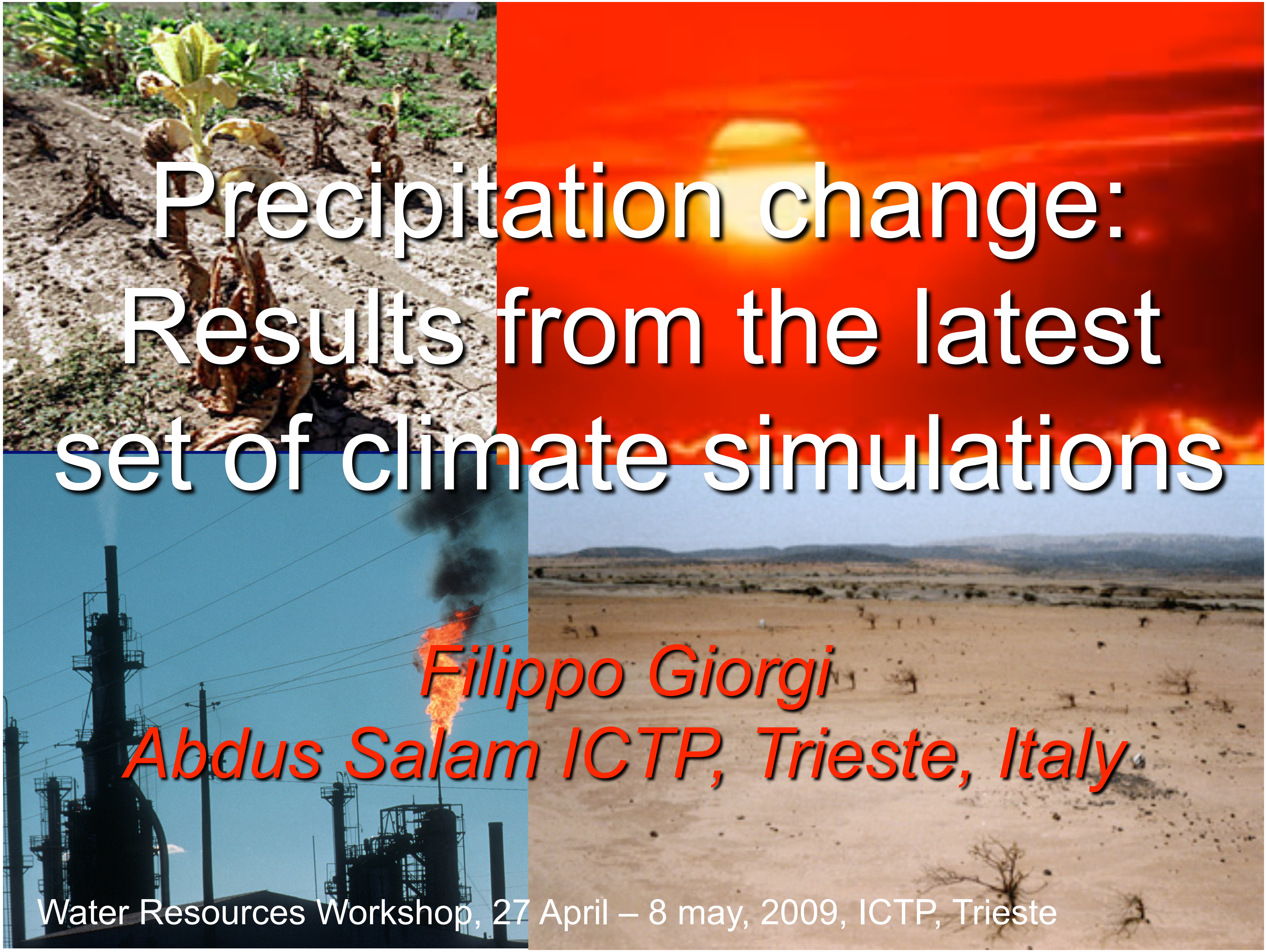


# Precipitation change: Results from the latest set of climate simulations

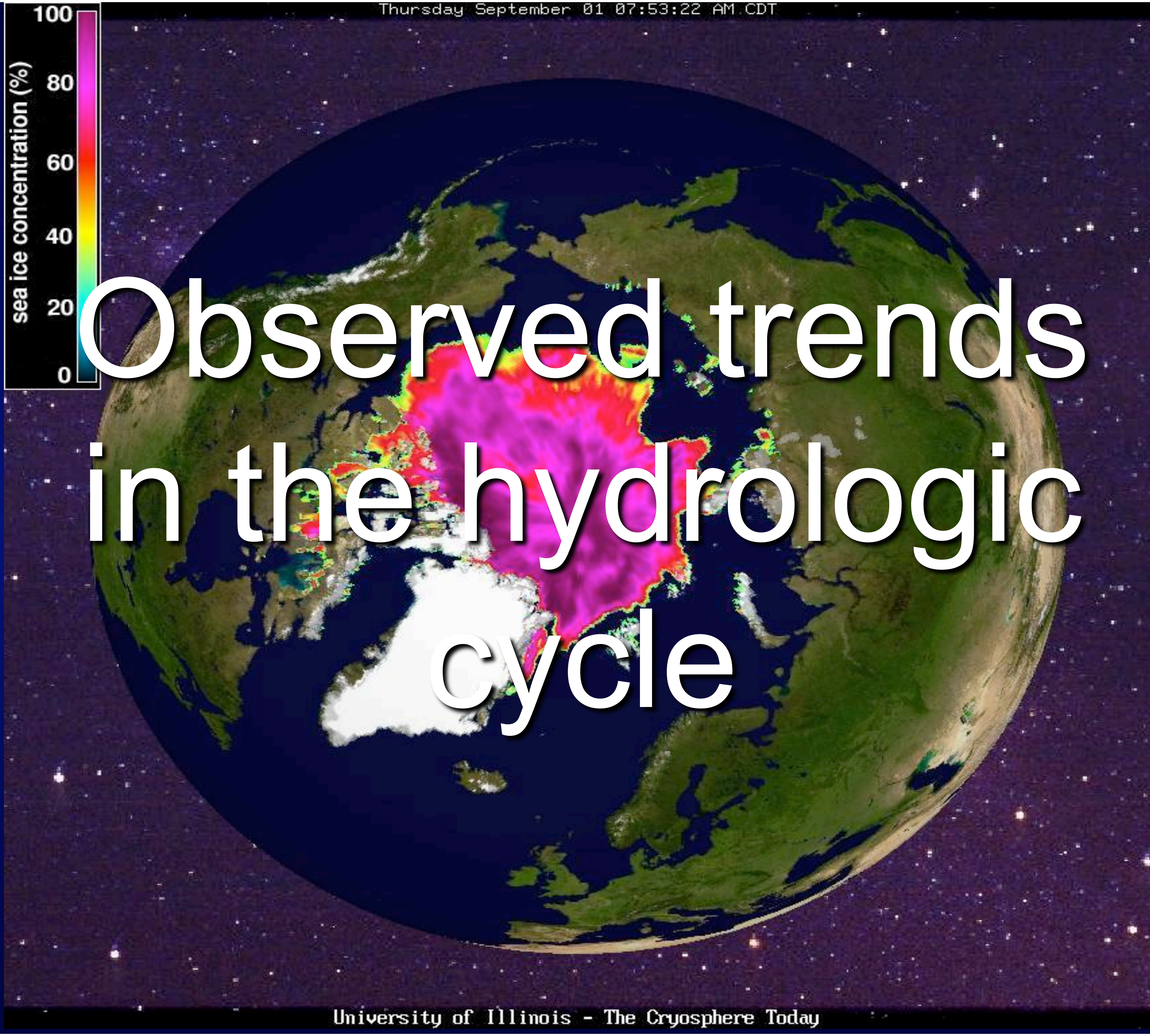

*Filippo Giorgi*
*Abdus Salam ICTP, Trieste, Italy*


Water Resources Workshop, 27 April – 8 may, 2009, ICTP, Trieste

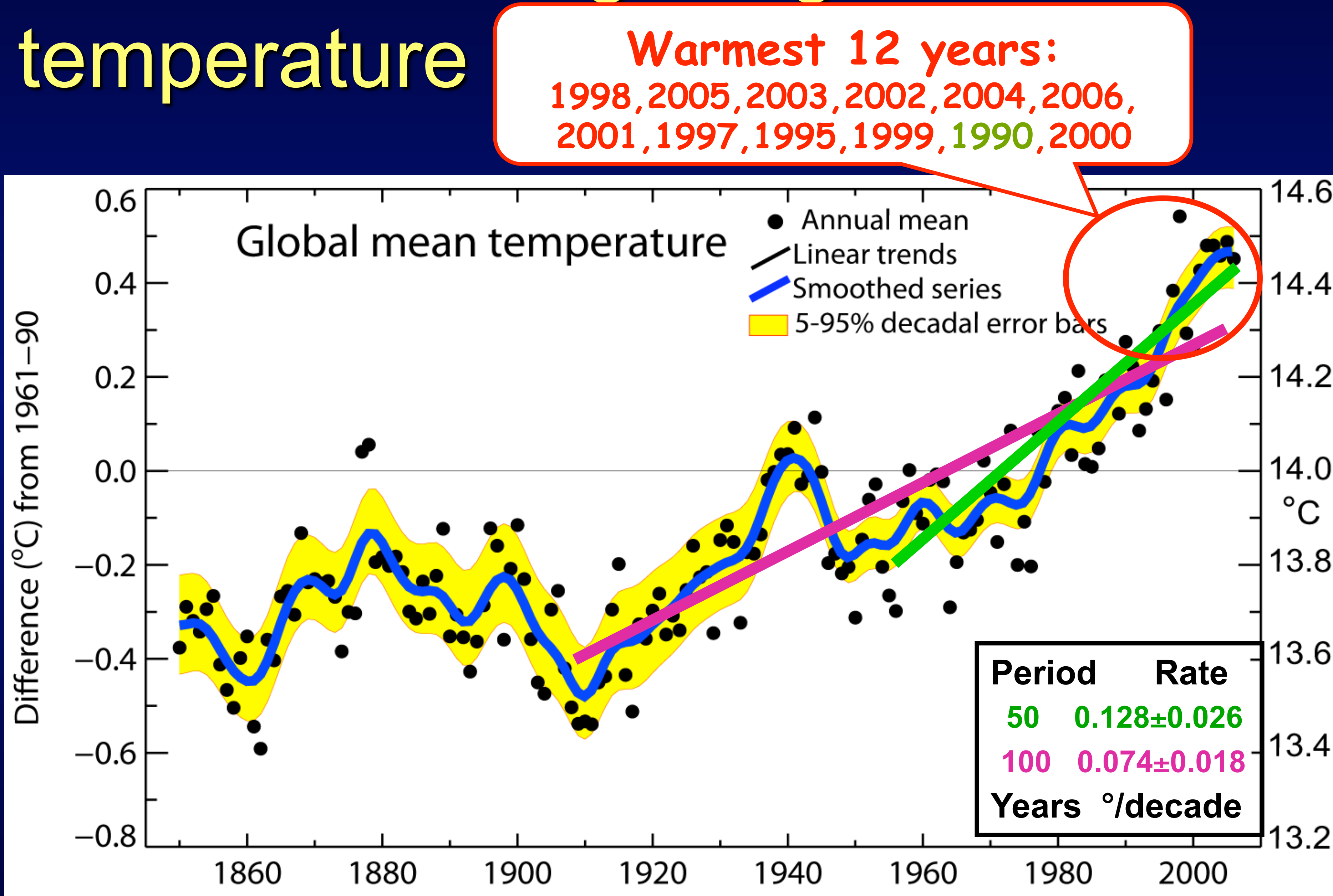
# Outline

- Observed trends in the hydrologic cycle
- Projected changes in the hydrologic cycle
- The time of emergence of precipitation change Hot-Spots

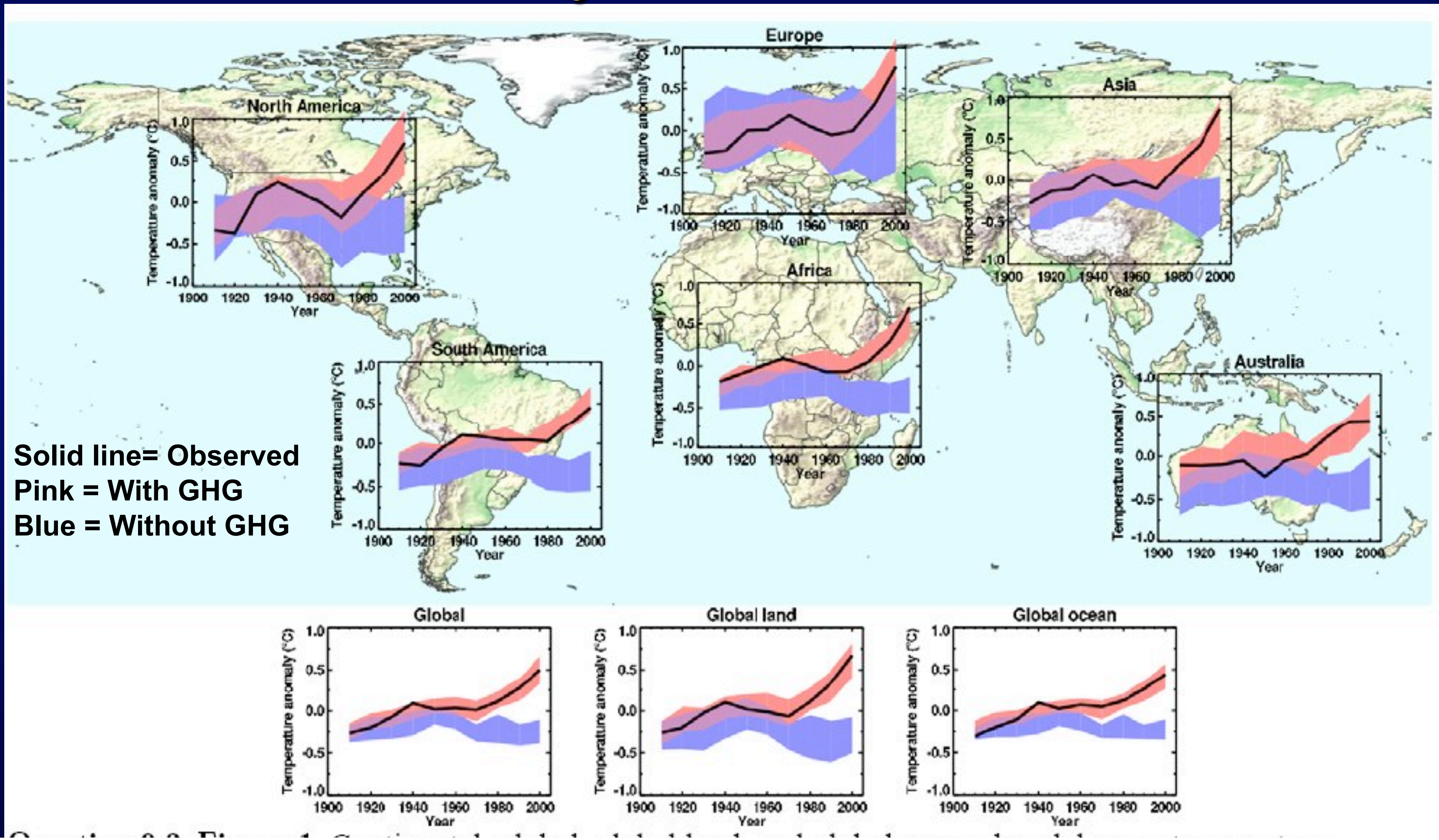
# Observed trends in the hydrologic cycle



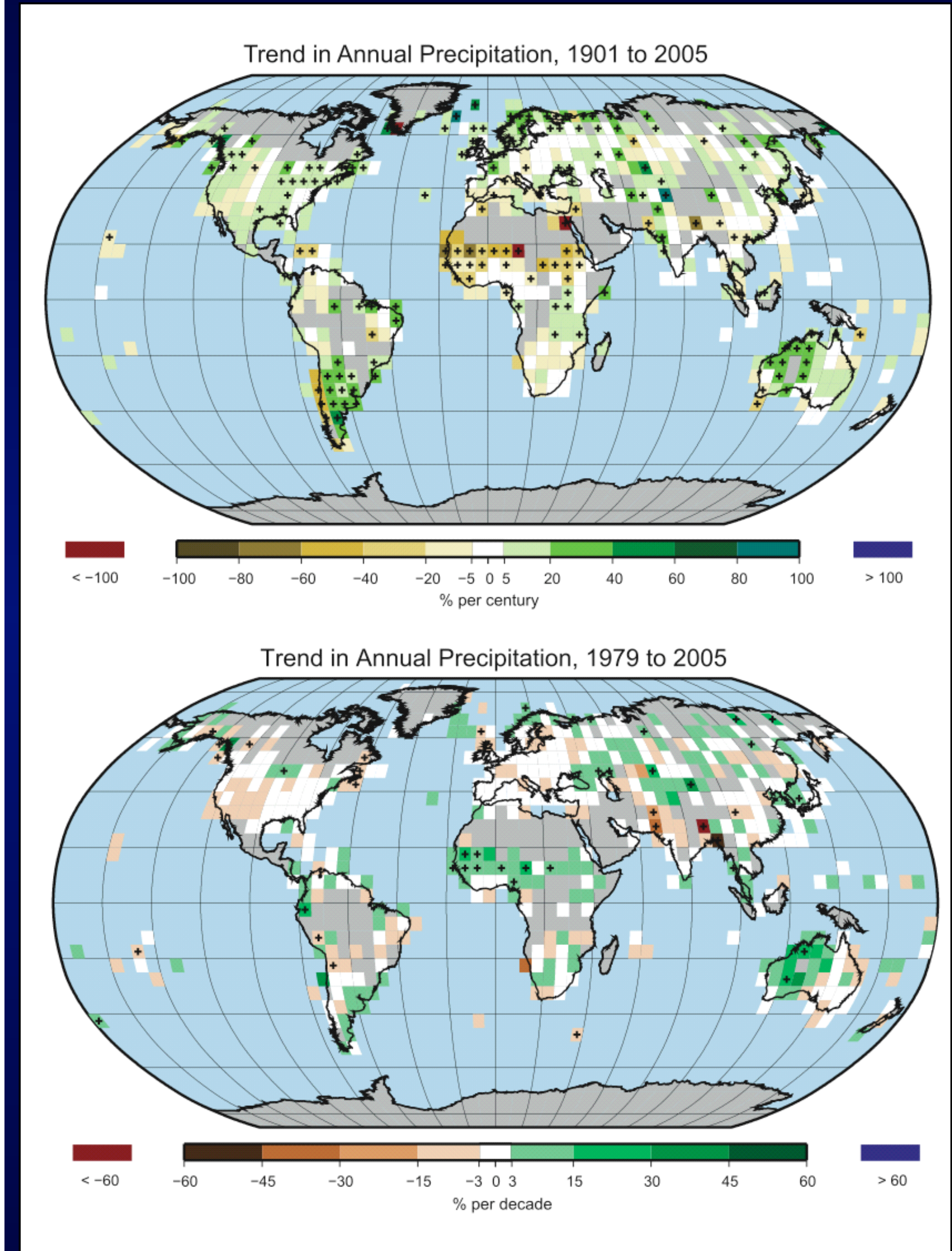
# Observed change in global surface temperature

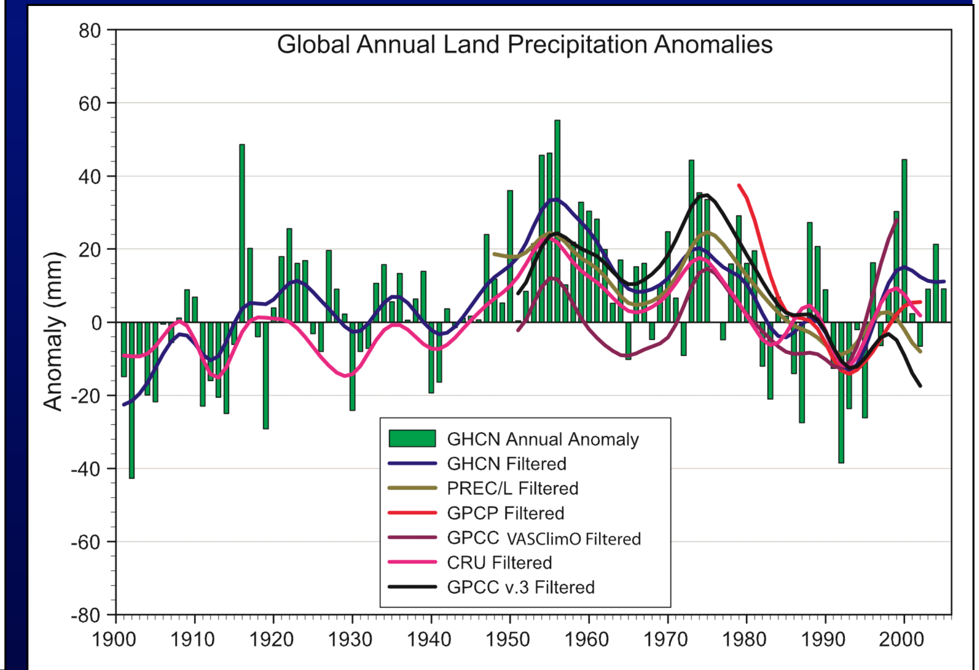


# The anthropogenic signature on continental scale temperature change has been firmly established

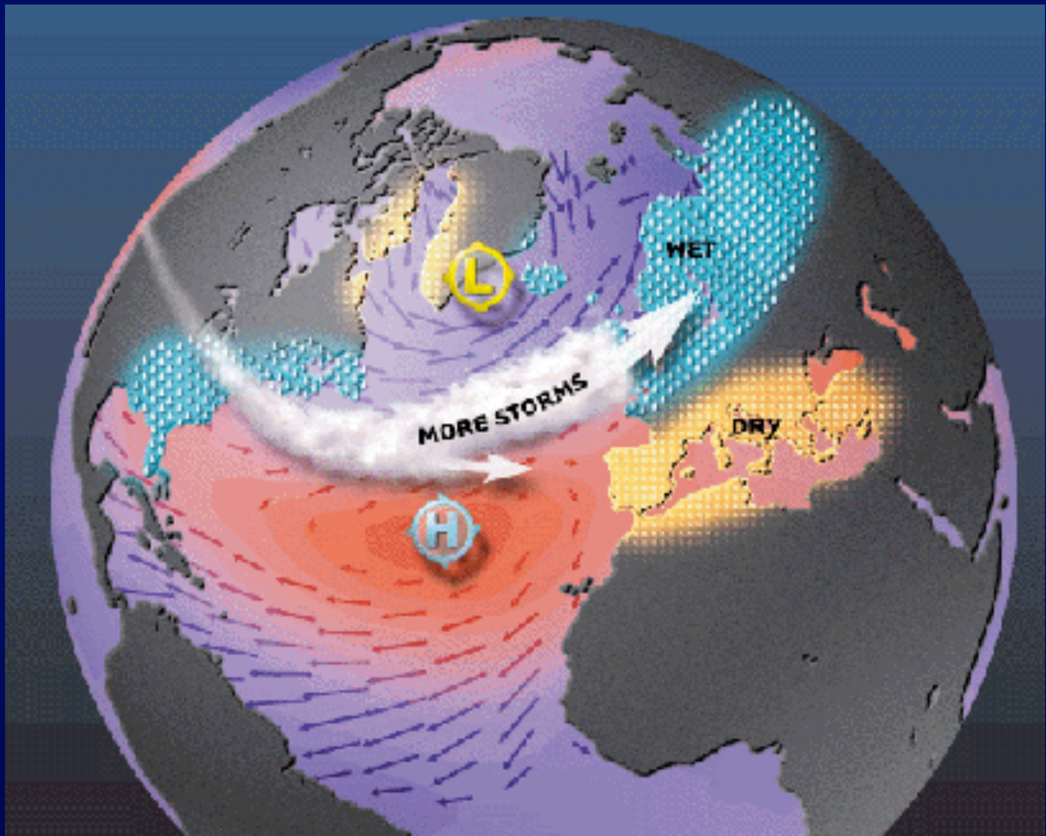


# Although precipitation trends have been detected, they have not been attributed to GHG forcing



# Other observed changes
## Circulation




Poleward shift of mid-latitude storm tracks

More intense westerlies

# Other observed changes

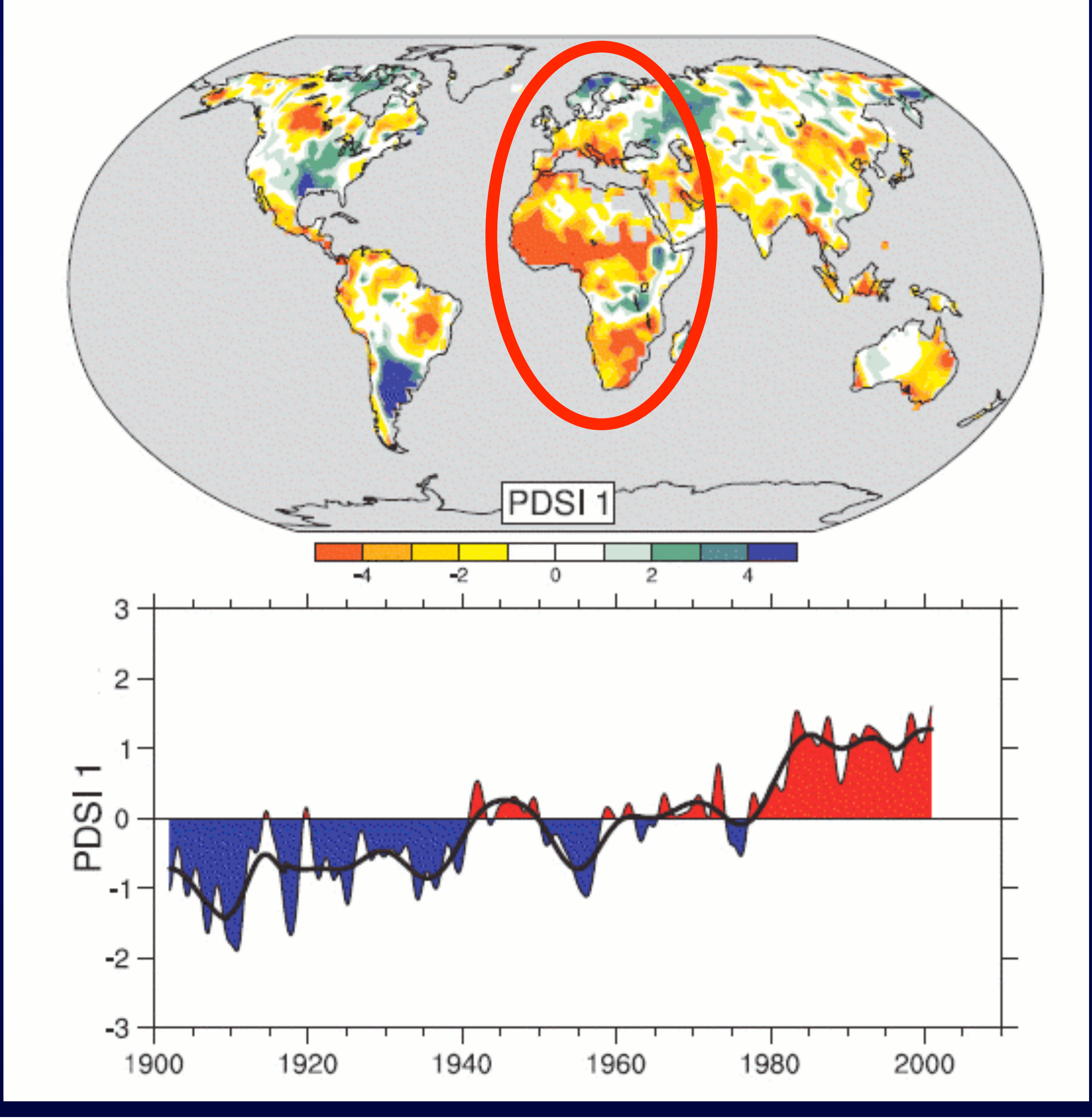
## Temperature and precipitation extremes

Increased frequency of heavy precipitation events

Warmer and more hot days, warmer and fewer cold days

Increased frequency of heat waves

# Other observed changes
## Droughts




Increase in length and intensity of droughts as measured by the PDSI

# IPCC 2007

Trends in some aspects of the hydrologic cycle have been observed. They are broadly consistent with what expected from GHG forcing but have not yet been attributed to it.

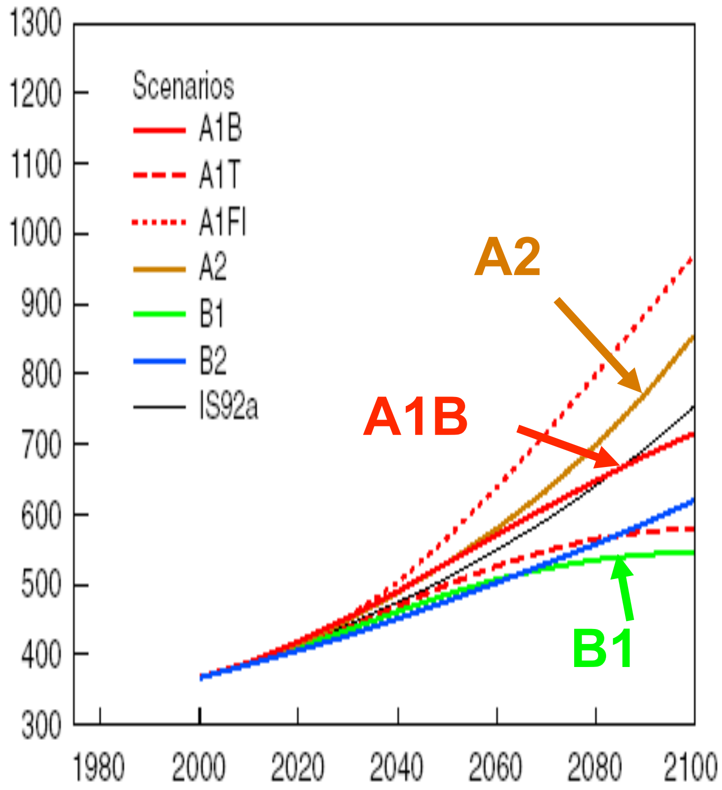

Projections of future
climate change

# The IPCC-CMIP3 Ensemble

## Models and simulations

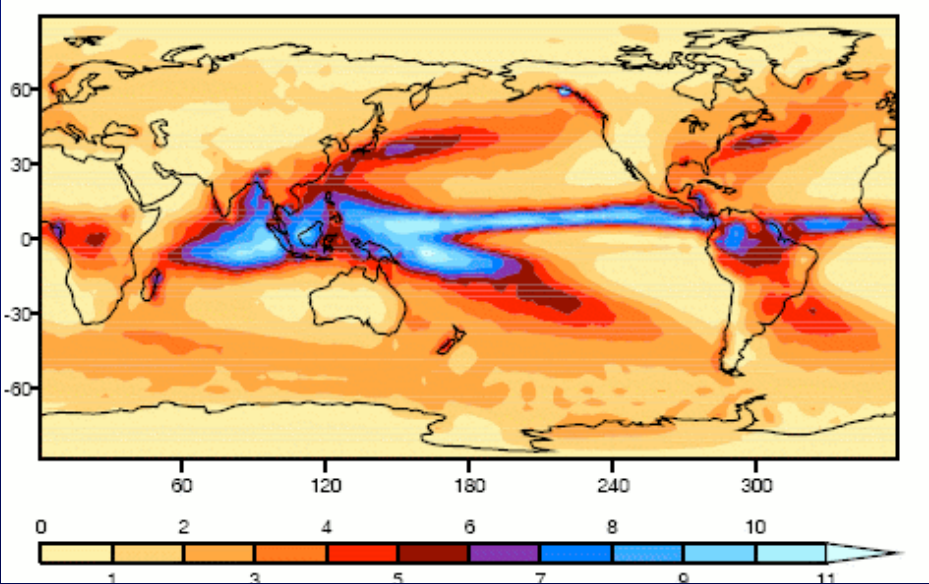
| Model | 20 Cent. | A1B | A2 | B1 |
|---|---|---|---|---|
| BCCR-BCM2-0 | 1 | - | 1 | 1 |
| CCMA-3-T47 | 5 | 4 | 2 | 4 |
| CNRM-CM3 | 1 | 1 | 1 | 1 |
| CSIRO-MK3 | 2 | 1 | 1 | 1 |
| GFDL-CM2-0 | 3 | 1 | 1 | 1 |
| GFDL-CM2-1 | 3 | 1 | 1 | - |
| GISS-AOM | 2 | 2 | - | 2 |
| GISS-EH | 5 | 4 | - | - |
| GISS-ER | 1 | 2 | 1 | 1 |
| IAP-FGOALS | 3 | 3 | - | 2 |
| INMCM3 | 1 | 1 | 1 | 1 |
| IPSL-CM4 | 1 | 1 | 1 | 1 |
| MIROC3-2H | 1 | 1 | - | 1 |
| MIROC3-2M | 3 | 3 | 3 | 3 |
| MIUB-ECHO-G | 5 | 3 | 3 | 3 |
| MPI-ECHAM5 | 3 | 2 | 3 | 3 |
| MRI-CGCM2 | 5 | 5 | 5 | 5 |
| NCAR-CCSM3 | 8 | 6 | 4 | 8 |
| NCAR-PCM1 | 4 | 3 | 4 | 2 |
| UKMO-HADCM3 | 1 | 1 | 1 | 1 |

## Scenarios

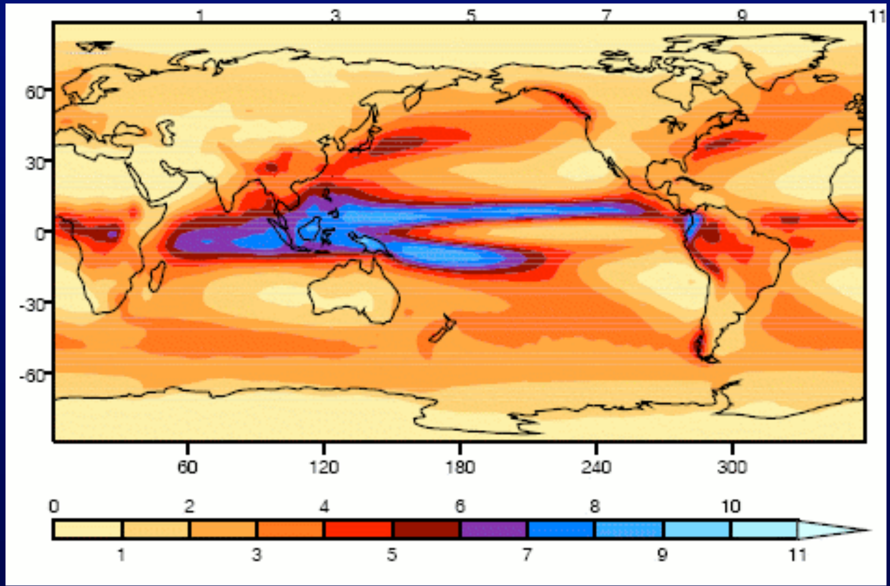


# Simulation of precipitation

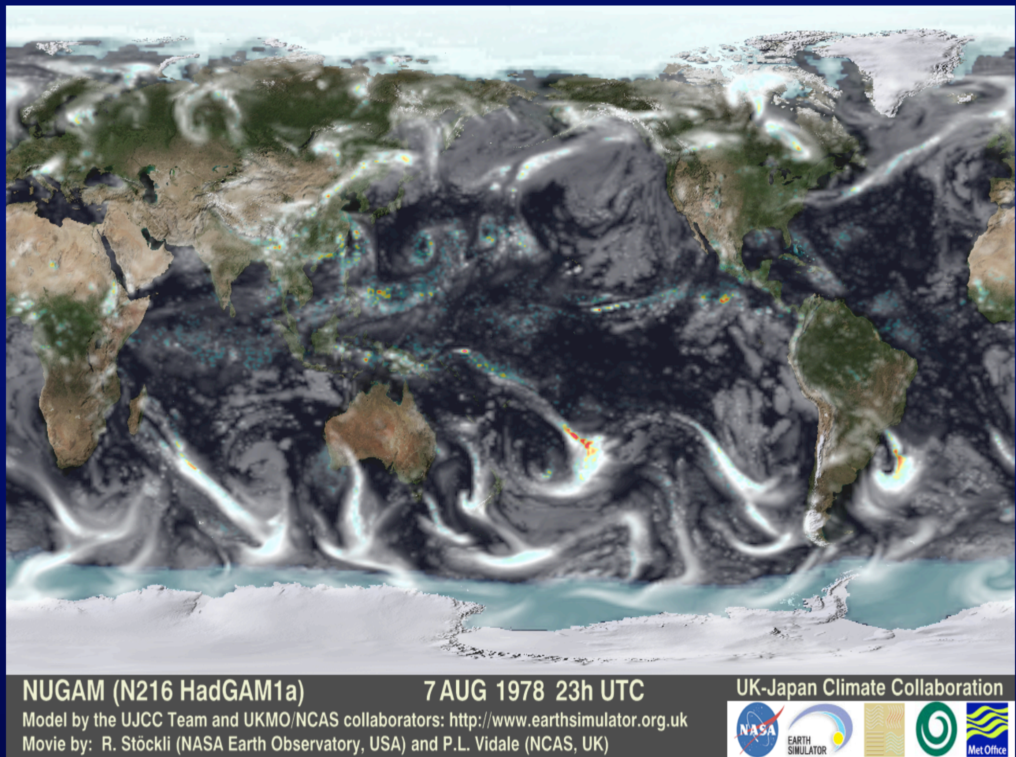
## Observations



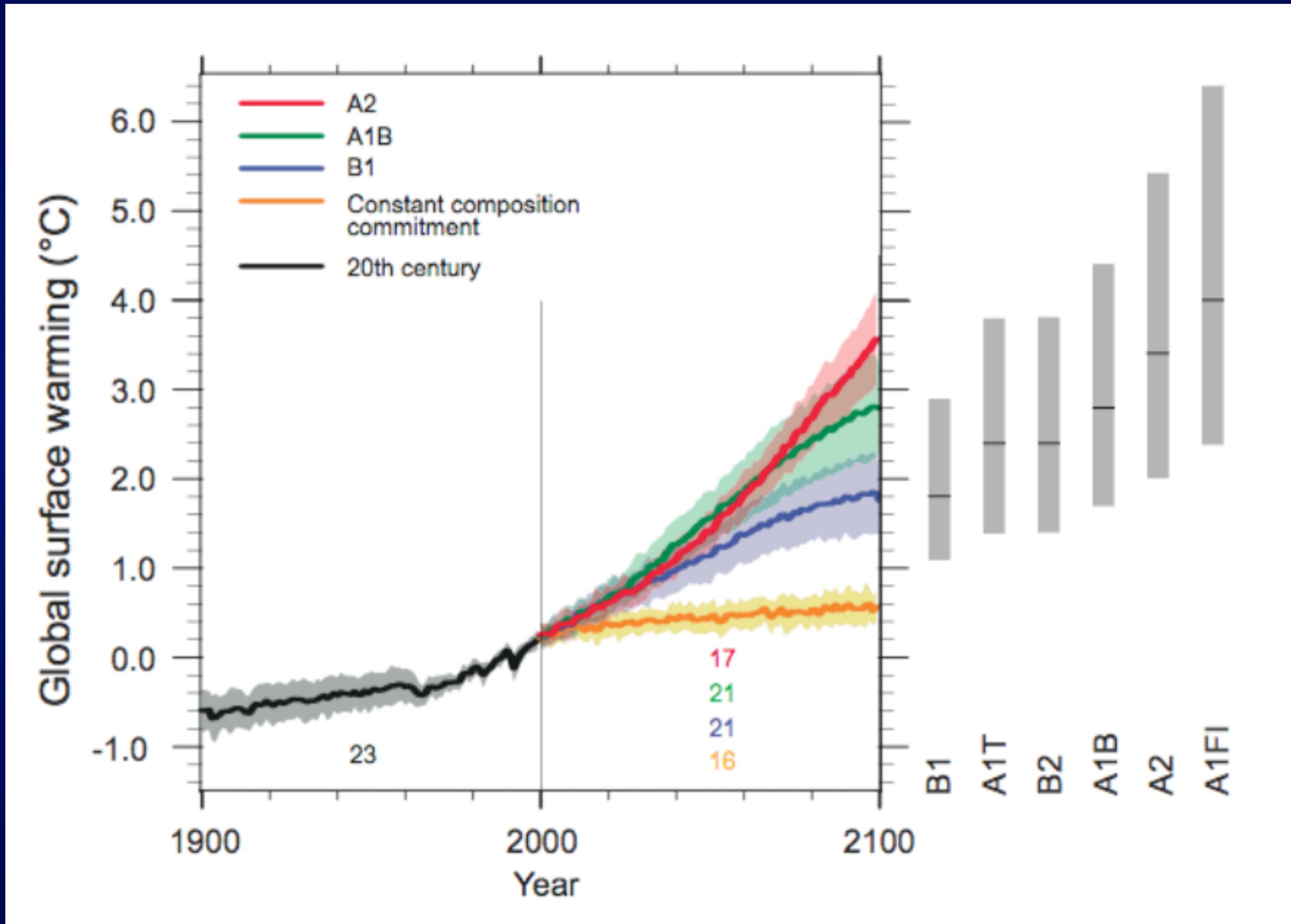

## CMIP3 Models



# High resolution models can produce a realistic description of synoptic systems




# IPCC – 2007: Global temperature change projections for the 21st century

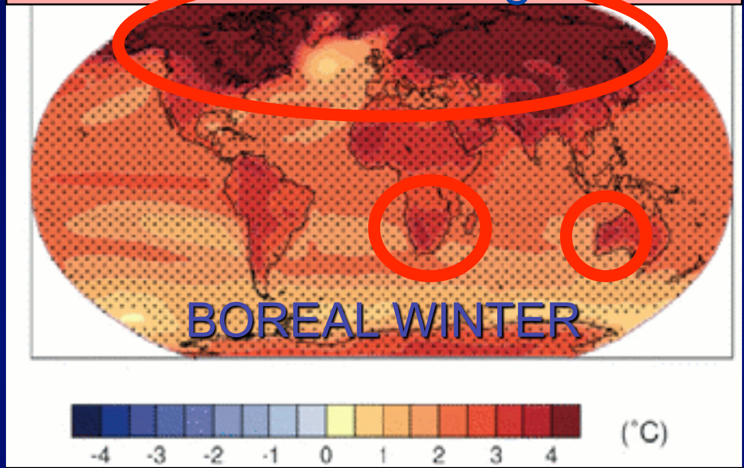



Corresponding changes in sea level rise are 19-58 cm

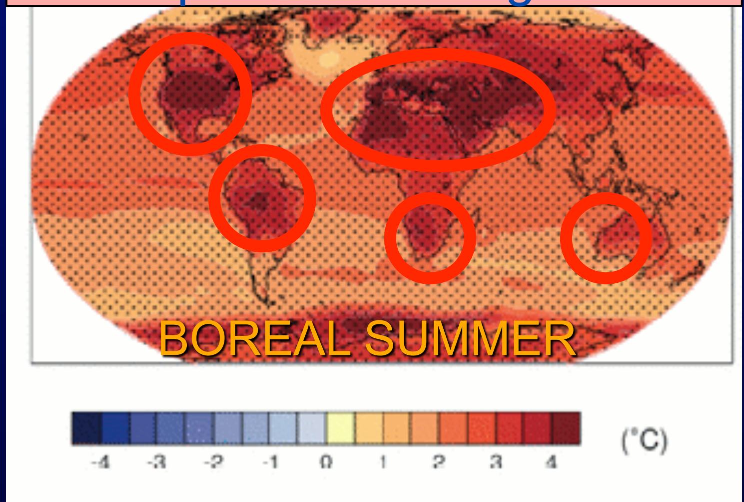
# Regional distribution of projected temperature and precipitation change

(A1B scenario, 2090-2100, 23 CMIP3 models)

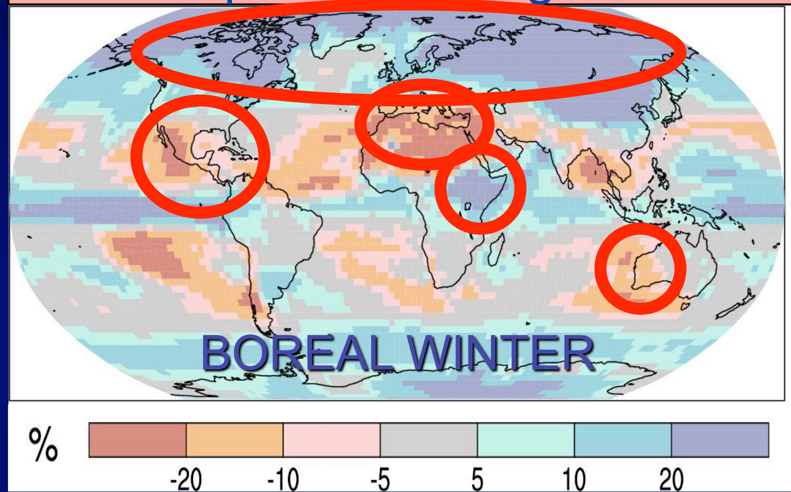
Temperature change DJF



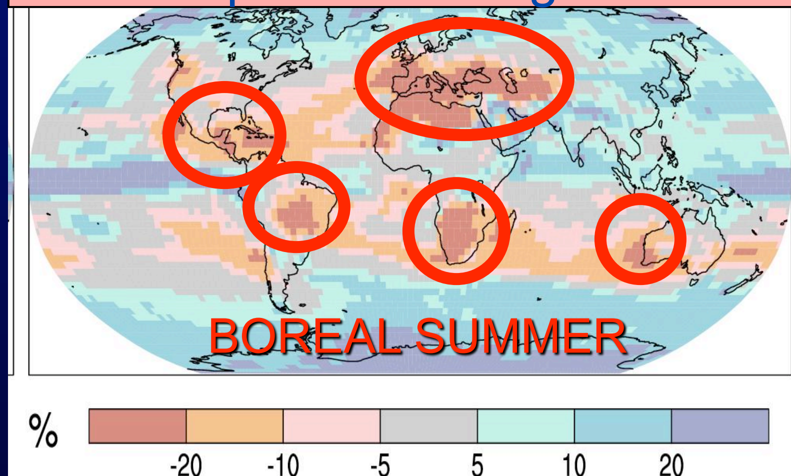

Temperature change JJA



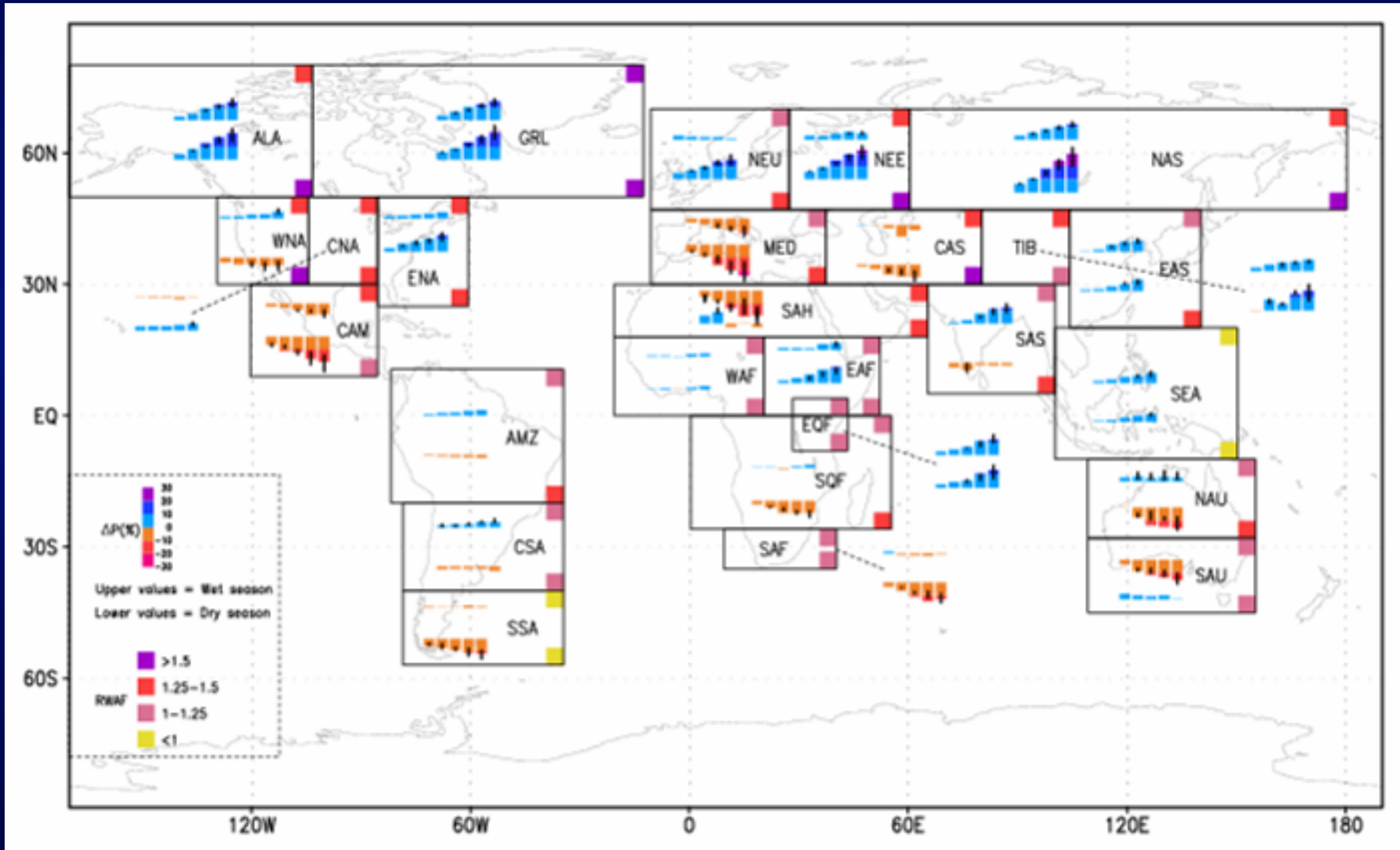

Precipitation change DJF



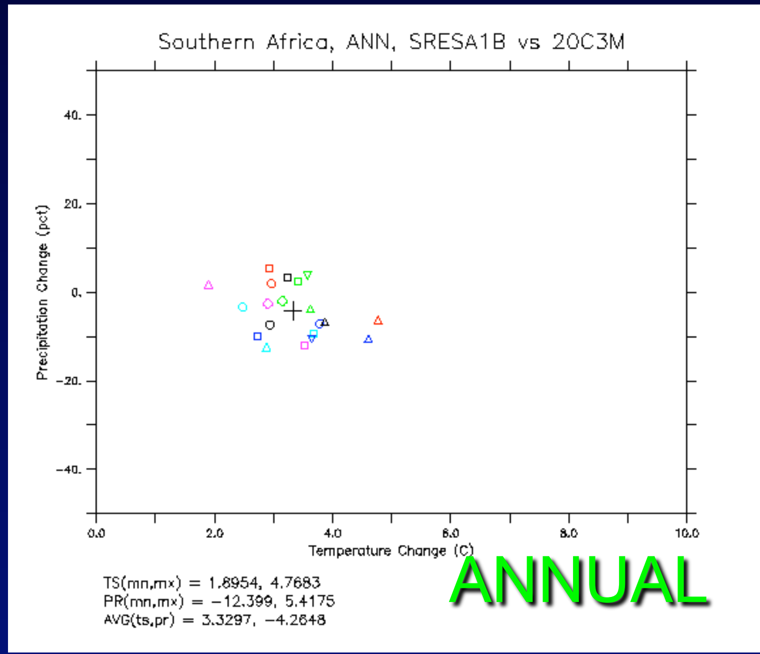

Precipitation change JJA

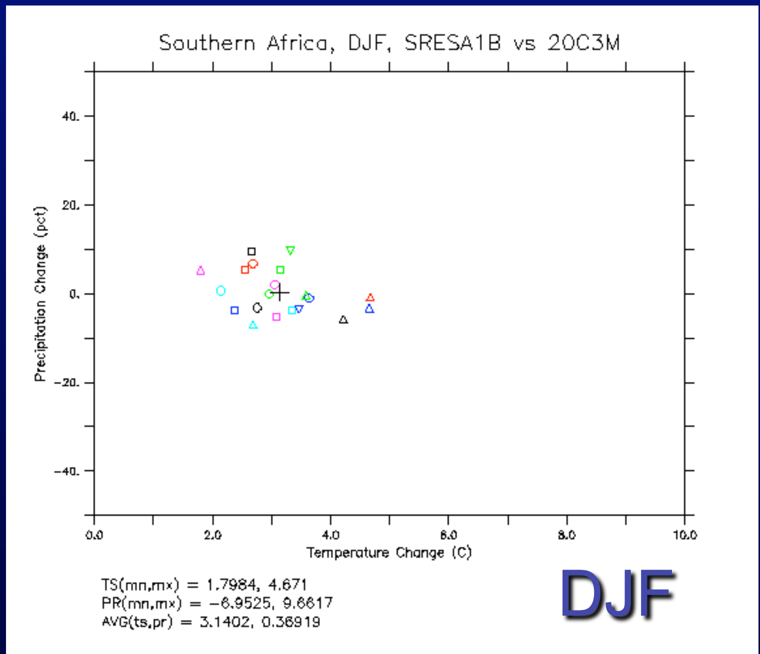


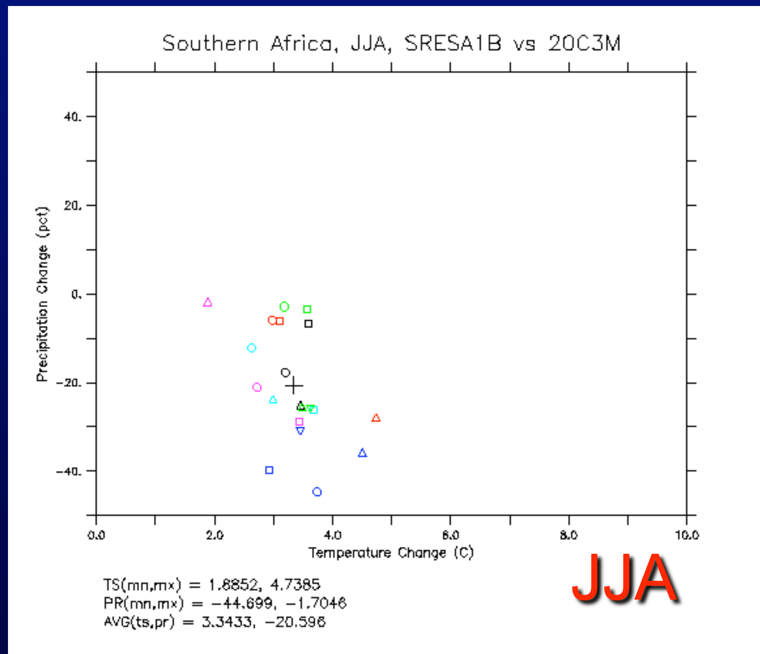
# Ensemble average regional precipitation changes for the 21st century (CMIP3 ensemble)



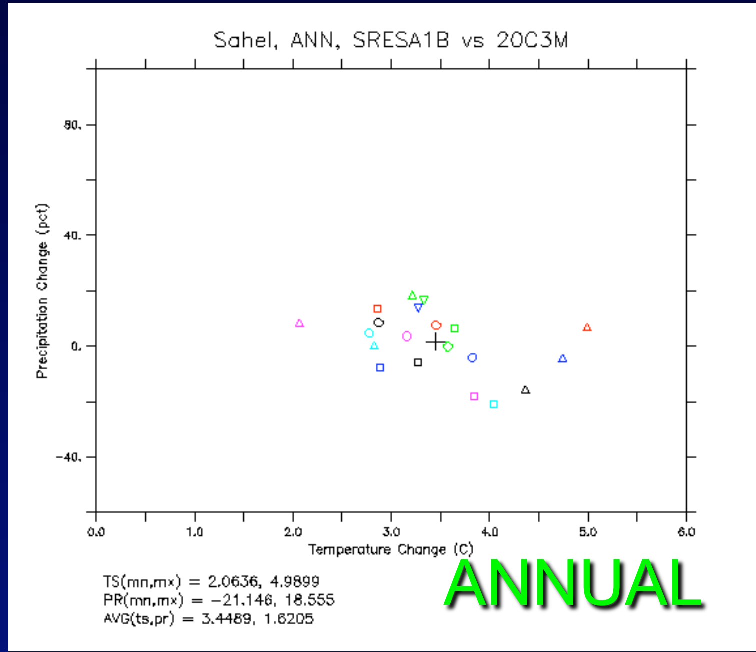
# Southern Africa region, P-change vs. T-change (2079-2098) – (1979-1998) A1B scenario, 21 models

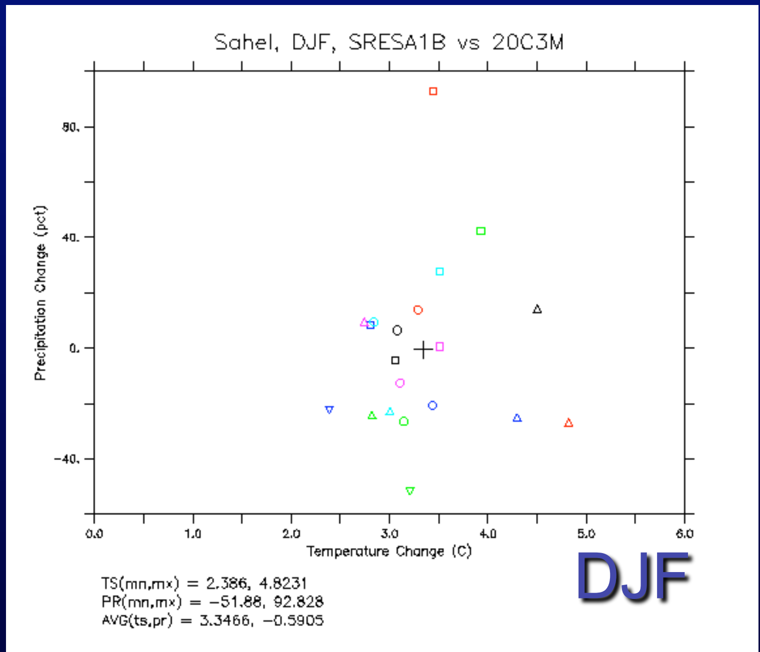


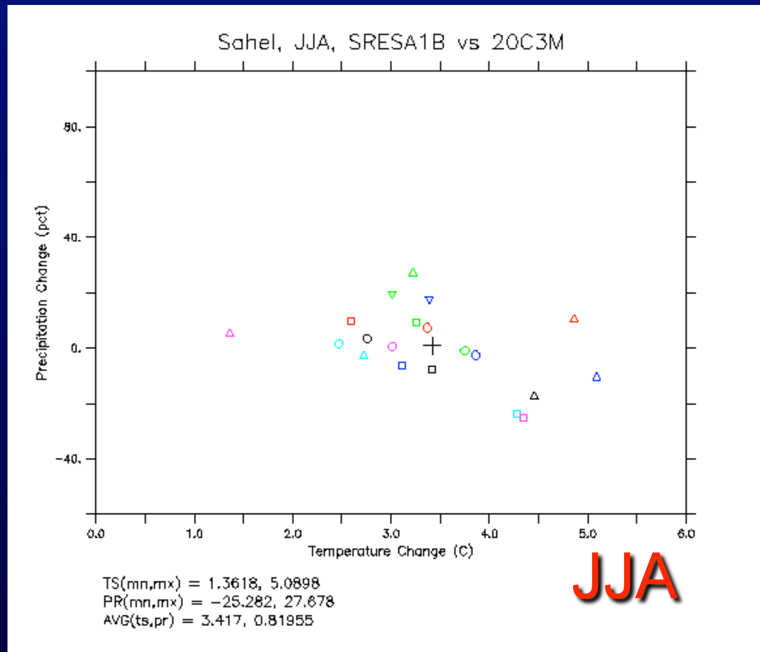



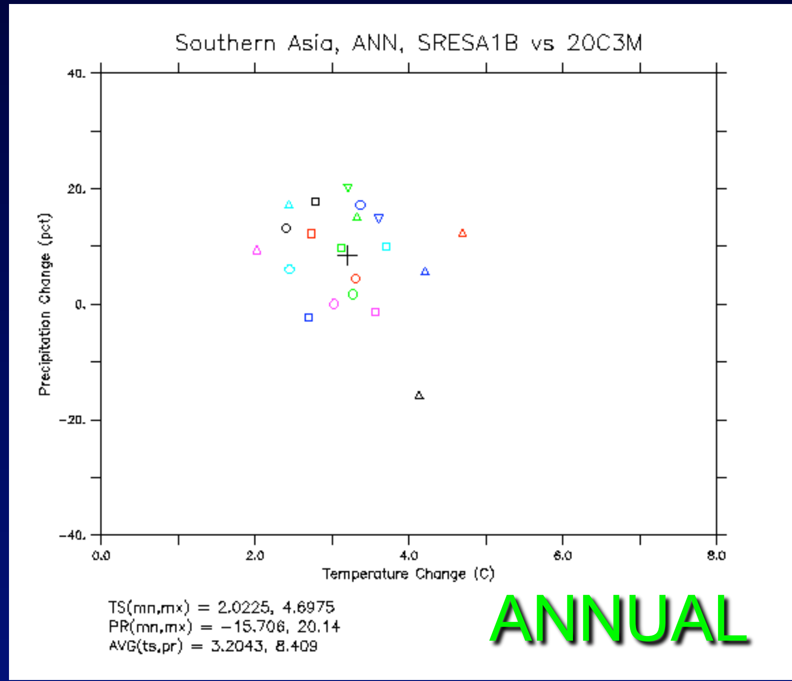
# Sahel region, P-change vs. T-change (2079-2098) – (1979-1998) A1B scenario, 21 models

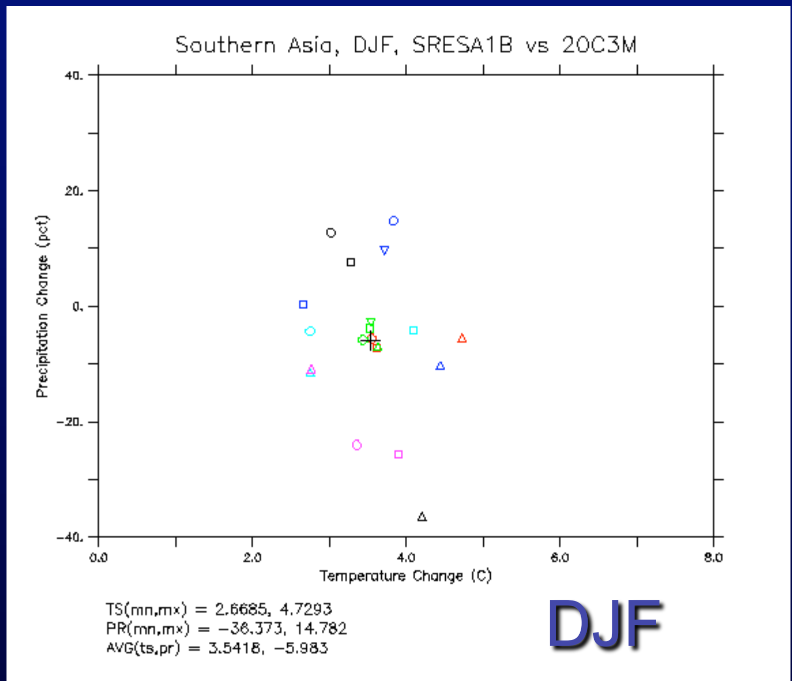


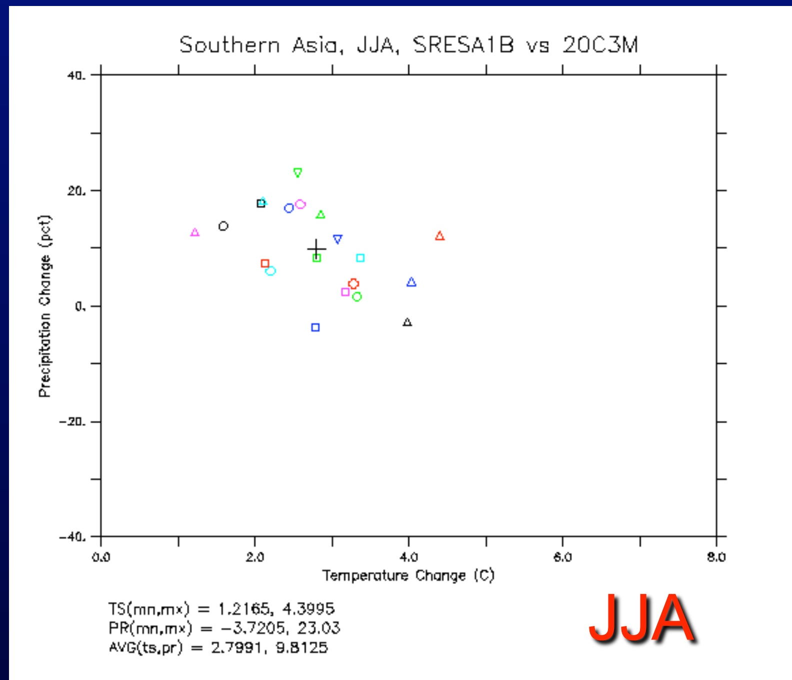



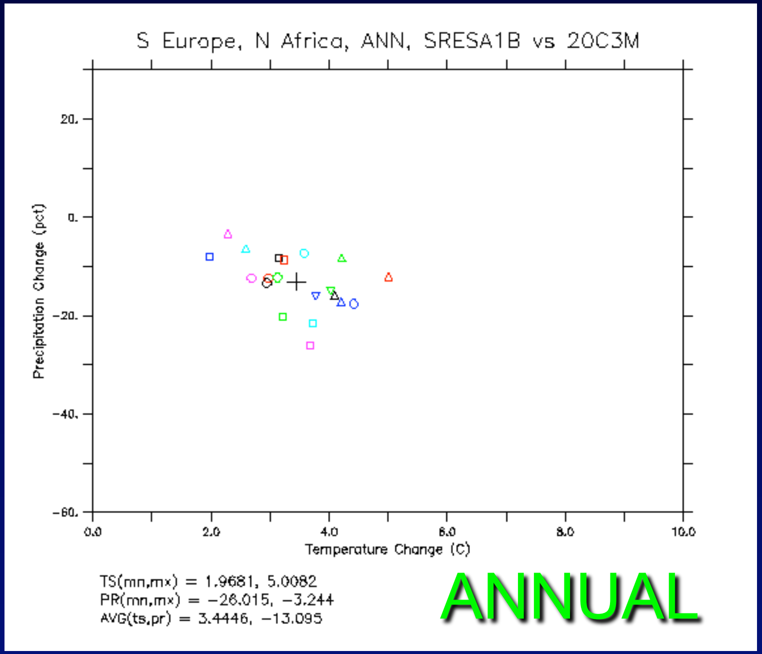
# South Asia region,
# P-change vs. T-change
# (2079-2098) – (1979-1998)
# A1B scenario, 21 models

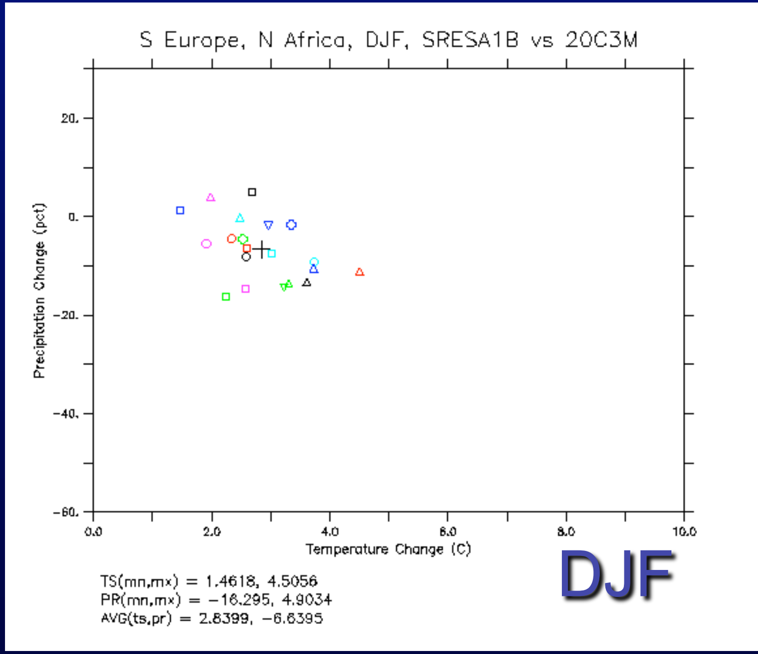


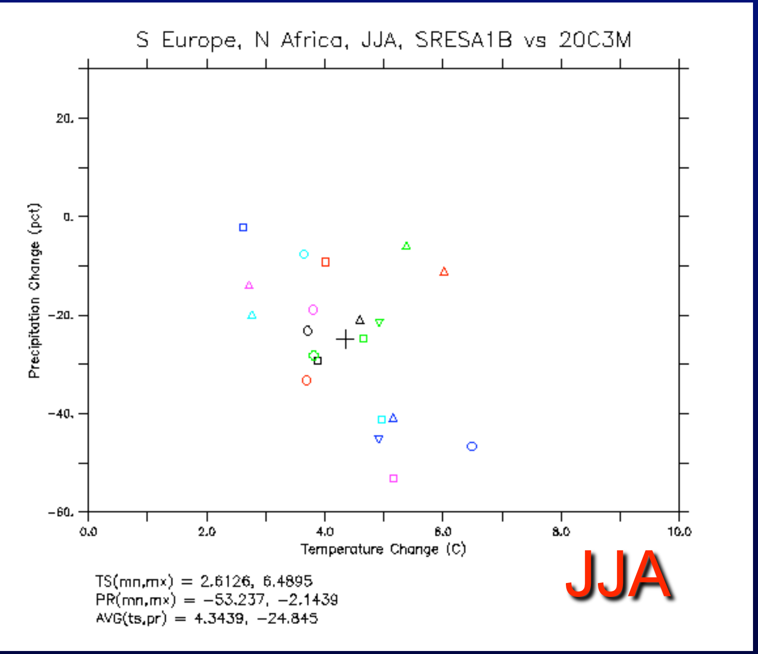



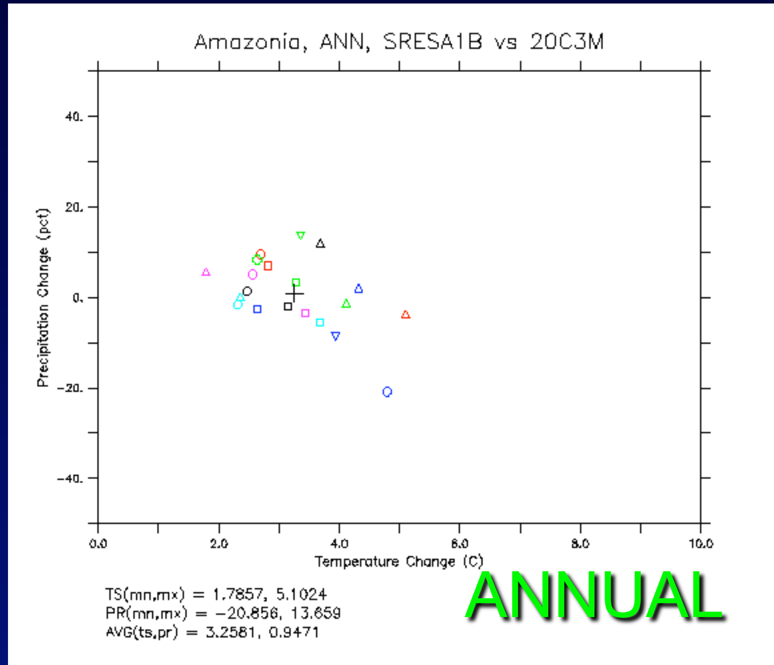
# Mediterranean region, P-change vs. T-change (2079-2098) – (1979-1998) A1B scenario, 21 models

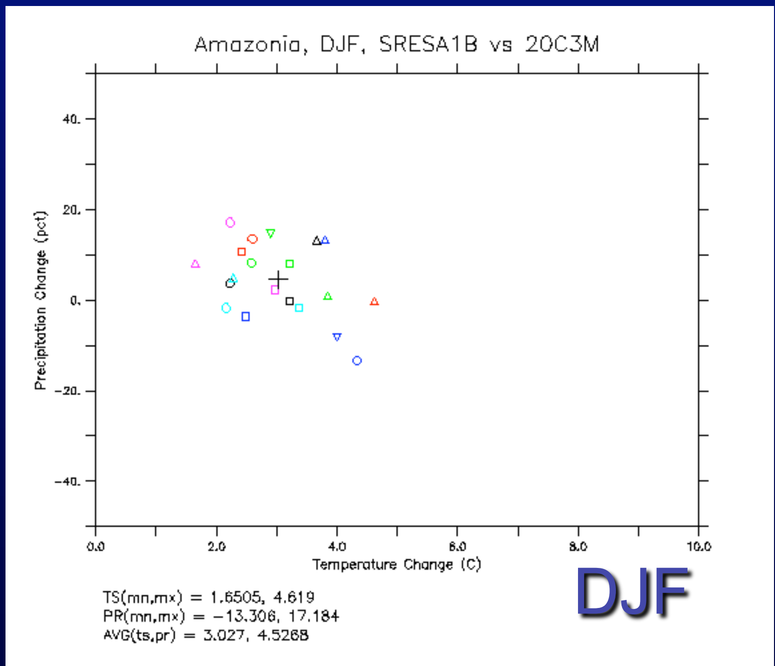


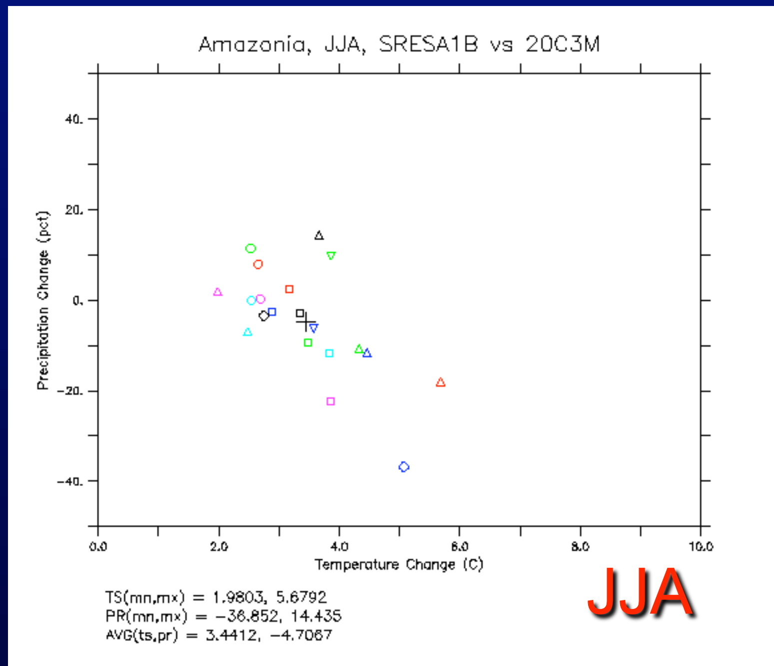



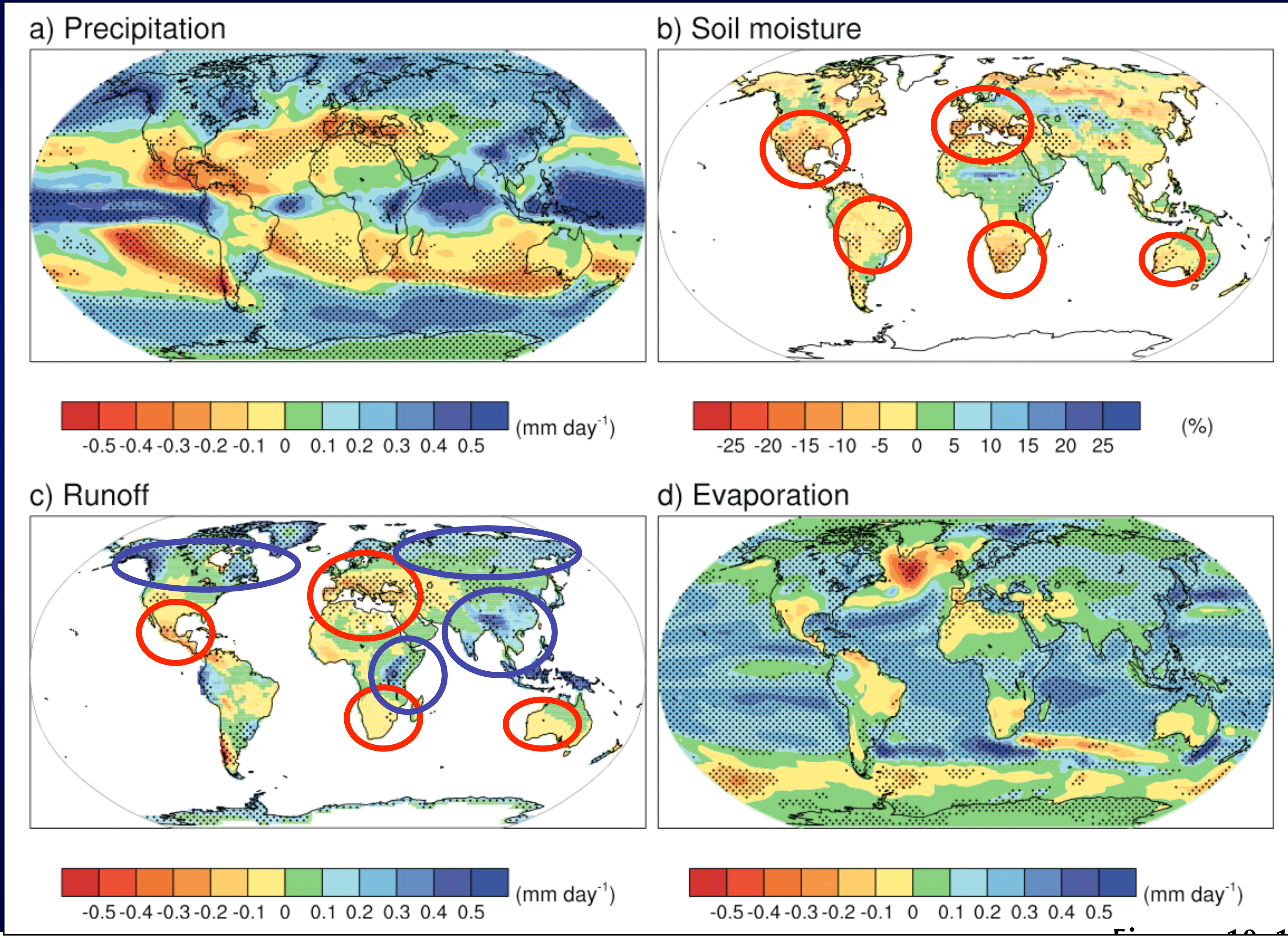
Amazonia region,
P-change vs. T-change
(2079-2098) – (1979-1998)
A1B scenario, 21 models



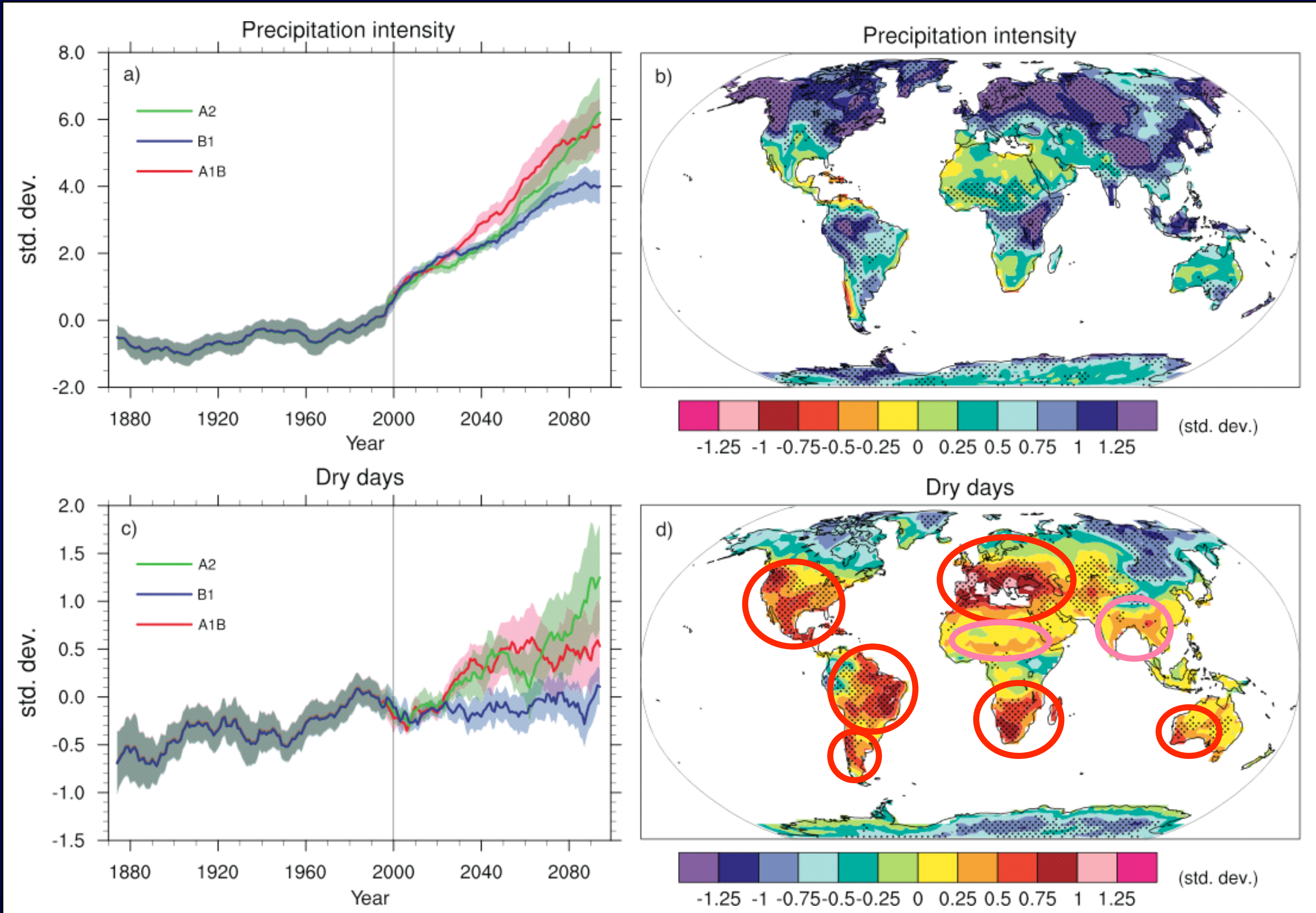



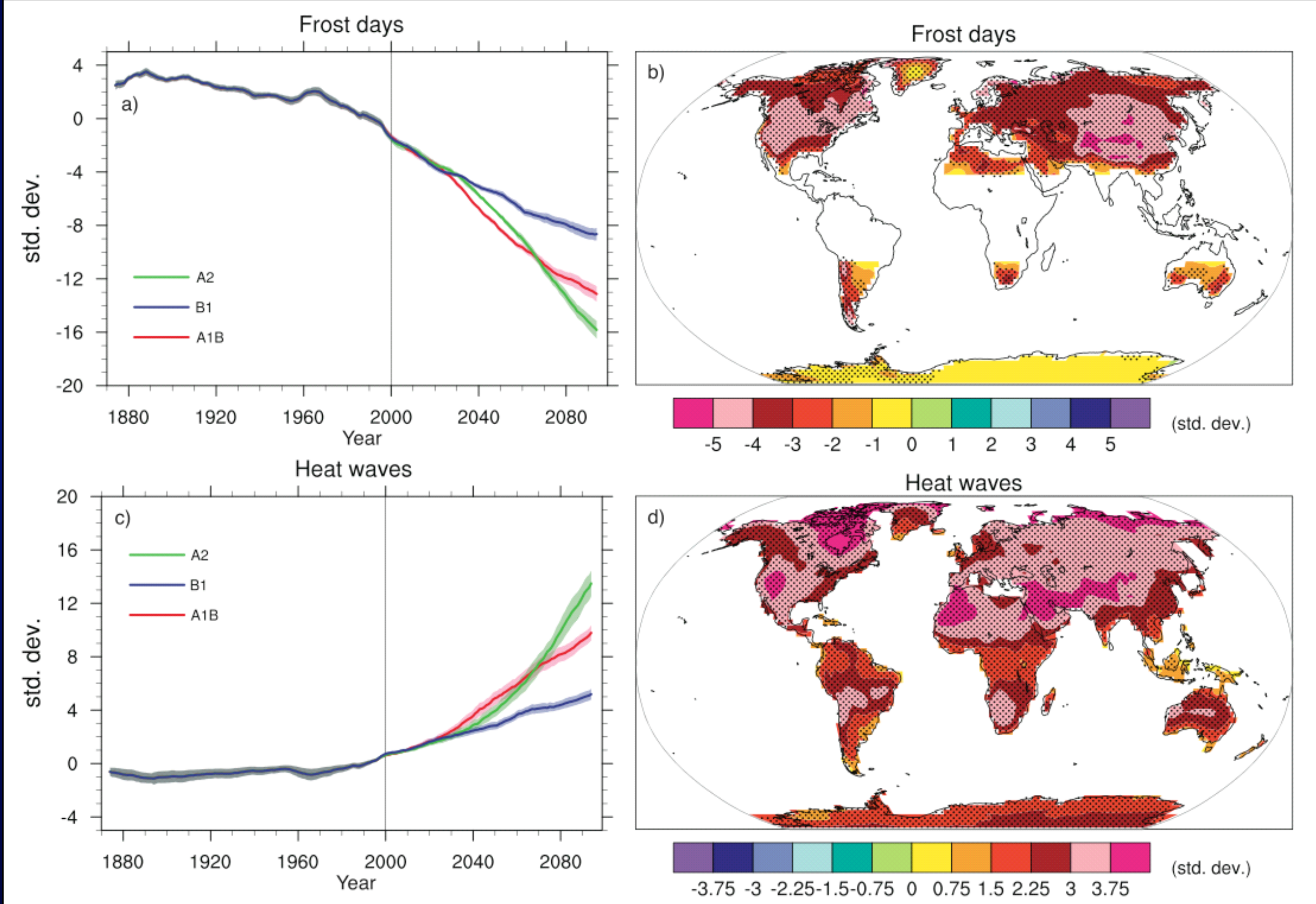
# Projected changes in the hydrologic cycle

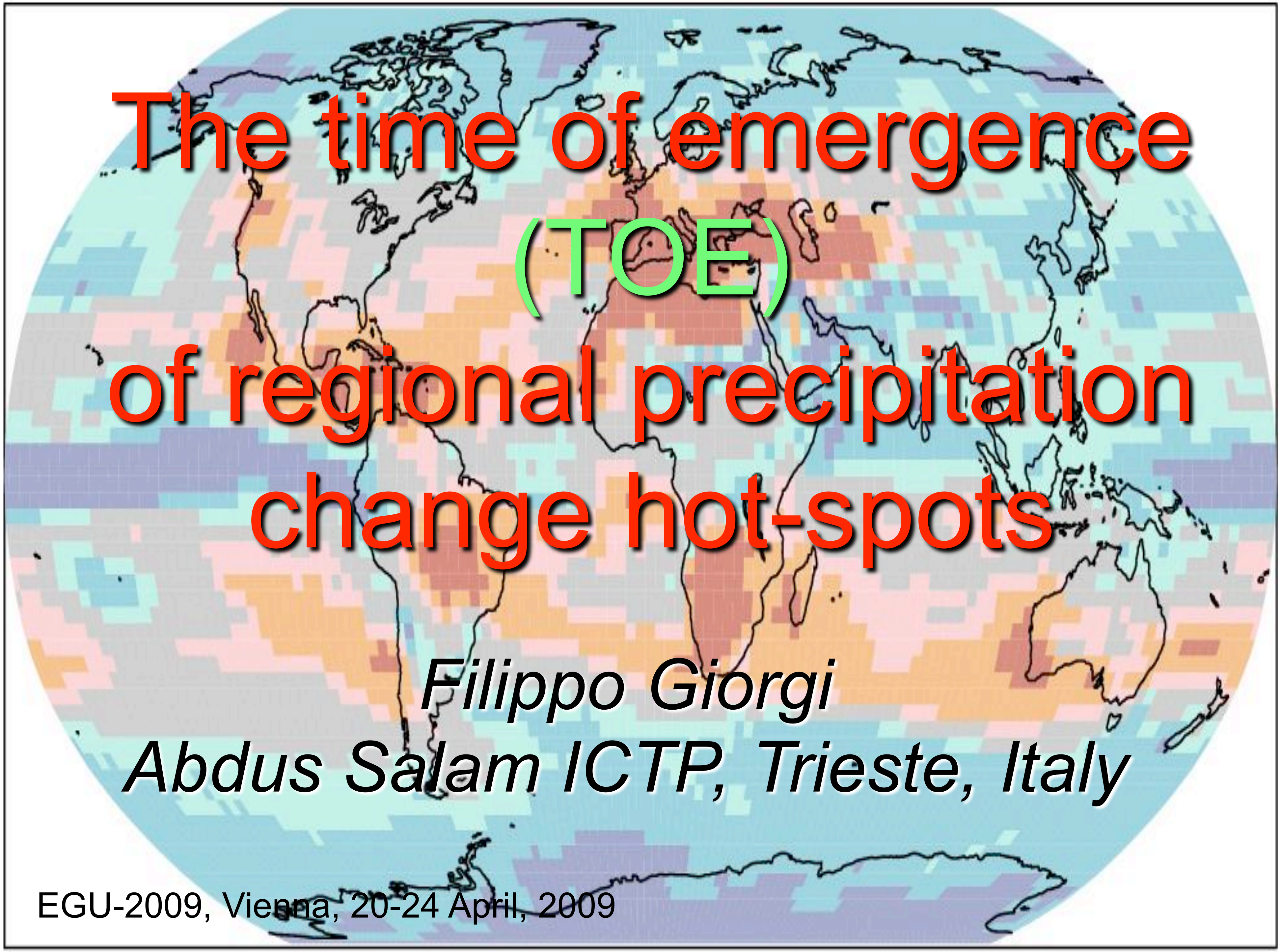


# Changes in precipitation characteristics



# Projected changes in extremes

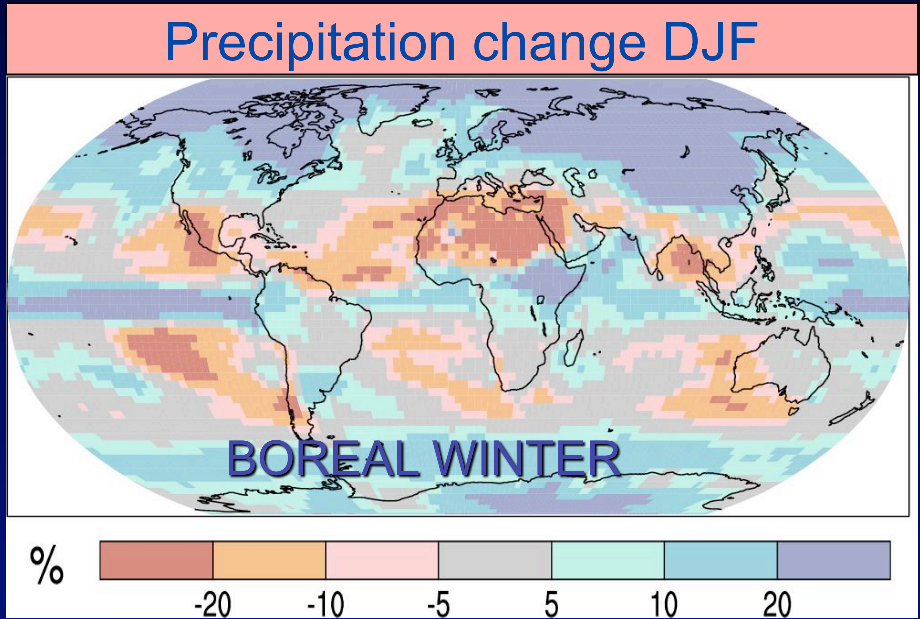


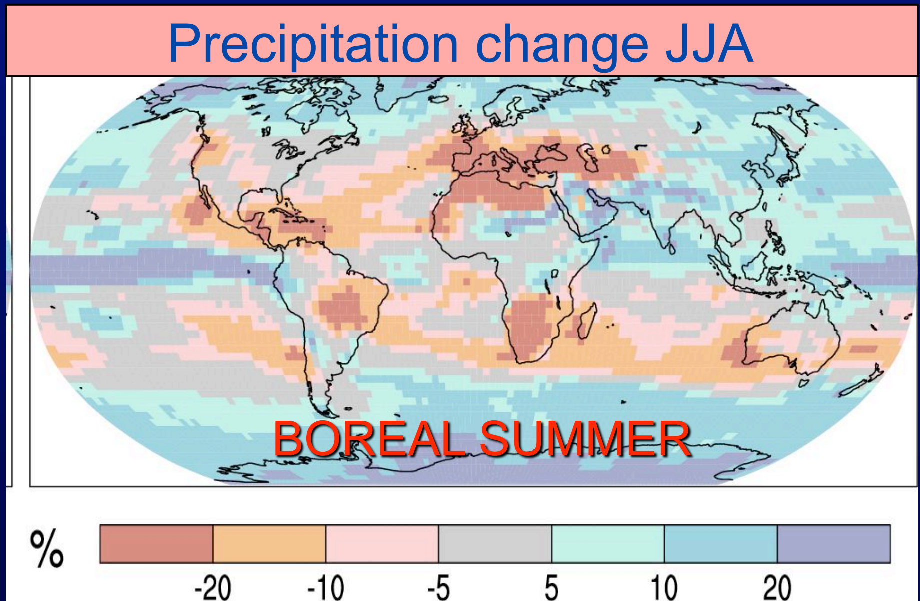


# The time of emergence (TOE) of regional precipitation change hot-spots

*Filippo Giorgi*
*Abdus Salam ICTP, Trieste, Italy*

EGU-2009, Vienna, 20-24 April, 2009



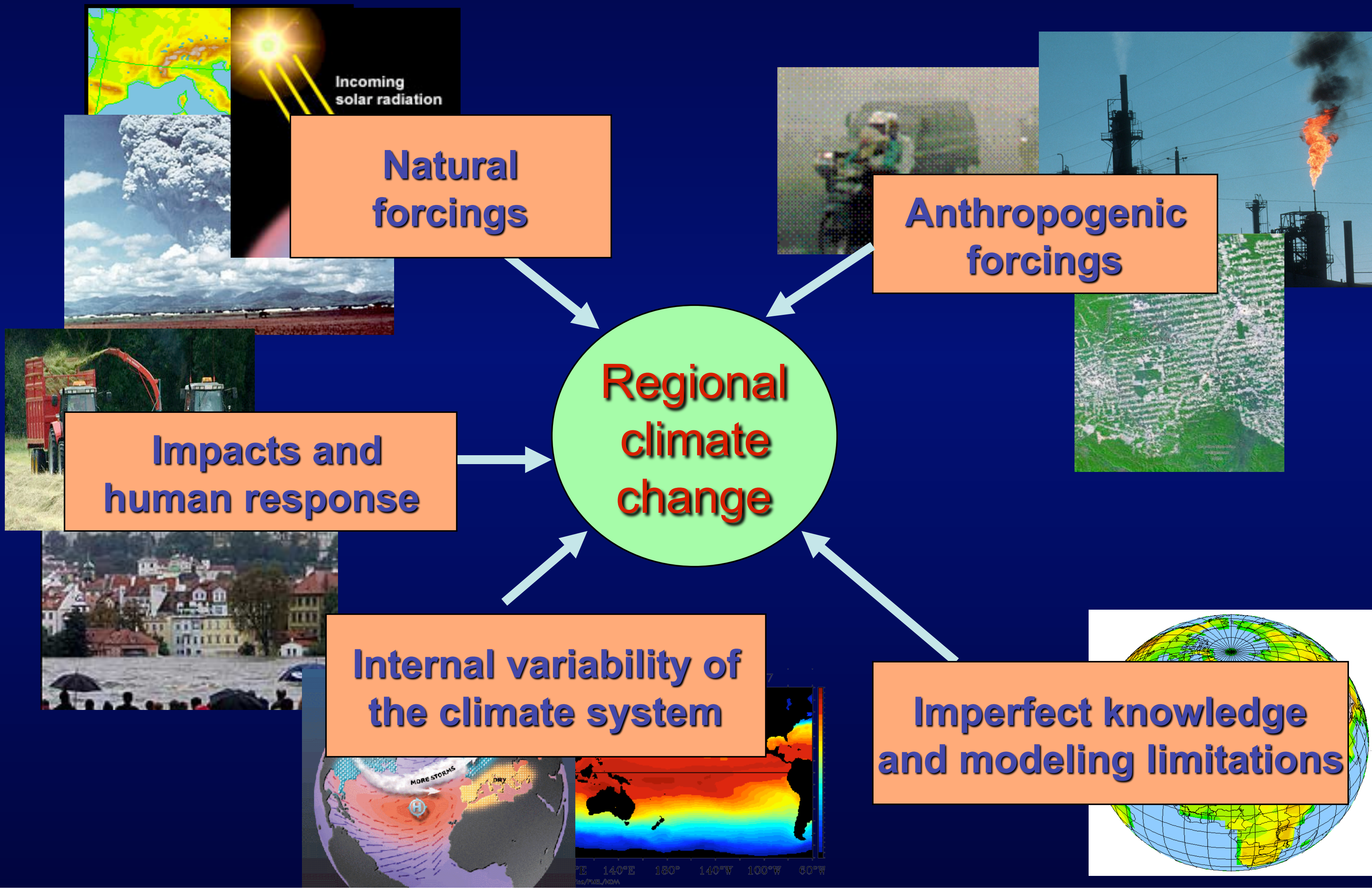

Climate model projections suggest the presence of consistent precipitation change patterns or hot-spots (PSPOTs)

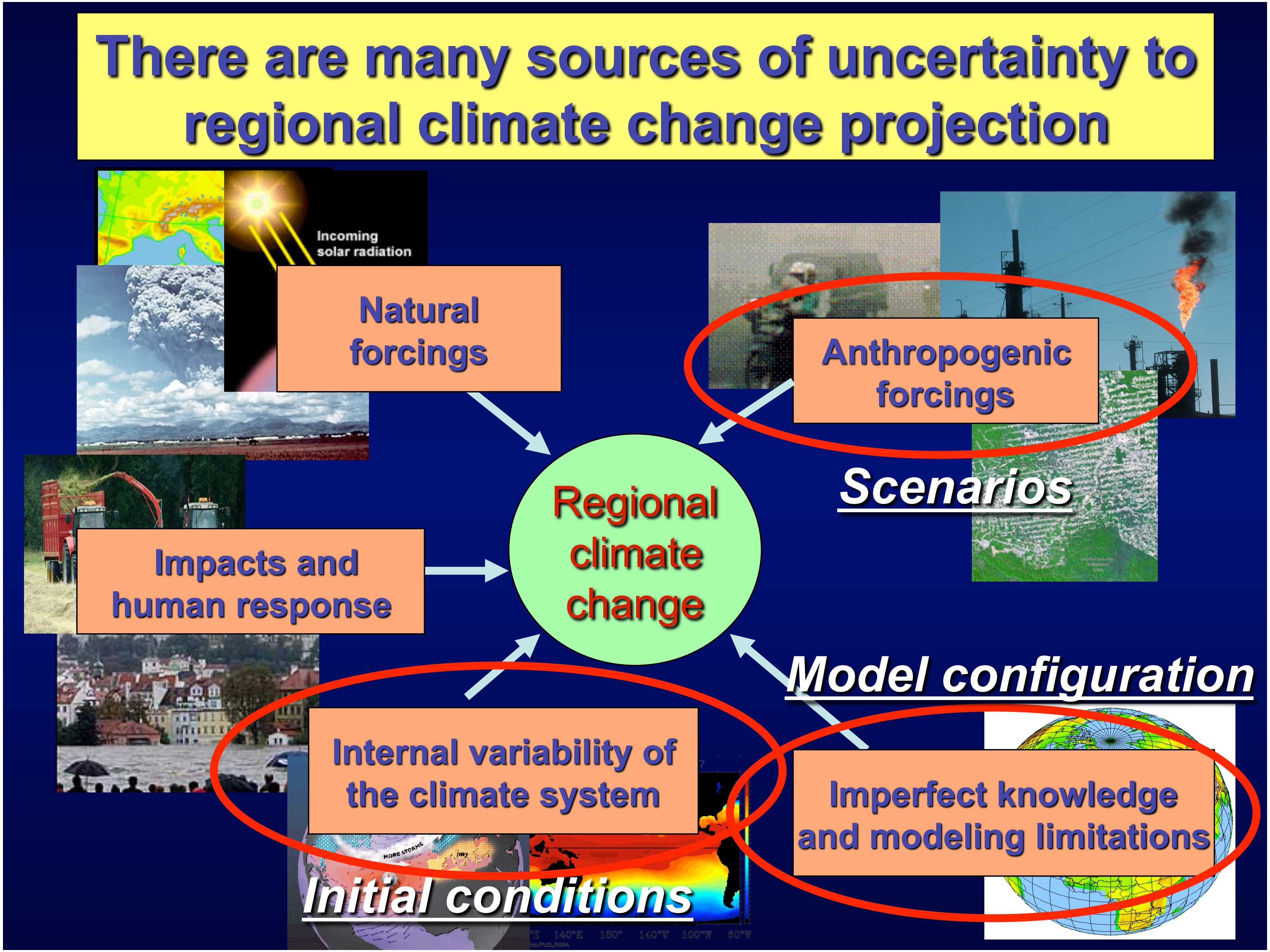
**When can we expect them to emerge from the underlying noise ?**

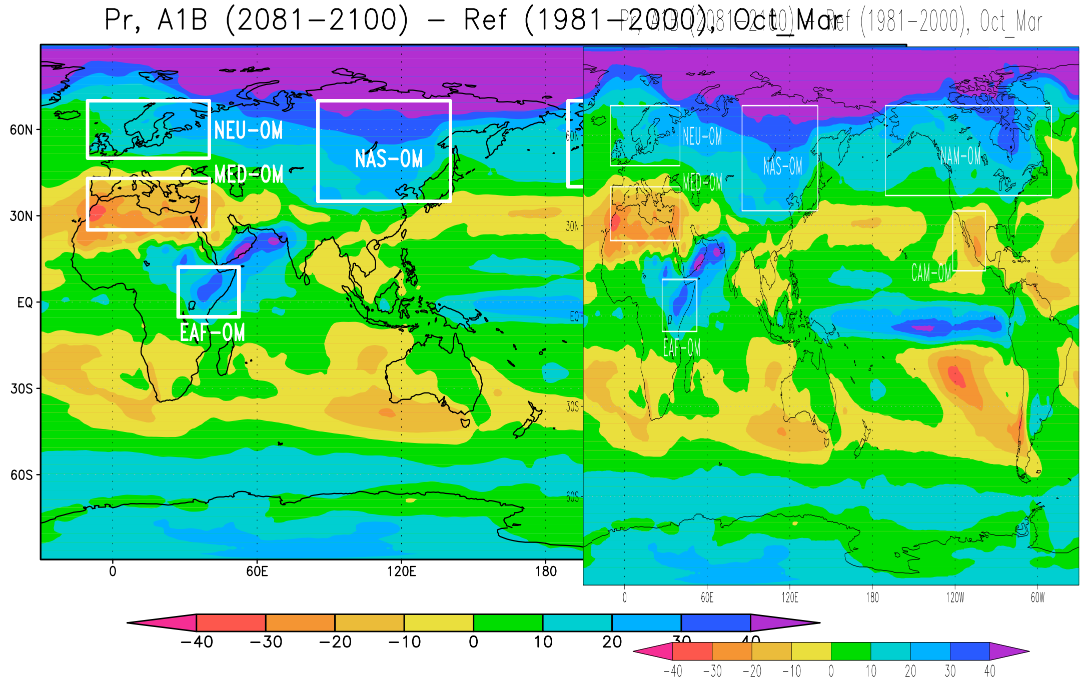
Issue of relevance for detection/attribution, decadal predictability impact/adaptation

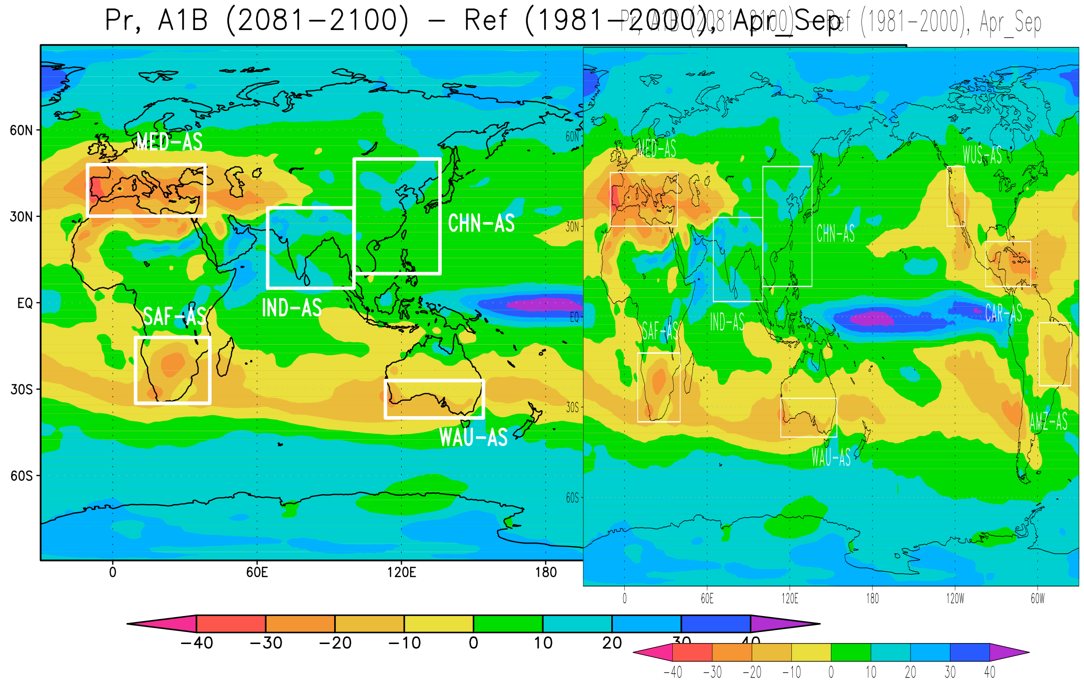
**Giorgi and Bi, GRL, 2009**

# There are many sources of uncertainty to regional climate change projection




There are many sources of uncertainty to regional climate change projection
Incoming
solar radiation
Natural forcings
Anthropogenic forcings
Scenarios
Impacts and human response
Regional climate change
Model configuration
Internal variability of the climate system
Imperfect knowledge and modeling limitations
Initial conditions




**14 land PSPOTS are subjectively identified from the ensemble mean projected precipitation change (2081-2100 vs. 1981-2000 CMIP3 models)**

# Definition of the Time of Emergence (TOE)

Signal = Ensemble average ΔP_20

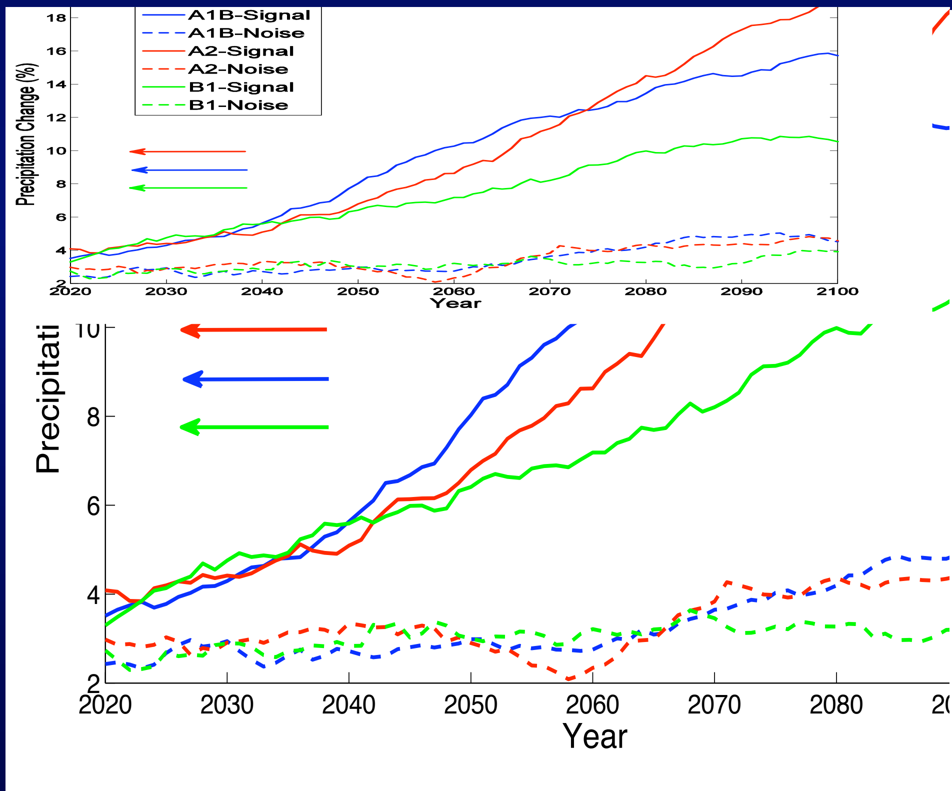
Noise = sqrt(VAR_im20 + VAR_iv20)

TOE = signal/noise > 0

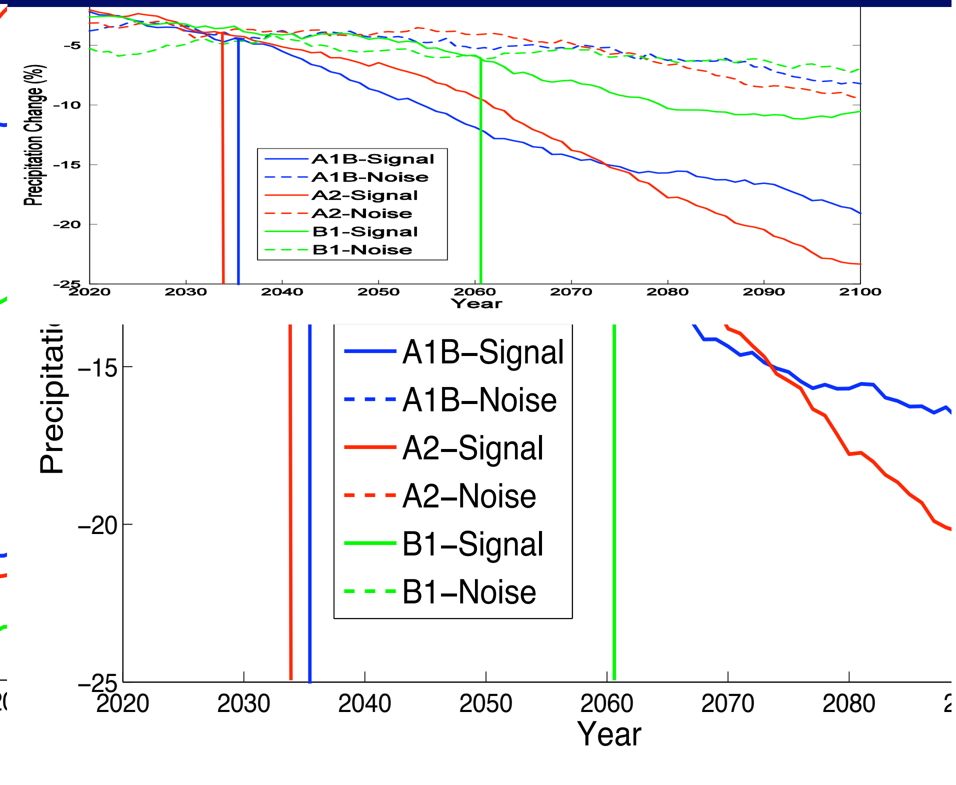
Calculations performed for each emission scenario

# The evolution of signal vs. noise for some PSPOTs (CMIP3 models)

## NEU - OM




## MED - AS



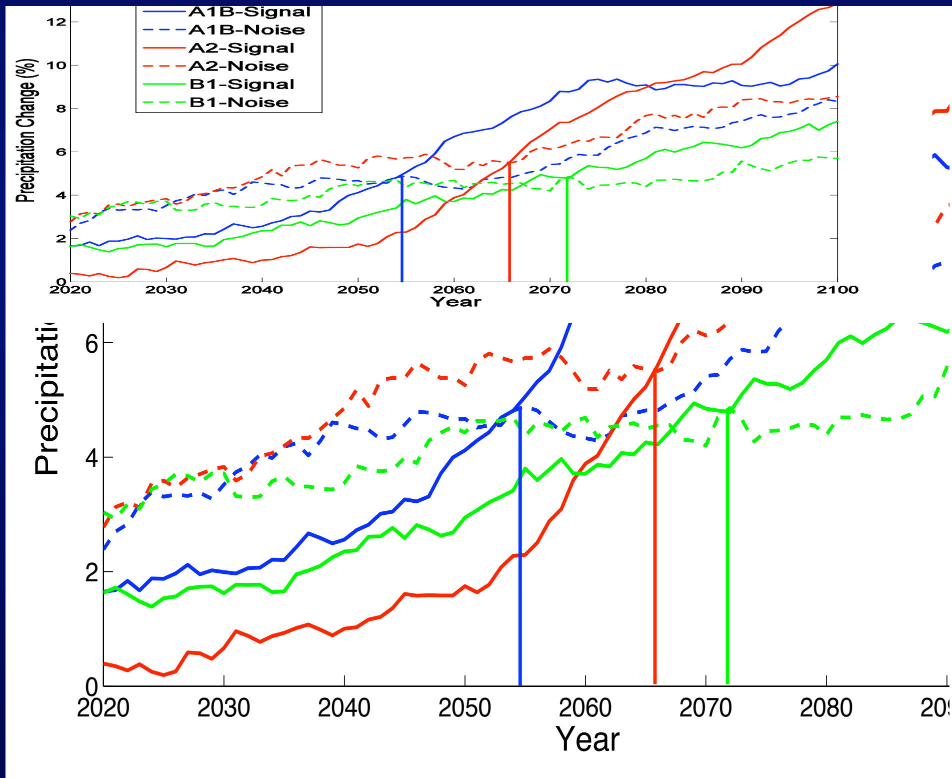

(NAS – OM, NAS – OM)

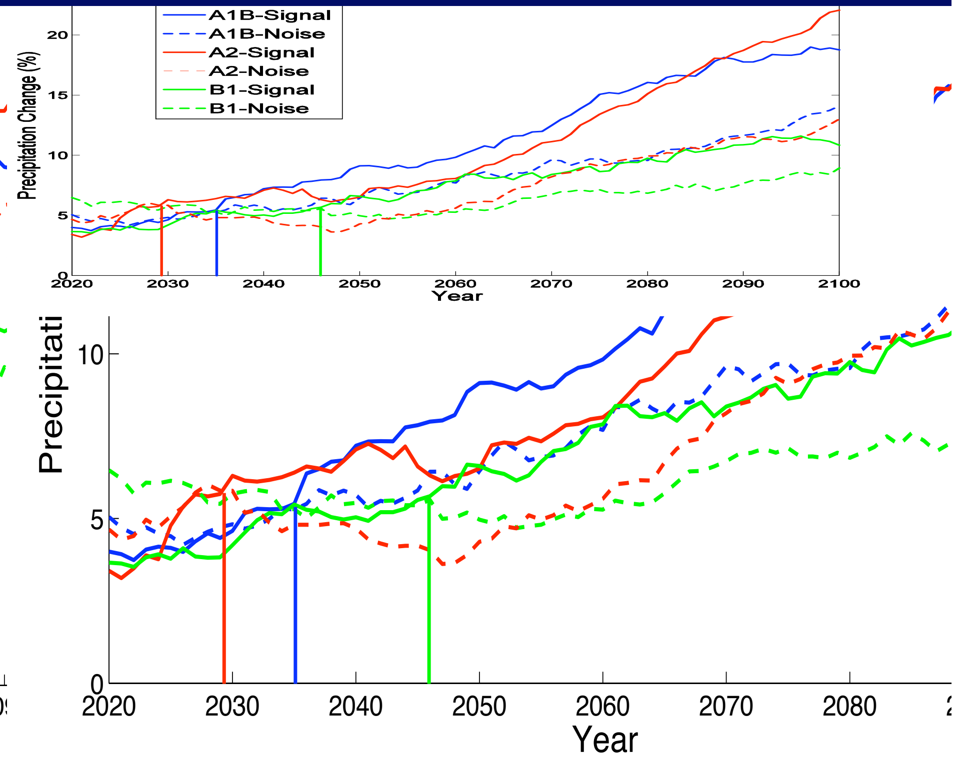
(MED – OM)

# The evolution of signal vs. noise for some PSPOTs (CMIP3 models)

IND - AS

EAF - OM

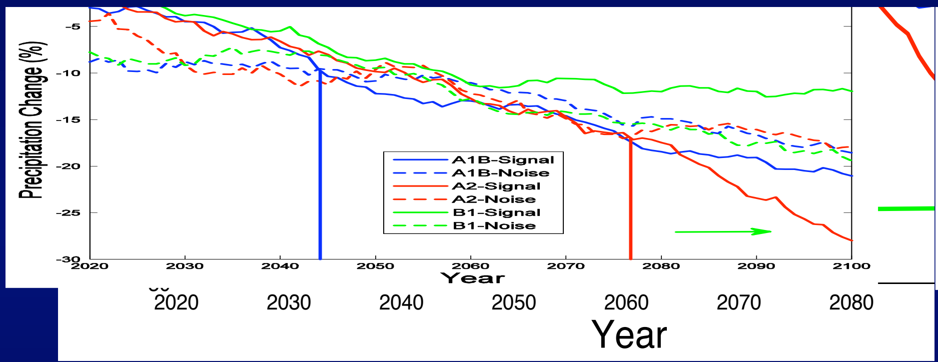


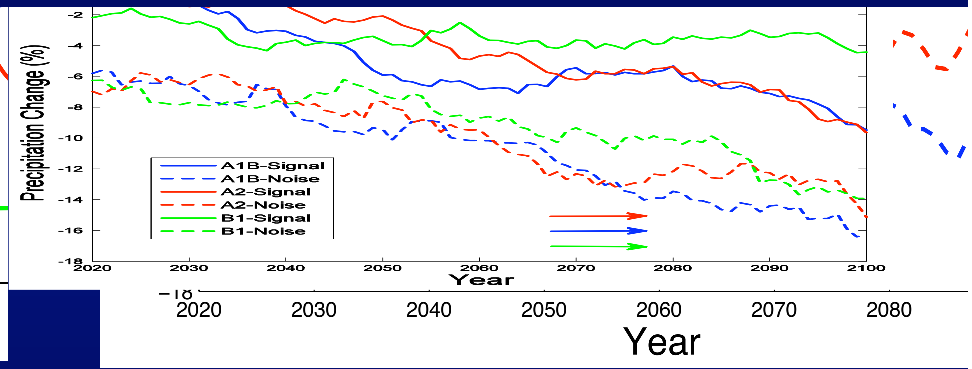

(CHN-AS)

# The evolution of signal vs. noise for some PSPOTs (CMIP3 models)

CAR - AS

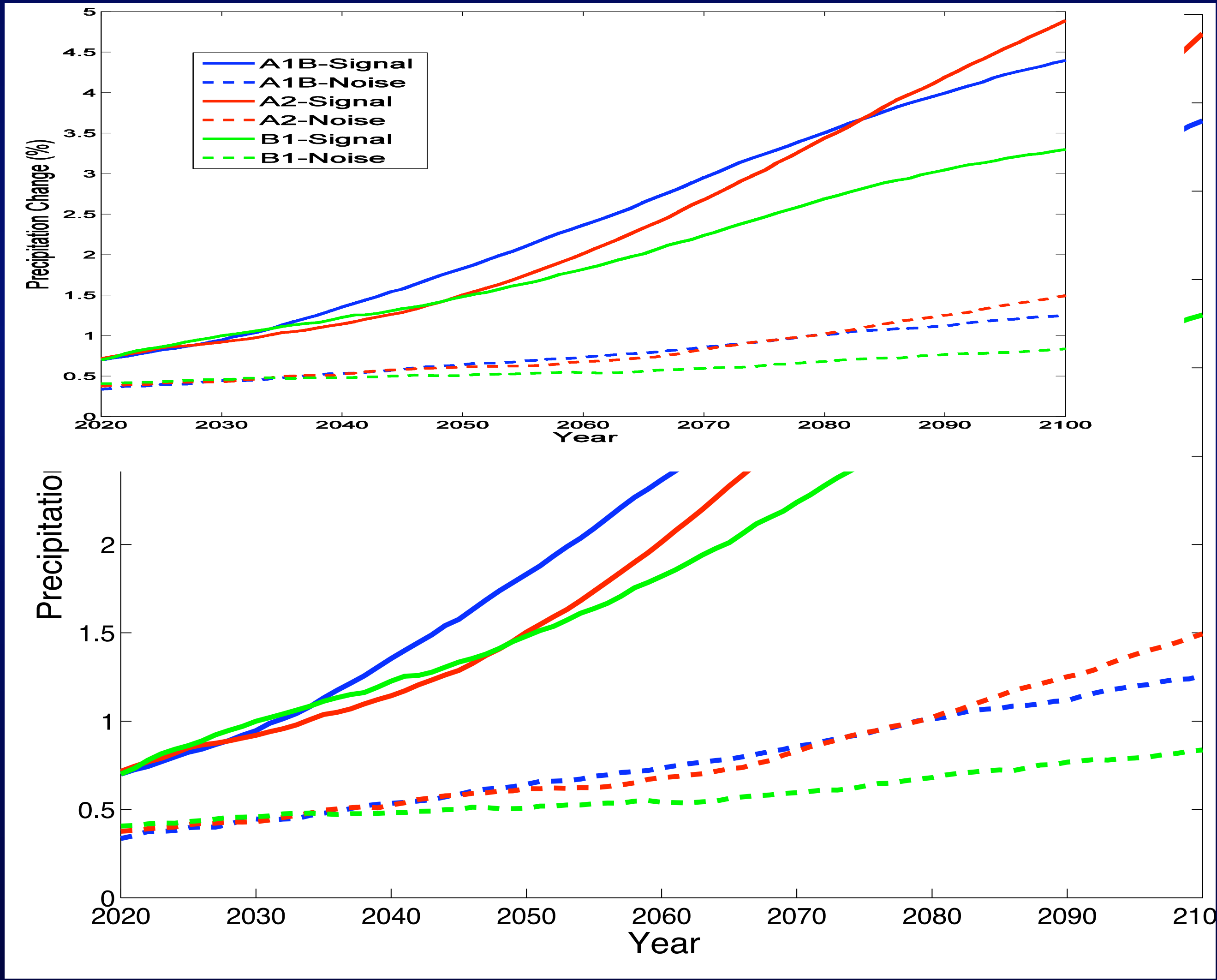



AMZ - AS




(SAF-AS, SAU-AS, WUS-AS, CAM-OM)

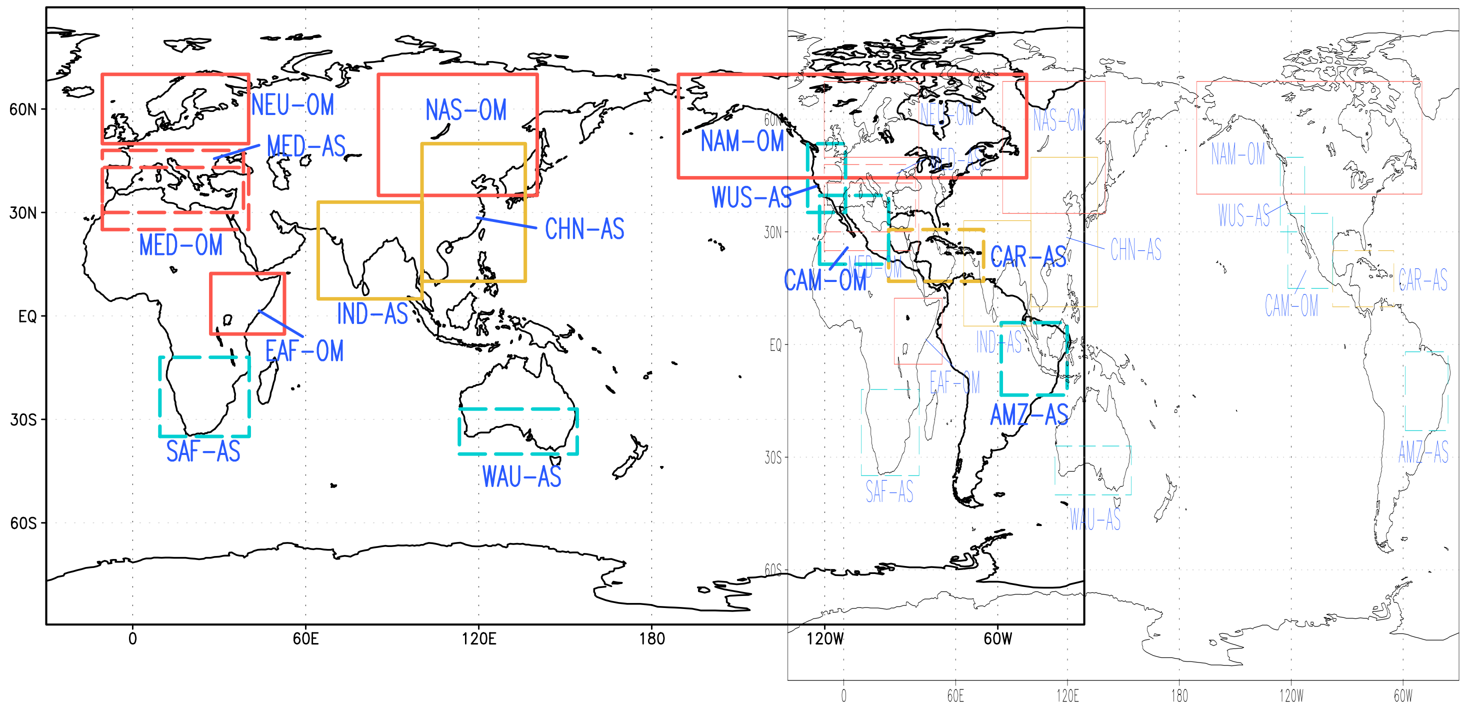
# The evolution of signal vs. noise for global precipitation (CMIP3 models)



# Definition of PSPOTs and values of TOE

| PSPOT | Latitude | Longitude | TOE-B1 | TOE-A1B | TOE-A2 |
|---|---|---|---|---|---|
| NEU-OM | 50 N – 70 N | 10.5 W – 40.5 E | <2020 | <2020 | <2020 |
| MED-AS | 30 N – 48 N | 10.5 W – 38.5 E | 2056 | 2023 | 2022 |
| MED-OM | 25 N – 43 N | 10.5 W – 40.5 E | 2025 | 2025 | 2032 |
| NAS-OM | 35 N – 70 N | 85.5 E – 140.5 E | <2020 | <2020 | <2020 |
| CHN-AS | 10 N – 50 N | 100.5 E – 140.5 E | 2047 | 2047 | 2058 |
| IND-AS | 5 N – 33 N | 64.5 E – 100.5 E | 2066 | 2052 | 2065 |
| EAF-OM | 5 S – 12 N | 27.5 E – 52.5 E | 2044 | 2029 | 2028 |
| SAF-AS | 35 S – 12 S | 9.5 E – 40.5 E | >2100 | 2043 | >2100 |
| NAM-OM | 40 N – 70 N | 170.5 W – 49.5 W | <2020 | <2020 | <2020 |
| WUS-AS | 30 N – 50 N | 125.5 W – 112.5 W | >2100 | >2100 | 2040 |
| CAM-OM | 15 N – 35 N | 121.5 W – 97.5 W | >2100 | 2090 | 2063 |
| CAR-AS | 10 N – 25 N | 97.5 W – 64.5 W | >2100 | 2044 | 2077 |
| AMZ-AS | 23 S – 2 S | 58.5 W – 35.5 W | >2100 | >2100 | >2100 |
| SAU-AS | 40 S – 27 S | 113.5 E – 154.5 E | >2100 | >2100 | >2100 |

# The time of emergence of GHG-forced PSPOTs

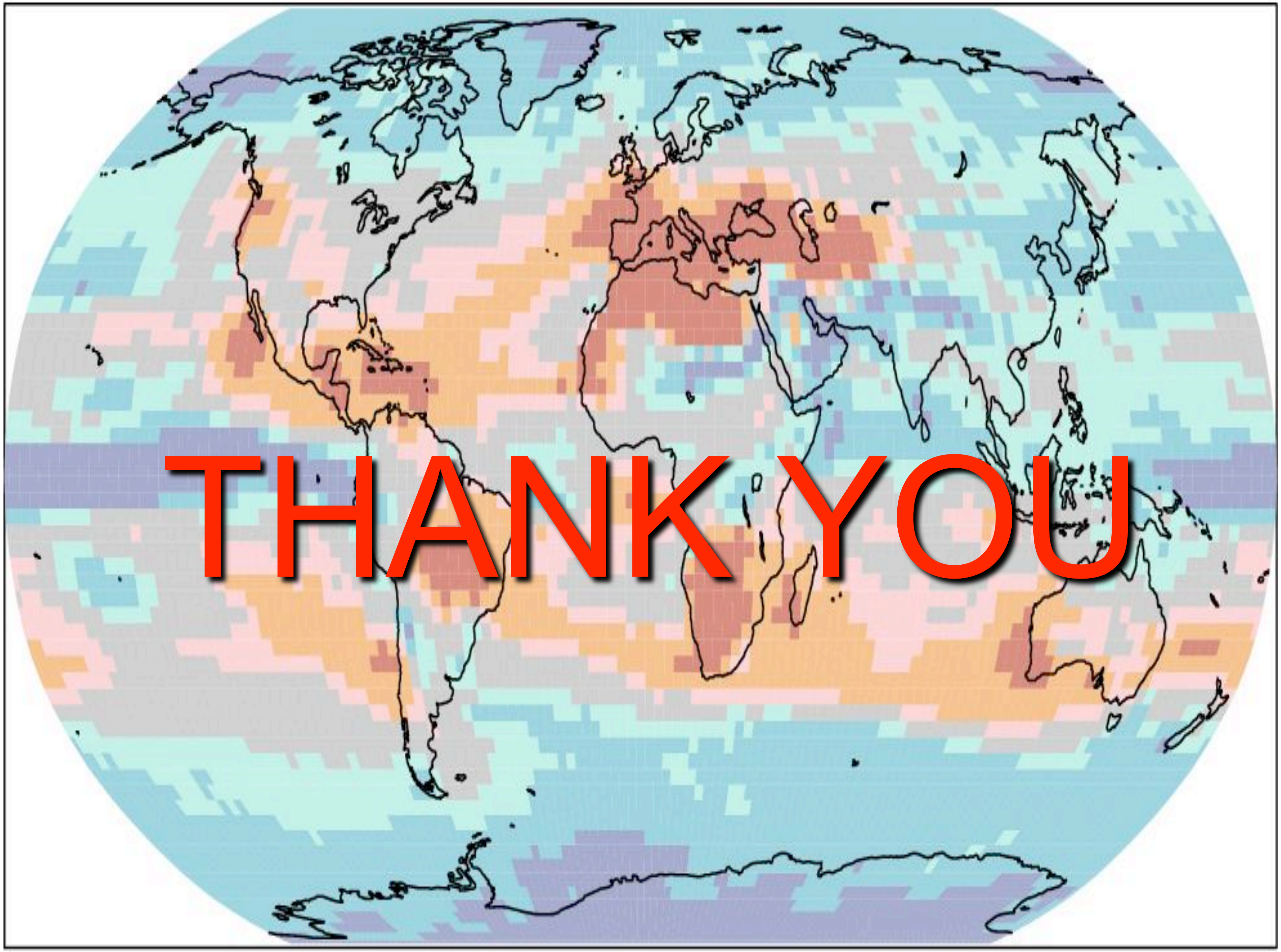



**Early 21st century (up to 2040)**
**Mid-21st century (2040-2080)**
**Late 21st century and beyond**

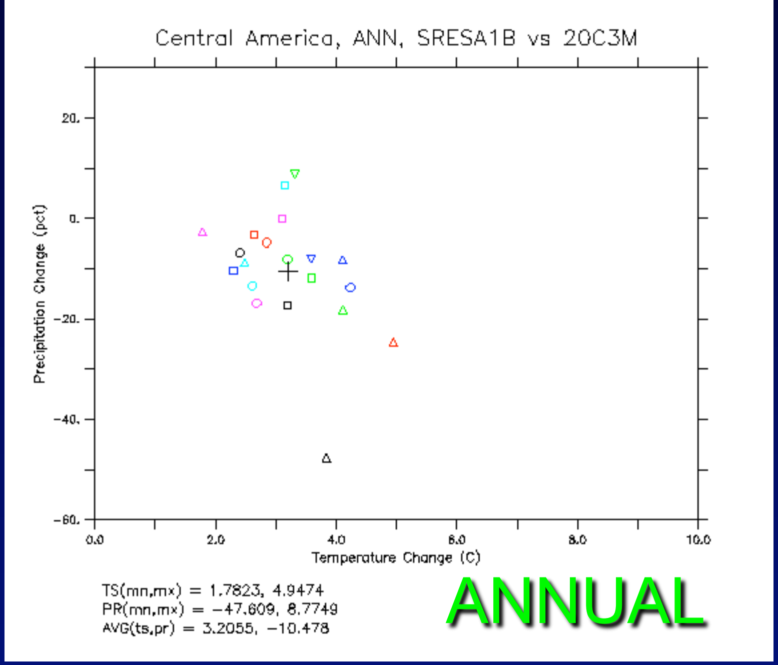
**Continous = Positive PSPOT**
**Dashed = Negative PSPOT**

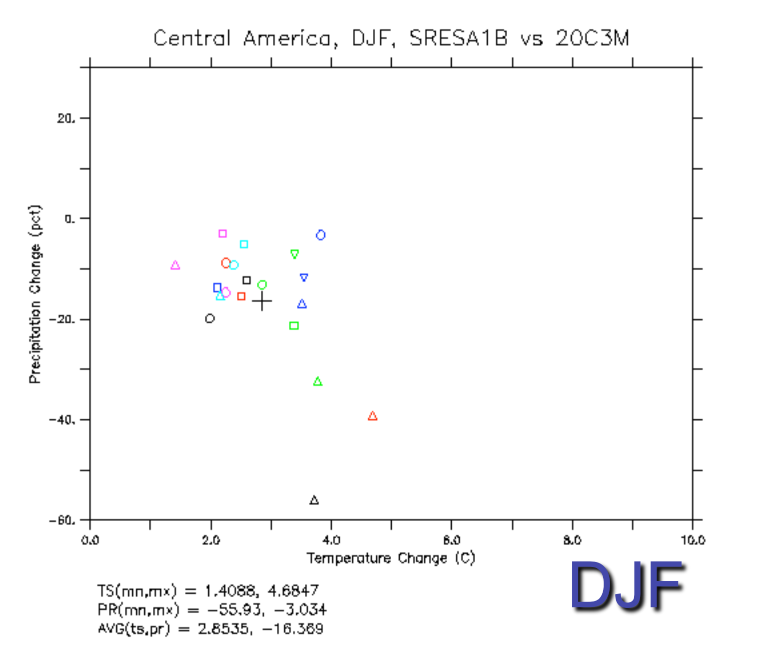
# Summary and conclusions

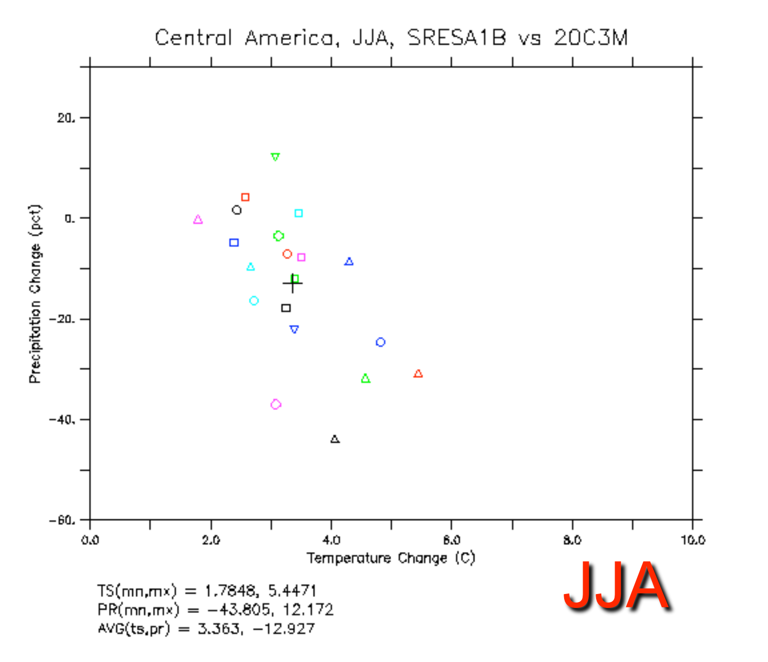
- Fourteen GHG-forced PSPOTS have been identified
- The TOE was calculated for the 14 PSPOTS and 3 IPCC emission scenarios (B1, A1B, A2; CMIP3 models)
  - Early 21$^{st}$ Century TOE (<2040): NEU-OM, MED-AS, MED-OM, NAS-OM, EAF-OM, NAM-OM
  - Mid 21$^{st}$ Century TOE (2040-2080): IND-AS, CHN-AS, CAR-AS
  - Late 21$^{st}$ Century (>2080): SAF-AS, WUS-AS, CAM-OM, AMZ-AS, SAU-AS
- The TOE has implications for detection/attribution decadal predictability and impact/adaptation studies
- The TOE only refers to GHG-forced PSPOTS
  - Ocean-forced PSPOTS may have a totally different structure


THANK YOU

# Central America region, P-change vs. T-change (2079-2098) – (1979-1998) A1B scenario, 21 models



# Eastern Asia region, P-change vs. T-change (2079-2098) – (1979-1998) A1B scenario, 21 models