UNDERSTANDING COASTAL FLOODING IN THE SAN FRANCISCO BAY DELTA

HOW CAN MODELLING HELP?

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CHALLENGE

As the climate continues to change, shifts in oceanic and atmospheric conditions result in higher sea levels and altered rainfall regimes.

Changing sea levels, in combination with changing land elevations, will result in more frequent coastal flooding of low-lying areas adjacent to rivers, delta's, estuaries and bays.

This past winter has demonstrated the flood potential associated with Atmospheric River events, while past coastal storms coincident with high tides, reveal the vulnerability of infrastructure and assets situated on low-lying land.

CHALLENGE

In estuaries and delta’s, coastal flooding is influenced by river runoff, tidal regimes, changes in mean sea level and vertical land motion.

Understanding how these processes interact and affect water levels throughout complex systems like the San Francisco Bay Delta is vital for making informed planning decisions, such as defend, adapt, or retreat.

While a multitude of data is collected throughout the region, it is difficult to unpick the processes which dominate coastal flooding at each location from these observations alone.

CHALLENGE

To better understand the potential impact river runoff, sea level rise, and tidal processes have on coastal flooding across the San Francisco Bay Delta, we conducted numerical experiments, to explore the effect different scenarios have on water levels throughout the San Francisco Bay/Delta region.

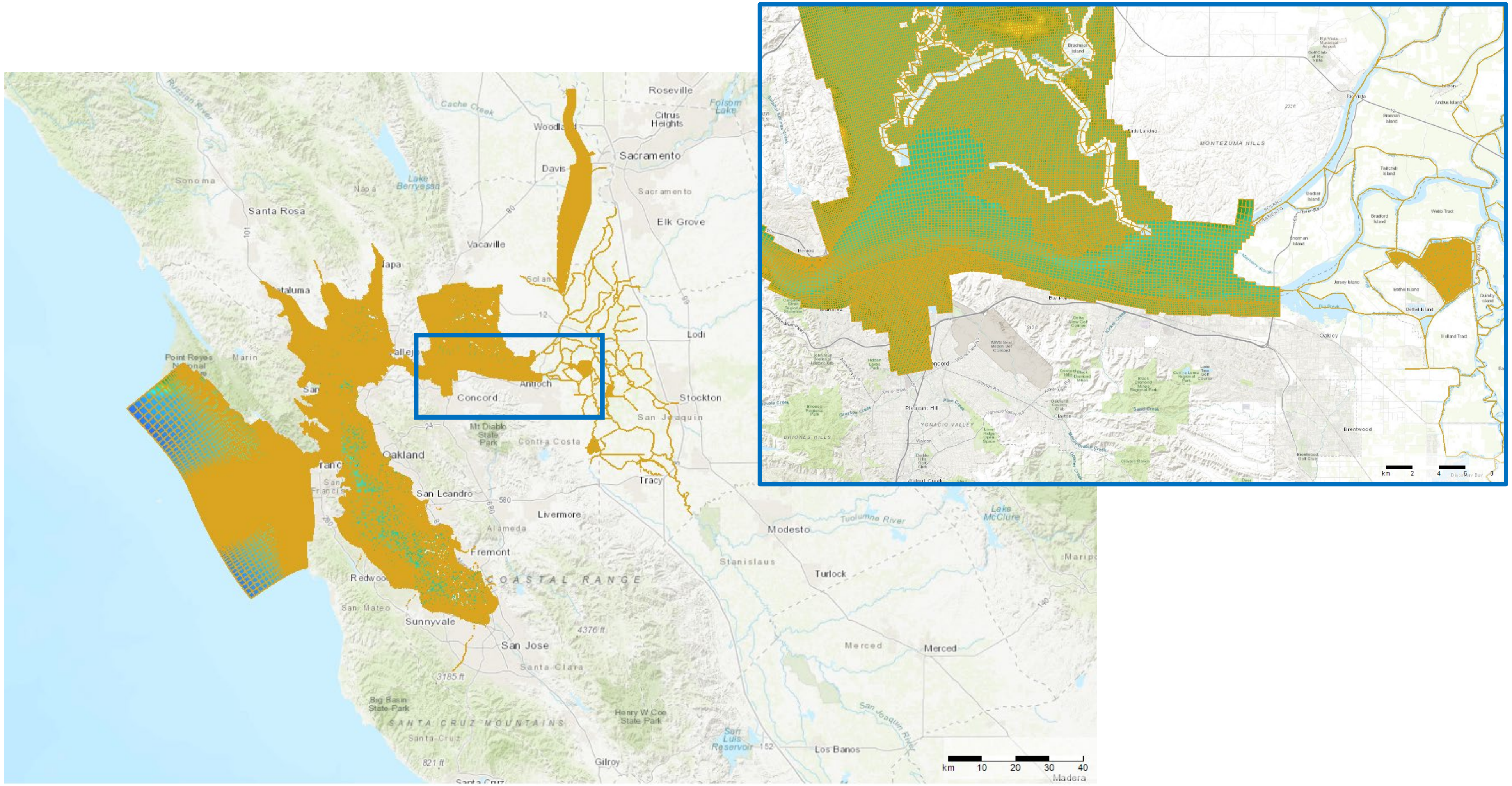
PROCESSES OF INTEREST

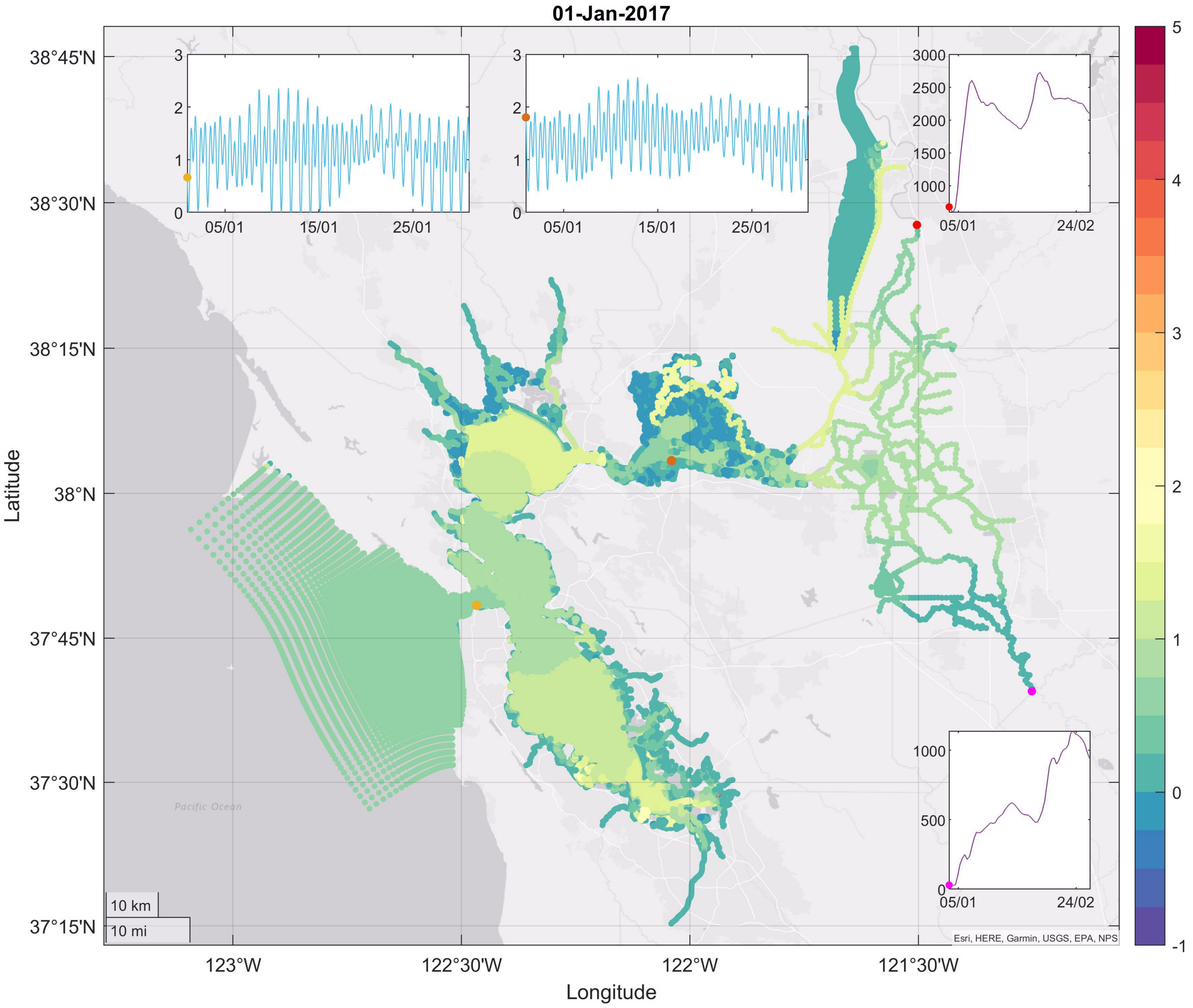
TIDES   RIVER DISCHARGE   SEA LEVEL RISE   VERTICAL LAND MOTION

DELFT FM Model Grid

Circulation is driven:

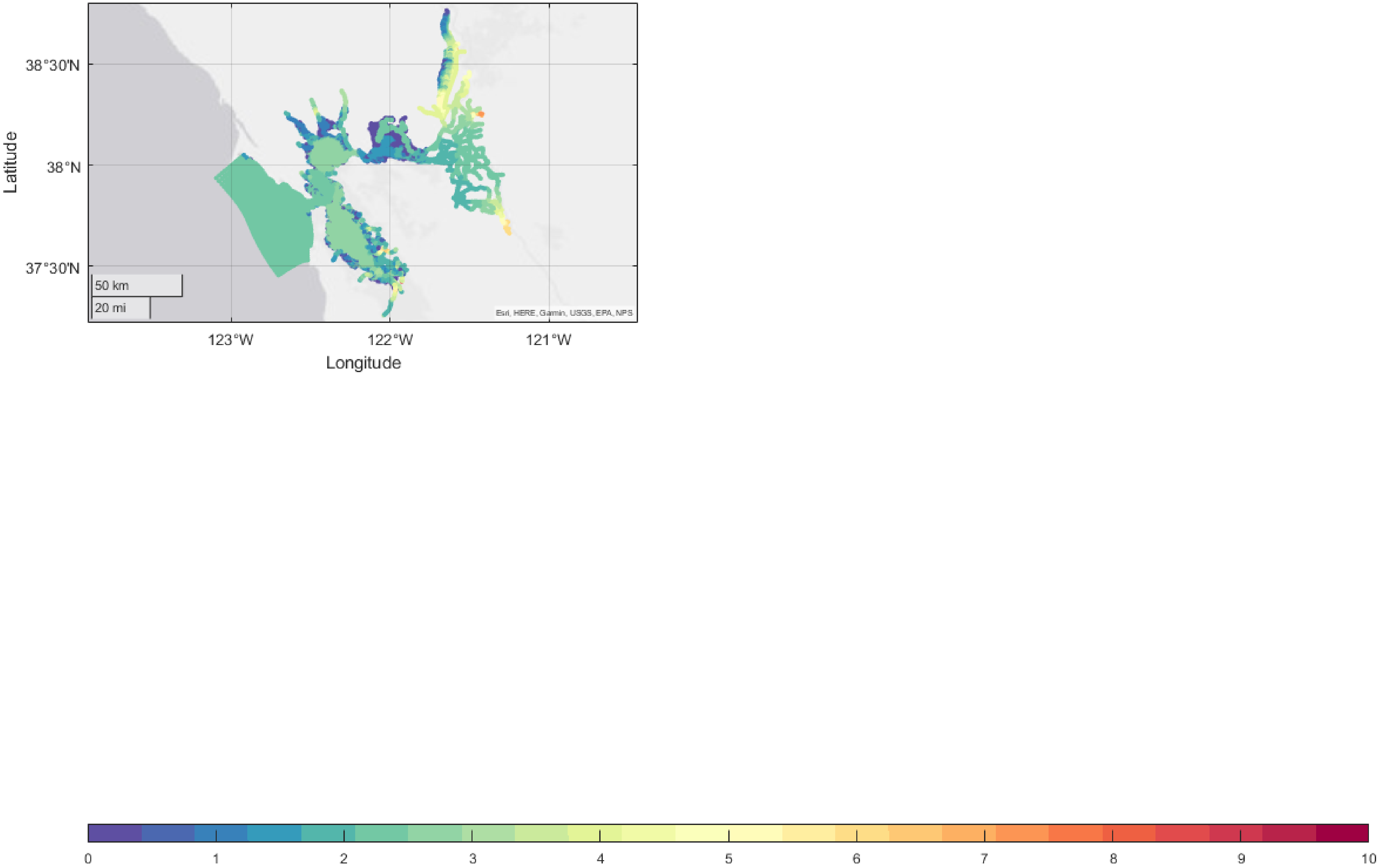
- Tidal forcing at the open ocean boundary
- River discharge at upstream locations, and
- Atmospheric forcing from ERA 5

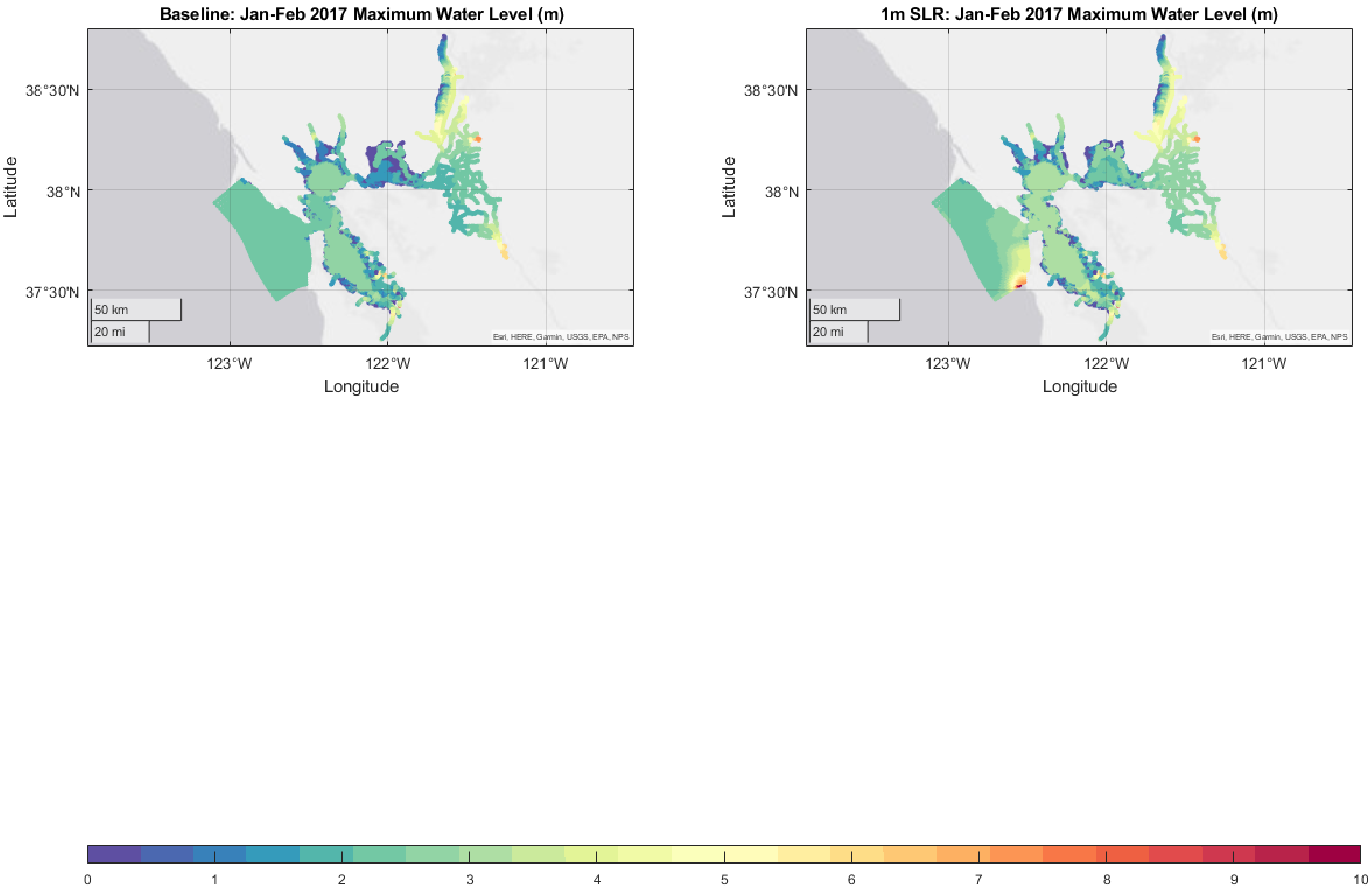




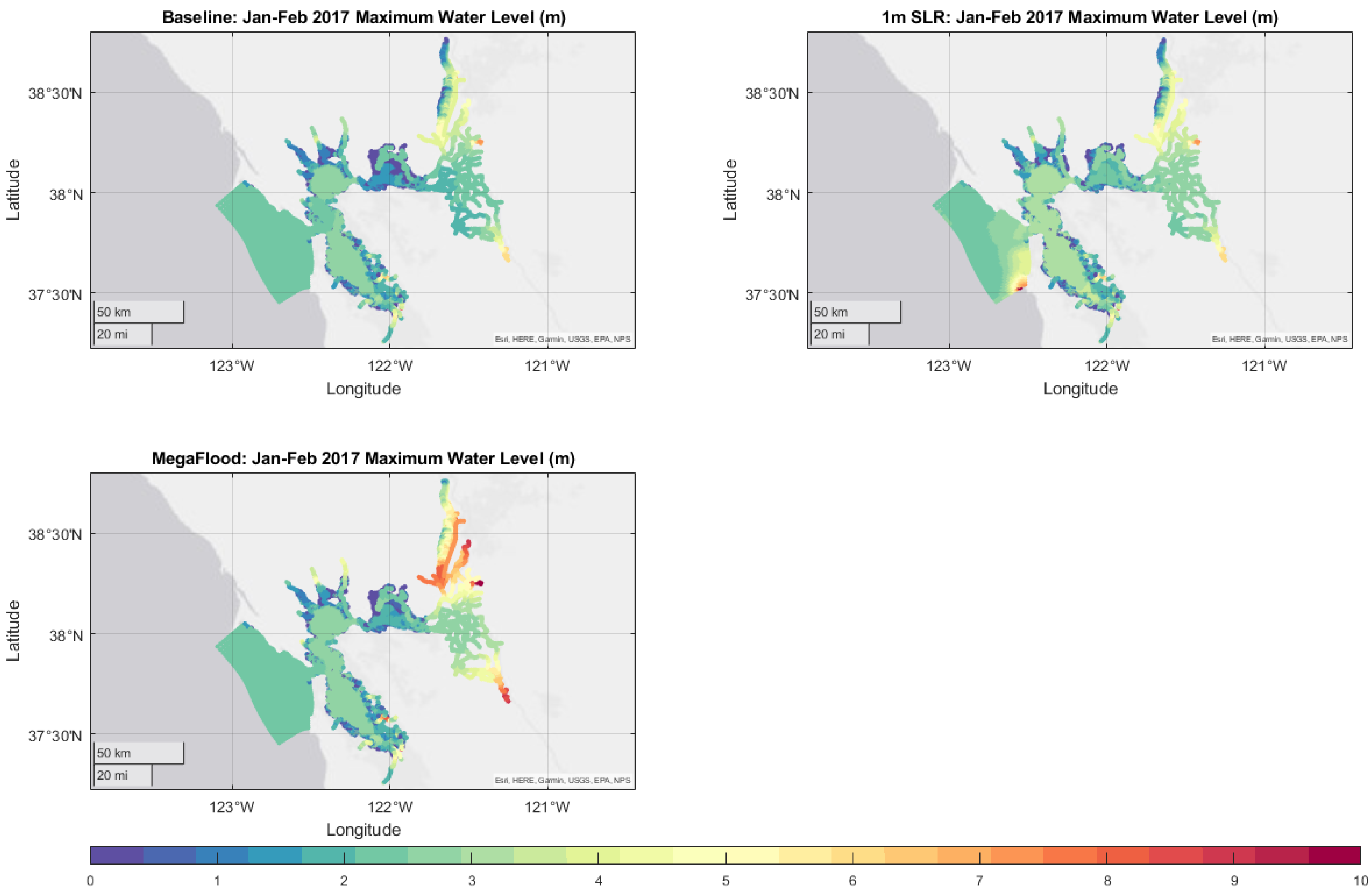
01-Jan-2017
38°45'N
38°30'N
38°15'N
38°N
37°45'N
37°30'N
37°15'N
123°W
122°30'W
122°W
121°30'W
Latitude
Longitude
05/01
15/01
25/01
24/02
Pacific Ocean
10 km
10 mi
Esri, HERE, Garmin, USGS, EPA, NPS

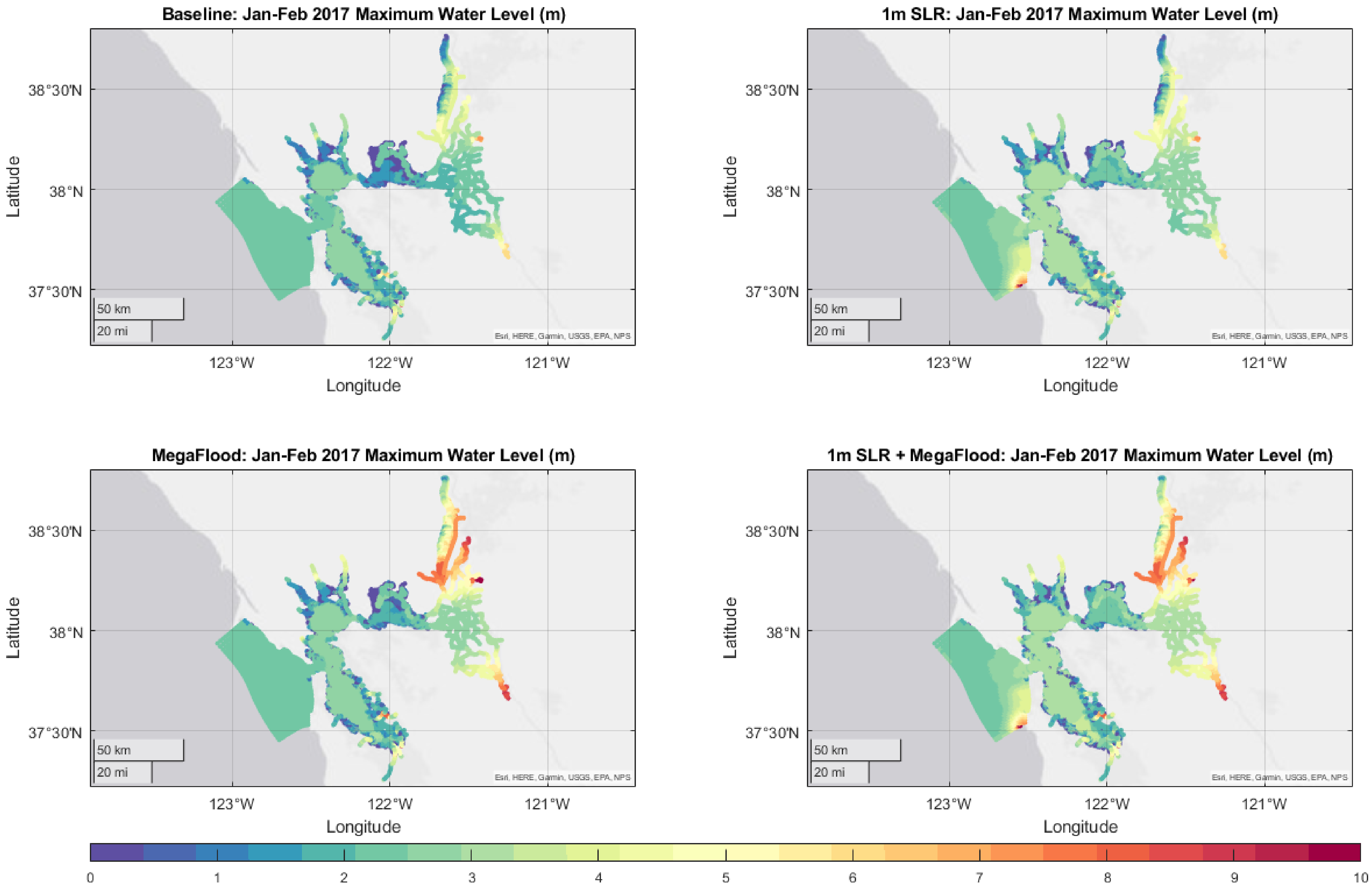
Baseline: Jan-Feb 2017 Maximum Water Level (m)



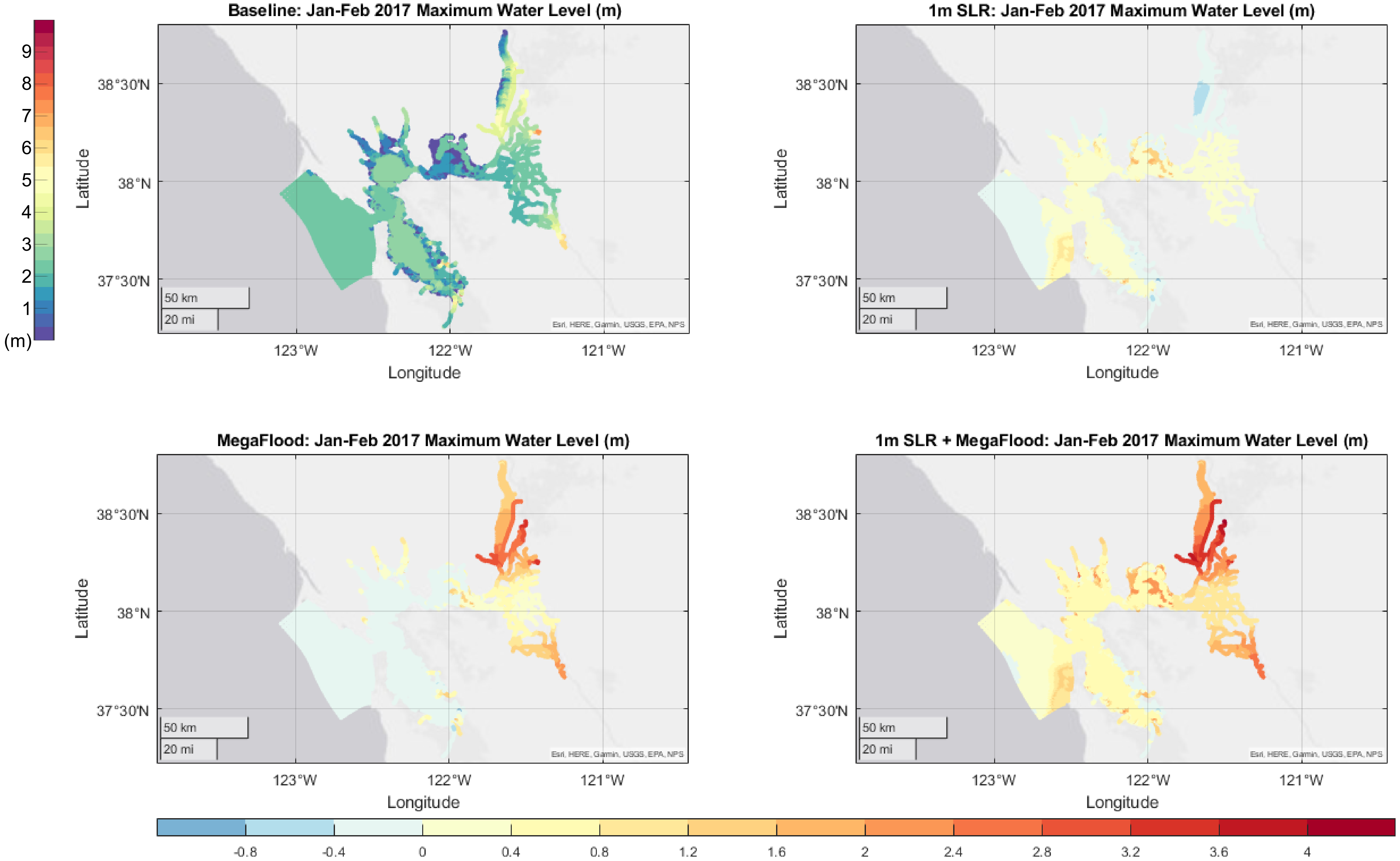


Baseline: Jan-Feb 2017 Maximum Water Level (m)
1m SLR: Jan-Feb 2017 Maximum Water Level (m)
Latitude
Longitude
38°30'N
38°N
37°30'N
123°W
122°W
121°W
50 km
20 mi
Esri, HERE, Garmin, USGS, EPA, NPS
0
1
2
3
4
5
6
7
8
9
10


Baseline: Jan-Feb 2017 Maximum Water Level (m)
1m SLR: Jan-Feb 2017 Maximum Water Level (m)
MegaFlood: Jan-Feb 2017 Maximum Water Level (m)
Latitude
Longitude
38°30'N
38°N
37°30'N
123°W
122°W
121°W
50 km
20 mi
Esri, HERE, Garmin, USGS, EPA, NPS
0
1
2
3
4
5
6
7
8
9
10



Baseline: Jan-Feb 2017 Maximum Water Level (m)
1m SLR: Jan-Feb 2017 Maximum Water Level (m)
MegaFlood: Jan-Feb 2017 Maximum Water Level (m)
1m SLR + MegaFlood: Jan-Feb 2017 Maximum Water Level (m)
Latitude
Longitude
38°30'N
38°N
37°30'N
123°W
122°W
121°W
50 km
20 mi
Esri, HERE, Garmin, USGS, EPA, NPS
0
1
2
3
4
5
6
7
8
9
10



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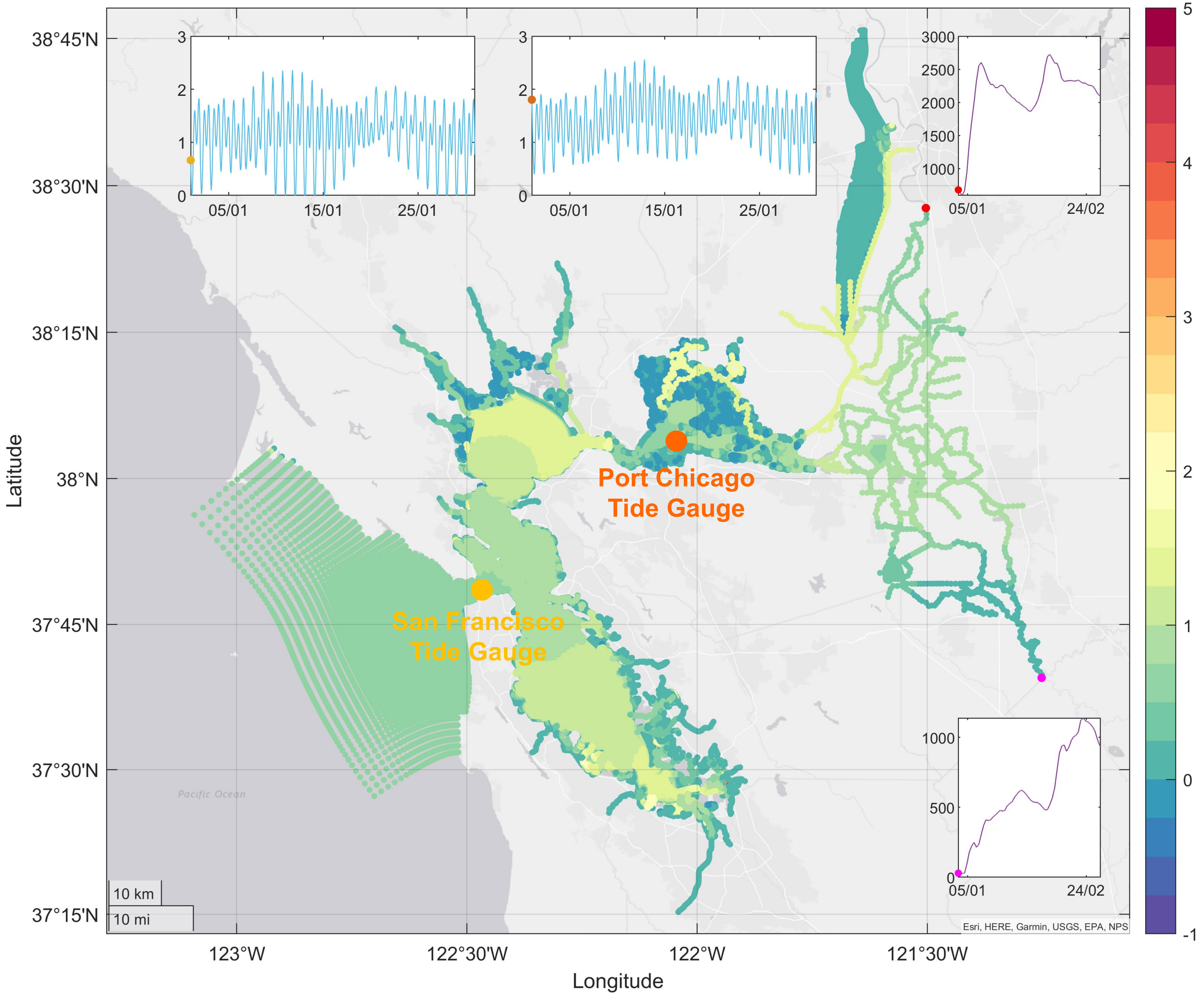
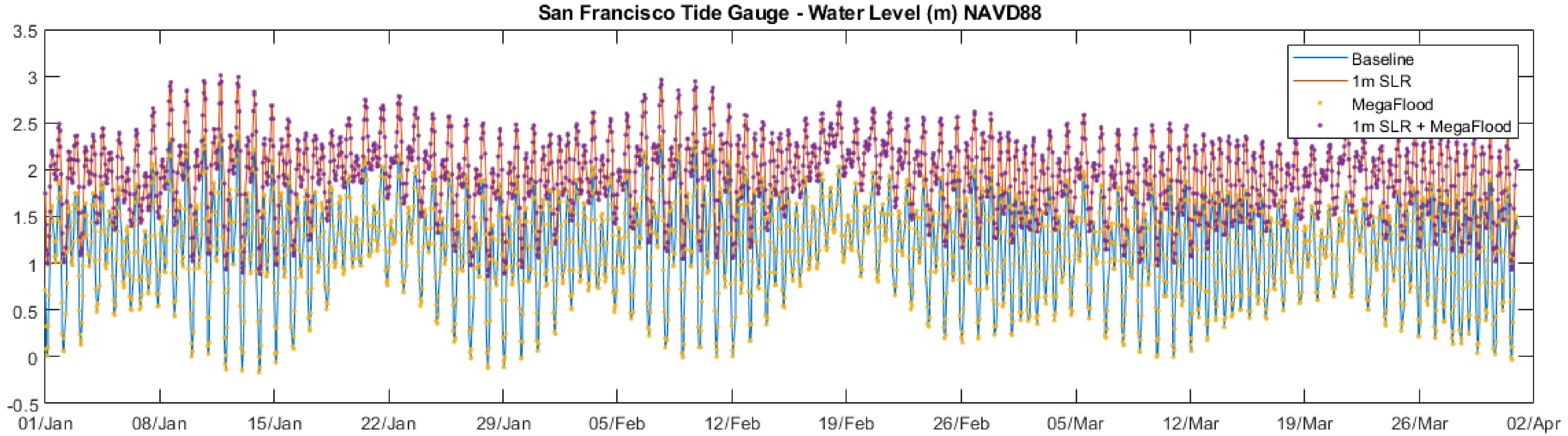
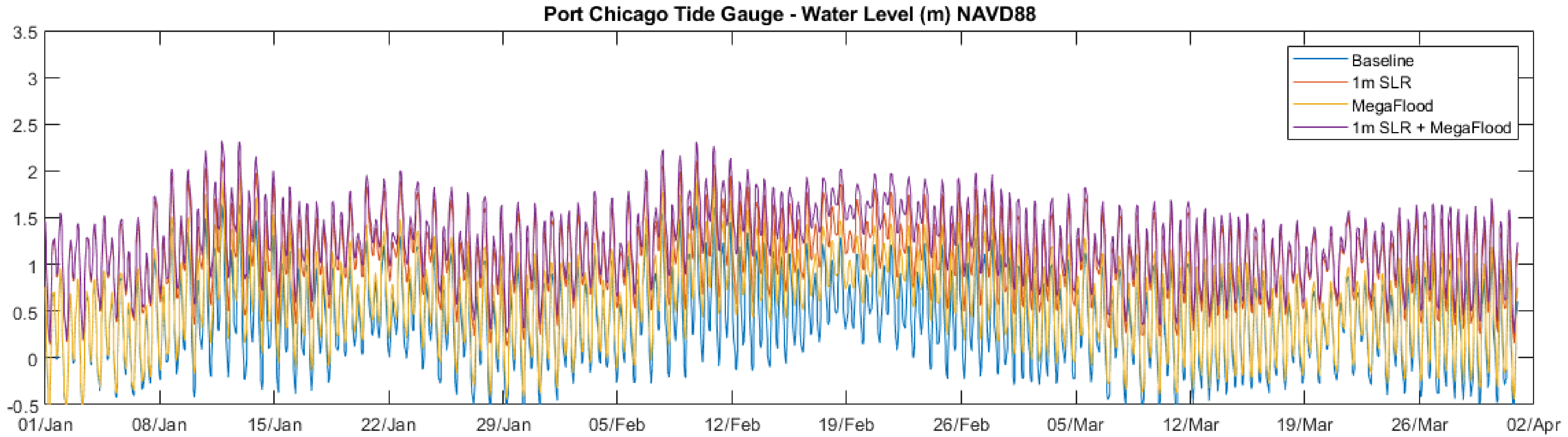
MegaFlood: Jan-Feb 2017 Maximum Water Level (m)
1m SLR + MegaFlood: Jan-Feb 2017 Maximum Water Level (m)
Latitude
Longitude
38°30'N
38°N
37°30'N
123°W
122°W
121°W
50 km
20 mi
Esri, HERE, Garmin, USGS, EPA, NPS
9
8
7
6
5
4
3
2
1
(m)
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
4



Port Chicago
Tide Gauge
San Francisco
Tide Gauge
Latitude
Longitude
38°45'N
38°30'N
38°15'N
38°N
37°45'N
37°30'N
37°15'N
123°W
122°30'W
122°W
121°30'W
05/01
15/01
25/01
05/01
24/02
3000
2500
2000
1500
1000
500
0
5
4
3
2
1
0
-1
10 km
10 mi
Pacific Ocean
Esri, HERE, Garmin, USGS, EPA, NPS


San Francisco Tide Gauge - Water Level (m) NAVD88
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
01/Jan
08/Jan
15/Jan
22/Jan
29/Jan
05/Feb
12/Feb
19/Feb
26/Feb
05/Mar
12/Mar
19/Mar
26/Mar
02/Apr
Baseline
1m SLR
MegaFlood
1m SLR + MegaFlood


Port Chicago Tide Gauge - Water Level (m) NAVD88
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
01/Jan
08/Jan
15/Jan
22/Jan
29/Jan
05/Feb
12/Feb
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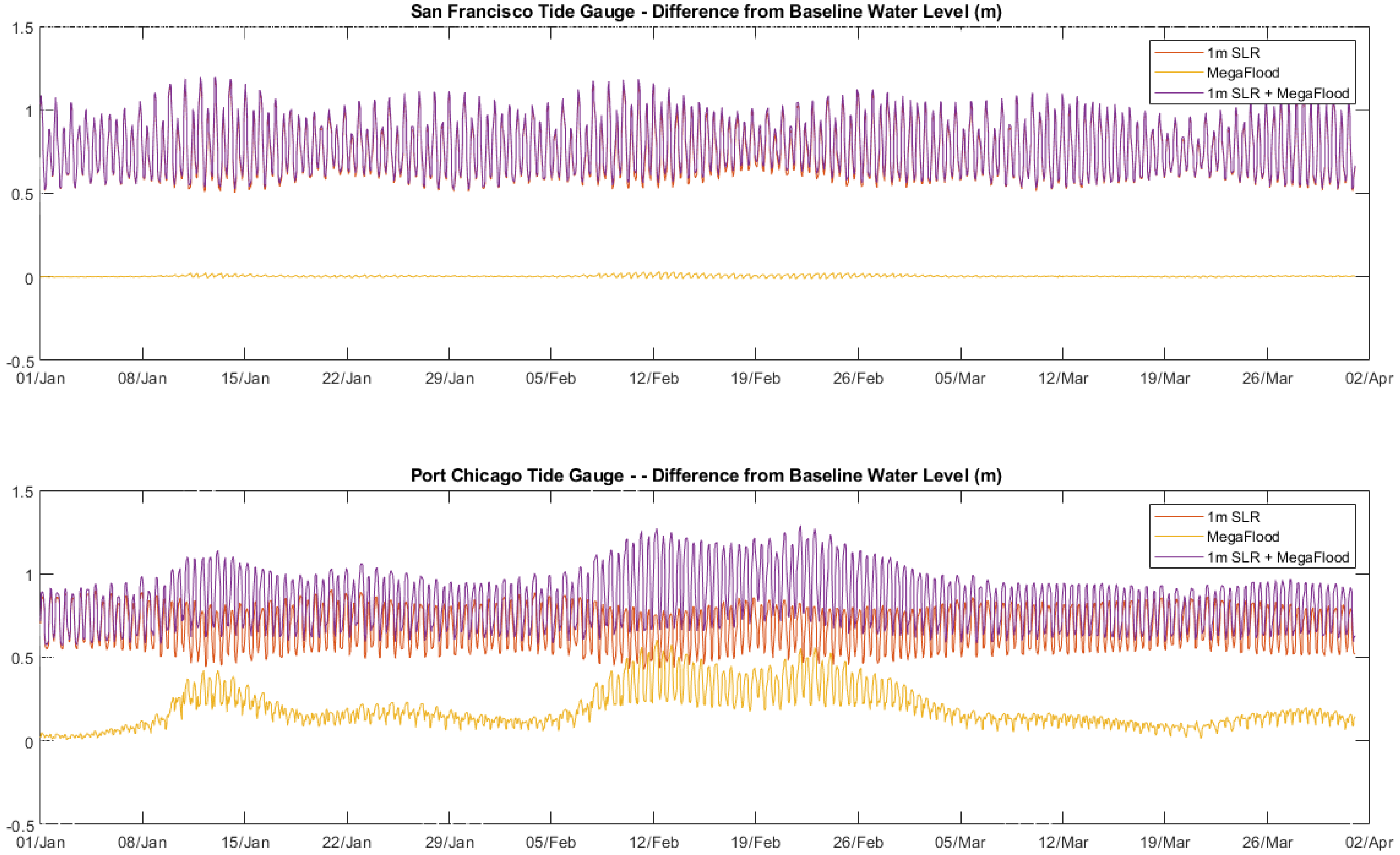

San Francisco Tide Gauge - Difference from Baseline Water Level (m)
1m SLR
MegaFlood
1m SLR + MegaFlood
1.5
1
0.5
0
-0.5
01/Jan
08/Jan
15/Jan
22/Jan
29/Jan
05/Feb
12/Feb
19/Feb
26/Feb
05/Mar
12/Mar
19/Mar
26/Mar
02/Apr
Port Chicago Tide Gauge - - Difference from Baseline Water Level (m)
1m SLR
MegaFlood
1m SLR + MegaFlood
1.5
1
0.5
0
-0.5
01/Jan
08/Jan
15/Jan
22/Jan
29/Jan
05/Feb
12/Feb
19/Feb
26/Feb
05/Mar
12/Mar
19/Mar
26/Mar
02/Apr

SUMMARY

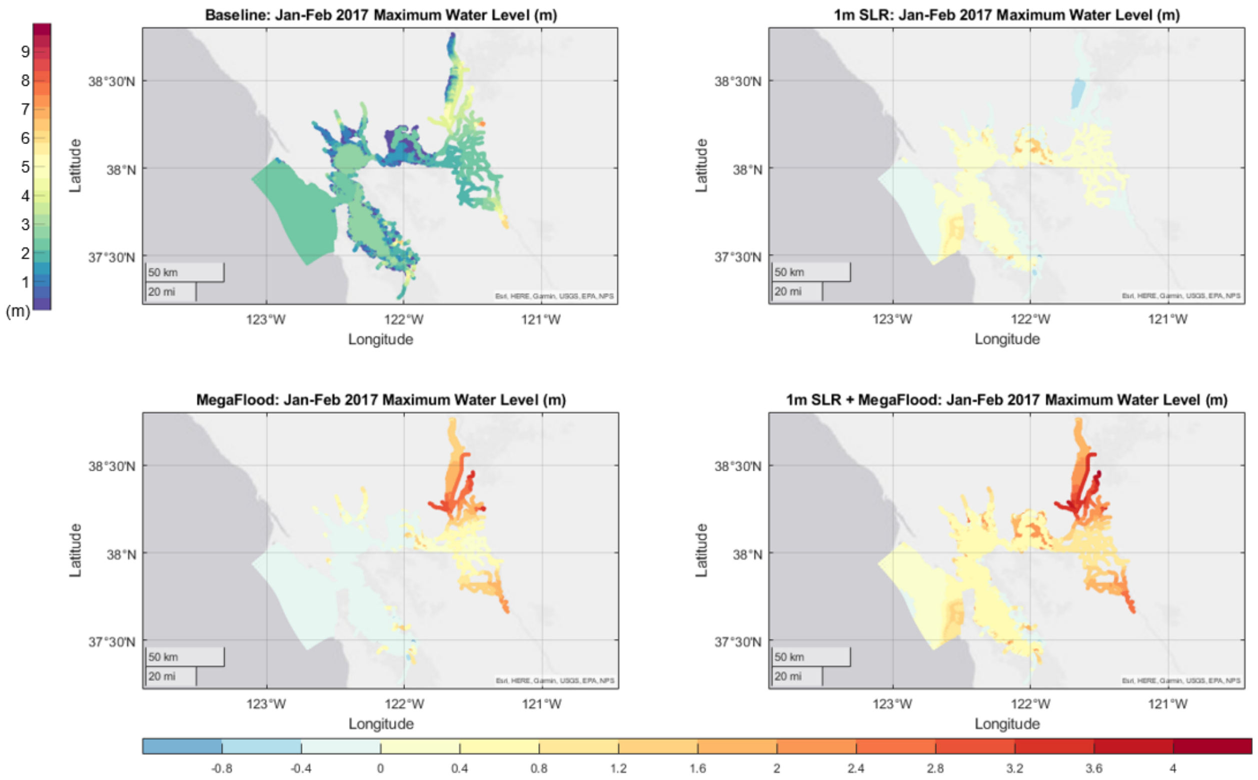
Our preliminary modelling experiments demonstrate that interactions between tidal processes and riverine processes, are complex and non-linear.

Water levels in upper bay and delta areas are most affected high riverine discharge, however higher runoff conditions affect sea levels in the lower bay, potentially reducing maximum water levels.

Similarly, interactions between tides and sea level rise invoke a non-linear response in this system.

While most of the system experiences an increase in maximum water level due to SLR, formerly non-tidal water bodies and riverine areas, appear to experience a slight decrease in maximum water level.

The combination of Megaflood conditions and SLR resulted in higher maximum water levels throughout the entire system.



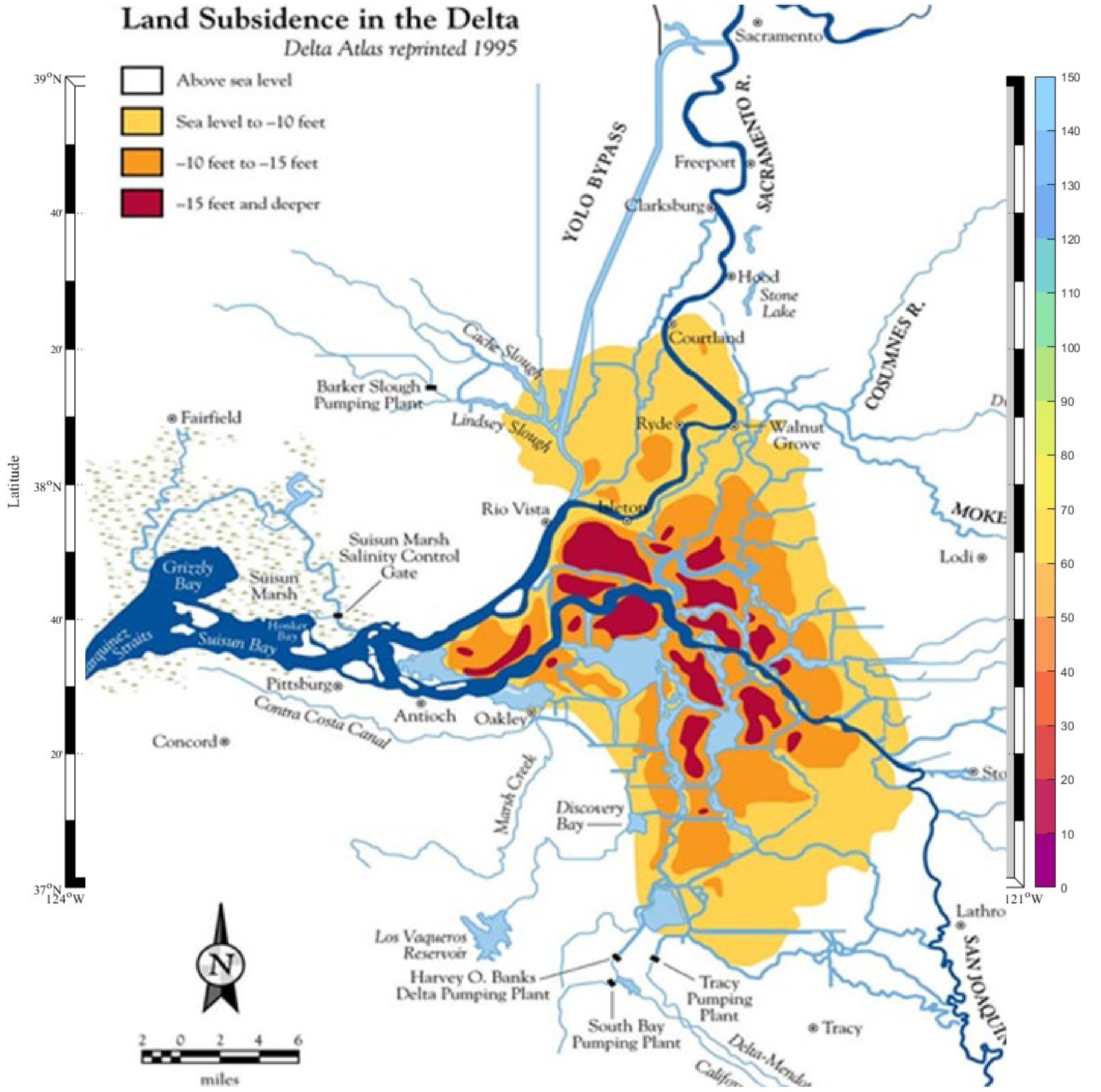
FUTURE WORK

We have utilized results from 70-year simulations (Kees et al., 2021) to estimate how far into the future nuisance flooding events will occur daily.

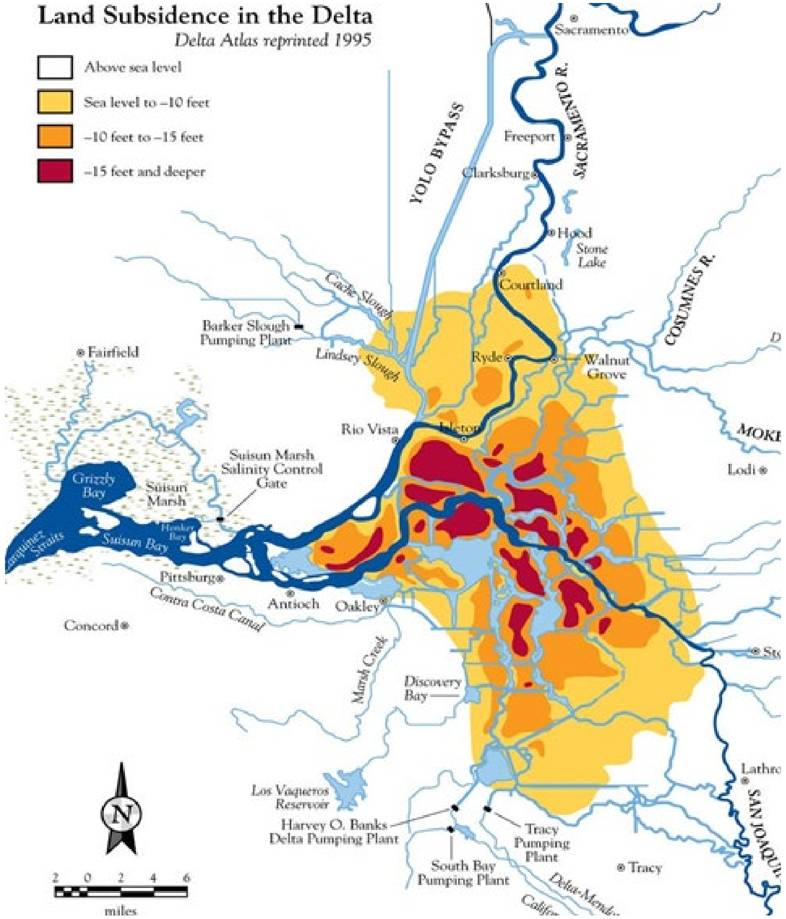
This preliminary assessment assumed a linear increase in water level based upon estimated sea level rise from the San Francisco Bay tidal gauge.

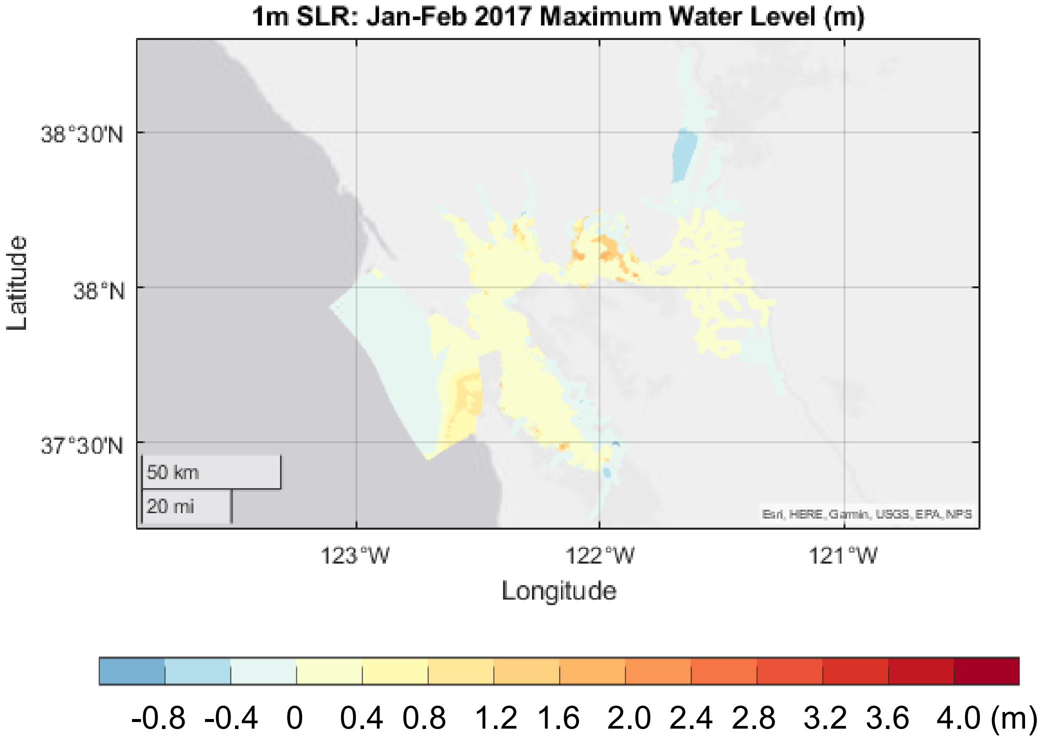
The modelling experiments discussed here indicate that the relationship between water levels and sea level rise is non-linear and spatially variable, and thus this more complicated relationship may alter such projected timeframes.

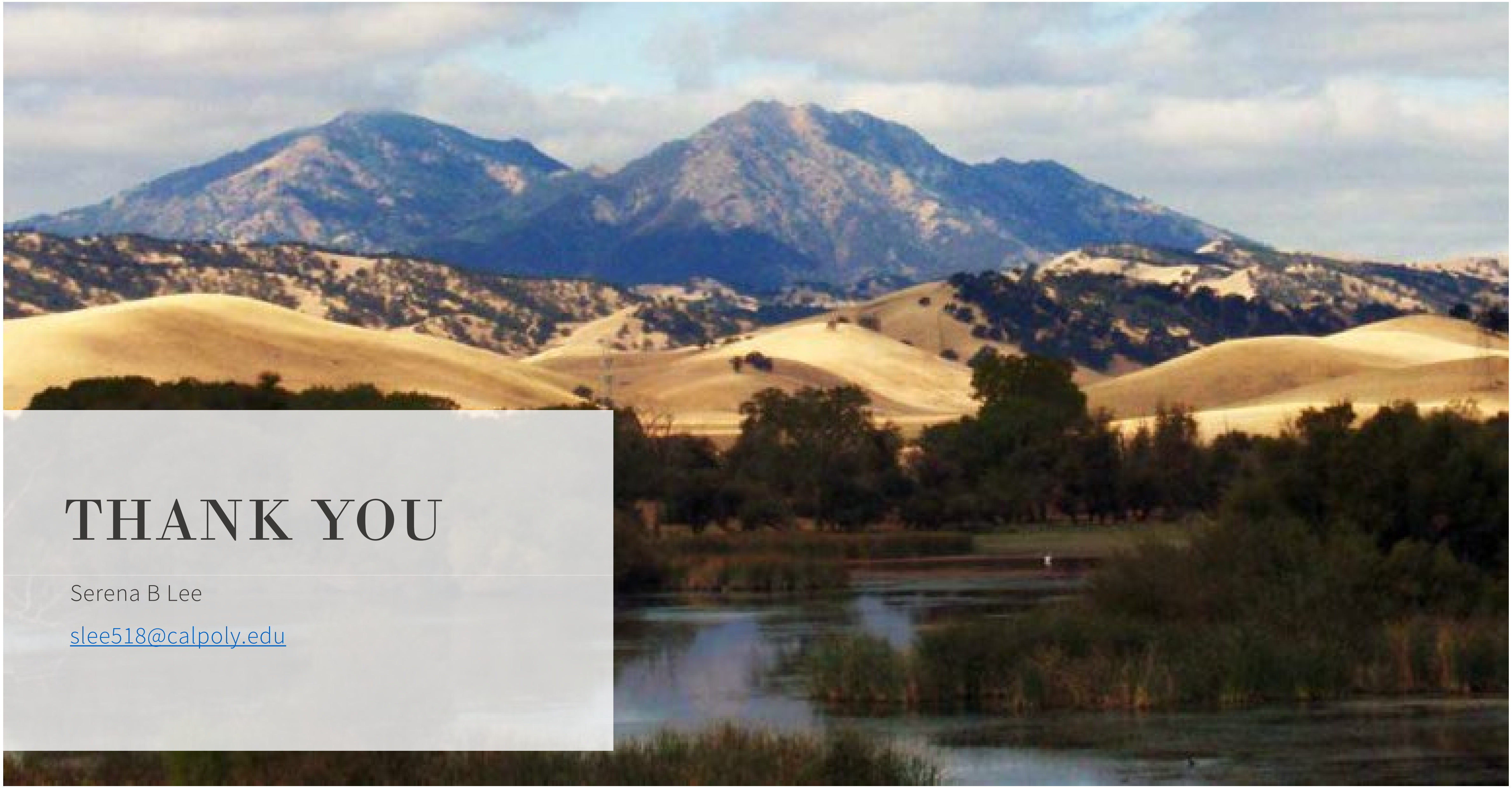
Given the high variability of vertical land motion in this region, our future experiments will explore methods by which we can account for changes in both land elevation and sea level rise.



HOW WILL VERTICAL LAND MOTION AFFECT FUTURE WATER LEVELS ?







THANK YOU

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