Managing Crises, Climate Change and Ecological Resilience in Complex Resource Systems

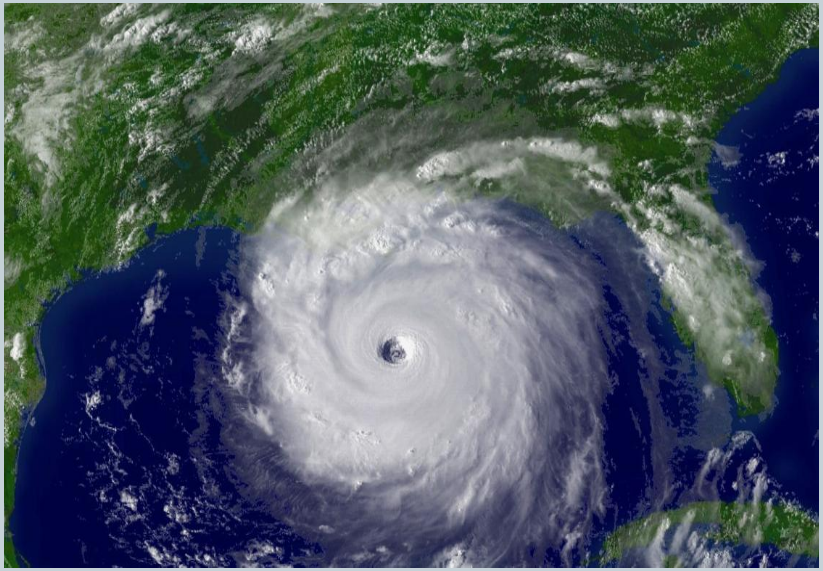
LANCE GUNDERSON* & KATHLEEN D. WHITE**

***EMORY UNIVERSITY**
ATLANTA GA, USA

****U.S. ARMY CORPS OF ENGINEERS,**
INSTITUTE FOR WATER RESOURCES
WASHINGTON DC USA

CRISIS = ABRUPT CHANGE, INSTABILITY

Tsunami, Japan, March 2011



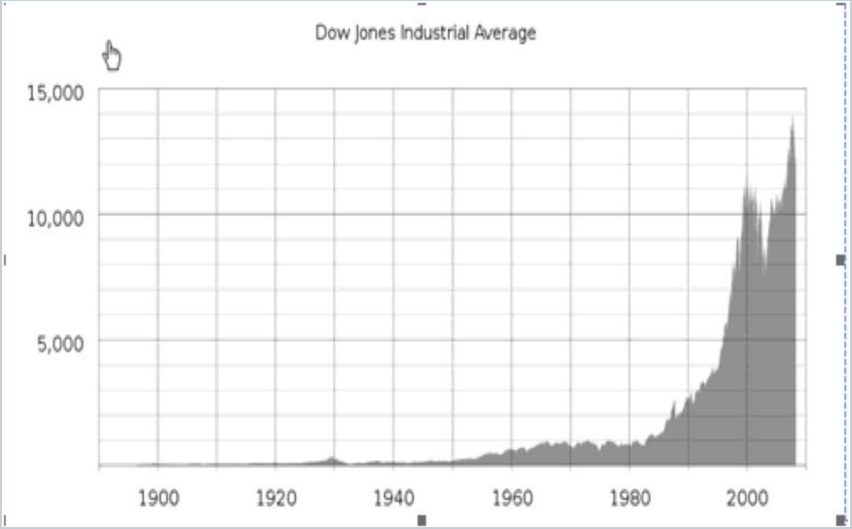
Hurricane Katrina, August 2005

Exogenous Crises

- Variation at larger scales

-Need for robust, diverse responses across scales

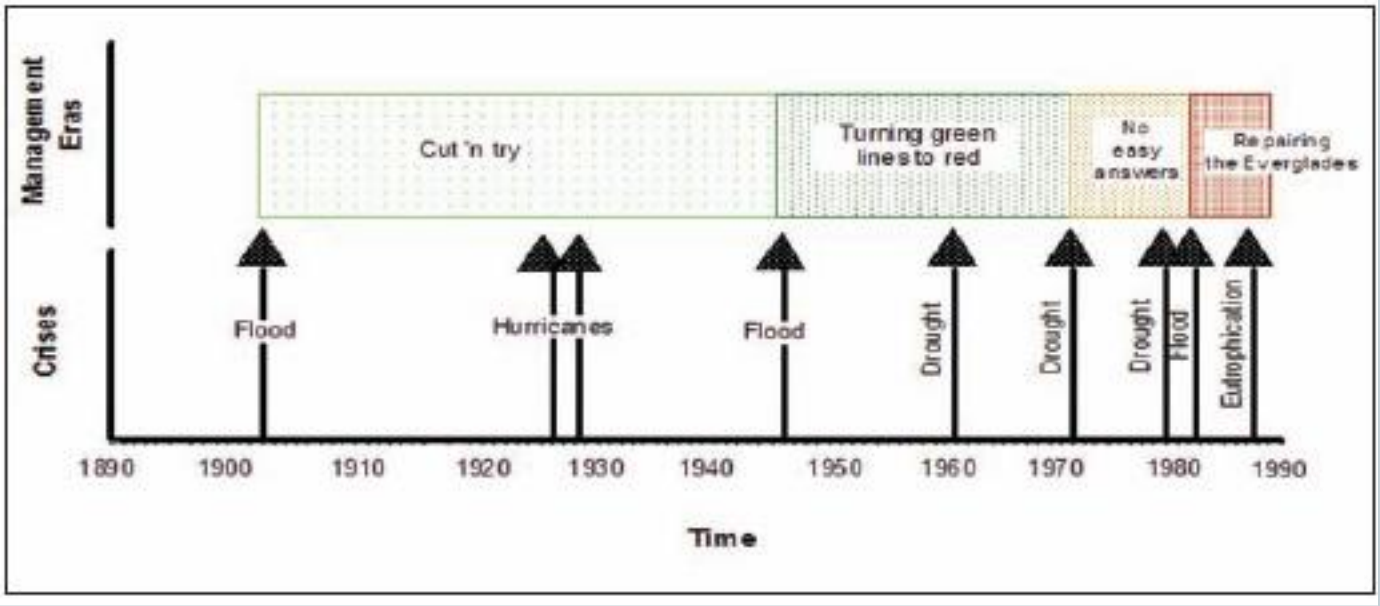
CRISIS = TURNING POINT



Endogenous Crises

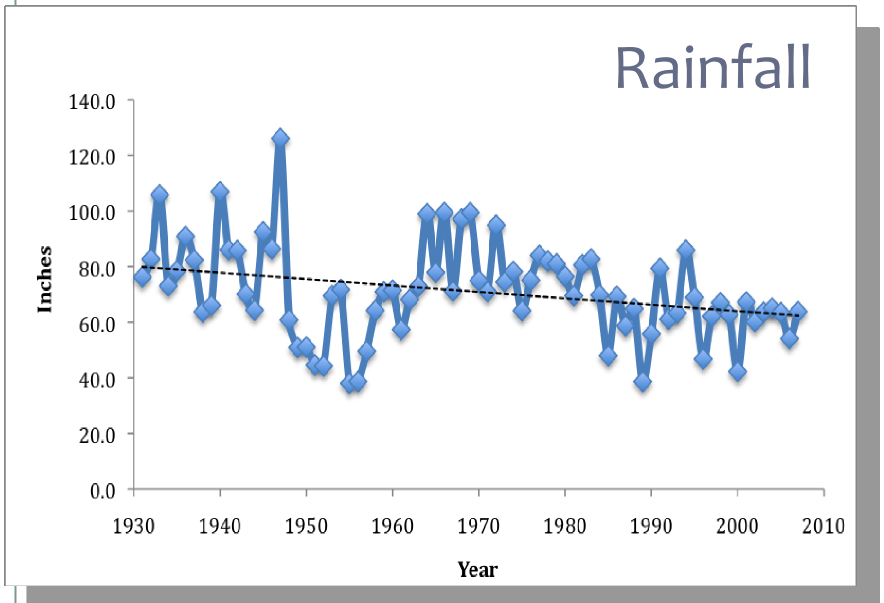
Increased Connections, Accumulation of Capital
Increase vulnerability, Shifting controls

Everglades History - Management Eras



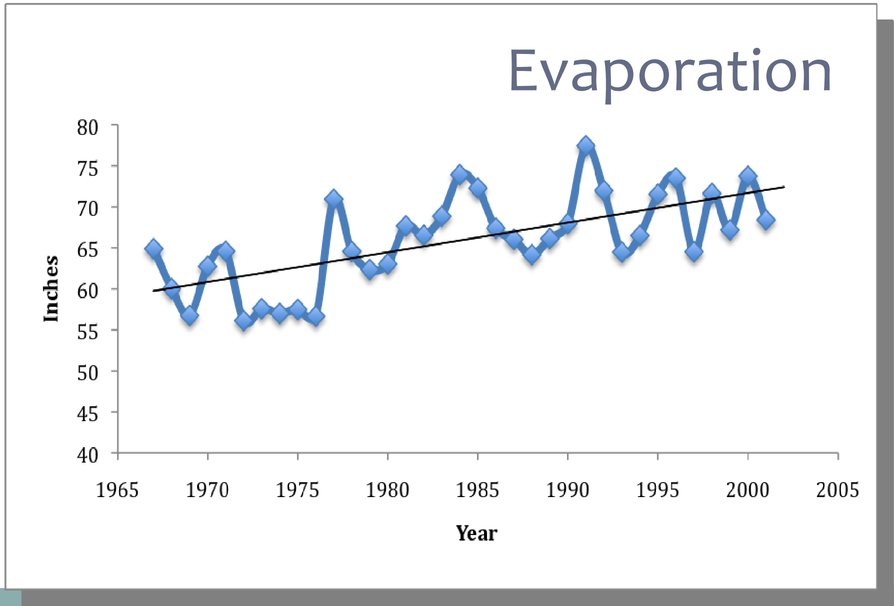
Climatic Driven Changes !

CLIMATE DATA- SOUTH FLORIDA



Stationarity ?

Increased variation

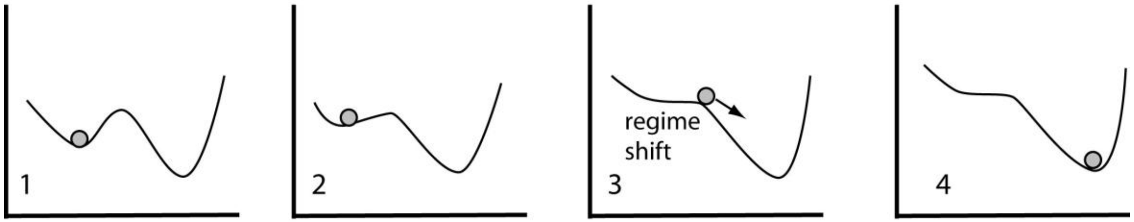


Climate Change: Increasing Surprises

- Changing long-term (Slow) variables
  - Flood and Drought cycles
    - Evaporation
    - Rainfall
  - Rising Sea Level
- Increase in Cyclonic frequency and intensity
- Increase in temperate wind variability

ADAPTIVE RESPONSES TO CLIMATE CHANGE

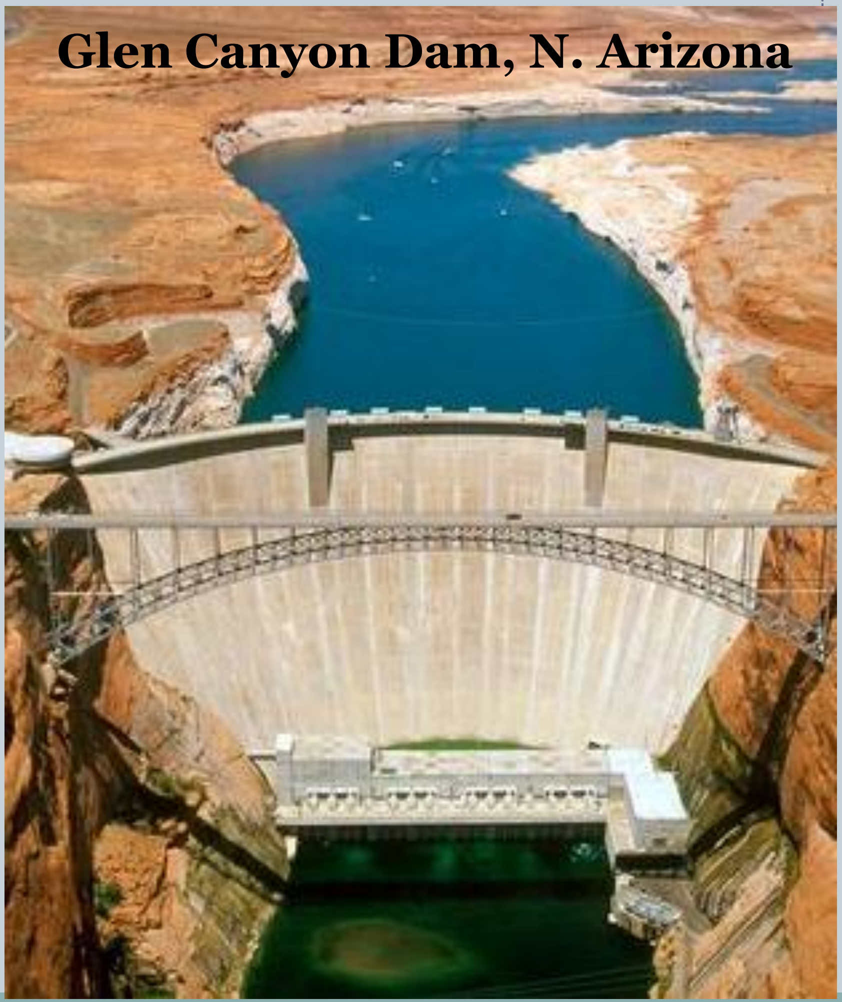
- **Linear Response**
  - scale bound
  - few variables
  - predictable responses
- **Resilient Response**
  - Non linear dynamics
  - Multiple regimes in socio-ecological systems
  - Knowledge of regimes
- **Transformational Response**
  - Little or no experience
  - No analytic solutions, hard to define issues/problems (Wicked)
  - New systems, configurations and interactions



Regime	Alteration	Trigger	New Regime
clear- water lakes	phosphorus accumulation in agricultural soil and lake mud	flooding, warming overexploitation of predators	turbid-water lakes
coral-dominated reefs	overfishing coastal eutrophication	disease, bleaaching hurricane	algae-dominated reefs
grasslands	fire prevention	good rains, continuous heavy grazing	shrub-bushland
grassland	hunting of herbivores	disease	woodland
kelp forests	functional elimination of apex predators	thermal event storm, disease	sea urchin dominance
pine forests	microclimate and soil changes, loss of pine regeneration	decreased fire frequency, increased fire intensity	oak forest
seagrass beds	removal of grazers lack of hurricanes salinity moderation spatial homogenization	thermal event	phytoplankton blooms
tropical lake with submerged vegetation	nutrient accumulation during dry spells	nutrient release with water table rise	floating-plant dominance

Carl Folke, Steve Carpenter, Brian Walker, Marten Scheffer, Thomas Elmqvist, Lance Gunderson, and C.S. Holling. 2004. **Regime Shifts, Resilience, And Biodiversity In Ecosystem Management.** *Annu. Rev. Ecol. Evol. Syst*. 35:557–81

RESTORATION = REGIME MANAGEMENT



- Sand for Beaches
- Endangered species
- Recreation - fishing, rafting, camping, hiking
- Power generation
- Non-native species
- Cultural history - claims
- Water allocation & delivery

ADAPTIVE MANAGEMENT EXPERIMENTS

FLOW EXPERIMENTS

1996, 2004, 2008

Sediment, Beaches, Biology?

PREDATION CONTROL

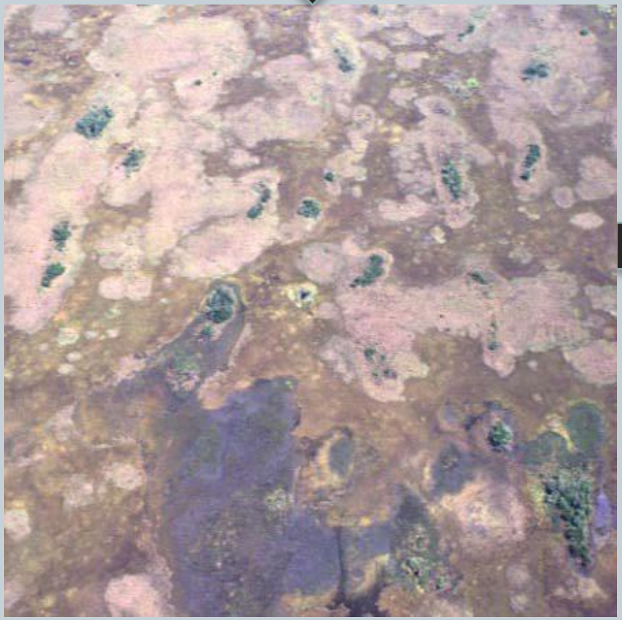
2002- present

Trout eating humpback chub

Grand Canyon: Experiments Critical to Social Learning and Restoration

- Experiments are costly
- Changed understanding
- Embedded leadership was necessary
- Forced addressing alternative hypotheses
- No long-term experimental design

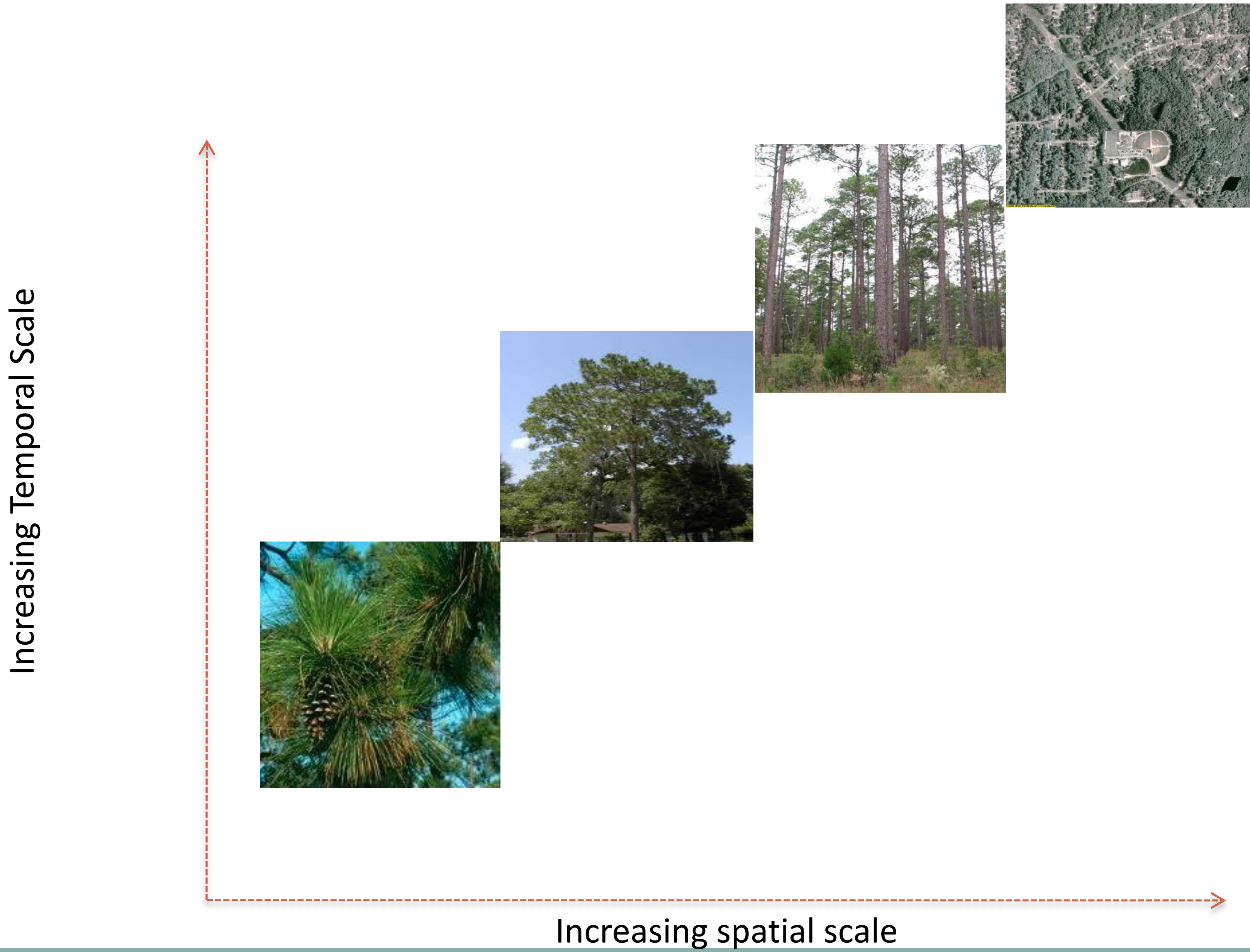
Everglades Restoration
1) Restore historic hydrologic regime
2) Detect and Avoid thresholds- undesired regimes

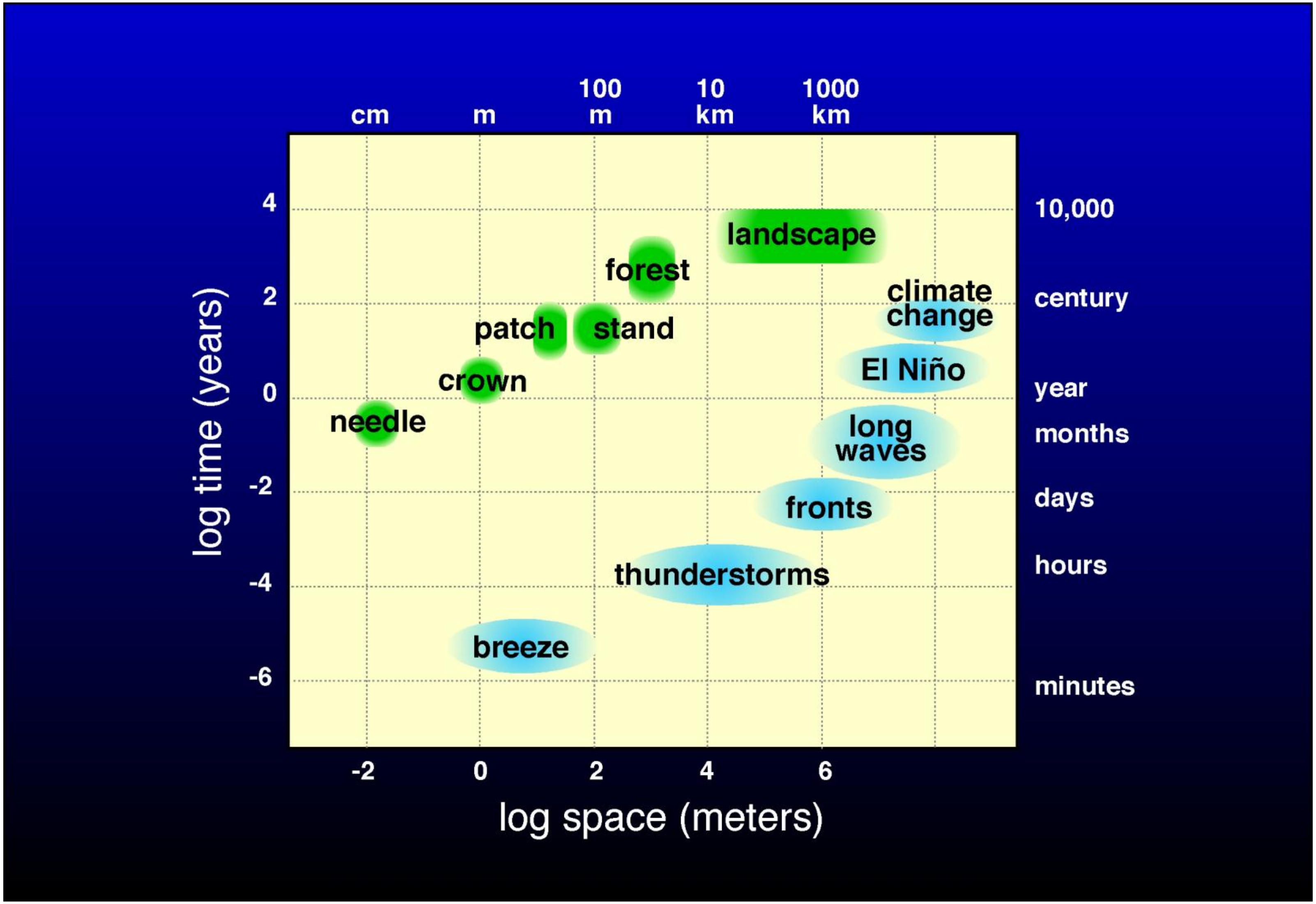


Nutrient Thresholds in Everglades

REGIME MANAGEMENT

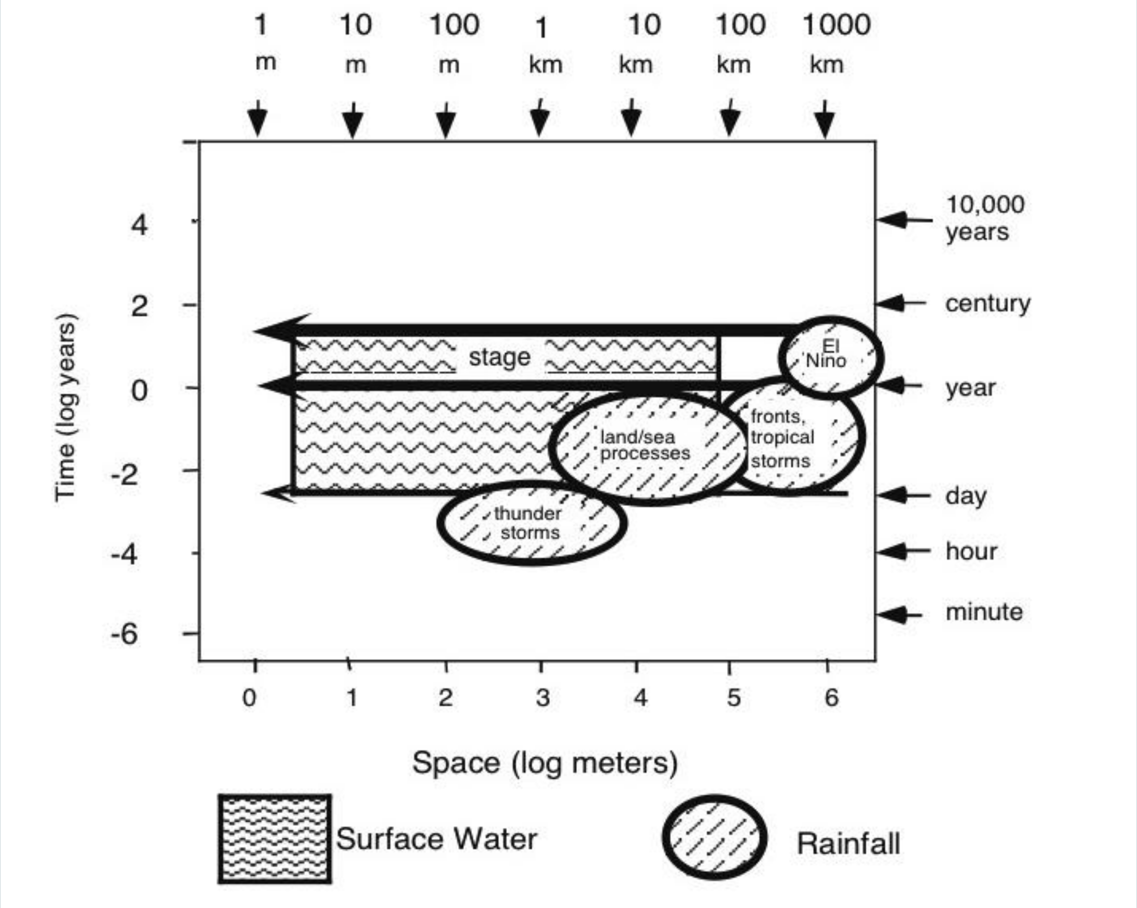
- Is Regime Shift Reversible?
  - Do Nothing (Ignore)
  - Manage to desirable state
    - Active adaptive management - actions, hysteresis
    - Passive adaptive management - time during transition
- Is Regime Shift Irreversible?
  - Do Nothing (Ignore)
  - Adapt to new state
    - Foster experiments for adaptation
    - Provide incentives for new solutions


Increasing Temporal Scale
Increasing spatial scale

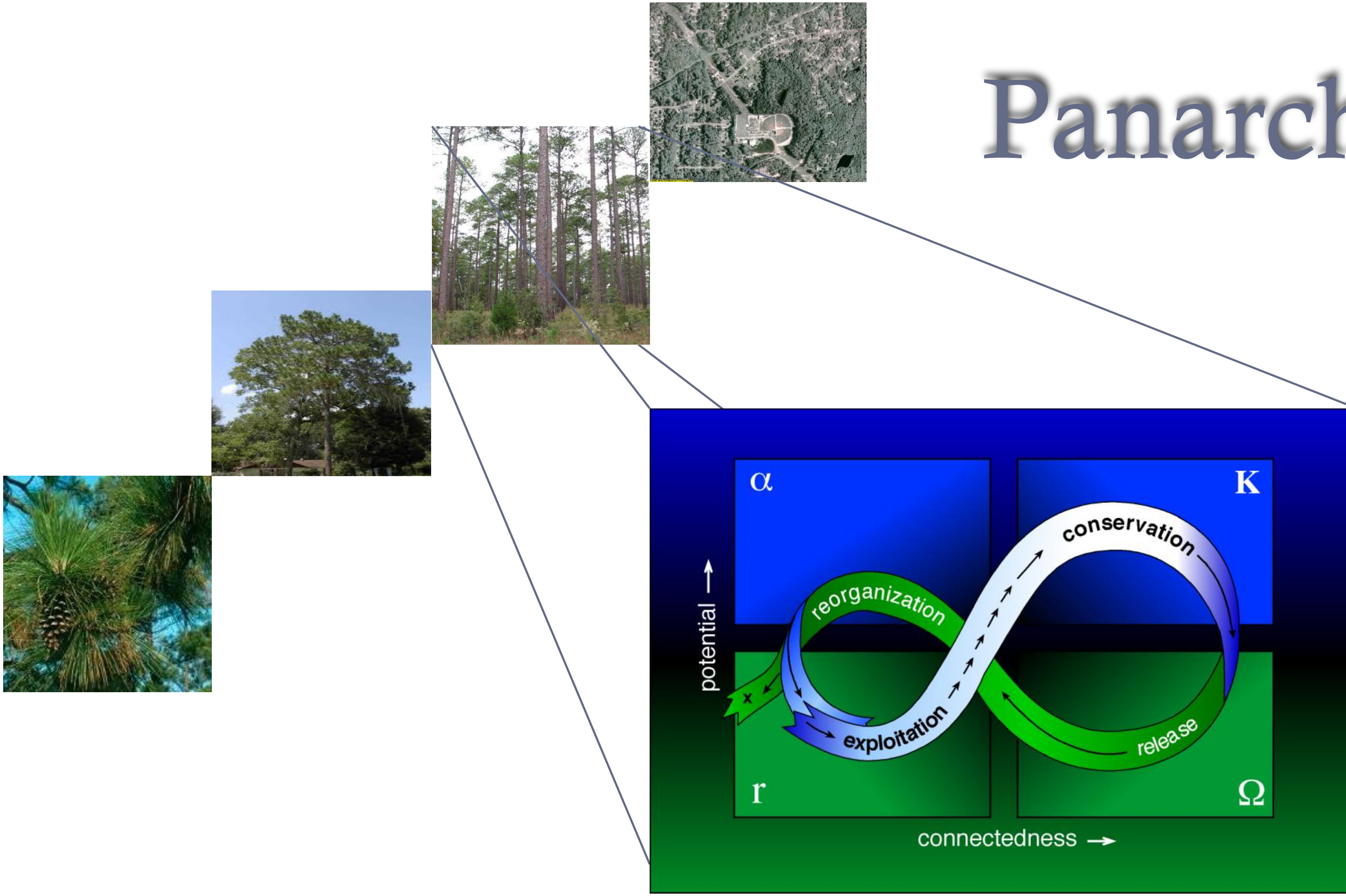


cm
m
100 m
10 km
1000 km
log time (years)
4
2
0
-2
-4
-6
10,000
century
year
months
days
hours
minutes
landscape
forest
patch
stand
crown
needle
climate change
El Niño
long waves
fronts
thunderstorms
breeze
-2
0
2
4
6
log space (meters)

Hydrologic Hierarchy Florida

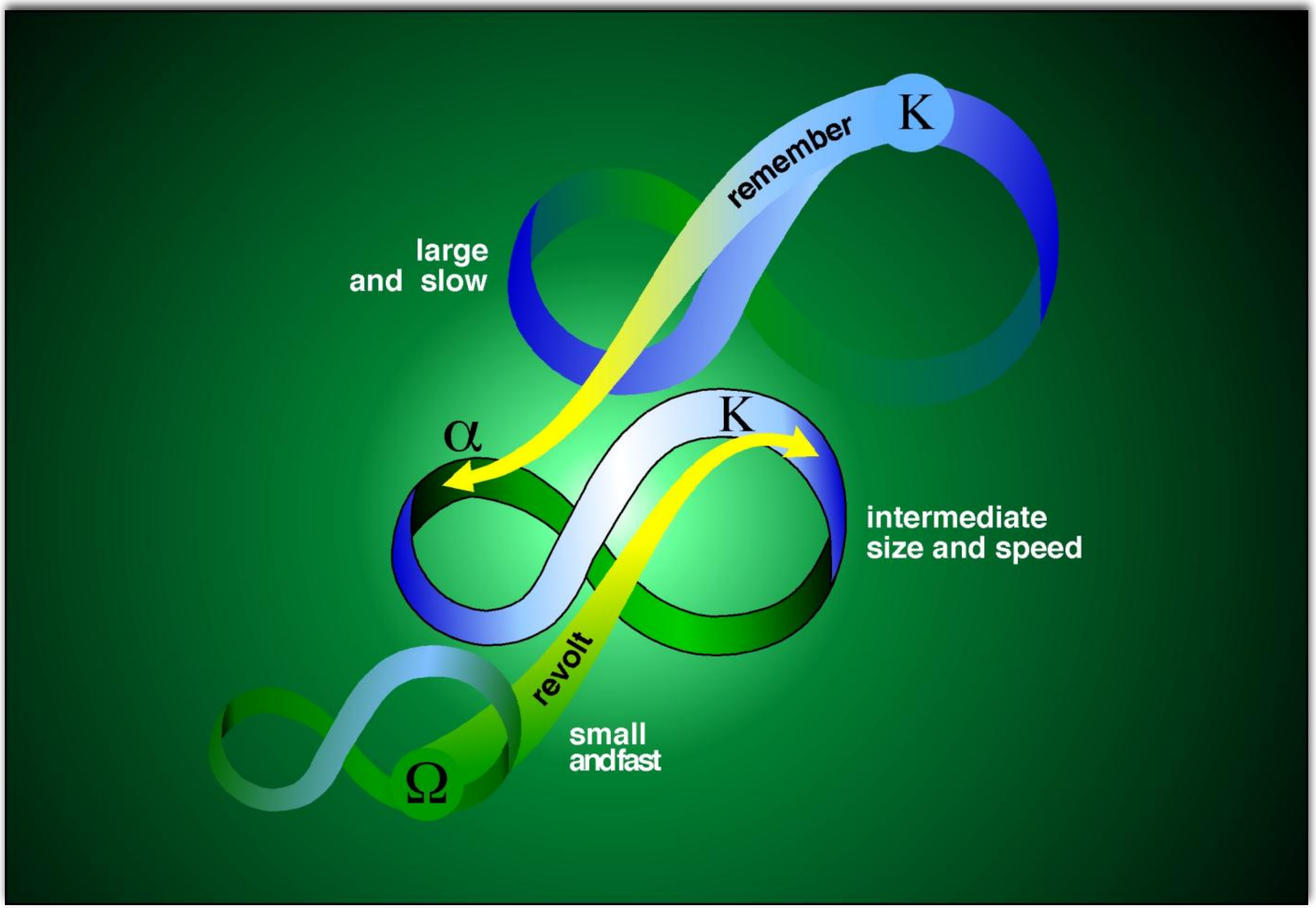


Panarchy



α
K
r
Ω
potential
connectedness
conservation
reorganization
exploitation
release
x

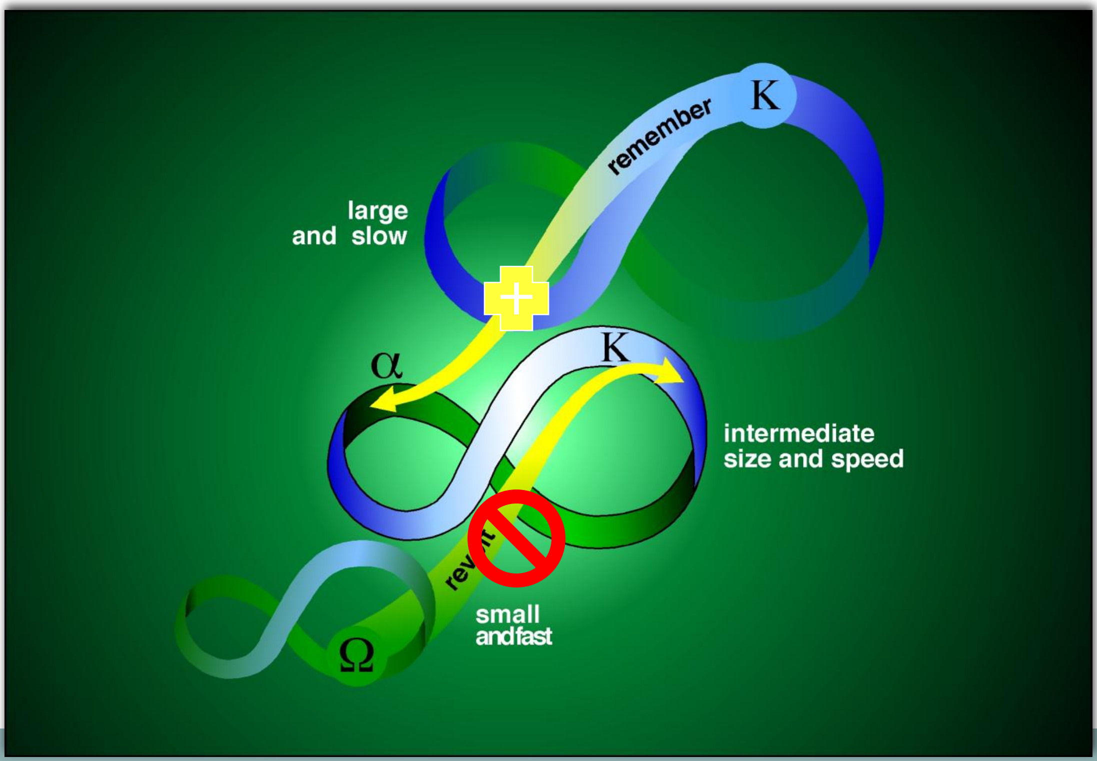
Panarchy



remember
K
large
and slow
K
α
intermediate
size and speed
revolt
small
andfast
Ω

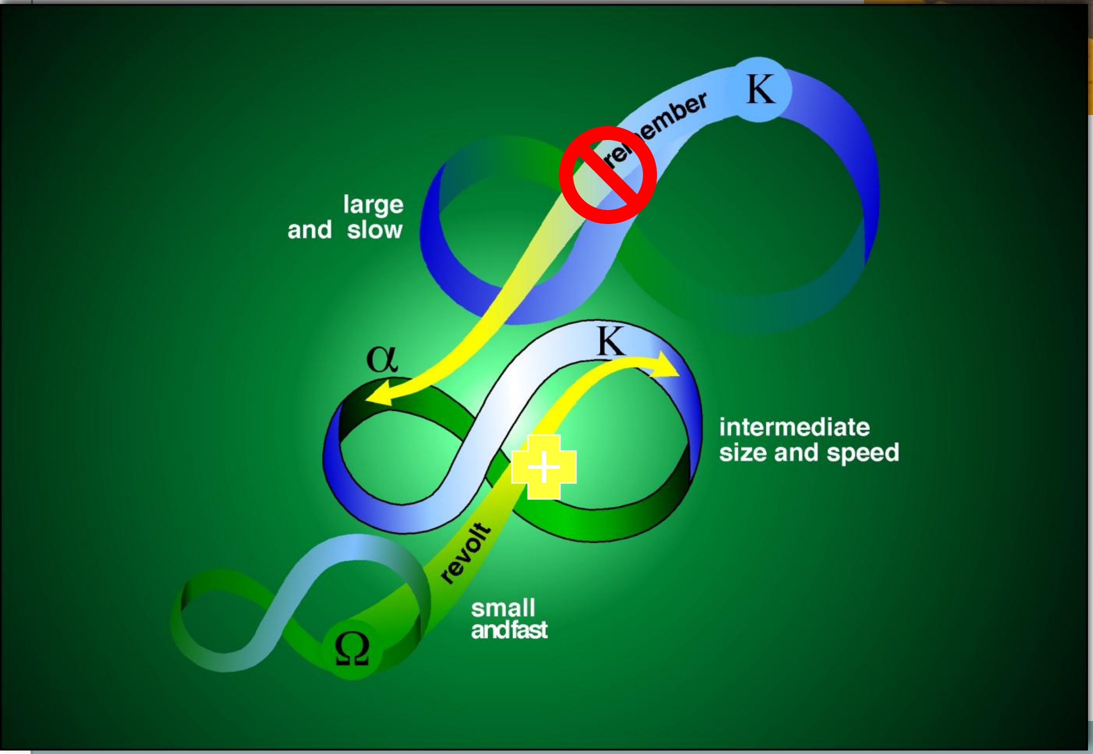
Rigidity Trap

- Maintenance of status quo
- Lots of capital/power
- Innovation/experimentation stifled
- Requires crisis to unlock



Poverty Trap

- •Maintenance of status quo
- •Decline in natural capital/structure
- •Erosion of external inputs
- •Unable to contain cascading effects



1927 - Mississippi Flood
2005 - Hurricane Katrina

SUGGESTIONS

- **Navigate Transitions**
  - Prepare for change
  - Develop shared views of alternative futures
- **Design flexible processes**
  - Discourses and collaborations, not fixed structures.
  - Focus on new ideas, solutions
- **Recognize opportunities**
  - Variation in climate = opportunities for experimentation

SUGGESTIONS

- **Develop Learning Based Institutions**
  - Evaluate and monitor outcomes of past interventions
  - Engage across sectors (ecological,economic, social)
  - Epistemic organizations (skunkworks)
- **Create incentives for flexibility**
  - Develop and maintain a portfolio of projects, waiting for opportunities to open.
  - Stimulate experiments
  - Actions that are safe to fail for individuals, institutions