Interaction of Atlantic and Tropical Pacific Multidecadal Variability as Modulated by ENSO

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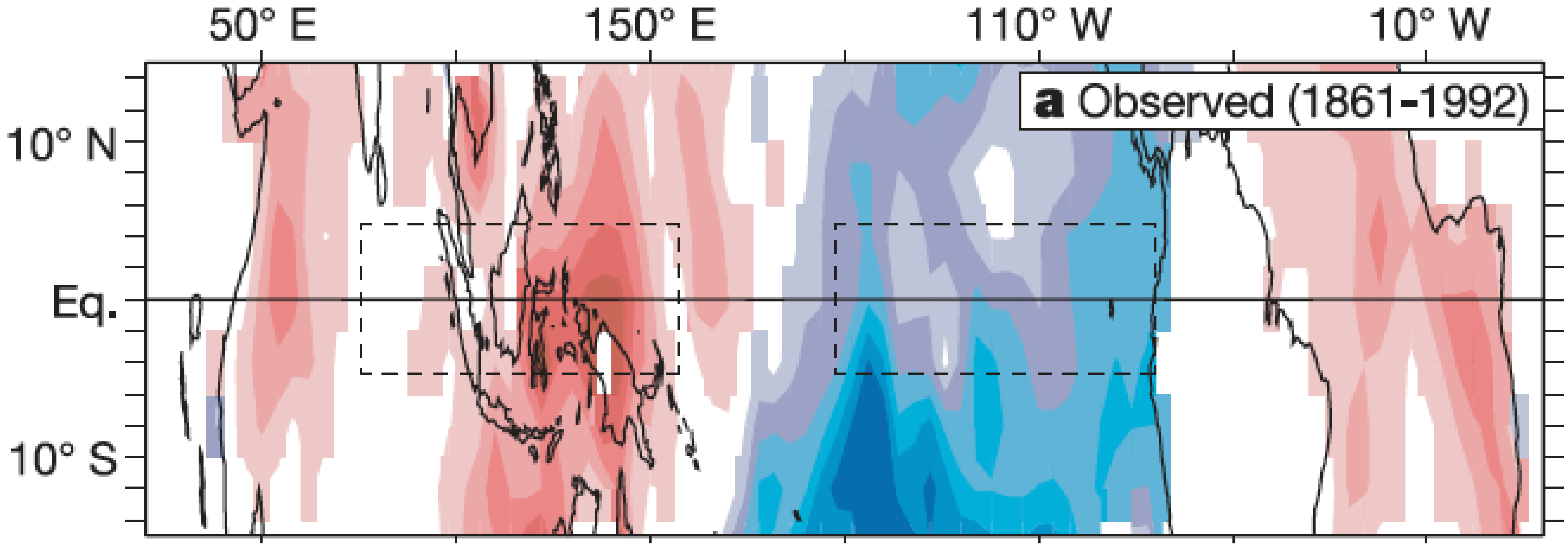
4^{th} ENSO CLIVAR conference

October 15, 2018

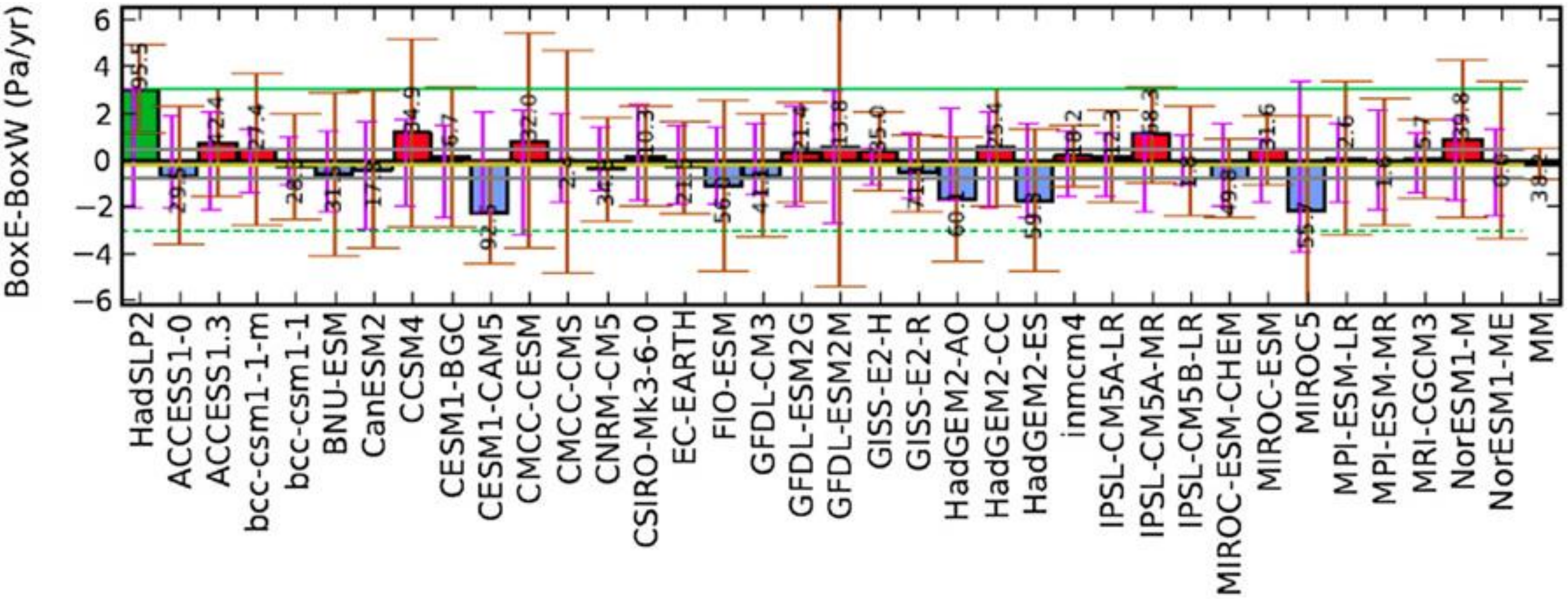
Thank you to Michael McPhaden, Dargan Frierson, and Elizabeth Maroon

Sea Level Pressure Trends

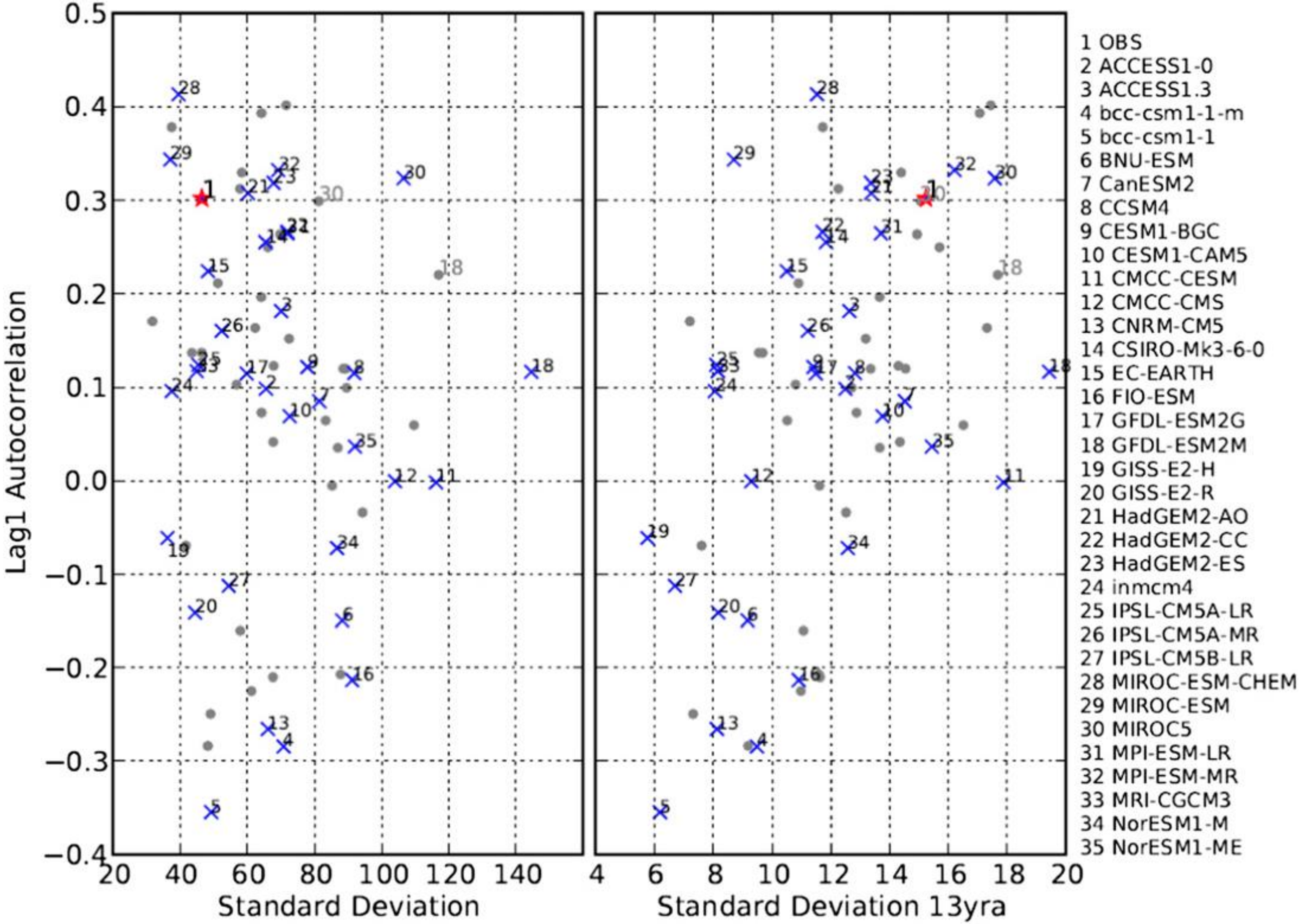


Vecchi et al 2006

Model Representation of Walker Circulation Trends

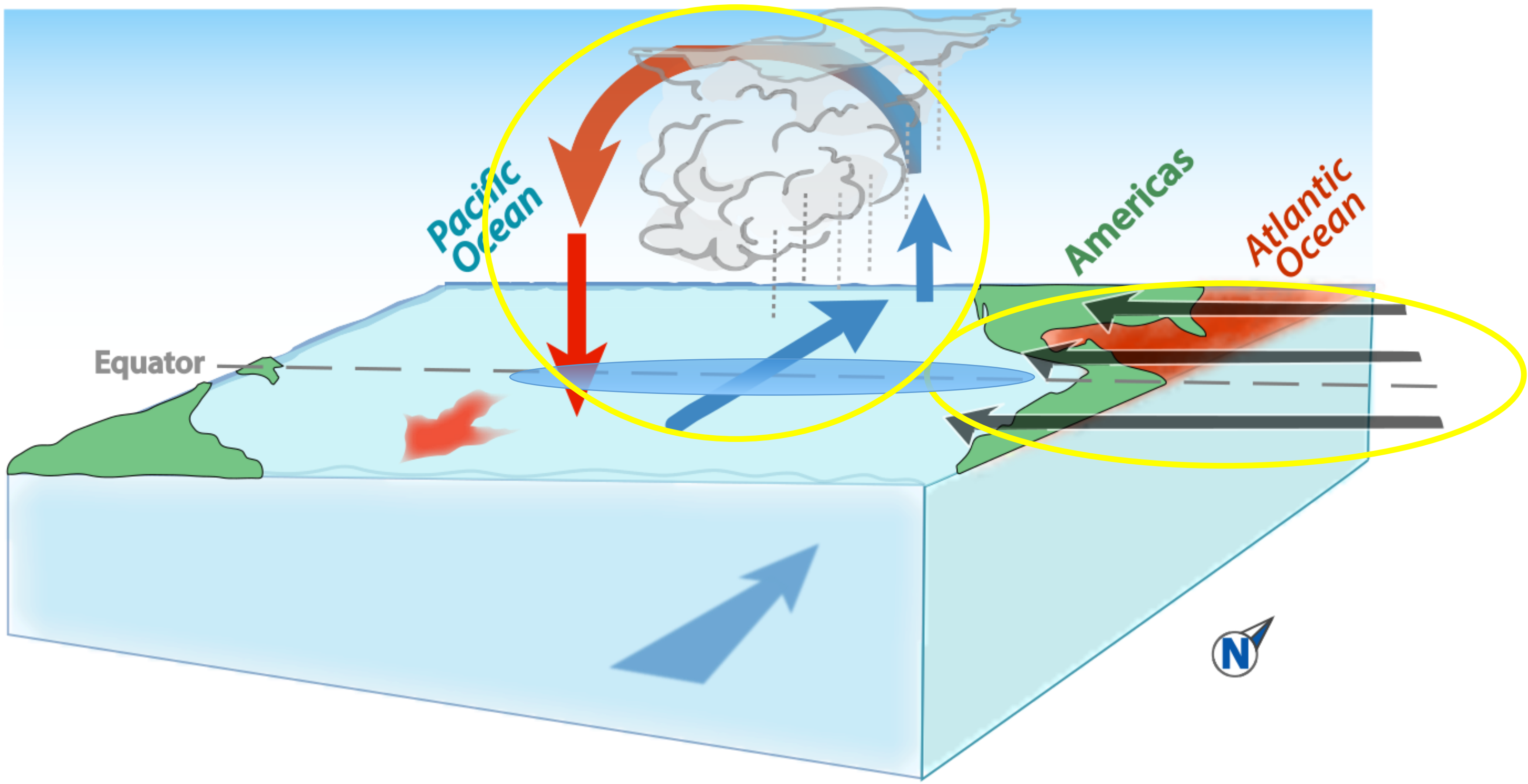


Kociuba and Power 2015



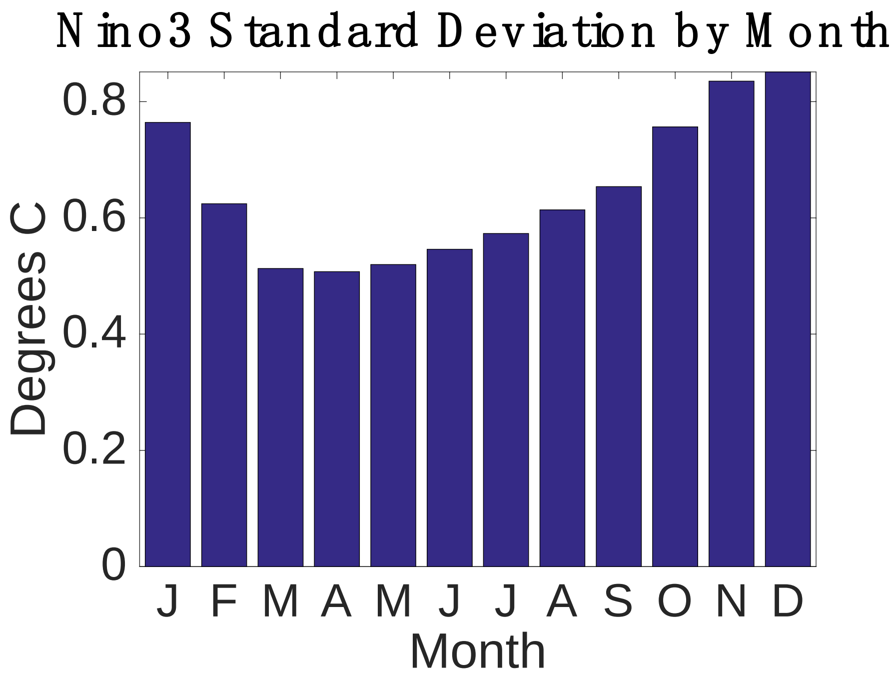
Kociuba and Power 2015

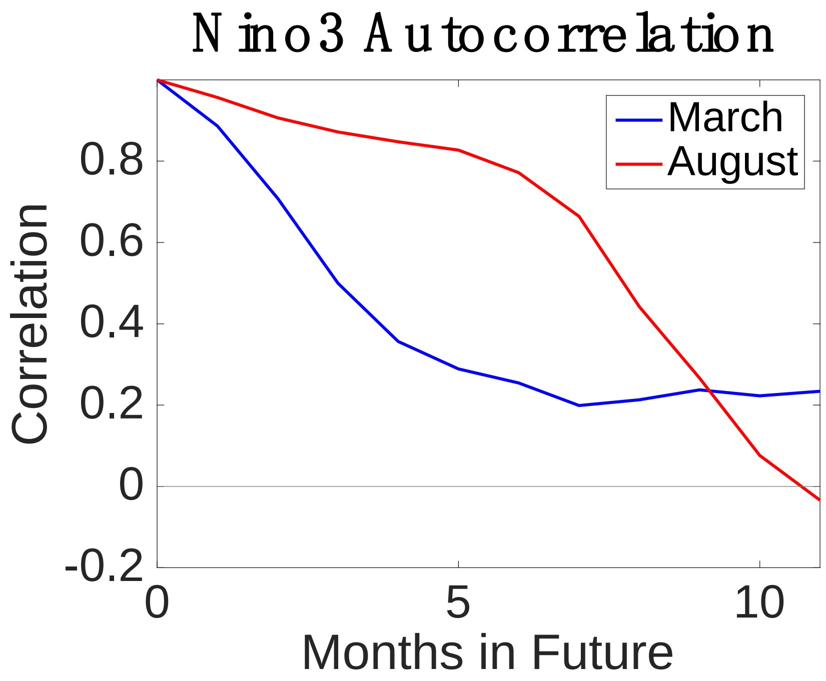
Mean State Impact



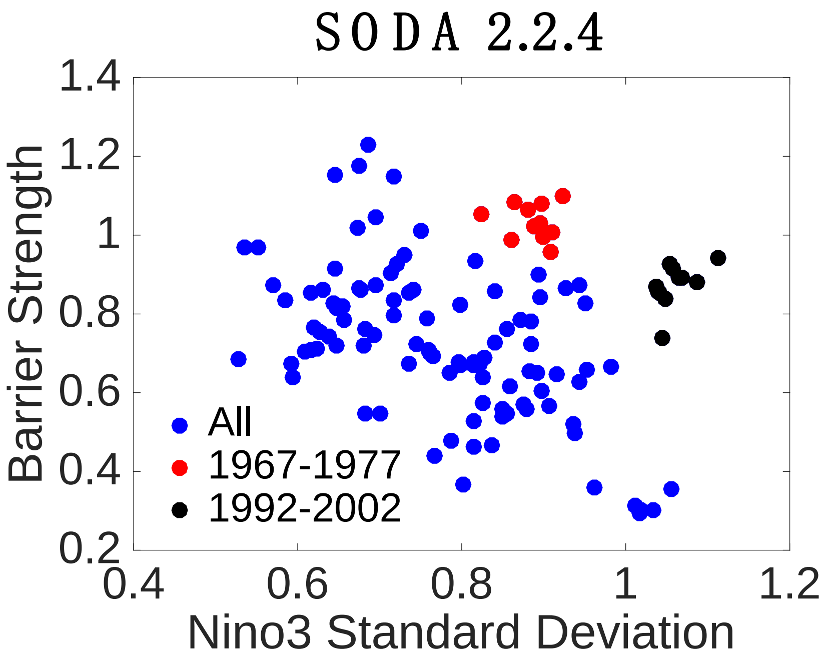
- Warm Atlantic →Stronger Trades (McGregor et al 2014)
- Stronger Trades → Stronger Cold Tongue (Li et al 2015)
- Stronger Cold Tongue → Changes in ENSO (Levine et al 2017, 2018)

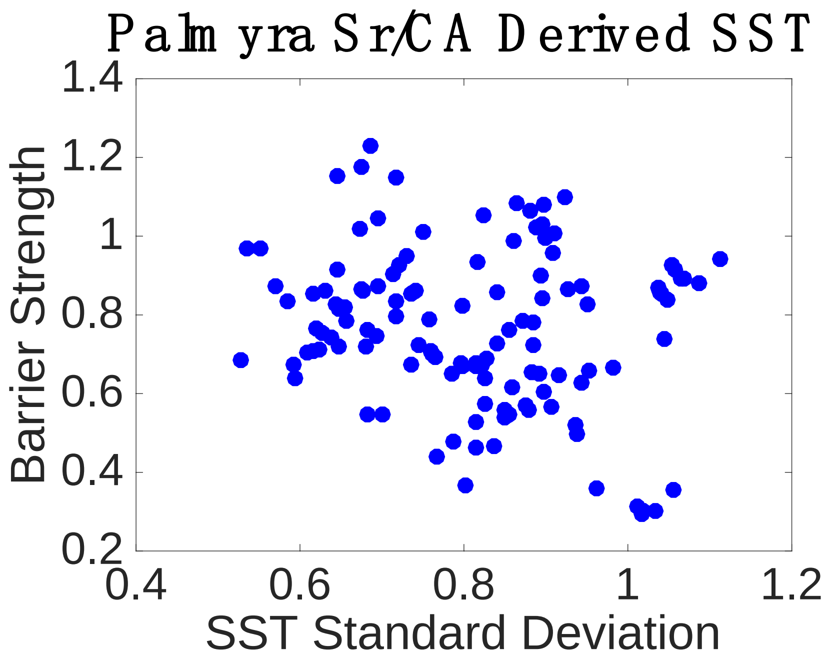
Seasonality of ENSO





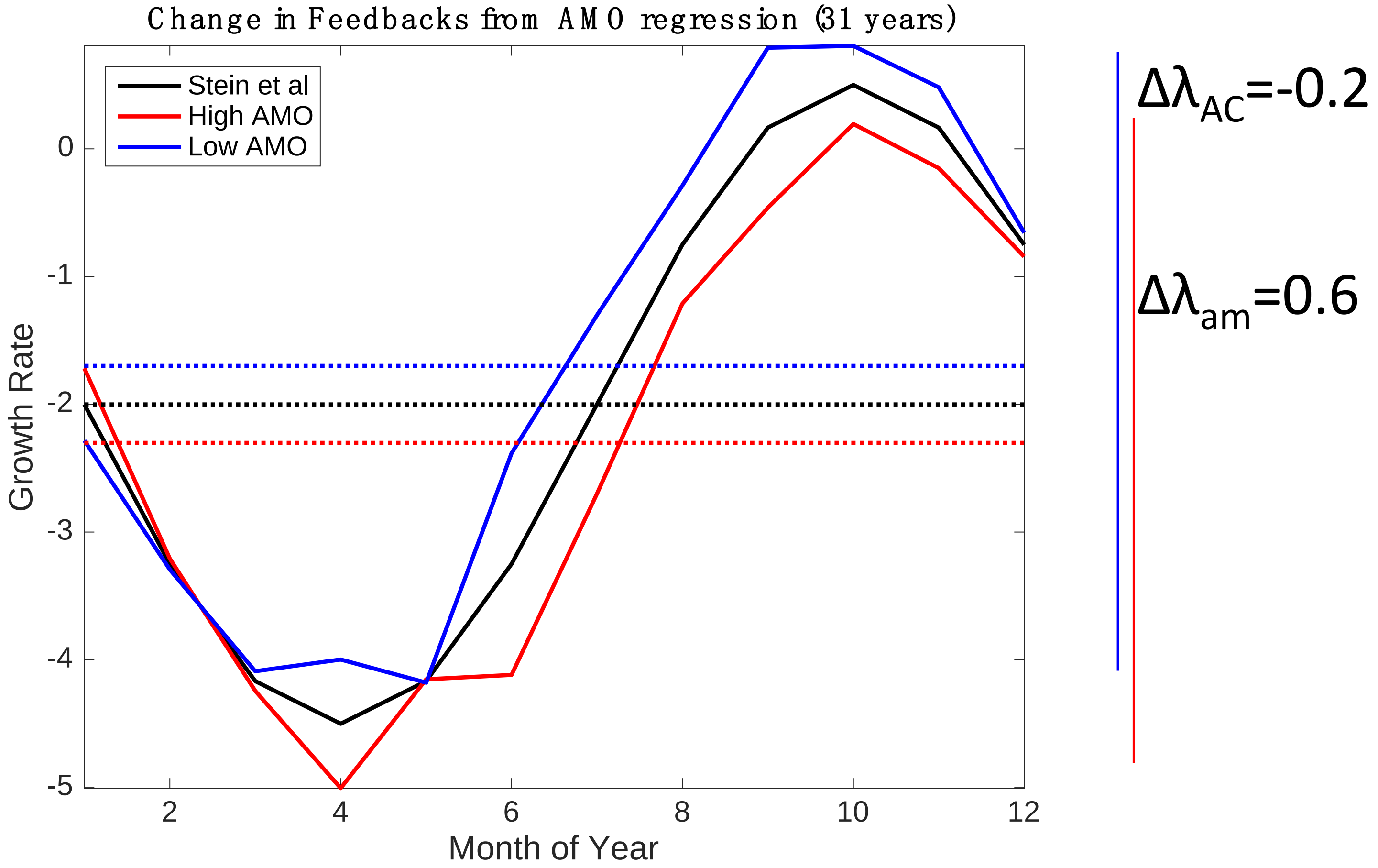
Relationship ENSO Annual Cycle and ENSO Variance





- Stronger annual cycle, weaker ENSO variance
- El Nino events are still strongly noise forced, so a strong event can happen at any time

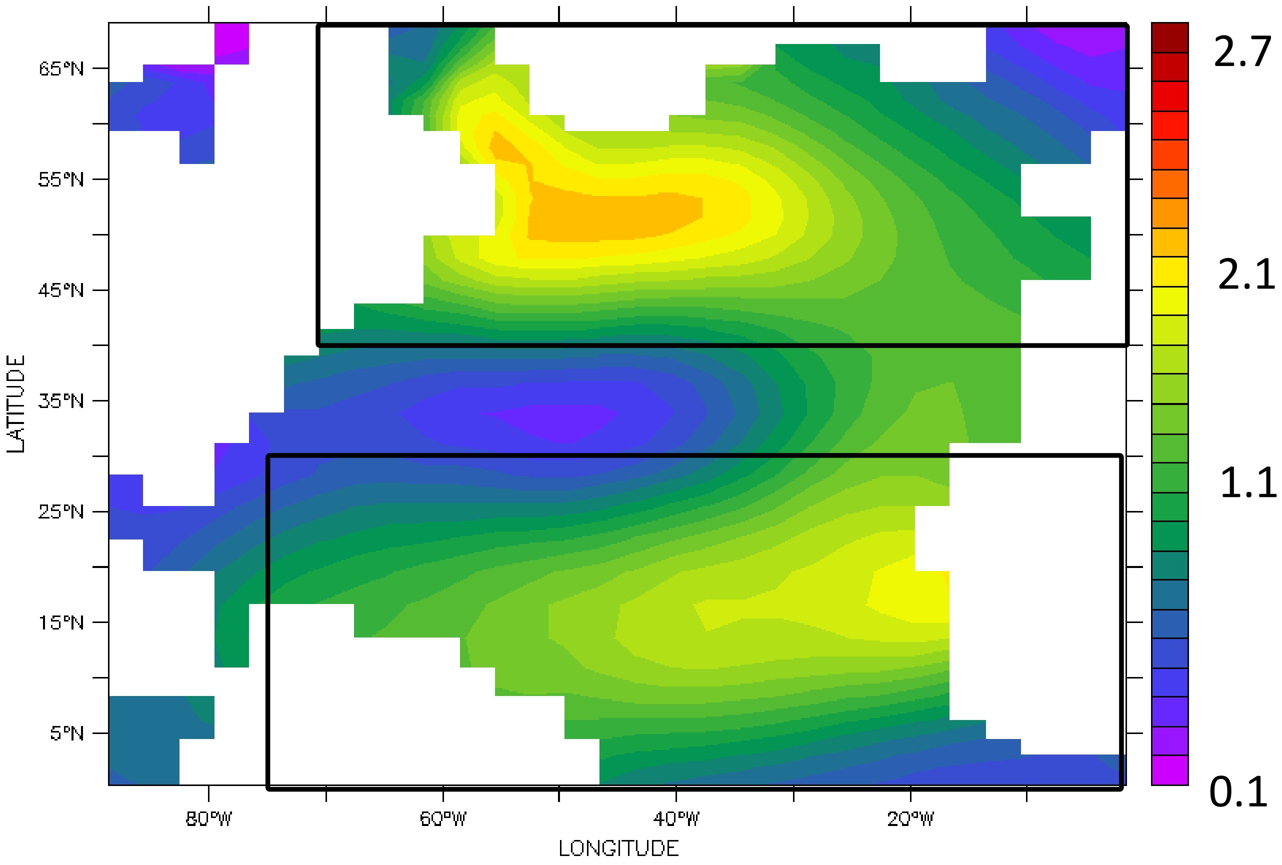
Changes in ENSO Growth Rate



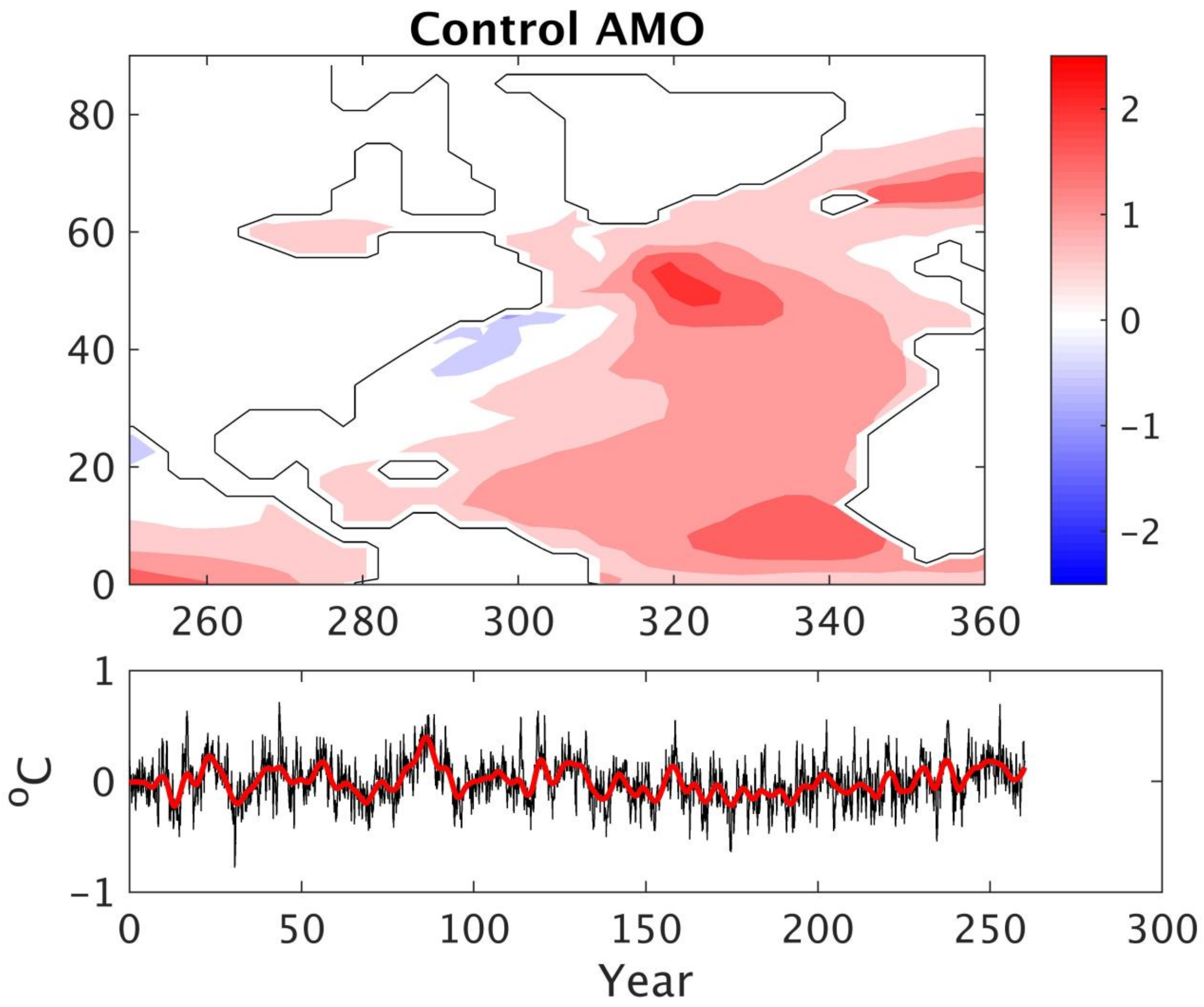
- Large seasonal changes in Damping from mean current, small in annual mean
- Annual cycle of growth rate and annual mean change fit what is expected from the conceptual model
  - Increased annual mean, decreased annual cycle
- Changes in both boreal spring and fall

Coupled Model

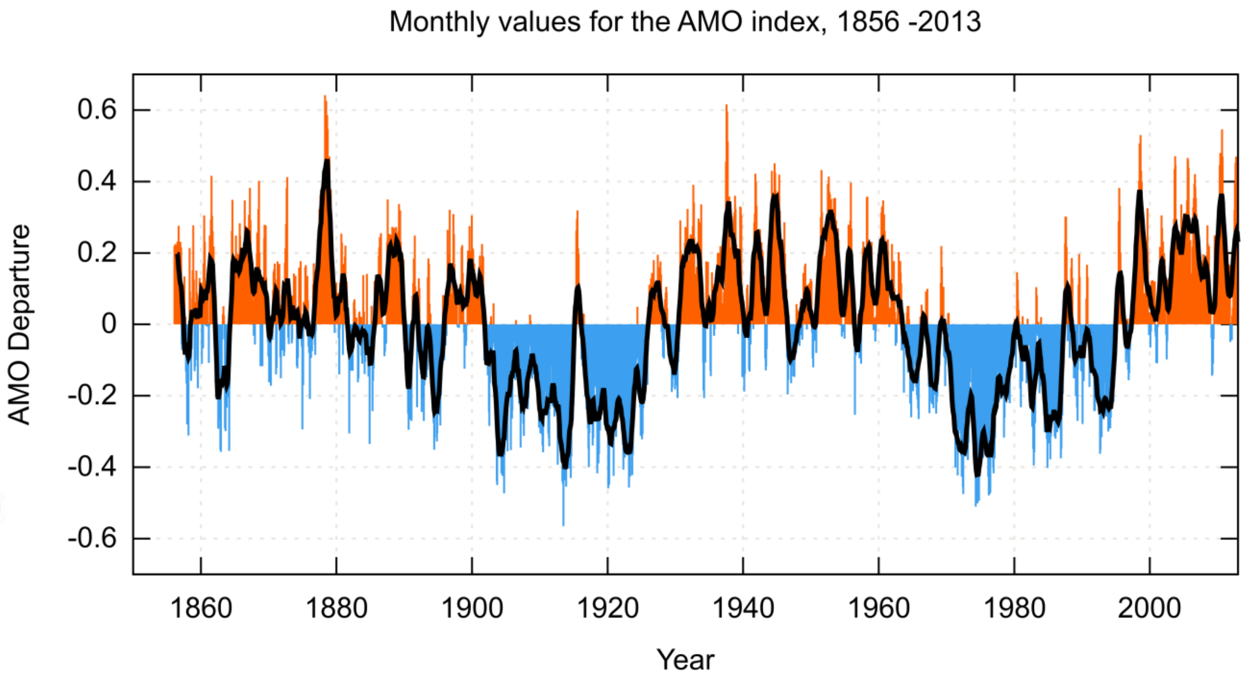
- Limited observational record
  - 1-2 cycles
  - 20CR reanalysis/ERSST
- Coarse resolution CM2M
  - Atm. 3.5 x 3 with 24 levels
  - Ocean 3 degree (0.6 in tropics), 5 levels in upper 50 m
  - Control simulation of 270 years



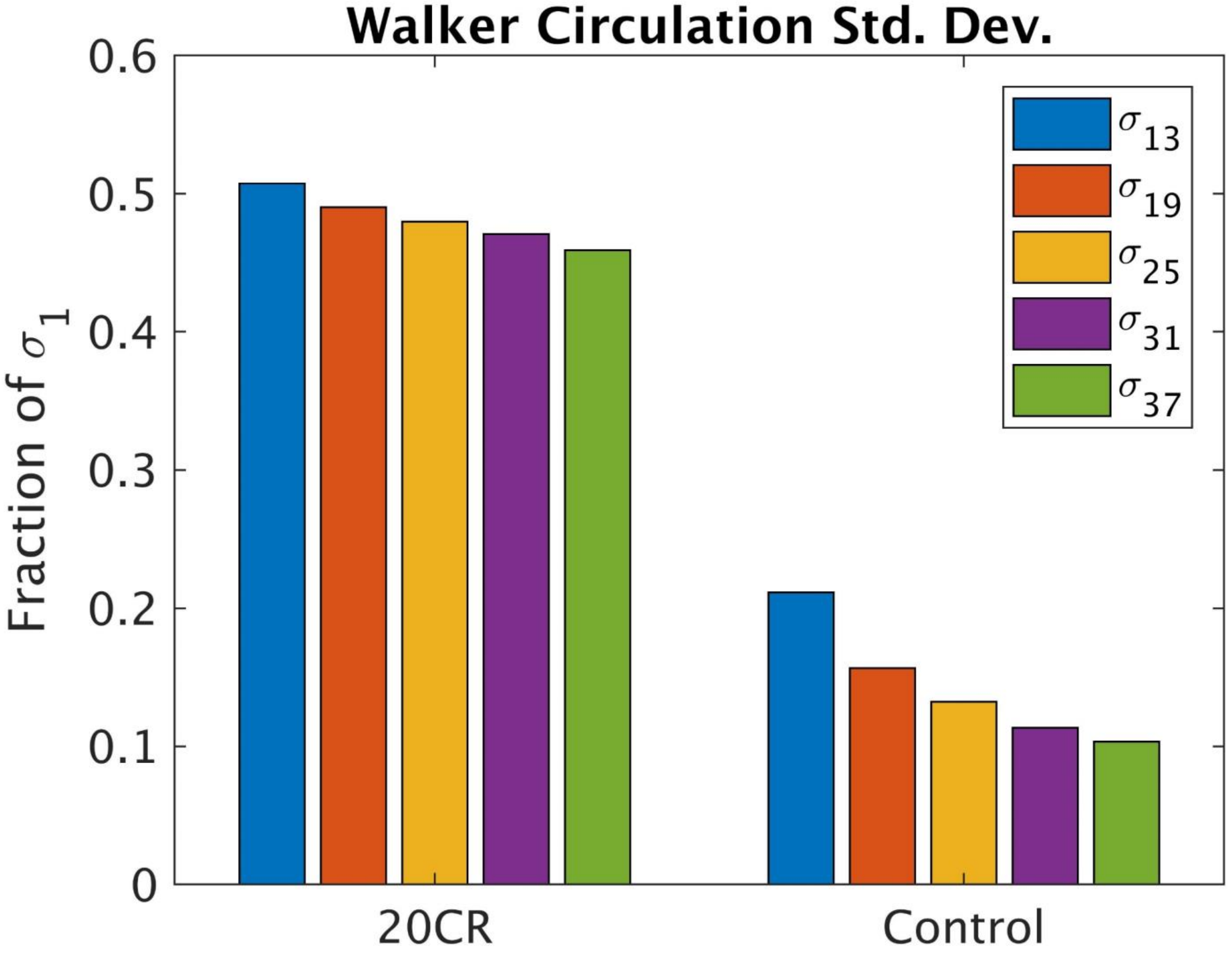
Model AMV



- Control simulation does not have sufficient multidecadal variability in Atlantic
- Common error among climate models (Frankignoul et al 2017)

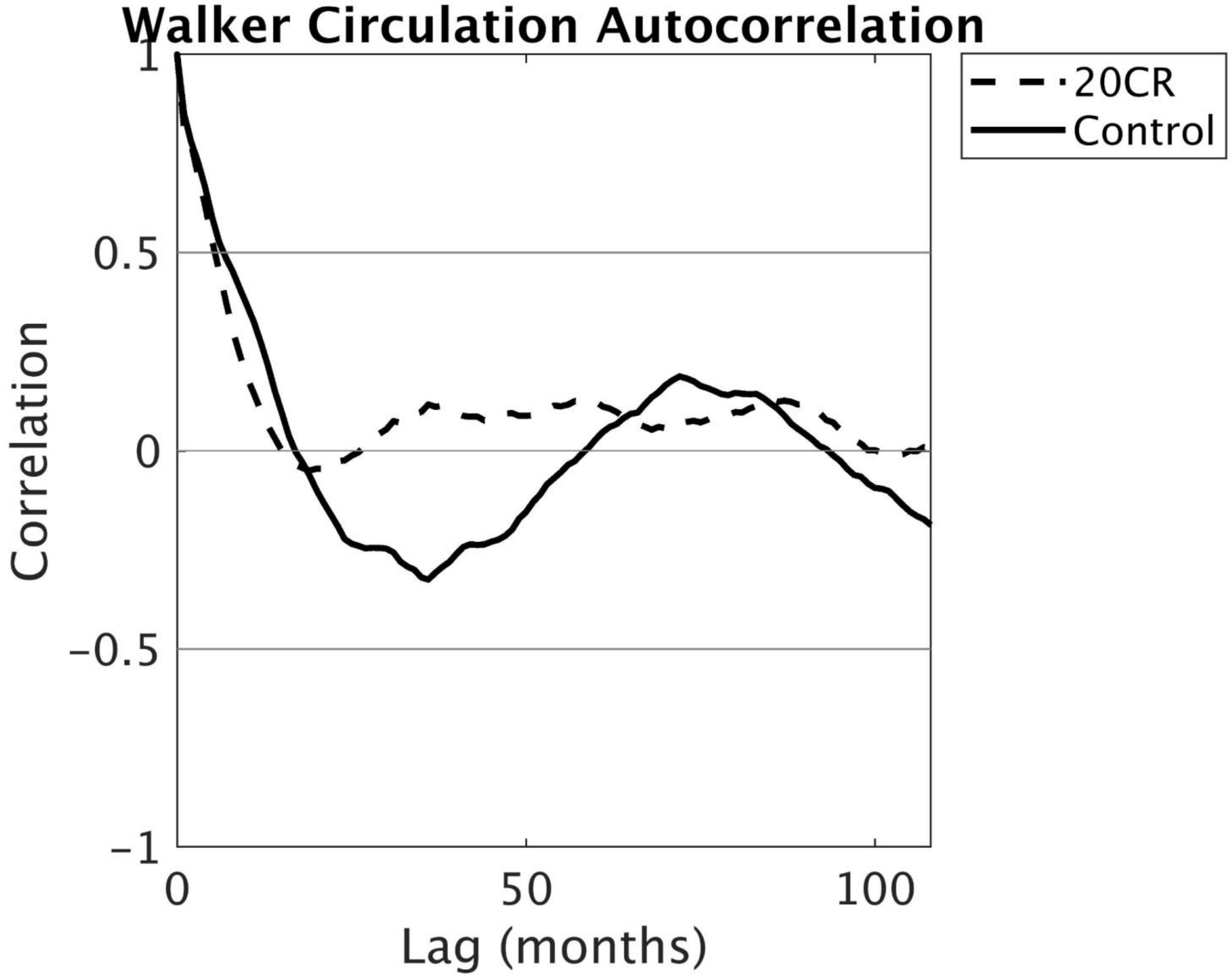


Multidecadal Walker Circulation in Control



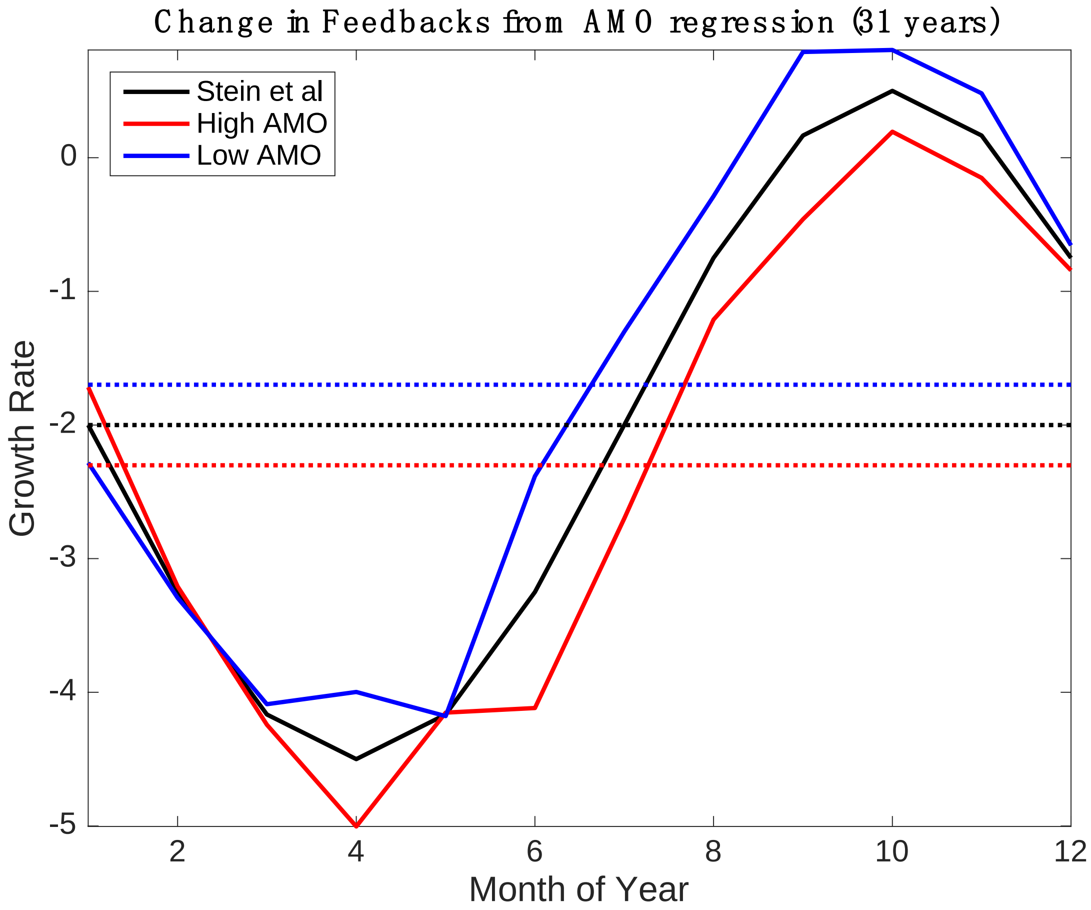
- Fraction of annual mean variability expressed at all multidecadal time periods significantly less in simulation than reanalysis
- Length of multidecadal period is more important in the model than in the reanalysis

Walker Circulation in Control Simulation



- Like Kociuba and Power, modelled ENSO is too periodic
- Clear minimum (r=-0.35) and secondary maximum (r=0.2)

Changes in ENSO Growth Rate



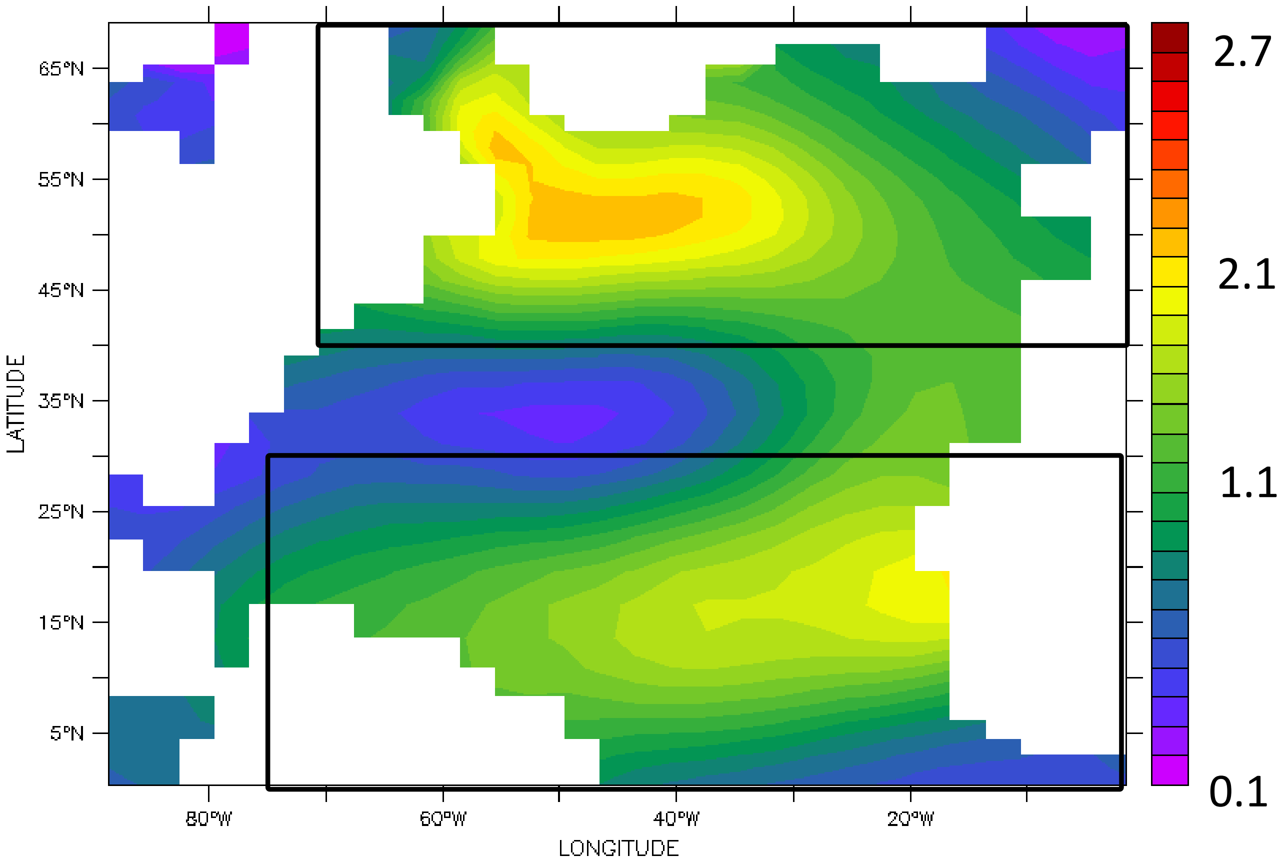
$\Delta\lambda_{AC}$=-0.2

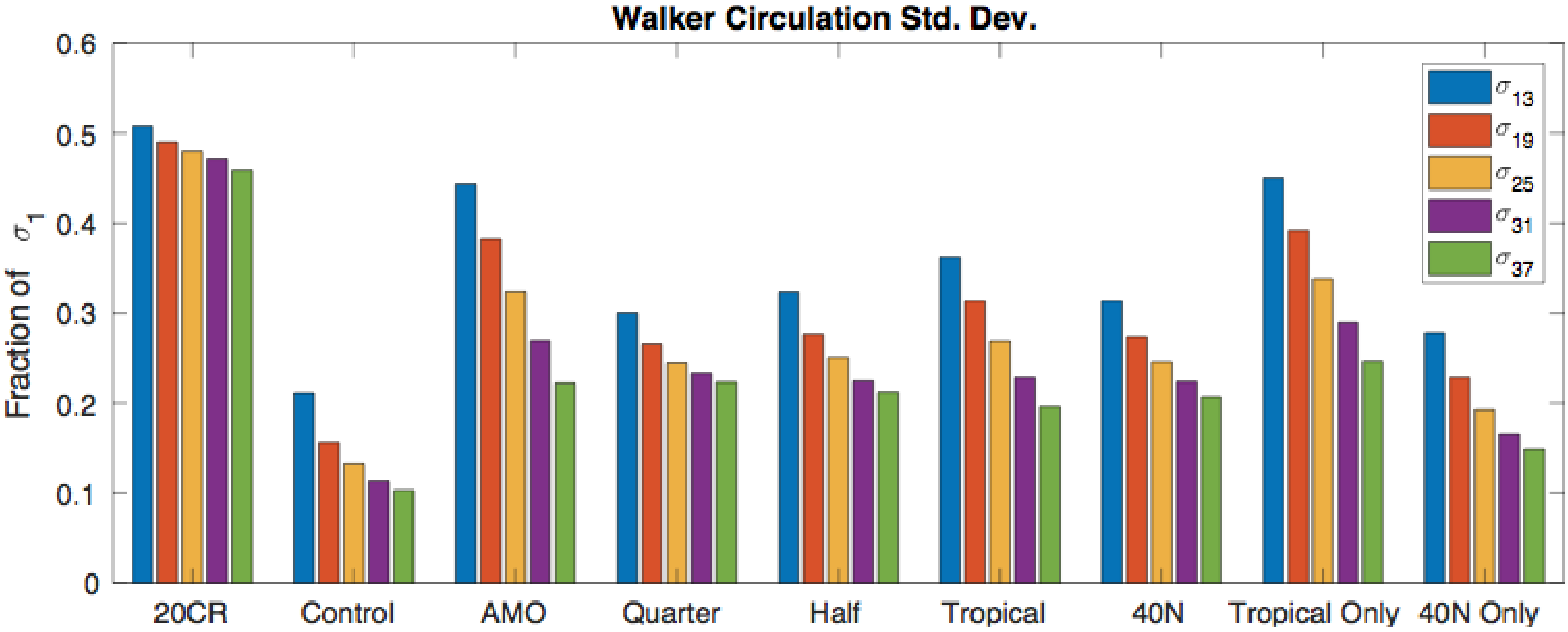
$\Delta\lambda_{am}$=0.6

- Either overall weakening on ENSO amplitude or stronger damping during boreal spring
  - Depends on phase of AMO
- BOTH should make ENSO less regular

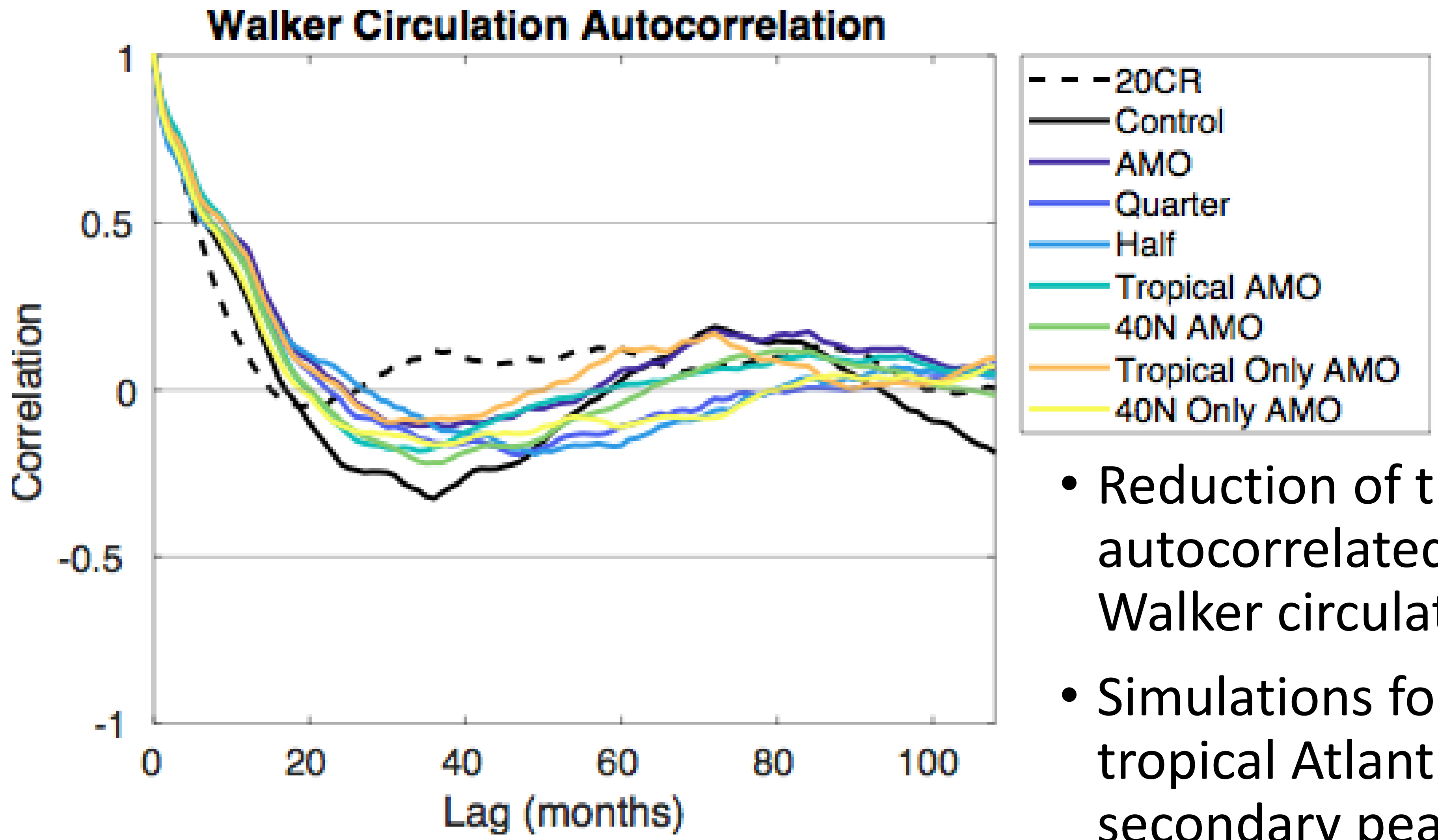
Coupled Model Experiment

- Coarse resolution CM2M
  - Atm. 3.5 x 3 with 24 levels
  - Ocean 3 degree (0.6 in tropics), 5 levels in upper 50 m
- AMO-forced experiments
  - AMO SSTs plus model seasonal cycle
  - 50-year AMO
  - Different Experiments
    - Whole AMO
      - Full SST amplitude
      - Half SST amplitude
      - Quarter SST amplitude
    - Sub Polar (40-70N box)
    - Tropical (0-30N box)

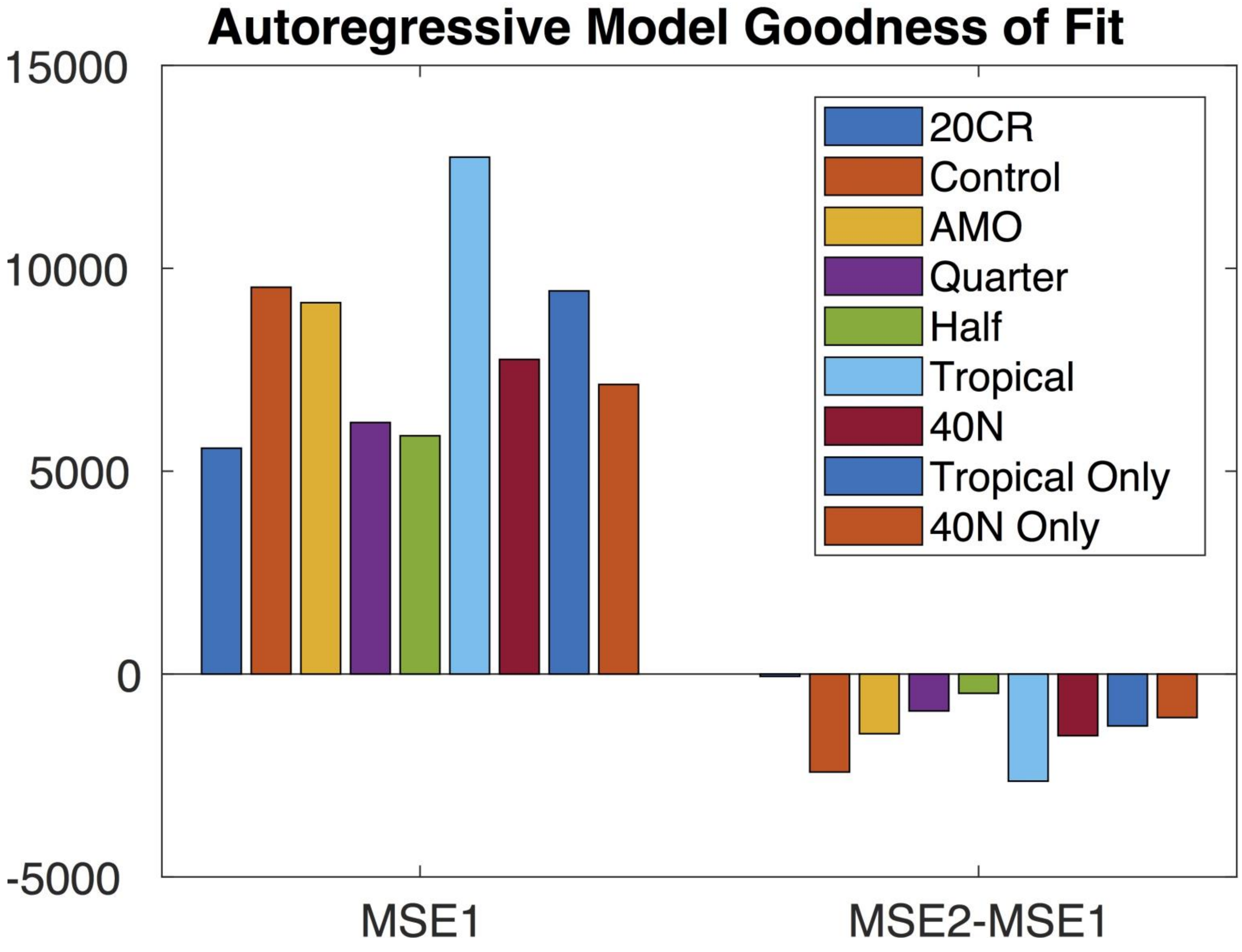




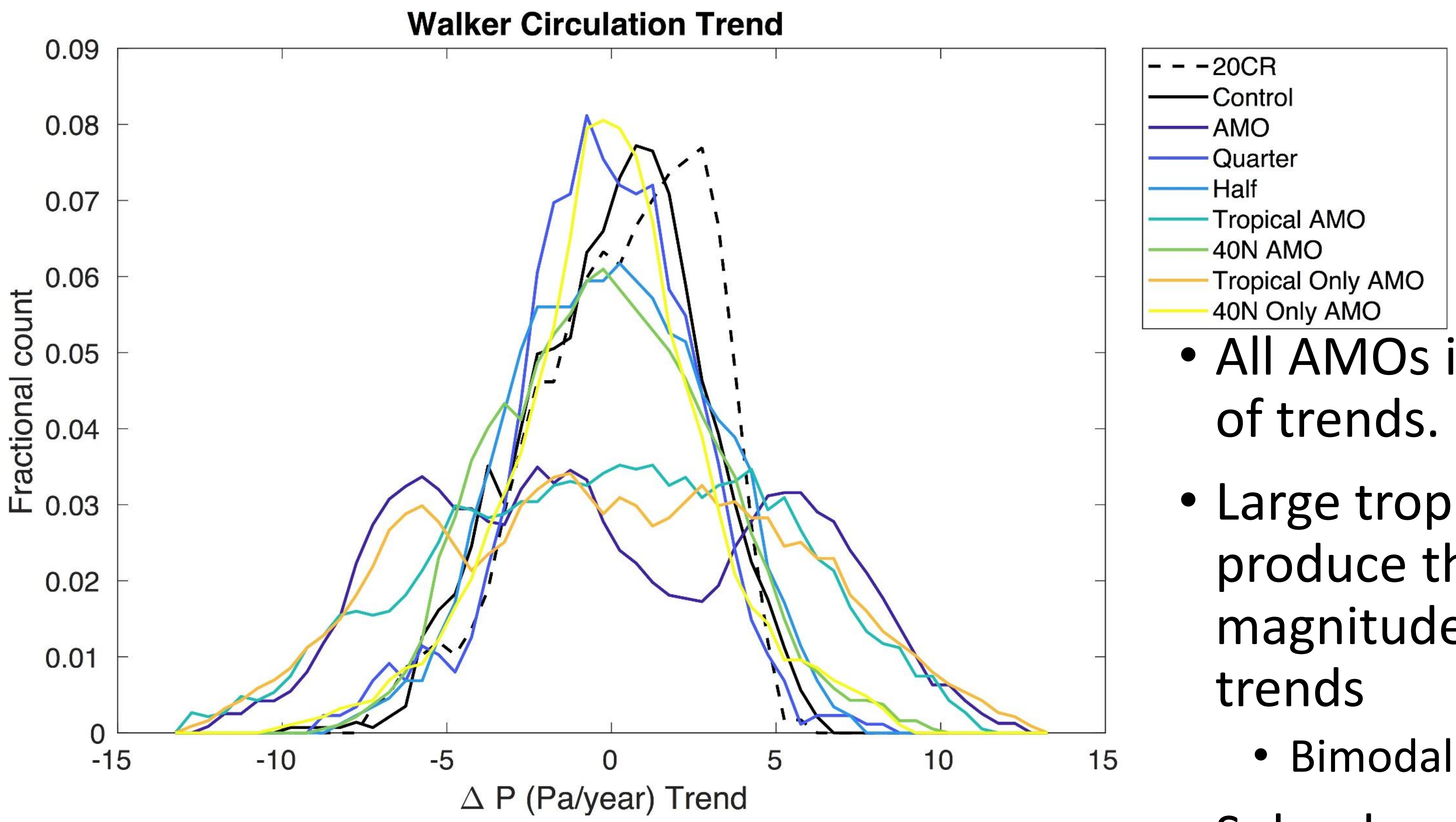
- Adding AMO increases tropical Pacific multidecadal variability at all timescales
- The tropical Atlantic forces larger changes than the extra-tropical Atlantic.
- Still timescale matters (red noise versus periodic Atlantic Multidecadal Variability)



- Reduction of the overall autocorrelated-ness of the Walker circulation
- Simulations forced with strong tropical Atlantic retain a secondary peak



- All AMO forced simulations still are AR2
- Improvement from control with all simulations
  - Particularly with reduced amplitude AMO



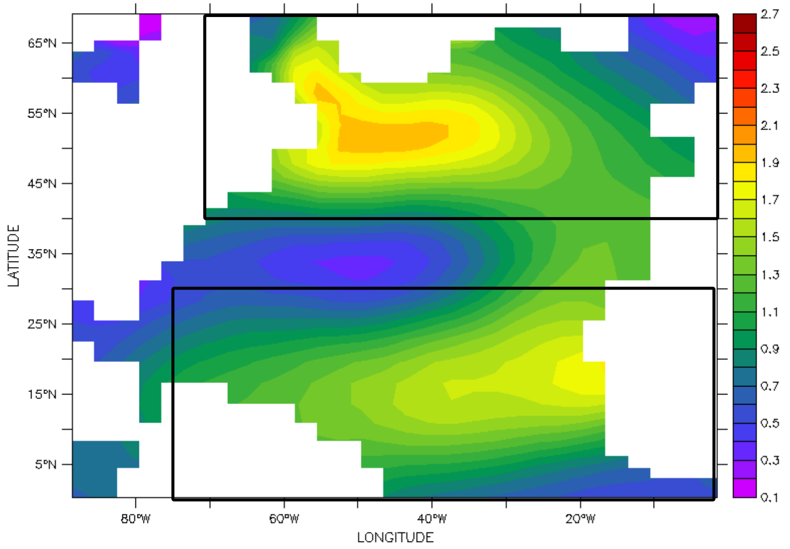
- All AMOs increase PDF width of trends.
- Large tropical forced AMOs produce the largest magnitude decadal WC trends
    - Bimodal distribution?
- Subpolar and reduced SST forced simulations expand trends and keep shape of trend PDF

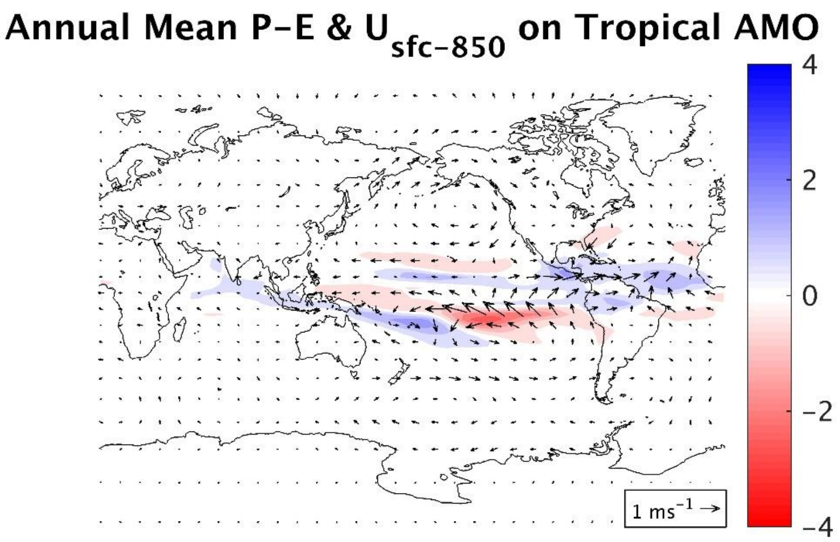
Conclusions

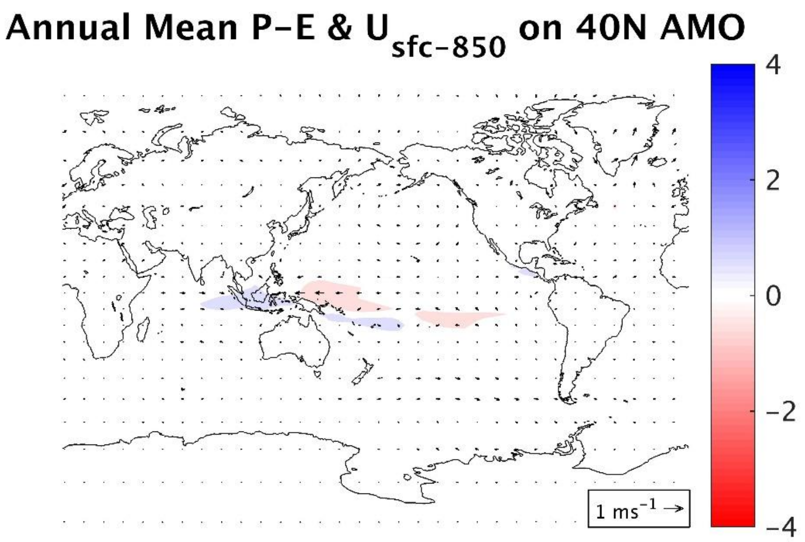
- AMO variability impacts tropical Pacific
  - Positive AMO increase in NH ITCZ precipitation
  - Decrease amplitude of ENSO and increase seasonal cycle
- Forced AMO variability decreases ENSO regularity
  - Increases variability for tropical decadal Pacific
  - Increases range of normal trends in multidecadal Walker circulation
    - Maybe the last 35 years are NOT that unusual

Extra Slides

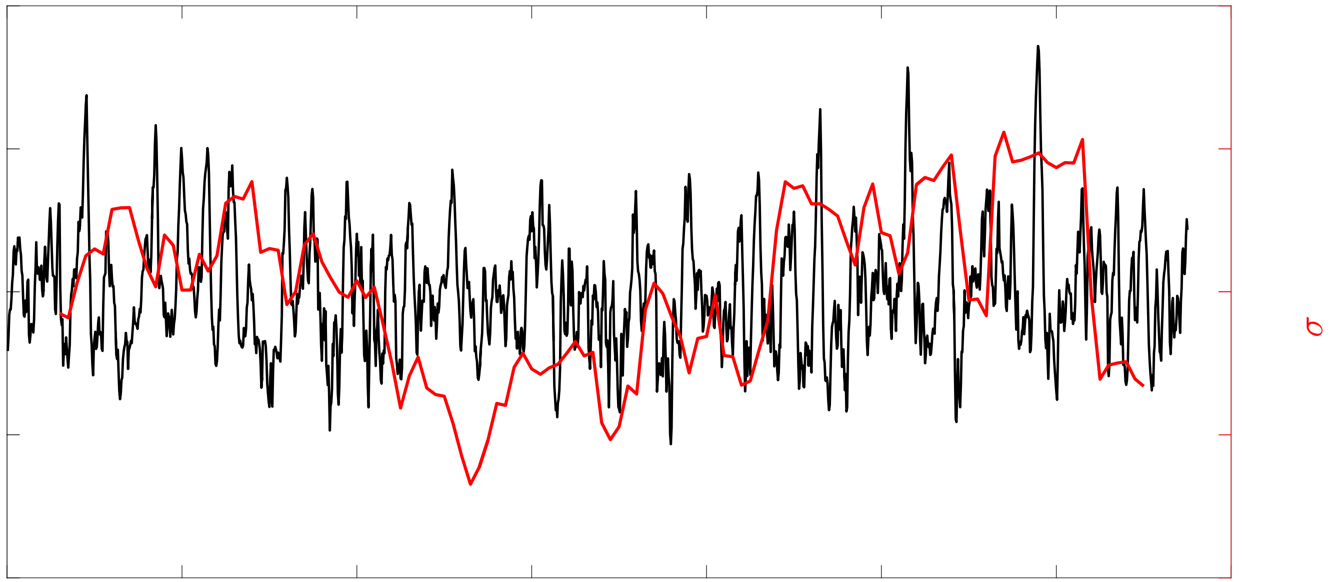
Regional Atlantic SST changes





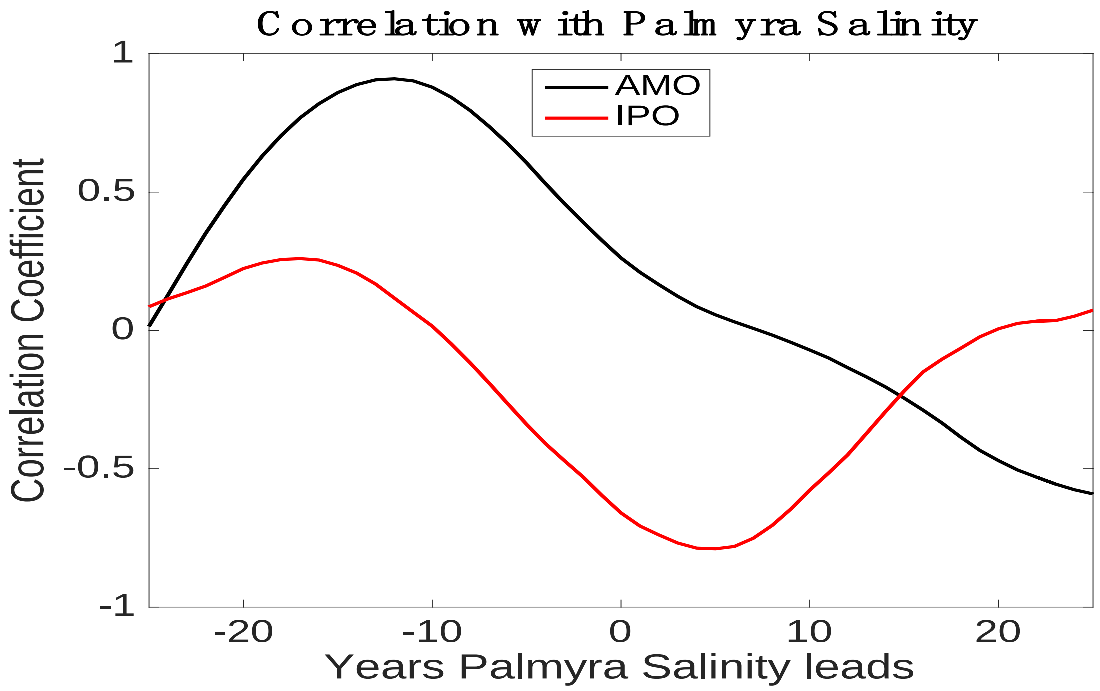


Multidecadal ENSO Variability



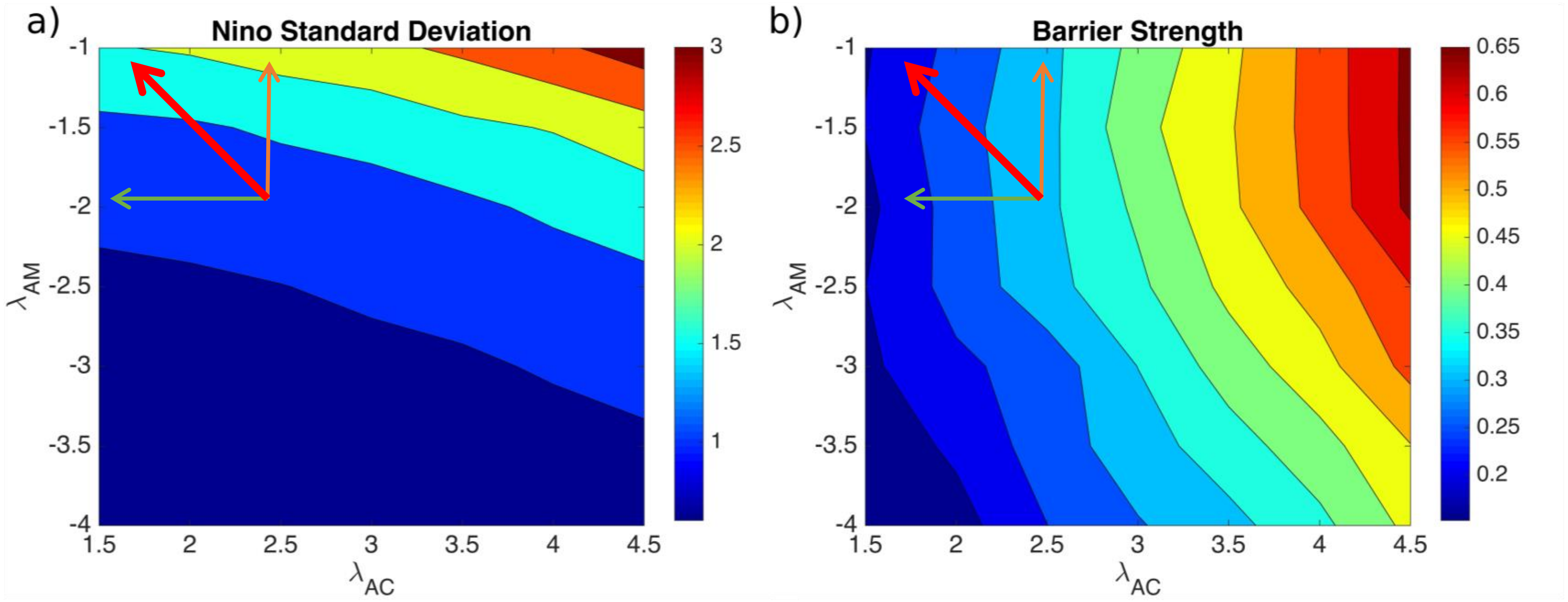
- 130 year reconstruction
- Periods of greater activity

AMO impacts on Salinity



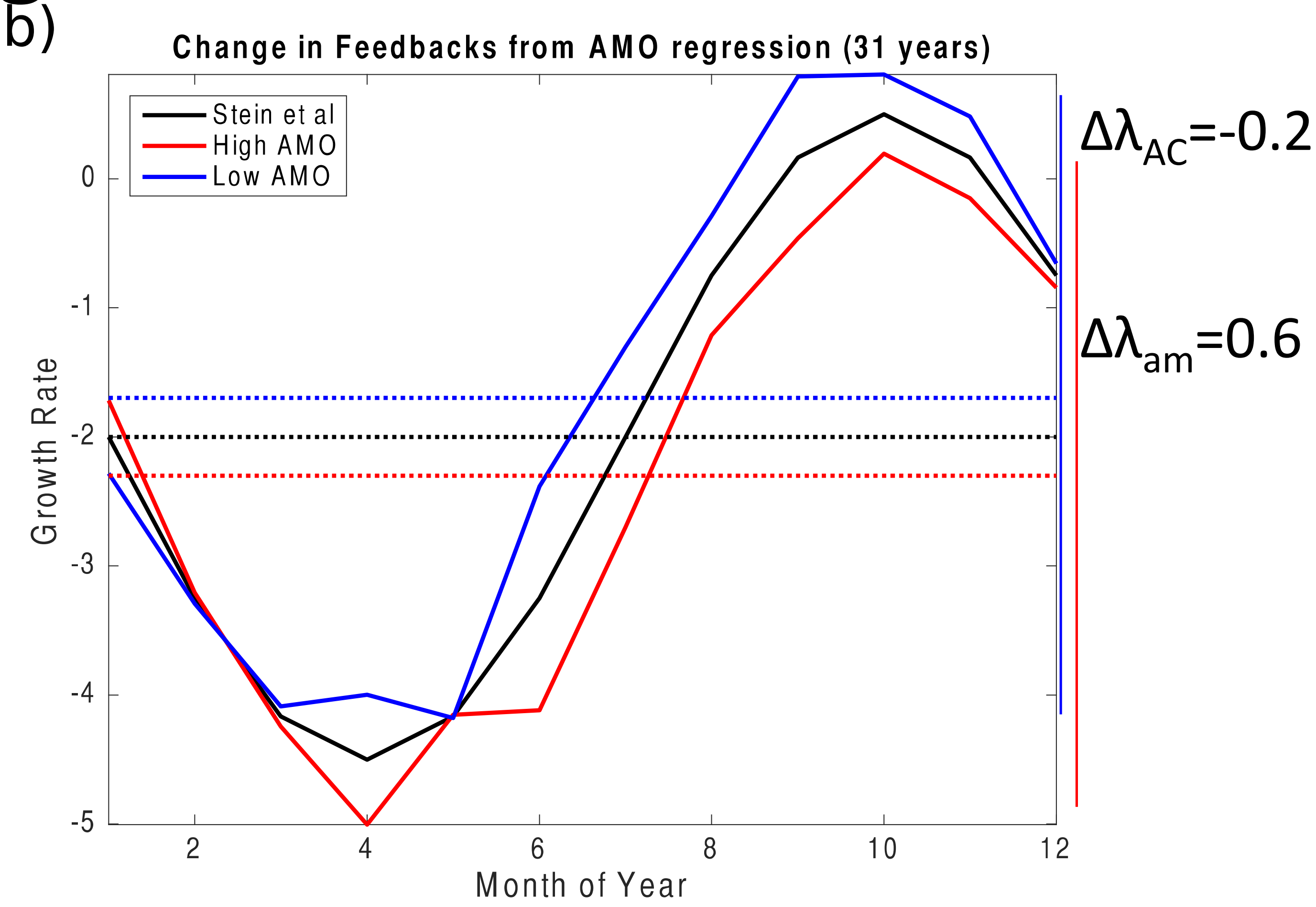
- Strong correlation with AMO leading by ~10 years
- IPO (or PDO) lags by ~5 years

Inverse Changes to Amplitude and Barrier Strength



- Decrease only λ_{AC}, decrease both variance and SPB
- Increase only λ_{am}, increase variance and SPB unchanged
- Instead need both to change together

Changes in ENSO Growth Rate



- Large seasonal changes in Damping from mean current, small in annual mean
- Annual cycle of growth rate and annual mean change fit what is expected from the conceptual model
  - Increased annual mean, decreased annual cycle
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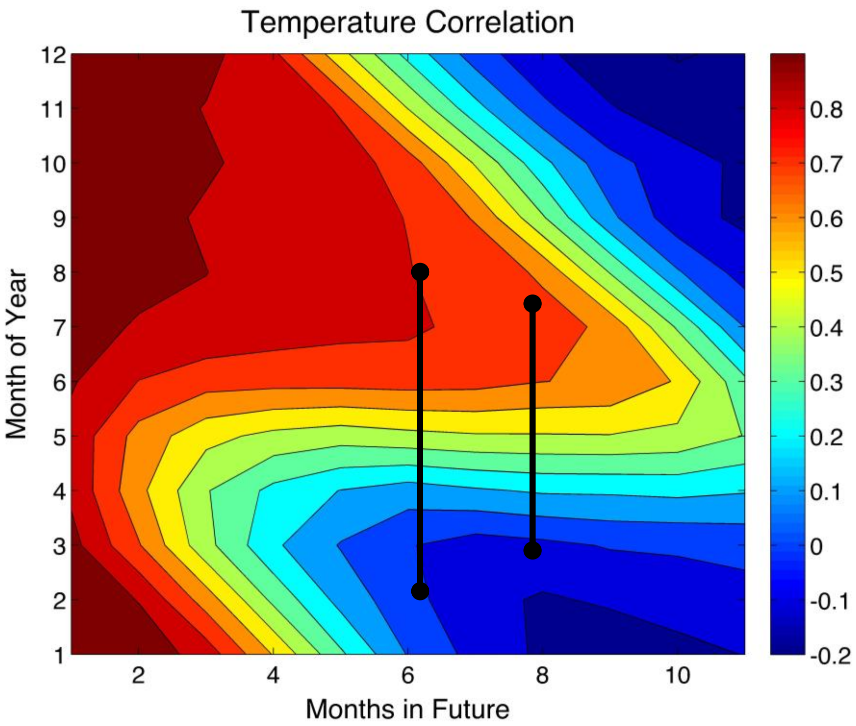
ENSO Annual Cycle



- ENSO standard deviation varies by month
- Peaks in boreal winter, minimum in boreal spring

- Find the maximum and minimum autocorrelation for all times t+τ
- Average the difference between maximum and minimum for τ from 1-12 months
- For example
  - τ=6, max from August r=0.85, min from February r=-.08, bstr=0.93
  - τ=8, max from August r=0.79, min from March r=-.16, bstr=0.95
  - From 1980-2014, value at 0.74
- Linear ENSO with an annual cycle in growth can recreate both properties (Stein et al 2010, Levine and McPhaden 2015)

Recharge Oscillator Model

$$\frac{dT}{dt} = -\lambda T + \omega h + \sigma \xi \qquad \lambda = \lambda_{am} + \lambda_{AC} \sin(\omega_{AC} t)$$

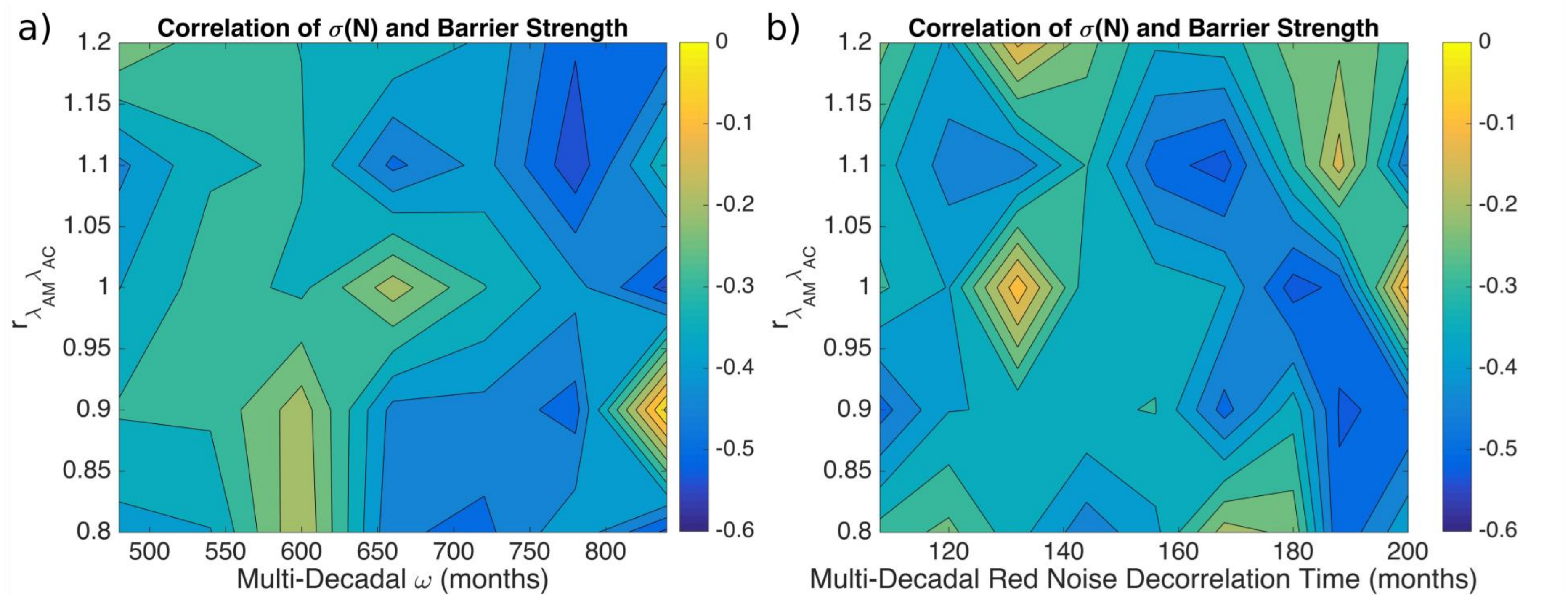
$$\frac{dh}{dt} = -\omega T \qquad \lambda_{am} = 2$$

$$\lambda_{AC} = 2.5$$

$$\frac{d\xi}{dt} = r\xi + w(t)$$

- Conceptual recharge oscillator model
- Captures basics of ENSO physics, heat content and temperature in quadrature
- Noise Forced
- With sinusoidal growth rate captures monthly variance and autocorrelation

Linked Growth Rates



$$\lambda = \lambda_{am} + \lambda_{AC}\sin(\omega_{AC} t)$$

$$\lambda_{AC} = \lambda_{AC0}\frac{\lambda_{am}}{\lambda_{am0}} r_{\lambda_{am}\lambda_{AC}}$$

$$\lambda_{am} = \lambda_{am0} + \Delta\lambda \sin(\omega_{D} t)$$