Ellipsoidal Referenced Surveys and the Changing Realization of the Hydrographic Vertical Datum

Jack L. Riley

NOAA National Ocean Service

Silver Spring, MD

Overview

Hydrography…ellipsoidal reference

- From whence do we reckon?
- NOAA VDatum

Engineering the VDatum validation

- Compare approved method to “new”
- “Tide gauges” with ellipsoidal tie
- Example dataset: Puget Sound, WA

Closing Remarks

Hydrography…ellipsoidal reference: From whence do we reckon?

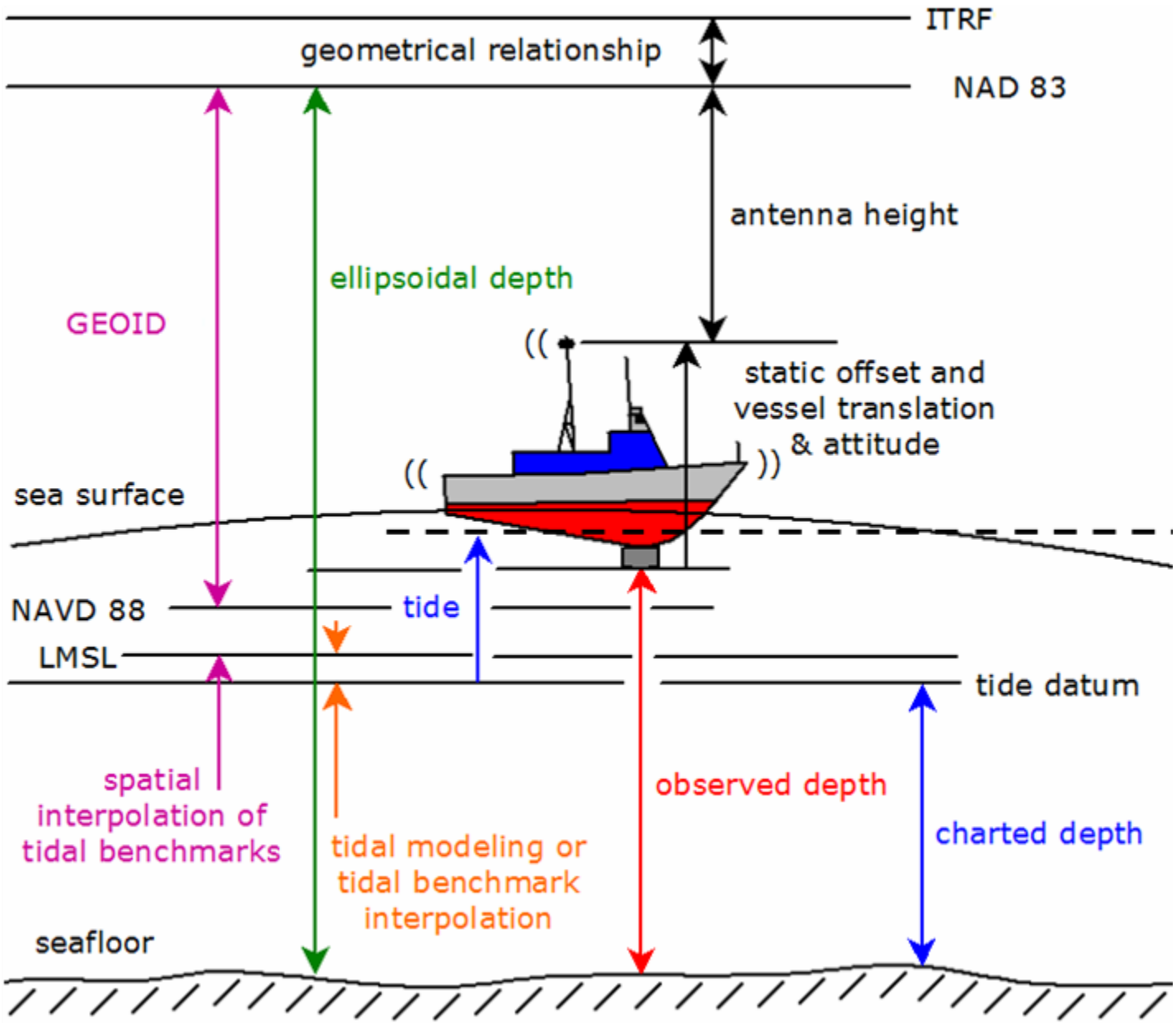
In situ water surface

- Local chart datum according to estimated *relative* tides; e.g., MSL - MLLW
- Vertical datum is not “flat” (3D)
- Geoid & topography of the sea surface (TSS)

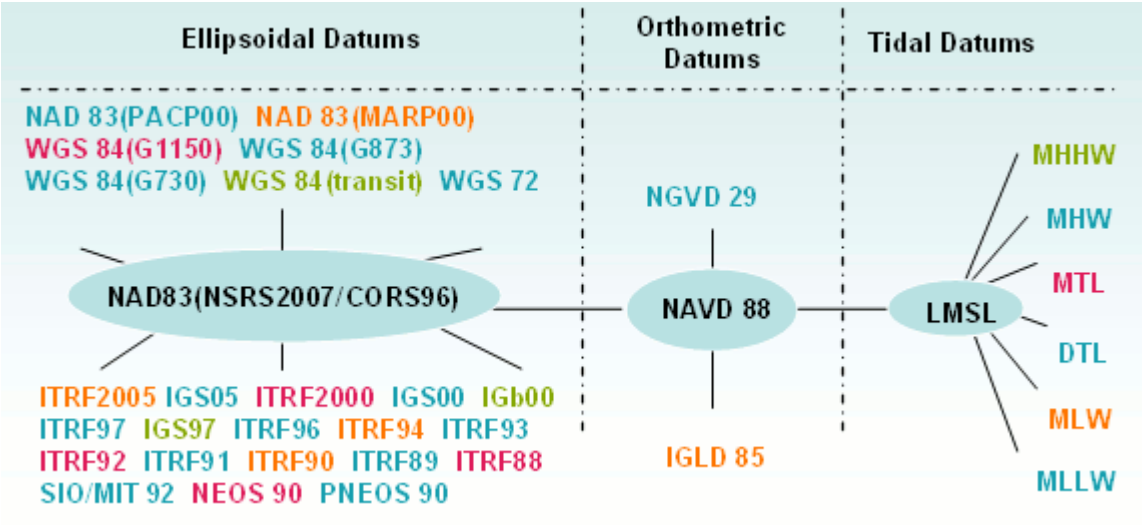
Vertical datum realized at time(s) of survey

- Zoned & interpolated tides; residuals
- Variations outside measurement bandwidth

Hydrography…ellipsoidal reference: From whence do we reckon?



Hydrography…ellipsoidal reference: NOAA VDatum



Ellipsoidal-height to MLLW-depth is best achieved as a combination of stepwise transformations; e.g.:

ITRFXX to NAD 83 (NSRS)

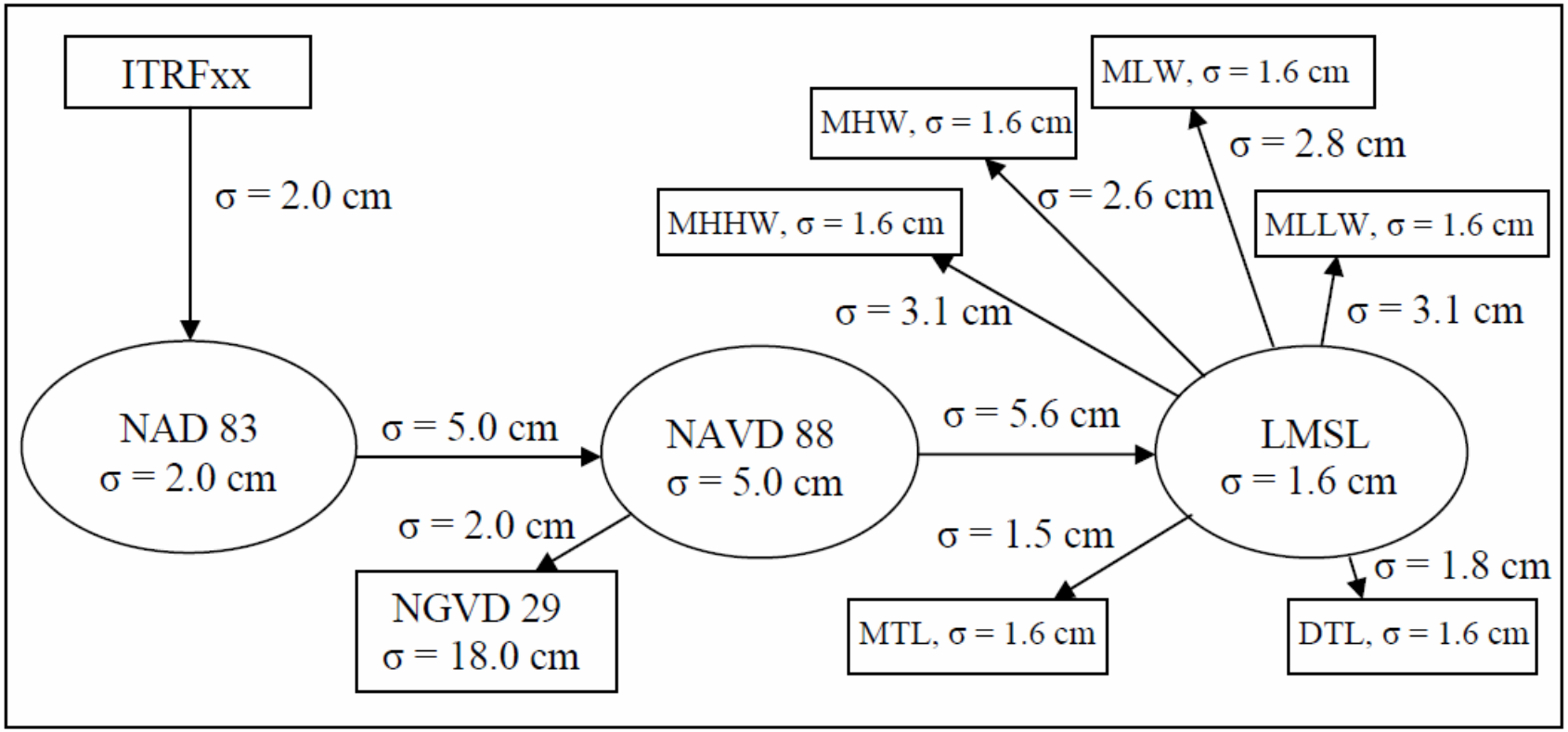
NAD 83 (NSRS) to NAVD 88

NAVD 88 to LMSL

LMSL to MLLW

Each transformation step should utilize the best available physics/theory and data

Hydrography…ellipsoidal reference: NOAA VDatum



Hydrography…ellipsoidal reference: NOAA VDatum

REGION	TRANSFORMATION							SOURCE DATA	MCU
	NAVD88 to MSL	MSL to MHHW	MSL to MHW	MSL to MTL	MSL to DTL	MSL to MLW	MSL to MLLW	All Tidal Datums	
New York/Connecticut/Rhode Island – Outer NY Bight, eastern Long Island Sound, Block Island Sound	4.3	3.2	3	2.4	2.7	4.8	4.8	1.5	10.2
New York - The Great South Bay	2.8	3.3	3.1	1.3	1.3	3.6	4.1	1.4	9.3
New Jersey/New York/Connecticut – Northern NJ, NY Harbor, western Long Island Sound	5.5	3.7	3.6	1.7	1.7	5.3	5.6	2.2	11.4
New Jersey - coastal embayment	5.9	2.6	2.8	0.9	0.8	3.1	3.1	1.8	10.4
Virginia/Maryland/Delaware/New Jersey - Mid-Atlantic Bight shelf	8.6	7.8	7	6.1	6.3	6.4	6.1	1.3	14
Delaware - Delaware Bay	1.8	3.3	2.9	1	1	3	3.1	2	9
Virginia/Maryland/Delaware - Coastal embayment	1.2	0.4	0.1	0.3	0.1	0.6	0.5	1.8	8.1
Virginia/Maryland - Chesapeake Bay	5.6	3.1	2.6	1.5	1.8	2.8	3.1	1.6	10.2
North Carolina – Coastal North	0.8	3.2	3	0.2	0.5	3.2	3.4	0.9	8.5
North Carolina – Coastal Central	0	0.6	0.5	0.2	0.4	0.2	0.3	1.5	7.9
North Carolina - Pamlico Sound (*)	7.7	4.3	4	1.2	1.7	3.7	3.5	1.7	11.9
Georgia/South Carolina/North Carolina – Sapelo Island GA to New River NC	4.9	8.3	7.6	6.1	6.5	7.2	7.5	1.6	12.5
Florida/Georgia – Fort Lauderdale FL to Sapelo Island GA	4.3	5.9	5.2	3.3	3.9	4.7	5.1	1.7	10.8
Florida – South Florida, Naples to Fort Lauderdale FL, and Florida Bay	3	3.3	3.1	1.1	1.6	3.1	4.3	1.8	9.6
Florida – Anclote Key to Naples	9.8	3.1	2.7	0.7	1.3	3	3.2	1.7	13
Florida – Apalachicola to Anclote Key	3.4	5.1	4.3	1.6	2.6	3.8	5.2	1.8	10.2
Florida - St. Joseph's Bay and the Gulf of Mexico	0.2	1.3	3.2	1.4	0.3	1	0.9	1.8	8.6
Florida - St. Andrew's Bay and the Gulf of Mexico	0.3	1	1	1.2	0.9	1.8	1.4	1.3	8
Florida - Perdido, Pensacola and Choctawhatchee Bays	0.6	1.7	1.6	0.5	0.4	1.7	1.8	1.8	8.3
Florida/Alabama - Gulf of Mexico from Mobile Bay to east of Choctawhatchee Bay	0	1.7	1.1	0.3	0.4	0.9	1.1	1.8	8.2
Alabama - Mobile Bay and Perdido Bay	0	0.1	0.6	0	0.1	0.6	0.3	1.9	8.1
Louisiana/Mississippi - Eastern Louisiana to Mississippi Sound	14.8	2.4	2.3	0.8	1	2.4	2.9	1.9	17.1
Louisiana - Lake Calcasieu and Charles East	N/A (insufficient tidal data)								
Louisiana - Lake Calcasieu and Charles Main	0	0.7	1.8	3	0.6	4.2	0.5	2.3	9.3
Louisiana - Lake Calcasieu and Charles West	N/A (insufficient tidal data)								
California - Southern California from Morro Bay south to US/Mexico border	1.6	1.4	0.9	0.1	0.4	0.8	0.9	1.3	8.1
California - Monterey Bay to Morro Bay	1.1	0.8	1	0.7	1	0.9	1.7	1.1	8
California - San Francisco Bay Vicinity	0.1	3.7	4.5	2	2.5	4.2	5.8	1.4	9.8
Oregon/ California – Punta Gorda to Cape Blanco	4.4	2	1.6	2.5	4.4	5.7	9.5	1.2	13.1
Oregon - Central Oregon	2.7	3.6	2.5	5.8	10.1	10.7	17.6	1.2	19.4
Washington/Oregon - Columbia River and Southern Washington	18.8	6.3	6.5	3.6	4.8	7.3	9.8	1.6	22.6
Washington – Strait of Juan de Fuca	7.9	5	5.8	2	2.7	8.5	7.5	1.4	14
Washington - Puget Sound	2.1	3.8	3	1.1	1.5	3.8	5.2	1.5	9.7

Engineering the VDatum validation: compare existing to “new”

Relative water level datum

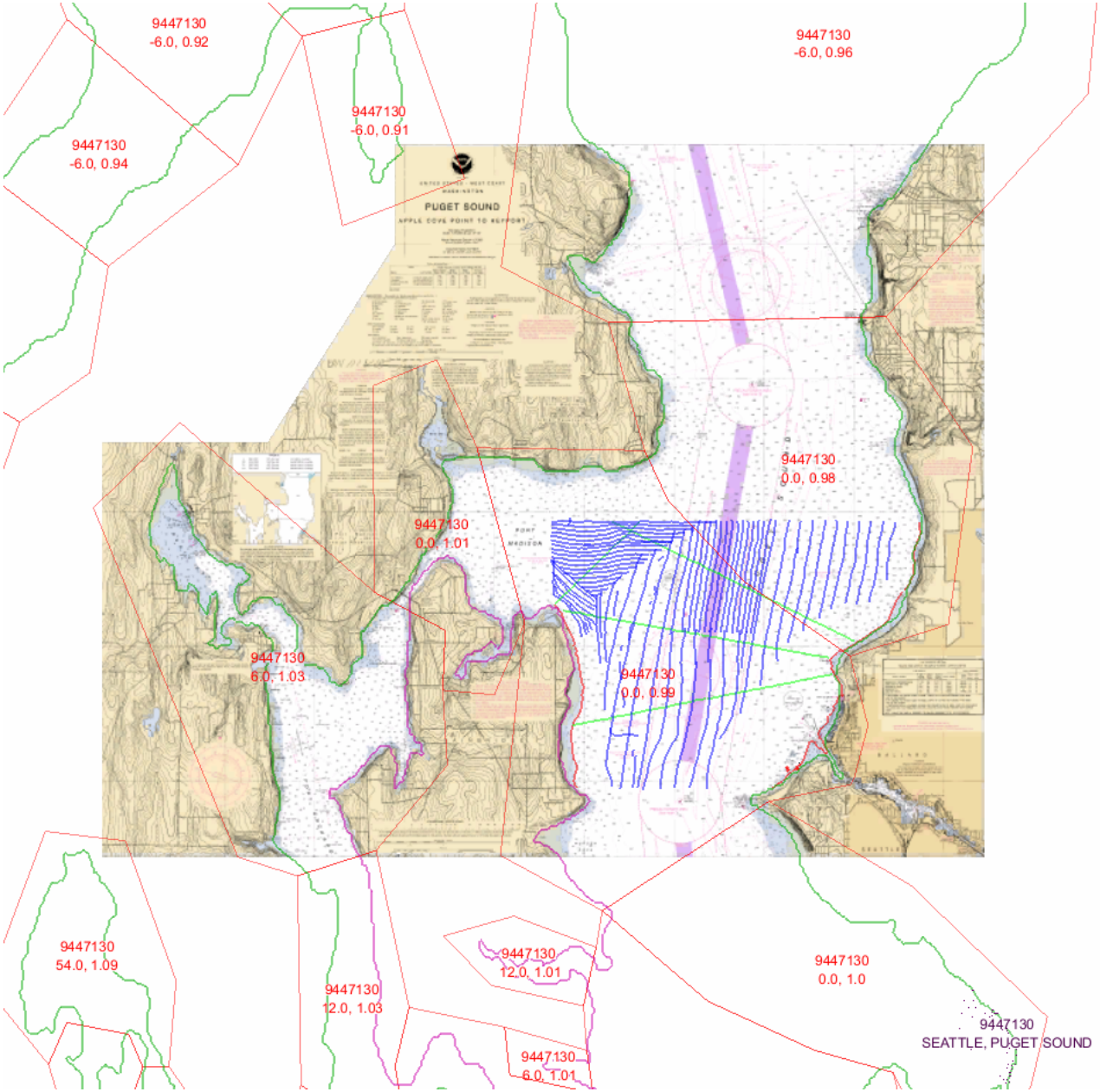
- Traditional zoning / interpolation package for virtual tide gauge
- Treat historic tide datum elevation difference as a water level

Ellipsoidal reference – tide “buoys”

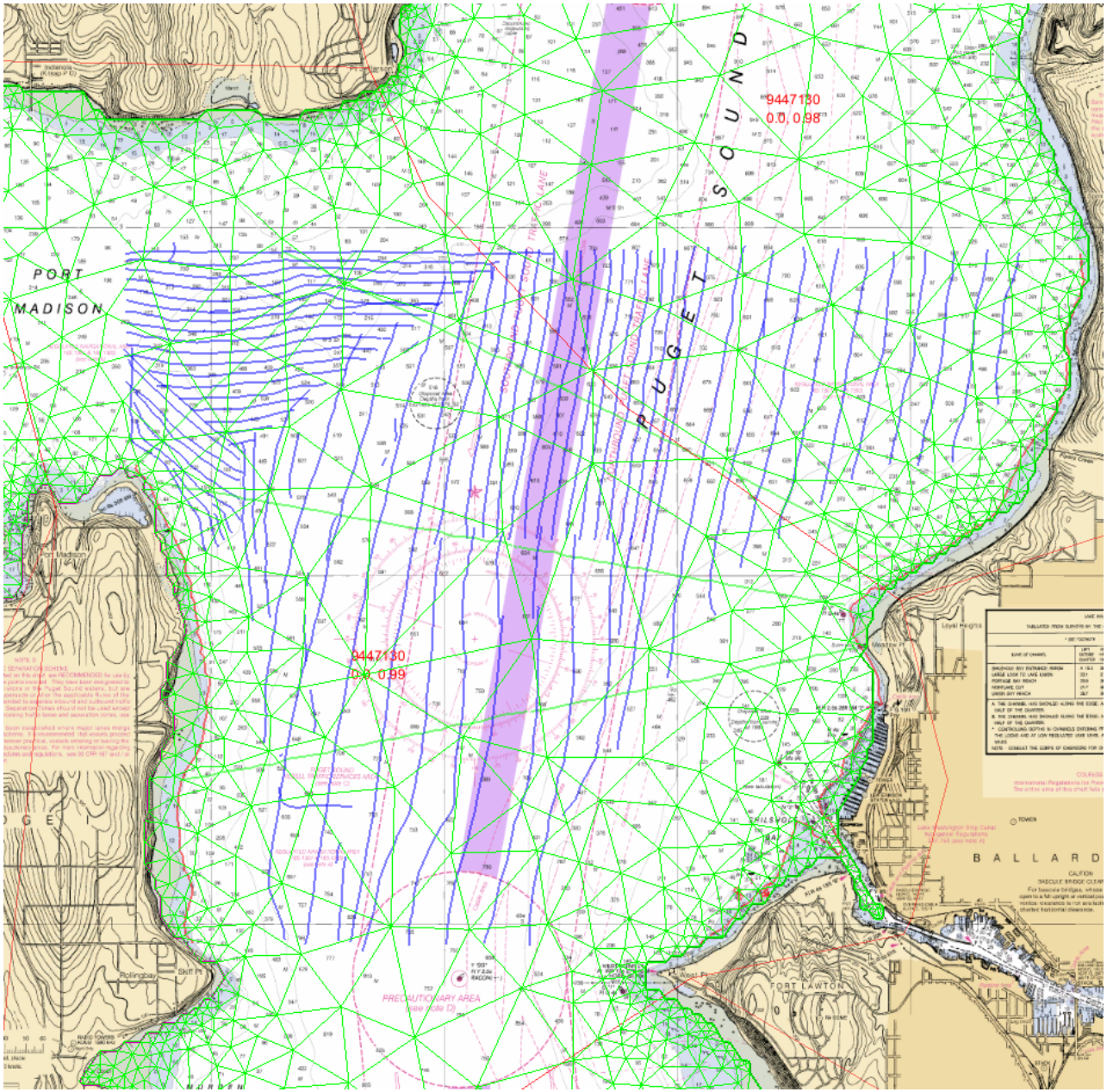
- GPS tide “vessel altimetry”; no bathy required
- Add in tide correction for ad hoc SEP
- Pitfalls: in situ water level uncertainty
- GPS tide buoy

Compare to VDatum

Example: Puget Sound, WA – NOAA Ship Rainier; tide zones



Example: Puget Sound, WA – zoned tides & TCARI grid



Puget Sound TCARI station info

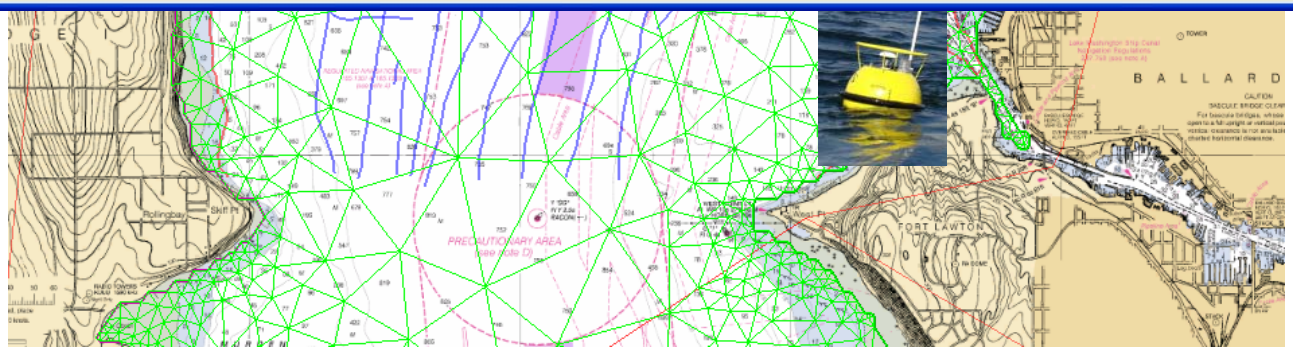
TCARI Gauge Information

Gauge Number	Latitude	Longitude	HCs	Residuals	Datum	Gauge Radius	Station Name
9444900	48.11166700	-122.75833300	✓	✓	✓	1500	PORT TOWNSEND, ADMIRALTY INLET
9445133	47.74833300	-122.72666700	✓		✓	1500	BANGOR, HOOD CANAL
9446484	47.26666700	-122.41480000	✓	✓	✓	1500	TACOMA, COMMENCEMENT BAY
9447130	47.60500000	-122.34323000	✓	✓	✓	1500	SEATTLE, PUGET SOUND
9448576	48.40000000	-122.54833300				1500	SNEEOOSH POINT, SKAGIT BAY
9448657	48.44500000	-122.55500000				1500	TURNER BAY, SIMILK BAY
9445478	47.35830000	-123.09800000	✓		✓	1500	UNION, HOOD CANAL
9445958	47.56170000	-122.62300000	✓		✓	1500	BREMERTON
9447659	47.98000000	-122.22333300	✓		✓	1500	EVERETT

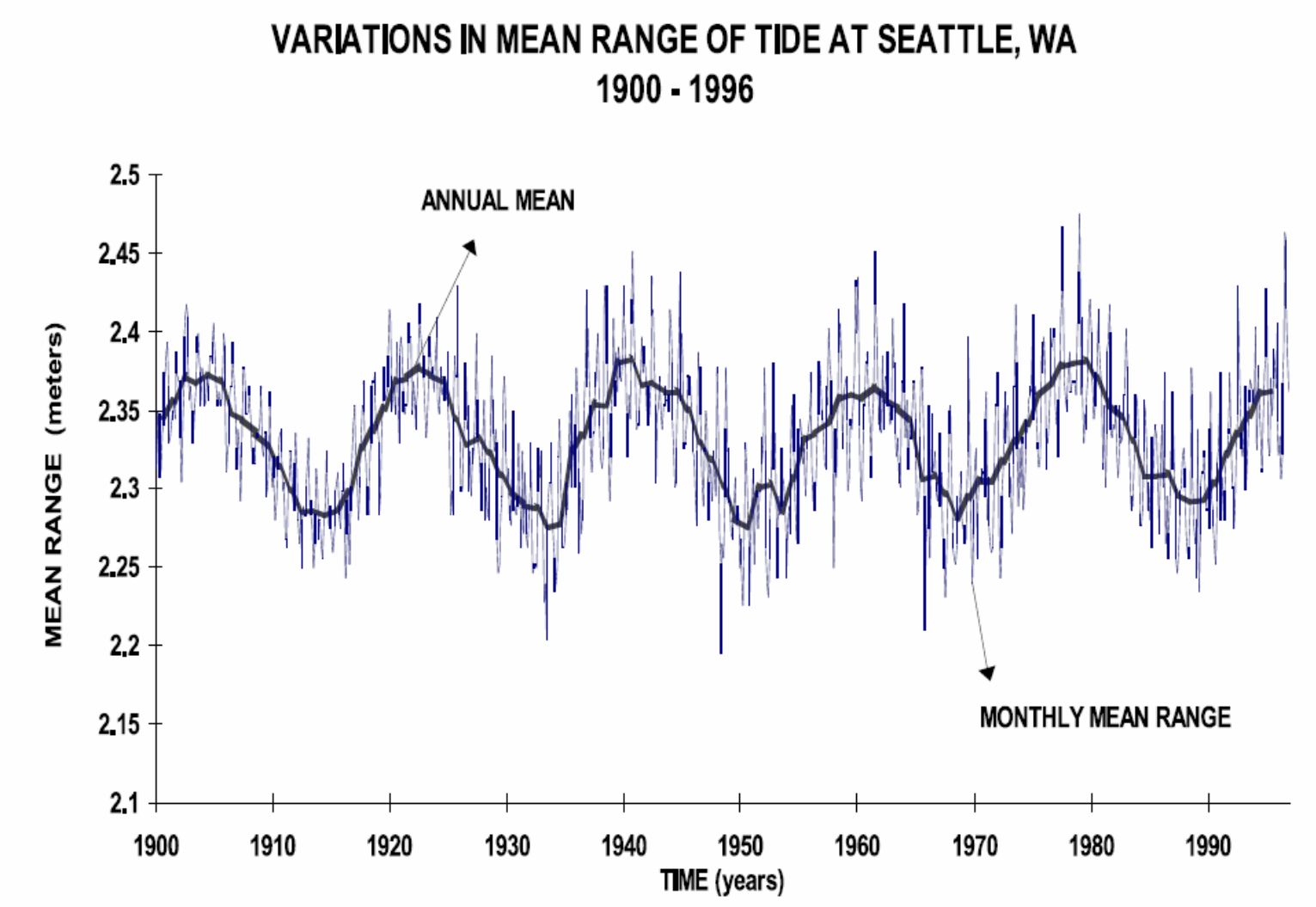
Remove | Clear Sols | ☑ Solve Combinations | Alpha= 0.9 | Convergence= 0.0001 | Save

☐ NAVD ☑ ELL ☐ DTL ☐ MHHW ☐ NGVD ☑ MLLW ☑ MLW ☐ MTL ☑ MHW ☑ MSL

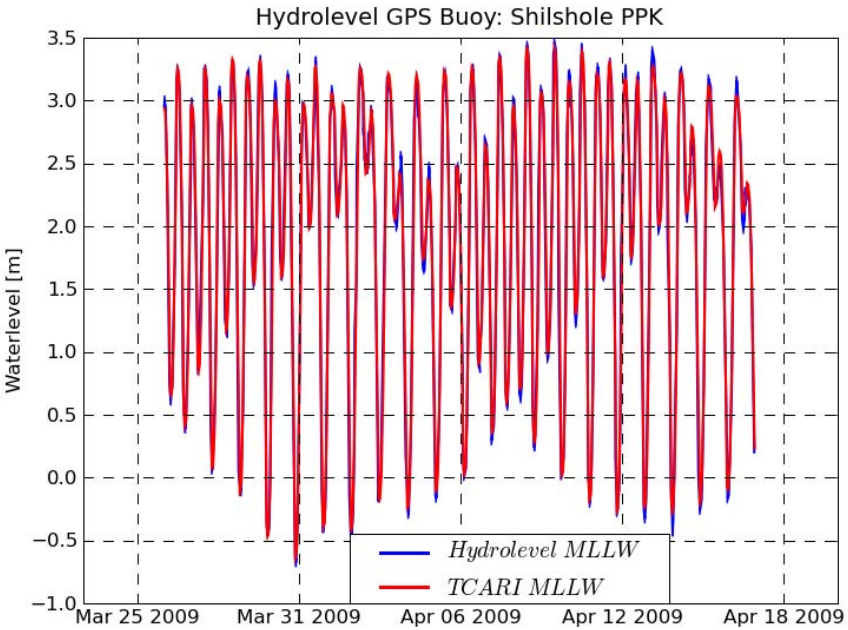
Close



NOAA SP NOS CO-OPS1: Effect of regression of moon's nodes



Hydrolevel™ GPS tide buoy data in Shilshole Bay, Puget Sound

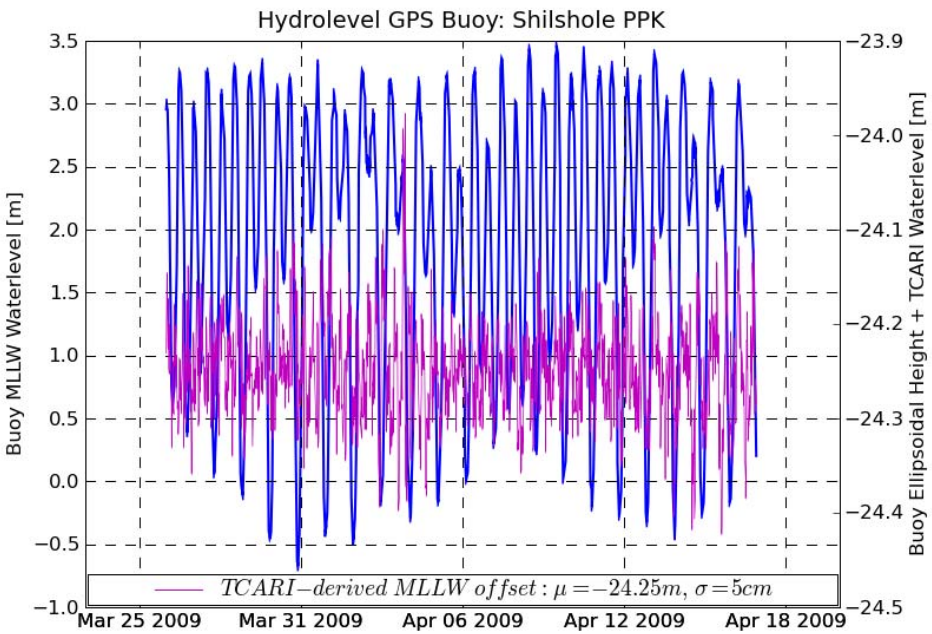


Vdatum MLLW SEP = -24.32 m

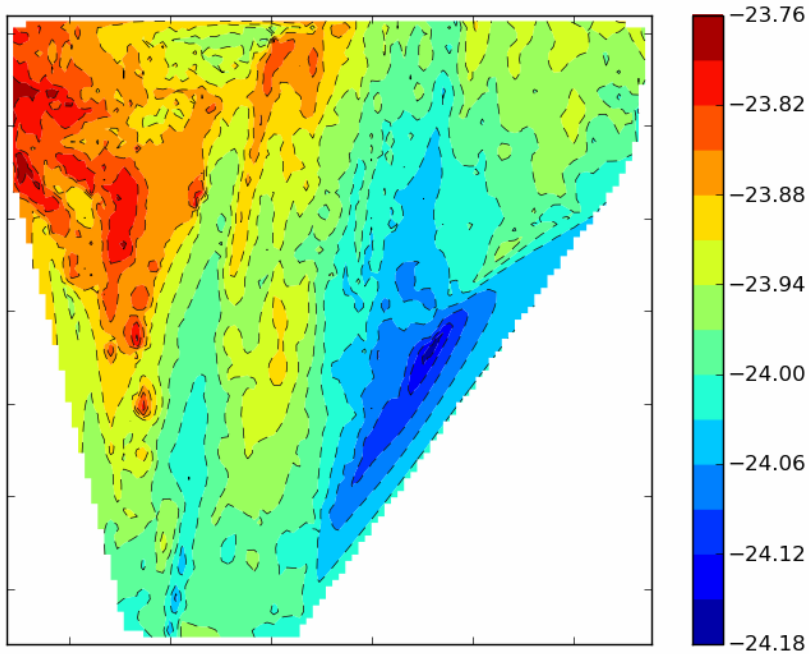
TCARI-derived = -24.25 m

PPK antenna models: ~ 8.3 cm

TCARI-derived' = ~ -24.33 m



Ad hoc MLLW SEP from survey platform GPS Tide + TCARI WLs



Ad hoc MLLW SEP TC[AR]I + GPS Tide

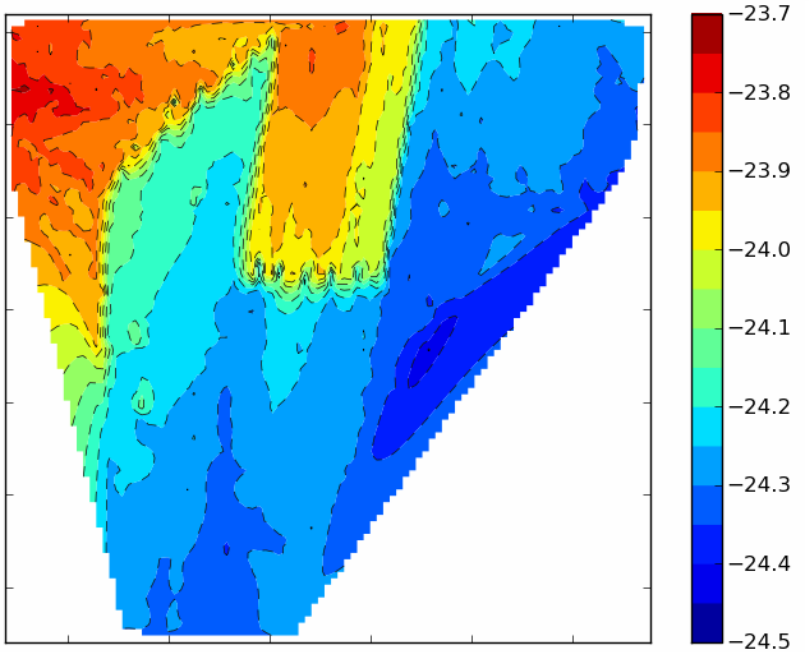
CCW from left:

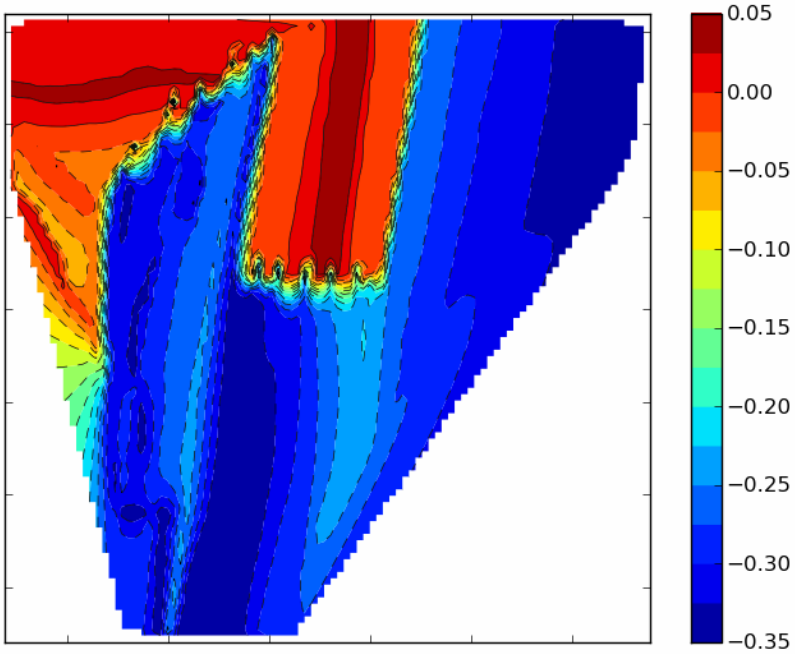
MLLW SEP w/ TCARI

MLLW SEP w/ TCI

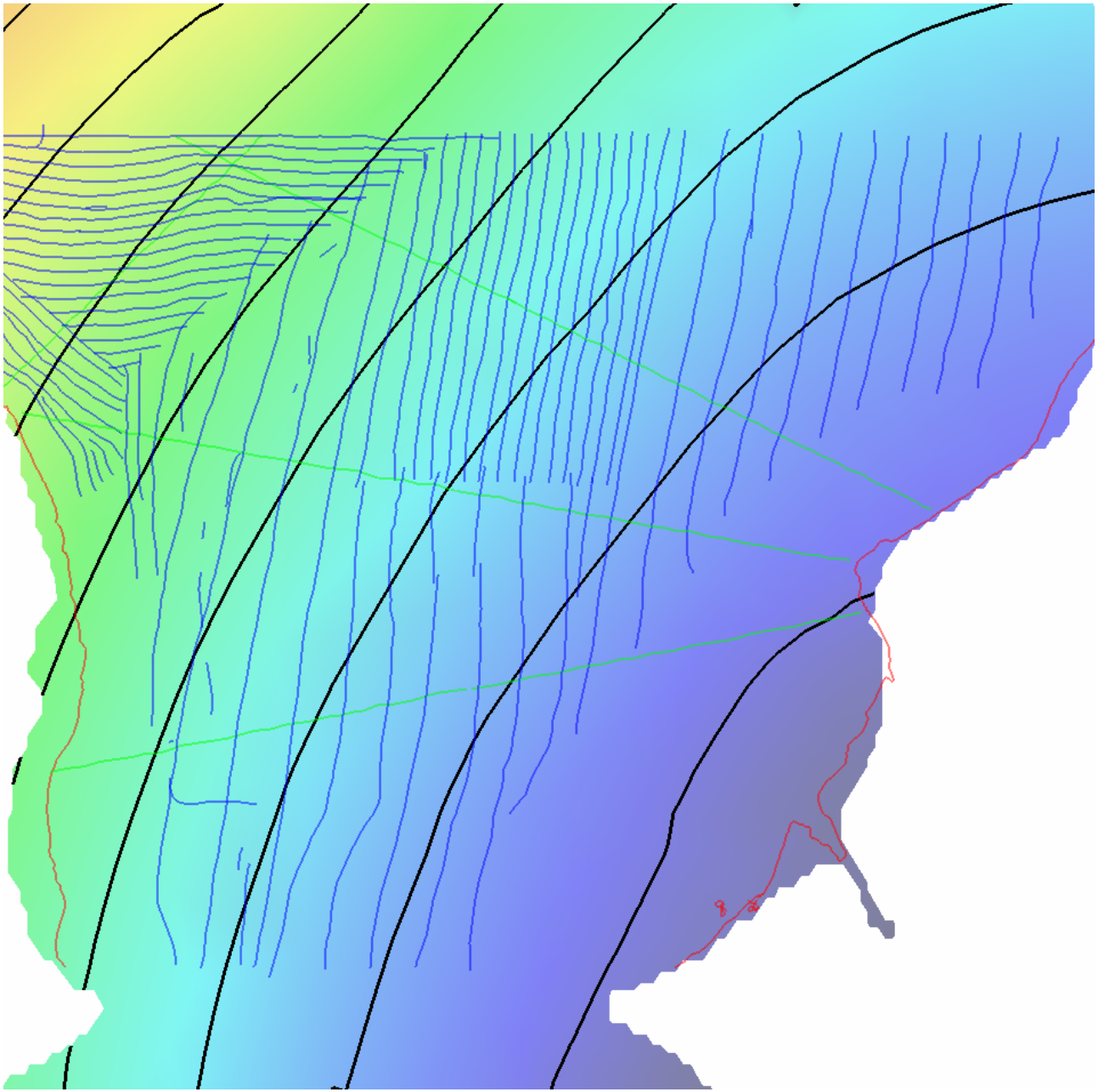
MLLW SEP TCARI Resdual*

* Note: 4 separate days of DAQ

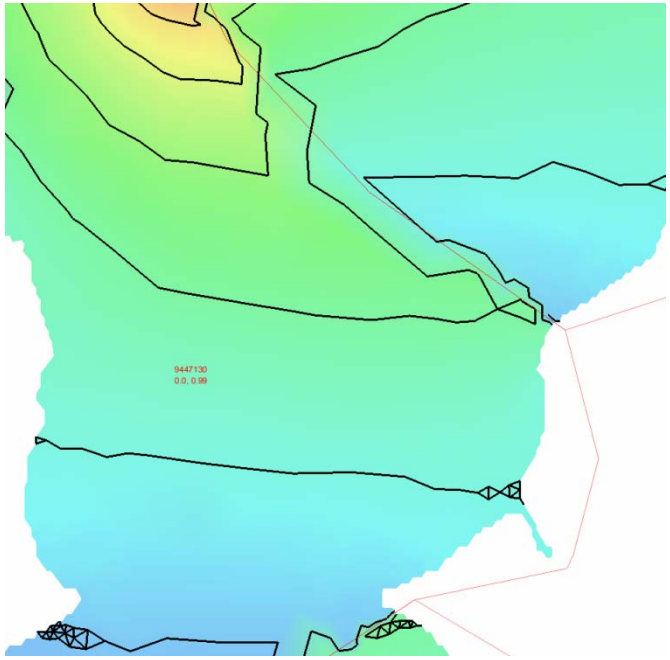




VDatum MLLW SEP – 8 contours, -24.30 to -23.88m (6-cm step)



Relative waterlevel comparisons: MSL - MLLW



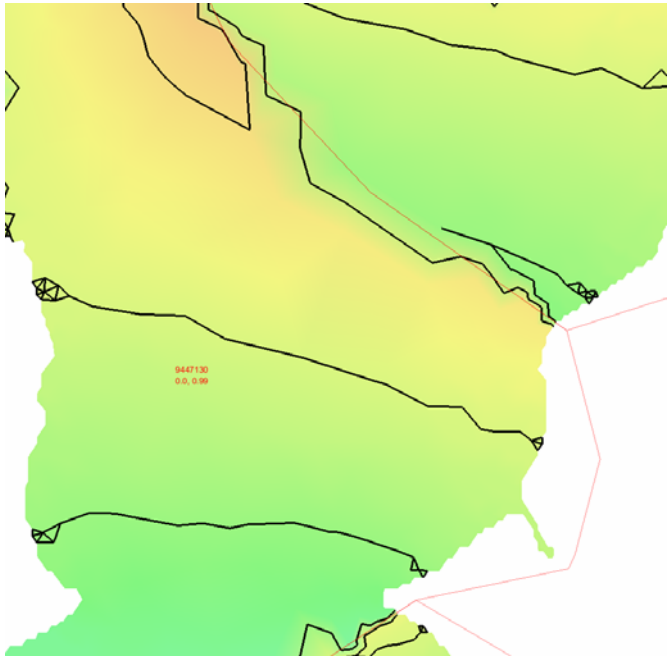
Relative waterlevels: MSL - MLLW

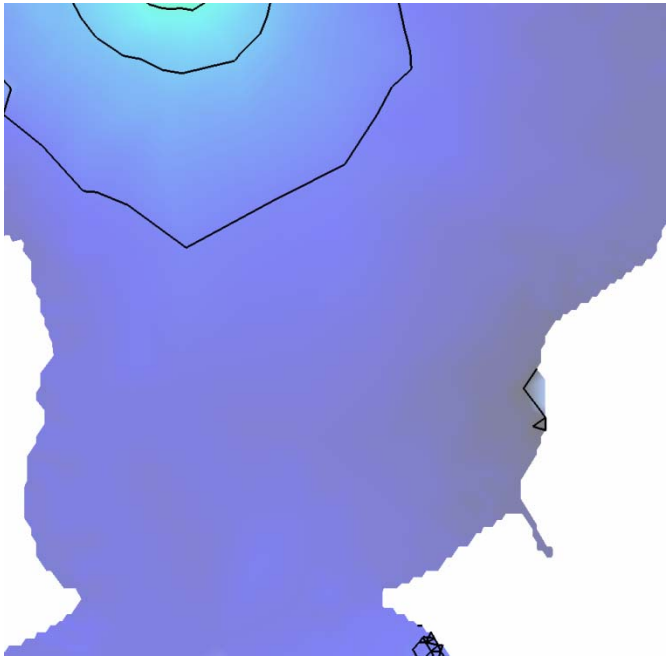
CCW from left:

Vdatum – Zoned, 6 contours: -1 to 4 cm (1-cm step)

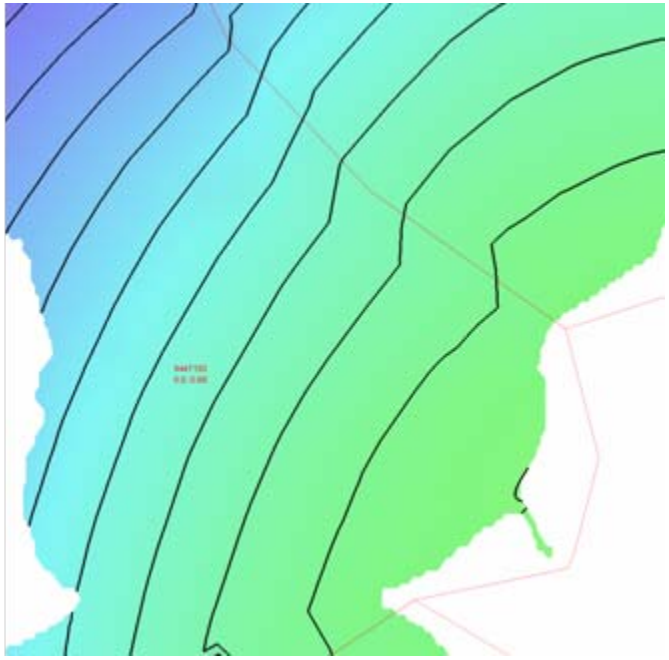
TCARI – Zoned, 3 contours: 2 to 4 cm (1-cm step)

Vdatum – TCARI, 4 contours: -3 to 0 cm (1-cm step)





MLLW SEP comparisons: ELL - MLLW



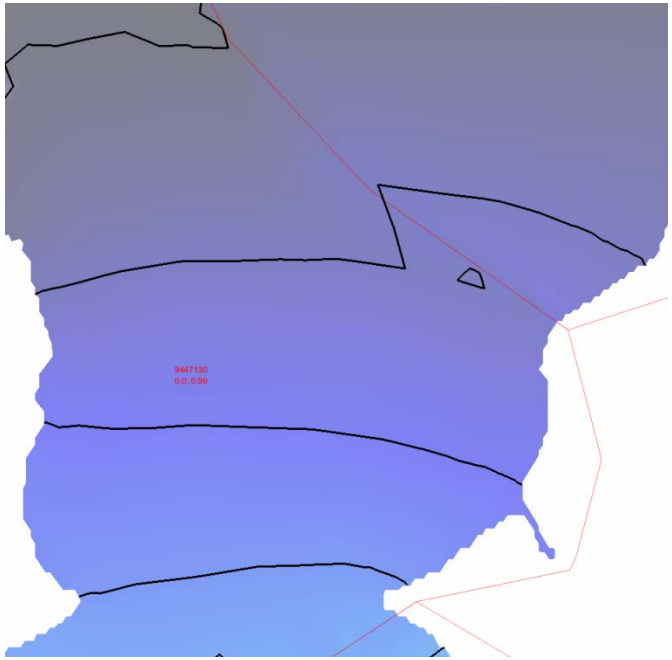
MLLW SEP comparisons: ELL - MLLW

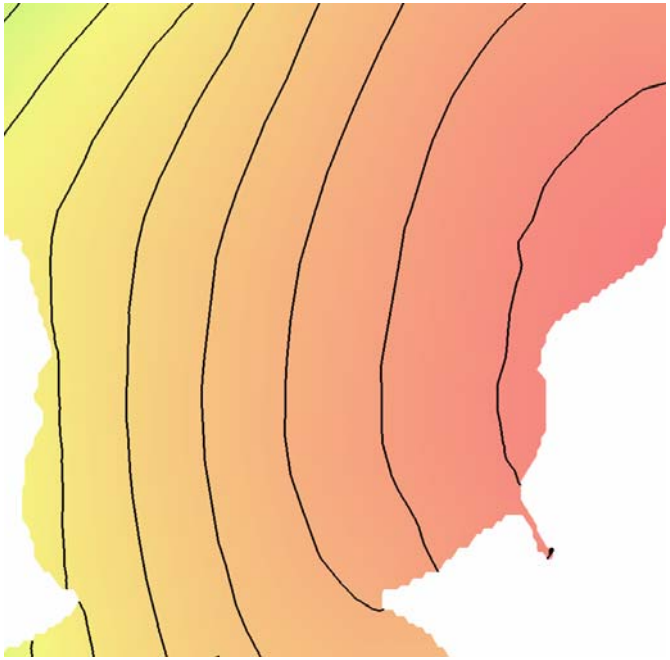
CCW from left:

Vdatum – Zoned, 10 contours: -5 to -50 cm (5-cm step)

TCARI – Zoned, 5 contours: -40 to -60 cm (5-cm step)

Vdatum – TCARI, 8 contours: 10 to 45 cm (5-cm step)





Closing remarks

Processing Details

- Axys Hydrolevel™ GPS tide buoy data
- CARIS HIPS GPS Tide
- Python Pydro / Pydro-TCARI

Datum realization gap vs. “tide” issues

- Tidal corrections vs. idealized [official] datum shape (3D)

Proceeding with an official model

- Relative WL sanity check in office
- How long to require in situ WL tie?
- Grav-D

Closing remarks

Special thanks

- Corey J. Allen
- Barry J. Gallagher