2020 RGMA PI meeting

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Surface Climate Decadal Predictability in a Multi-Model Collection of Large Ensembles

Haiyan Teng[1], Grant Branstator[2], Claudia Tebaldi[1], Flavio Lehner[2,3]

October 14, 2020

Supported by U.S. DEPARTMENT OF ENERGY Office of Science Catalyst and HiLAT SFAs

1: PNNL 2: NCAR. 3: Cornell University

The multi-model LE Repository

(Deser et al. 2020)

Modelling centre	Model version	Resolution (atmosphere/ocean)	Years	Initialization	No. of members
CCCma	CanESM2	-2.8°x2.8°/-1.4°x0.9°	1950-2100	Macro and micro	50
CSIRO	MK3.6	-1.9°x1.9°/-1.9°x1.0°	1850-2100	Macro	30
GFDL	ESM2M	2.0°x2.5°/1.0°x0.9°	1950-2100	Macro	30
GFDL	CM3	2.0°x2.5°/1.0°x0.9°	1920-2100	Micro	20
MPI	MPI-ESM-LR	-1.9°x1.9°/nominal 1.5°	1850-2100	Macro	100
NCAR	CESM1	-1.3°x0.9°/nominal 1.0°	1920-2100	Micro	40
SMHI or KNMI	EC-Earth	-1.1°x1.1°/nominal 1.0°	1860-2100	Micro	16

**Daily data from MPI are unavailable.*

How large is the forced predictability in daily TAS/precipitation in the near term?
How significant is the forced predictability compared to that produced by ENSO?

Relative Entropy
Shannon's information theory

- **Kullback-Leibler divergence**

$$\mathrm{D_{KL}}(\mathrm{p} \| \, q) = \int_X \mathrm{p(x)} \, log_2 \frac{p(x)}{q(x)} dx$$

A way to compare distributions, but not a proper distance, as $\mathrm{D_{KL}}(\mathrm{p} \| \, q) \neq \mathrm{D_{KL}}(q \, \| \, p)$

1 bit of info: reduce uncertainty by 2

- **n-dimensional Gaussian distribution**

$$\mathrm{D_{KL}}(\mathrm{p} \| \, q) = \; const * \left\{ ln \left[\frac{\det(\sigma_q^2)}{\det(\sigma_p^2)} \right] + tr \left[\sigma_p^2 (\sigma_q^2)^{-1} \right] + (\vec{\mu^p} - \vec{\mu^q})^T (\sigma_q^2)^{-1} (\vec{\mu^p} - \vec{\mu^q}) - n \right\}$$

To quantify predictability limit:

Kleeman 2002 Branstator and Teng 2010, Teng and Branstator 2011, Teng et al. 2011, Branstator and Teng 2012, Branstator et al. 2012 (annual mean subsurface temp)

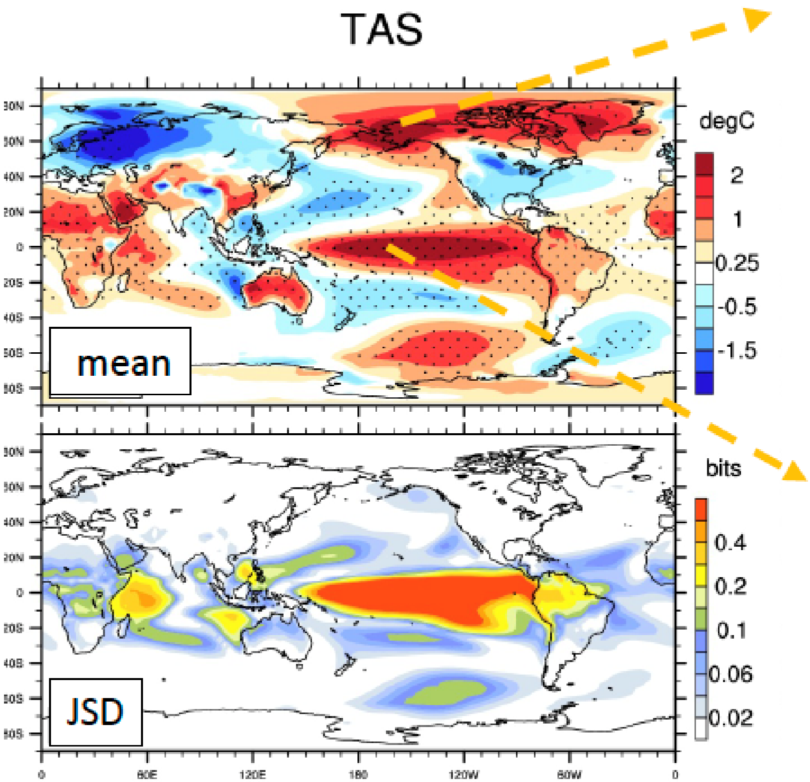
- **Jensen-Shannon divergence (JSD)**

$$JSD(p \, \| \, q) = \frac{1}{2} \mathrm{D_{KL}}(\mathrm{p} \| \, M) + \frac{1}{2} \mathrm{D_{KL}}(q \, \| \, M), M = \frac{1}{2}(\mathrm{p+q})$$

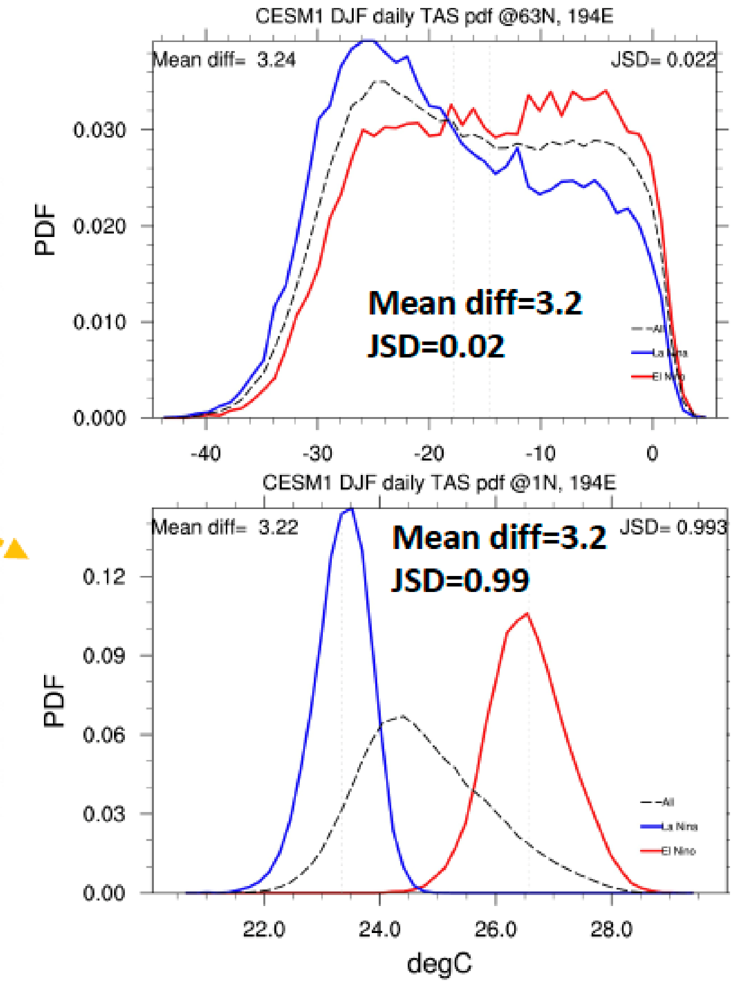
symmetric, smoothed ([0,1]) version of KLD

- **Cost function for machine learning tasks, but has not been widely used in climate research**

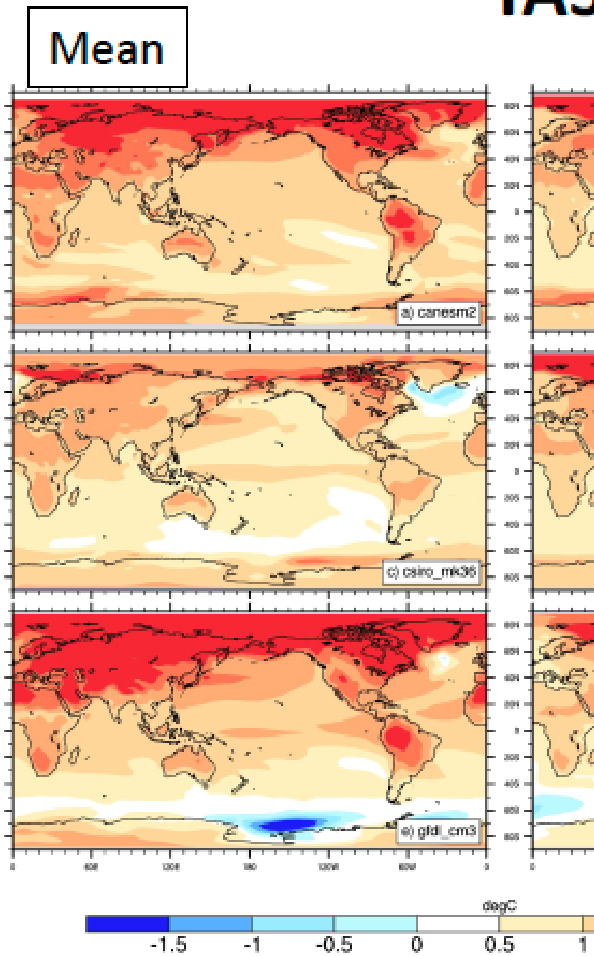
El Nino vs. La Nina in CESM1 1800-yr picontrol

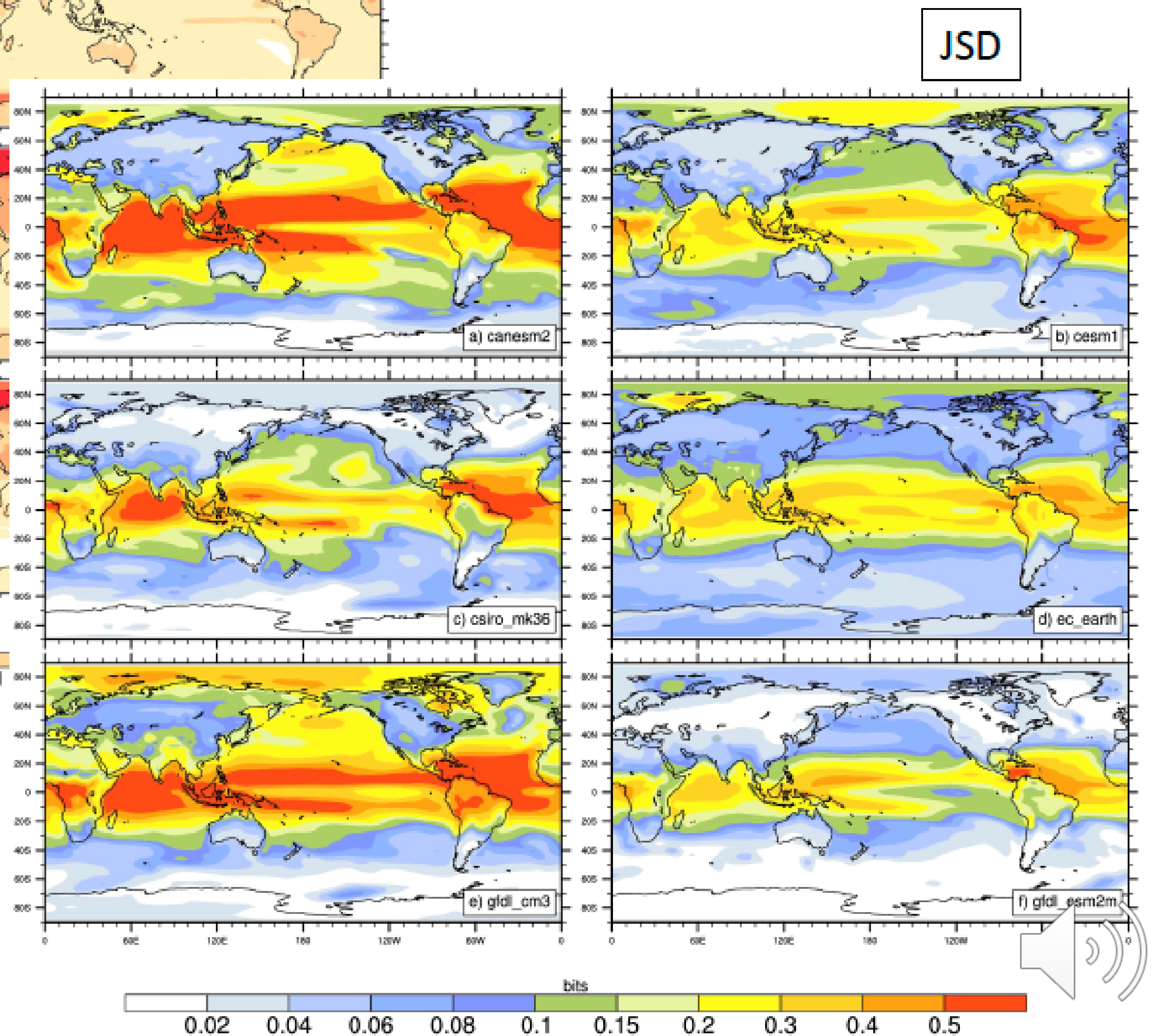


based on 280 El Nino, 247 LaNina



TAS 2028-2032 vs. 1980-2000

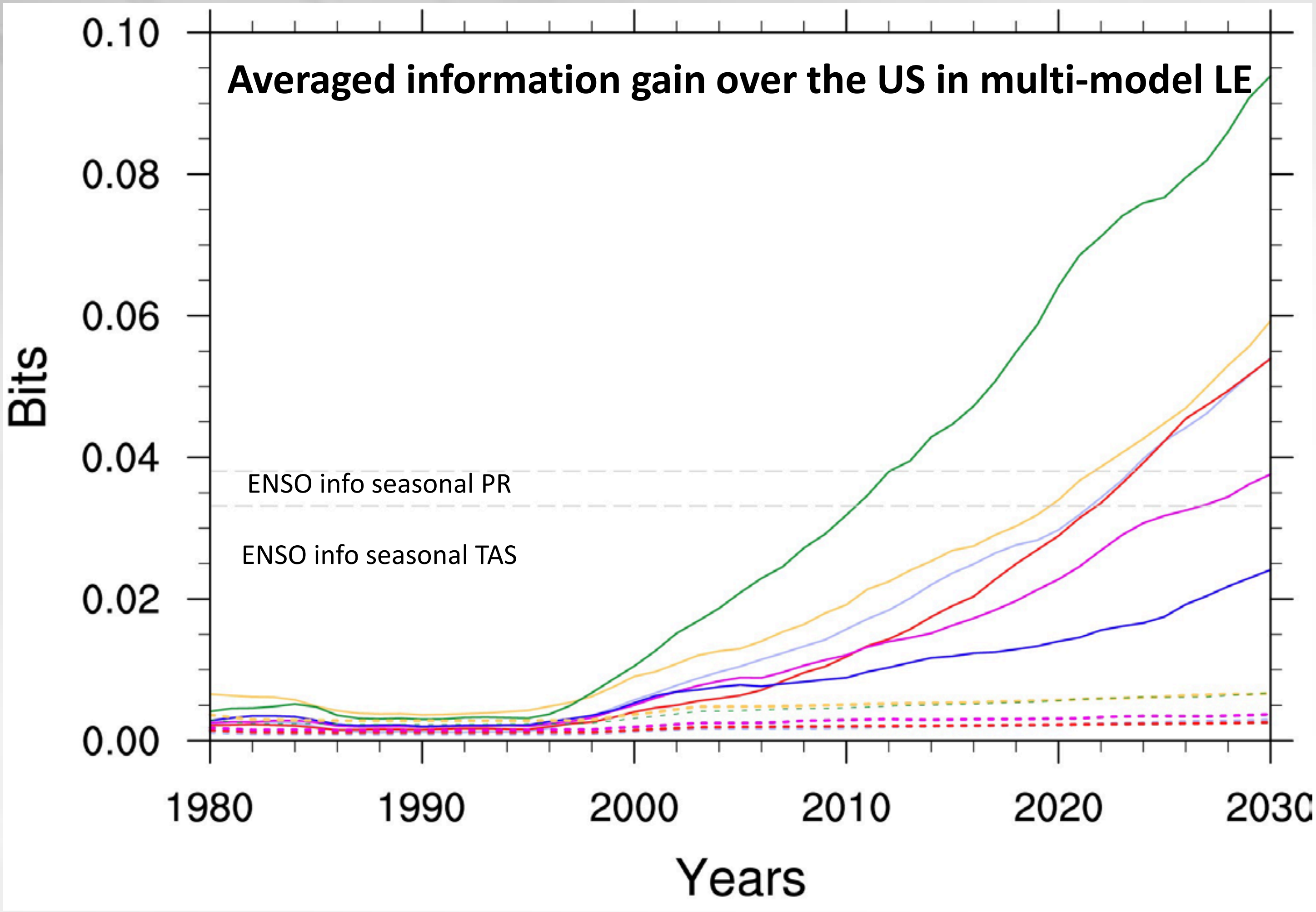




How significant is the forced predictability compared to that produced by ENSO?

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965



With relative entropy we can quantify and compare predictability (of both forced and initial-value) on S2D time scales