Evaluations of VDATUM in California

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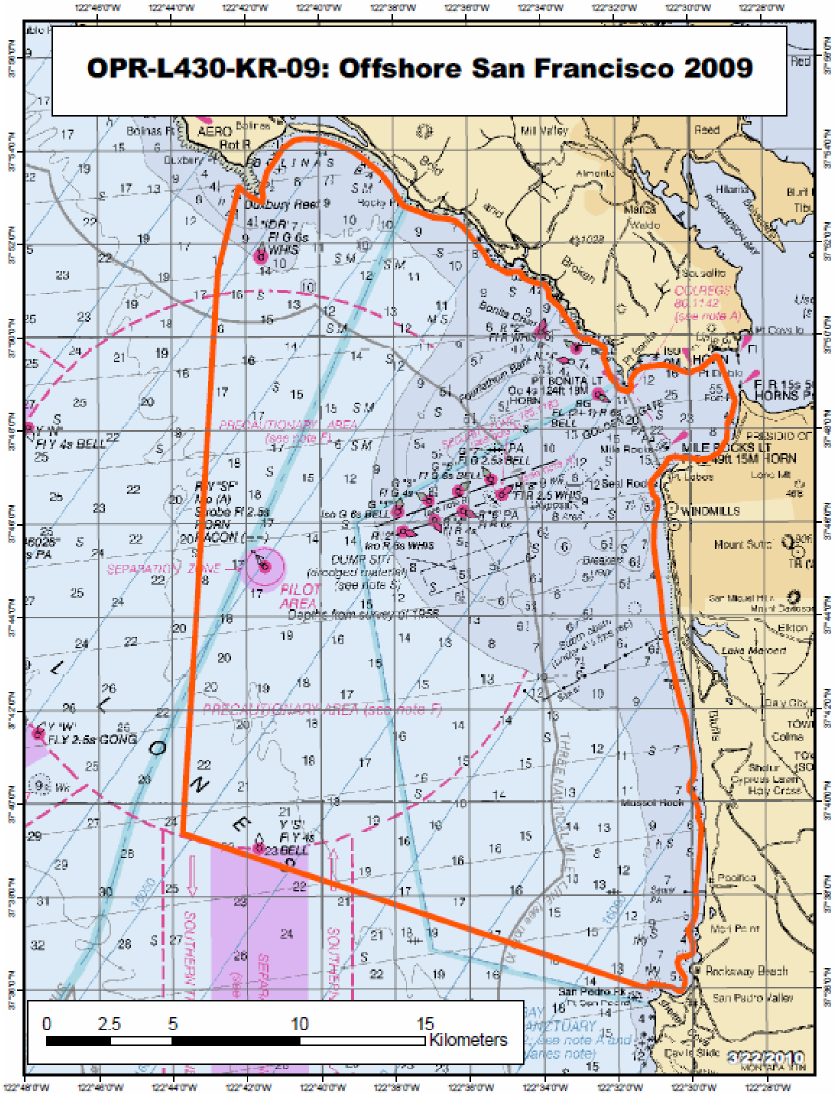
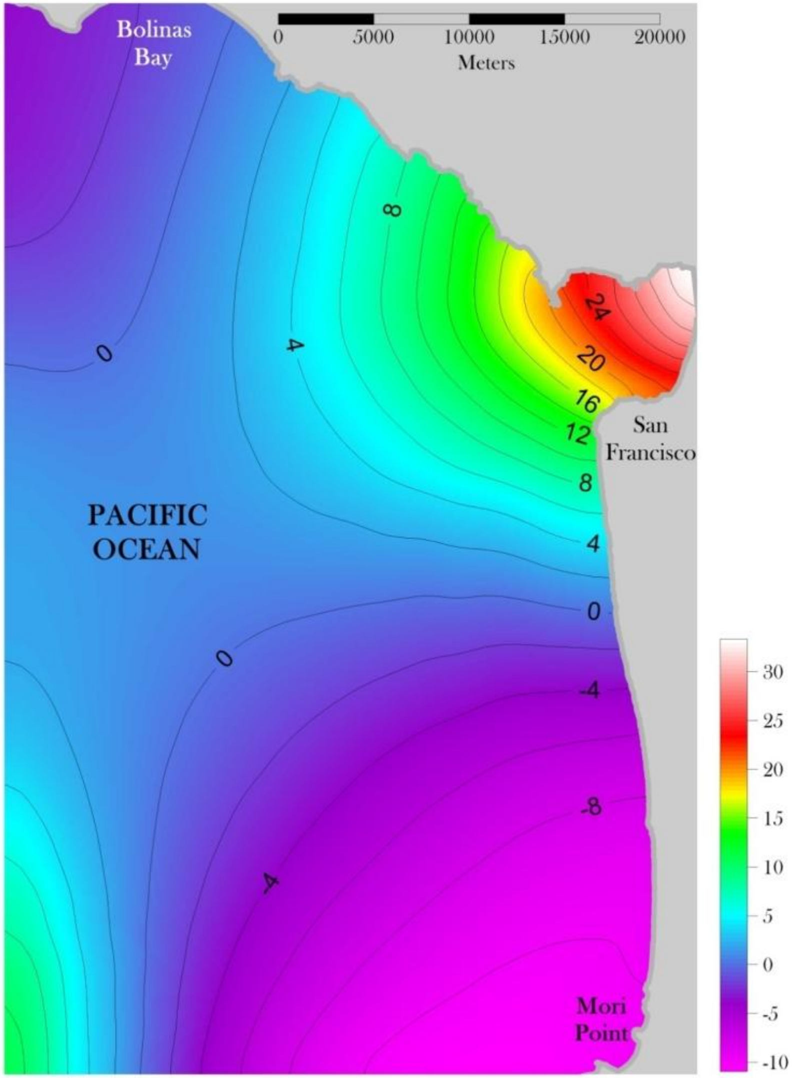
NOAA charting survey, vicinity of Golden Gate

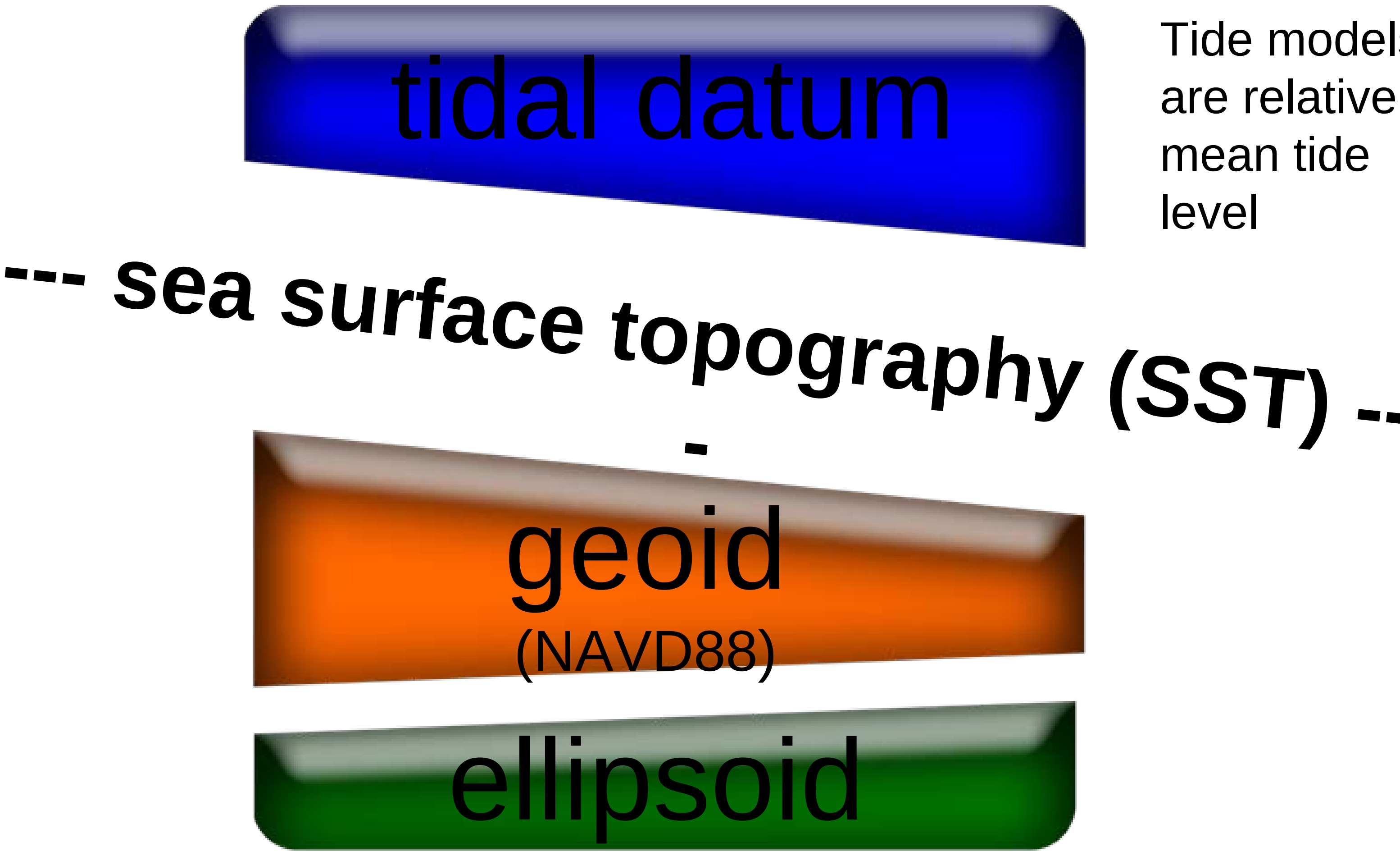




Evaluations of VDATUM in California

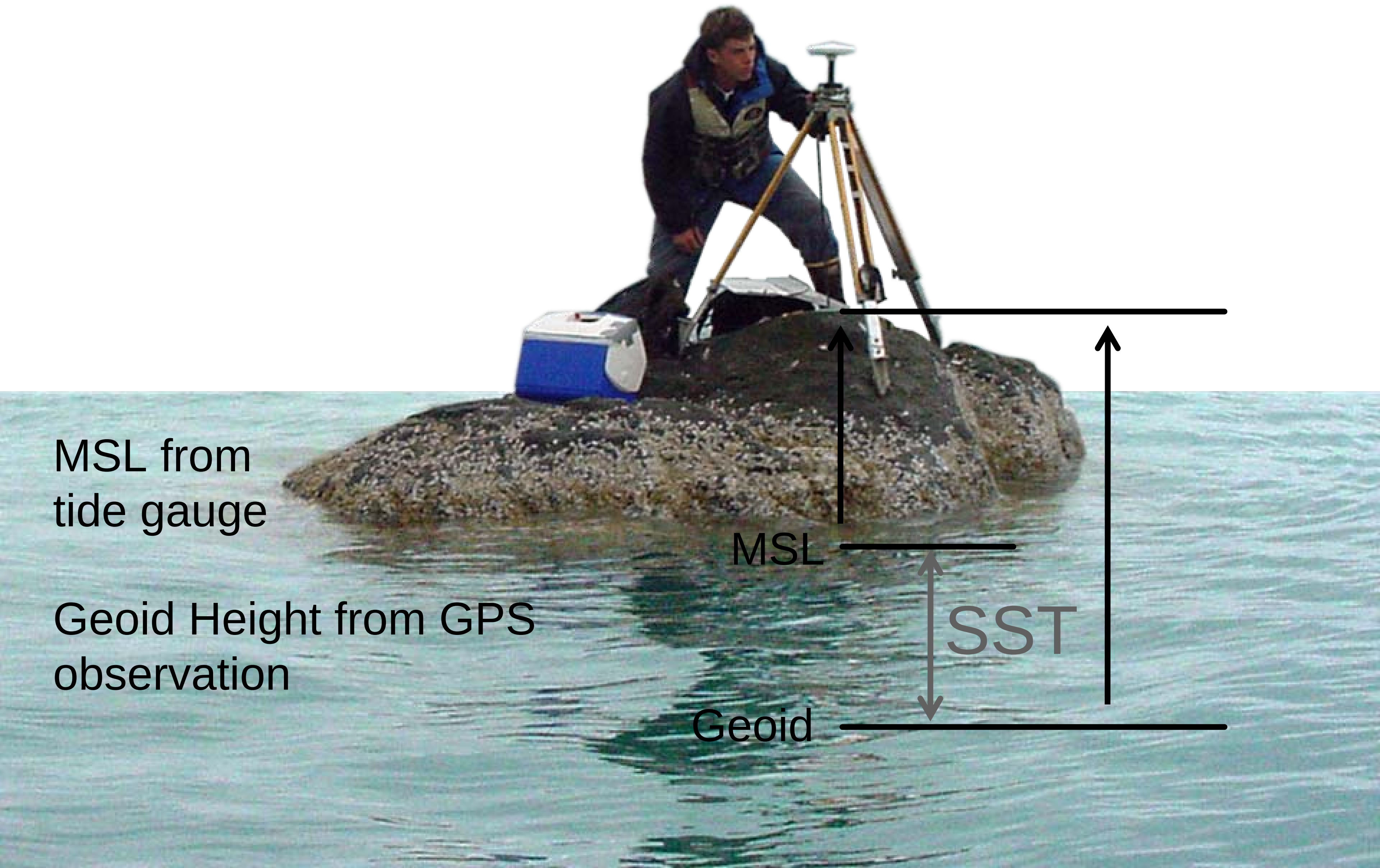
- Two Assessments of VDATUM using data from California
- First is vessel-based GPS water level observations in San Francisco area offshore the Golden Gate
  - Nautical charting survey for NOAA Office of Coast Survey in 2009
  - Includes task to assess VDatum using data and observations from this nautical charting survey

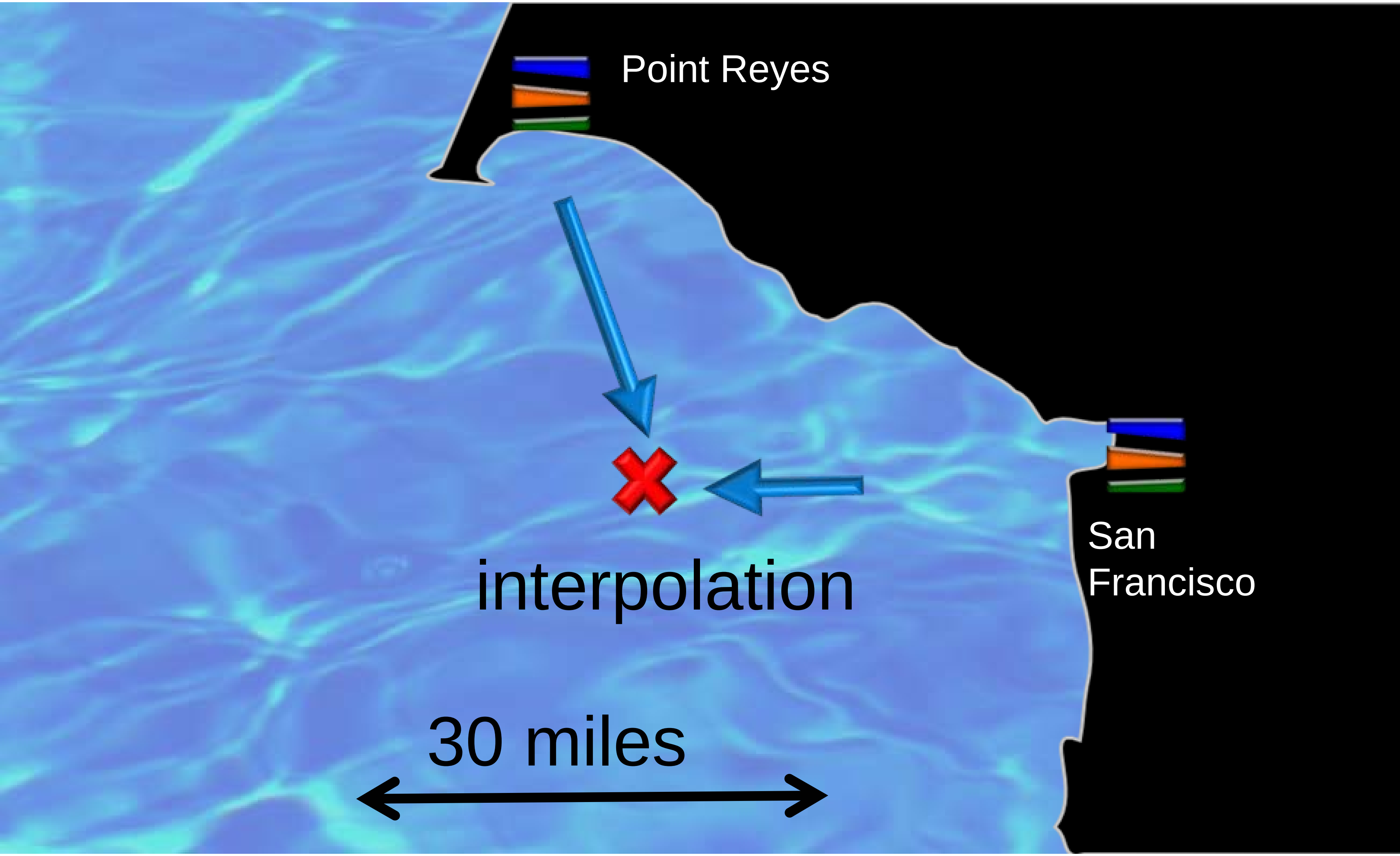
- Second is a brief evaluation of the sea surface measurements produced as a component of airborne LiDAR hydrographic surveying
  - In Southern California between two NWLON tide stations: La Jolla and San Diego

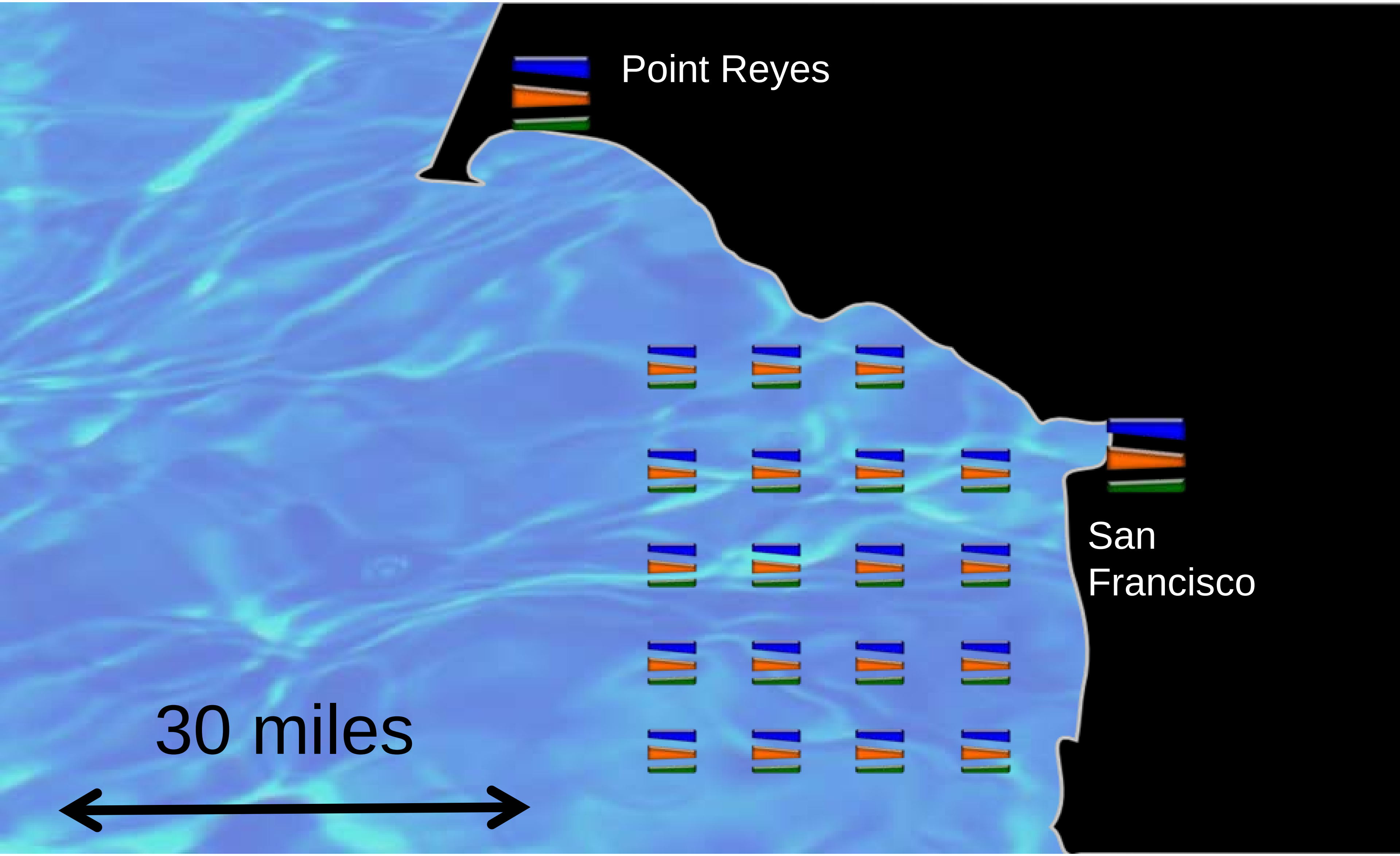


Tide models are relative to mean tide level

Sea Surface Topography (SST)

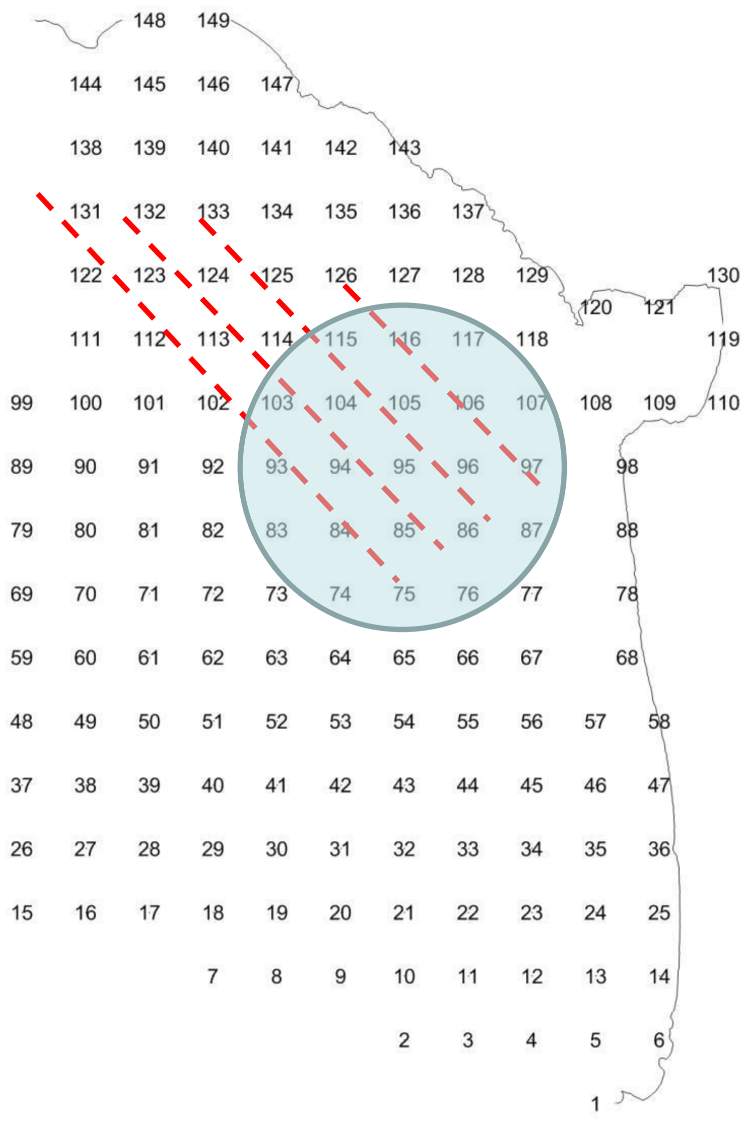



Point Reyes
San
Francisco
interpolation
30 miles


Point Reyes
San Francisco
30 miles

GRID

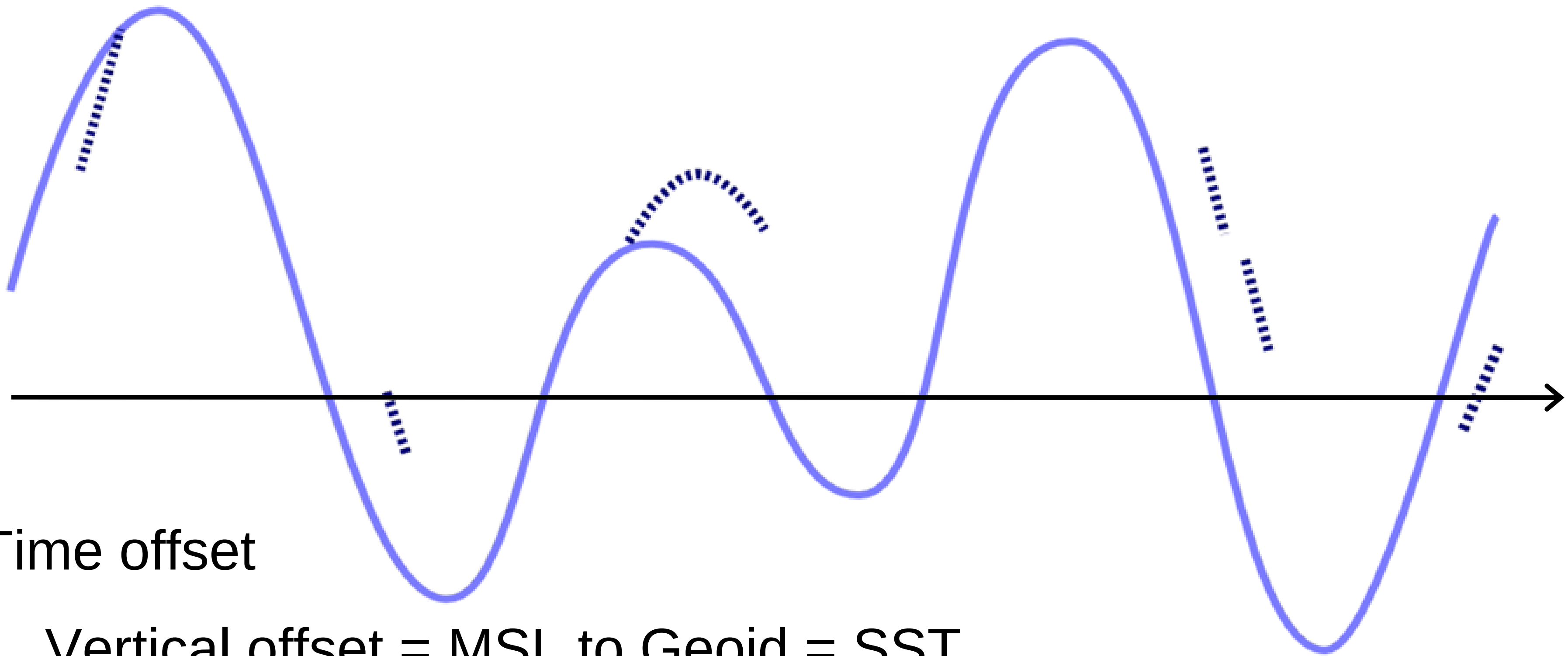
- 2km spacing for grid points
- 4km buffer around each point (overlap)
- 1300 to 22000 points per grid point



least squares fit

GPS waterline from boat, corrected to geoid

MSL tide curve from NOAA tide station

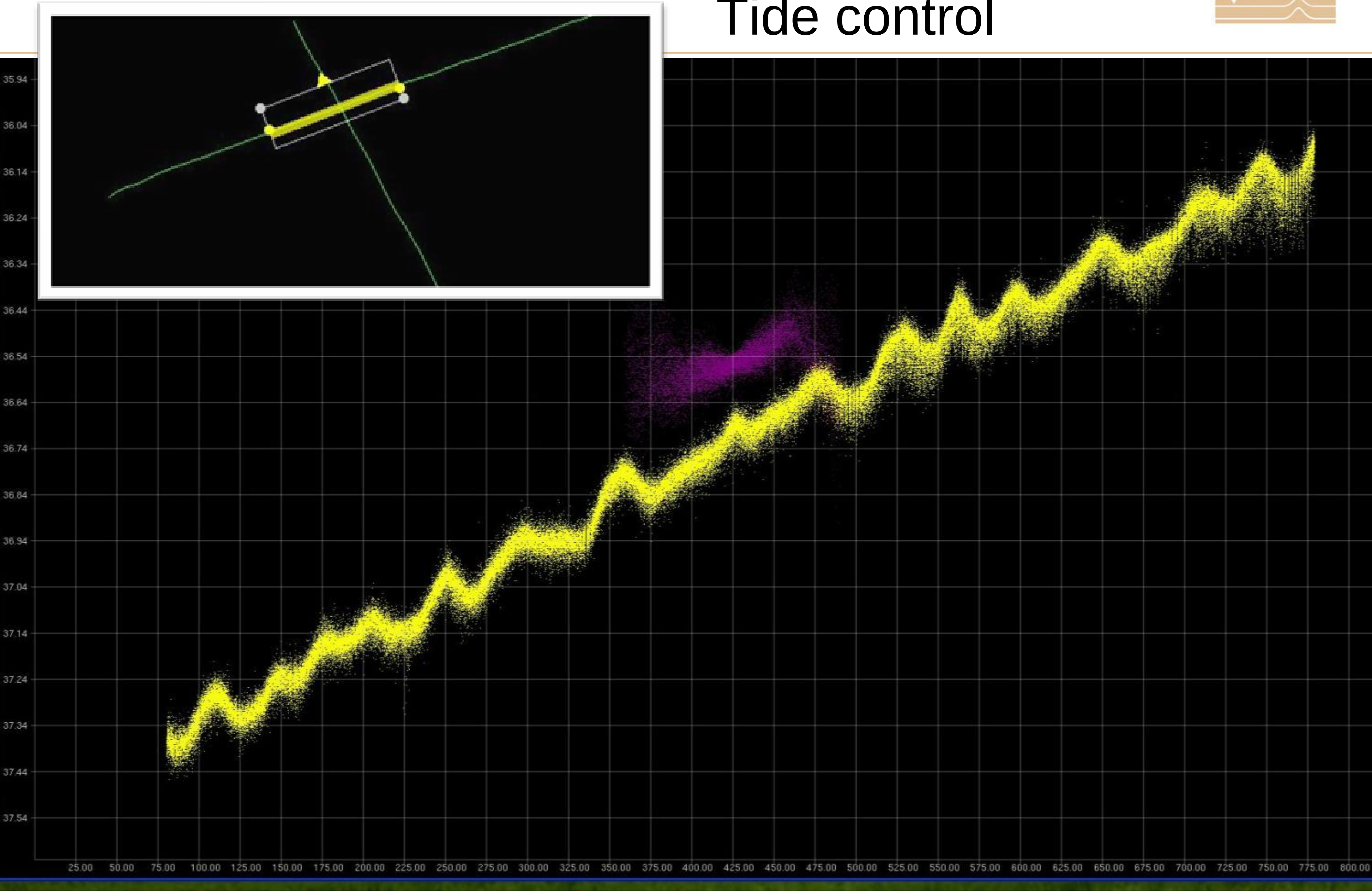


Time offset

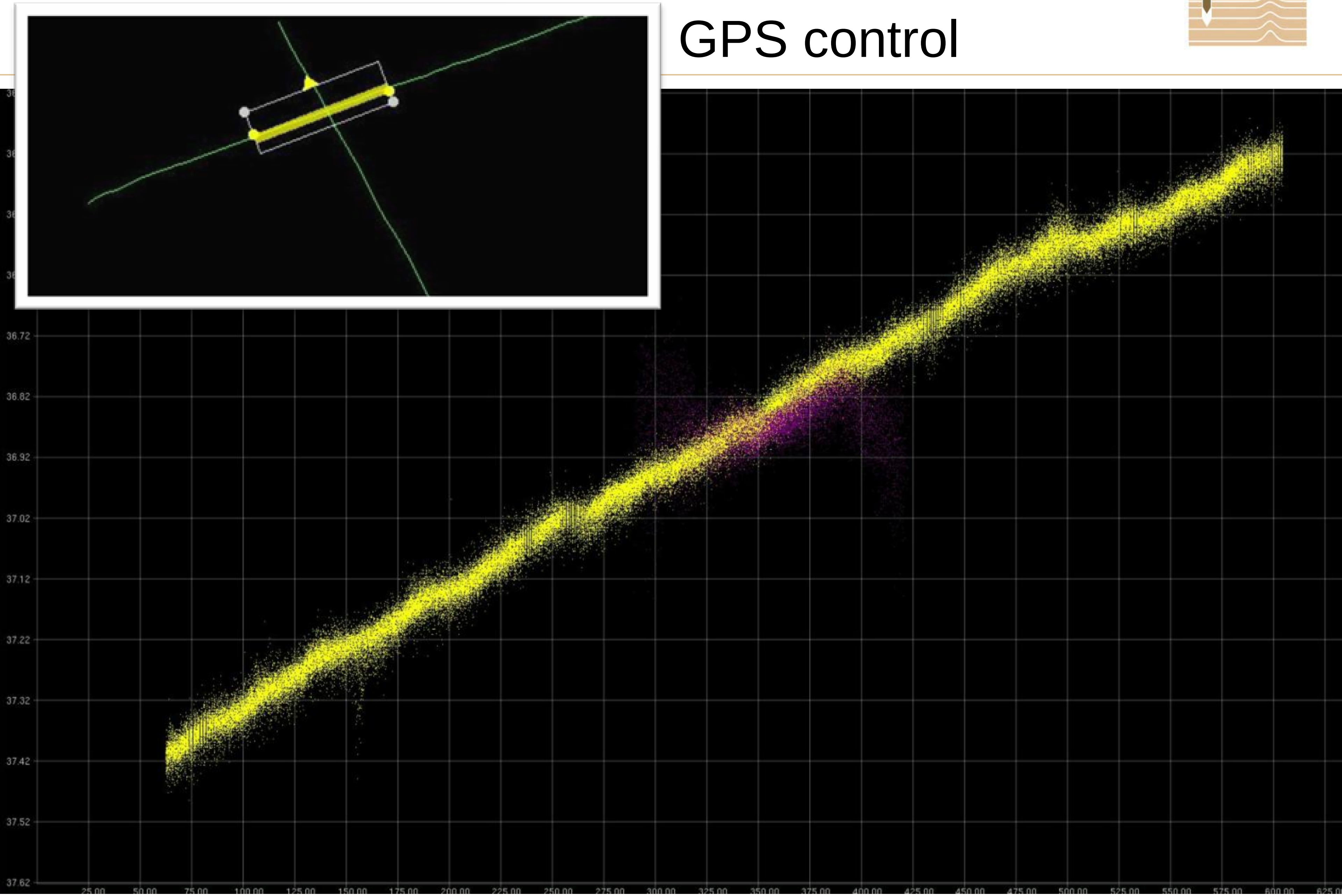
Vertical offset = MSL to Geoid = SST

Scaling = tide range ratio

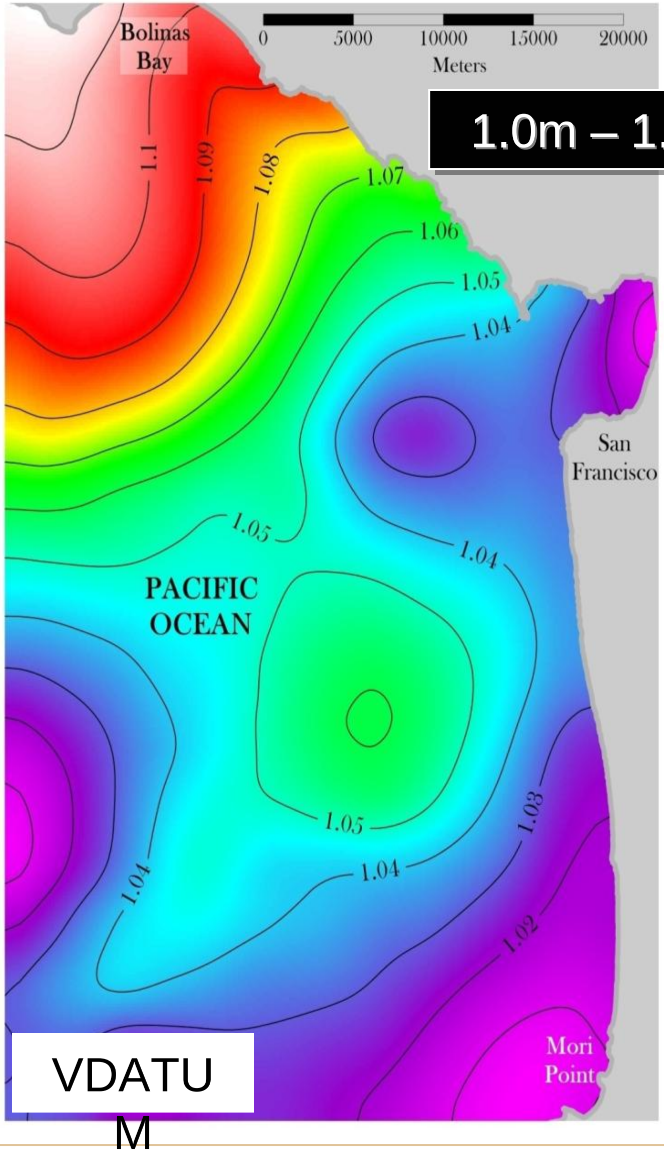
Tide control

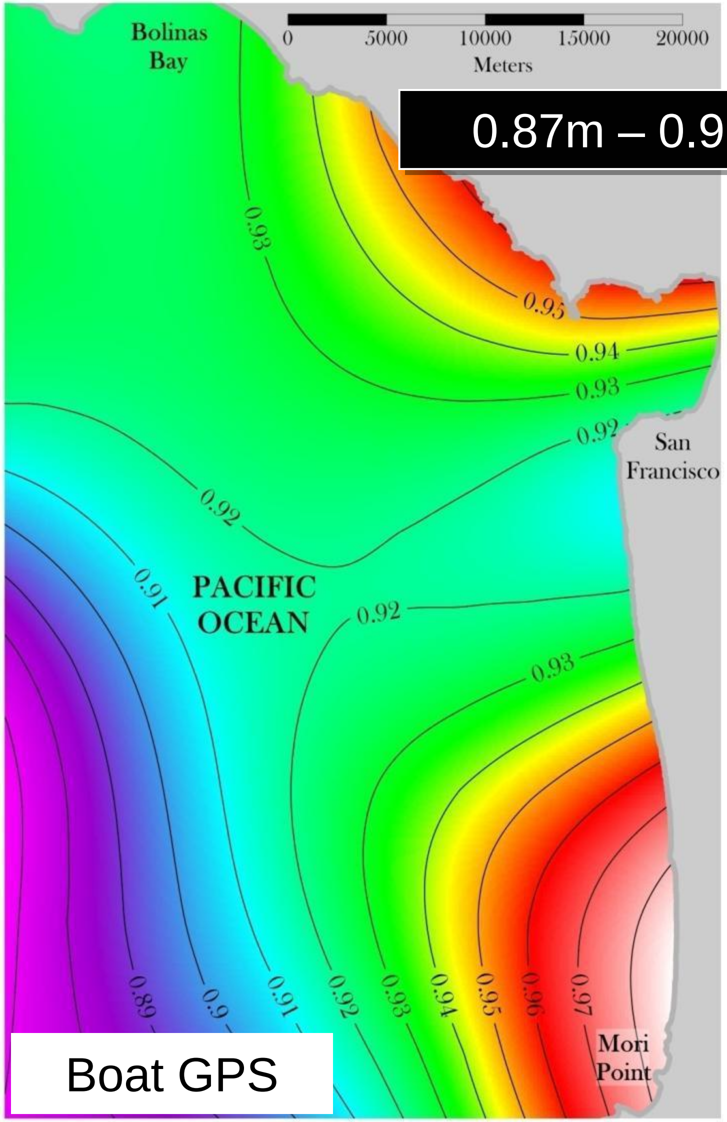


GPS control


36.72
36.82
36.92
37.02
37.12
37.22
37.32
37.42
37.52
37.62
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
275.00
300.00
325.00
350.00
375.00
400.00
425.00
450.00
475.00
500.00
525.00
550.00
575.00
600.00

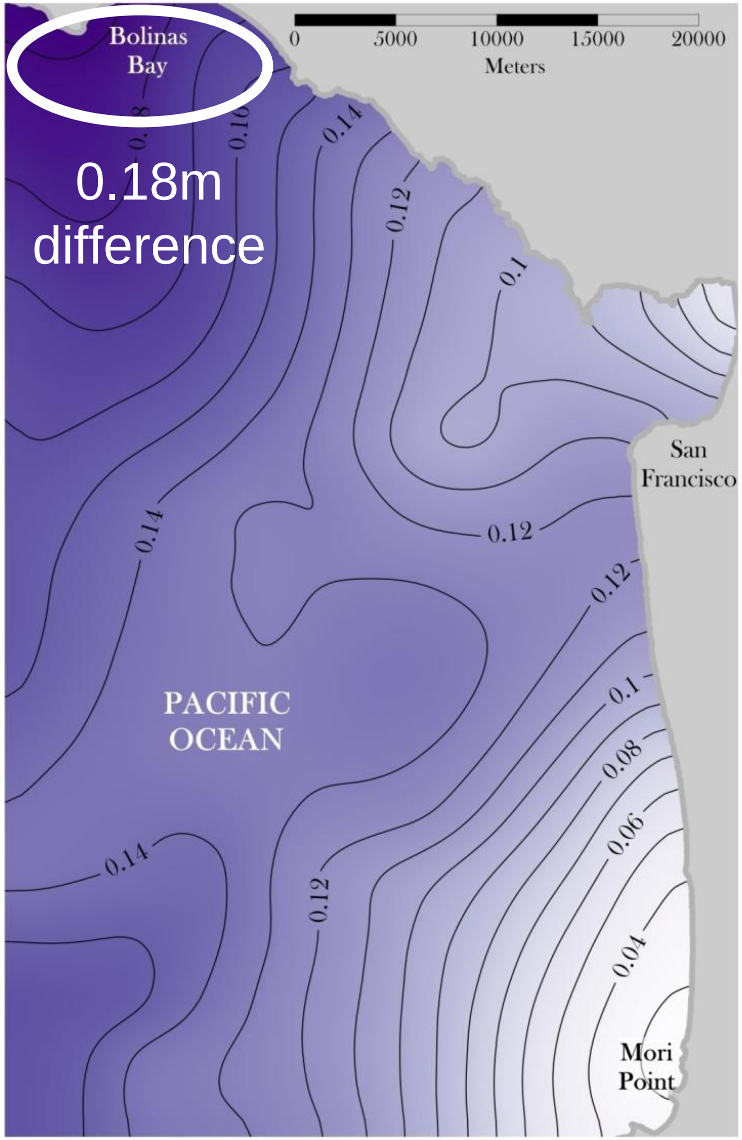
SST: Geoid - MSL



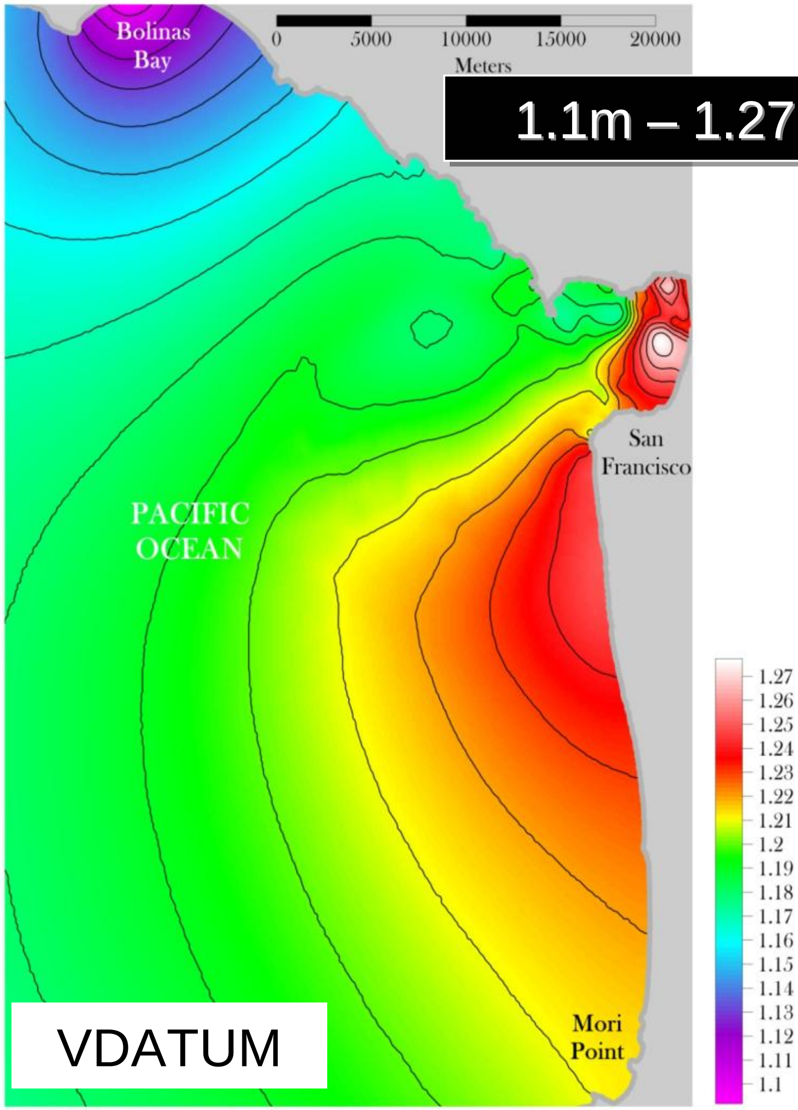


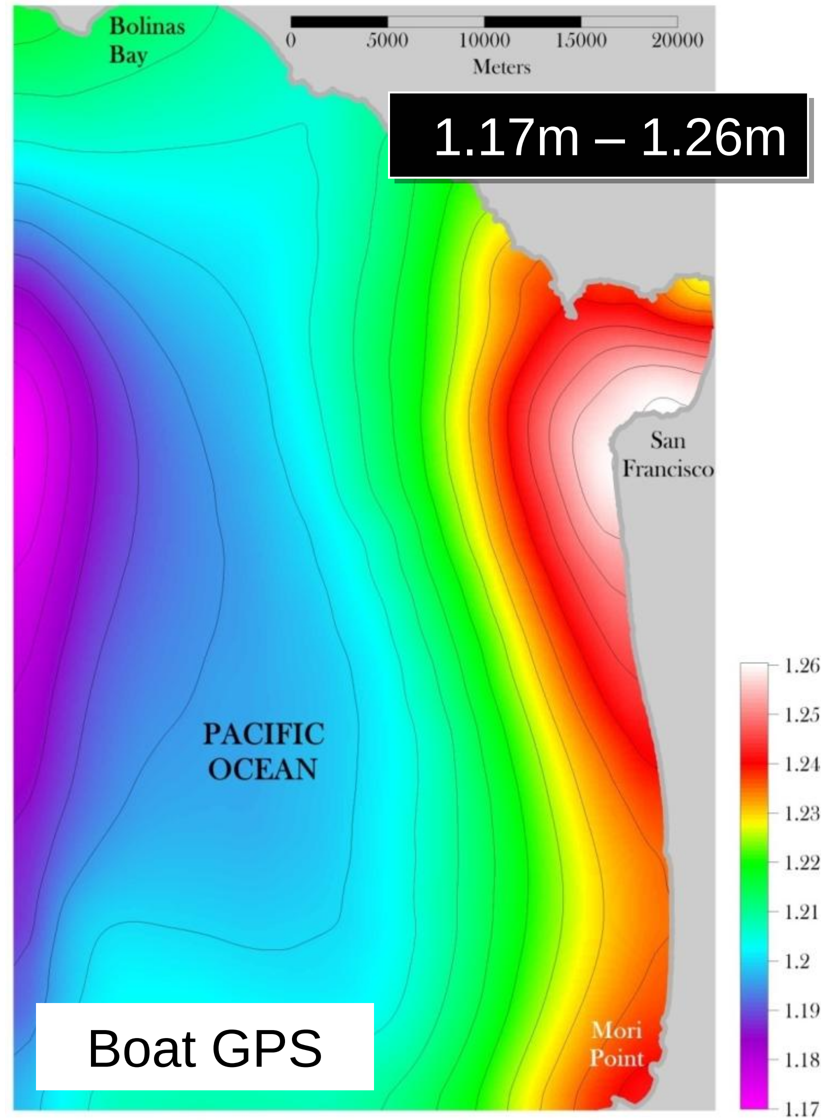
SST Differences

On average, VDATUM places MSL 0.12m higher relative to the geoid than the Boat GPS measurements



Tide Range (MHW – MLW)

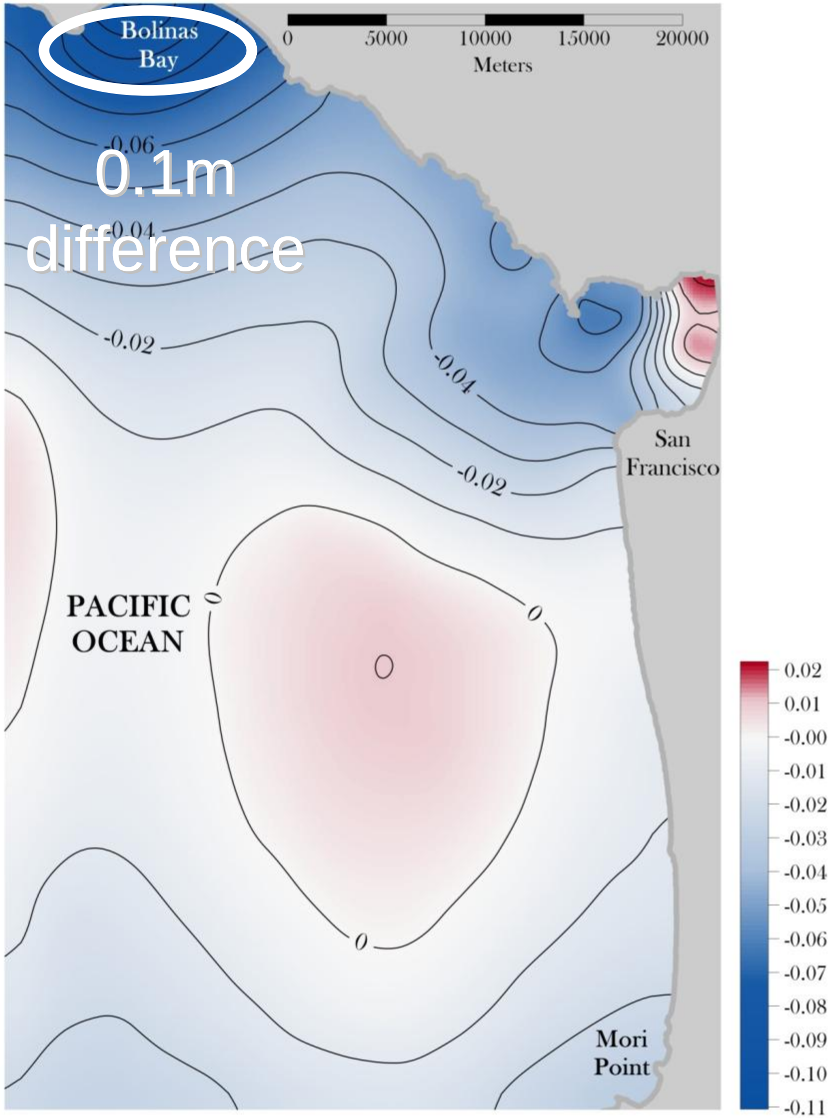




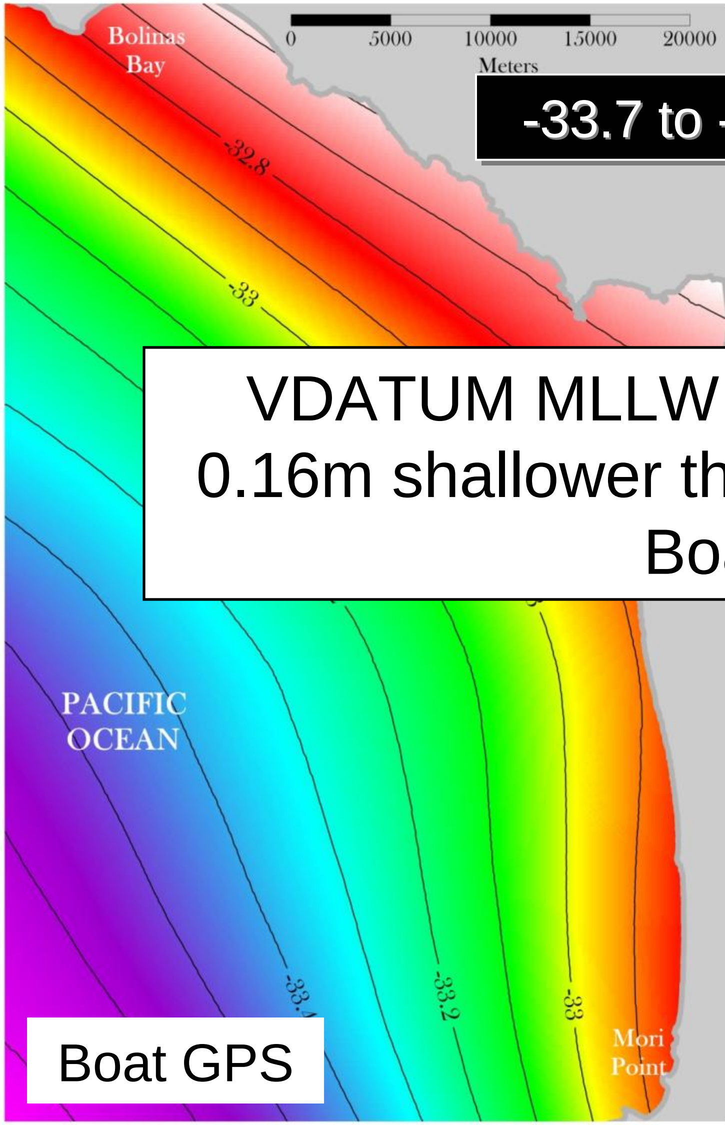
Tide Range

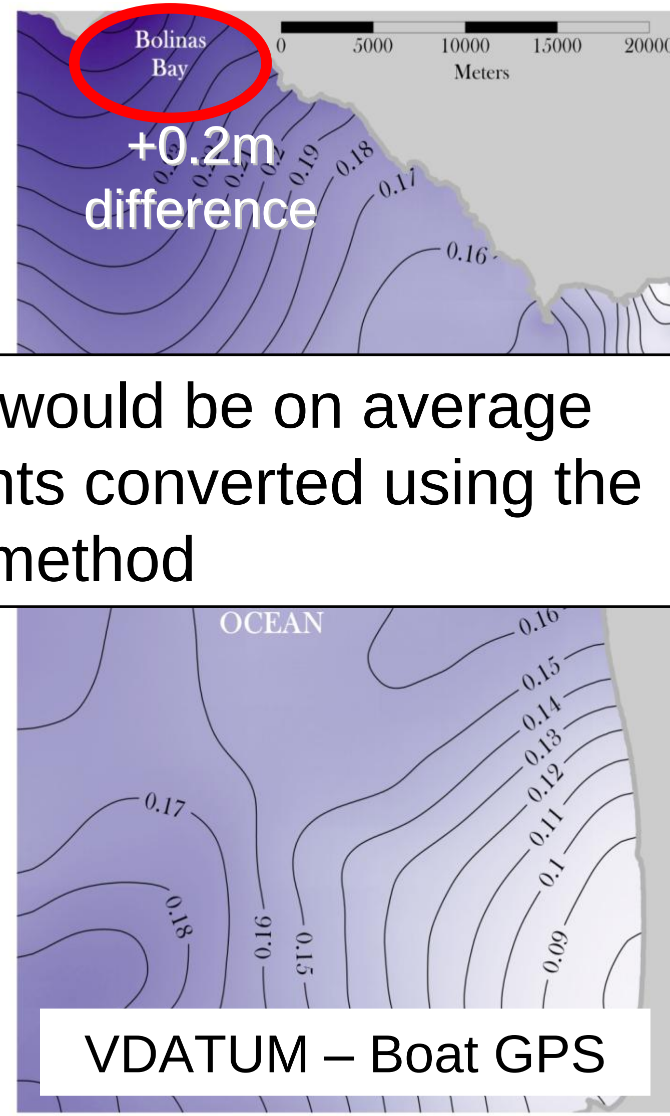
Tide range agreement very good, except up north near Bolinas Bay.

Independent tide gauge observation near Bolinas Bay confirm Boat GPS tide range



Ellipsoid to MLLW



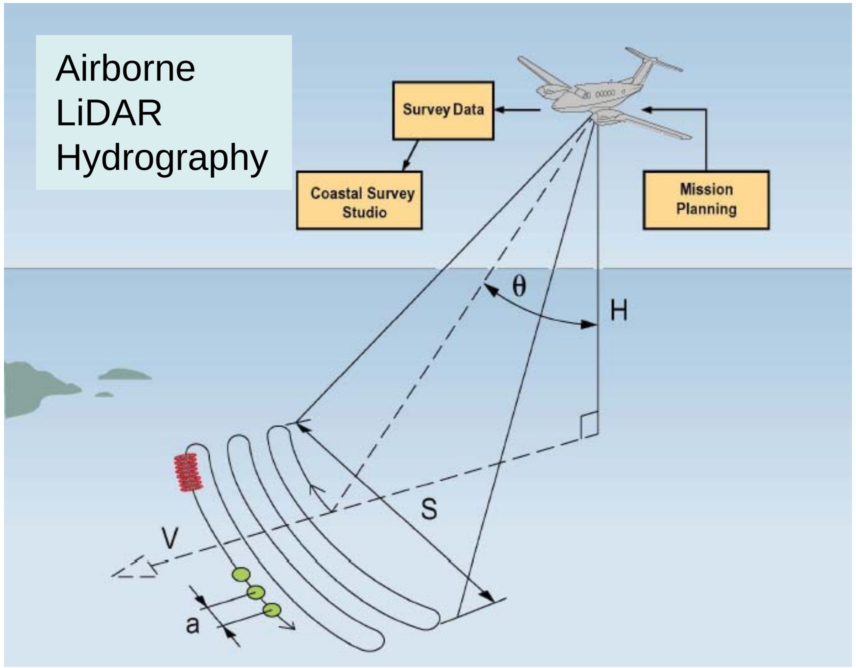


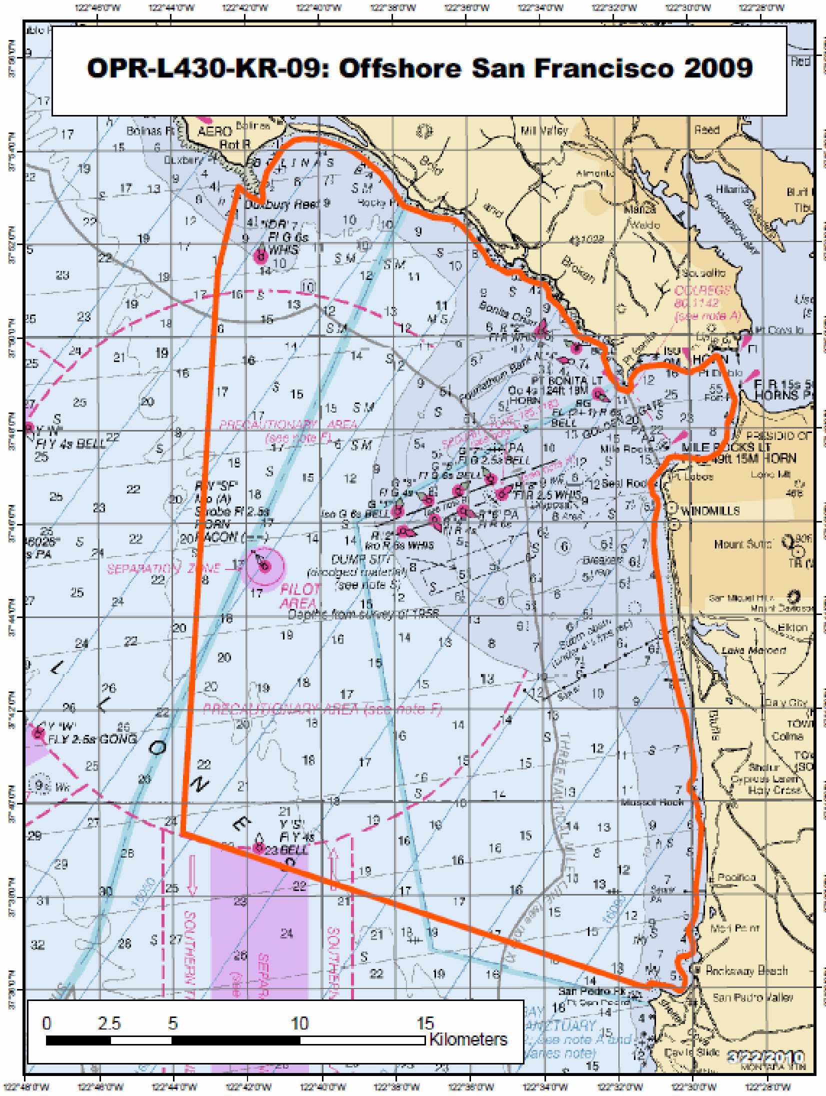
VDATUM MLLW heights would be on average 0.16m shallower than heights converted using the Boat GPS method

Results from Boat GPS Analysis

1. Boat GPS measurements generally confirm the VDATUM SST and tide models
2. The two methods (Boat GPS and VDATUM) would produce MLLW soundings for this survey within 0.23m at 2 sigma
3. VDATUM places MSL 0.12m higher relative to the geoid than the Boat GPS method
4. Level of confidence in the Boat GPS data is not sufficient to suggest the differences are errors in the VDATUM model
5. The VDATUM model should be investigated in the north end of the project

What might bathymetric LiDAR tell us about Vdatum?

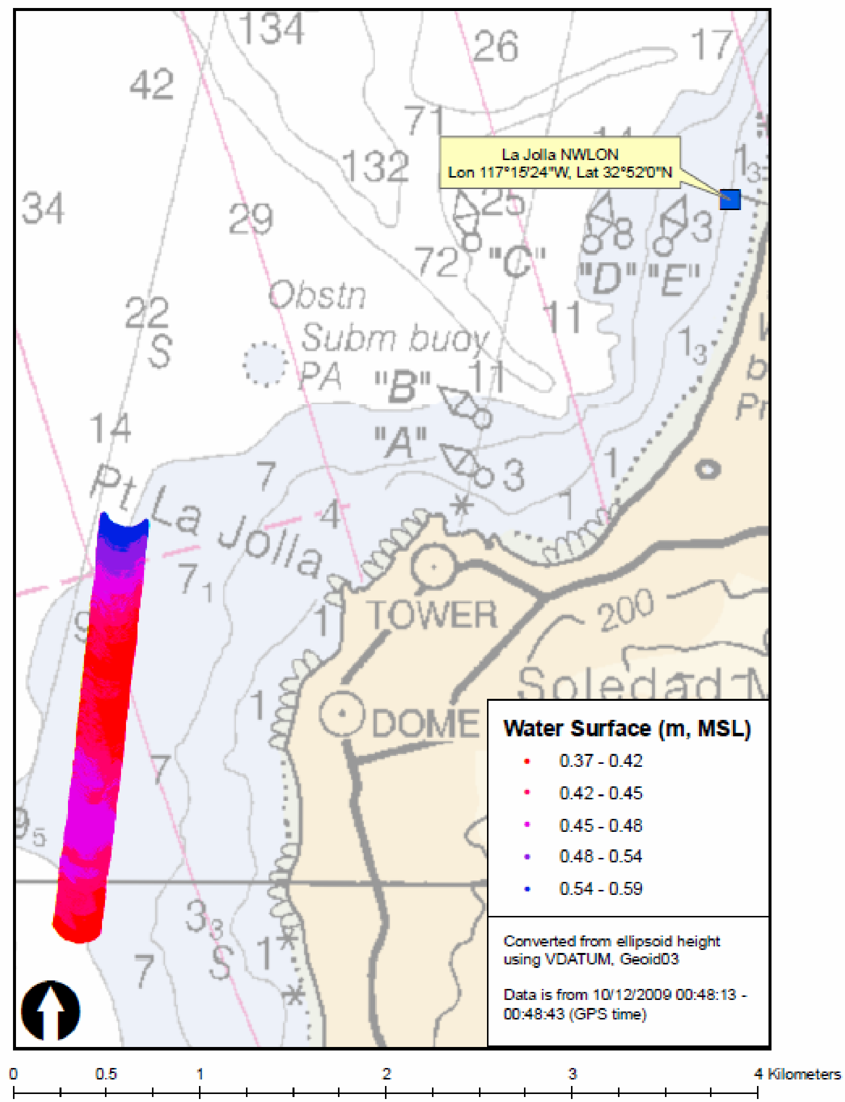




Sea Surface Elevation Data from Hydrographic Lidar

- Bathymetric lidar sea surface heights relative to the ellipsoid
- Flight line proceeds south about 2.2km, offshore from La Jolla, CA
- Flight line duration was 30 seconds
- Between 2 NOAA NWLON stations at La Jolla and San Diego

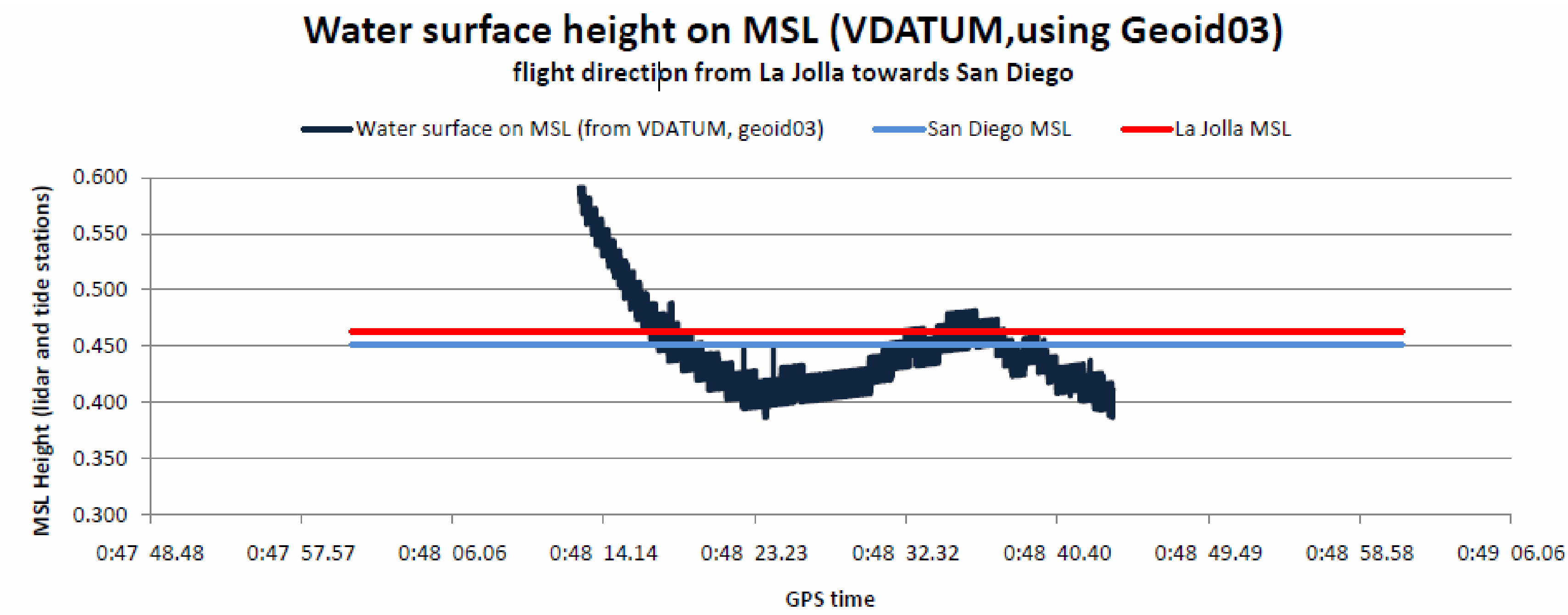
Water Surface from Bathy Lidar on MSL



Sea Surface Elevation Data from Hydrographic Lidar

Bathy sea surface ellipsoid heights and the VDATUM model work together quite well

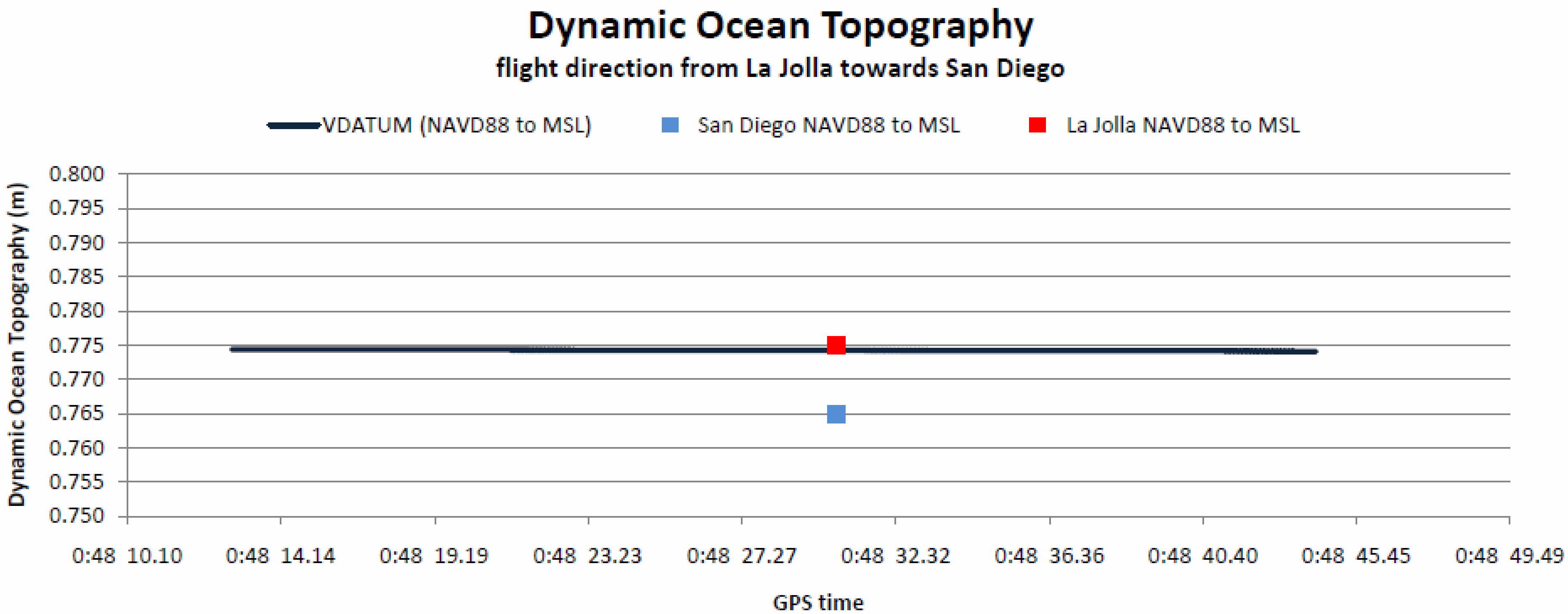
MSL sea surface from the bathymetric lidar as corrected by VDATUM is quite consistent with the MSL heights from the La Jolla and San Diego NWLON (+/-5cm) except for the beginning of the line



Sea Surface Elevation Data from Hydrographic Lidar

Apparent sea surface variation over this line (relative to MSL, about 20cm). Possible causes:

- Error in the plane measurement (GPS, IMU, filtering, laser)
- Sea surface variation is "real", and represents long period ocean waves (maybe 7cm amplitude, 17 sec period…give or take)
- Variation is actually in dynamic ocean topography. Based on the tide data from the 2 closest NWLON tide stations at La Jolla and San Diego, there is no appreciable tide change. However the airborne GPS water elevation variation is within the range of difference between the La Jolla and San Diego DOT values (10cm)



Lessons learned

Boat GPS

1. is an efficient means to evaluate VDATUM over a large area.
2. Not as accurate as stationary, longer term observations (tide gauge).
3. Better static draft measurement tools, especially on large boats would help.
4. Frequent, short GPS buoy deployments as check.

LiDAR GPS

1. LiDAR survey lines are probably too brief to give a useful trend for the tide curve.
2. Perhaps longer lines could indicate the accuracy of the vdatum tidal model, but data are impacted by geostrophic and meterological effects too.

Thank You

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Difference between PPK GPS and traditional tide gauge water level heights.

San Francisco is a NOAA NWLON station, the other six stations were underwater tide gauges deployed by JOA and Fugro-Pelagos. The offshore stations were outside of the survey area, and their selection radius was enlarged in order to capture more PPK GPS data for the comparison.

	Bolinas Bay	Mori Point	North Channel	South Channel	Offshore 1	Offshore 2	San Francisco
radius	2km	2km	2km	2km	4km	5km	2km
count	1703	379	610	1869	633	90	1939
mean	-0.892	-0.916	-0.962	-0.924	-0.839	-0.843	-0.950
min	-1.090	-0.946	-1.09	-1.069	-0.897	-0.890	-1.101
max	-0.723	-0.834	-0.828	-0.805	-0.771	-0.804	-0.803
standard deviation	0.055	0.020	0.060	0.053	0.029	0.024	0.048

Mean difference by individual survey vessel	**Bolinas Bay**	**Mori Point**	**North Channel**	**South Channel**	**Offshore 1**	**Offshore 2**	**San Francisco**
Pacific Star	-0.887	-0.914	-0.971	-0.945	-0.839	-0.843	-0.955
R2	-0.927	-0.925	-0.952	-0.897			-0.939
D2	-0.881		-0.937	-0.99			-0.963

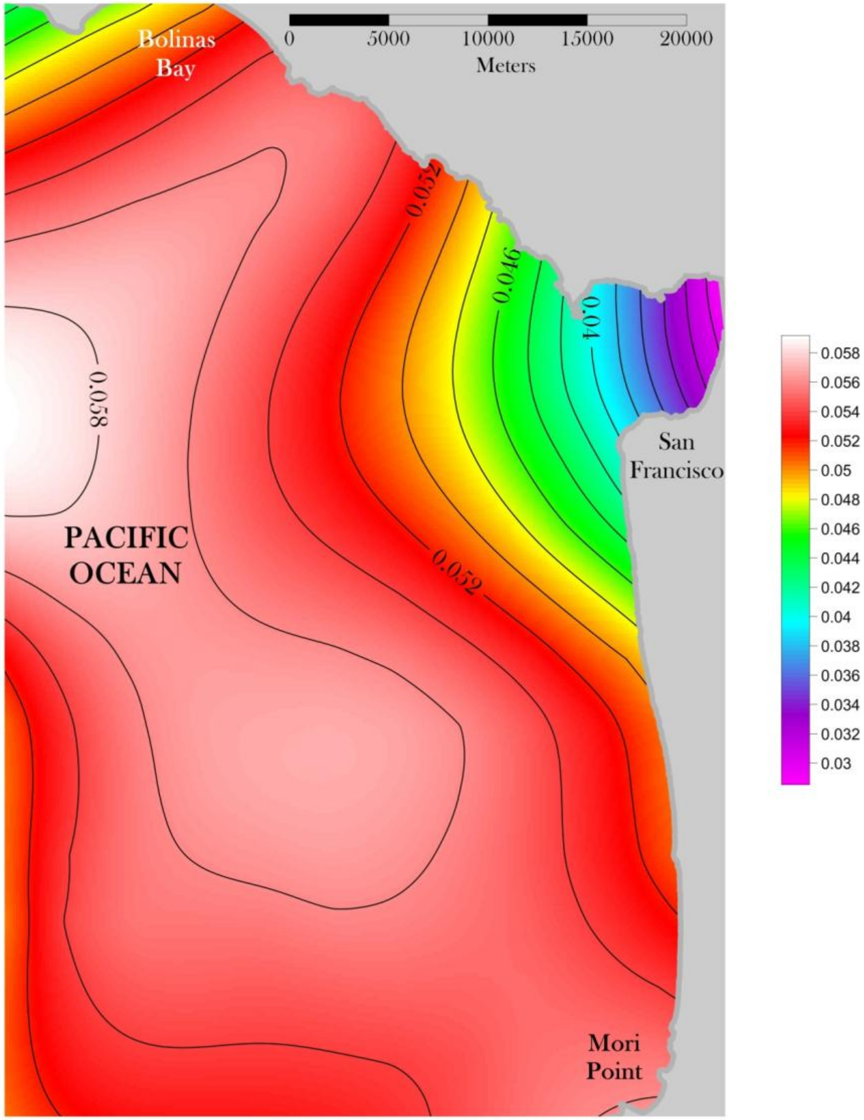
Table 2. Boat to boat comparison of water level heights within a given distance of each other. The radius for the Pacific Star comparisons was increased to include more data. The difference between R2 and D2 is significant, but not consistent with the results of the Pacific Star comparisons, or with the comparisons of those two vessels to tide gauges. It is an indicator of the level of inconsistency in the PPK GPS water level heights.

	D2 - Pacific Star	R2 - Pacific Star	R2 - D2
radius	5km	5km	2km
count	4924	4389	10464
mean	-0.030	-0.027	0.061
median	-0.025	-0.044	0.058
min	-0.212	-0.160	-0.106
max	0.137	0.175	0.194
standard deviation	0.066	0.081	0.039

Table 3. Mean Tide Range (Mn): difference between underwater tide gauge TBYT computation, PPK GPS model and VDATUM

Tide Station	TBYT Mn	PPK GPS Mn	PPK GPS Residual	VDATUM Mn	VDATUM Residual
Bolinas Bay	1.197	1.205	0.008	1.145	-0.052
North Channel	1.236	1.239	0.003	1.185	-0.051
South Channel	1.314	1.257	-0.057	1.254	-0.060
Mori Point	1.212	1.230	0.018	1.212	0.000
Offshore 2	1.187	(outside of model)		1.170	-0.017
Offshore 1	1.187	1.188	0.001	1.180	-0.007

RMS of lsq fit



MSL (1 month, 720pts)

Compare average of hourly tide heights to “control” station.

MLLW (1 month, 30 pts)

Compare average of lower low tides each day to “control” station average for same time period.

Least squares

use ALL available data for comparison, compare per point, not average. Determine MSL and tide range, then derive MHW, MLW, MLLW etc.

Number

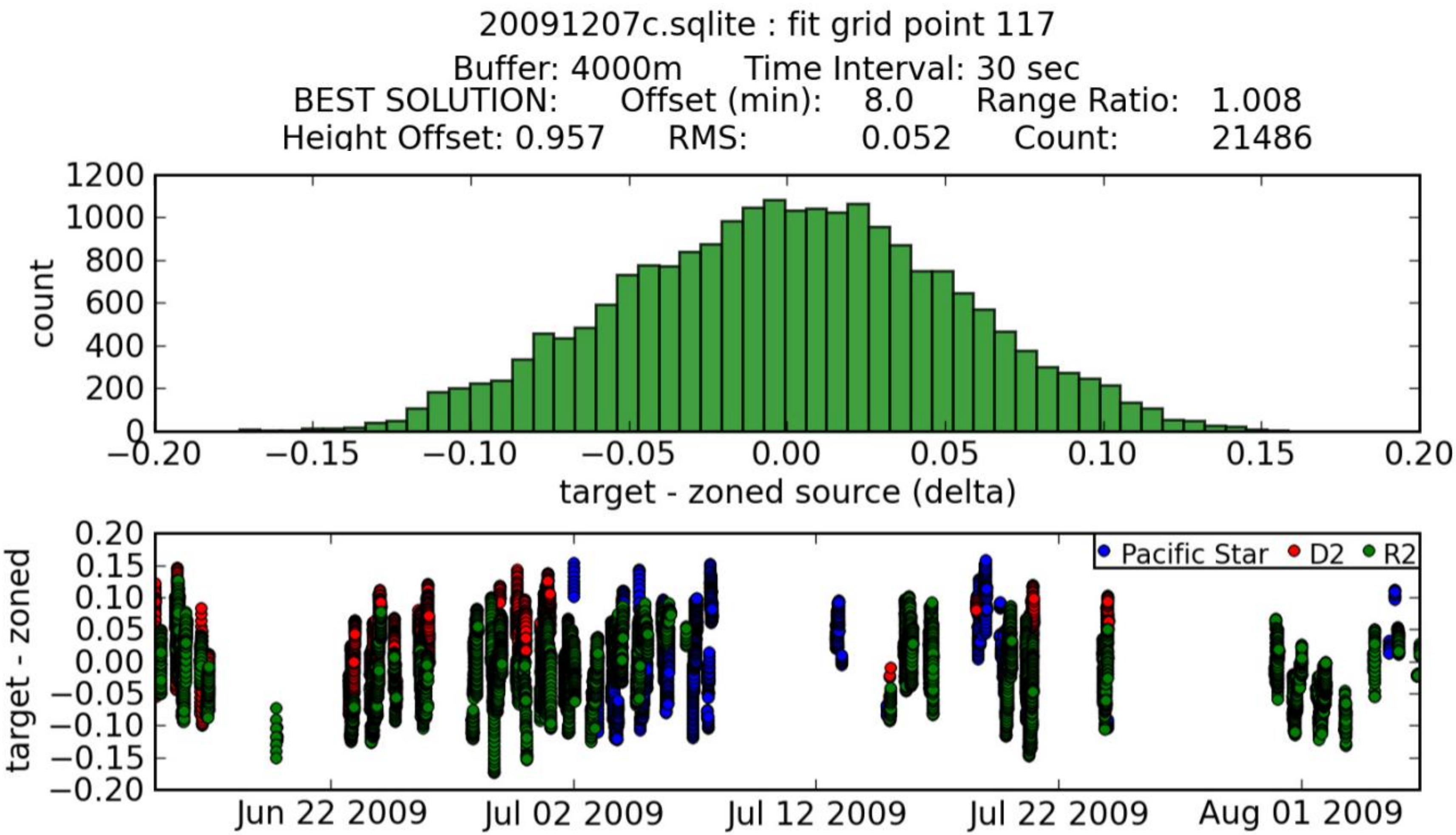
149 grid cells in project area

9000 (avg) data points per grid cell

36 iterations (avg) per grid cell

5,364 least squares solutions

DATUM



20091207c.sqlite : fit grid point 117
Buffer: 4000m Time Interval: 30 sec
BEST SOLUTION: Offset (min): 8.0 Range Ratio: 1.008
Height Offset: 0.957 RMS: 0.052 Count: 21486
count
target - zoned source (delta)
target - zoned
Pacific Star
D2
R2
Jun 22 2009
Jul 02 2009
Jul 12 2009
Jul 22 2009
Aug 01 2009