Modeling Mechanical Effects in Tissue Formation

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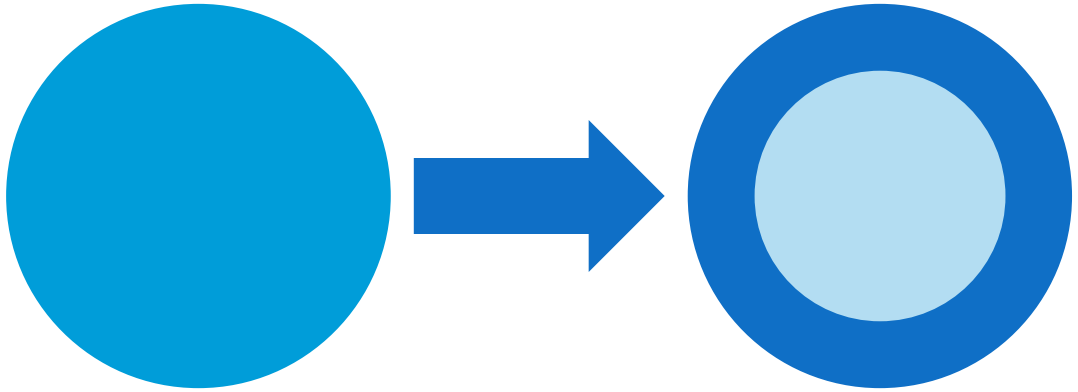
AUGUST 6, 2020

Motivation

- Specialization requires signaling
- Mechanical Signaling- Neural Plate Induction
- Continuum Model



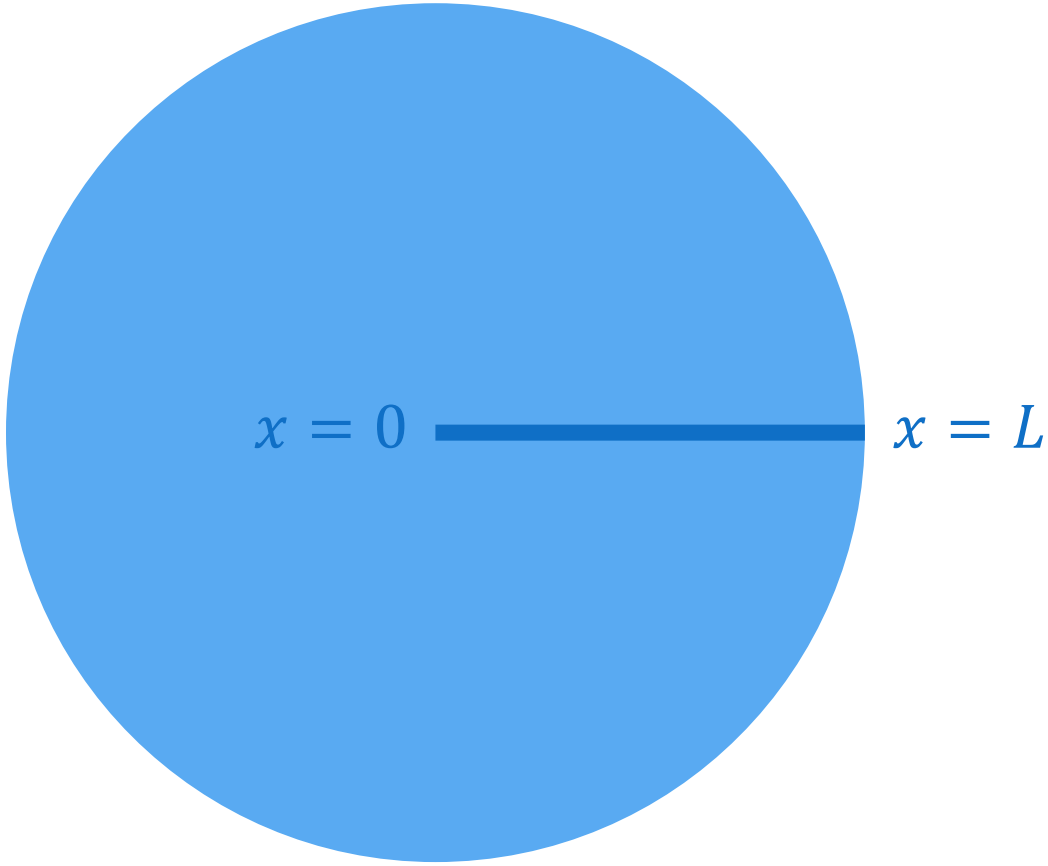
Guiding Questions

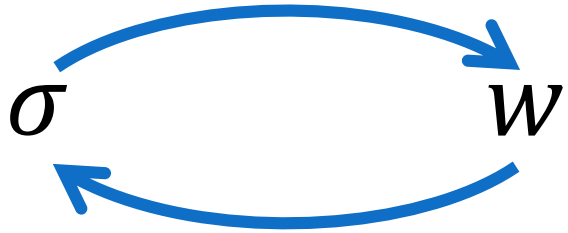
- Does a discrete model produce domain wall patterns reliably?

- How do the discrete and continuum models compare for the same parameter values?

The Model

- Regular 1D lattice of N cells with positions x_i
- Cell type w_i from ~0 (NP) to ~1 (NPB)
- Cells couple to each other via stress



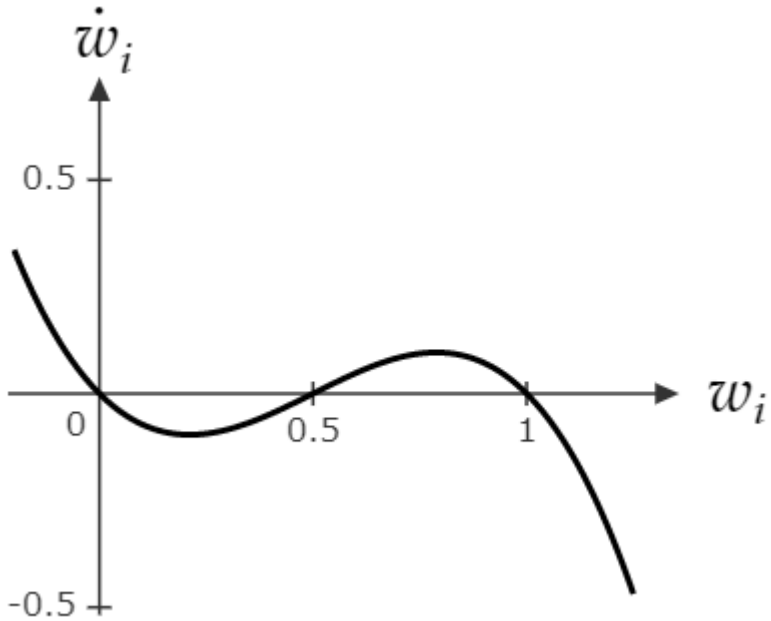


The Model

- w_{mid}- Asymmetry factor
- g- Coupling constant
- $S_{ij}w_j$- Dimensionless stress due to cell j
- $\alpha\sigma^*$- Constant stress on all cells

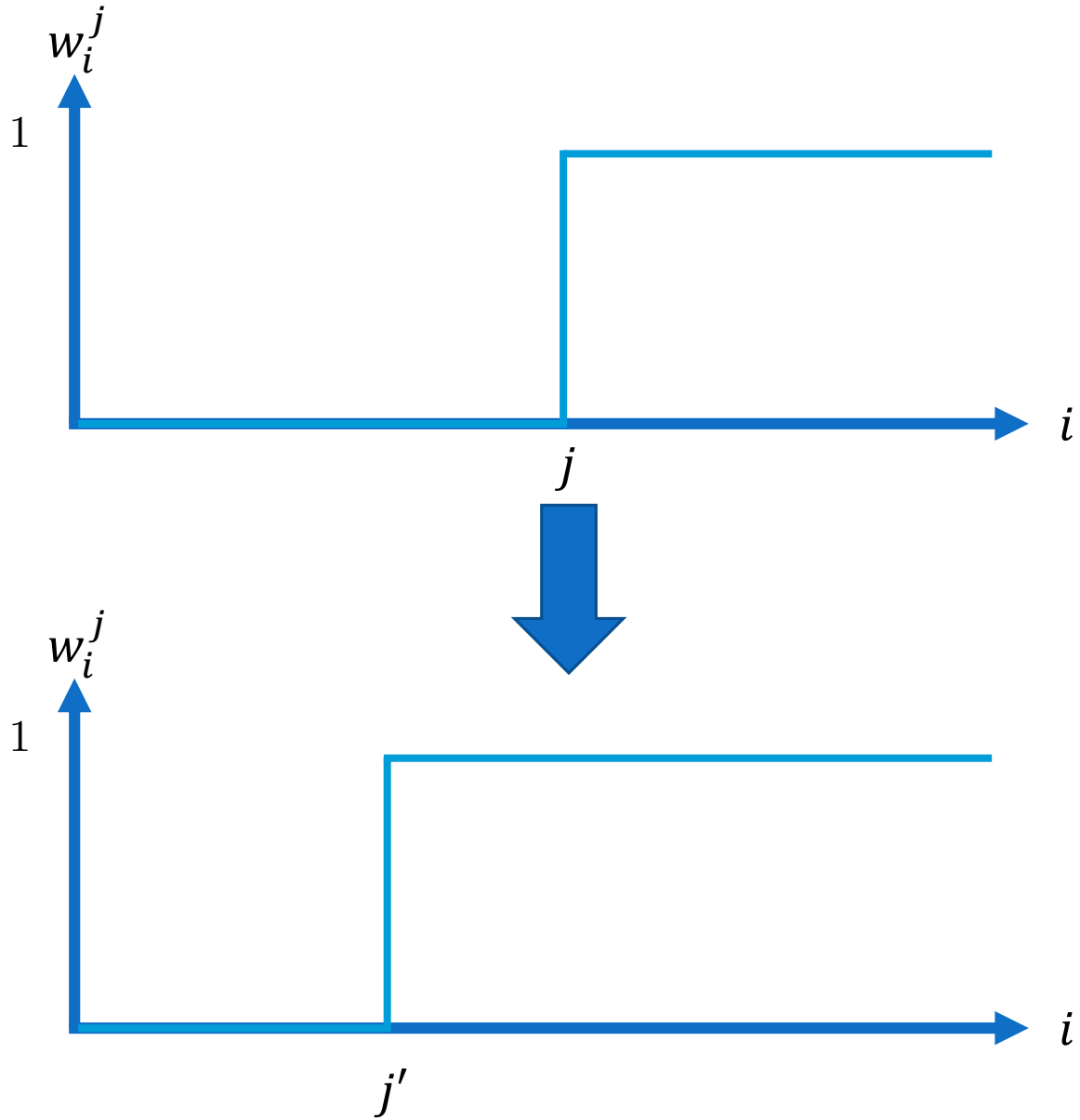
$$\dot{w}_i = w_i(1 - w_i)(w_i - w_{\text{mid}}) + g\sum_j S_{ij}w_j - \alpha\sigma^*$$

Cell's own preference Feedback Constant



Numerical Simulation

- Create test states $\boldsymbol{w}^j$ s.t. $w_i^j = \theta(i - j)$
- Solve ODEs numerically
- Check new domain wall position



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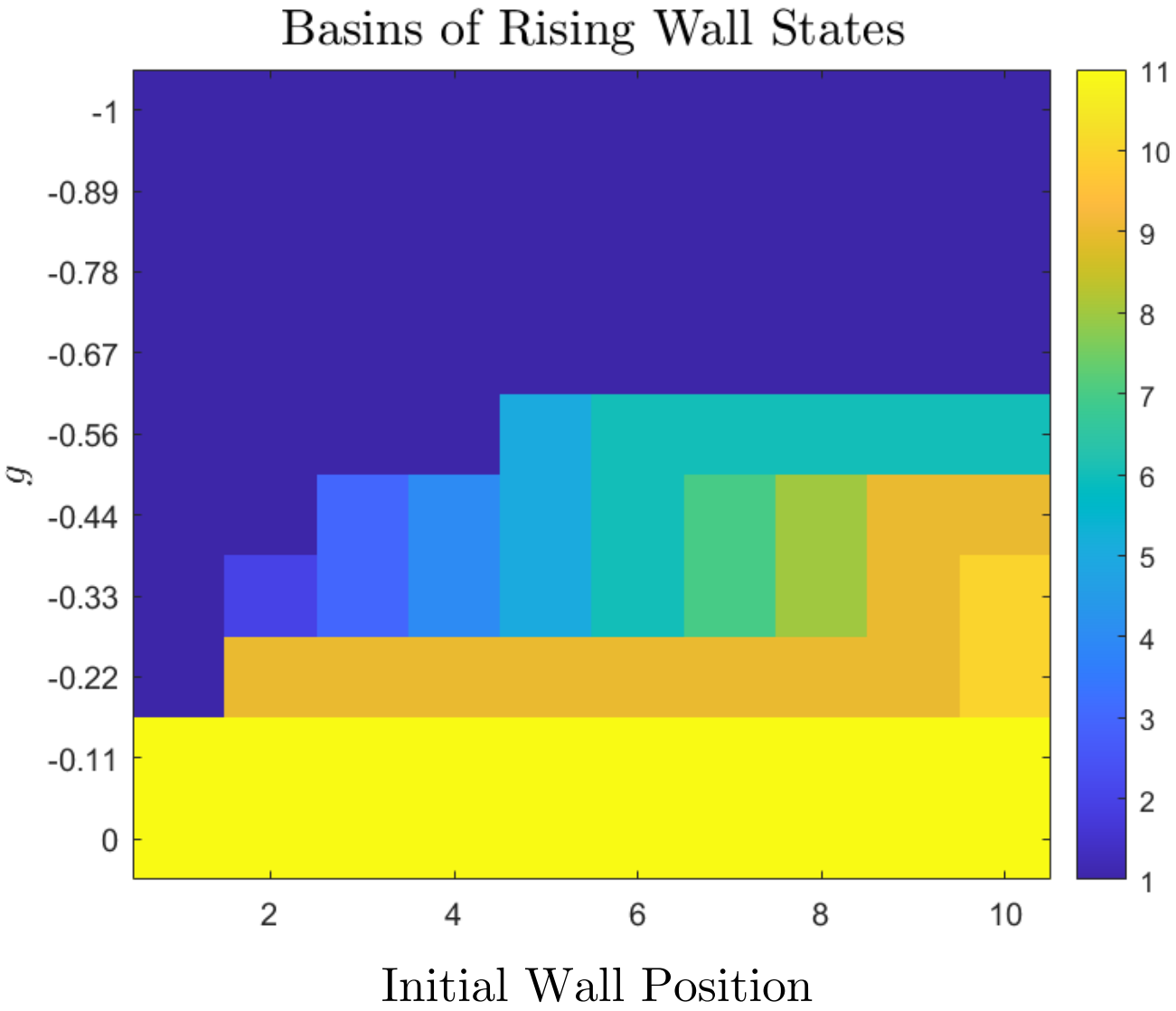
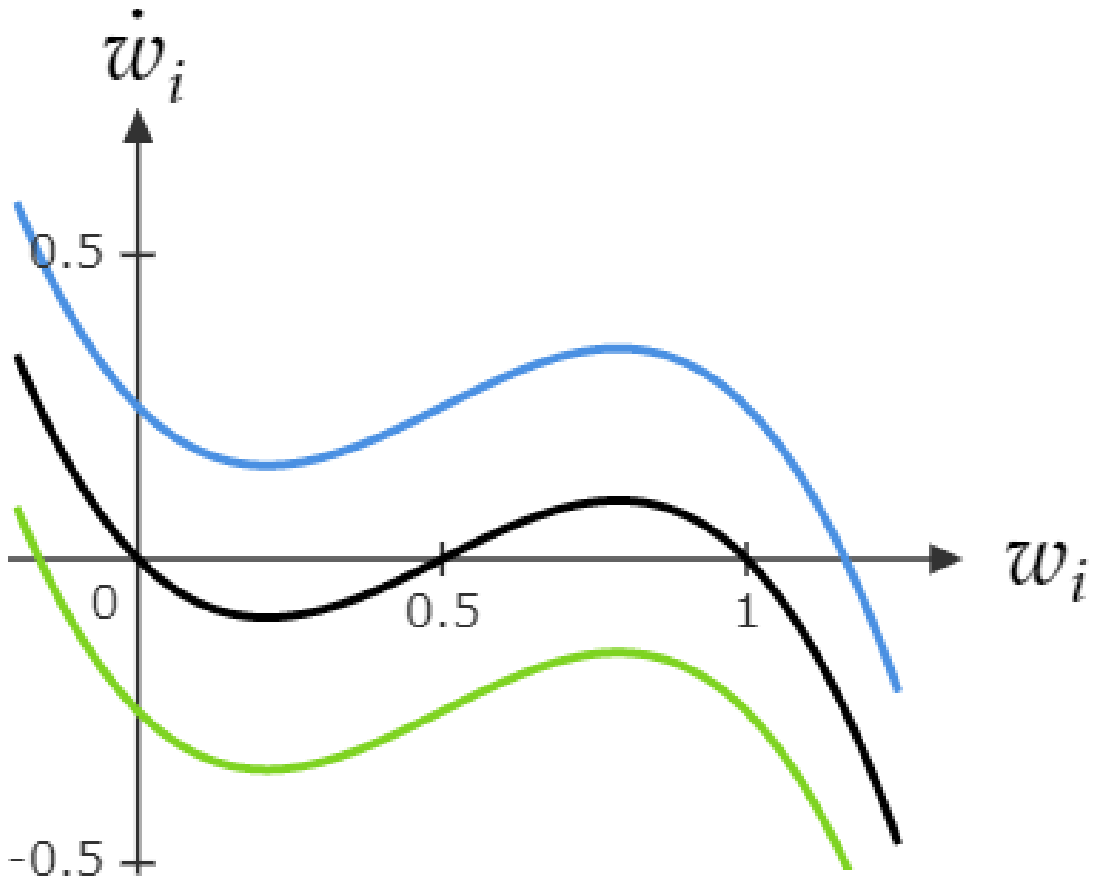


Consistency

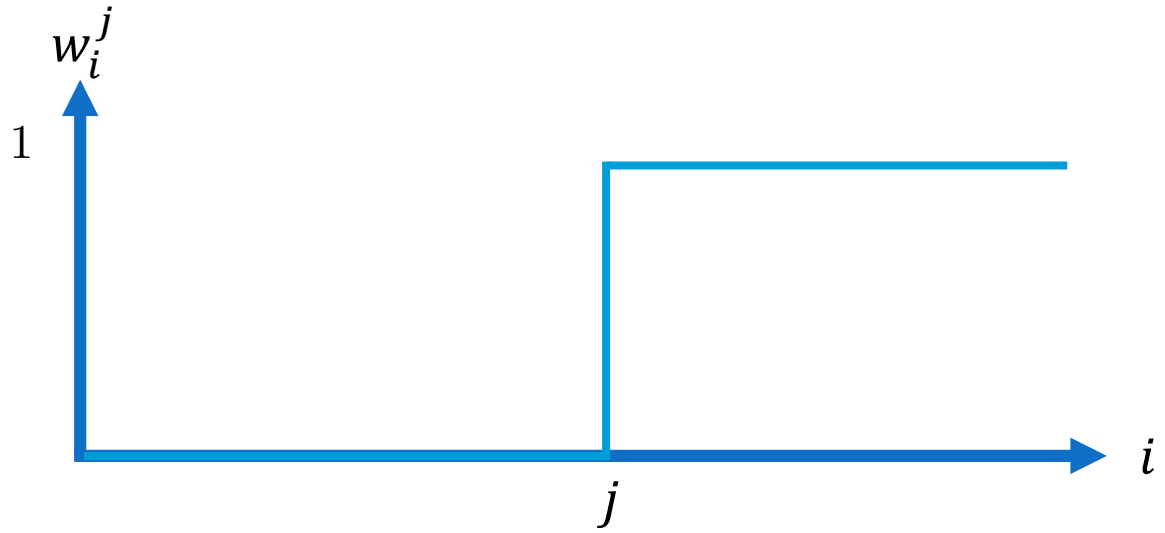
- Fixed points of model - → $\dot{w}_i = \mathbf{0}$
- $\dot{w}_i(w_i)$ is cubic with 1 or 3 roots
- Stress → Shift
- Total stress must be in some window for all 3 roots to exist

$$\dot{w}_i(w_i) = f(w_i) + gs_i(x_i)w_i + \text{const.}$$

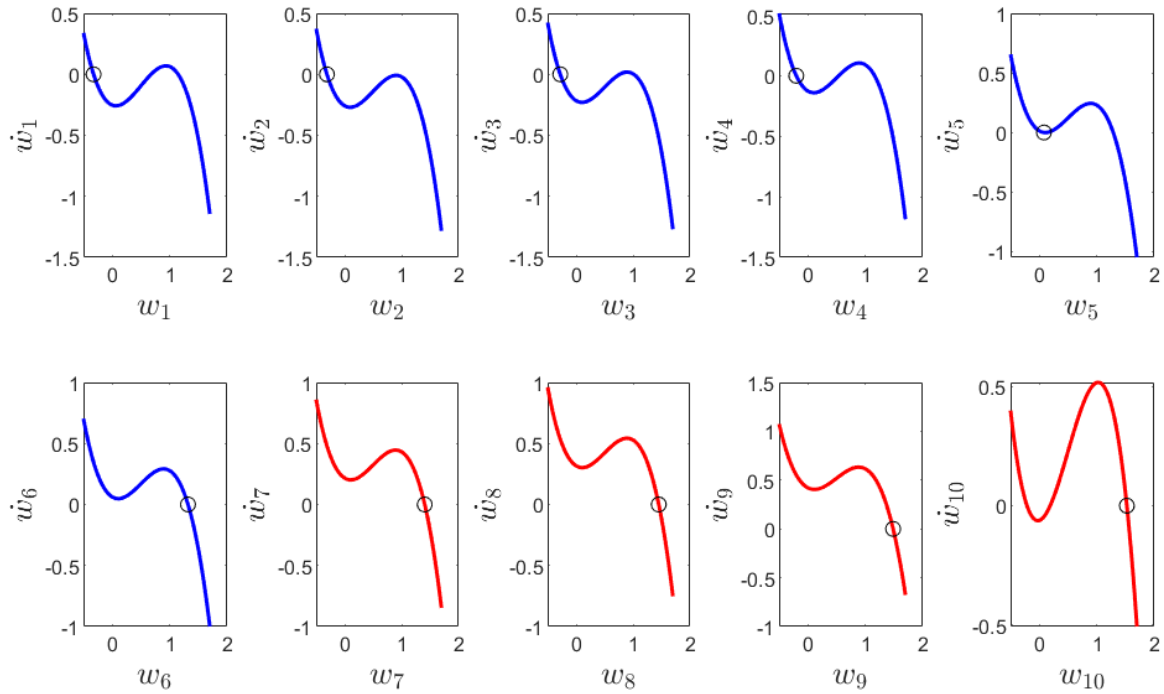


Consistency

- Use same test states
- Check roots of $\dot{w}_i(w_i)$ for each cell
- See if desired roots exist



Ex) $j = 7$



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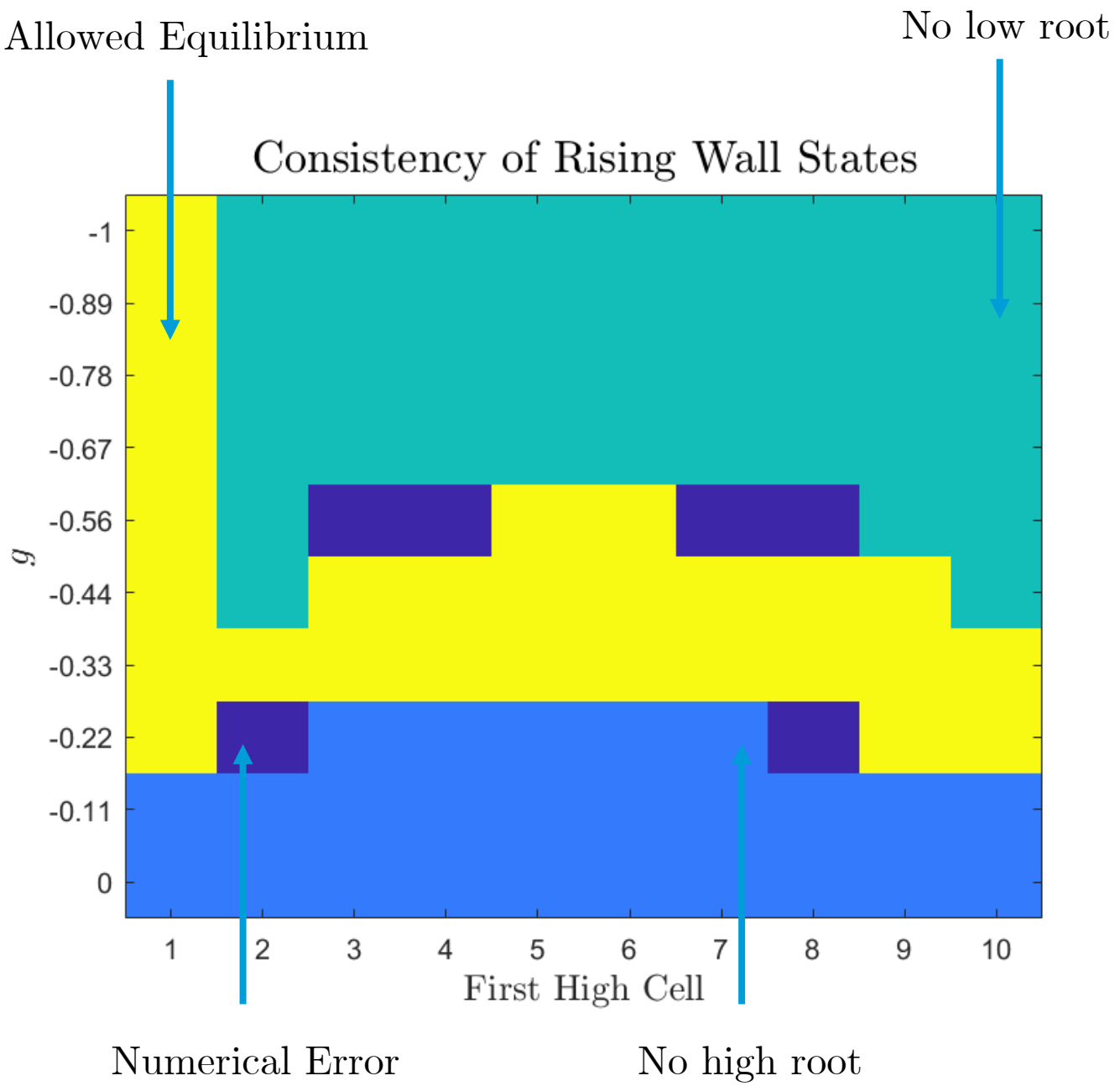
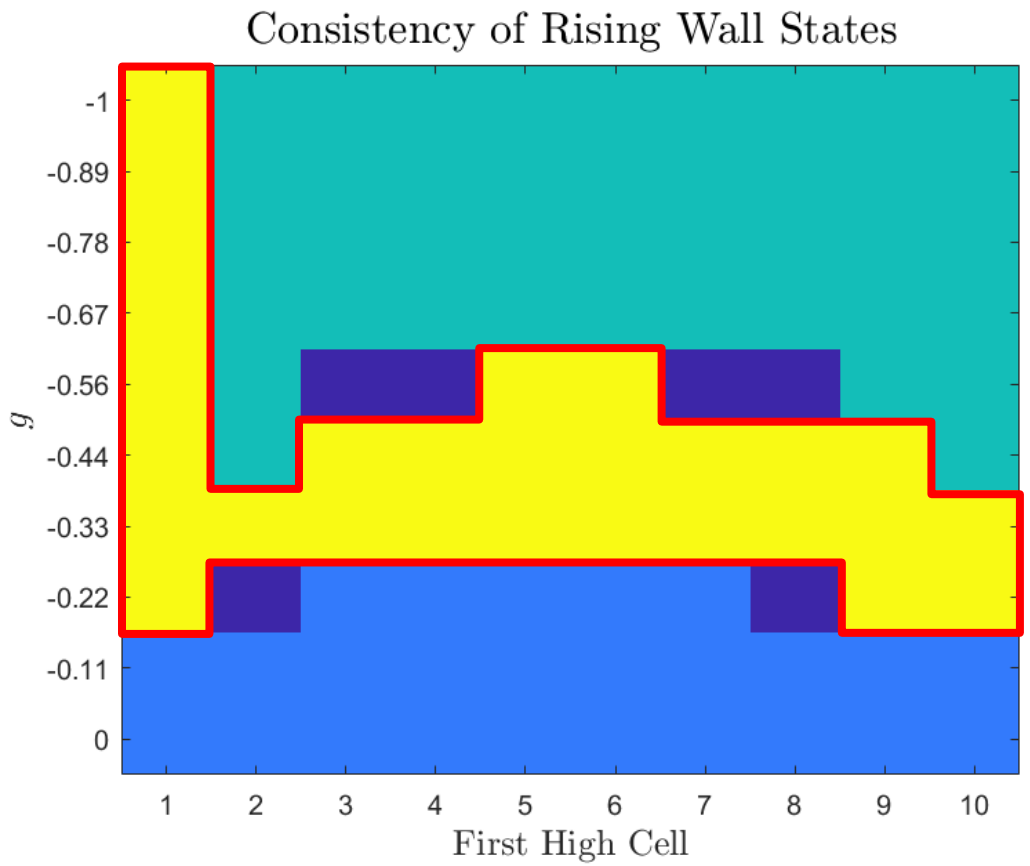
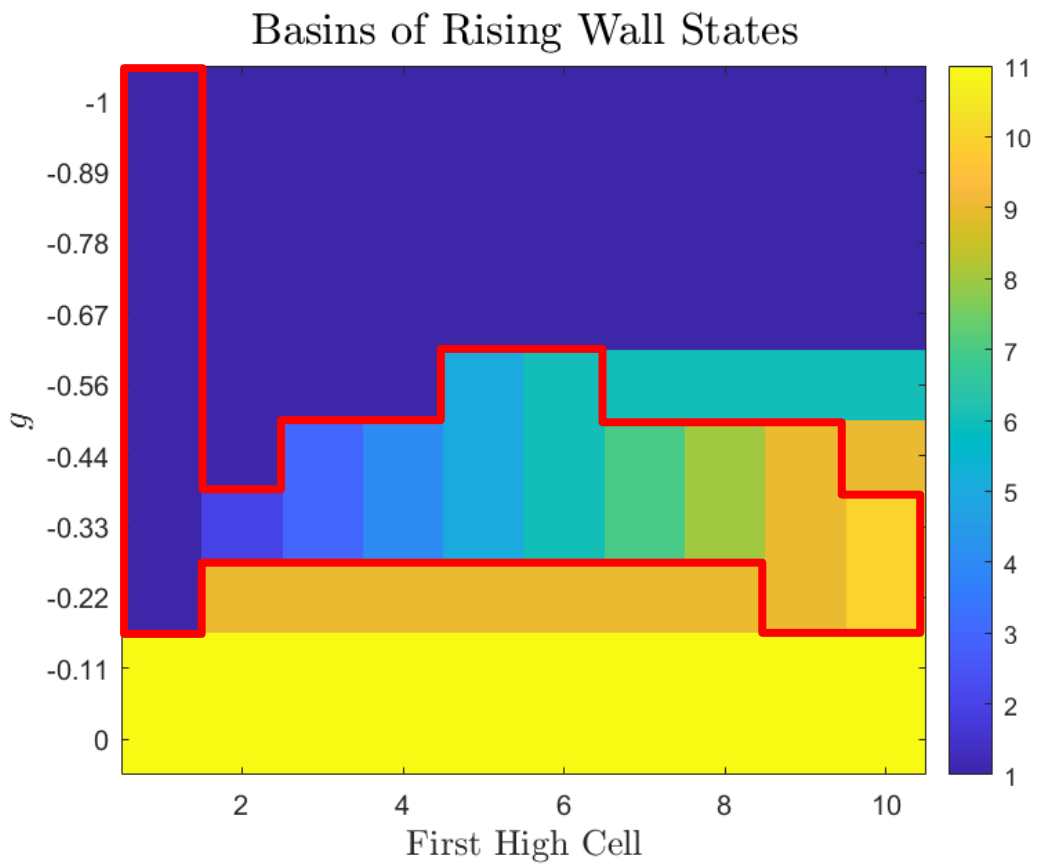


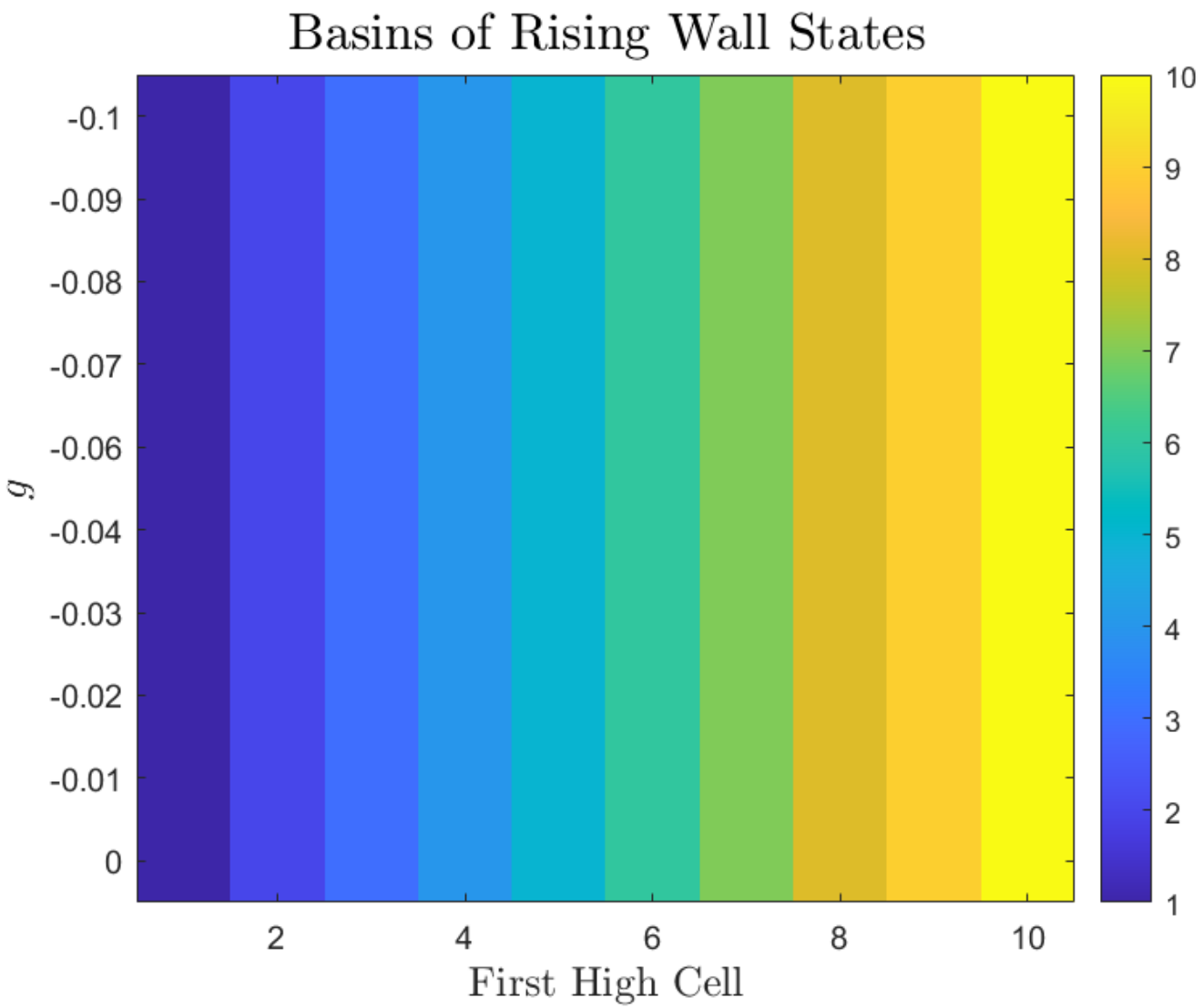
Comparing the Two





"Real" Parameters

- $\alpha\sigma^* = 0.03$ vs 0.2
- $g = -0.04$
- Walls "stick" where they start



Conclusions

- Model can reliably produce and sustain domain walls
- Coupling in discrete model is too weak to allow only a single stable domain wall
- Future work: expand to 2D

Acknowledgements

- Profs. David Lubensky, James Liu, Myron Campbell

- Hayden Nunley

- NSF