Understanding ENSO event precursors

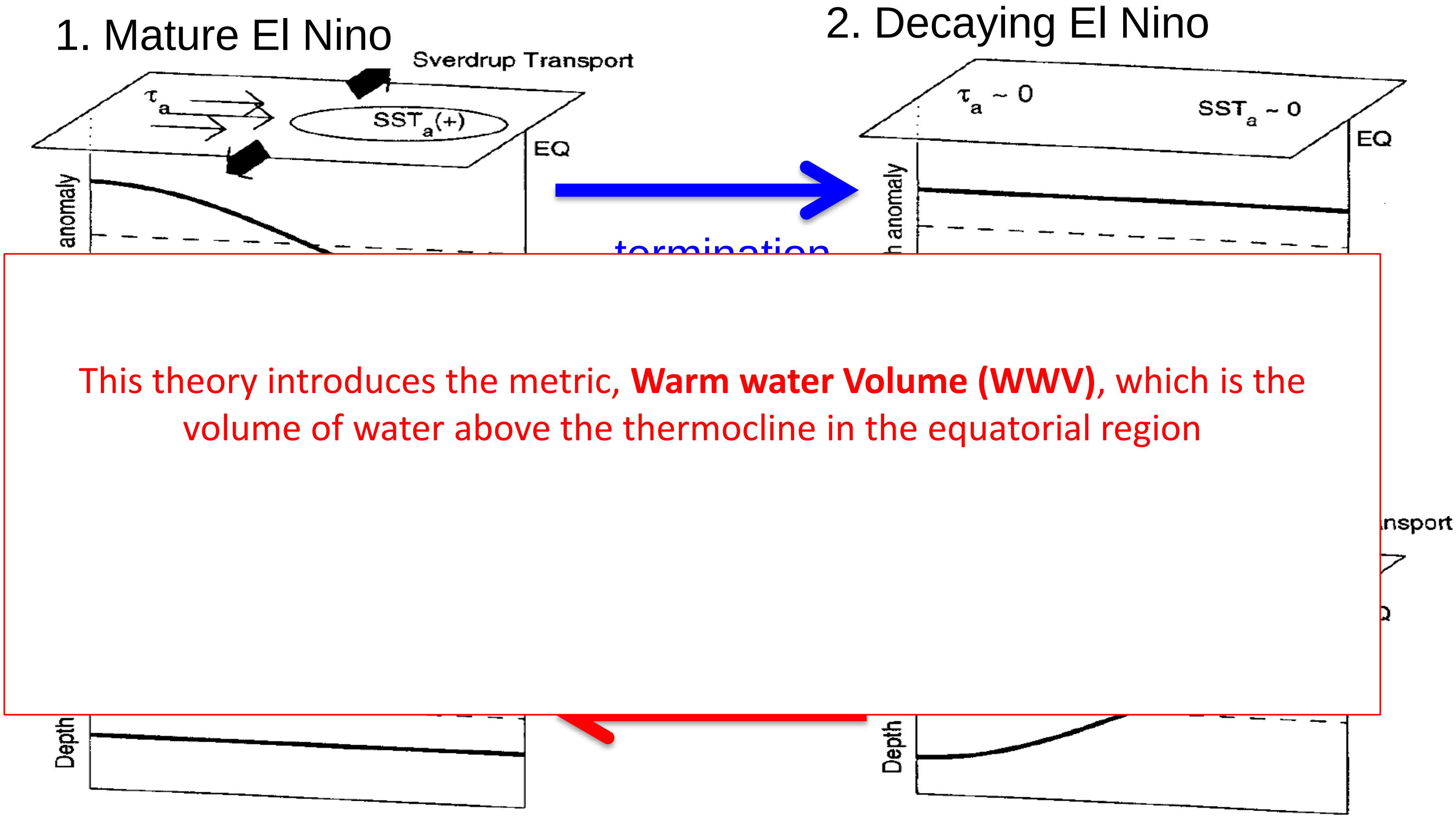
In Collaboration with
Sonja Neske, Axel Timmermann, Fei-Fei Jin, and
William Kessler

McGregor, S., Timmermann, A., Jin, F.-F., & Kessler, W. S. (2016). Charging El Niño with off-equatorial westerly wind events. Climate Dynamics, 47(3-4), 1111–1125. https://doi.org/10.1007/s00382-015-2891-8.

Neske, S., & McGregor, S. (2018). Understanding the warm water volume precursor of ENSO events and its interdecadal variation. Geophysical Research Letters, 45. https://doi.org/10.1002/2017GL076439

Traditional view of ENSO (1980s-90s)

Recharge oscillator of Jin (1997)

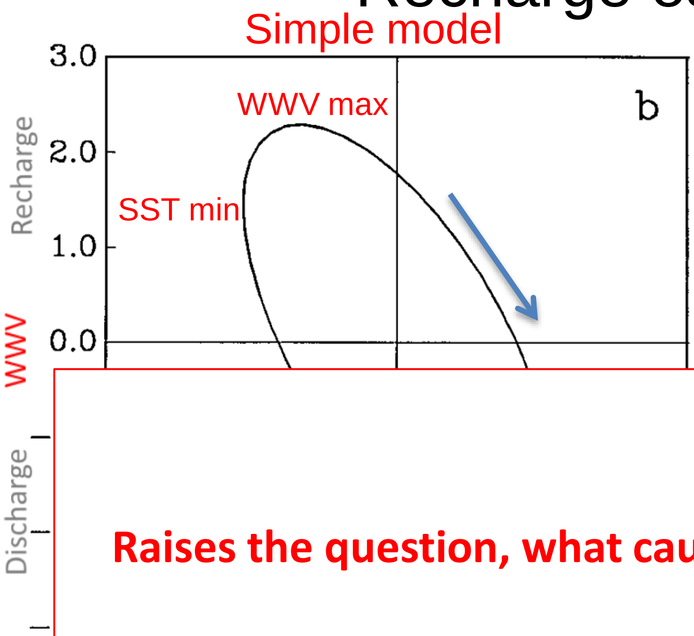


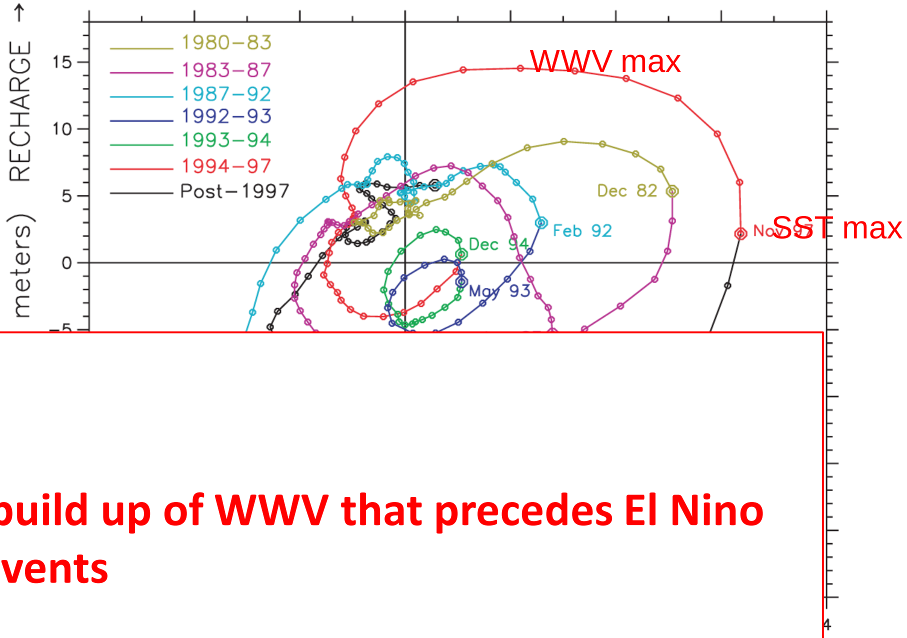
This theory introduces the metric, **Warm water Volume (WWV)**, which is the volume of water above the thermocline in the equatorial region

Source: Meinen and McPhaden 2000

Traditional view of ENSO (1980s-90s)

Recharge oscillator of Jin (1997)





Source: Jin

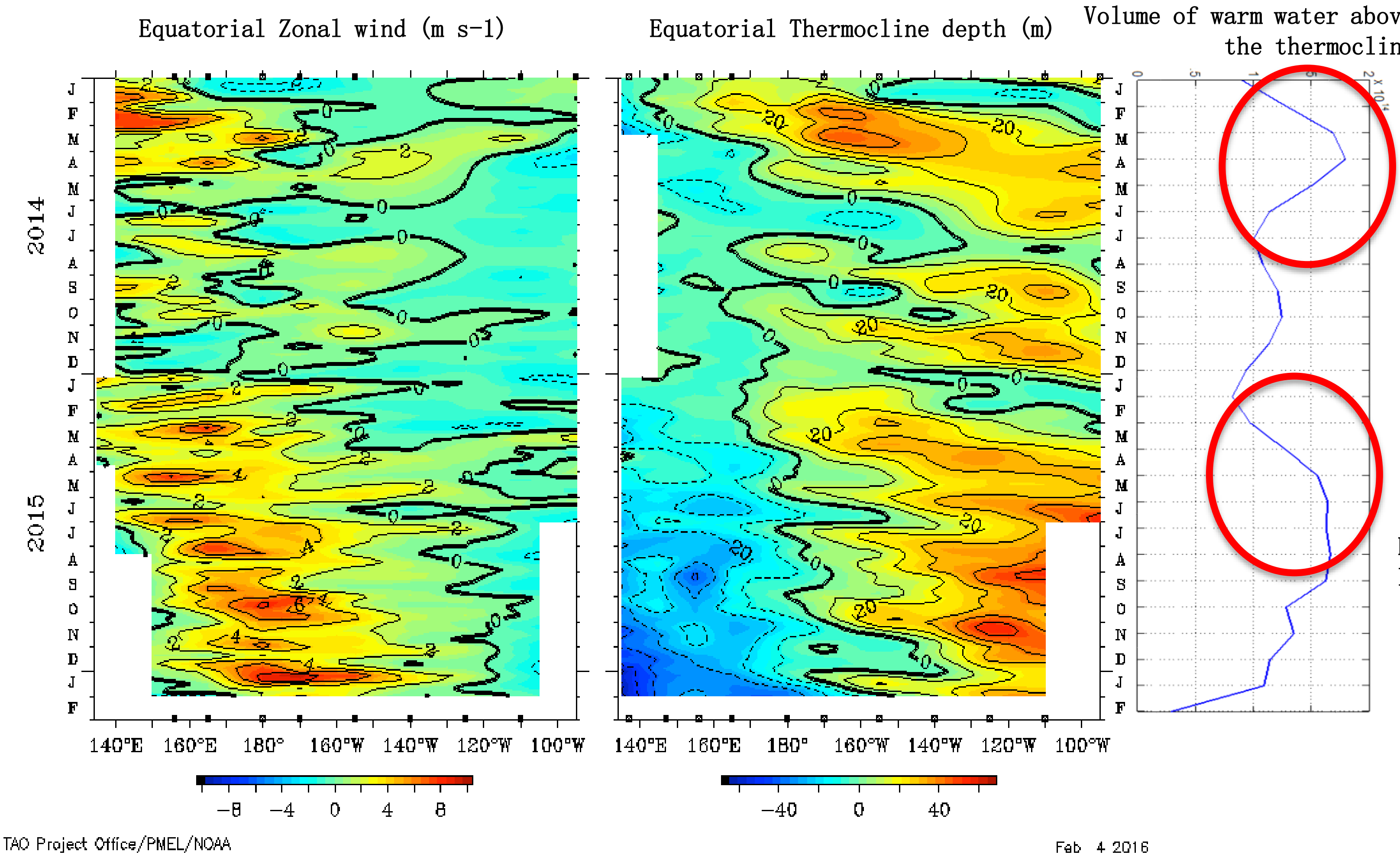
Source: Kessler 2002

Raises the question, what causes the build up of WWV that precedes El Nino events

and the observations (slope).

2. The observations actually spend a long time in the top left quadrant, which indicates these are events rather than an oscillation…

2014-15 Observations add to the motivation



Equatorial Zonal wind (m s−1)

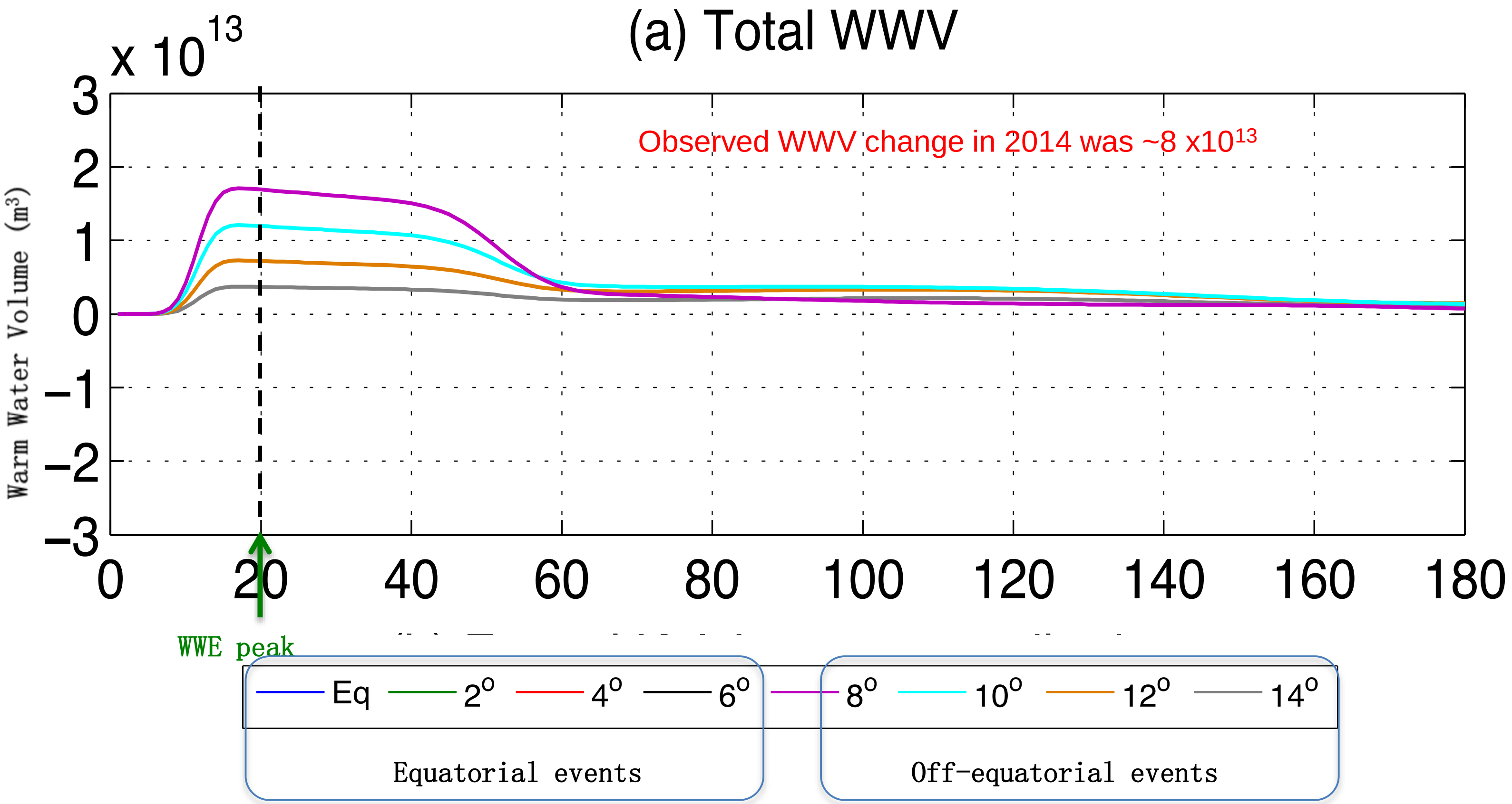
Equatorial Thermocline depth (m)

Volume of warm water above the thermocline

Sudden jump led many experts to start talking about the possibility of an El Nino, while the magnitude led many to highlight the possibility of it being large.

More sustained here…

WWV response


(a) Total WWV

Observed WWV change in 2014 was ~8 x10^{13}

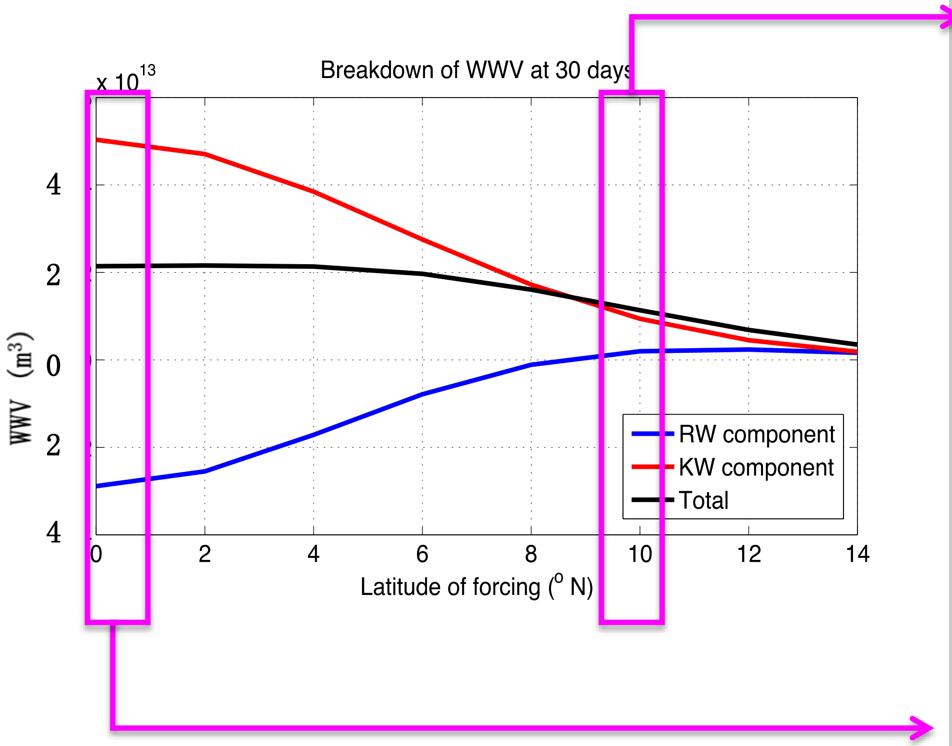
WWE peak

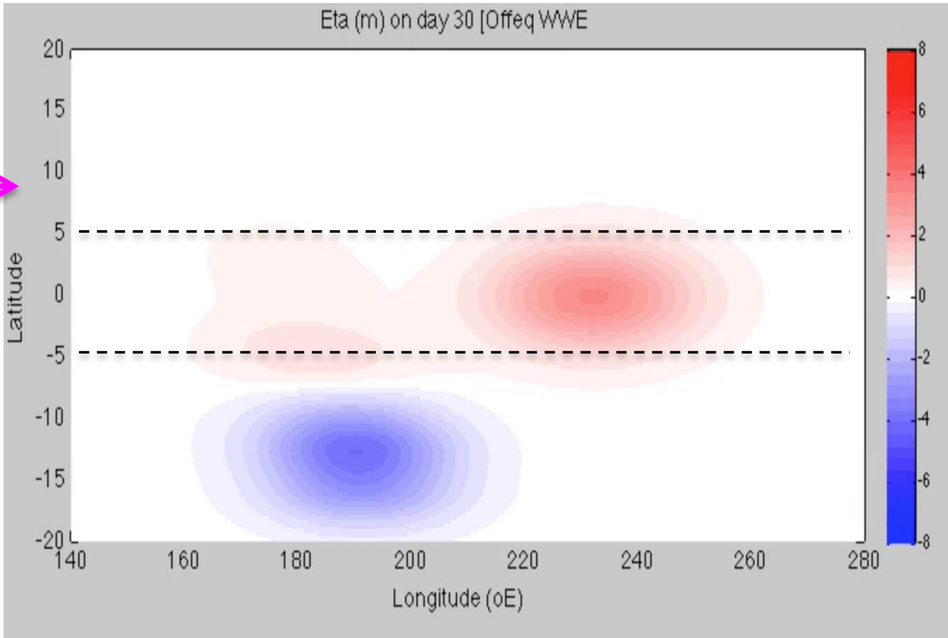
WWB do generate changes in WWV that are significant in magnitude

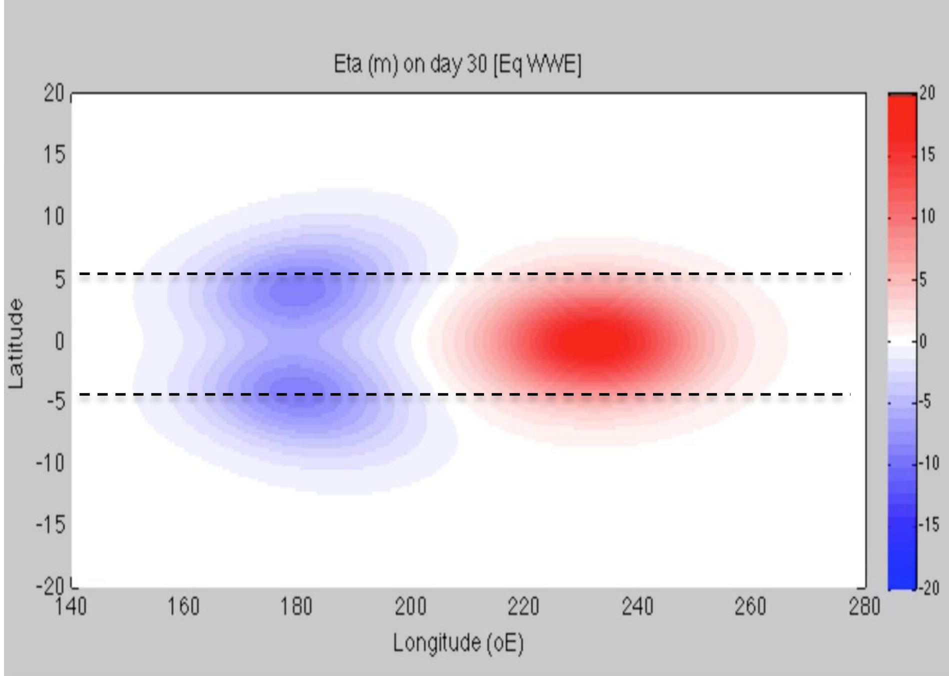
Equatorial WWB generate changes in WWV but ultimately act to discharge heat content (consistent with RDO)

Off-equatorial WWB also generate changes in WWV that are significant in magnitude, but have no subsequent discharge.

Decomposed WWV response (30 days)





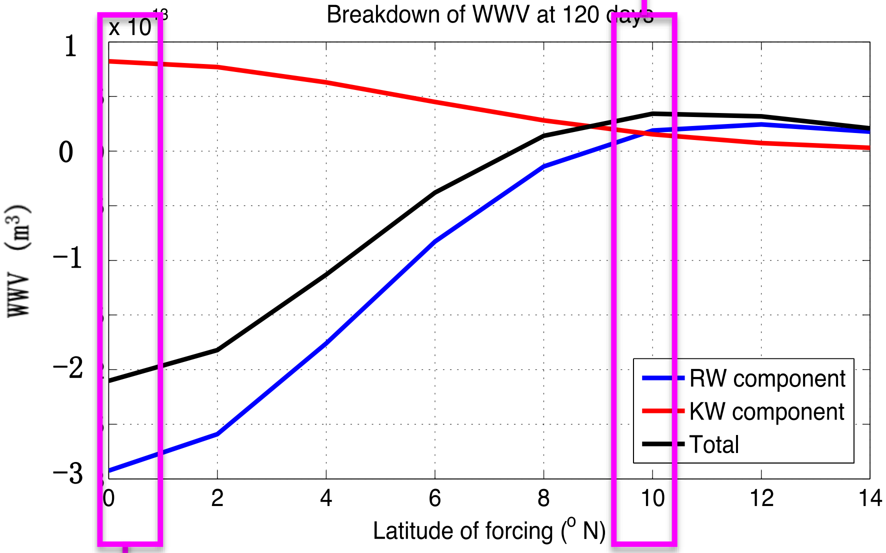


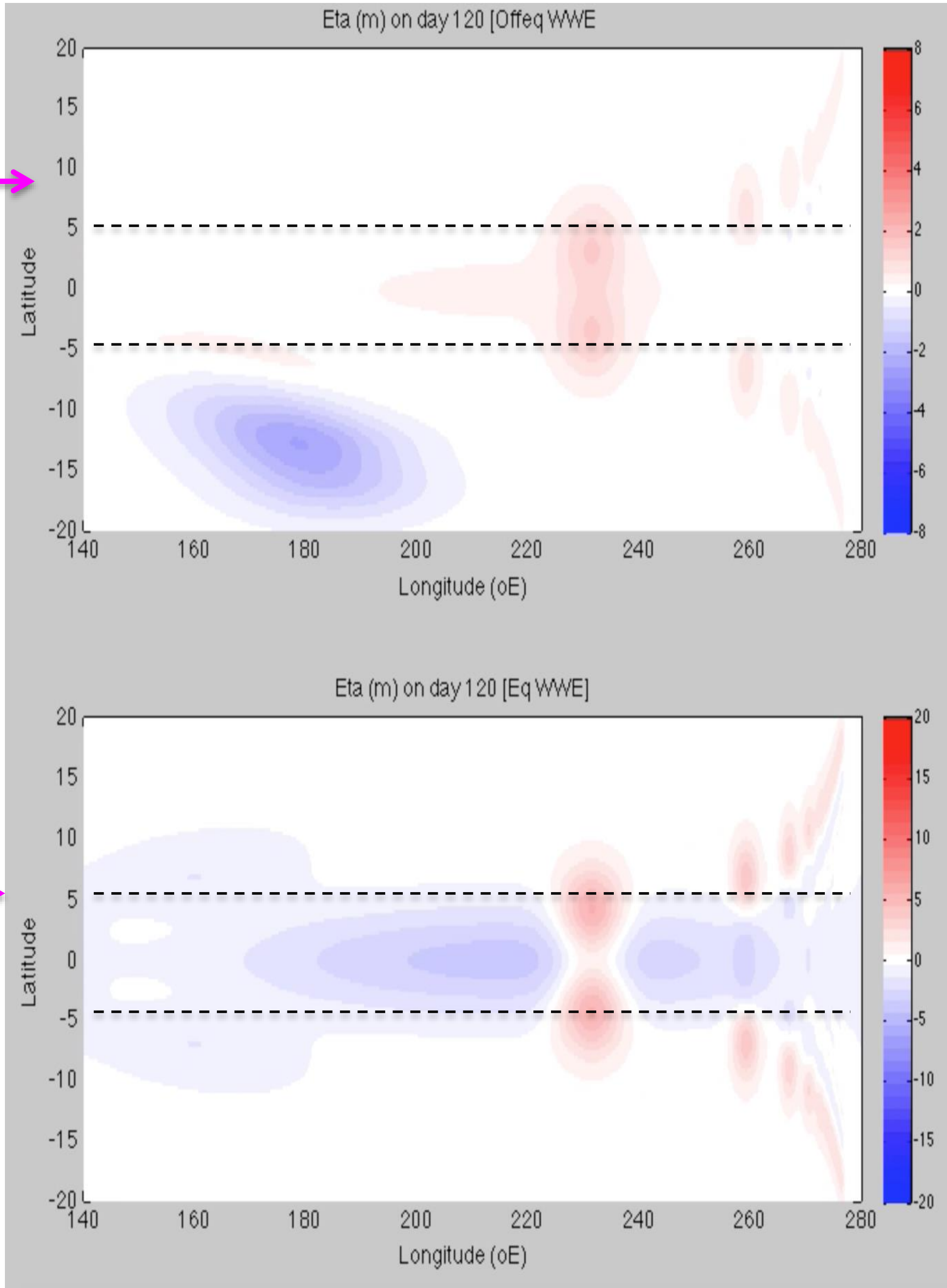
Total WWV after 30 days is largely controlled by the equatorial Kelvin wave

WWV offset by n=1 Rossby waves decays faster as latitude increases than the KW.

Allows for the smaller KW to have a large WWV impact.

Decomposed WWV response (120 days)

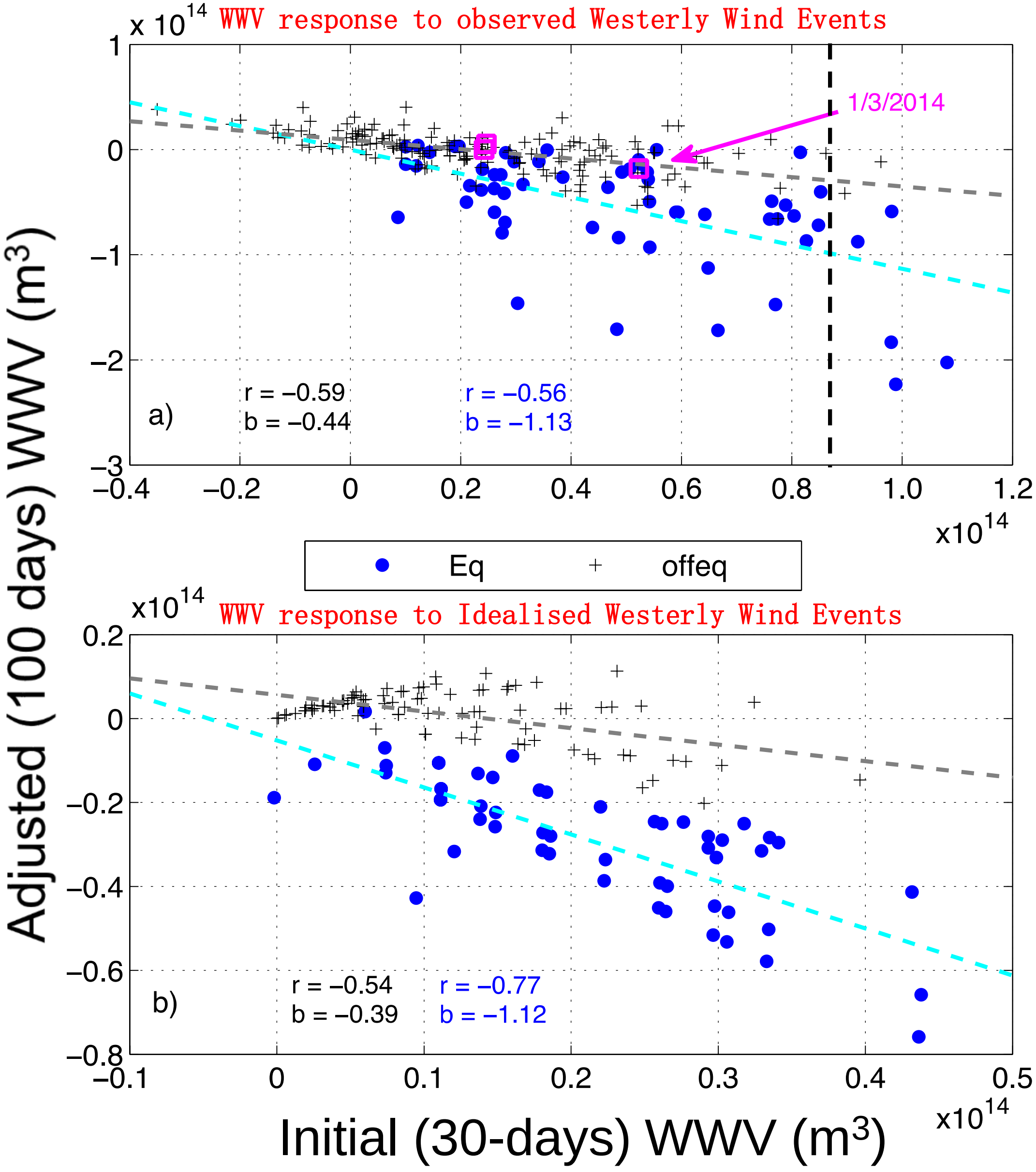




Total WWV after 120 days is largely controlled by the n=1 Rossby wave

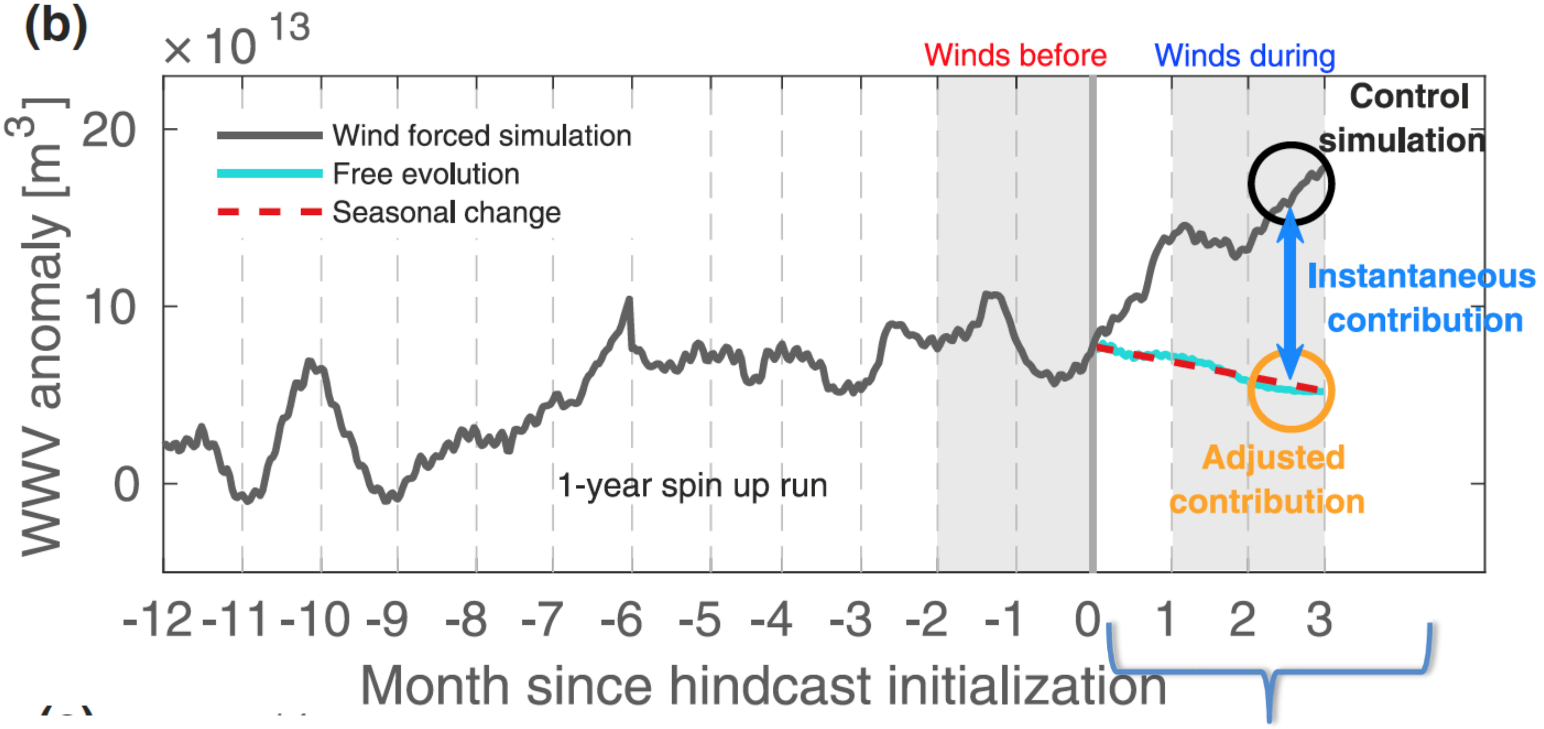
The small n=1 Rossby wave projection for WWE latitudes greater than 8° allows the initial buildup of WWV to persist for longer than 120 days.

Initial and adjusted WWV response



What drives the observed changes in WWV?

- Hindcast SWM simulations run for 3 months, monthly 1980-2016
- Each has a 12 month wind stress forced spin up
- Left to freely evolve for the 3 months (free evolution)
- 3rd month WWV changes are identified as “adjusted contribution”



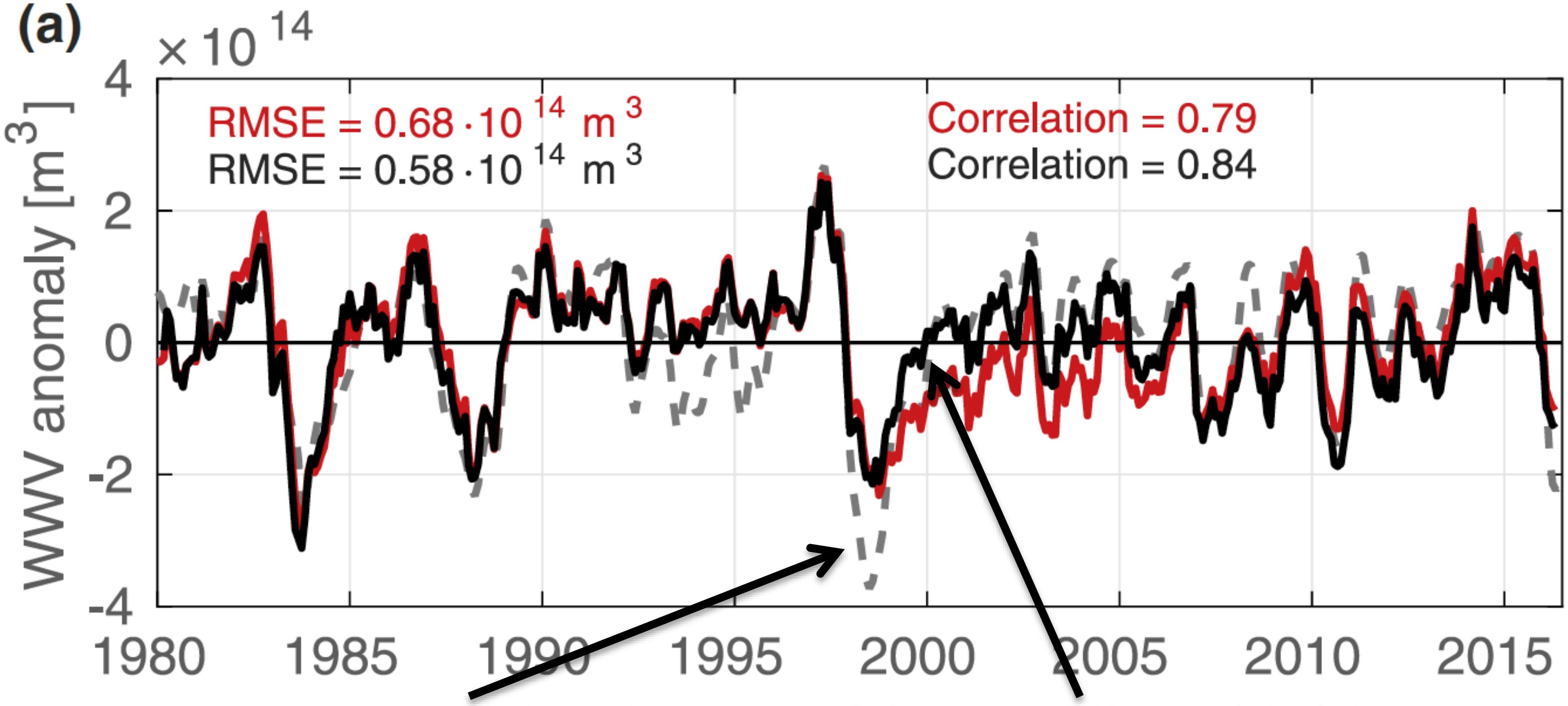
Free evolution
(no wind stress forcing)

Source: Neske and McGregor 2018

Model validation

Control simulation is the last wind stress forced month of the hindcasts

- Generally compares very well with the observations



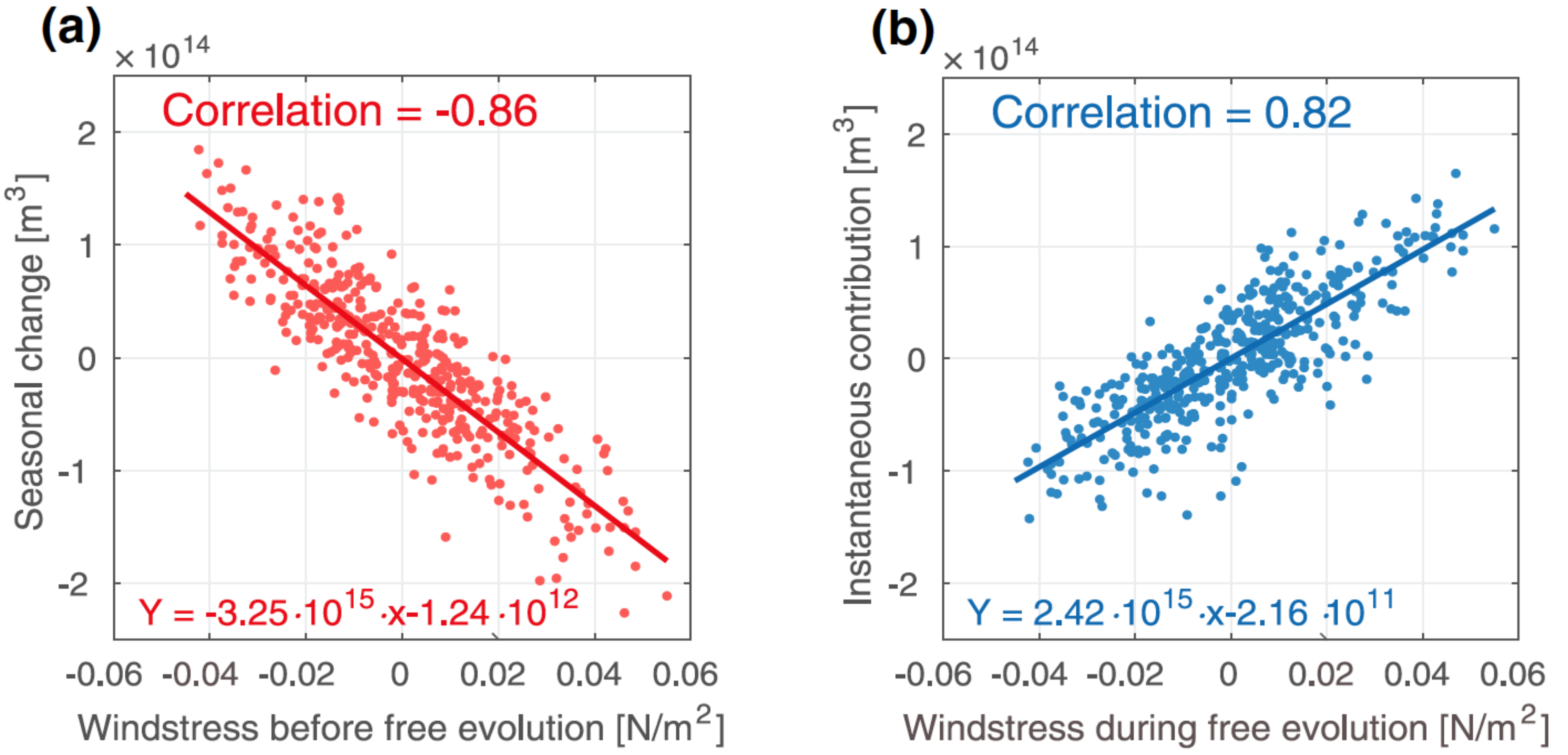
Observed WWV

Control simulation WWV

Source: Neske and McGregor 2018

Validation of WWV separation

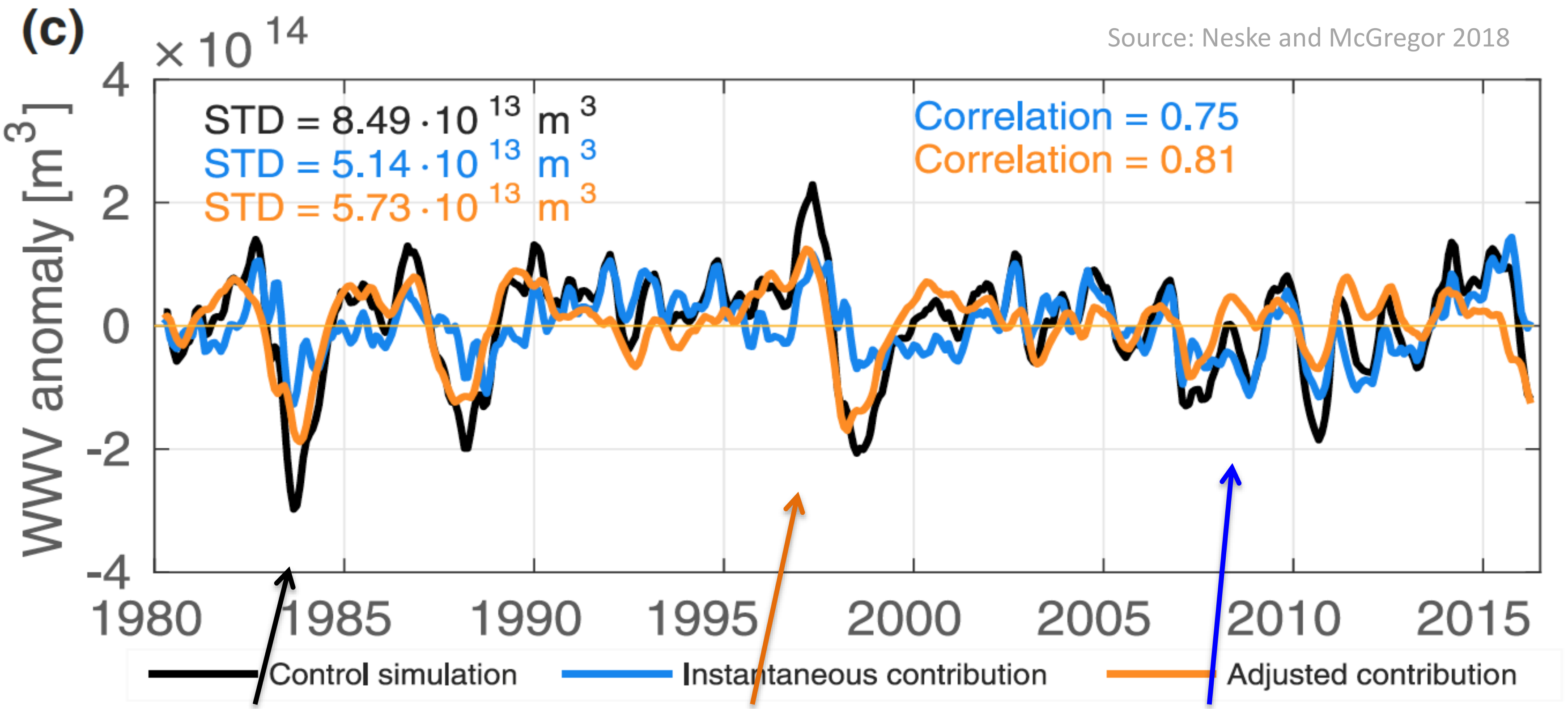
- Strong negative relationship between pre-free evolution zonal WP wind stress and the seasonal WWV change
- Strong positive relationship between coincident zonal WP wind stress and the instantaneous WWV change



Source: Neske and McGregor 2018

What drives the WWV?

Adjusted contribution slightly more dominant overall, but the instantaneous contribution clearly plays a strong role in driving WWV changes



Source: Neske and McGregor 2018

Control simulation

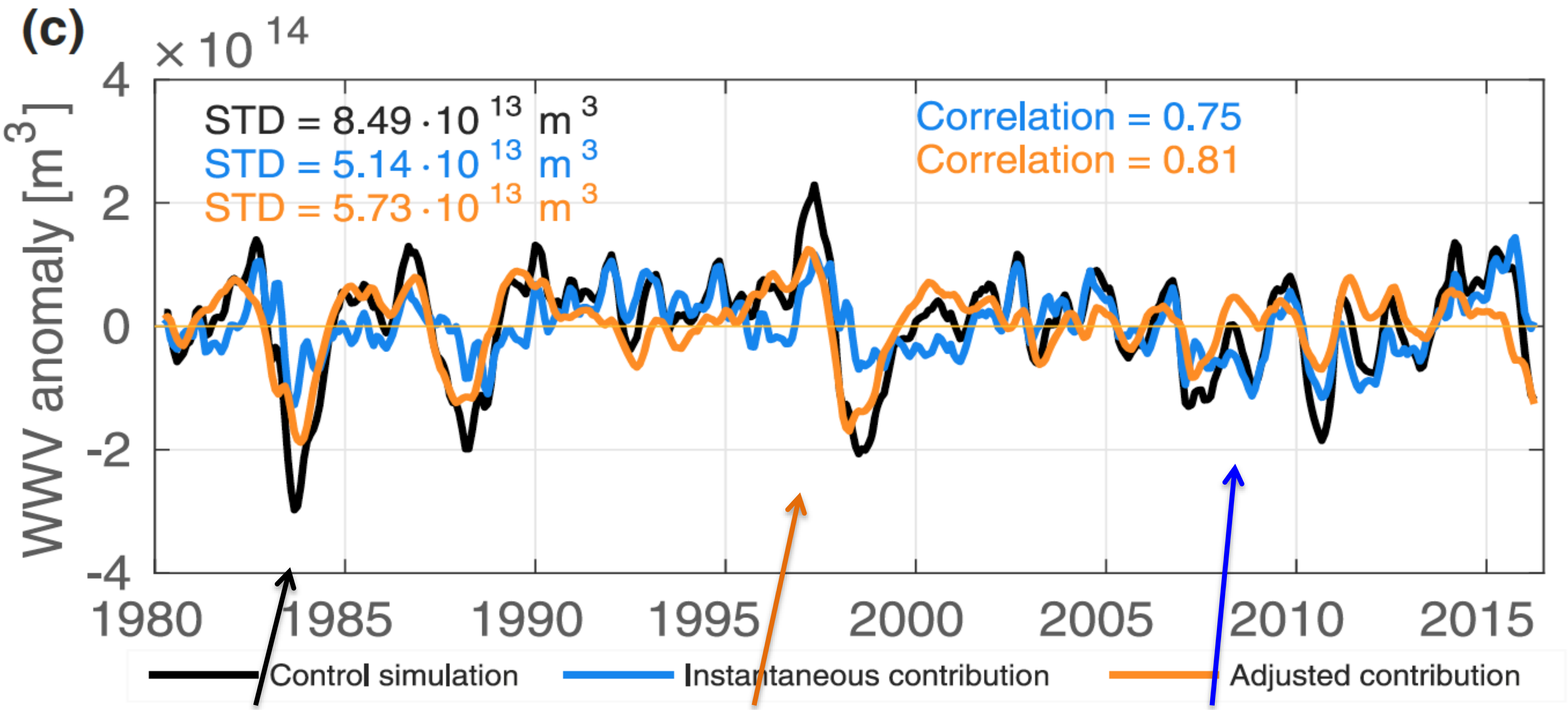
Adjusted contribution

Instantaneous contribution

What drives the WWV?

30% reduction in WWV since 2000, is largely due to changes in the adjusted WWV.

Pre 2000	Post 2000
STD = $4.79 \cdot 10^{13}$ m^3 ; R =0.74	STD = $5.49 \cdot 10^{13}$ m^3 ; R =0.82
STD = $6.88 \cdot 10^{13}$ m^3 ; R =0.88	STD = $3.86 \cdot 10^{13}$ m^3 ; R =0.6



Control simulation

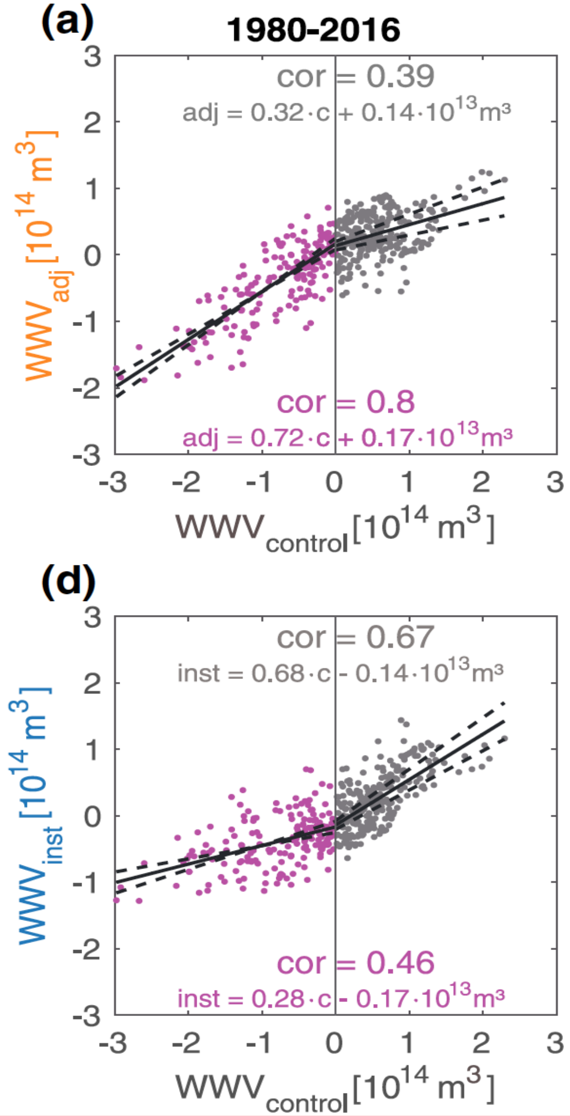
Adjusted contribution

Instantaneous contribution

Source: Neske and McGregor 2018

ENSO phase WWV asymmetry

Source: Neske and McGregor 2018



Discharged WWV

- Adjusted component is the dominant driver (r = 0.8, B = 0.72)
- Instantaneous contribution accounts for a much smaller proportion (r = 0.46, B = 0.28)

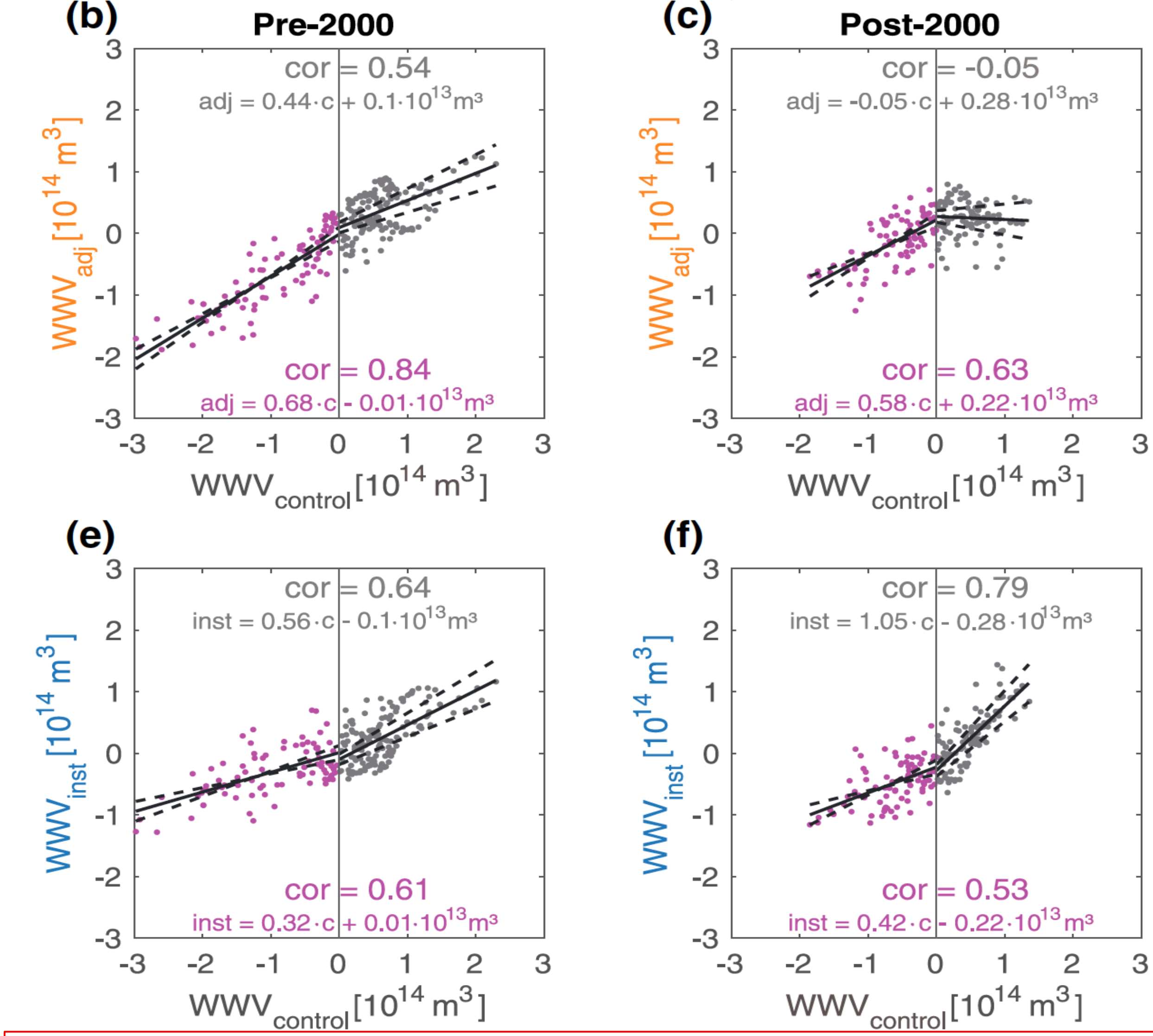
Recharged WWV

- Instantaneous component is the dominant driver (r = 0.67, B = 0.68)
- Adjusted contribution accounts for a much smaller proportion (r = 0.39, B =0.32)

WWV changes preceding La Nina events more predictable than those for El Nino events

Pre and post 2000 differences.

Source: Neske and McGregor 2018



Recharged WWV

Adjusted WWV contribution decreases significantly in the post-2000 period

Instantaneous WWV contribution increases significantly in the post-2000 period.

Discharged WWV

Both adjusted and instantaneous WWV contributions shows slight decreases in correlation post-2000, but relatively little regression change

WWV changes preceding El Nino events have become less predictable post-2000

Pre and post 2000 differences

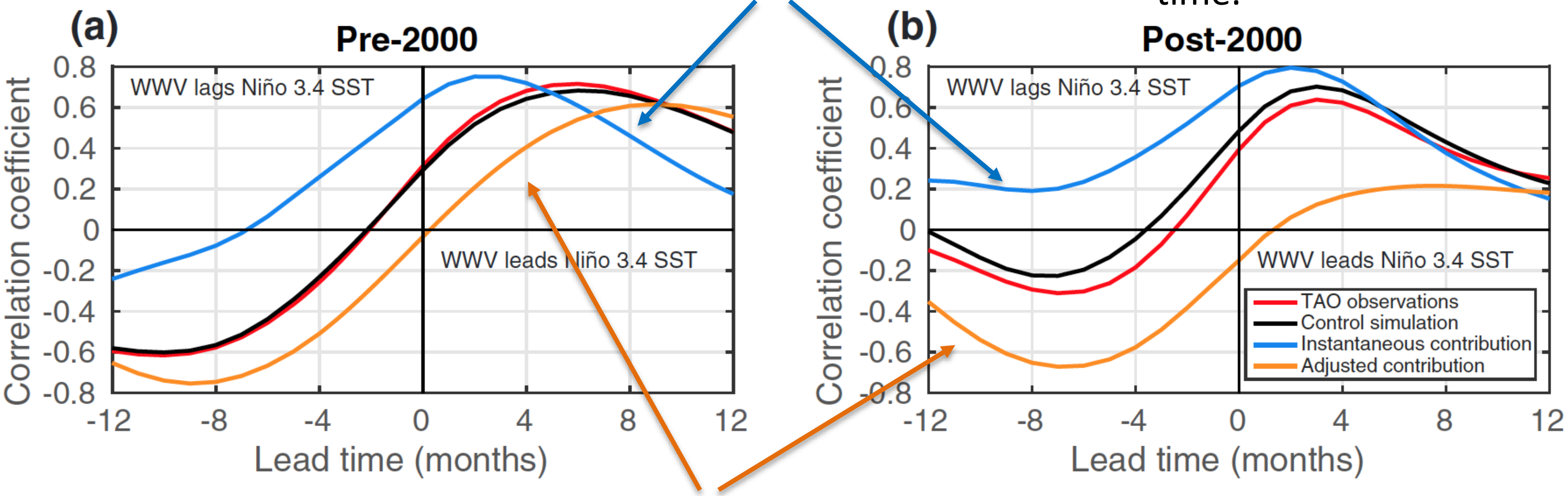
Pre-2000

Both adjusted (2-month peak) and instantaneous (9 month peak) WWV contributions play a role in control simulations.

Post-2000

Adjusted contribution has no clear peak, while instantaneous has a 2-month peak. This leads the control to largely reflect the instantaneous simulations short lead time.

Instantaneous contribution



Adjusted contribution

Source: Neske and McGregor 2018

Conclusions

- WWV changes can generated directly by winds (instantaneous), or via ocean dynamics (adjusted).
- WWV can be decomposed into an instantaneous and adjusted contributions.
  - Adjusted contribution has strong relationship to the WWV of the western Pacific, which suggests our results are consistent with those of Izumo et al. 2018 and Planton et al. 2018.
- Both explain a significant amount of the control WWV variability.
- Pre and post 2000 changes in the STD of WWV appear to be solely due to changes in the adjusted WWV.
- A clear WWV phase asymmetry is identified that suggests WWV preceding La Nina events is more predictable than El Nino events.
- Pre-post 2000 WWV changes are also found, predominantly decreases in the adjusted WWV contribution, meaning El Nino events are less predictable now.
- These results explain the change in WWV/SST lead time noted since 2000 (e.g., McPhaden 2012; Hori et al. 2012).

References

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