Hierarchies of climate models in the AI Era

Isaac Held

"Man is not a circle with a single center;
he is an ellipse with a double focus.
Facts form one of these, and ideas the other." Victor Hugo

Hierarchies of climate models in the AI Era

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”Science is not a circle with a single center;
it is an ellipse with a double focus.
Facts form one of these, and ideas the other."

Need theory to expand into “out-of-sample” parts of phase space

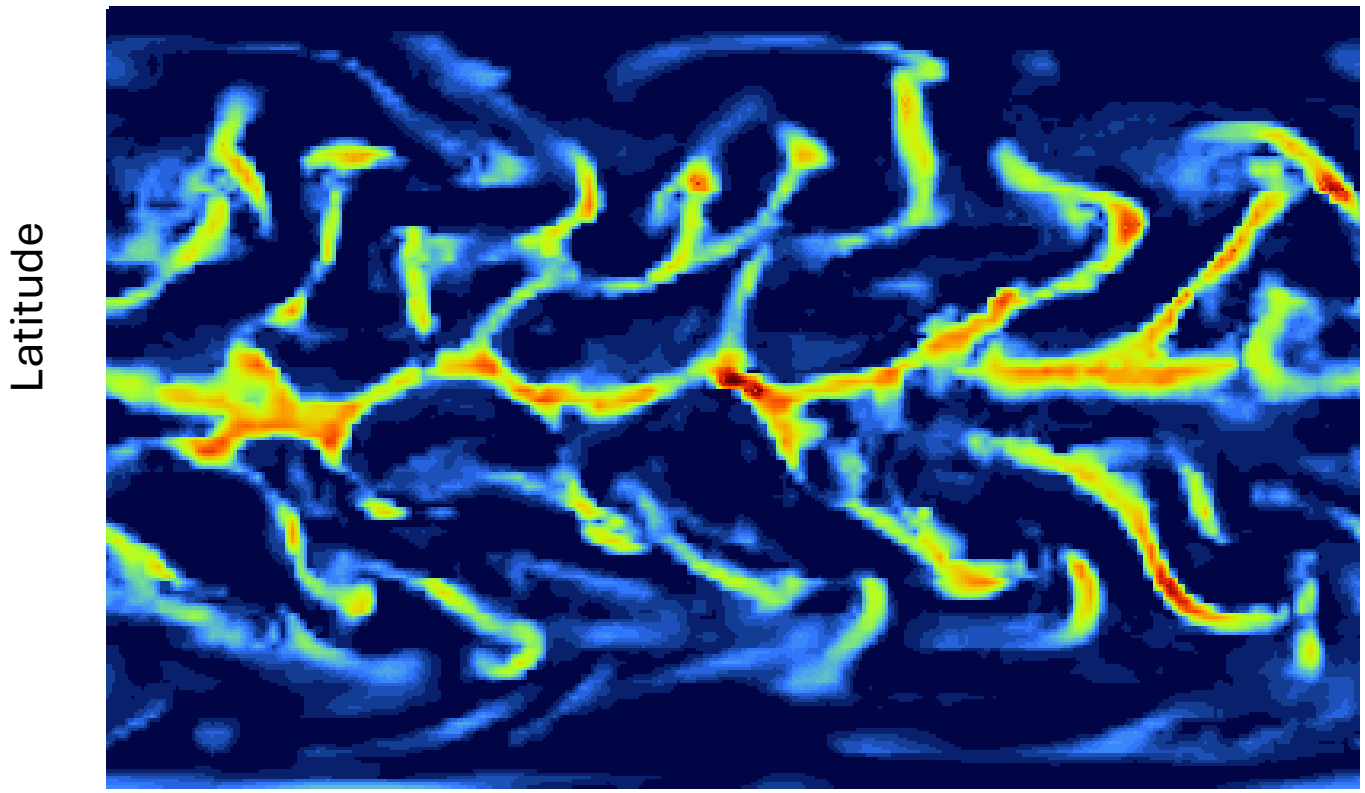
Hierarchies of simpler models
provide raw material for testing the kinds of
theories needed

Aquaplanet examples

Aqua planet --fixed zonally symmetric SSTs

or “slab’ lower boundary --

no continents, no ocean circulation, no seasons

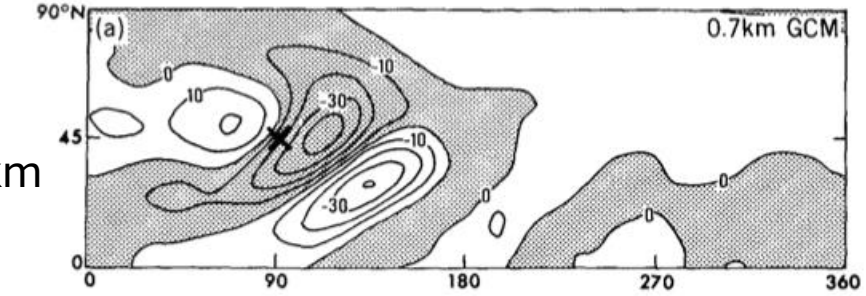


Snapshot of precipitation over globe with prescribed SSTs symmetric about equator

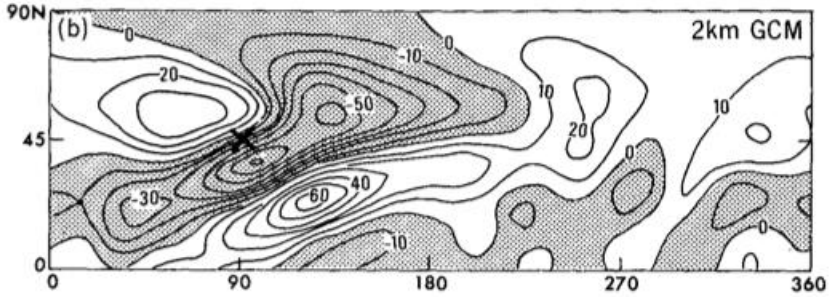
h/t Dargan Frierson

Based on climate of aquaplanet, develop theories of the zonally asymmetric climate by adding the boundary conditions/forcings that create climate asymmetries

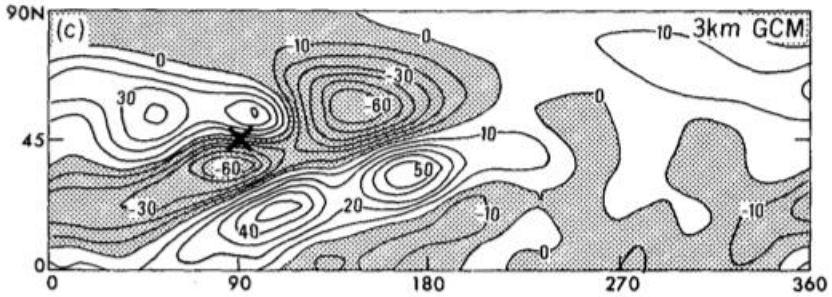
0.7 km



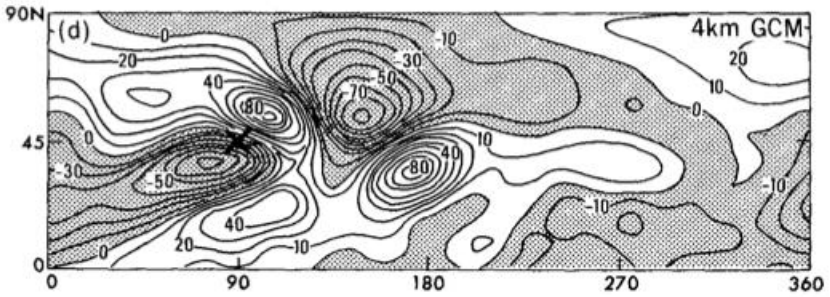
2 km



3 km



4 km

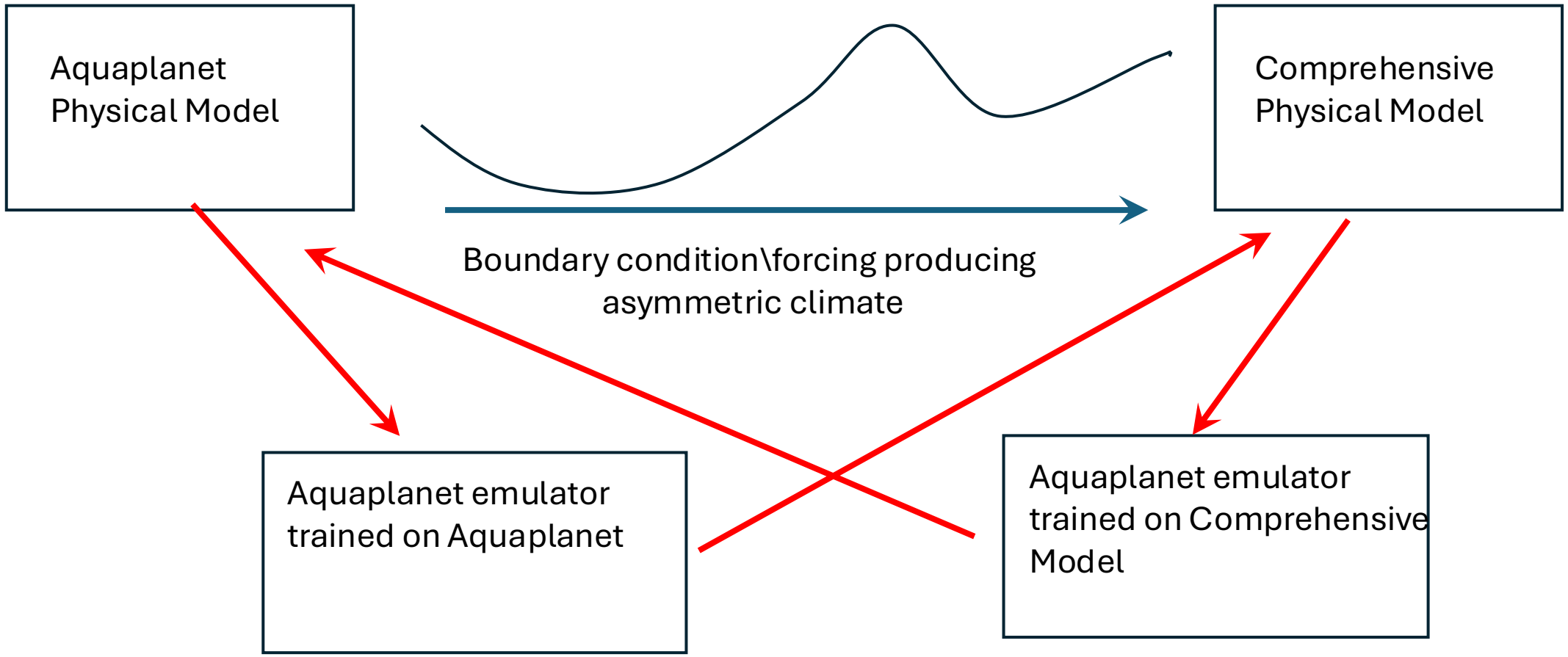


Responses to isolated topography of different amplitudes added to aquaplanet

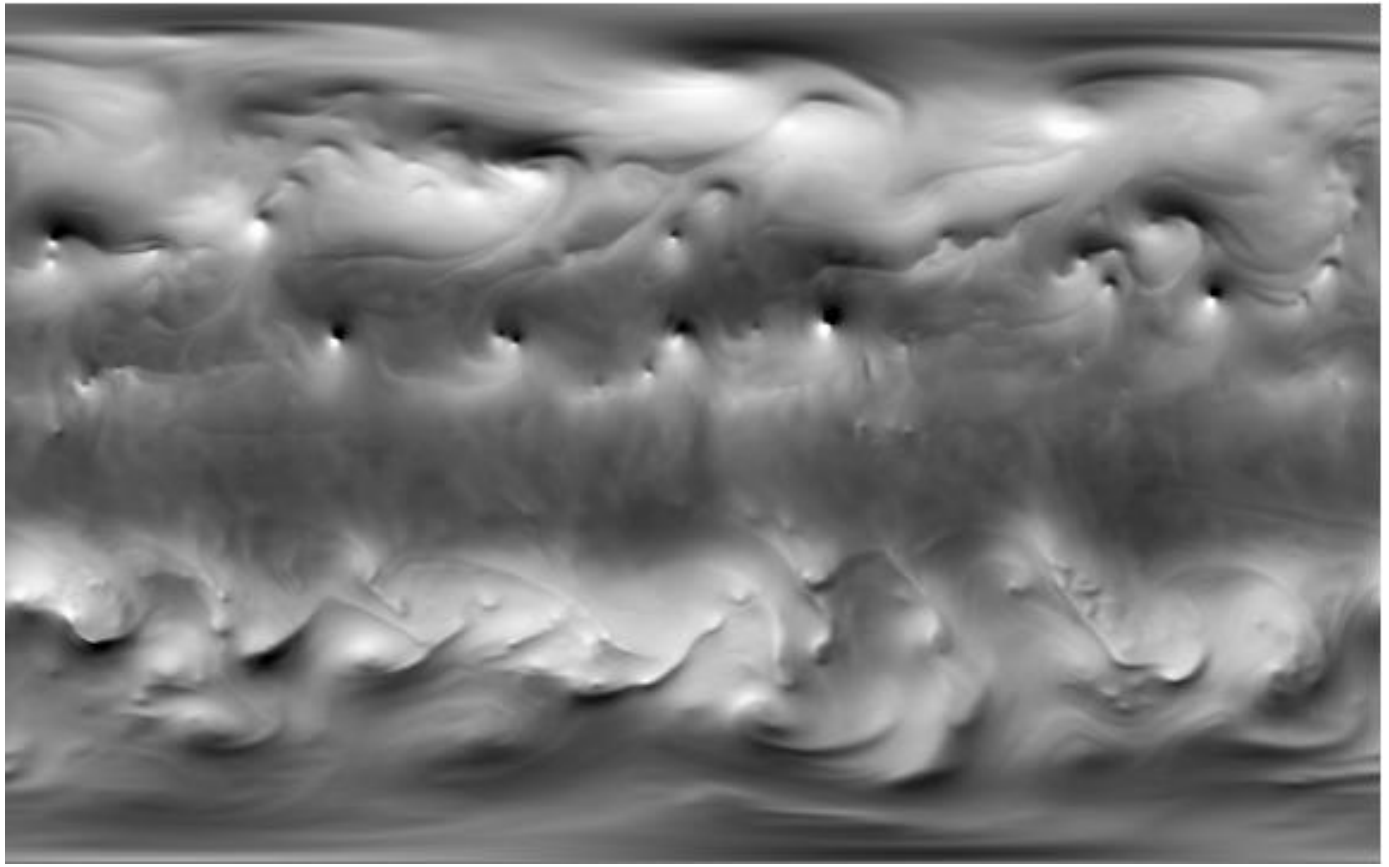
Cook and Held, JAS, 1992

350 hPa stationary eddy streamfunction

Can we understand this nonlinearity?


Aquaplanet
Physical Model
Comprehensive
Physical Model
Boundary condition\forcing producing
asymmetric climate
Aquaplanet emulator
trained on Aquaplanet
Aquaplanet emulator
trained on Comprehensive
Model

Aqua-planet with "slab ocean" and with zonally symmetric and N-S symmetric climate
– perturbed by poleward zonally symmetric "ocean" heat flux Q
– Merlis, Zhao, Held 2013 GRL

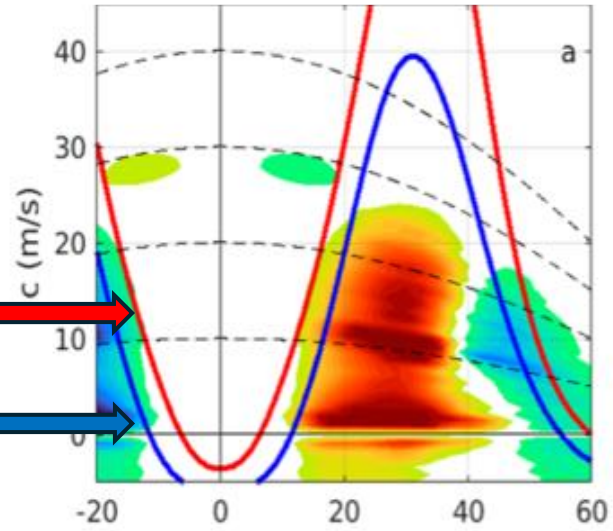


Can an emulator trained with Q = 0 regenerate this N-S asymmetric climate by perturbing Q

Superrotation in Aquaplanet generated by warming poles

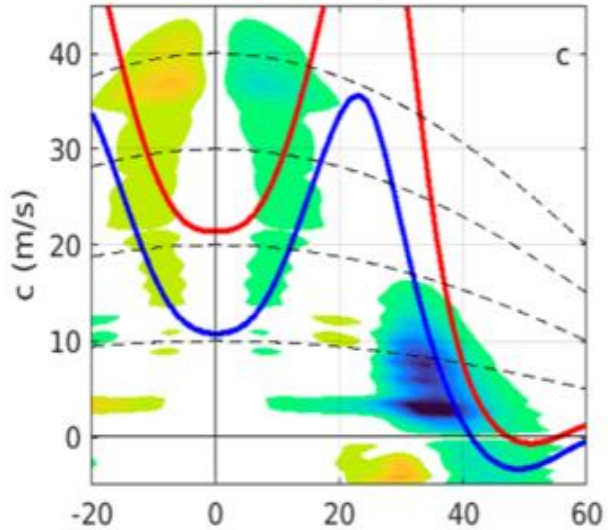
Zonal mean U
150 hPa

350 hPa



Control

Latitude-phase speed co-spectrum of eddy momentum flux



SST: 7K warmer at poles, unmodified at equator

Zurita-Gotor and Held, JAS 2024