Sea Level Rise & Key West

Remembering it may be the "little" things that mean a lot!

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http://weather.gov

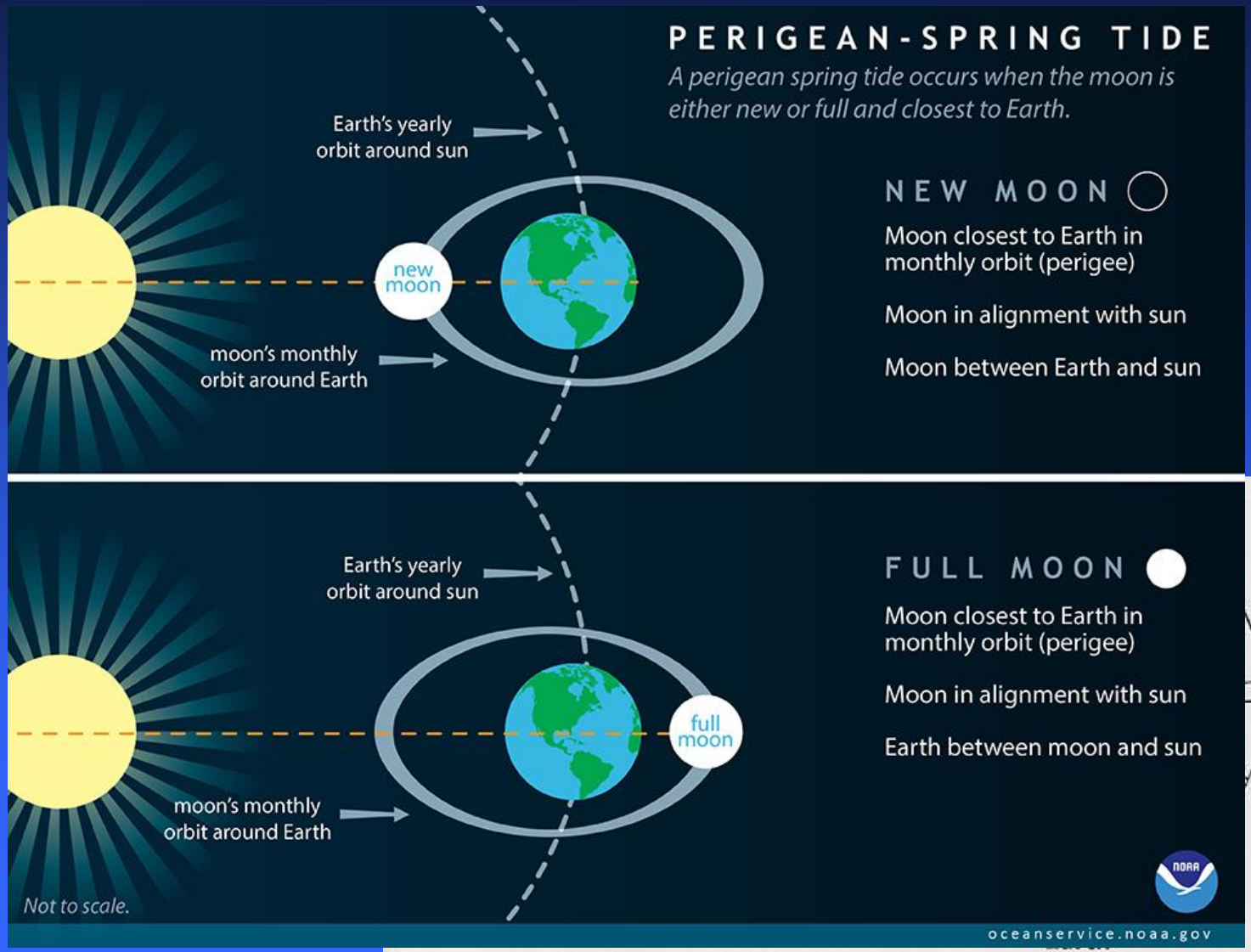
Topics

- Tides & Tidal Anomalies
- Impacts from Storm Surge
- Climate Change – Rainfall Budget & Rates

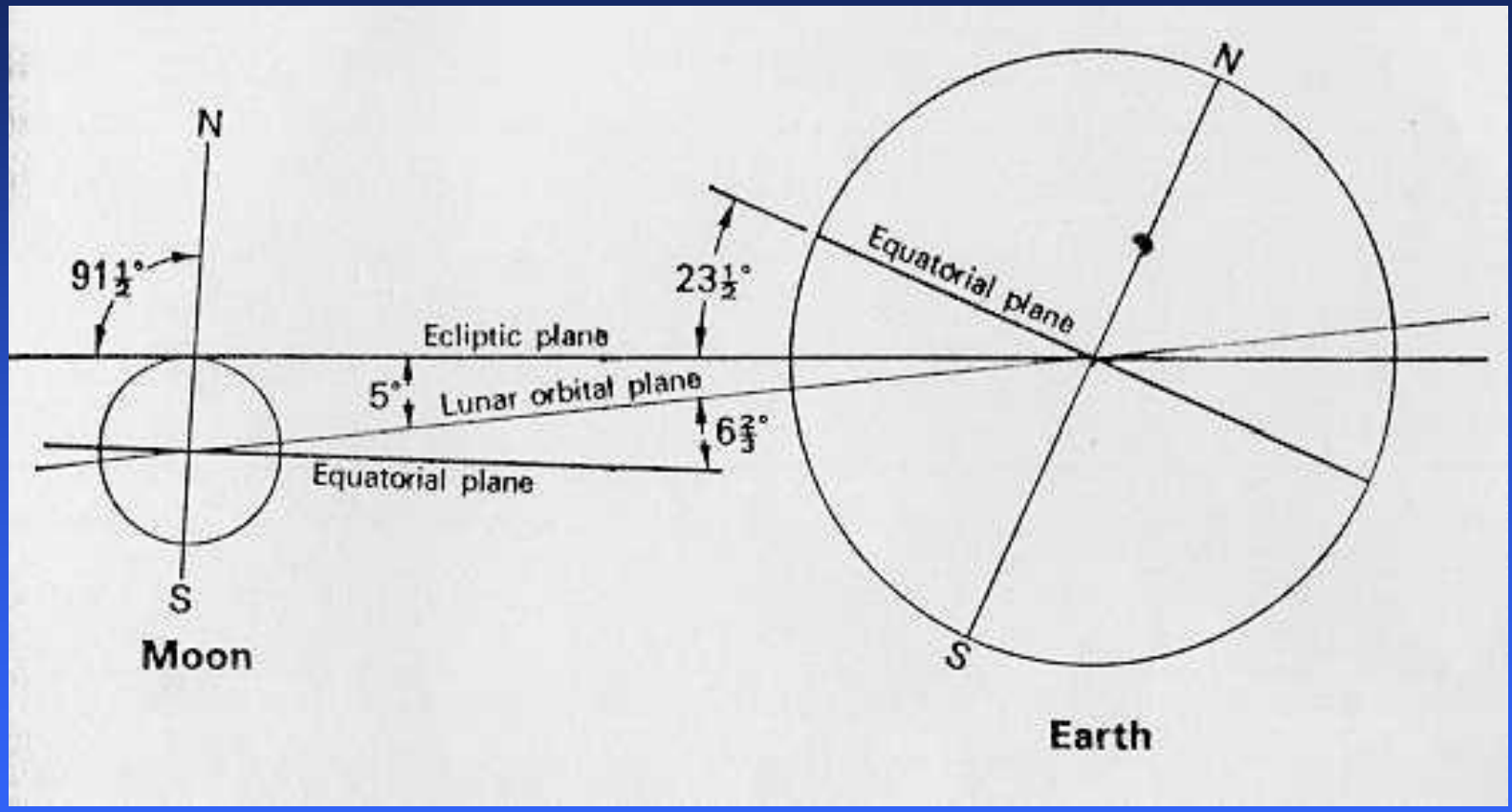
Definitions

- "Predicted" Tides
  - Calculated due to position of the moon and sun
- Spring Tide
  - Tides around the time of new or full moon
- King Tide
  - Non-scientific term for exceptionally high tides
  - Often associated with the perigean spring tide, when Spring Tide coincides with closest point in the moon's orbit to the earth

The Moon and Tides



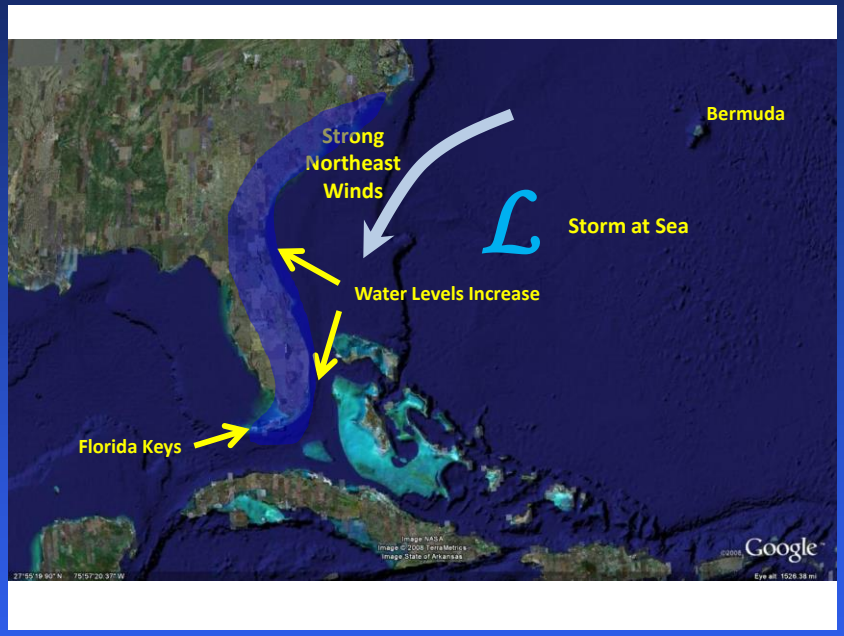
The Moon and Tides

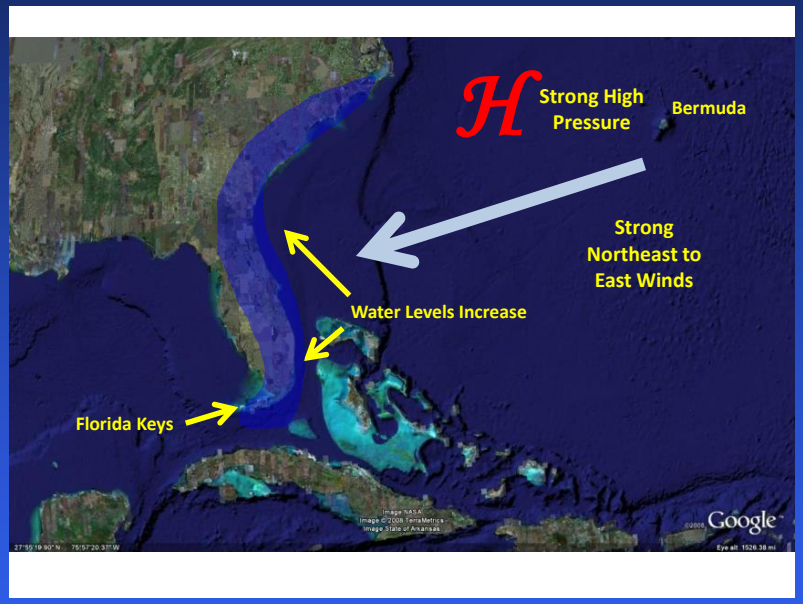


Tides: Baseline for "Predicted"

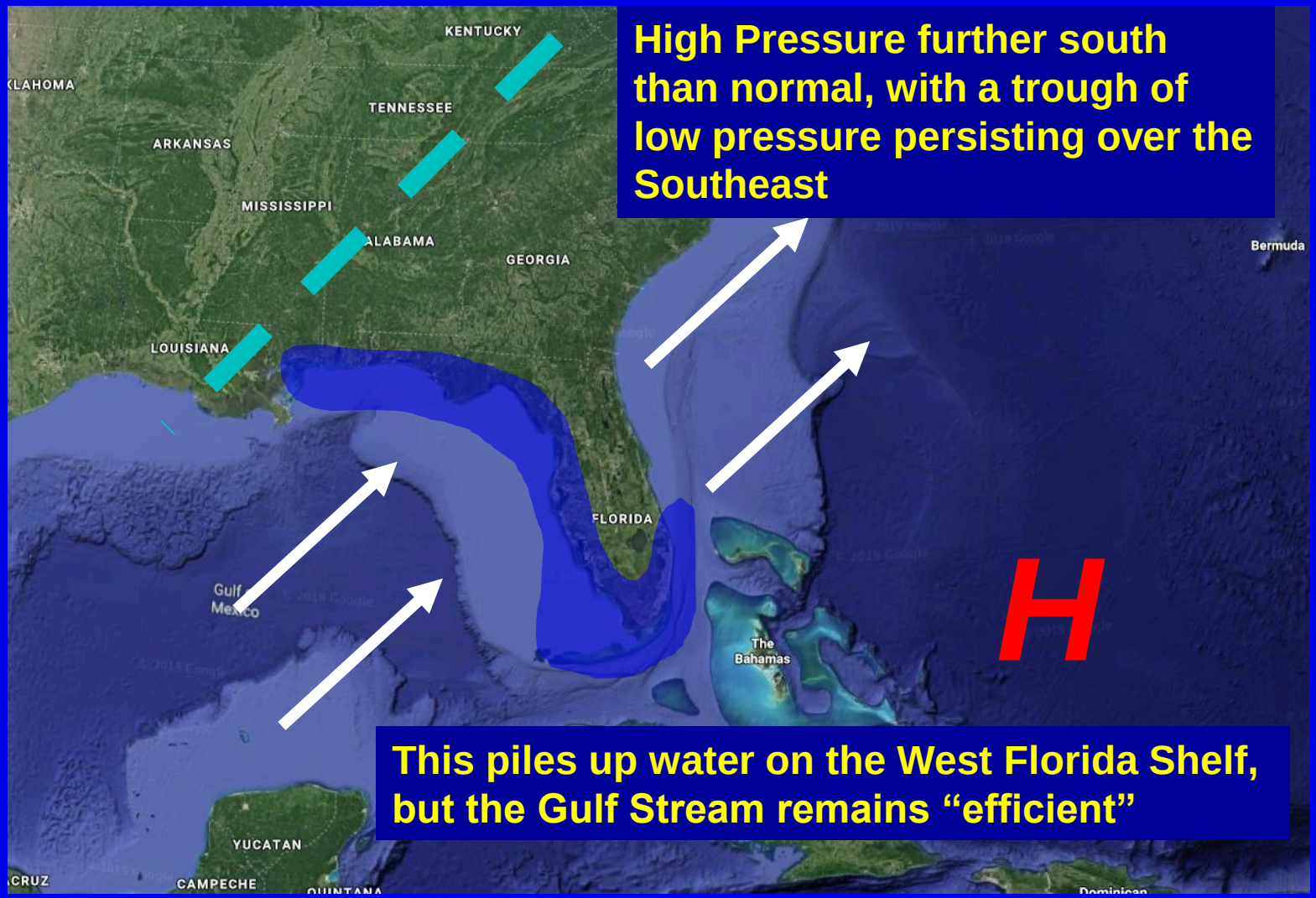
- National Tidal Datum Epoch
  - 19-year cycle covering multiple seasons and lunar positions
  - All datums (MSL, MLLW, MHHW, etc. are calculated based on observations during the epoch
  - Current epoch is 1983-2001
  - Mandated to be revised every 25 years
  - Best estimate – next revision 2023-2025

Why Anomalies Occur





Jul-Aug 2019 Anomaly



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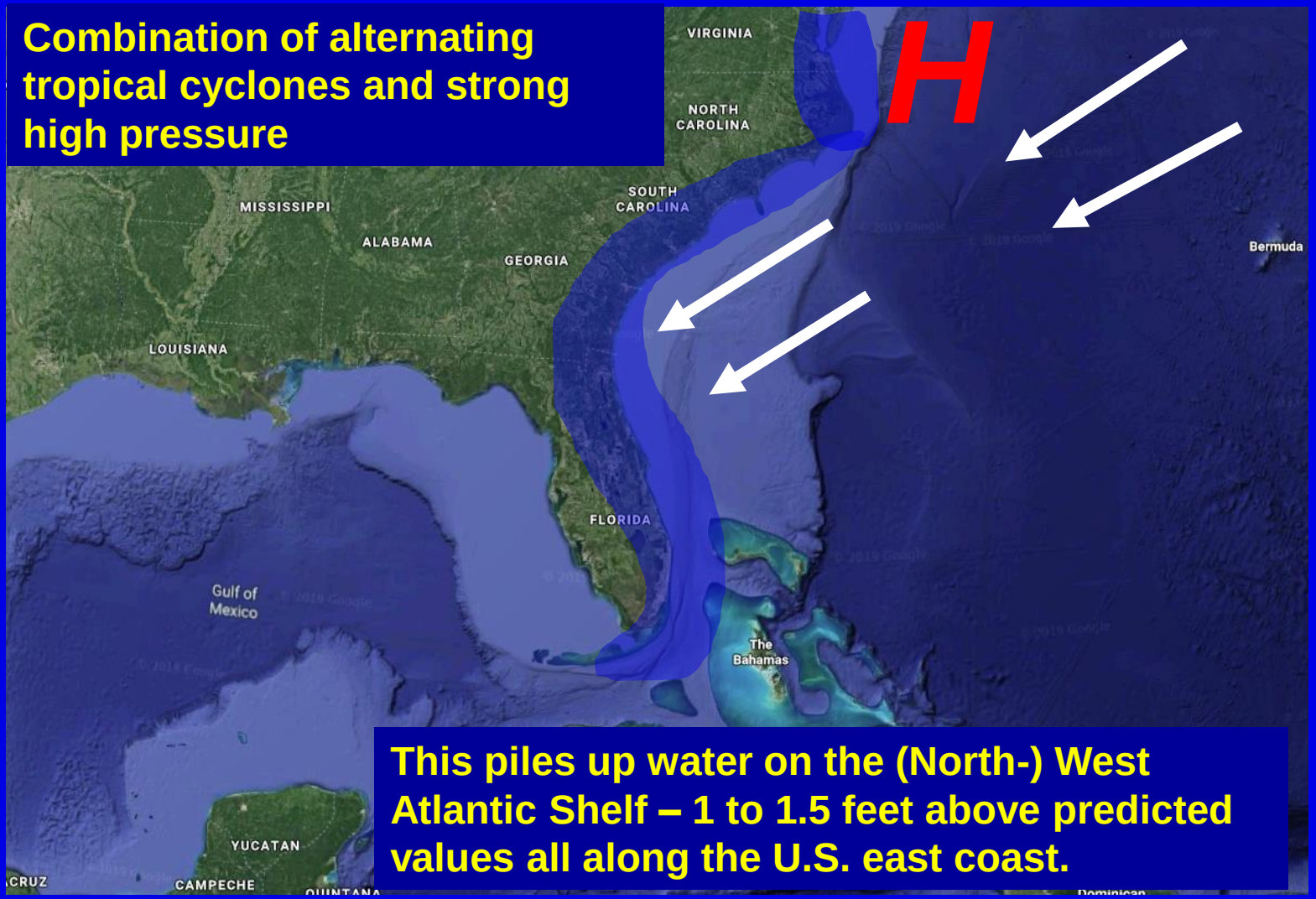
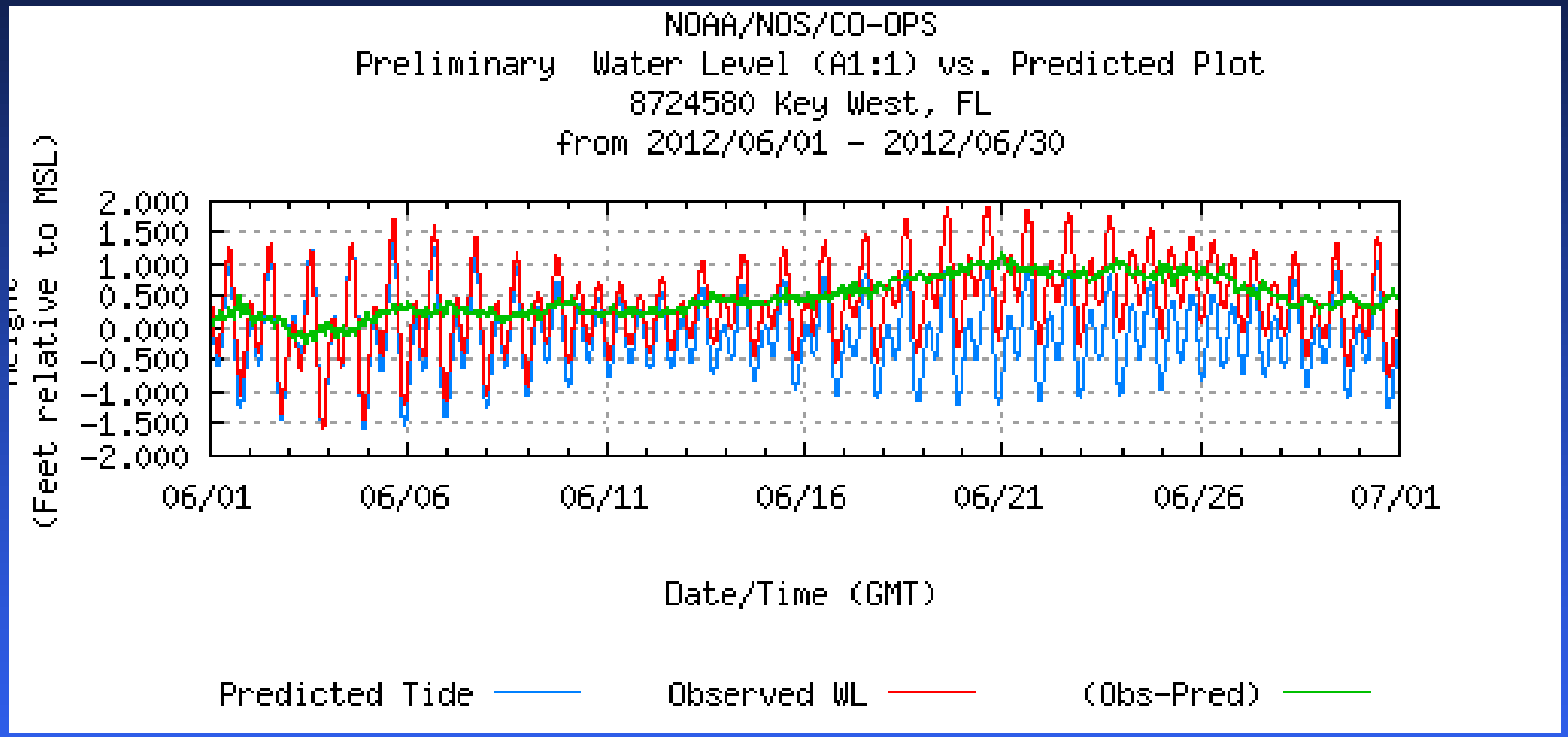
Sep-Oct 2019 Anomaly



http://weather.gov

Tidal Anomaly June 2012



Anomaly near +1.0 foot Jun 20-26

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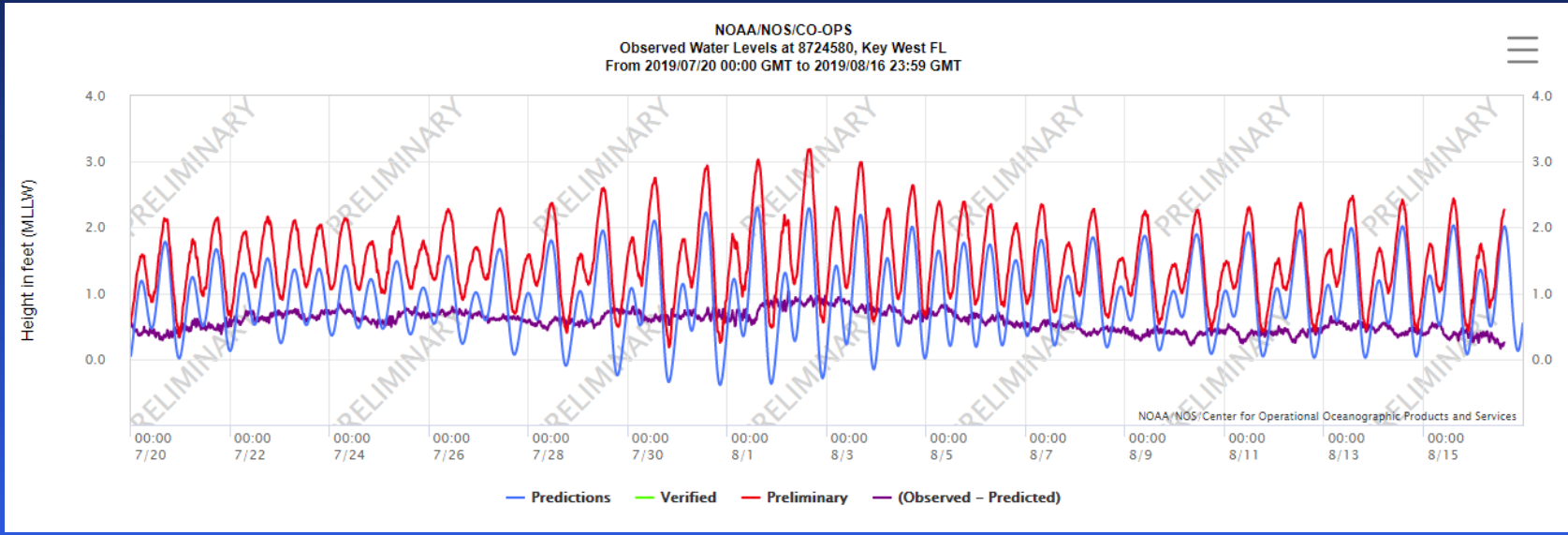
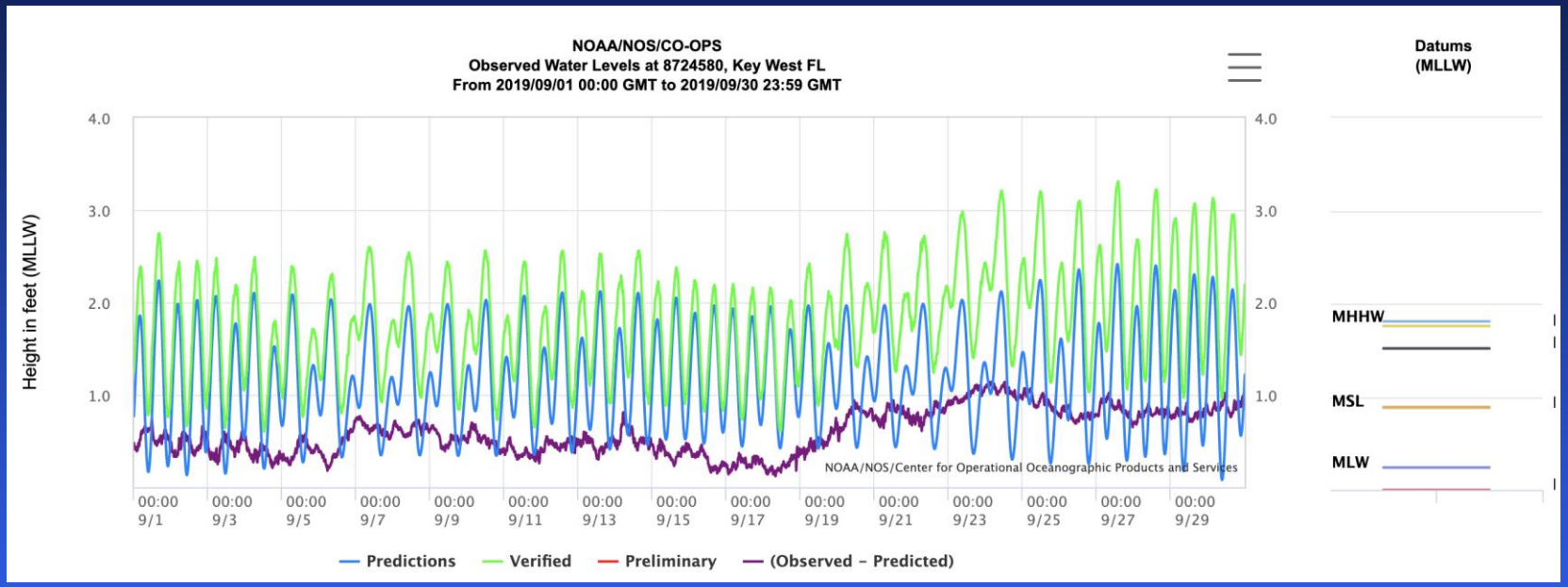
Tidal Anomaly Jul-Aug 2019



Anomaly approached +1.0 foot the beginning of August

Tidal Anomaly Sep 2019



Anomaly was near +1.0 foot Sep 23-24

Major Hurricane Humberto passed west of Bermuda just 3 to 4 days earlier.

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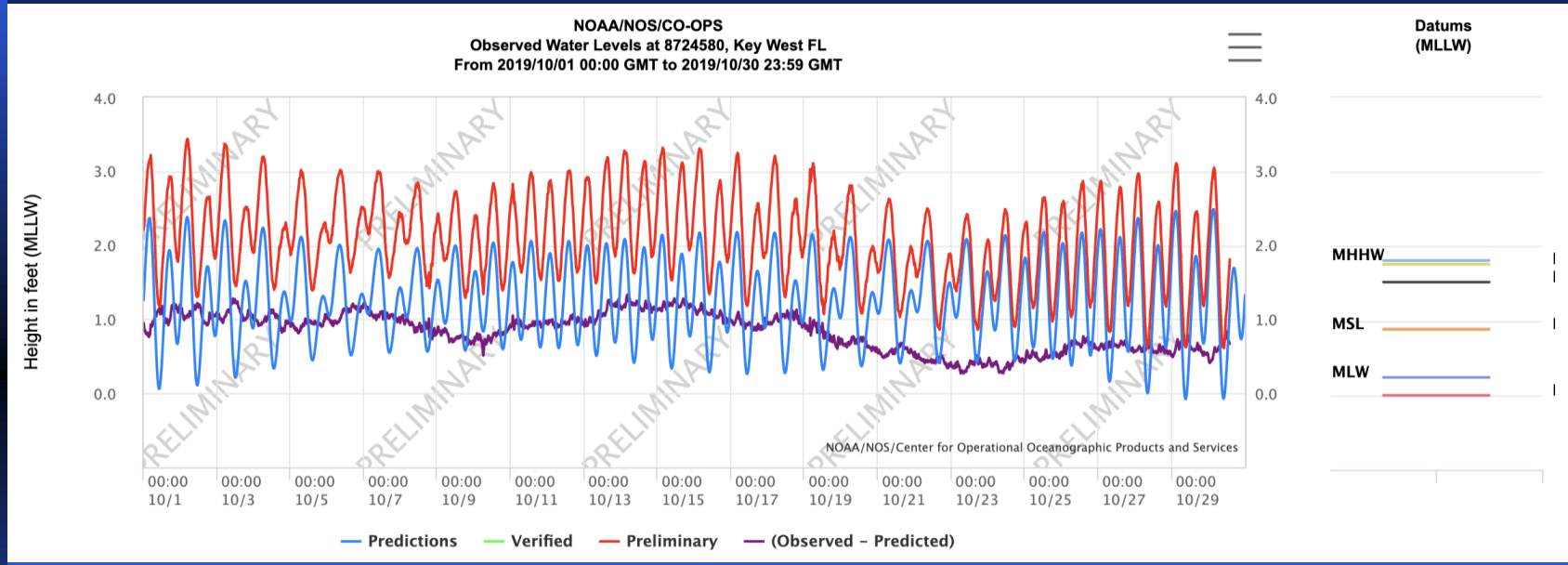
Tidal Anomaly Oct 2019



Anomaly in excess of +1.0 foot

Oct 1-7, and again Oct 11-18

Jerry, Karen, and Melissa formed between periods of strong high pressure over New England and the Mid Atlantic.

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Elevations on Mean Lower Low Water

Station: 8724580, Key West, FL
Status: Accepted (Aug 24 2010)
Units: Feet
Control Station:
T.M.: 0
Epoch: 1983-2001
Datum: MLLW

Datum	Value	Description
MHHW	1.81	Mean Higher-High Water
MHW	1.52	Mean High Water
MTL	0.88	Mean Tide Level
MSL	0.89	Mean Sea Level
DTL	0.90	Mean Diurnal Tide Level
MLW	0.24	Mean Low Water
MLLW	0.00	Mean Lower-Low Water
NAVD88	1.76	North American Vertical Datum of 1988
STND	-4.56	Station Datum
GT	1.81	Great Diurnal Range
MN	1.28	Mean Range of Tide
DHQ	0.29	Mean Diurnal High Water Inequality
DLQ	0.24	Mean Diurnal Low Water Inequality
HWI	2.77	Greenwich High Water Interval (in hours)
LWI	8.40	Greenwich Low Water Interval (in hours)
Max Tide	4.94	Highest Observed Tide
Max Tide Date & Time	10/24/2005 08:42	Highest Observed Tide Date & Time
Min Tide	-1.66	Lowest Observed Tide
Min Tide Date & Time	02/19/1928 03:06	Lowest Observed Tide Date & Time
HAT	2.65	Highest Astronomical Tide
HAT Date & Time	10/17/1989 03:18	HAT Date and Time
LAT	-0.80	Lowest Astronomical Tide
LAT Date & Time	05/24/1986 21:24	LAT Date and Time

Tidal Datum Analysis Periods

01/01/1983 - 12/31/2001

Datums

Mean Higher High Water (MHHW) is…

0.92 feet above Mean Sea Level (MSL)

0.05 feet above NAVD88

NOAA considers exceeding MHHW the point at which coastal flooding begins

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Tidal Datum Analysis Periods

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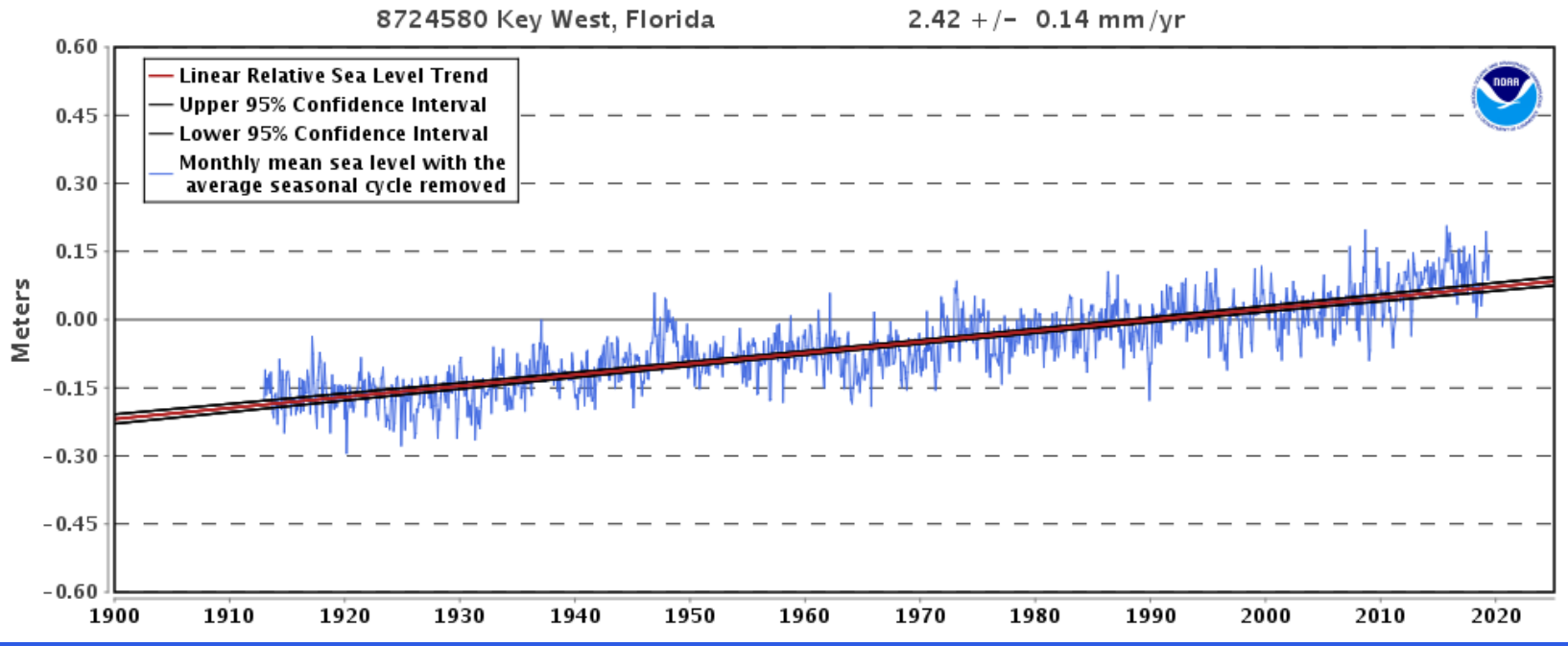
Datums

Note: The 1983-2001 Tidal Epoch is the current operational tidal epoch.

This is why “1992” appears in the Sea Level Rise Compact – the “midpoint” of the current tidal epoch.

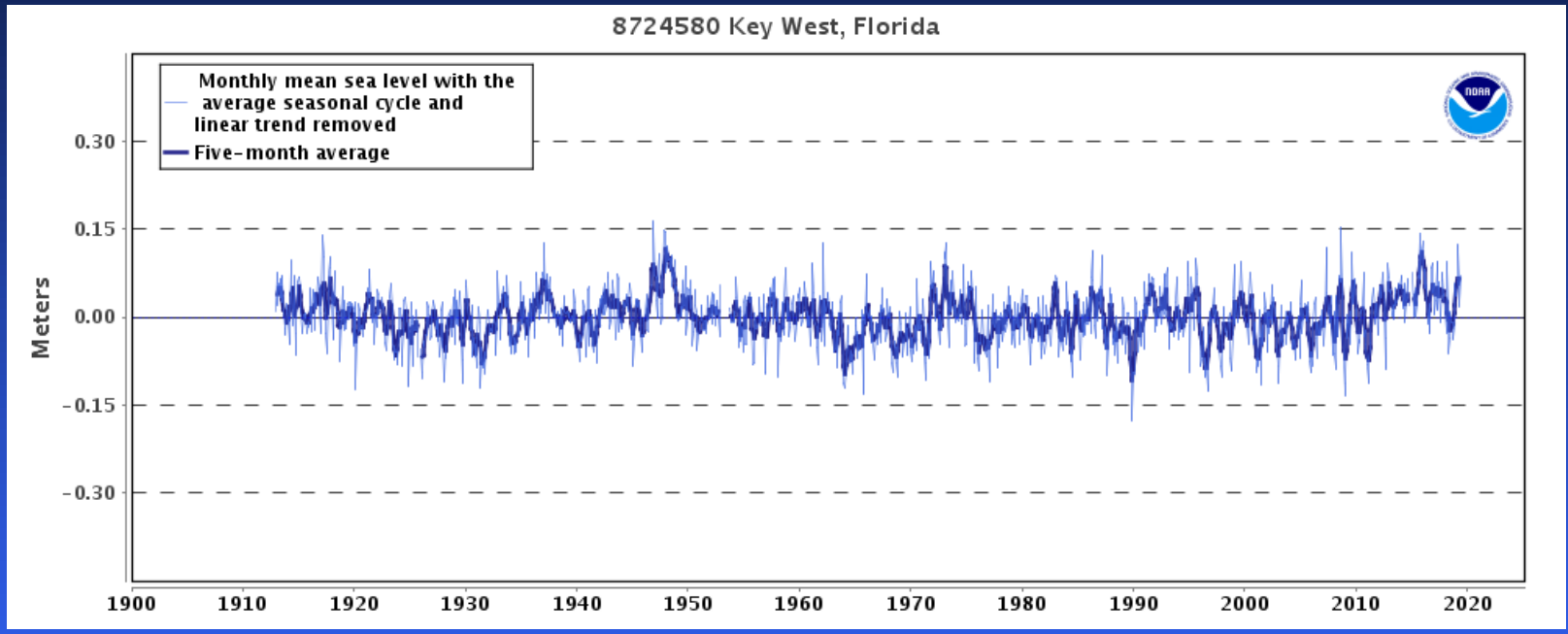
Expect the next epoch to be calculated and released 2022-2024.

Sea Level Trend (Linear)



Mean Sea Level increase of 9.5 inches per 100 years

Interannual Variation



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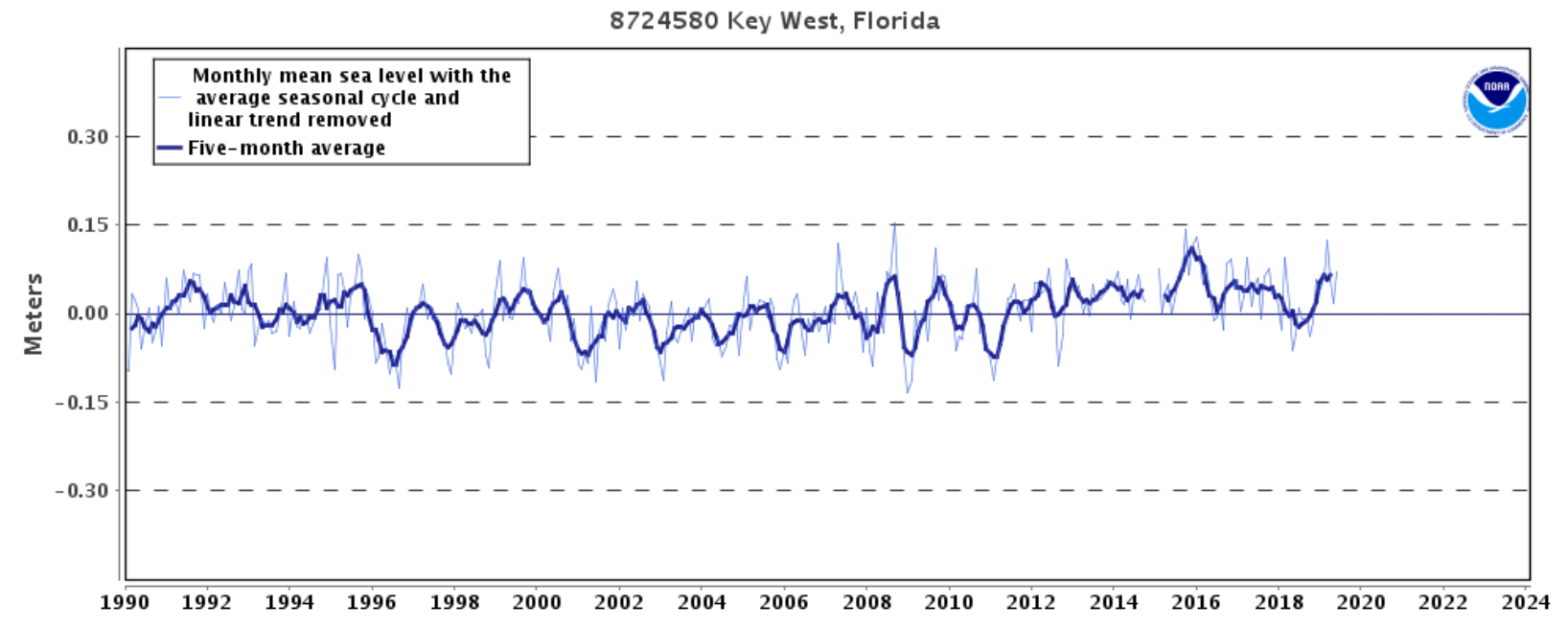
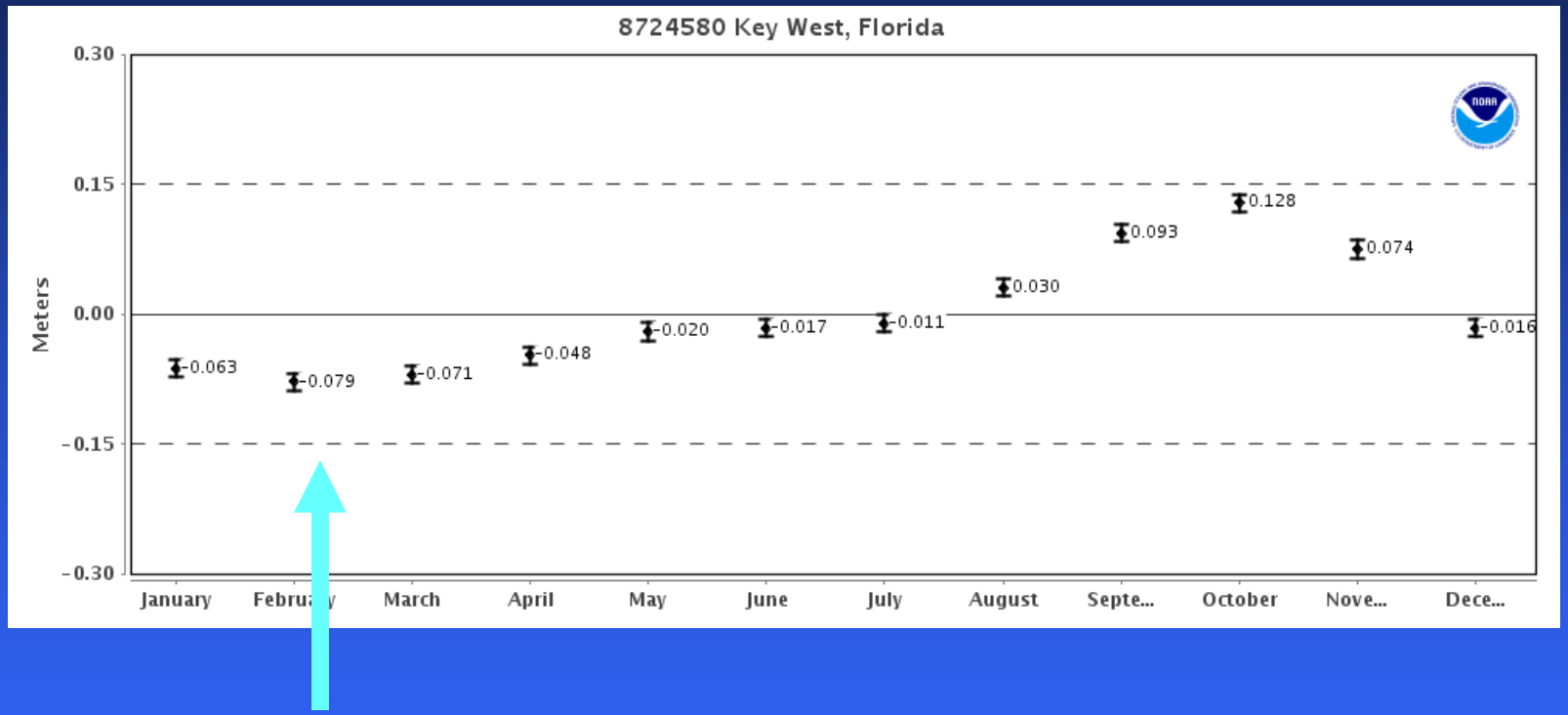
Interannual Variation (Since 1990)



1-Month Averages can vary around 1 foot

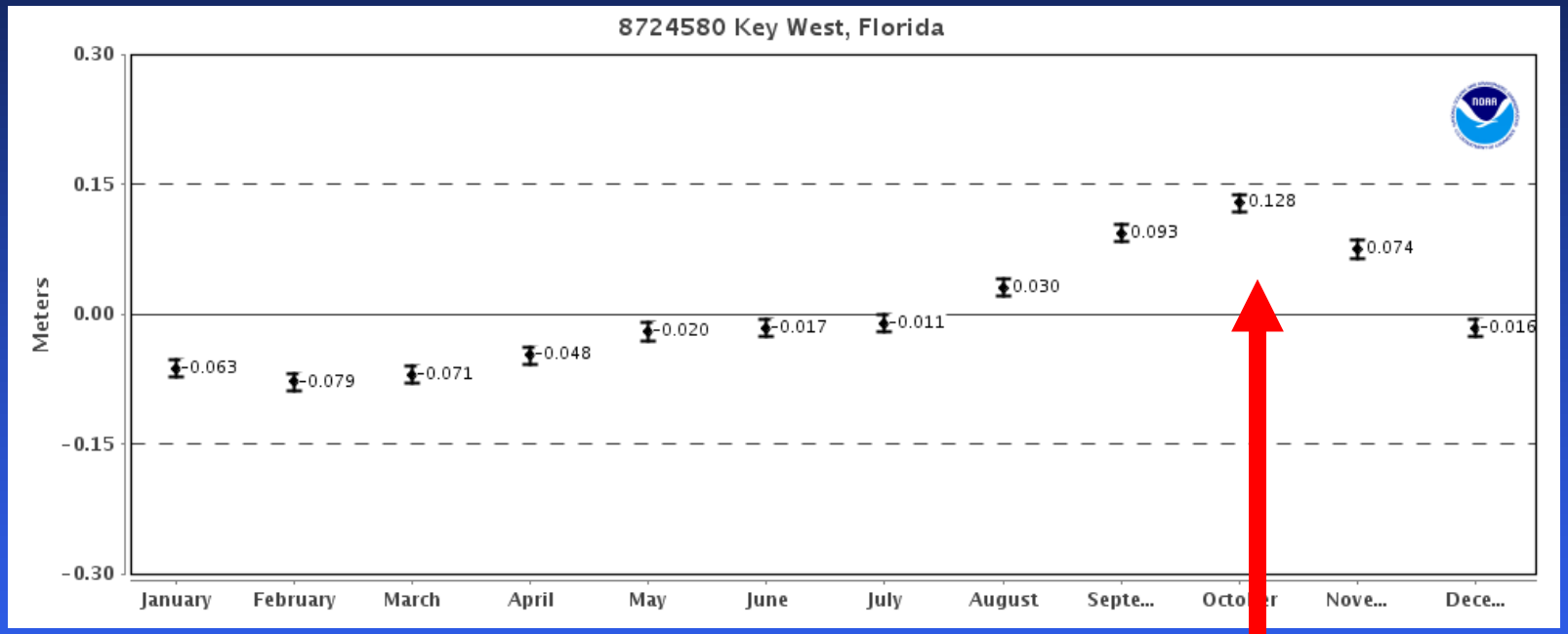
5-Month Averages can vary around ½ foot

Seasonal Sea Level



February Water Levels are lowest, near 3 inches below the mean

Seasonal Sea Level



October Water Levels average the highest, about 5 inches above the mean

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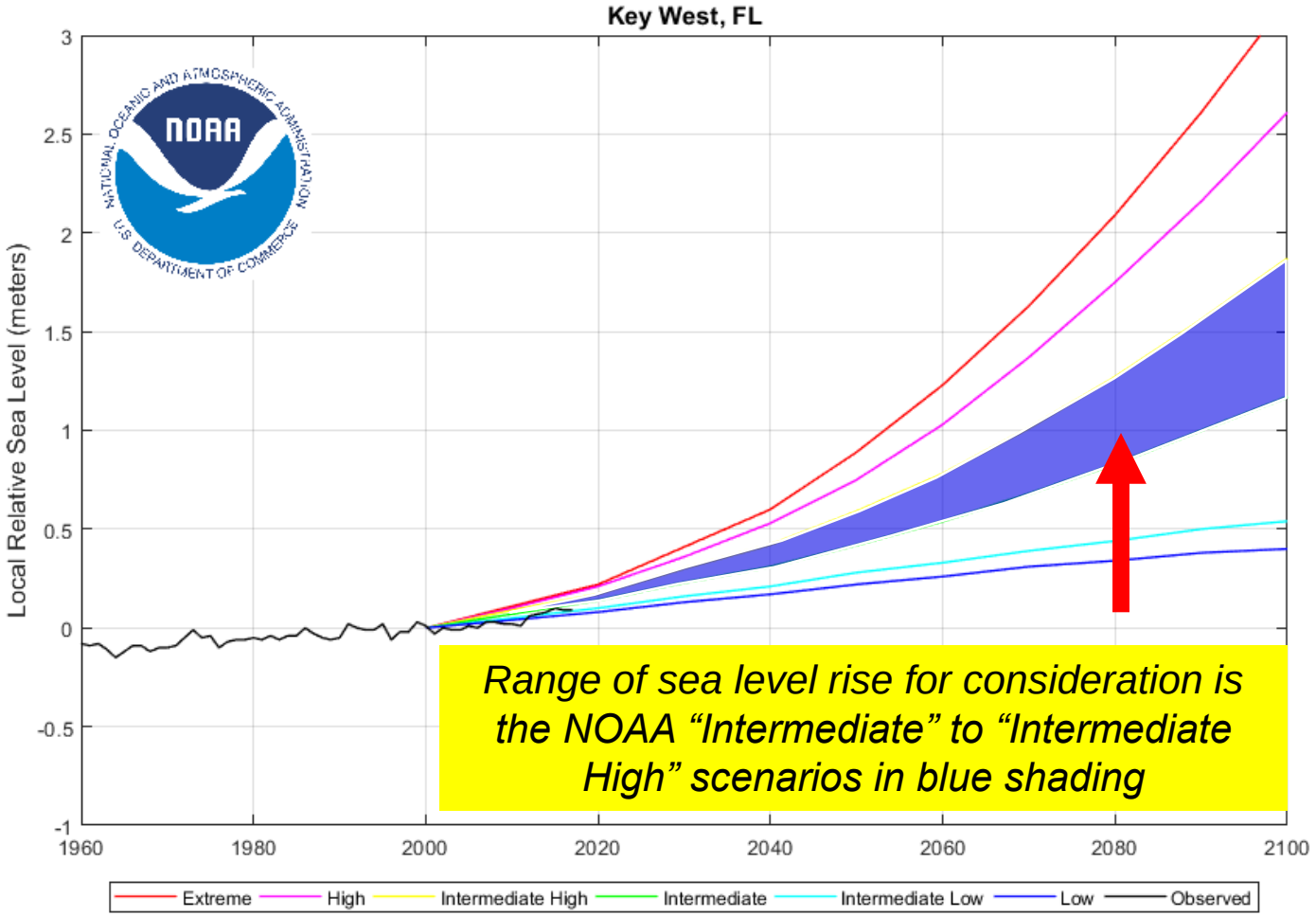
Regional Sea Level Rise Scenario Illustration Purposes Only



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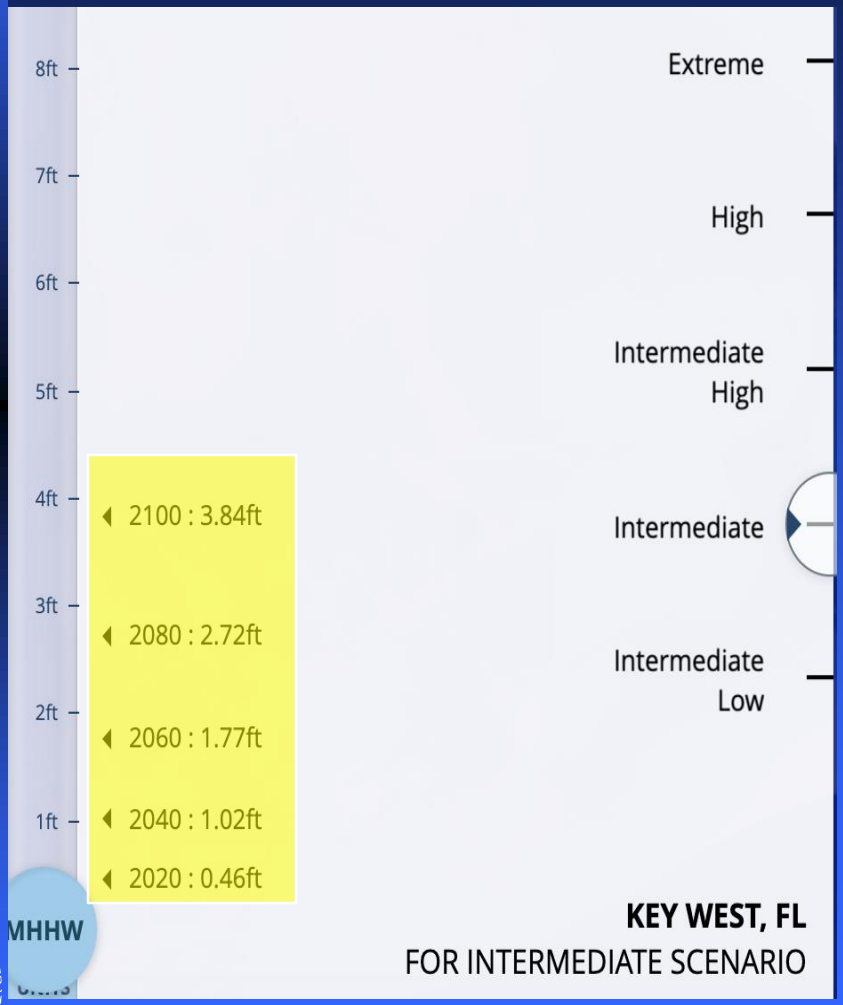
PATTERNS AND PROJECTIONS OF HIGH TIDE FLOODING ALONG THE U.S. COASTLINE USING A COMMON IMPACT THRESHOLD

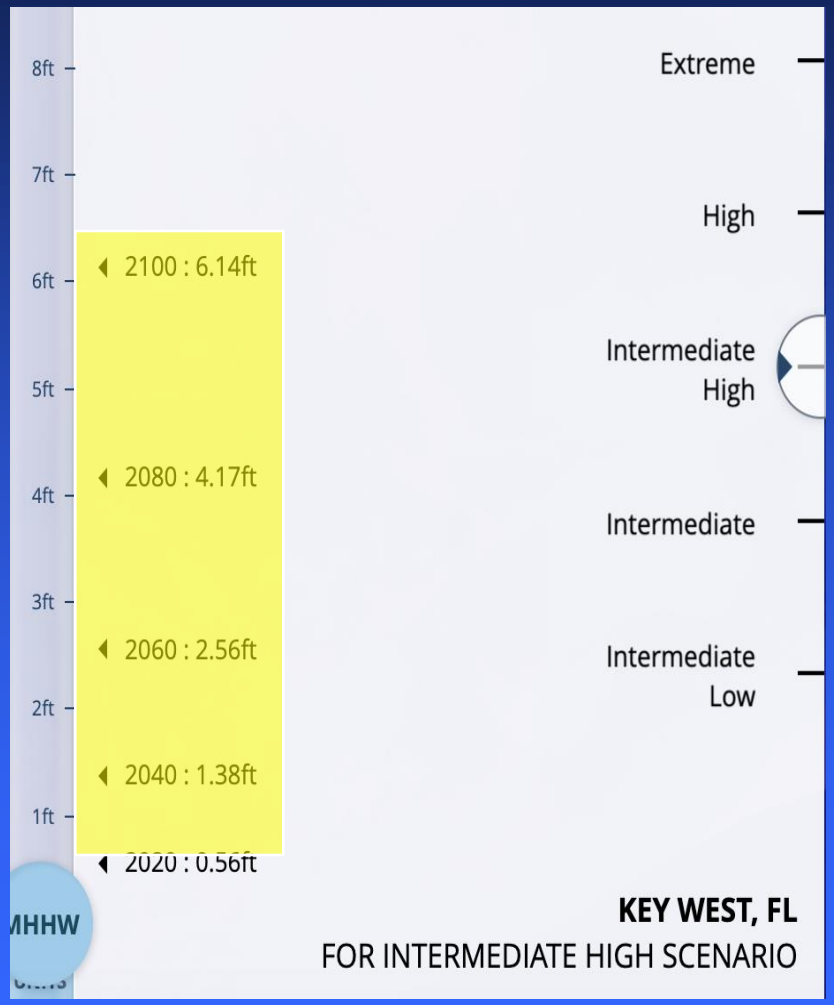
Photo: New York City Harbor

Silver Spring, Maryland
February 2018

Regional Sea Level Rise Scenario

2019 Update



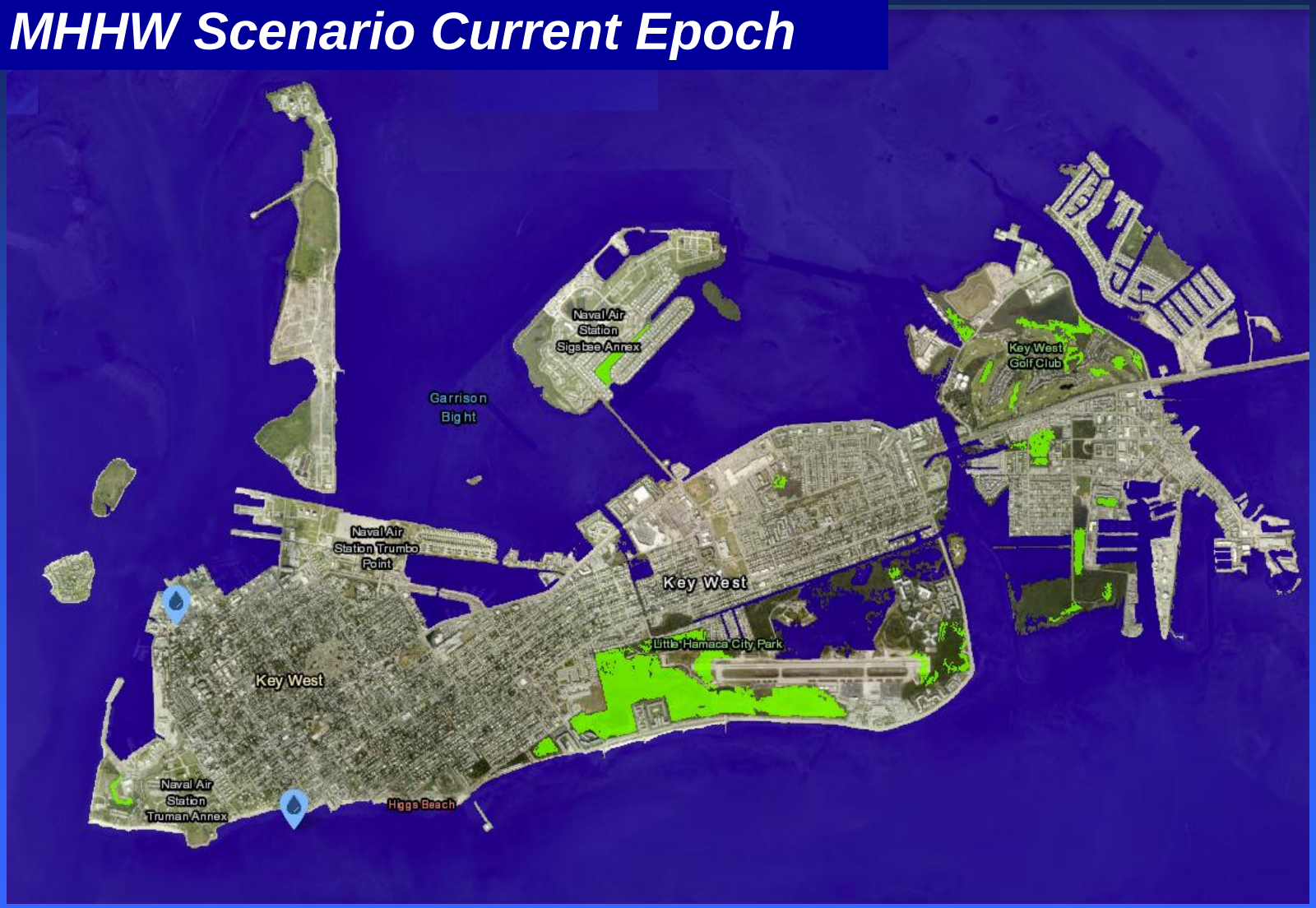


http://weather.gov

NOAA Coast Sea Lever Rise Viewer

https://coast.noaa.gov/digitalcoast/tools/slr.html

MHHW Scenario Current Epoch



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NOAA Coast Sea Lever Rise Viewer

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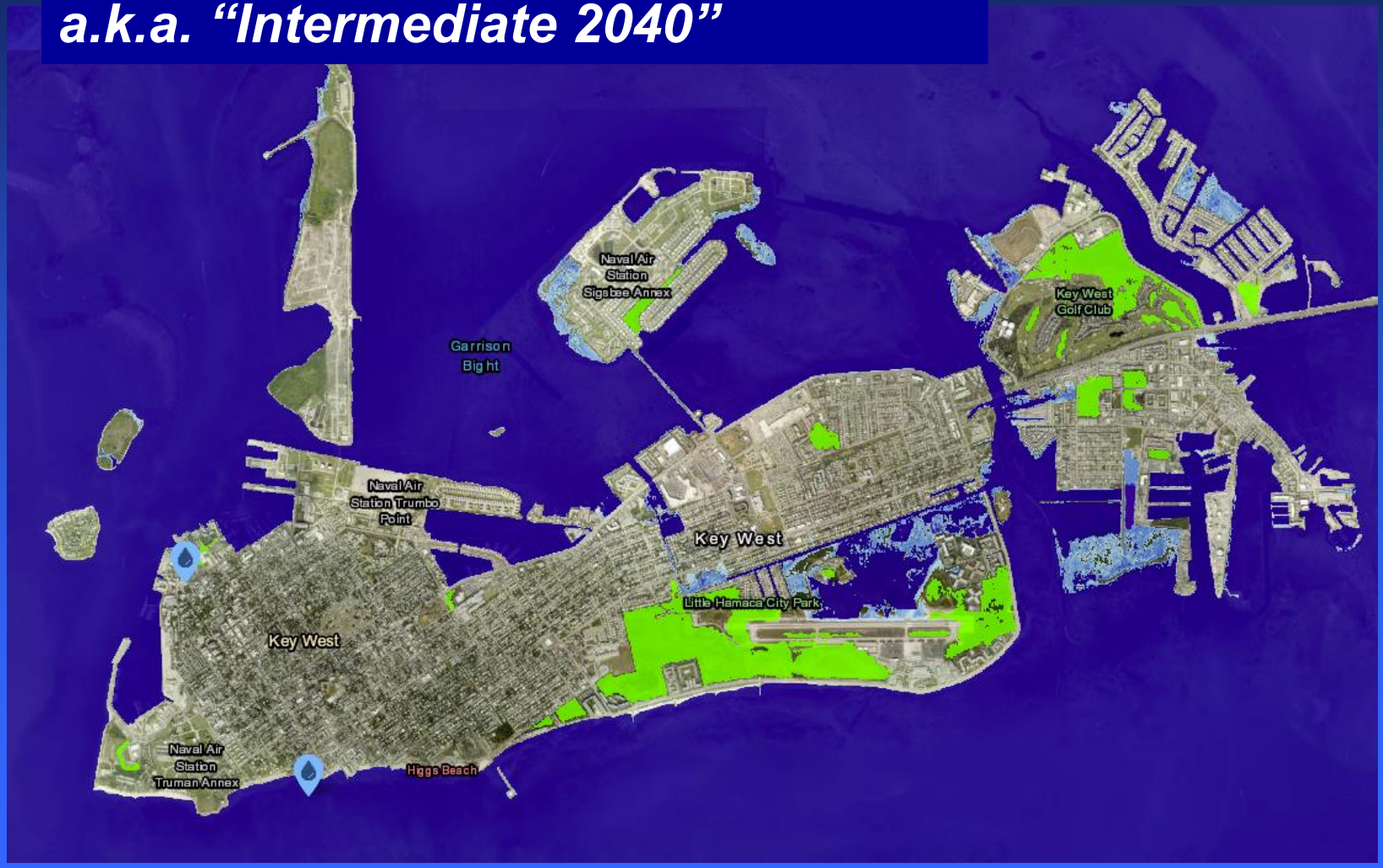
1 foot above MHHW Scenario
a.k.a. "Intermediate 2040"



http://weather.gov

NOAA Coast Sea Lever Rise Viewer

https://coast.noaa.gov/digitalcoast/tools/slr.html

2 feet above MHHW Scenario
"Intermediate cerca 2065"
"Intermediate High cerca 2050"

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NOAA Coast Sea Lever Rise Viewer

https://coast.noaa.gov/digitalcoast/tools/slr.html

3 feet above MHHW Scenario
"Intermediate cerca 2085"
"Intermediate High cerca 2065"

http://weather.gov

Storm Surge Prediction

Hurricanes passing within 50 nm

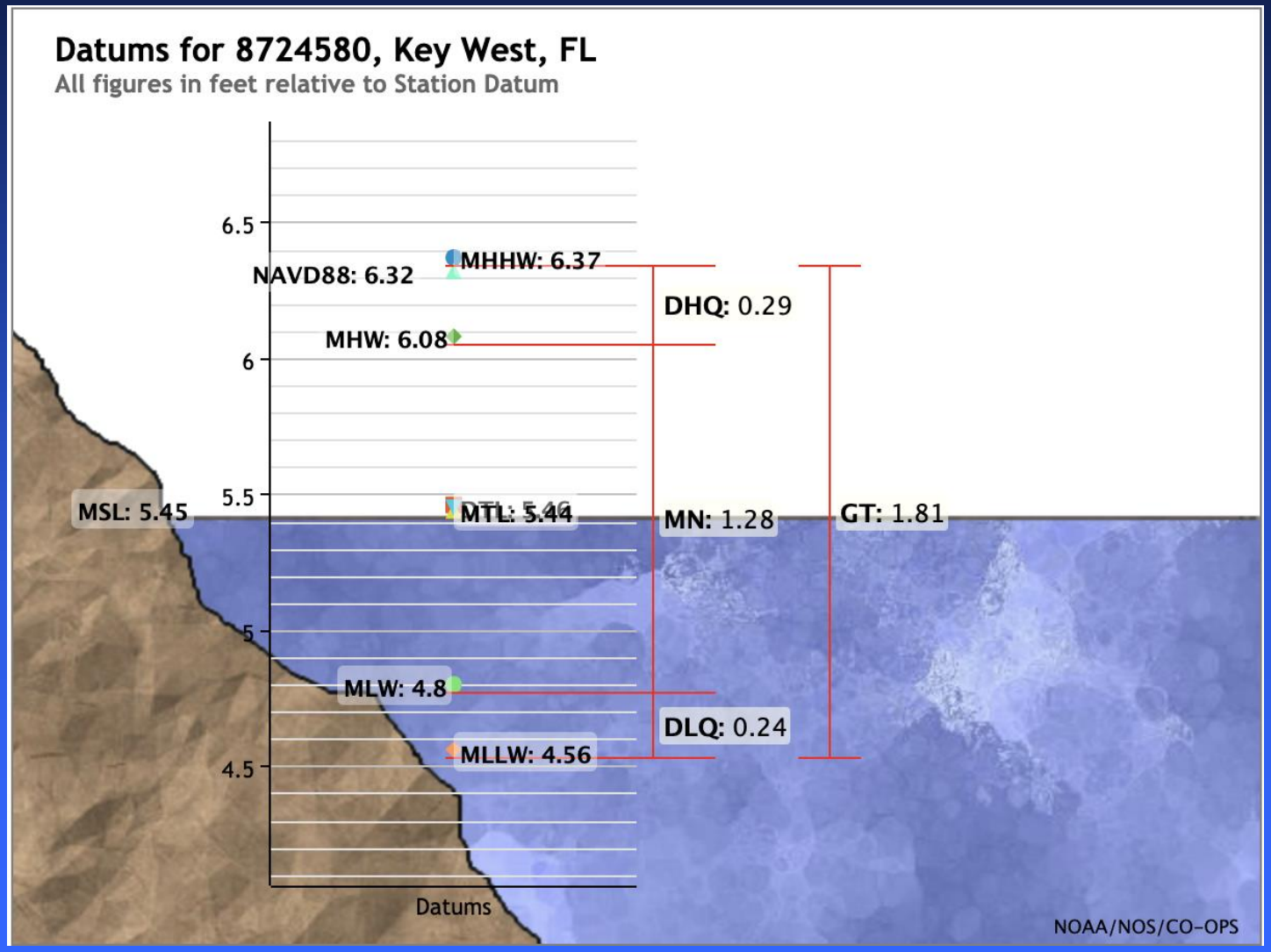
Cat 1 or greater: 7 to 8 years

Cat 3 or greater: 17 to 19 years

Know Your Datums

- NAVD88 – new standard
  - Used in all new storm surge modeling
- Mean Sea Level
  - Generally 0.9 feet lower than NAVD88
- NGVD27 – your flood certificate
  - 1.3 to 1.4 feet lower than NAVD88 from KW to OR

Know Your Datums



http://weather.gov

Know Your Datums

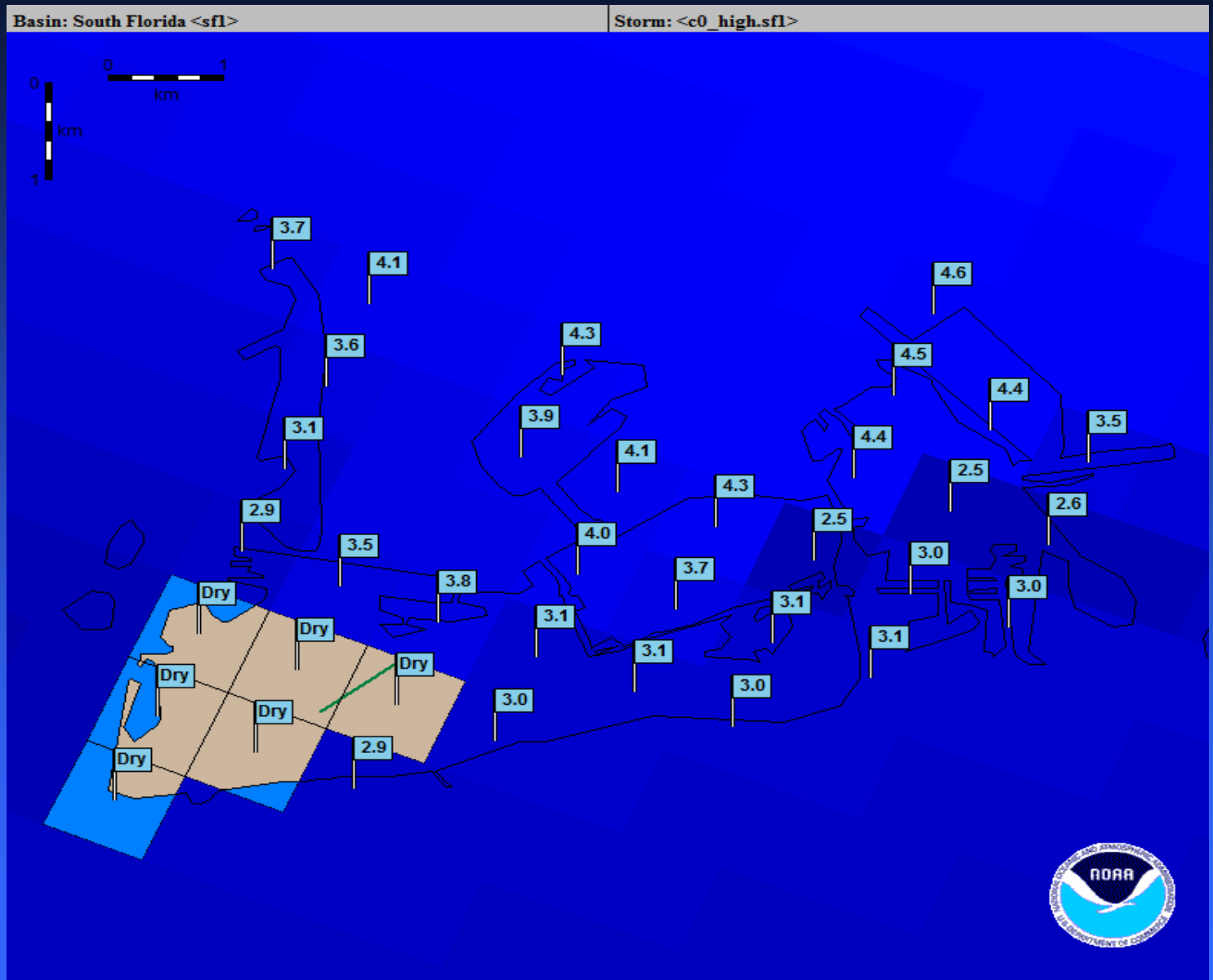
- Mean Higher High Water (MHHW)
  - NOAA refers to as a ”coastal flood” state when exceeded.

Our highest King Tides this year reached 1.5 MHHW

Source: NOAA Digital Coast

https://coast.noaa.gov/digitalcoast/tools/slr.html

Tropical Storm Storm Surge MOM



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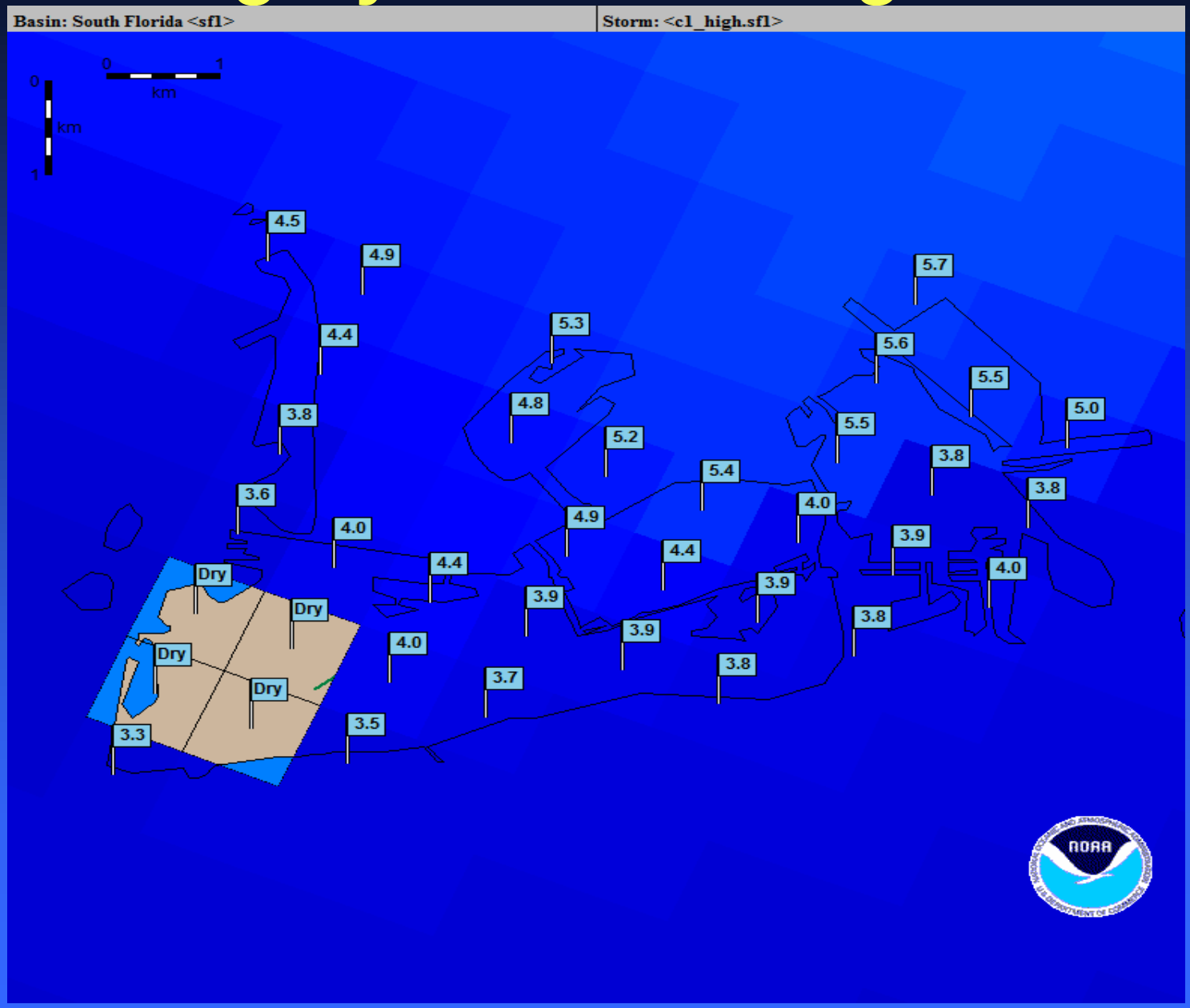
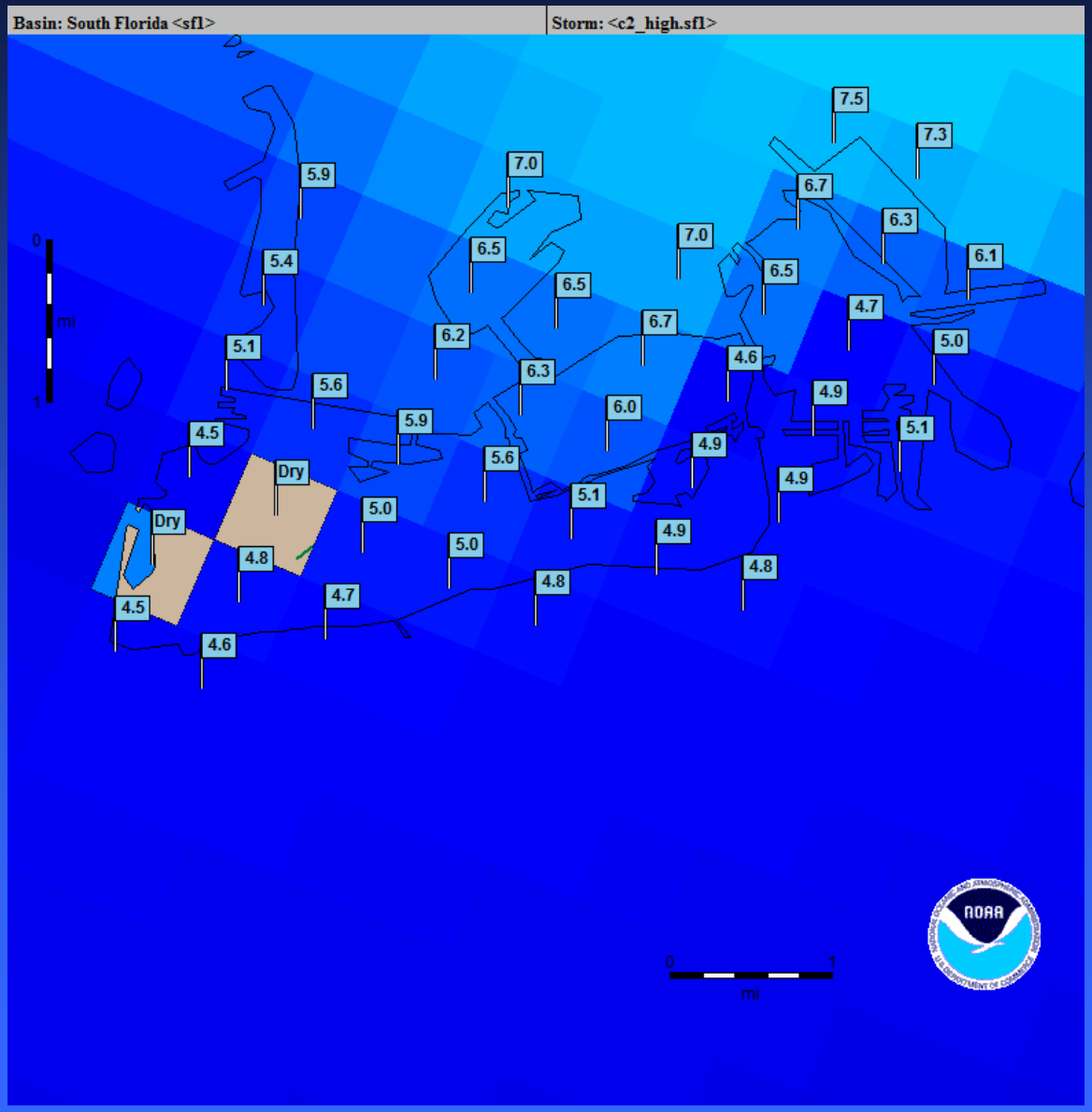
Category 1 Storm Surge MOM

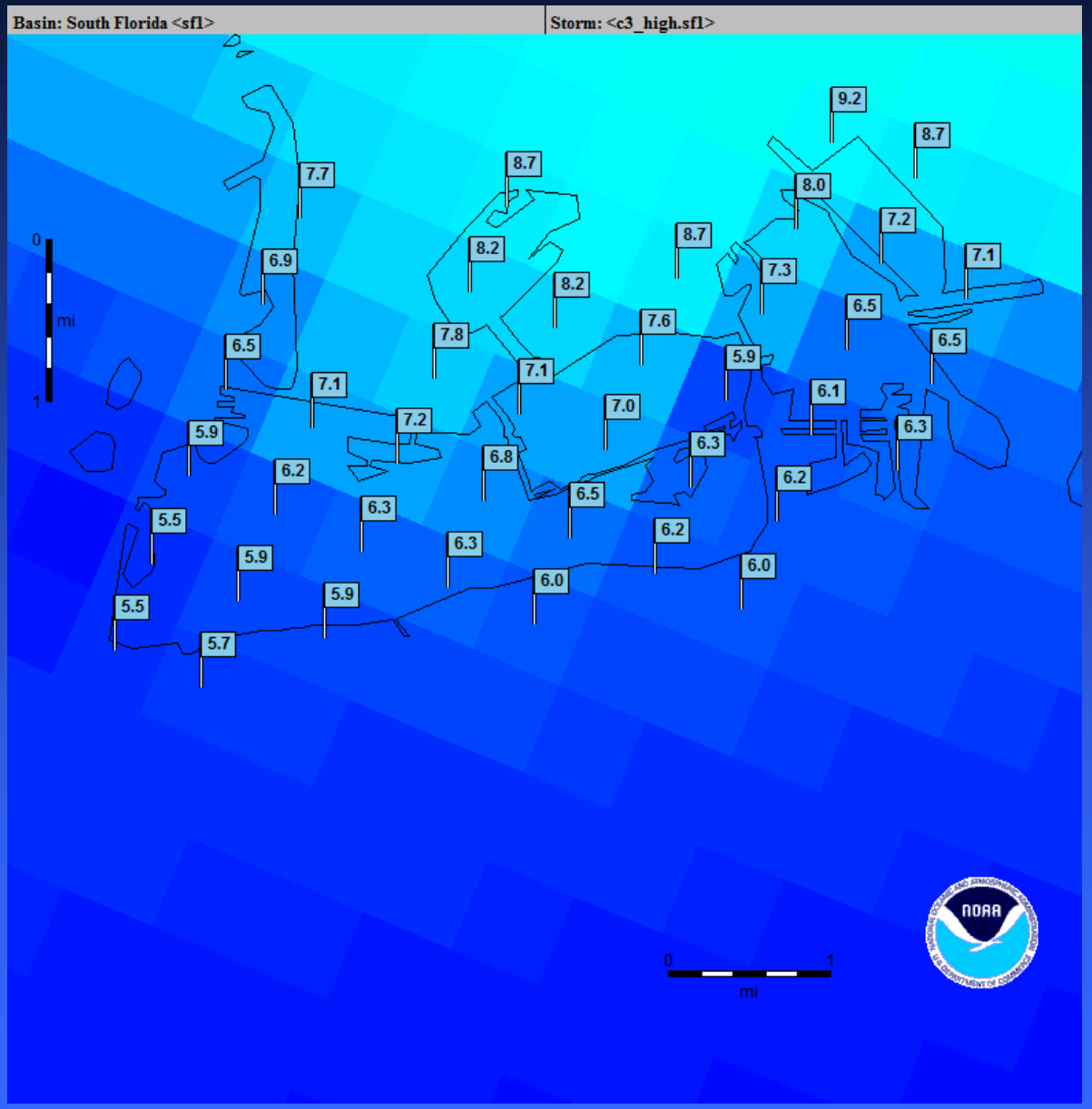


Category 2 Storm Surge MOM



http://weather.gov

Category 3 Storm Surge MOM



“Normals” – 1981-2010

Normal Temperature (degrees Fahrenheit), Precipitation (inches)

KEY WEST *(1981-2010)*	Average Daily High Temperature	Average Daily Low Temperature	Average Monthly Precipitation
January	74	64	2.04
February	76	66	1.49
March	78	68	2.05
April	81	72	2.05
May	85	76	3.00
June	88	79	4.11
July	89	80	3.55
August	89	80	5.38
September	88	79	6.71
October	85	76	4.93
November	80	72	2.30
December	76	67	2.22

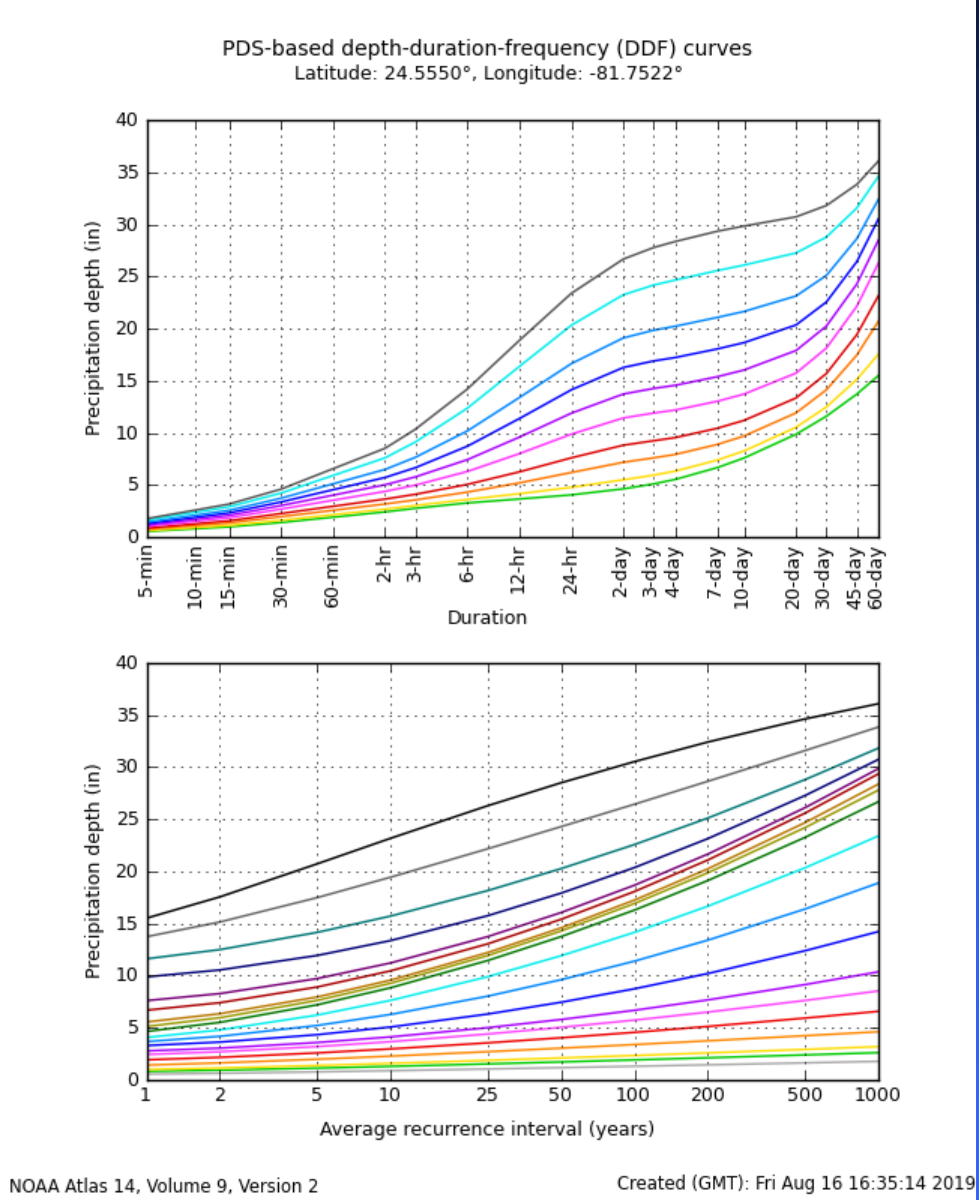
“Averages” – Running 1989-2018

Month	1981-2010 MAX T	1989-2018 MAX T	1981-2010 MIN T	1989-2018 MIN T	1981-2010 Rainfall	1989-2018 Rainfall
Jan	74	75	64	65	2.04	2.14
Feb	76	77	66	66	1.49	1.57
Mar	78	79	68	68.4	2.05	1.92
Apr	81	82	72	72	2.05	2.23
May	85	85	76	76	3.00	3.28
Jun	88	88	79	79	4.11	4.05
Jul	89	90	80	80	3.55	3.74
Aug	89	90	80	80	5.38	5.34
Sep	88	88	79	79	6.71	6.69
Oct	85	85	76	76	4.93	5.10
Nov	80	81	72	72	2.30	2.07
Dec	76	77	67	68	2.22	2.22

Annual Rainfall

- 1981-2010 Normal: 39.73”
- 1989-2018 (Raw Average): 40.35”
- Trend: Up about 0.6 inches

Key West Airport – Climate Station

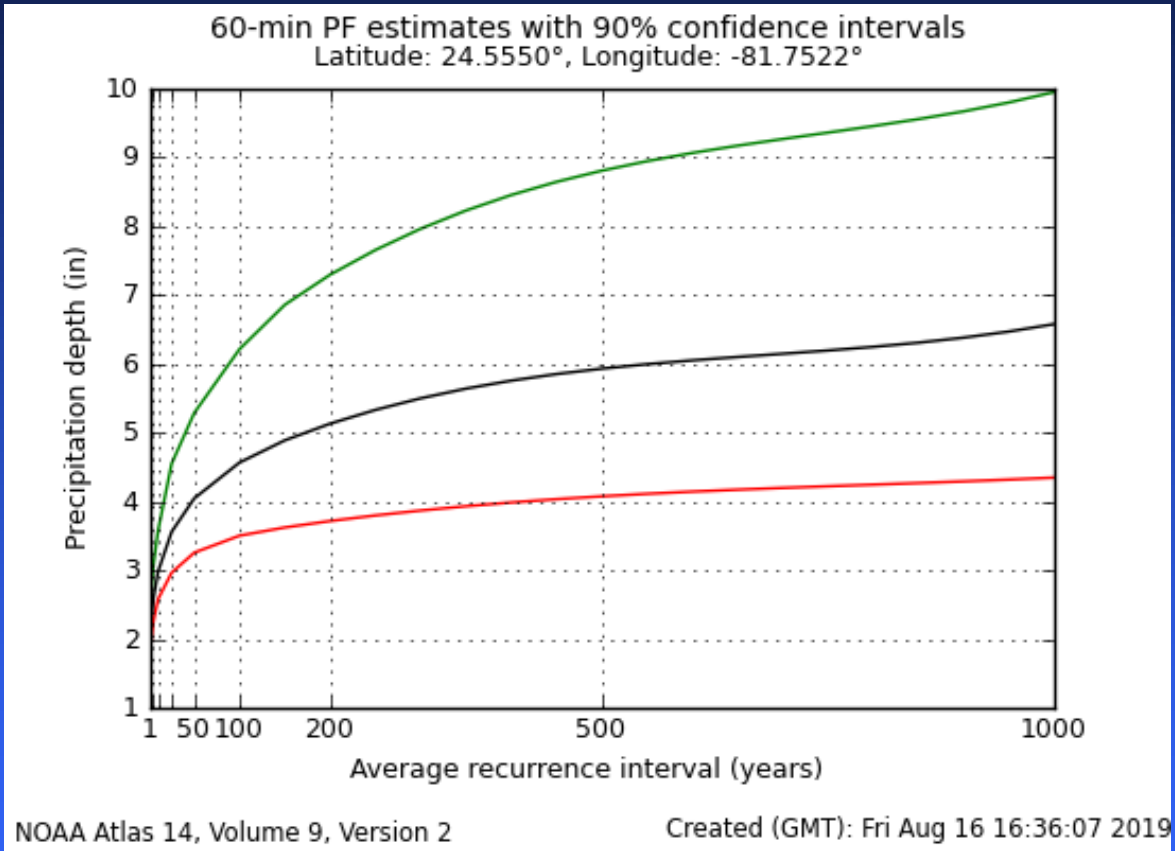


Key West Airport – Climate Station

http://weather.gov

Duration:

- 5-min
- 10-min
- 15-min
- 30-min
- (•) 60-min
- 2-hr
- 3-hr
- 6-hr
- 12-hr
- 24-hr
- 2-day
- 3-day
- 4-day
- 7-day
- 10-day
- 20-day
- 30-day
- 45-day
- 60-day



Precipitation Frequency Data Server

https://hdsc.nws.noaa.gov/hdsc/pfds/

http://weather.gov

Key West Airport – Climate Station

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.565** (0.496-0.668)	**0.644** (0.564-0.763)	**0.777** (0.678-0.925)	**0.891** (0.771-1.07)	**1.05** (0.872-1.33)	**1.18** (0.948-1.53)	**1.32** (1.00-1.78)	**1.45** (1.05-2.05)	**1.64** (1.13-2.42)	**1.79** (1.18-2.71)
10-min	**0.827** (0.726-0.979)	**0.943** (0.827-1.12)	**1.14** (0.993-1.35)	**1.31** (1.13-1.57)	**1.54** (1.28-1.95)	**1.73** (1.39-2.25)	**1.93** (1.47-2.60)	**2.13** (1.54-3.01)	**2.40** (1.65-3.55)	**2.62** (1.73-3.96)
15-min	**1.01** (0.885-1.19)	**1.15** (1.01-1.36)	**1.39** (1.21-1.65)	**1.59** (1.38-1.91)	**1.88** (1.56-2.38)	**2.11** (1.69-2.74)	**2.35** (1.80-3.17)	**2.60** (1.87-3.67)	**2.93** (2.01-4.33)	**3.19** (2.11-4.83)
30-min	**1.43** (1.25-1.69)	**1.64** (1.43-1.94)	**1.99** (1.73-2.37)	**2.29** (1.98-2.74)	**2.71** (2.24-3.43)	**3.05** (2.44-3.95)	**3.40** (2.60-4.59)	**3.76** (2.71-5.30)	**4.24** (2.91-6.27)	**4.62** (3.06-7.00)
60-min	**1.94** (1.70-2.29)	**2.17** (1.90-2.57)	**2.59** (2.26-3.09)	**2.98** (2.58-3.57)	**3.56** (2.96-4.55)	**4.05** (3.26-5.29)	**4.57** (3.50-6.21)	**5.13** (3.72-7.30)	**5.93** (4.08-8.81)	**6.58** (4.35-9.95)
2-hr	**2.44** (2.15-2.87)	**2.71** (2.38-3.19)	**3.20** (2.81-3.78)	**3.67** (3.19-4.37)	**4.41** (3.70-5.63)	**5.04** (4.09-6.58)	**5.74** (4.44-7.79)	**6.51** (4.75-9.23)	**7.62** (5.28-11.3)	**8.53** (5.67-12.8)
3-hr	**2.79** (2.47-3.26)	**3.05** (2.70-3.58)	**3.59** (3.16-4.23)	**4.13** (3.60-4.90)	**5.01** (4.25-6.43)	**5.80** (4.73-7.58)	**6.68** (5.20-9.09)	**7.68** (5.64-10.9)	**9.14** (6.37-13.5)	**10.4** (6.92-15.5)
6-hr	**3.30** (2.93-3.84)	**3.63** (3.23-4.23)	**4.34** (3.83-5.08)	**5.08** (4.45-5.99)	**6.32** (5.41-8.13)	**7.45** (6.13-9.74)	**8.74** (6.85-11.9)	**10.2** (7.55-14.5)	**12.4** (8.69-18.3)	**14.2** (9.56-21.2)
12-hr	**3.68** (3.29-4.25)	**4.19** (3.73-4.85)	**5.22** (4.63-6.07)	**6.28** (5.53-7.36)	**8.03** (6.90-10.3)	**9.61** (7.94-12.5)	**11.4** (8.97-15.4)	**13.4** (9.97-18.9)	**16.4** (11.6-24.0)	**18.9** (12.8-27.9)
24-hr	**4.07** (3.65-4.68)	**4.80** (4.30-5.52)	**6.22** (5.55-7.18)	**7.62** (6.75-8.87)	**9.89** (8.53-12.6)	**11.9** (9.87-15.4)	**14.1** (11.2-19.0)	**16.7** (12.5-23.3)	**20.3** (14.4-29.6)	**23.4** (15.9-34.3)
2-day	**4.65** (4.19-5.31)	**5.52** (4.97-6.31)	**7.20** (6.45-8.26)	**8.83** (7.86-10.2)	**11.4** (9.90-14.4)	**13.7** (11.4-17.6)	**16.3** (12.9-21.6)	**19.1** (14.4-26.5)	**23.2** (16.6-33.6)	**26.7** (18.3-38.9)
3-day	**5.13** (4.64-5.82)	**5.97** (5.39-6.79)	**7.62** (6.85-8.71)	**9.26** (8.26-10.7)	**11.9** (10.4-15.0)	**14.3** (11.9-18.2)	**16.9** (13.5-22.4)	**19.9** (15.0-27.4)	**24.2** (17.3-34.8)	**27.8** (19.1-40.4)
4-day	**5.56** (5.03-6.30)	**6.35** (5.75-7.21)	**7.95** (7.16-9.06)	**9.56** (8.55-11.0)	**12.2** (10.6-15.3)	**14.6** (12.2-18.6)	**17.2** (13.8-22.8)	**20.2** (15.3-27.9)	**24.7** (17.7-35.4)	**28.4** (19.6-41.1)
7-day	**6.69** (6.08-7.54)	**7.41** (6.73-8.36)	**8.90** (8.05-10.1)	**10.5** (9.38-11.9)	**13.0** (11.4-16.2)	**15.4** (13.0-19.5)	**18.1** (14.5-23.8)	**21.1** (16.1-28.9)	**25.6** (18.5-36.5)	**29.3** (20.4-42.3)
10-day	**7.61** (6.94-8.54)	**8.28** (7.54-9.31)	**9.71** (8.81-11.0)	**11.2** (10.1-12.8)	**13.7** (12.1-17.0)	**16.0** (13.6-20.2)	**18.7** (15.1-24.4)	**21.6** (16.6-29.6)	**26.1** (19.0-37.1)	**29.8** (20.8-42.8)
20-day	**9.88** (9.05-11.0)	**10.5** (9.65-11.8)	**11.9** (10.9-13.4)	**13.4** (12.1-15.1)	**15.7** (13.9-19.2)	**17.9** (15.2-22.3)	**20.4** (16.5-26.3)	**23.1** (17.8-31.3)	**27.3** (19.9-38.4)	**30.7** (21.5-43.8)
30-day	**11.6** (10.7-12.9)	**12.5** (11.5-13.9)	**14.1** (12.9-15.8)	**15.7** (14.2-17.7)	**18.1** (15.9-21.8)	**20.3** (17.2-24.9)	**22.6** (18.3-28.8)	**25.1** (19.3-33.6)	**28.8** (21.1-40.2)	**31.8** (22.4-45.2)
45-day	**13.7** (12.7-15.2)	**15.1** (13.9-16.8)	**17.5** (16.0-19.4)	**19.4** (17.7-21.8)	**22.2** (19.3-26.1)	**24.3** (20.6-29.3)	**26.4** (21.4-33.2)	**28.6** (22.0-37.7)	**31.6** (23.1-43.5)	**33.8** (23.9-47.9)
60-day	**15.5** (14.3-17.1)	**17.5** (16.2-19.4)	**20.7** (19.0-23.0)	**23.2** (21.1-25.9)	**26.3** (22.8-30.5)	**28.5** (24.0-34.0)	**30.5** (24.7-37.9)	**32.4** (24.8-42.1)	**34.6** (25.2-47.1)	**36.1** (25.5-50.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Sea Level Rise & Key West

Remembering it may be the "little" things that mean a lot!

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