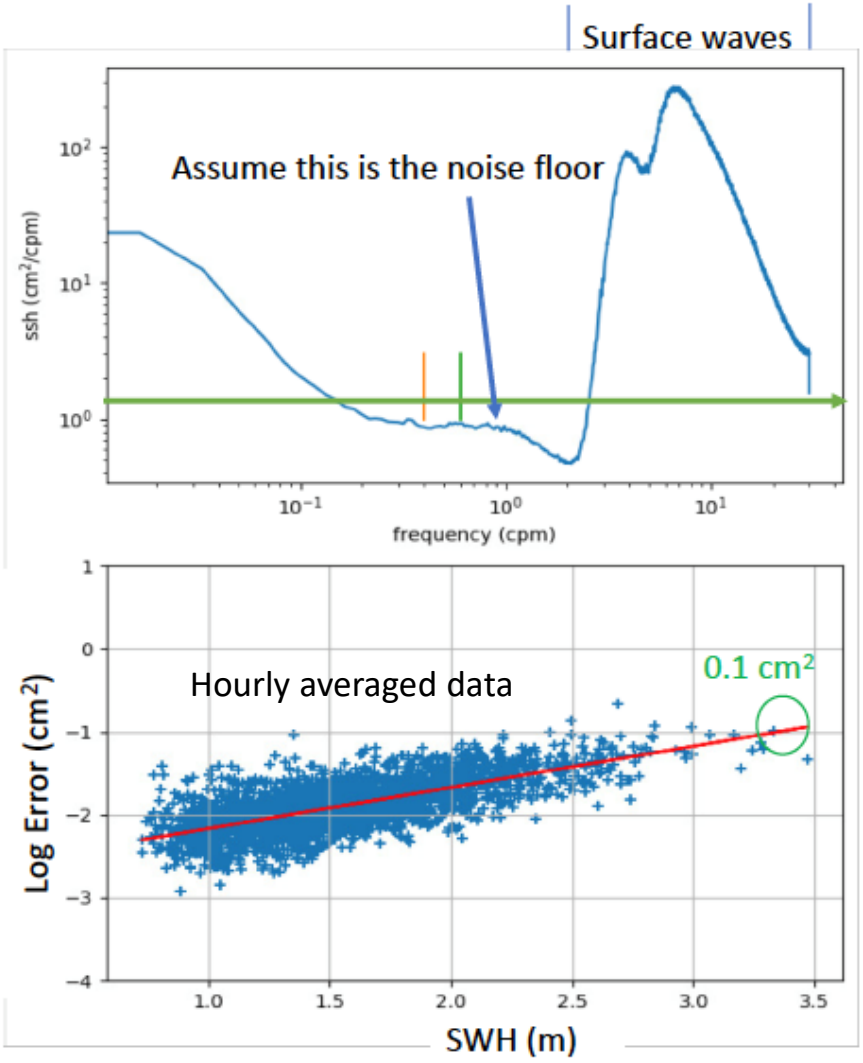
# GPS error estimate from the Daisy Bank Experiment

## Daisy Bank data (1Hz)

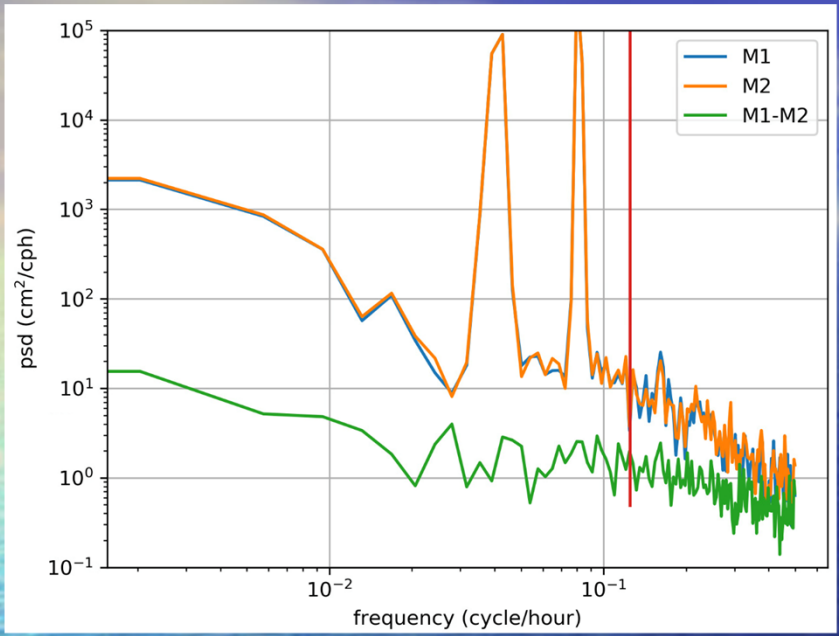

The derived relationship between SWH and GPS error is shown in the lower panel

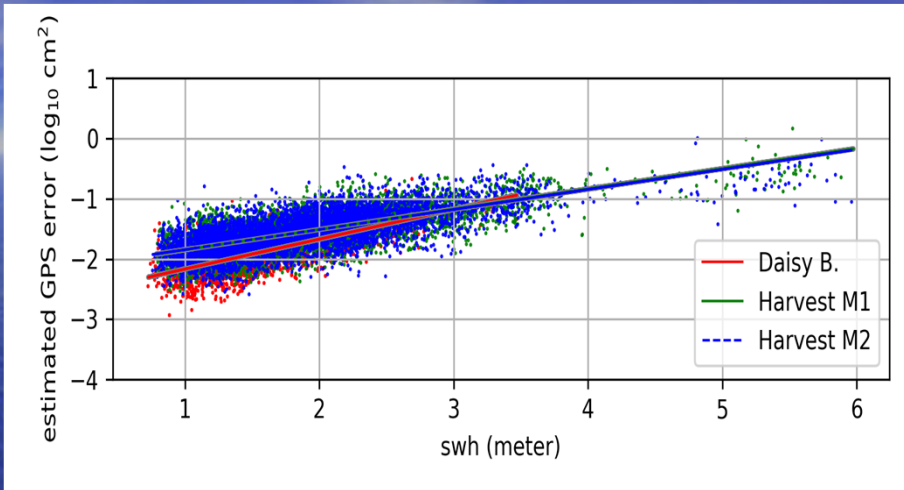
The estimated GPS error reaches 0.1cm$^2$ at SWH=3.3m.

**Conclusion**: **Hourly-averaged GPS signal has less than 0.32 cm noise for SWH<3.3m, meeting the SWOT CalVal requirement.**

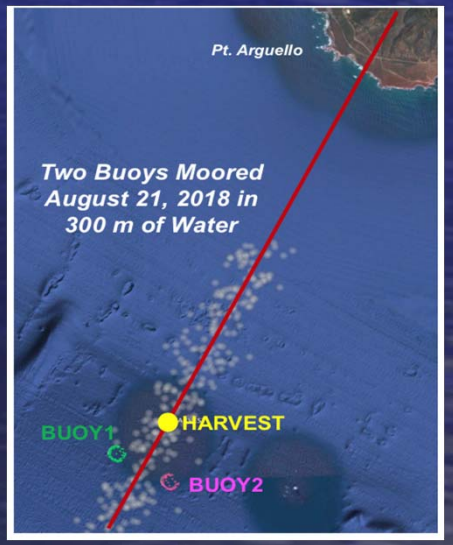


# GPS error estimate from on a pair of GPS buoys




- With 1.5 km separation, the two GPSs should observe the same ocean signals except for the surface waves.
- The SSH-difference indicates GPS errors.
- Integration of the green line gives 0.6 cm RMS.
- Divided by sqrt(2), the rms error is ~0.42 cm, approaching the 0.37 cm requirement.
- The Harvest data suggest that the threshold SWH for meeting SWOT CalVal requirement is ~ 4 m.



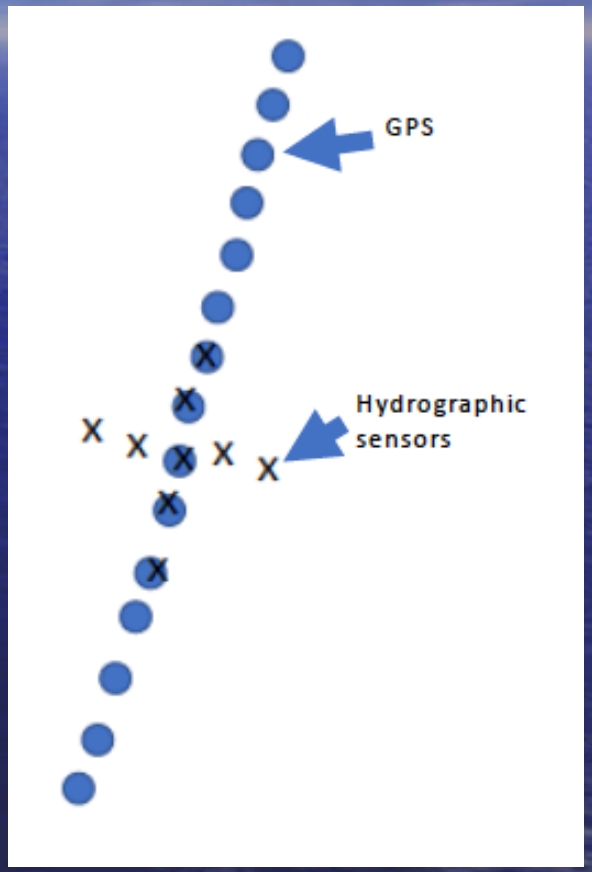
# Meeting the challenge of CalVal with an in-situ observing system

A strawman design (pending on the pre-launch campaign):

- An along-track array of GPS buoys for SSH validation

The minimum length of the GPS array needs to be ~ 120 km, according to a modeling study of the long-wavelength calval by the SWOT nadir altimeter.

- A two-dimensional array of hydrographic sensors (gliders, moored wire walkers/CTDs, etc.) for oceanographic understanding and validation.



# Concluding Remarks

- Preliminary analyses of the data from Daisy Bank and the Harvest Platform suggest that the high-frequency noise from surface waves can be reduced to ~ 4 mm for SWH < 4m, after hourly averaging, meeting the requirement for validating SWOT SSH on 7.5 km grids.
- We still need to evaluate the low-frequency GPS errors.
- The prelaunch campaign will allow the test of the closure of the sea level equation for assessing the various contributions to the errors of in-situ SSH measurement (e.g., water vapor effects and MSS errors)
- The array should be consist of buoys ~ 7.5 km apart over a distance ~ 120 km. (Wang and Fu, 2019: https://doi.org/10.1175/JTECH-D-18-0148.1). The actual length of the array will be decided after the pre-launch campaign.