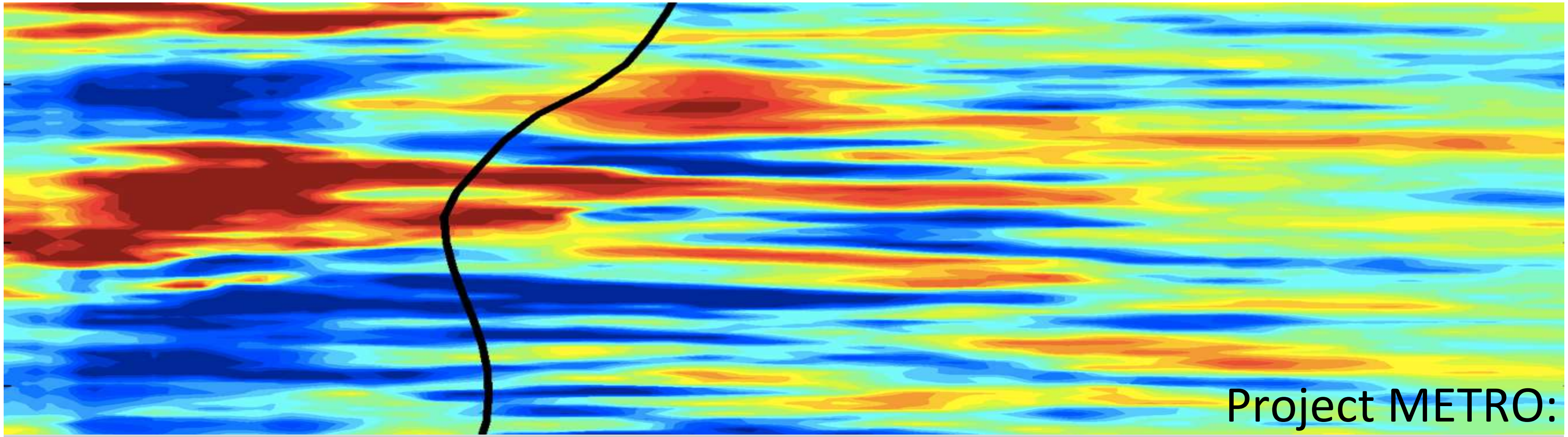

Project METRO:

Upper ocean stratification and response to westerly wind bursts:

Links between intraseasonal variability and ENSO

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26 Jan 2012

quasi-periodic
self-sustaining
oscillation

El Niño –
Southern
Oscillation

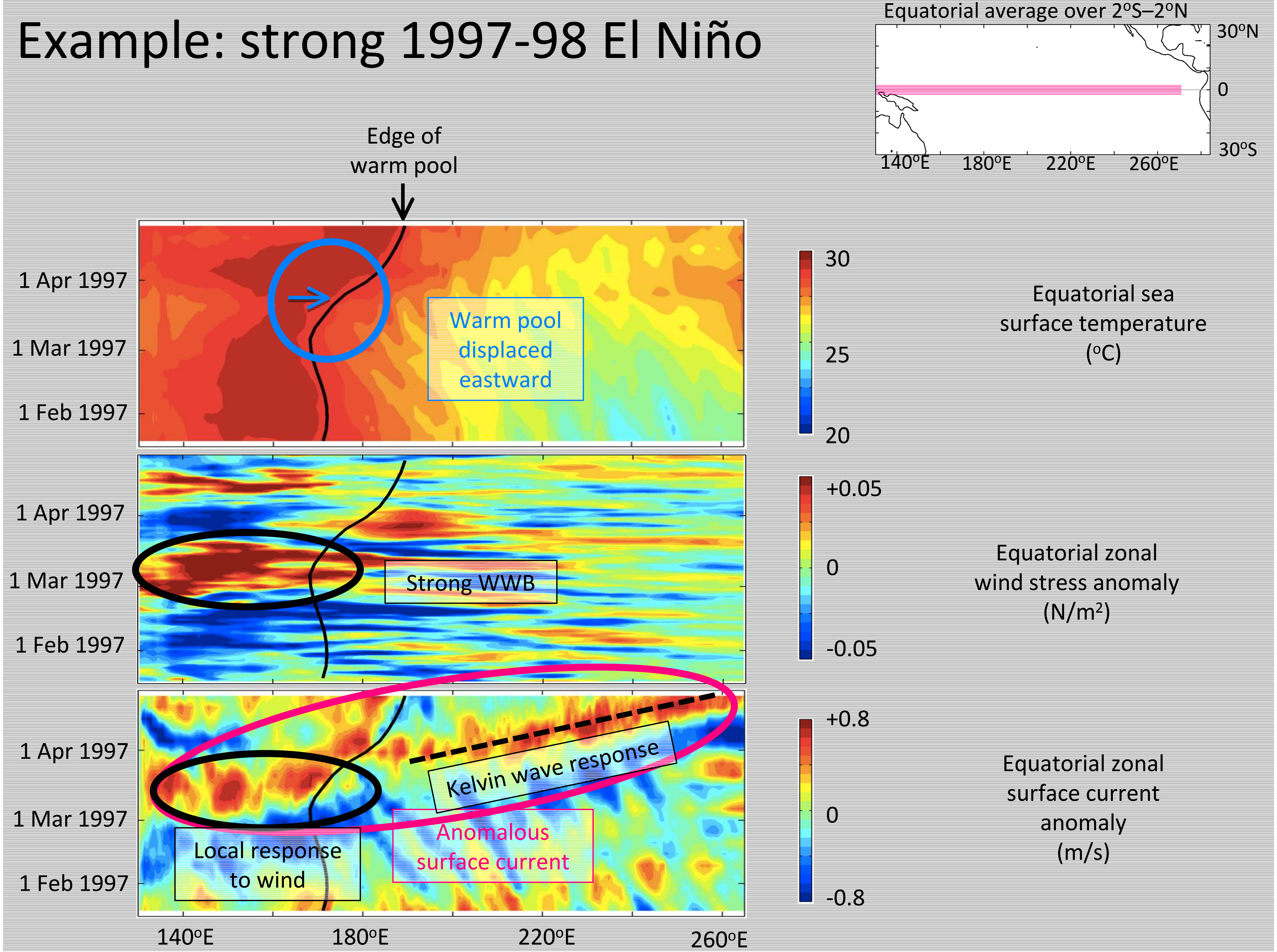
vs.

$\boxed{\text{damped, and excited by high-frequency atmospheric activity}}$

"westerly wind bursts" (WWBs)
precede El Niño events

{
~20^{o} longitude span
~8 days duration
~7 m/s

Example: strong 1997-98 El Niño



This study:

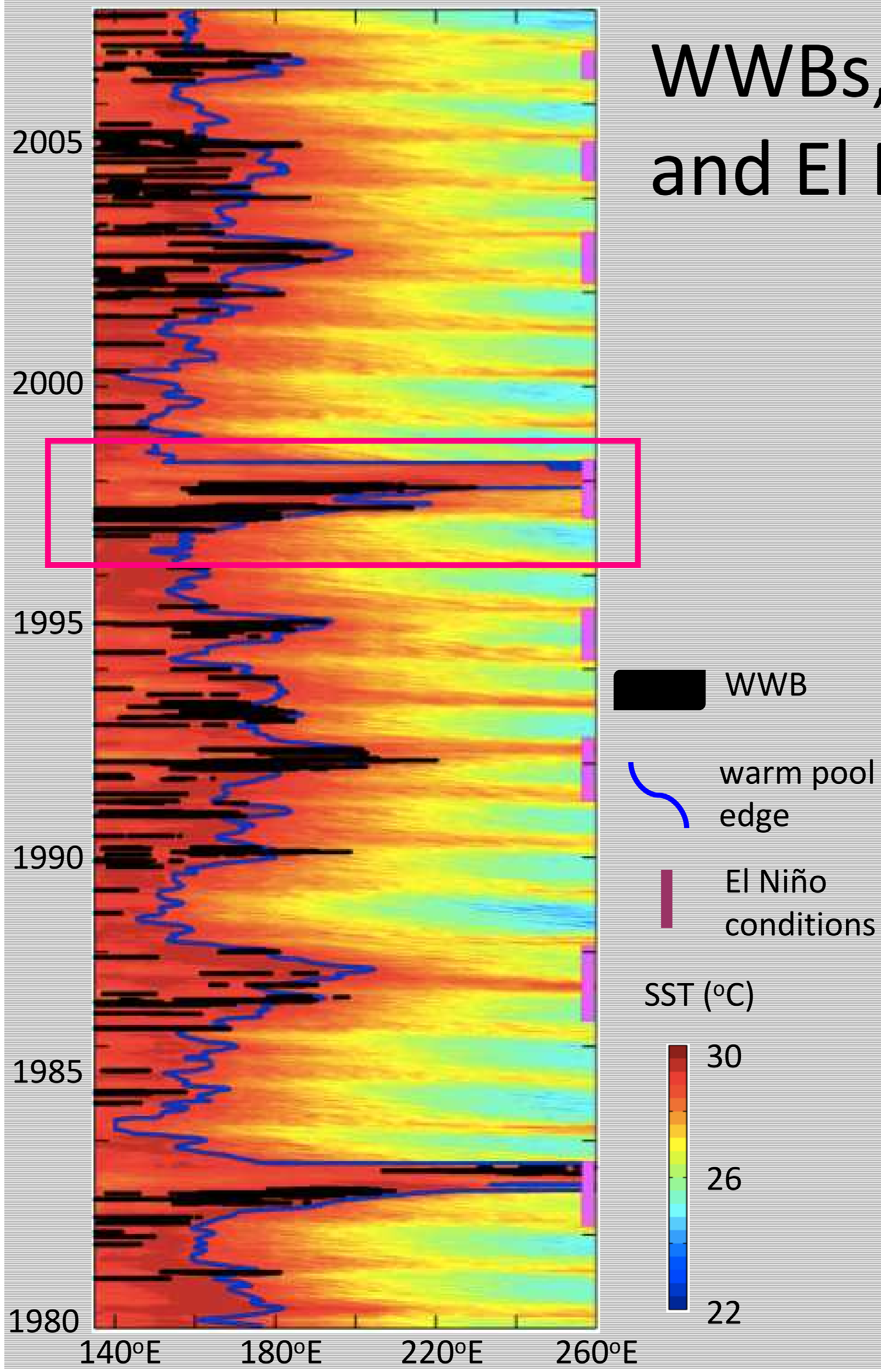
How are WWBs & warm pool advection related?

- Why do only some WWBs displace the warm pool eastward?
- Which processes are important?
- What are the feedbacks between WWBs and ENSO?

Strategy:

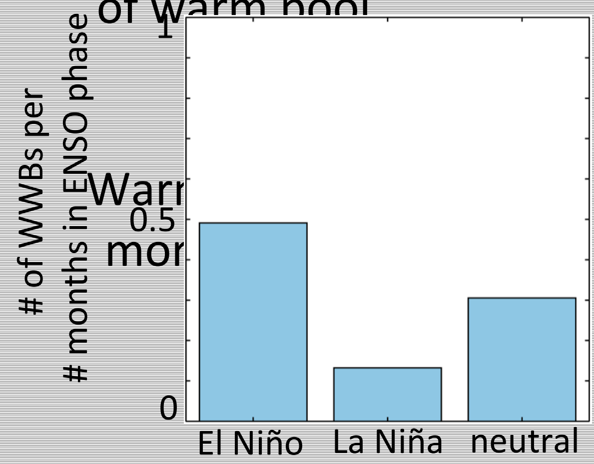
- ORCA025 model – DRAKKAR run
  - Based on the NEMO OGCM
  - **Forcing**: shortwave fluxes & surface meteorological variables using the DFS3 bulk formula (based on ERA-40); radiation from ISCCP.
  - **output resolution**: 5-day, 0.25°x0.25°, vertical resolution 6-m (surface) to 250-m (depth)
  - **output fields** (present study): temperature, salinity, zonal currents
- Define WWBs:
  - At each time-step, locate points for which: { wind stress > 0.02 N/m^2; wind stress anomaly > 0.06 N/m^2
  - WWBs defined as patches of having **zonal extent > 10° & duration ≥ 5 days**
  - Using 1980-2007 (28 years, ~120 WWBs)

WWBs, warm pool advection, and El Niño



WWBs precede eastward advection of warm pool

Interannual distribution of WWBs:



Warr

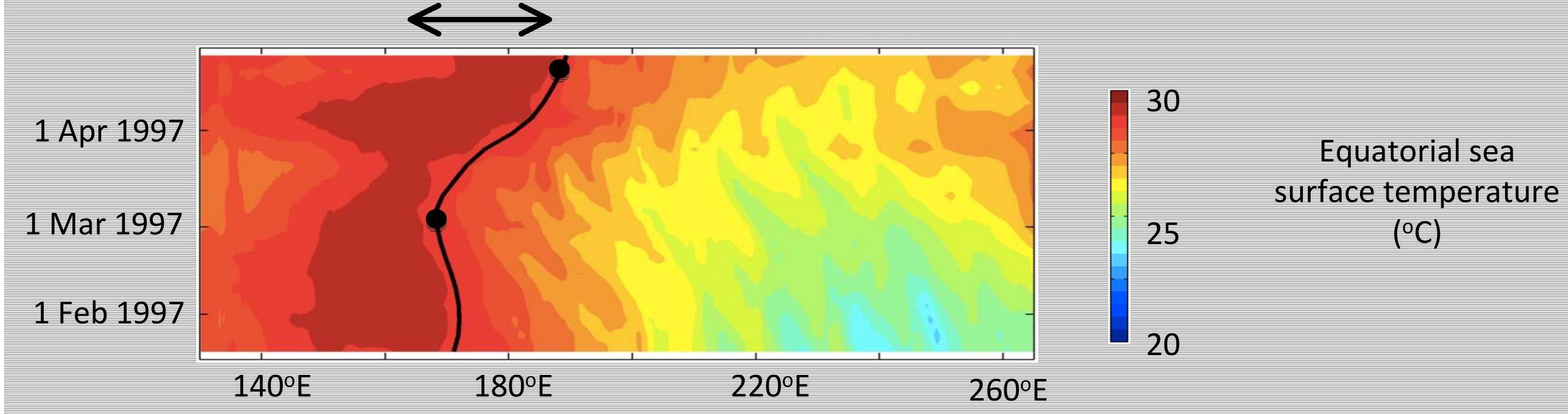
mor

WWB occurrence moves eastward with warm pool

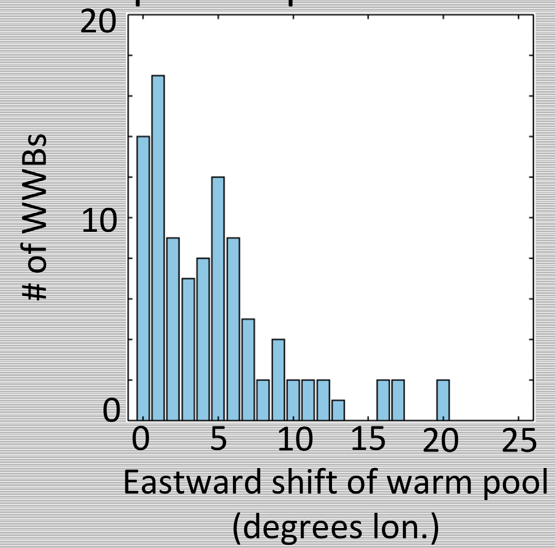
ENSO can modulate WWB occurrence via large-scale atmospheric & oceanic conditions:

Possible feedbacks

Series of WWBs may be important for El Niño onset "warm pool displacement"



Distribution of warm pool displacement



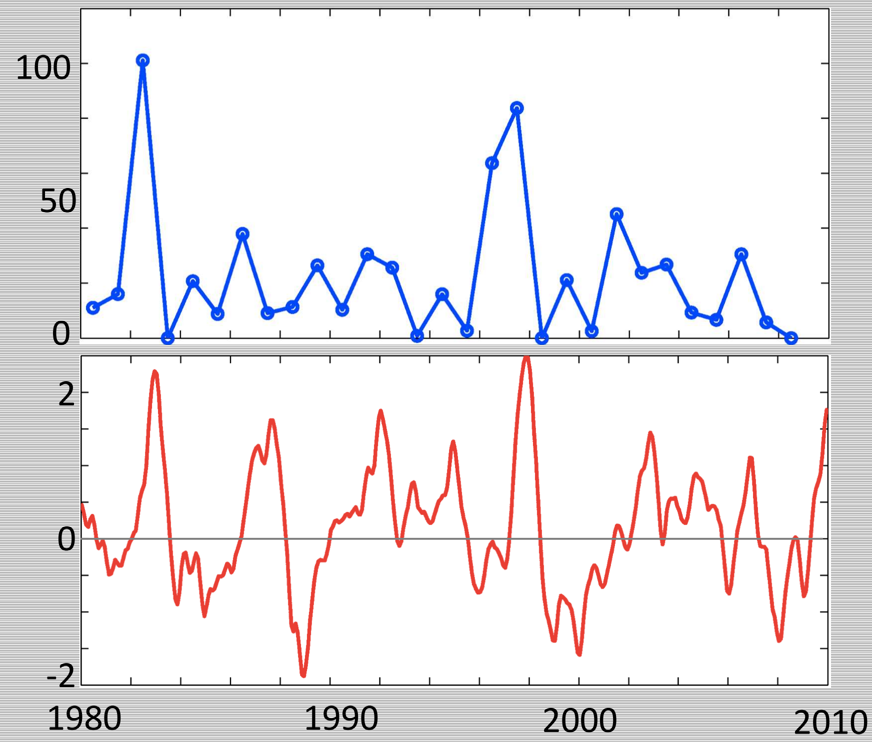
Most WWBs only shift the warm pool a few degrees eastward

Importance of *series* of WWBs?

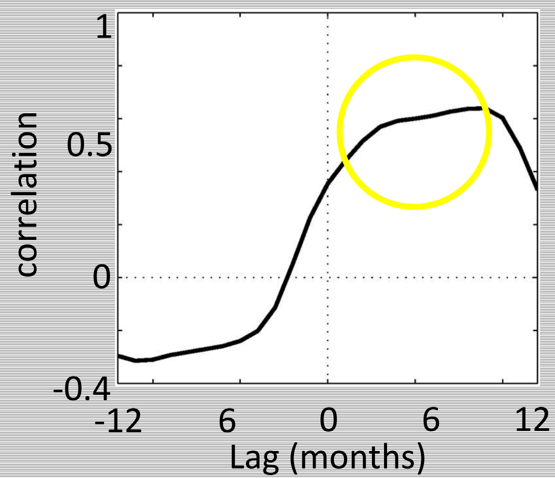
Series of WWBs and warm pool displacement: relationship to ENSO

Annual sum of WWB-related warm pool displacement (degrees lon.)

Nino 3.4 index (^{o}C)



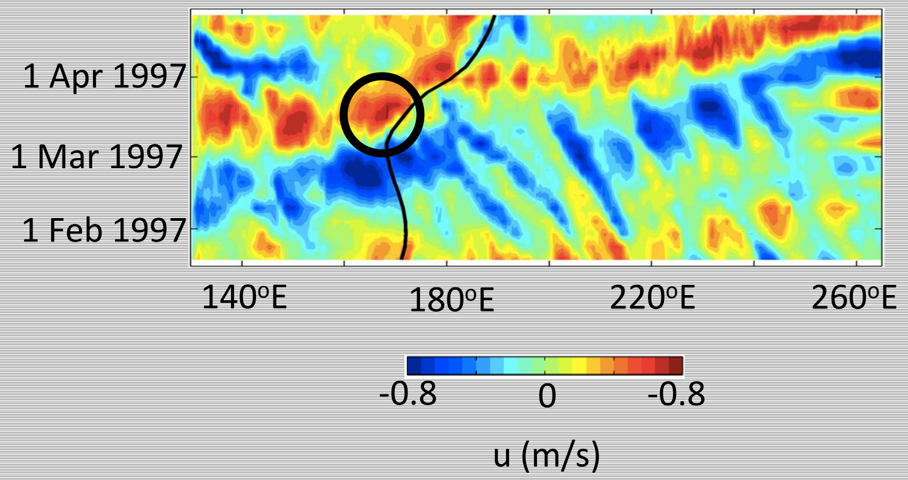
Lagged correlation between Nino-3.4 index & annual warm pool displacement

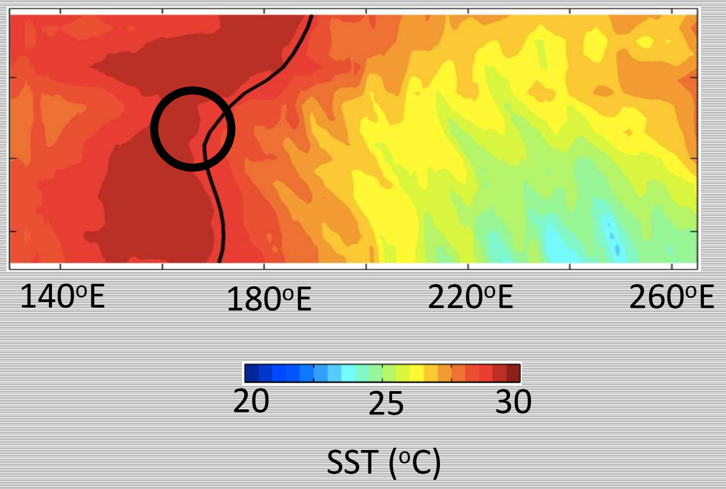


Nino-3.4 warming follows warm pool displacement by 3–9 months

What drives WWB-related warm pool displacement?

Zonal SST advection: $$\frac{\partial T}{\partial t} \sim -u\frac{\partial T}{\partial x}$$

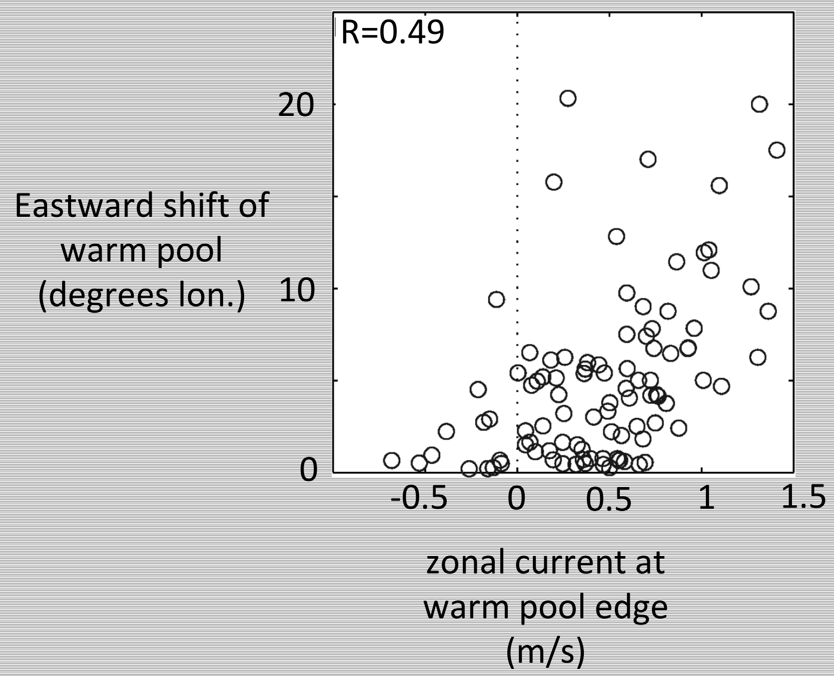




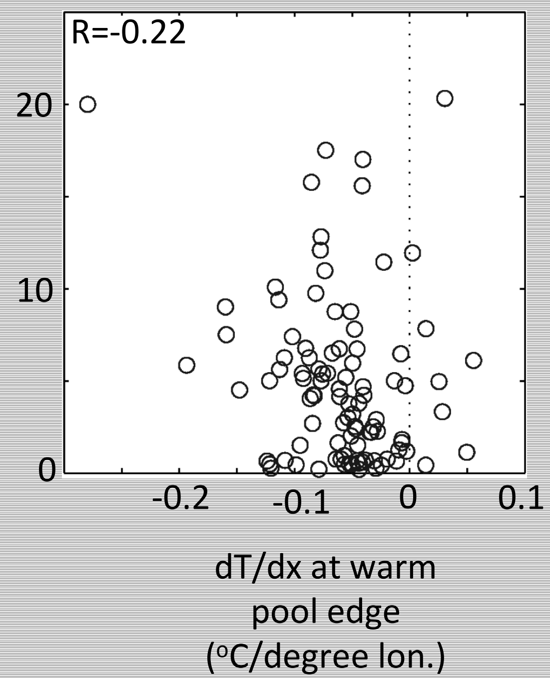
What drives WWB-related warm pool displacement?

Zonal SST advection: $$\frac{\partial T}{\partial t} \sim -u\frac{\partial T}{\partial x}$$

Role of u



Role of $\frac{\partial T}{\partial x}$



Zonal **surface currents** play a more important role than zonal SST gradient

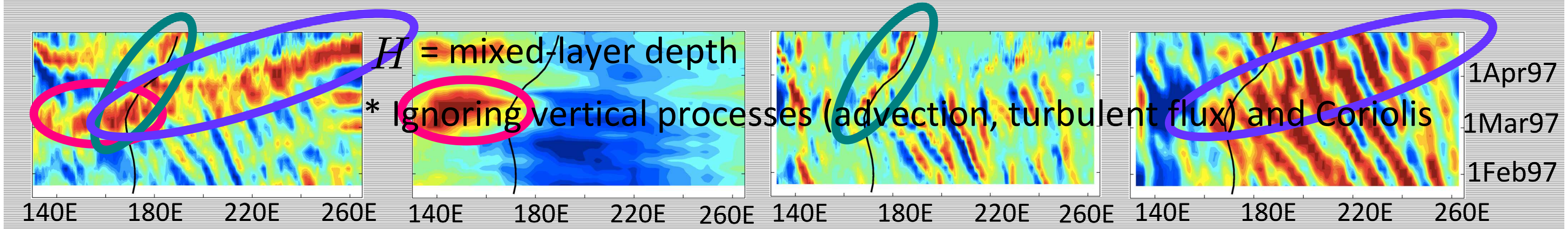
What processes drive surface current anomalies?
Simplified momentum balance:

$$\frac{\partial u}{\partial t} \sim \frac{\tau^x}{\rho H} - u\frac{\partial u}{\partial x} - \frac{1}{\rho}\frac{\partial p}{\partial x}$$

surface current acceleration | wind forcing | advection | pressure gradient force

H = mixed-layer depth

* Ignoring vertical processes (advection, turbulent flux) and Coriolis



Below WWB: **wind stress** dominates

At warm pool edge: **zonal advection**

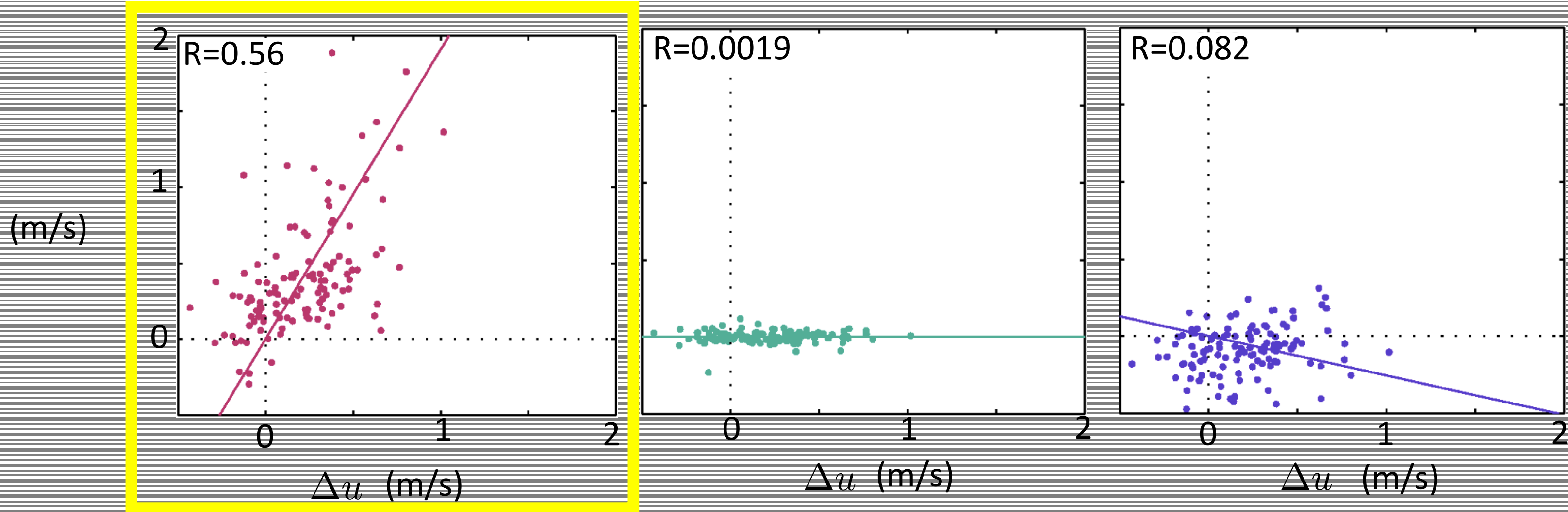
Along Kelvin wave path: **pressure gradient**

Momentum balance (integrated) for all WWBs

Below the WWB

$$\Delta u \sim \left(\int_{t=t_o}^{t=t_f} \frac{\tau^x}{\rho H} - u\frac{\partial u}{\partial x} - \frac{1}{\rho}\frac{\partial p}{\partial x} \right) dt$$

surface current acceleration — wind forcing — advection — pressure gradient force



Below the WWB, **wind stress dominates** the zonal current acceleration

H = 100m
t_o = start of WWB
t_f = end of WWB

Momentum balance (integrated) for all WWBs

At the warm pool edge

$$\Delta u \sim \left(\int_{t=t_o}^{t=t_f} \frac{\tau^x}{\rho H} \boxed{- u \frac{\partial u}{\partial x}} \boxed{- \frac{1}{\rho} \frac{\partial p}{\partial x}} \right) dt$$

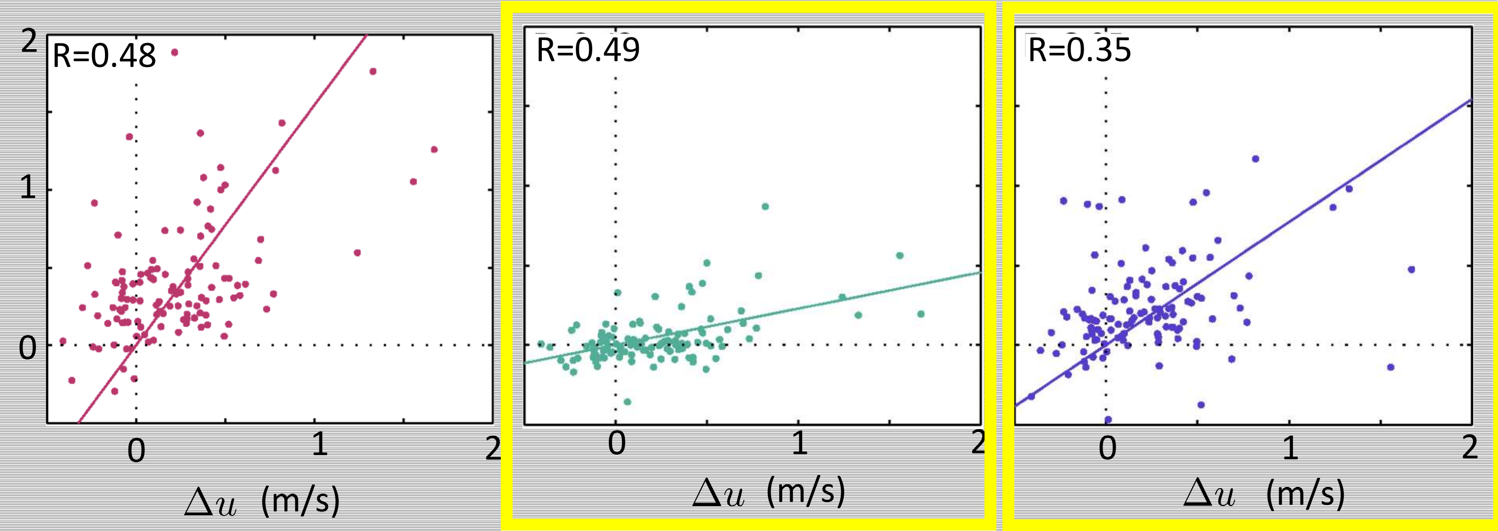
surface current acceleration

wind forcing

advection

pressure gradient force

(m/s)



At the **edge of the warm pool, advection** and **pressure gradient** are also important

H = 100m
t_o = start of WWB
t_f = end of WWB

Summary:

1. **Westerly wind bursts drive eastward zonal surface currents:**
   - **Wind stress** dominates current acceleration locally.
   - At the edge of the warm pool, **momentum advection** and **zonal pressure gradient** are also critical.

2. **Warm pool displacement is more sensitive to surface currents** than to local temperature gradient.

3. WWB-related warm pool displacement **leads El Niño-related warming by 3–9 months.**

Next steps:

- Re-run model with higher time resolution and full momentum budget:
  - Diagnose processes and quantify impacts more carefully.
- Explore the impacts of temperature and salinity variations:
  - Pressure gradient forcing.
  - Effect of barrier layers.
- Explore the feedbacks between ENSO and WWBs:
  - How large-scale conditions related to ENSO impact WWB properties (occurrence, intensity, location) and upper ocean response, and how this can feed back onto ENSO via the warm pool.