Adopting a risk-based approach to incorporate climate information into resource management

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Greater Yellowstone Hydrologists Meeting

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Goal of PACE fellowship is to connect climate information with decision-making

PACE

(Postdocs Applying Climate Expertise)

Climate Center:

NCAR

National Center for Atmospheric Research, Boulder, CO

Climate knowledge production

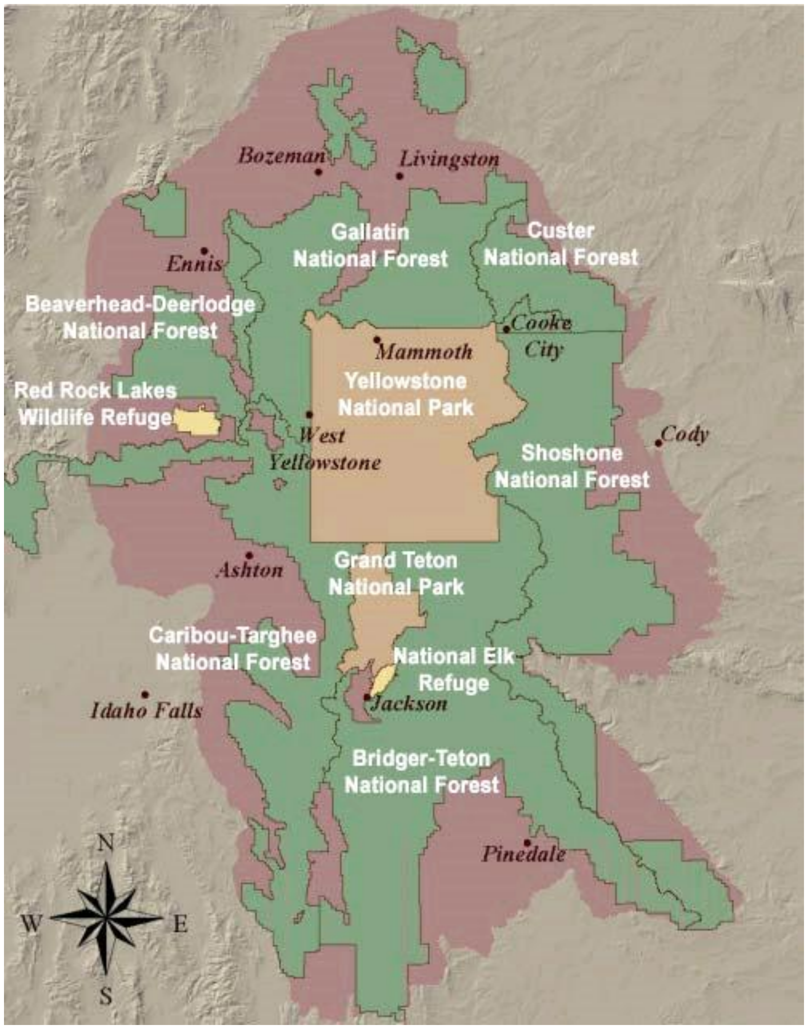
Decision-Making Institute:

USGS science for a changing world

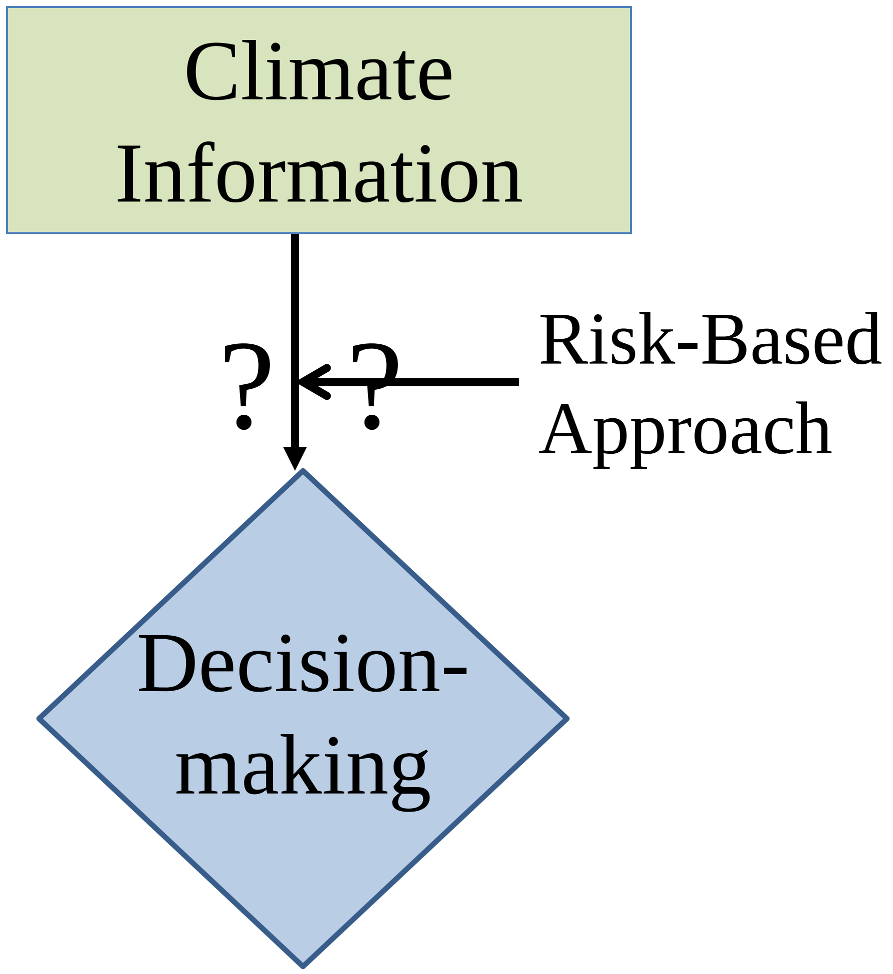
Northern Rocky Mountain Science Center, Bozeman, MT

Impact and response

Focus is on natural resource management in the Northern Rockies



How can climate information be incorporated into management?

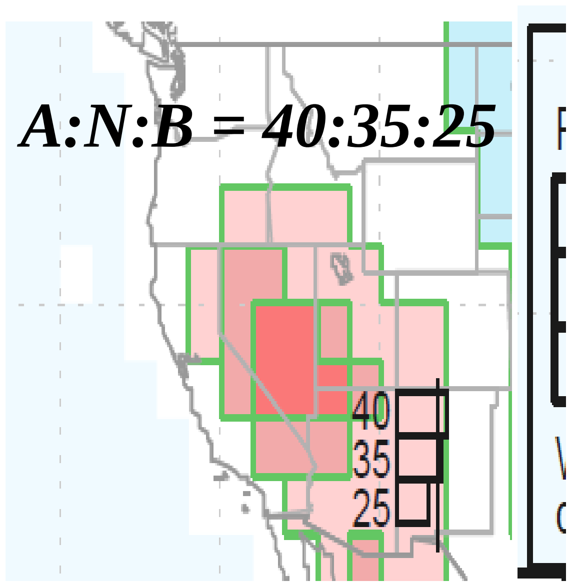


Risk-based approaches rely on an understood and accepted definition

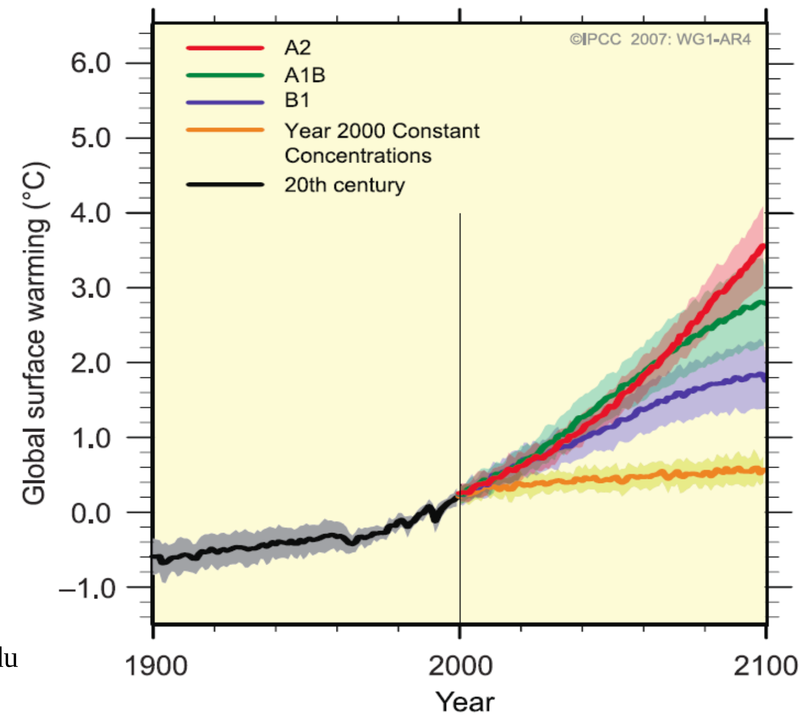
$$Risk = Likelihood \times Consequence$$

(i.e., probability)

Climate information is inherently probability-based across time scales



Source: http://portal.iri.columbia.edu



Source: Solomon et al. 2007

Weather Forecast
50% chance showers

Seasonal Forecast
40% chance of above normal temperatures

Future Projection
Likely to be warmer

Probabilistic information is routinely factored into decisions

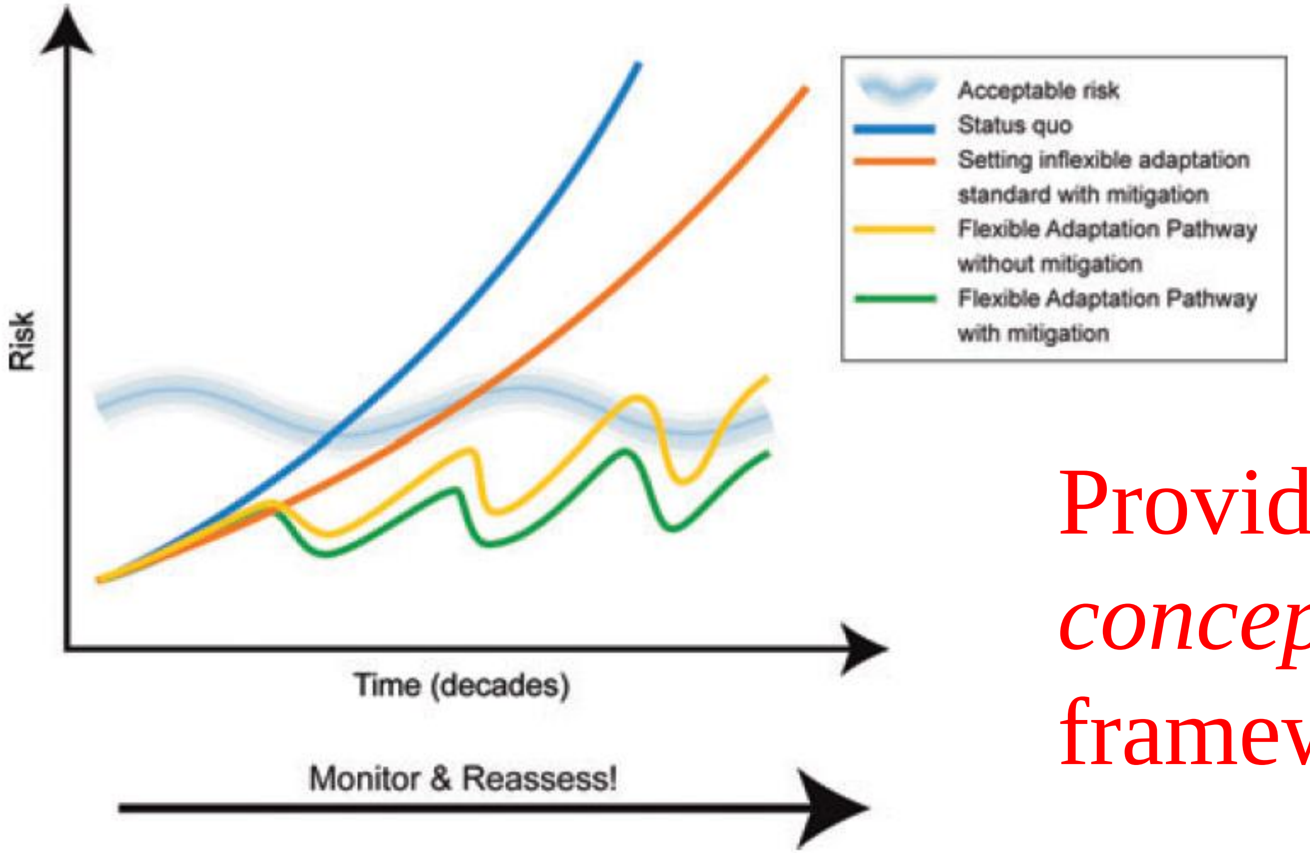
Weather Information

Decision

Exercise:

"Ad hoc" approach: Risk perception is situation-specific and experience-based

Risk-approach needs to be formalized, but still flexible and iterative

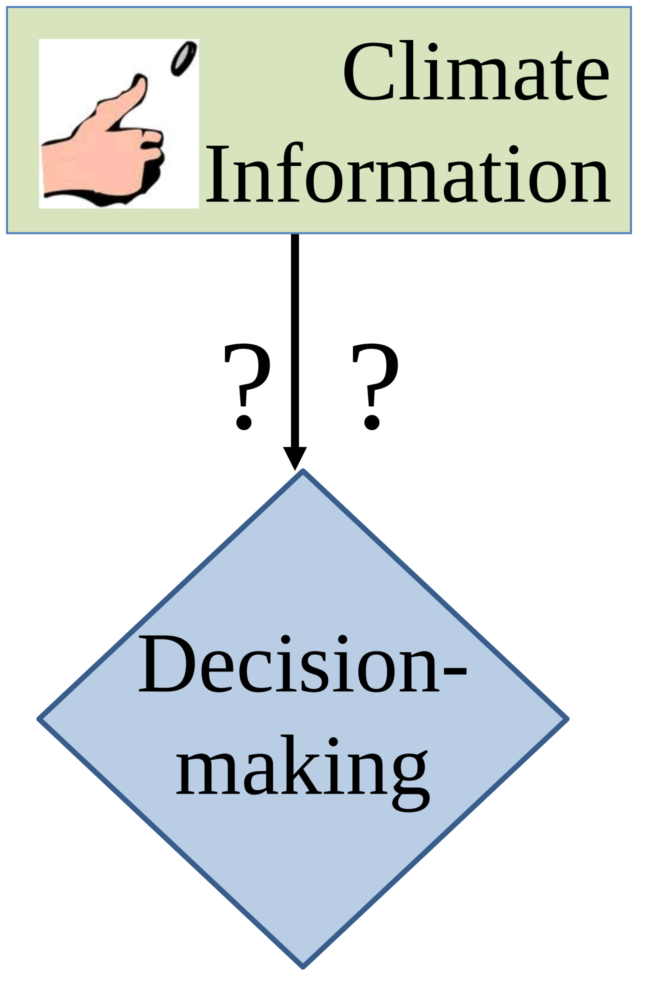


Provides *conceptual* framework

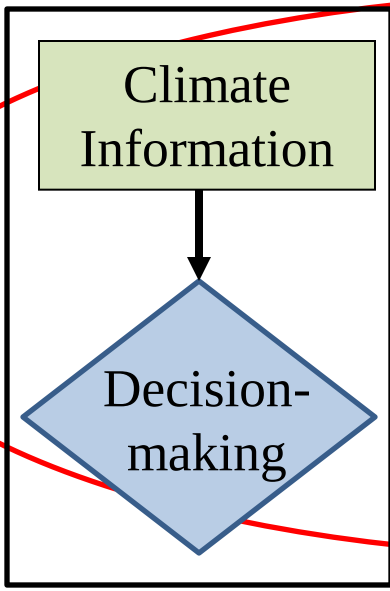
Figure 2.1. Flexible adaptation and mitigation pathways. Adapted from City of London, "The Thames Estuary 2100 Plan," April 2009.

(Yohe, G. and Leichenko, R. 2010)

Need to develop an *operational* framework for risk-based approach



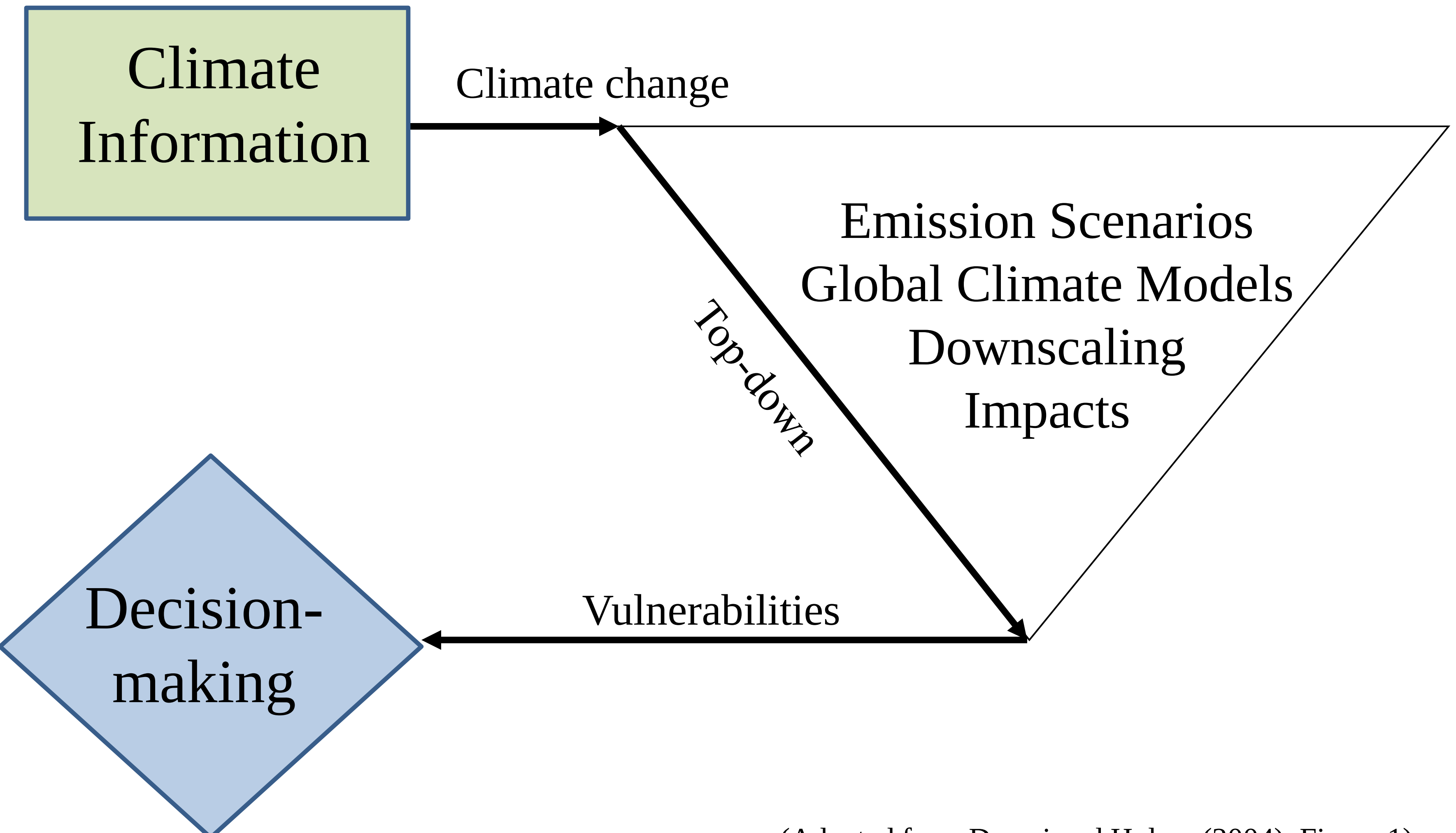
Agenda



1. How can climate information be incorporated into adaptation planning?

2. Example of using climate information for adaptation planning

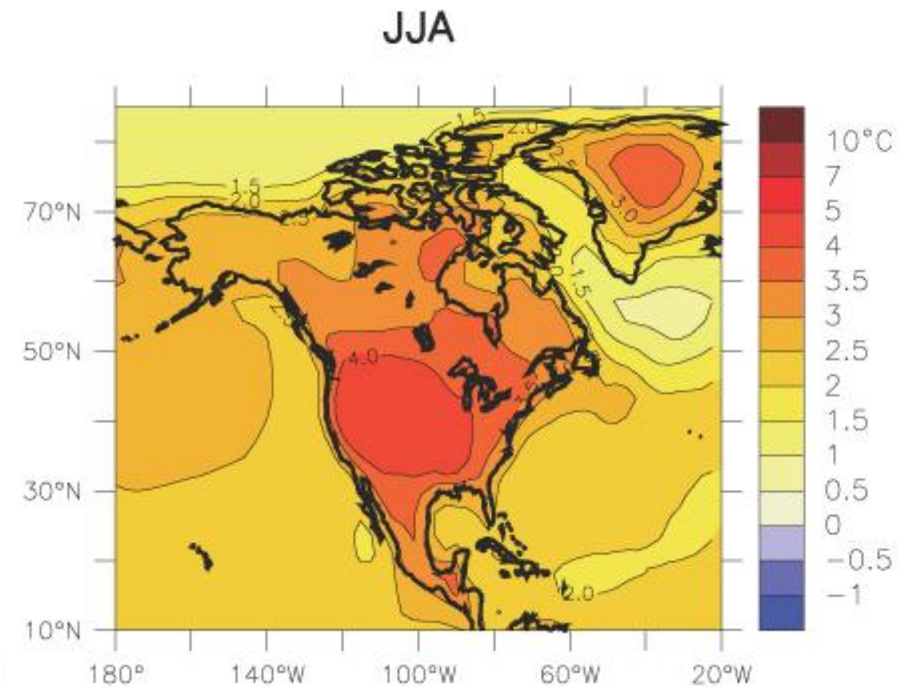
Climate change information is often considered from the top-down



(Adapted from Dessai and Hulme (2004); Figure 1)

Top-down does address vulnerability questions and motivates action…

Temp response (deg. C)



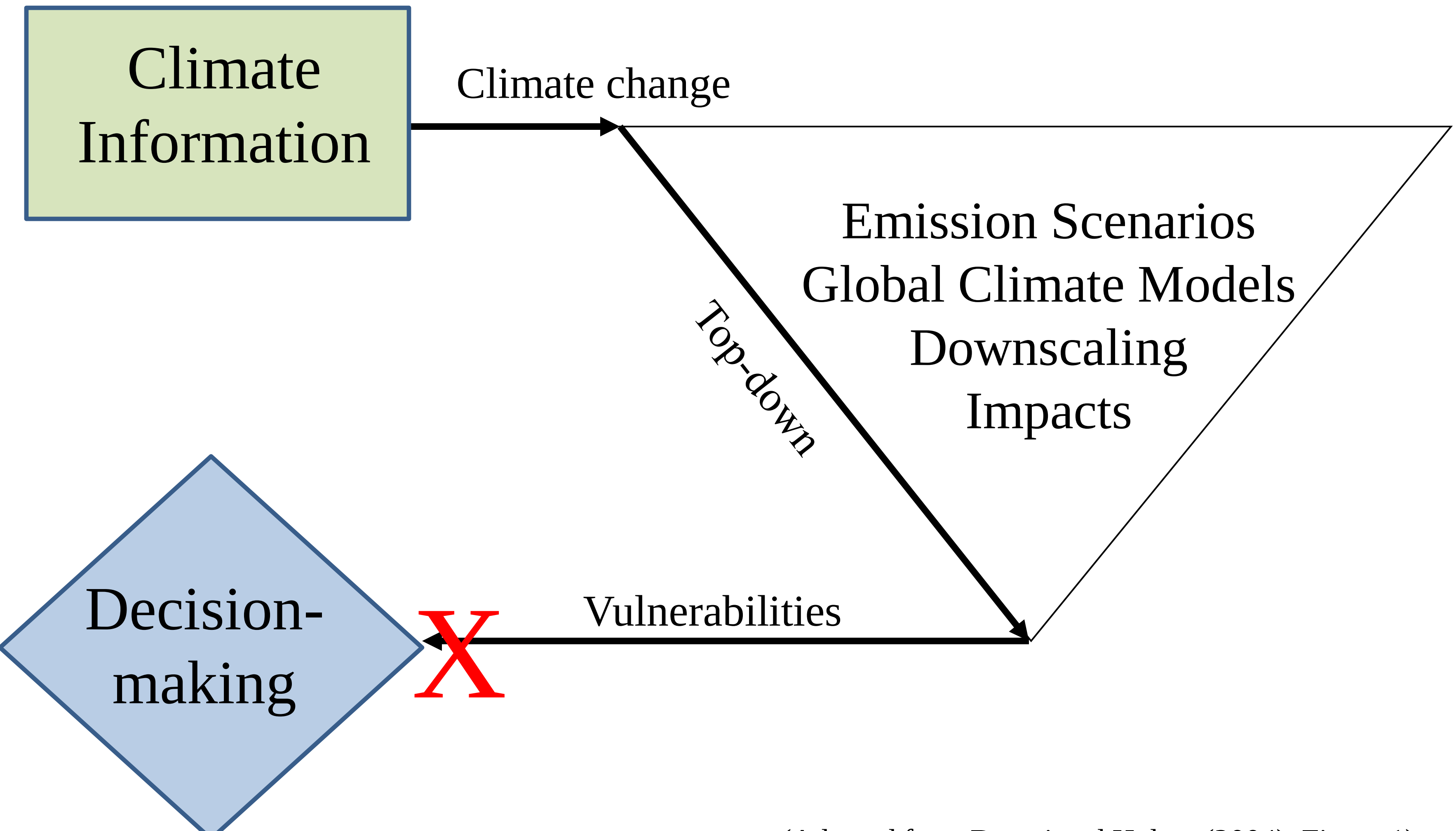
…but issues still exist:

-Scale, uncertainty, and variability

-Applicability to decisions or actions

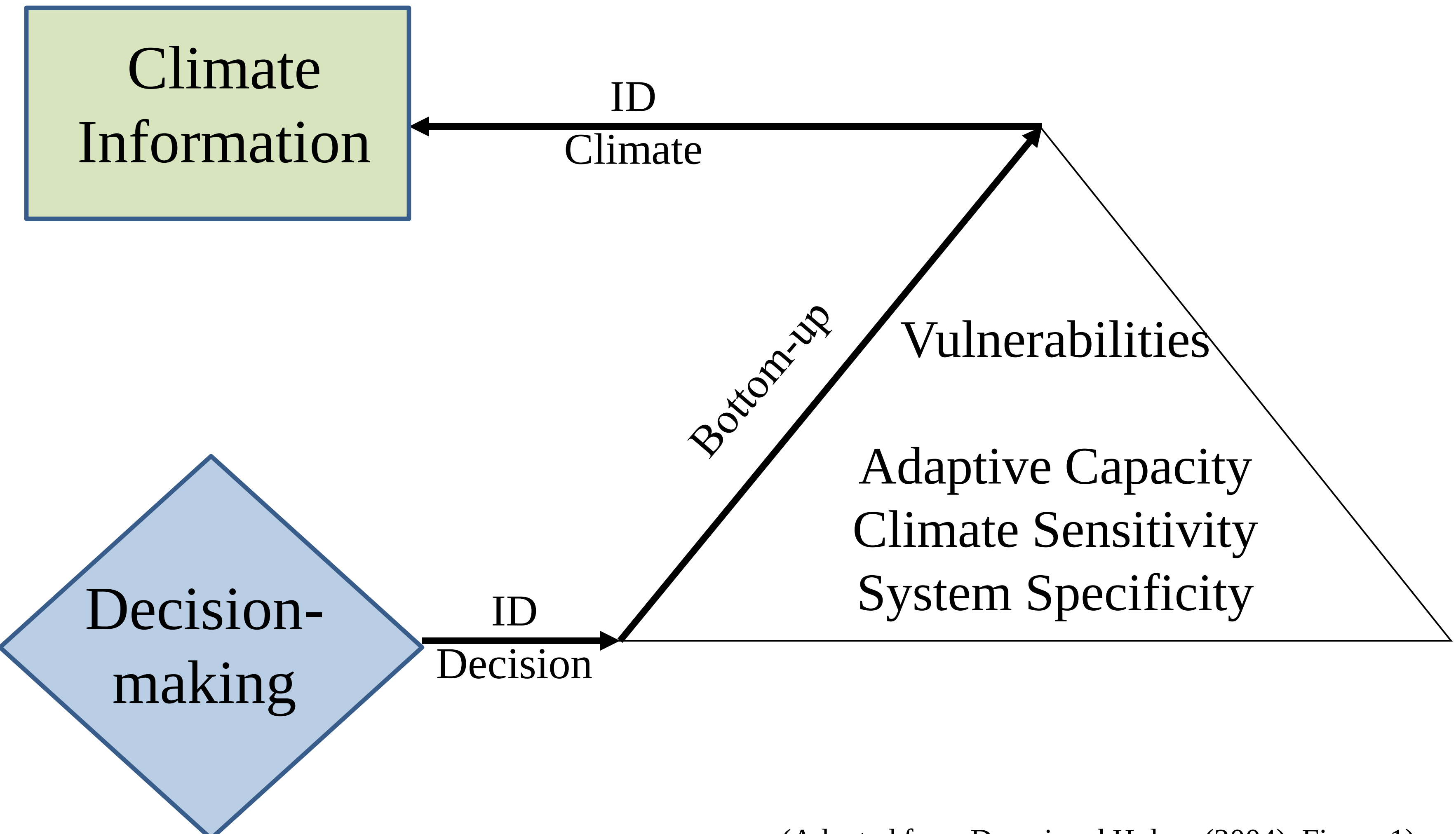
(IPCC (2007); Figure 11.12)

Few top-down approaches result in adaptation measures



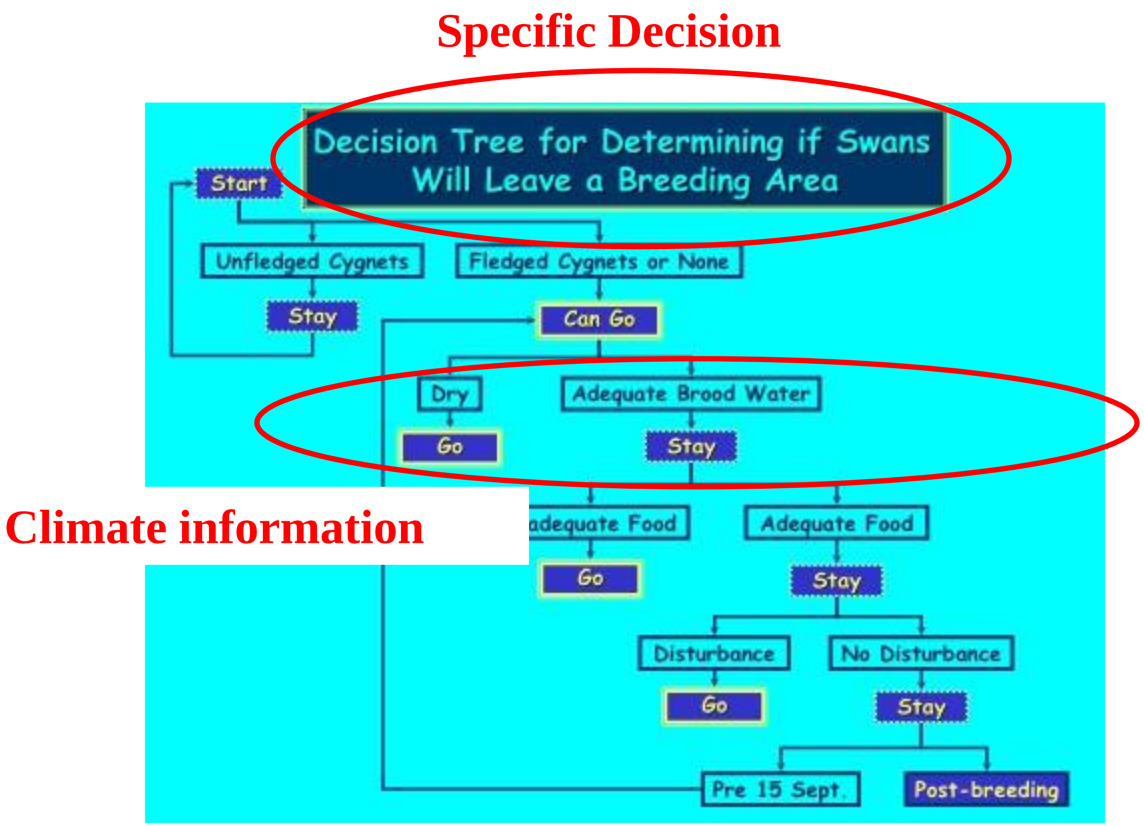
(Adapted from Dessai and Hulme (2004); Figure 1)

Bottom-up methods provides a complementary approach



(Adapted from Dessai and Hulme (2004); Figure 1)

Bottom-up identifies specific decisions and needed climate information



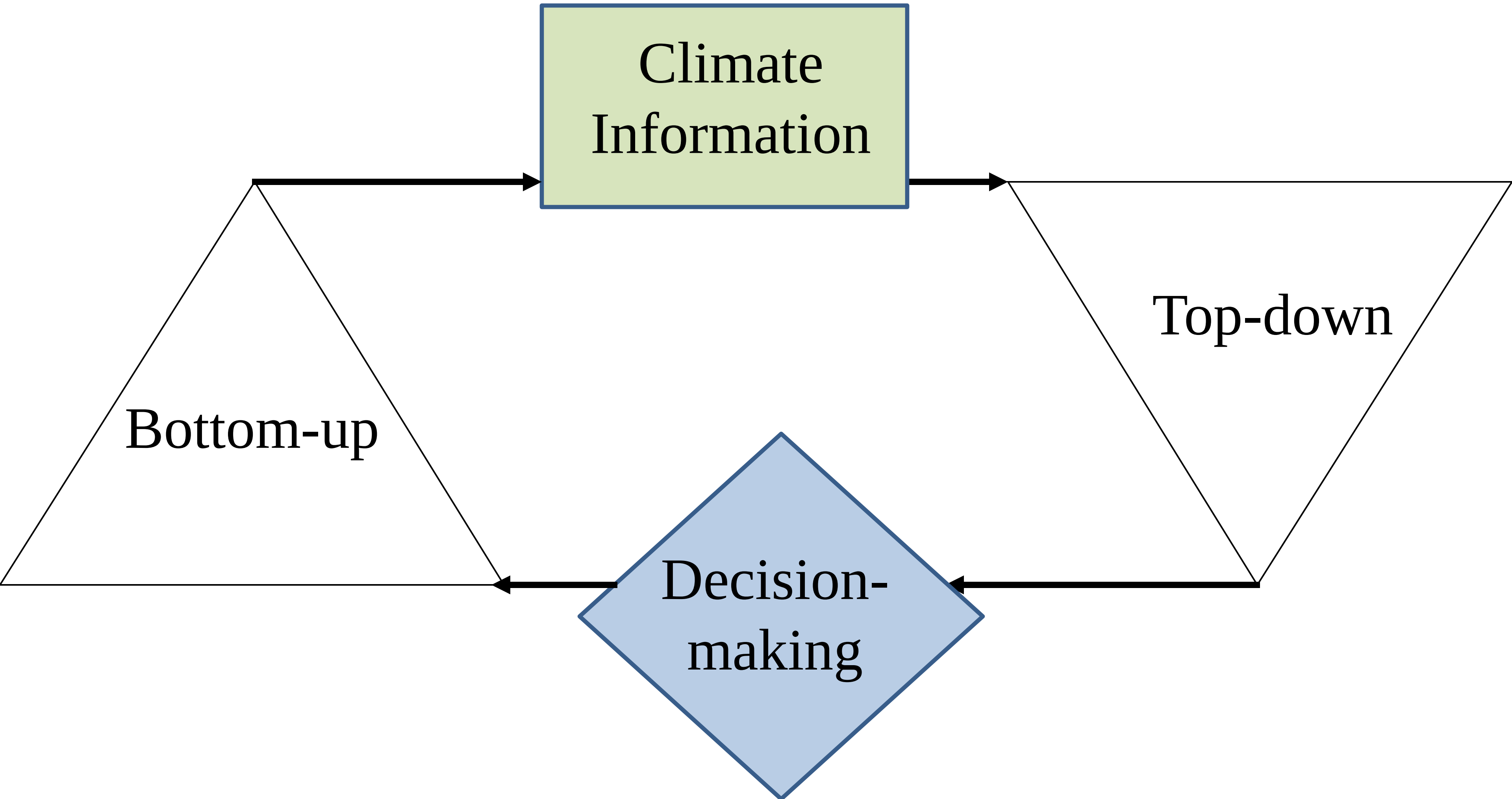
…but issues still exist:

-Climate is only part of the decision

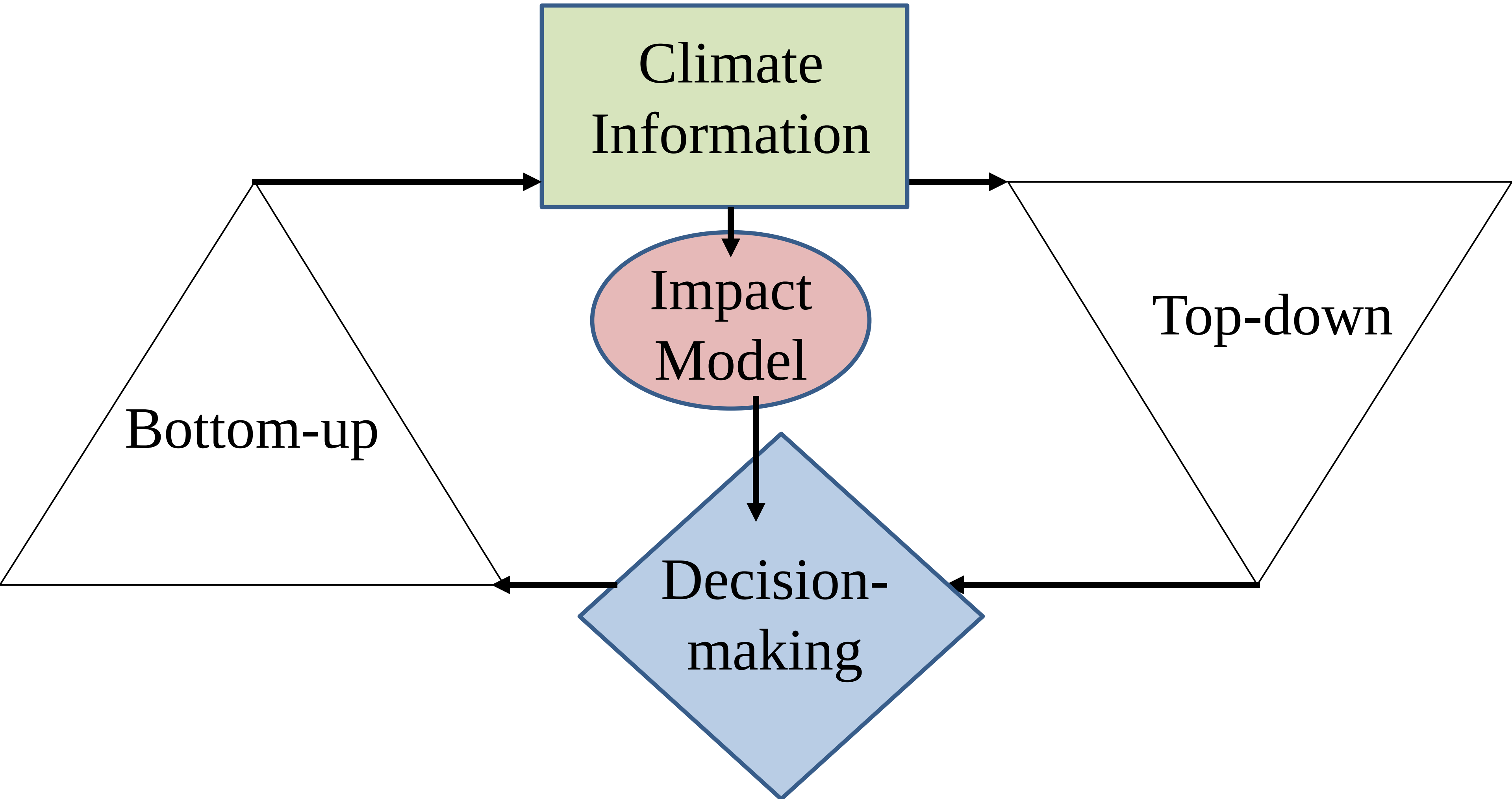
-Requires in-depth system knowledge

(Sojda 2002)

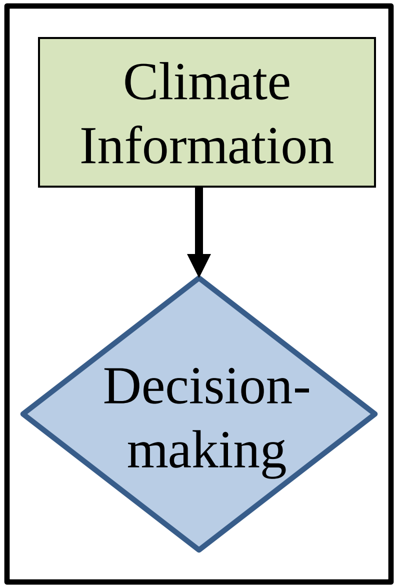
Adaptation planning will benefit from a combined approach



Impact model is a way to relate climate information to decisions



Agenda



1. How can climate information be incorporated into adaptation planning?

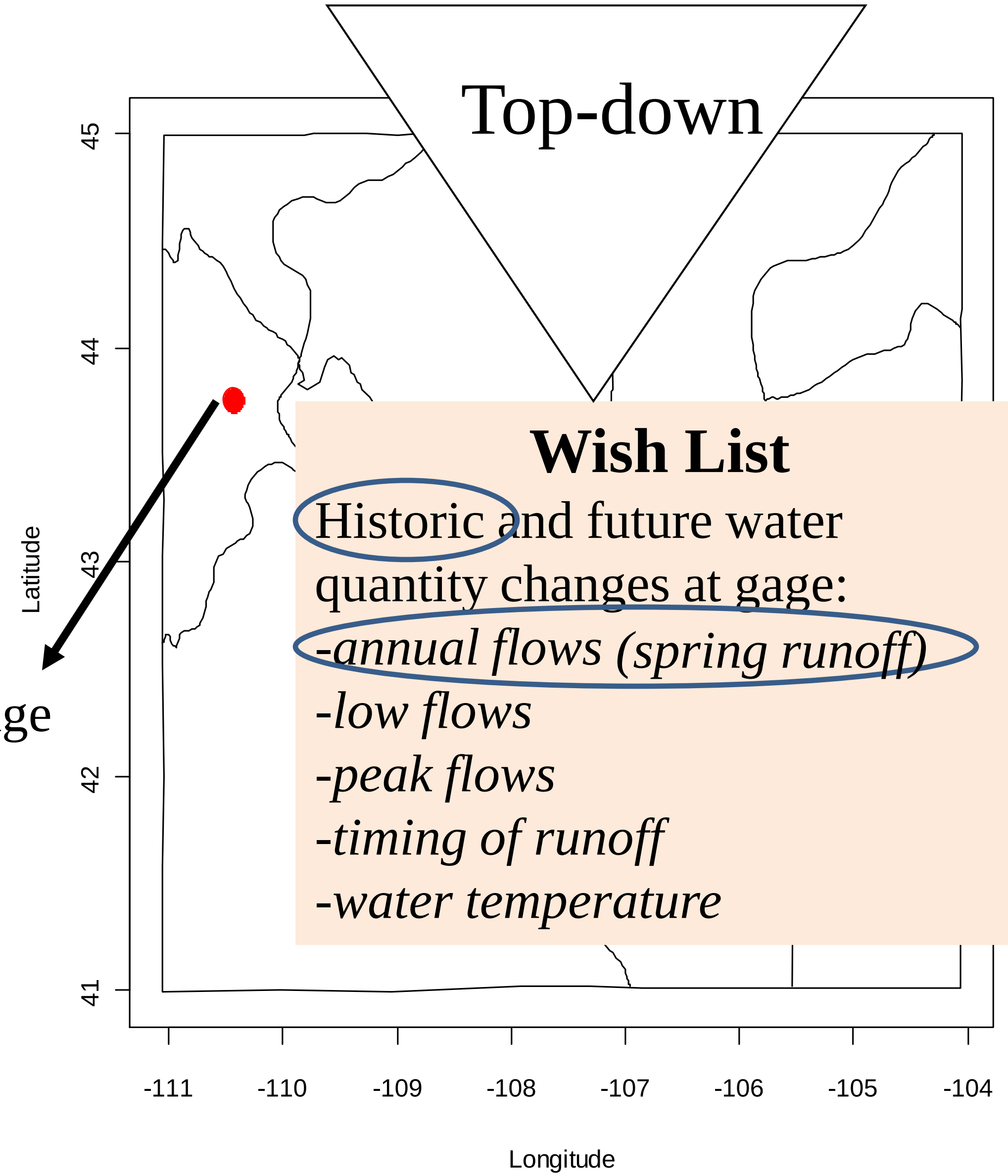
2. Examples of using climate information for adaptation planning

Example #1: Gros Ventre R. flows

USGS Gros Ventre River at Zenith gage

Variable	Flow
Time	Daily
Space	Gage
Dates	1987-present*

* No winter records



Wish List

Historic and future water quantity changes at gage:

-annual flows (spring runoff)

-low flows

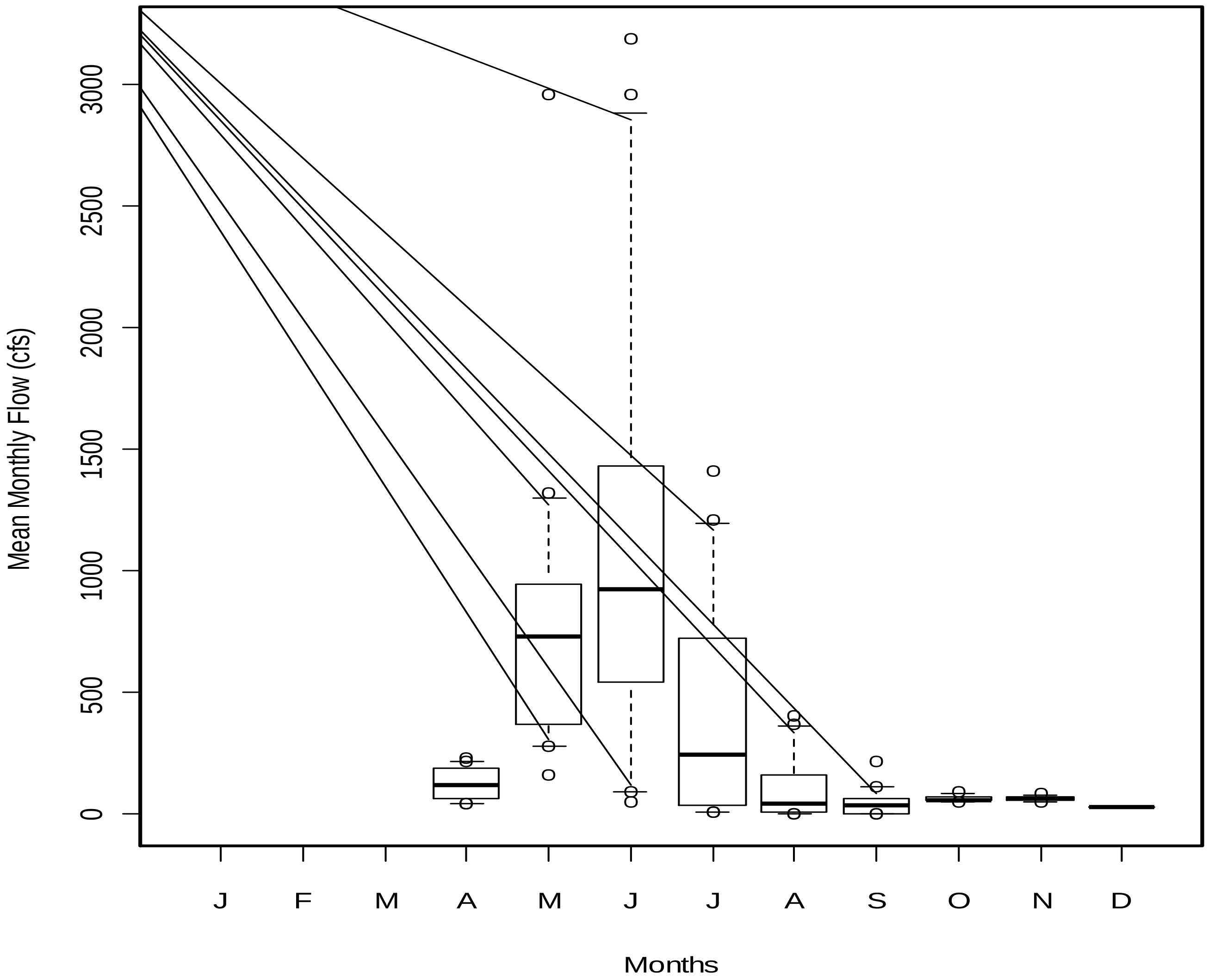
-peak flows

-timing of runoff

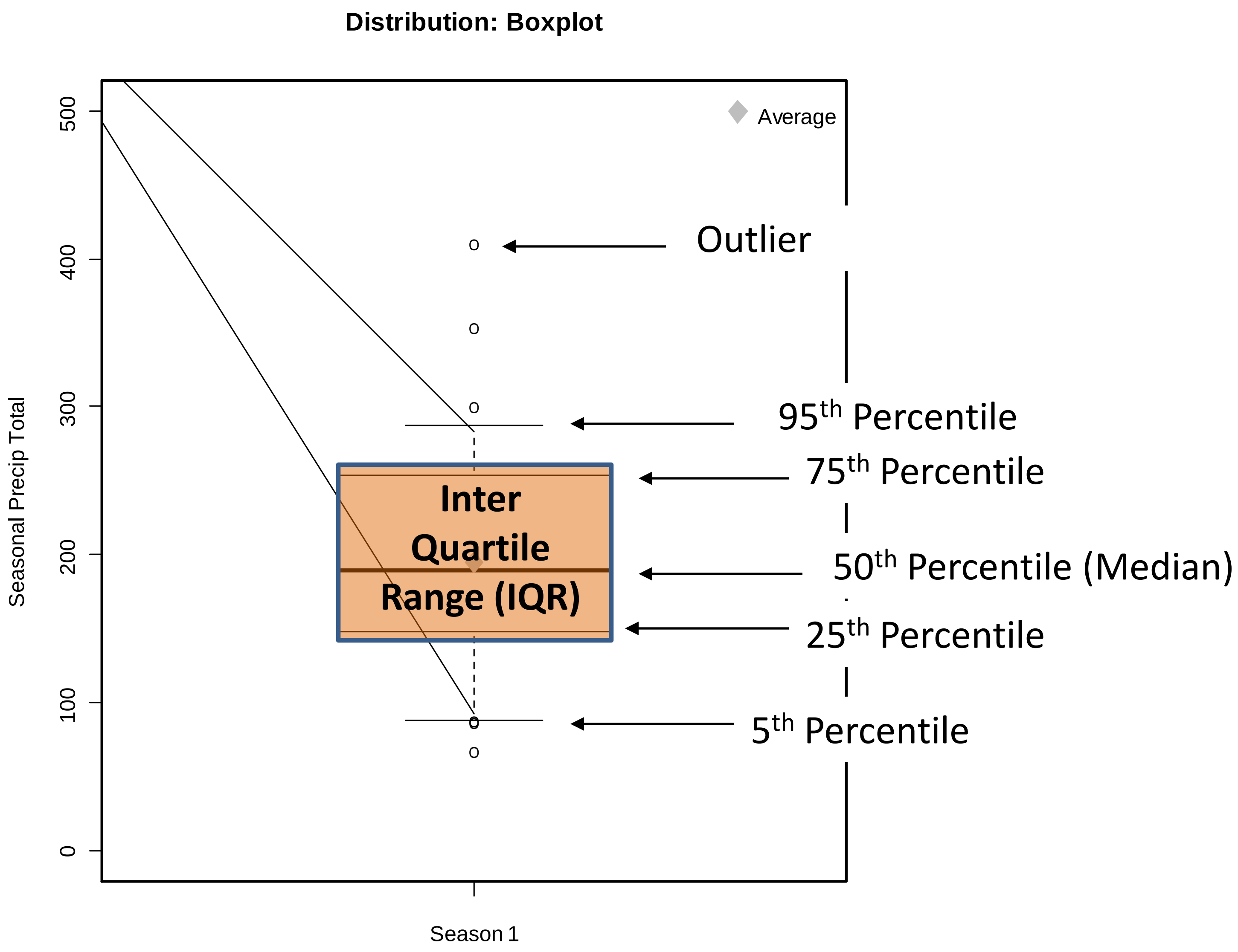
-water temperature

Ex. #1

Flow records show variability in spring runoff

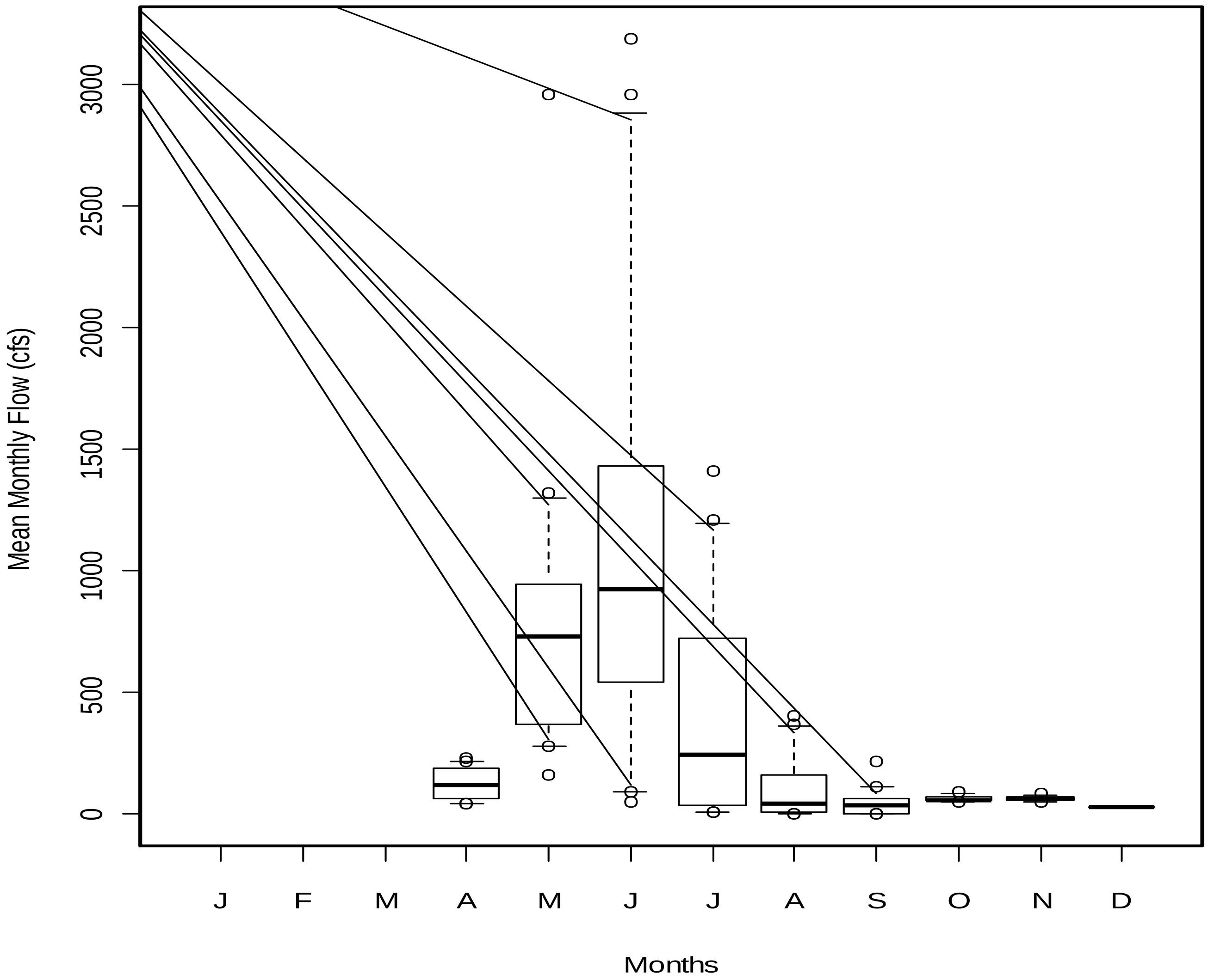


Sidebar 1: Distributions



Ex. #1

Flow records show variability in spring runoff

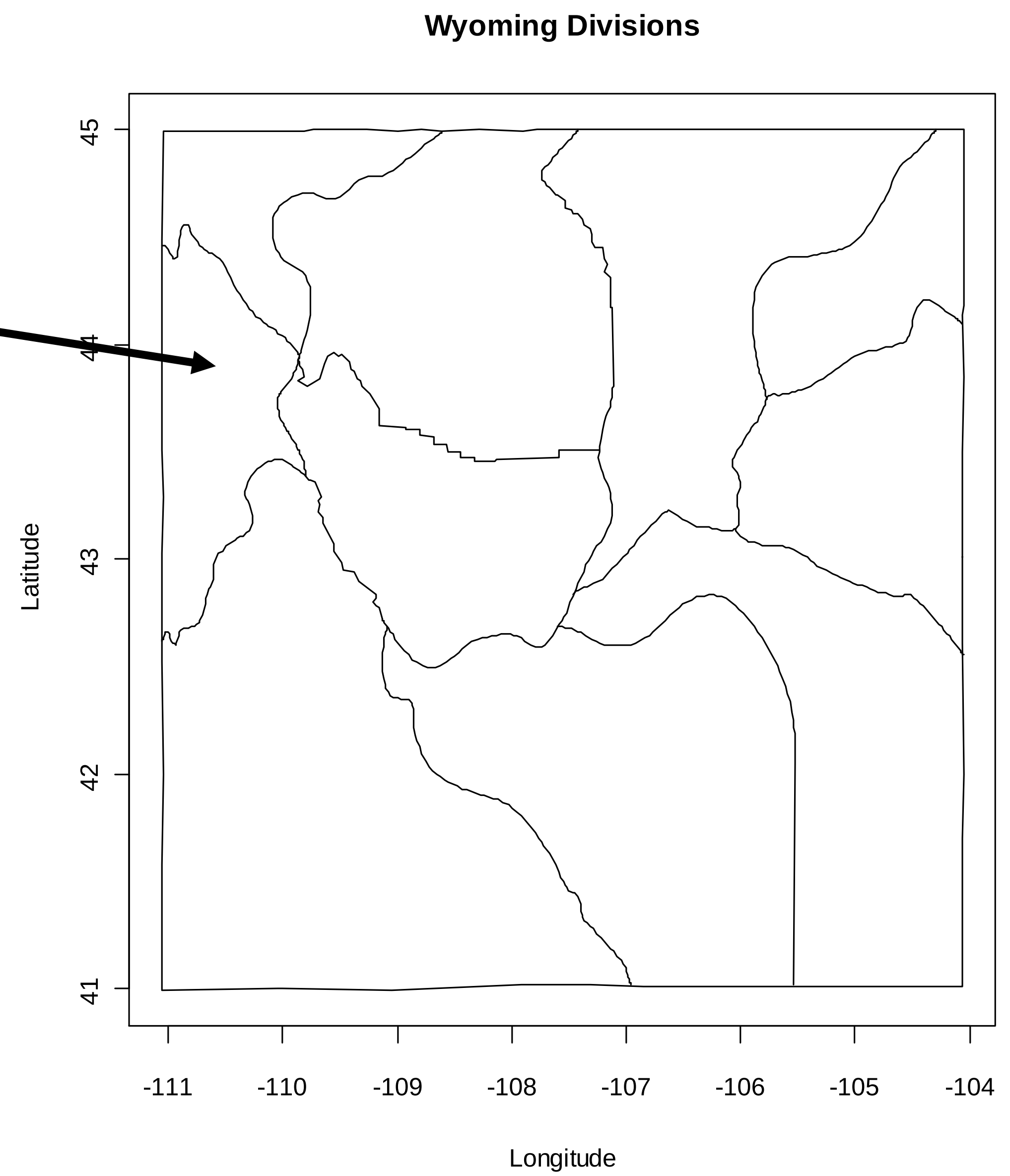


Ex. #1

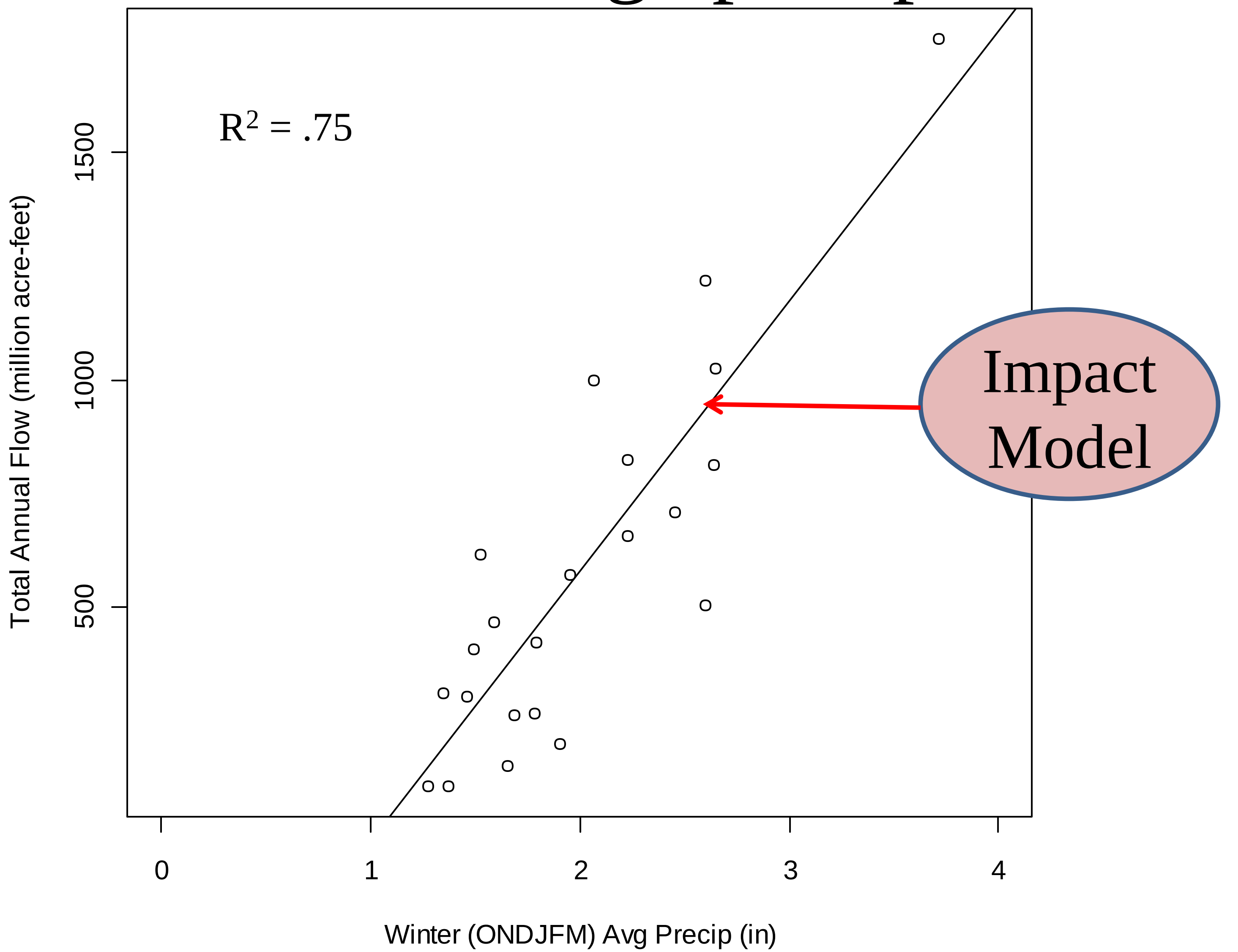
Explore associated historic precipitation

NOAA Wyoming Division 2
(Snake Drainage)

Variable	Precipitation
Time	Monthly
Space	Divisional
Dates	1895-present

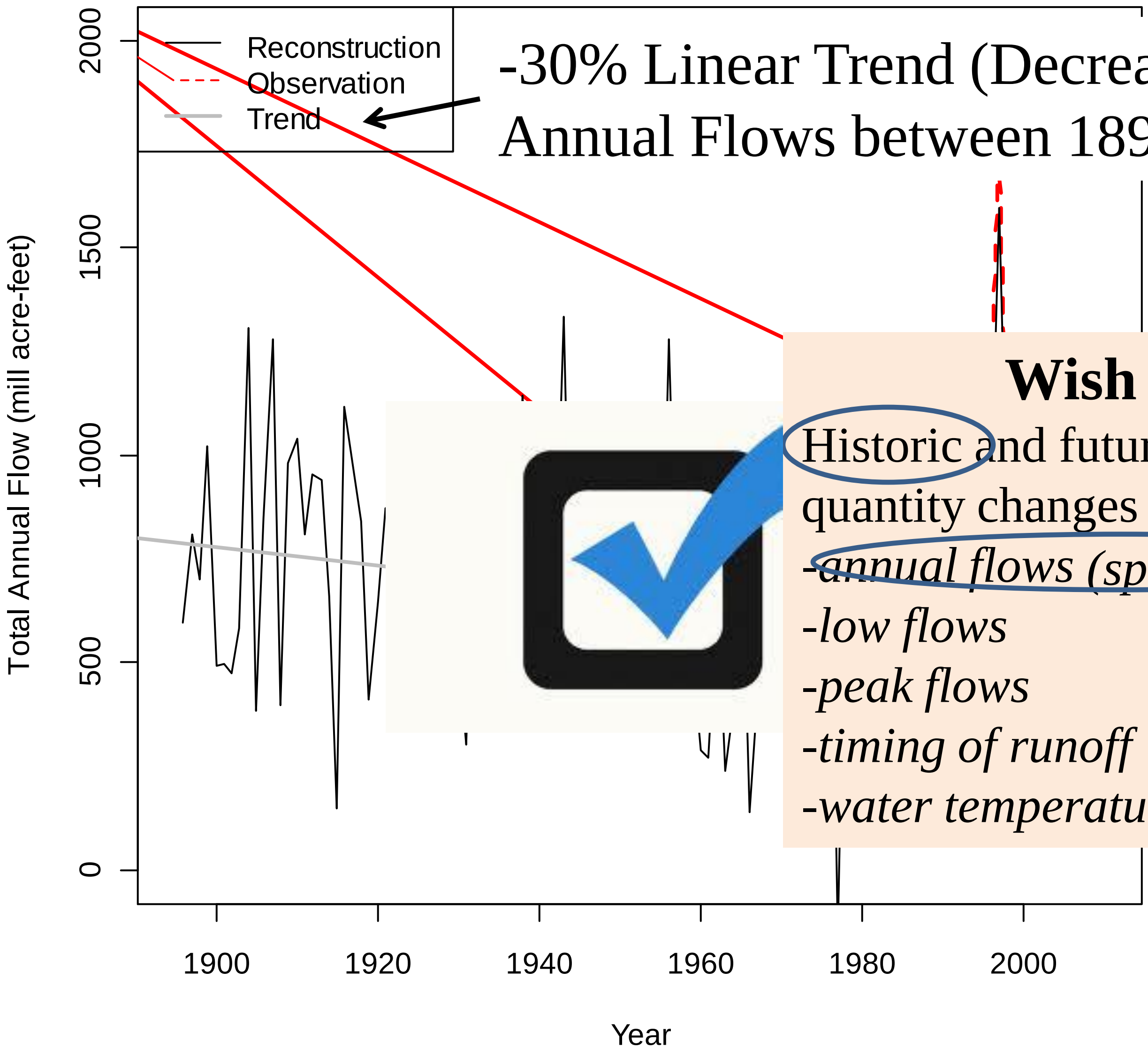


Annual flows track linearly with winter average precip



Reconstruct annual flows from precip

Ex. #1



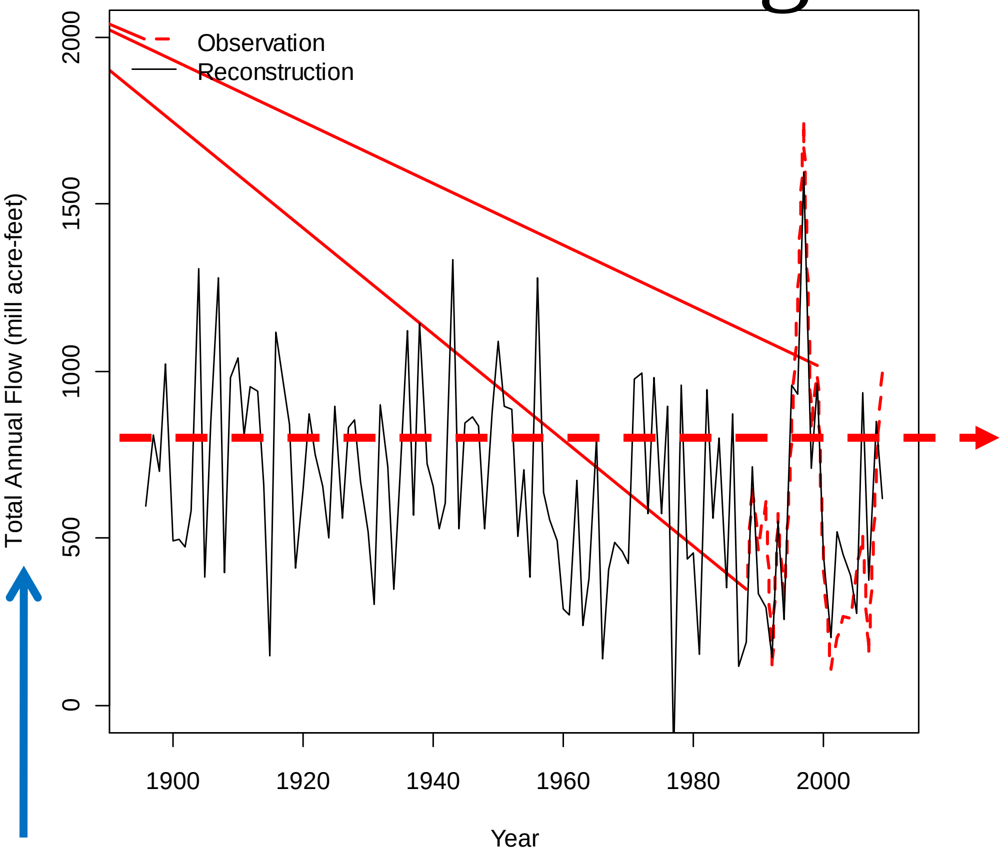
-30% Linear Trend (Decrease) in Annual Flows between 1896 & 2009

Wish List

Historic and future water quantity changes at gage:

-annual flows (spring runoff)
-low flows
-peak flows
-timing of runoff
-water temperature

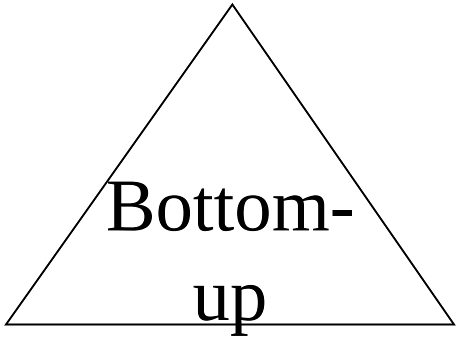
Need to identify how (and if) decisions change with these results



Is there a **threshold** that causes an **impact** (e.g., disease outbreak) or **action** (e.g., decrease diversions)?

Identify **impacts** (e.g., ecological changes) or **actions** (e.g., management decisions) from decreasing trend

Or, do **impacts** and **actions** depend on a different time of year (e.g., summer) or shorter time step (e.g., daily)?



Limited resources require identifying key climate information needs

Wish List

-Overwhelming *amount of information*
-Time-consuming *to produce*
-May or may not be useful *to decisions*

Fish are adversely affected (**impact**) when daily flows are <5 cfs (**threshold**) for 3 days in a row in summer (**time scale**), so I reduce upstream diversions (**action**).

Identify needs

Limited resources require identifying key climate information needs

Needs

~~Wish~~ List

-Relationship between fish and flow

-Daily low flows (summer)

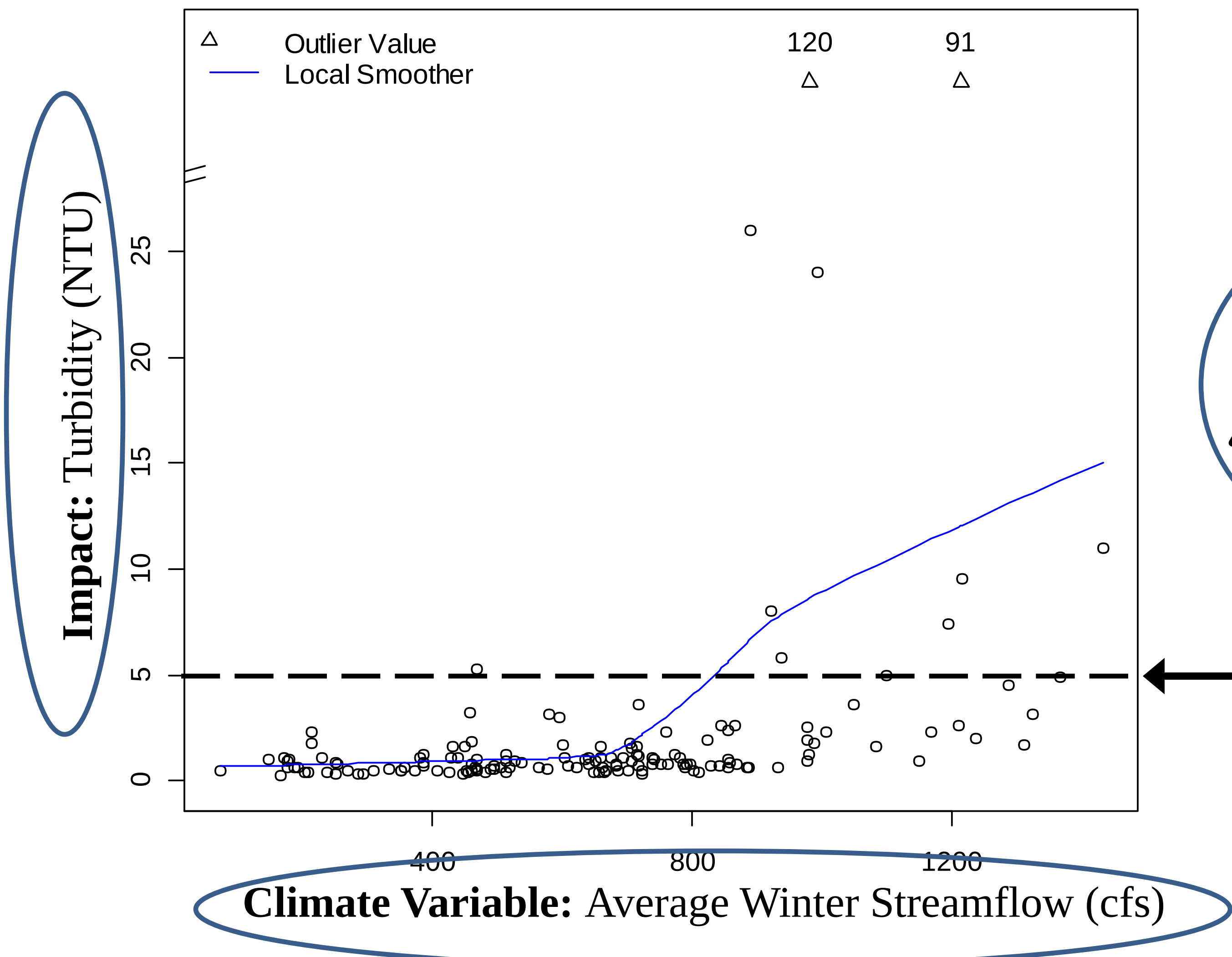
-Past/future risk of <5 cfs for three days

-Adaptive capacity (available alternatives past/future)

Fish are adversely affected (**impact**) when daily flows are <5 cfs (**threshold**) for 3 days in a row in summer (**time scale**), so I reduce upstream diversions (**action**).

Identify needs

Example #2: Risk of a water quality (turbidity) exceedance



Action: Above threshold drinking utility must switch to groundwater source ($$)

Threshold: 5 NTU

(Towler et al. 2010)

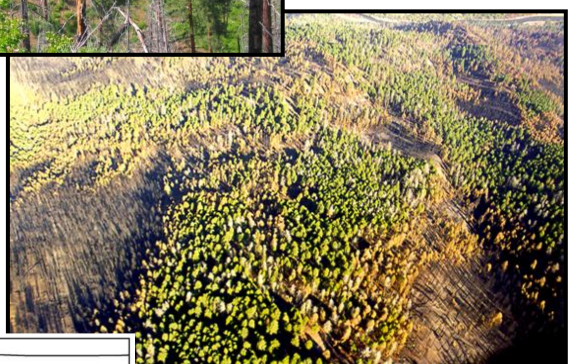
Example #3: Climate Impact Assessment of Daily Survival Rates of Nesting Lewis's Woodpeckers

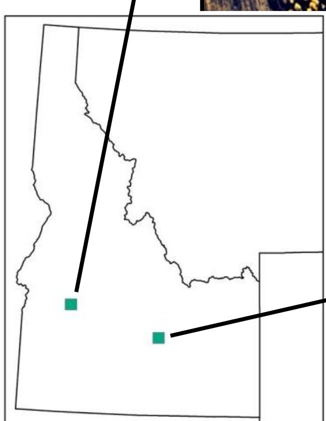
(Saab and Towler in prep)

Field studies identify factors controlling nesting ecology of Lewis's Woodpecker

Impact Model

Burned Pine
1994 - 2004





Aspen Woodlands
2002 - 2004

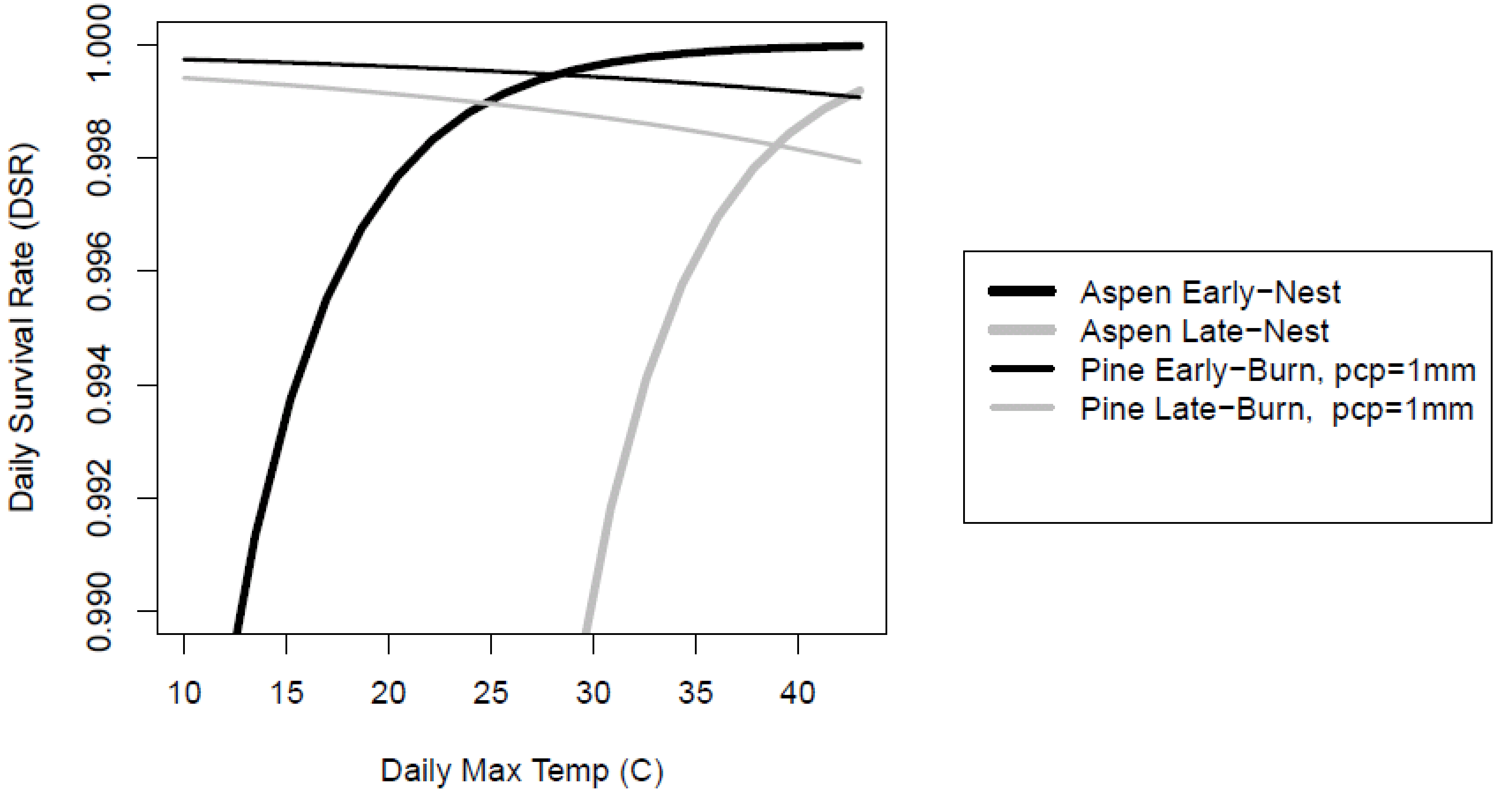
(Saab et al. 2011; Newlon and Saab 2011)

Impact model is developed to predict nest survival using covariates

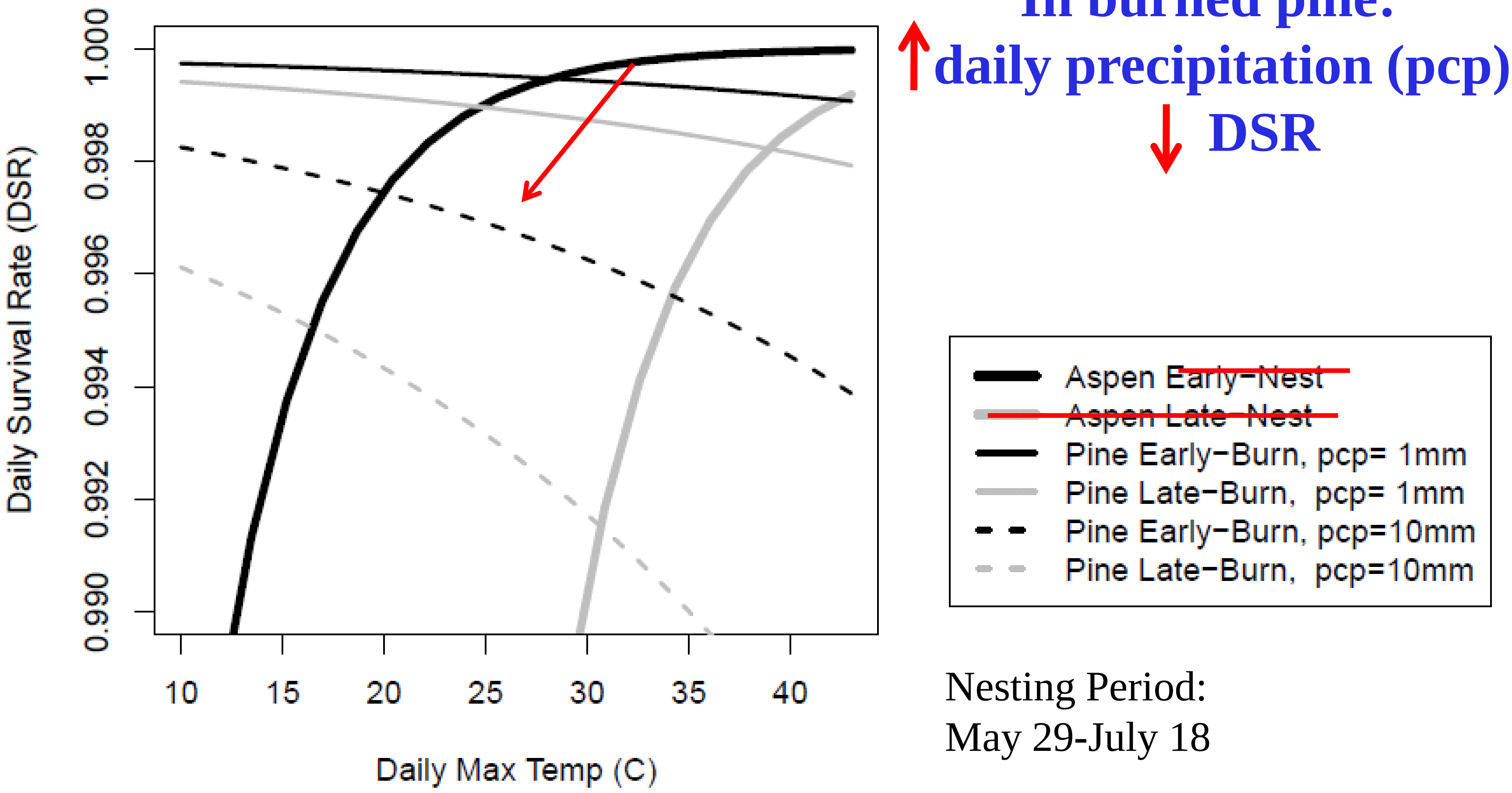
Covariate	Burned Pine (N = 716)	Aspen Woodlands (N = 76)
Temperature (daily max)	—	+
Precipitation (daily total)	—	ns
Temporal (time since fire & initiation date)	—	—
Nest tree characteristics	ns	ns
Habitat conditions	ns	ns

+/- : Significant covariates & direction of response, 95% C.I. did not include zero

Higher daily temperatures increase (decrease) nest survival in aspens (burned pine).



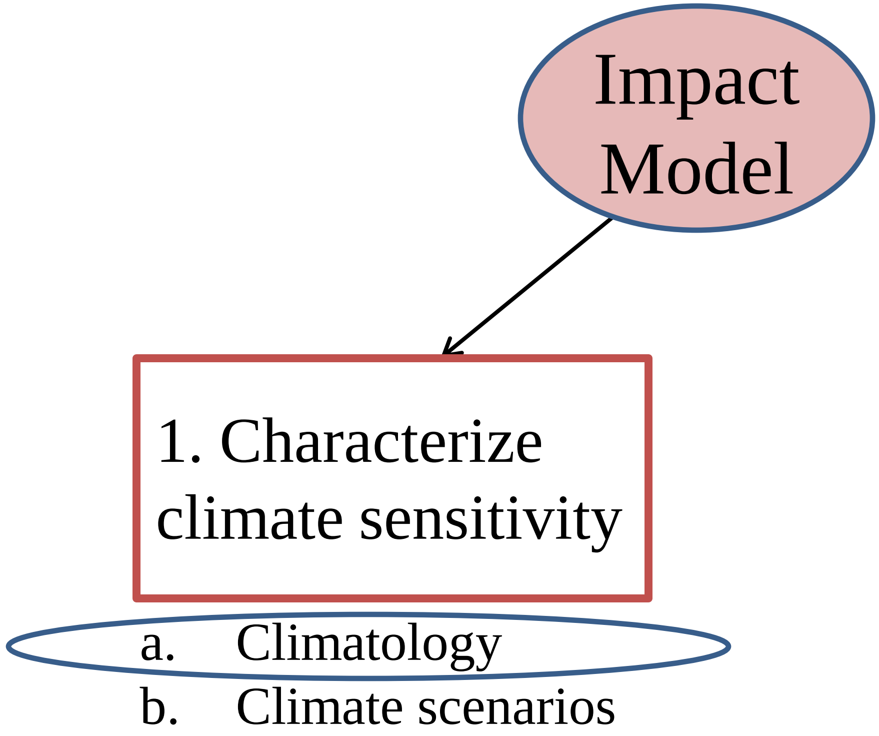
Higher daily temperatures increase (decrease) nest survival in aspens (burned pine).



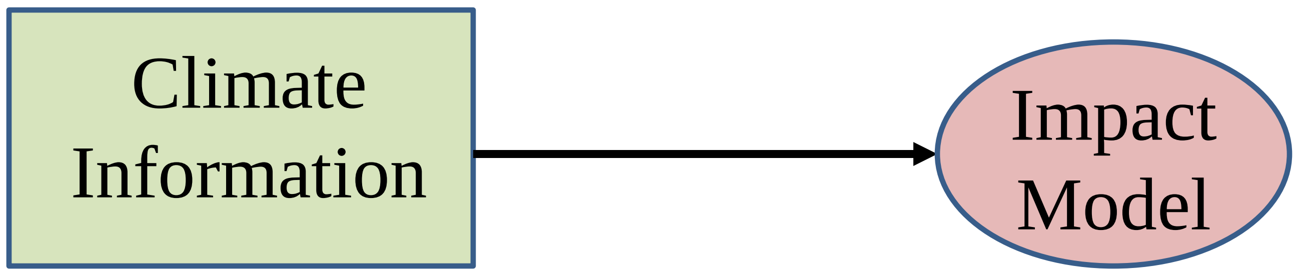
In burned pine:
↑ daily precipitation (pcp)
↓ DSR

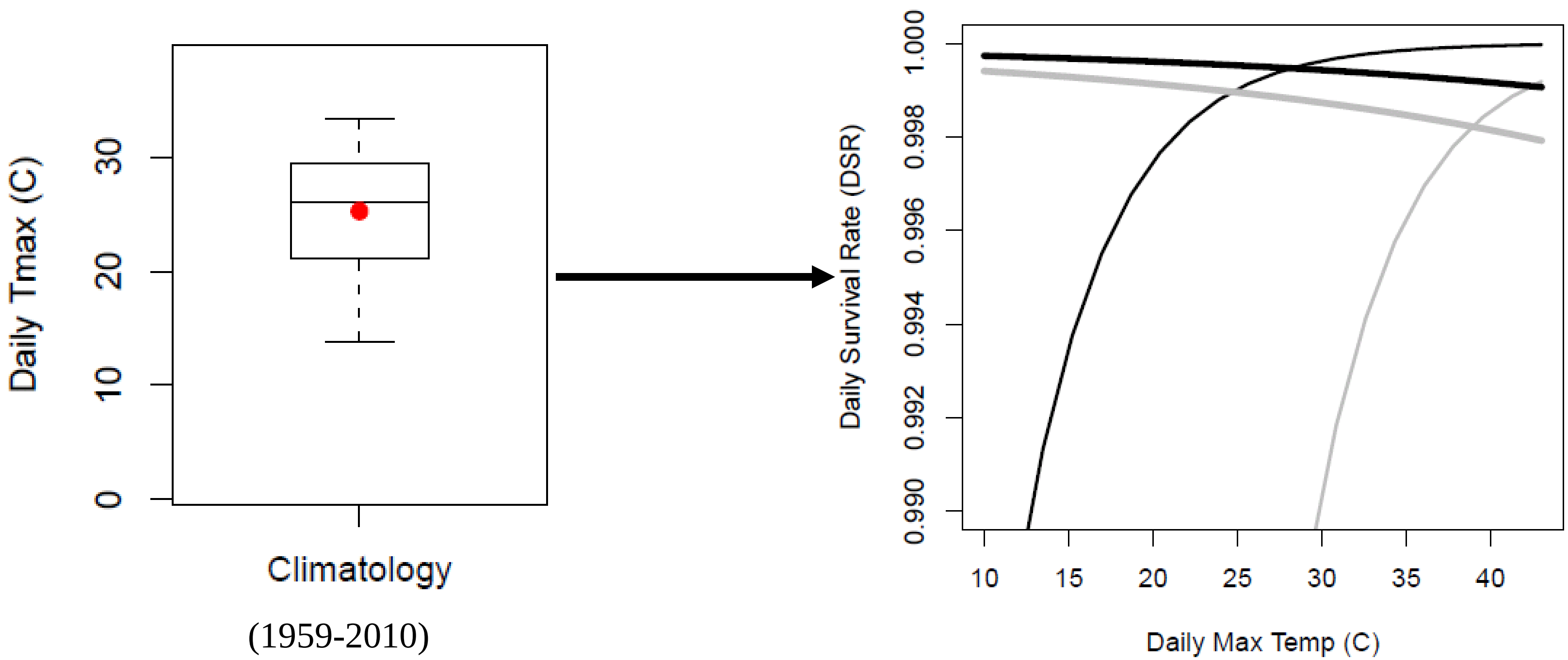
Nesting Period:
May 29-July 18

Impact model facilitates the incorporation of climate information

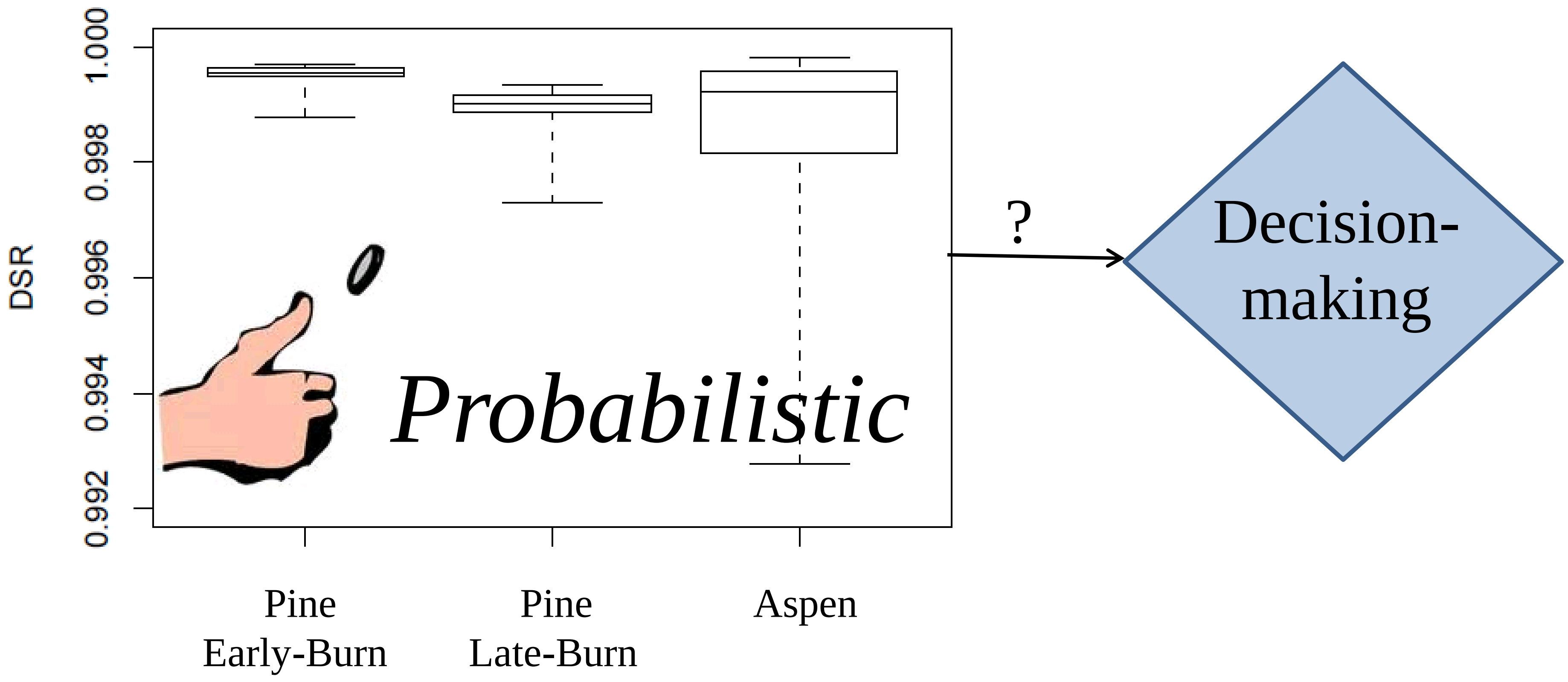


Use ensembles with model to test sensitivity under climate variability

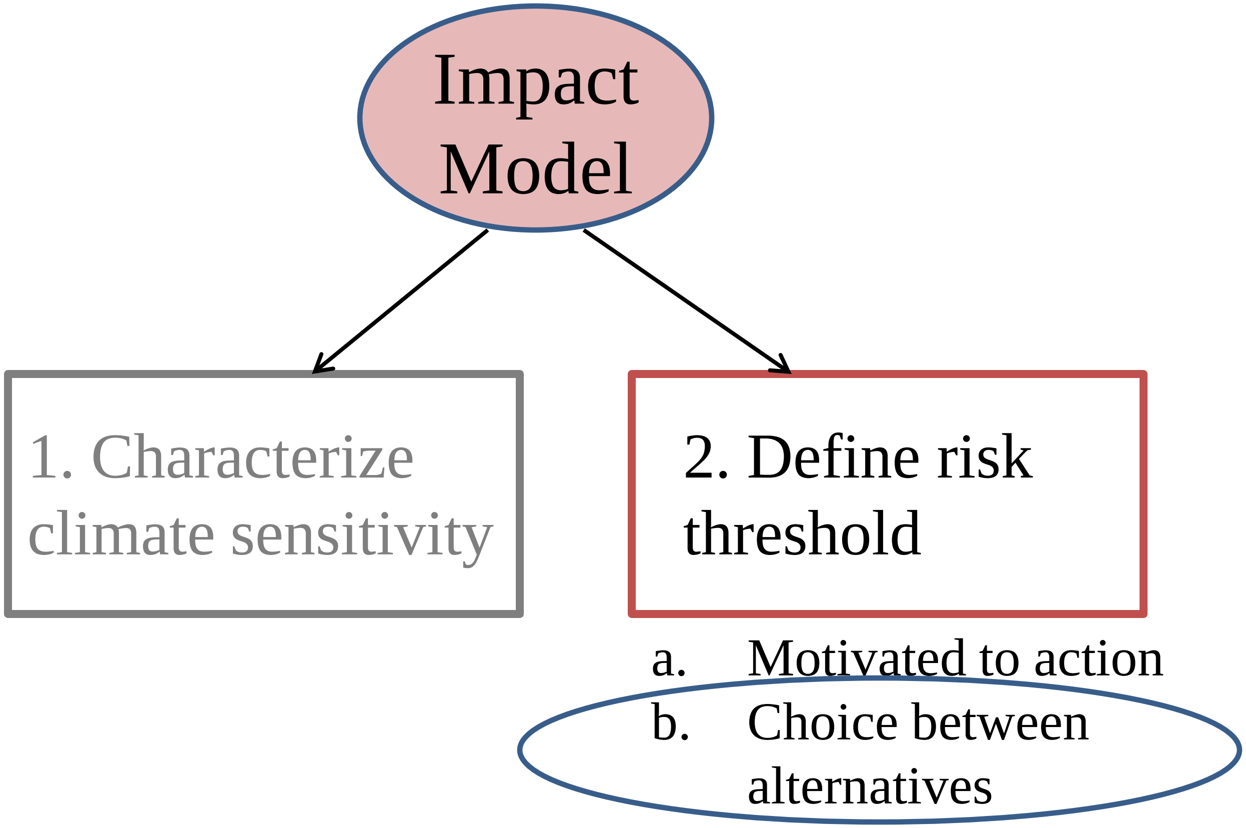




Results show that DSR values overlap and that burned pine have a tight distribution

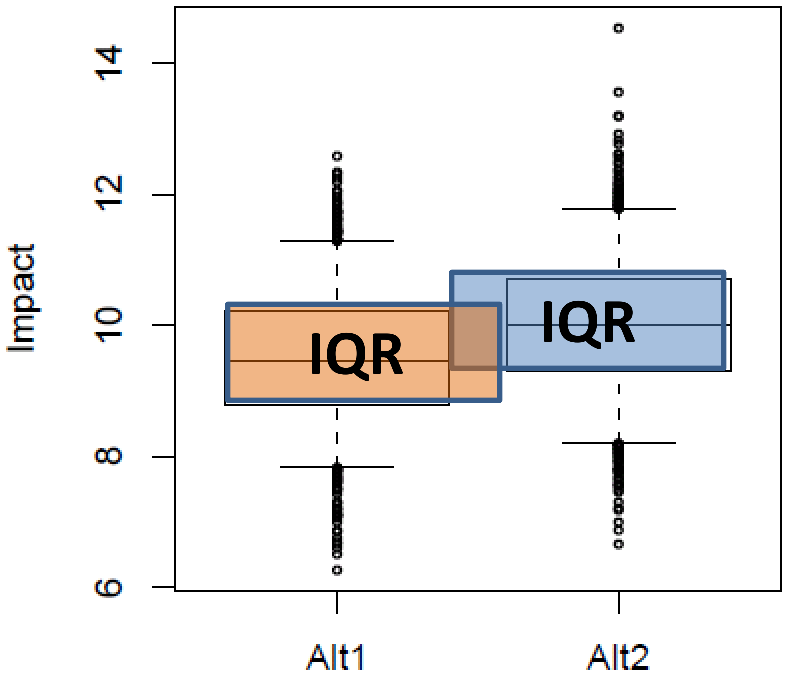


2. Adopt a risk threshold for decision



Sidebar 2: Risk framework

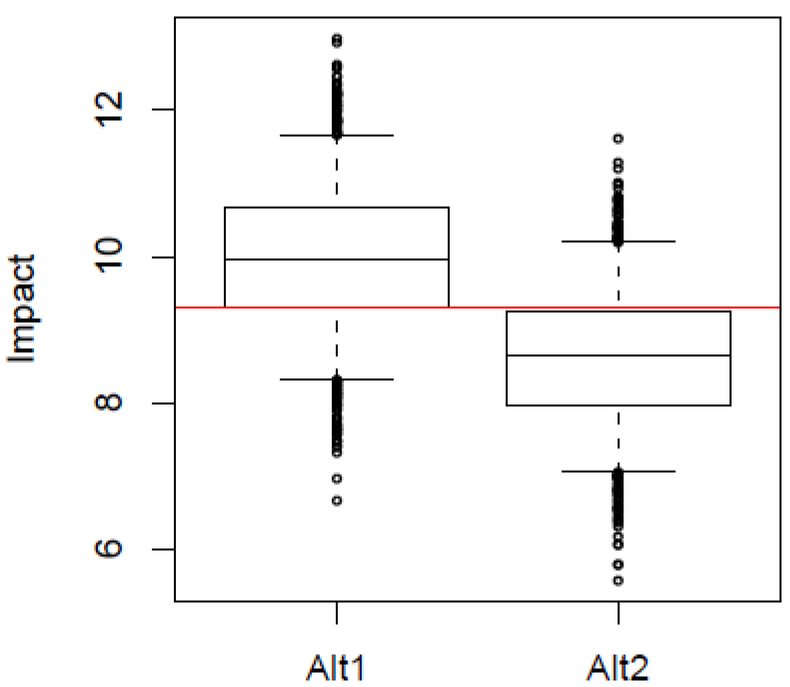
Define “alternative neutral” for case where inter quartile ranges (IQRs) overlap



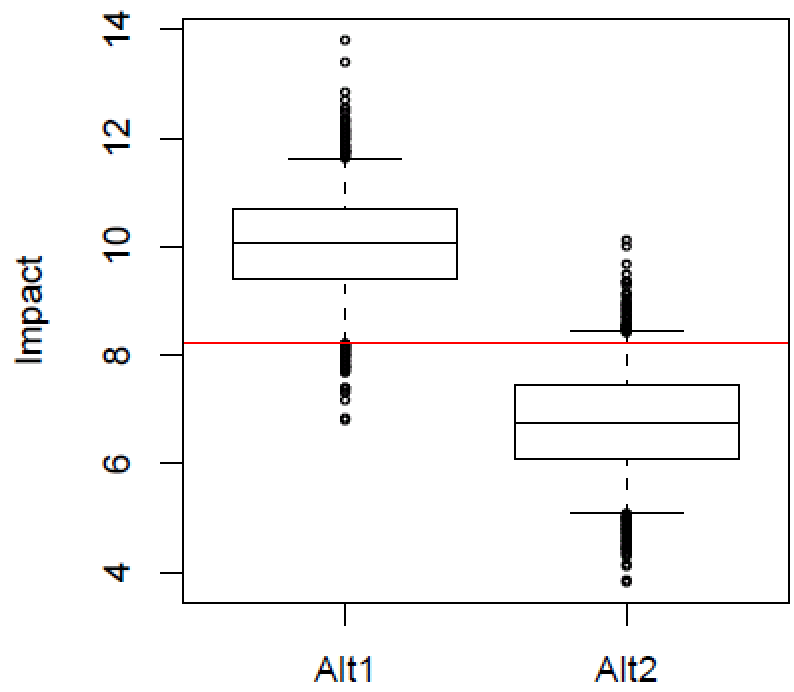
Sidebar 2: Risk framework

Define a risk threshold to decide between alternatives

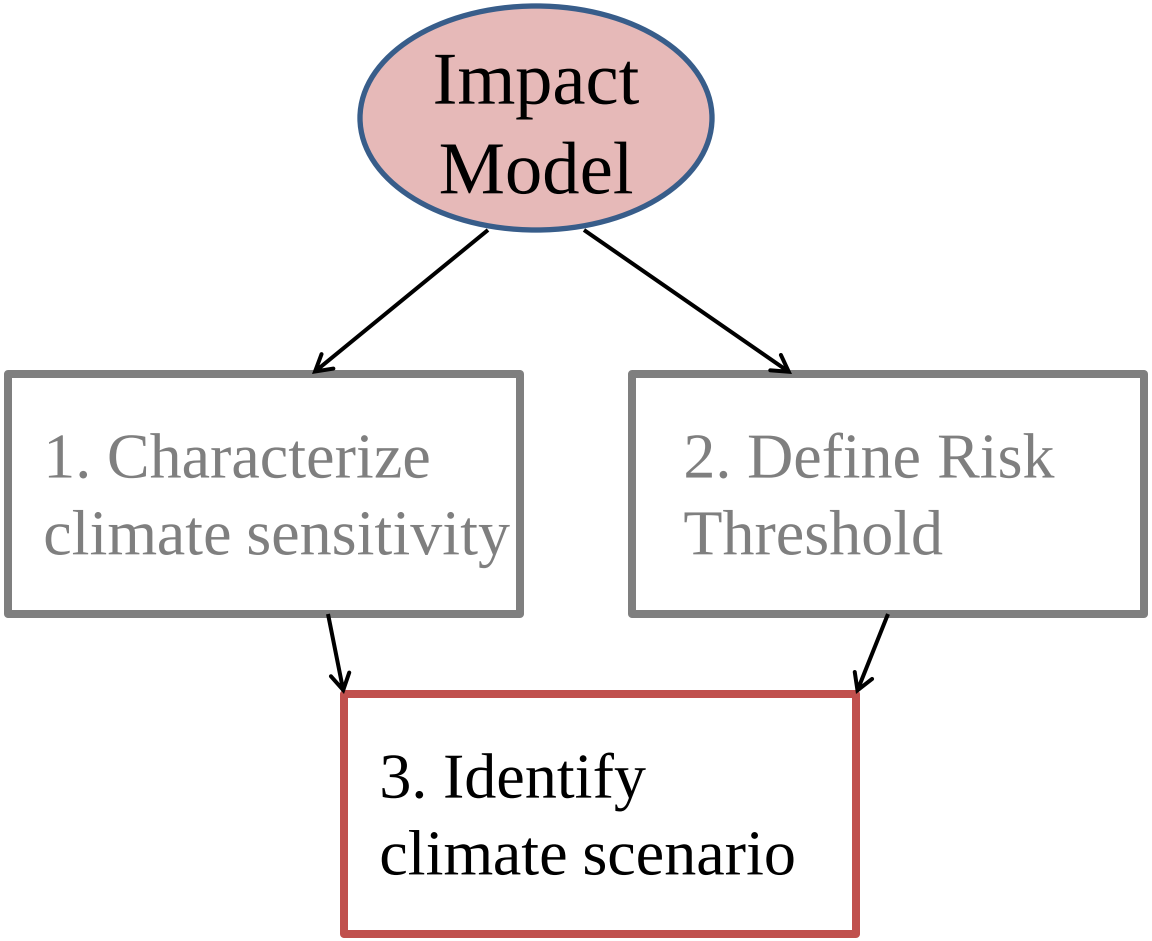
Case 1: Moderate Decision Threshold
(Impact better/worse 75% of time)
Alt #1 is “better”, pick Alt#1 over Alt#2



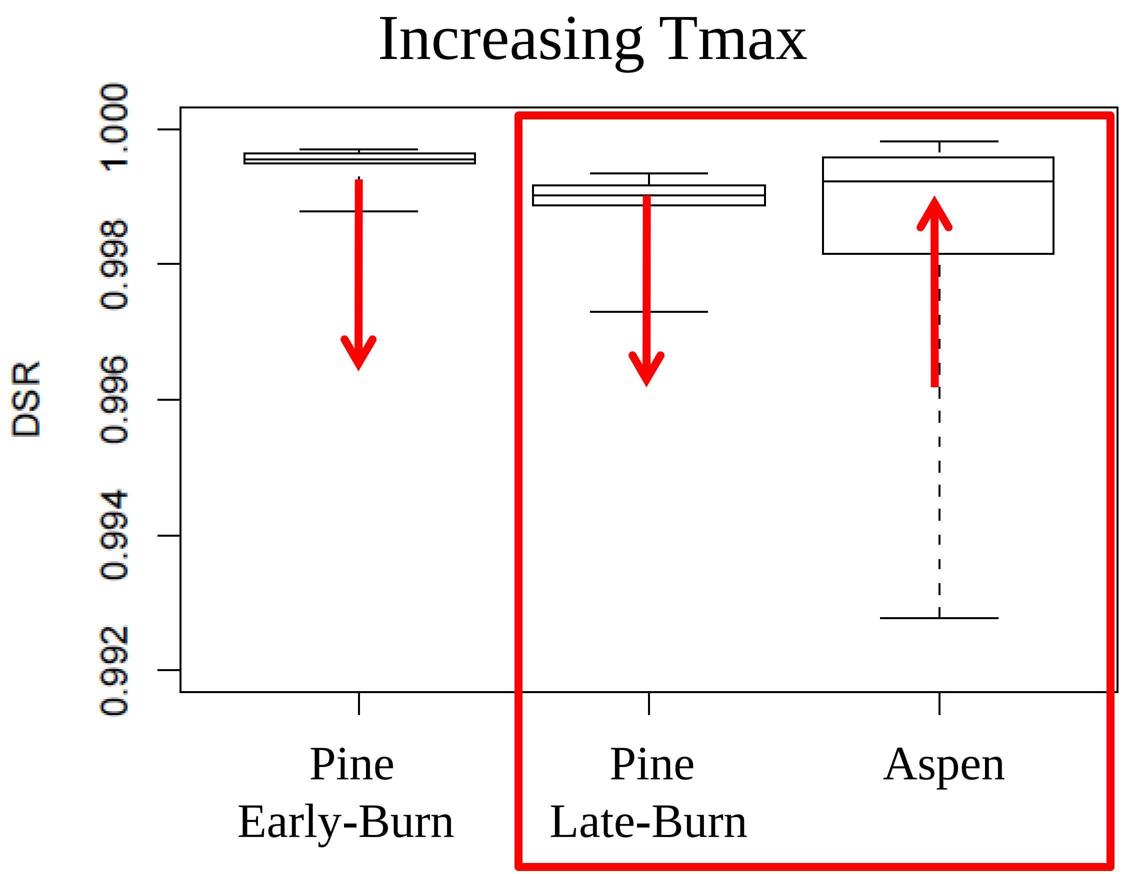
Case 2: Stringent Decision Threshold
(Impact better/worse 95% of time)
Alt #1 is “better”, pick Alt#1 over Alt#2.



3. Identify climate scenario that meets risk threshold

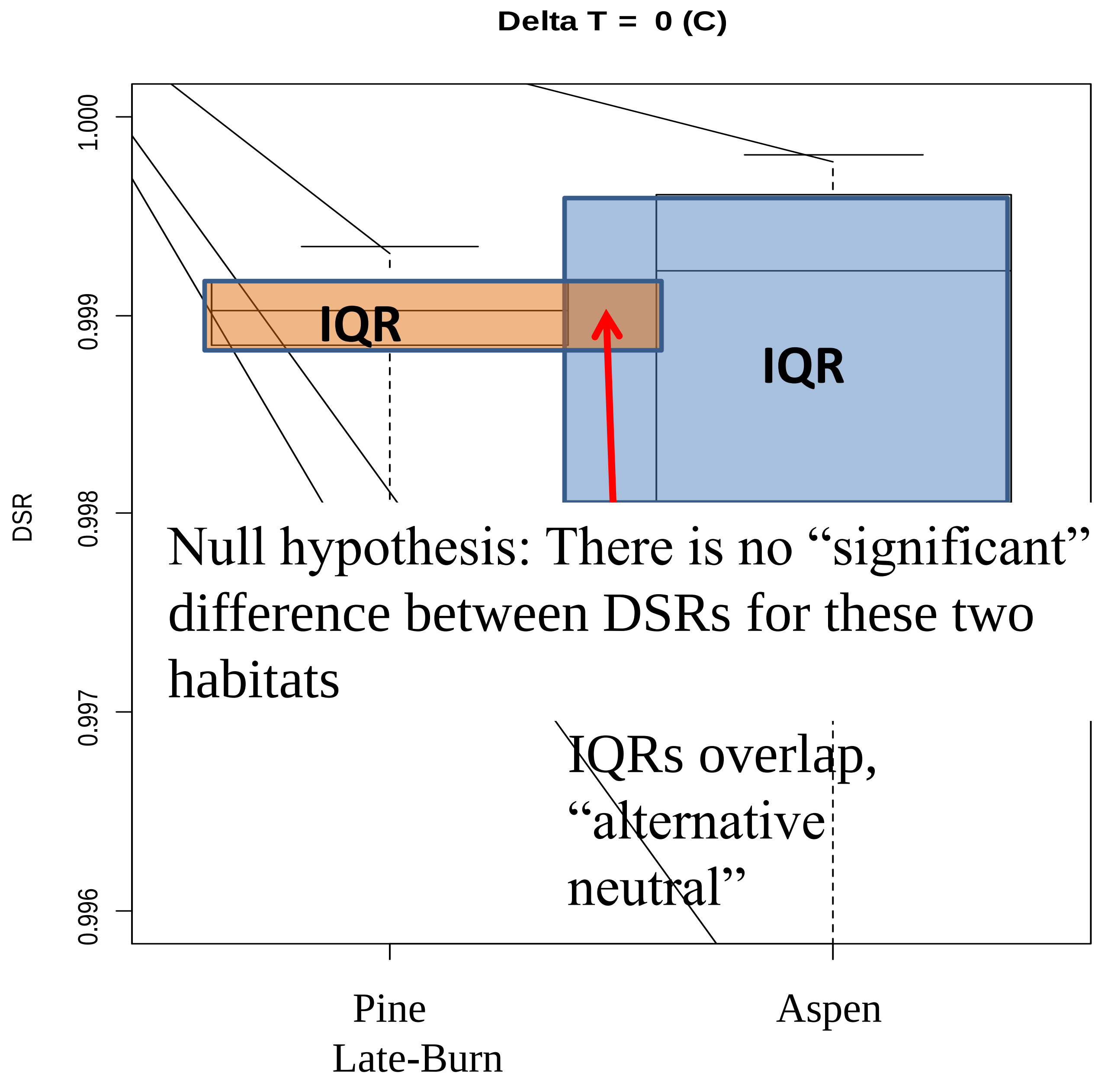


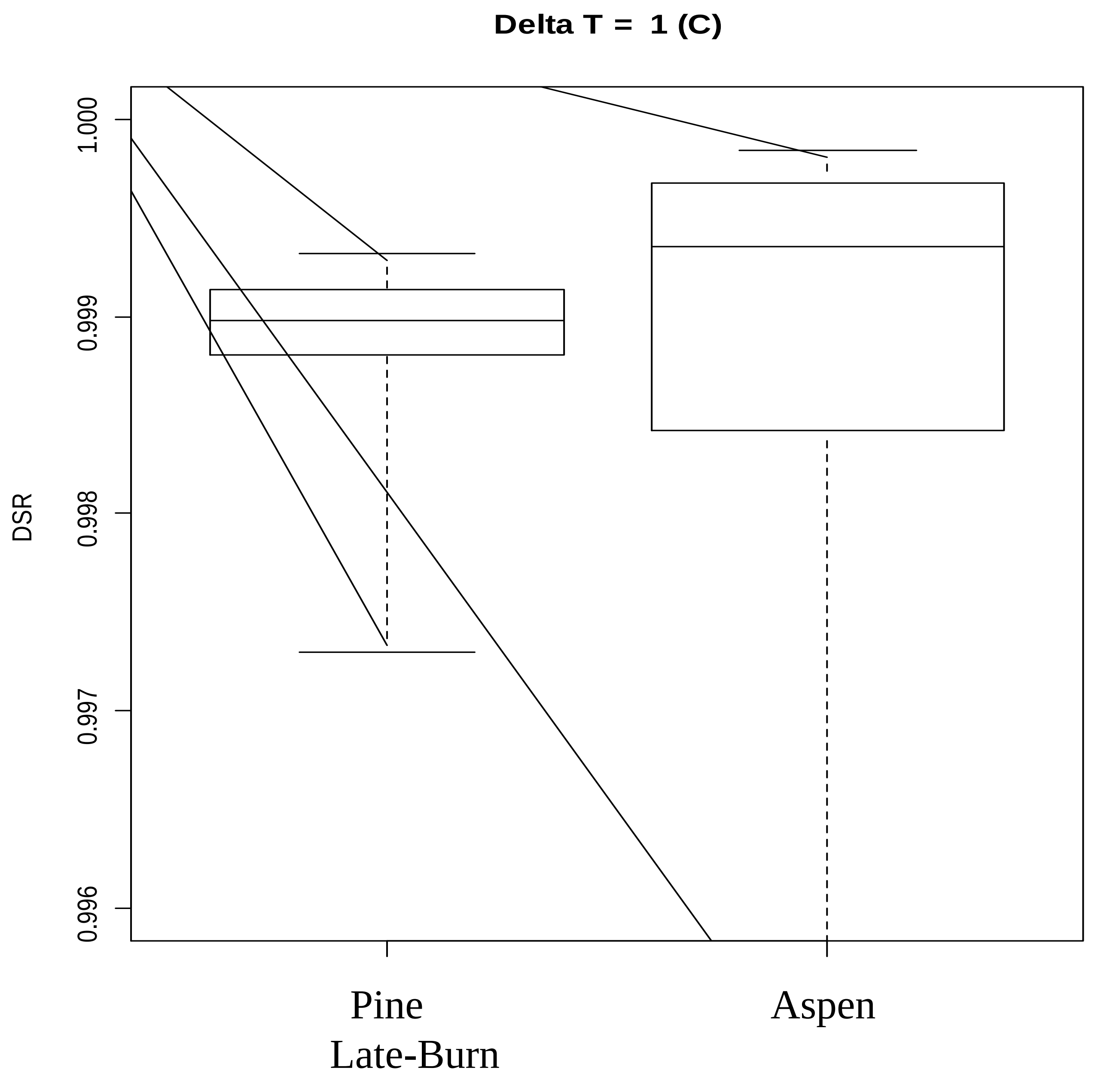
Currently "alternative neutral", but increasing Tmax scenario increases (decreases) DSR for aspen (burned pine)

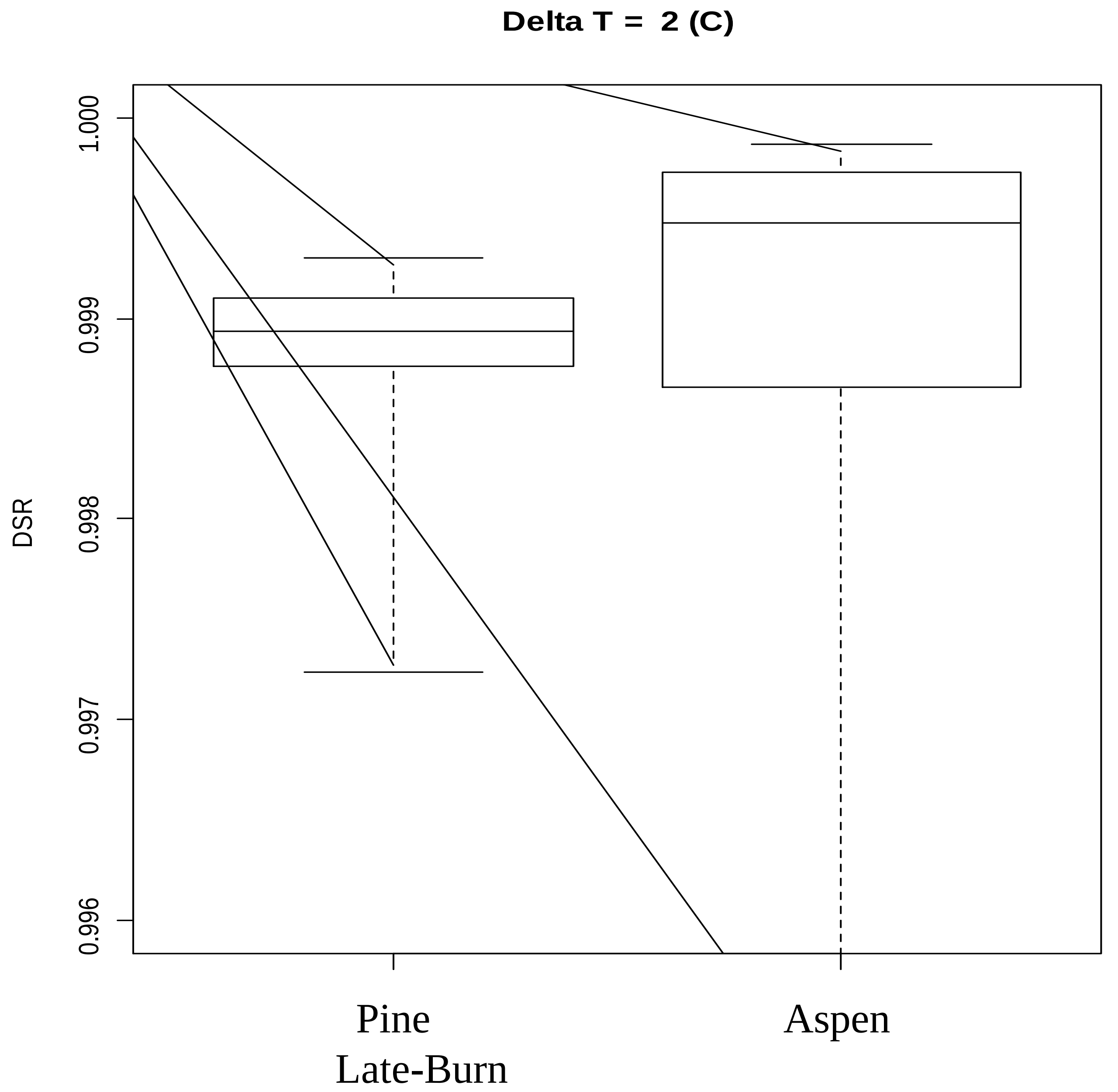


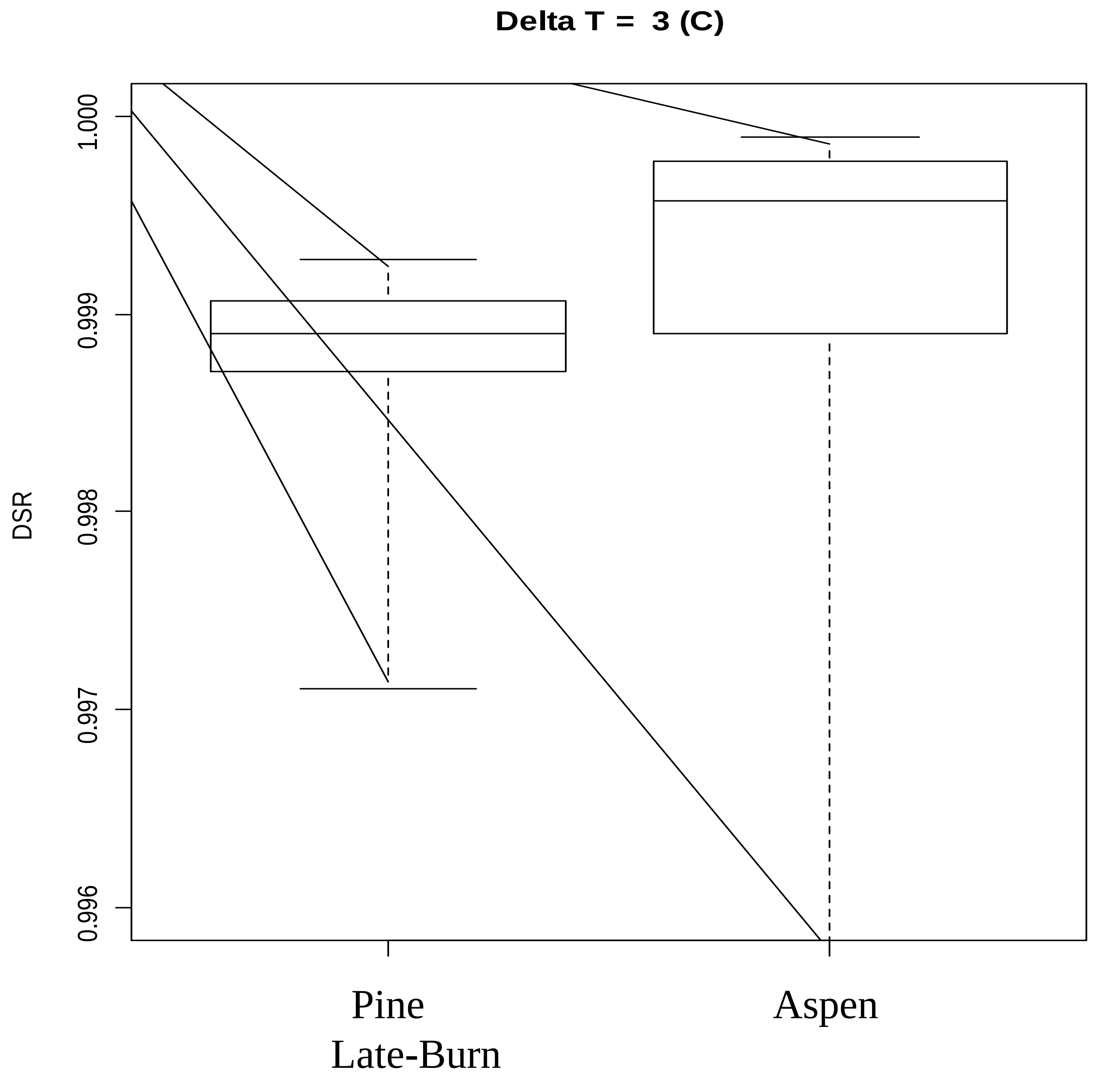
Use methods to add heat and create warmer scenarios

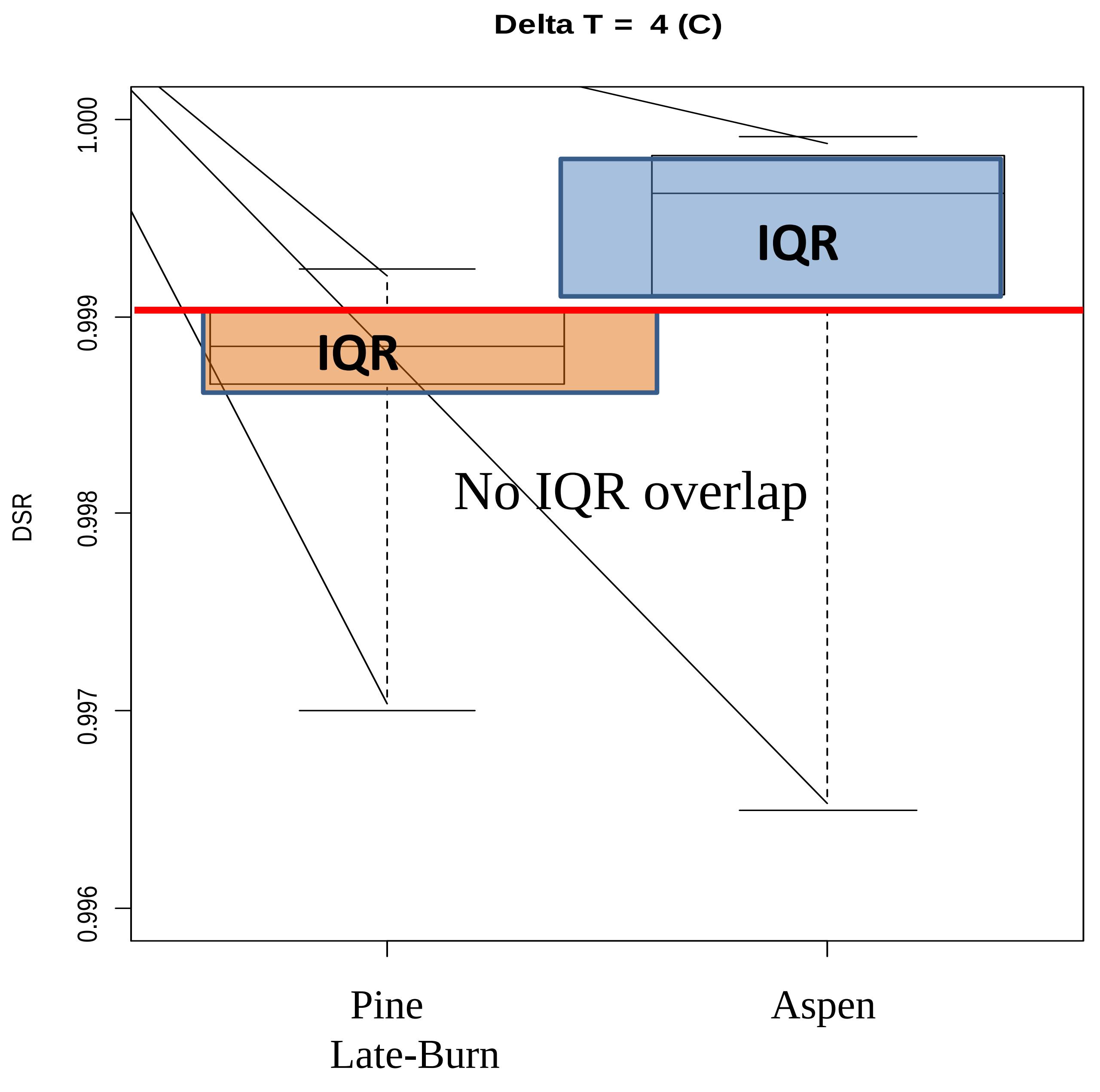
Historic resample
+
Delta method

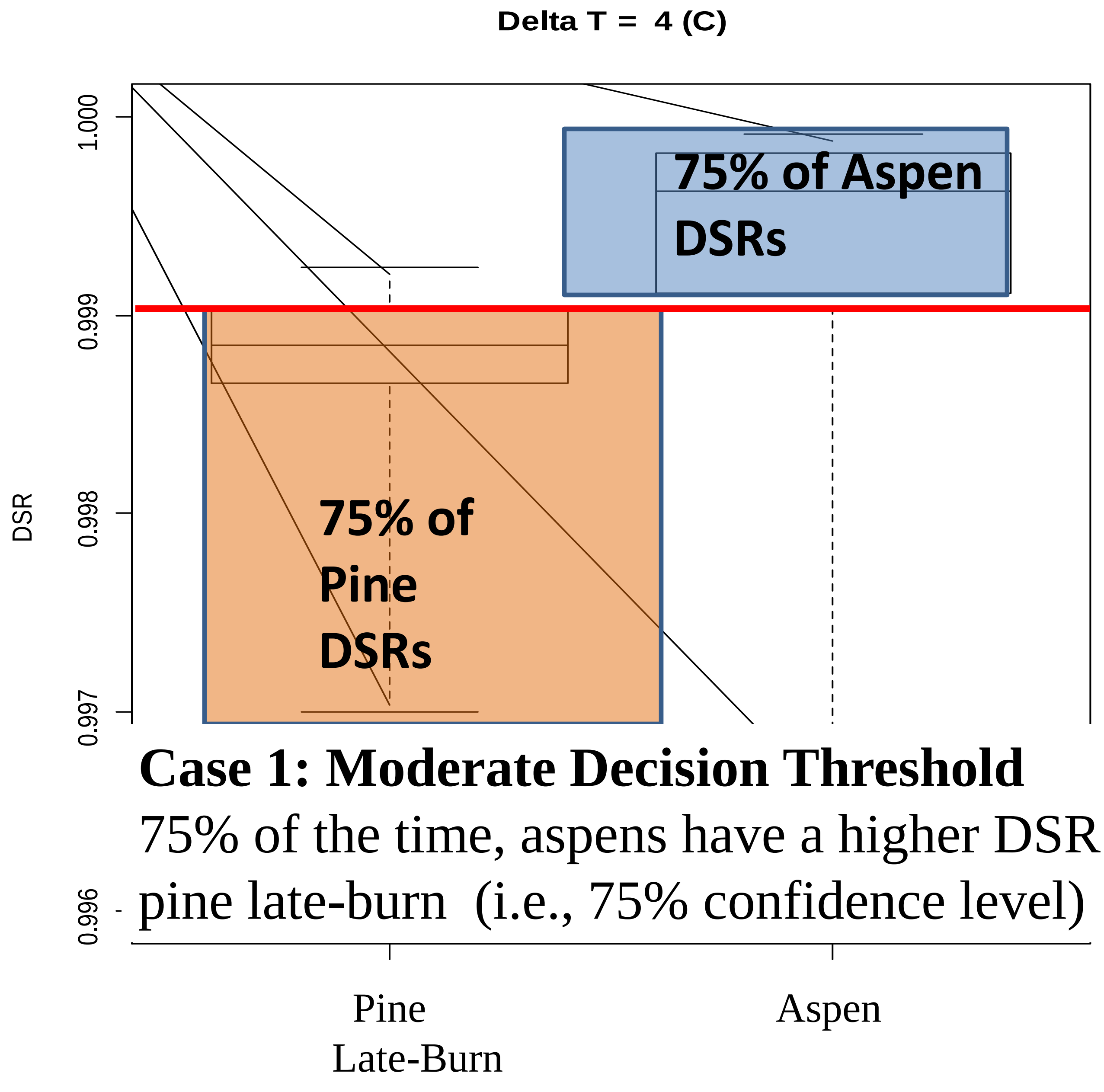

Delta T = 0 (C)
DSR
1.000
0.999
0.998
0.997
0.996
IQR
IQR
Null hypothesis: There is no "significant" difference between DSRs for these two habitats
IQRs overlap, "alternative neutral"
Pine
Late-Burn
Aspen


Delta T = 1 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen


Delta T = 2 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen

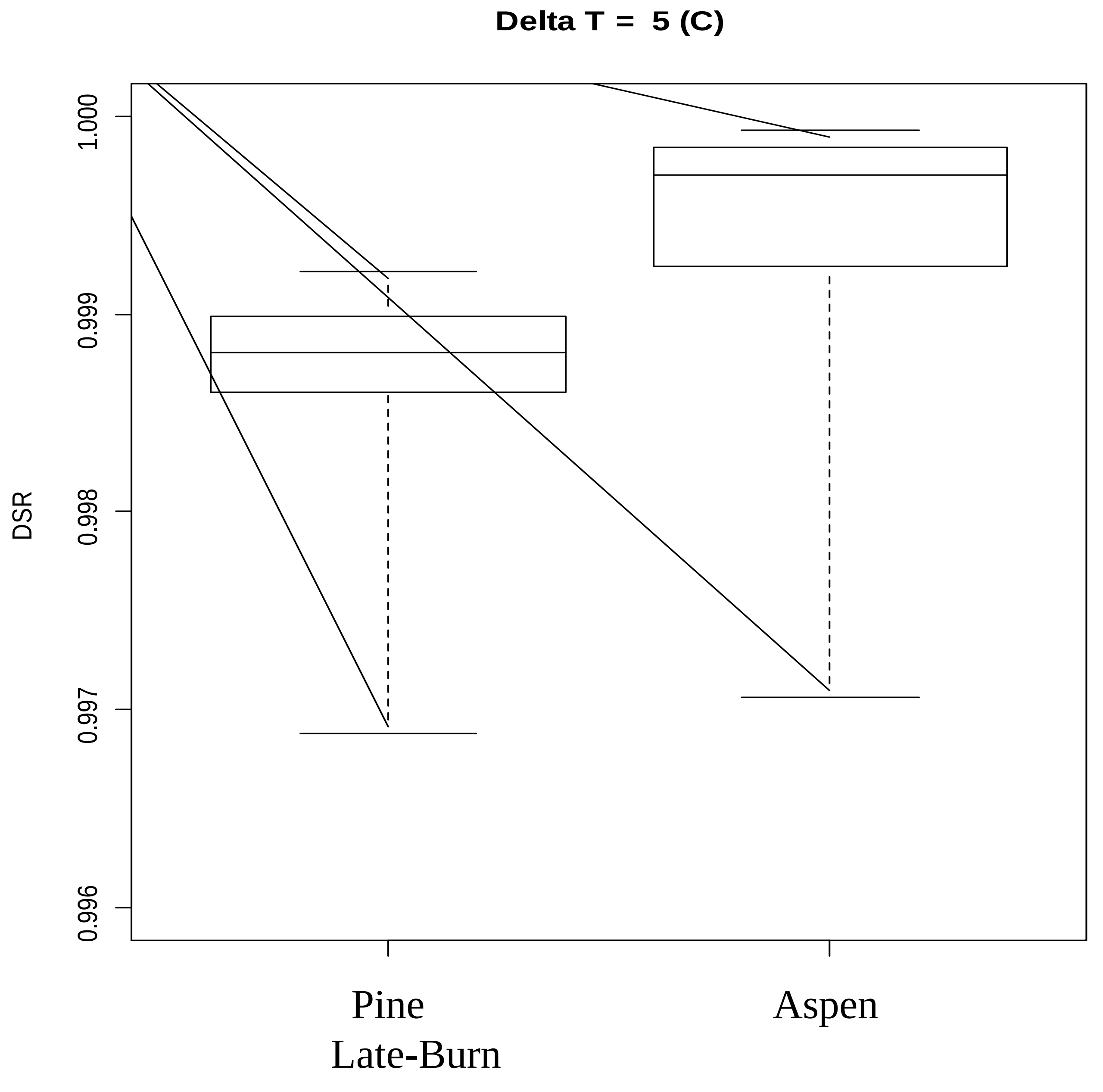

Delta T = 3 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen

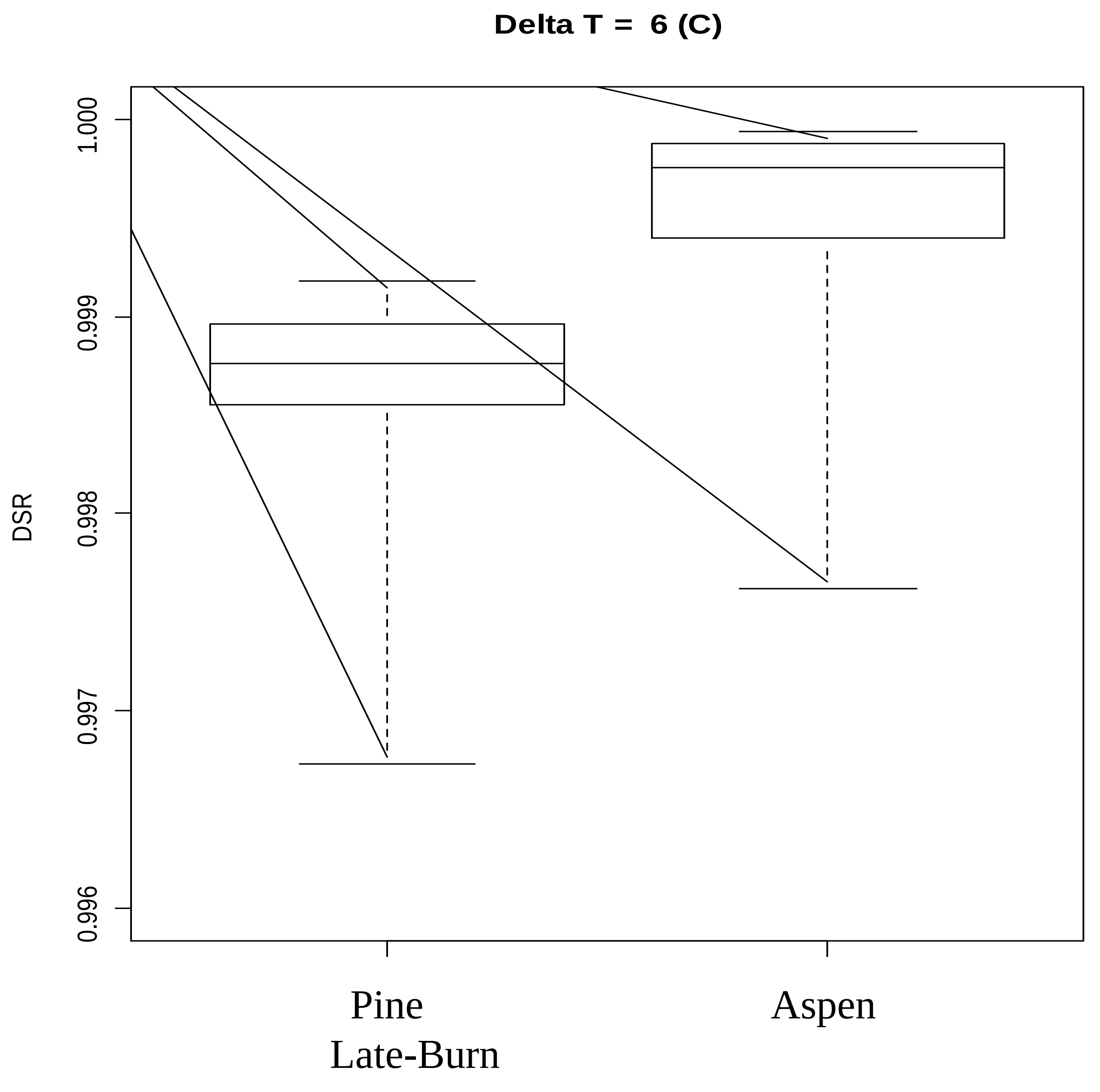

Delta T = 4 (C)
DSR
1.000
0.999
0.998
0.997
0.996
IQR
IQR
No IQR overlap
Pine
Late-Burn
Aspen

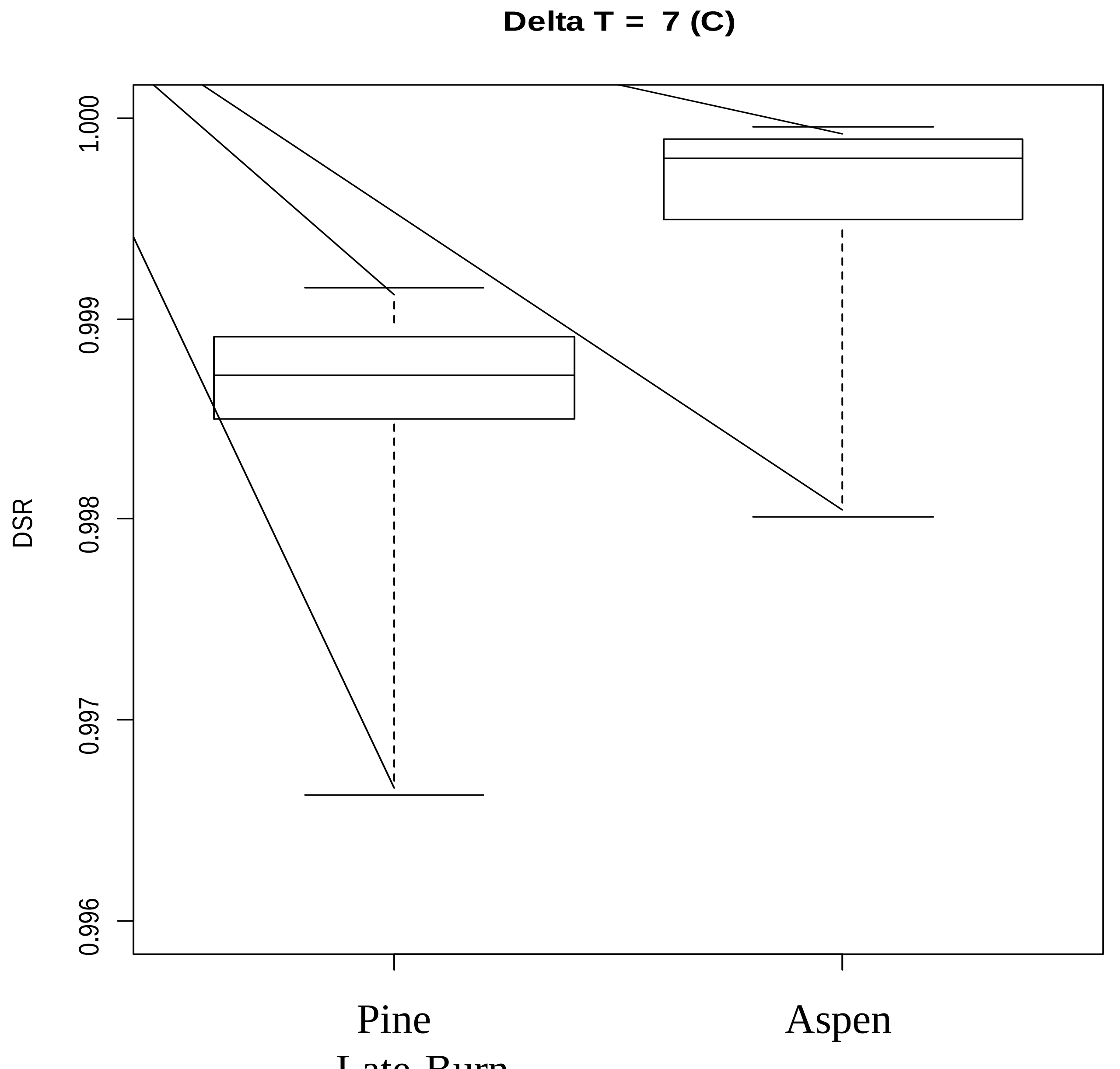


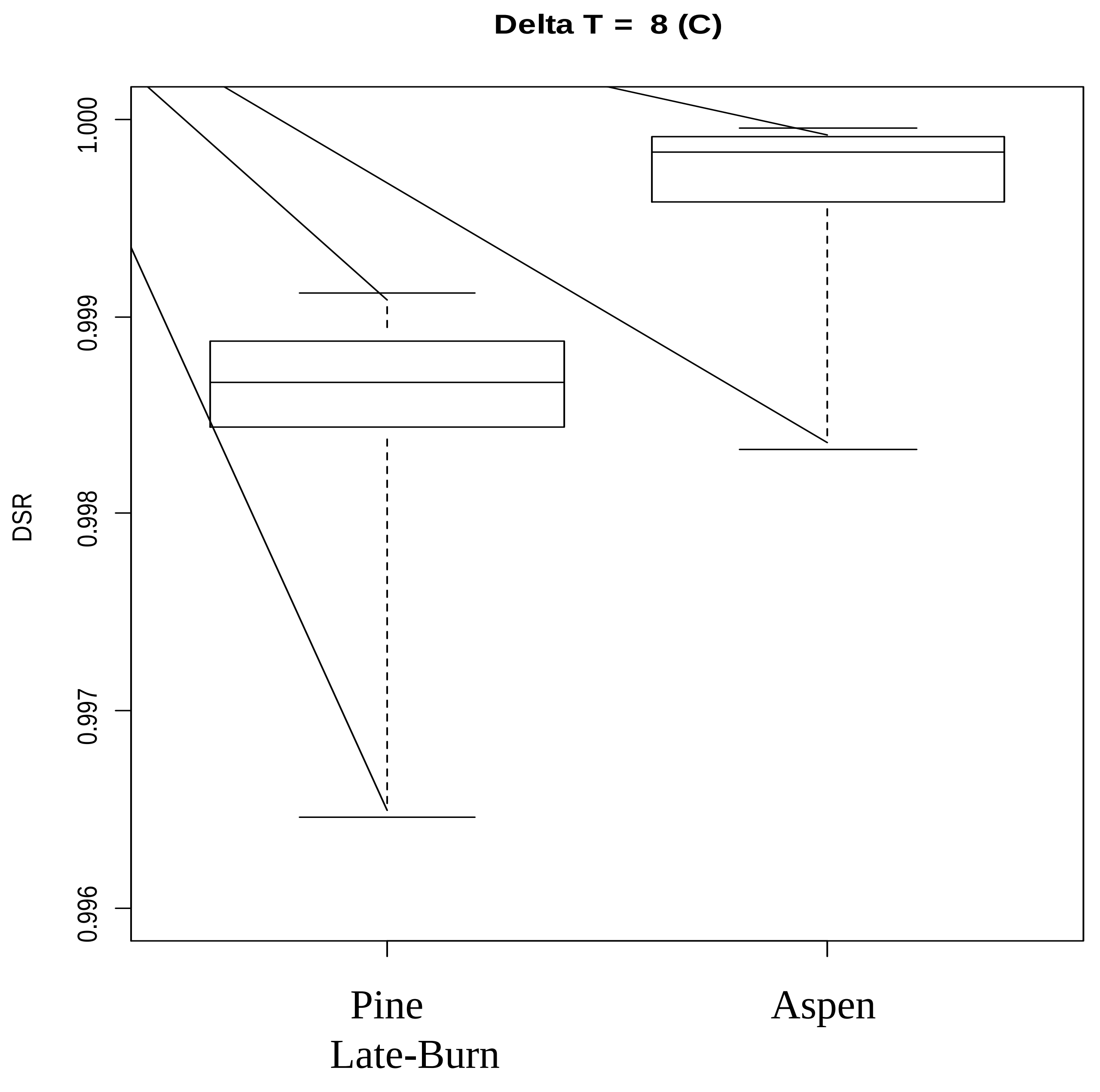
Case 1: Moderate Decision Threshold

75% of the time, aspens have a higher DSR than pine late-burn (i.e., 75% confidence level)

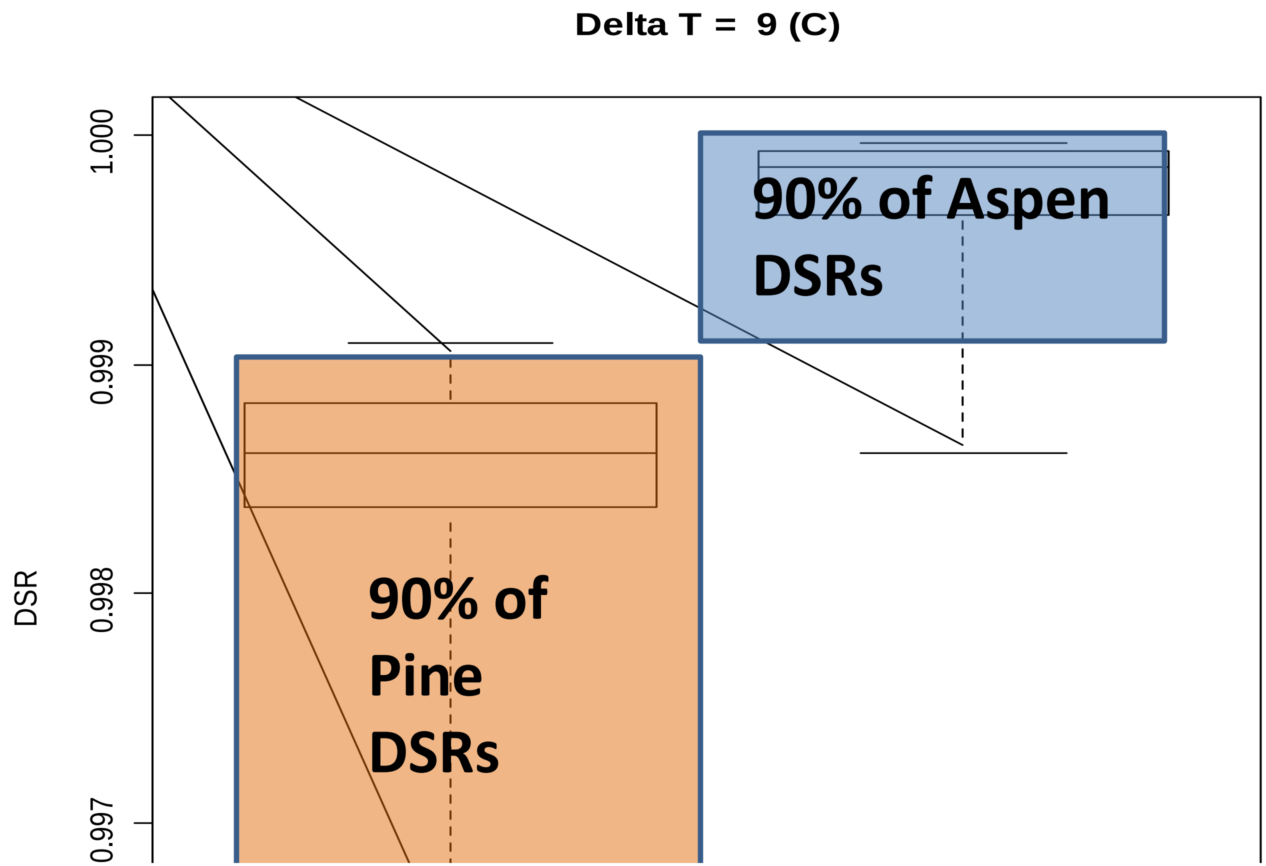

Delta T = 5 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen


Delta T = 6 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen


Delta T = 7 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen



Delta T = 8 (C)
DSR
1.000
0.999
0.998
0.997
0.996
Pine
Late-Burn
Aspen



Case 2: Stringent Decision Threshold

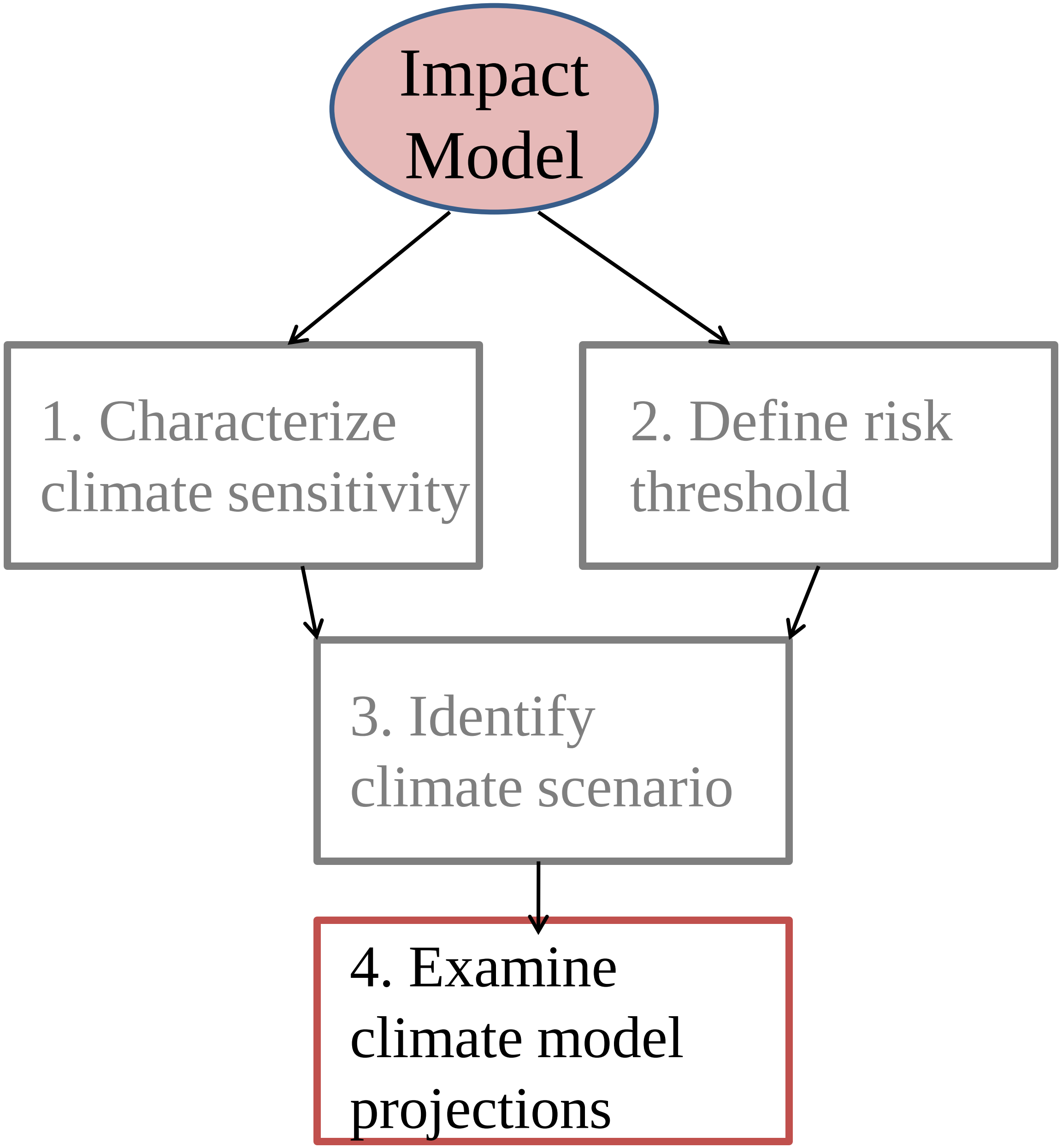
90% of the time, aspens have a higher DSR than pine late-burn (i.e., it takes +9 degrees to get a 90% confidence level)

Pine Late-Burn   Aspen

Relevant scenarios for comparing aspens with burned pine habitat can be found

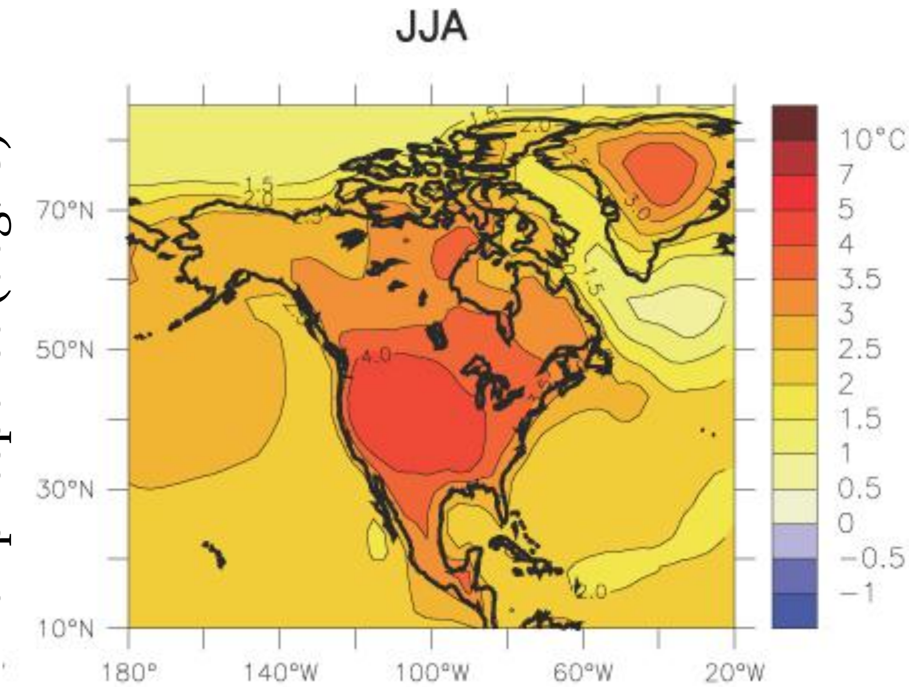
	Average Tmax (C) Increase	
	Aspen vs. Early-Burn	Aspen vs. Late-Burn
Case1 (25th and 75th tie)	8	4
Case2 (10th and 90th tie)	12	9

4. Examine global climate model projections



Global models agree that *average* summer temperatures are going to increase

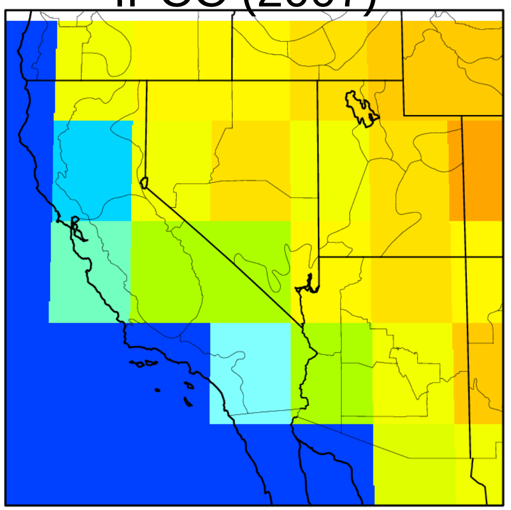
Temp response (deg. C)



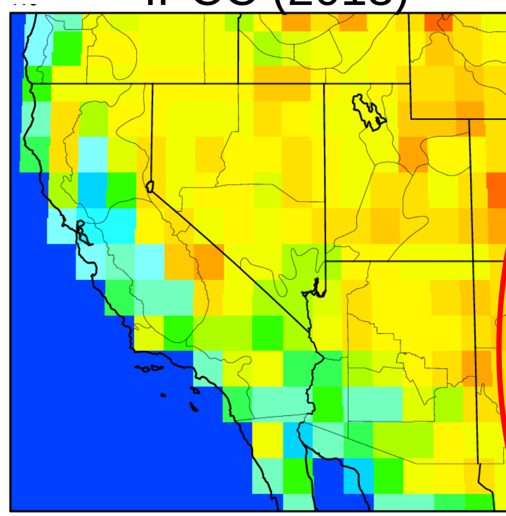
(IPCC (2007); Figure 11.12)

Modeling groups are working to increase climate model resolution

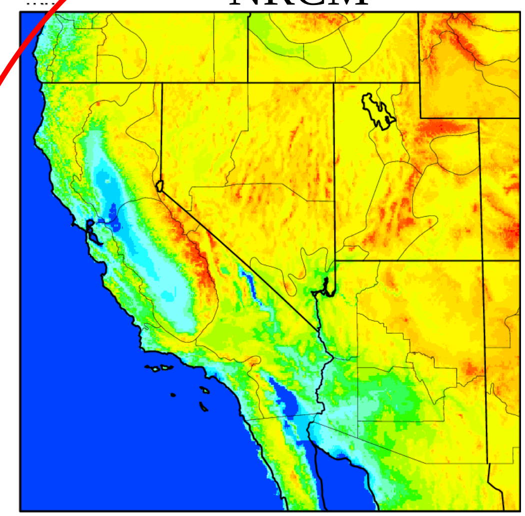
IPCC (2007)



IPCC (2013)



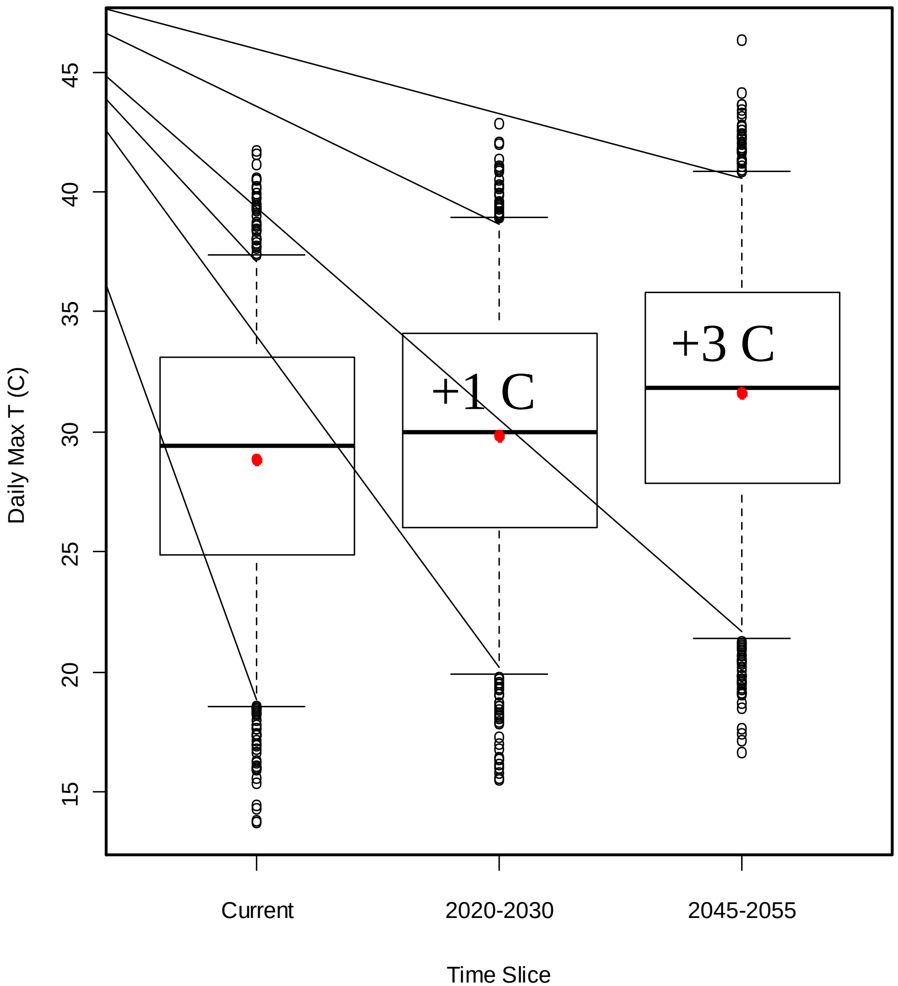
NRCM*



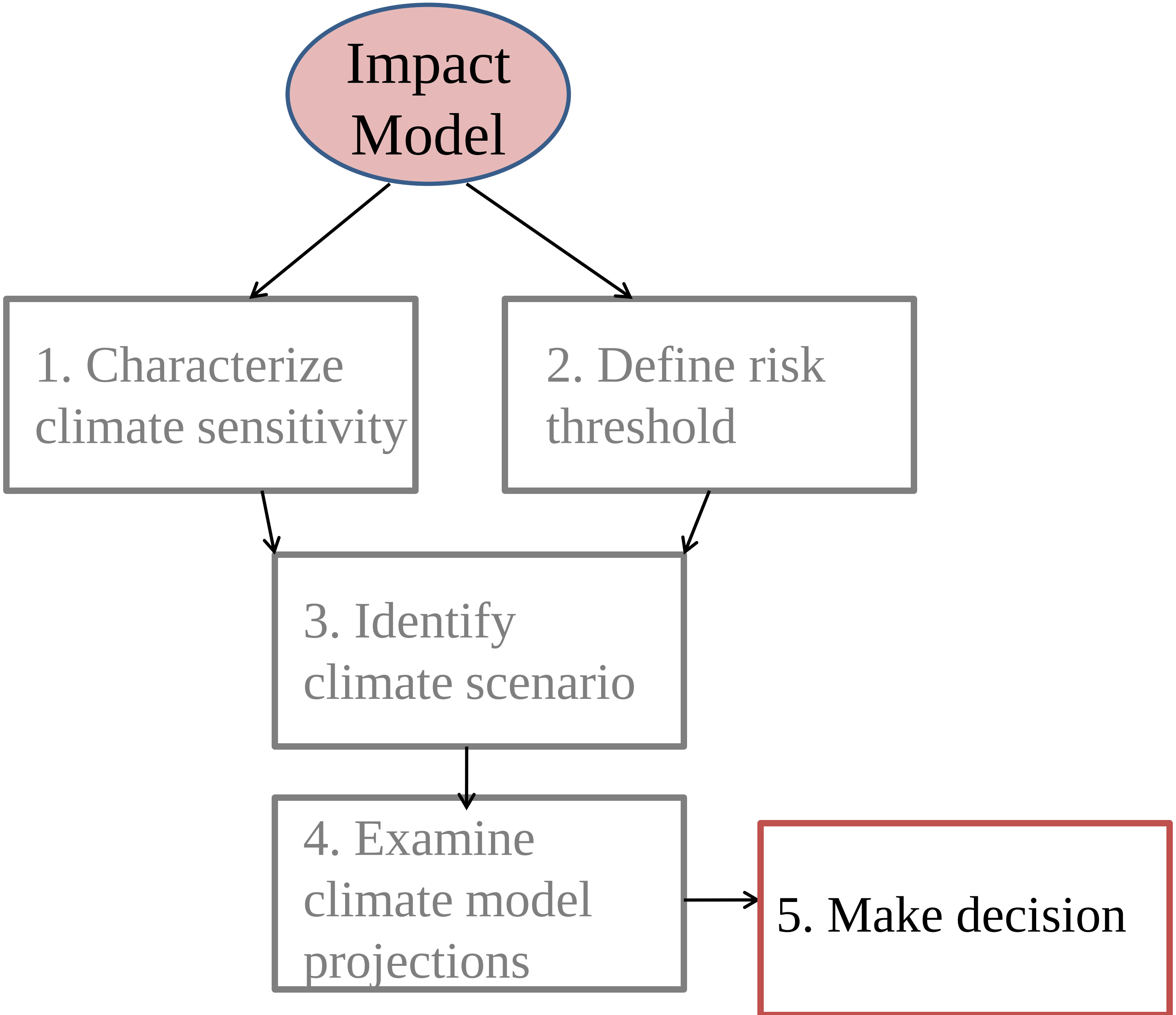
* Nested Regional Climate Model

(Hurrell 2008)

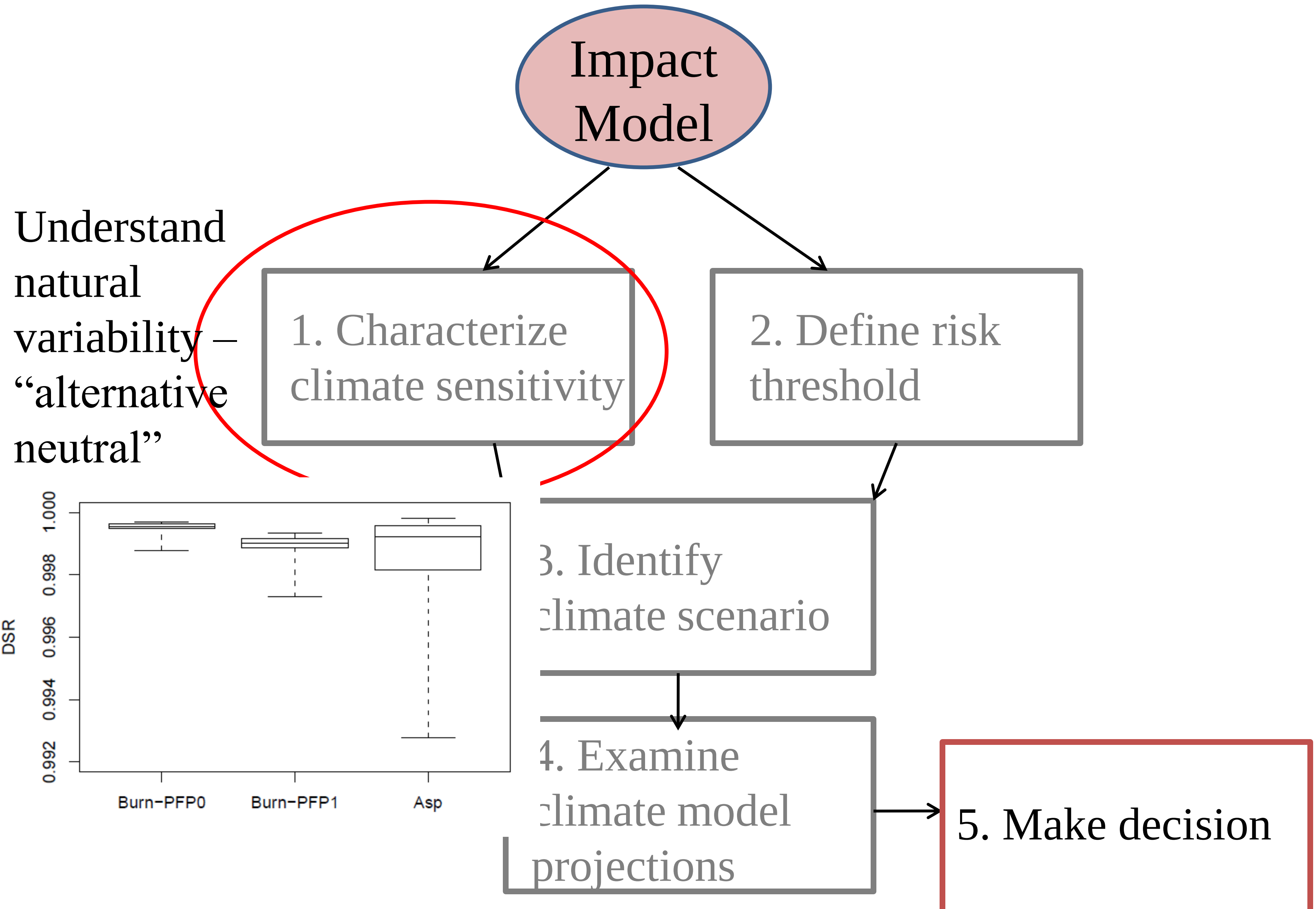
NRCM (regional model) shows increase in *maximum* summer temperatures



5. Use information to make decision



5. Use information to make decision



5. Use information to make decision

Impact Model

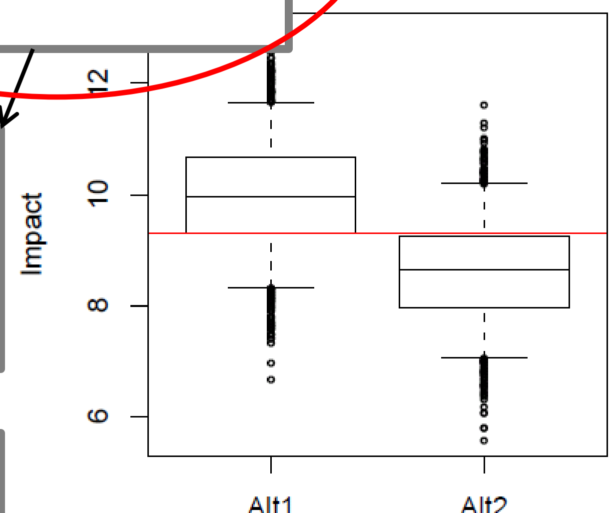
1. Characterize climate sensitivity

2. Define risk threshold

Subjective, but is formalized and defensible

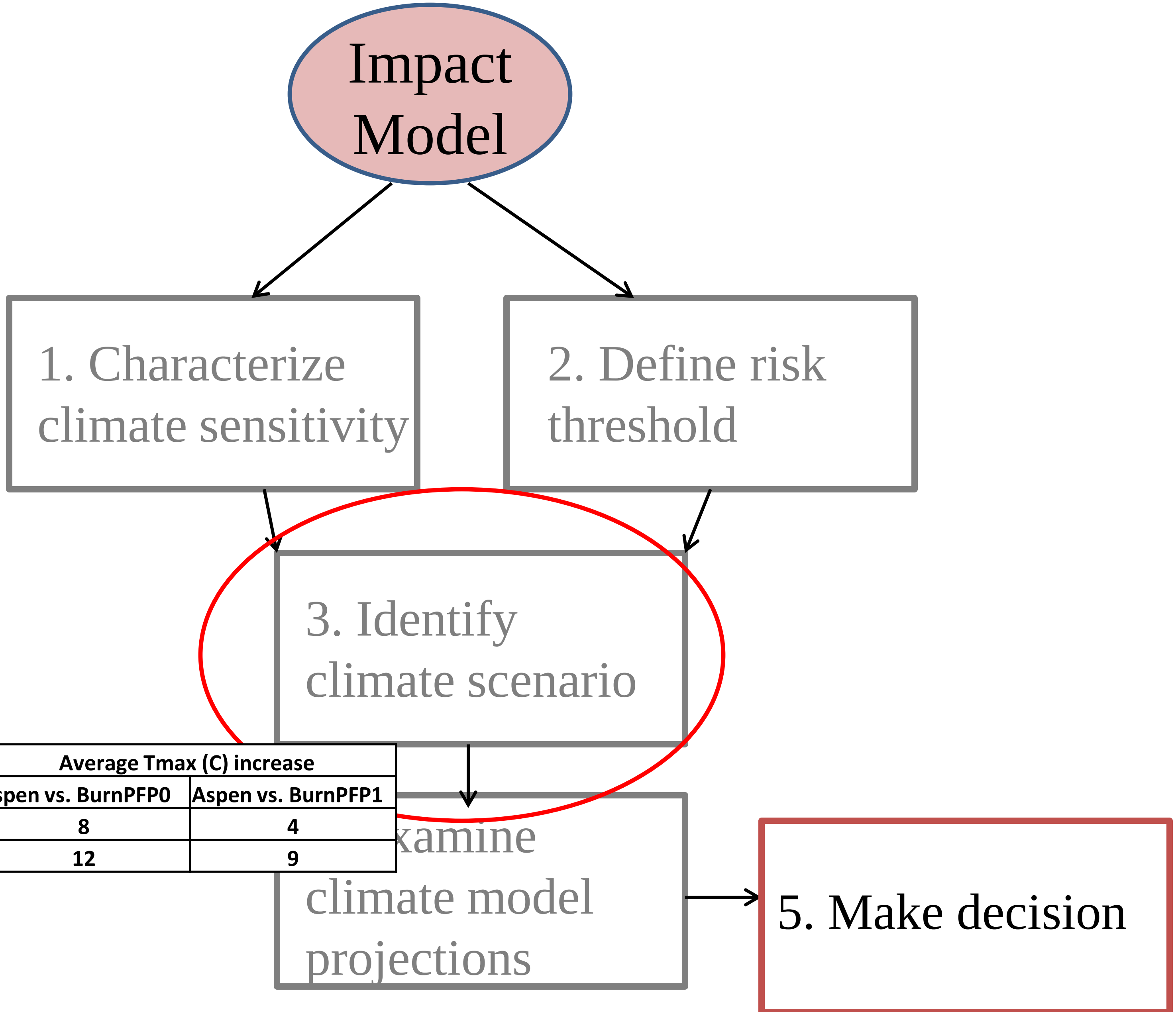
3. Identify climate scenario

4. Examine climate model projections



Case 1: Moderate Decision Threshold (Impact better/worse 75% of time)

5. Use information to make decision



	Average Tmax (C) increase	
	Aspen vs. BurnPFP0	Aspen vs. BurnPFP1
Case1 (25th and 75th tie)	8	4
Case2 (10th and 90th tie)	12	9

5. Use information to make decision

Impact Model

1. Characterize climate sensitivity

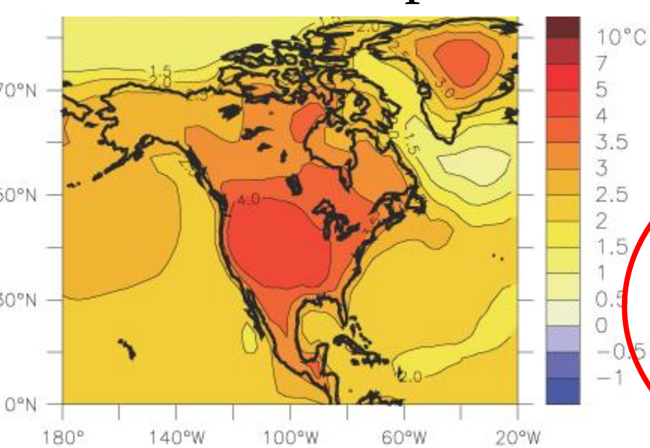
2. Define risk threshold

3. Identify climate scenario

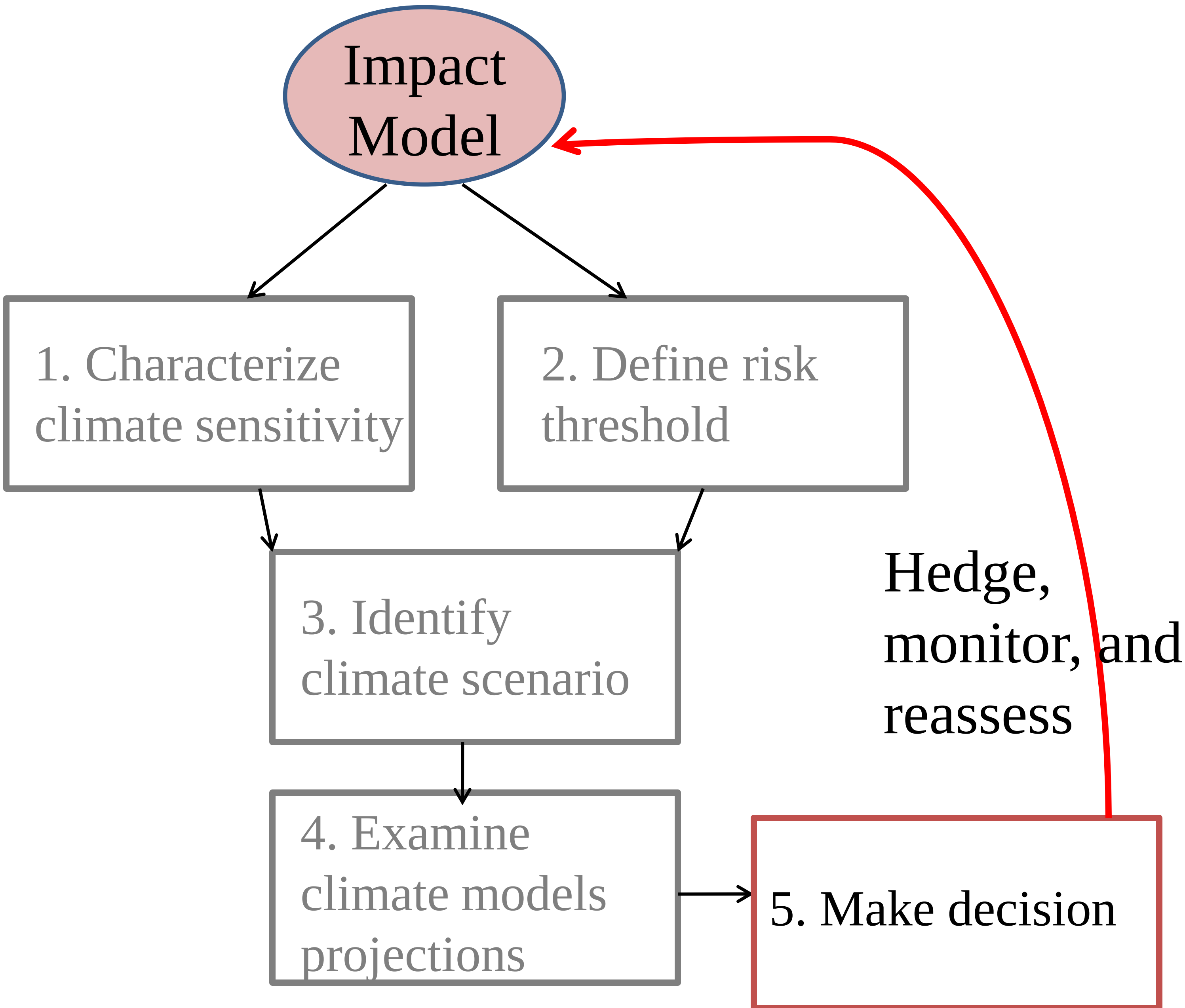
4. Examine climate model projections

5. Make decision

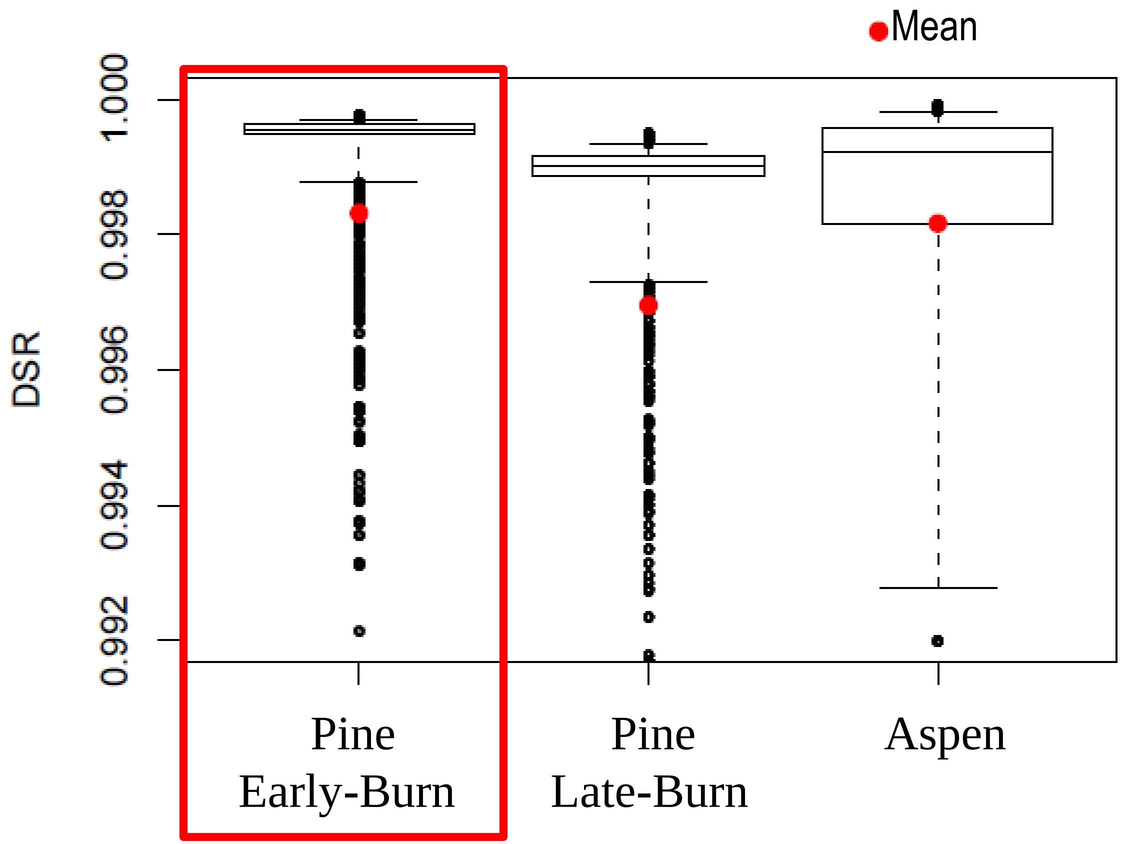
Analysis is updated as models improve



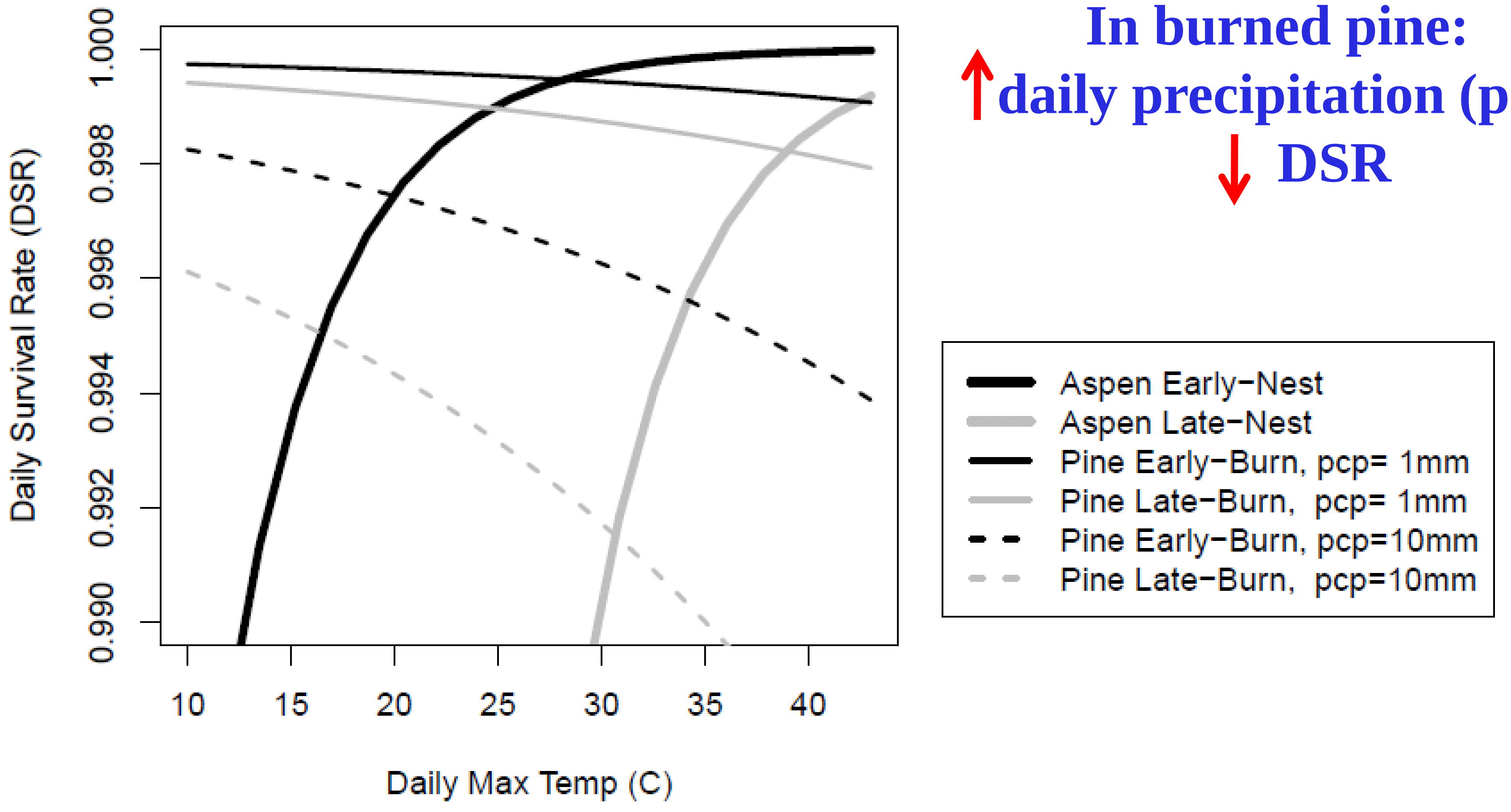
5. Use information to make decision



But wait! What about the extremes?



Extreme precipitation is driving low DSR values for burned pine

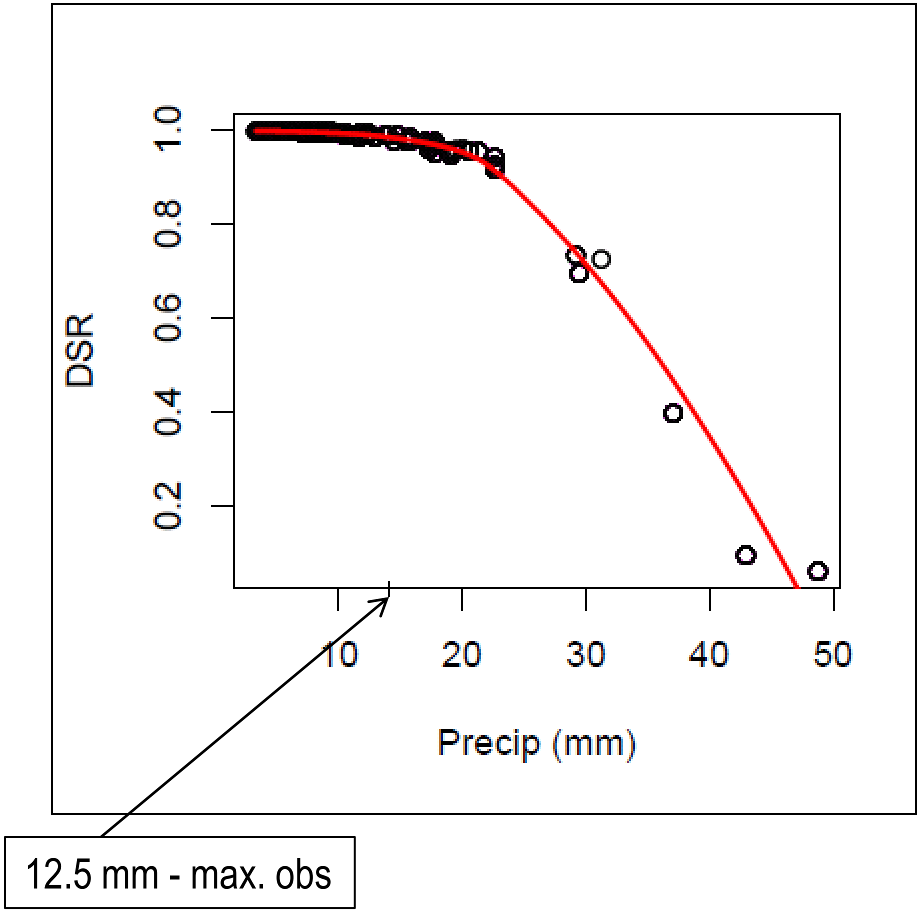


In burned pine:

↑ daily precipitation (pcp)

↓ DSR

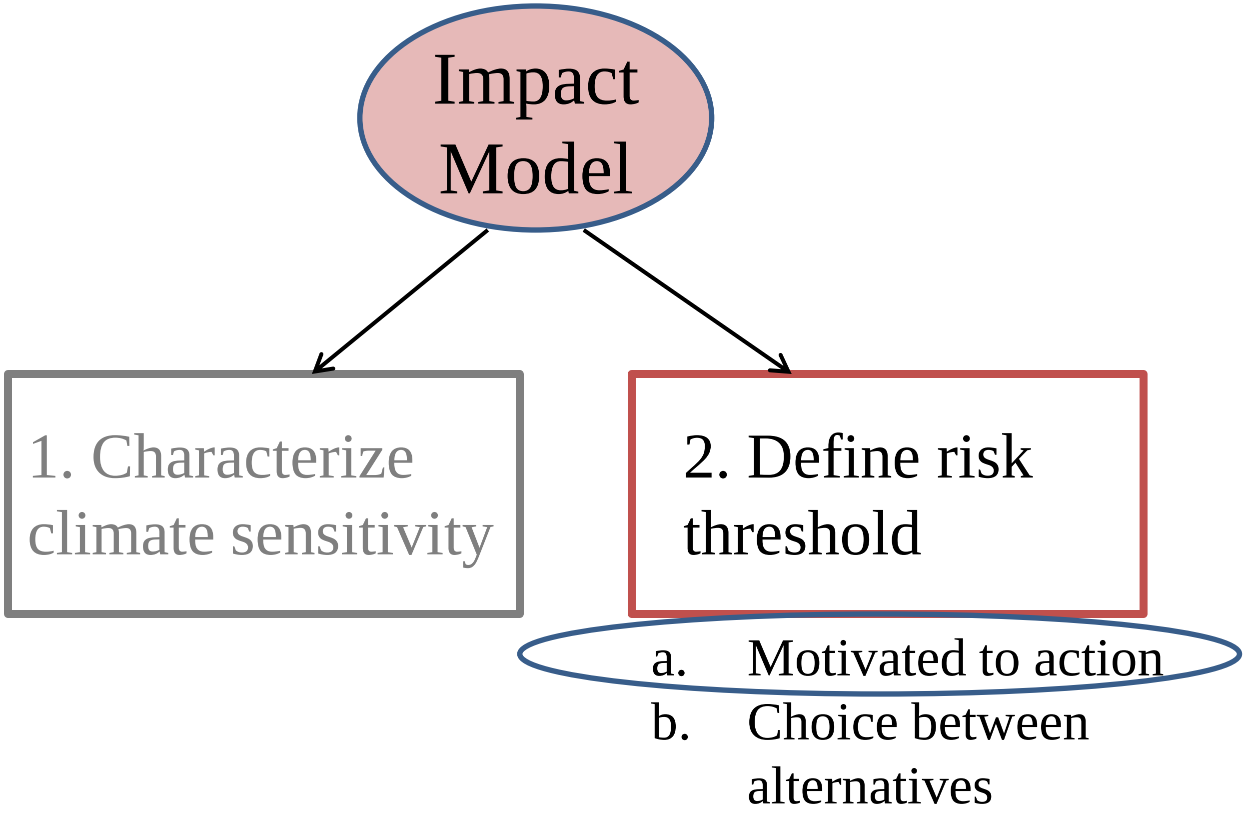
Extreme precipitation is driving low DSR values for burned pine



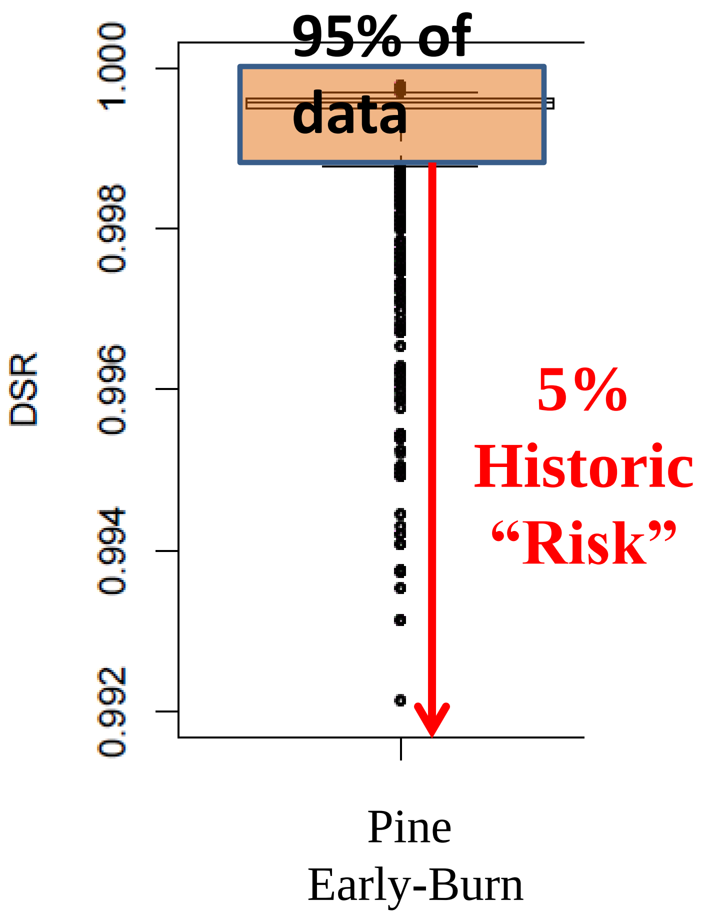
- Only bottom 5% (i.e., outliers), low probability, high consequence

BIRDS AND BURNS NETWORK

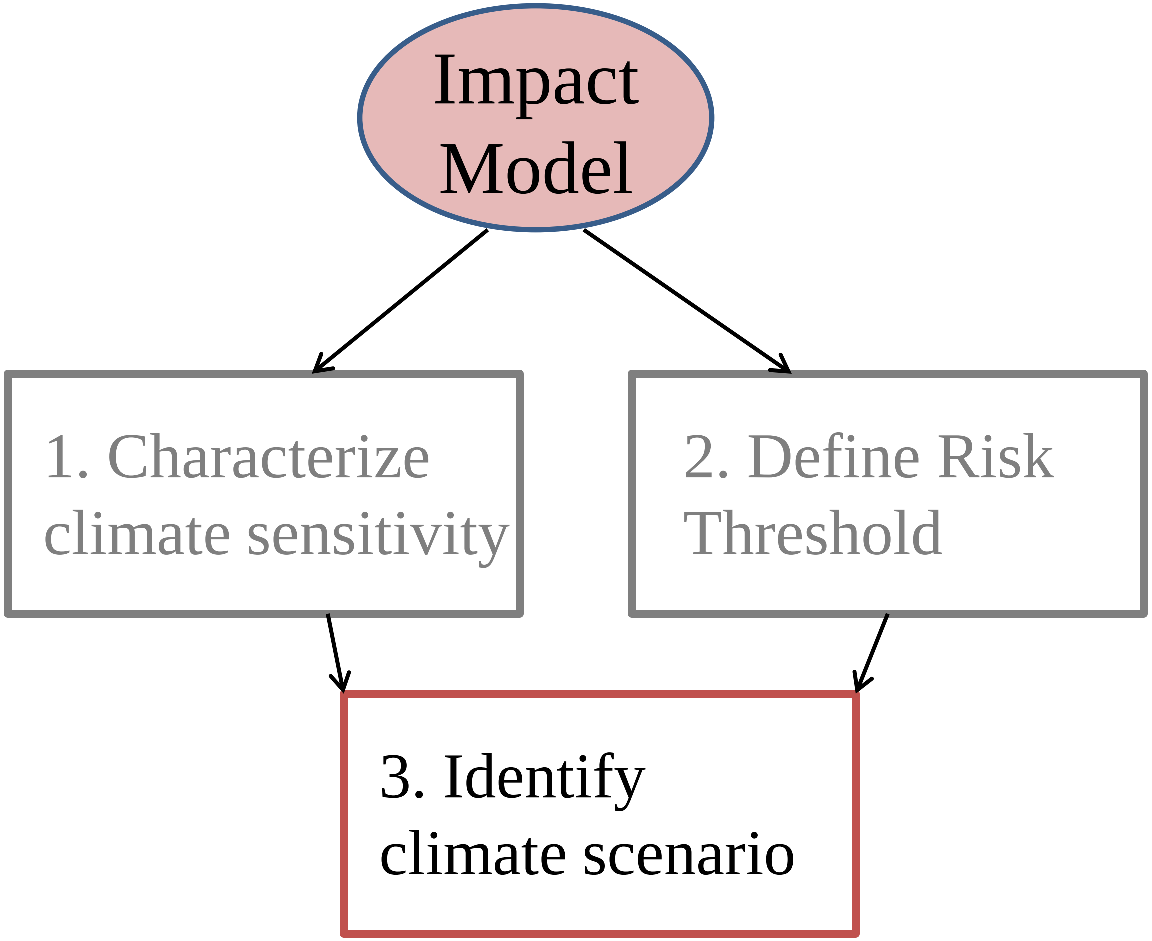
2. Define the impact risk threshold for decision



There is an assumed level of "acceptable risk"

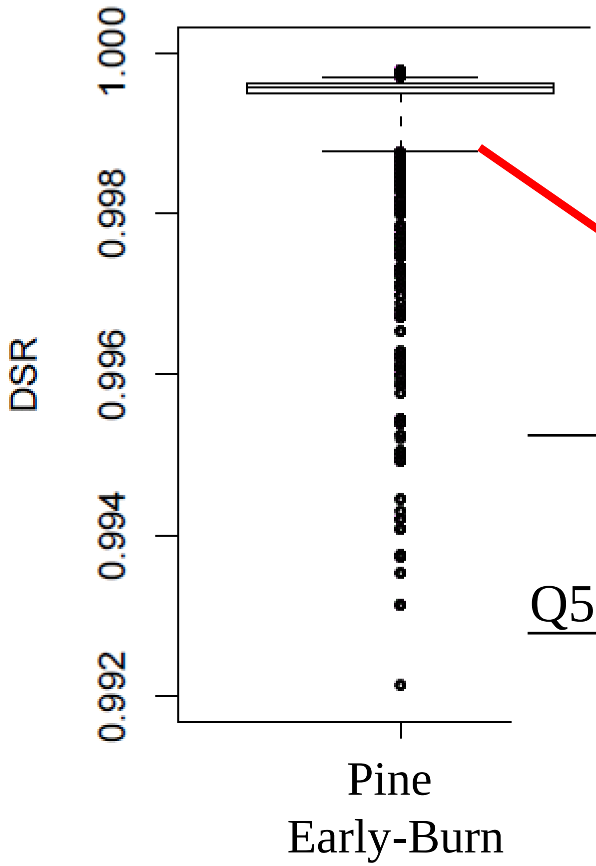


3. Identify climate scenario that meets risk threshold



What precipitation scenarios move us from the 5% risk to (i) 7% or (ii) 10% risk?

Use historic Q5 as a baseline for risk assessment

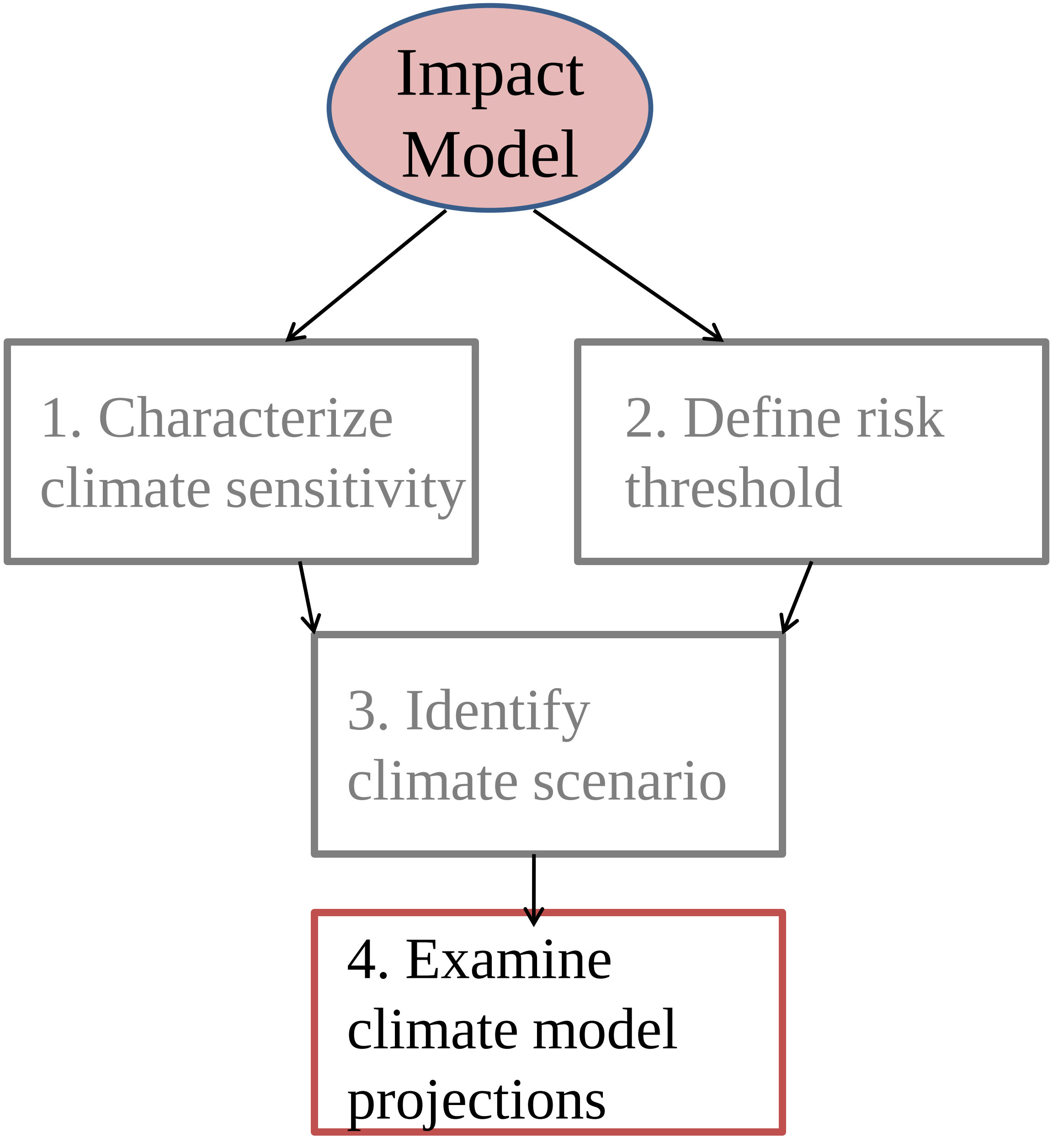


	Early-Burn
	DSR
Q5 Climatology	0.9988

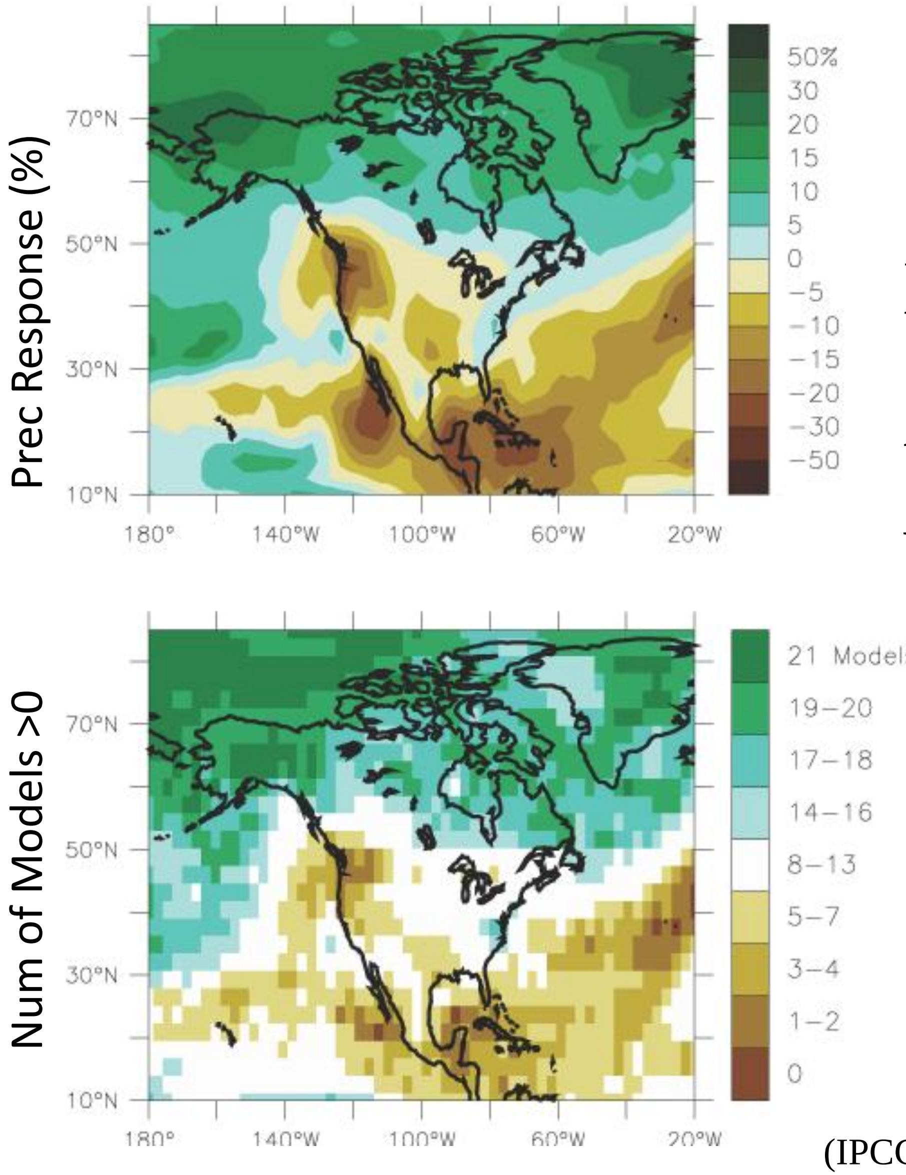
Relevant scenarios for risk increases can be found

	Early-Burn
	DSR
Q5 Climatology	0.9988
	Avg. % increase in Precipitation
Case1 (5% to 7% Risk)	41-56%
Case2(5% to 10% Risk)	90-100%

4. Examine global climate model projections



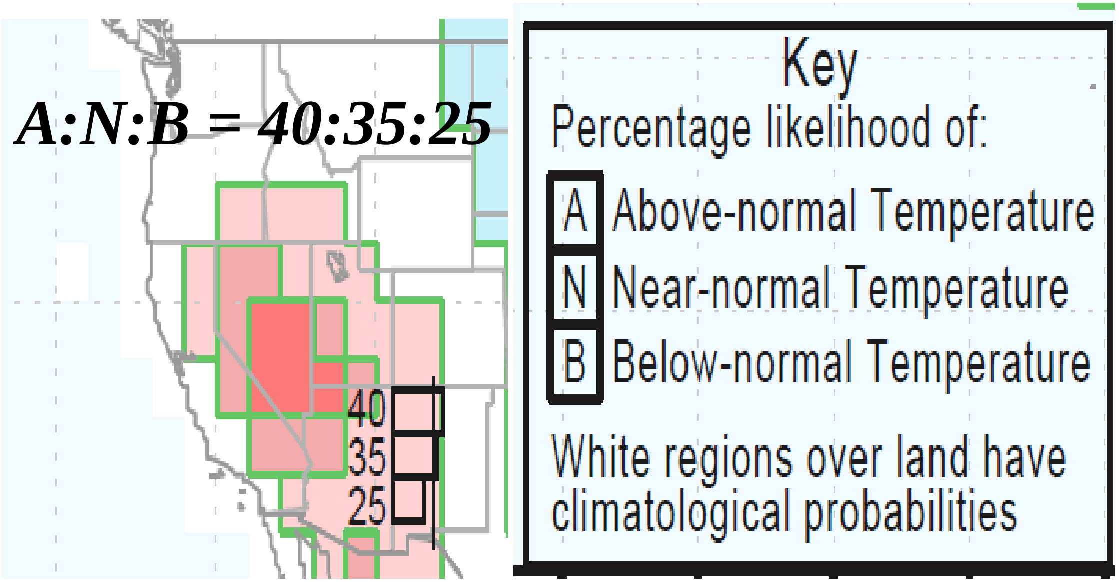
Models indicate summer precipitation reduction in Western US, but results are uncertain



- Extreme precipitation events likely to increase with climate change

(IPCC (2007); Figure 11.12)

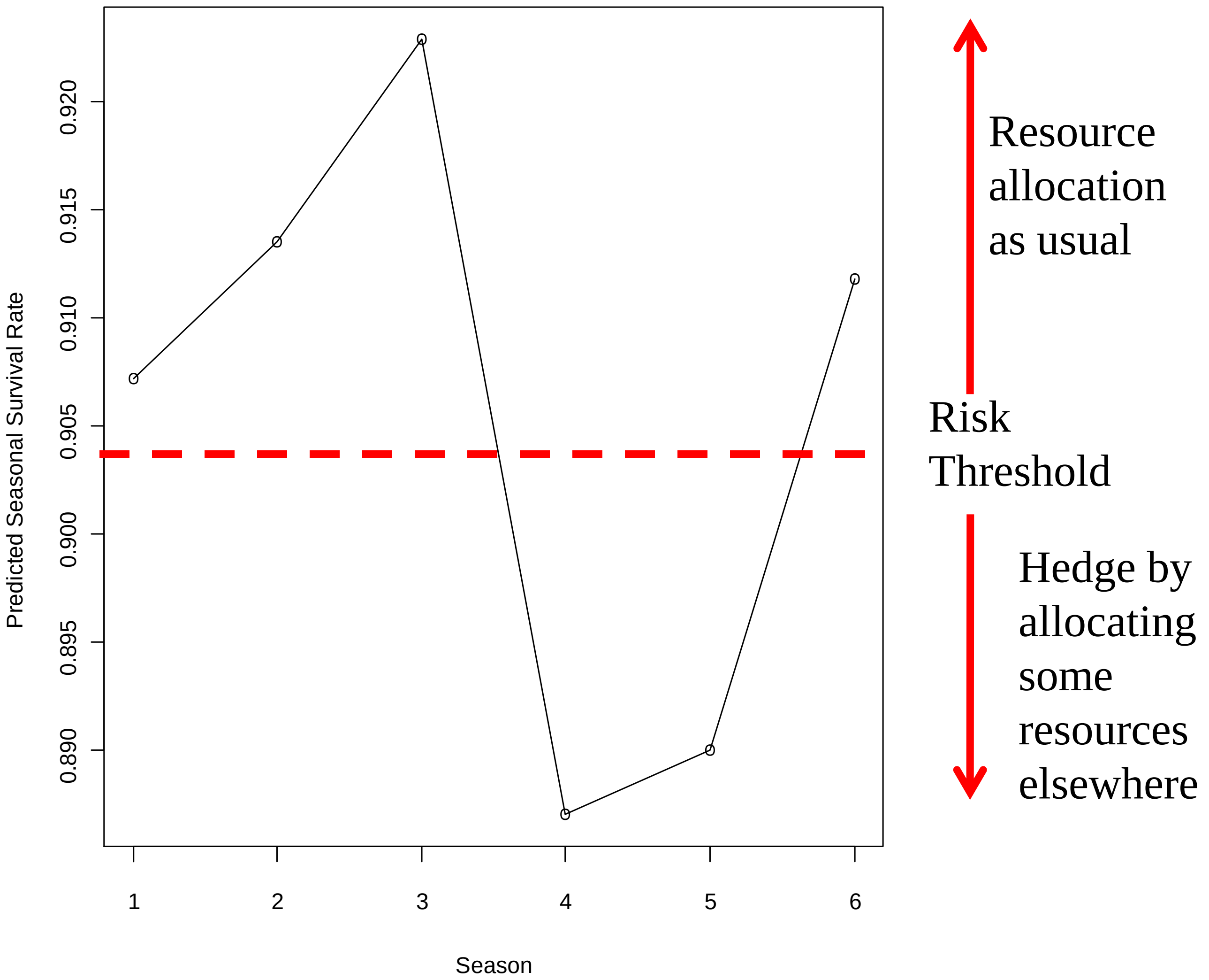
Seasonal climate forecasts are available and skill is improving



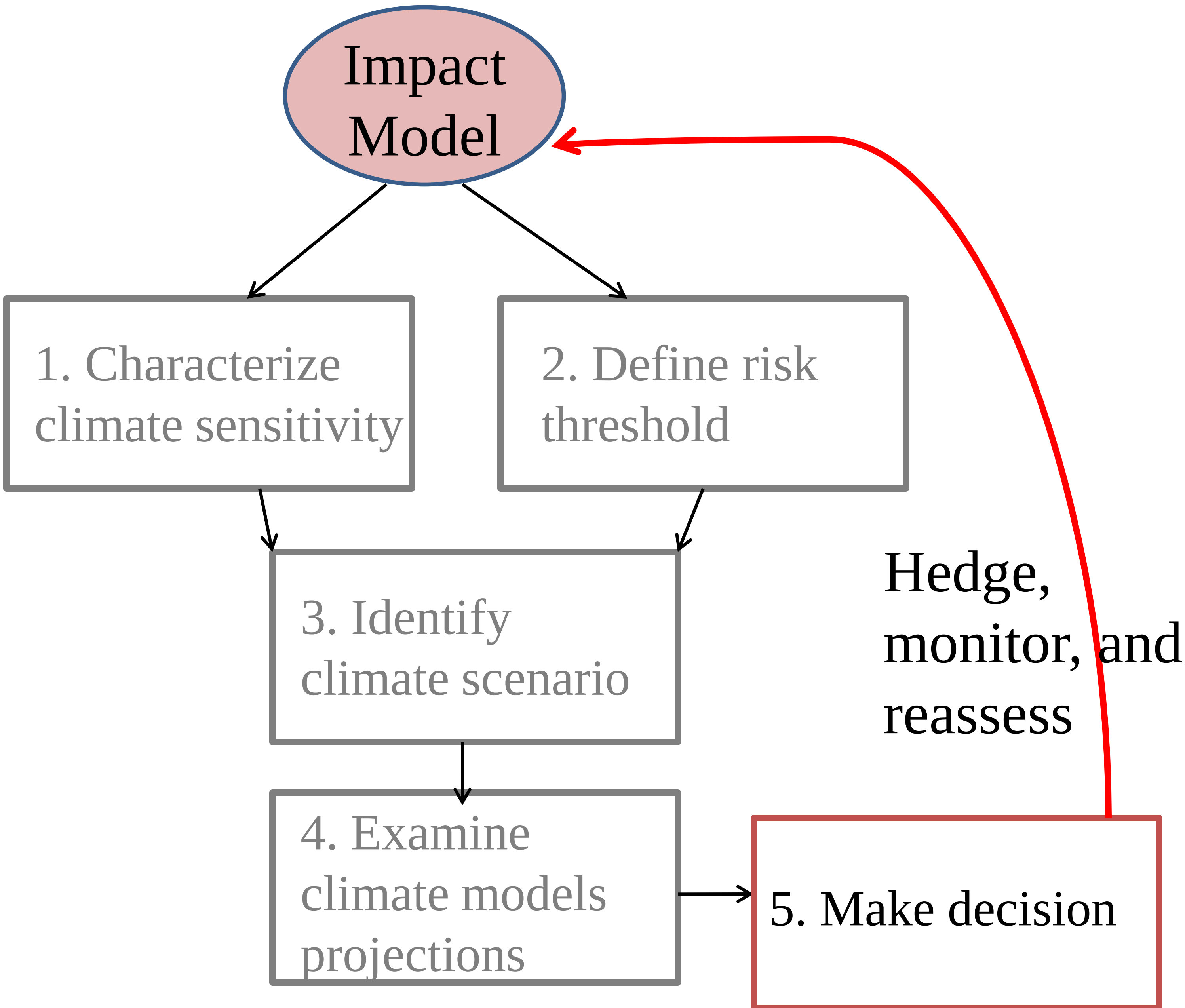
Source: http://portal.iri.columbia.edu

Seasonal Forecast
40% chance of above normal precipitation

Flexible decision-making can incorporate probabilistic climate information



5. Use information to make decision



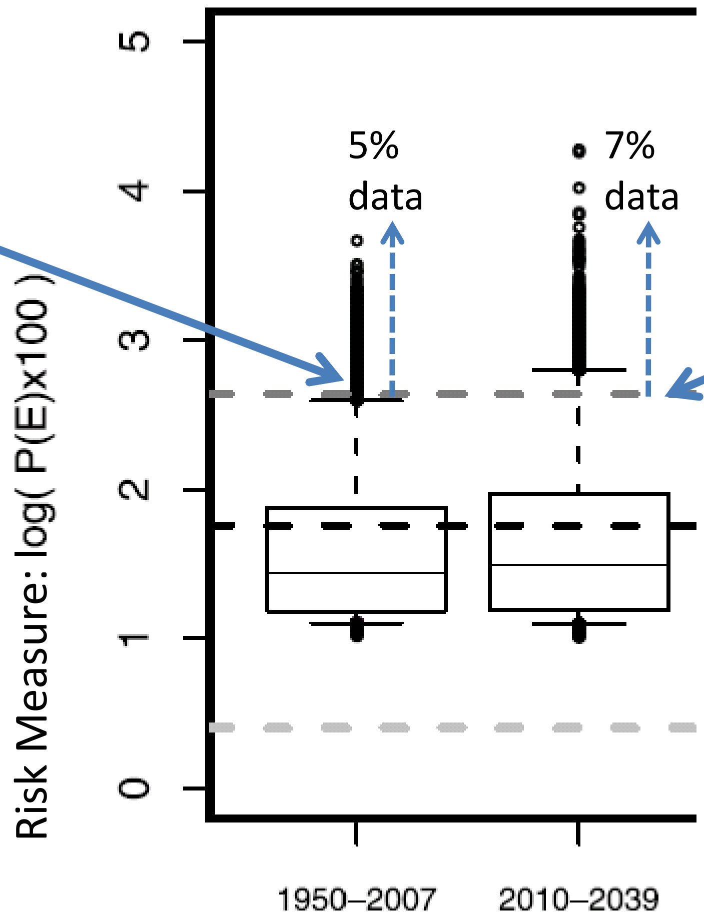
Example #4: Flood Risk

Infrastructure is designed for 100-year flood. Acceptable risk of 1/100 = .01 Risk threshold = 1%.

How should we manage campgrounds where flood risk increases?

May need to make decisions under increasing risk…

Historic risk = 5%



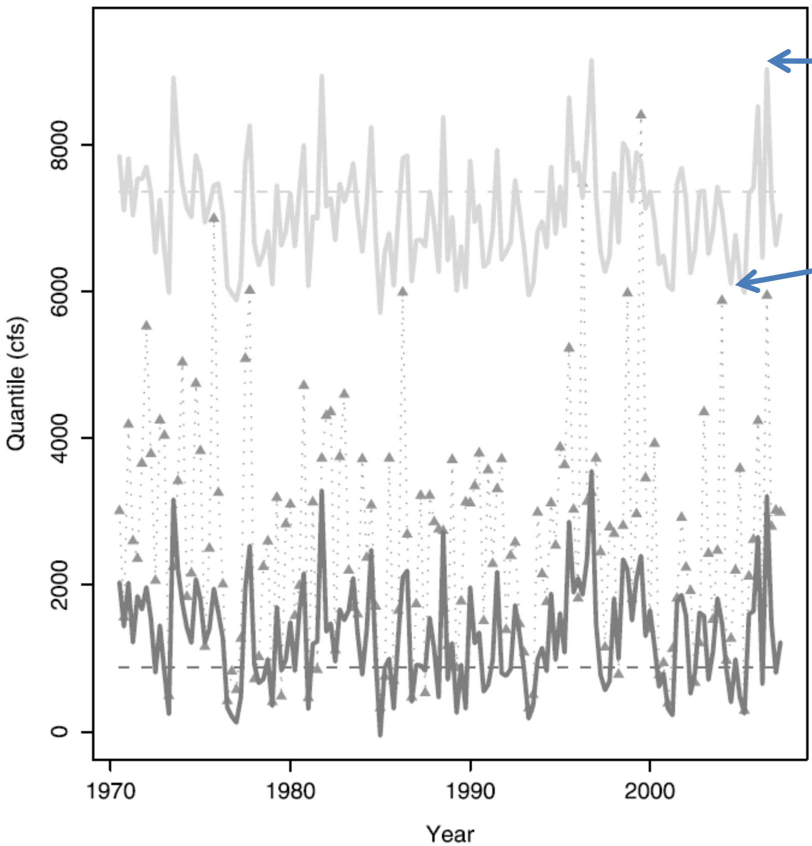
CC risk = 7%.

Install flood warning system if risk is > 5%.

Towler et al. 2010

May need to be flexible in decision-making

Close campgrounds during seasons when forecasts suggest that risk is high.



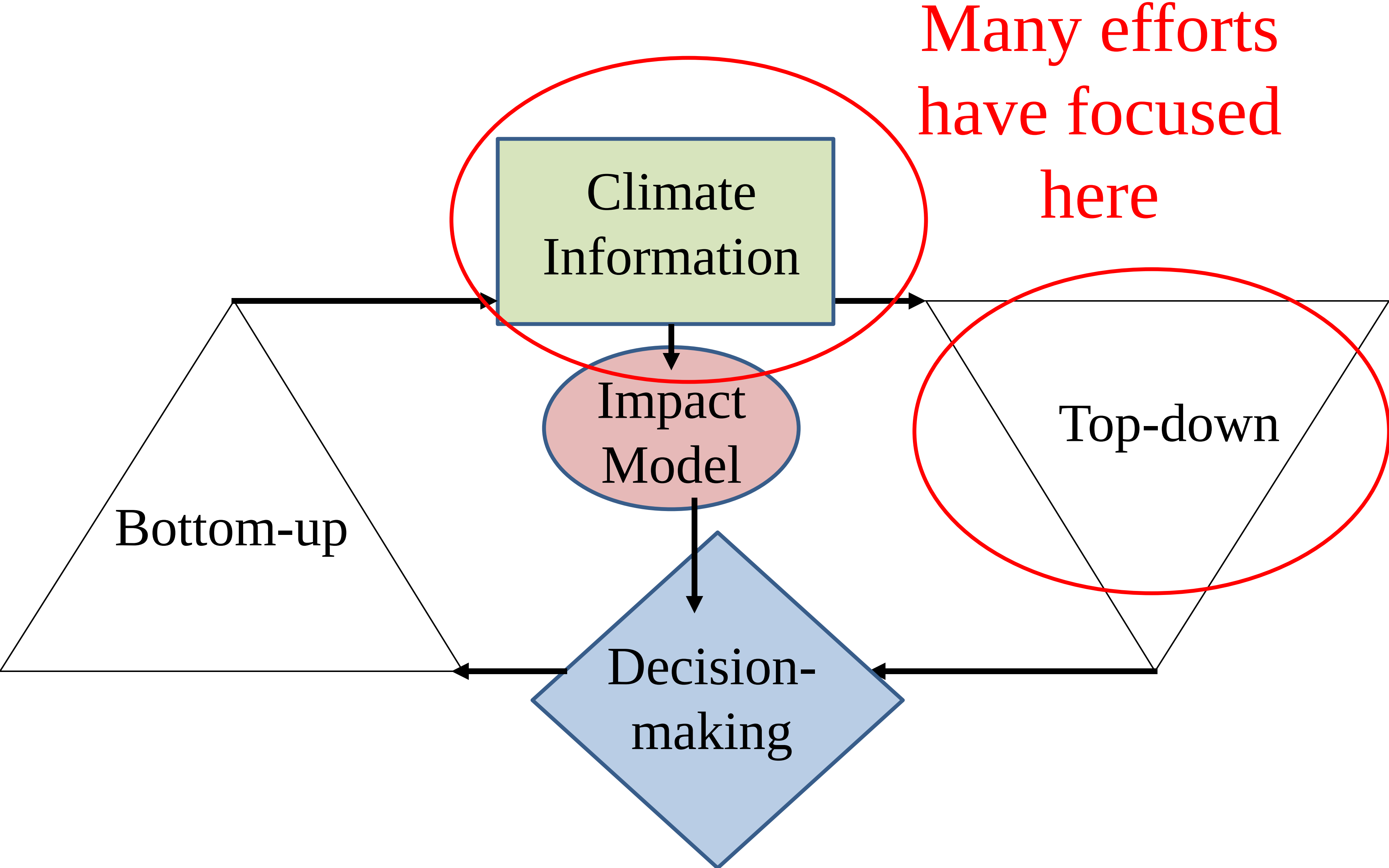
High risk year -closed

Low risk year -open

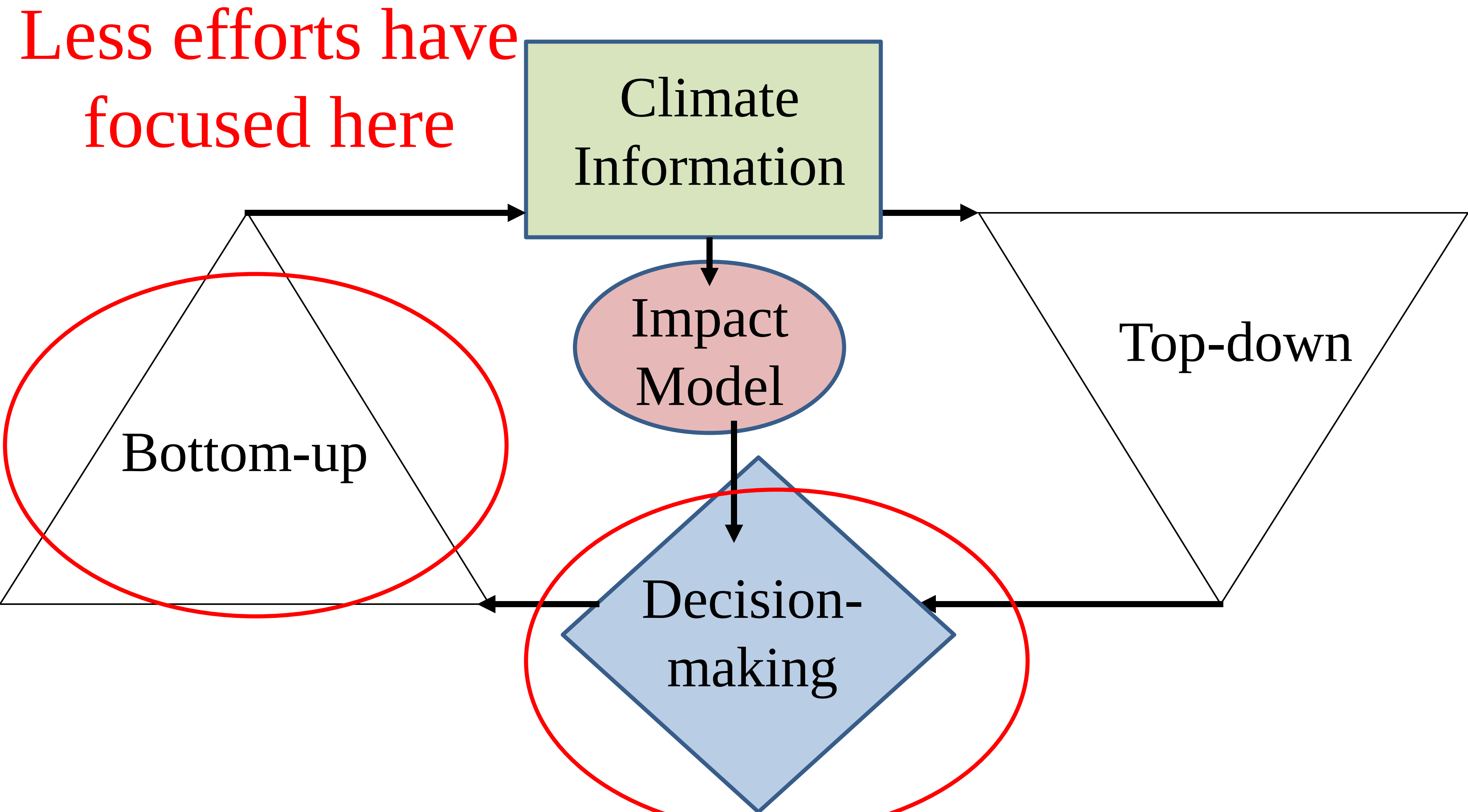
- Use climate covariates (seasonal forecasts or climate models)

Towler et al. 2010

Summary

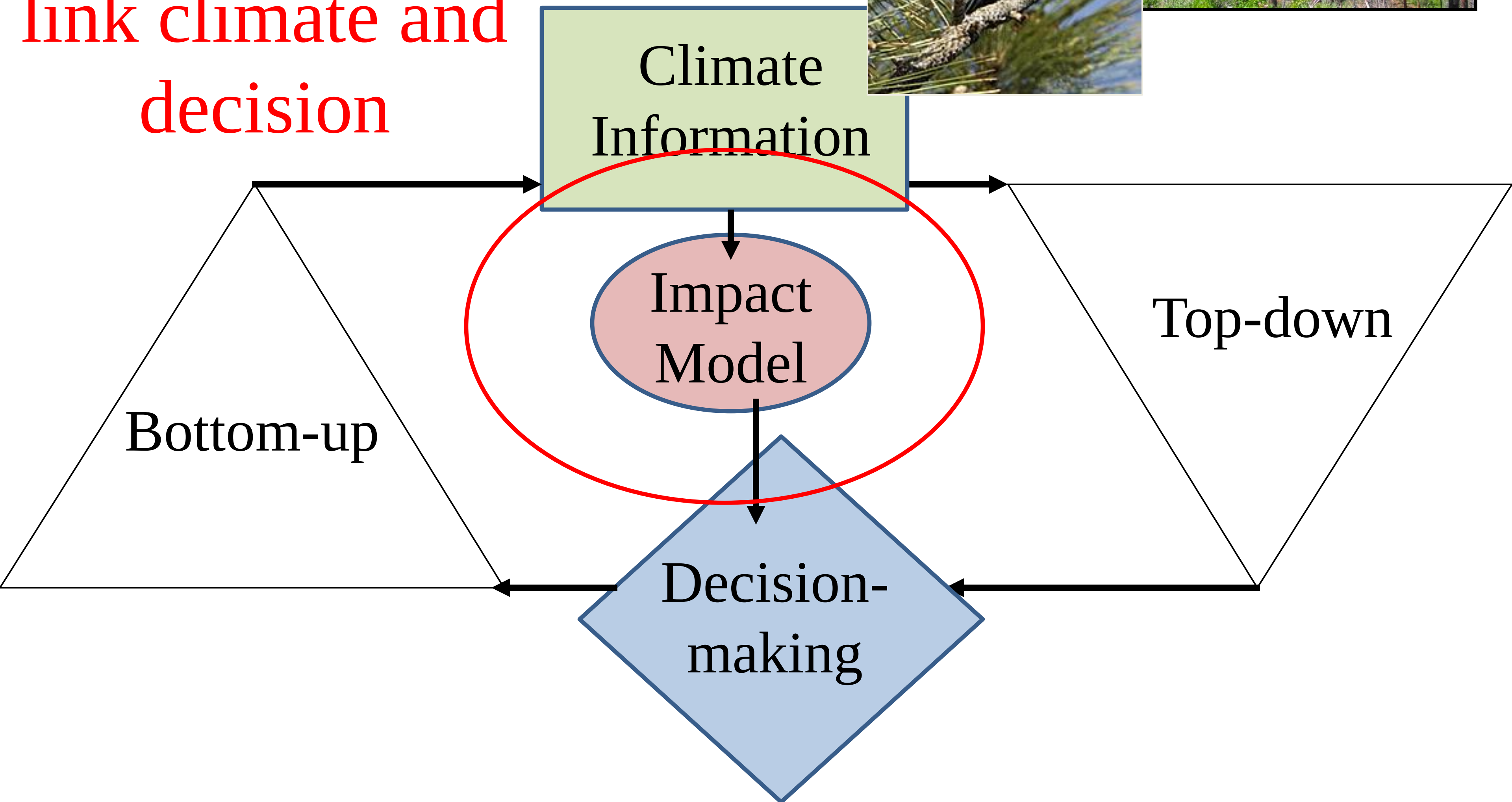

Many efforts have focused here
Climate Information
Impact Model
Bottom-up
Top-down
Decision-making

Summary

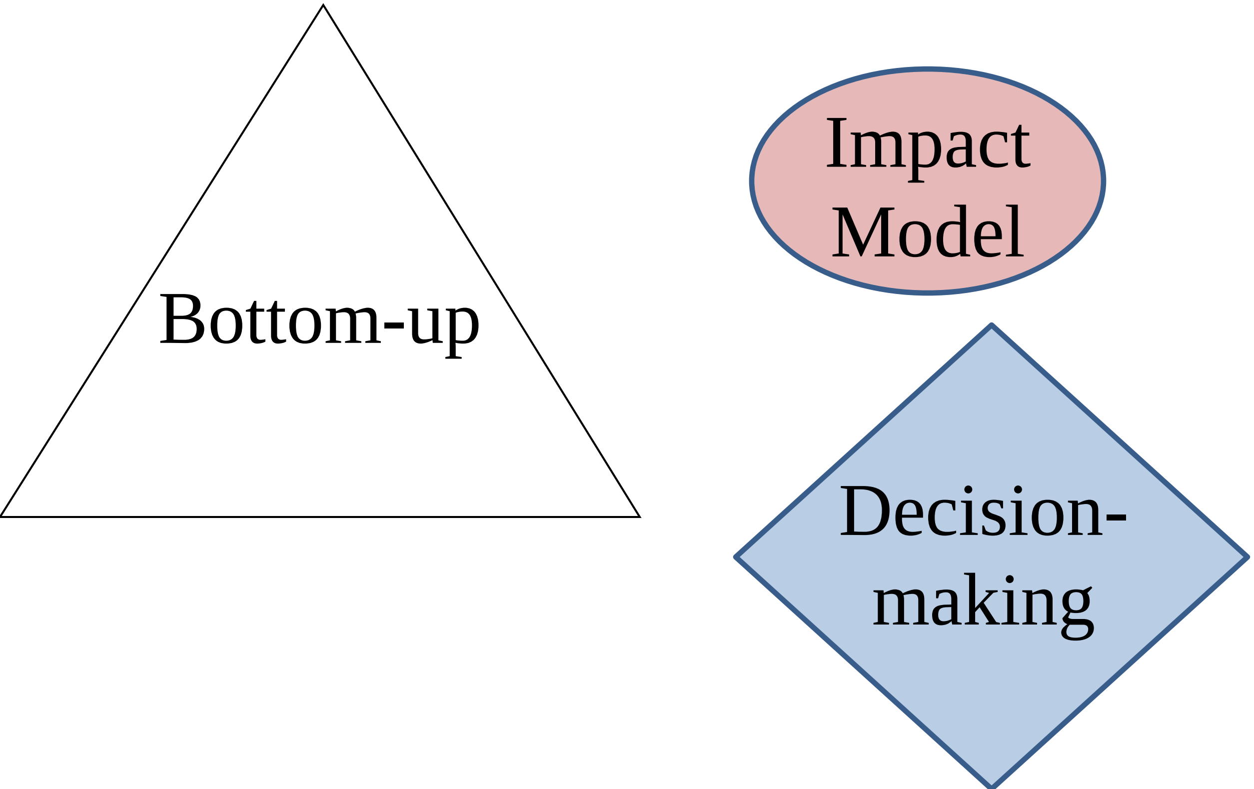

Less efforts have focused here
Climate Information
Impact Model
Top-down
Bottom-up
Decision-making

Summary

Impact models can effectively link climate and decision



Identifying bottom-up decisions requires **your** expert knowledge



Questions?

Do you have a program that could use these tools and risk-based approaches?

towler@ucar.edu

USGS science for a changing world

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