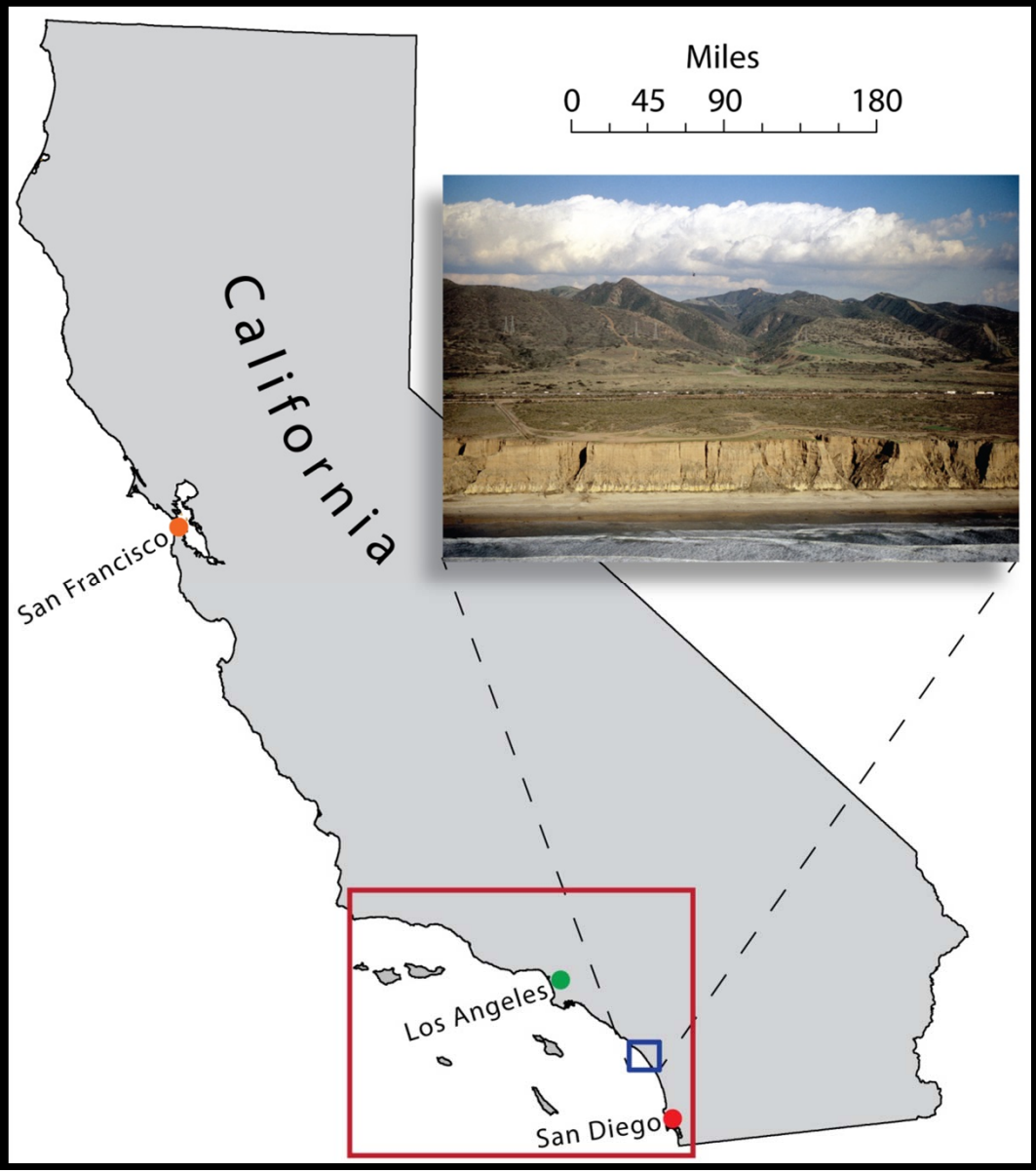
What, where, when?

- Forecast sea cliff retreat in Southern California (~400 km) through 21st century
- Include wave impacts, sea level rise, and rainfall
- Use hybrid, ensemble approach

Phase I: NOW

Phase II: ~July 2016



controls on cliff behavior

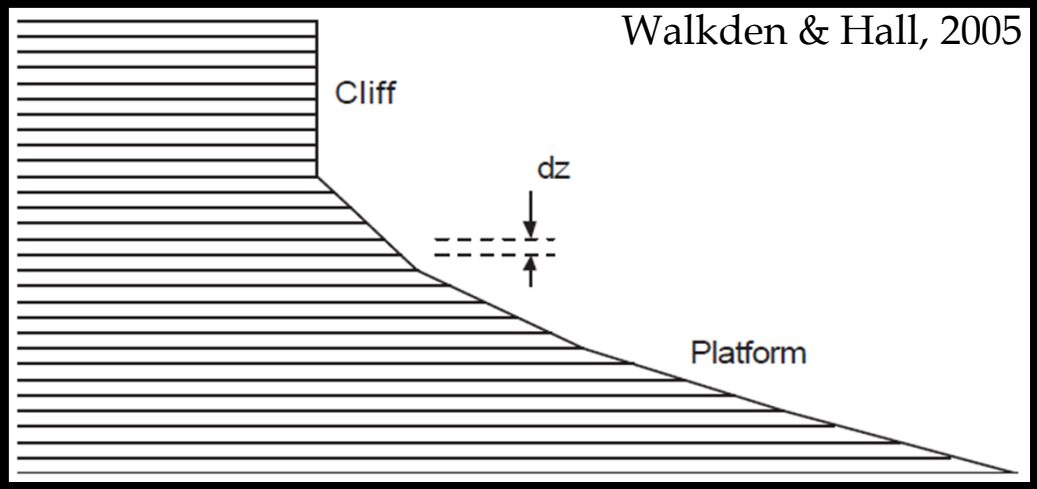
Start simple, add complexity

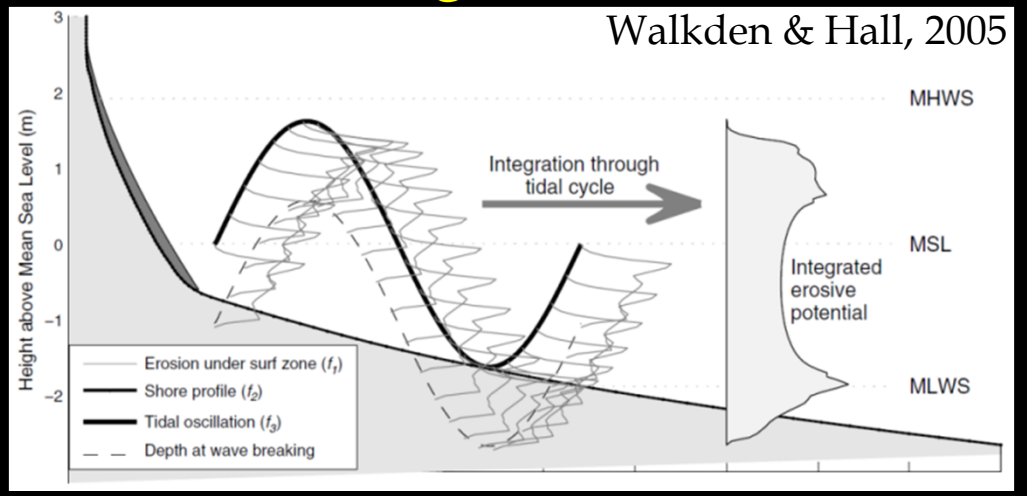
Sea cliff retreat =

$$f\Big(\text{Tectonic activity},\ \text{Permafrost thaw},\ \text{Tidal range},\ \text{Rock strength/ geology},\ \text{Human impacts},\ \text{Beach \& sea cliff dynamics},\ \text{Waves},\ \text{Sea level rise},\ \text{Rainfall}\Big)$$

cliff profile models

Waves + SLR + tides + rock strength





SCAPE

(Walkden & Hall, 2005, 2011; Walkden & Dickson, 2009; Carpenter et al., 2014; iCOASST)

$$E = \frac{H_b^{13/4} T^{3/2} \tan\alpha}{R}$$

Trenhaile Model

(Trenhaile, 2000, 2002, 2005, 2009, 2010, 2011, etc.)

@ sea level

$$E_{bf} = N_o K_{bf} (S_F - S_{Fcr})$$

$$S_F = \left[0.5\gamma (H_b/0.78) e^{-\chi^{Sw}}\right] \sin^2 \varphi$$

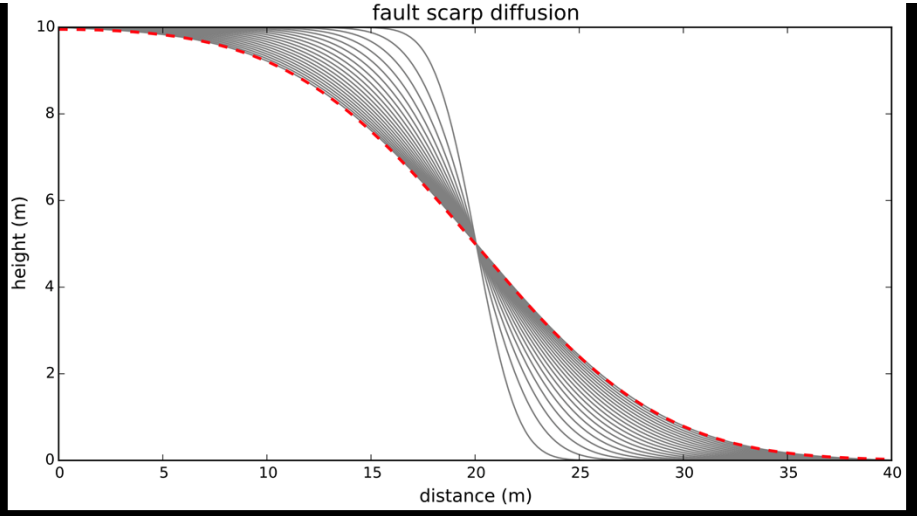
< sea level

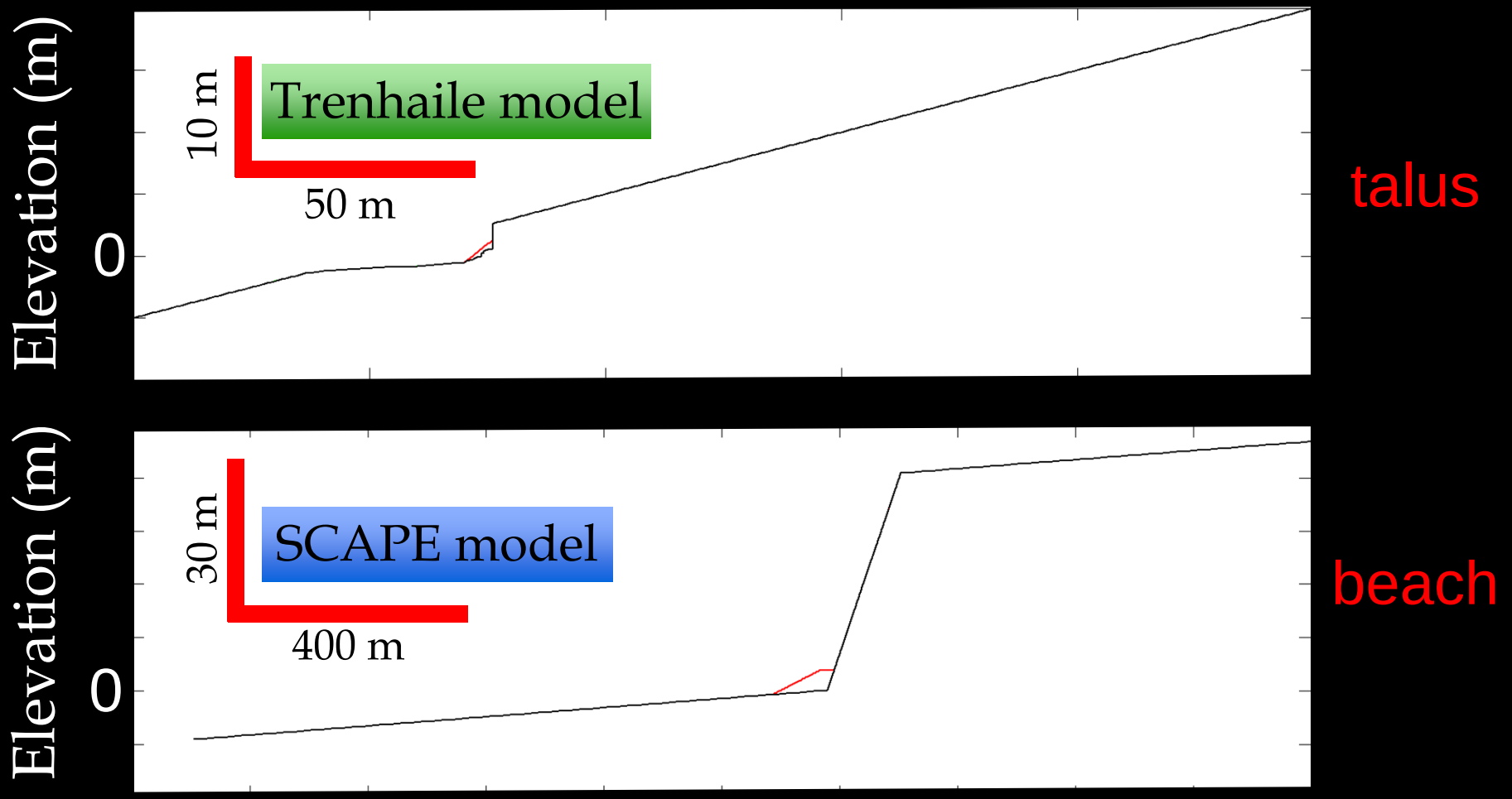
$$E_{ss} = N_o K_{ss} (\tau - \tau_c)^p$$

$$\tau = 0.5\, F_w\, \rho u_o^2$$

cliff profile models

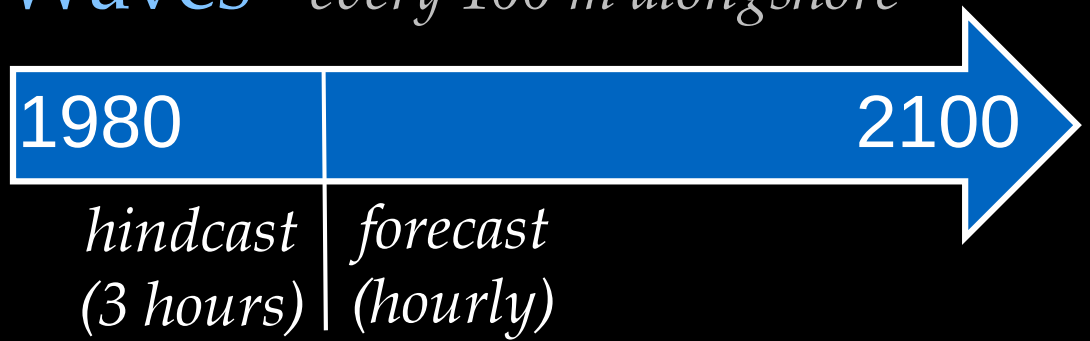
Working modules: undercutting, talus, dynamic beach, wave run-up, subaerial erosion *(hillslope diffusion & rain intensity/duration thresholds)*





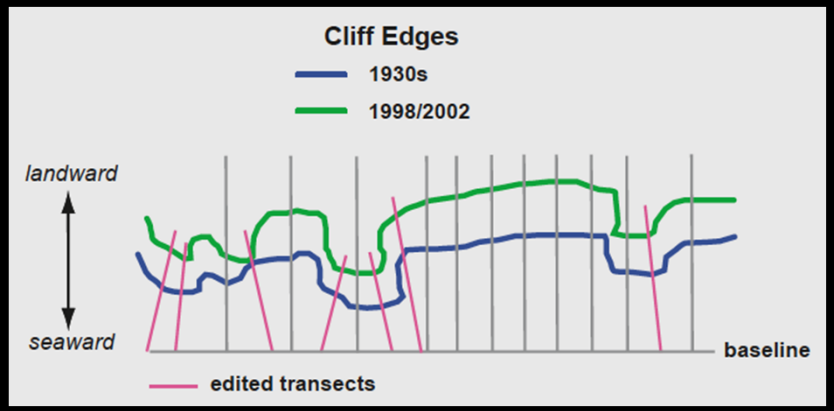
{ available data

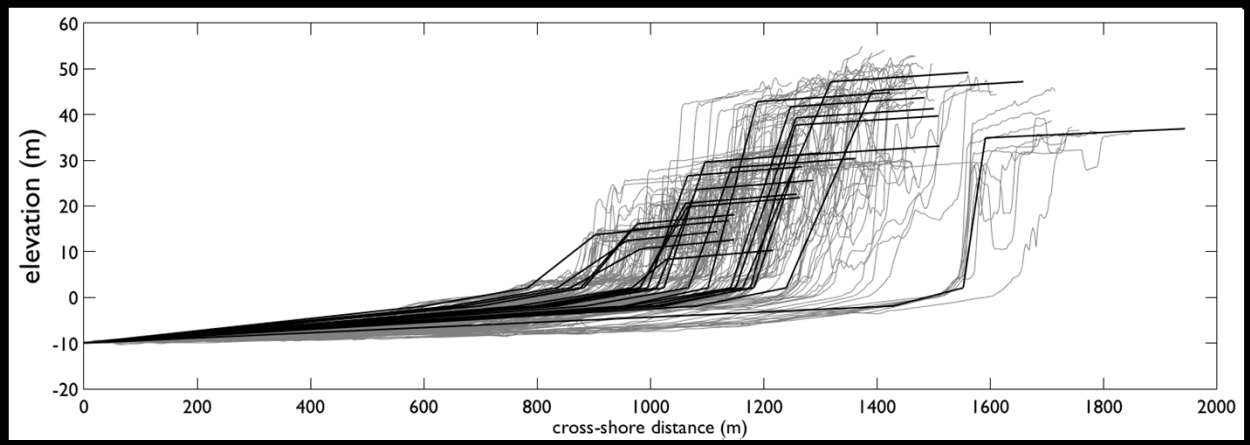
Waves *every 100 m alongshore*



Cliff retreat rates & profiles

Hapke & Reid, 2007





Submarine slope, intertidal slope, beach (yes/no), cliff toe elevation, cliff face slope, cliff height, humans

CA Coastal Records Project

Dealing with humans

Phase one: ‘hold the line’

Phase two: gradual or sudden removal of structures; how much SLR needed to ‘activate’ impeded cliff toe (see above)?

Applying the cliff models

Fails:

1) Calibrating model coefficients for each MOP line
2) Daily time step (resolving short-term dynamics)
3) *Using Bayes network to assimilate model behavior and make forecast

$$P(E \mid O) = \frac{P(O \mid E) \cdot P(E)}{P(O)}$$

Current methods:

1) Use calibrated MOP lines (~1000) to run cliff profile models over different sea level scenarios (~5000 runs)

2) Use model output to train an Artificial Neural Network (ANN)

3) ANN learns quantitative relationship between model input & output *(iterative nonlinear/multivariate regression)*

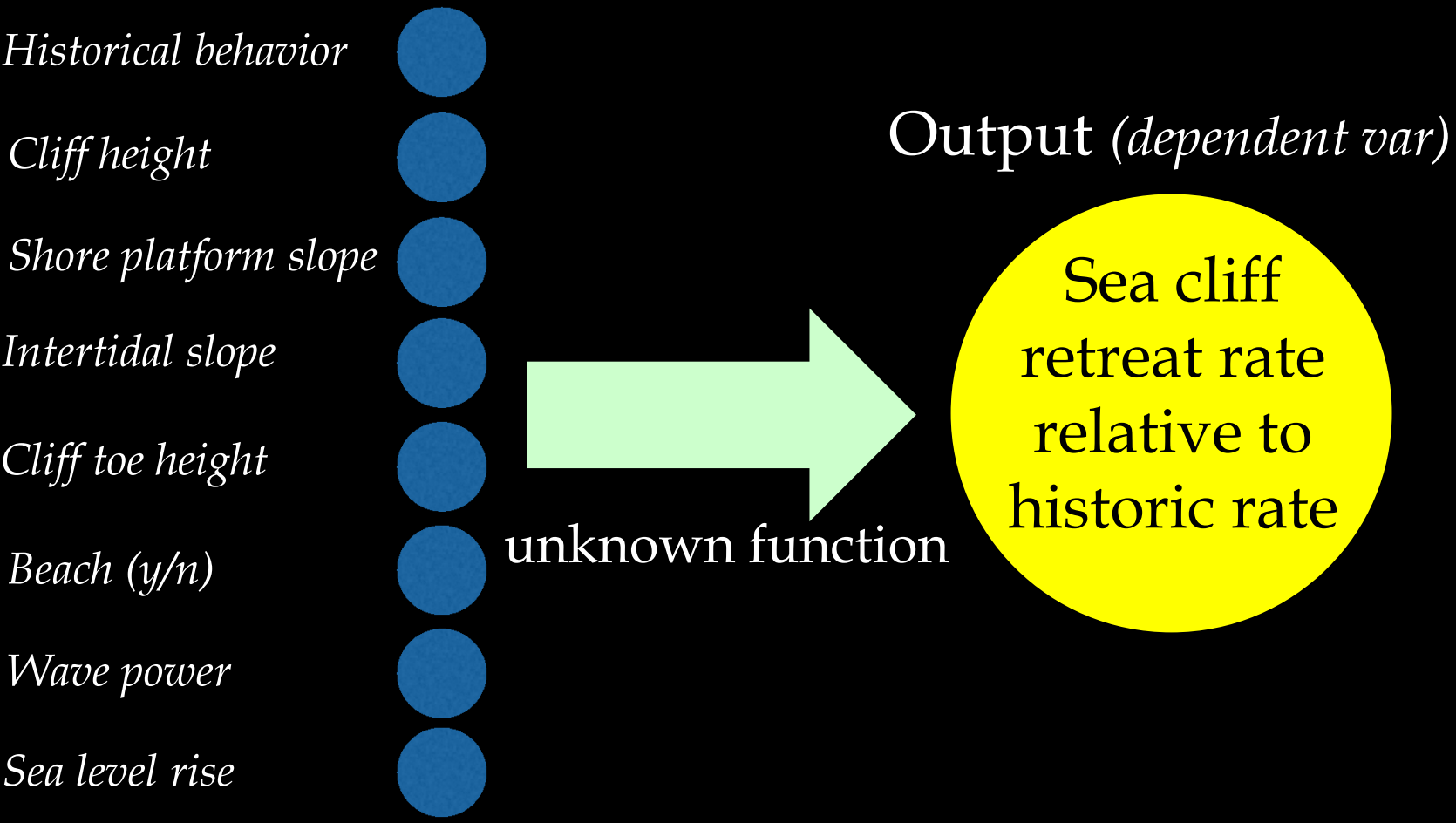
4) ANN becomes her own standalone model: input → predictions (very fast & easily updatable)

ANN results

Independent tests for ANNs trained by both cliff profile models:

R^2 = 0.89 – 0.95

RMSE = <0.1 m/yr



Future directions and needs

-Continuous cliff profile model refinement (sensitivity analyses)

-Beach/sea cliff dynamics (cliff composition)

-Rock hardness

-Two-way coupling with Sean's model (include AST)

-Dynamic water levels (surge, infragravity, etc.)

-Include more models in ensemble

-Need updated long-term retreat rates to calibrate models

-Need additional cliff edges to test models

-Rainfall?