Machine Learning Applied to Sewer Overflows and Sea Level Rise

(Compound Flooding – extreme weather)

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Santa Rosa Sound 2012

Florida Stormwater Association, July 17, 2020

Sanitary Sewer Overflow (SSO)

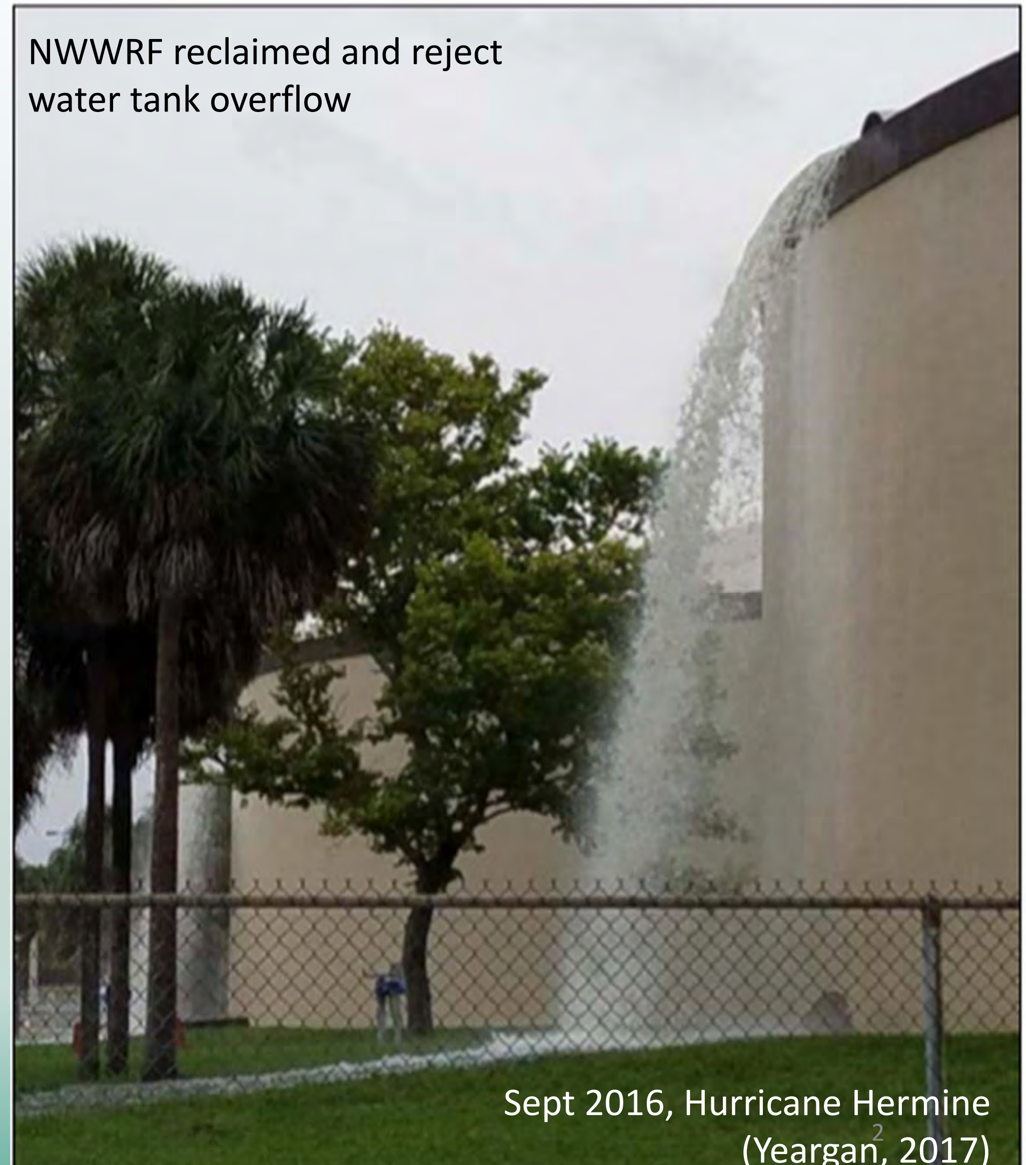
CF generates:

1) Heavy rain creates inflow and infiltration

2) Surge blocks drainage

Release of untreated and partially-treated sewage:

- Surface discharge
- Deep well injection



NWWRF reclaimed and reject water tank overflow

Sept 2016, Hurricane Hermine (Yeargan, 2017)

Outline

1. Pinellas County
2. Changing climate
3. Logistic Regression
4. Future SLR
5. Past SLR
6. Conclusions

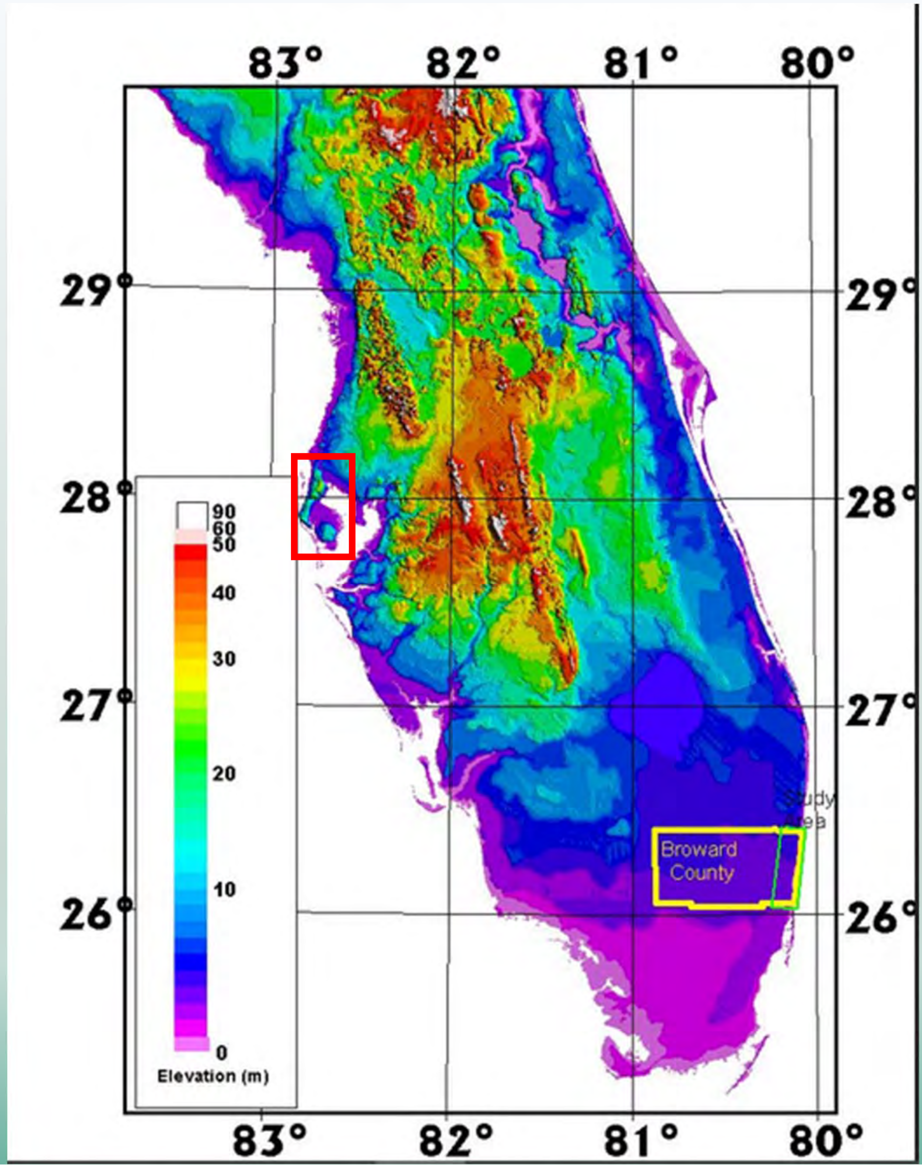
NWWRF reclaimed and reject water tank overflow

Sept 2016, Hurricane Hermine

Elevation Peninsular FL

Pinellas County

low-lying shoreline
→ surge can block drains



LIDAR
Florida International University
Int'l Hurricane Research Center

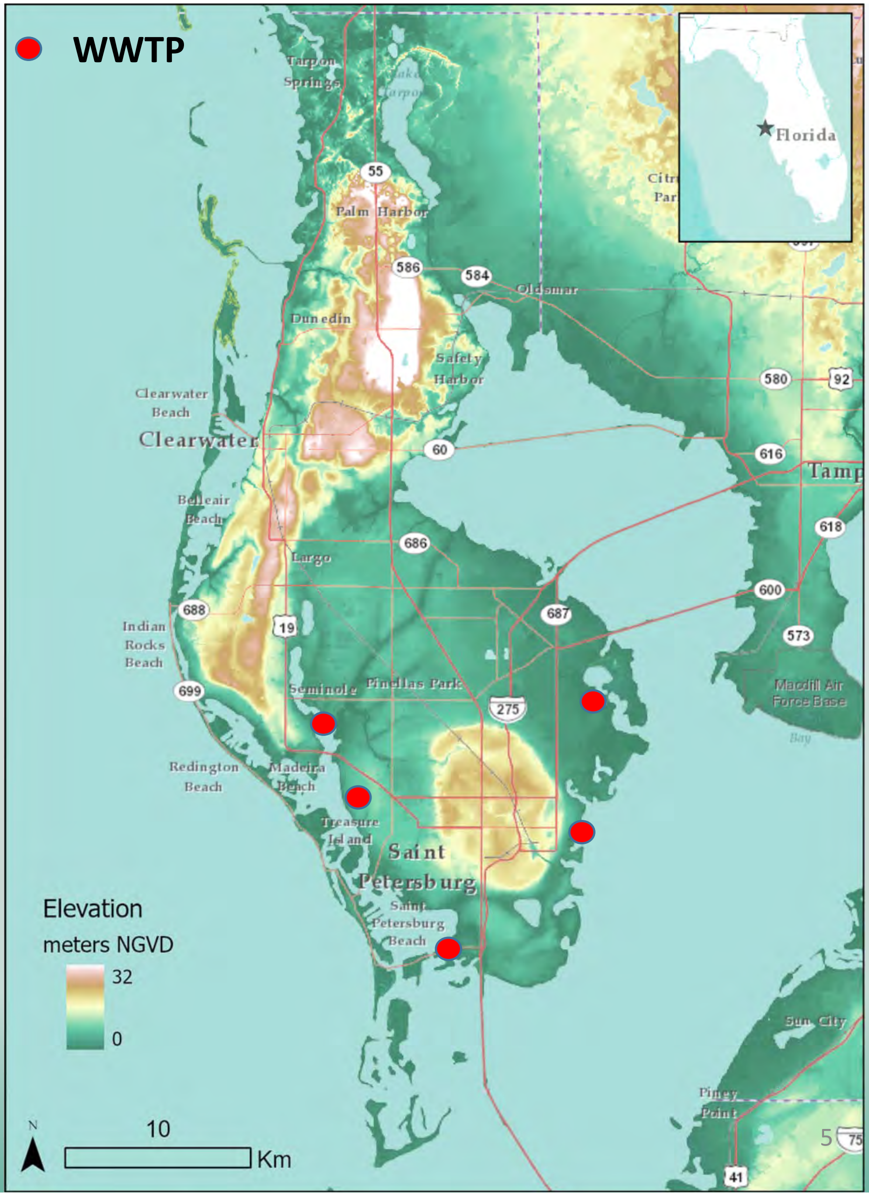
http://www.ihrc.fiu.edu/research/projects/storm-surge-broward/

Pinellas County

Population 975,000
<1% annual growth

~95% land area built

typical homes prior 1975
=> aging lines subject to
inflow and infiltration



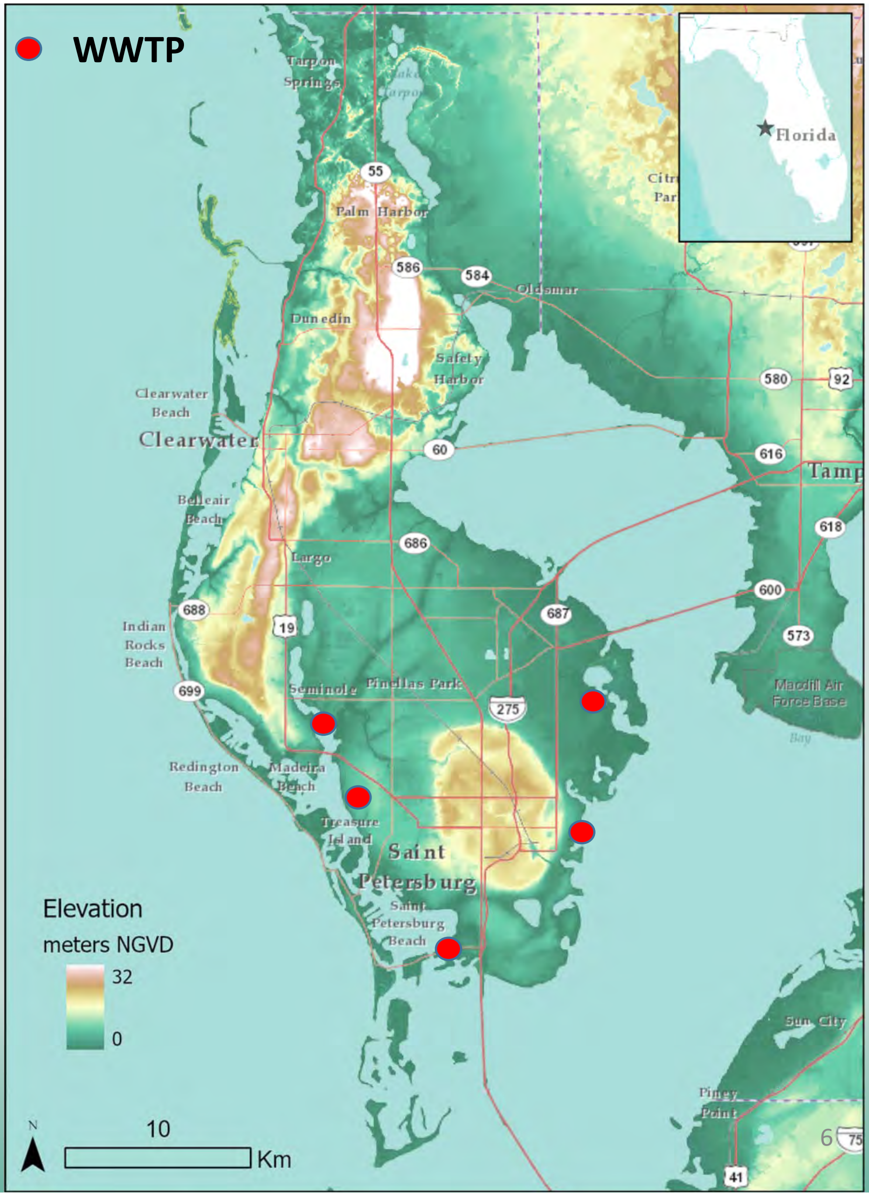
Pinellas County (southern)

2000-2017

5 WWTP had ~900 SSO days
total 200,000,000+ g

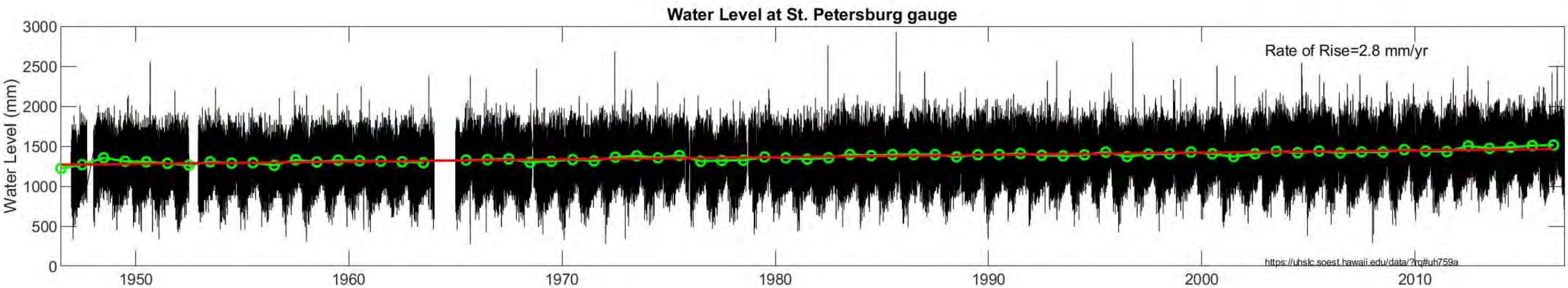
Median: 200 g
176 released >1000 g
62 released > 10,000 g

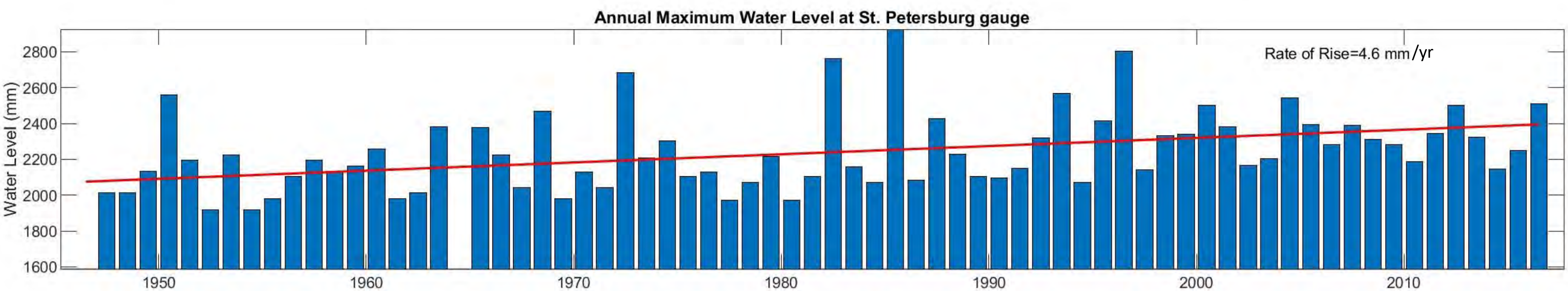
6 associated CF:
51% of total discharge
critical to understand risk



How will climate change impact rate of SSO?

Sea Level Rise



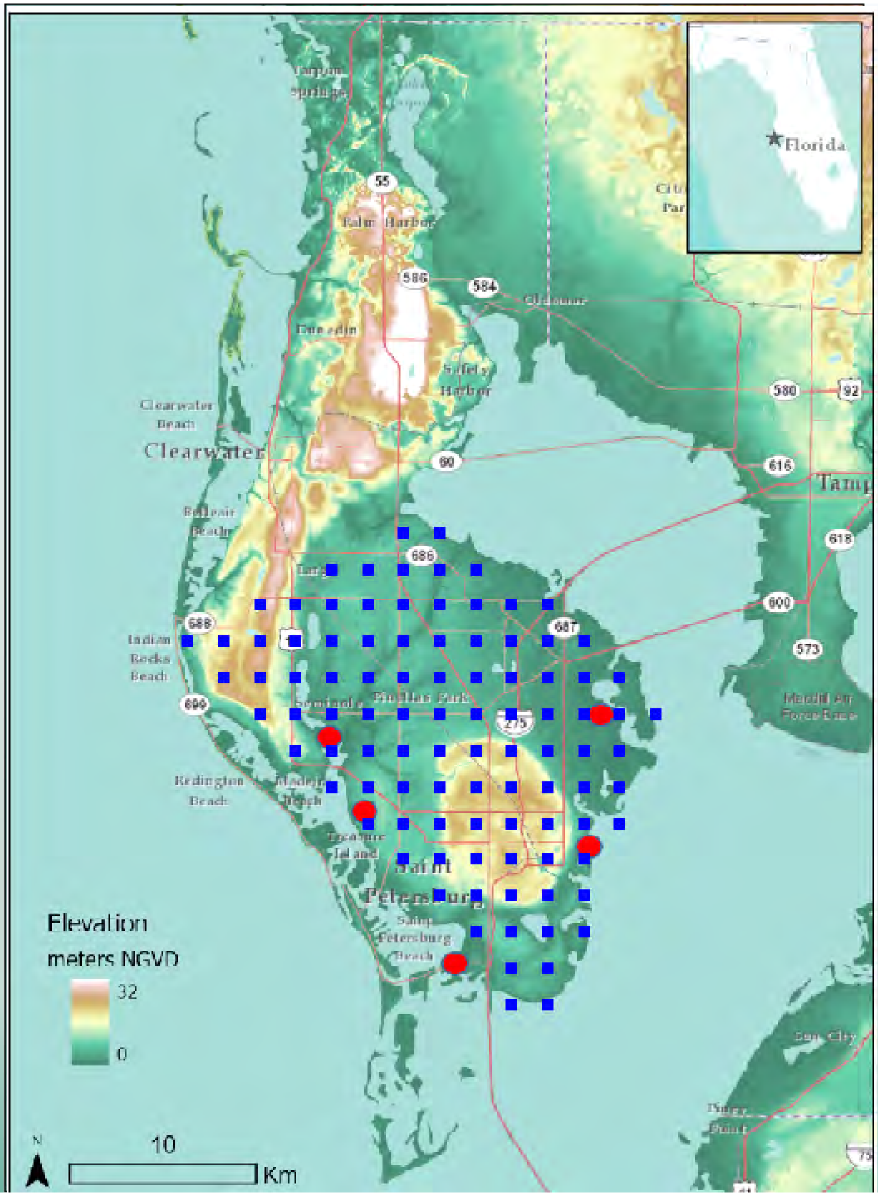


How will climate change impact SSO?

Statistical model:
logistic regression

Compound flooding +
saturated soil -> SSO

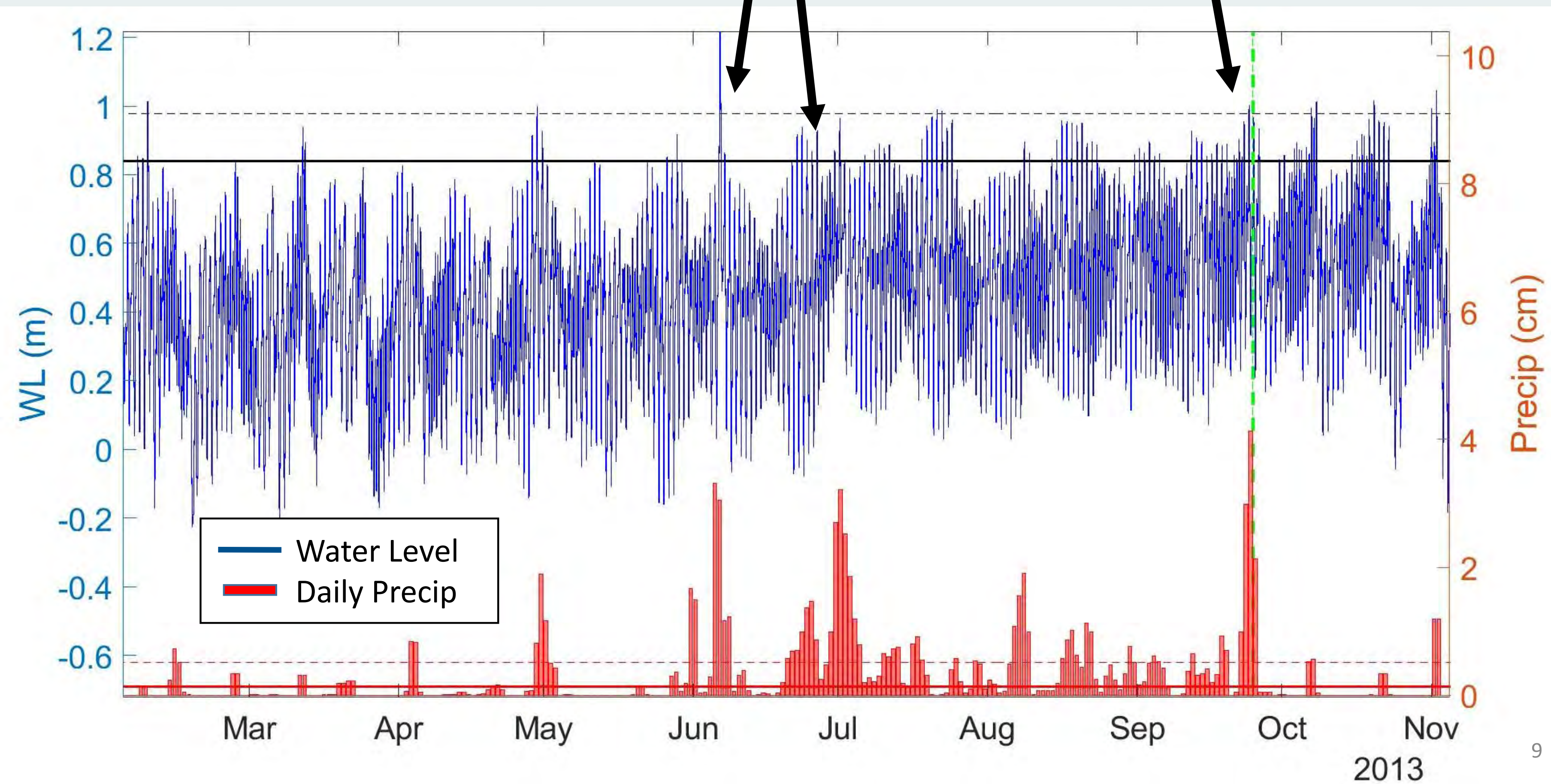
1. Water Level – Tide Gauge
2. Precipitation - NEXRAD



Example:

No SSO

SSO



Logistic Regression Model (LRM)

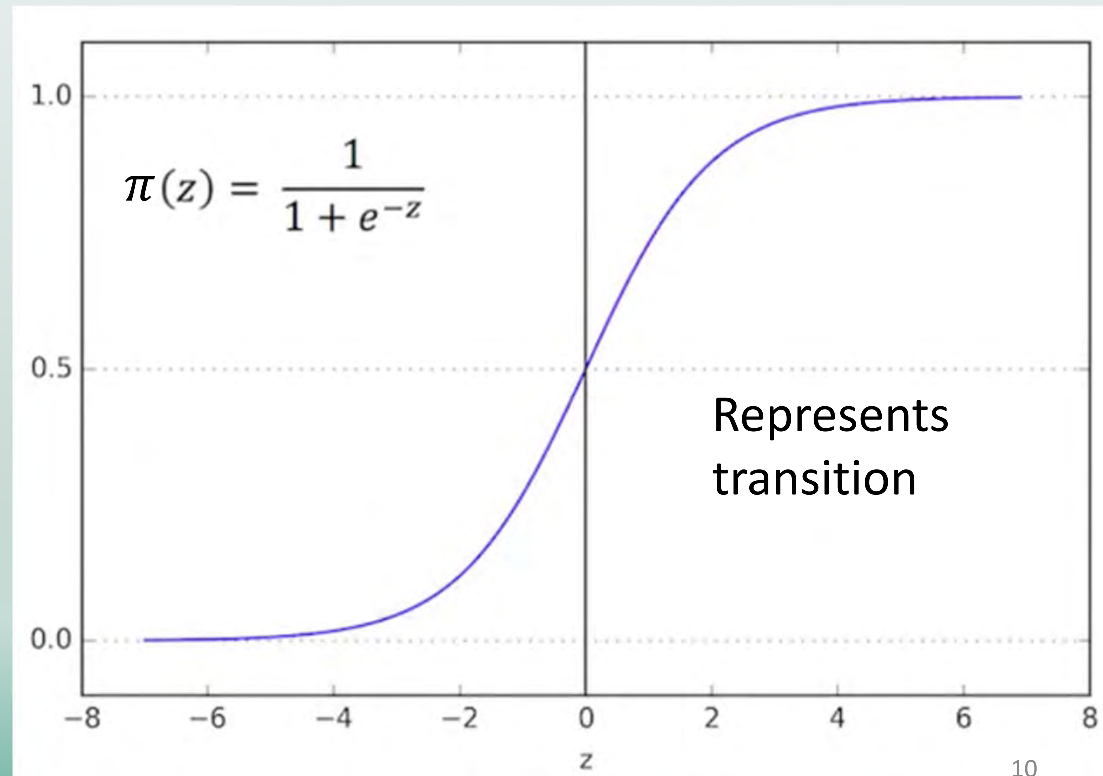
Probability π of an event is given by:

$$\ln\left(\frac{\pi}{1-\pi}\right) = \sum_i \beta_i X_i + c_0$$

β: fitting coefficients
X: independent variables
c_0: constant

Widely used in machine learning

Previously used in flooding and precip-only SSO, not CF



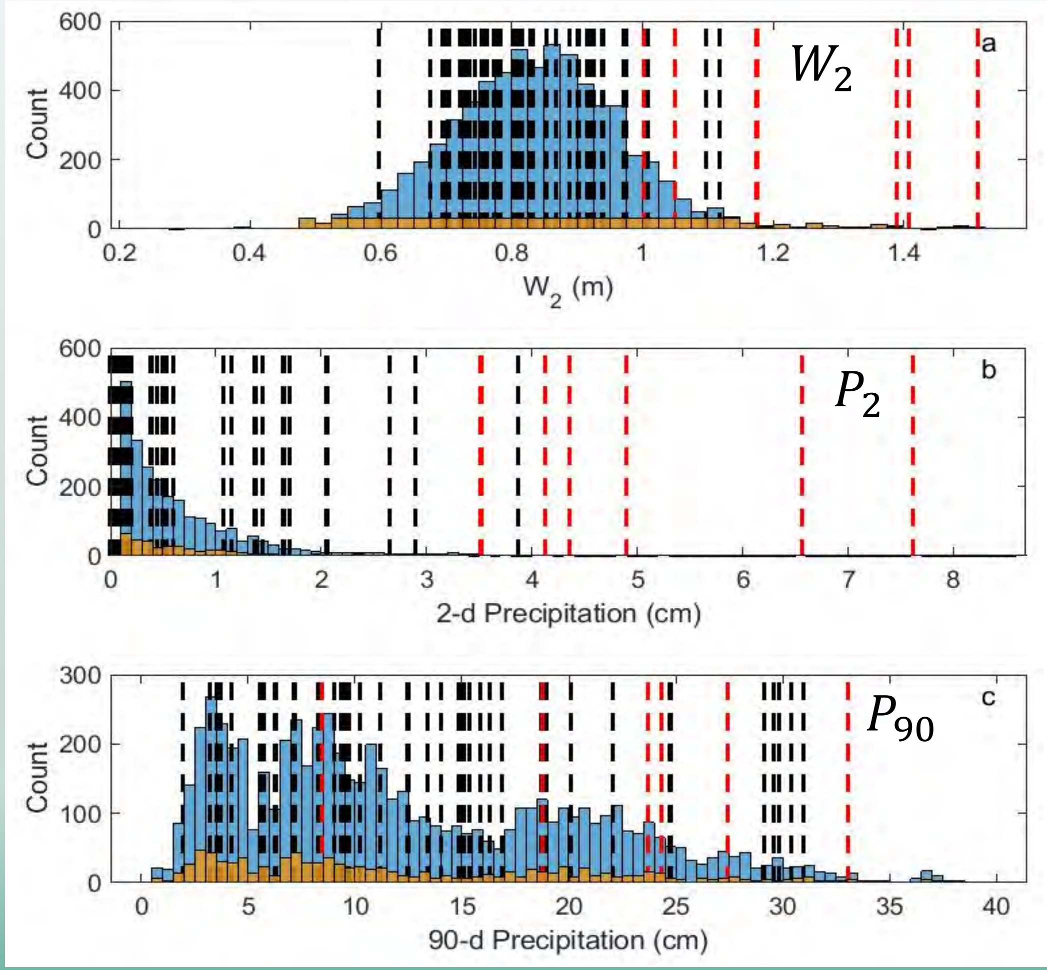
Selection of Dependent Training Data

2000-2017
48 days had SSO
volume > 10,000 g

to be CF:

1) $W_2 > \overline{W_2}$ + std(W_2)
2) $P_2 > \overline{P_2}$ + std(P_2)
3) non-mechanical

=> 6 events (red)



Self-selects extreme P_2

Selection of Independent Training Data (1)

Compound Flooding: Time scales?

1) Precipitation – short term ………. 1, 2, 7 d
2) Maximum water level ………………. 1, 2, 3 d

Soil Saturation:

3) Precipitation – long term …………. 14, 30, 90 d

How to choose?

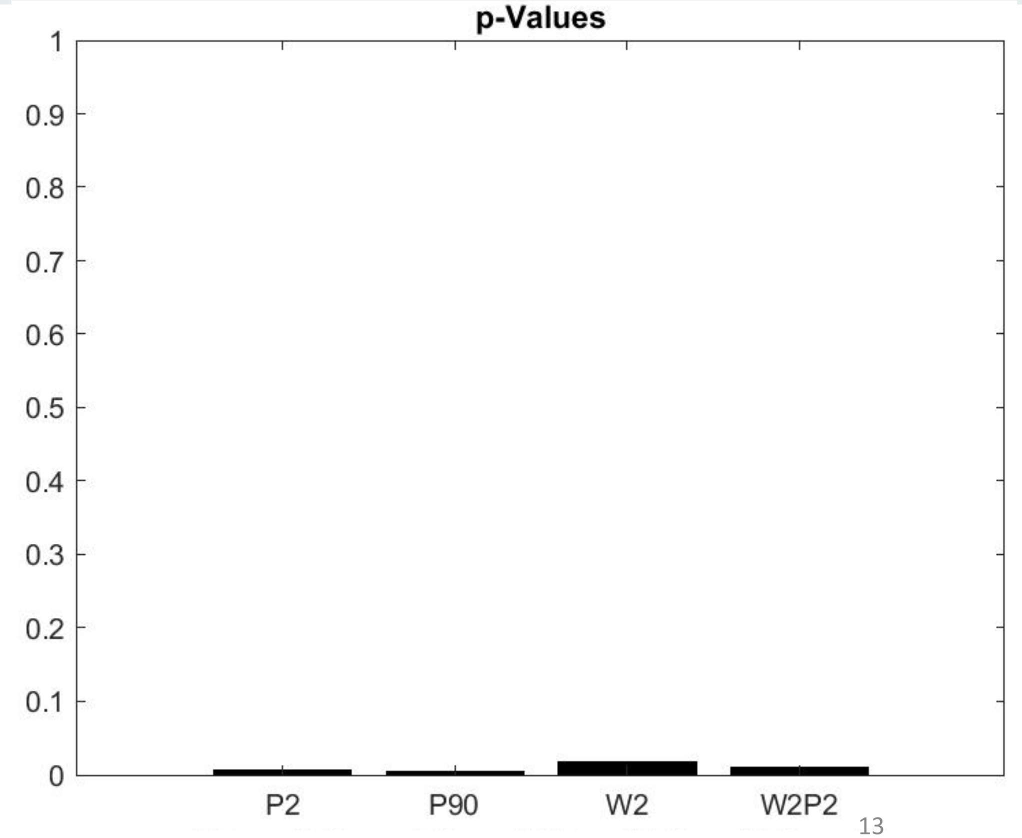
Selection of Independent Training Data (2)

p-values and π errors, p>0.05 rejected

Start with just precipitation: only P_2 and P_{90} had p<0.05

Add $W_2, p \gg 0.05$ → reject?

Interaction Terms:
P_2P_{90}, $\boxed{P_2W_2}$, W_2P_{90}

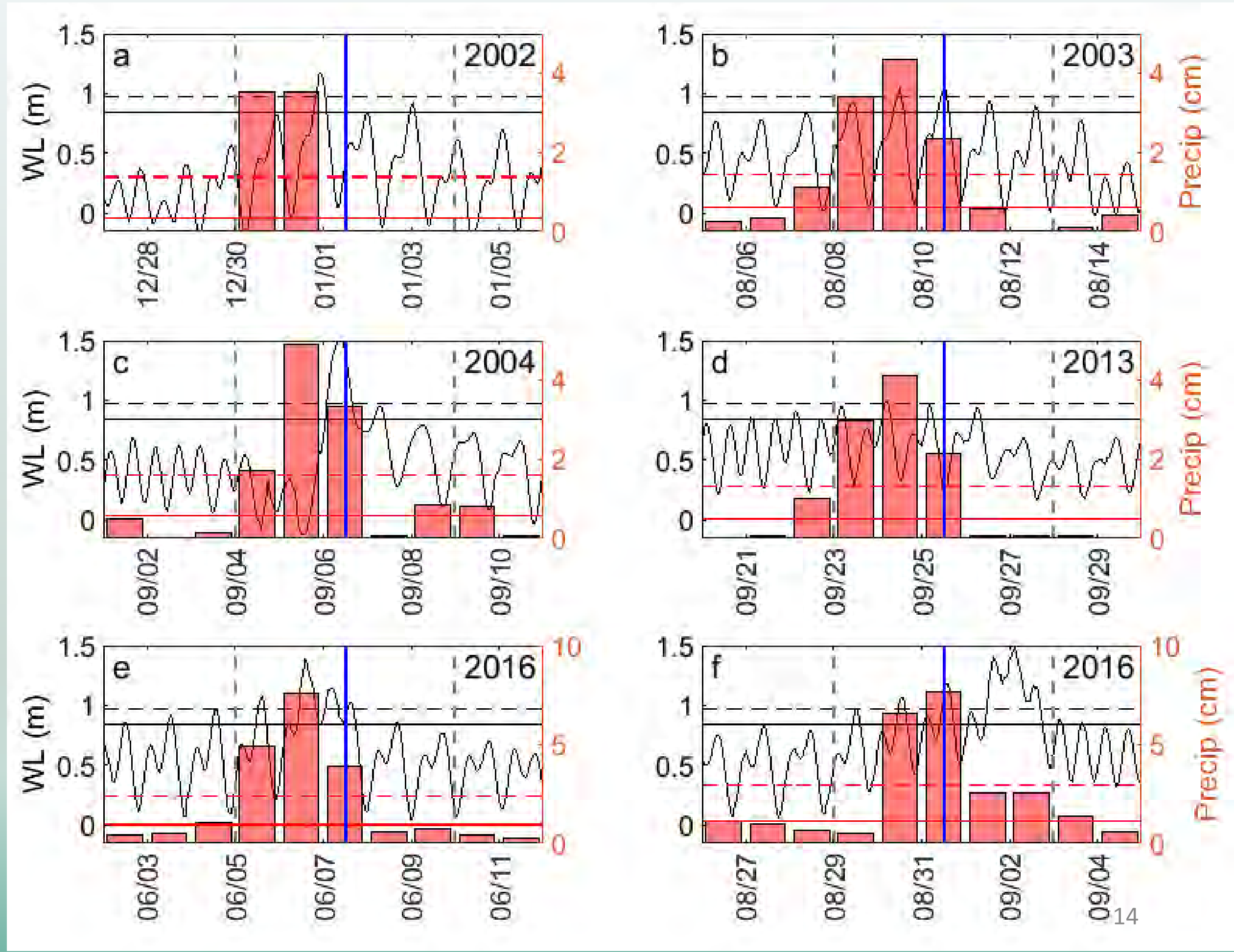


Sanity Sewer Overflows (2000-2017)

Precip coupled WL > 1 day

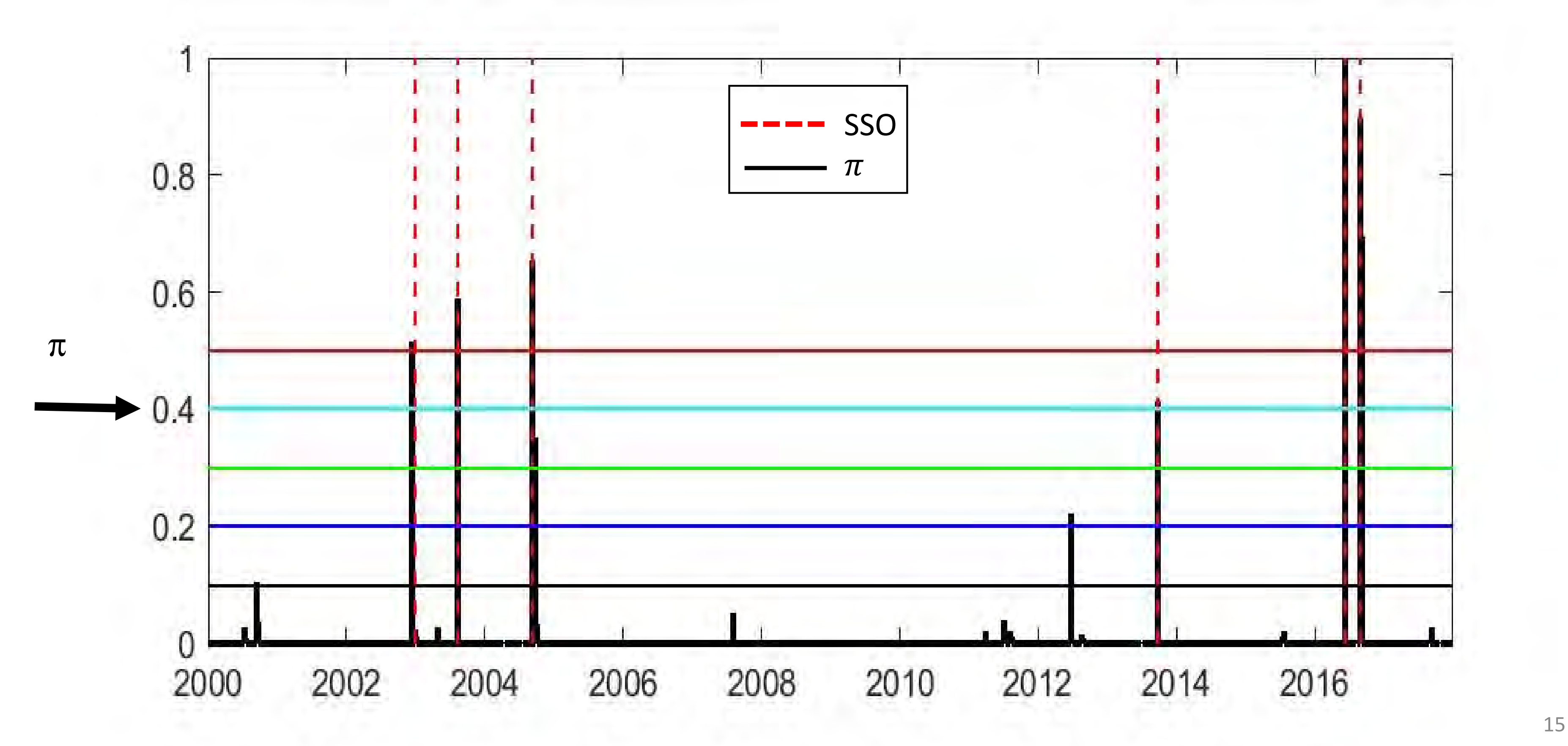
Spills can last > 1 d

Recorded date



LRM Yields Probability of Overflow

Events match high model probability…threshold?



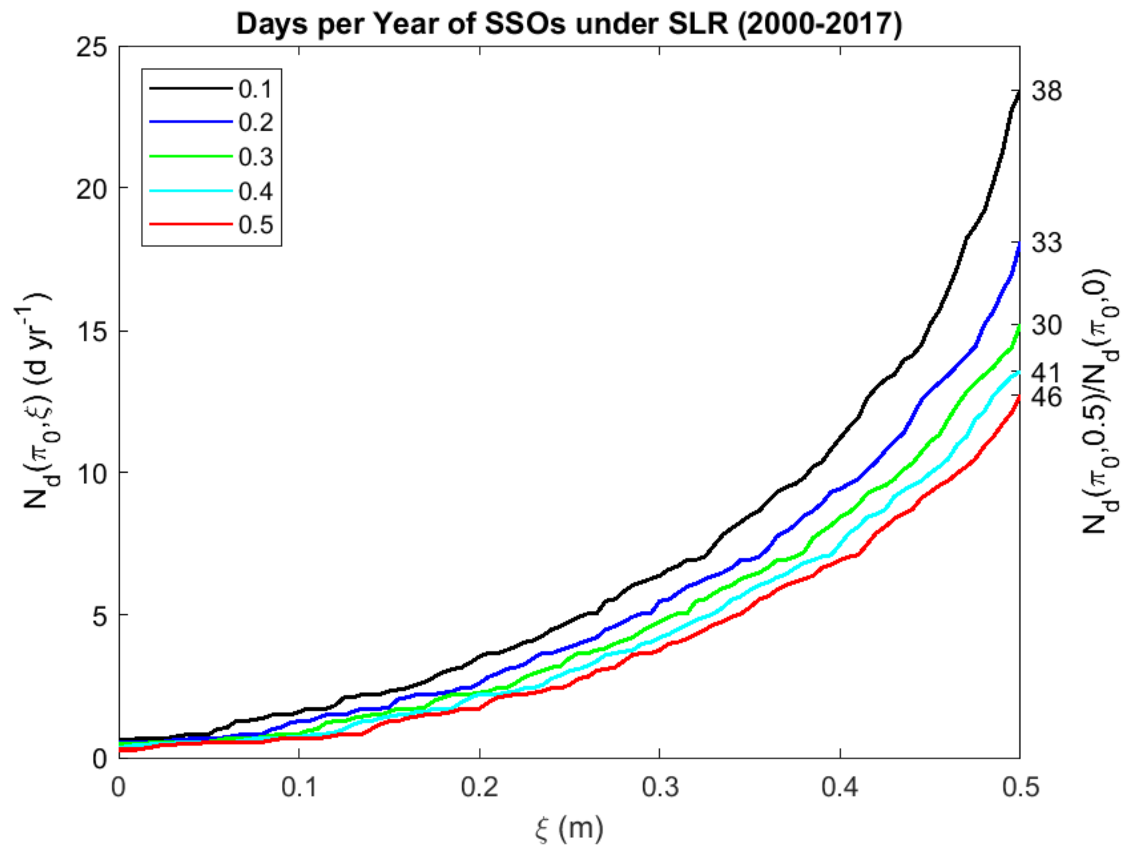
Increased Probability with SLR

days/yr above probability threshold

$\boxed{W_2 \text{ -> } W_2 + \xi}$

ξ = 0 to 0.5 m

Are sequential days same event?



Increased Probability with SLR

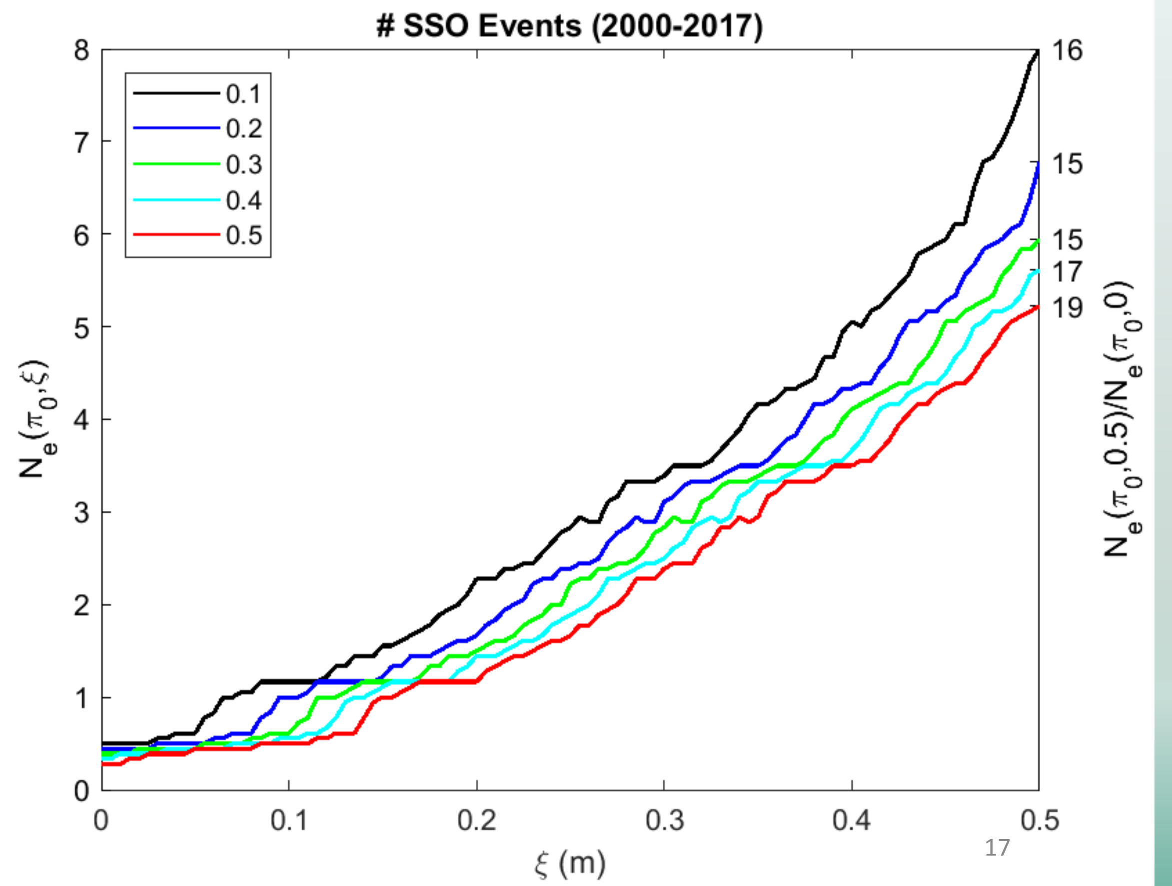
events above probability threshold separated by 7+ days

$\boxed{W_2 \text{ -> } W_2 + \xi}$

ξ = 0 to 0.5 m

Fit to exponential:

π doubles ~0.1 m



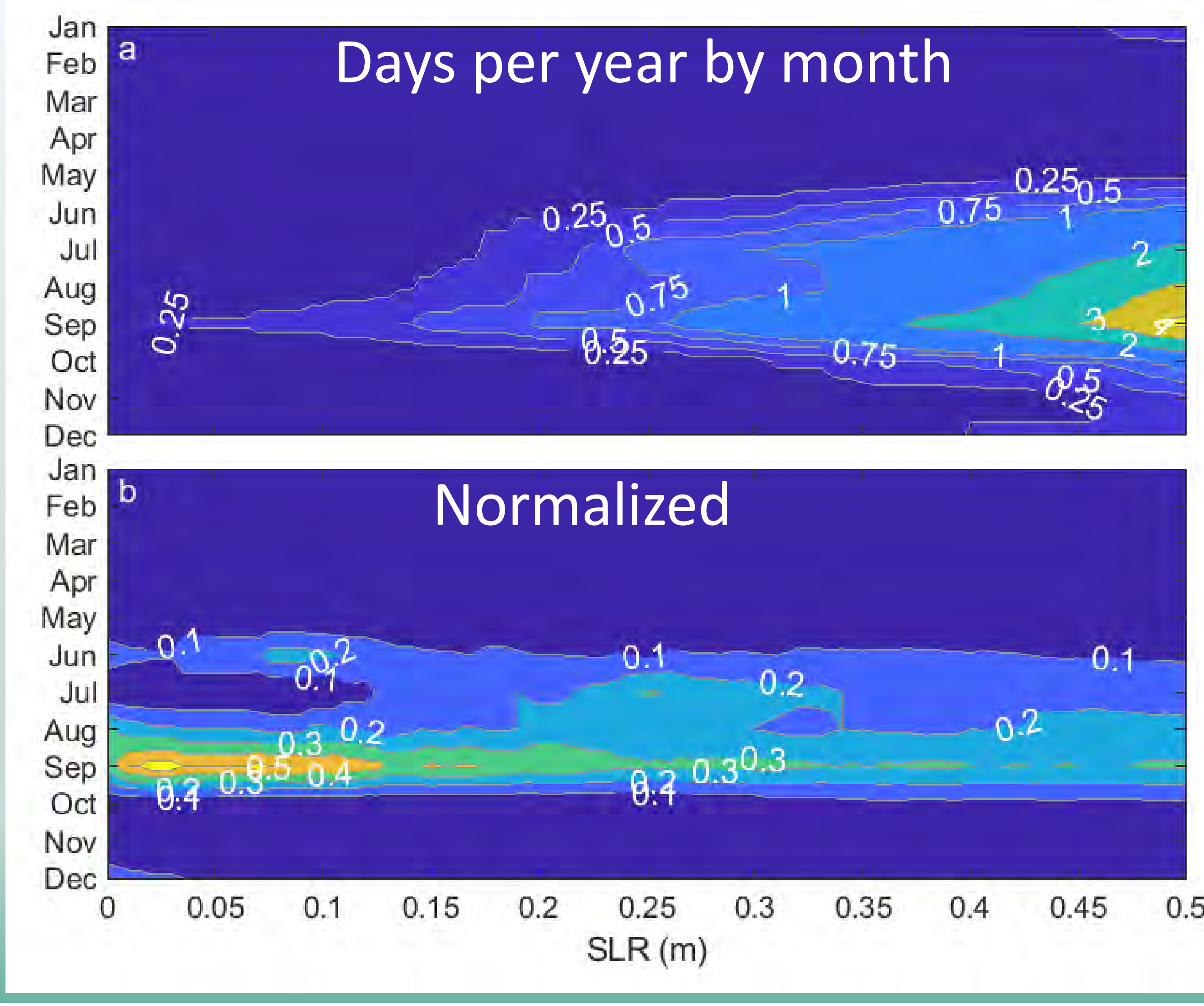
Seasonality

$\boxed{W_2 \text{ -> } W_2 + \xi}$

ξ = 0 to 0.5 m

max(π): September

Spreading ~0.15 m, June-Nov



Question:

Has sea level rise already had an impact on the rate of SSOs in Pinellas County?

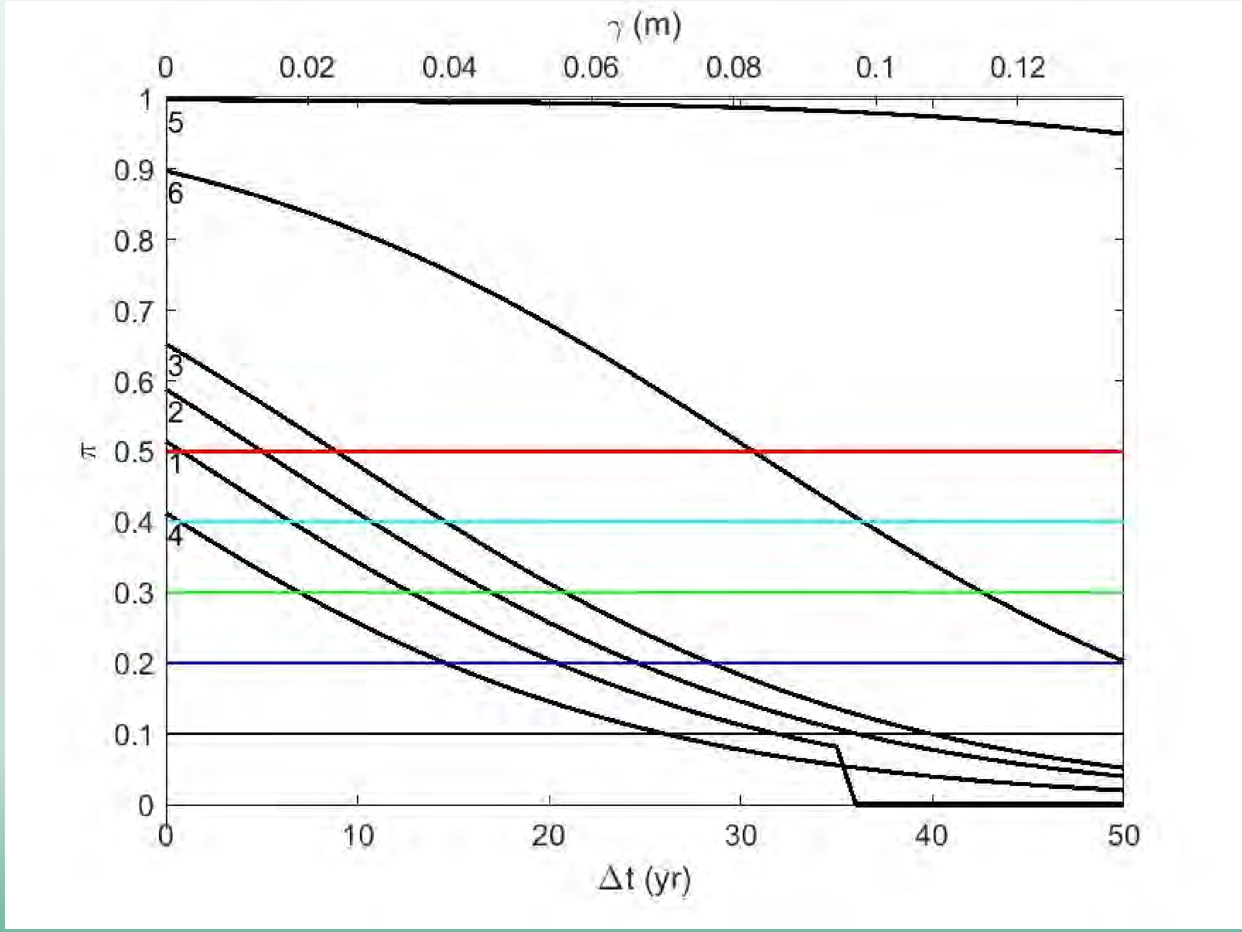
Remove SLR and reapply LRM

W_2 -> $W_2 - (\alpha t - \gamma)$

α: rate of SLR (2.7 mm/yr)

$\gamma = -\alpha T$: SLR prior to study

Prior SLR:



W_2 -> $W_2 - (\alpha t - \gamma)$

α: rate of SLR (2.7 mm/yr)

$\gamma = -\alpha T$: SLR prior to study

Conclusions

- LRMs can be developed to model infrastructure failure due to CF
- Requires subjective and objective variable selection
- Doubling every ~0.1 m of rise
- Remain confined to hurricane season
- SSOs already triggered by SLR

Thank you