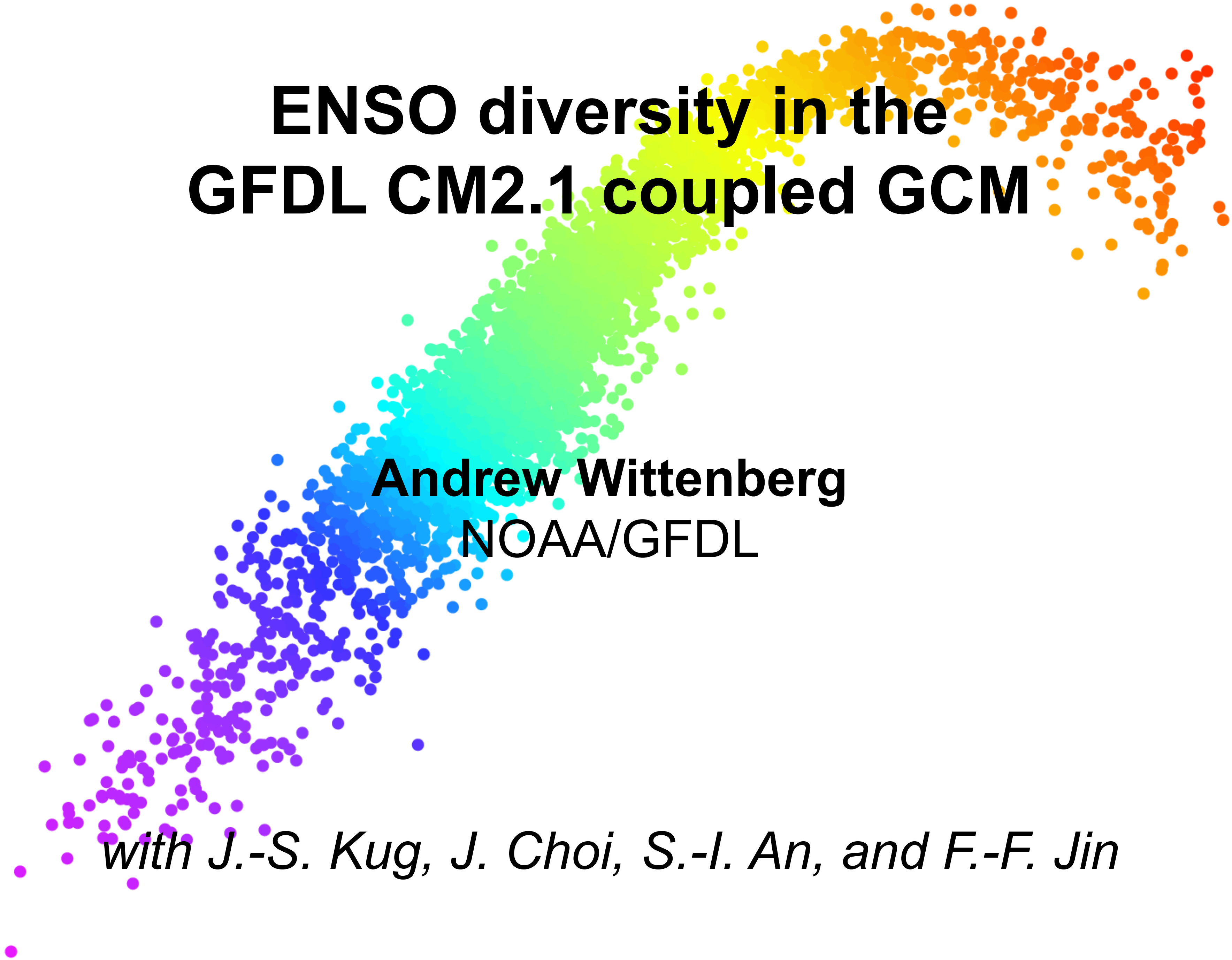

ENSO diversity in the GFDL CM2.1 coupled GCM

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GFDL CM2.1 global coupled GCM

atmos: 2°x2.5°xL24 finite volume

ocean: 1°x1°xL50 MOM4 (1/3° near equator)

2hr coupling; ocean color; no flux adjustments

ENSO & tropics rank among top CMIP3 models

SI forecasts; parent of GFDL CMIP5 models

(**ESM2M, ESM2G, CM3, CM2.5**, CM2.6, FLOR, CM2Mc)

4000-year pre-industrial control run

1860 atmospheric composition, insolation, land cover

220yr spinup from 20th-century initial conditions

big investment: 2 years on 60 processors

Delworth et al., Wittenberg et al., Merryfield et al., Joseph & Nigam (JC 2006), Wittenberg (GRL 2009)
Zhang et al. (MWR 2007); van Oldenborgh et al. (OS 2005); Guilyardi (CD 2006); Reichler & Kim (BAMS 2008)
Kug et al. (JC 2010), Vecchi & Wittenberg (WIREsCC 2010), Collins et al. (Nature Geosci. 2010)
Emile-Geay et al. (JC 2013ab); Vecchi et al. (2013)

What sort of ENSO do we simulate?

CM2.1 SST anomaly (°C)
2°S–2°N, running annual mean

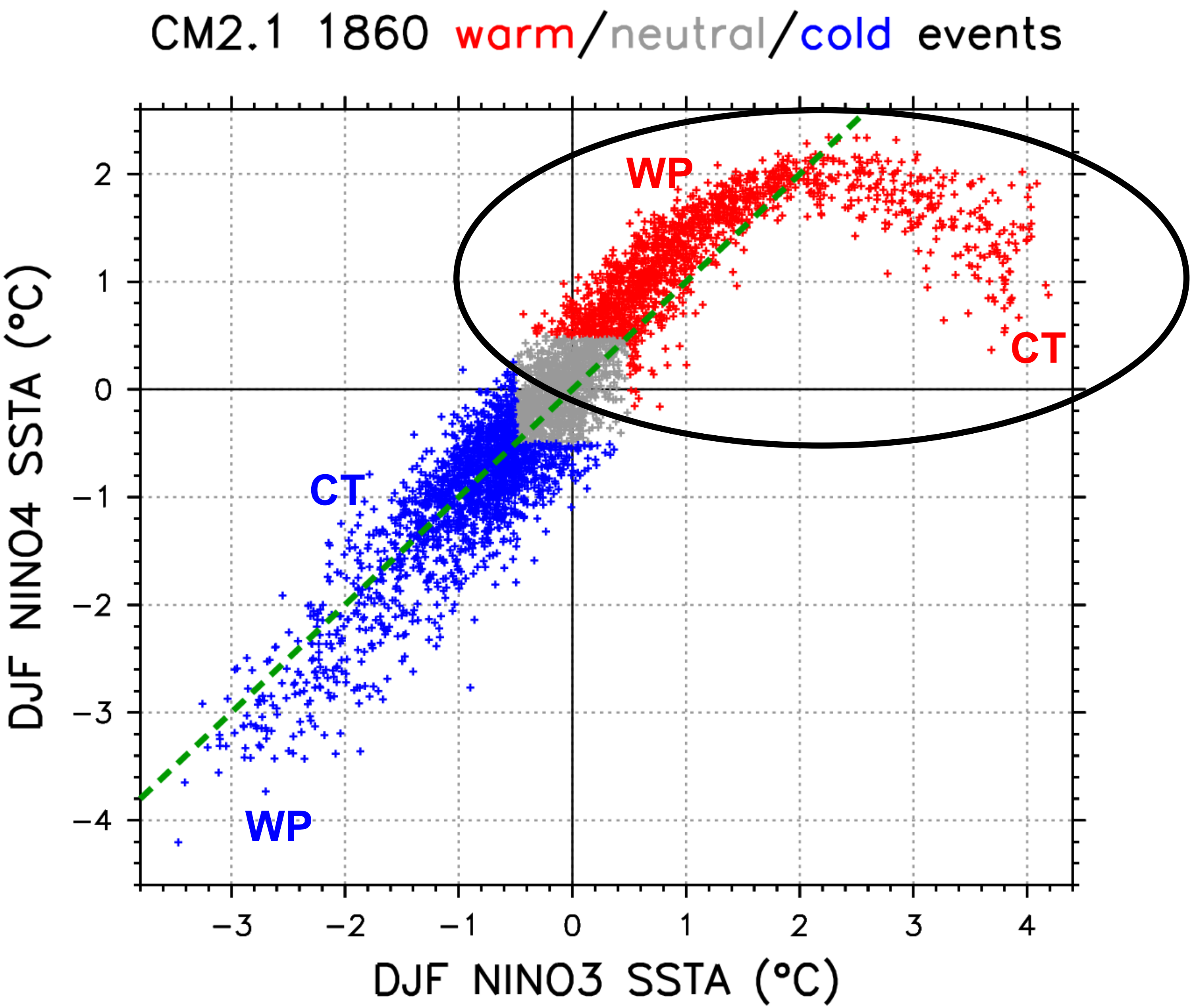
strong, skewed,
long period,
eastward propagating
(1980s & late 1990s)

weak, biennial, "Modoki"
(early 1990s & 2000s)

regular &
westward propagating
(1960s & 70s)

All from a
single run with
unchanging forcings!

An ENSO continuum



Composite CM2.1 warm events (NDJ anomalies)

SST

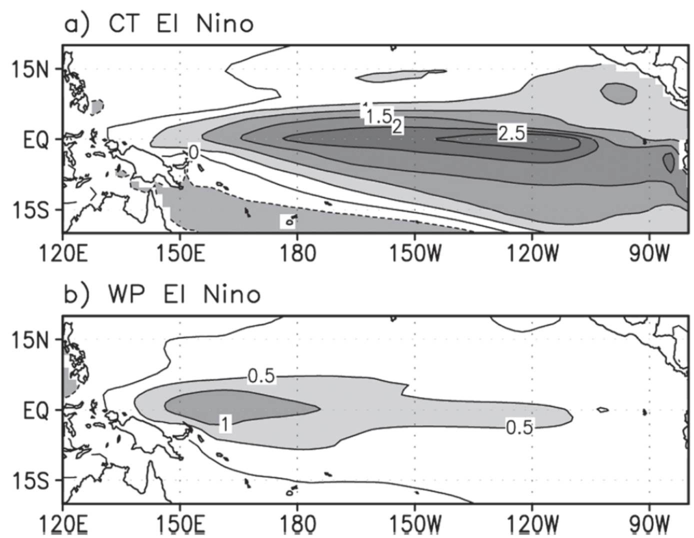


FIG. 3. SST anomaly (°C) composite of the (a) CT El Niño and (b) WP El Niño during ND(0)J(1).

precip

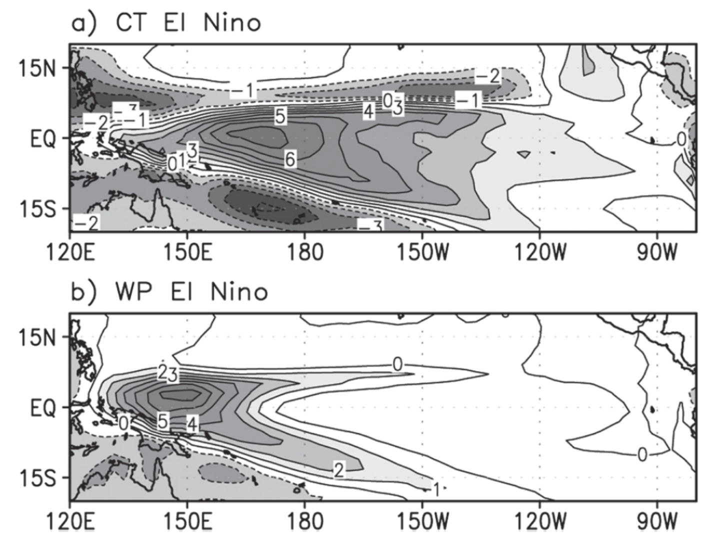


FIG. 4. As in Fig. 3, except for precipitation (mm day^{-1}).

zonal wind (925mb)

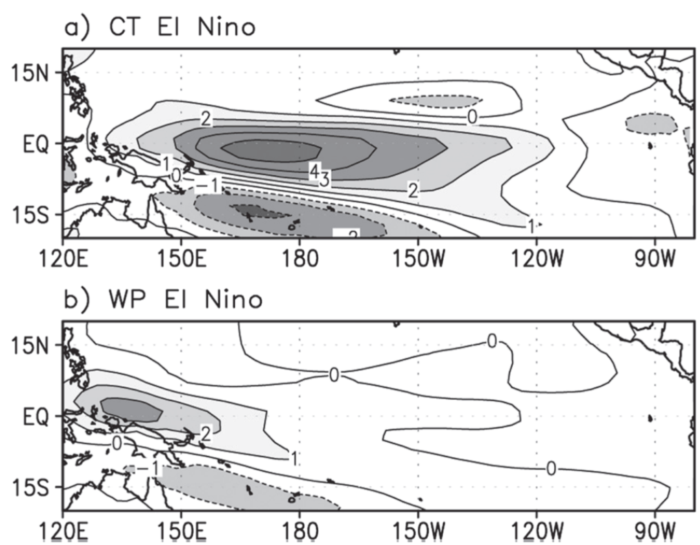


FIG. 5. As in Fig. 3, except for zonal wind at 925 hPa (m s^{-1}).

heat content (top 300m)

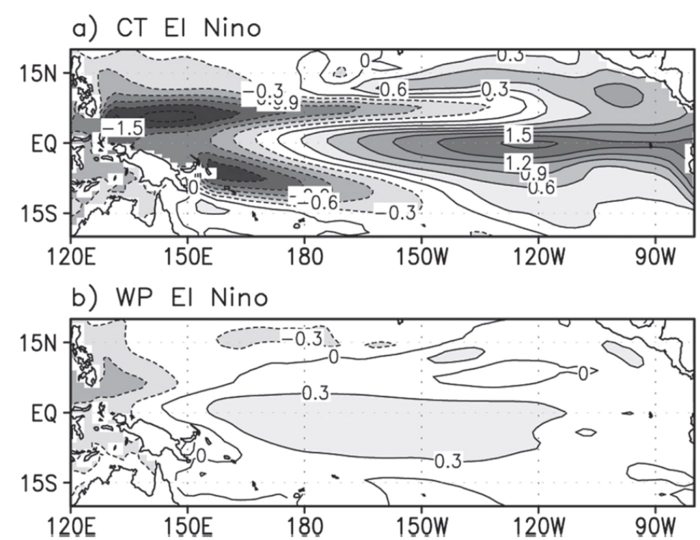
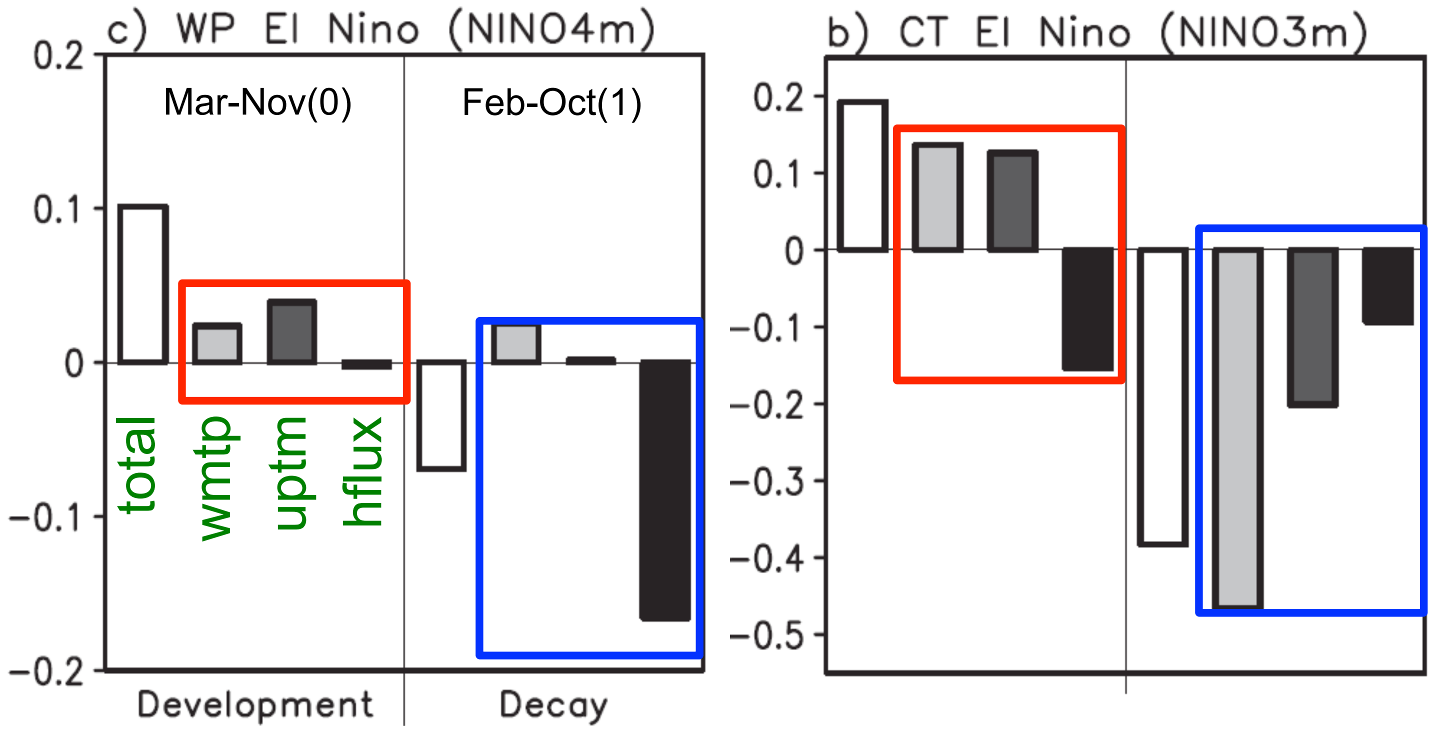


FIG. 6. As in Fig. 3, except for heat content (K).

Kug et al. (JC 2010)

CM2.1 SSTA tendency terms

growth via zonal & vertical advection



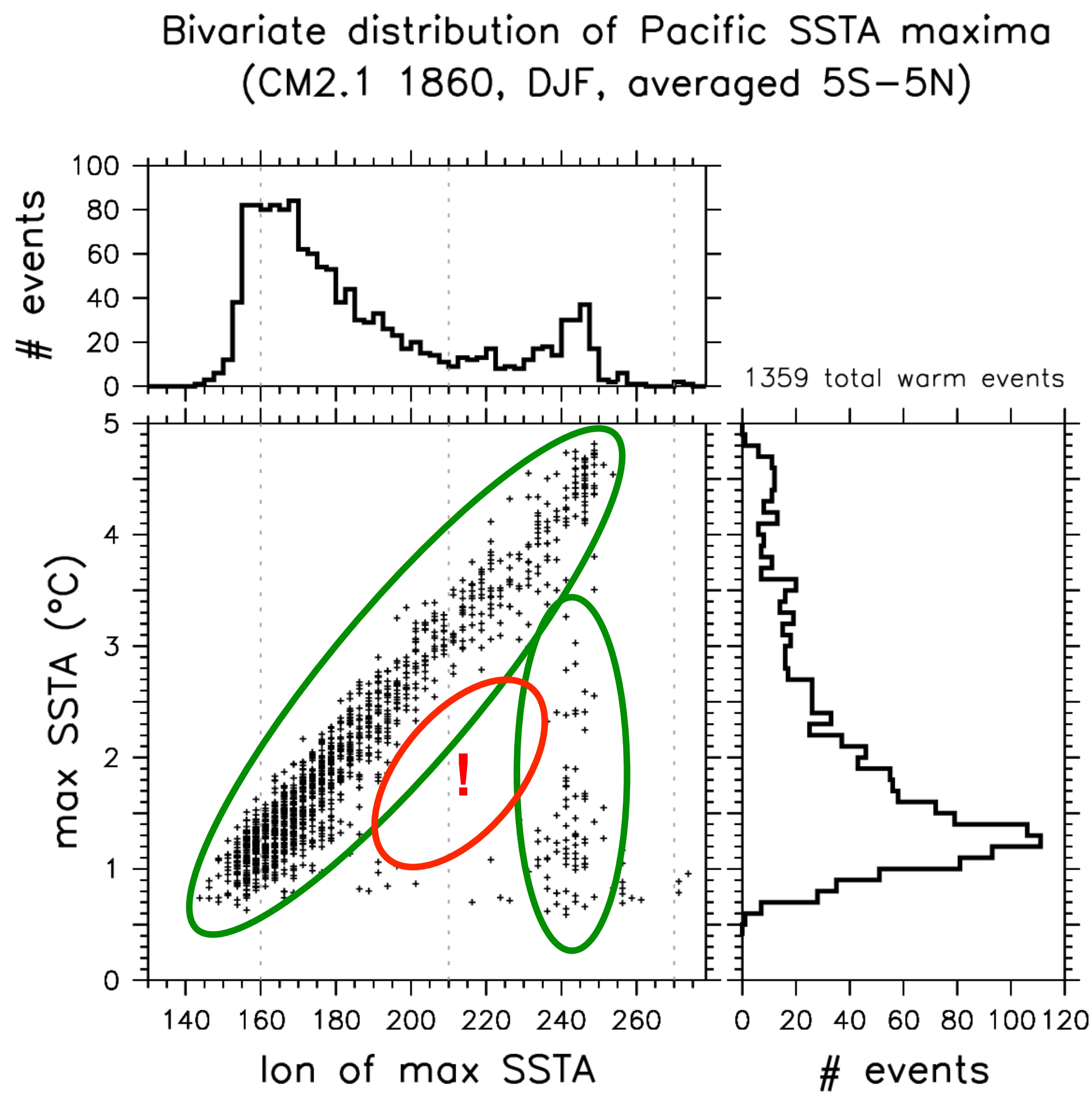
evaporation & cloud shading

poleward HC discharge & thermocline re-tilt

FIG. 11. SST tendency (open bar), SST tendency according to the thermocline feedback (light-gray bar), the zonal advective feedback (dark-gray bar), and net flux (black bar) for (a),(b) CT El Niño and (c),(d) WP El Niño (K month^{-1}). Each magnitude is calculated over 2°S–2°N, 170°–110°W [(b),(d) Niño-3m region] or 2°S–2°N, 140°E–170°W [(a),(c) Niño-4m region]. Period of development (decay) is defined from March (0) to November (0) [from February (1) to October (1)].

Kug et al. (JC 2010)

El Niño strength vs. peak longitude of SSTA



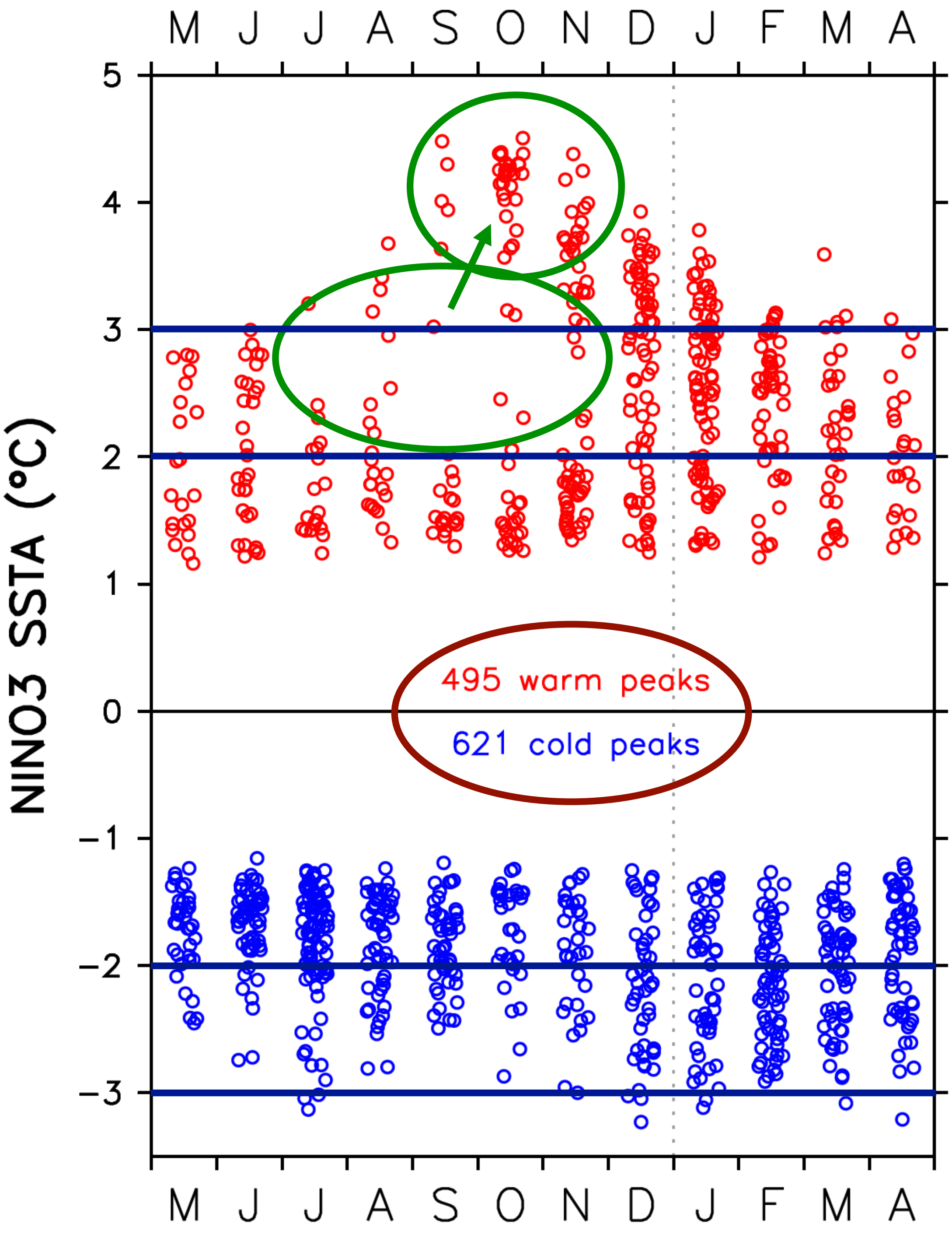
CM2.1 SSTA peaks vs. calendar month

abs(NINO3) > 1 stddev

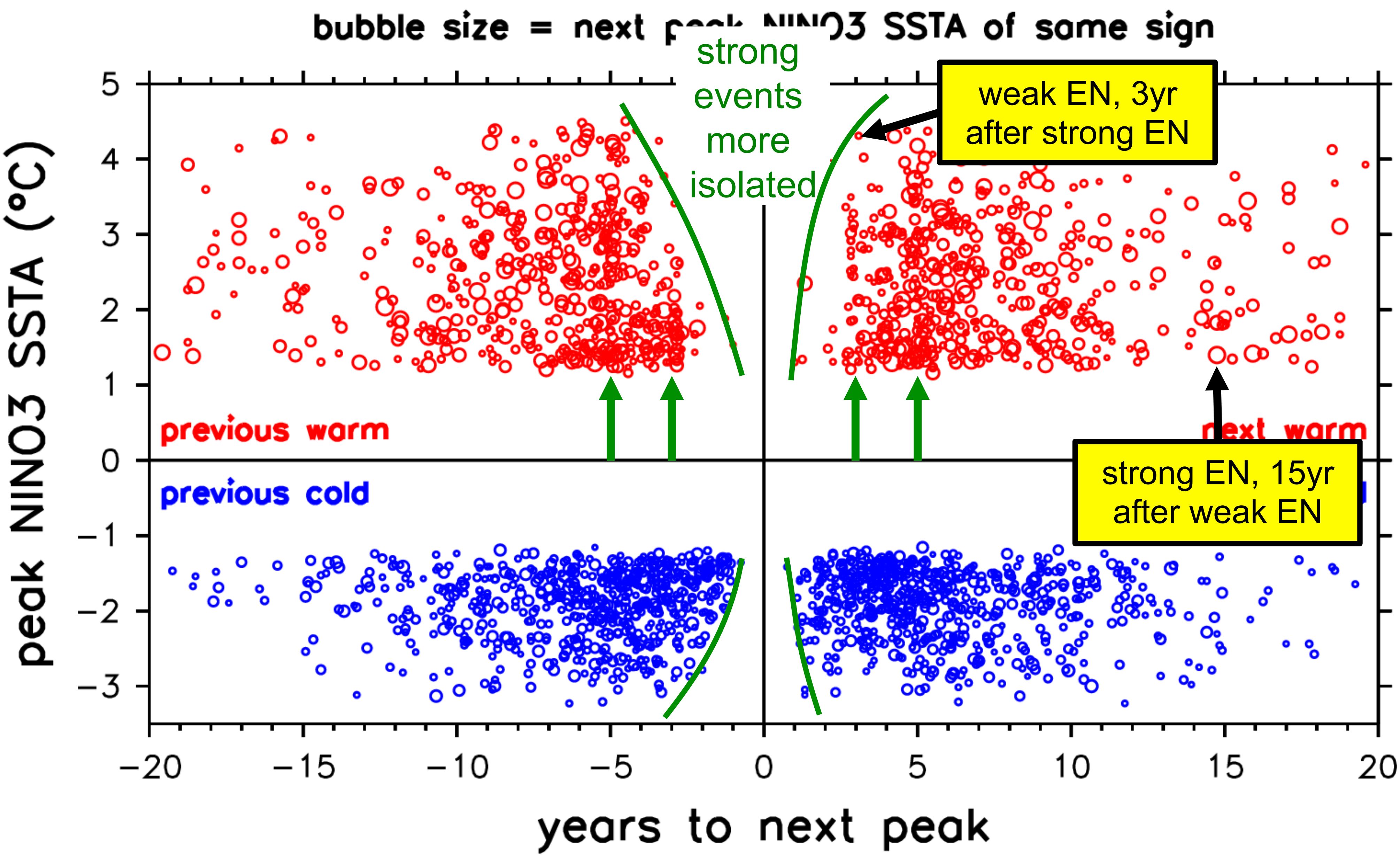
warm events are stronger & rarer than cold events

strong warm events peak in SON

less synchronization of cold events & weak warm events



ENSO events and their nearest neighbors



Summary

1. CM2.1 (& descendants) a fascinating resource

a. Diverse & fairly realistic ENSO behaviors

b. Long simulations, numerous sensitivity studies & forcing scenarios

2. *Continuum* of ENSO behaviors

a. Interesting extremes: **WP**/**CT** or **weak**/**strong**

b. Different patterns, teleconnections, mechanisms

c. Subtle evidence for thresholds ("types")

- Weak warmings rarely peak in central Pacific (local- vs. basin-scale feedbacks)
- Moderate warmings rarely peak Jul-Oct (boosted by seasonal upwelling?)

3. Weak El Ninos:

a. Weak Bjerknes & thermocline feedbacks

b. SSTAs peak in central Pacific; rain/wind anomalies confined to west

c. Decay by evaporation & cloud shading

4. Strong El Niños:

a. Earlier onset; strong Bjerknes & thermocline feedbacks

b. SSTAs peak in east Pacific; rain/wind anomalies mid-basin

c. Strong seasonal synchronization

d. Decay by equatorial discharge & seasonal southward shift of tau_x'

e. Equatorial ITCZ; delayed SSTA termination in east

f. More likely to overshoot into La Niña; wait longer until next El Niño