ENSO Predictability and Dynamics

Presented by

Andrew Wittenberg

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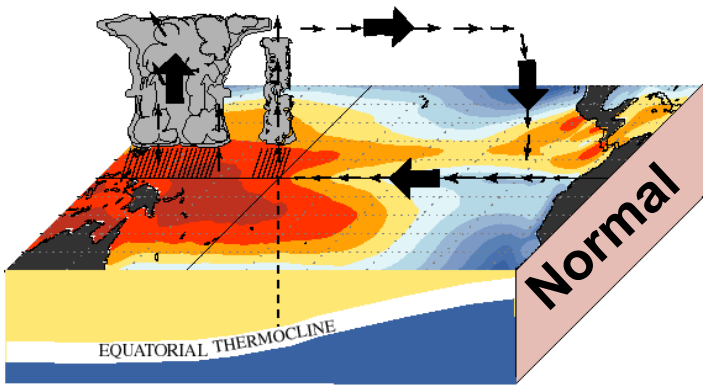
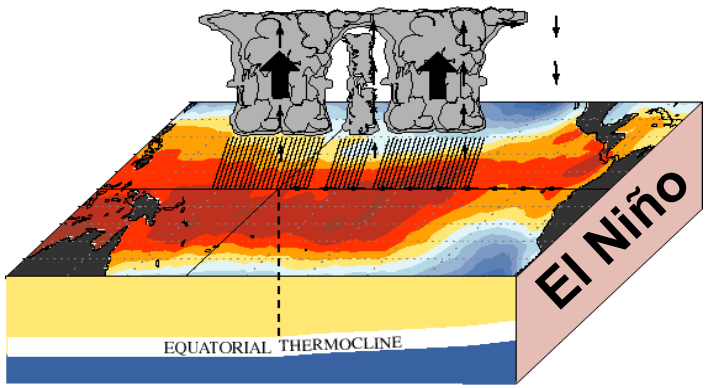
ENSO: Earth's dominant interannual climate signal





Global Impacts:

- **weather & climate**, natural disasters, transportation
- **ecosystems**, fisheries, agriculture
- **economies:** commerce, energy, water, food, health

How vulnerable are we to future ENSO events?

- **natural vs. anthropogenic risks**
- changes in **dynamics** vs. **impacts**
- short, gappy, nonstationary observing system -> **models crucial**
- coupling & scale interactions -> **key test** for models

GFDL: Strongly positioned in the ENSO community

ENSO simulations among the best in the world

- **realistic** ENSO patterns, mechanisms, teleconnections
- **rich** spectrum of ENSO behavior
- **stable** 4000-year control run
- complementary **assimilation & forecast** systems

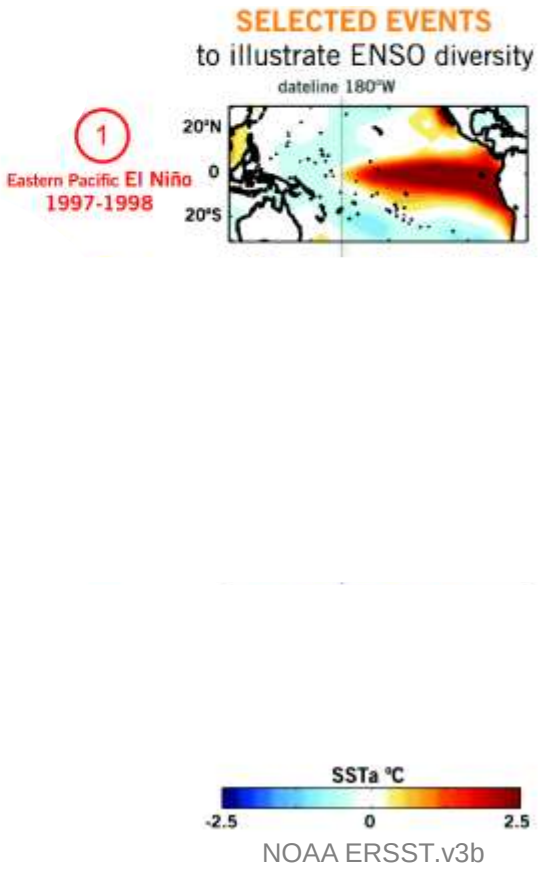
Wittenberg (2009); Vecchi & Wittenberg (2010); Kug et al. (2010); Delworth et al. (2012); Choi et al. (2013); Capotondi & Wittenberg (2013); Wittenberg et al. (2014); Bellenger et al. (2014); Jia et al. (subm); Wittenberg et al. (in prep)

Groundbreaking ENSO research & collaborations

- **diversity, sensitivities,** mechanisms
- **historical & proxy reconstructions**
- **predictability**, forecasts, observing system evaluation
- extratropical impacts, drought, decadal signals
- conceptual models, statistical emulators, community metrics

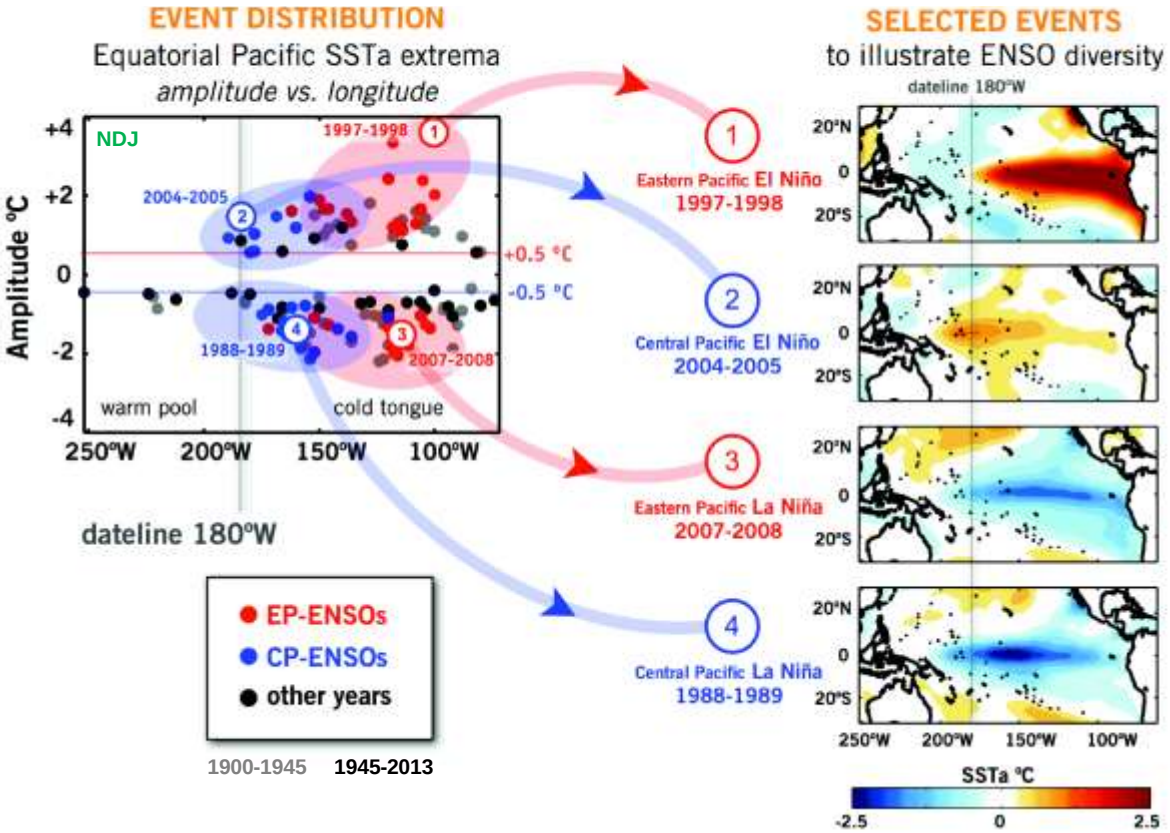
Sample of external collaborations: *Collins et al. (2010); DiNezio et al. (2010, 2011, 2012, 2013); Chen et al. (2011); Guilyardi et al. (2012ab); Watanabe & Wittenberg (2012); Watanabe et al. (2012); Emile-Geay et al. (2013ab); U.S. CLIVAR (2013); Ogata et al. (2013); McGregor et al. (2013); Karamperidou et al. (2014); Graham et al. (2014); Cai et al. (2014); Capotondi et al. (subm); Graham et al. (in prep); Erb et al. (in prep); Chen et al. (in prep); Atwood et al. (in prep)*

ENSO diversity in observations



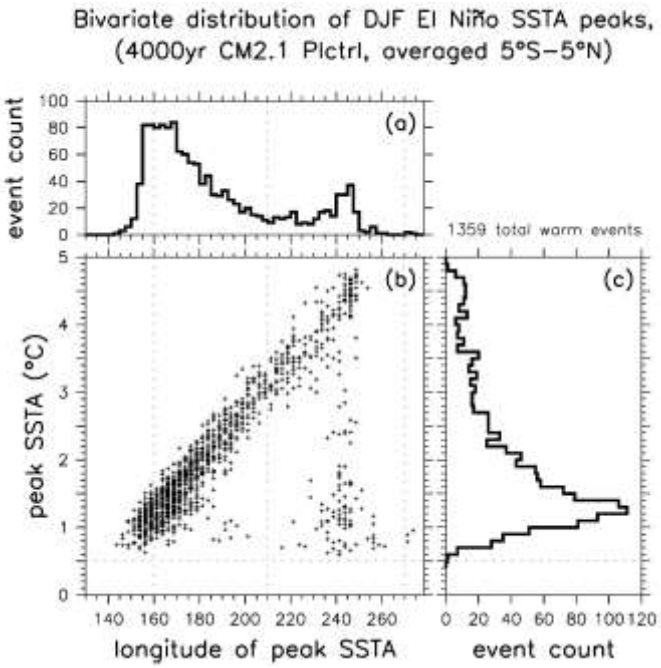
U.S. CLIVAR Working Group on ENSO Diversity: *Capotondi, Wittenberg, et al. (BAMS, subm. 2014)*
Kug et al. (2010); Chen et al. (in prep); Atwood et al. (in prep)

ENSO diversity in observations & models



NOAA ERSST.v3b

CM2.1 simulation



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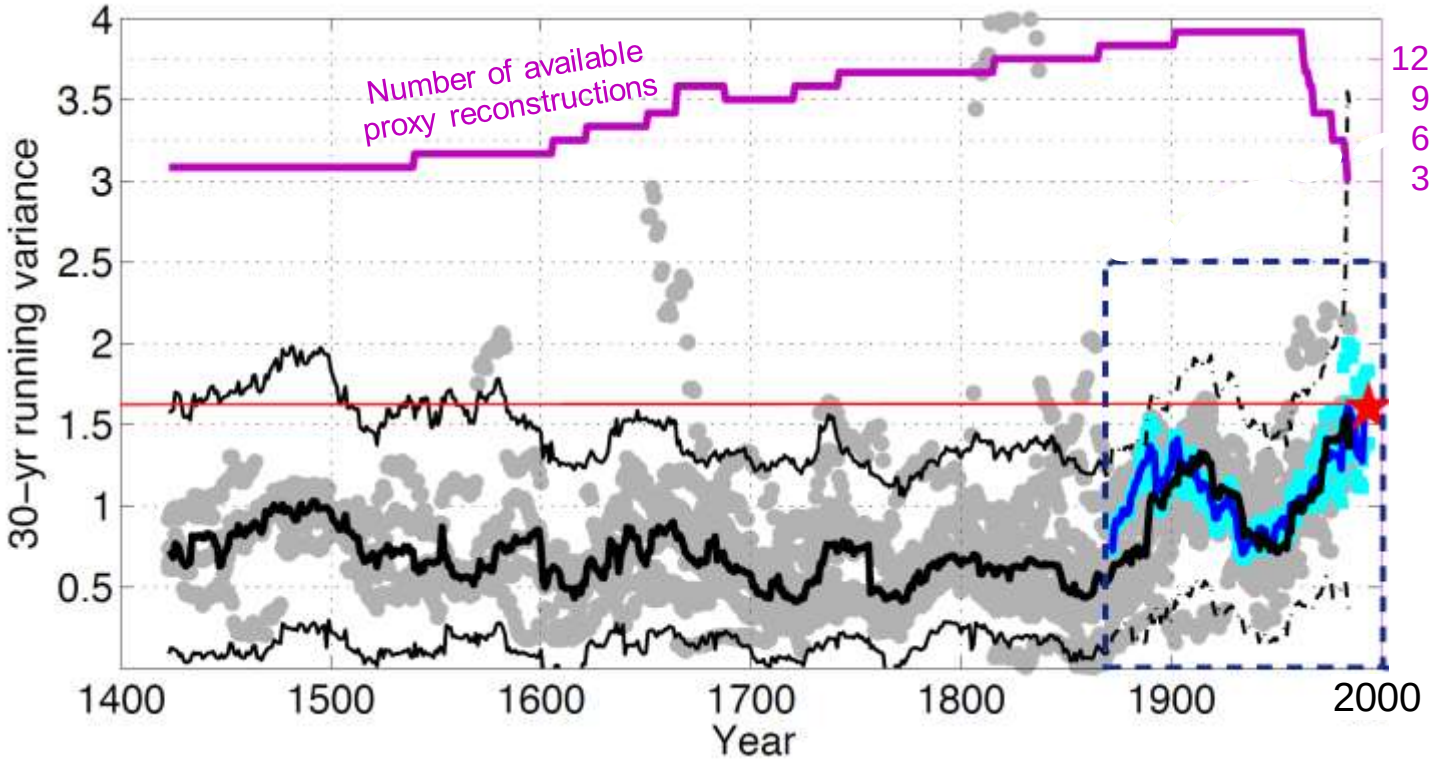
Reconstructing past variations in ENSO

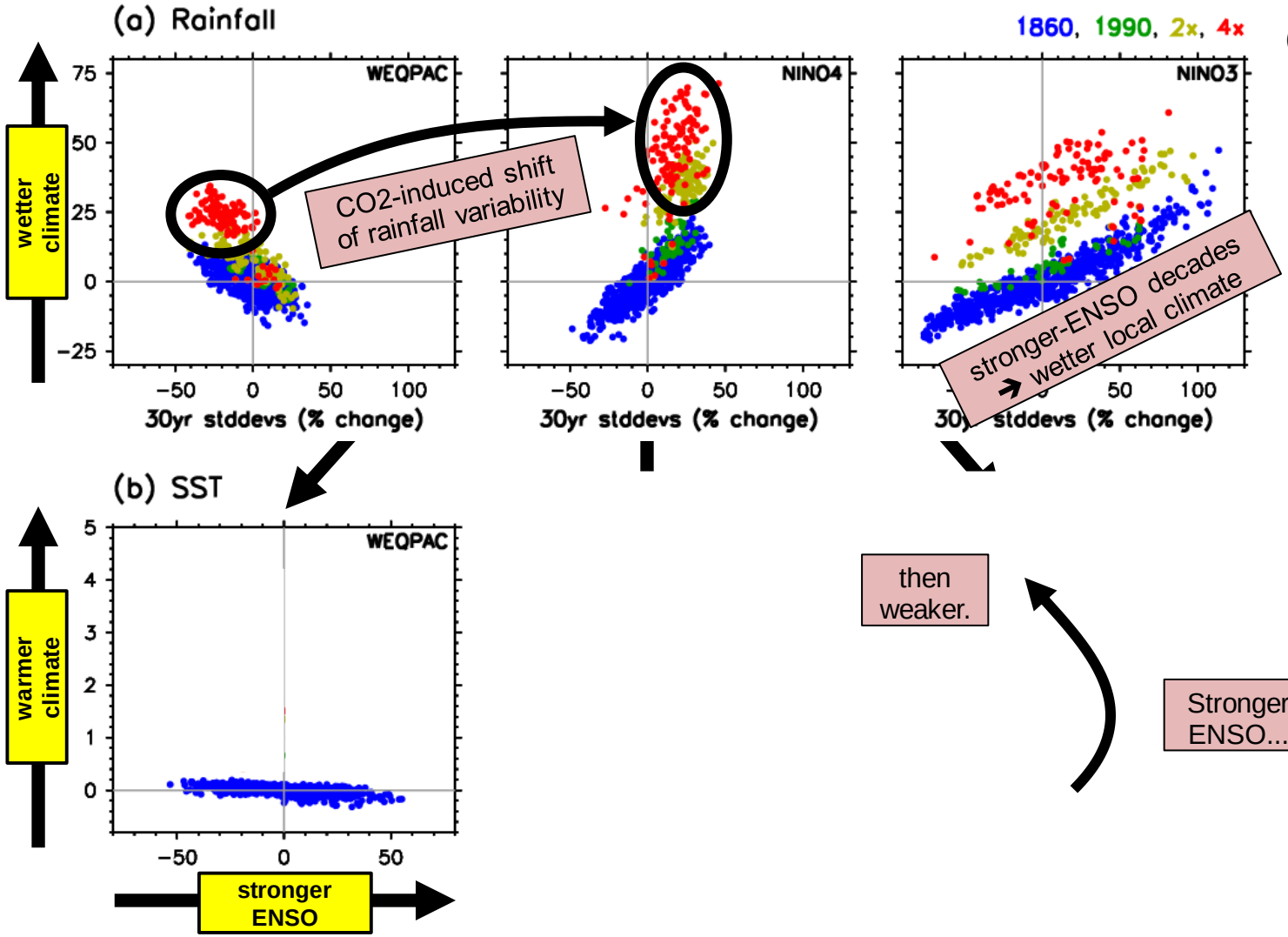
Proxy evidence suggests that ENSO has waxed & waned, with a significant amplification in recent decades.



Multiproxy meta-reconstruction (from corals, tree rings, lake sediments & ice cores) of 30-year running variance of 10-yr lowpass July-June annual-mean NINO3.4 SSTs.

McGregor et al. (Clim. Past, 2013); Emile-Geay et al. (2013ab)

ENSO response to increasing CO_2



CM2.1 simulations show interplay of intrinsic ENSO modulation, decadal variation, and regional responses to increasing CO_2

Vecchi & Wittenberg (2010)

Collins et al. (2010)

Xie et al. (2010)

DiNezio et al. (2012)

atanabe & Wittenberg (2012)

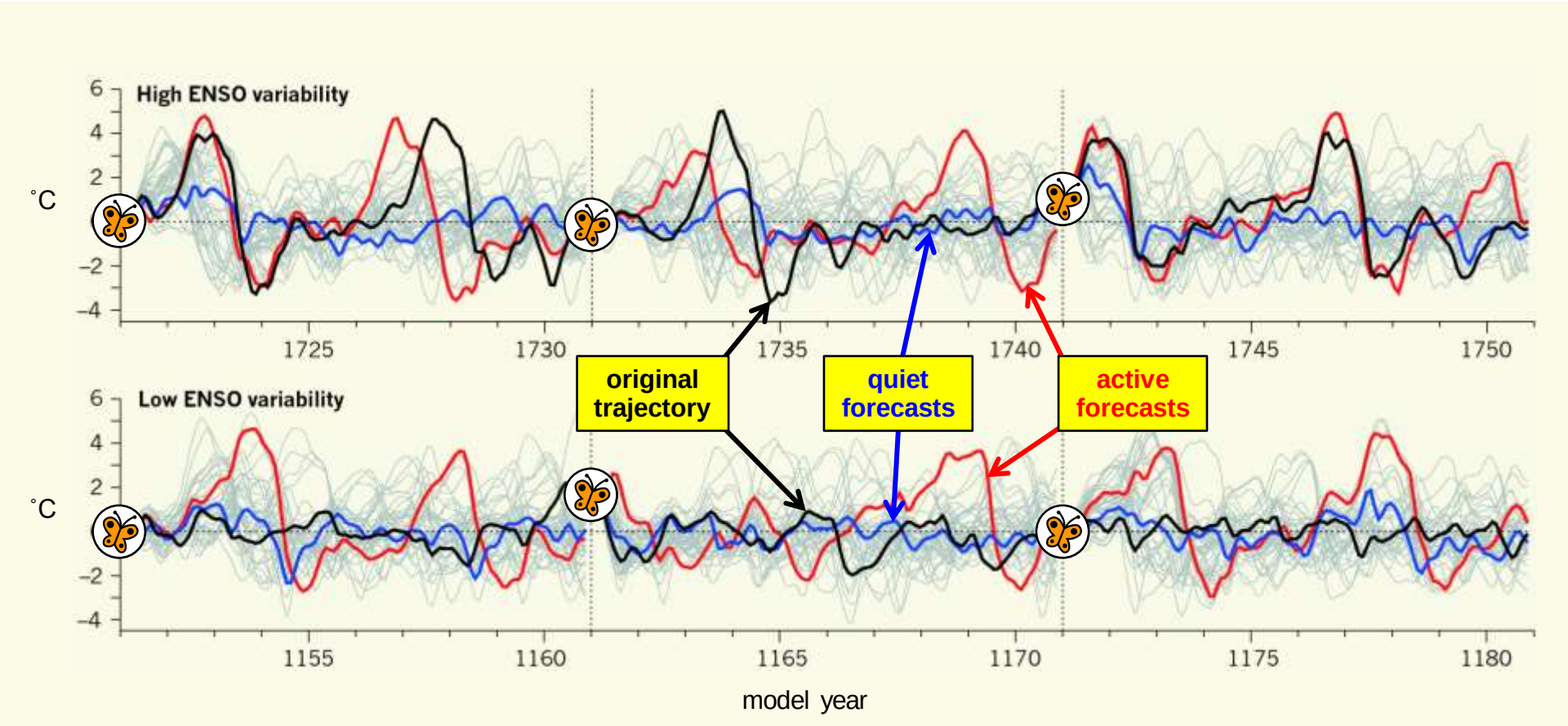
Watanabe et al. (2012)

Ogata et al. (2013)

Cai et al. (2014)

ENSO modulation: Is it decadally predictable?

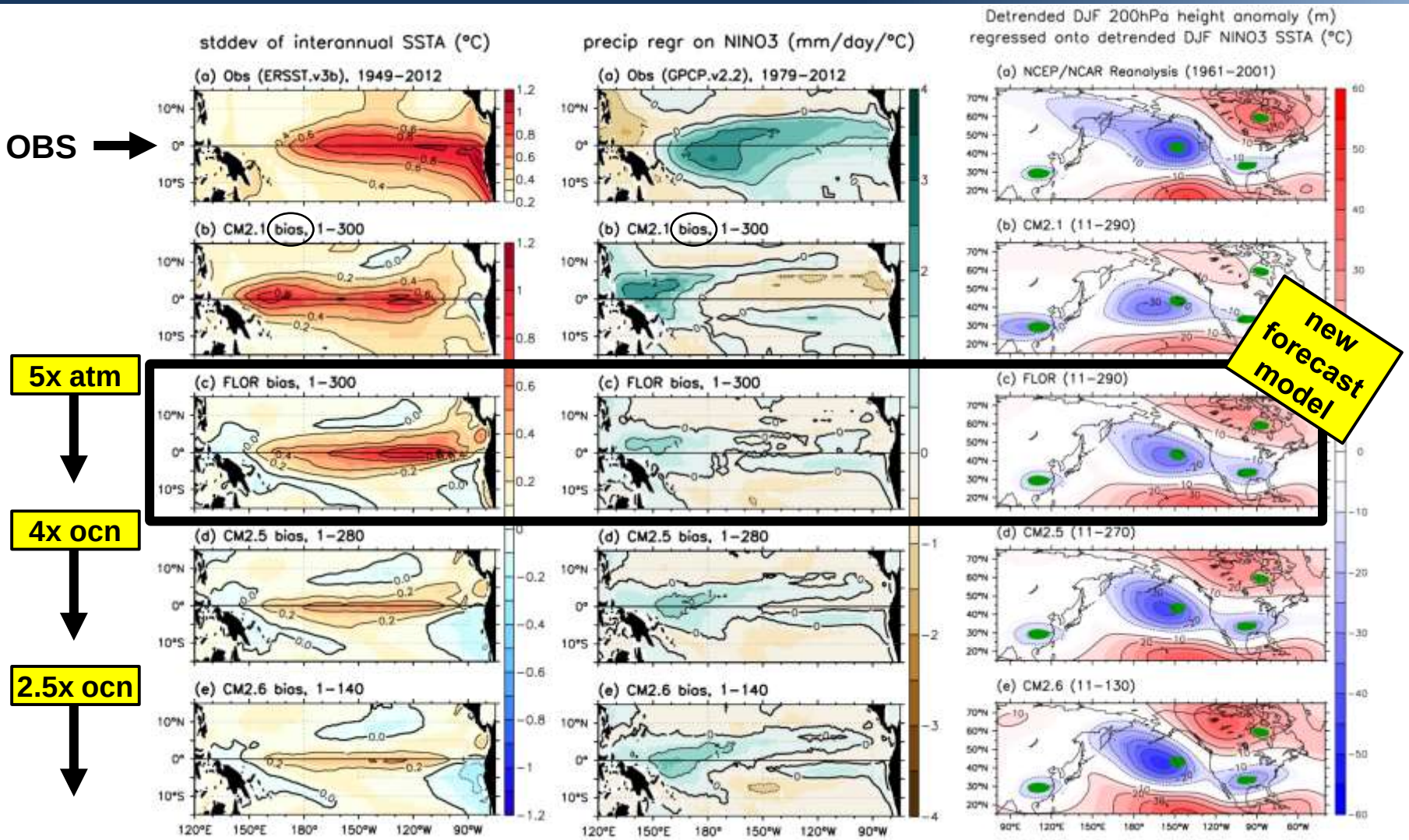
"Perfect-model" forecasts of NINO3 SSTA, for extreme-ENSO epochs simulated by CM2.1



(External forcings **held fixed** at 1860 values.)

Wittenberg et al. (J. Climate, 2014)

ENSO improvements with increasing resolution



Delworth et al. (2012); Jia et al. (subm); Wittenberg et al. (in prep)

ENSO Summary

1. ENSO's future depends on both **intrinsic modulation** and **external forcings**.

2. GFDL's simulations are among the **best in the world**, and improving.

3. GFDL is rapidly **advancing community understanding** of ENSO's diversity, dynamics, sensitivities, and predictability.

GFDL's recent publications on ENSO

Wittenberg, A. T., et al., **2014**: ENSO modulation: Is it decadally predictable? *J. Climate*, 27, 2667-2681. doi: 10.1175/JCLI-D-13-00577.1.

Cai, W., et al., **2014**: Greenhouse warming leads to increasing frequency of extreme El Niño events. *Nature Climate Change*, 4, 111-116. doi: 10.1038/NCLIMATE2100.

Karamperidou, C., et al., **2014**: Intrinsic modulation of ENSO predictability viewed through a local Lyapunov lens. *Climate Dyn.*, 42, 253-270. doi: 10.1007/s00382-013-1759-z.

Chiodi, A.M., D.E. Harrison and G.A. Vecchi, **2014**: Subseasonal atmospheric variability and El Niño waveguide warming; observed effects of the Madden-Julian Oscillation and westerly wind events. *J. Climate*, published online. doi: 10.1175/JCLI-D-13-00547.1.

Graham, F. S., et al., **2014**: Effectiveness of the Bjerknes stability index in representing ocean dynamics. *Climate Dyn.*, published online. doi: 10.1007/s00382-014-2062-3.

Choi, K.-Y., G. A. Vecchi, and A. T. Wittenberg, **2013**: ENSO transition, duration and amplitude asymmetries: Role of the nonlinear wind stress coupling in a conceptual model. *J. Climate*, 26, 9462-9476. doi: 10.1175/JCLI-D-13-00045.1

McGregor, S., et al., **2013**: Inferred changes in El Niño-Southern Oscillation variance over the past six centuries. *Clim. Past*, 9, 2269-2284. doi: 10.5194/cp-9-2269-2013.

Ogata, T., et al., **2013**: Interdecadal amplitude modulation of El Niño/Southern Oscillation and its impacts on tropical Pacific decadal variability. *J. Climate*, 26, 7280-7297. doi: 10.1175/JCLI-D-12-00415.1.

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DiNezio, P.N., G.A. Vecchi, and A.C. Clement, **2013**: Detectability of changes in the walker circulation in response to global warming. *J. Climate*, doi:10.1175/JCLI-D-12-00531.1.

Watanabe, M., et al., **2012**: Uncertainty in the ENSO amplitude change from the past to the future. *Geophys. Res. Lett.*, 39, L20703. doi: 10.1029/2012GL053305.

Watanabe, M., and A. T. Wittenberg, **2012**: A method for disentangling El Niño-mean state interaction. *Geophys. Res. Lett.*, 39, L14702. doi: 10.1029/2012GL052013.

DiNezio, P. N., et al., **2012**: Mean climate controls on the simulated response of ENSO to increasing greenhouse gases. *J. Climate*, 25, 7399-7420. doi: 10.1175/JCLI-D-11-00494.1.

Guilyardi, E., et al., **2012**: A first look at ENSO in CMIP5. *CLIVAR Exchanges*, 17, 29-32.

Guilyardi, E., et al., **2012**: New strategies for evaluating ENSO processes in climate models. *Bull. Amer. Met. Soc.*, 93, 235-238. doi: 10.1175/BAM S-D-11-00106.1.

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Vecchi, G. A., and A. T. Wittenberg, 2010: El Niño and our future climate: Where do we stand? *Wiley Interdisciplinary Reviews: Climate Change*, 1, 260-270. doi: 10.1002/wcc.33.

Kug, J.-S., et al., **2010**: Warm pool and cold tongue El Niño events as simulated by the GFDL CM2.1 coupled GCM. *J. Climate*, 23, 1226-1239. doi: 10.1175/2009JCLI3293.1.

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Harrison, D.E., A.M. Chiodi and G.A. Vecchi, **2009**: Effects of surface forcing on the seasonal cycle of the eastern equatorial Pacific. *J. Marine Research*, 67(6), 701-729.

DiNezio, P.N., et al., **2009**: Climate response of the equatorial Pacific to global warming. *J. Climate*, 22, 4873-4892. doi: 10.1175/2009JCLI2982.1

Lengaigne, M. and G.A. Vecchi, **2009**. Contrasting the termination of moderate and extreme El Niño events in coupled general circulation models. *Climate Dyn.*, doi: 10.1007/s00382-009-0562-3