Global Warming Caused By Increased Absorbed Solar Radiation

J.T. Fasullo and K.E. Trenberth
NCAR

Simulated Global Warming Caused By Increased Absorbed Solar Radiation

J.T. Fasullo and K.E. Trenberth
NCAR

Outline

Outline

- Science Questions

Outline

- Science Questions
- Background / Expectations

Outline

- Science Questions
- Background / Expectations
- Evolution of Simulated Global Budgets

Outline

- Science Questions
- Background / Expectations
- Evolution of Simulated Global Budgets
- Regional and Latitudinal Structure

Outline

- Science Questions
- Background / Expectations
- Evolution of Simulated Global Budgets
- Regional and Latitudinal Structure
- Processes?

Outline

- Science Questions
- Background / Expectations
- Evolution of Simulated Global Budgets
- Regional and Latitudinal Structure
- Processes?
- Implications

Our Questions: What Drives Simulated Climate Change?

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?
  - What are its spectral and regional characteristics?
  - What is its temporal evolution?

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?
  - What are its spectral and regional characteristics?
  - What is its temporal evolution?
- What **processes** govern the energy budget?

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?
  - What are its spectral and regional characteristics?
  - What is its temporal evolution?
- What **processes** govern the energy budget?

Set 2: General

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?
  - What are its spectral and regional characteristics?
  - What is its temporal evolution?
- What **processes** govern the energy budget?

Set 2: General

- Why has the inter-model spread of simulated climate sensitivity remained so large in successive model generations?

Our Questions: What Drives Simulated Climate Change?

Set 1: Immediate / Specific

- What is the basic **character** of the planetary imbalance?
  - What are its spectral and regional characteristics?
  - What is its temporal evolution?
- What **processes** govern the energy budget?

Set 2: General

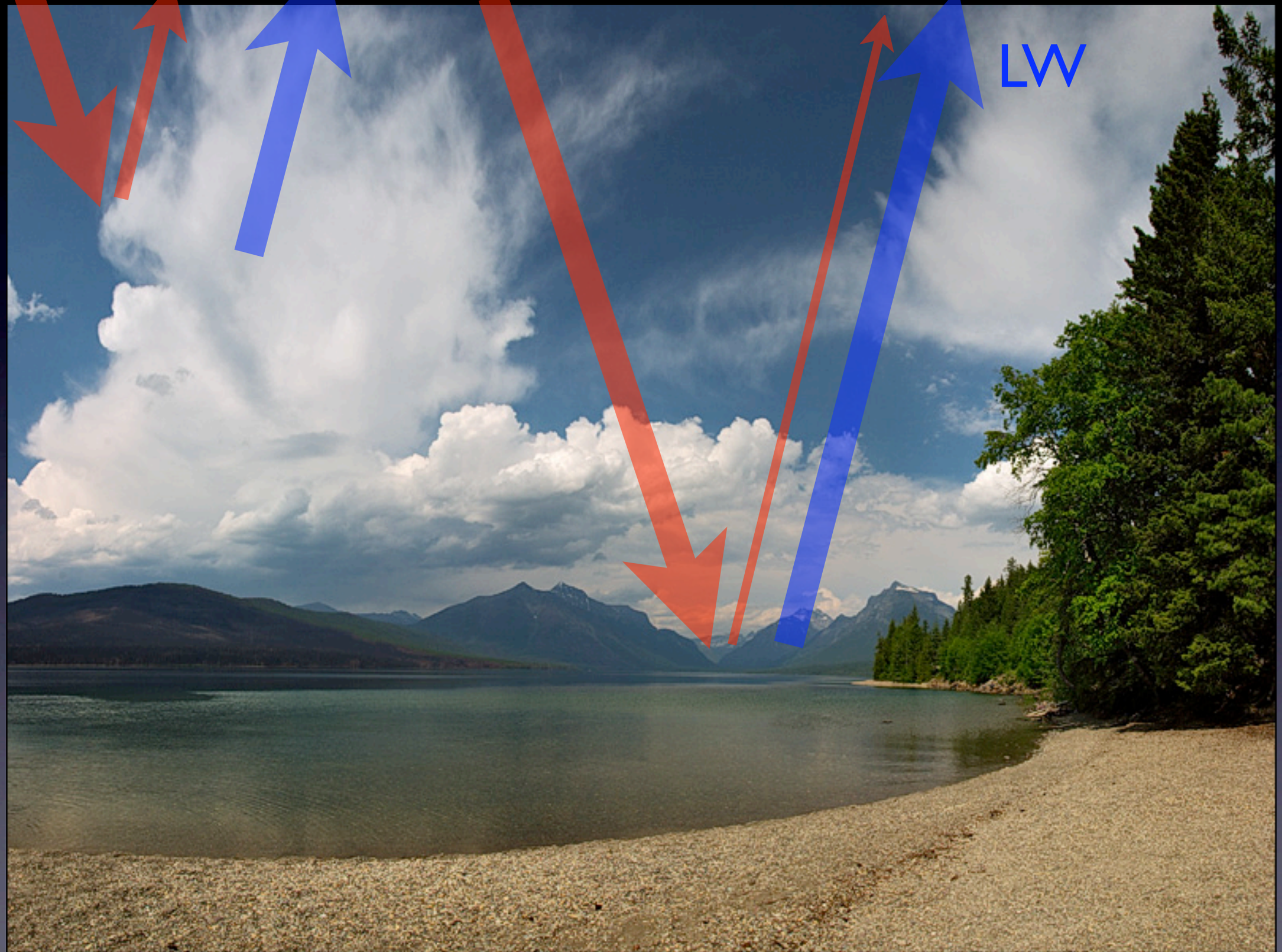
- Why has the inter-model spread of simulated climate sensitivity remained so large in successive model generations?
- Do meaningful observational proxies of sensitivity exist?

Our expected view of Climate Change

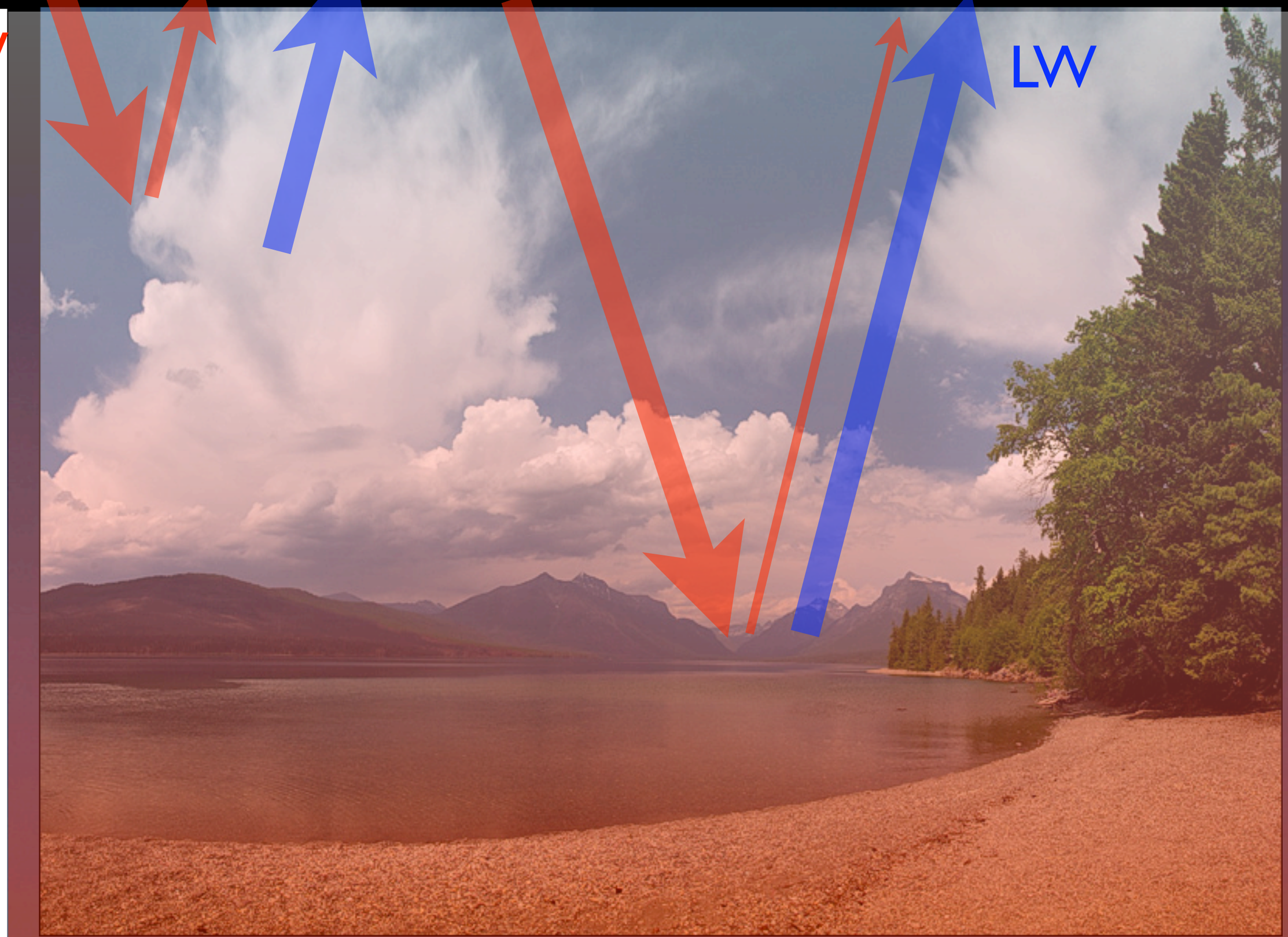
Our expected view of Climate Change

SW

Our expected view of Climate Change

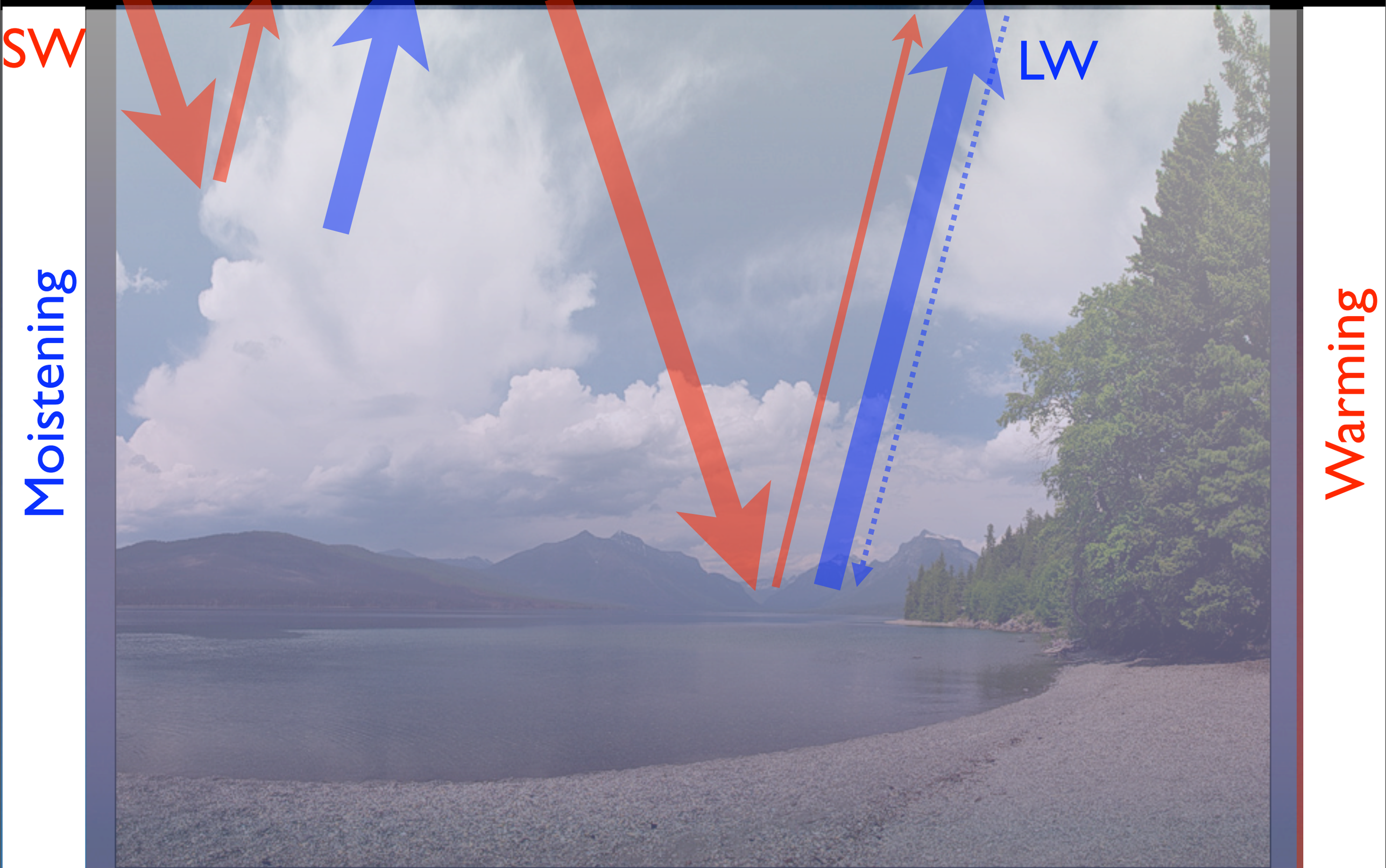


Our expected view of Climate Change

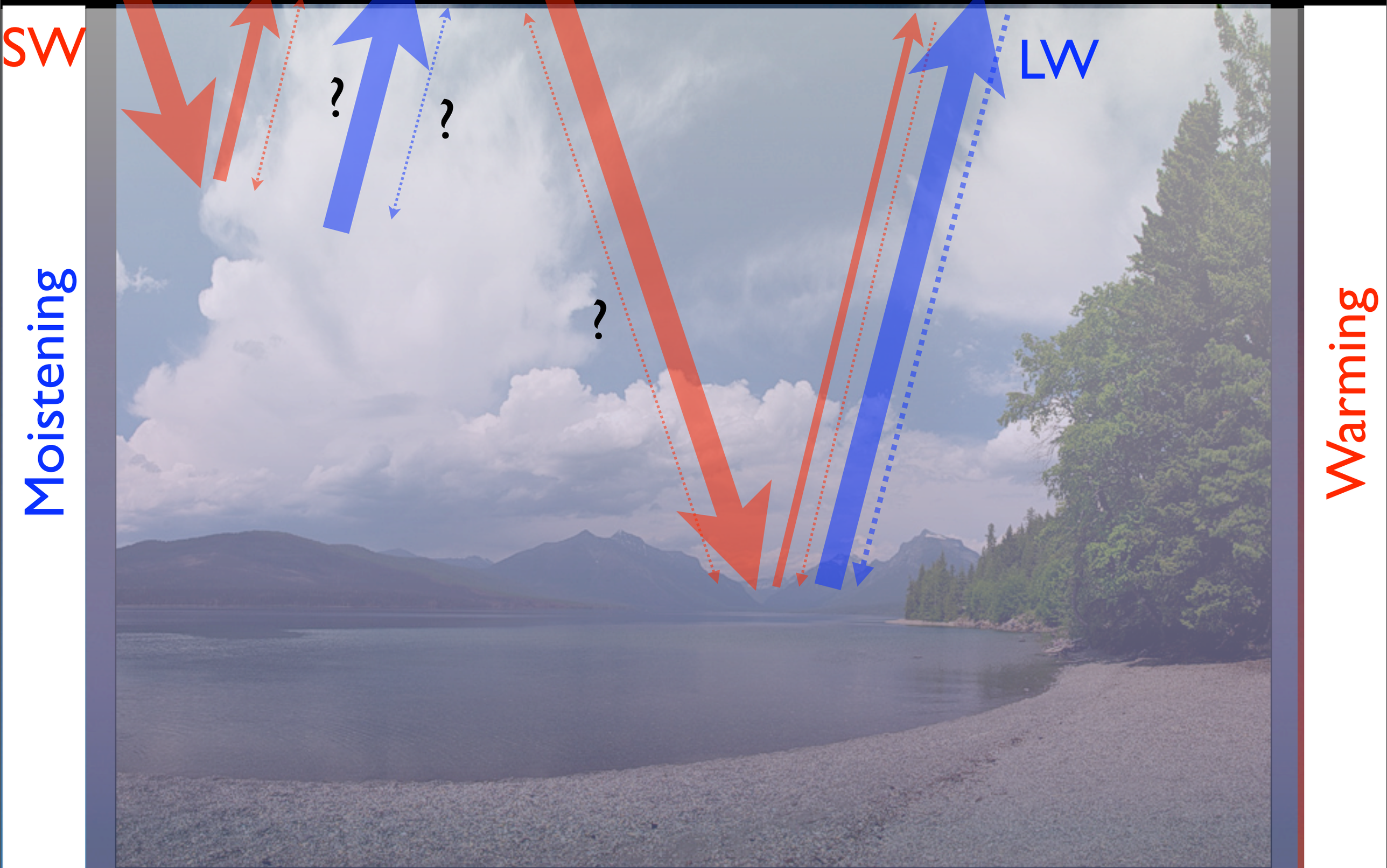


Our expected view of Climate Change

Our expected view of Climate Change



Our expected view of Climate Change



Our expected view of Climate Change

SW

LW

?

?

Other expectations

Moistening

Warming

Our expected view of Climate Change

SW

LW

?

?

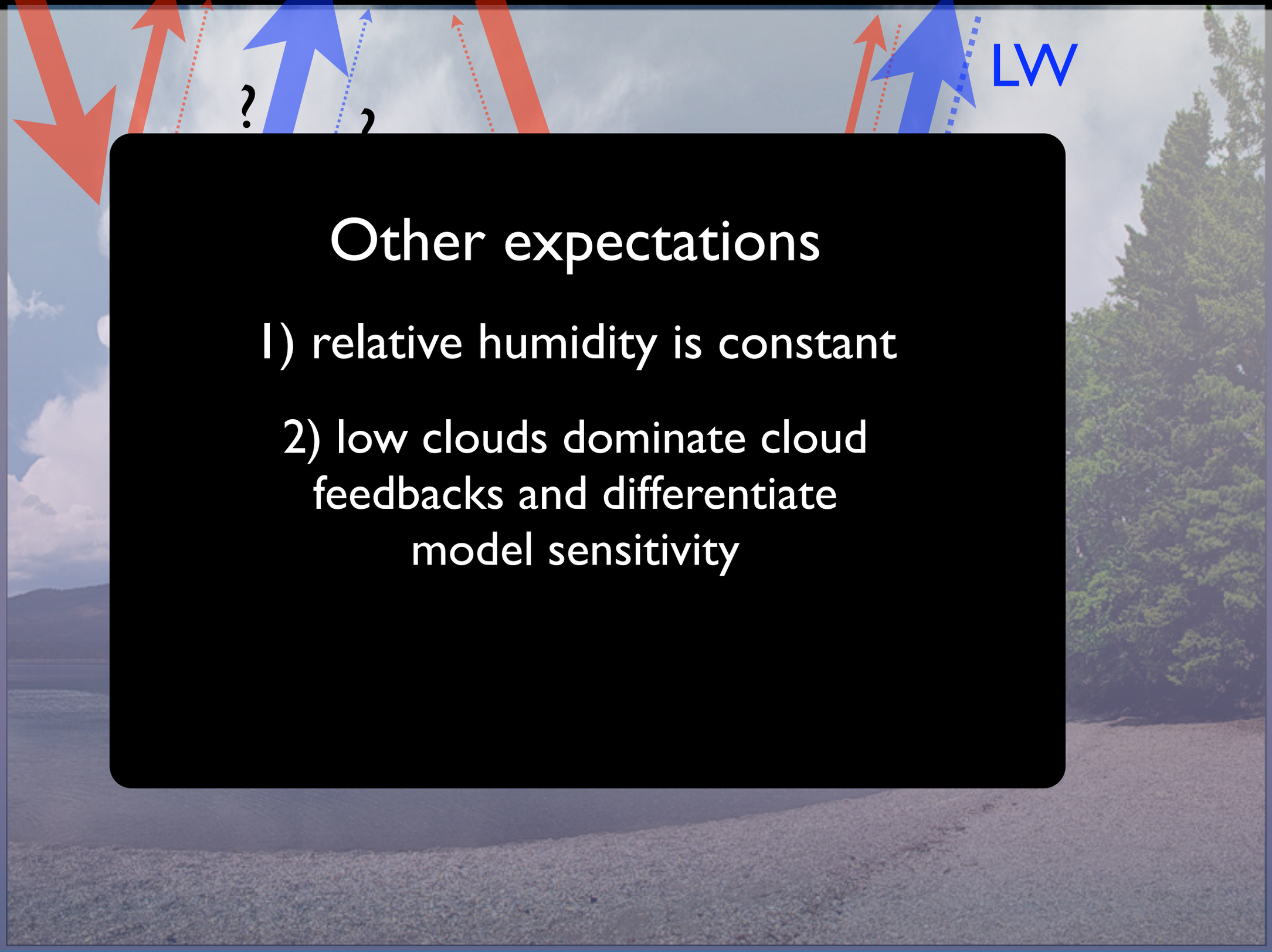
Moistening

Warming

Other expectations

1) relative humidity is constant

Our expected view of Climate Change



Other expectations

1) relative humidity is constant

2) low clouds dominate cloud feedbacks and differentiate model sensitivity

Our expected view of Climate Change

SW

LW

?

?

Moistening

Warming

Other expectations

1) relative humidity is constant

2) low clouds dominate cloud feedbacks and differentiate model sensitivity

3) greatest warming is at high latitudes

The CMIP3 Archive

The CMIP3 Archive

- 24 coupled simulations spanning the 20th and 21st centuries from 18 modeling centers
- SRES-A1b

The CMIP3 Archive

- 24 coupled simulations spanning the 20th and 21st centuries from 18 modeling centers
- SRES-A1b

- Excluded simulations that include flux corrections, large errors in the atm budget or in the archive.

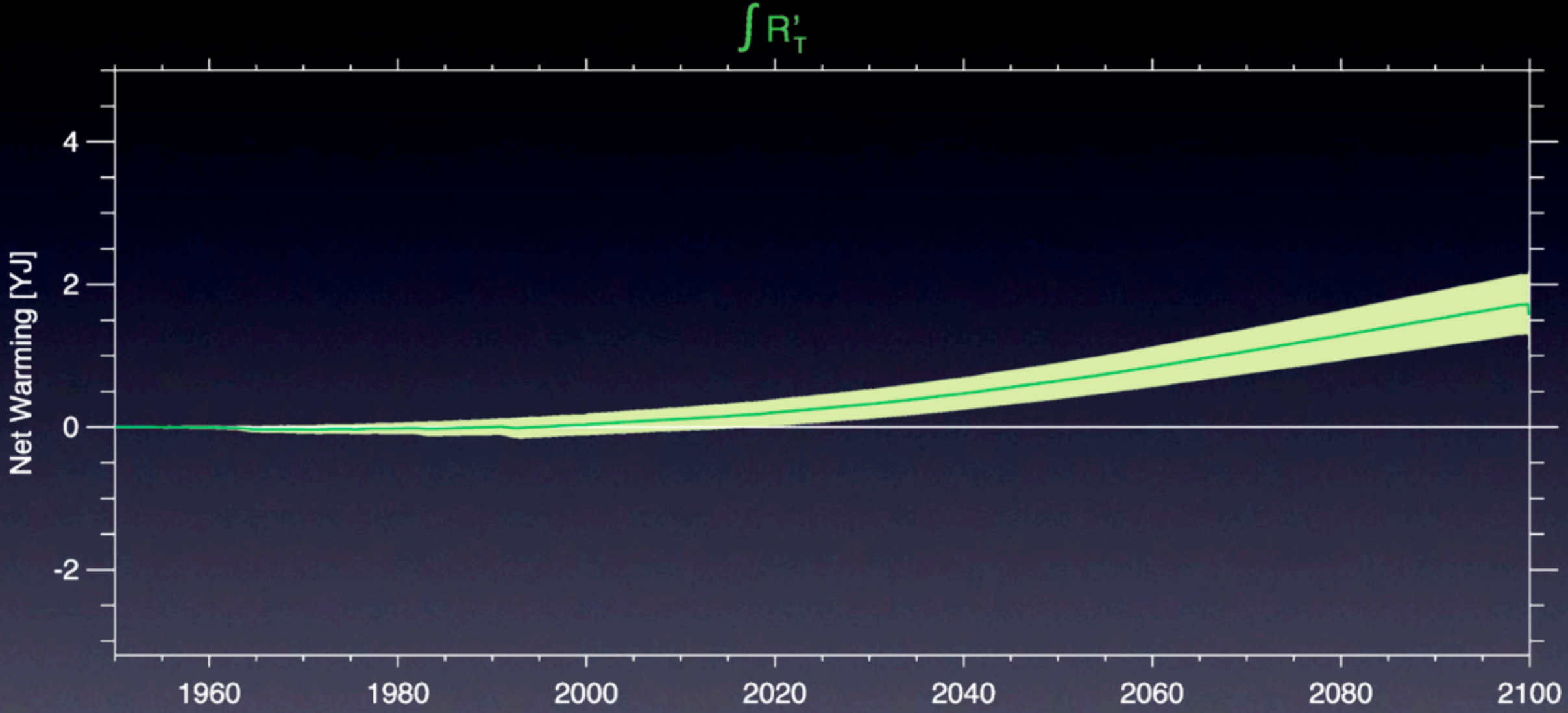
The CMIP3 Archive

- 24 coupled simulations spanning the 20th and 21st centuries from 18 modeling centers
- SRES-A1b

- Excluded simulations that include flux corrections, large errors in the atm budget or in the archive.

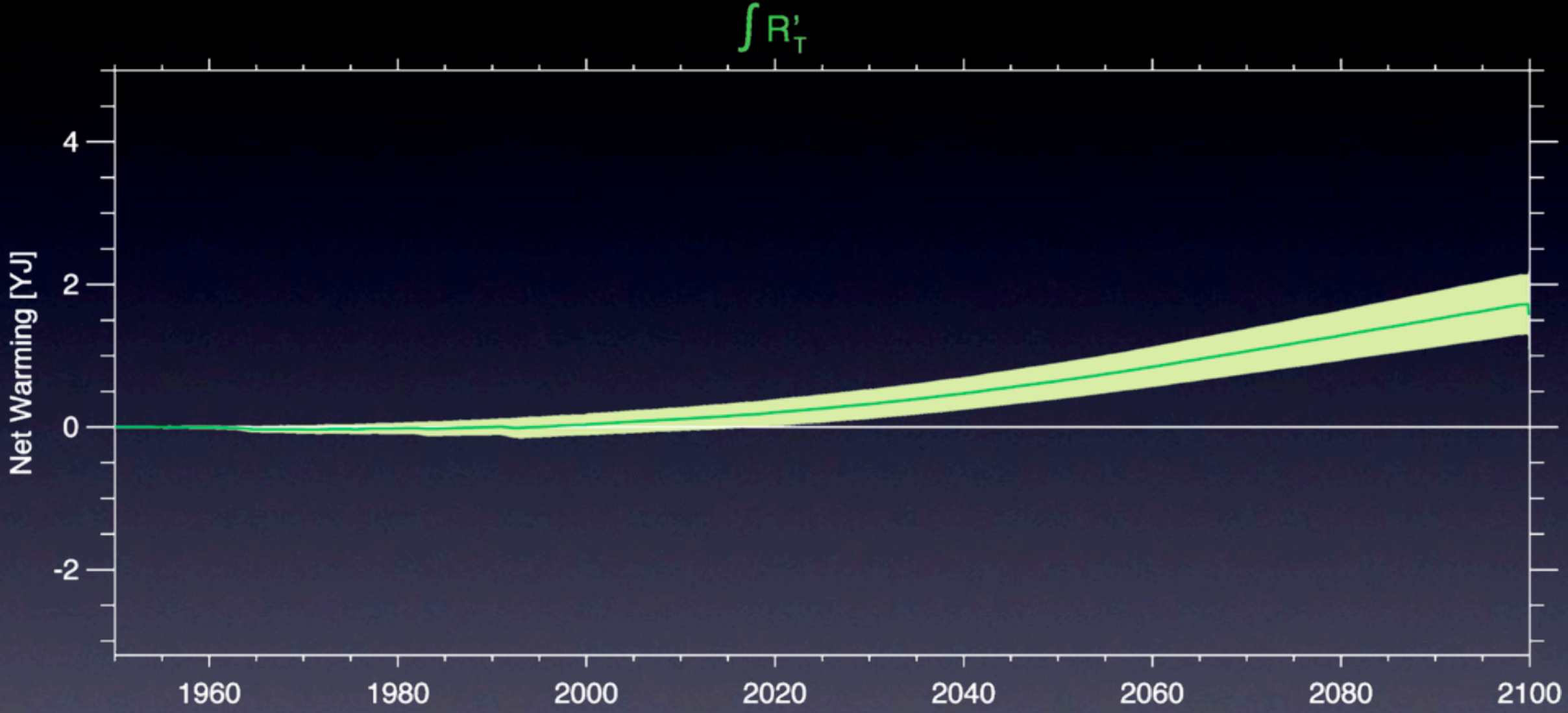
- This leaves us with 13 simulations.

The Planetary Imbalance



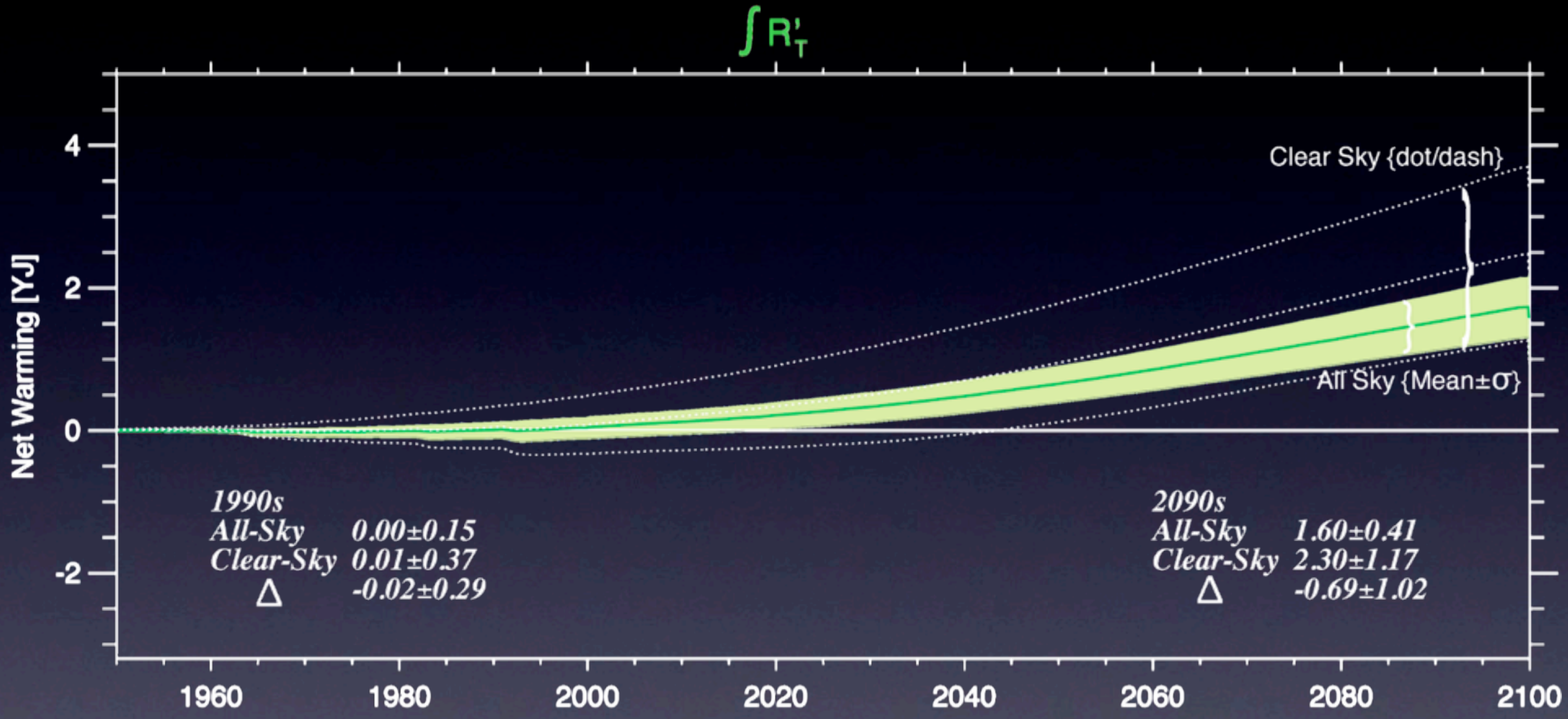
- Net planetary imbalance increases through the 21st century

The Planetary Imbalance



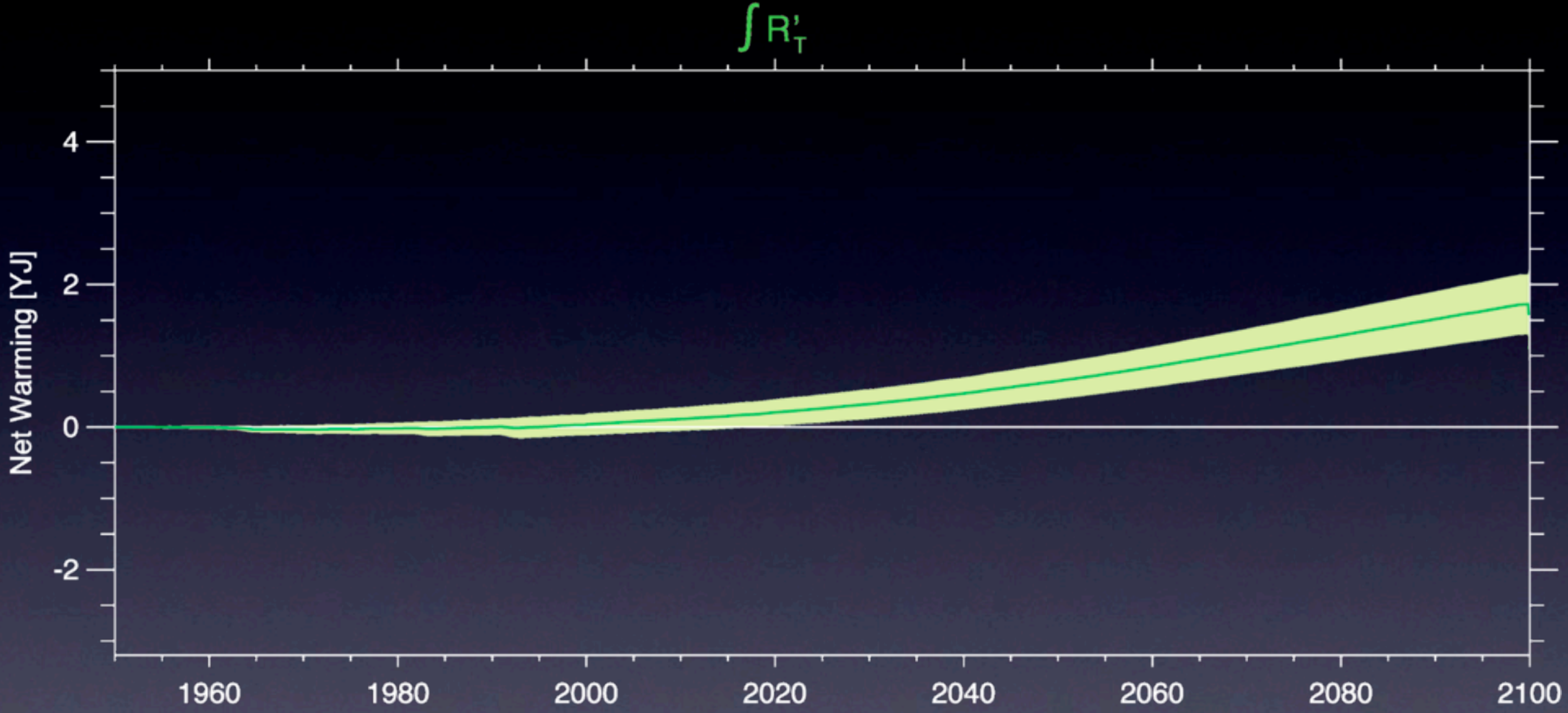
- Net planetary imbalance increases through the 21st century

The Planetary Imbalance



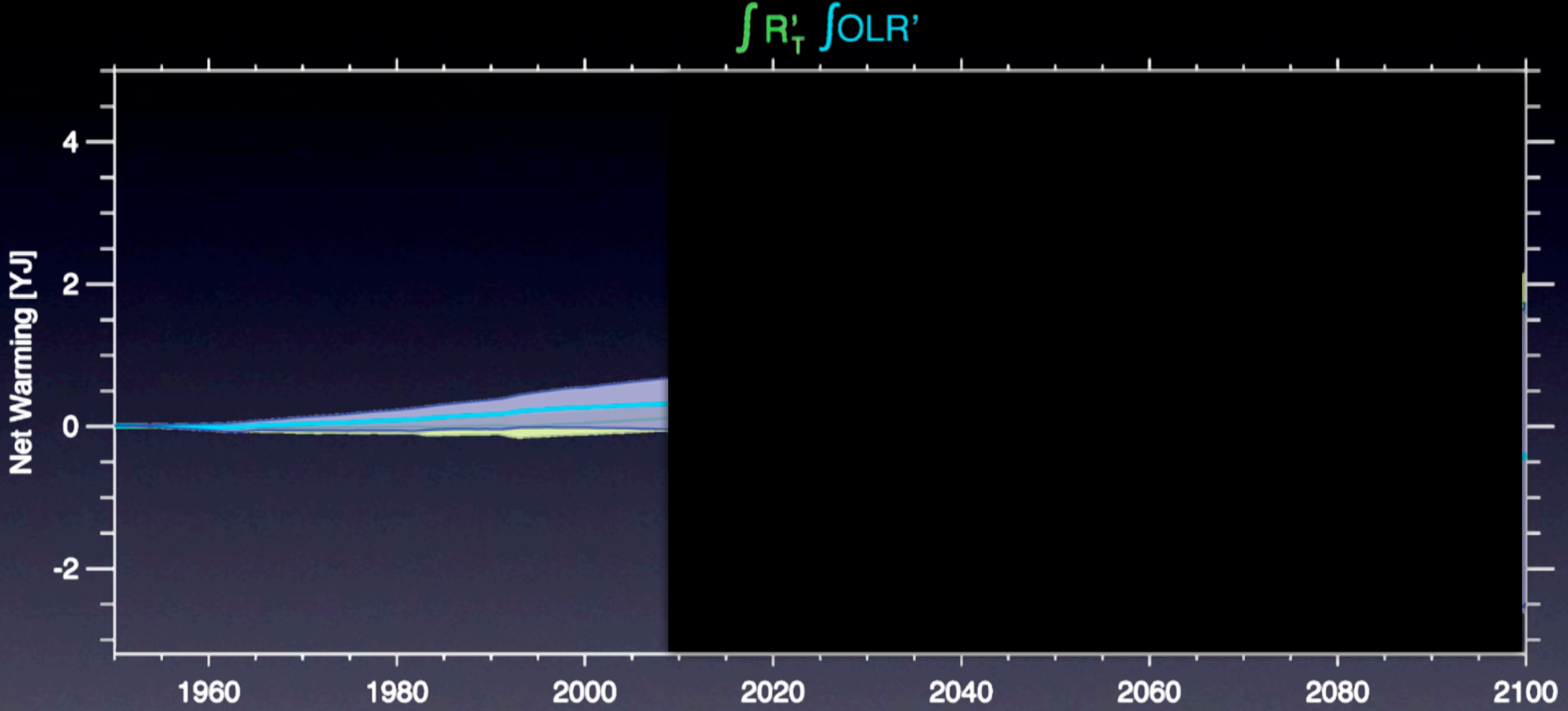
- Net planetary imbalance increases through the 21st century
- Clouds lessen the imbalance. (Mean State - Not feedback!)

The Planetary Imbalance



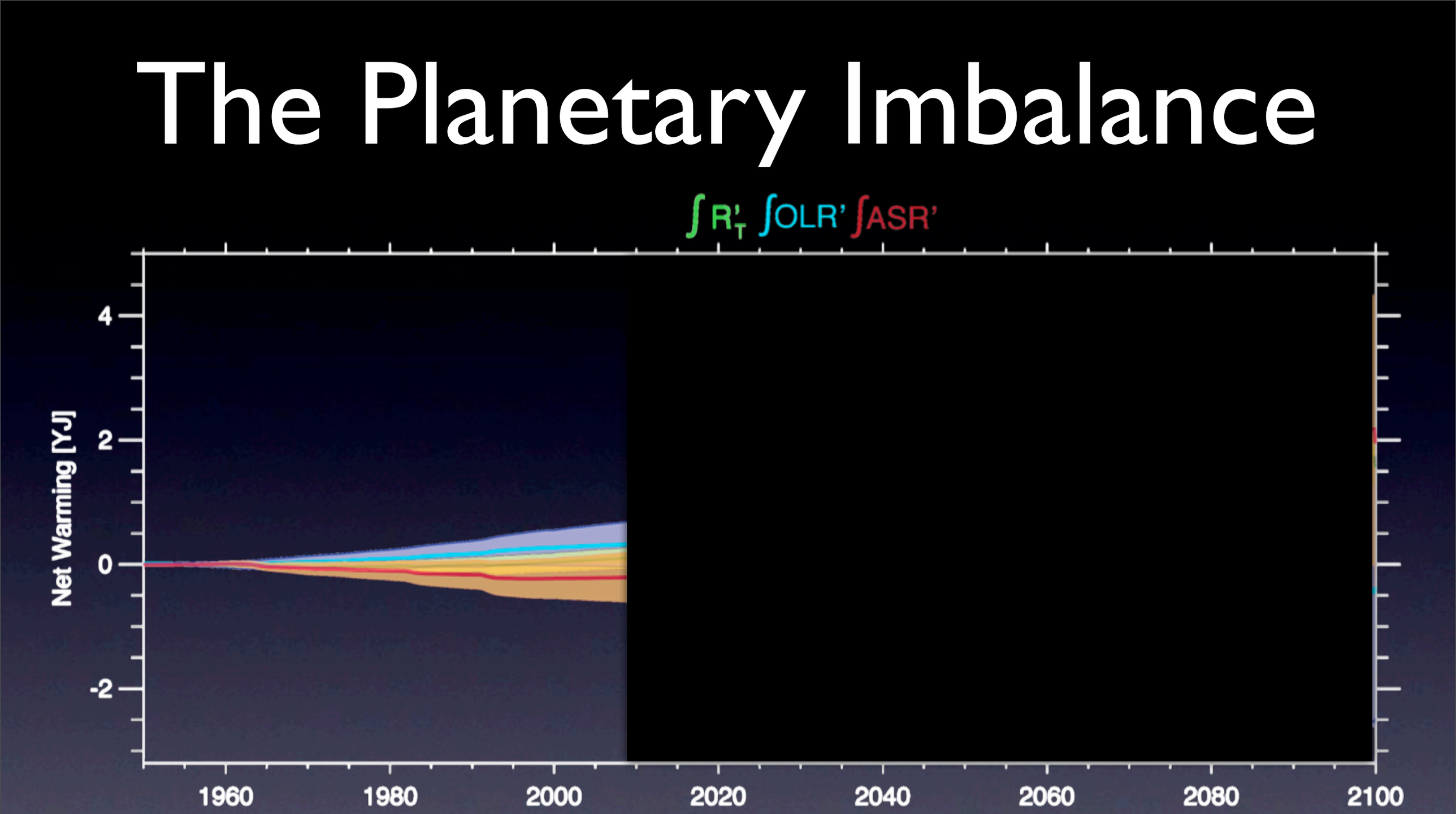
- Current imbalance is ~0.8 W m^{-2}
- Late 21st century imbalance is ~1-2 W m^{-2} and begins to decline

The Planetary Imbalance



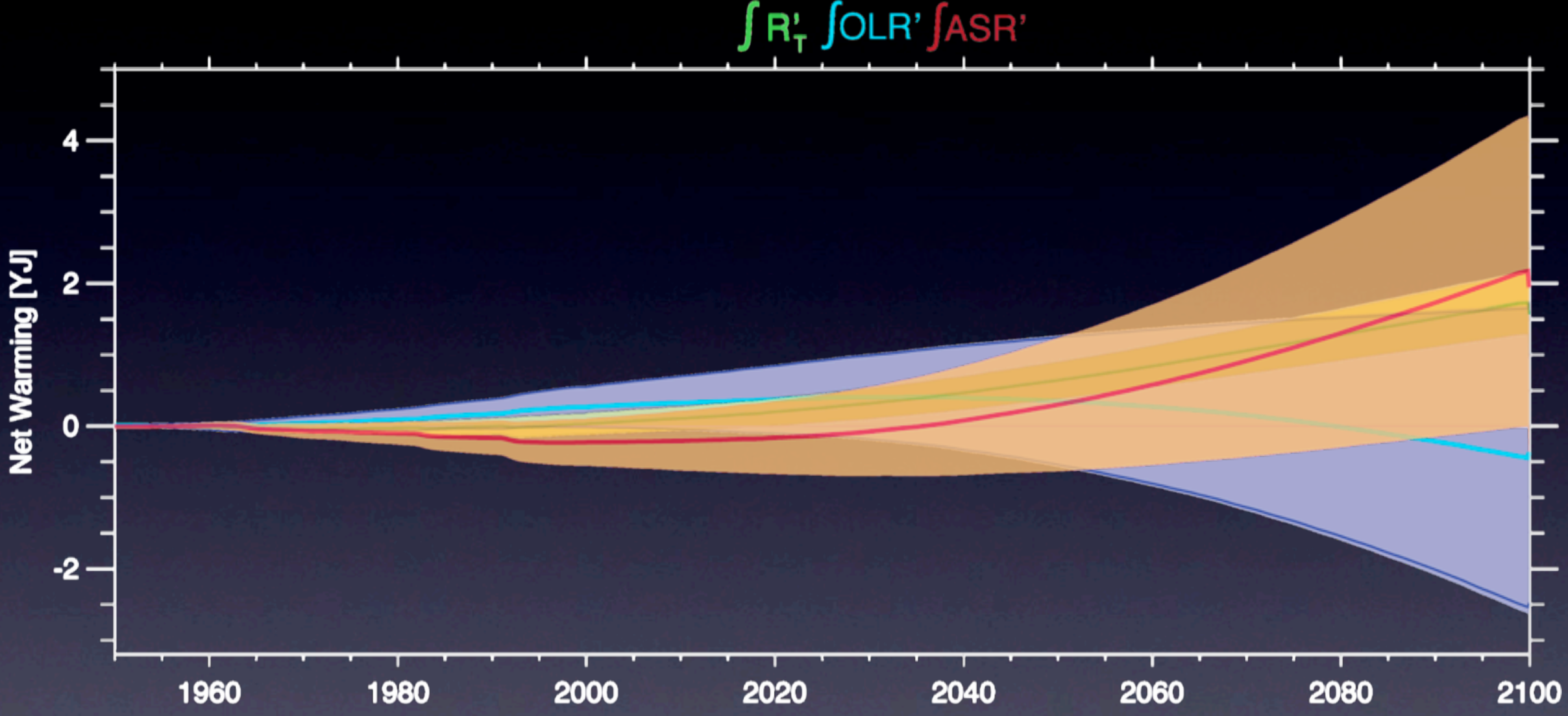
- In current climate OLR' heat the planet. Aerosols cool it.

The Planetary Imbalance



- In current climate OLR' heat the planet. Aerosols cool it.

The Planetary Imbalance



- In current climate OLR' heat the planet. Aerosols cool it.
- Feedbacks in ASR drive the imbalance after 2100 and to equil.

What regions are processes are suggested?

What regions are processes are suggested?

OLR

lapse rate feedback?

water vapor feedback?

cloud feedback?

What regions are processes are suggested?

OLR

lapse rate feedback?

water vapor feedback?

cloud feedback?

ASR

ice albedo feedback?

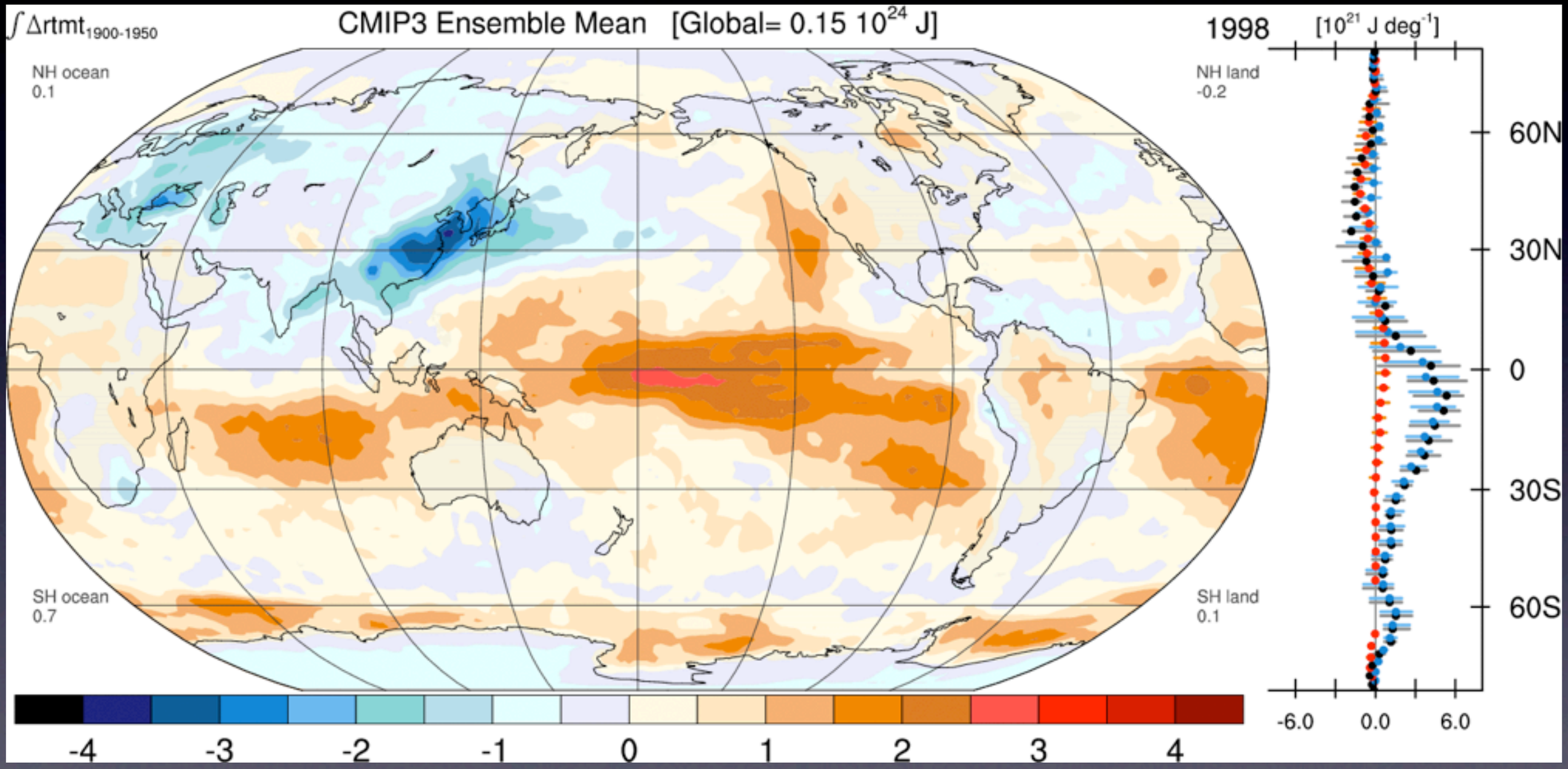
cloud feedback?

land snow feedback?

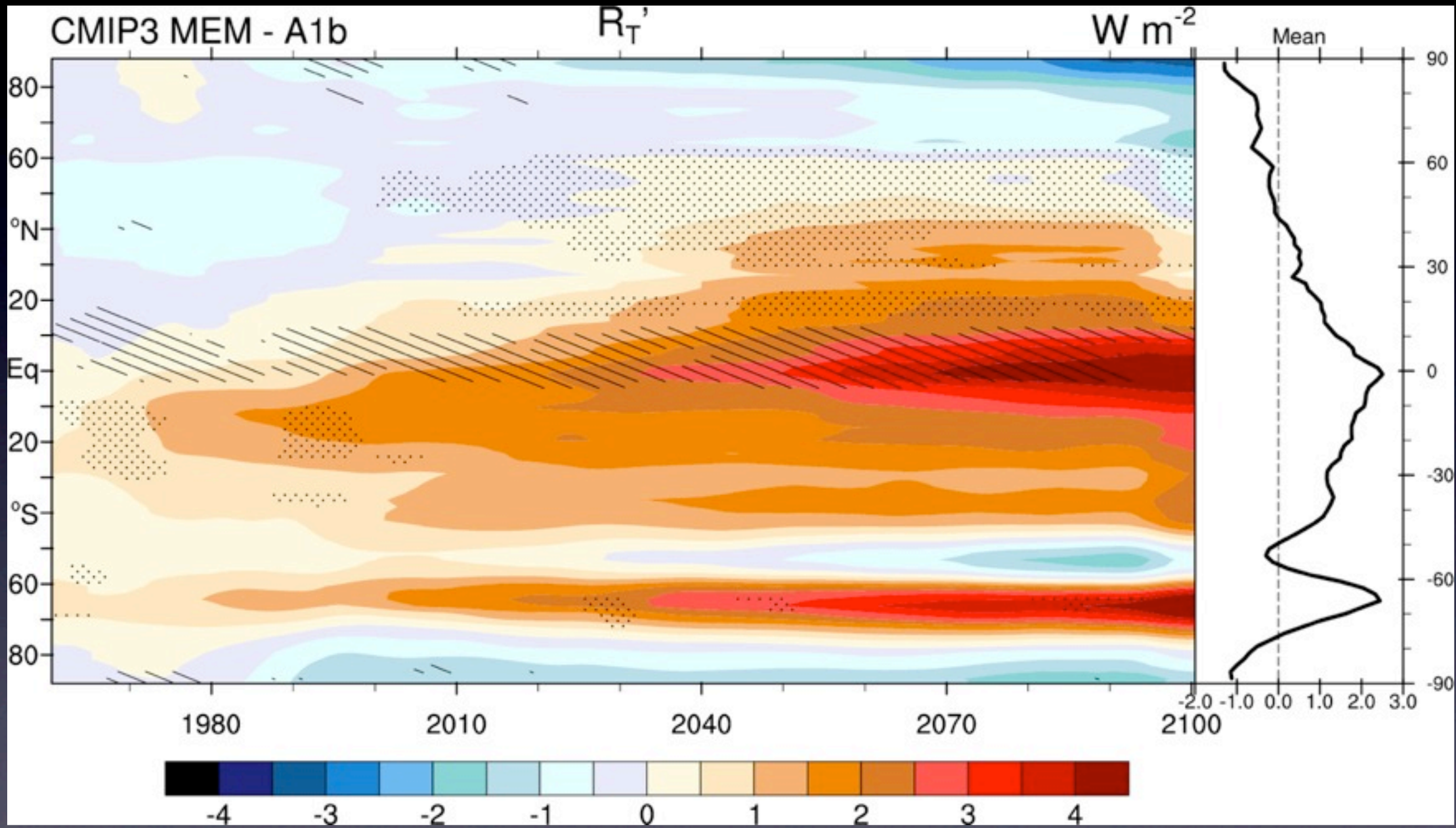
aerosol forcing?

Regional Structure

Regional Structure

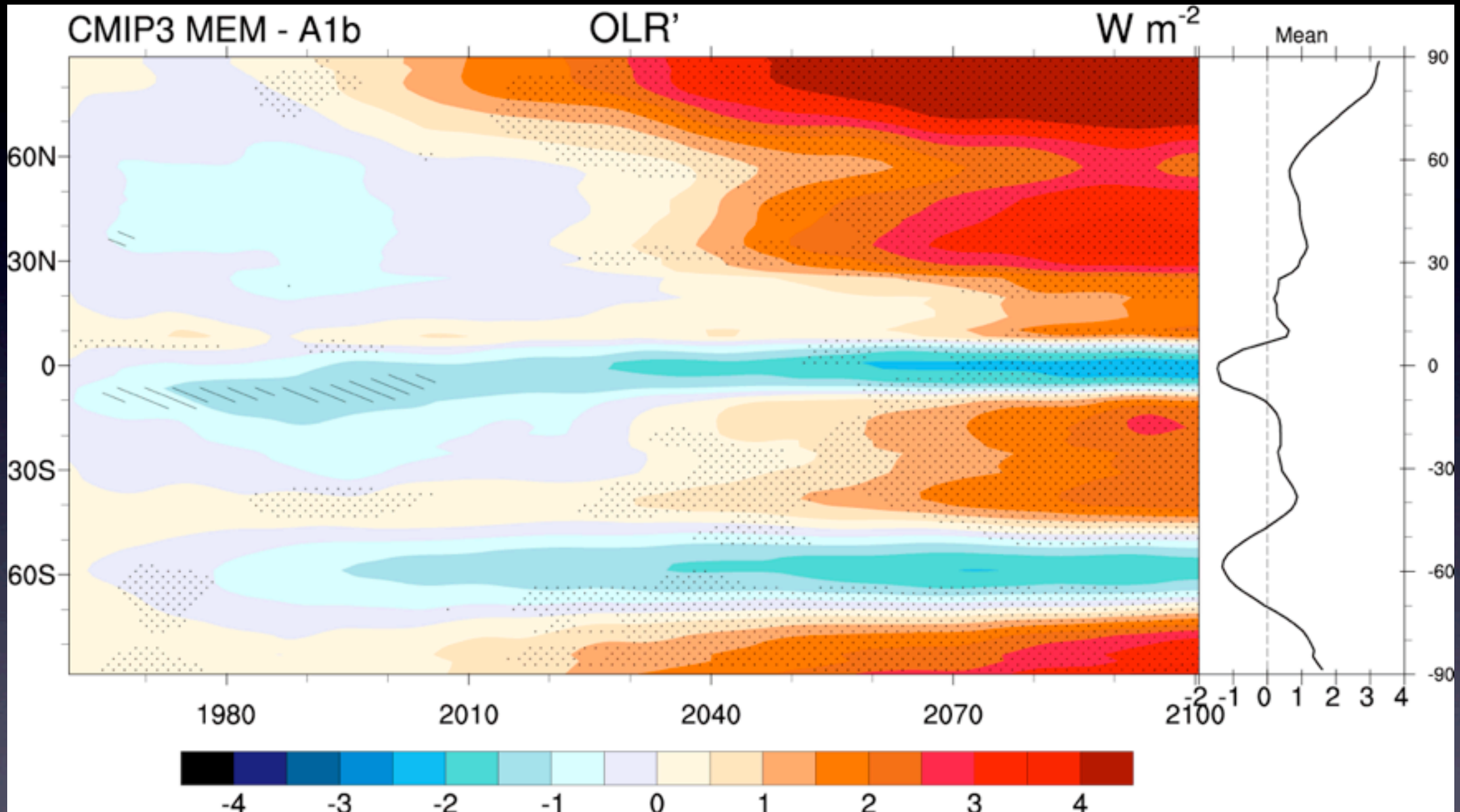


Lat/Time Structure of the Imbalance



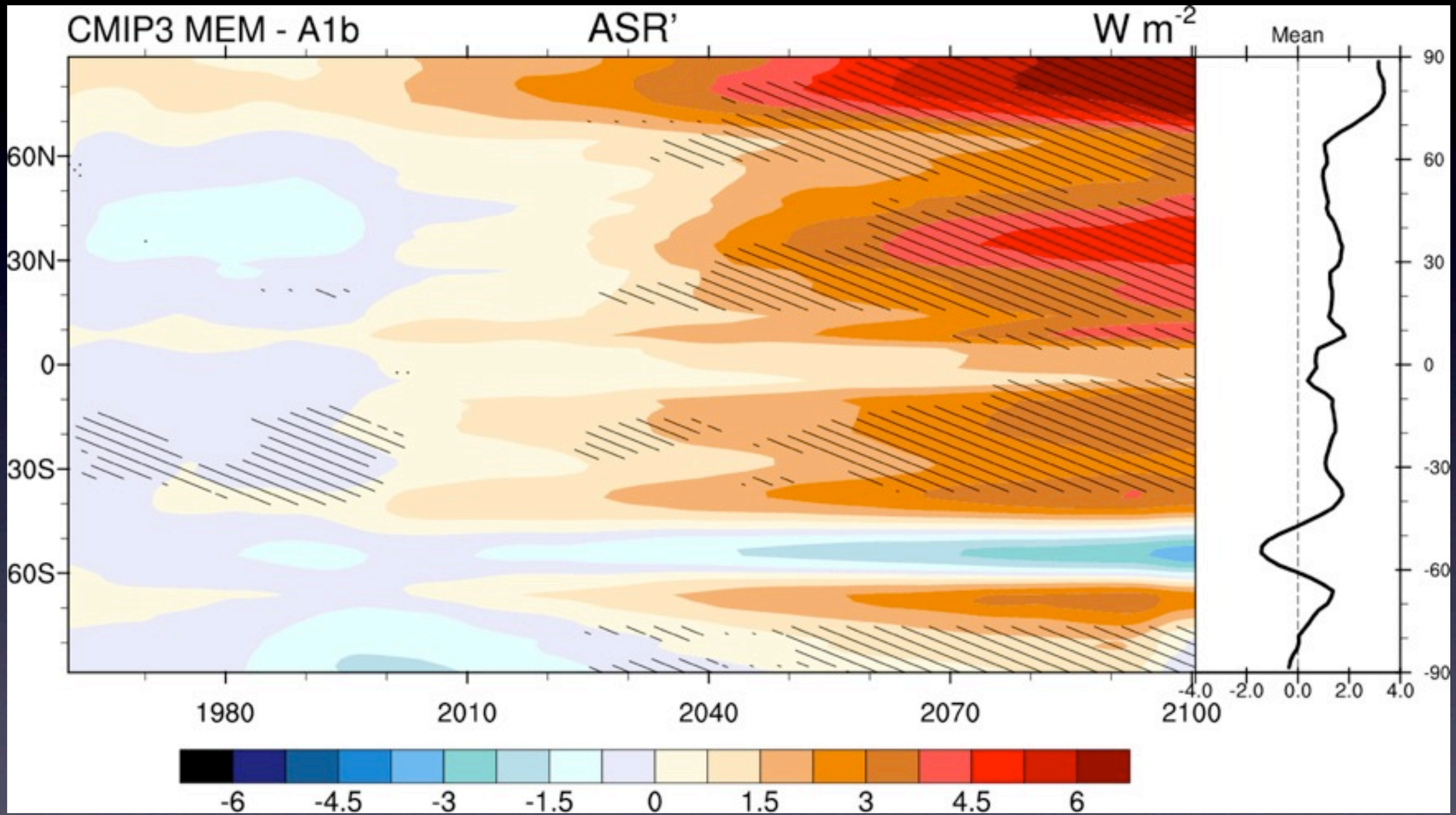
- Planetary Imbalance >0, 50N-50S, ice-albedo feedback suggested to be weak

Lat/Time Structure of OLR Anomalies



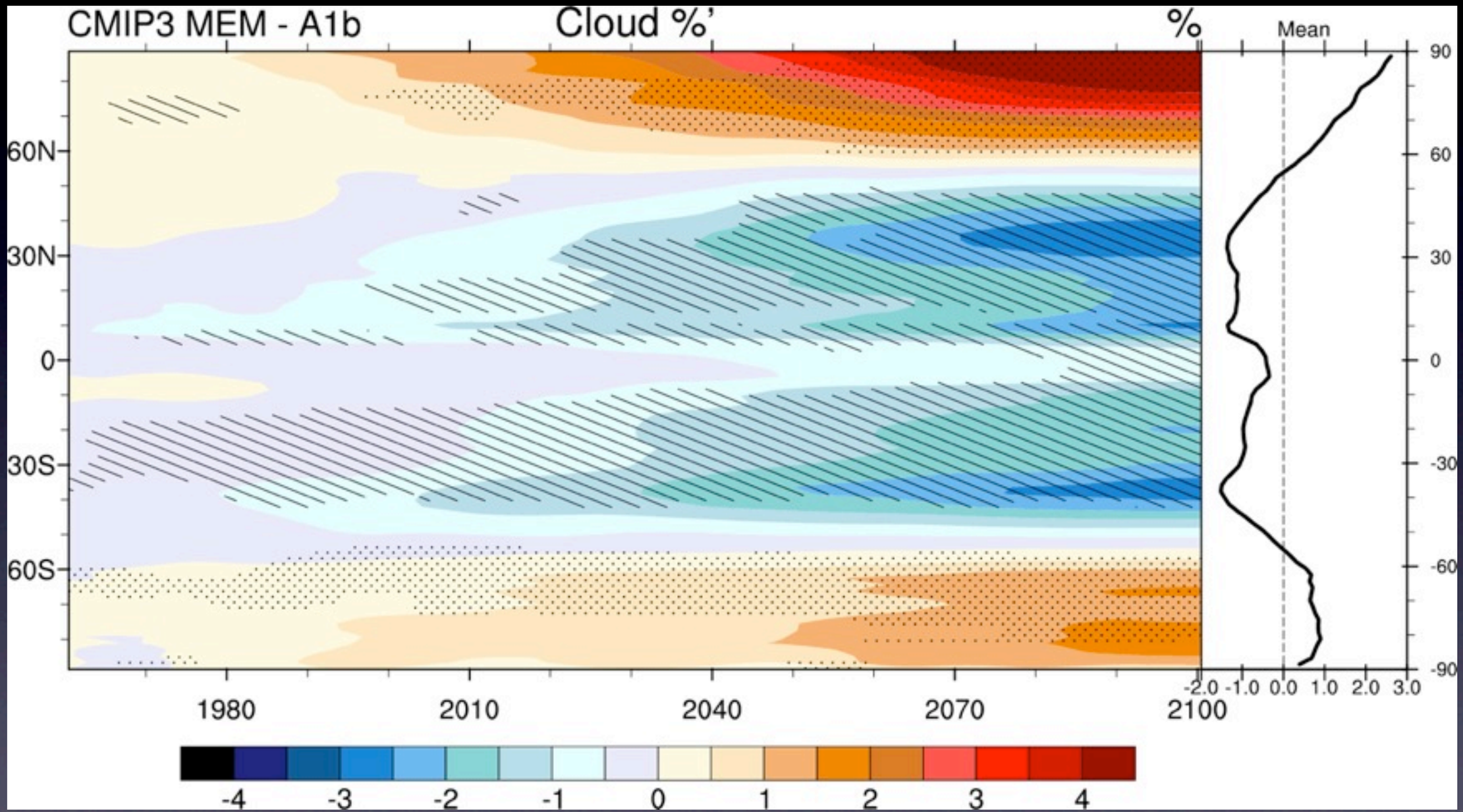
- OLR anomalies > 0 except for deep tropics and southern oceans

Lat/Time Structure of ASR Anomalies



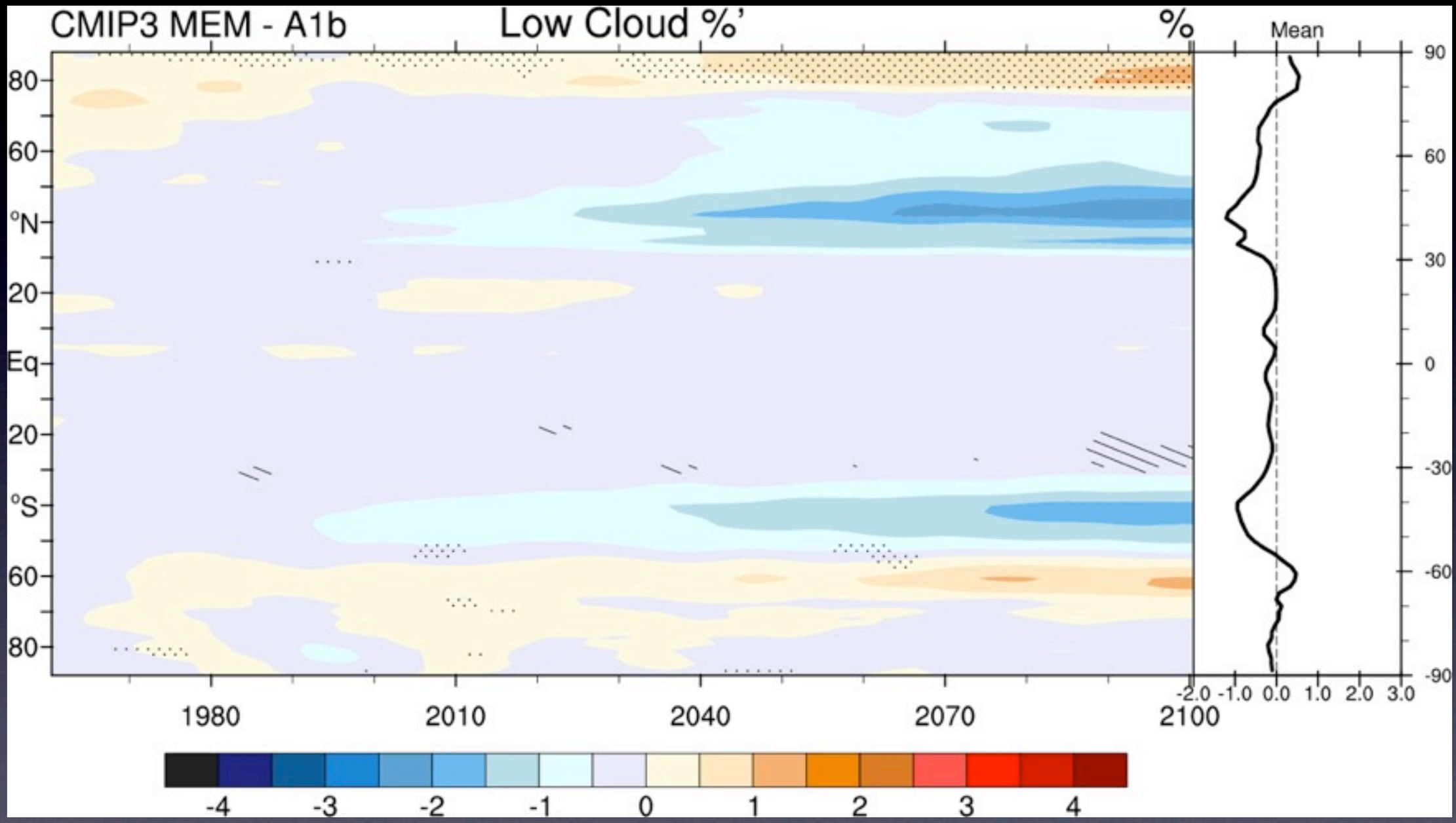
- ASR increases at all latitudes except 45-65S

Lat/Time Structure of Cloud %



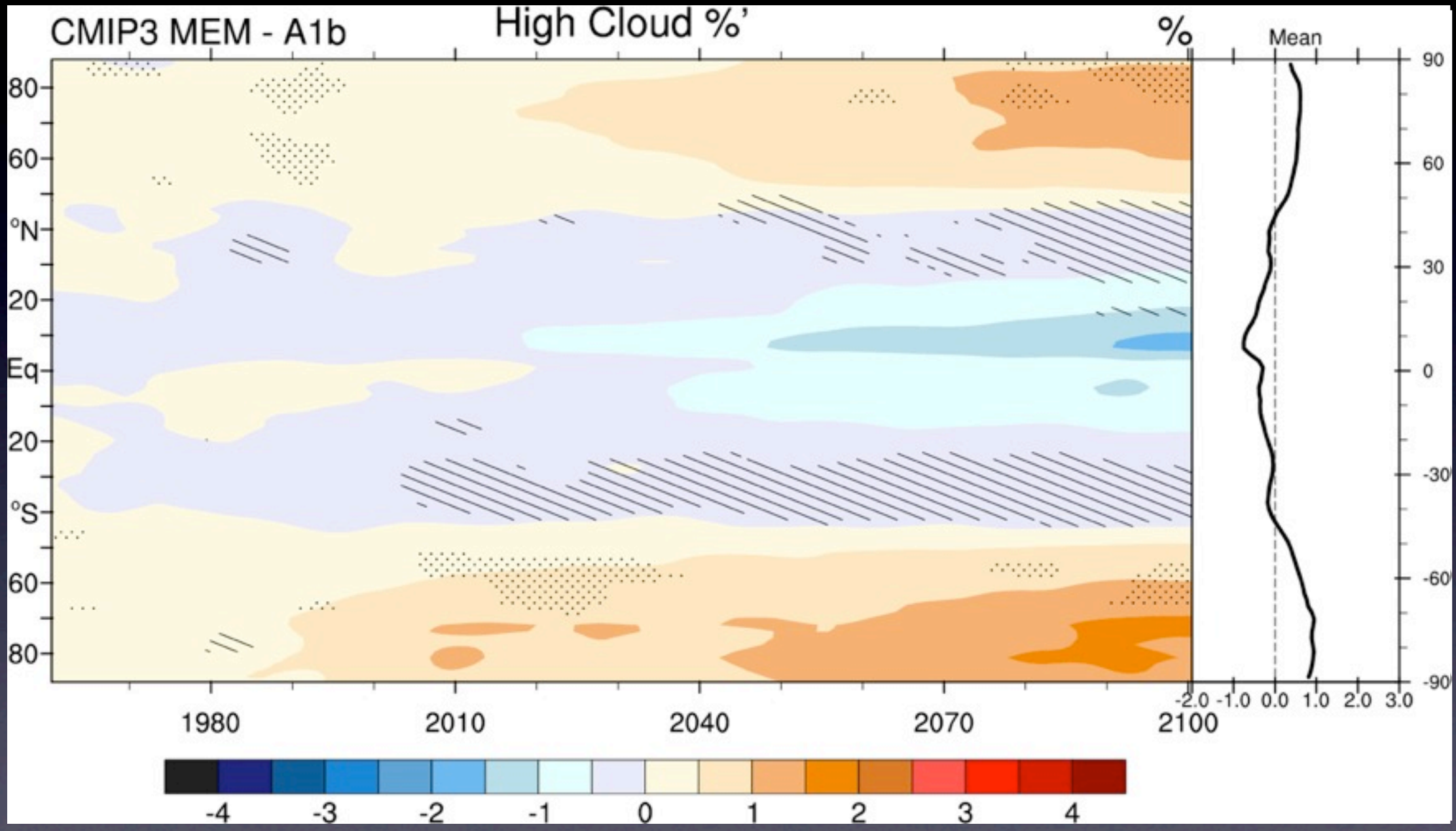
- In regions of R_T and ASR increase, cloud change is < 0

Lat/Time Structure of Cloud %



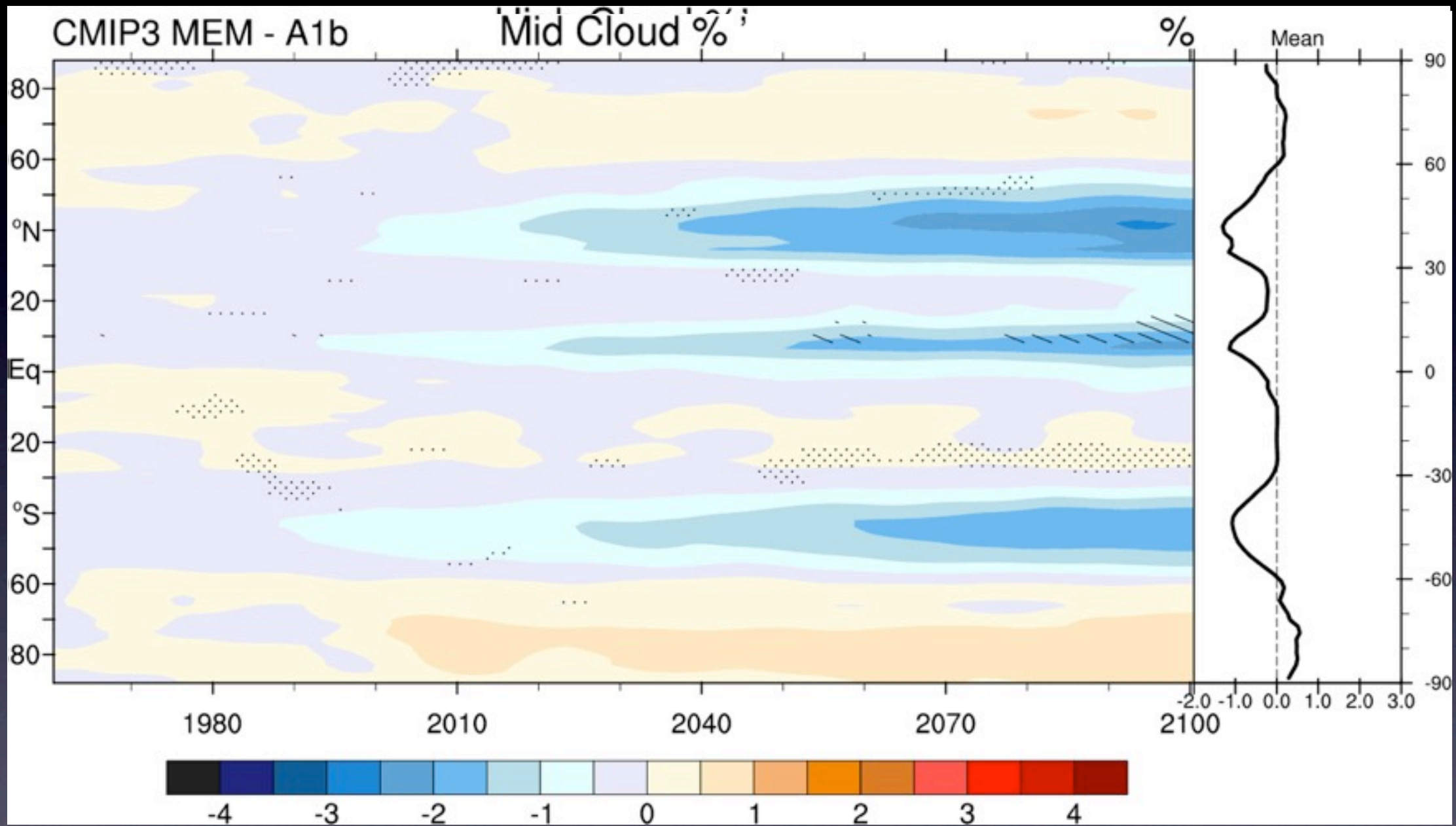
- Loss of mid-level clouds is more intense and extensive than for other types.

Lat/Time Structure of Cloud %



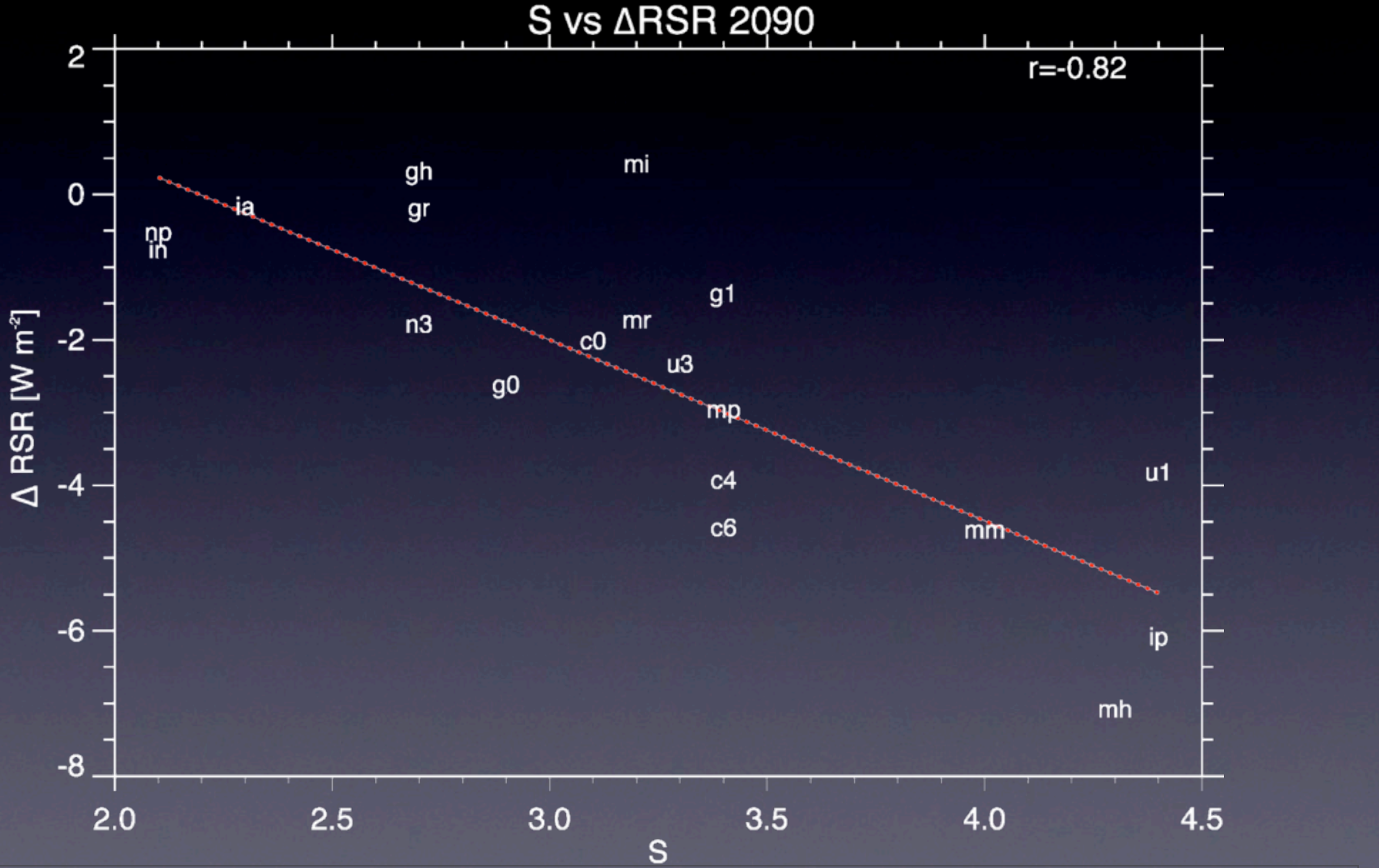
- Loss of mid-level clouds is more intense and extensive than for other types.

Lat/Time Structure of Cloud %

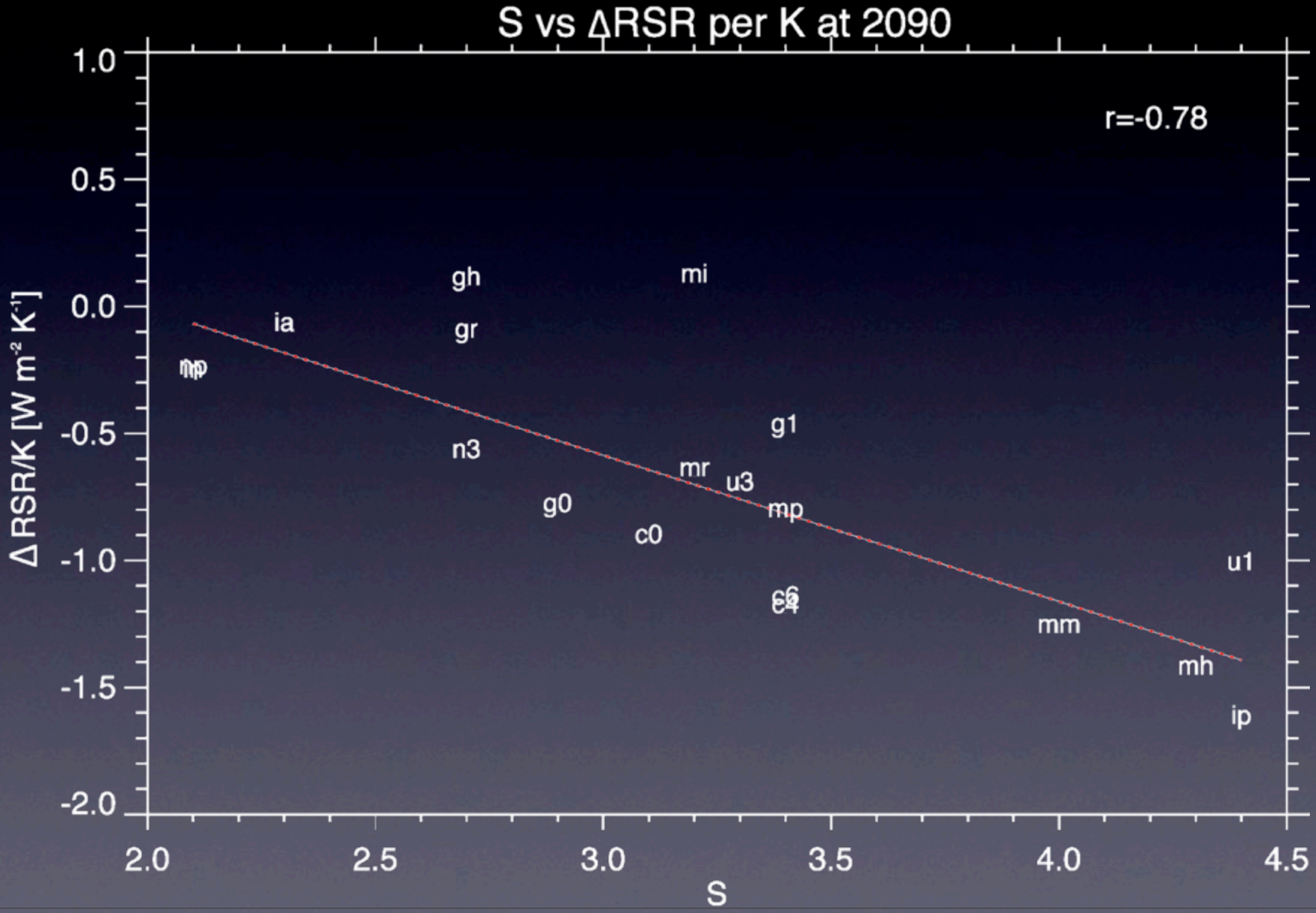


- Loss of mid-level clouds is more intense and extensive than for other types.

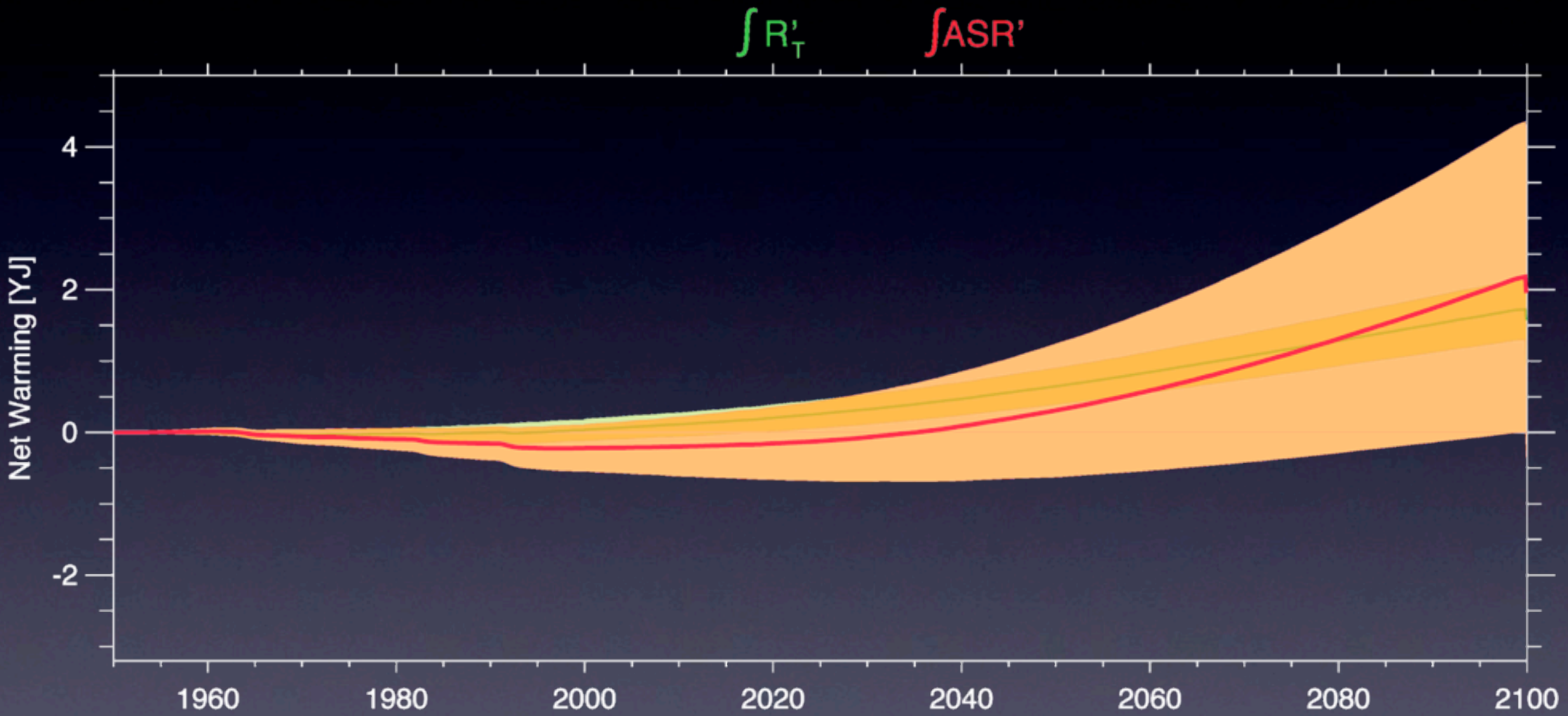
Relationship to Sensitivity



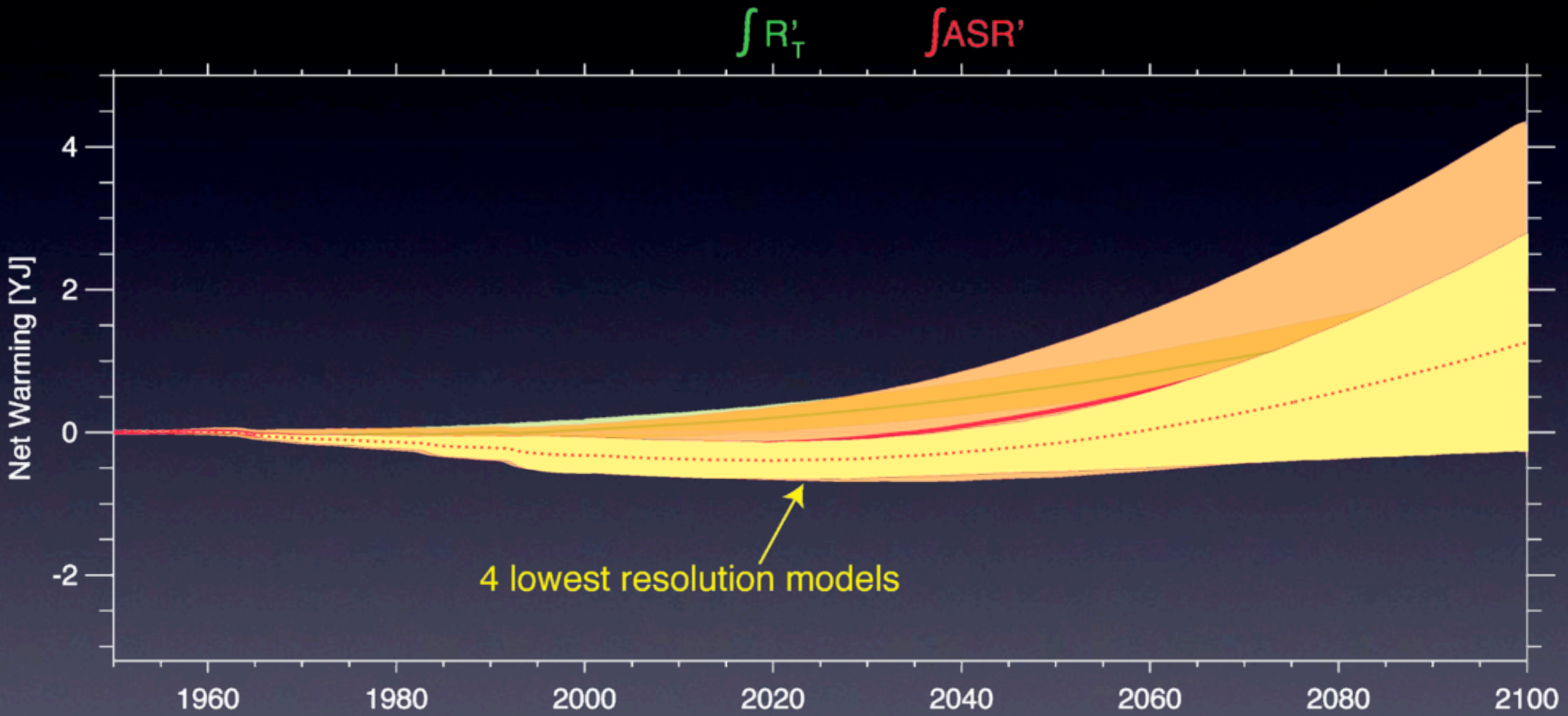
Relationship to Sensitivity



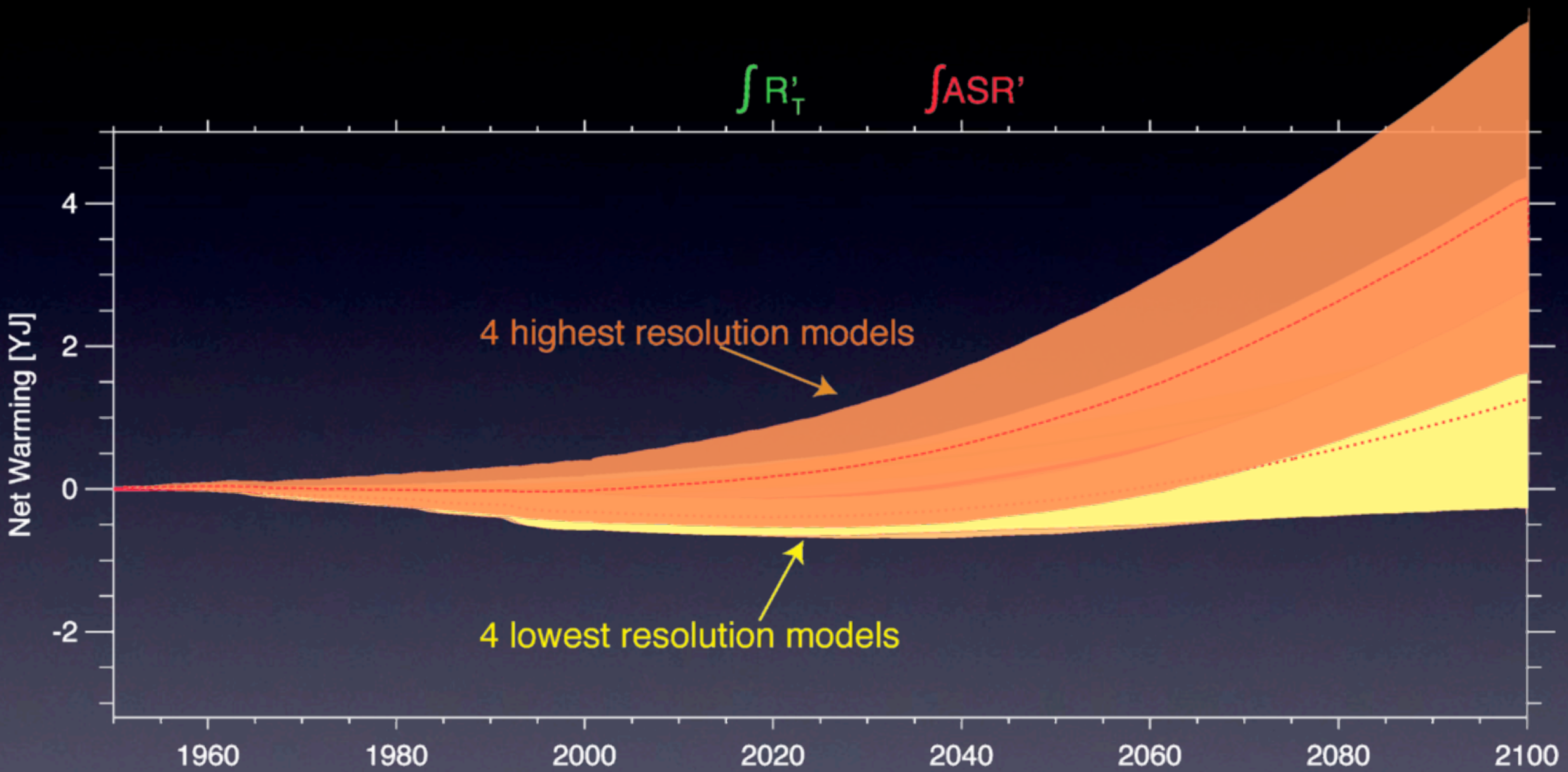
Role of Model Resolution



Role of Model Resolution



Role of Model Resolution



Conclusions: Set 1

Conclusions: Set 1

- Spectral contributions to the planetary imbalance evolve.
  - LW 20th and early 21st centuries
  - SW mid- to late-21st century and beyond
  - (LW is a net negative feedback)

Conclusions: Set 1

- Spectral contributions to the planetary imbalance evolve.
  - LW 20th and early 21st centuries
  - SW mid- to late-21st century and beyond
  - (LW is a net negative feedback)

- Cloud loss largely drives the reduction in Albedo

Conclusions: Set 2

- Cloud loss sensitivity largely determines S

- Large implications for efforts to gauge sensitivity based on present-day variability. Models suggest that current warming is NOT driven or distinguished by the processes that primarily determine S.