

**Chugach Mtns  
Near Portage Glacier  
Spring 1976**



# Climate Change Consequences

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Climate sets the stage  
upon which the evolutionary  
and ecological play is  
enacted

# Thinking About Water

Water has always appeared available,  
we don't often think directly about what services  
this vital resource provides-

Water is rare, in northern/polar deserts.

Life becomes possible and is sustainable in  
otherwise extreme and variable northern  
environments.





**Kugluktuk, Nunavut  
May 1998**



# Accelerating Climate Change: A Warming World and Consequences for Sustainability and Safety of Arctic Water and Food Resources

Conference on Water Innovations for Healthy Arctic Homes  
Anchorage, Alaska/ September 2016

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Eric P. Hoberg

US National Parasite Collection  
Agricultural Research Service, US Department of Agriculture  
and  
Smithsonian Institution

# Climate and Biodiversity

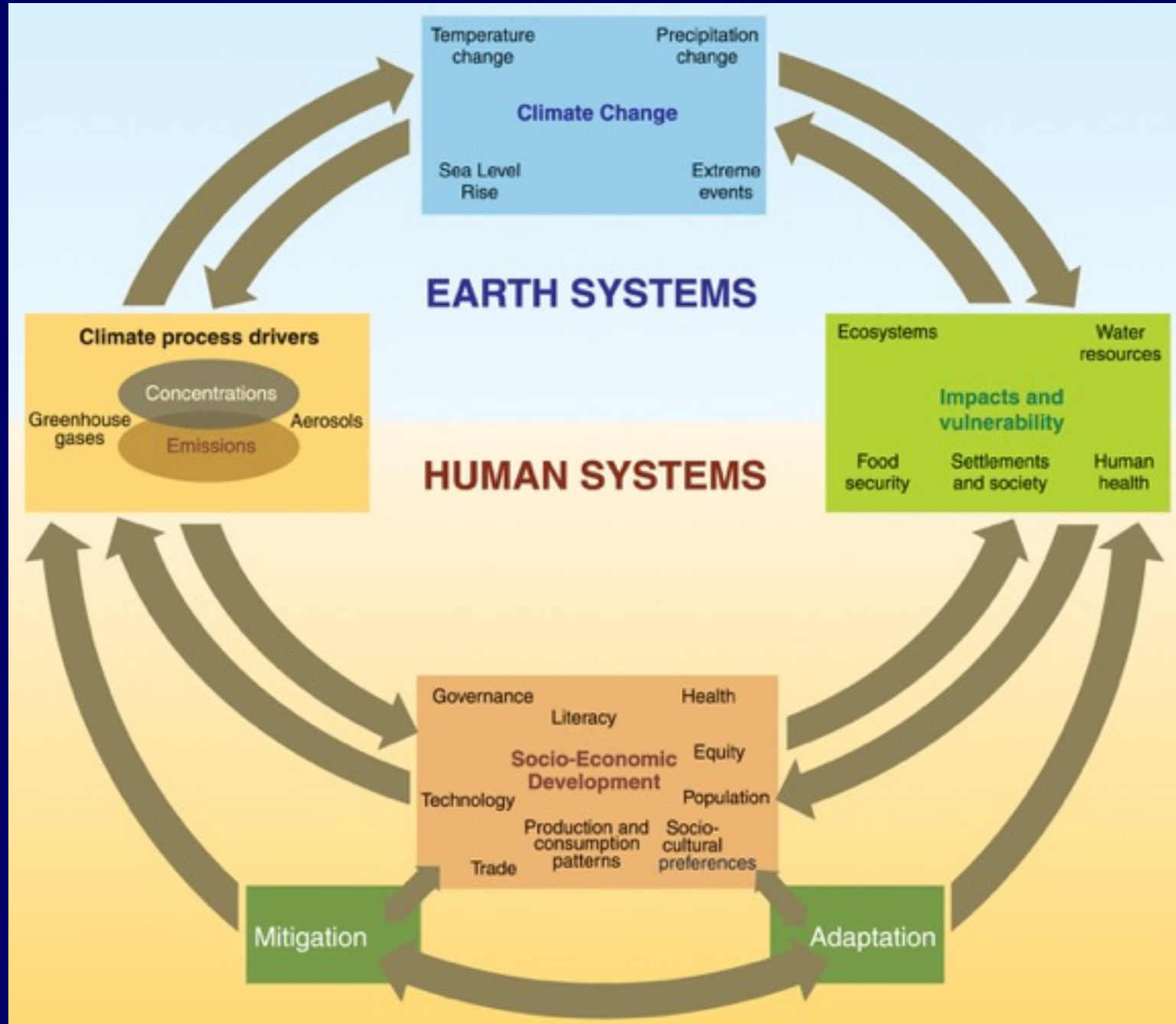
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Climate- mediates distribution and persistence of permissive environments

Climate- alternating episodes of perturbation and stability mediate faunal assembly/ emergent disease

Climate interacts with evolution, ecology and biogeography determining the structure of the biosphere





## Phases of Water



**Pallasjärvi, Finland  
June 2004**



# Phases of Water

Water and phases of water are central to living in circumpolar environments.

## Phenology/ Phases of Water Determine-

- Drinking sources, suitability, availability, safety
- Travel pathways (duration of ice versus liquid)
- Integrity of aquatic ecosystems
- Access, availability, security for food resources

# Climate – Water Challenges

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Lack of consistent access to potable drinking water/ sanitation infrastructure

Increasing exposures to contaminated surface water resources

Circulation of pollutants and pathogens in traditional diets drives loss of access to reliable water-based food resources



Anticipating  
Climate Warming

Pallasjärvi, Finland  
June 2004



# Anticipating Climate Warming

- High sensitivity to accelerating warming
- Declining snow fall, reduced precipitation in a dry environment
- Reduced duration- snow and ice cover
- Frequency spring floods/ storm surges
- Accelerated melt, glaciers/ permafrost
- Declining lake abundance, draining wetlands on discontinuous permafrost

# Increasing Temperature

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- Broadening seasonal windows for circulation and exposures to pathogens
- New permissive conditions/ development
- Geographic range expansion/ invasion
- Extended persistence of pathogens
- Tipping points & thresholds in transmission
  - Shifts in years, not months
- Potential for extinction and extirpation

# Consequences Climate Warming

- Unpredictable water availability
  - Fragile infrastructure water/sanitation
- Long range atmospheric transport      organic pollutants
- Bioamplification through food-chains for mercury and POP's
- Increasing anthropogenic stressors
- Cumulative and synergistic effects



# Influence of Climate/ Water

- Spatial/ Temporal distributions of wildlife/ migration, habitat use
- Wildlife numbers, population structure
- Access to wildlife resources
- Pathogens are part of equation
- Reduced reliance on wildlife resources?
- Cascading effects on a subsistence culture in northern communities?



**Deline, NW Territories/ S. Kutz Photo**

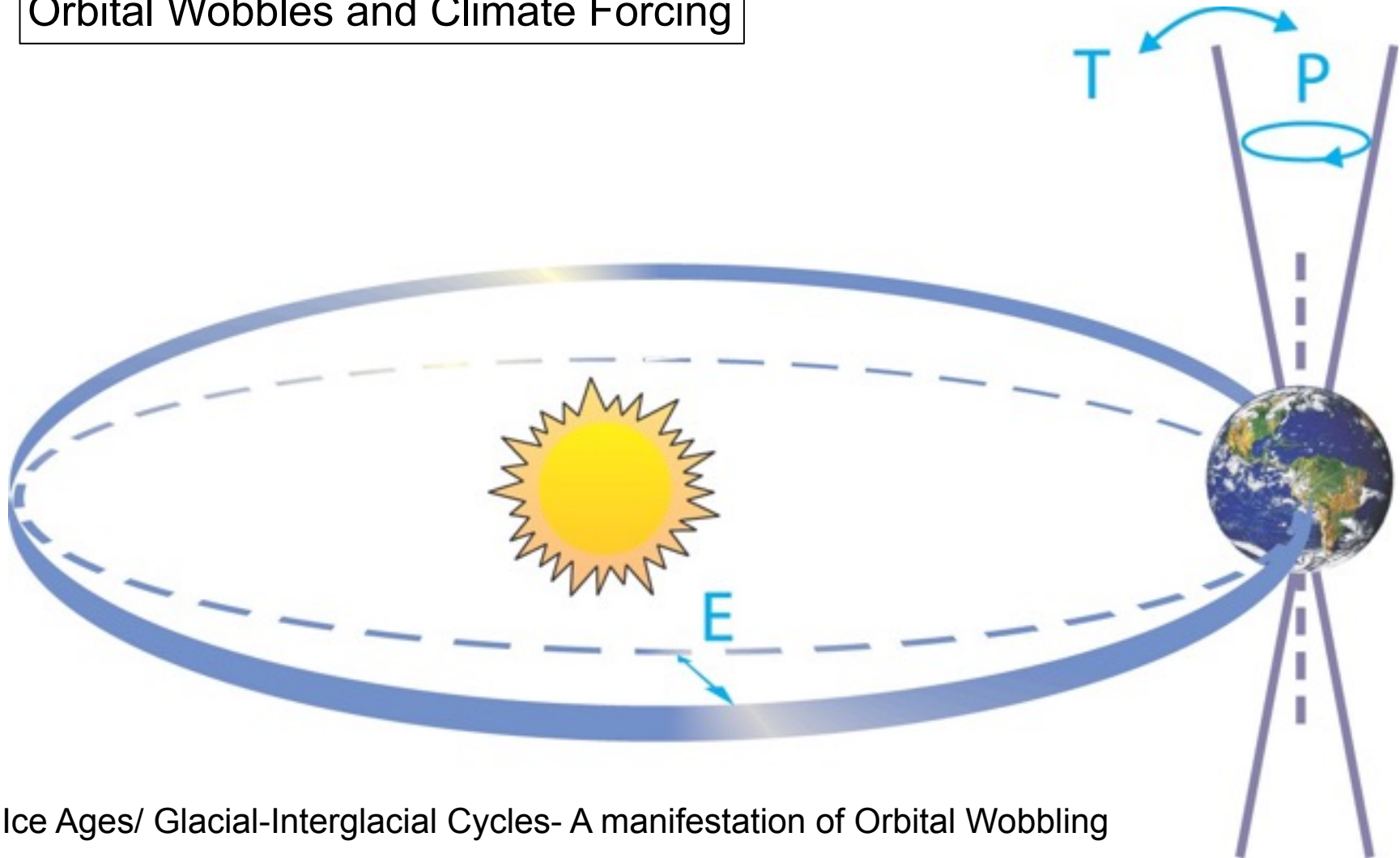


# Wobbling Climate = Complexity

- Geological scale- (orbital dynamics)
  - glacial-interglacial
  - Trends in regional geography/ faunal dynamics
- Millennial scale (orbital/ solar dynamics)
- Decadal Oscillations/ Ephemeral Events
  - Ocean-atmosphere interactions, volcanism
  - ENSO, PDO, NAO (Regime Shifts)
  - Shifting balances in permissive environments
- Anthropogenic, directional warming

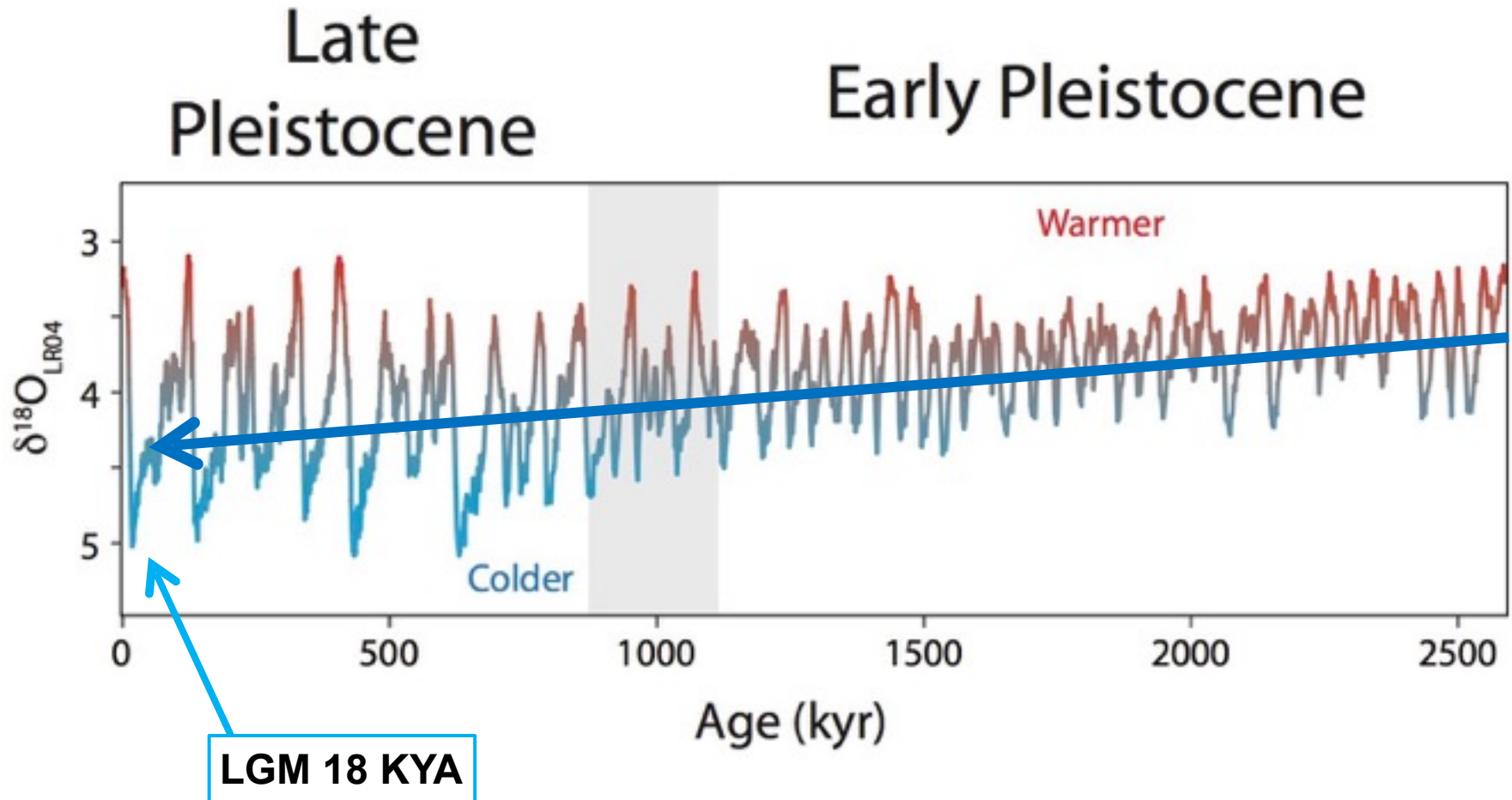


## Orbital Wobbles and Climate Forcing



Ice Ages/ Glacial-Interglacial Cycles- A manifestation of Orbital Wobbling

## Quaternary Climate Oscillations, 2.5 MY/ Milankovitch Cycling



- Environmental cooling from late Pliocene
- Filter bridge- Northern intercontinental expansion and exchange
- Glacial-Interglacial episodes define Quaternary history (> 20)
- High amplitude, 100 KY cycles after 1 MYA (sea levels)

# Wobbling Climate Drivers- Cycles Within Cycles/ Ecological Collision

Time

**Cumulative - Long term**

Geological, Millennial, Centennial  
Orbital forcing  
Evolutionary Time

**Ephemeral Oscillations- Short term**

Months- Seasonal- Annual- Decadal  
Ocean-Atmosphere      Anthropogenic  
El Nino, Pacific Decadal, North Atlantic  
Ecological Time/ Regime shifts

**Anthropogenic Forcing**

Cumulative “Long term”/ Extreme “Short Term”  
Seasonal, Annual, Decadal, Centennial  
Ecological Time/ Regime Shifts

## Tipping Points

broad geographic scales  
global, continental, regional  
faunal dynamics, assembly  
ecological assemblages  
range expansion/contraction

## Shifting Balances

landscape scales  
permissive environments  
range expansion/contraction  
peripheries of range  
ecological assemblages  
invasion, emerging disease  
feedbacks

Layered, multifactorial, hierarchical, across evolutionary/ ecological time.  
Interacting with developmental rates, thresholds, tolerances, resilience.



# Oscillating Climate Drivers

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- Ecosystems in episodic collision
- Dynamics of faunal mixing (Mosaics)
  - Opportunity for host switching
- **Equivalence of mechanisms/ outcomes**
  - Spatial- Continental to Landscape
  - Temporal- Evolutionary to Ecological time
- Establishes historical foundation

**Northern Biosphere  
In Transition**



**Arctic Coastal Plain  
Chukotka –  
August 1981**

# Themes for a Northern Fauna

- Dynamic climate variation over time
- Crucible of Ecological Perturbation
- Episodic, cyclical or recurrent processes
  - Waves of faunal expansion / isolation
- Invasions on temporal scales linking evolutionary to ecological time
- Spatial scales from landscapes to regions
- Faunal mosaics in space and time





Natl. Geographic Magazine

# A Contemporary Framework-

## Anthropogenic Climate Drivers- Accelerating Change

- Novel environments/ Invasion
- Changing geographical distribution of environments/ Habitats in transition
- Rapid changes in faunal distribution
- Secondary contact zones (recombination)
- Accelerated host switching
  - introduction of novel pathogens
- Development of Geographic Mosaics
- Ephemeral emergence for disease



**Inukshuk  
Coppermine River  
Nunavut**



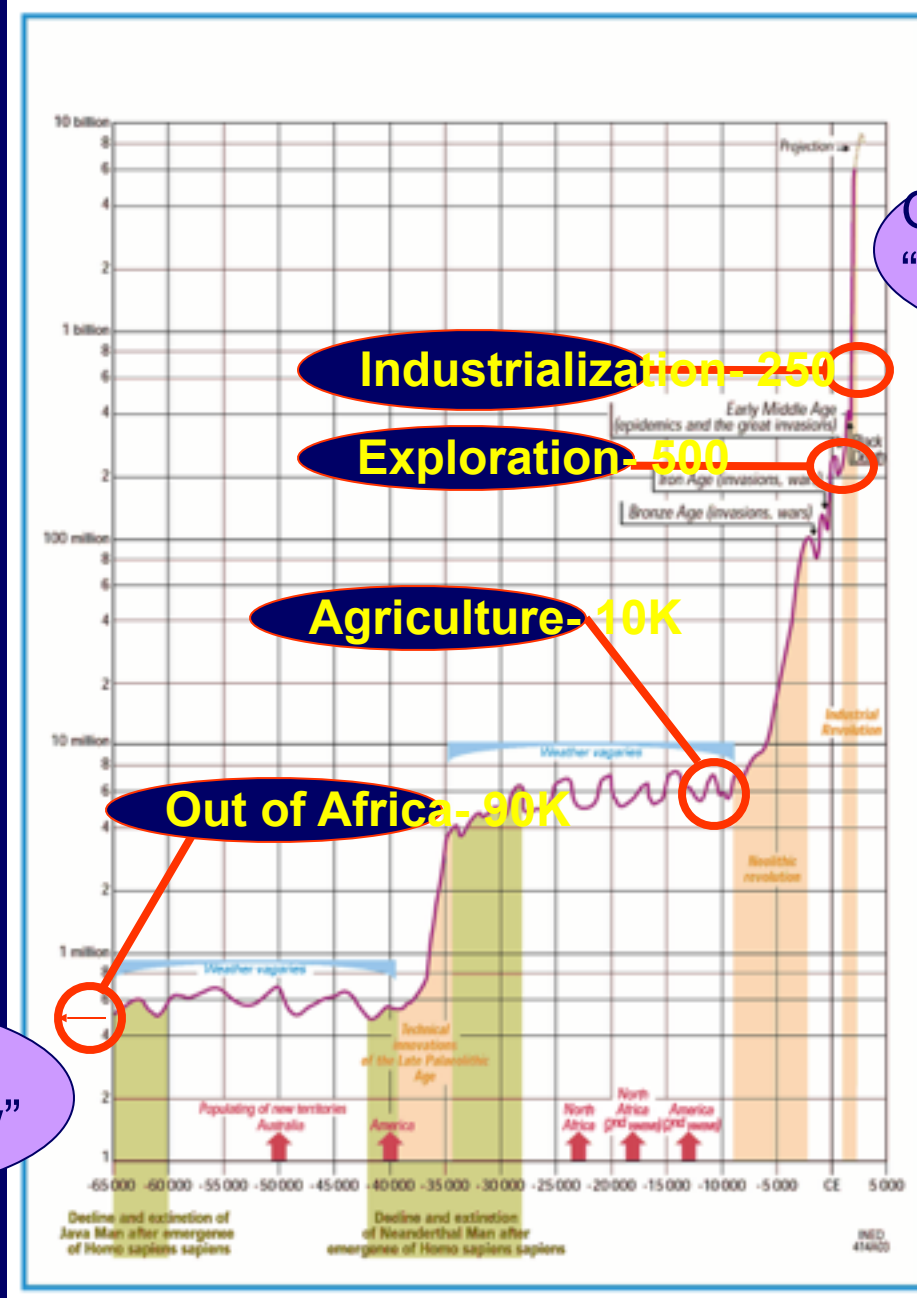
**Human  
Dimensions**



## -Tipping Points- -Thresholds-

Convergence  
of  
Earth  
&  
Human History

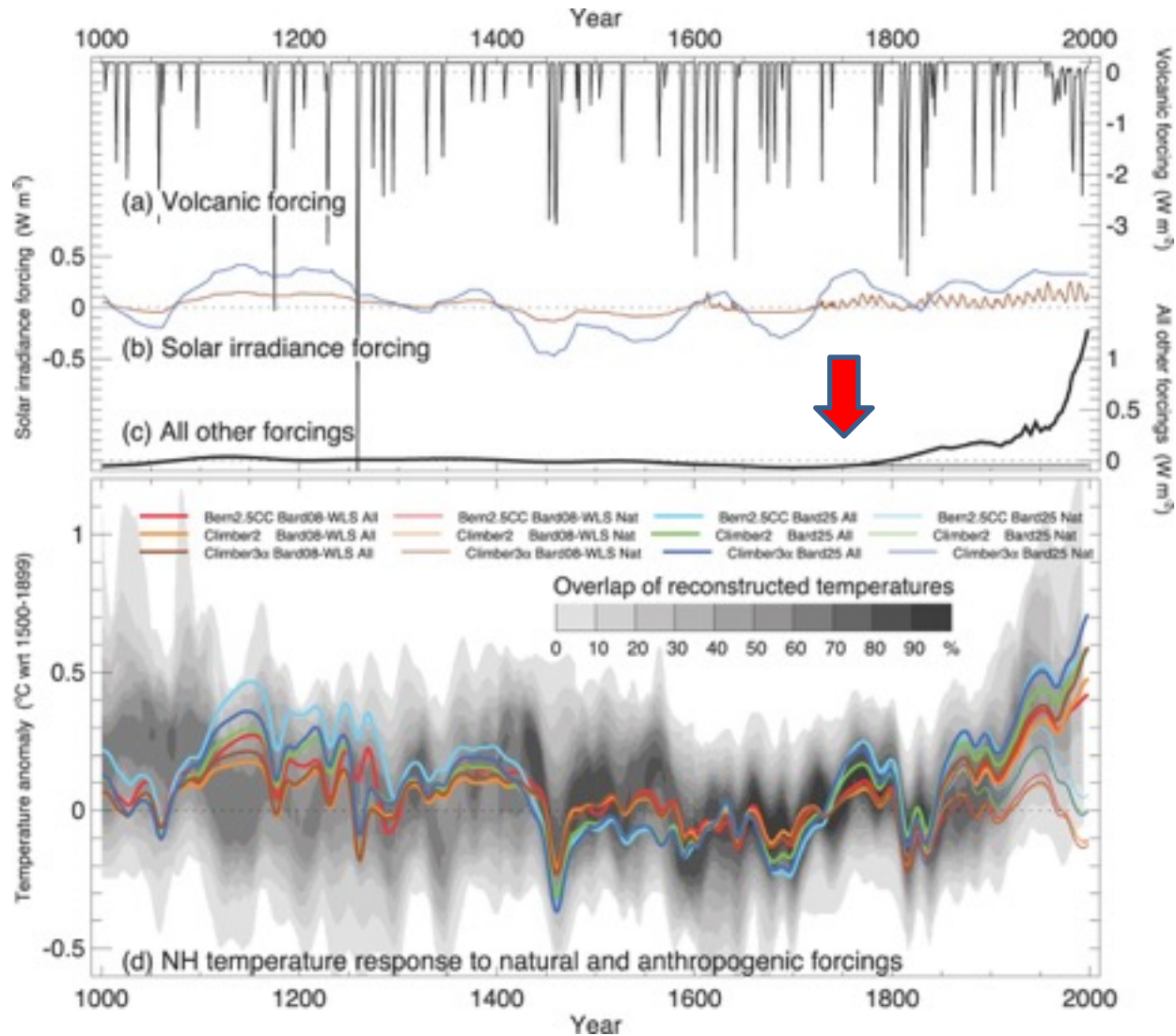
Global Scale  
“Small & Rapid”



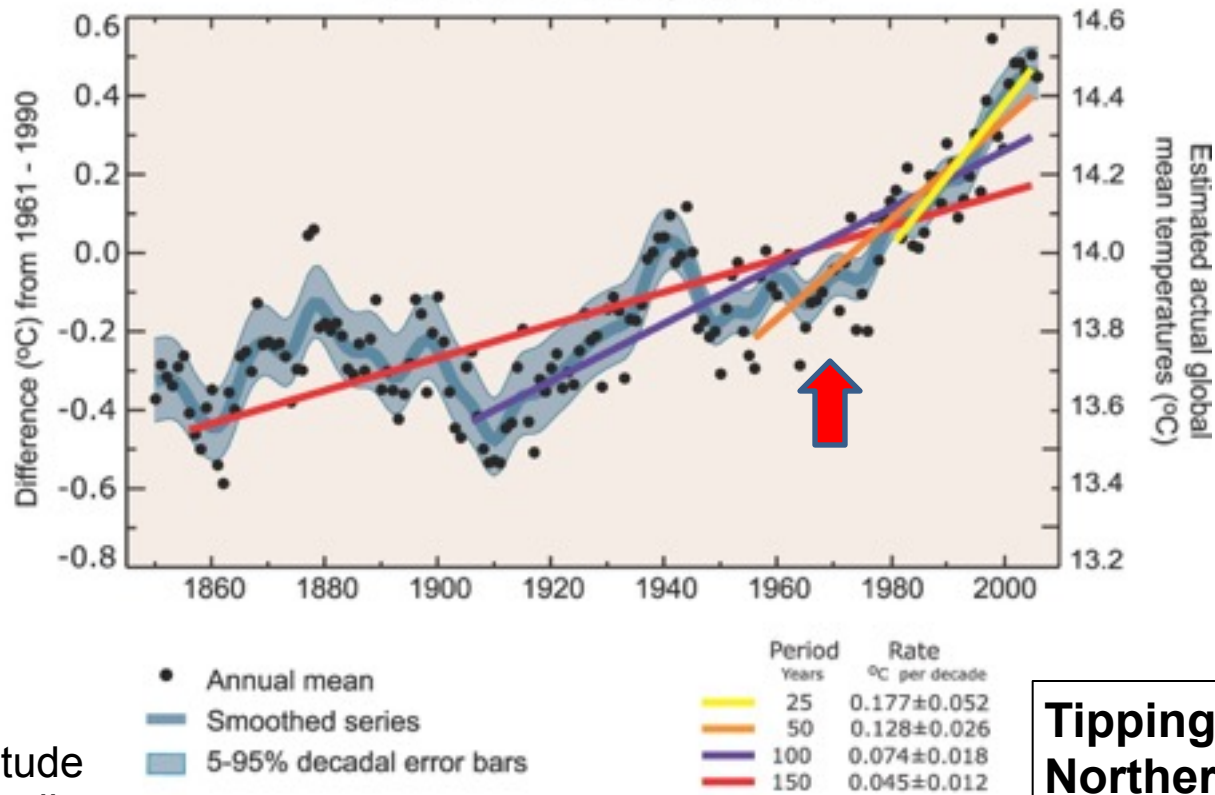
Global Scale  
“Large & Slow”

Modified from- Institut national d' études  
Démographiques (2008)

# Climate/ Temperature Forcing Past 1KY

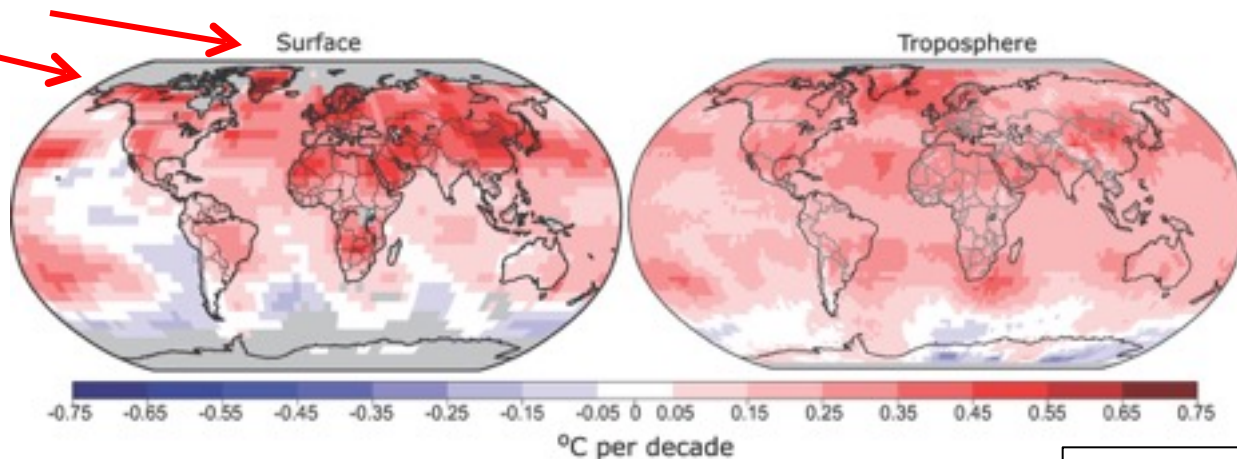


## Global Mean Temperature



**Tipping Point 1970's Northern Systems**

Northern High Latitude Temperature Anomalies

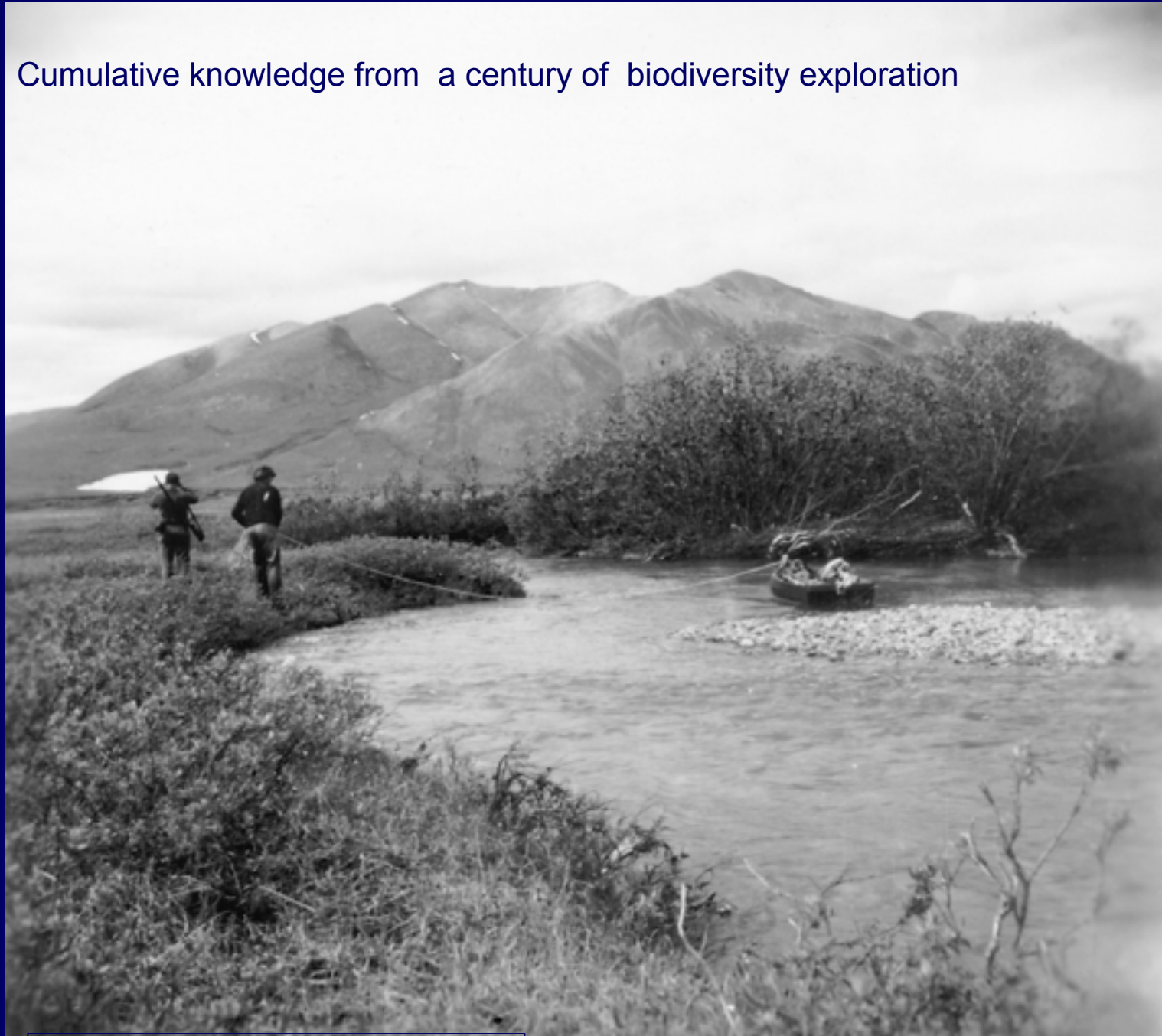


Rates of temperature increase > 2 times global average in past 50 yrs

IPCC AR5 WGI (2013)



Cumulative knowledge from a century of biodiversity exploration



**Brooks Range, Alaska 1949**

**Photo: R.L. Rausch; Courtesy U Ala**

# Arctic Parasite Context-

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- Viruses, Bacteria, Protozoa, Fungi, Metazoa
- 40-50% of global diversity/ 75% trophic links
- 7100 spp. metazoan parasites in vertebrates?
  - Validate diversity through survey and inventory
  - Diversity of viral and bacterial pathogens?
- Considerable cryptic diversity?
- Absence of long term baselines
- Highly responsive to perturbation

# Arctic Parasite Stories-

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- Key ecological drivers, shaping ecosystems
- Disease agents, wildlife/ humans (zoonoses)
- Food safety, food security, sustainability
- Historical ecological/ biogeographic indicators
- Indicators of ecological stability and change
  - Conditions on distant flyways/ staging areas
  - Altered Phenology, Mismatches, Trophic shifts
  - Invasions, Faunal Mixing, Emergence
  - Changing Interfaces and Ecotones



# Pathogens & Climate Change

- Long term/ Cumulative “in situ” processes
  - Responses to trends in warming
  - Decadal and longer
  - Extension of growth season; tolerance, development & generation time; amplification; emerging disease
  - Tipping points for changing dynamics of transmission
  - Latitudinal & altitudinal range shifts
  - Host-switching? Sympatry, “Ecotone” or Border effects
  - Subtle effects- challenge to identify
- Short-term/ Ephemeral “external” processes
  - Responses to extreme weather events
  - Temperature anomalies/ humidity
  - Explosive emergence of disease

# Outcomes of Climate Warming

- Northern biotic expansion
- Ecosystems in collision/ faunal mixing
- Breakdown in ecological isolation
  - Host switching by parasites at interface newly emerging ecotones (contact zones)
- Shift in permissive environments
  - Altered developmental thresholds
  - Accelerated development/ amplification
  - Extinctions related to resilience

# Climate - Water - Pathogens

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- Northern expansion over time/ potential for invasion or introduction
- New pathogens/ *Ichthyophonus*
- Increasing abundance of pathogens now limited by temperature
- *Vibrio* bacteria distribution



# Climate - Water - *Vibrio*

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- 50-100 years, shifting distribution
  - 15 C threshold for *Vibrio* development
- Rising sealevel/ temperature
  - Changing precipitation/ runoff, salinity
- *Vibrio* habitat increases 60% in Alaska
  - Naturally occurring pathogen coastal zone
  - Gastroenteritis, septicemia



Kugluktuk, Nunavut- April 1994



# Human-Climate Intersection

- Increasing population pressure
- Irreversible infrastructure
  - Changing access (e.g., mineral extraction)
  - Permanent road systems
- Eutrophication in rivers/lakes      exacerbated by reduced flows
- Impacts on availability aquatic-based      foods (fishes, invertebrates)





**Future Of  
Accelerating  
Perturbation**

**Jökül Sarlon  
Southern Iceland  
2004**

# Things We Know?

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- Climate change is accelerating
- Increasing abundance of pathogens
- Climate has direct influence on distribution for pathogens/ diseases
- Host-Species distributions change
- Switching to new hosts drives disease
- Aquatic, Marine, & Terrestrial systems

# Things We Need to Know?

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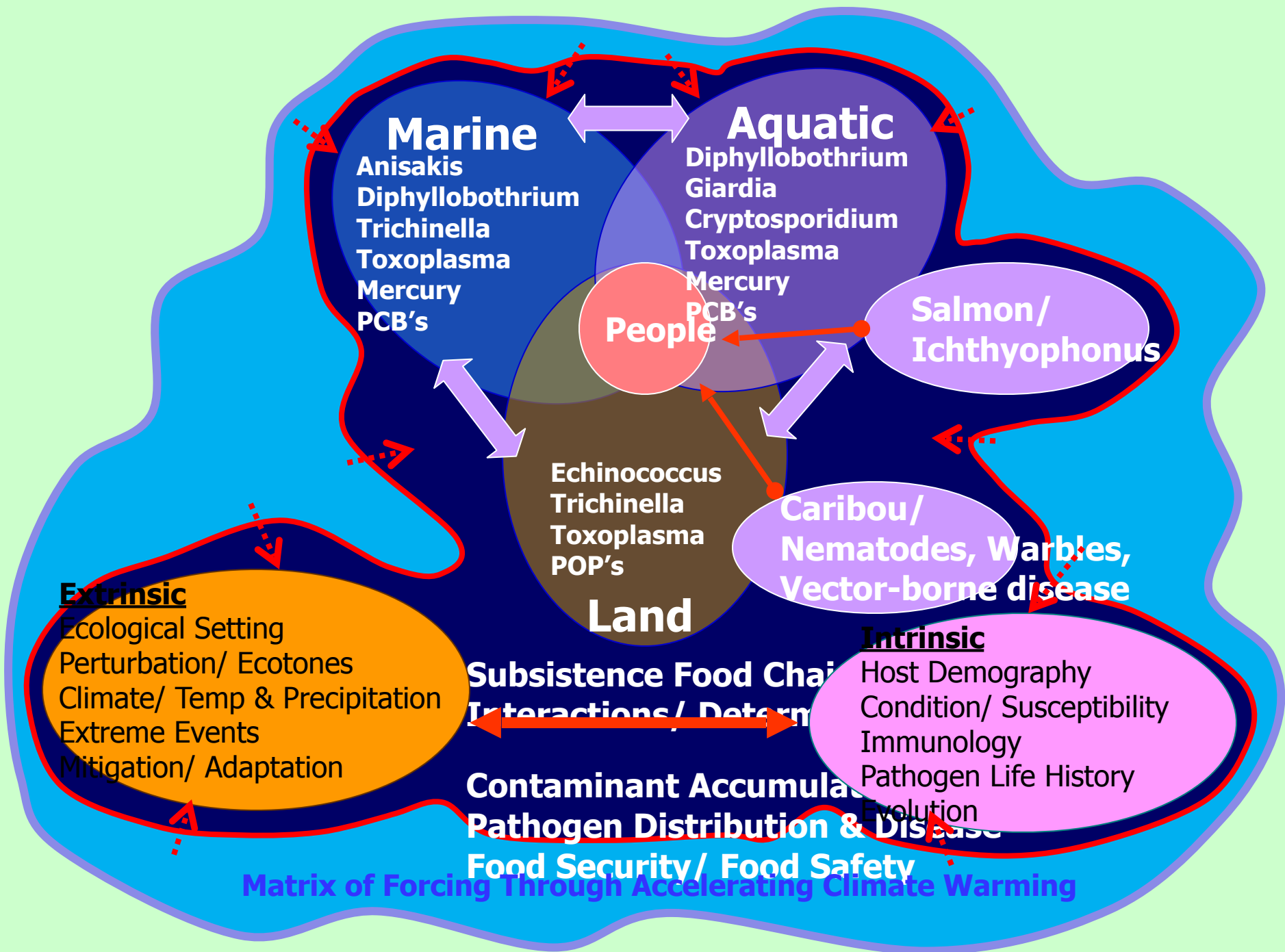
- Pathogen diversity
- Distribution- hosts & geography
- Effects on hosts
- Potential for interaction with climate
  - development, thresholds, tipping points,
  - Resilience, tolerances



# Things We Don't Know?

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- Challenge to predict dynamic change
- Specific biological parameters
- Detailed data for pathogen distribution
- Unanticipated cascades
- Consequences for perturbation of key vertebrates/invertebrates



# BioDiversity Information?

- Ecosystems in collision
- Environments in Rapid Transition
  - Indicators of loss, introduction, stability?
  - New associations/ emergent disease
- Permanent Record of Faunal Structure?
- Baselines to Assess Stability & Change
  - What is in an environment?
  - What is nearby and can invade?
  - Understanding the players = identification of pathways
- Survey, monitoring & archives



# Transboundary Pathways

Landscapes → Information Webs

Integrating Specimens - Observations

Ecosystems - Faunas – Species – Populations

Informatics Cross-Disciplinary Synergy

Archives for Biodiversity – Geography - Genetics - Genomics

Baselines, Surveillance, Temporal-Spatial Modeling

Using/Developing Information Linking TEK to Research Networks

Physical Processes

Biological Outcomes

Tracking/ Anticipating/ Mitigating  
Change Over Space and Time

# Climate Change Cascades

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Climate change can modify the interface for people & environment.

Exposure to pathogens through water-borne & food-borne pathways will be altered.

Pathogens & diseases in key mammalian, avian & fish species can influence availability, sustainability & suitability of food resources.

Pathogens & emergence of diseases can disrupt structure for aquatic, terrestrial & marine ecosystems.

# Climate Change Predictions

Climate change will eliminate ecological barriers & constraints on development & distribution for pathogen transmission.

-creates new conditions-

Maps for distributions of hosts, pathogens & diseases will be redrawn.

Emergence of diseases & unanticipated “cascades” can influence terrestrial, aquatic and marine ecosystems.





**Matakiet Is., Sea of Okhotsk, August 1988**