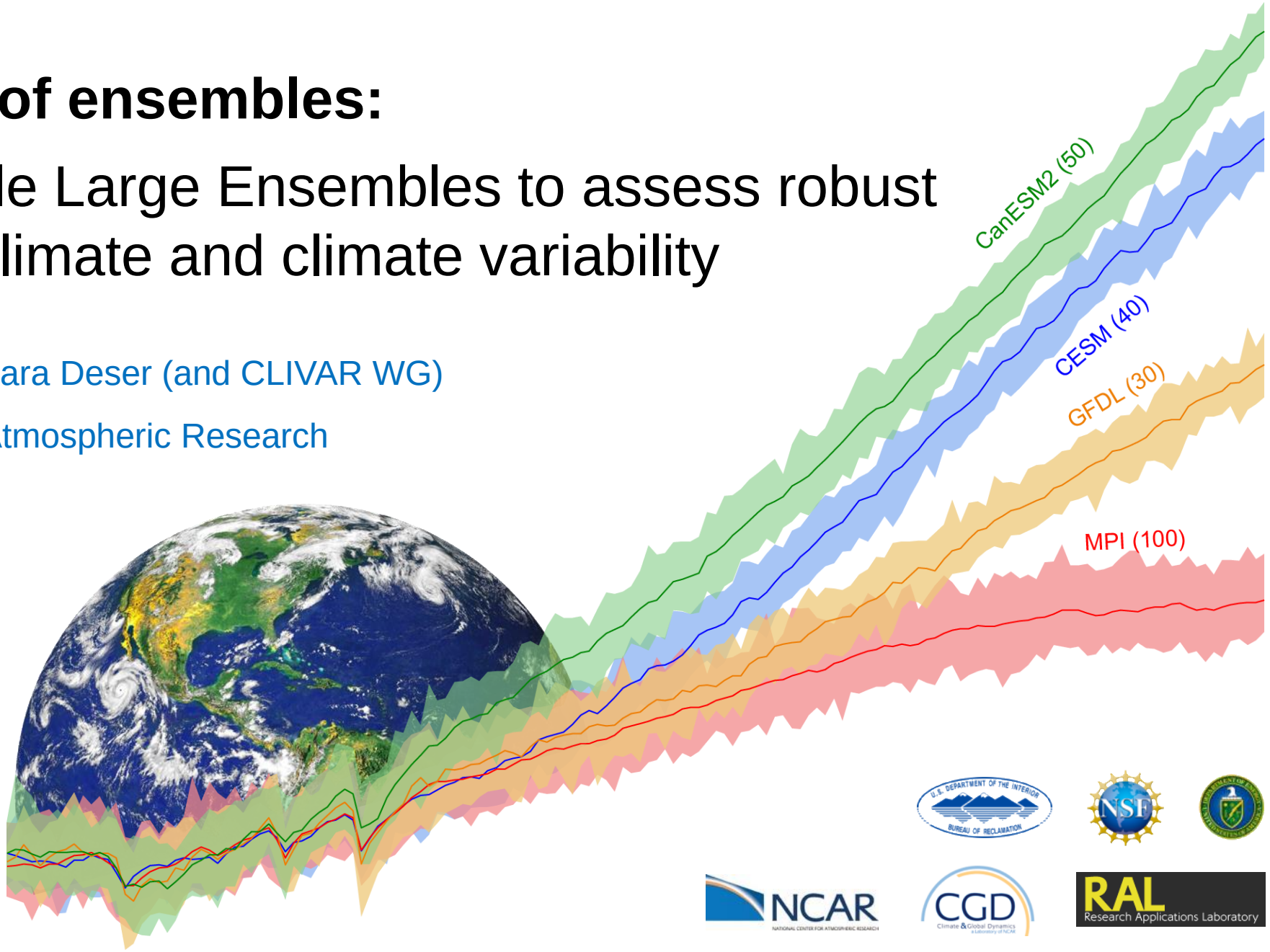
Ensembles of ensembles:

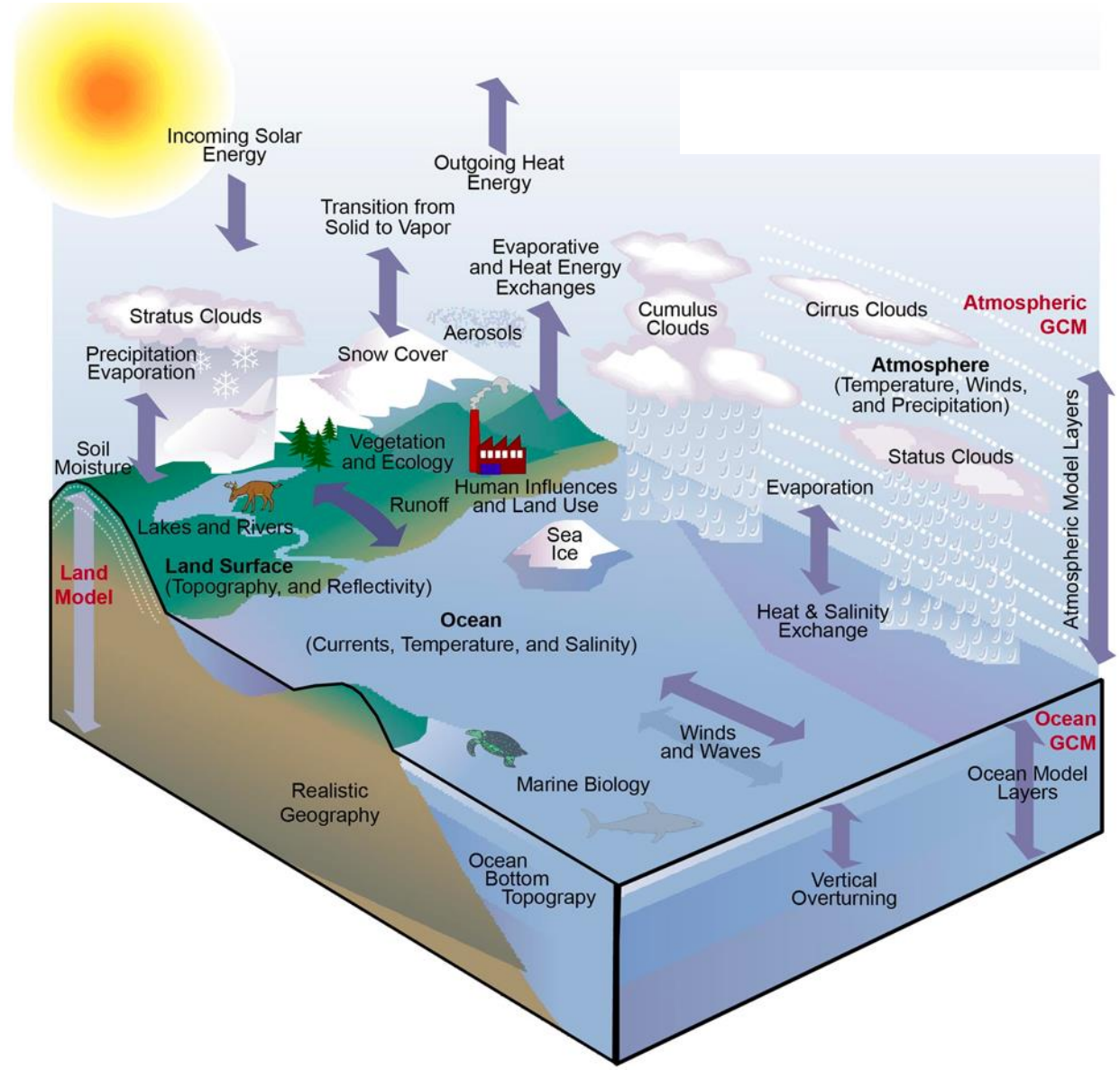
Using multiple Large Ensembles to assess robust changes in climate and climate variability

Flavio Lehner and Clara Deser (and CLIVAR WG)

National Center for Atmospheric Research



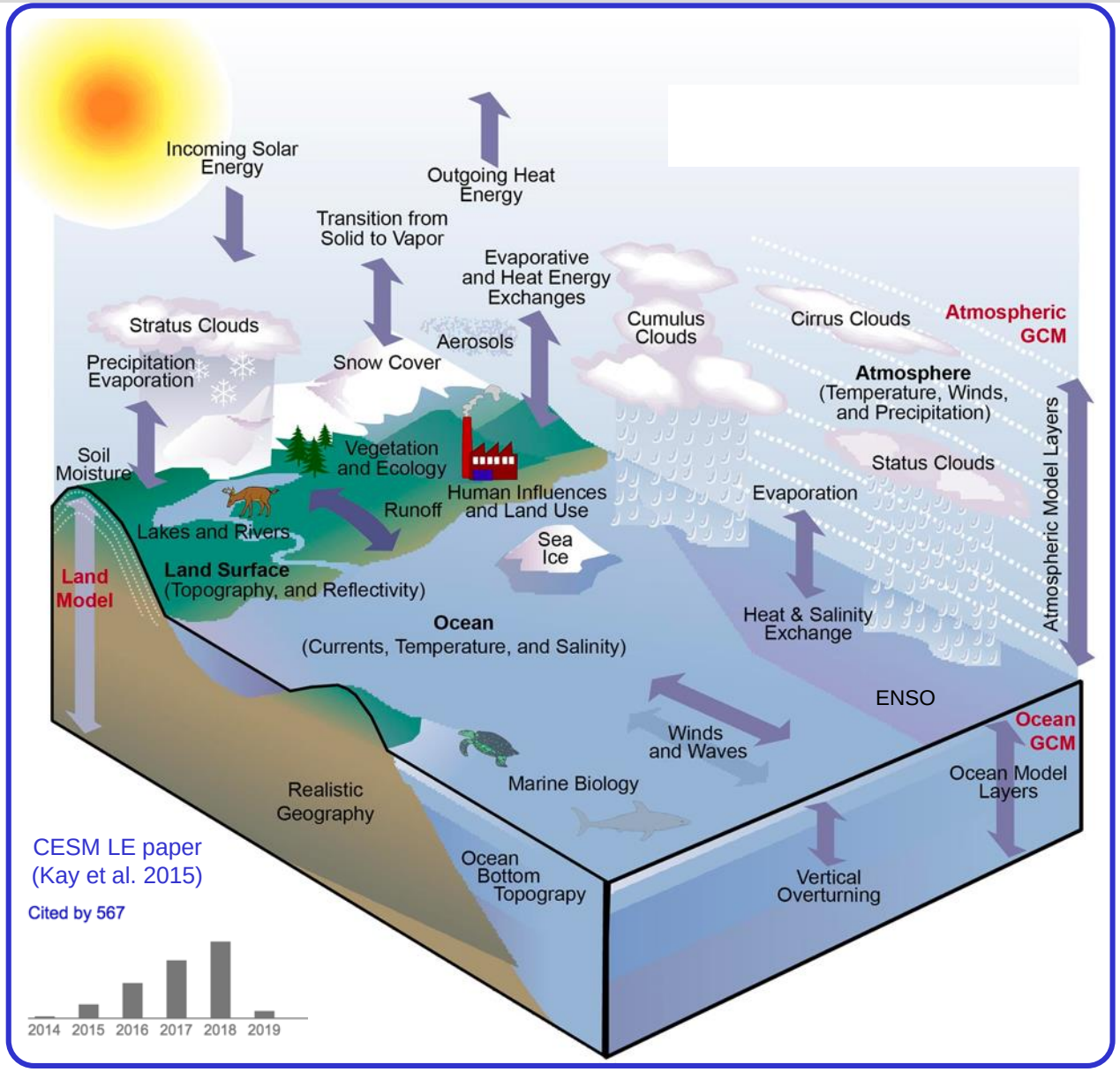
Applications of (multiple) Large Ensembles



Large Ensembles are useful for:

- ✓ Assessment of Signal, Noise, and Signal-to-Noise

Applications of (multiple) Large Ensembles

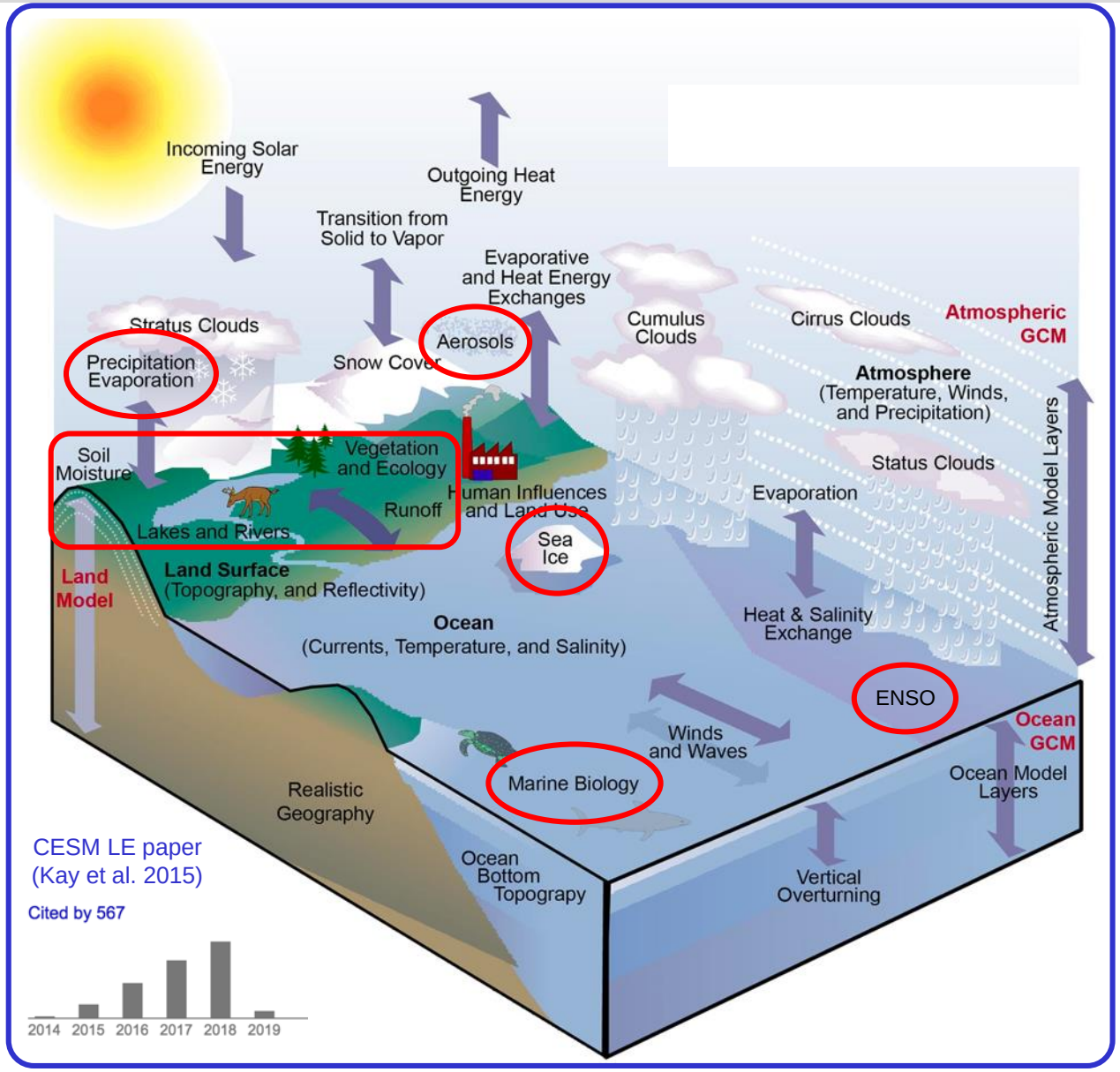


Large Ensembles are useful for:

- ✓ Assessment of Signal, Noise, and Signal-to-Noise

  (*many contributors!*)

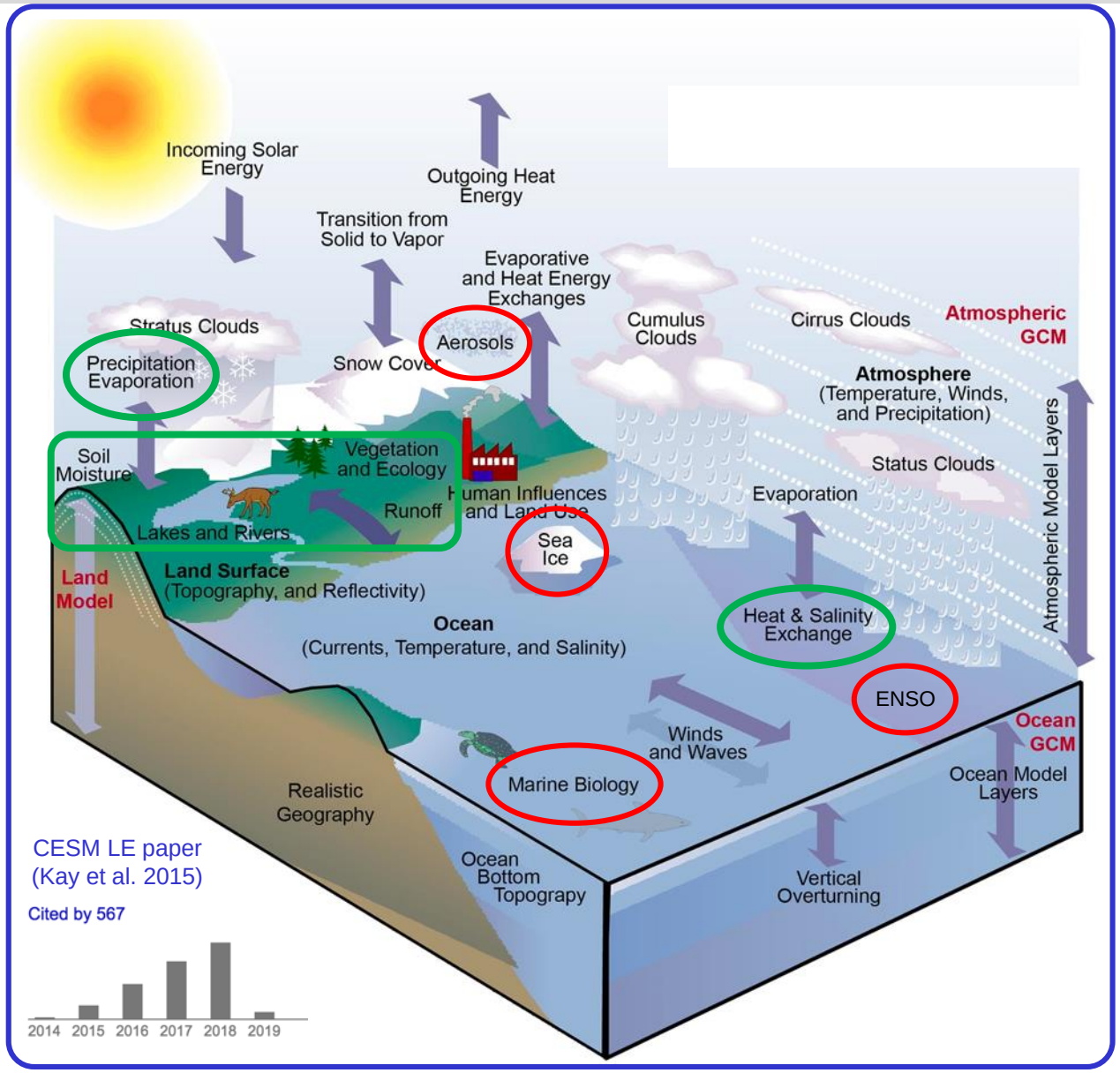
Applications of (multiple) Large Ensembles



Large Ensembles are useful for:

- ✓ Assessment of Signal, Noise, and Signal-to-Noise
- ✓ Variability and changes in variability *(Pendergrass et al., 2017; Stevenson et al., 2012; Alexander et al., 2018; Screen and Deser 2018; etc)*

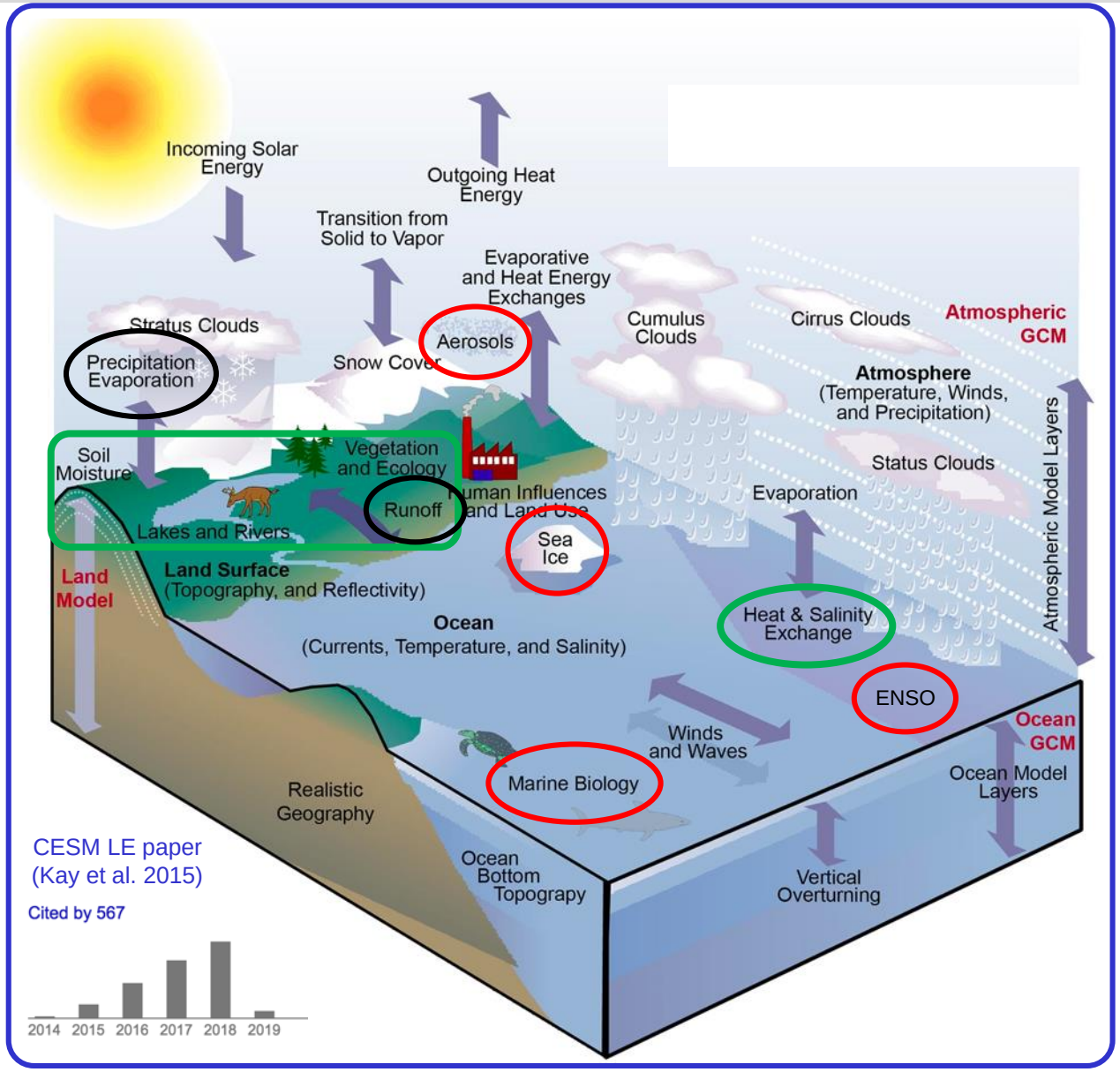
Applications of (multiple) Large Ensembles



Large Ensembles are useful for:

- ✓ Assessment of Signal, Noise, and Signal-to-Noise
- ✓ Variability and changes in variability
- ✓ Methodological testbed *(Deser et al., 2016; Lehner et al., 2017; Guo et al., 2019; McKinnon and Huybers 2016; Coats and Mankin 2017; etc)*

Applications of (multiple) Large Ensembles



Large Ensembles are useful for:

- ✓ Assessment of Signal, Noise, and Signal-to-Noise
- ✓ Variability and changes in variability
- ✓ Methodological testbed
- ✓ Extreme/compound events *(Otto et al., 2018; van der Wiel et al., 2019; etc)*

New initiative and tool

CLIVAR Working Group on Large Ensembles

- Public data repository with 7+ models with >15 ensemble members

New initiative and tool

CLIVAR Working Group on Large Ensembles

- Public data repository with 7+ models with >15 ensemble members
- Development of an ”observational” large ensemble for temperature, precipitation, and SST

New initiative and tool

CLIVAR Working Group on Large Ensembles

- Public data repository with 7+ models with >15 ensemble members
- Development of an ”observational” large ensemble for temperature, precipitation, and SST
- Design of protocol for next generation of Large Ensembles

New initiative and tool

CLIVAR Working Group on Large Ensembles

- Public data repository with 7+ models with >15 ensemble members
- Development of an ”observational” large ensemble for temperature, precipitation, and SST
- Design of protocol for next generation of Large Ensembles
- Do science on open questions that require Large Ensembles:
  - Move beyond mean state model validation to validation of subseasonal to decadal variability
  - Assess forced changes in variability
  - Explicit statstics of extreme and compound events
  - …

New initiative and tool

CLIVAR Working Group on Large Ensembles

- Public data repository with 7+ models with >15 ensemble members
- Development of an ”observational” large ensemble for temperature, precipitation, and SST
- Design of protocol for next generation of Large Ensembles
- Do science on open questions that require Large Ensembles:
  - Move beyond mean state model validation to validation of subseasonal to decadal variability
  - Assess forced changes in variability
  - Explicit statstics of extreme and compound events
  - …

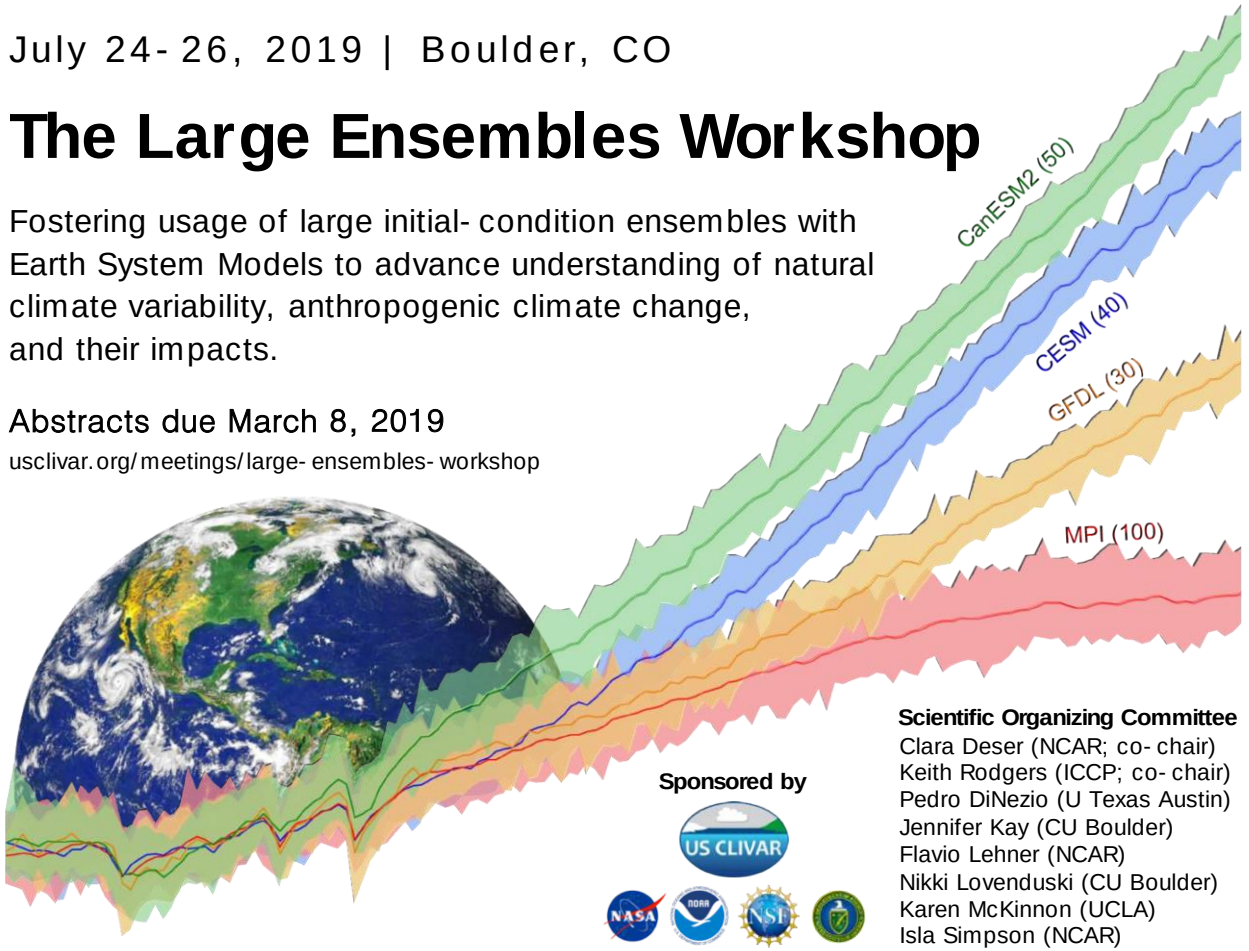
July 24- 26, 2019 | Boulder, CO

The Large Ensembles Workshop

Fostering usage of large initial- condition ensembles with Earth System Models to advance understanding of natural climate variability, anthropogenic climate change, and their impacts.

Abstracts due March 8, 2019

usclivar.org/meetings/large- ensembles- workshop



Sponsored by

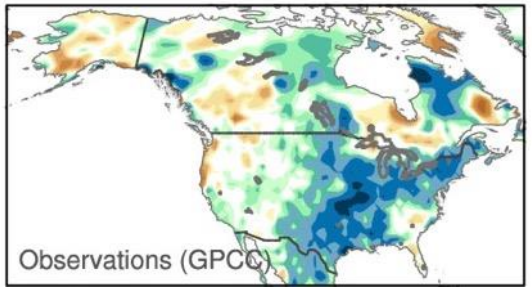
US CLIVAR

Scientific Organizing Committee

Clara Deser (NCAR; co- chair)
Keith Rodgers (ICCP; co- chair)
Pedro DiNezio (U Texas Austin)
Jennifer Kay (CU Boulder)
Flavio Lehner (NCAR)
Nikki Lovenduski (CU Boulder)
Karen McKinnon (UCLA)
Isla Simpson (NCAR)

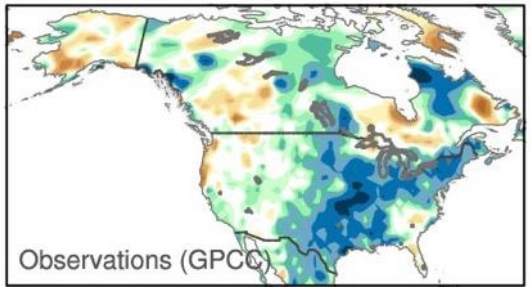
Bookend maps

PR Trends annual 1951-2010

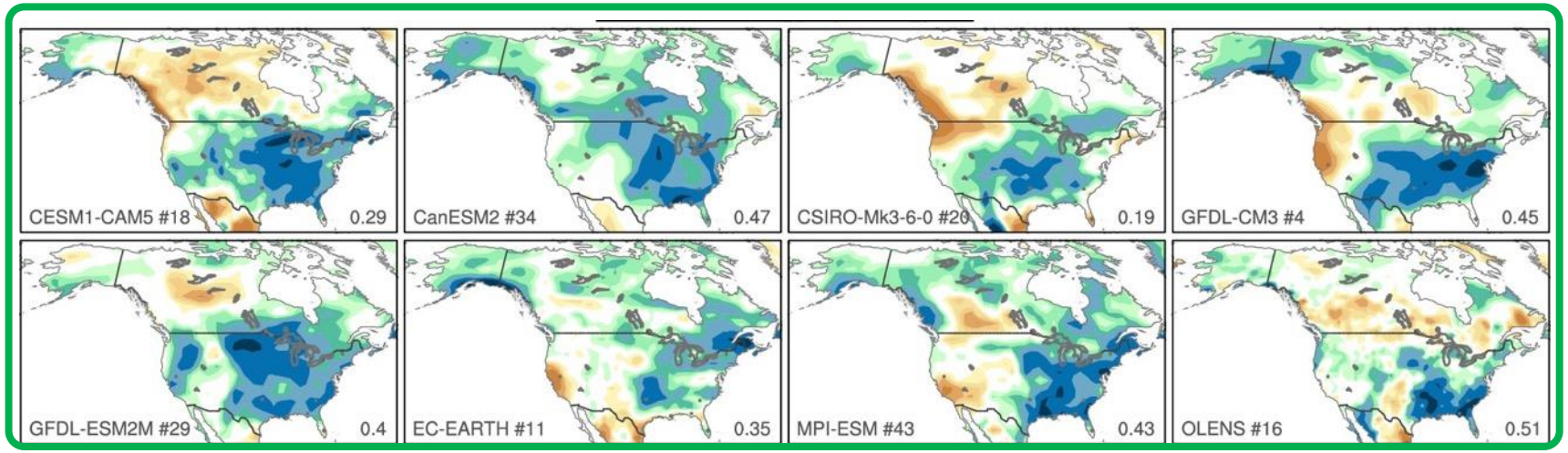


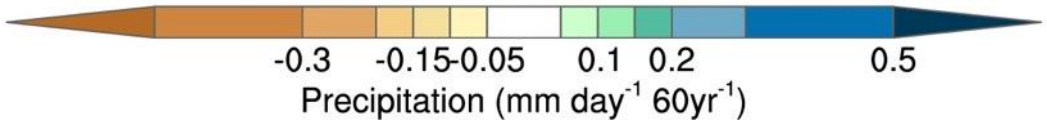
Bookend maps

PR Trends annual 1951-2010



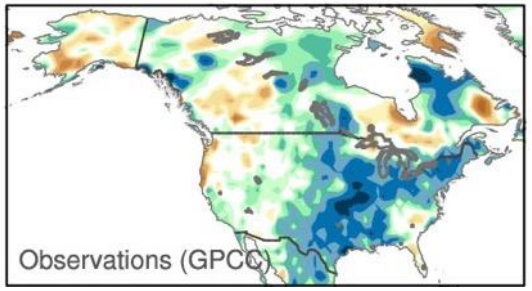
High pattern correlation

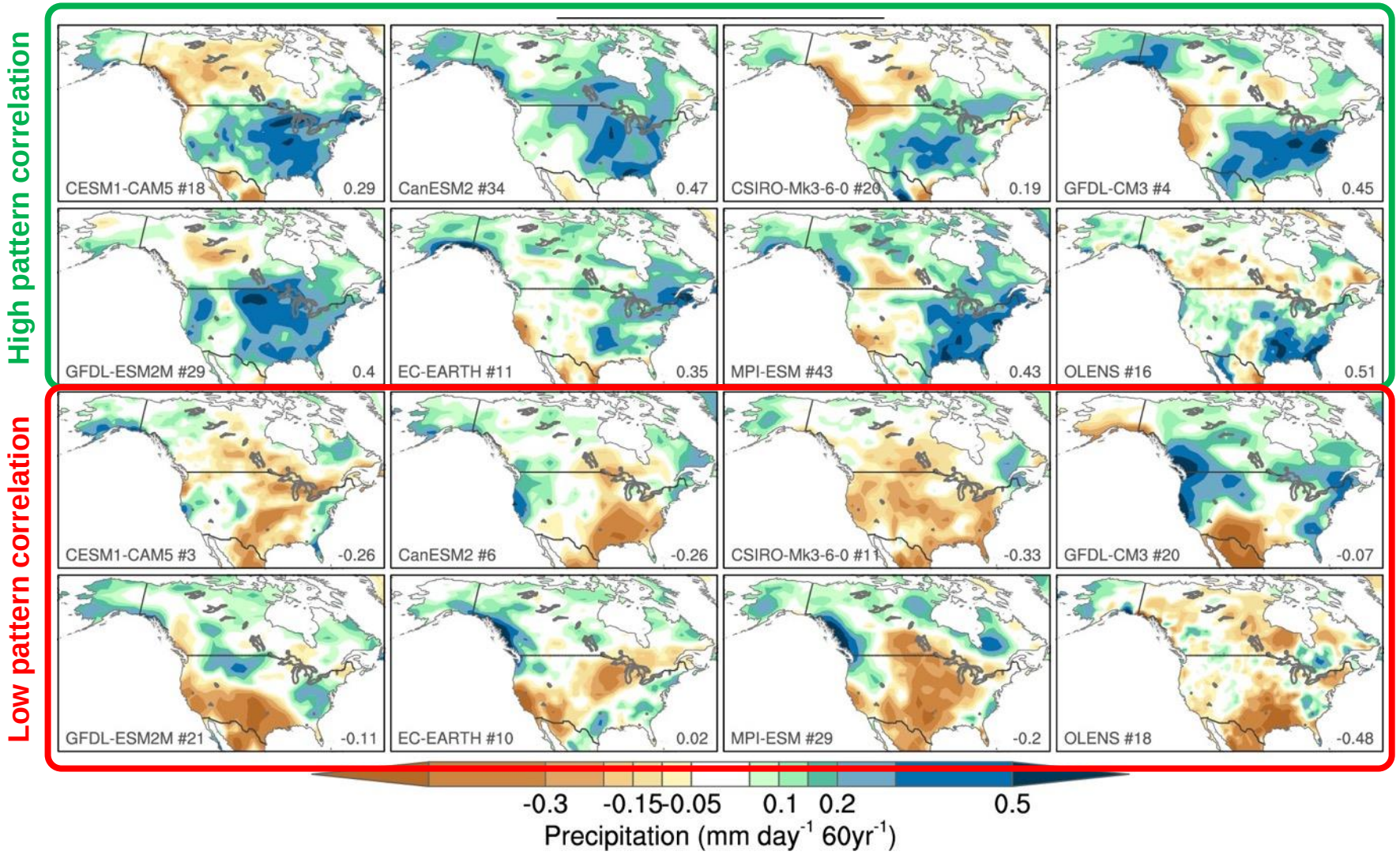




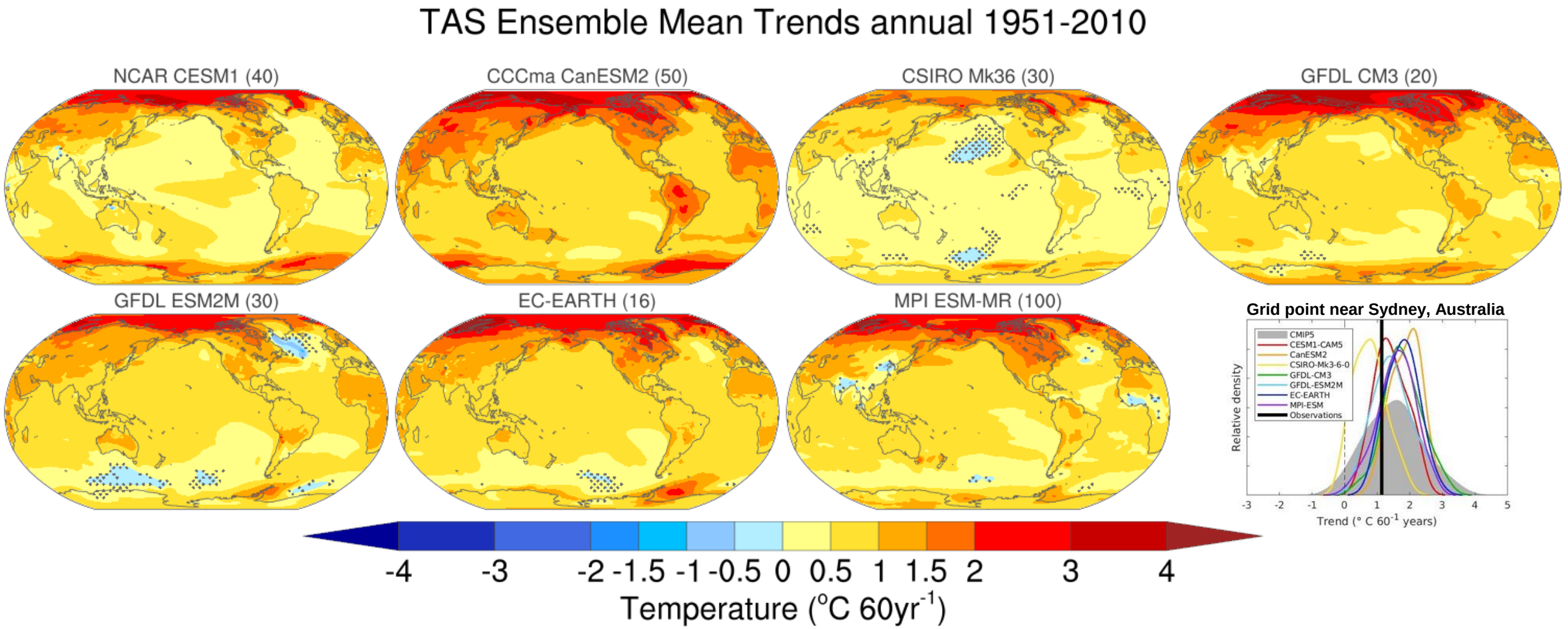
Bookend maps

PR Trends annual 1951-2010

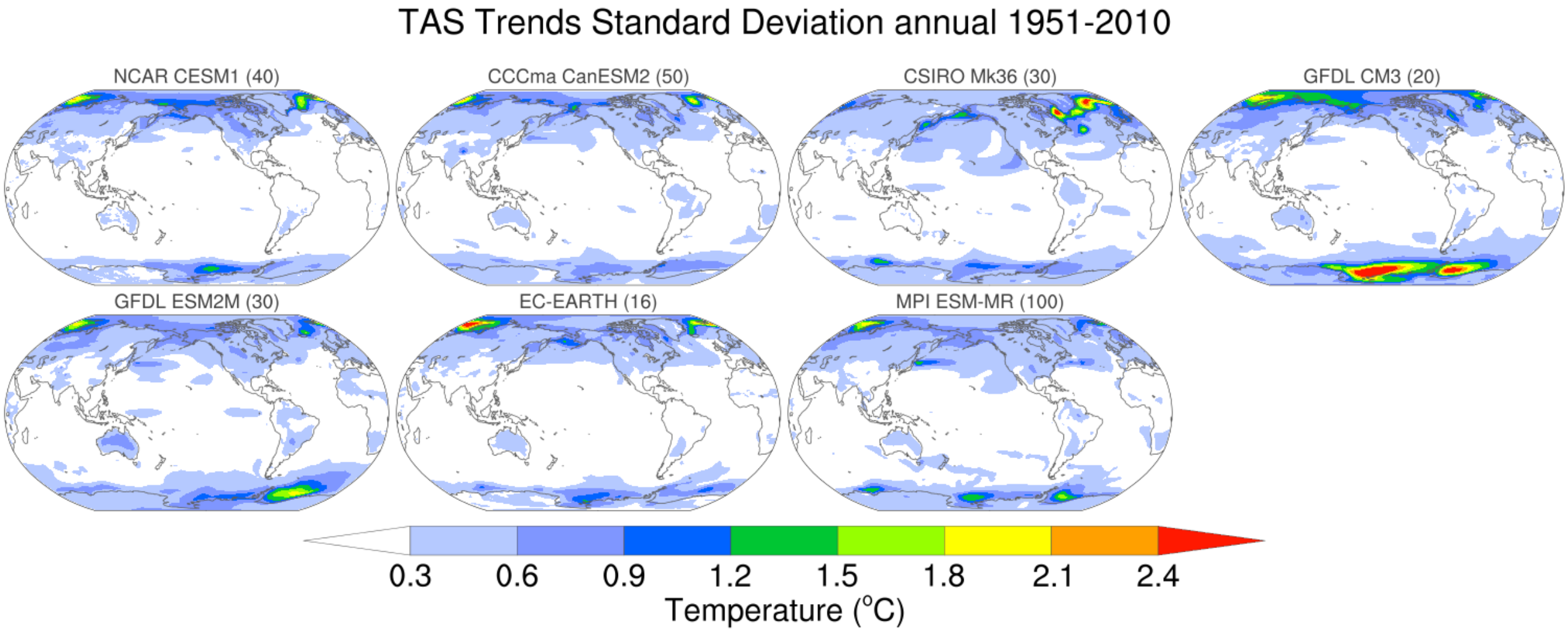




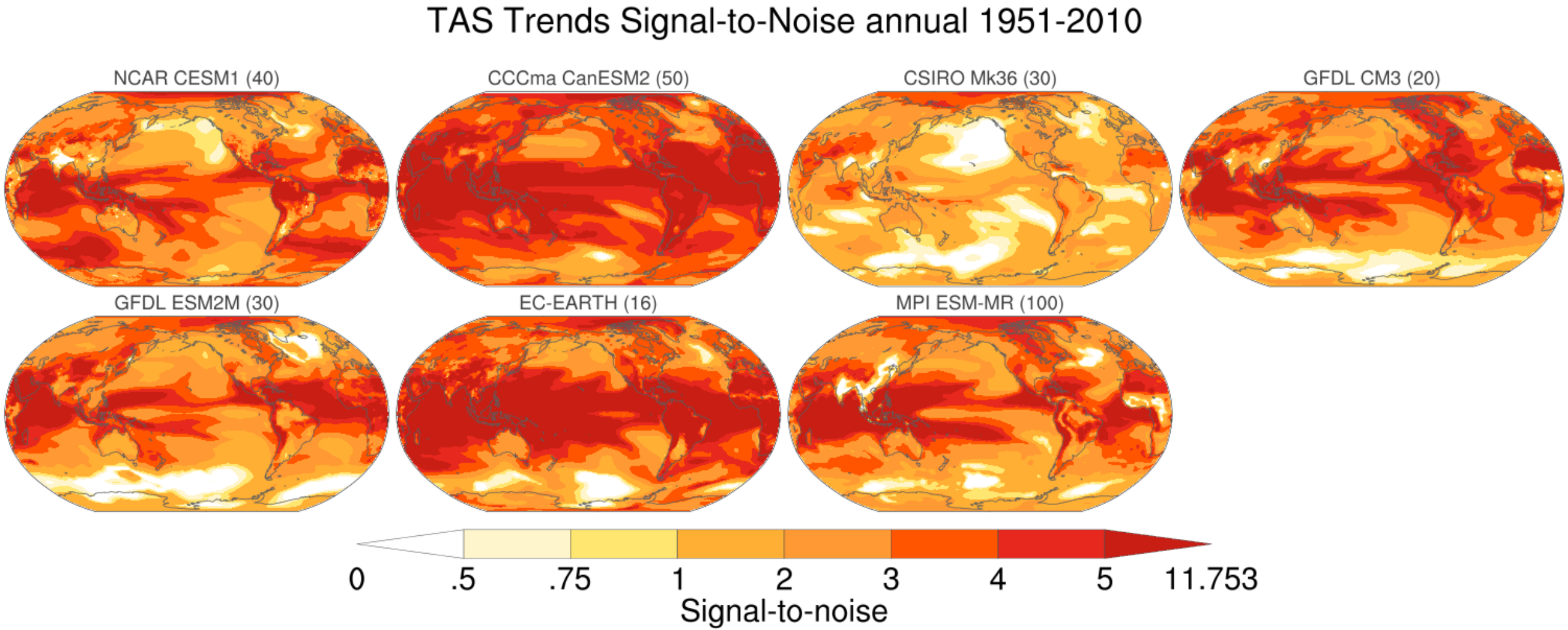
Signal-to-noise (here: signal)



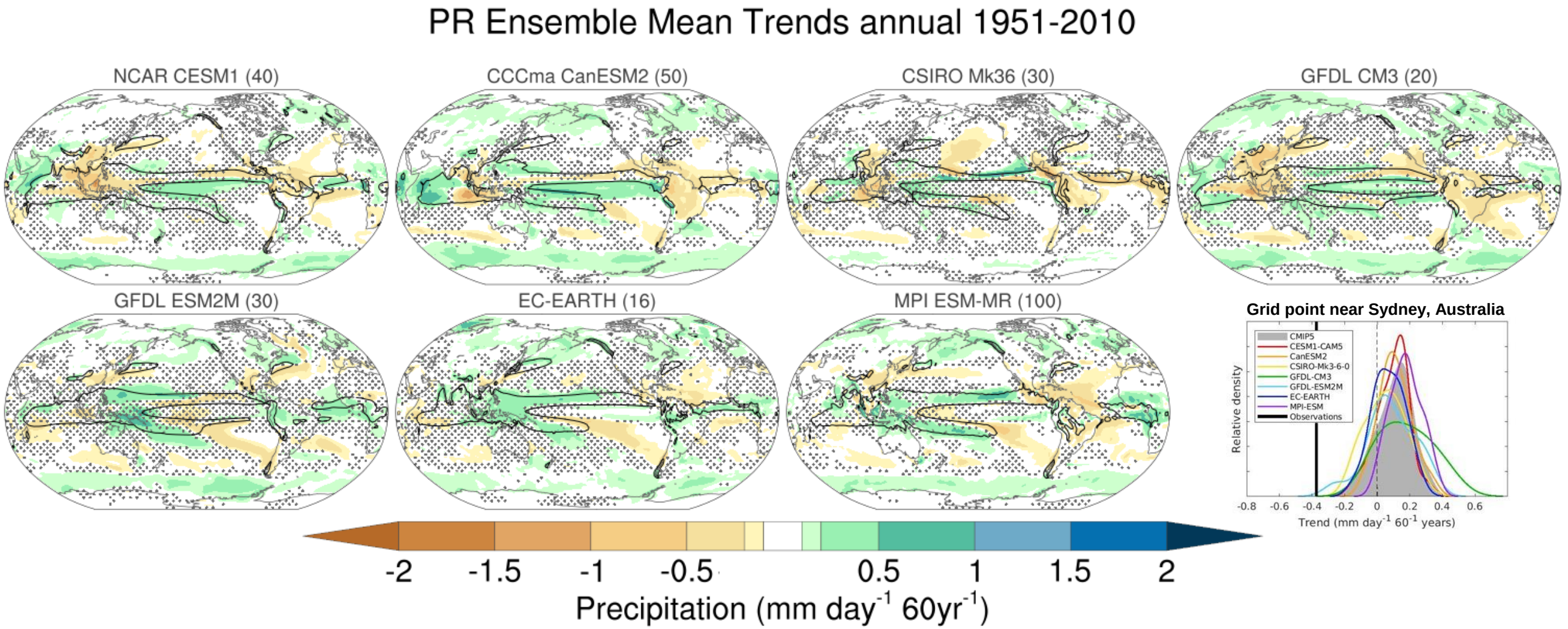
Signal-to-noise (here: noise)



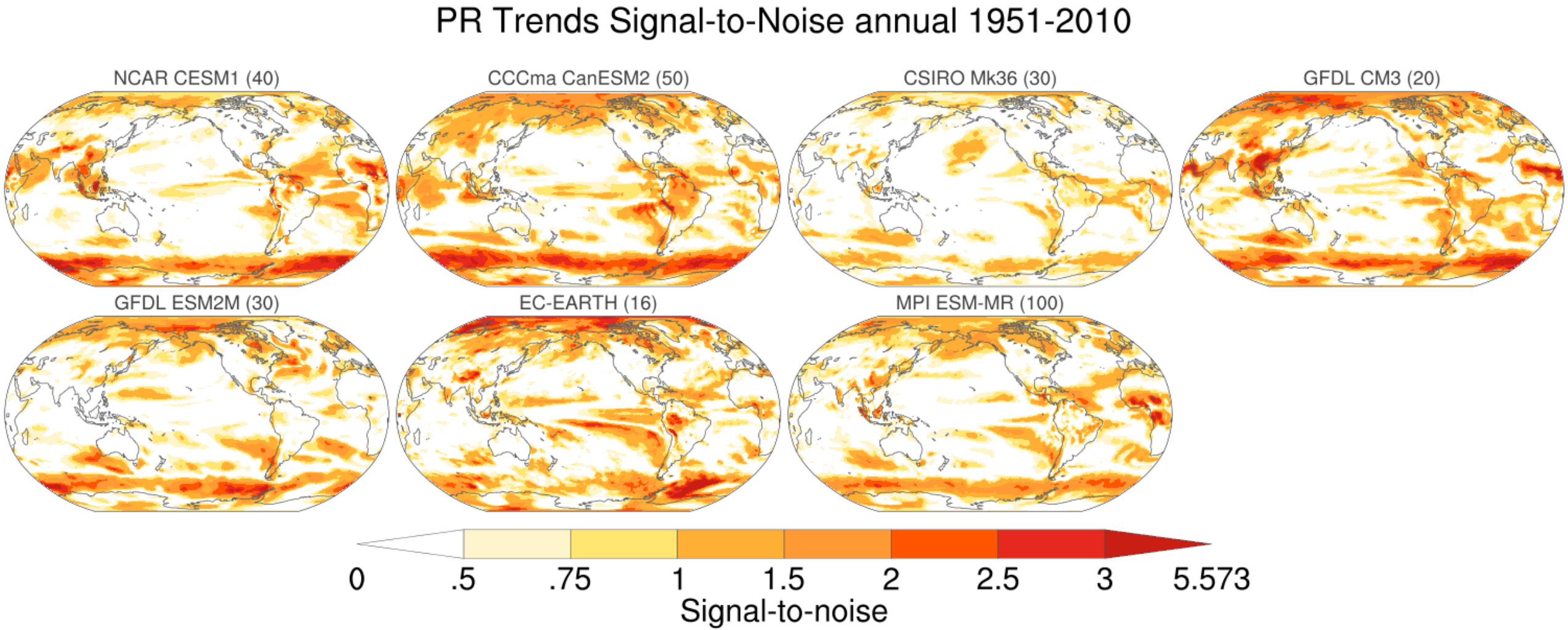
Signal-to-noise



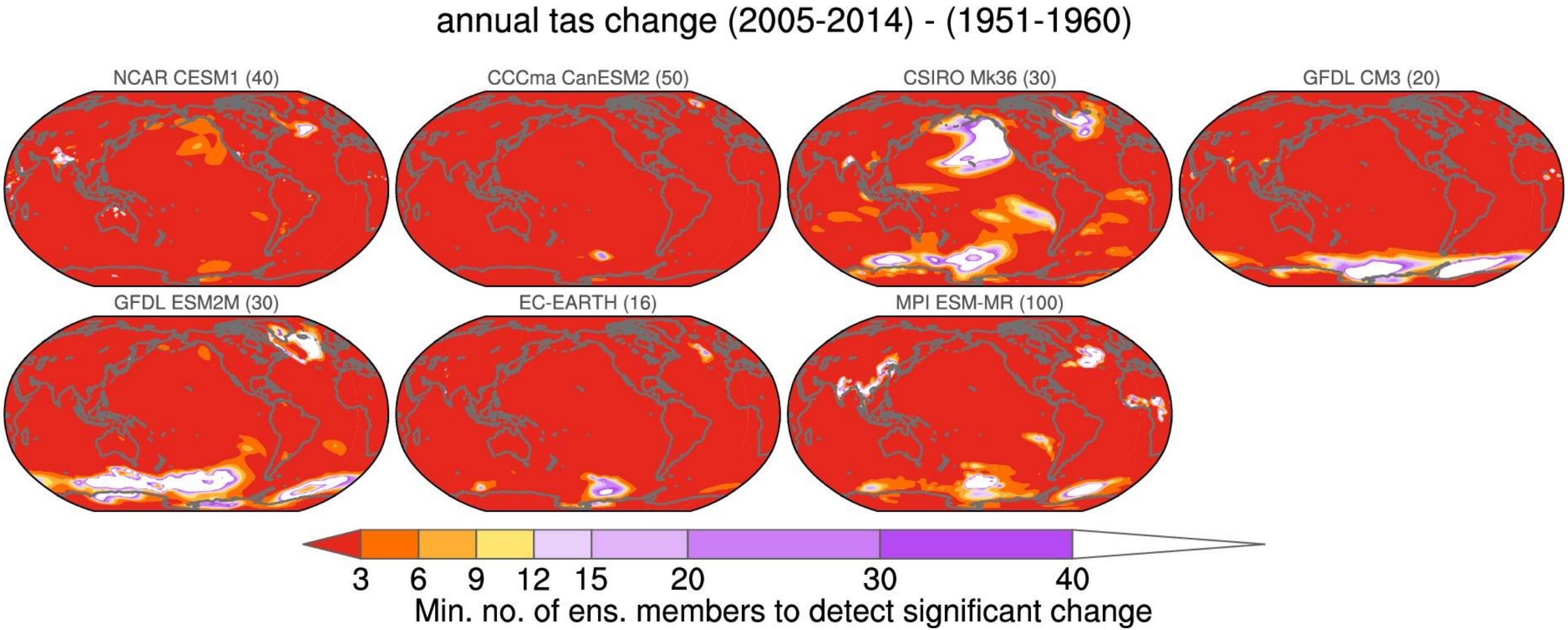
Signal-to-noise (here: signal)



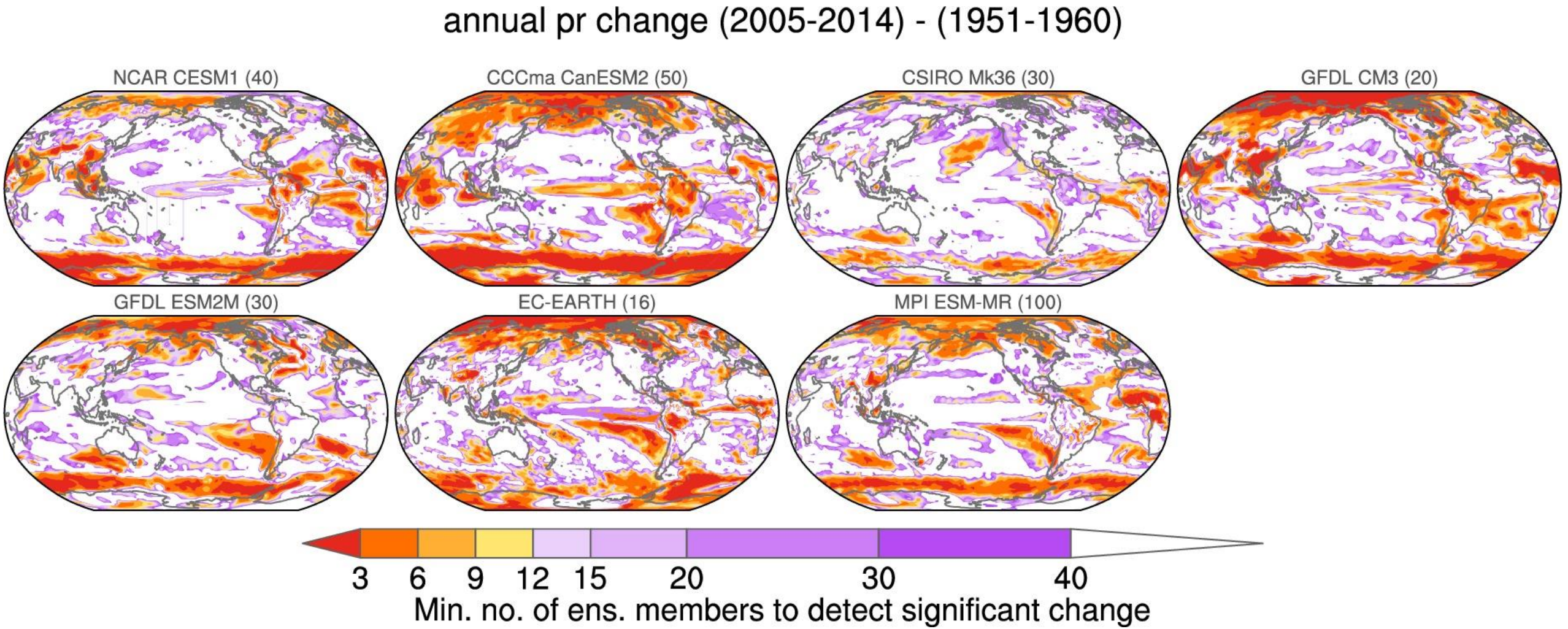
Signal-to-noise



How many ensemble members do I need?



How many ensemble members do I need?

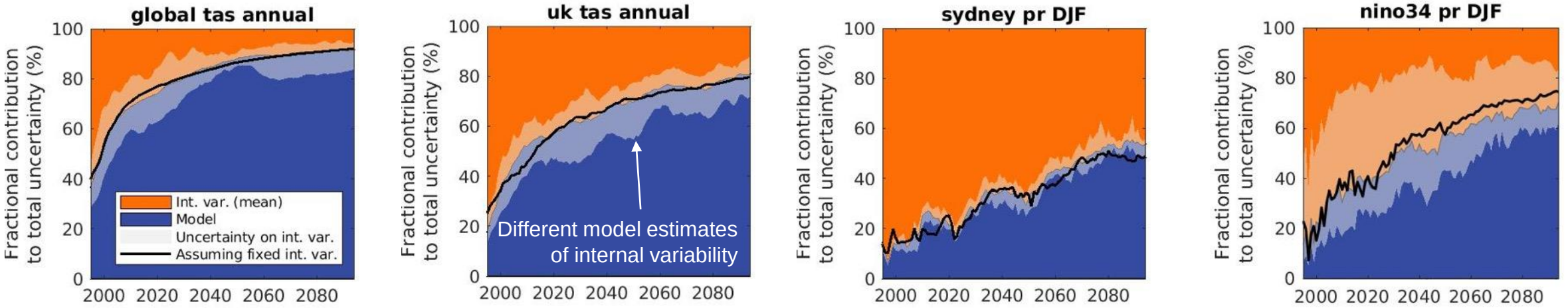


Hawkins&Sutton-type figures

Original Hawkins & Sutton figures:

- Used 4th order polynomial to define forced response
- Assumed internal variability to be constant

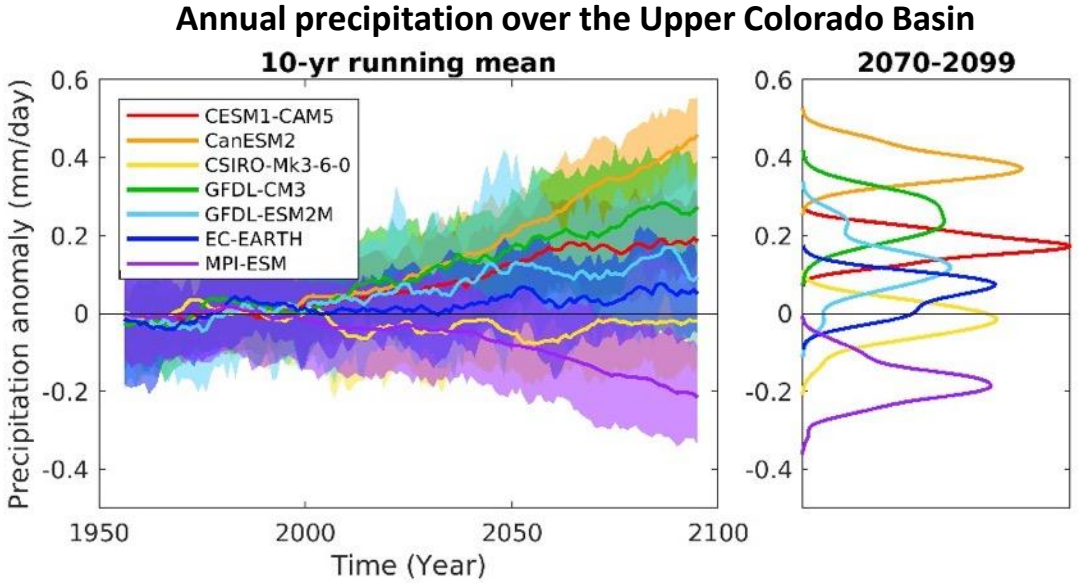
Sources of uncertainty in decadal mean



Changes in variability

How are LEs informing future decision making?

- Illustrate where there is agreement/disagreement on mean changes



"Let's build more houses in AZ!" *

?

"We have to divert the Columbia!" *

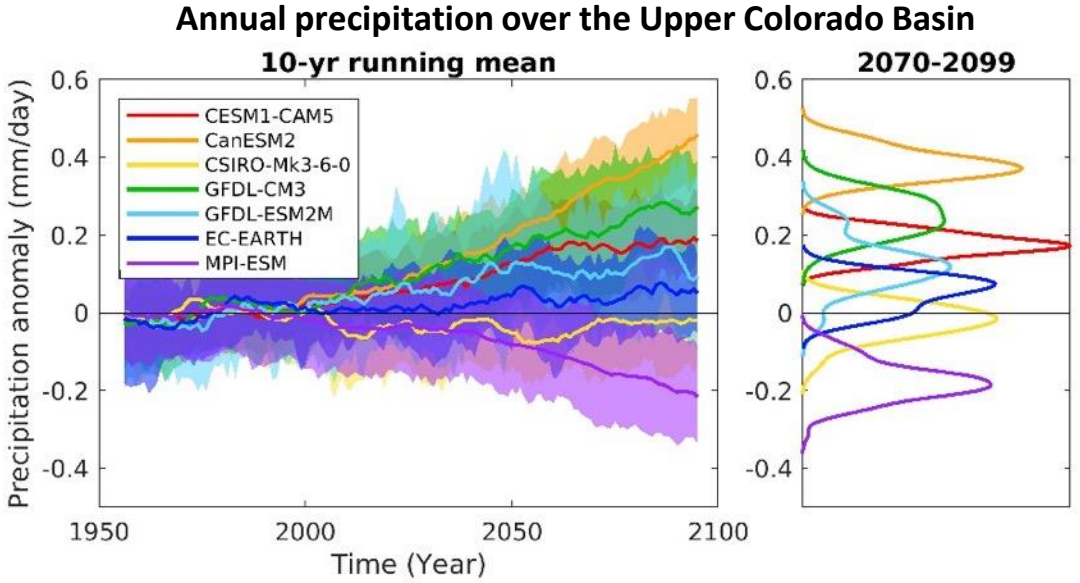
* The author is not actually advocating for any of this

Changes in variability

How are LEs informing future decision making?

- Illustrate where there is agreement/disagreement on mean changes

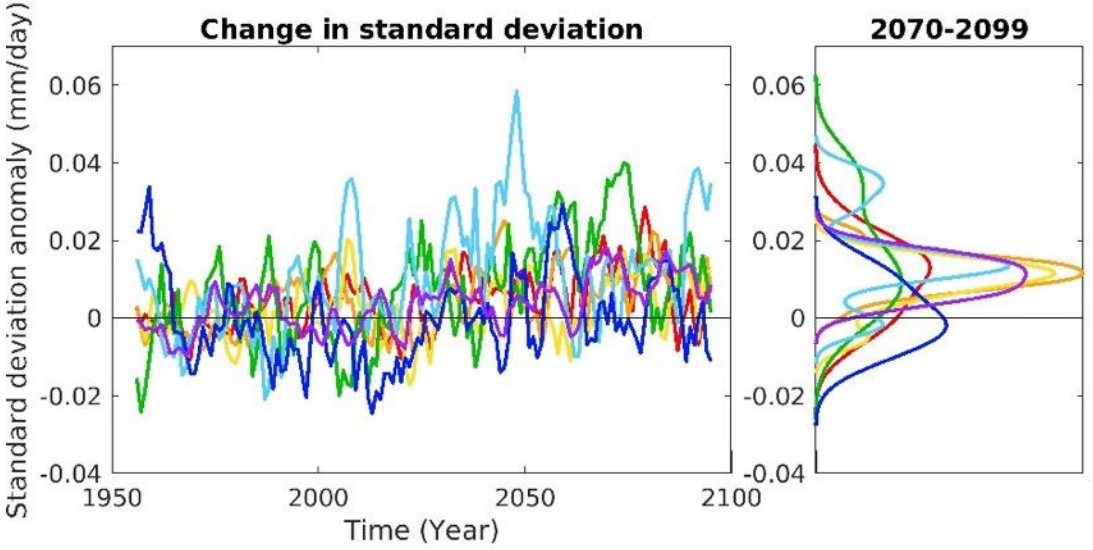
- Enable assessment of changes in variability



"Let's build more houses in AZ!" *

?

"We have to divert the Columbia!" *



"Storage!" *

* The author is not actually advocating for any of this

Conclusions and access to LE repository

Large Ensembles remain useful tools to study climate variability and change.

Thanks! flehner@ucar.edu

Conclusions and access to LE repository

Large Ensembles remain useful tools to study climate variability and change.

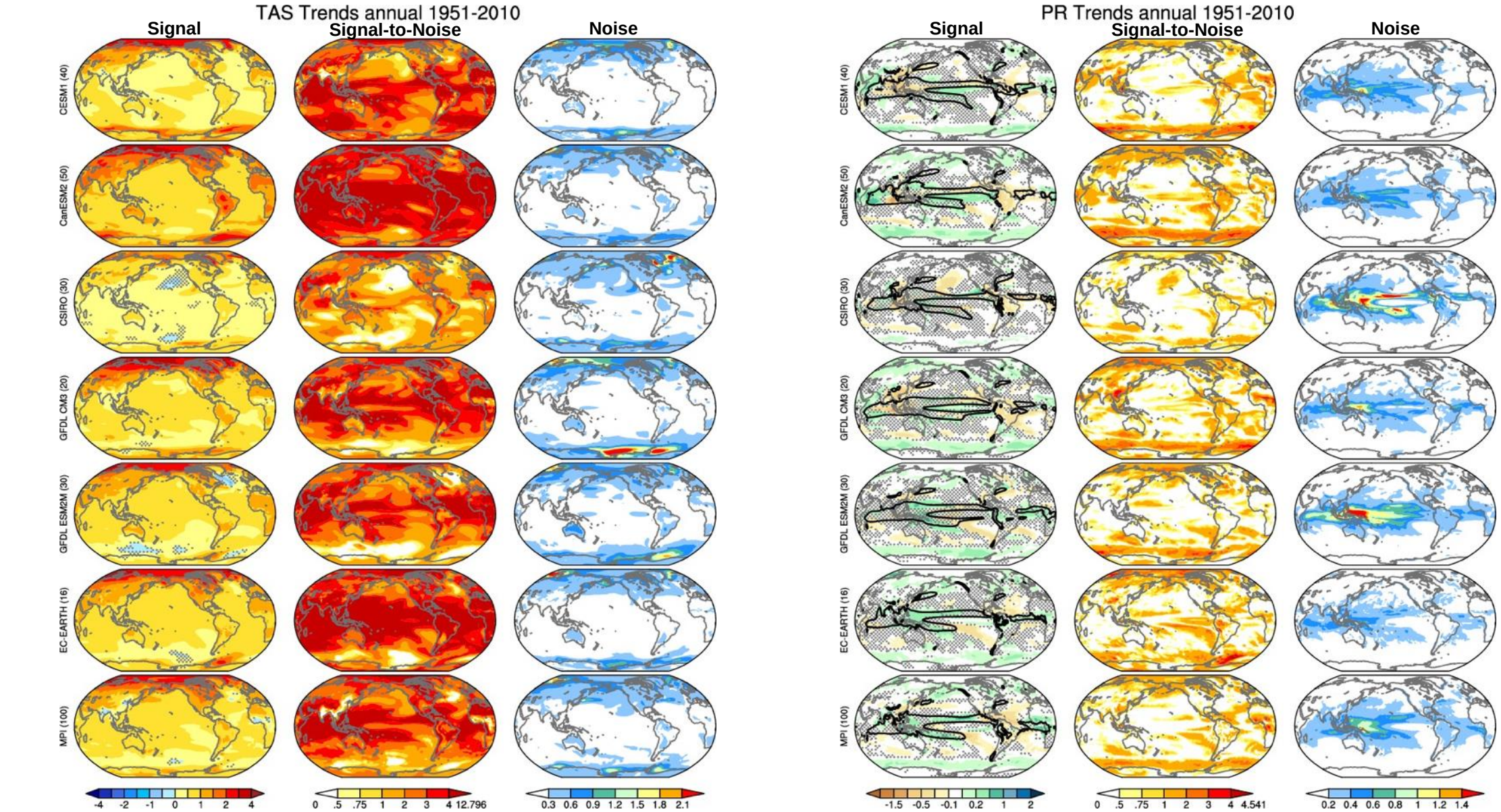
Thanks! flehner@ucar.edu

Repository access:

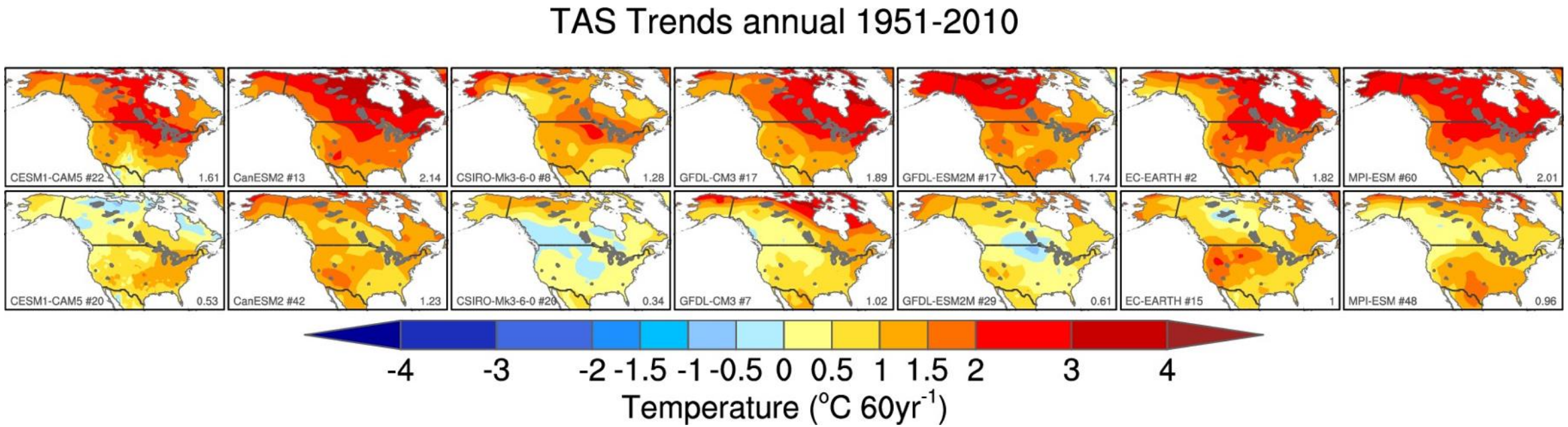
1. Through UCAR's Cheyenne supercomputer:
   - /glade/collections/cdg/data/CLIVAR_LE/
     - ✓ canesm2_lens, cesm_lens, csiro_mk36_lens, ec_earth_lens, gfdl_cm3_lens, gfdl_esm2m_lens
     - ✓ mpi_lens
     - ✓ olens_mckinnon

2. Through Climate Data Gateway (CDG):
   - Register here if you don't yet have a CDG (former ESG) account: https://www.earthsystemgrid.org/ac/guest/secure/registration.html
   - Data can be found here: https://www.earthsystemgrid.org/dataset/ucar.cgd.ccsm4.CLIVAR_LE.html
     - ✓ canesm2_lens, cesm_lens, csiro_mk36_lens, ec_earth_lens, gfdl_cm3_lens, gfdl_esm2m_lens

Fig. 1: signal-to-noise maps



Bookend maps



Bookend maps