

Tidal Datum Computations

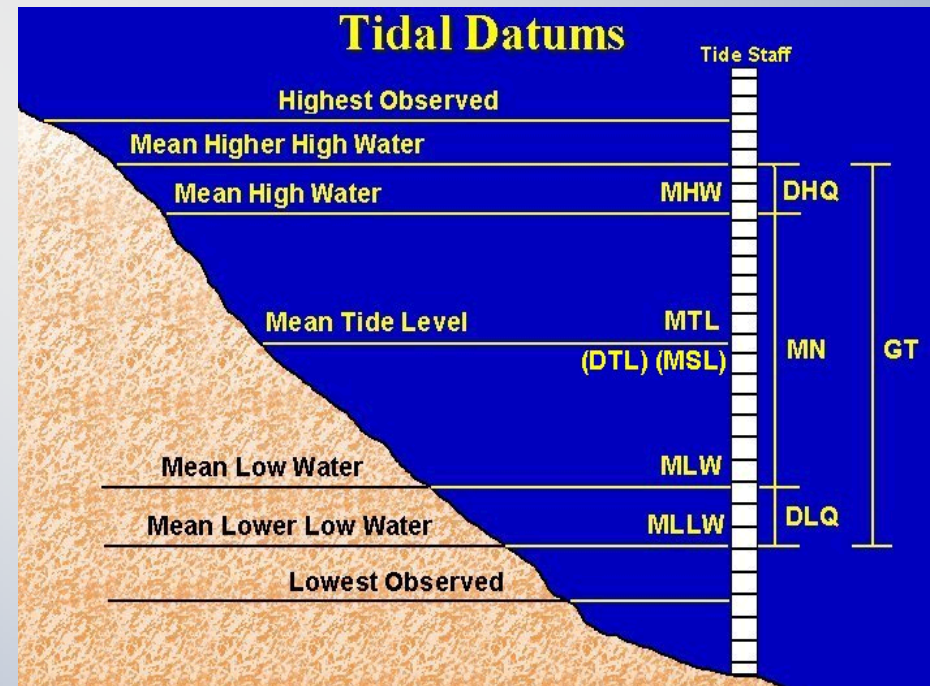
Methods for Computing Tidal Datums

Tidal Datums Team
nos.coops.datums@noaa.gov

Primary Determination – Average of 19-year data series defined by the National Tidal Datum Epoch to obtain Accepted Values

Secondary or Tertiary Determination – Comparison of means or tides to obtain an 19-year equivalent mean

- Modified Range Ratio Method
- Standard Method
- Direct Methods



Tidal Datums

Tide Staff

Highest Observed

Mean Higher High Water

Mean High Water

MHW

DHQ

Mean Tide Level

MTL

(DTL) (MSL)

MN

GT

Mean Low Water

MLW

Mean Lower Low Water

MLLW

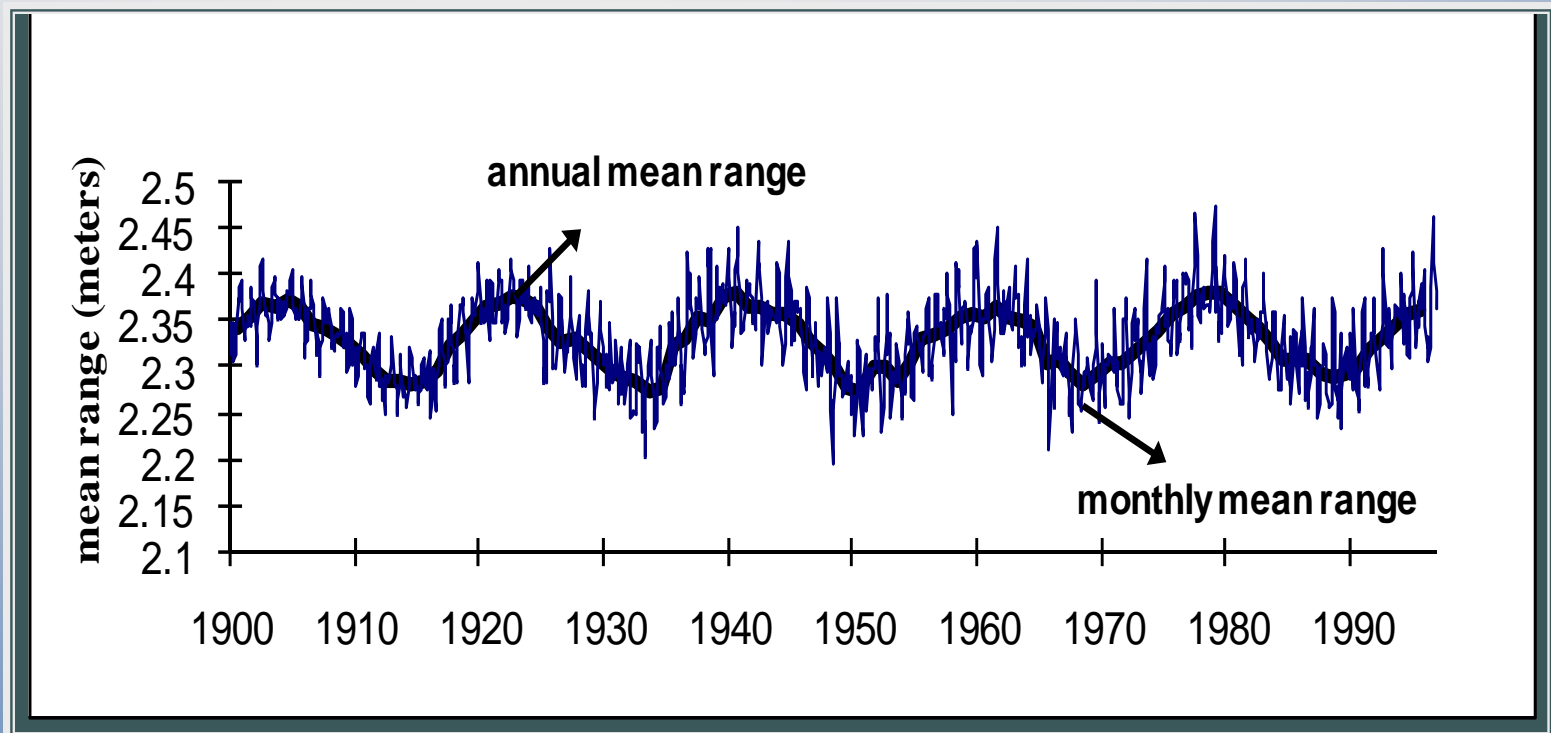
DLQ

Lowest Observed



SEATTLE, PUGET SOUND, WA VARIATIONS IN MEAN RANGE OF TIDE: 1900 – 1996

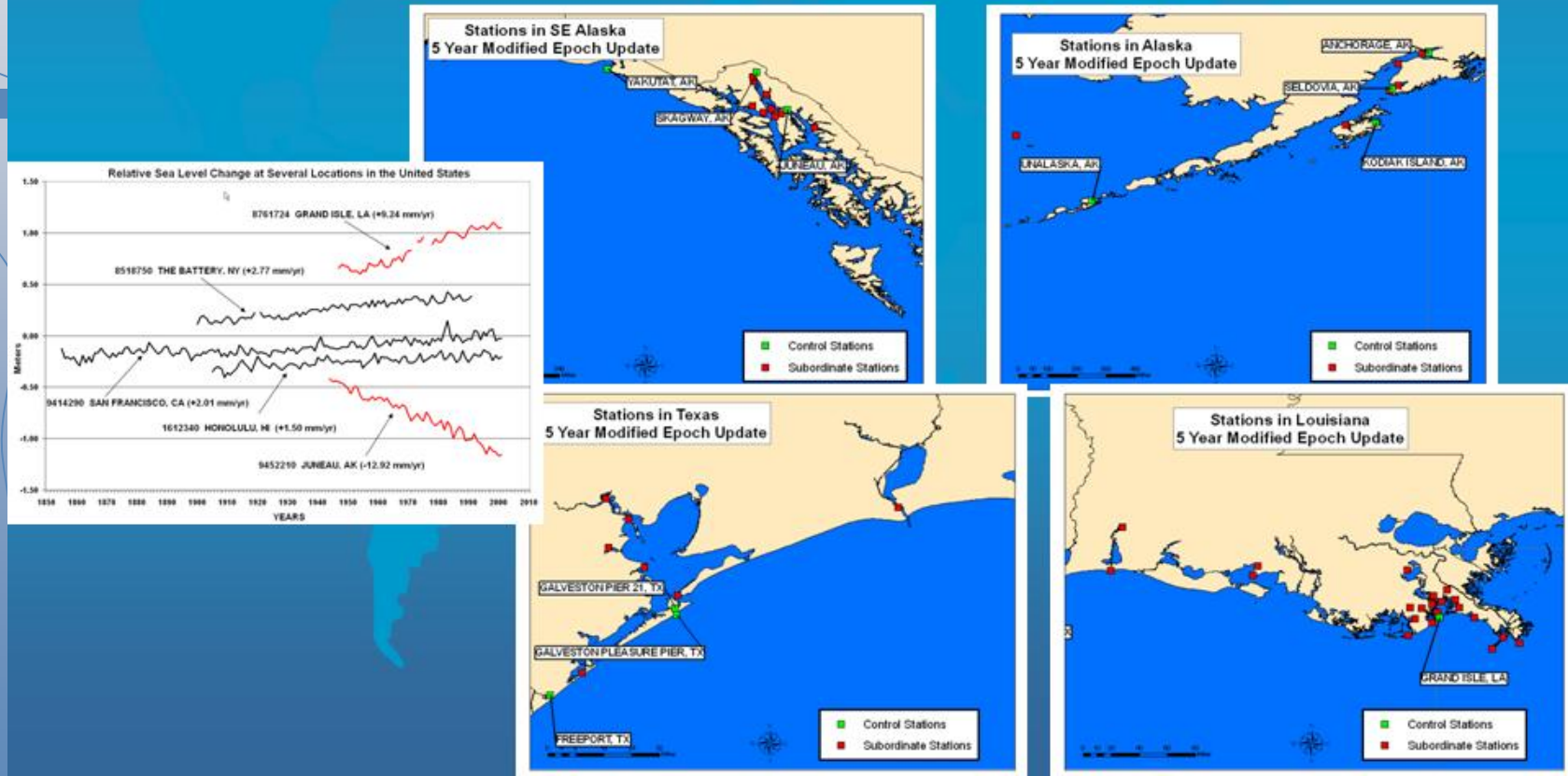
Due to the 19-year cycle of “Regression of the Moon’s Nodes”



Use of 19 Year and 5 Year Tidal Epochs Deliver Meaningful Tidal Datums to User Communities

COMPUTING TIDAL DATUMS IN AREAS OF ANOMALOUS SEA LEVEL TRENDS

- Areas of Louisiana, Texas, SE Alaska and SW Alaska have anomalous sea level trends compared to average trend for United States.
- A 5 Year period (2002-2006) is being used to compute tidal datums in these regions so that published tidal and geodetic relationships are representative of current mean sea level conditions.



TYPES OF TIDE STATIONS

■ Control

- Long-term stations (several years) with accepted tidal datums
- Primary and Long-term Secondary
- Monitoring for sea level trends

■ Subordinate

- Secondary stations (≥ 1 yr & < 19 yrs)
- Tertiary (< 1 year)



Tidal Datum Calculation

Method of Comparison of Simultaneous Observations is a two-step process:

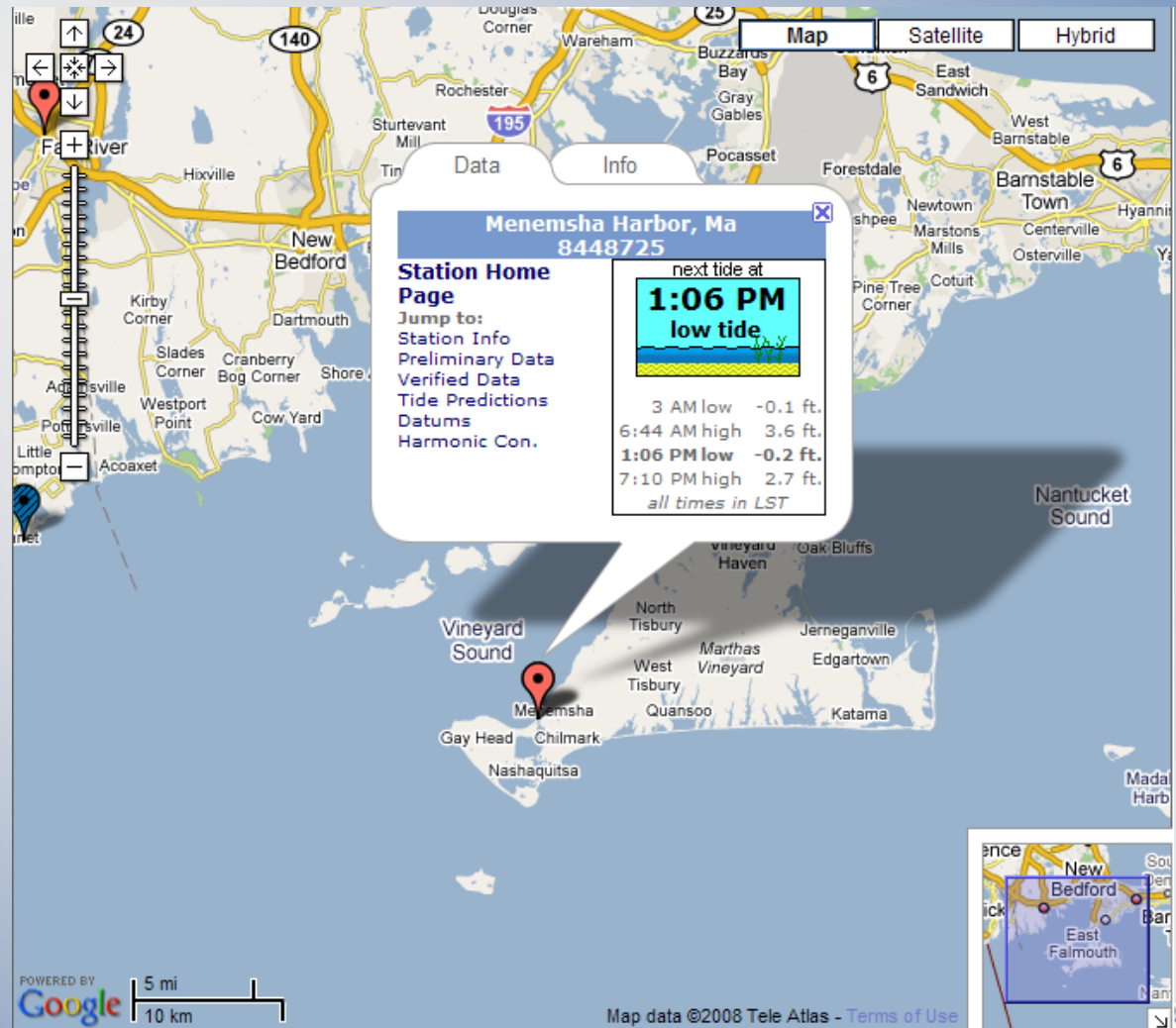
1. **Compute the differences and/or ratios** in the tidal parameters and differences in mean values between short-term and control stations over the period of simultaneous comparison.
2. **Apply the differences and ratios** computed above to the NTDE Accepted Values at the control station. This provides equivalent NTDE values for the short-term station.



Choose Control Station

Example

- Subordinate Station ID: 8448725
- Subordinate Station Name: Menemsha Harbor, MA



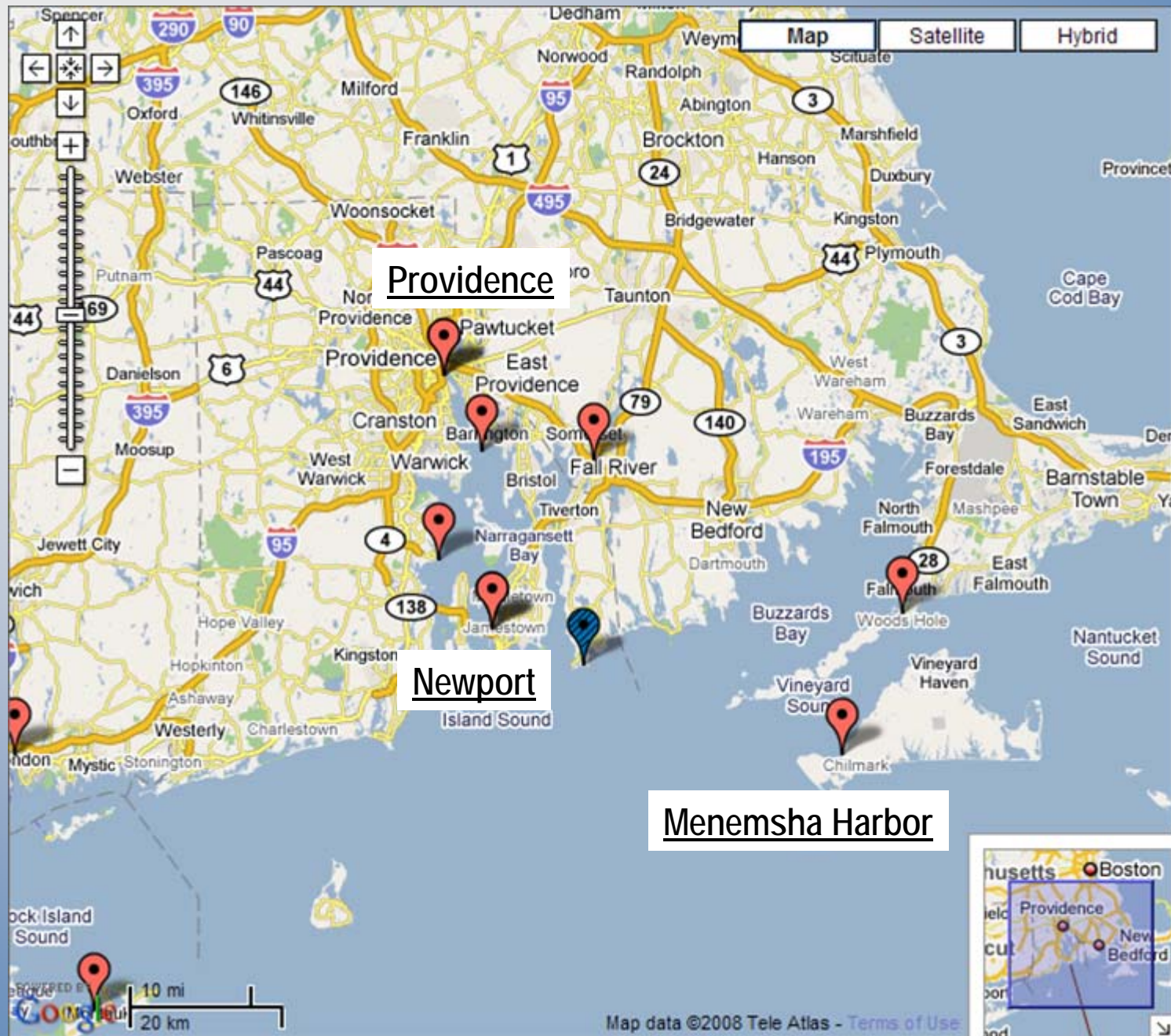
Requirements for a Control Station

- Close to the subordinate
- Similar tidal characteristics
- Long term station (ideally 19 years)
- Simultaneous water level data

Two possible candidates for control – which one?

- Providence, RI (8454000)
- Newport, RI (8452660)





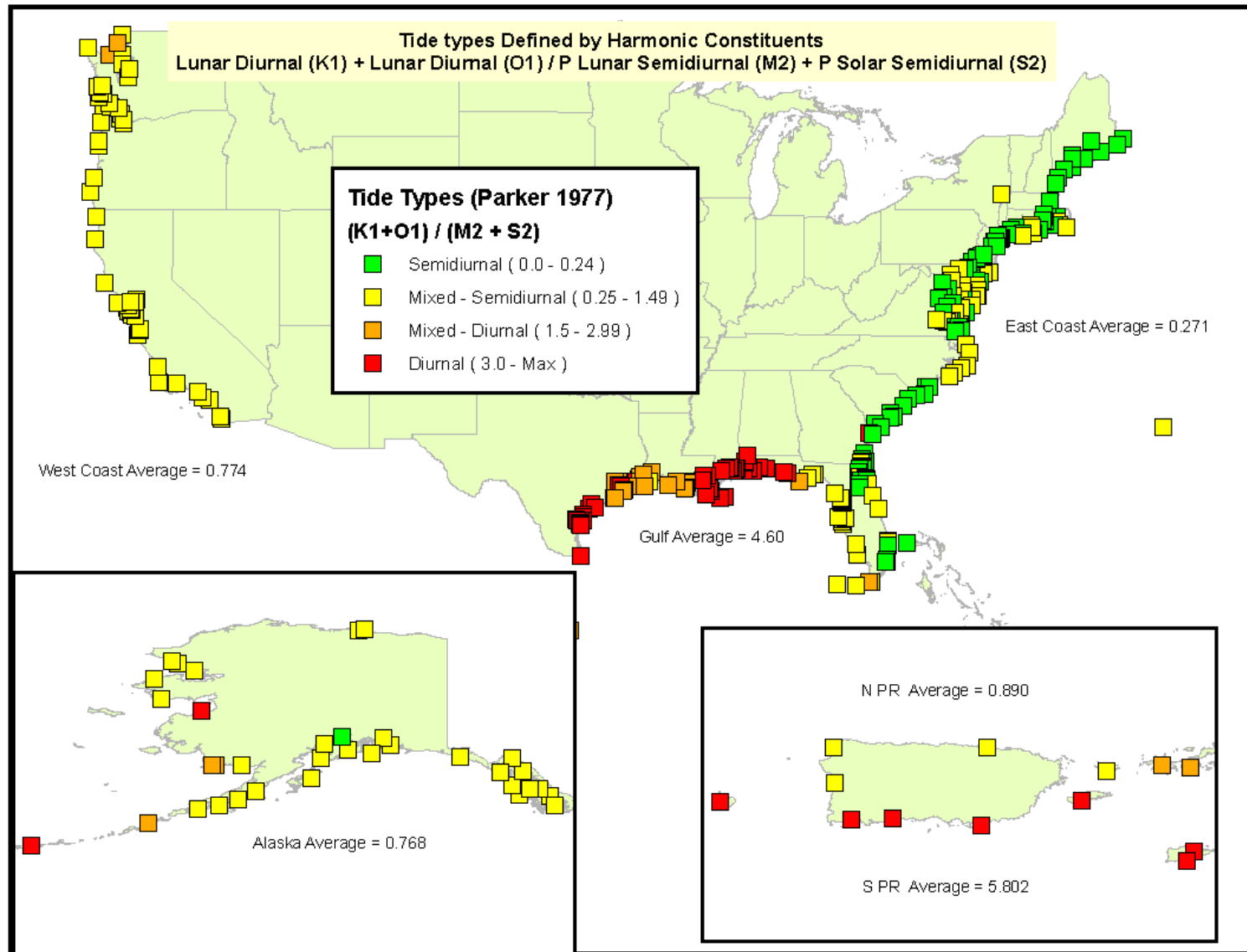
Water Level Data Availability

Water level data available for datum computation

- Menemsha Harbor: 06/2008 – Present
- Newport: 10/1930 - Present
- Providence: 06/1938 - Present



Classification of Tide Types at Water Level Stations with Accepted Datums



Tidal Characteristics

Tide type from harmonic results: $(K1+O1)/(M2+S2)$

- >1.5 Diurnal
- ≤ 1.5 Semidiurnal/Mix
- <0.25 Semidiurnal

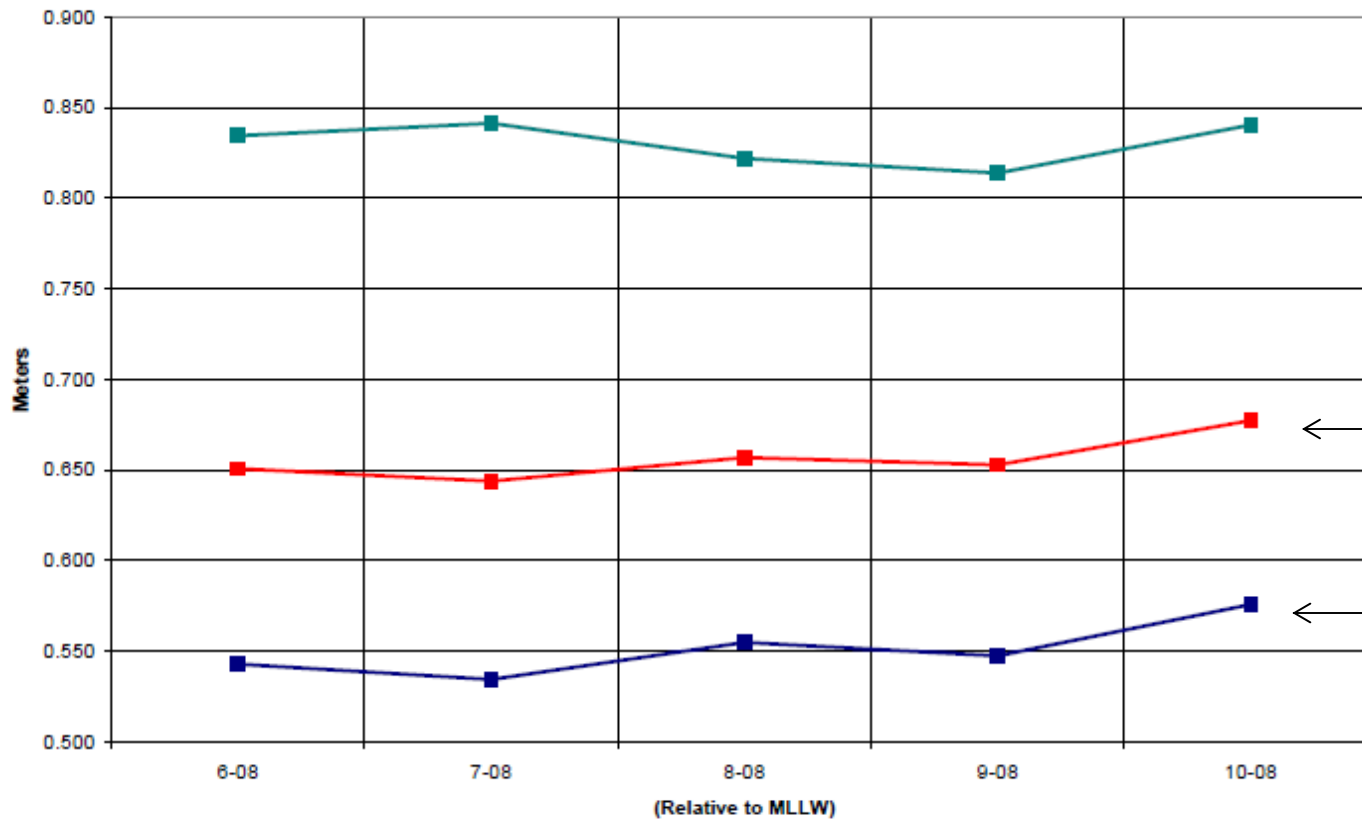
- **Menemsha Harbor: 0.245**
- **Newport: 0.181**
- **Providence: 0.165**

Simultaneous Data Plot

11/12/2008

8448725 MENEMSHA HARBOR MA
8452660 NEWPORT, NARRAGANSETT BAY RI
8454000 PROVIDENCE, PROVIDENCE RIVER RI

8448725 - MTL - WL 8452660 - MTL - WL 8454000 - MTL - WL



← Newport

← Menemsha



ESTIMATING ACCURACIES OF TIDAL DATUMS FROM SHORT TERM OBSERVATIONS

The Bodnar Report

Bodnar (1981), drawing upon Swanson (1974) applied regression equations estimating the accuracy of computed datums

Bodnar developed formulas for
Mean Low Water (MLW) and Mean High Water (MHW).

The 3 Month equation for Mean Low Water is presented below.

$$\text{Error} = 0.0043 \text{ ADLWI} + 0.0036 \text{ SRGDIST} + 0.0255 \text{ MNR} + 0.029$$



Bodnar Analysis

BODNAR Equation Formula for MLW (Based on a 3 Month Datum): Semi-diurnal/Mixed Station Only

Station Name (ID)	LAT			LONG			LWM	hrs.	n. miles	SQRT DIST	MN	ratio	Bodnar (feet)
	Deg	Min	Decimal Deg	Deg	Min	Decimal Deg							
Subordinate: Menemsha Hbr, MA (8448725)	41	21.4	41.3566667	70	46.3	70.7716667	6.93	1.01	26.5	5.15064	0.860	0.1856	0.0566
Control #1: Newport, RI (8452660)	41	30.3	41.5050000	71	19.6	71.3266667	5.92				1.056		0.0290
Acceptable Control													

Optional

Station Name (ID)	LAT			LONG			LWM	hrs.	n. miles	SQRT DIST	MN	ratio	Bodnar (feet)
	Deg	Min	Decimal Deg	Deg	Min	Decimal Deg							
Subordinate: Menemsha Hbr, MA (8448725)	41	21.4	41.3566667	70	46.3	70.7716667	6.93	1.01	39.1	6.25539	0.860	0.3611	0.0651
Control #2: Providence, RI (8454000)	41	48.4	41.8066667	71	24.1	71.4016667	5.92				1.346		0.0290
Look for a more suitable control.													

Optional

Station Name (ID)	LAT			LONG			LWM	hrs.	n. miles	SQRT DIST	MN	ratio	Bodnar (feet)
	Deg	Min	Decimal Deg	Deg	Min	Decimal Deg							
Subordinate: Menemsha Hbr, MA (8448725)	41	21.4	41.3566667	70	46.3	70.7716667	6.93	6.93	4545.3	67.41883	0.860		
Control #3:													

$$S3M = 0.0043 ADLWI + 0.0036 SRGDIST + 0.0255 MNR + 0.029$$

ADLWI : average difference between low water intervals

SRGDIST: square root of the distance between stations

MNR: mean range of the tide signal



Newport is chosen for the following reasons

- Long term observation
- Simultaneous water level data
- Similar tidal characteristics
- Smaller Error - Bodnar value



Tidal Datum Computation

First Reduction (FRED): Average of all data.

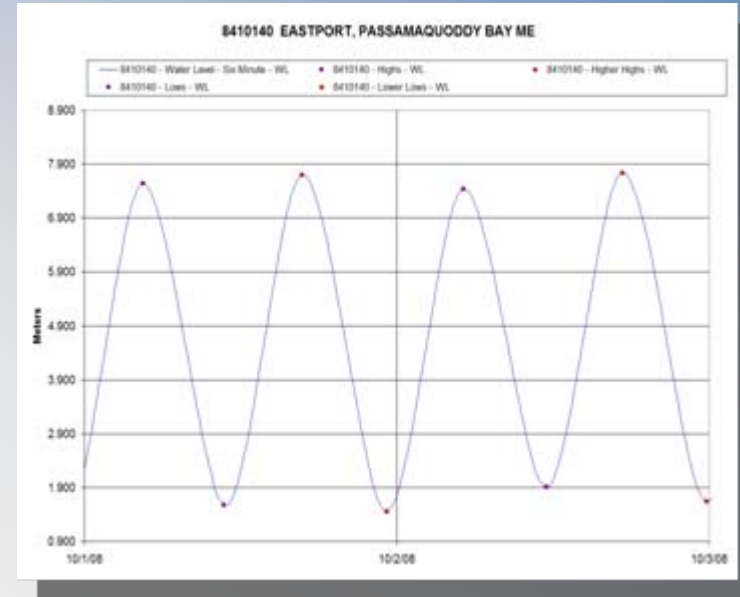
- **Monthly Mean** Comparison: collected water level data is long enough to allow monthly mean to be computed
 - Modified Range Ratio Method
 - Standard Method
 - Direct Method
- **Tide-By-Tide** Comparison: monthly mean is not available
 - Modified Range Ratio Method
 - Standard Method
 - Direct Method



Modified-Range Ratio Method

East and Gulf Coasts and Caribbean Island Stations

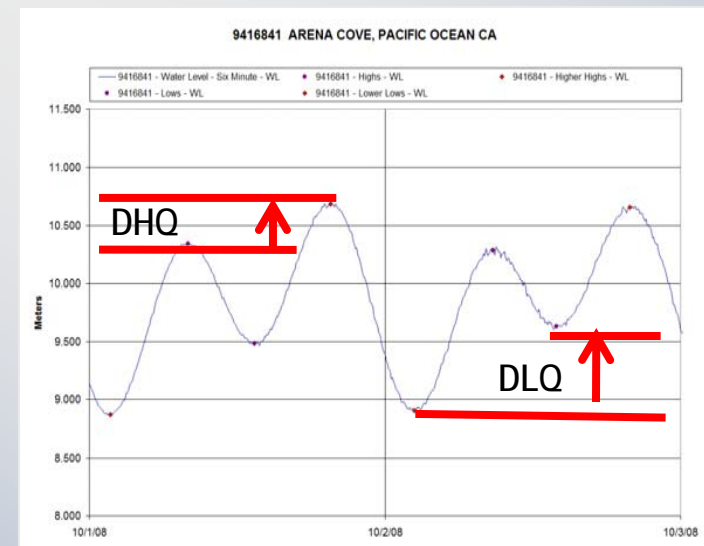
- $MLW = MTL - (0.5 \times Mn)$
- $MHW = MLW + Mn$
- $MLLW = DTL - (0.5 \times Gt)$
- $MHHW = MLLW + Gt$



Standard Method

West Coast and Pacific Island stations

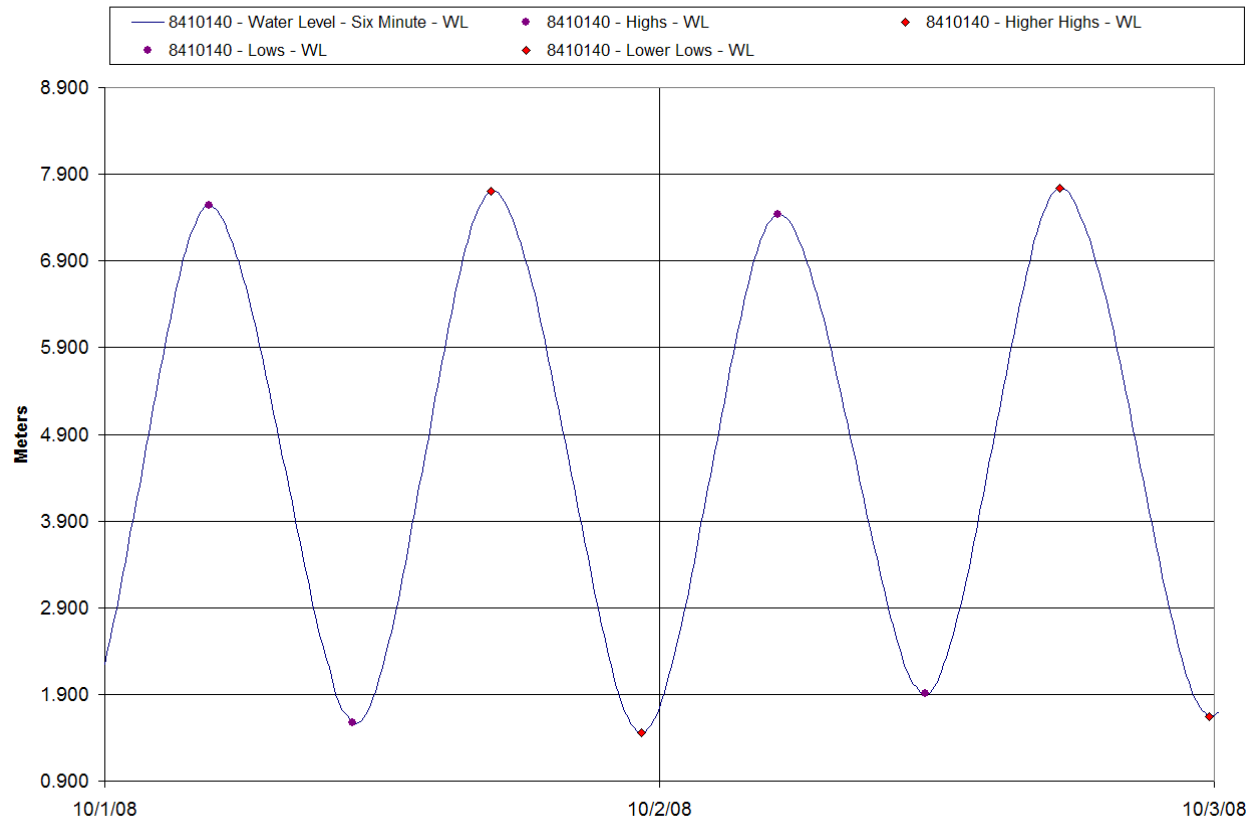
- $MLW = MTL - (0.5 \times Mn)$
- $MHW = MLW + Mn$
- $MLLW = MLW - DLQ$
- $MHHW = MHW + DHQ$

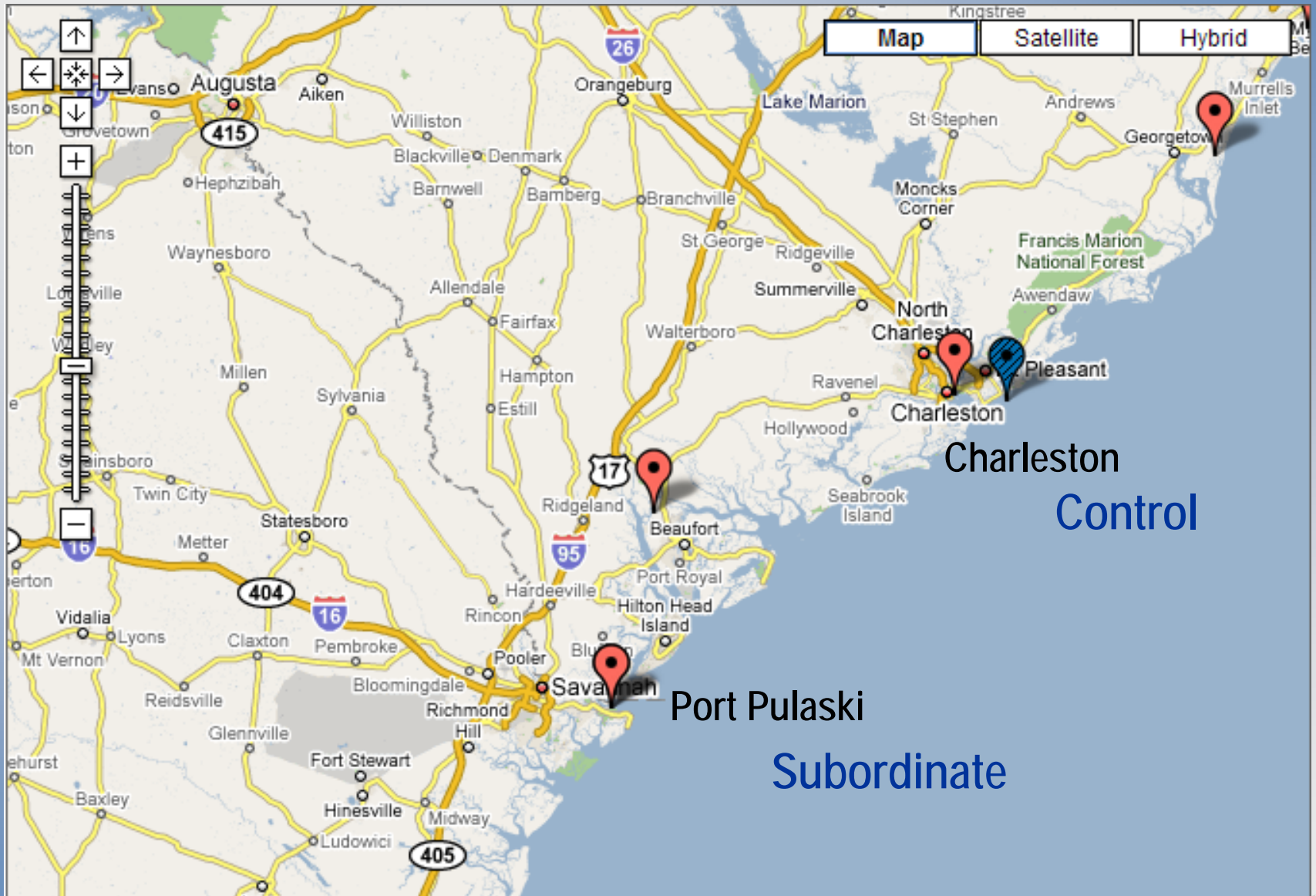


Modified-Range Ratio Method for Monthly Mean Comparison

*East Coast, Gulf Coast and Caribbean Island
Semidiurnal and Diurnal*

Charleston





Charleston
Control

Port Pulaski
Subordinate



Modified-Range Ratio Method

- $MLW = MTL - (0.5 \times Mn)$
- $MHW = MLW + Mn$
- $MLLW = DTL - (0.5 \times Gt)$
- $MHHW = MLLW + Gt$

- **MTL, MN, DTL and GT** have to be determined before computing MLW, MHW, MLLW, and MHHW



Computation Flow of Monthly Mean Comparison

Monthly Mean of each datum at Subordinate
Monthly Mean of each datum at Control



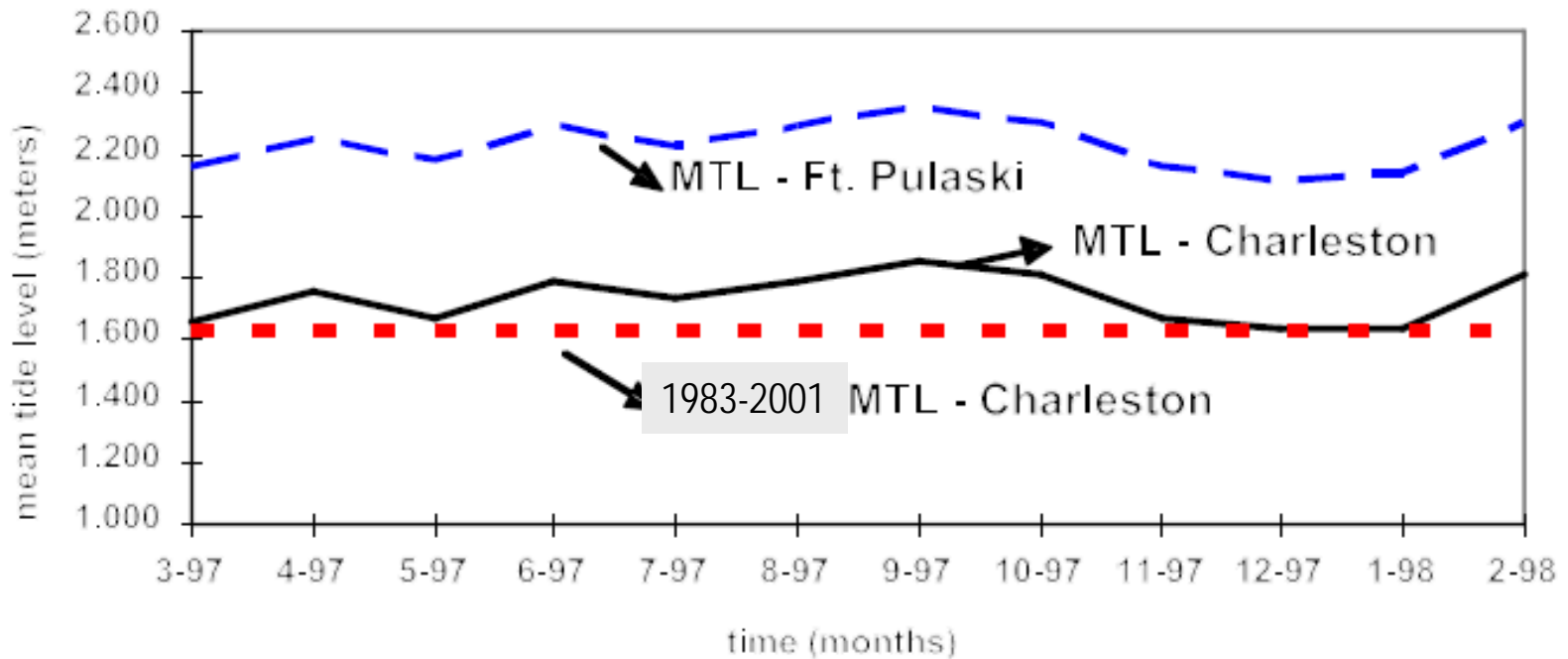
Average difference/Ratios between Monthly Mean of each datum between subordinate and control



Use the average difference/ratios as corrector to adjust accepted 19-year datums at control station to derive 19-year datums at subordinate

Simultaneous Comparison of MTL

Comparison of Monthly Mean Tide Level (MTL) for Charleston, SC and Ft. Pulaski, GA



Presently Accepted 19-year Epoch Datum at Control Station

Data are in Meters above STND, time intervals are on UTC (GMT).
8665530 Charleston, Cooper River Entrance, SC, USA

Station	MHHW	MHW	DTL	MTL	MSL	MLW	MLLW	GT	MN
8665530	2.527	2.423	1.643	1.622	1.658	0.817	0.759	1.768	1.606
DHQ	DLQ	HWI	LWI						
0.104	0.058	0.35	6.57						

Accepted Datums

MTL

$$MTL_{CORRECTED\ FOR\ A} = MTL_{ACCEPTED\ FOR\ B} + \left(\frac{1}{N}\right) \sum_{I=1}^N (MTL_A(I) - MTL_B(I))$$

- (A) SUBORDINATE STATION 8670870 FORT PULASKI, SAVANNAH RIVER
(B) STANDARD STATION 8665530 CHARLESTON, COOPER RIVER ENTRANCE

Mon	Year	A	B	A - B
		METER	METER	METER
Mar	1997	2.156	1.662	0.494
Apr	1997	2.248	1.751	0.497
May	1997	2.188	1.673	0.515
Jun	1997	2.291	1.792	0.499
Jul	1997	2.225	1.730	0.495
Aug	1997	2.295	1.789	0.506
Sep	1997	2.353	1.851	0.502
Oct	1997	2.305	1.807	0.498
Nov	1997	2.158	1.669	0.489
Dec	1997	2.118	1.635	0.483
Jan	1998	2.135	1.634	0.501
Feb	1998	2.300	1.811	0.489

SUMS	5.968
TOTAL MONTHS	12.000
MEANS	0.497
ACCEPTED FOR B	1.622
CORRECTED FOR A	2.119

$$\underline{2.119 = 1.622 + 0.497}$$

DTL

$$DTL_{CORRECTED\ FOR\ A} = DTL_{ACCEPTED\ FOR\ B} + \left(\frac{1}{N}\right) \sum_{I=1}^N (DTL_A(I) - DTL_B(I))$$

Mon	Year	DTL		
		A	B	A - B
		METER	METER	METER
Mar	1997	2.159	1.672	0.487
Apr	1997	2.259	1.763	0.496
May	1997	2.208	1.699	0.509
Jun	1997	2.320	1.818	0.502
Jul	1997	2.253	1.758	0.495
Aug	1997	2.309	1.807	0.502
Sep	1997	2.369	1.870	0.499
Oct	1997	2.321	1.824	0.497
Nov	1997	2.182	1.692	0.490
Dec	1997	2.139	1.661	0.478
Jan	1998	2.152	1.665	0.487
Feb	1998	2.304	1.821	0.483

SUMS	5.925
TOTAL MONTHS	12.000
MEANS	0.494
ACCEPTED FOR B	1.643
CORRECTED FOR A	2.137

$$\underline{2.137 = 1.643 + 0.494}$$

MN

$$Mn_{CORRECTED\ FOR\ A} = Mn_{ACCEPTED\ FOR\ B} \times \left(\frac{1}{N} \right) \sum_{I=1}^N \frac{Mn_A(I)}{Mn_B(I)}$$

Mon	Year	A	Mn	B	A / B
		METER	METER		RATIO
Mar	1997	2.195	1.629		1.347
Apr	1997	2.193	1.646		1.332
May	1997	2.235	1.666		1.342
Jun	1997	2.196	1.644		1.336
Jul	1997	2.230	1.653		1.349
Aug	1997	2.153	1.611		1.336
Sep	1997	2.123	1.606		1.322
Oct	1997	2.096	1.586		1.322
Nov	1997	2.150	1.618		1.329
Dec	1997	2.207	1.648		1.339
Jan	1998	2.243	1.674		1.340
Feb	1998	2.222	1.653		1.344

SUMS	16.038
TOTAL MONTHS	12.000
MEANS	1.337
ACCEPTED FOR B	1.606
CORRECTED FOR A	2.146

$$\underline{2.146 = 1.606 \times 1.337}$$



GT

$$Gt_{CORRECTED\ FOR\ A} = Gt_{ACCEPTED\ FOR\ B} \times \left(\frac{1}{N} \right) \sum_{I=1}^N \frac{Gt_A(I)}{Gt_B(I)}$$

Mon	Year	A	B	A / B
		METER	METER	RATIO
Mar	1997	2.335	1.766	1.322
Apr	1997	2.327	1.771	1.314
May	1997	2.408	1.820	1.323
Jun	1997	2.377	1.815	1.310
Jul	1997	2.427	1.830	1.326
Aug	1997	2.301	1.751	1.314
Sep	1997	2.252	1.724	1.306
Oct	1997	2.210	1.697	1.302
Nov	1997	2.311	1.774	1.303
Dec	1997	2.394	1.823	1.313
Jan	1998	2.426	1.846	1.314
Feb	1998	2.405	1.807	1.331

SUMS	15.778
TOTAL MONTHS	12.000
MEANS	1.315
ACCEPTED FOR B	1.768
CORRECTED FOR A	2.325

$$\underline{2.325 = 1.768 \times 1.315}$$



Results

- **MLW = MTL - (0.5 x Mn)**
- **MHW = MLW + Mn**
- **MLLW = DTL - (0.5 x Gt)**
- **MHHW = MLLW + Gt**

$$MLW = MTL - 0.5 \times Mn = 2.119 - 0.5(2.146) = 1.046$$

$$MHW = MLW + Mn = 1.046 + 2.146 = 3.192$$

$$MLLW = DTL - 0.5 \times Gt = 2.137 - 0.5(2.325) = 0.974$$

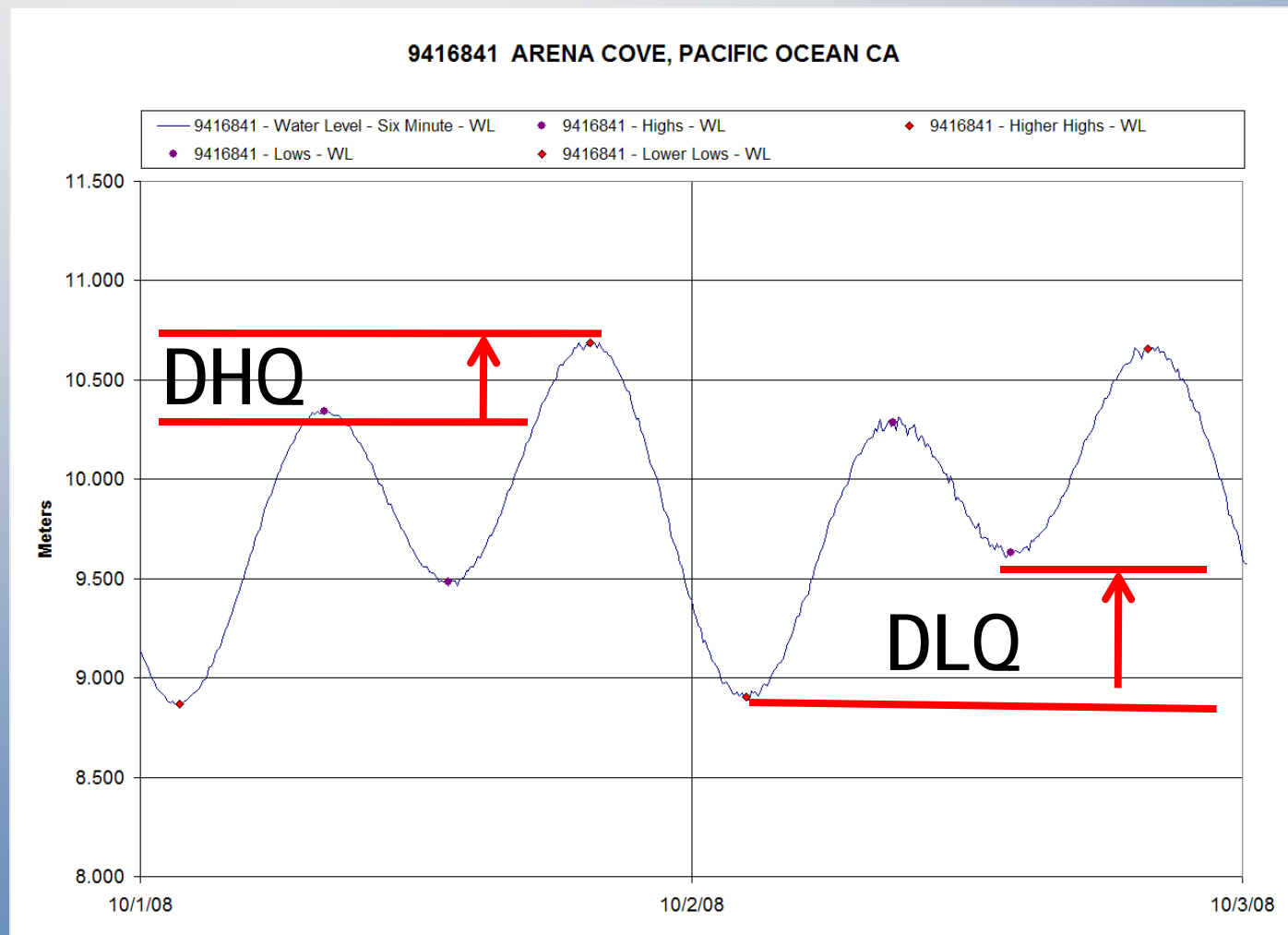
$$MHHW = MLLW + Gt = 0.974 + 2.325 = 3.299.$$

$$DHQ = MHHW - MHW = 3.299 - 3.192 = 0.107$$

$$DLQ = MLW - MLLW = 1.046 - 0.974 = 0.072.$$

Standard Method

West Coast and Pacific Island Mix Tide



Standard Method

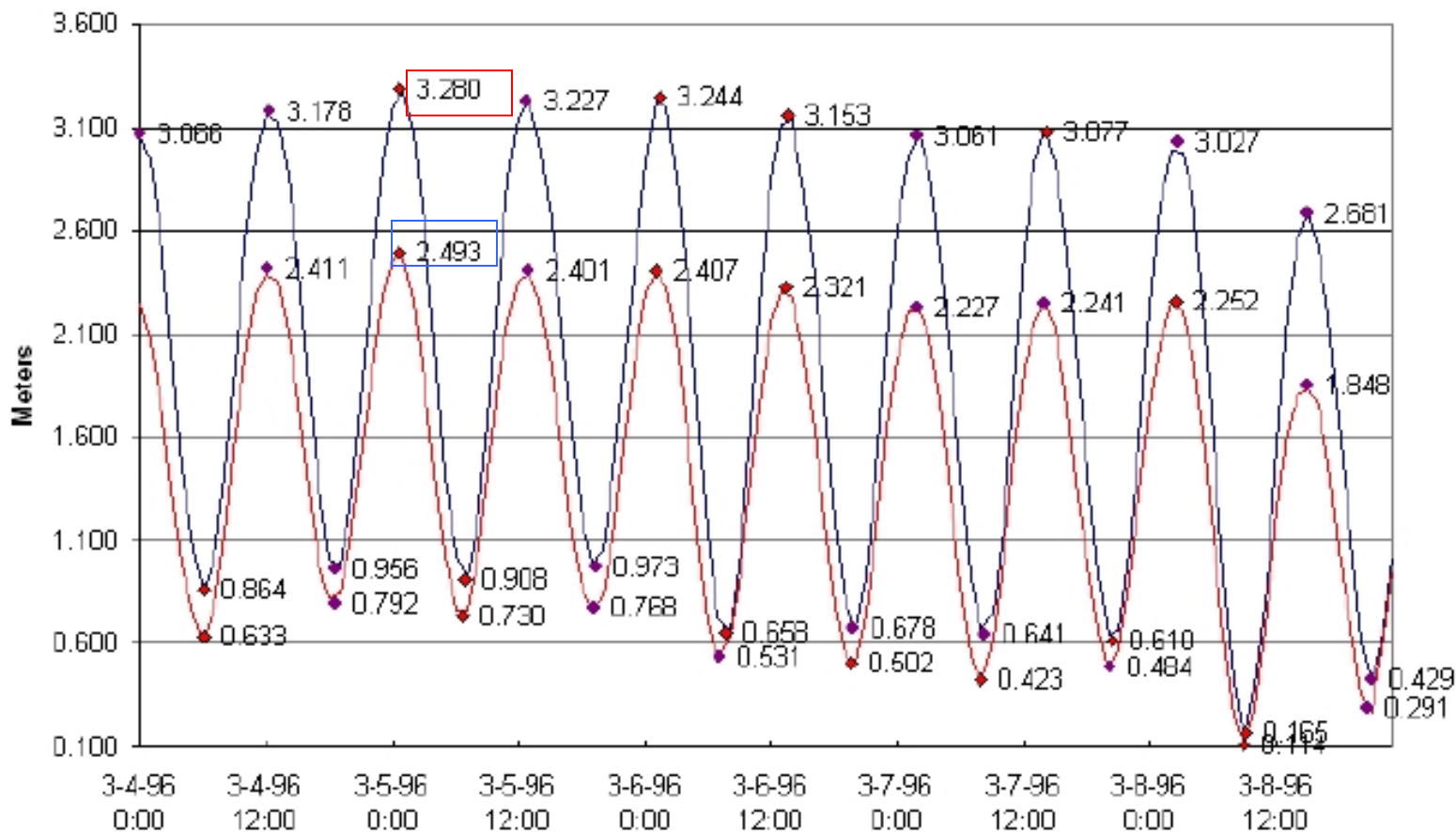
- $MLW = MTL - (0.5 \times Mn)$
- $MHW = MLW + Mn$
- $MLLW = MLW - DLQ$
- $MHHW = MHW + DHQ$
- **MTL, MN, DHQ and DLQ** have to be determined before computing MLW, MHW, MLLW, and MHHW

Tidal Datum Computation

- First Reduction of a 19+ year time series
- Monthly Mean **Comparison**
 - Modified Range Ratio **Method**
 - Standard **Method**
 - Direct **Method**
- **Tide-By-Tide Comparison**
 - Modified Range Ratio **Method**
 - Standard **Method**
 - Direct **Method**

TBYT Simultaneous Comparison of Highs and Lows

8670870 FORT PULASKI, SAVANNAH RIVER GA
 8665530 CHARLESTON, COOPER RIVER ENTRANCE SC



Computation Flow of Tide-By-Tide Comparison

Monthly Mean Comparison

Monthly Mean of each datum at Subordinate
Monthly Mean of each datum at Control



Differences/Ratios between Monthly Mean of each datum between subordinate and control



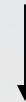
Use the differences/ratios as corrector to adjust accepted 19-year datums at control station to derive 19-year datums at subordinate

Tide-By-Tide Comparison

Average differences of the Highs at the subordinate and control as well as the differences of their lows



Mean of each datum at Subordinate



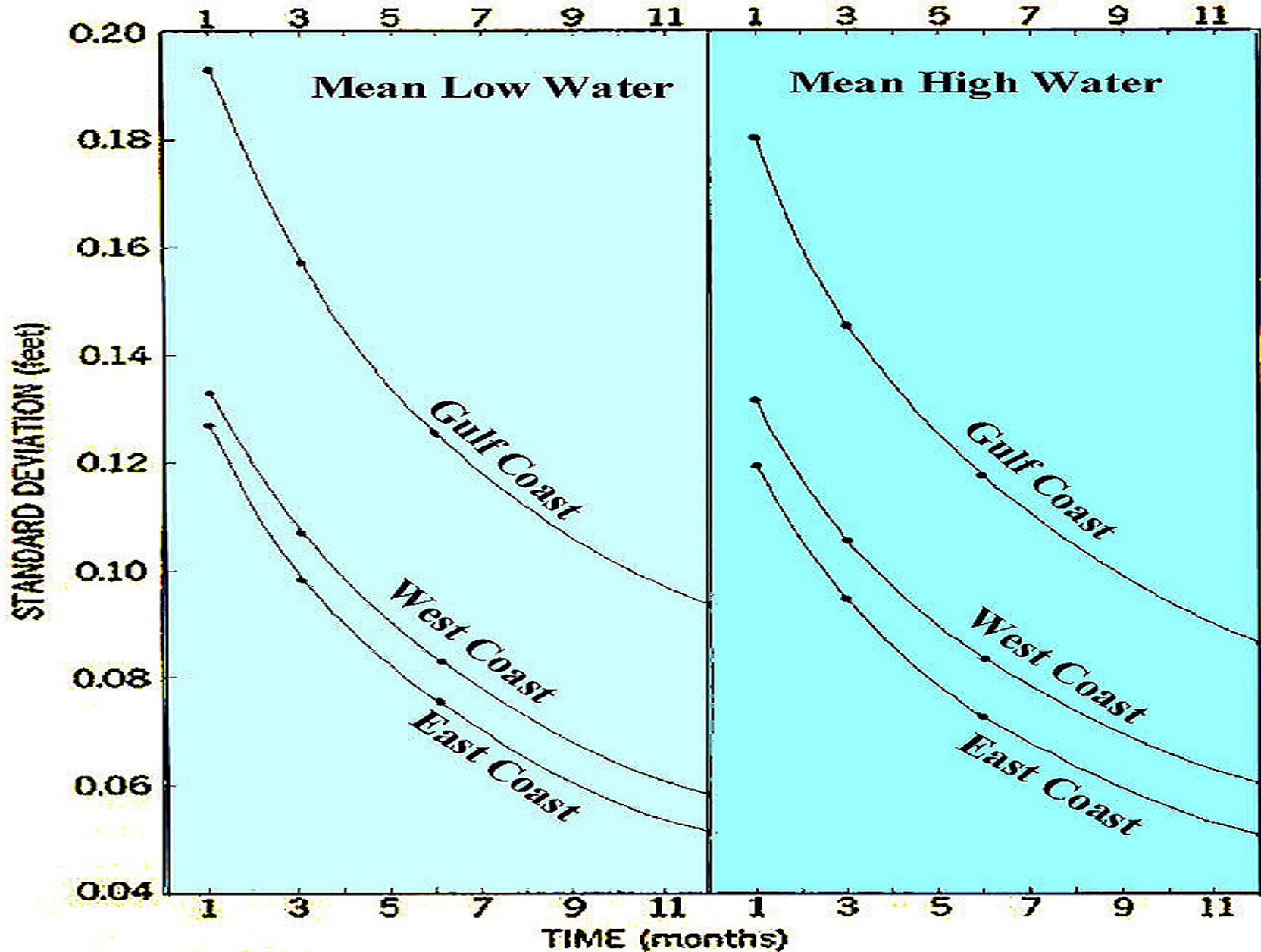
Averages differences/Ratios of each datum between subordinate and control



Use the differences/ratios as corrector to adjust accepted 19-year datums at control station to derive 19-year datums at subordinate



Error Bounds



References

NOAA Special Publication NOS CO-OPS 2

COMPUTATIONAL TECHNIQUES FOR TIDAL DATUMS HANDBOOK



Silver Spring, Maryland
September 2003

U.S. DEPARTMENT OF COMMERCE
Don Evans, Secretary

National Oceanic and Atmospheric Administration
Conrad C. Lautenbacher, Jr.
Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator

National Ocean Service
Dr. Richard W. Spinrad
Assistant Administrator Ocean Services and Coastal Zone Management

Center for Operational Oceanographic Products and Services
Michael Szabados, Director

NOAA Special Publication NOS CO-OPS 1

TIDAL DATUMS AND THEIR APPLICATIONS

This special publication was prepared under the editorship of:
Stephen K. Gill and John R. Schultz

Contributors:
Wolfgang Scherer, William M. Stoney, Thomas N. Mero, Michael O'Hargan,
William Michael Gibson, James R. Hubbard, Michael I. Weiss, Ole Varmer,
Brenda Via, Daphne M. Friot, Kristen A. Tronvig.

February 2001



noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
Don Evans, Secretary

National Oceanic and Atmospheric Administration
Scott B. Gudes, Acting Under Secretary for Oceans and
Atmosphere and NOAA Administrator

National Ocean Service
Margaret A. Davidson, Acting Assistant Administrator
for Ocean Services and Coastal Zone Management

Center for Operational Oceanographic Products and Services
Michael Szabados, Acting Director

<http://tidesandcurrents.noaa.gov/pub.html>



Tidal Datum Computations

Methods for Computing Tidal Datums

Tidal Datums Team
nos.coops.datums@noaa.gov

Primary Determination – Average of 19-year data series defined by the National Tidal Datum Epoch to obtain Accepted Values

Secondary or Tertiary Determination – Comparison of means or tides to obtain an 19-year equivalent mean

- Modified Range Ratio Method
- Standard Method
- Direct Methods

