# Surge Response Surface Determination for Coastal Flooding Risk Assessment

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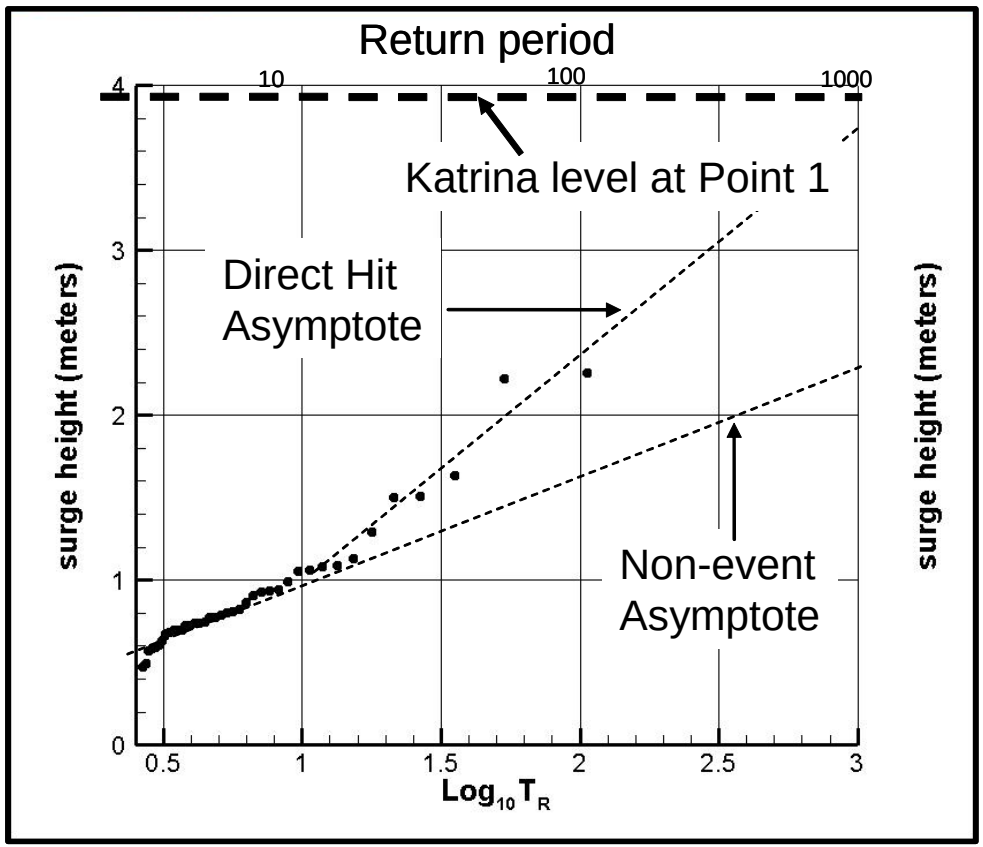
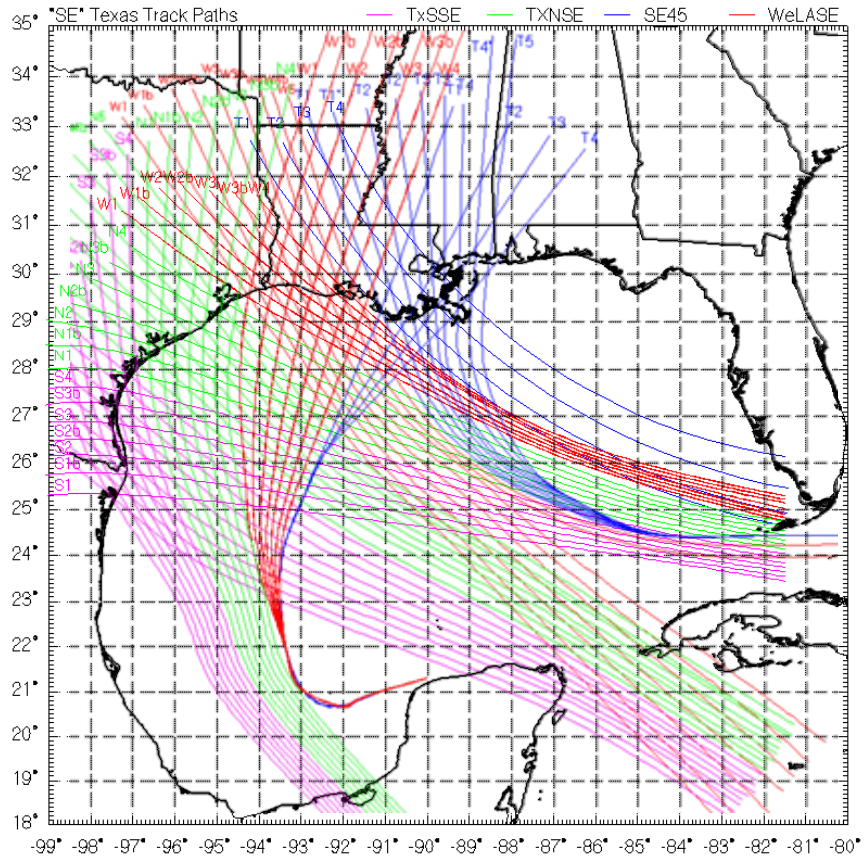
- Motivation
- Methodology summary
- Main conclusions
- Background
- Methodology:
    - Response surfaces
    - Test surface development
    - Open coast prediction
    - New Orleans prediction
- Results
- Conclusions

# Surge Response Surface Determination

## Motivation

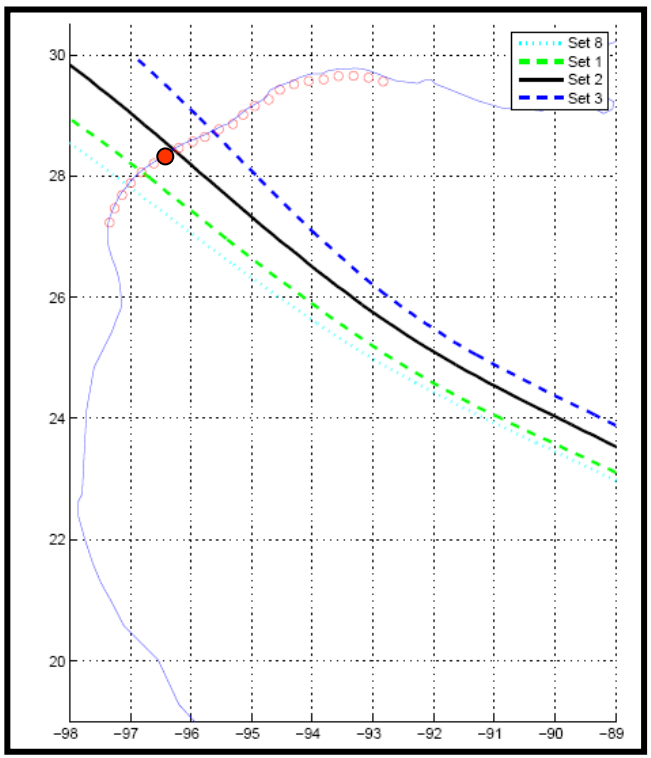
An improved, efficient, and accurate risk-assessment method for coastal flooding is required.

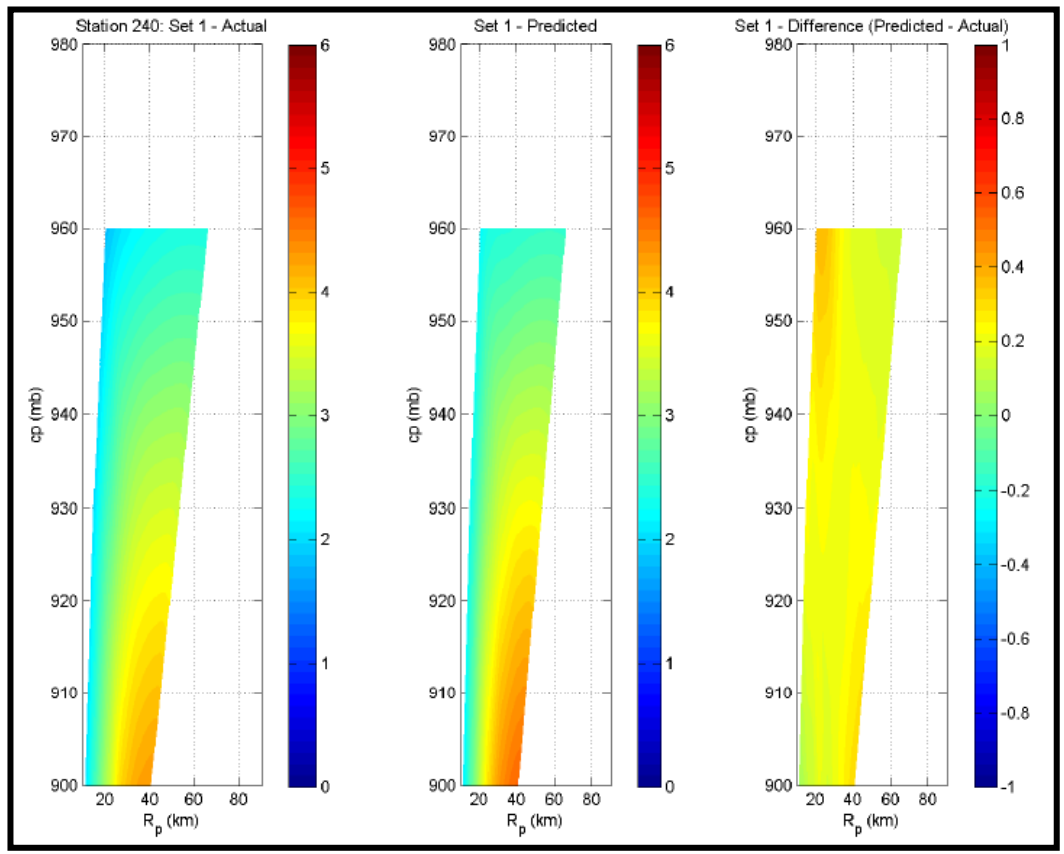


# Surge Response Surface Determination
## Methodology Summary

- Surge response surface: $\zeta(x,t) = \Phi(\underline{G}, \underline{W} \mid c_p, R_{\max}, v_f, \theta, S(t), t)$
- Use surge parameterization to predict response surface throughout area of interest from limited number of simulations or observations
- Combines information from both statistics and physical scaling relationships

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# Surge Response Surface Determination
## Main Conclusions

- Surge response approach presents solution to extreme-value statistics for coastal flooding
- Definable characteristics of response surfaces – given a single track:
  - Peak surge location scales with $R_p$
  - Alongshore distribution scales with peak surge and $R_p$
  - Surge at a given location for a given $R_p$ varies linearly with $p_0$ - $c_p$
- Overall methodology must include a means to reflect uncertainty in predicted response surfaces
- Response surface prediction has potential to extend applicability of limited observation set (i.e. surges in stronger and weaker storms can be estimated)
- Response surface prediction reduces numerical simulation requirements by allowing functional interpolation between simulation results

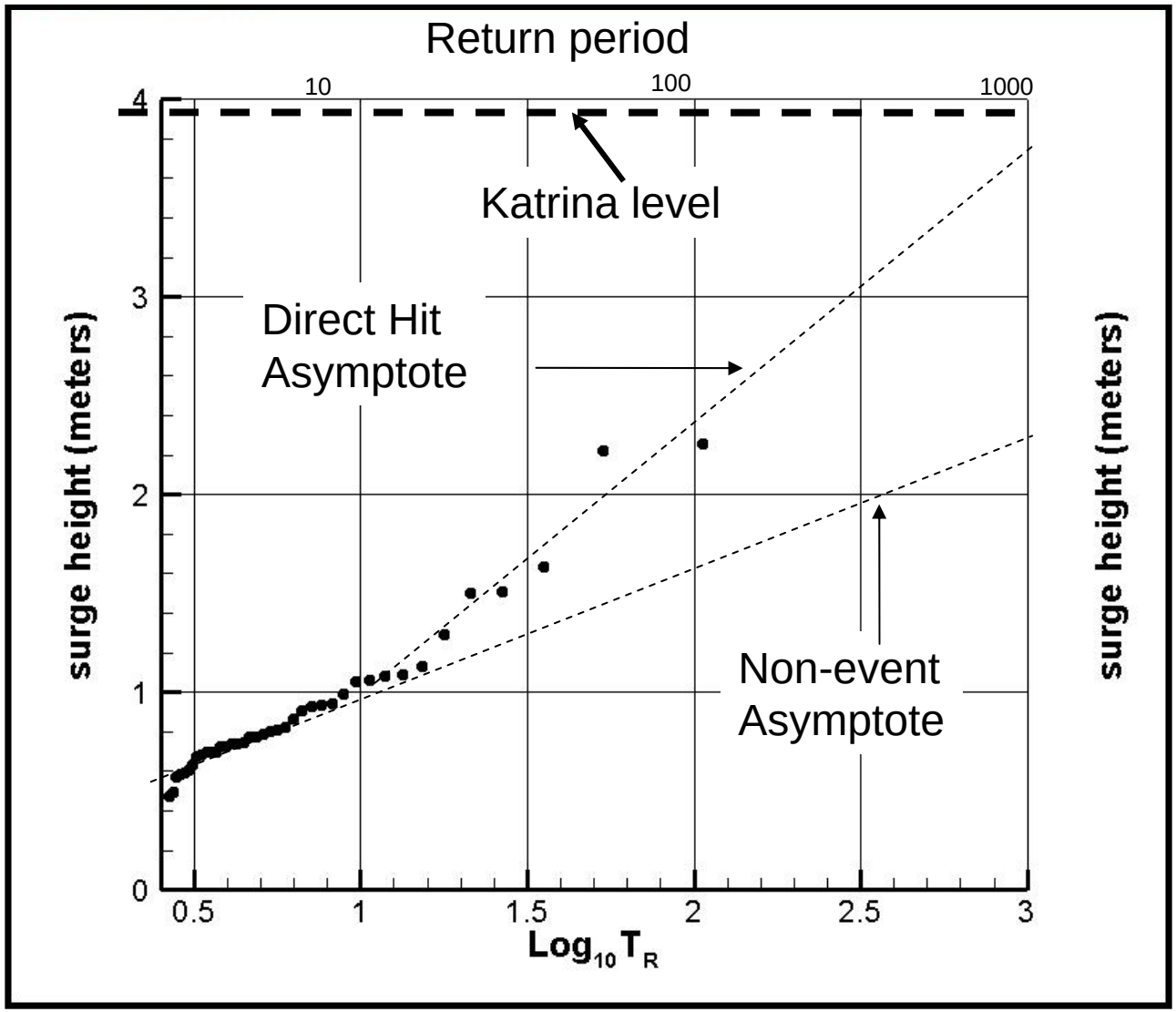
# Surge Response Surface Determination

## Background – Historical Approach

- Form data set of “largest” storms (measurements or hindcasts)
- Typical applications:
  - Points over Threshold (POT)
  - Annual series
- PARAMETRIC (GEV, Weibull, Log Normal or other assumed form):
  - Considers sampling size effects on “fitted” curve
  - Uses various fitting methods (MLM, MOM, etc.)
  - Allows parametric estimation of return periods larger than given by the historical record
- NON-PARAMETRIC (e.g., EST):
  - No assumptions on data’s probability distribution in interior
  - Uses data to develop distribution in interior
  - Still extrapolates beyond data range using parametric “fit” to data
- Results extremely sensitive to record length
- Storms assumed to be from a homogeneous parent population
  - Climate variability typically excluded

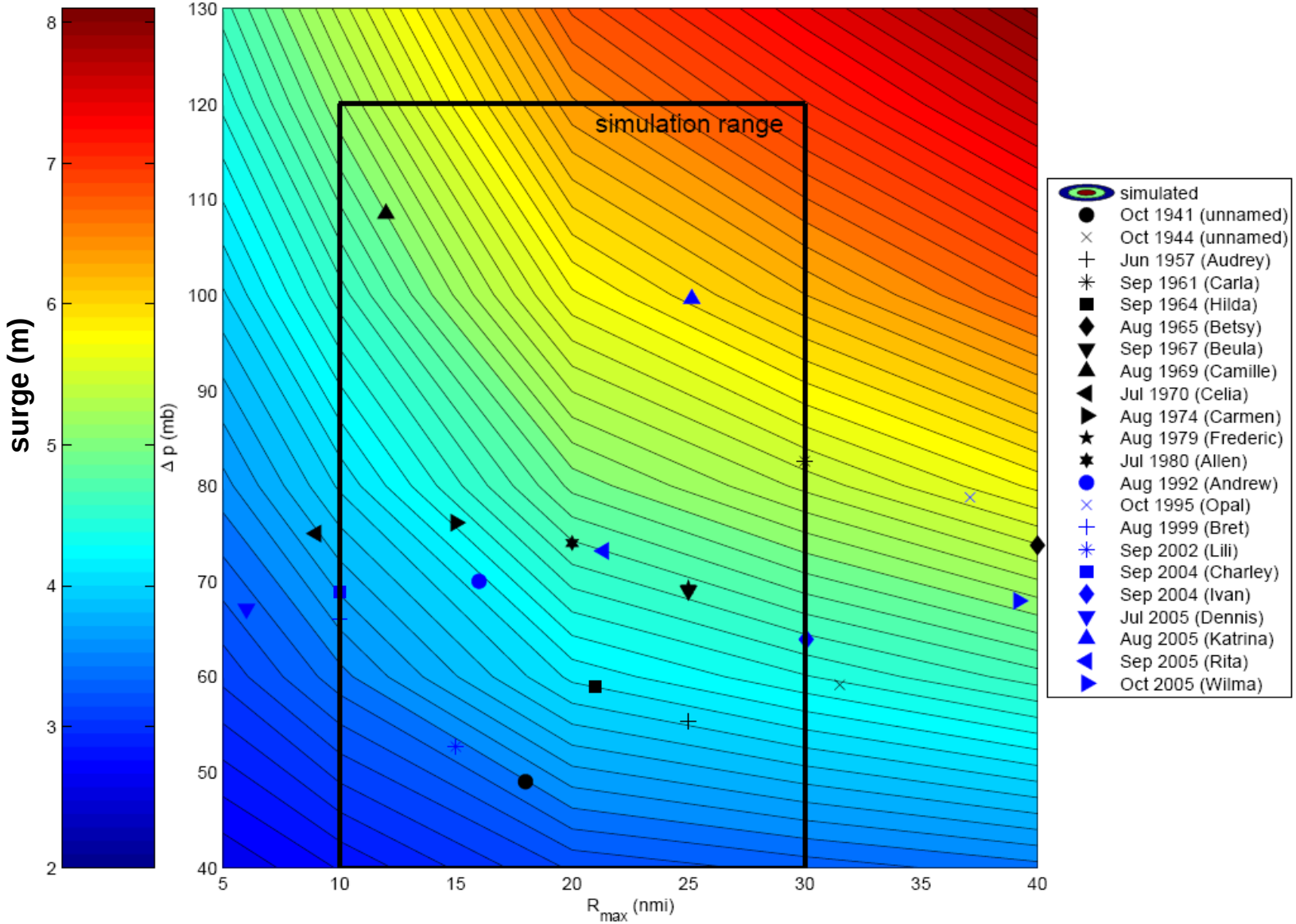
# Surge Response Surface Determination

## Background – Historical Approach



# Surge Response Surface Determination

## Background – Idealized Surge Response



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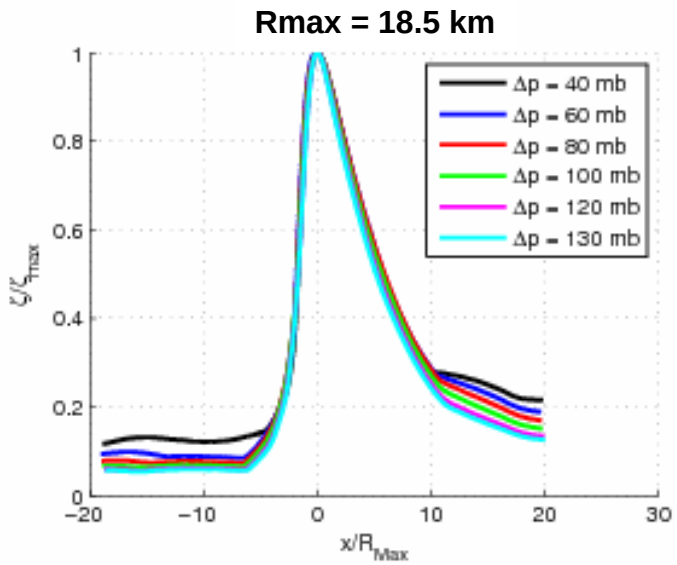


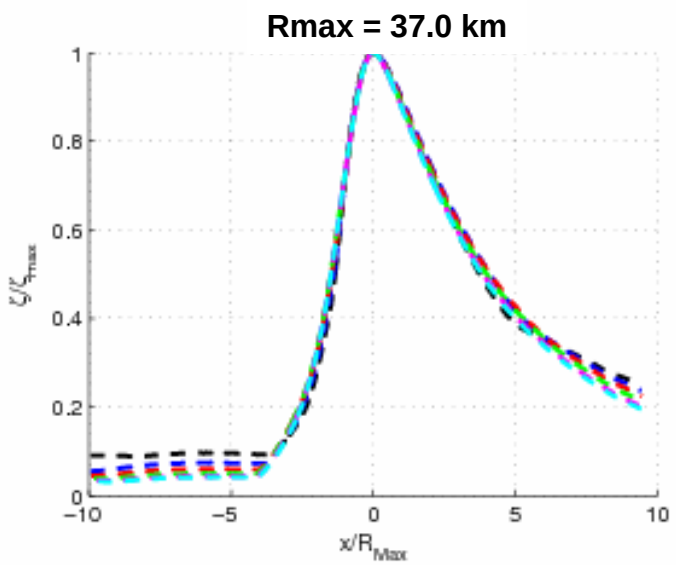


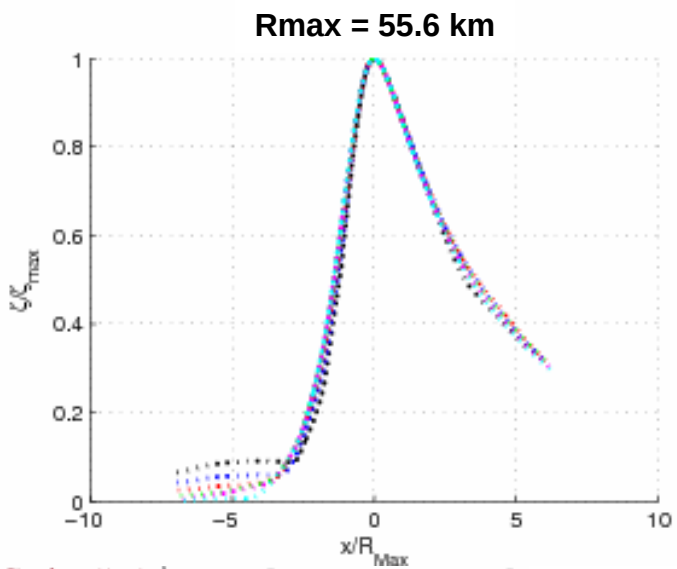


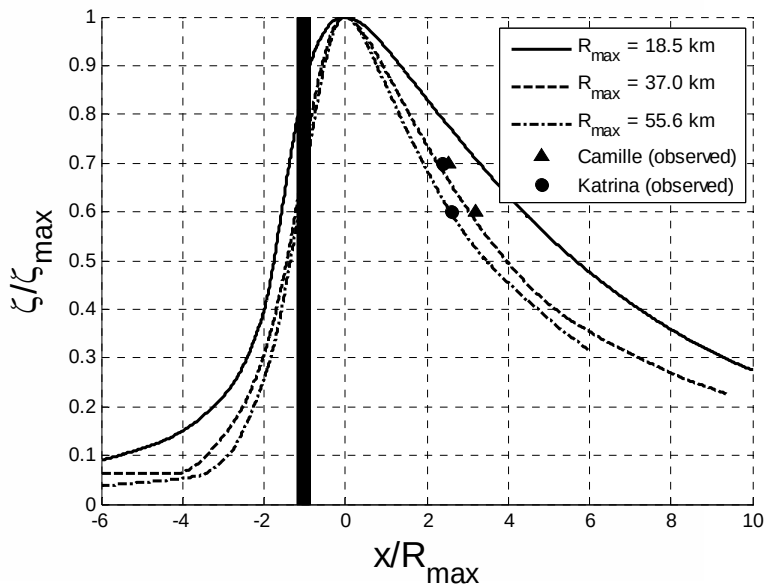


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# Surge Response Surface Determination

## Methodology – Response Surface Approach

**General form for surge response at location x and time t:**

$$\zeta(x,t) = \Phi(\underline{G}, \underline{W} \mid c_p, R_{\max}, v_f, \theta, S(t), t)$$

where

$\zeta(x,t)$ is the storm surge at location x and time t,

$\Phi$ is a numerical model used to generate surges over a grid,

$\underline{G}$ is a time invariant grid of bathymetry/topography,

$\underline{W}$ is a wind field over the grid at time t,

$c_p$ is the central pressure,

$R_{\max}$ is the radius to maximum wind speed from the center of the storm,

$v_f$ is the forward velocity of the storm,

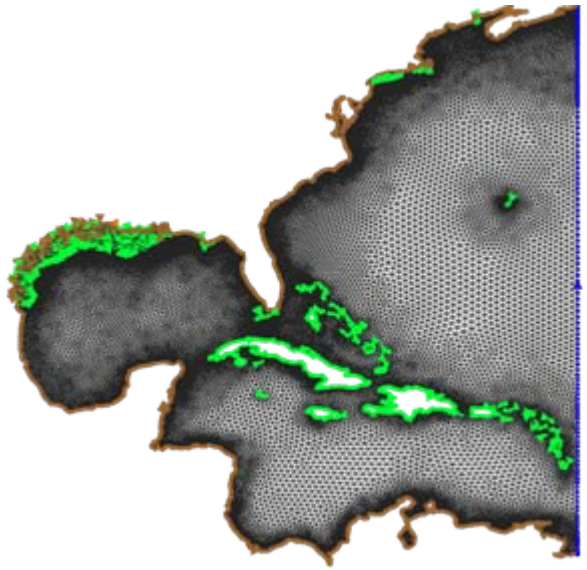
$\theta$ is the geographic angle of the track, and

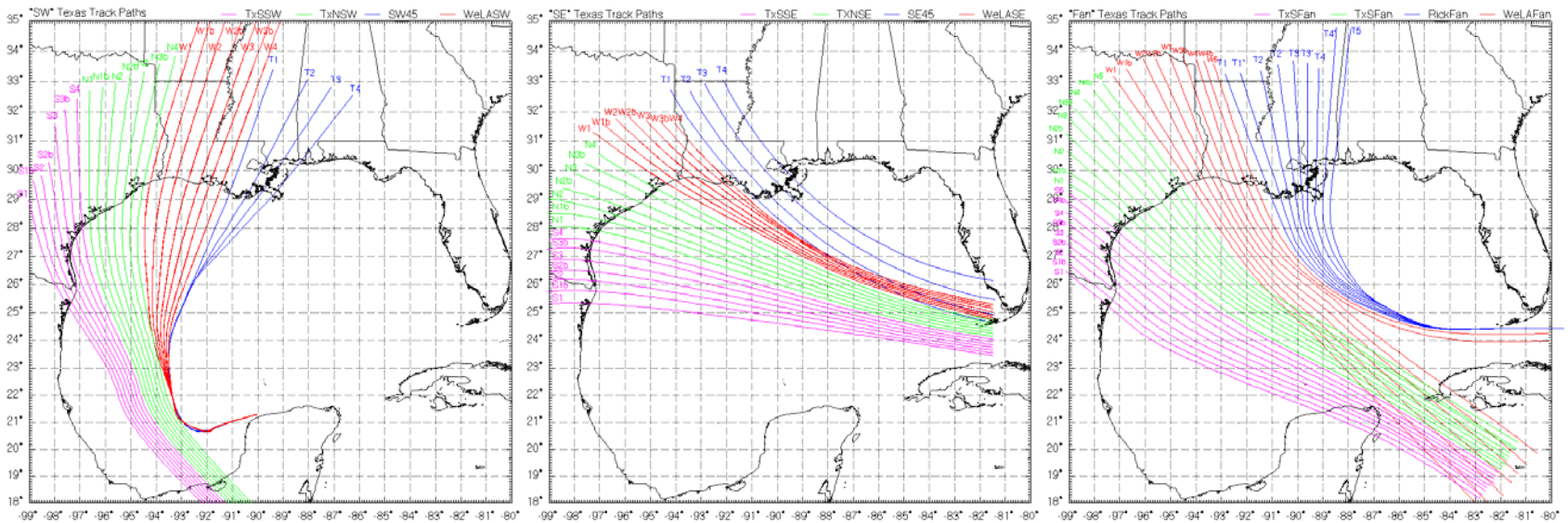
$S(t)$ is the position of the storm along the track at time t,

# Surge Response Surface Determination

## Methodology – Test Surface Development

- ADCIRC:
  - Wind stress
  - Barometric pressure
- Planetary Boundary Layer Model (OWI):
  - Input *Vf, θ*, cp, Rp, track position, …
  - 80 storms simulated





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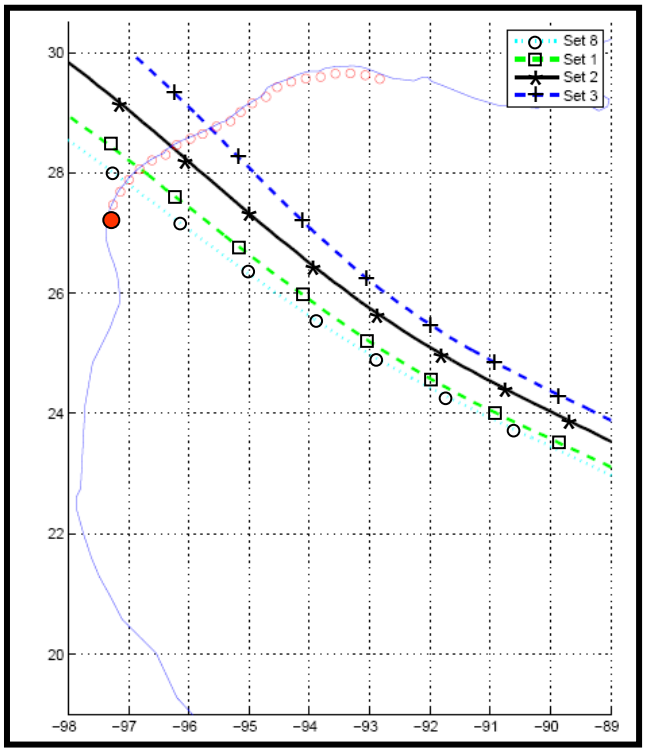


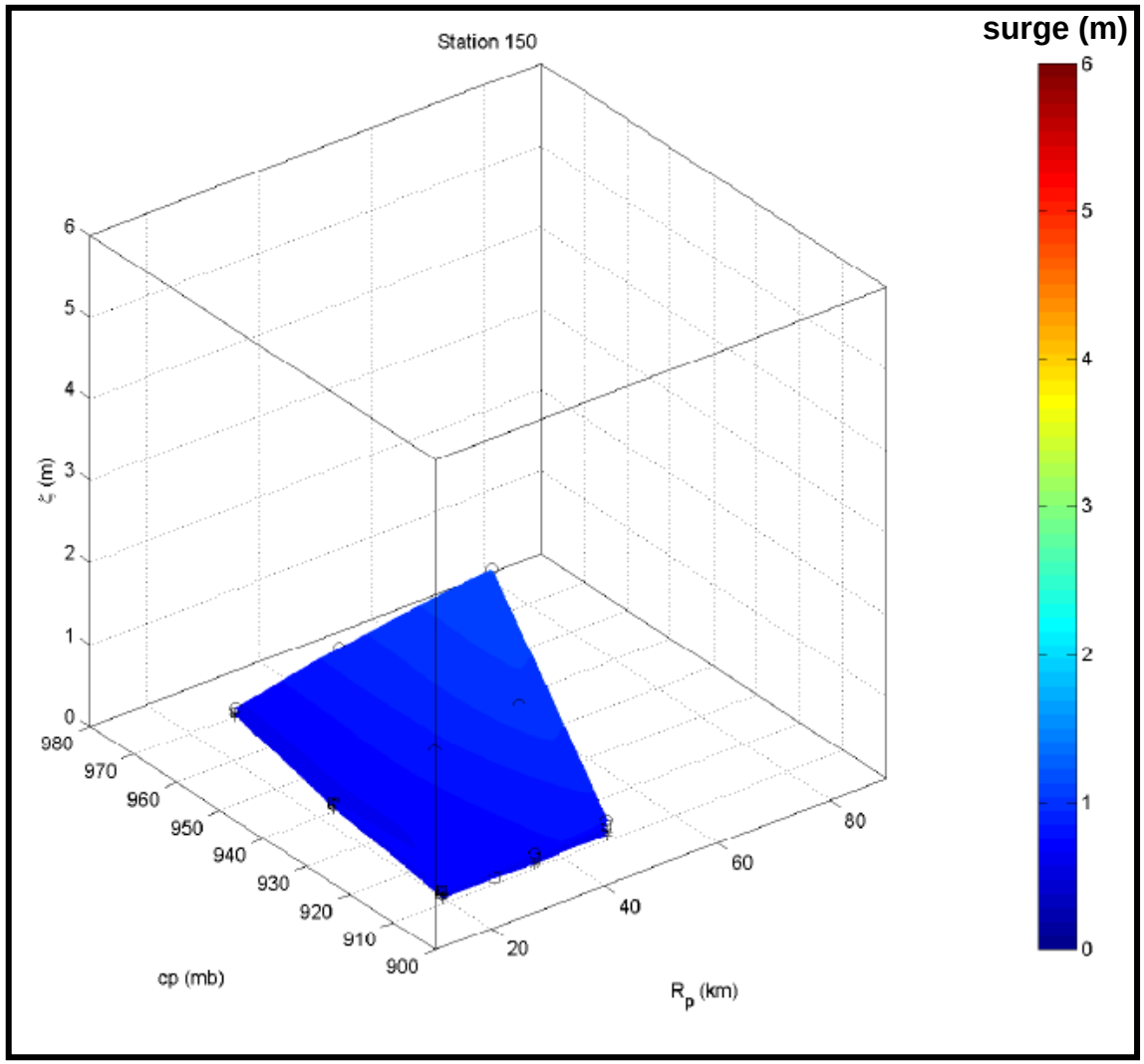

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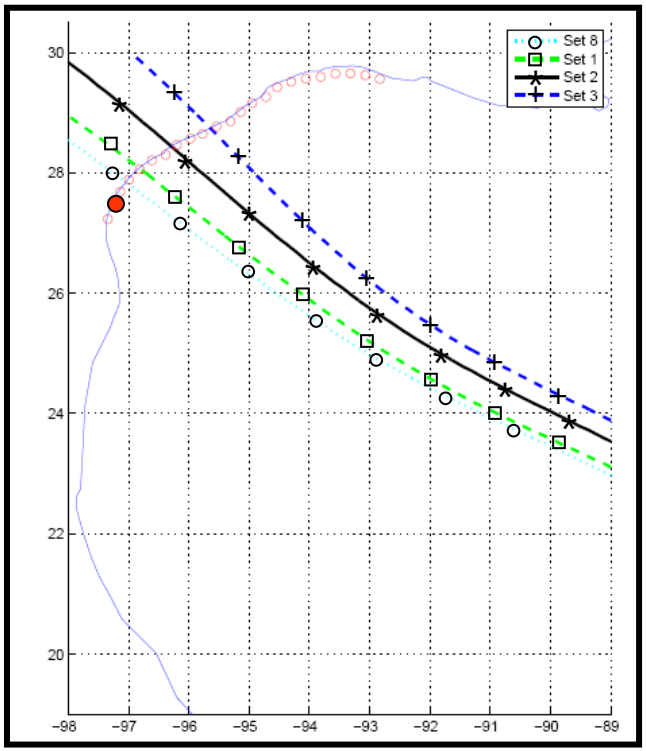


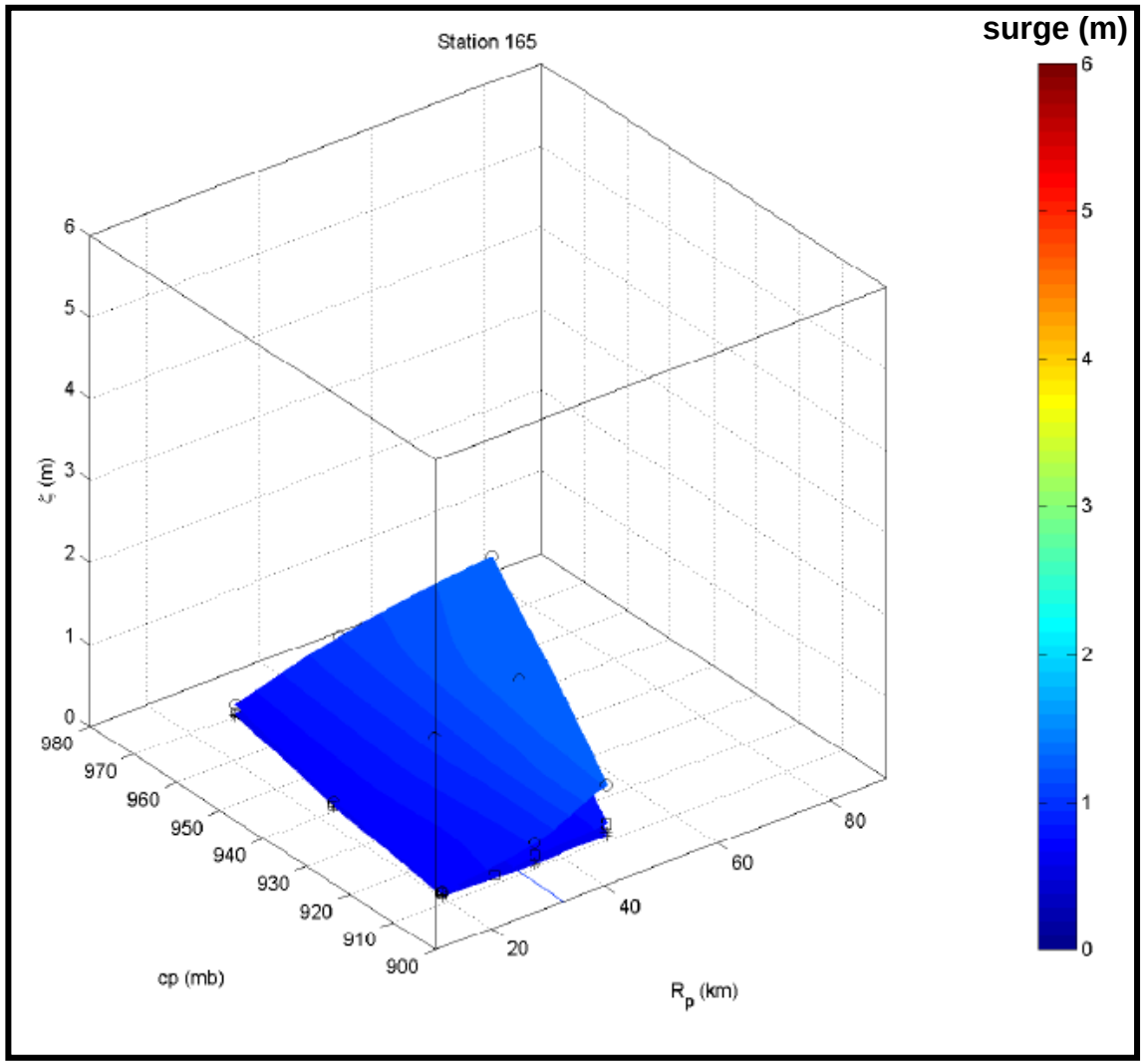

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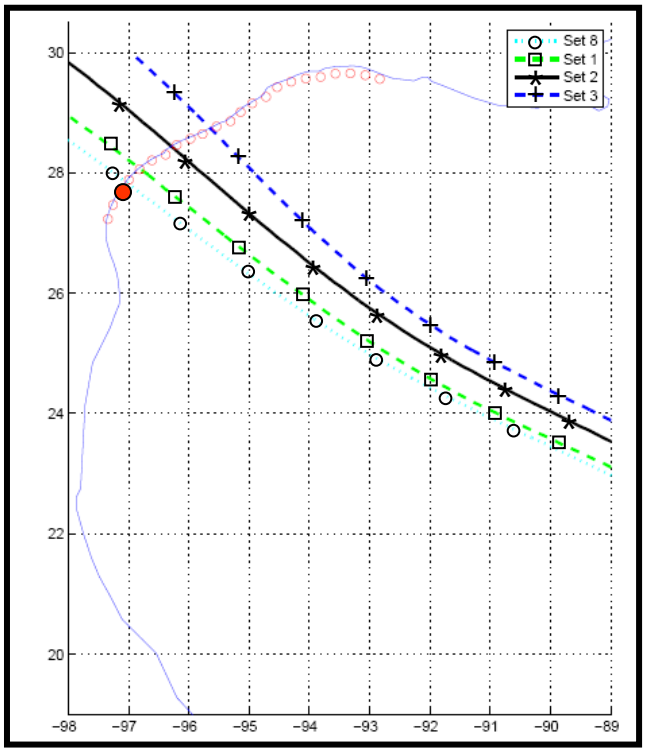


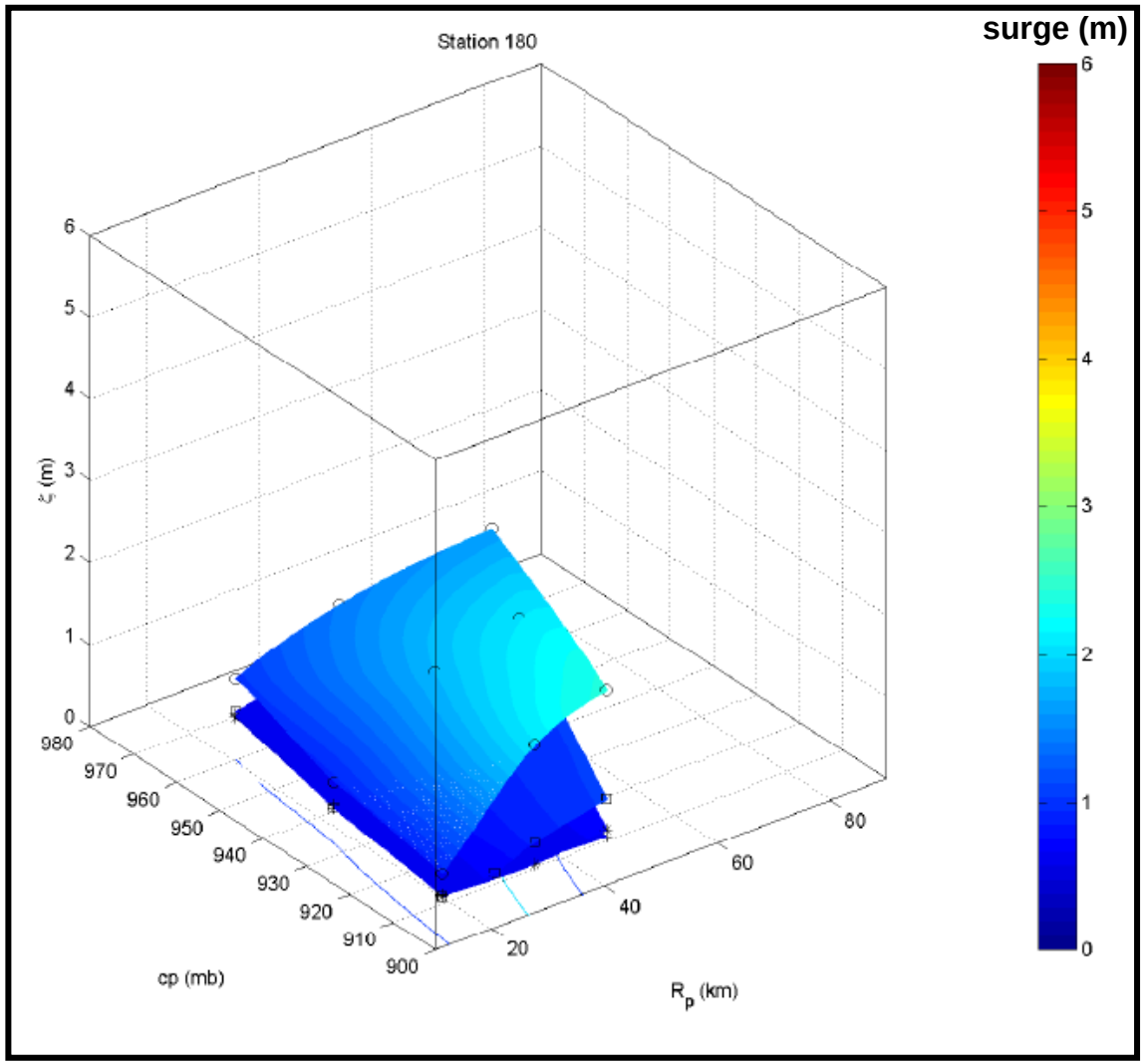

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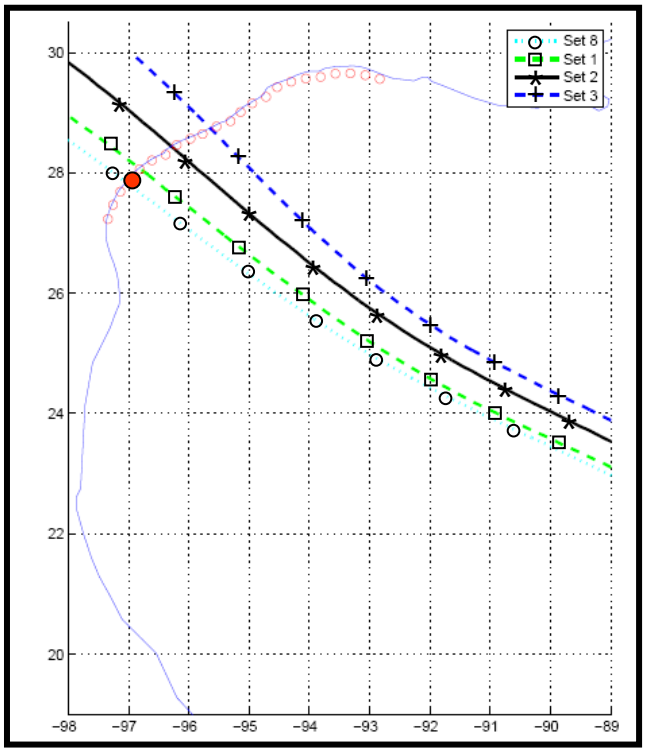


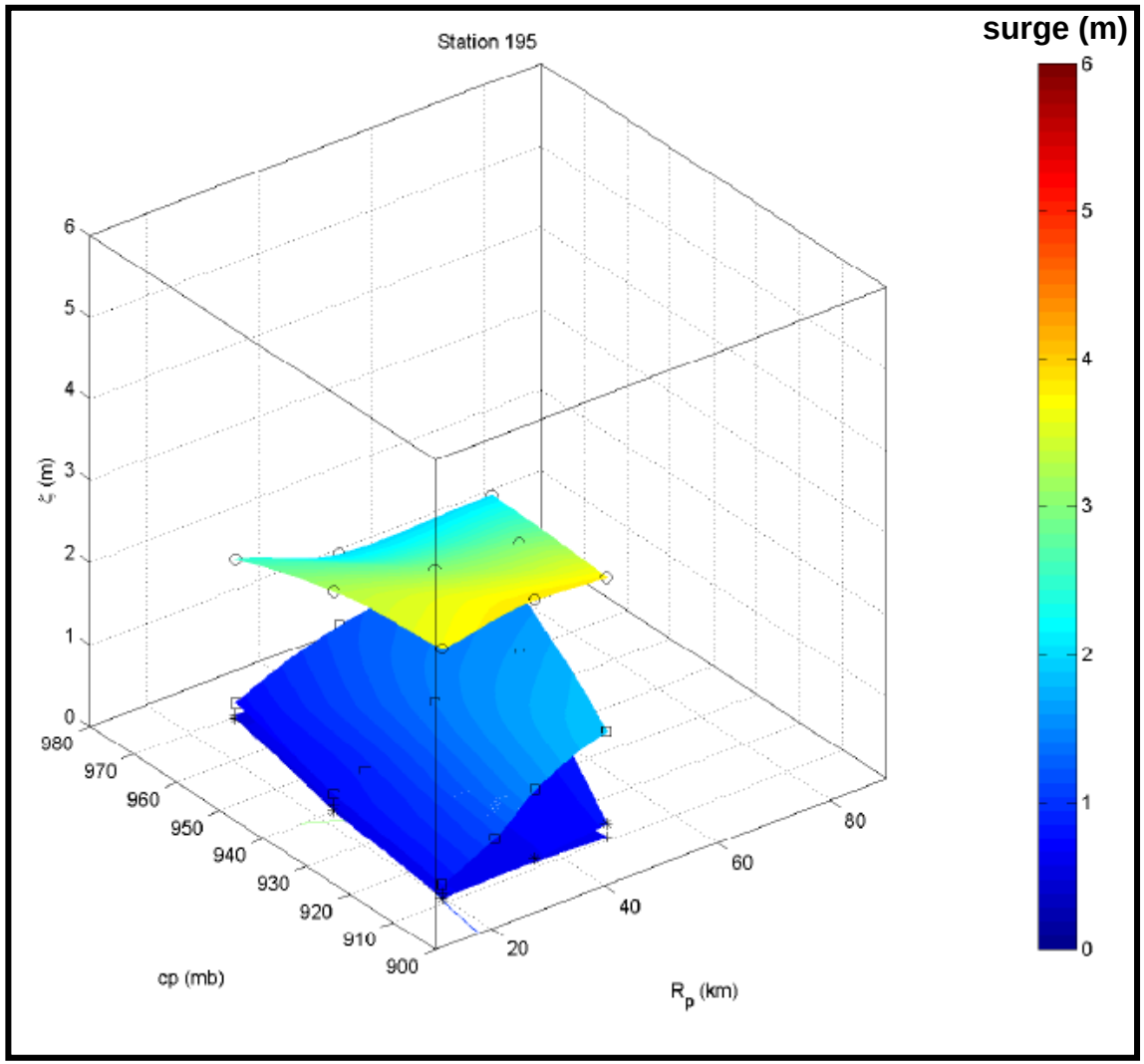

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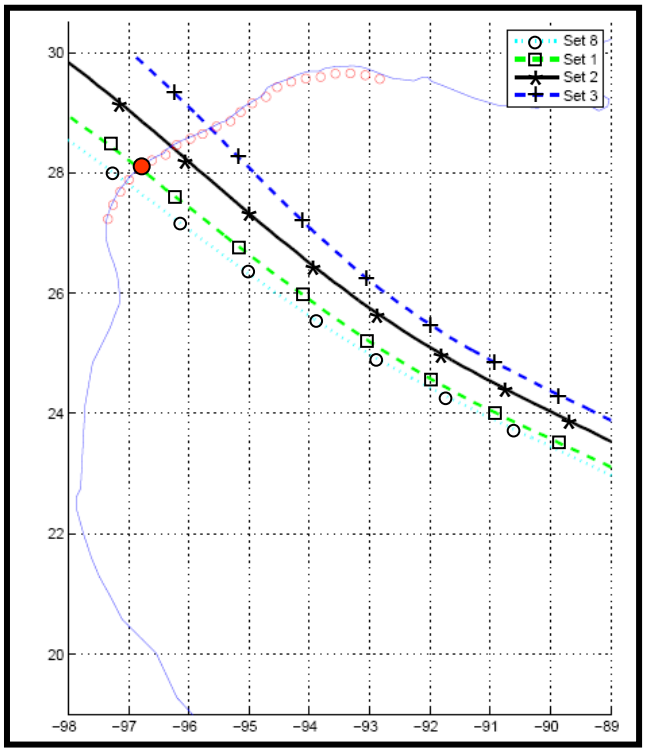


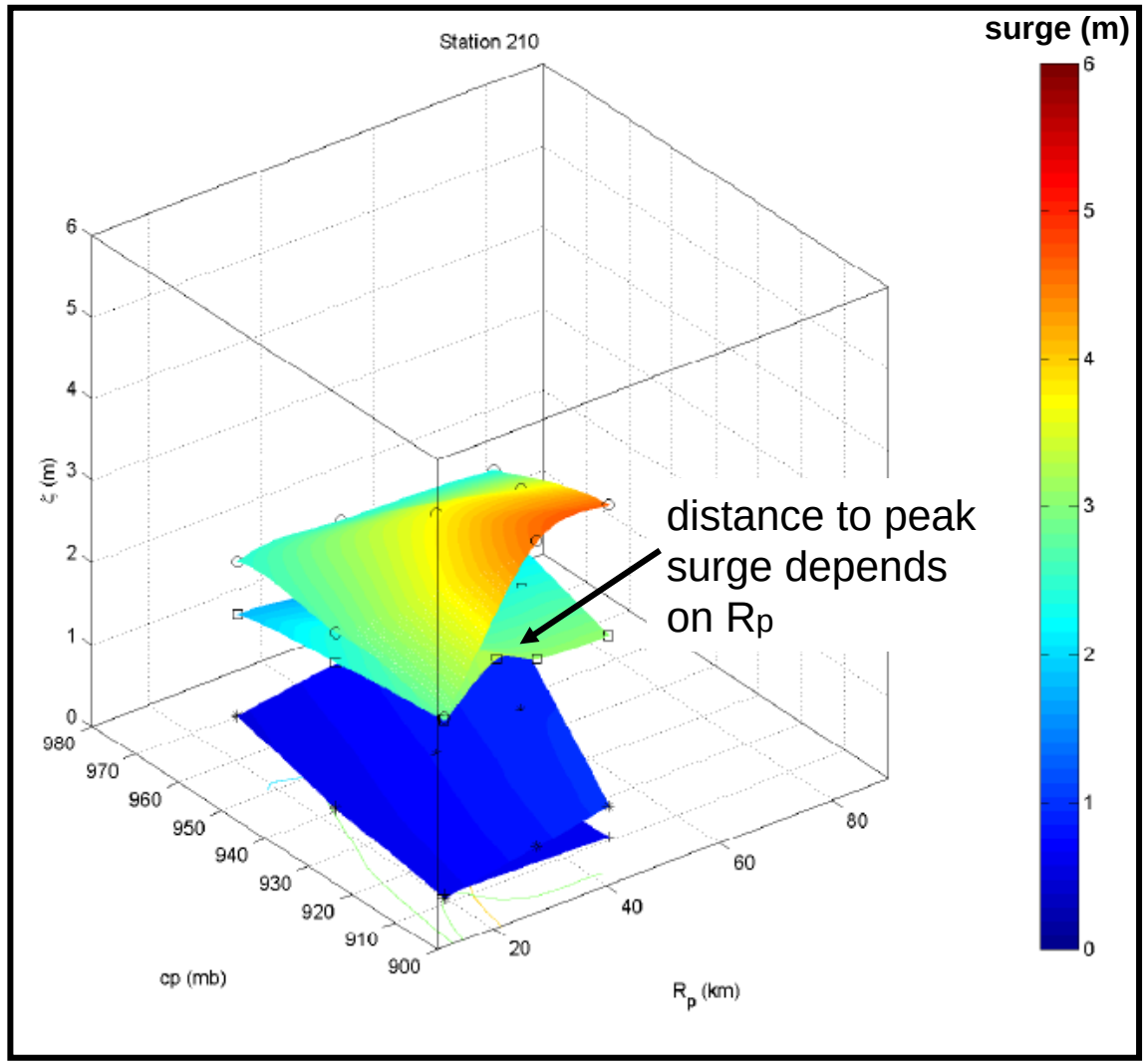

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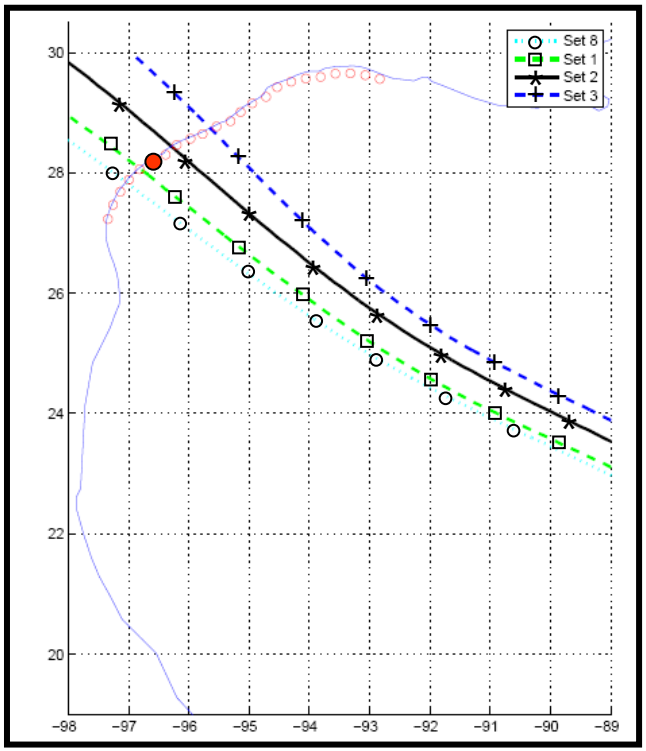


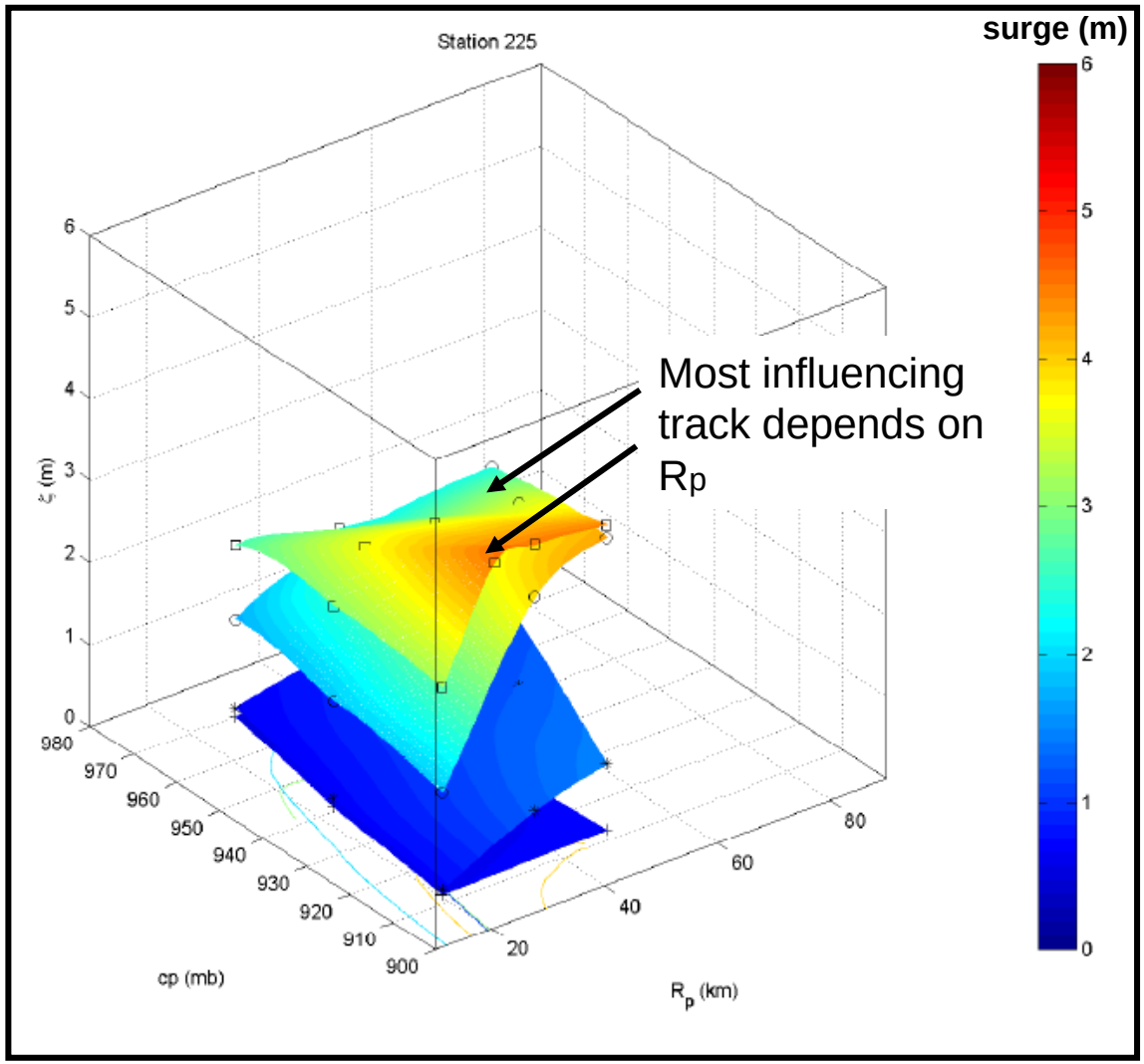

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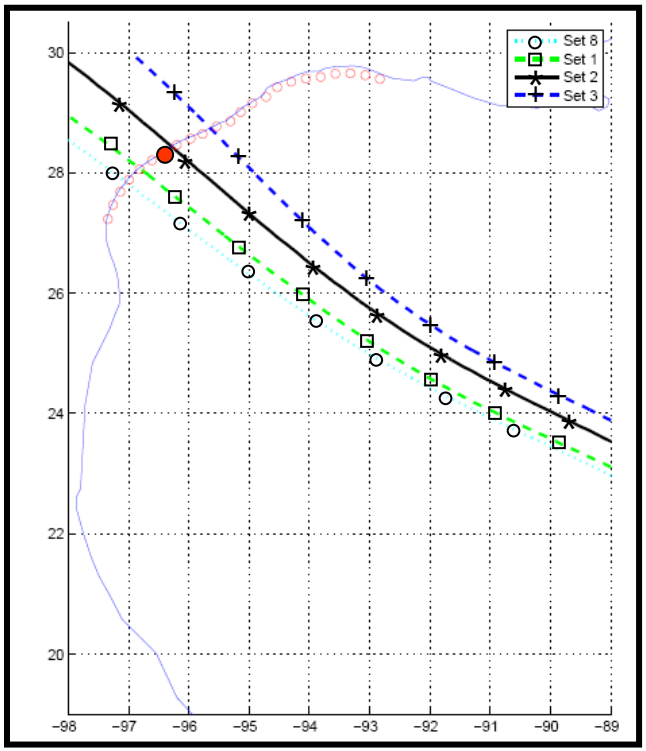


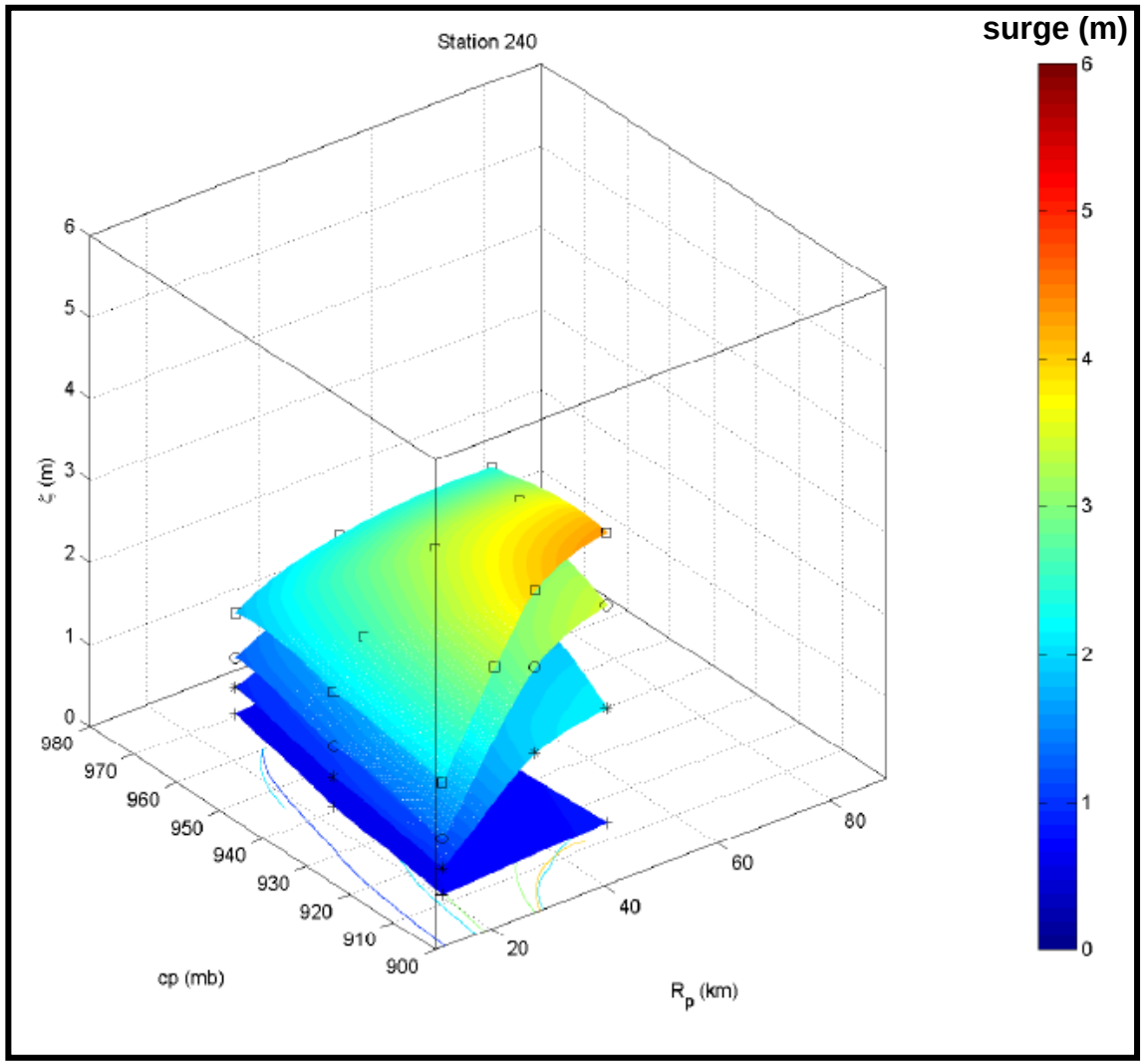

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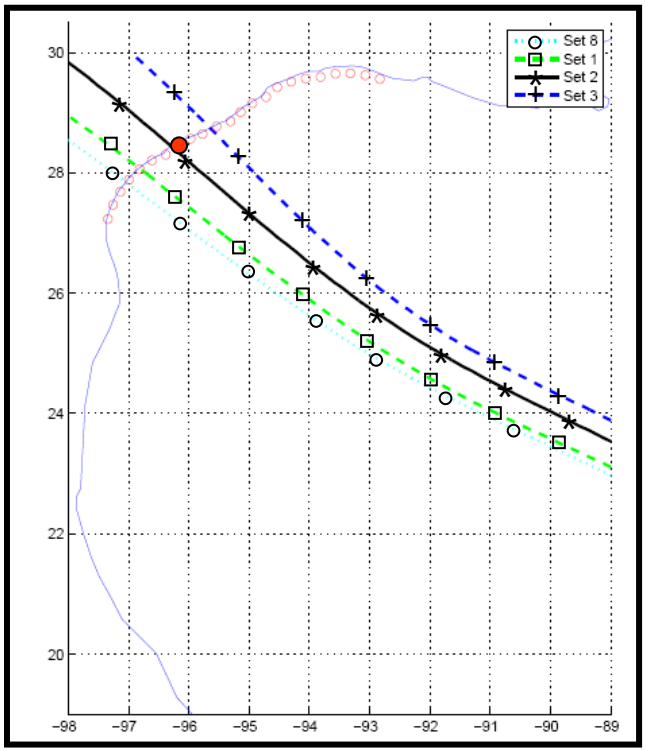


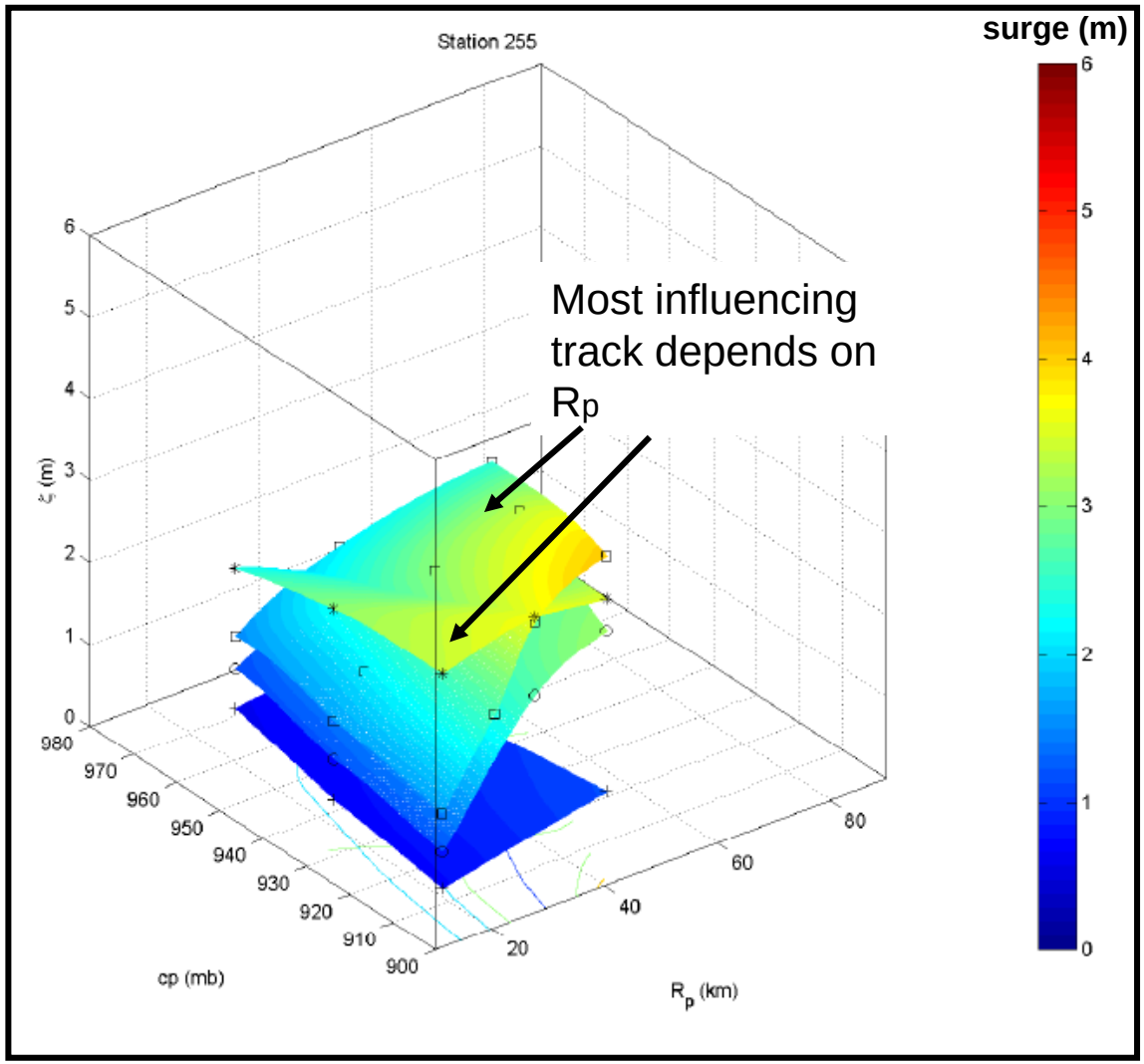

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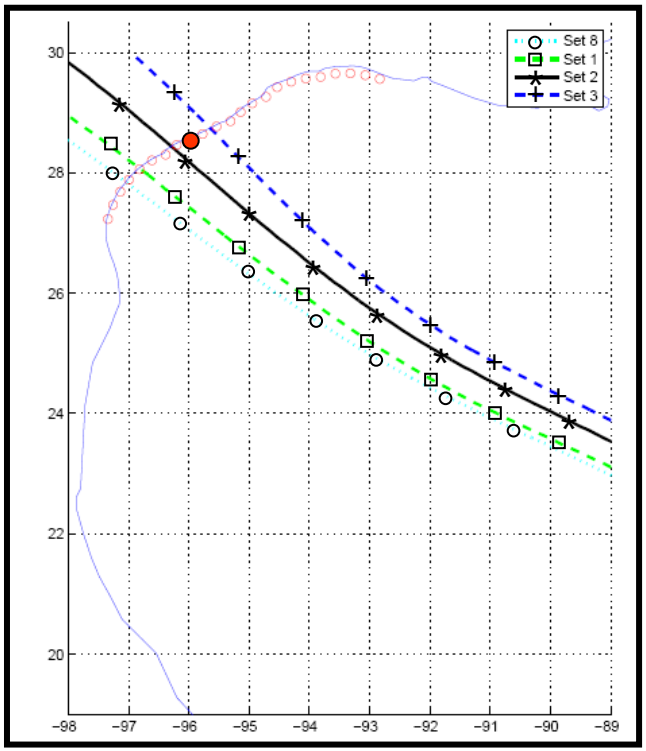


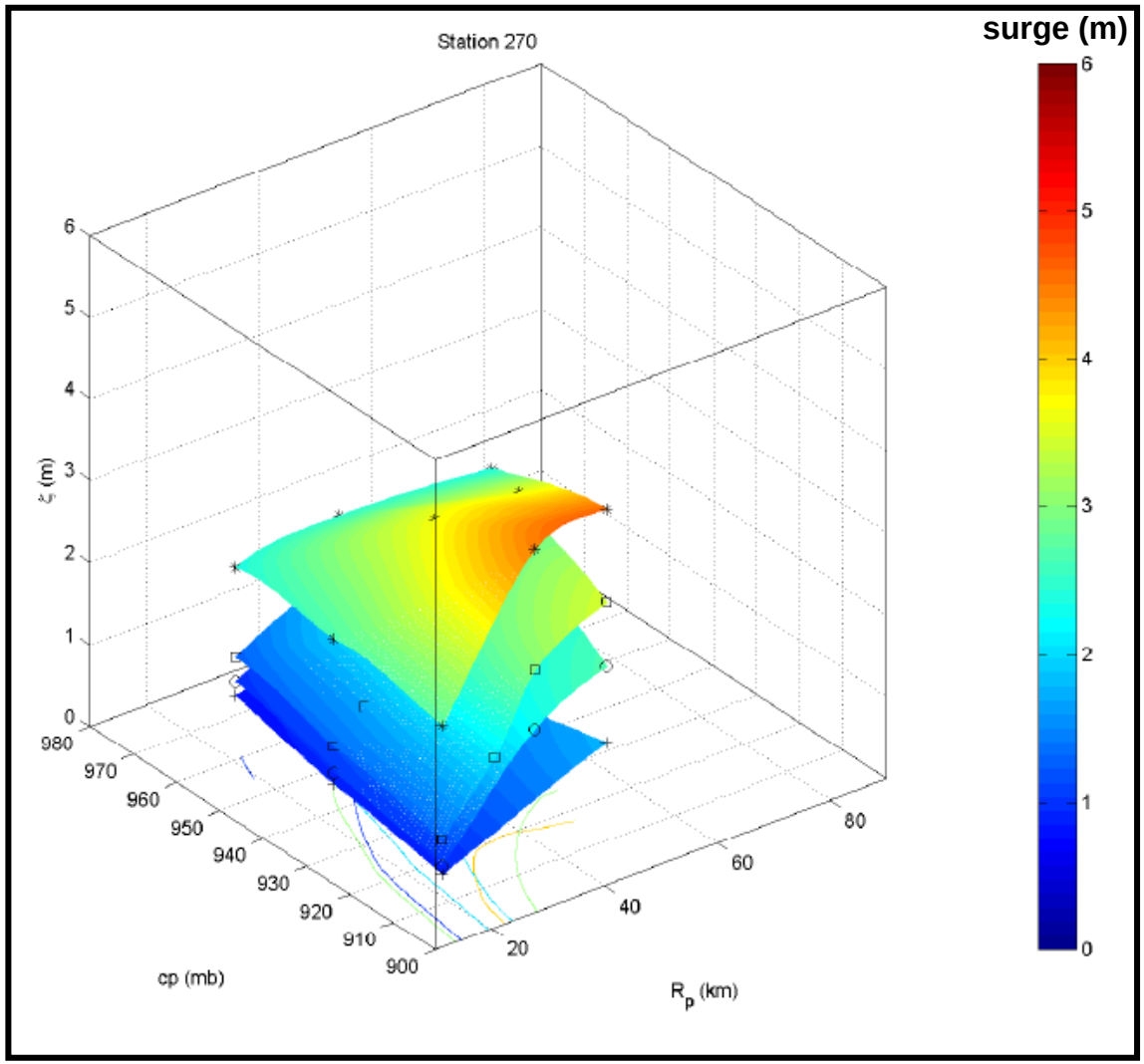

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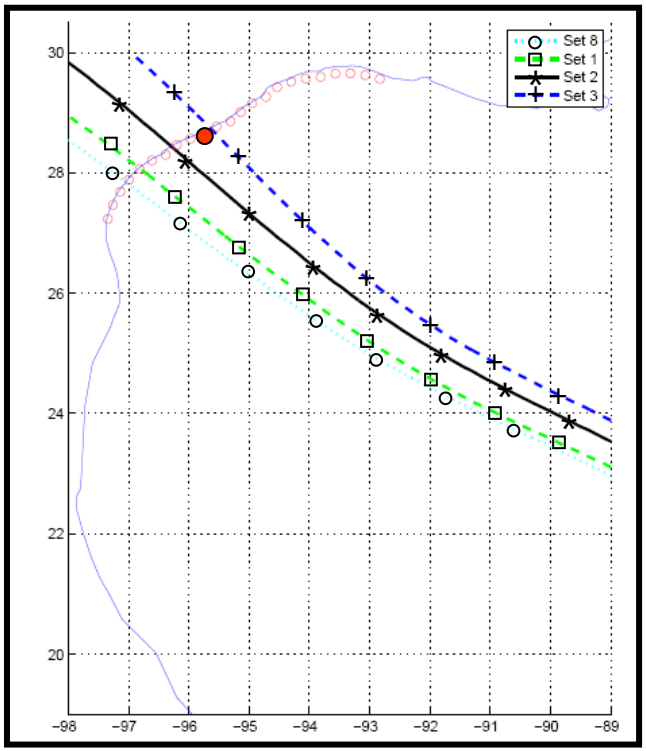


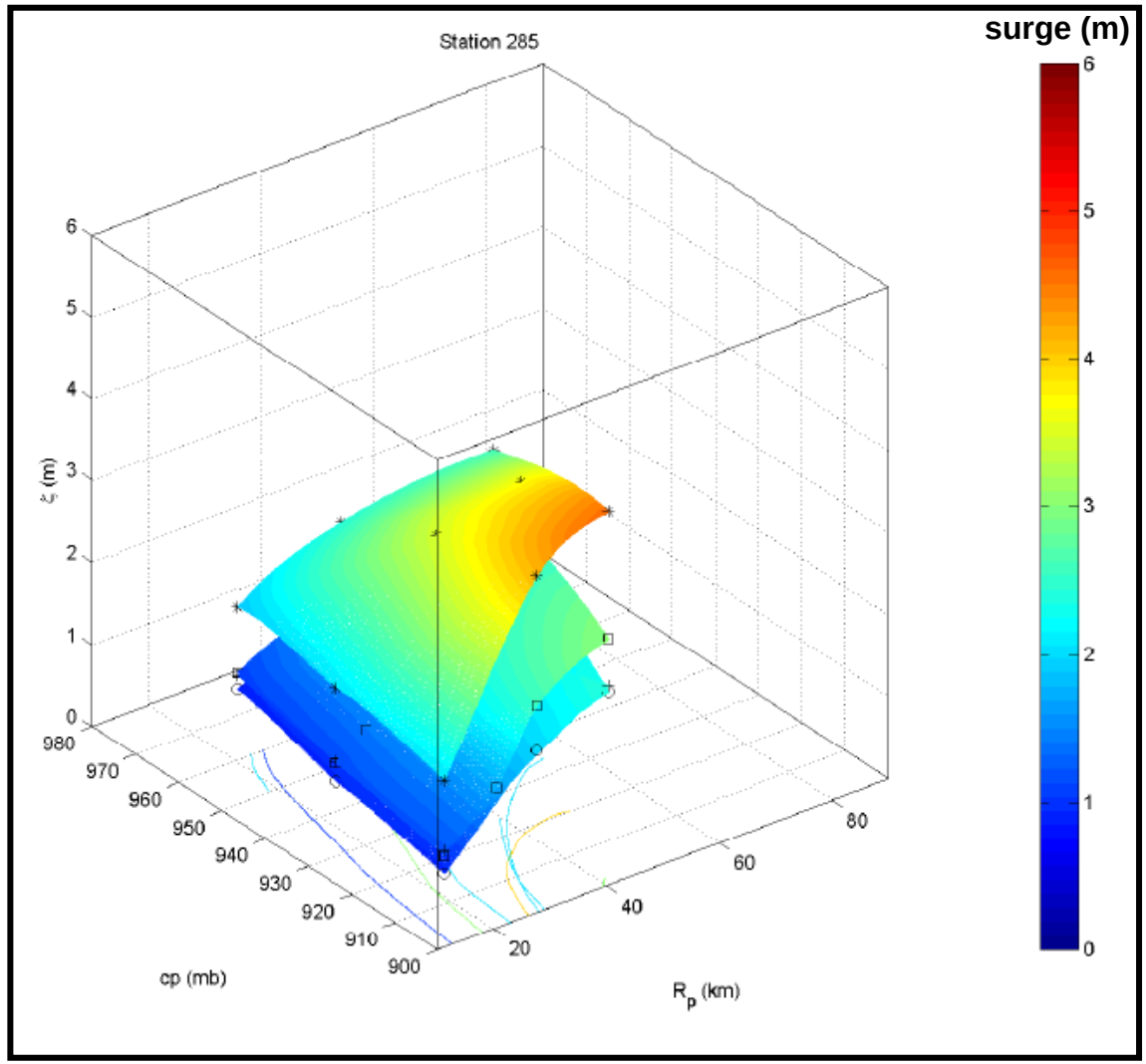

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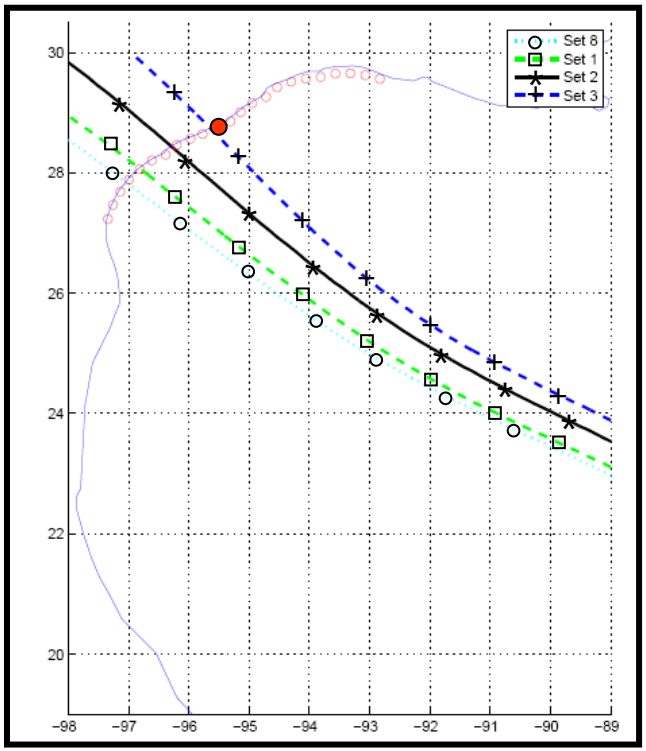


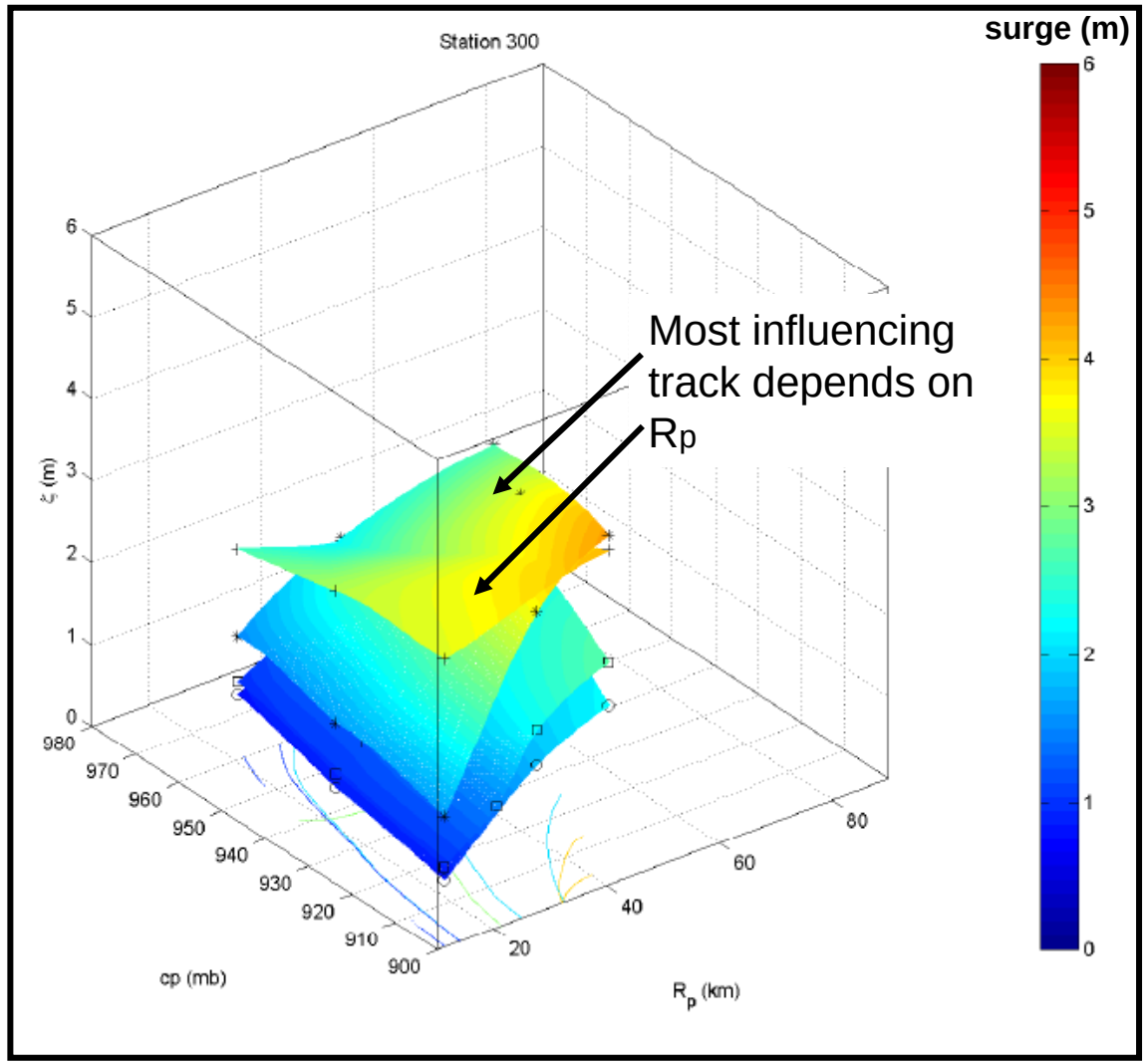

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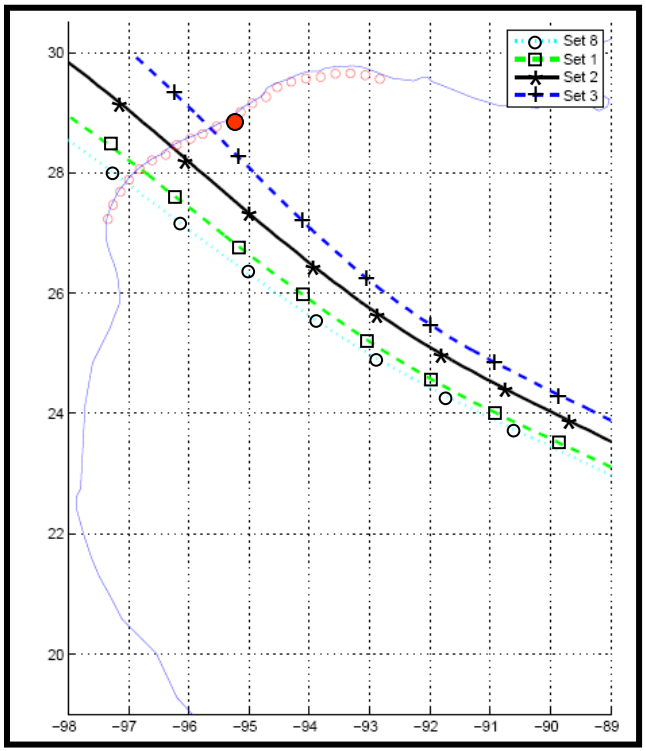


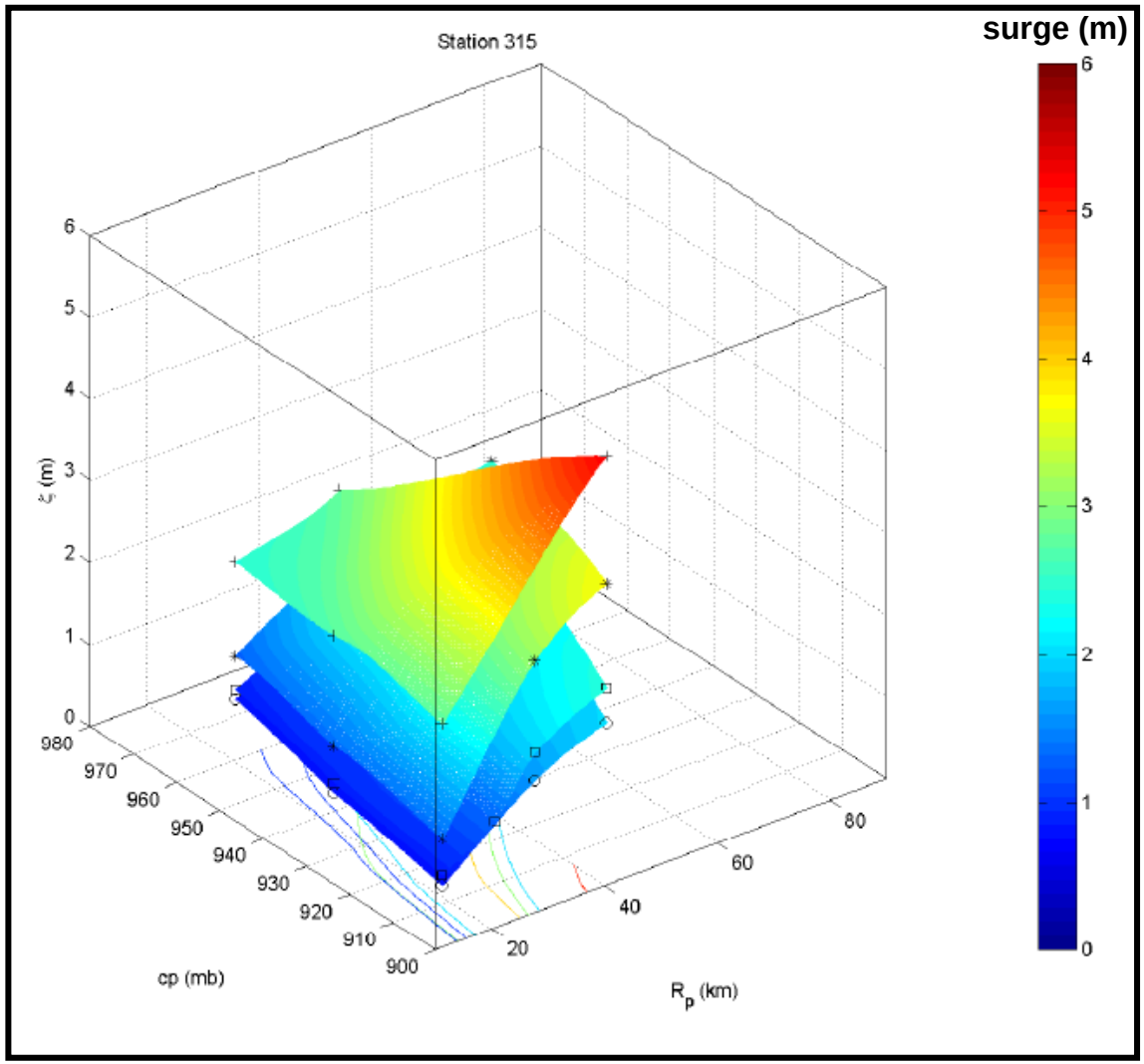

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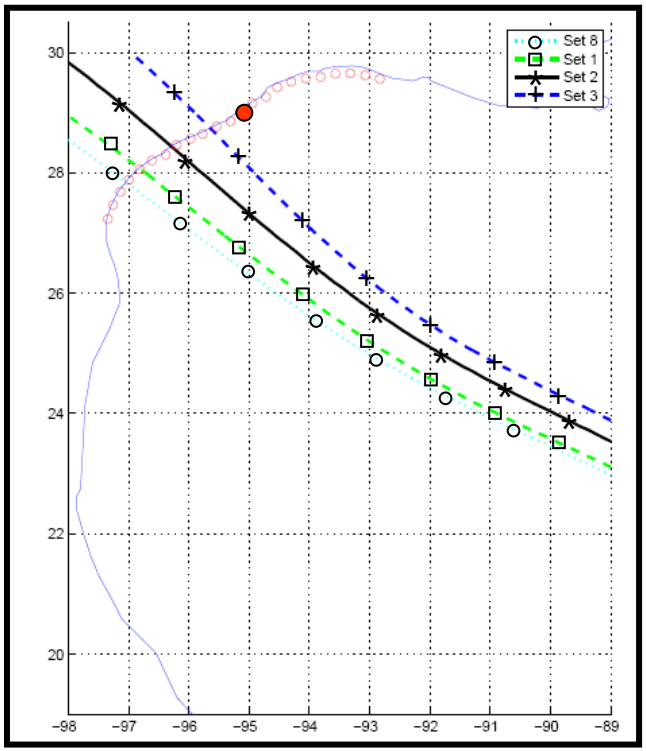


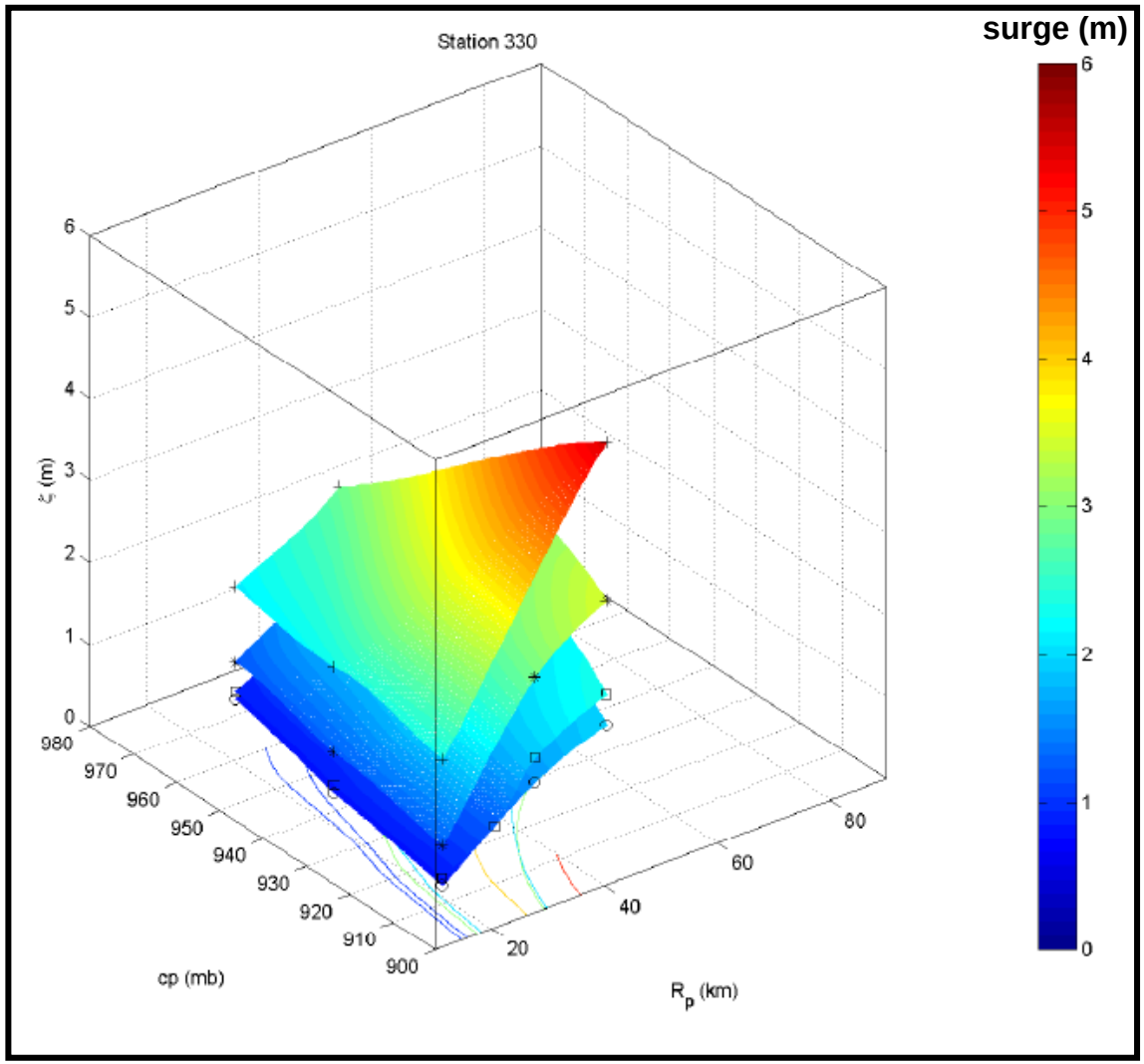

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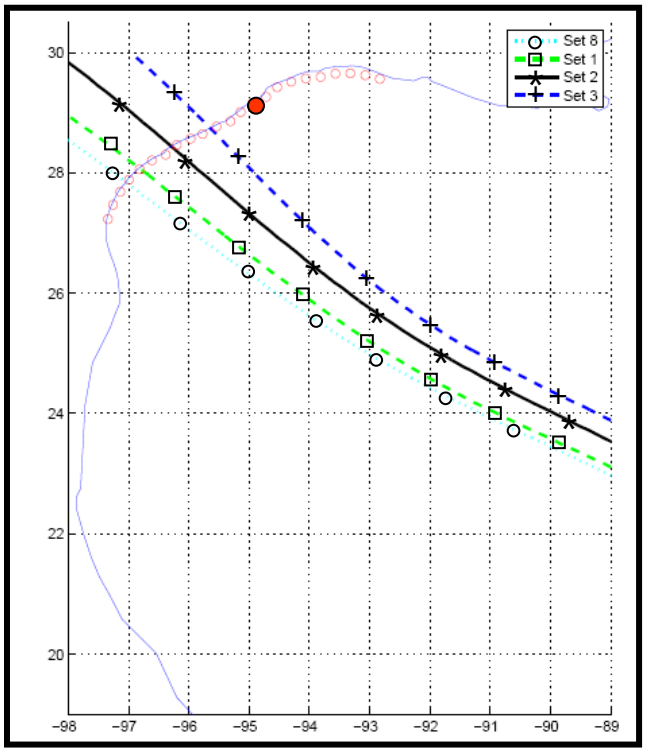


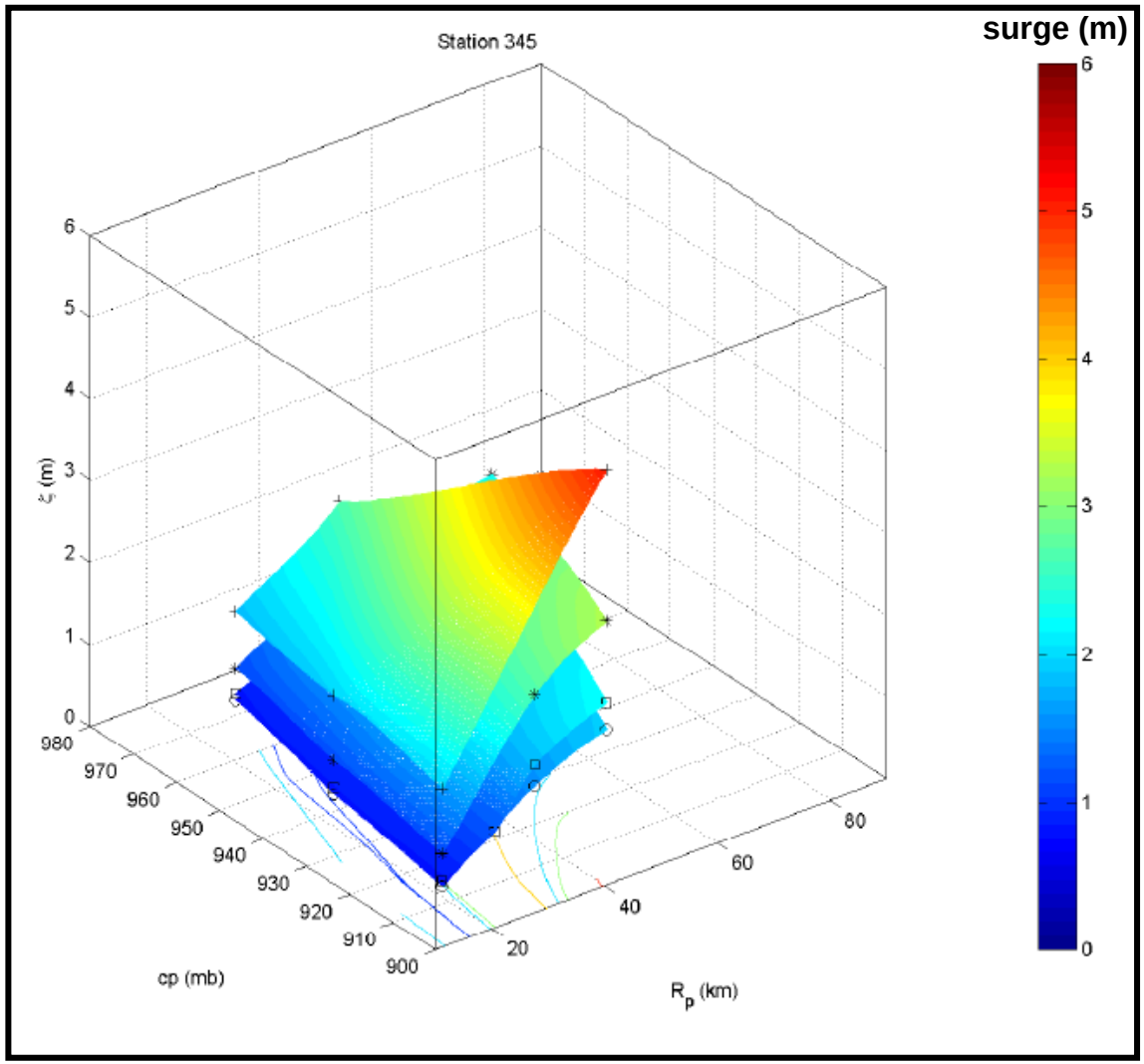

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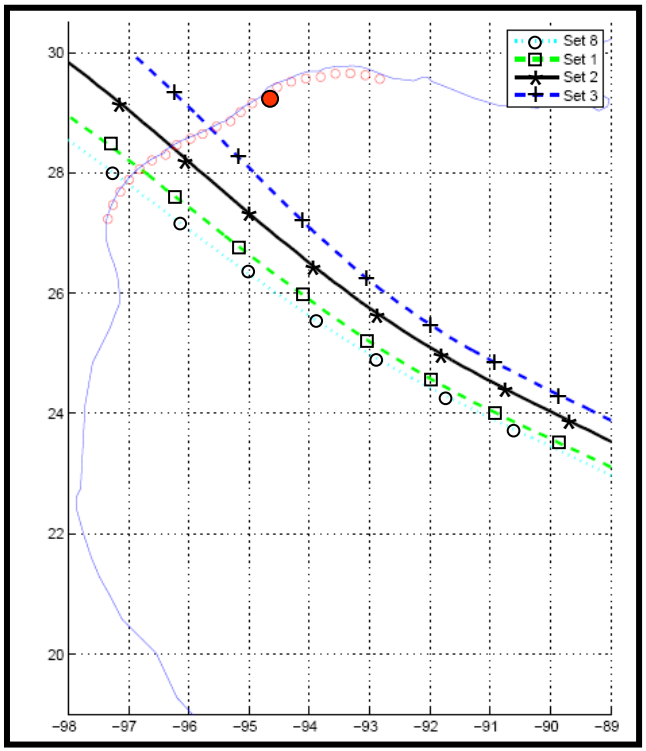


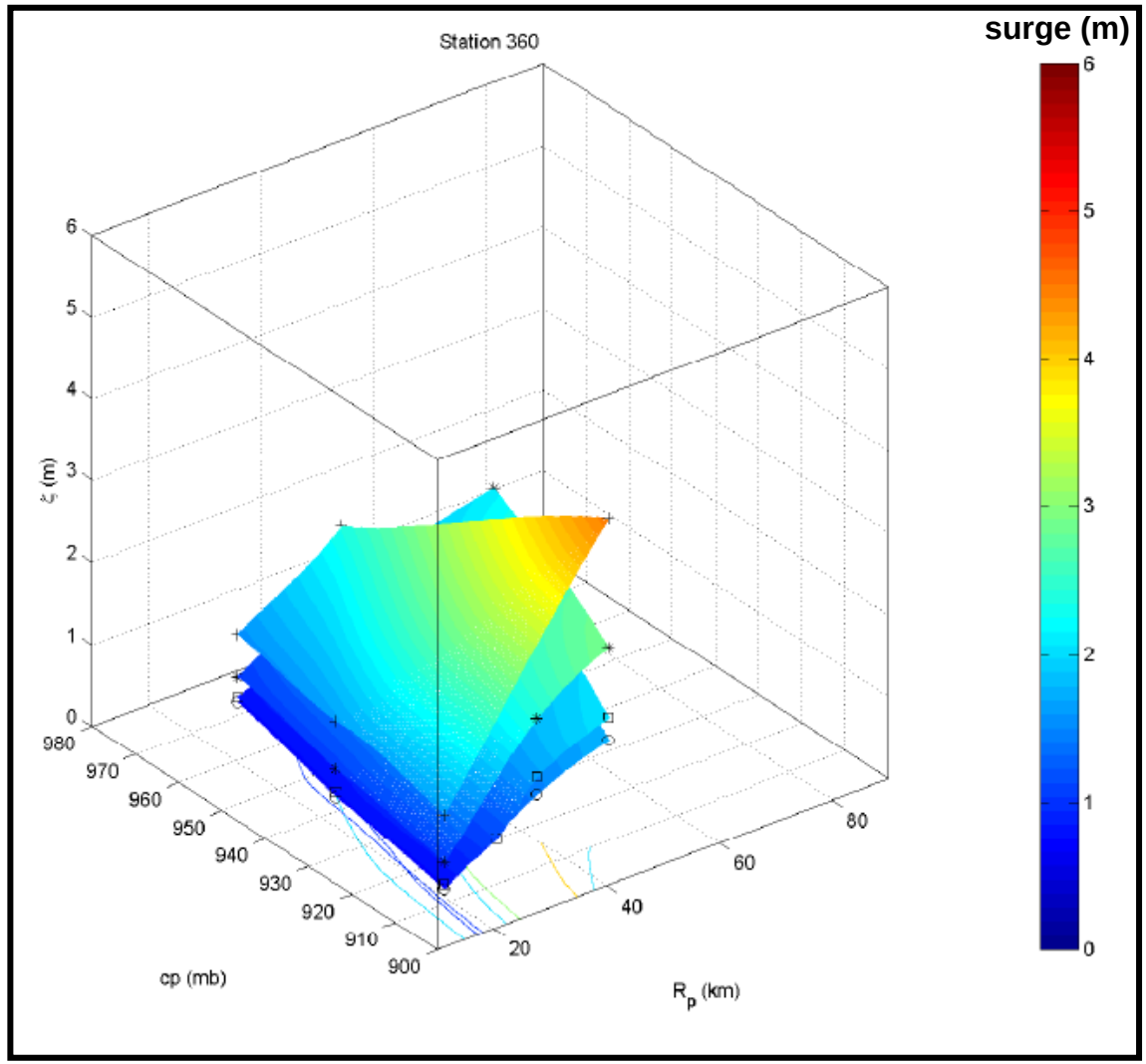

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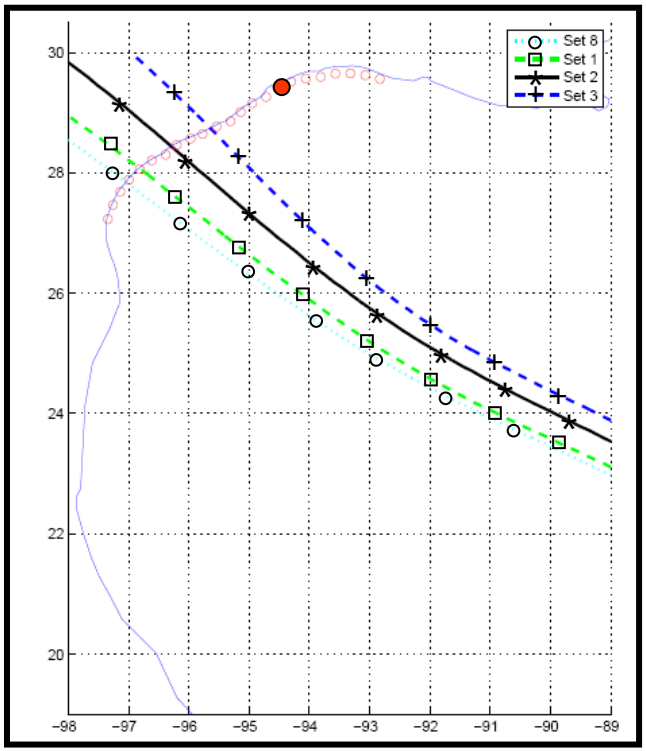


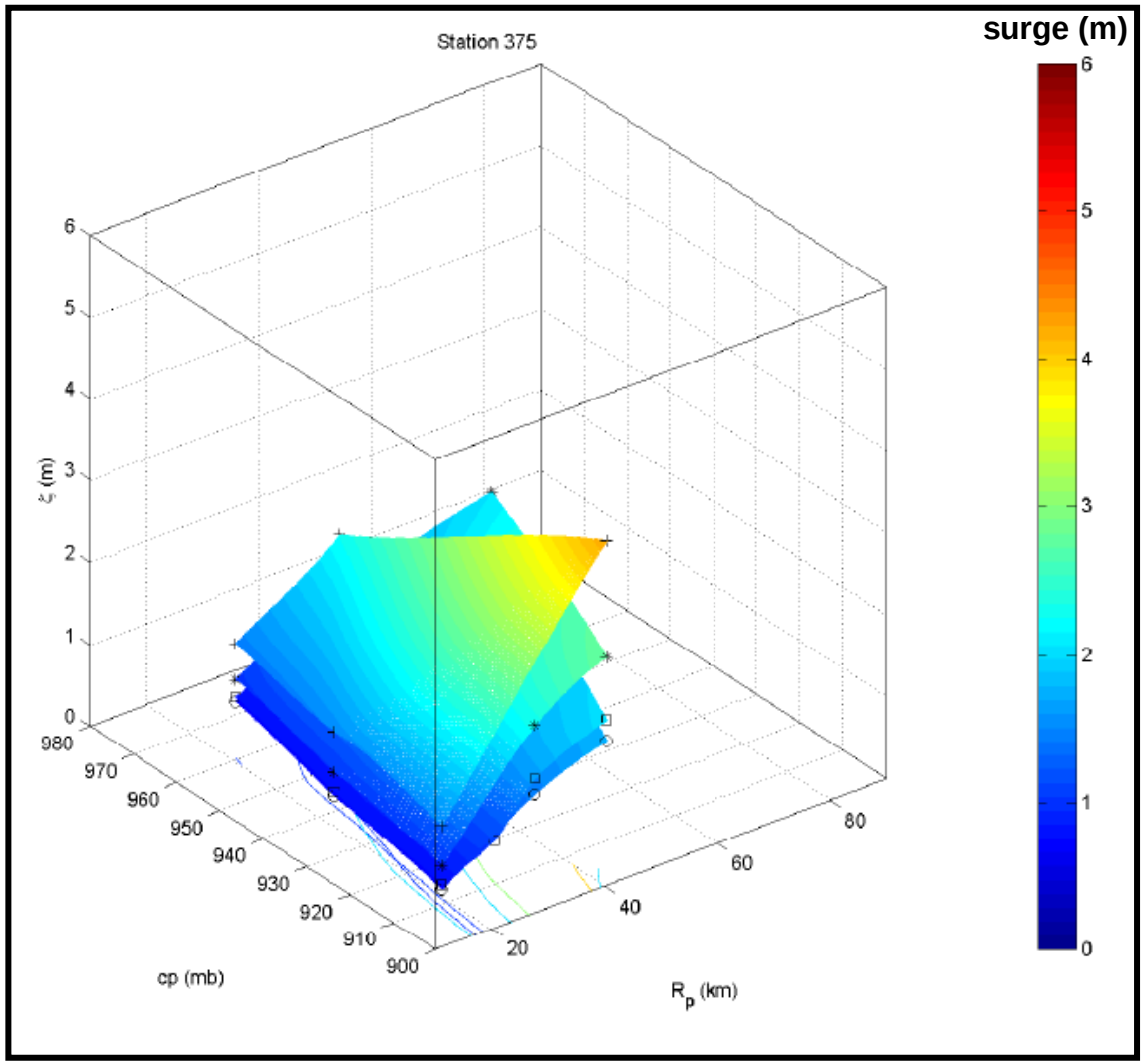

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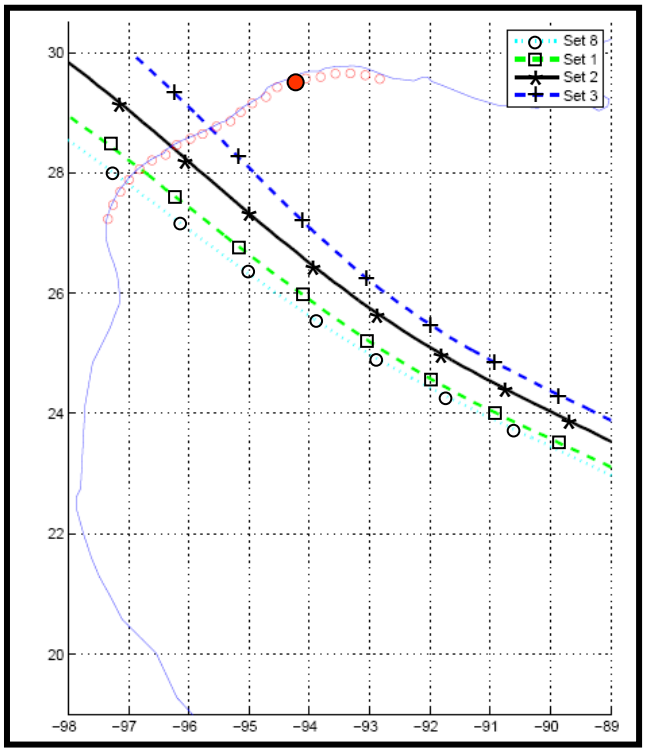
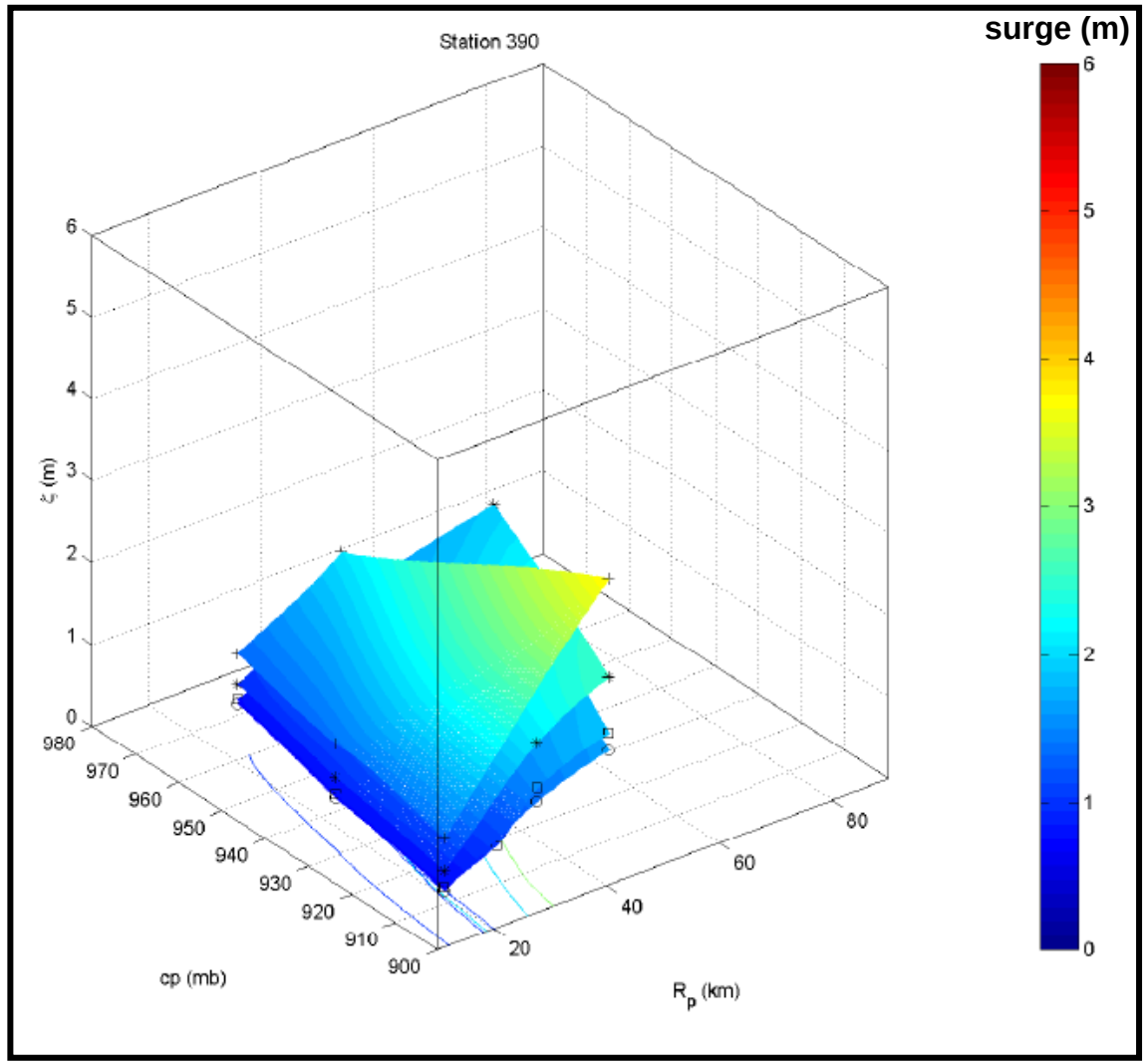


# Surge Response Surface Determination

## Methodology – Open Coast Surface Prediction

- Surge response surface:

$$\zeta(x,t) = \Phi(\underline{G}, \underline{W} \mid c_p, R_{\max}, v_f, \theta, S(t), t)$$

Maximum surge at given ocean location (x) for a given $V_f$ and $\theta$:

- Distance to peak ocean surge from given eye position ($x_o$) scales with Rp:

$$x_{\zeta_{\max}} - x_o = g\left(x_o, R_p\right) \qquad (1)$$

- Peak ocean surge a function of $c_p$, $R_p$, and landfall location (landscape):

$$\zeta_{\max} = q\left(x_o, \left[c_p, R_p\right]\right) \qquad (2)$$

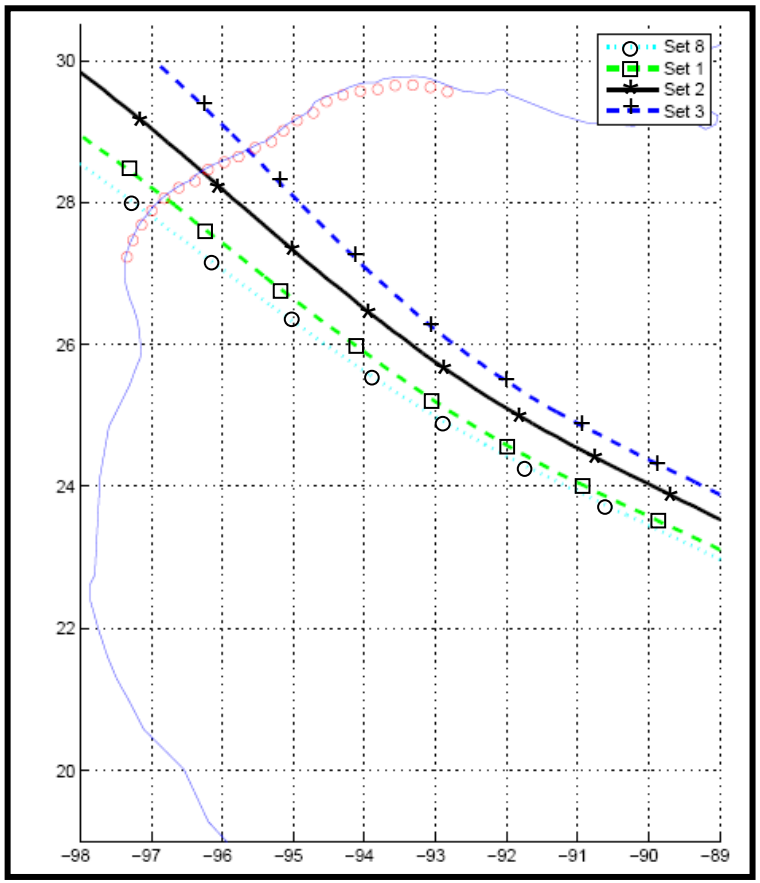
- Shape of alongshore surge distribution scales with $R_p$:

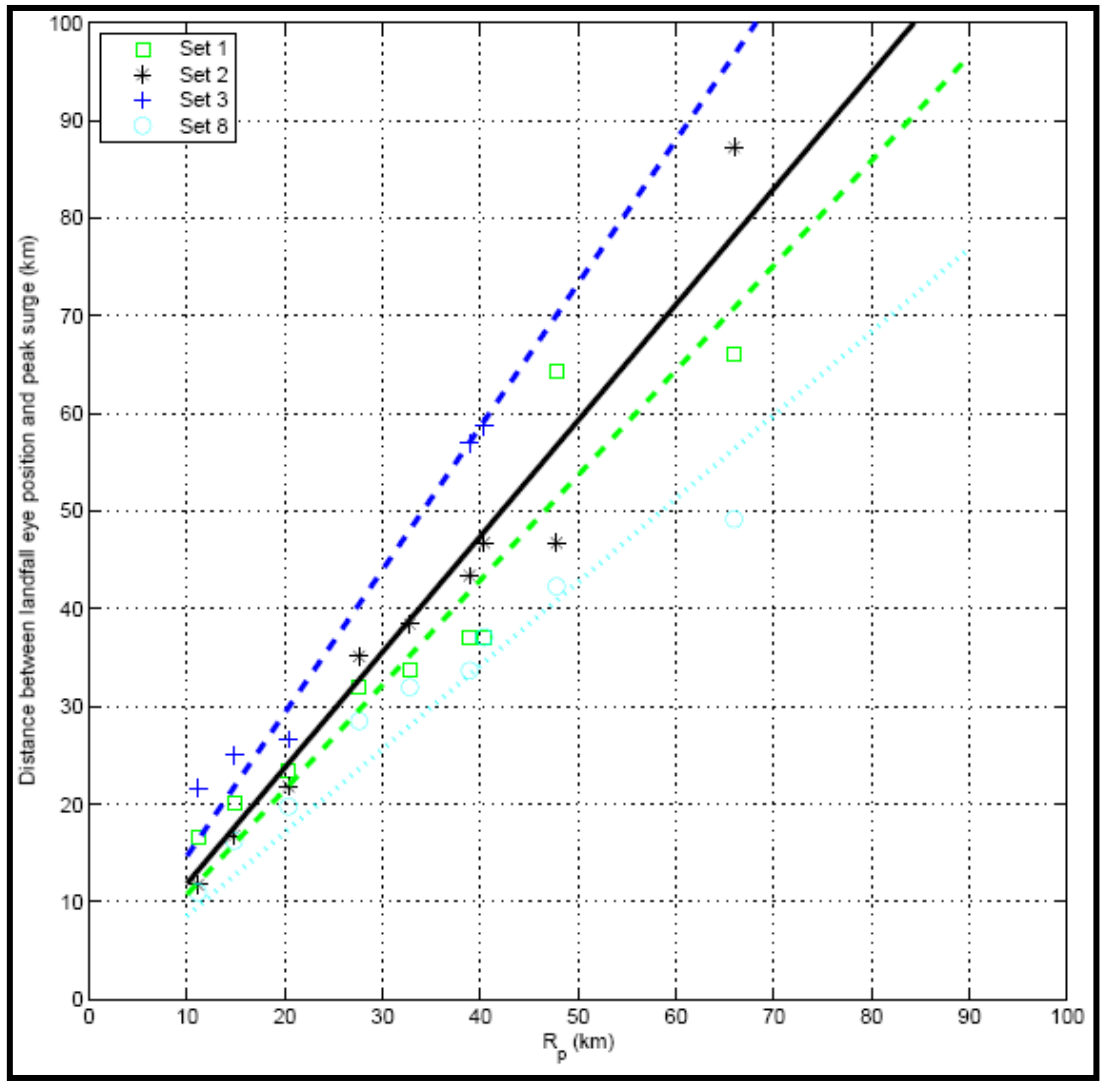
$$\frac{\zeta_{x'}}{\zeta_{\max}} = f\left(x_o, \frac{x'}{R_p}\right) \qquad \text{where: } x' \equiv x - x_{\zeta_{\max}} \qquad (3)$$

# Surge Response Surface Determination

## Methodology – Open Coast Surface Prediction

(1) $$x_{\zeta_{\max}} - x_o = g\left(x_o, R_p\right) \cong m_{x_o} R_p$$

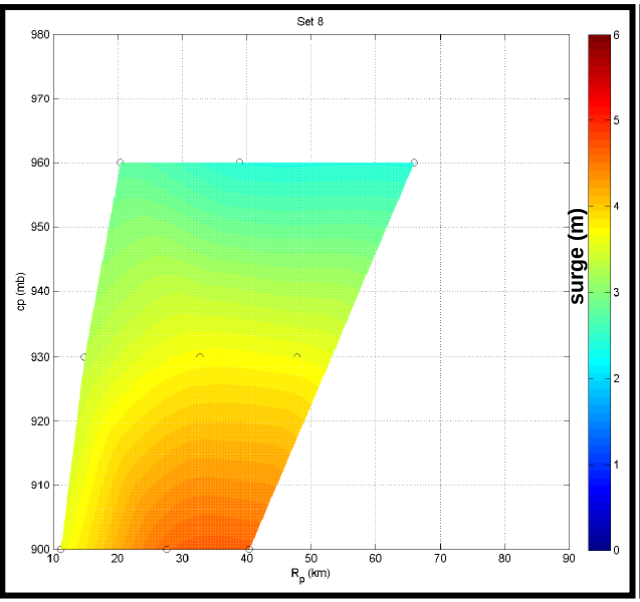


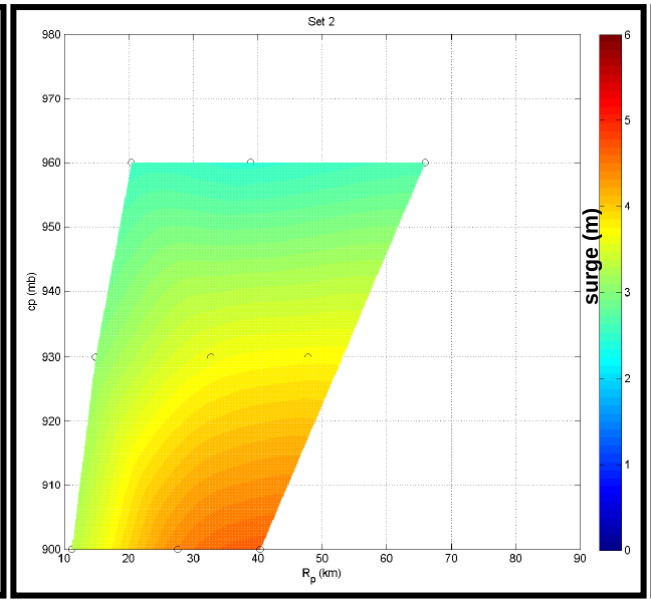



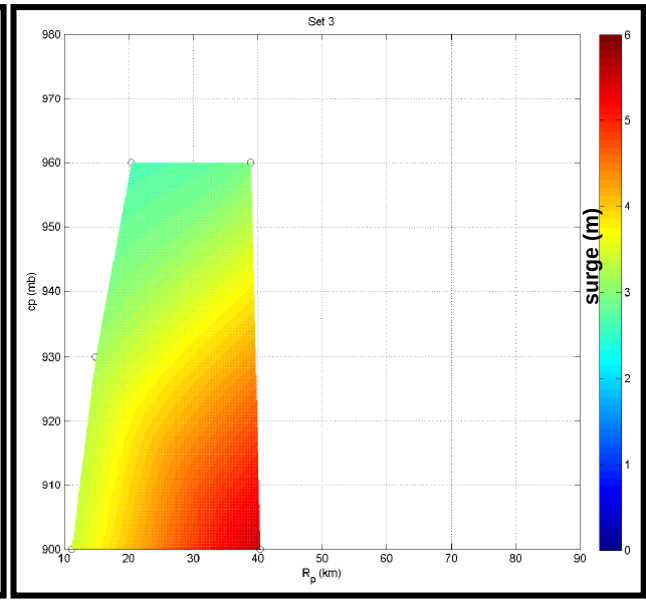
# Surge Response Surface Determination

## Methodology – Open Coast Surface Prediction

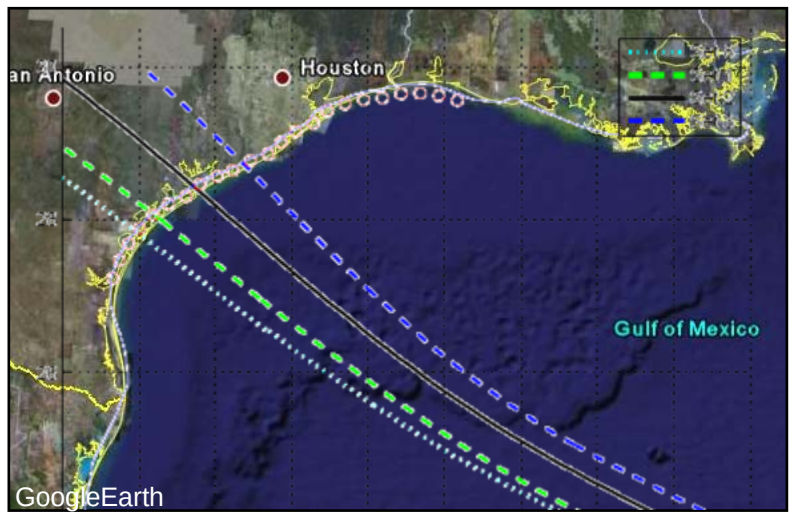
(2) $\zeta_{\max} = q\left(x_o, \left[c_p, R_p\right]\right)$



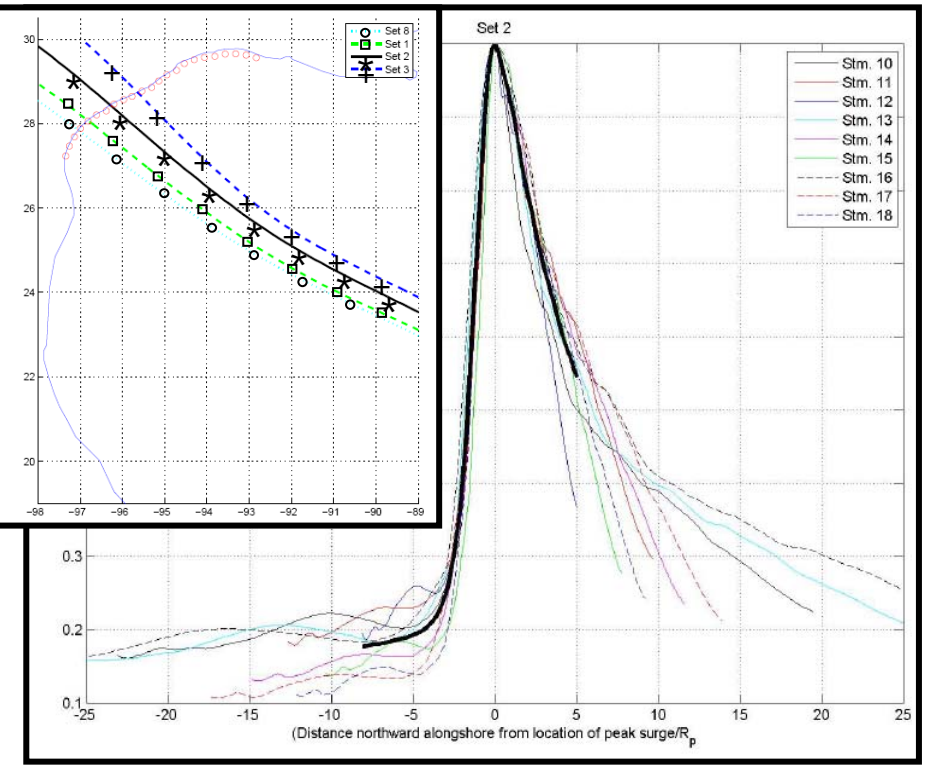

- Regional geometry important:
  - Shelf slope
  - Shoreline shape
    - .
    - .
    - .

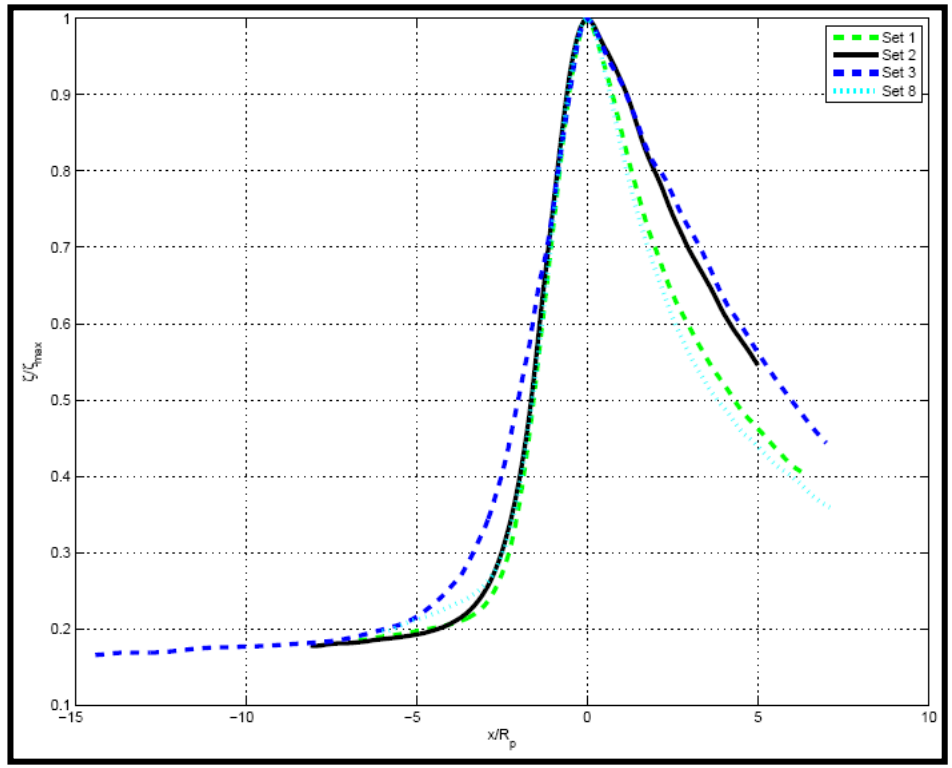


# Surge Response Surface Determination

## Methodology – Open Coast Surface Prediction

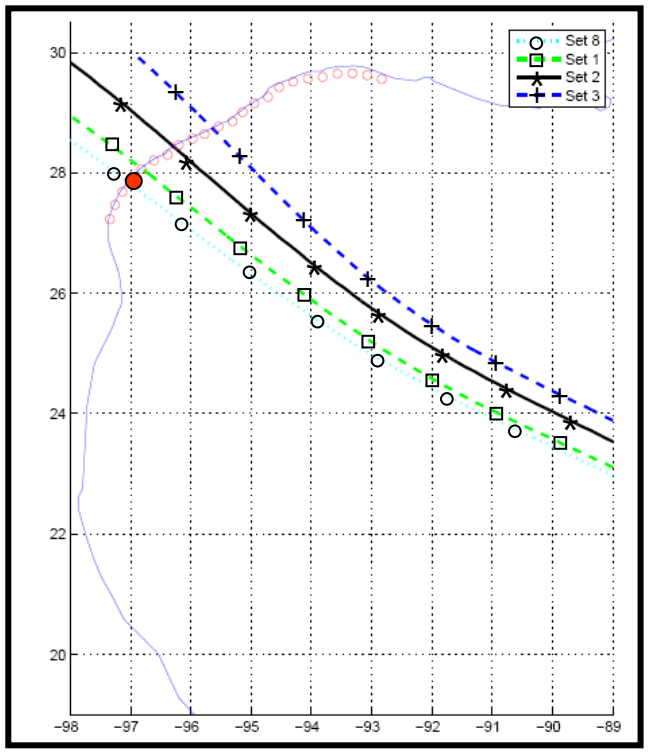
$$(3)\quad \frac{\zeta_{x'}}{\zeta_{\max}} = f\left(x_o, \frac{x'}{R_p}\right) \qquad \text{where:} \quad x' \equiv x - x_{\zeta_{\max}}$$



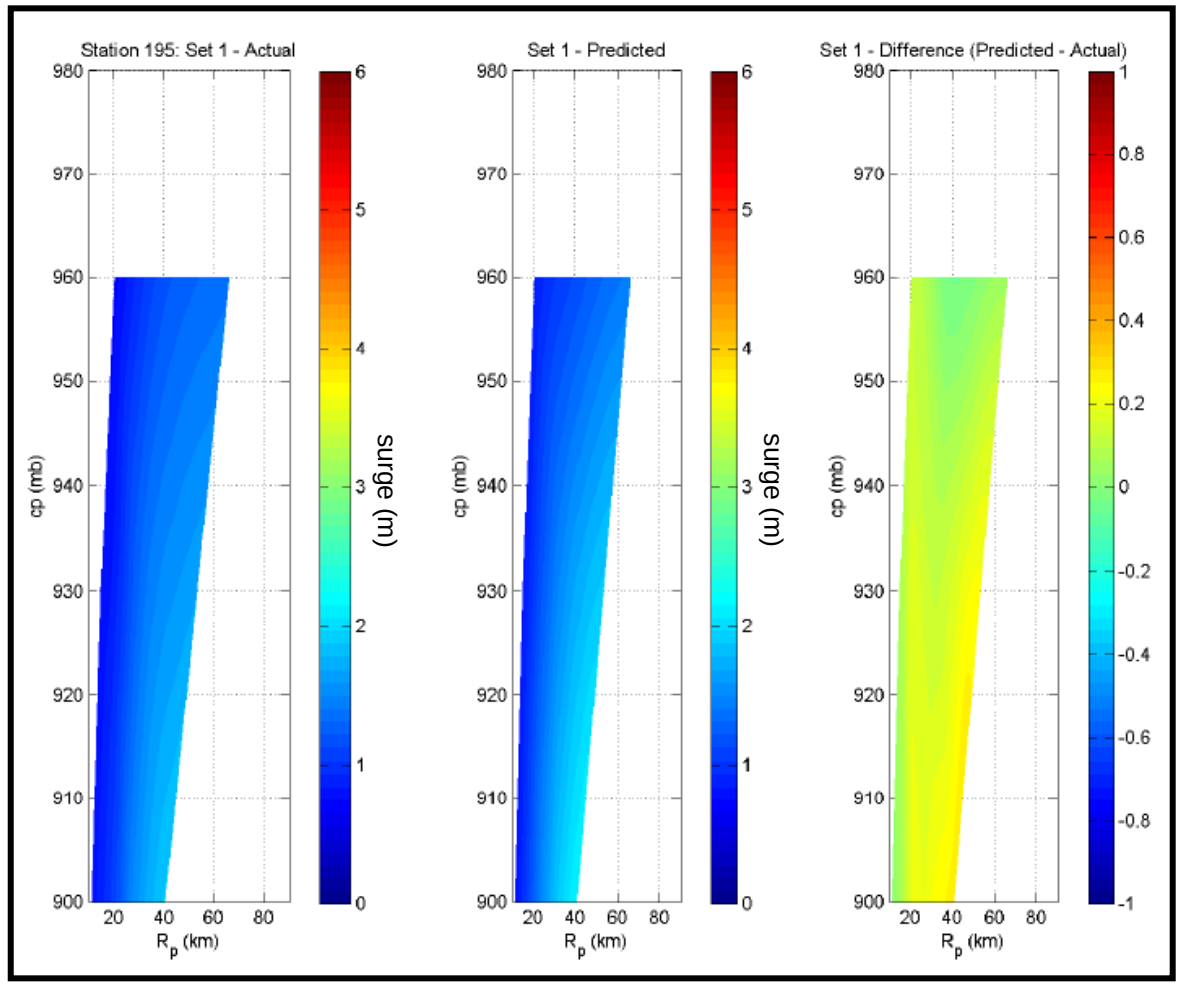



# Surge Response Surface Determination

## Results – Open Coast Surface Prediction



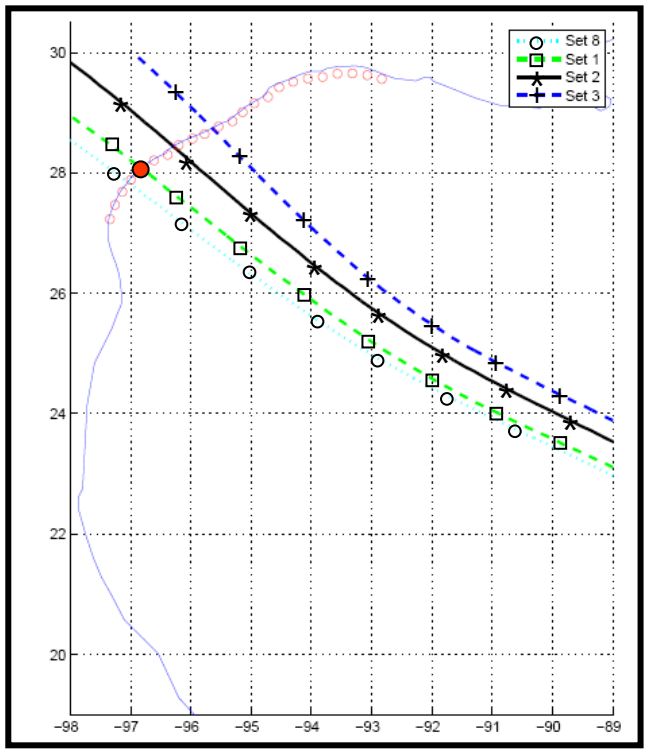

$x - x_o = -25$ km



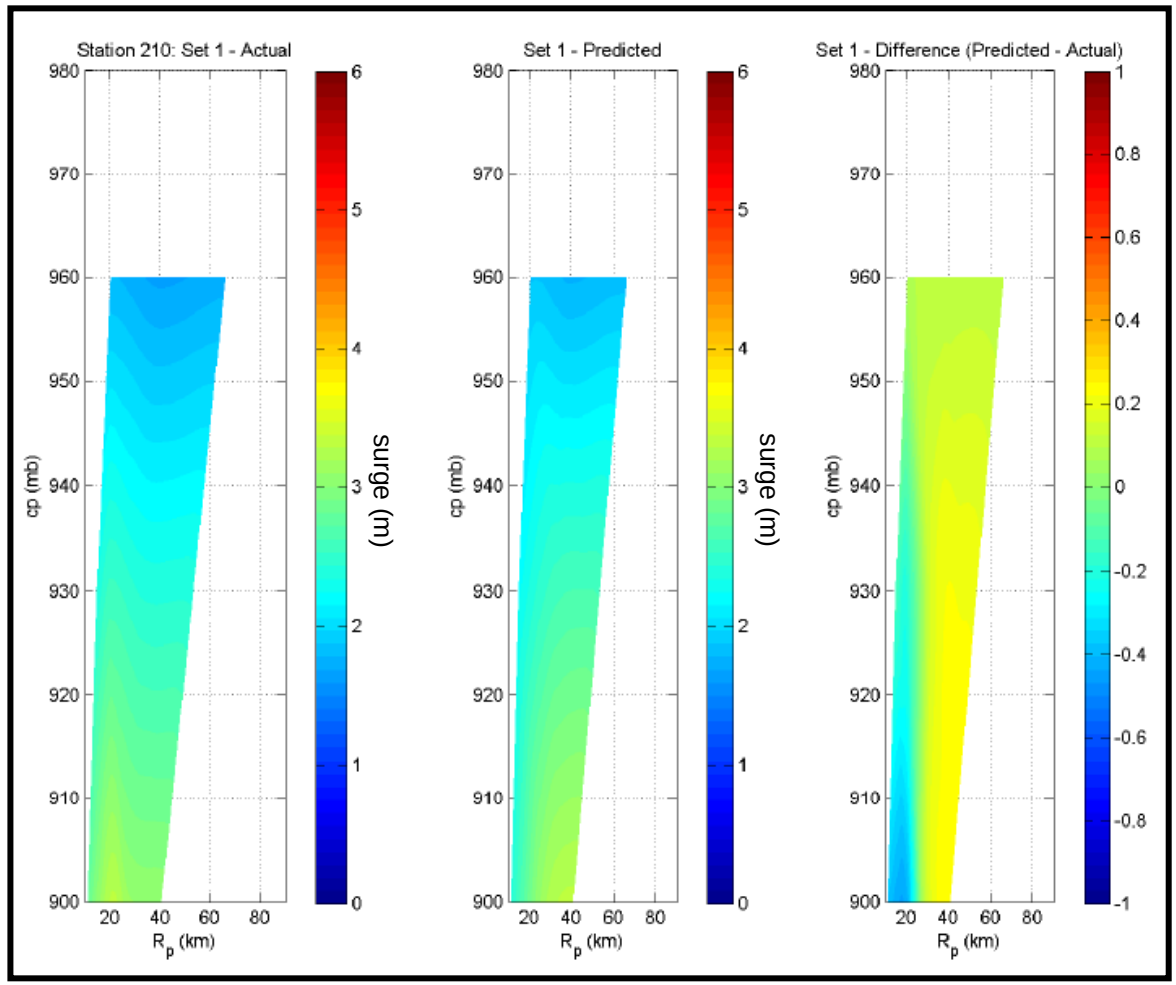

TEXAS A&M ENGINEERING

# Surge Response Surface Determination

## Results – Open Coast Surface Prediction



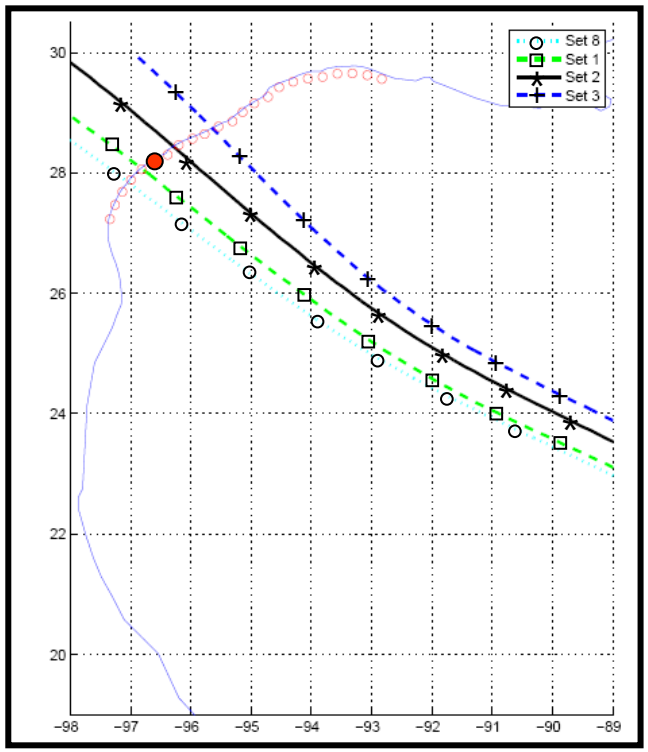

$x - x_o = 0$ km



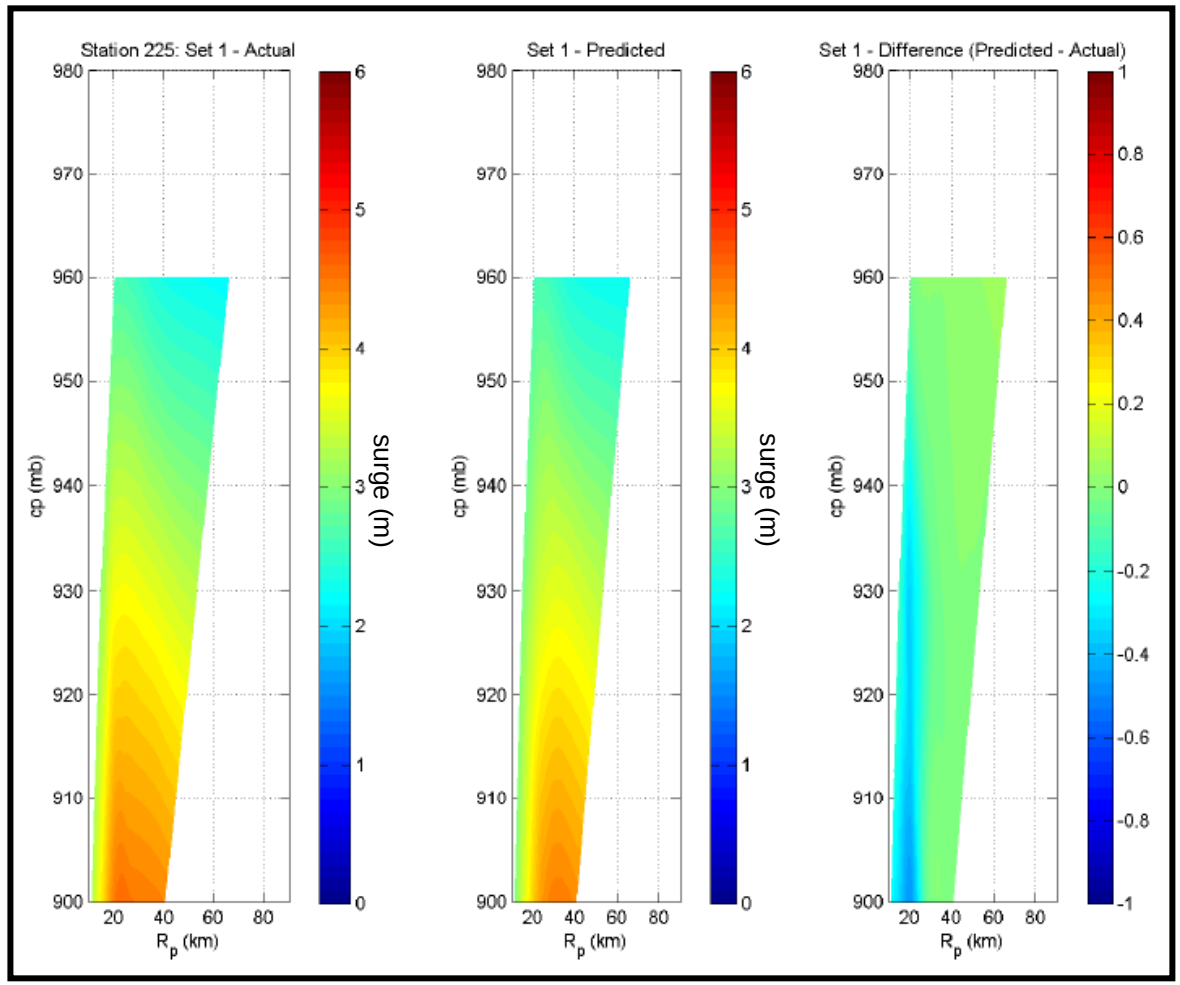

TEXAS A&M ENGINEERING

# Surge Response Surface Determination

## Results – Open Coast Surface Prediction



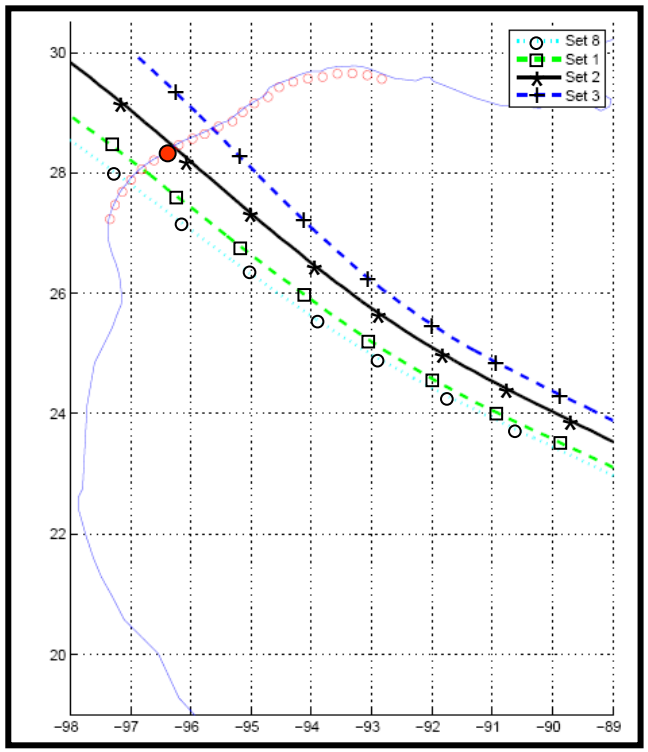

$x - x_o = +25$ km



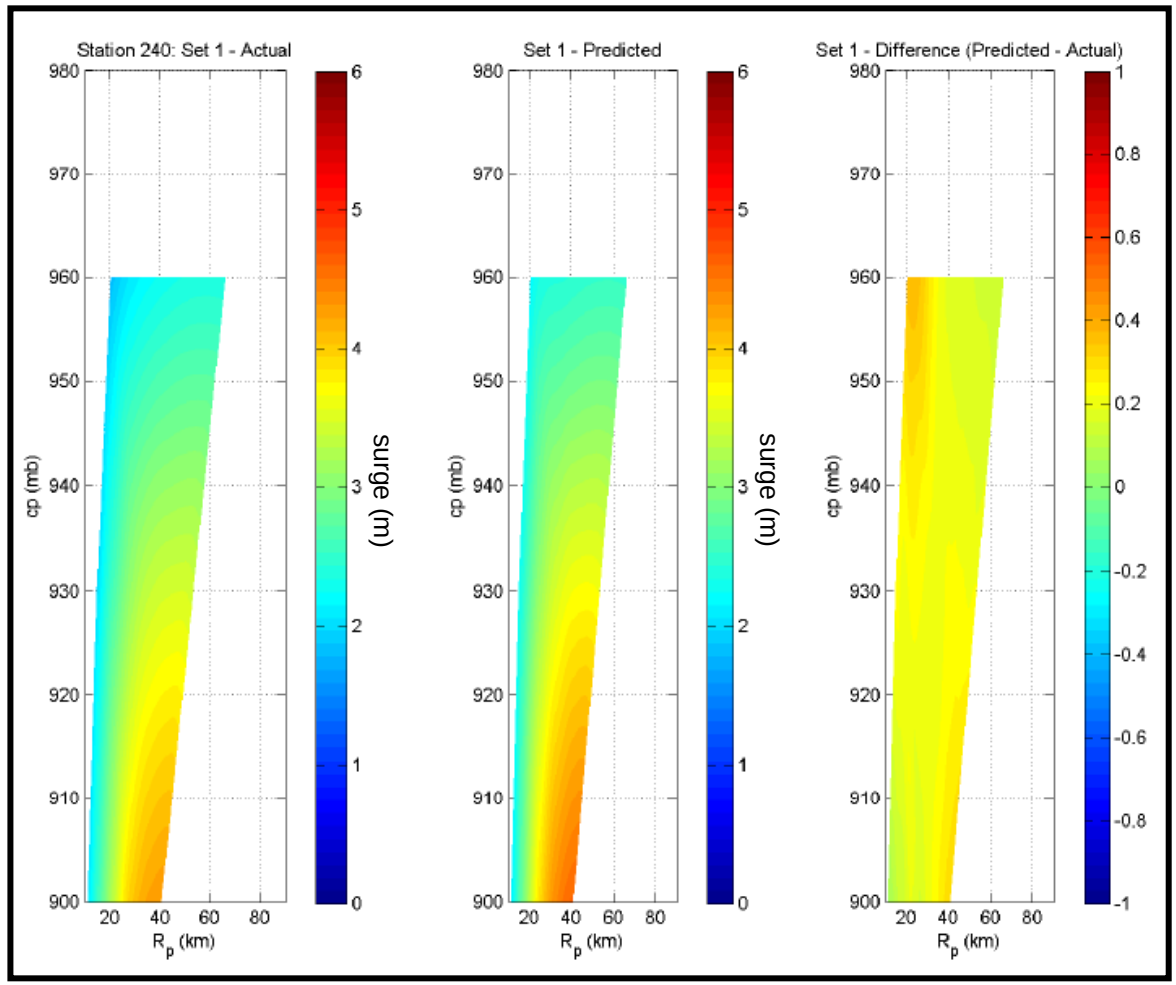

TEXAS A&M ENGINEERING

# Surge Response Surface Determination

## Results – Open Coast Surface Prediction



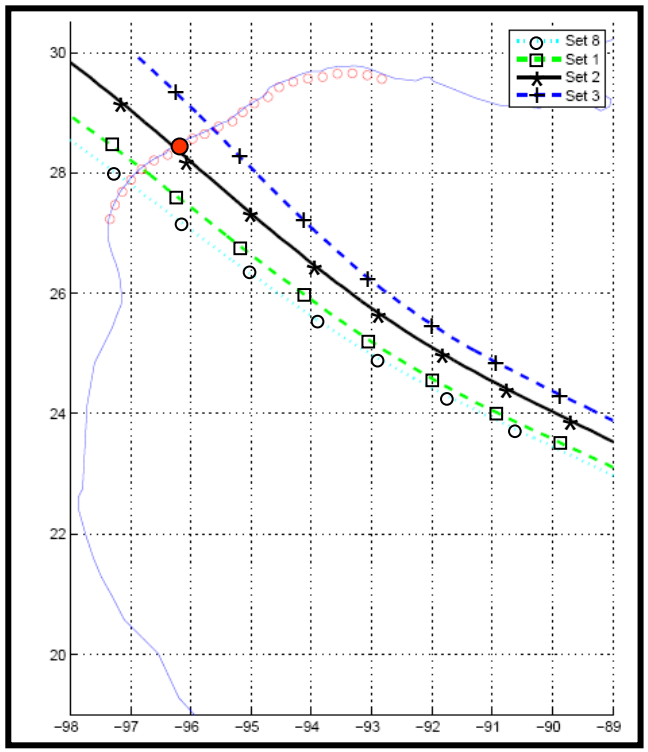

$x - x_o = +50$ km



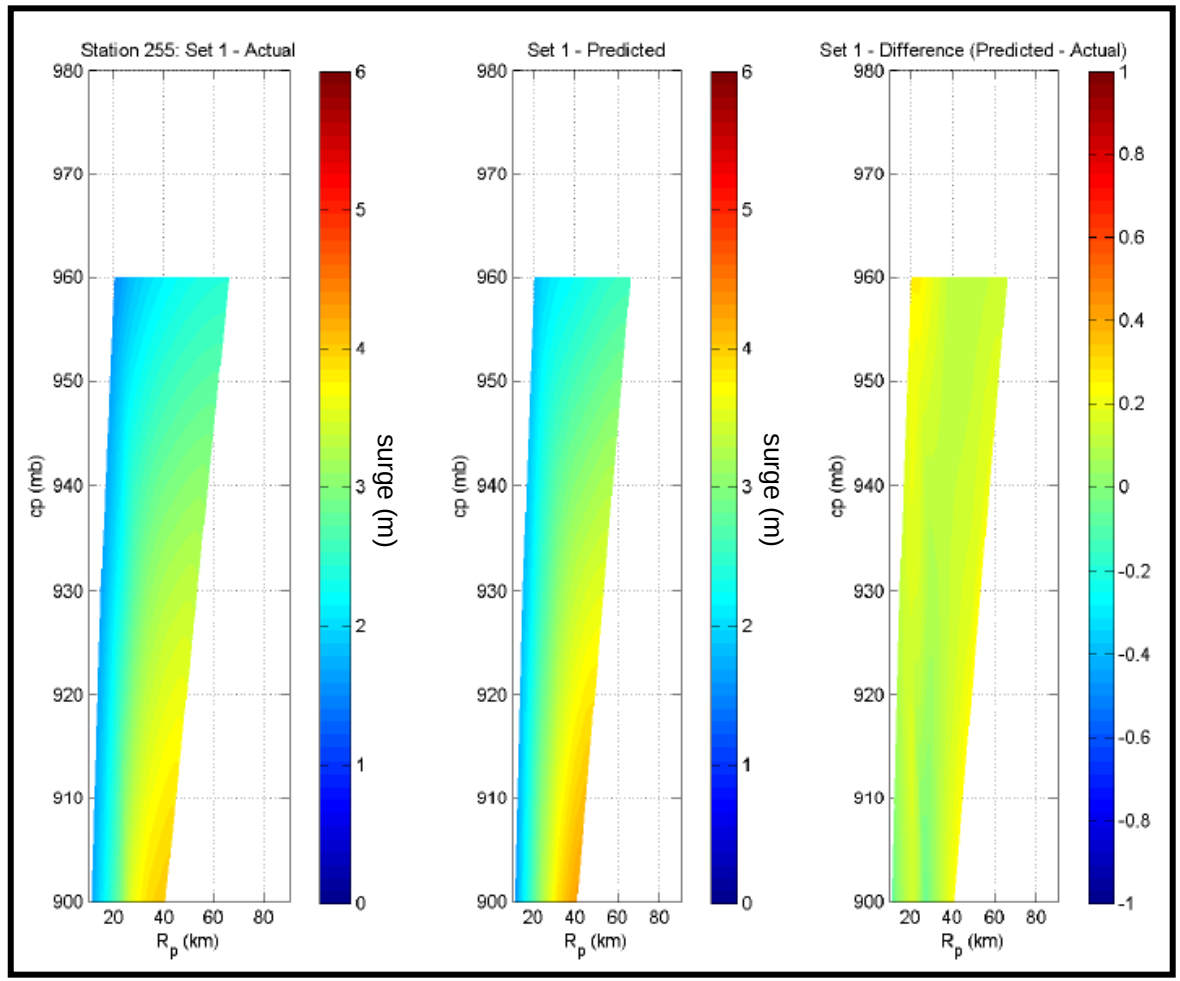

TEXAS A&M ENGINEERING

# Surge Response Surface Determination

## Results – Open Coast Surface Prediction



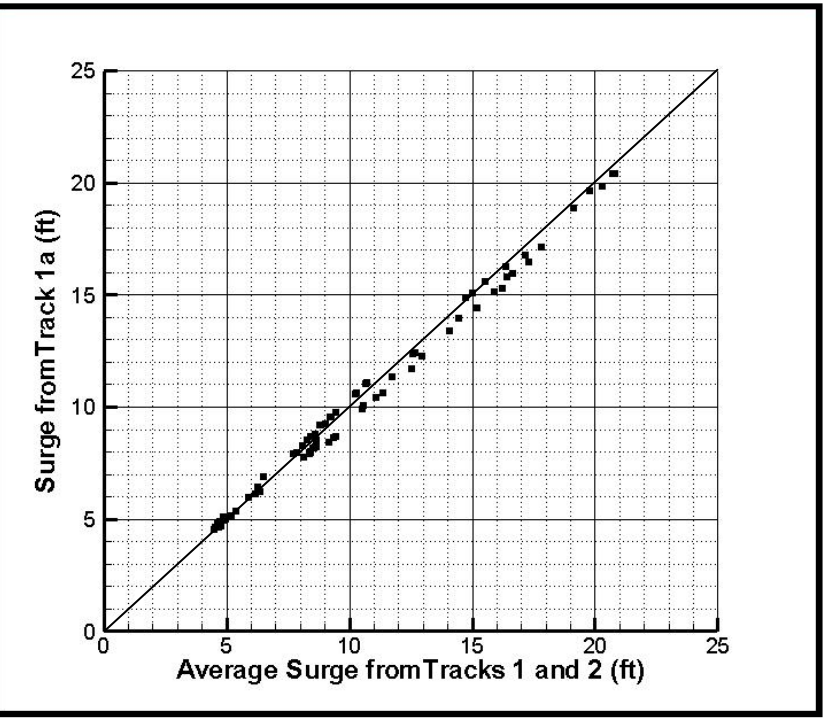

$x - x_o = +75$ km

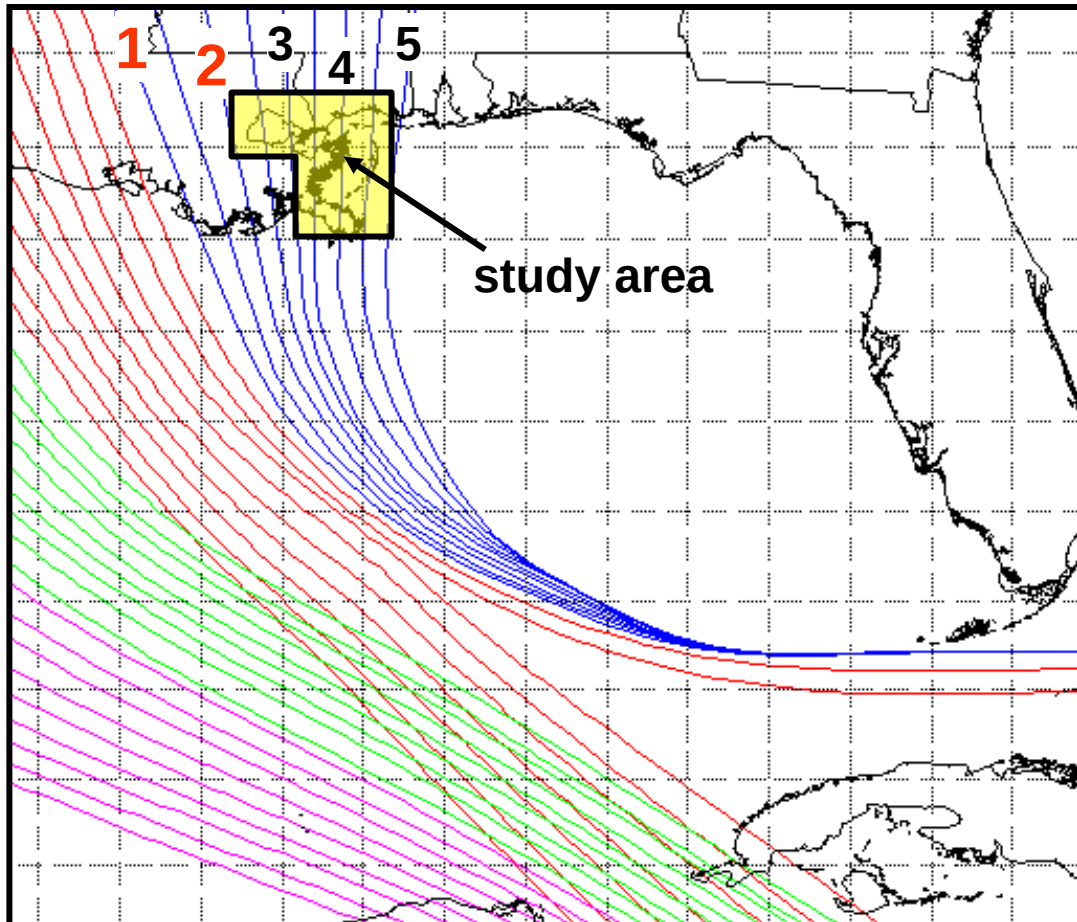



TEXAS A&M ENGINEERING

# Surge Response Surface Determination

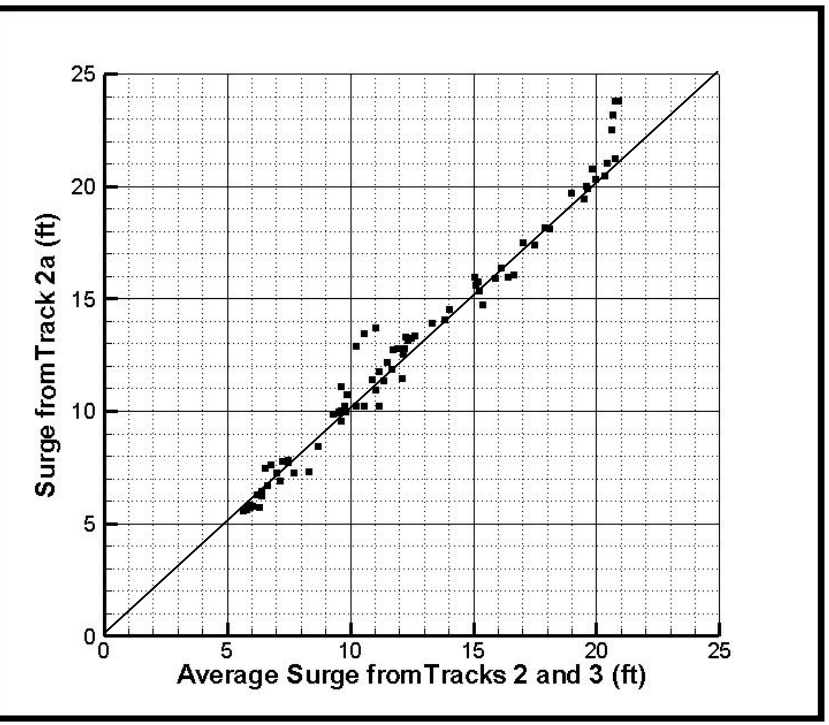
## Results – New Orleans Surface Prediction

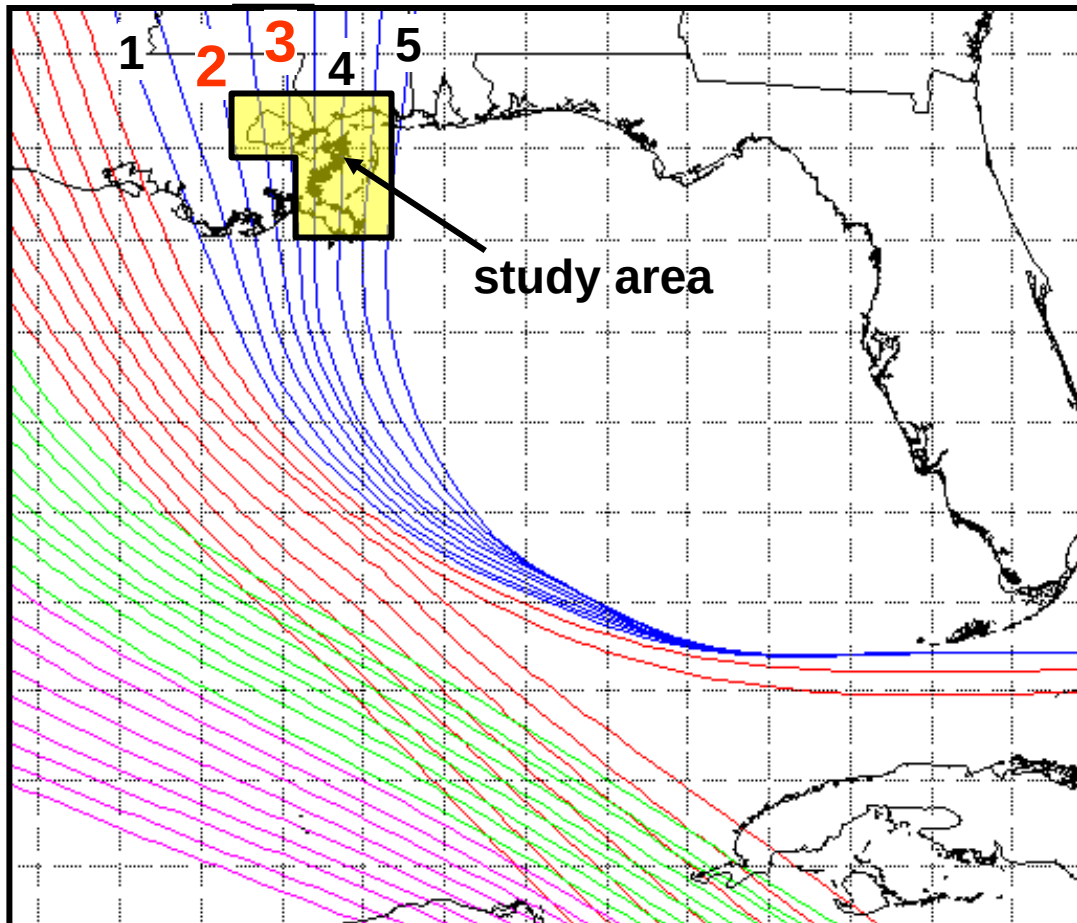


# Surge Response Surface Determination

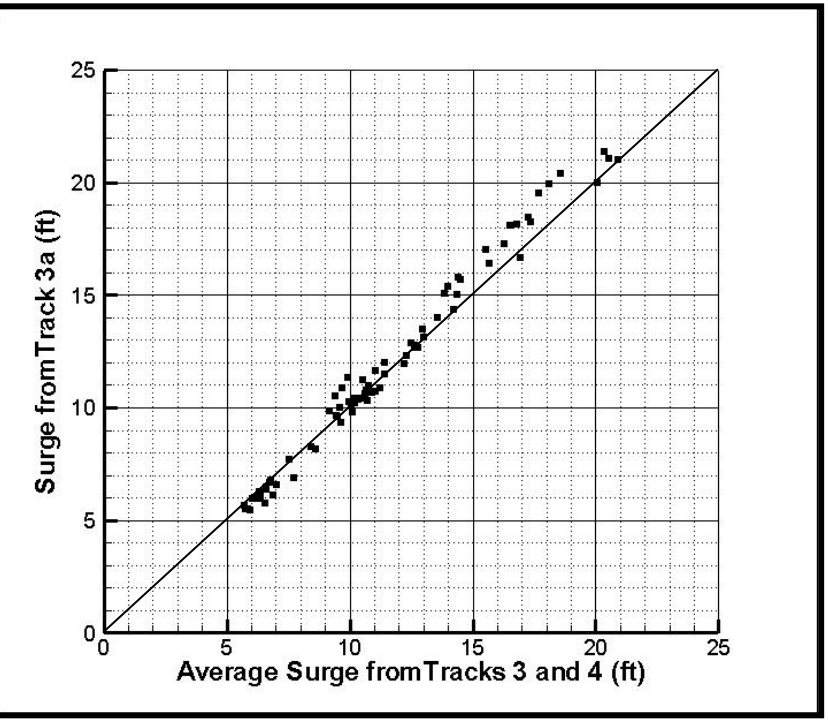
## Results – New Orleans Surface Prediction

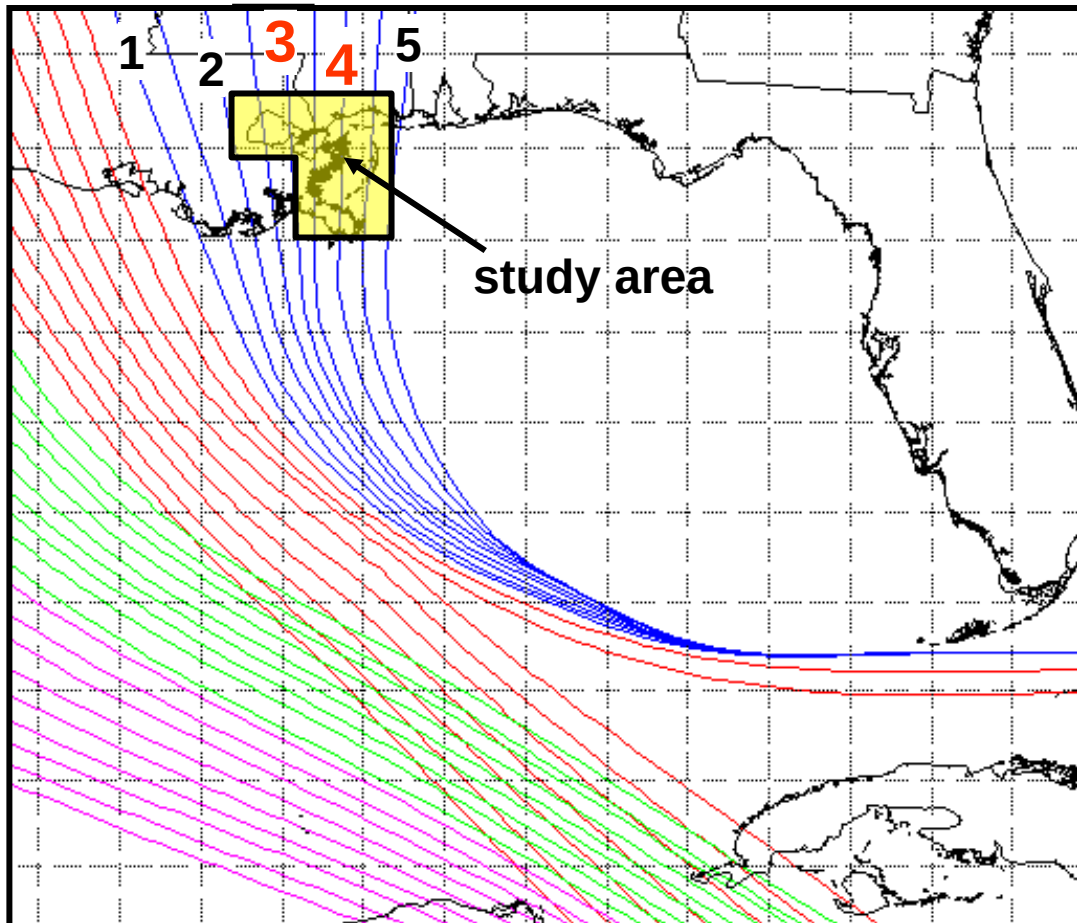


# Surge Response Surface Determination

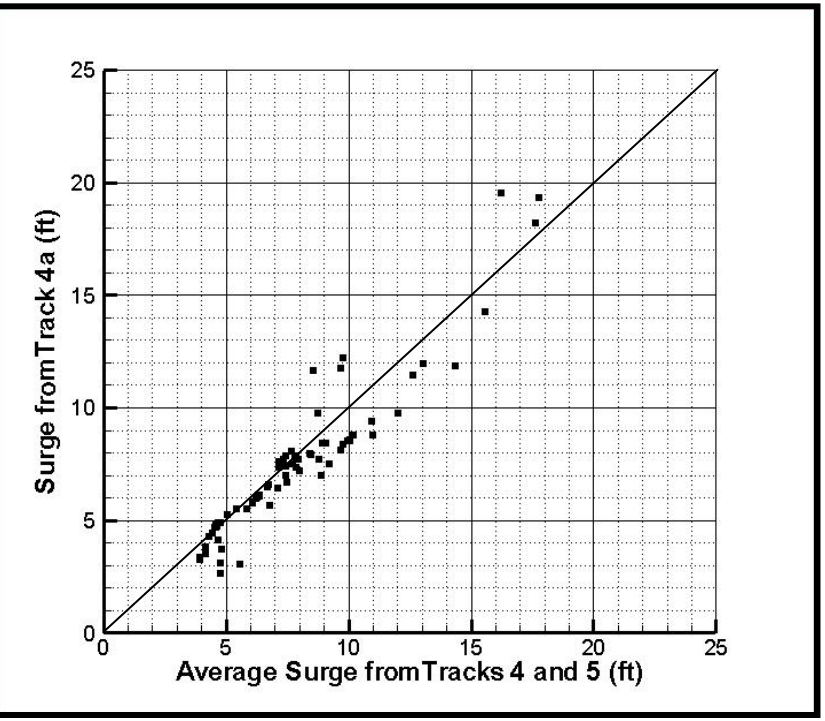
## Results – New Orleans Surface Prediction

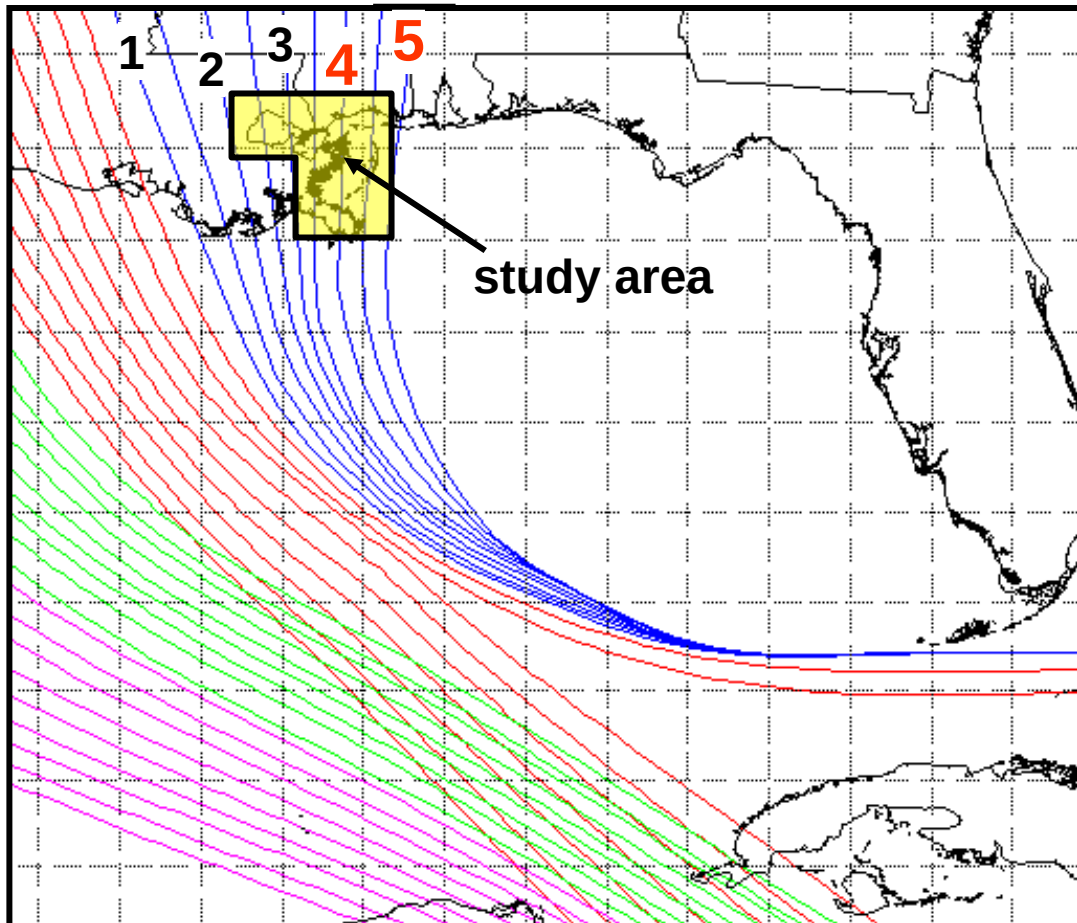


# Surge Response Surface Determination

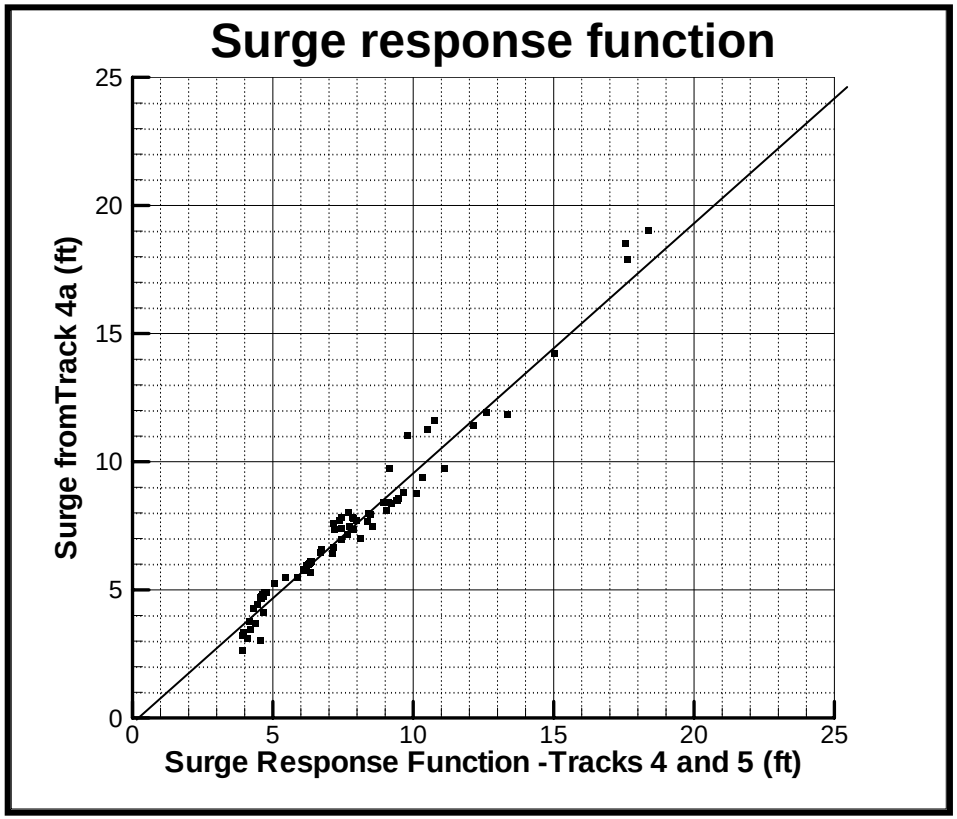
## Results – New Orleans Surface Prediction

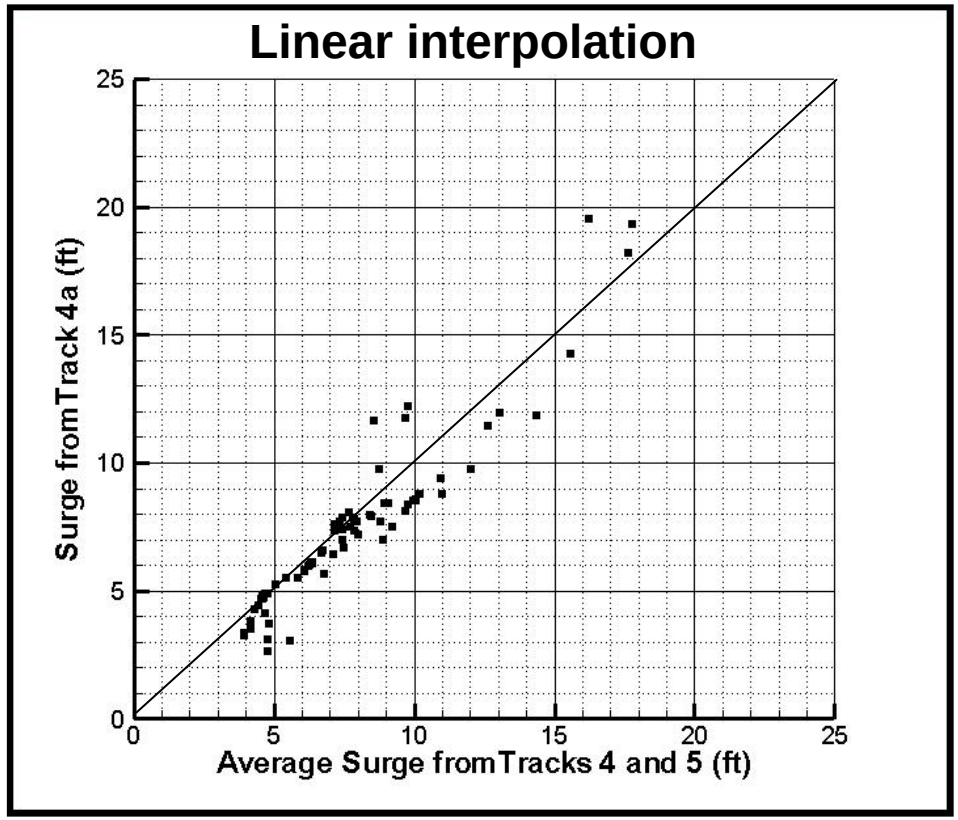


# Surge Response Surface Determination

## Results – New Orleans Surface Prediction



# Surge Response Surface Determination
## Conclusions

- Surge response approach presents solution to extreme-value statistics for coastal flooding
- Definable characteristics of response surfaces – given a single track:
  - Peak surge location scales with $R_p$
  - Alongshore distribution scales with peak surge and $R_p$
  - Surge at a given location for a given $R_p$ varies linearly with $p_0$ - $c_p$
- Overall methodology must include a means to reflect uncertainty in predicted response surfaces
- Response surface prediction has potential to extend applicability of limited observation set (i.e. surges in stronger and weaker storms can be estimated)
- Response surface prediction reduces numerical simulation requirements by allowing functional interpolation between simulation results

# Surge Response Surface Determination

## Conclusions – Future Work

- Consideration of alternate $V_f$ and $\theta$
- Transfer response approach to coastal bays
- Transfer response approach to historical observations/non-peak values