A Multi-Model Large Ensemble Archive

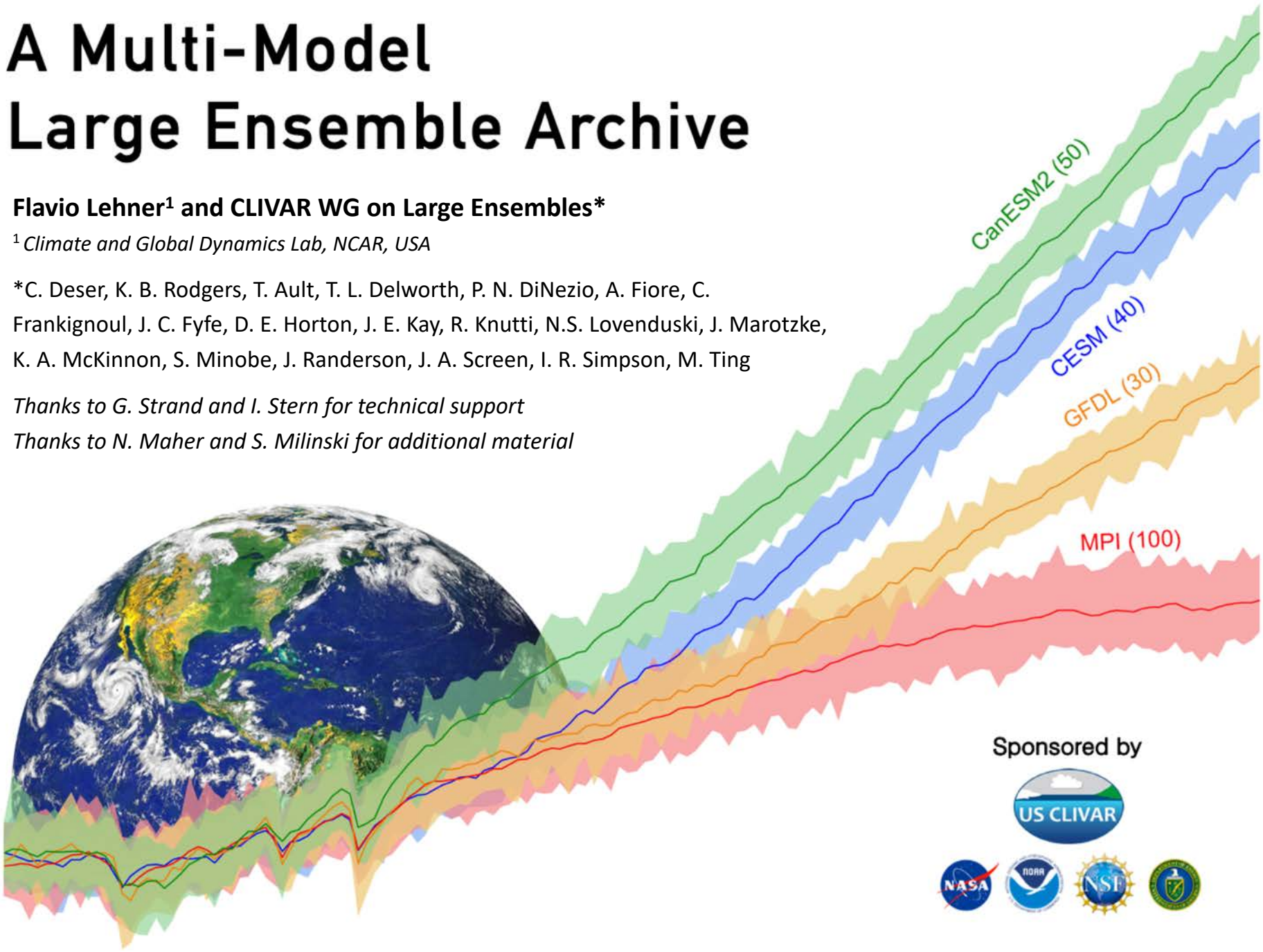
Flavio Lehner[1] and CLIVAR WG on Large Ensembles*

[1] *Climate and Global Dynamics Lab, NCAR, USA*

*C. Deser, K. B. Rodgers, T. Ault, T. L. Delworth, P. N. DiNezio, A. Fiore, C. Frankignoul, J. C. Fyfe, D. E. Horton, J. E. Kay, R. Knutti, N.S. Lovenduski, J. Marotzke, K. A. McKinnon, S. Minobe, J. Randerson, J. A. Screen, I. R. Simpson, M. Ting

Thanks to G. Strand and I. Stern for technical support

Thanks to N. Maher and S. Milinski for additional material



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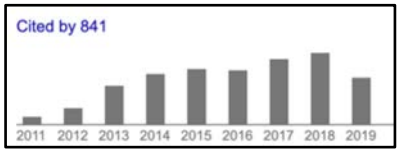
LEs as a community science tool – a success story

Clim Dyn (2012) 38:527–546
DOI 10.1007/s00382-010-0977-x

Uncertainty in climate change projections: the role of internal variability

Clara Deser · Adam Phillips · Vincent Bourdette · Haiyan Teng



nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 26 OCTOBER 2012 | DOI: 10.1038/NCLIMATE1562

Communication of the role of natural variability in future North American climate

Clara Deser[1]*, Reto Knutti[2], Susan Solomon[3] and Adam S. Phillips[1]

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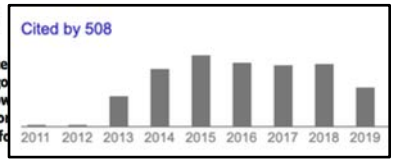

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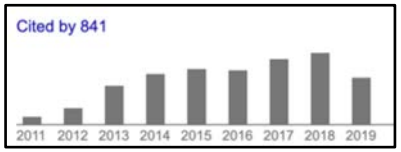

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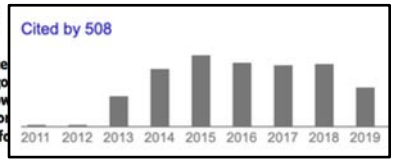
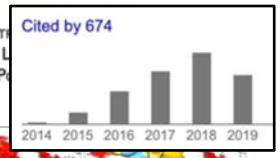
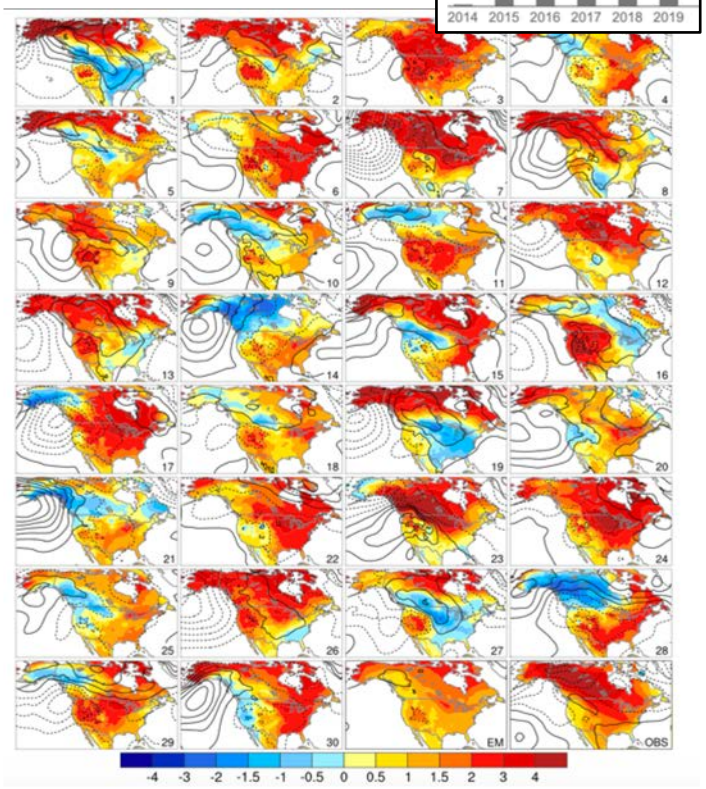


THE COMMUNITY EARTH SYSTEM MODEL (CESM) LARGE ENSEMBLE PROJECT

A Community Resource for Studying Climate Change in the Presence of Internal Climate Variability

BY J. E. KAY, C. DESER, A. PHILLIPS, A. MAI, C. HANNAY, G. ST
G. DANABASOGLU, J. EDWARDS, M. HOLLAND, P. KUSHNER, J.-F. L
A. MIDDLETON, E. MUNOZ, R. NEALE, K. OLESON, L. P





Limitations of a single LE

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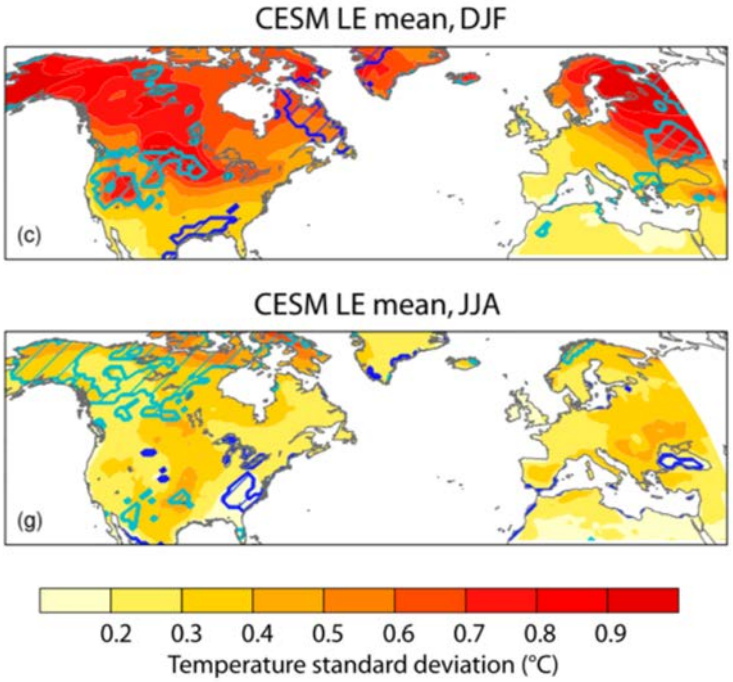
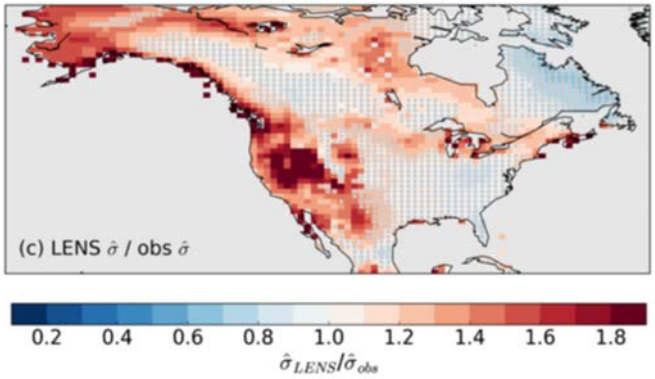


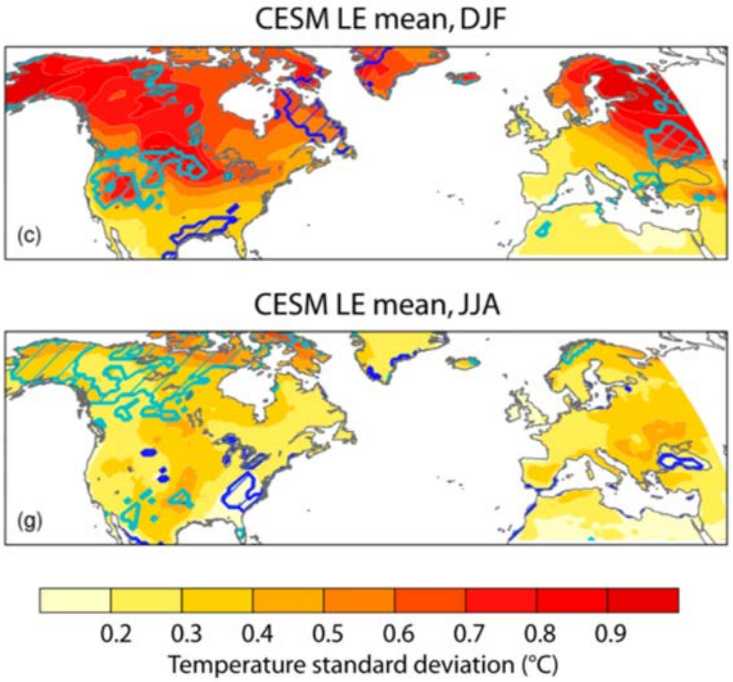
Model biases in decadal variability

CESM DJF temperature trends



Model biases in 50-year trends, assessed using an observational LE

Limitations of a single LE

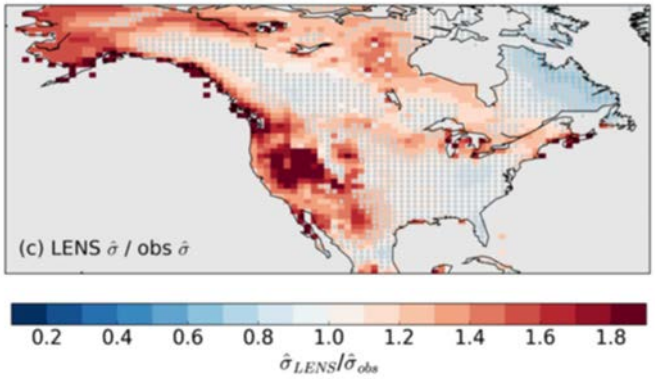


Model biases in decadal variability

"…indicating that the forced warming signal emerges earlier in observations than suggested by models."

Lehner at al. (2017)

CESM DJF temperature trends



Model biases in 50-year trends, assessed using an observational LE

"…[it] is easier to detect the historical climate change signal in observations than in any given member of LENS."

McKinnon at al. (2017)

Beyond a single LE

US CLIVAR Working Group on Large Ensembles

"Foster exchange of ideas relevant to LEs across disciplines (i.e., atmosphere, ocean, land, biogeochemistry)"

usclivar.org/working-groups/large-ensemble-working-group

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Creation of a Multi-Model Large Ensemble Archive (MMLEA)**:**

- Set of variables from different CMIP5-class LEs
- CMORized and publicly available (CDG/ESG and Cheyenne)
- Includes Observational-LE for temperature, precipitation and sea level pressure (Karen's talk)
- Goal of facilitating model comparison and evaluation - accelerating scientific discovery
- Idea for it to grow with community input (more variables, new LEs, new Observational-LEs, etc.)

Modeling Center	Model Version	Model Resolution (atm/ocn)	Years	Initialization Method	Number of Members	Forcing	Reference
CCCma	CanESM2	~2.8°x2.8°/~1.4°x0.9°	1950-2100	Macro and Micro	50	historical, rcp85	Kirchmeier-Young et al. (2017)
CSIRO	MK3.6	~1.9°x1.9°/~1.9°x1.0°	1850-2100	Macro	30	historical, rcp85	Jeffrey et al. (2013)
GFDL	ESM2M	~2.0°x2.5°/~1.0°x0.9°	1950-2100	Macro	30	historical, rcp85	Rodgers et al. (2015)
GFDL	CM3	~2.0°x2.5°/~1.0°x0.9°	1920-2100	Micro	20	historical, rcp85	Sun et al. (2018)
MPI	MPI-ESM-LR	~1.9°x1.9°/nominal 1.5°	1850-2100	Macro	100	historical, rcp26, rcp45, rcp85	Maher et al. (2019)
NCAR	CESM1	~1.3°x0.9°/nominal 1.0°	1920-2100	Micro	40	historical, rcp85	Kay et al. (2015)
SMHI/KNMI	EC-EARTH	~1.1°x1.1°/nominal 1.0°	1860-2100	Micro	16	historical, rcp85	Hazeleger et al. (2010)

cesm.ucar.edu/projects/community-projects/MMLEA/

Application #1: Interpretation of observational record

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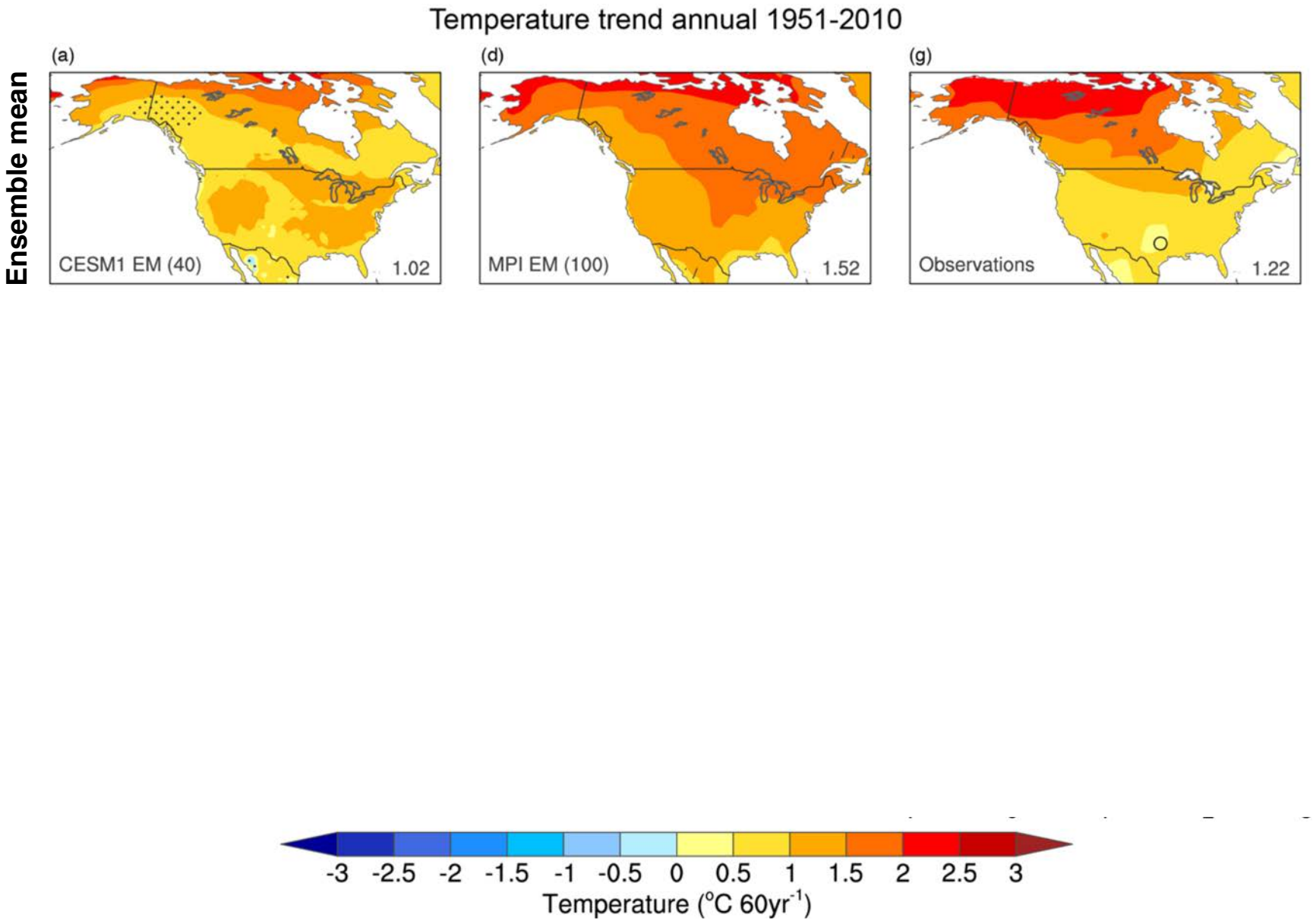

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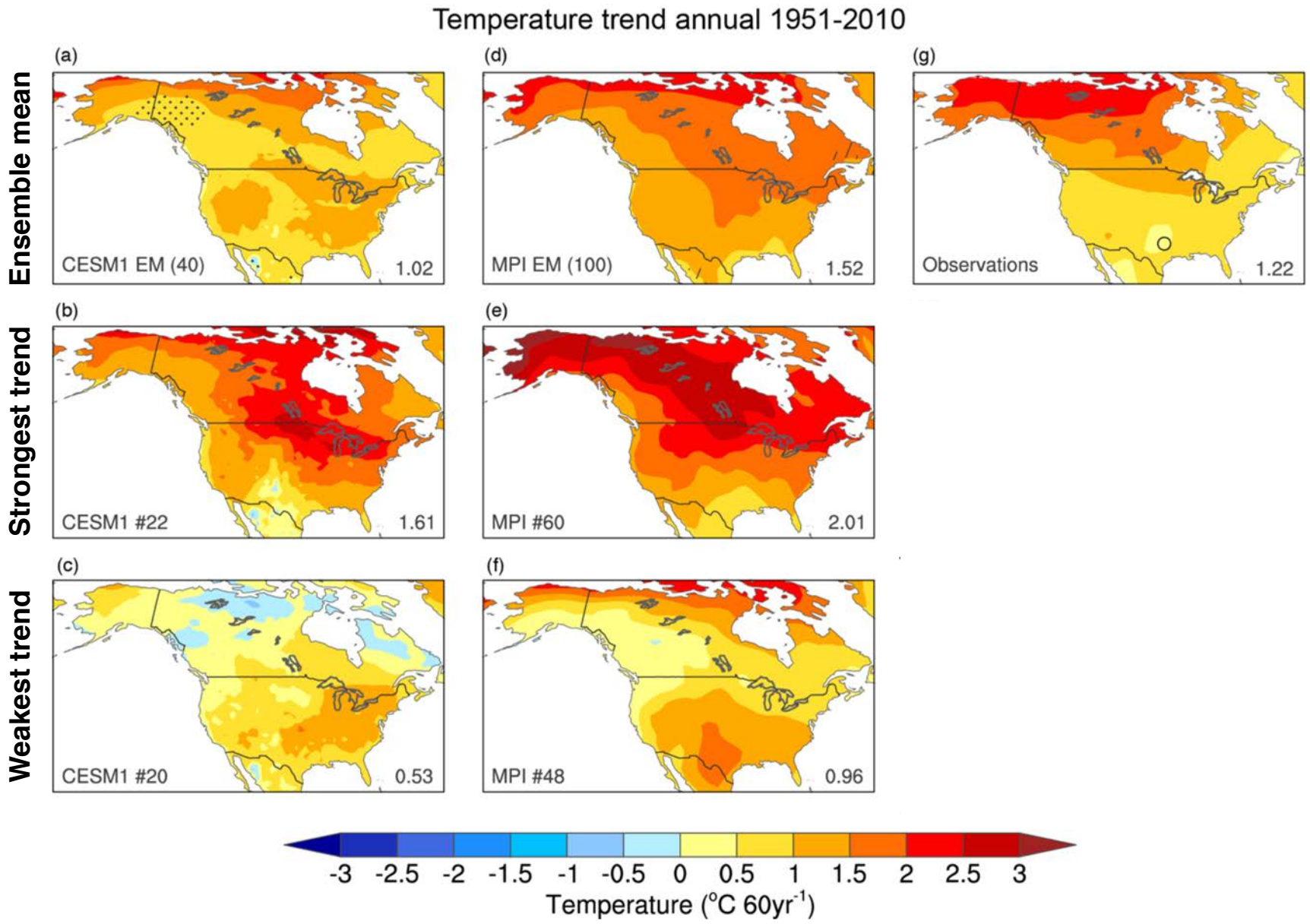

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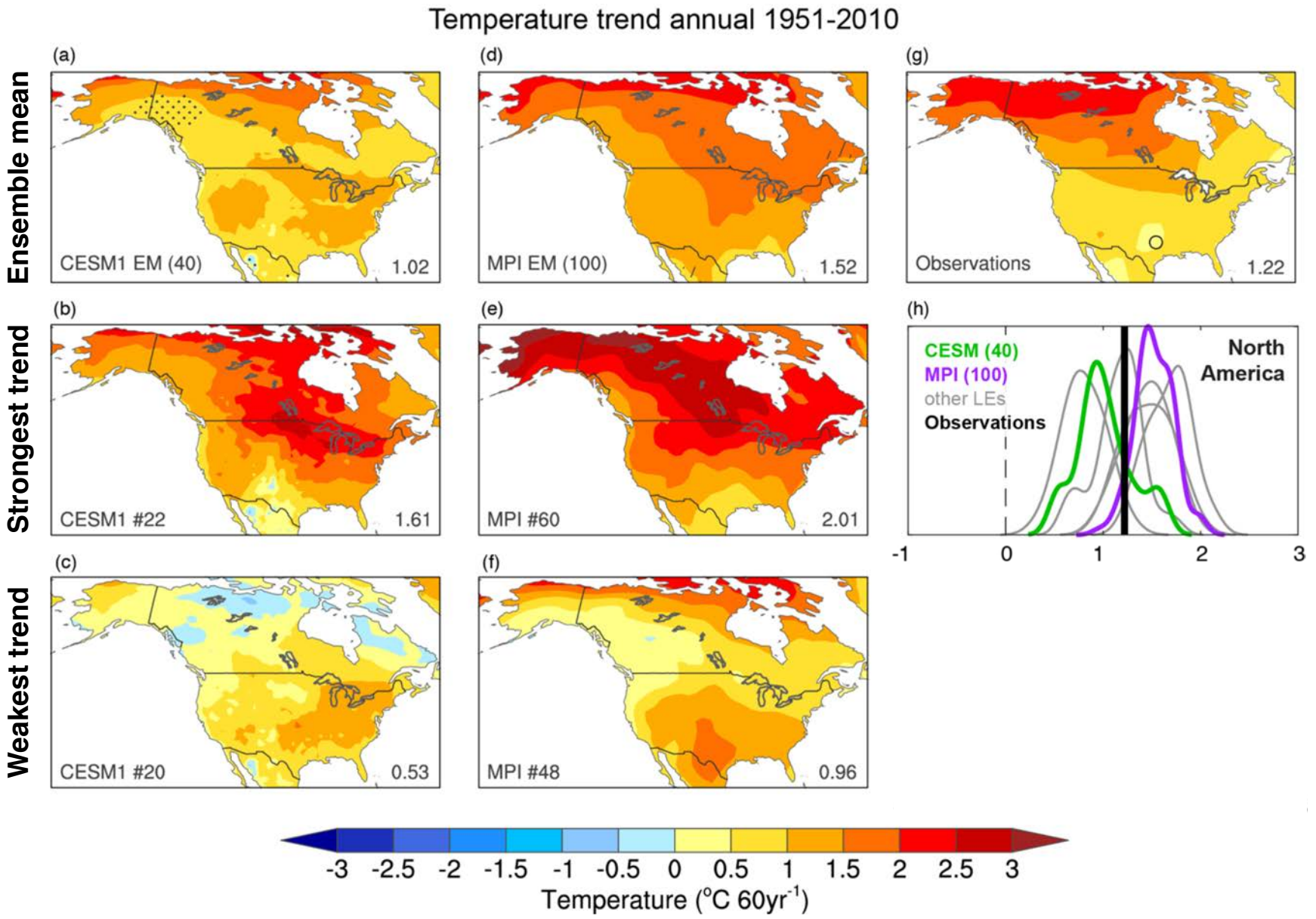

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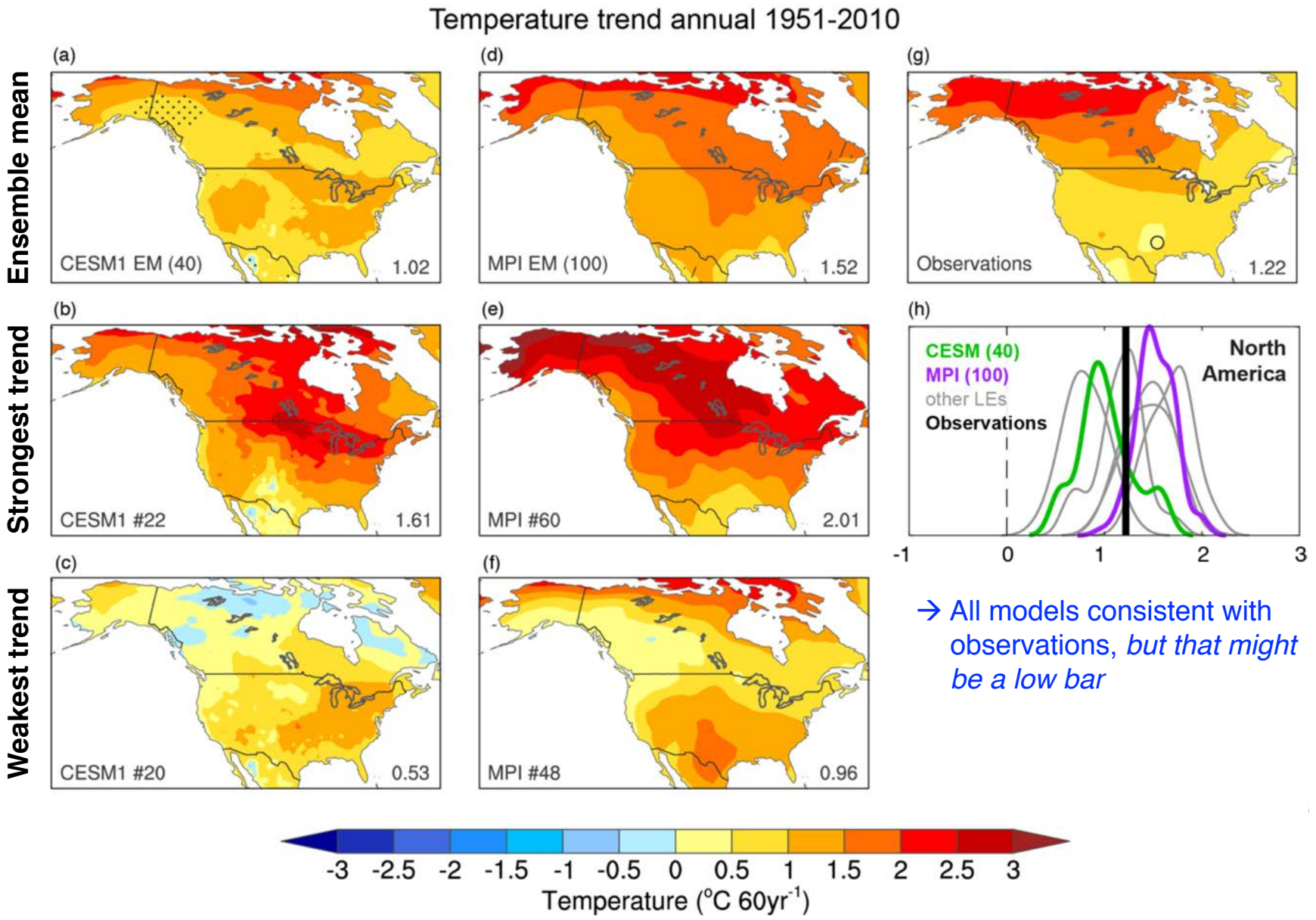
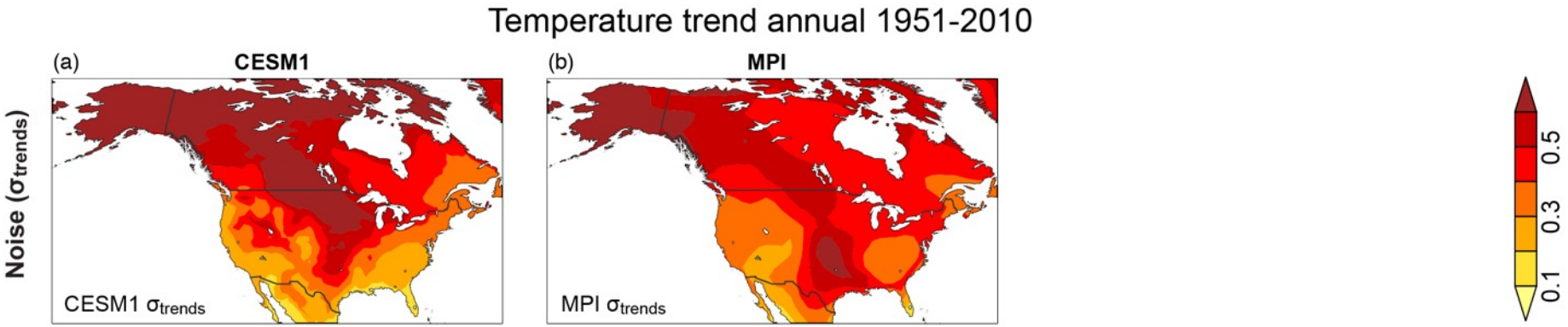


→ All models consistent with observations, *but that might be a low bar*

Application #2: Evaluation of model variability



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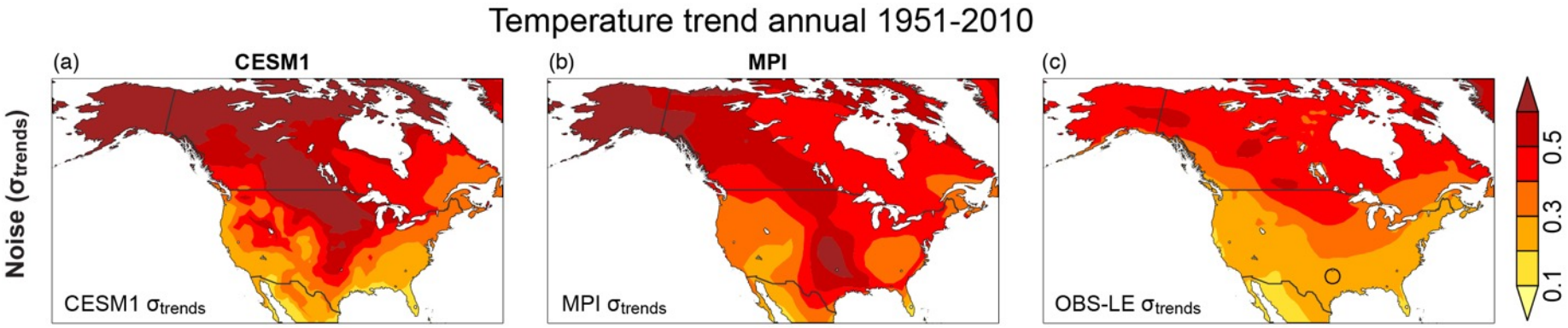

↳ OBS-LE: estimate of real-world variability in trends

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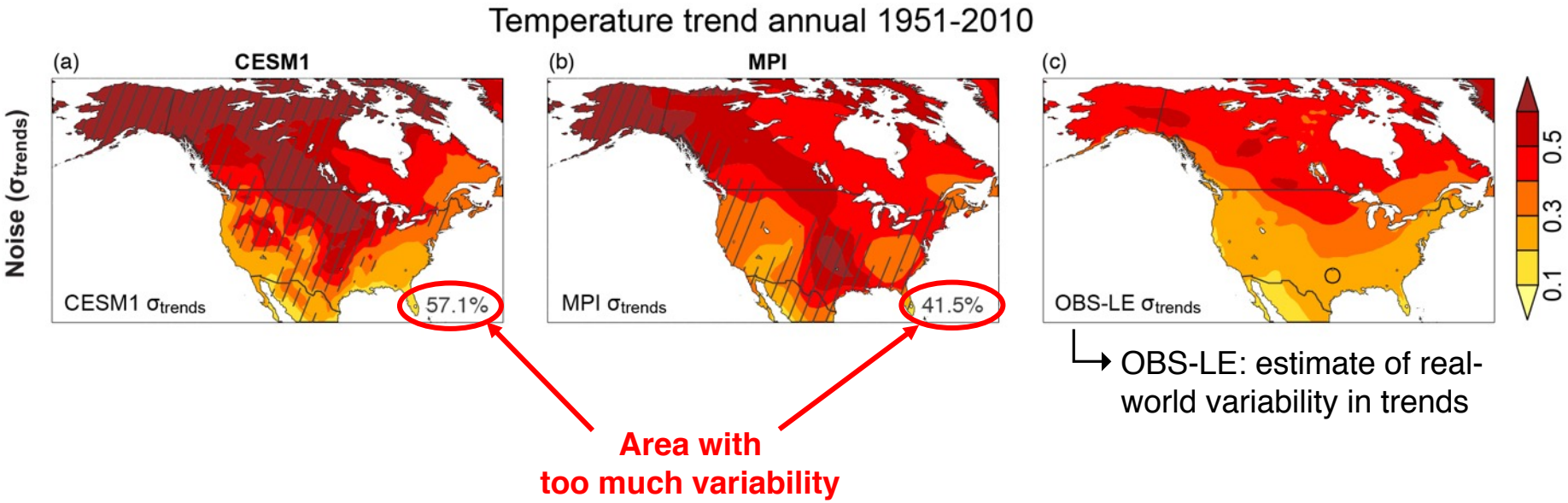
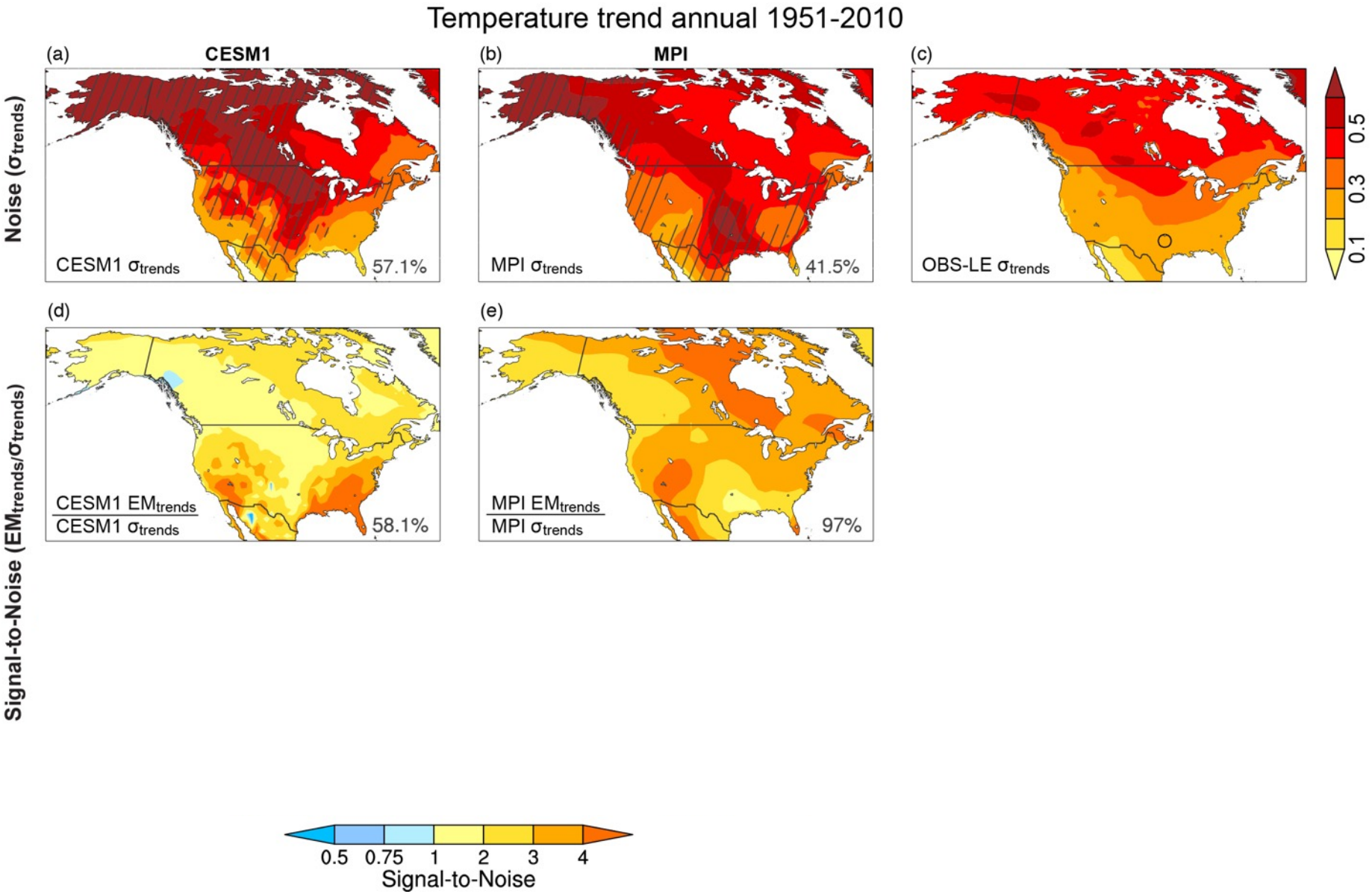


OBS-LE: estimate of real-world variability in trends

Area with too much variability

Application #2: Evaluation of model variability



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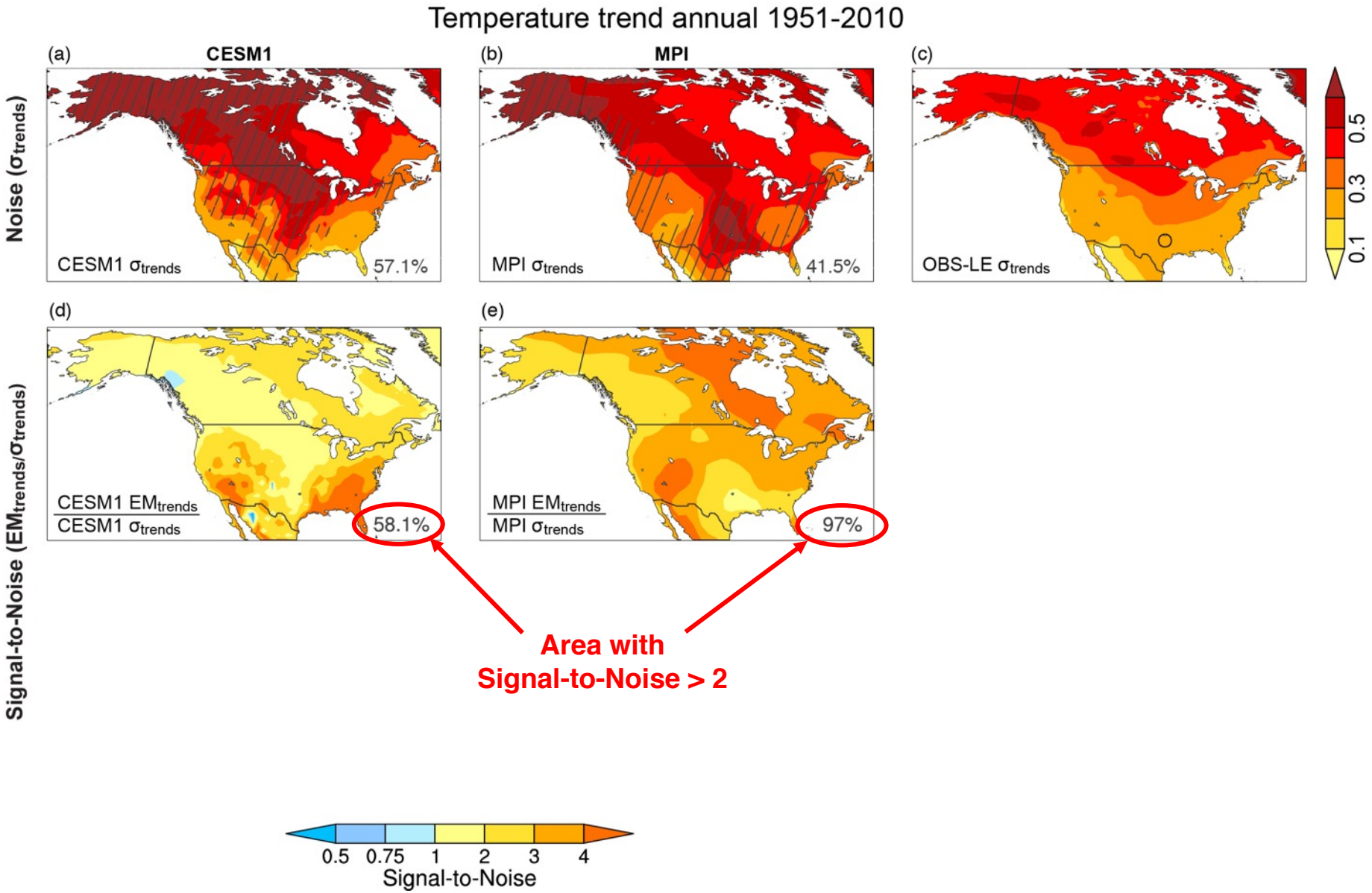

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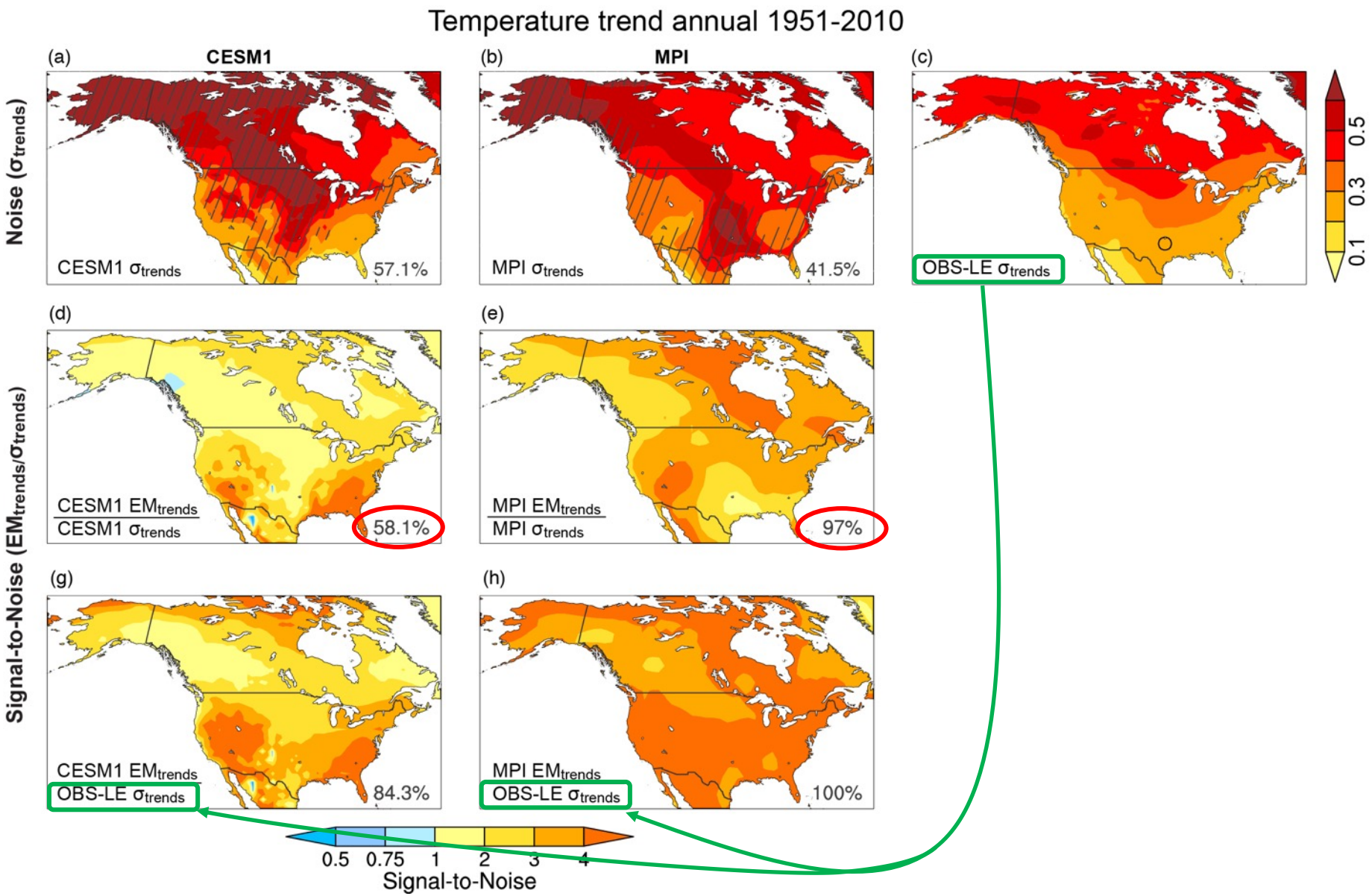

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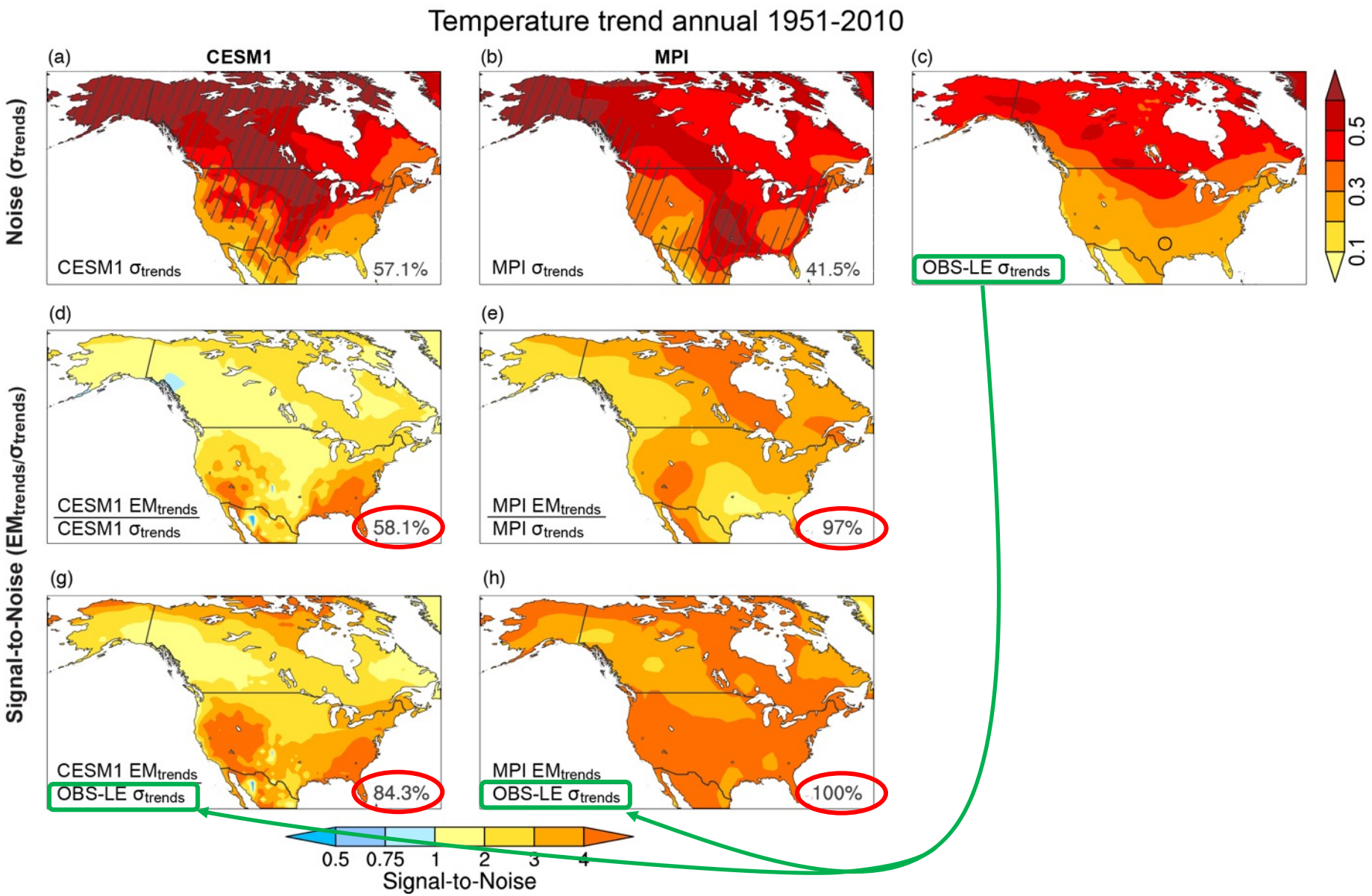

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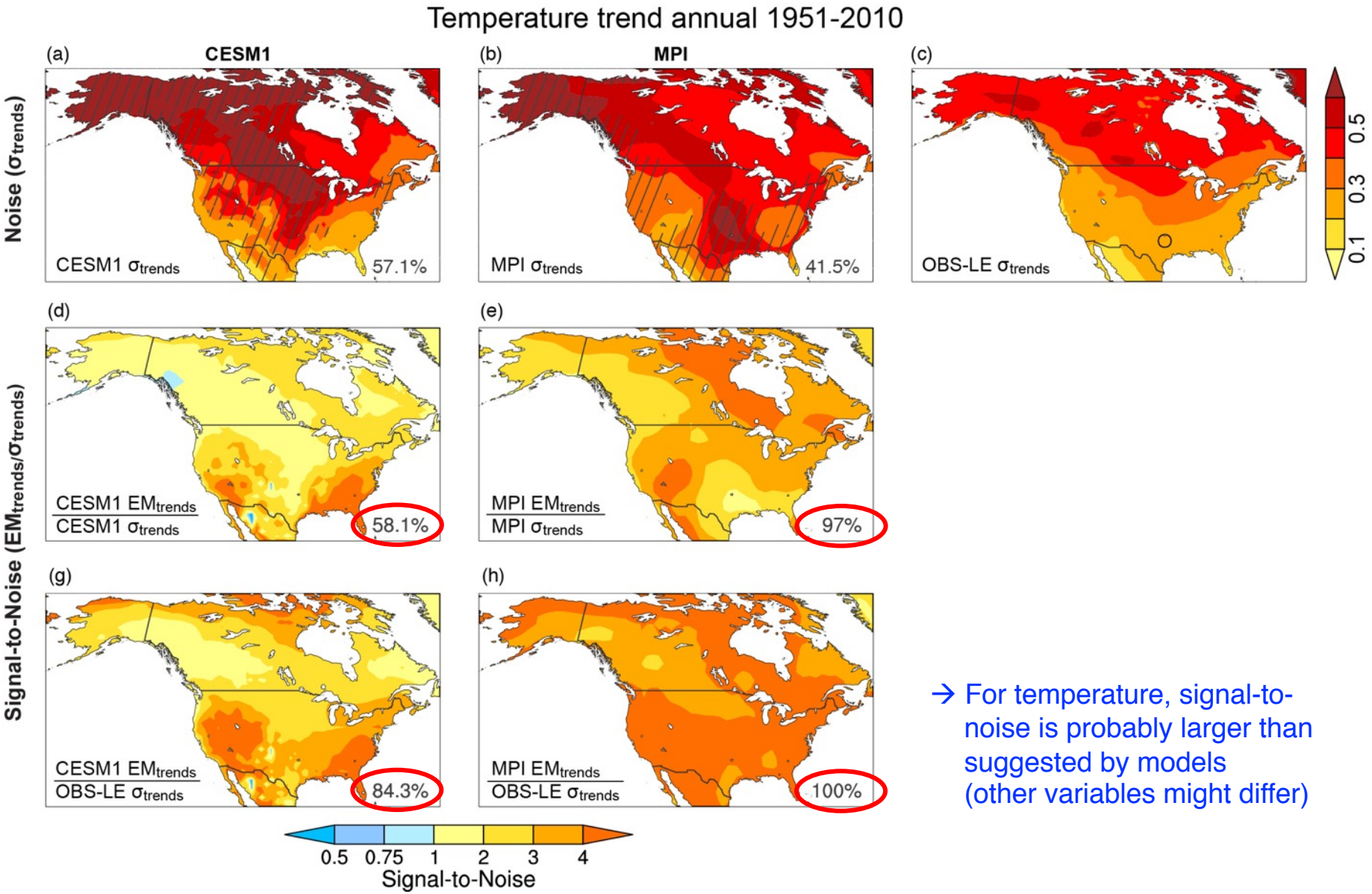
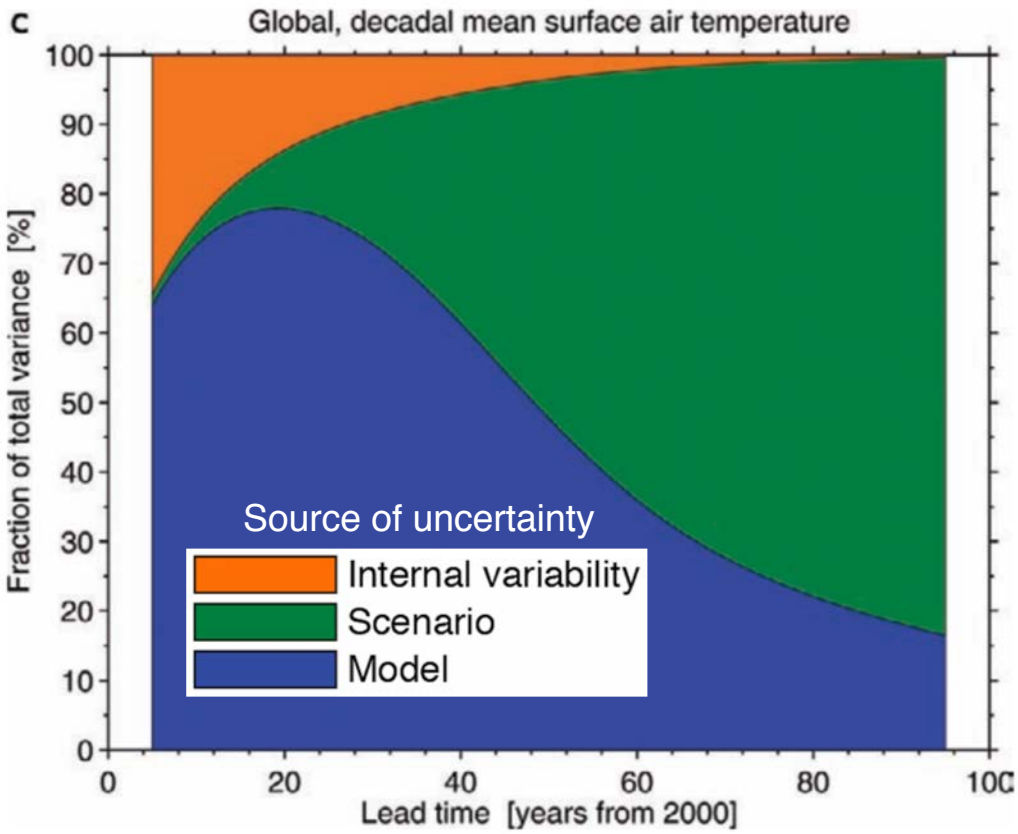


→ For temperature, signal-to-noise is probably larger than suggested by models (other variables might differ)

Application #3: Uncertainty partitioning



Hawkins and Sutton (2009)

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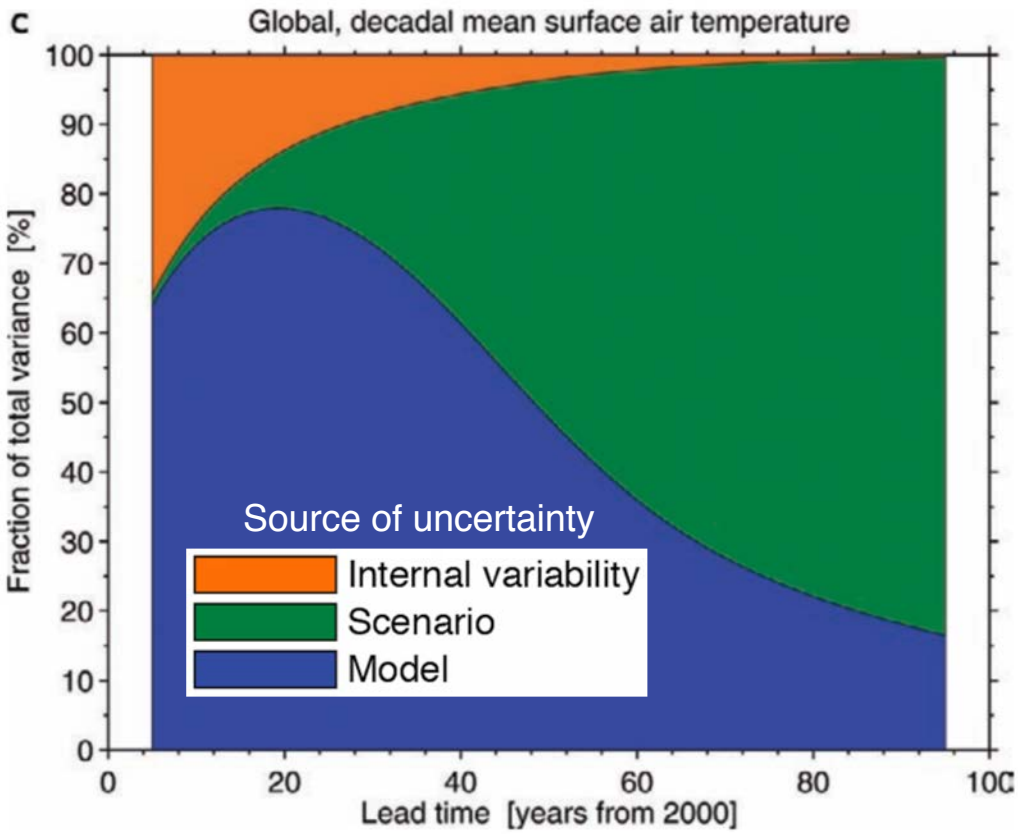

H&S09 didn't have LEs, thus needed to make assumptions:

- 4th order polynomial fit to a single ensemble member to estimate forced response
- No changes in internal variability over time

Hawkins and Sutton (2009)

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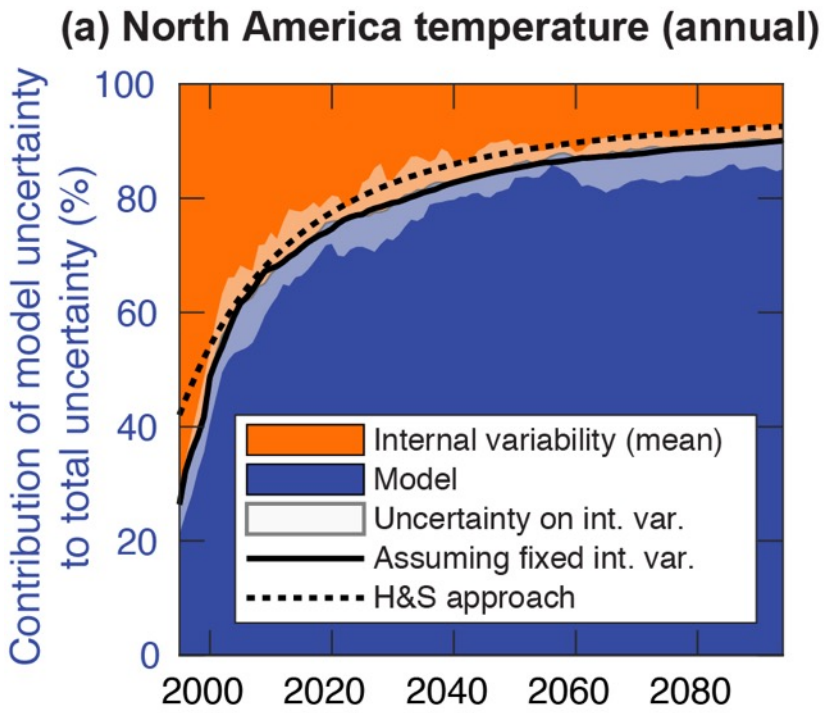

Repeat H&S09 analysis with 7 LEs

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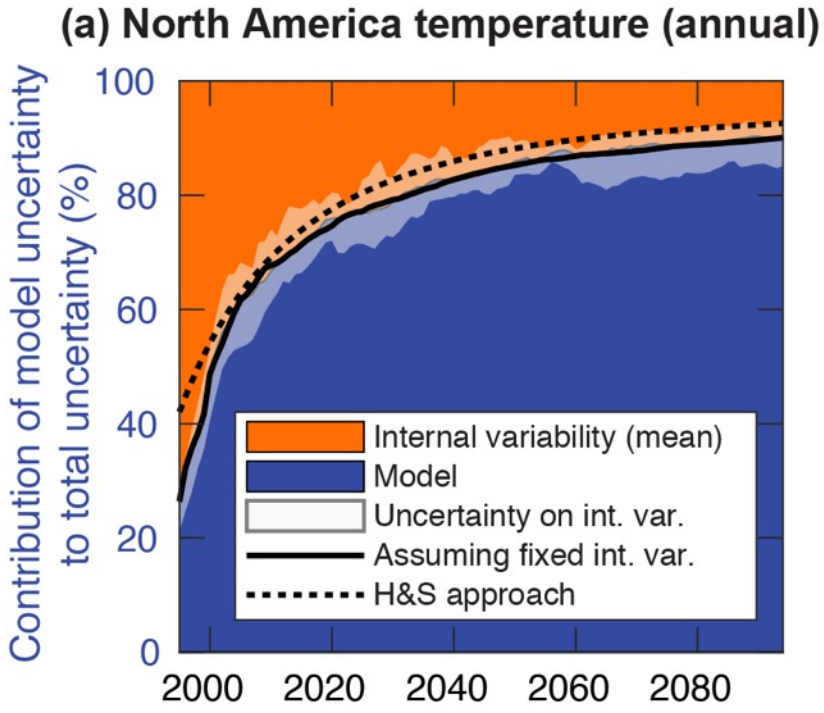

→ H&S09 original approach works well for certain quantities and regions

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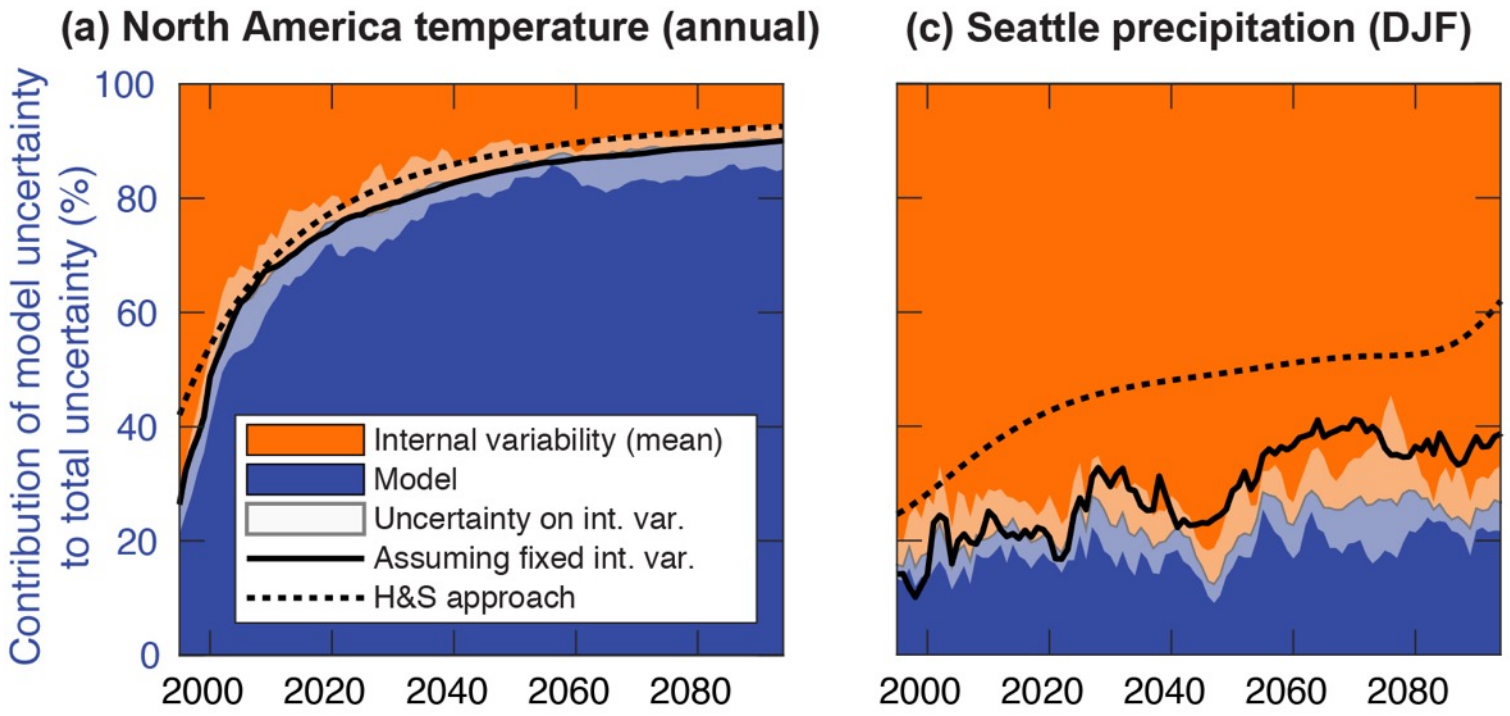

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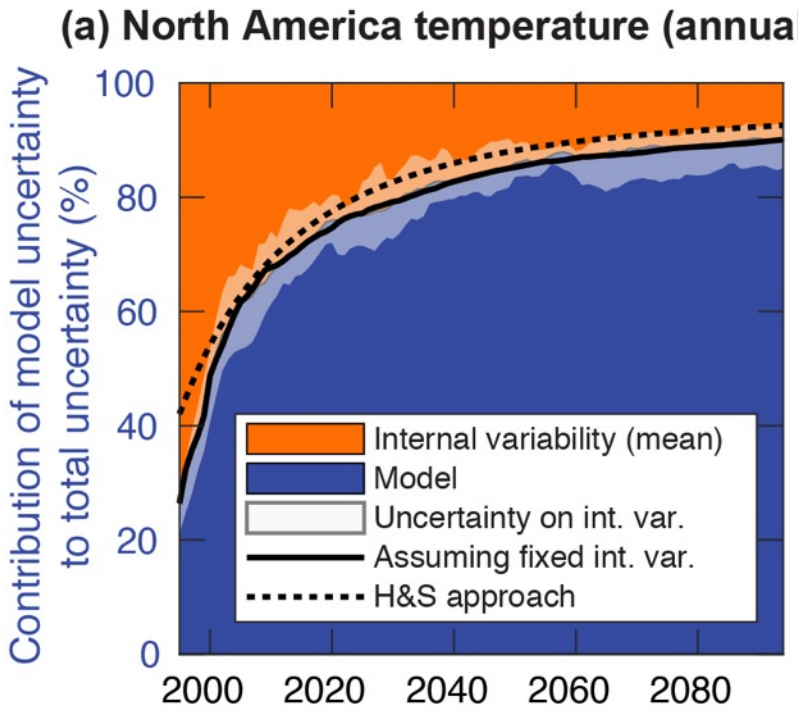

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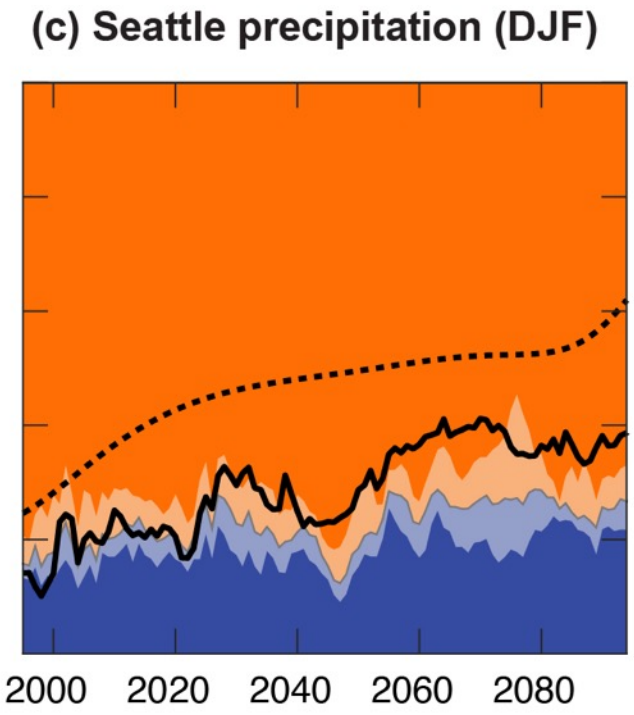

→ H&S09 original approach has limitations for some quantities and regions due to decadal variability as well as *forced changes in variability*

Other applications and documentation of MMLE Archive

Strength in Numbers: The Utility of Large Ensembles with Multiple Earth System Models

US CLIVAR Working Group on Large Ensembles
[C. Deser*, F. Lehner, K.B. Rodgers, T. Ault, T.L. Delworth, P.N. DiNezio, A. Fiore, C. Frankignoul, J. C. Fyfe, D.E. Horton, J.E. Kay, R. Knutti, N.S. Lovenduski, J. Marotzke, K.A. McKinnon, S. Minobe, J. Randerson, J.A. Screen, I.R. Simpson and M. Ting]

Perspective submitted 21 June 2019 to *Nature Climate Change*

Submitted draft available on Clara's website

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Feedback on and contributions to the MMLE Archive are welcome!

Updates and bug fixes planned for later this summer

flehner@ucar.edu
@ClimateFlavors

What do LE users want?

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CESM2 Large Ensemble is being planned and your input is desired

[CCSM-Participants] CESM2-LE

To: CESM-Participants@cgd.ucar.edu

Dear CESM community,

We are in the planning stages for an initial condition Large Ensemble (LE) with the 1-degree version of CESM2 and would like to solicit your input on its design. The CESM2-LE will be developed through a research partnership between the CESM project and the IBS Center for Climate Physics in Busan, South Korea, and will consist of 100 members spanning the period 1850-2100. The simulations will be conducted by the IBS in South Korea and output from the new runs will be distributed through a coordinated effort between the two entities. Each ensemble member will begin from an extended 1850 control run, with initial condition options described below. We propose to save high-frequency (6-hourly or shorter) output over the entire duration of the simulation for up to 10 members, in addition to output from the Cloud Feedback Model Intercomparison Project Observational Simulator Package (COSP), which is a satellite simulator for clouds and precipitation (see https://climatedataguide.ucar.edu/climate-data/cosp-cloud-feedback-model-intercomparison-project-cfmip-observation-simulator-package). All output will be made CMIP6-compliant, meaning that the output will be converted to timeseries format, variable names converted to CMIP6 requirements, and ocean data will be regridded to a lat/lon grid.

We are bound by resource and other constraints; therefore, the number of ensemble members is fixed; however, there are other design features for which we would like your input. We consider this first set of 100 members to be the foundation of the CESM2-LE and anticipate that related ensemble sets, such as single-forcing or other "one-offs," will be conducted as resources become available. Please respond to this email (bates@ucar.edu) by 22 July 2019 with your suggestions.

1) Initialization. The CESM1-LE used "pertlim" in the atmosphere to create ensemble spread, with each member beginning from the identical ocean/land/cryosphere state with the surface temperature in the atmosphere slightly perturbed (order 10^-14 K). We shall refer to this as a "micro" ensemble. One option is to use the same protocol for the CESM2-LE. Another option is to use restarts from different years of the 1850 control run so that the entire coupled earth system begins from a different state (a so-called "macro" ensemble). These restart dates may be chosen at random or based on the state of AMOC, ENSO, etc. Please state your opinion and rationale for the possible choices of initialization below. Please also include your thoughts on which ensemble members should include high-frequency and COSP output.

a) 100-member micro ensemble
b) A combination of micro and macro (please state the number of each you suggest noting that the total number of simulations must equal 100)
c) Other (please state)

2) Future emissions scenario. Historical radiative forcing will be applied for the period 1850-2014. For the future portion of the ensemble, we propose the following options:
a) SSP5-8.5 (which corresponds most closely to RCP-8.5, which was used for the CESM1-LE)
b) SSP3-7.0 (considered the 'baseline' scenario in ScenarioMIP; see O'Neill et al., 2016, for an overview over some scenarios: https://www.geosci-model-dev.net/9/3461/2016/gmd-9-3461-2016.pdf)
c) Other: please state.

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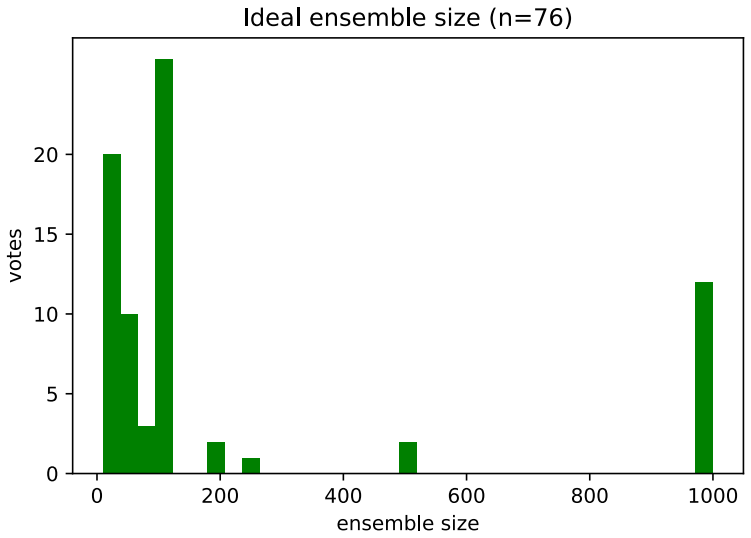

Courtesy of S. Milinski and N. Maher

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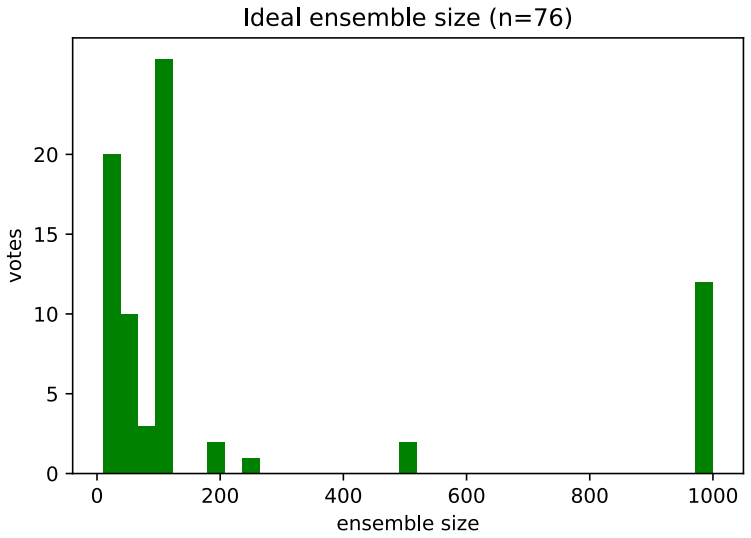

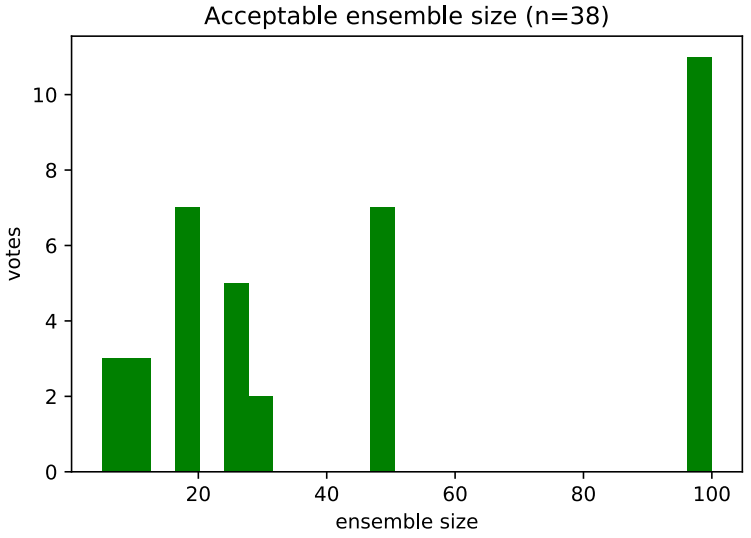

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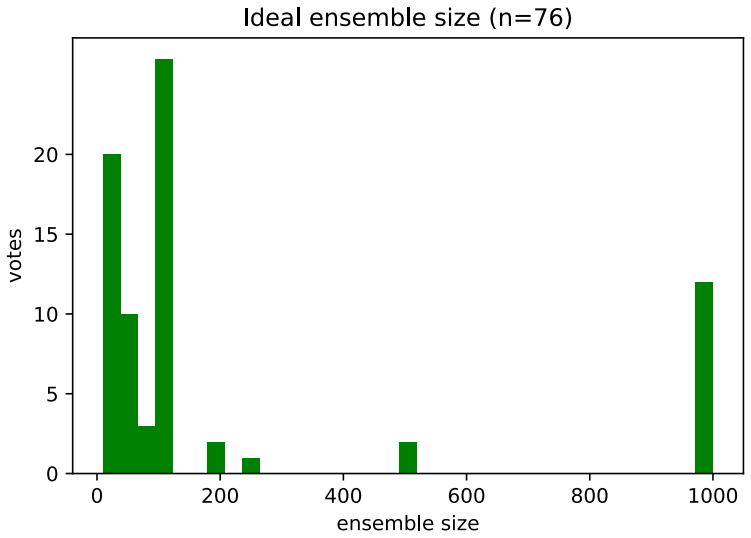
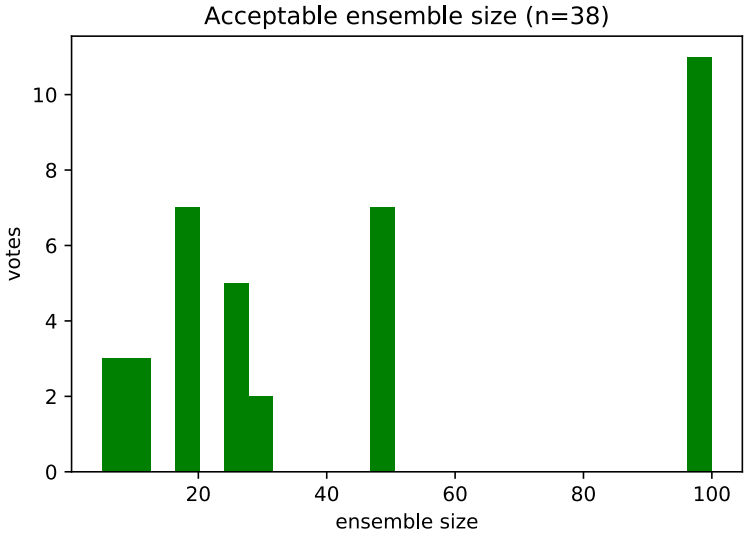
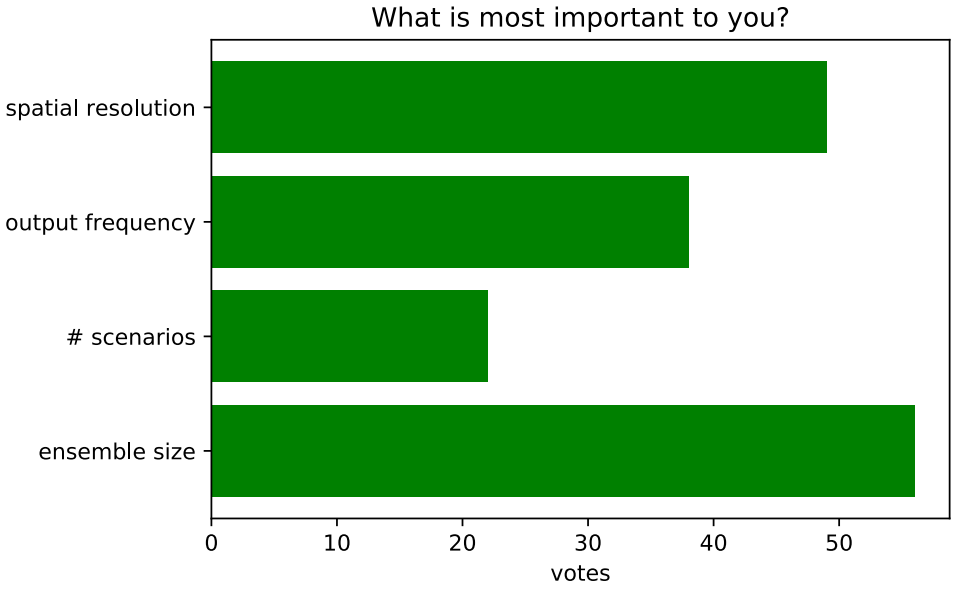
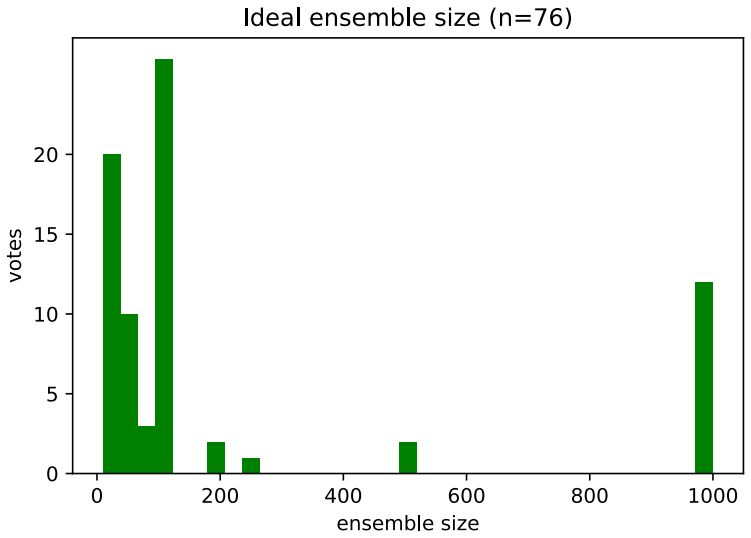
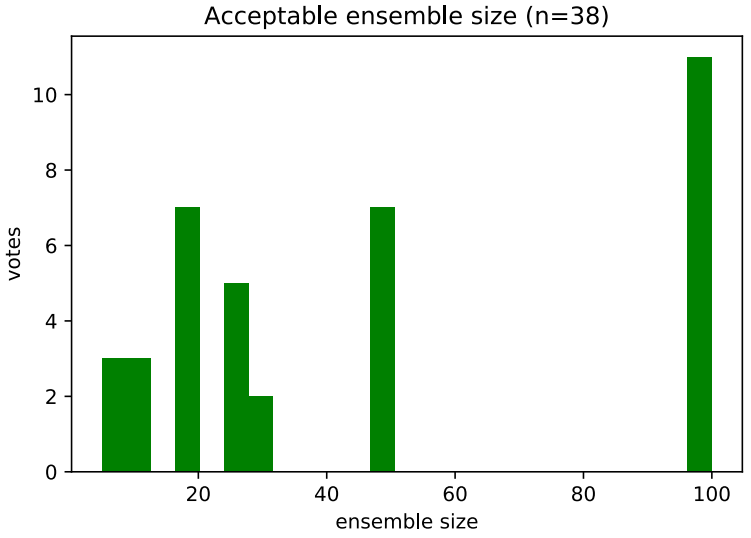


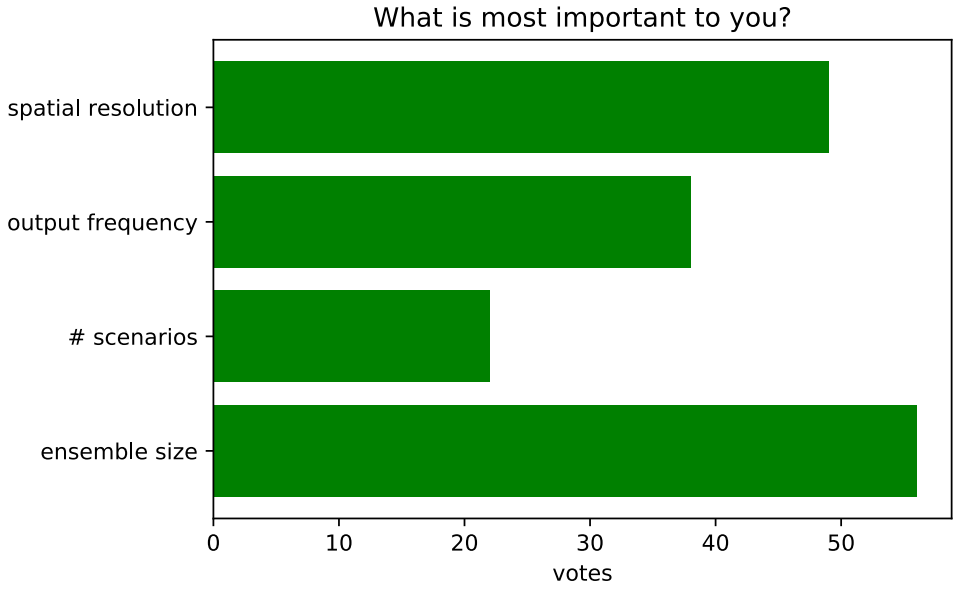




What do LE users want?







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Other Large Ensembles resources

- **Multi-Model Large Ensemble Archive**

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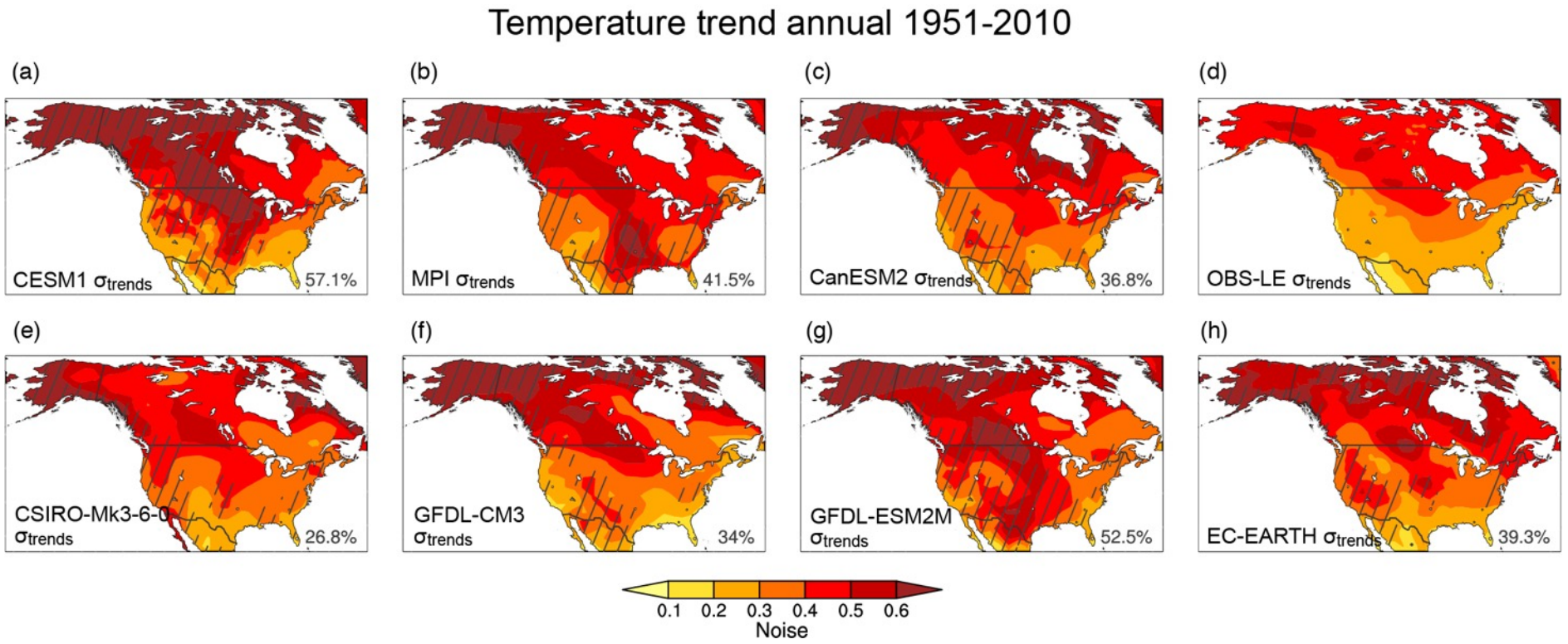
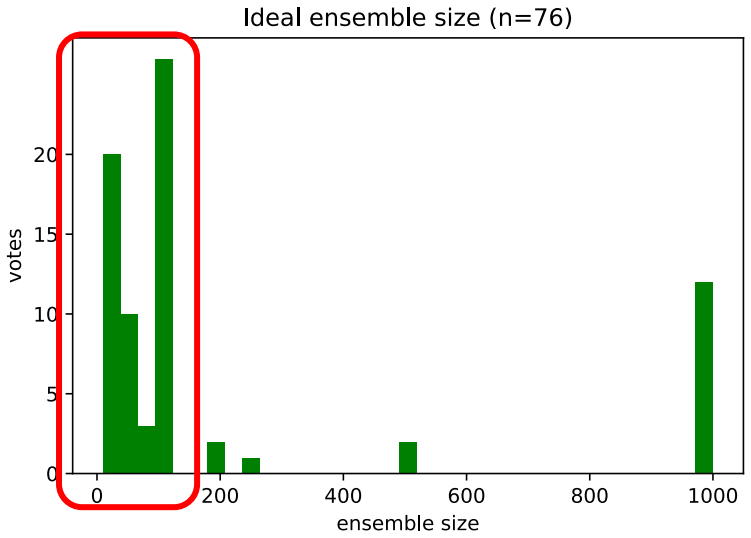
Thanks!

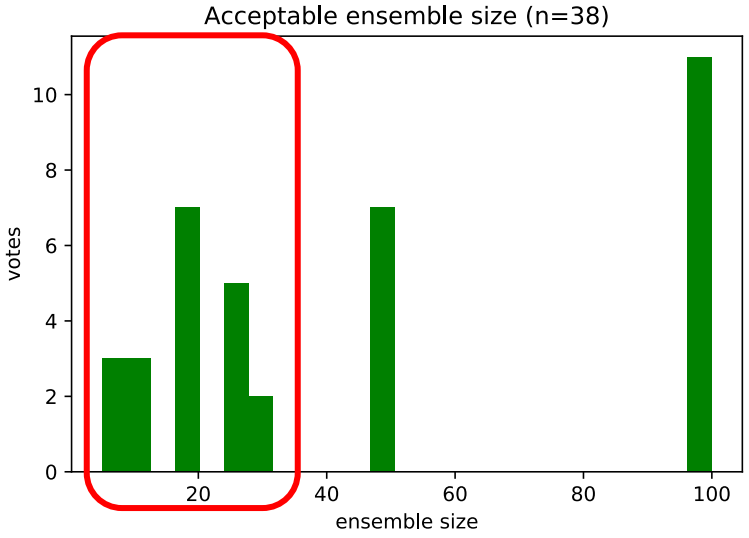
Extra

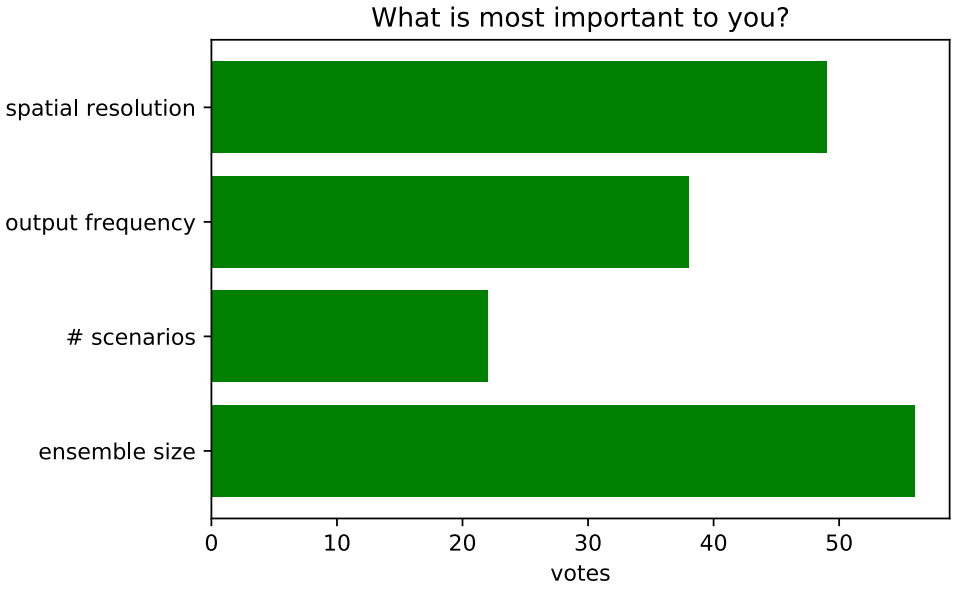
Application #2: Evaluation of model variability



What do LE users want?







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