Coastal Storm Modeling System (CoSMoS)

Goal: Simulate shoreline change in 2100 on 400+ km of So. Cal. coast

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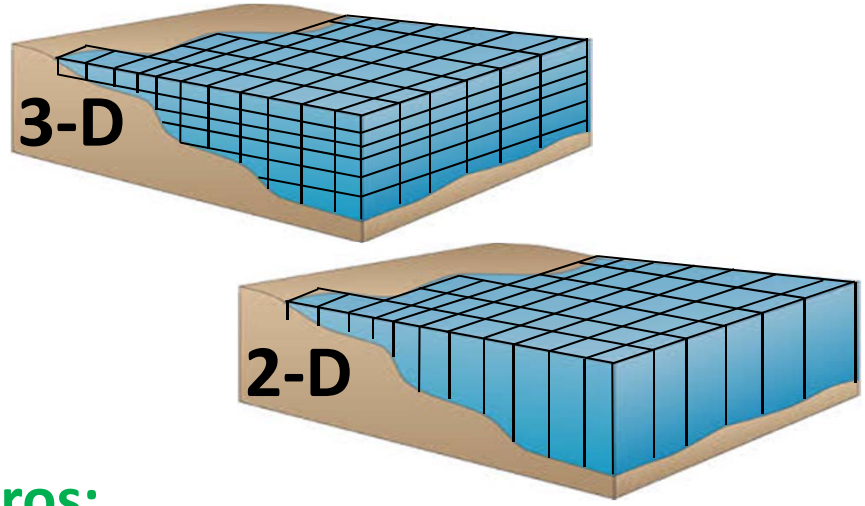
2 different approaches to predict shoreline change:

Coupled hydrodynamics, waves, sediment transport, and morphology models, e.g. Delft3D, Mike21, XBeach, ROMS, etc.



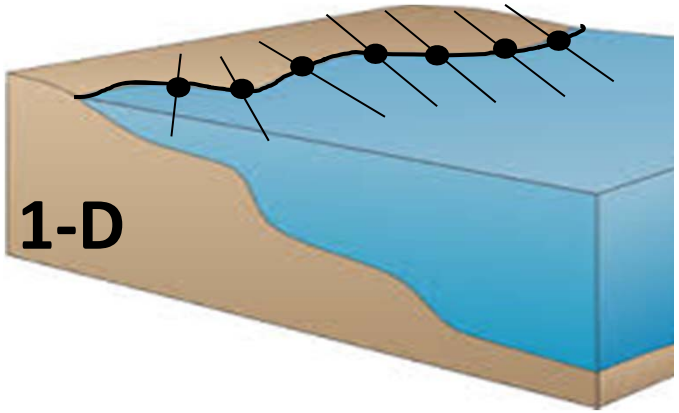
Pros:

- De facto standard for sediment transport modeling, widely used
- Treats most of the important physical processes, e.g. waves, currents, tides, sea-level rise, sed. transport, morphology, etc.

Cons:

- Computationally expensive, time-consuming
- Difficult to apply for large space & time scales
- Precise info on sediment supply/budget needed for boundary conditions

Historical shoreline erosion rate, Bruun rule, or one-line models



Pros:

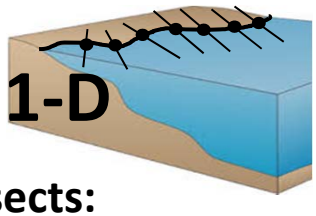
- Simple
- Cheap, fast, easy
- Constructed from (real) shoreline data
- Applicable to large spatial scales

Cons:

- (overly) simple
- Not based on physics (like conservation of mass, momentum)
- Prediction is only as good as the quality & quantity of data
- Deals with past behavior not a changing climate

CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool

- **Intended to be a hybrid between physics-based models and empirical models**
- **A process-based, one-line (1-D) shoreline model on shore-normal transects:**

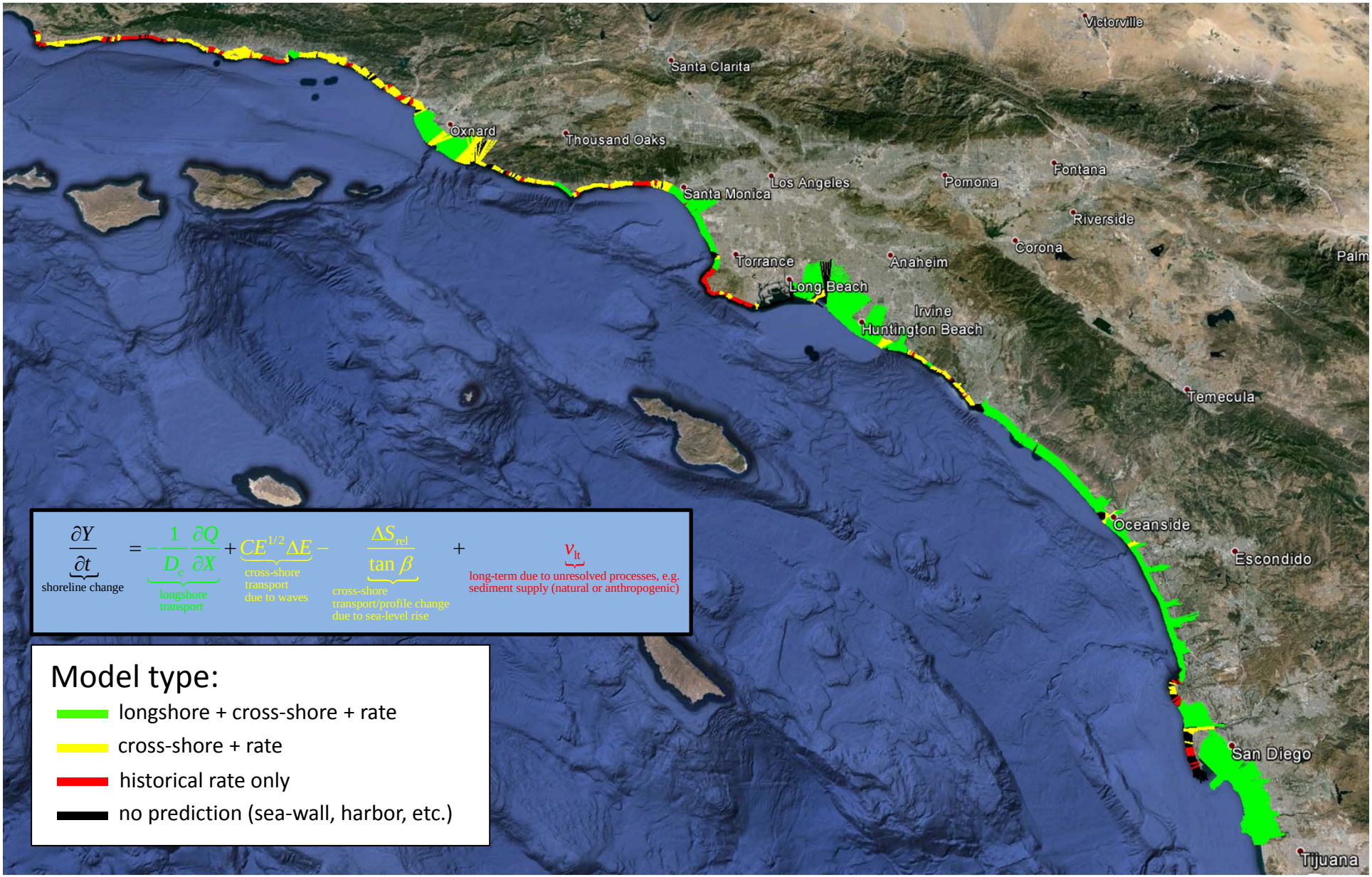


- **Numerically solves a coupled set of differental equations on a series of transects:**

$$\underbrace{\frac{\partial Y}{\partial t}}_{\text{shoreline change}} = \underbrace{-\frac{1}{D_c}\frac{\partial Q}{\partial X}}_{\text{longshore transport}} + \underbrace{CE^{1/2}\Delta E}_{\text{cross-shore transport due to waves}} - \underbrace{\frac{\Delta S_{\text{rel}}}{\tan\beta}}_{\text{cross-shore transport/profile change due to sea-level rise}} + \underbrace{v_{\text{lt}}}_{\text{long-term due to unresolved processes, e.g. sediment supply (natural or anthropogenic)}}$$

- **Model is synthesized from process-based models in the literature:**
  - Longshore transport: Pelnard-Considere 1956, Larson et al. 1997, Vitousek & Barnard 2015
  - Equilibrium shoreline change models: Miller & Dean 2004, Yates et al. 2009
  - Cross-shore transport due to sea-level rise: Bruun 1954, Davidson-Arnot 2005, Anderson et al. 2015
- **Uses data assimilation** (Long & Plant 2012) **to auto-tune the model & improve performance.**
- **Implemented in Matlab**
  - The main script has ~1000+ lines of code

Model has ~4800 transects with ~100 m grid spacing



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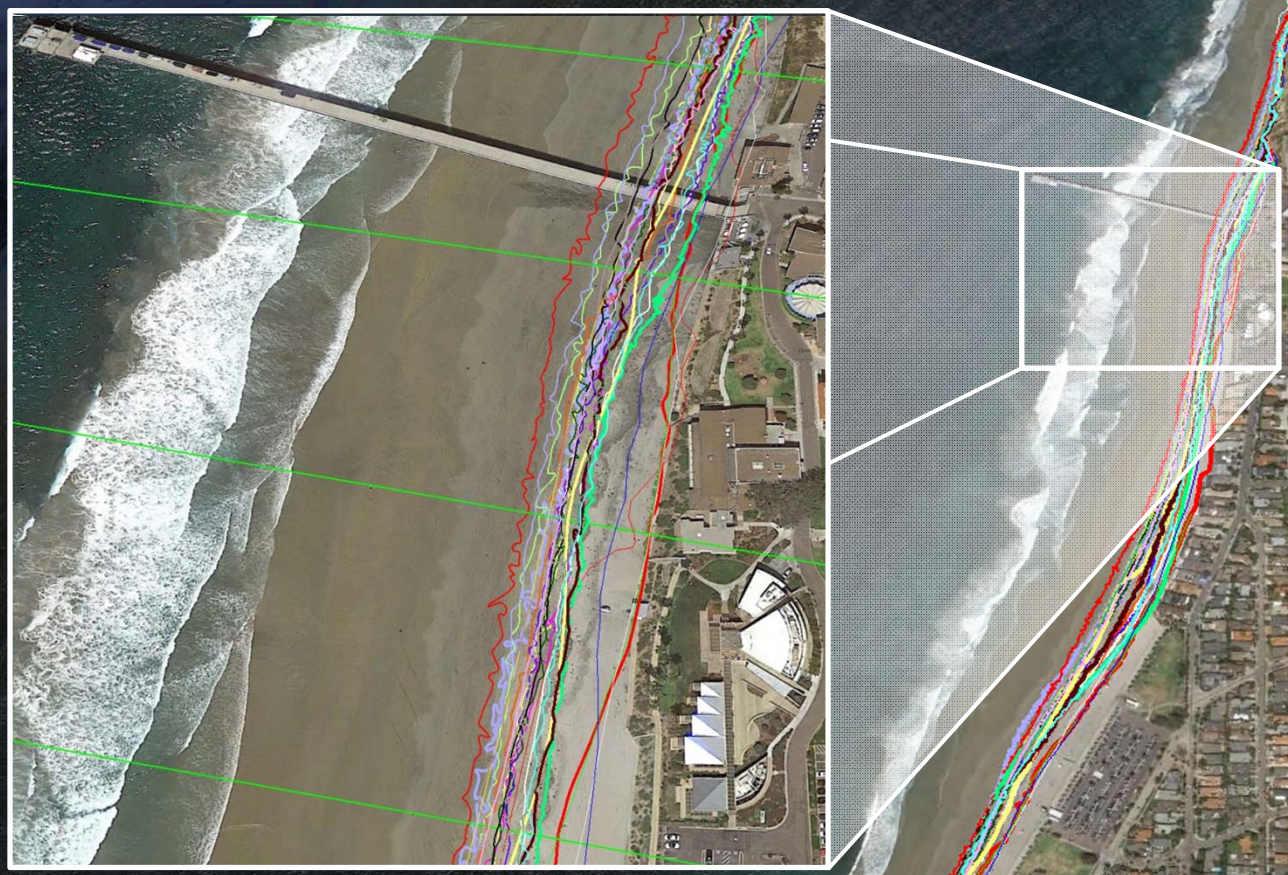
Model type:

- longshore + cross-shore + rate
- cross-shore + rate
- historical rate only
- no prediction (sea-wall, harbor, etc.)

Shoreline Data:



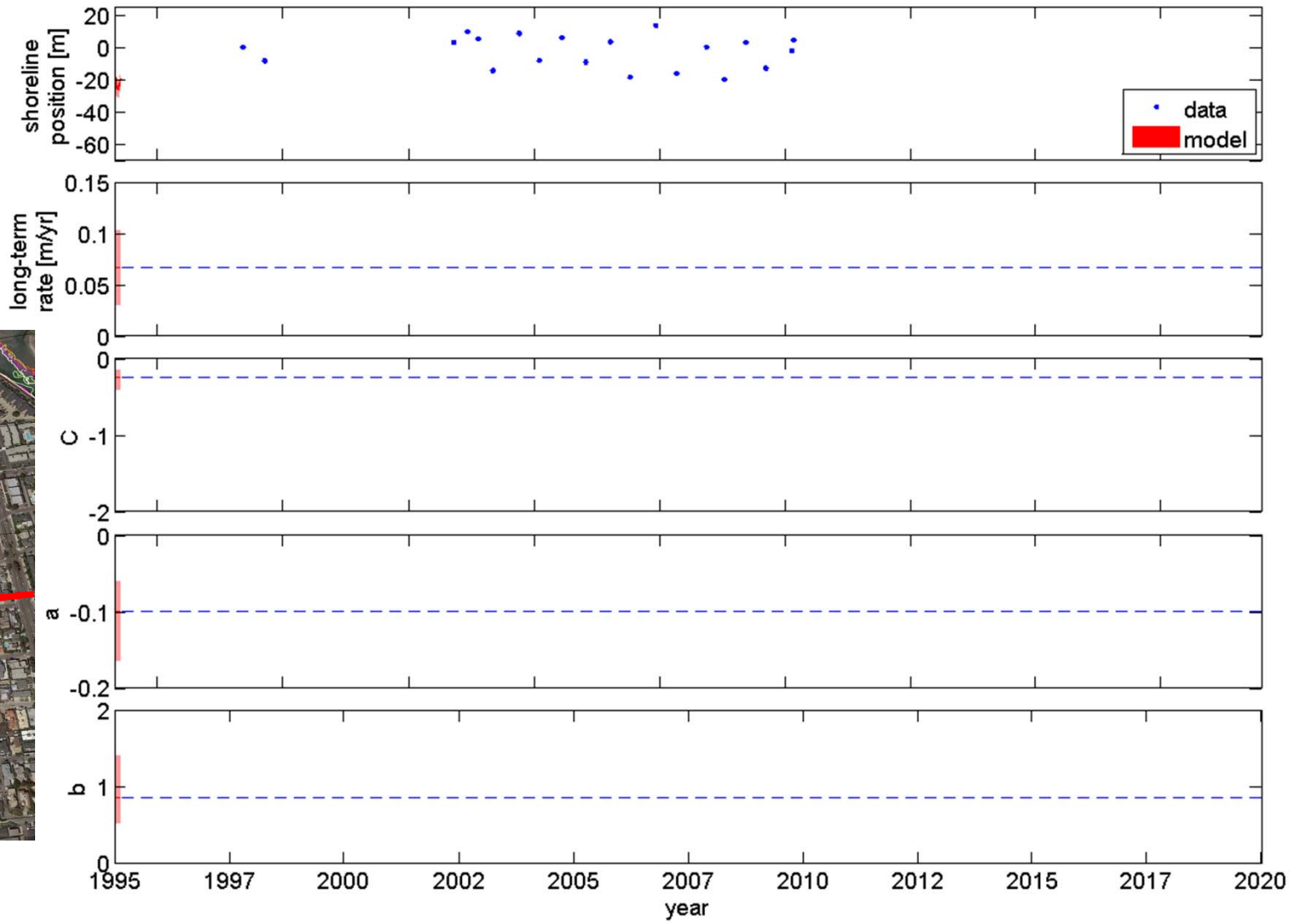
- **5 shorelines** from **USGS National Assessment**
- **20 shorelines** extracted from **LIDAR surveys**
  (most are from SCRIPPS 2003 – 2009; most are south of Long Beach)
- **20 shorelines** from **USGS surveys**
  (only in Santa Barbra area 2005 - present)
- ***We need MORE!***

Data Assimilation

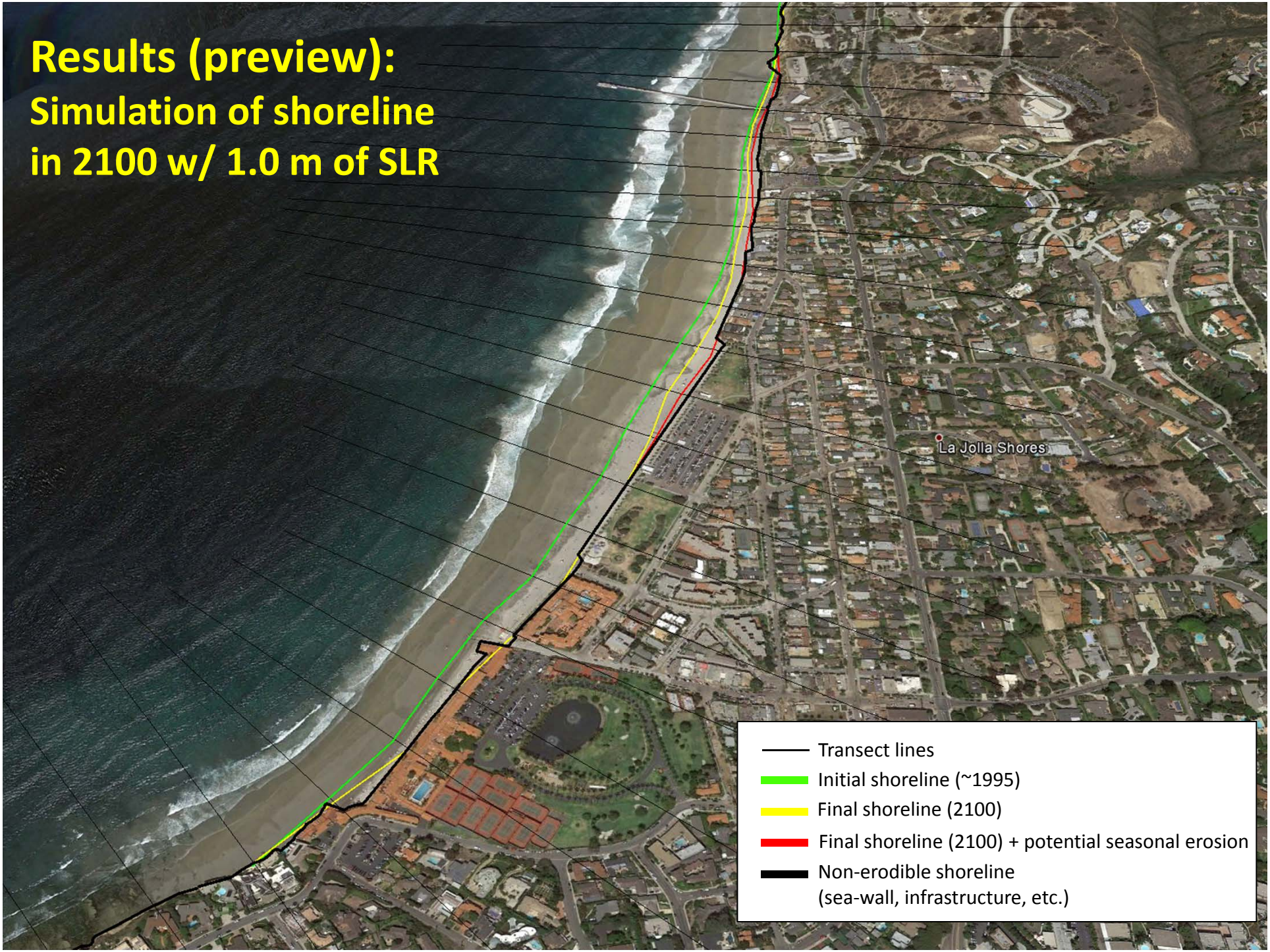
We use the *extended Kalman filter method* of Long & Plant 2012

- Auto-tunes model parameters for each transect to best fit the historical shoreline data
- We improved the method to handle sparse shoreline data and ensure that parameters are positive or negative.

Simulation output for a single transect at Del Mar Beach:

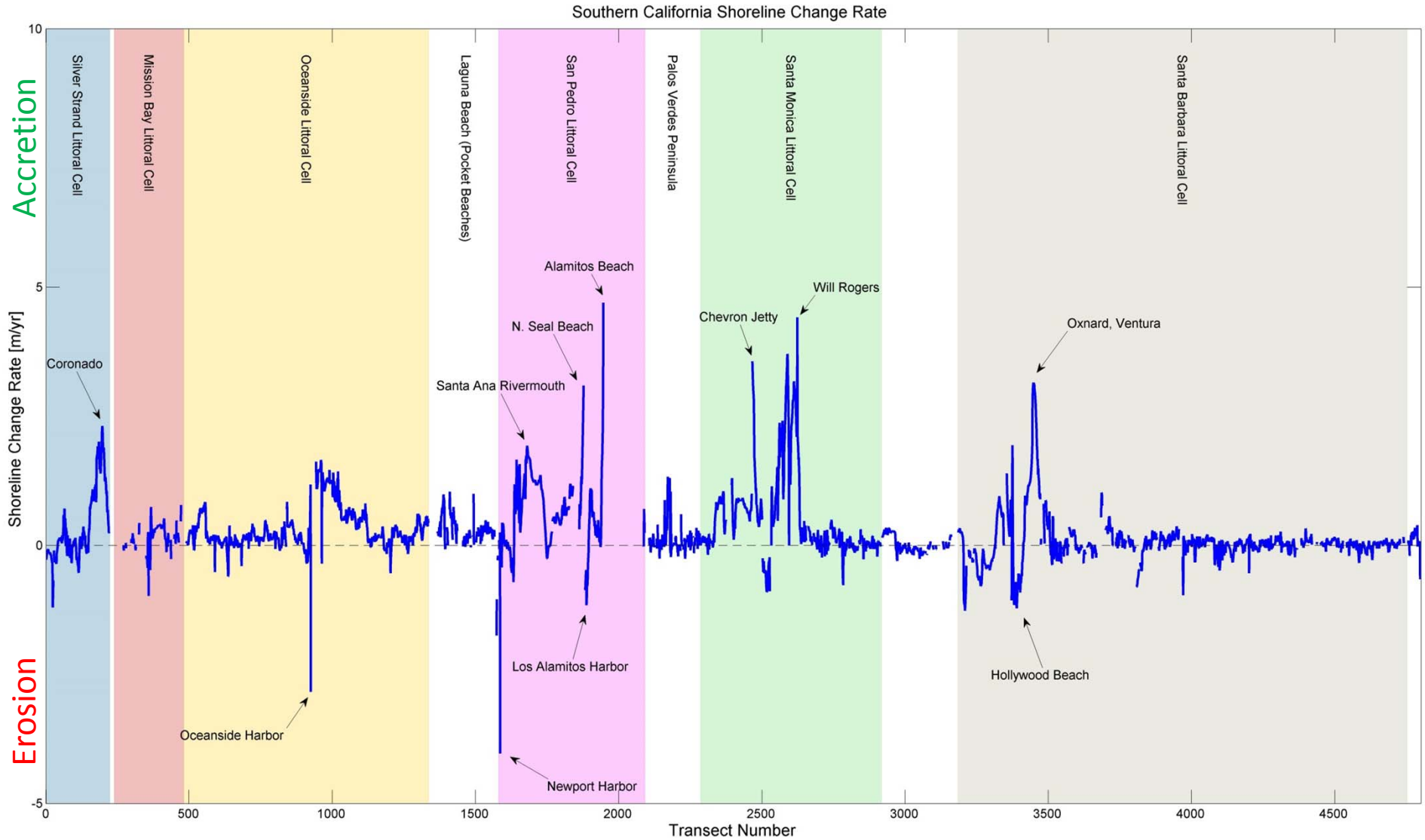


Results (preview):
Simulation of shoreline in 2100 w/ 1.0 m of SLR



Results (preview):

Historical Shoreline change rates (derived from shoreline data only)



Conclusions

- **Long-term simulations w/ standard numerical models are difficult** (impossible)**:**
  - Morphologic time scales Hydrodynamic time scales

- **We need to reduce the complexity & computational cost of long-term shoreline simulations**
  - It is difficult (impossible) to explicitly account for all processes controlling shoreline evolution

- **There are many sources of uncertainty in long-term shoreline predictions**
  - sources of uncertainty: Chaotic behavior of climate, sea-level rise, wave climate, sediment supply, ***anthropogenic effects***

- **We have developed a new model to predict long-term shoreline change: CoSMoS-COAST**
  - It is synthesized from many process-based models in the literature
  - It uses data assimilation to auto-tune the models and increase believability.
    However, *"All models are wrong. Some models are useful."*

- **We need more shoreline data**
  - *More shoreline data would **substantially improve performance** of the model*

- **Many Beaches in Southern California are anthropologically-controlled**
  - Shoreline prediction: The future beach state will be *what we want it to be* (by way of nourishments)
  - Still, the model may help answer many questions pertaining to the future of the coast