Tropical Pacific Sea Level Pressure Trends Indicate a Strengthening Walker Circulation

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Background

The Walker circulation is expected to weaken due to anthropogenic climate change

- according to vast majority of CMIP3/5 model experiments and a few observations

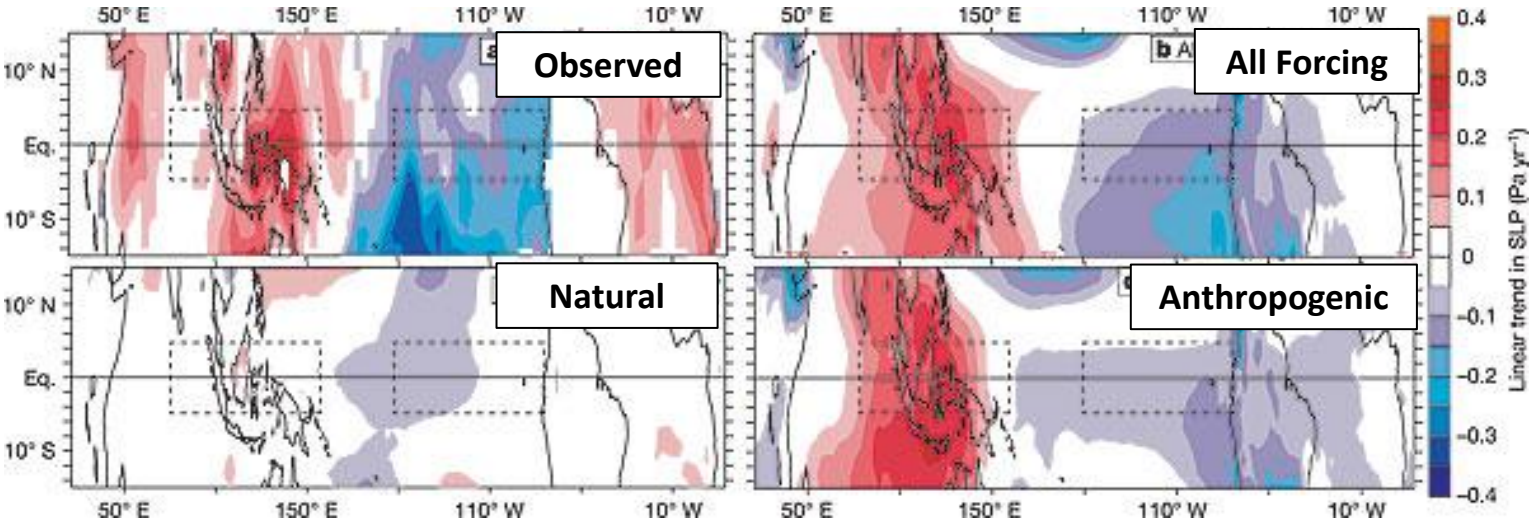


Figure from Vecchi et al. 2006

Physical basis:

- **P ≈ Mq**, where **P** is a precipitation increase of ~2-3%/K, and **q** is an increase in vapor of ~6-7%/K per Clausius Clapeyron, which means **M** (atmospheric mass flux) must slow to compensate.

- **Q = *w*σ**, where **Q** is radiative cooling increase of ~2-3%/K, and **σ** is a static stability increase of ~6-7%/K, which means ***w*** (vertical motion) must slow.

DiNezio et al., accepted; Vecchi and Soden, 2007; Vecchi et al., 2006; Held and Soden, 2006; Knutson and Manabe, 1995

Hints that the Walker circulation is strengthening?

Recent Research:

Sohn et al. (2012), Lyon and DeWitt (2012), Li and Ren (2012), Merrifield and Maltrud (2011), Zahn and Allan (2011), Sohn and Park (2010): Several variables (water vapor, low-level winds, SLP, convection, sea level) and datasets are examined that imply a strengthening of the Walker circulation; all are looking at periods after 1979

Durack et al. (2012), from 1950-2000, measurements of global salinity imply intensification of the water cycle of ~8%/K.

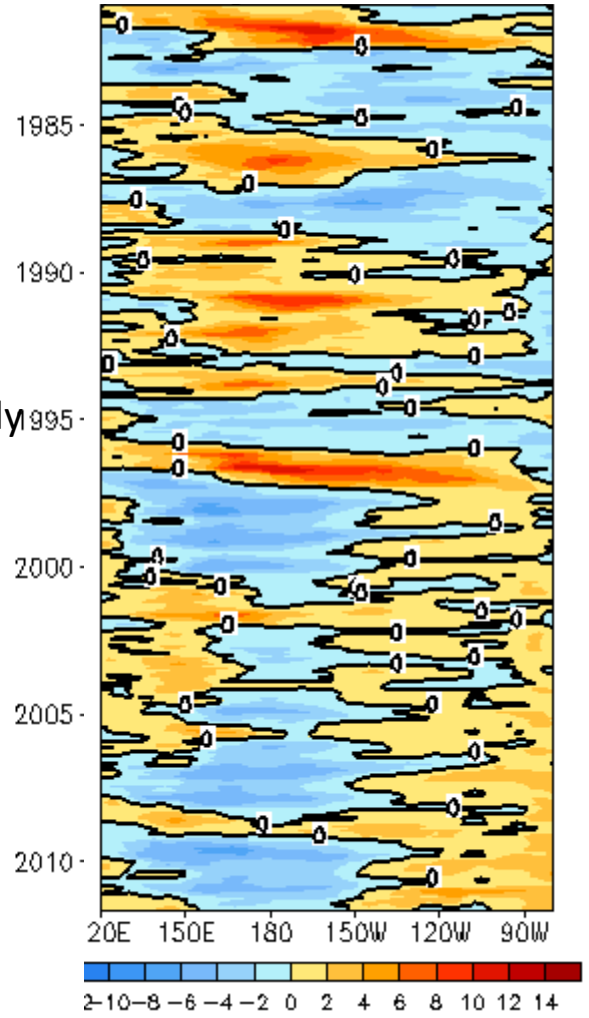
Wentz et al. (2007) from 1987-2006, satellite precipitation is much higher (on order of 7%/K increase) than models

Fu et al (2011) from 1979-2010, appears CMIP3 models exaggerate the increase in static stability

Motivation: Features in NOAA CPC Monitoring Products

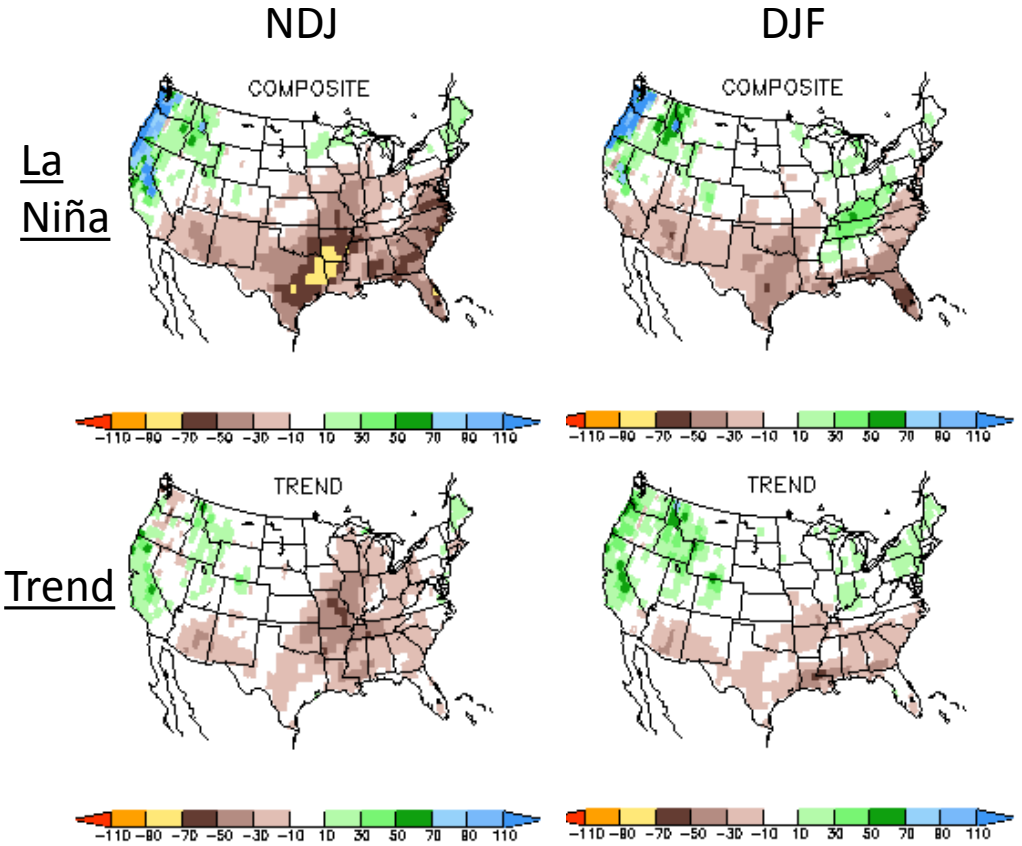
From the Ocean Briefing sequence page:

2S-2N 850-hPa zonal wind anomalies over the Equatorial Pacific (3mth running mean)



Increases in the central equatorial Pacific easterly trade winds (NCEP/NCAR Reanalysis

Optimal Climate Normal (OCN) or "The Trend" (15yrs) and similarity to La Niña



The Approach

- Use a relatively well observed variable with a long historical record across the tropical Pacific: **Sea Level Pressure (SLP)**

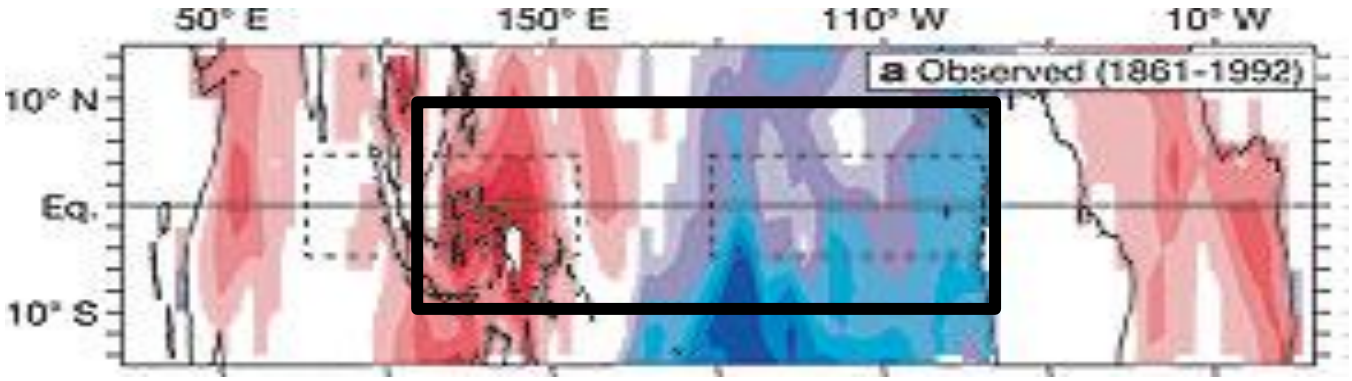
- Use multiple monthly averaged datasets that are available from 1900-2011:
  - 6 Reanalysis datasets (conventional + 20thC Reanalysis)
  - 3 Reconstructed datasets (statistical)
  - 1 in situ only dataset: ICOADS Release 2.5

- Examine linear trends over different length periods: 10-years, 20-years, 30-years, and 40-years

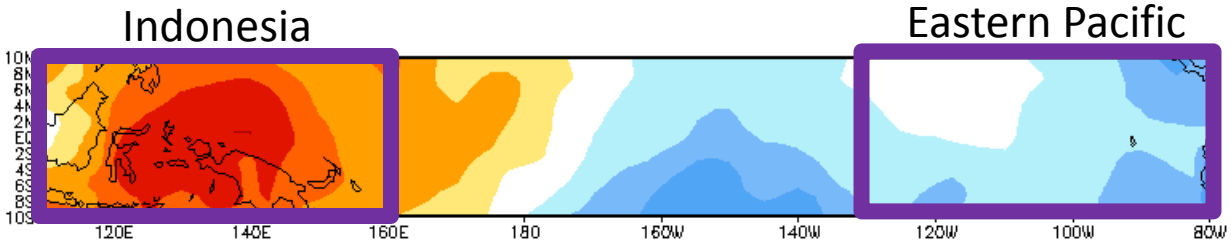
- To increase sample size and reduce sensitivity to end points, calculate running trends shifted by 6 months

Centennial Linear Trend in SLP data

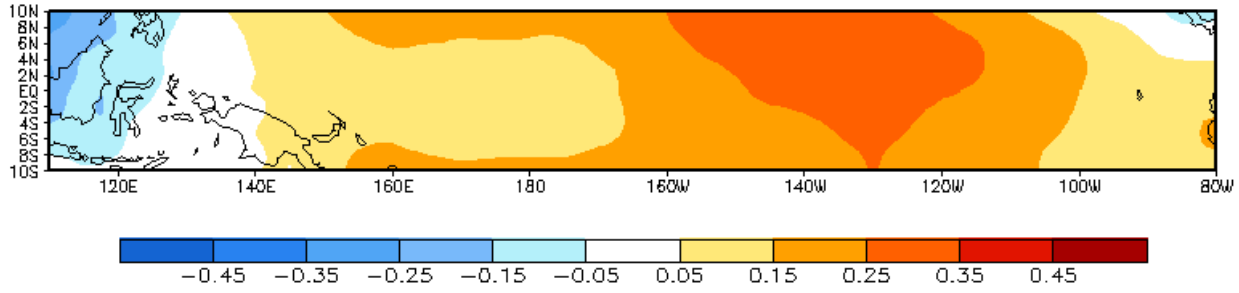
- Clear limitations in using a single linear fit through a monthly SLP dataset



Trend using Kaplan SLP from 1861-1992 (from Vecchi et al., 2006)



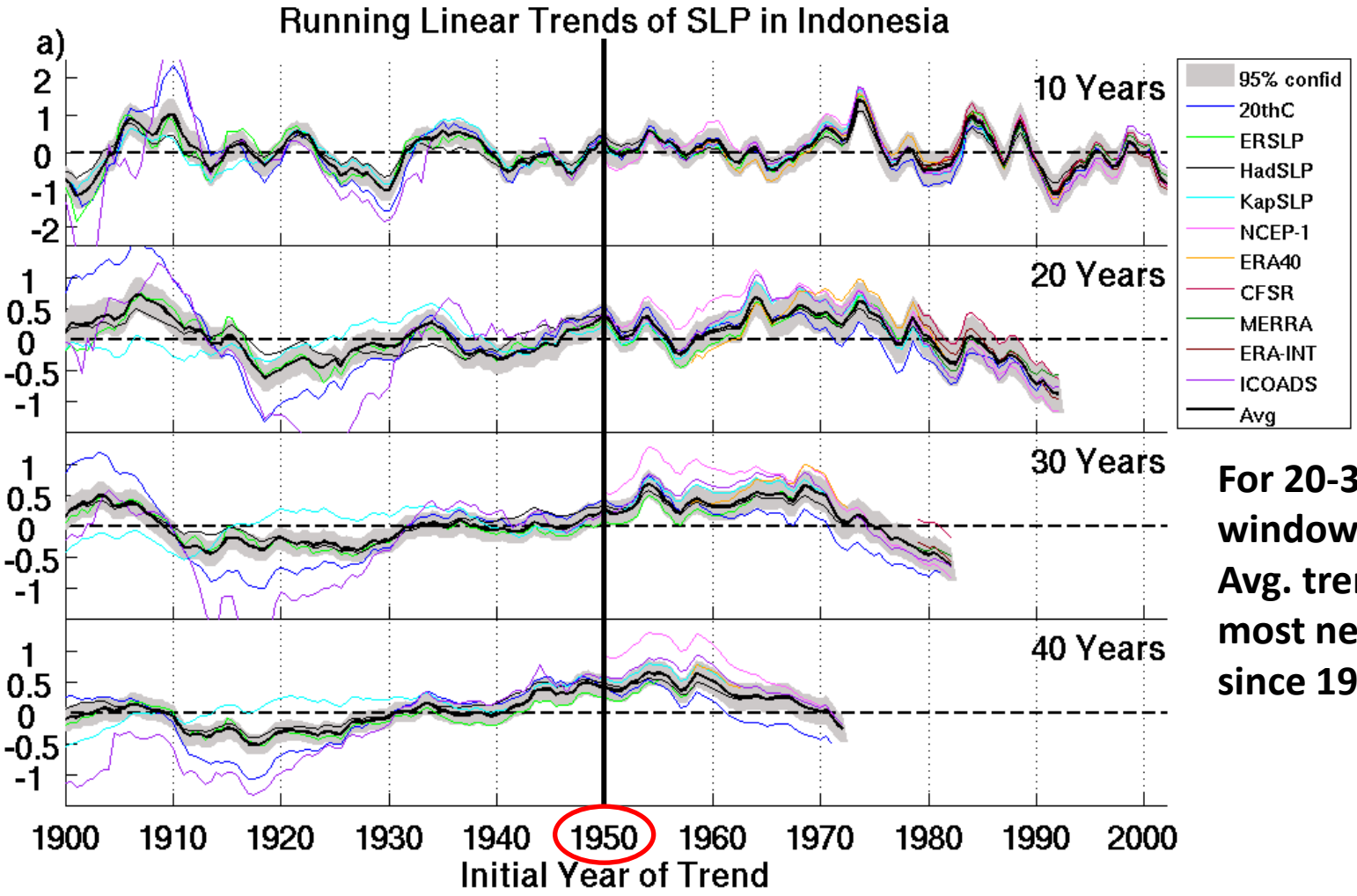
Trend using the avg. of KapSLP/ HadSLP from 1900-1992



Trend using the avg. of all available datasets 1900-2011

QUESTION: Do the observational-based SLP datasets over the tropical Indo-Pacific capture significant linear trends?

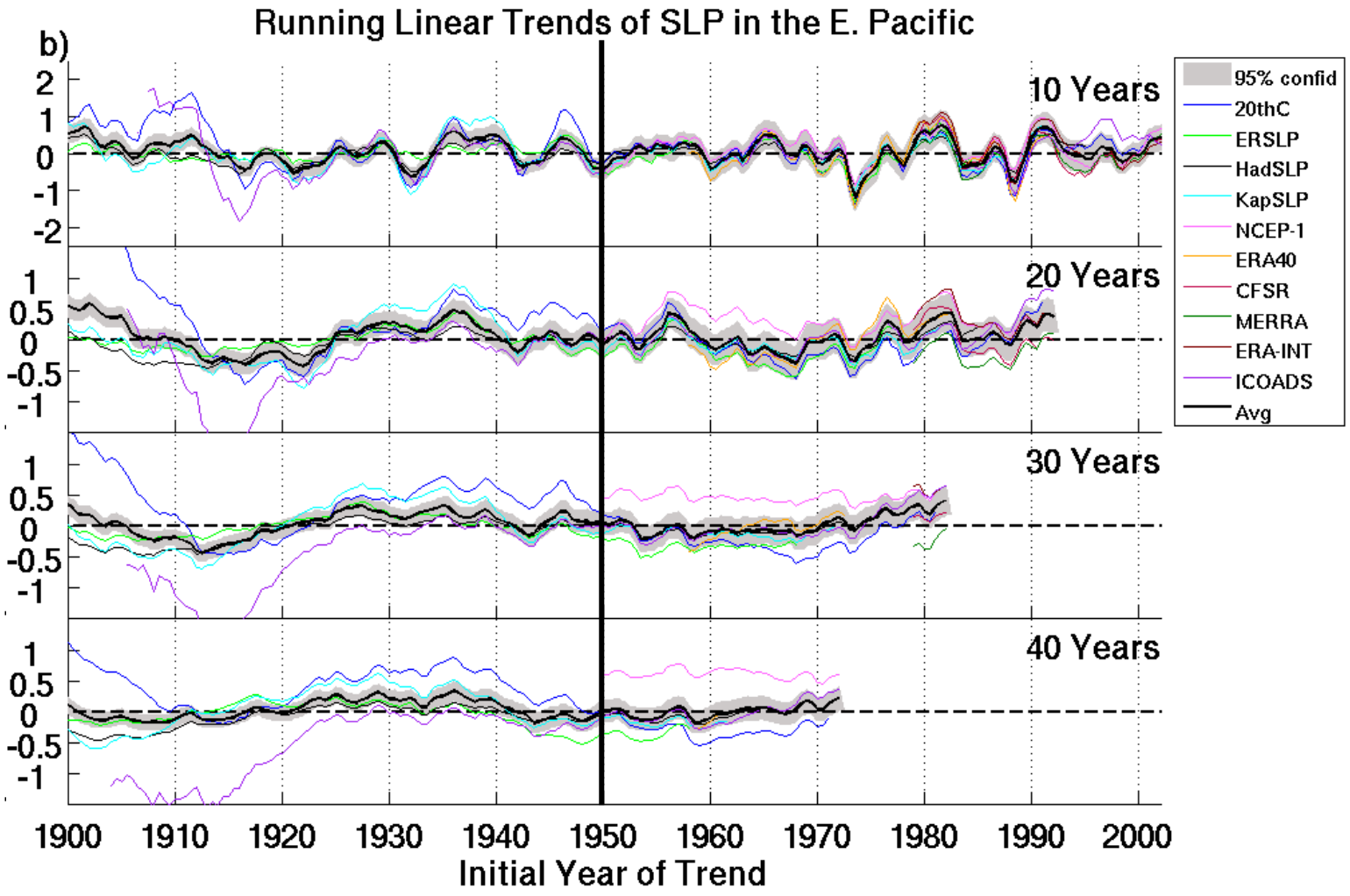
Running SLP trends over Indonesia



For 20-30 year windows, latest Avg. trend is most negative since 1900

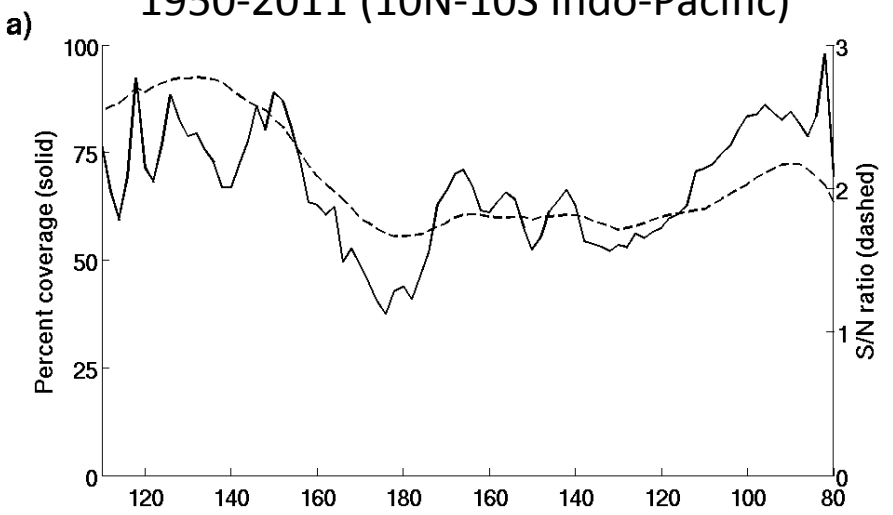
- **For 20-40 yr windows, a negative trajectory in running SLP trends starting in late 1950s (40yr trend) to mid 1970s (20yr trend)**

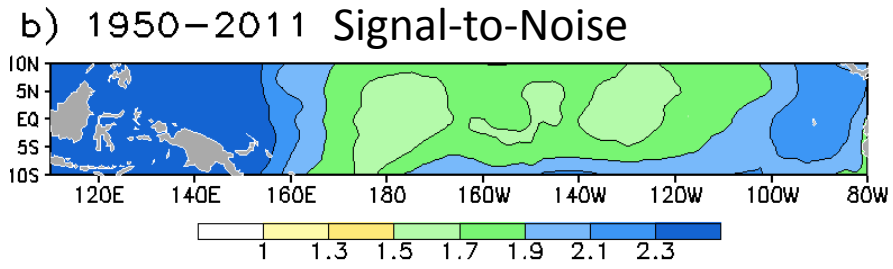
Running SLP trends in the Eastern Pacific

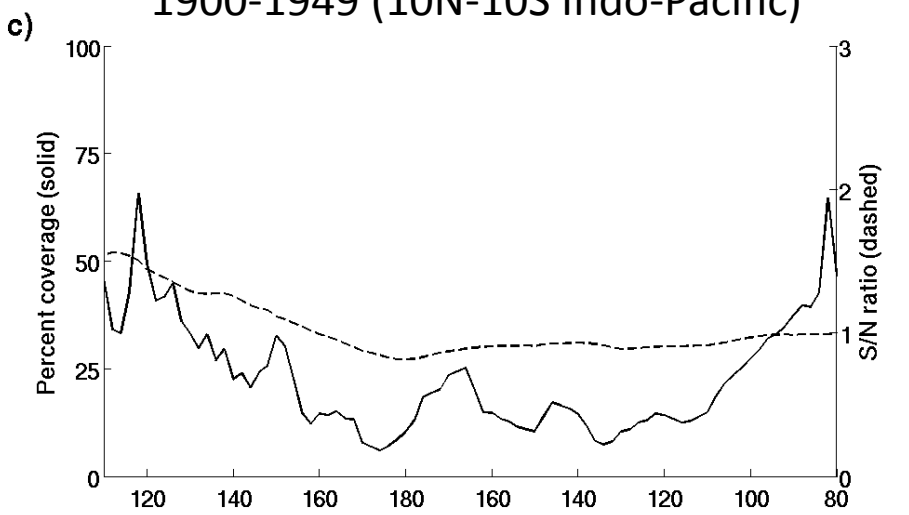


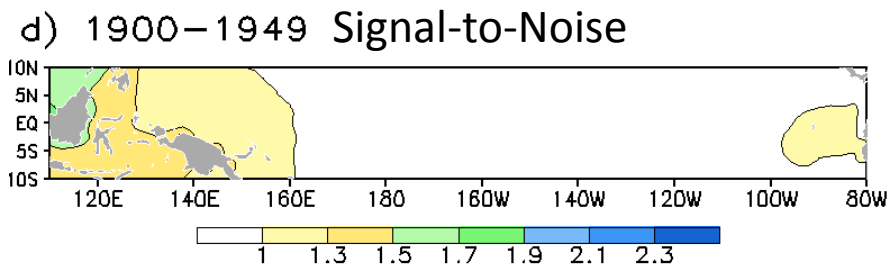
- **SLP trends are not as strong or significant compared to Indonesia, but appear roughly inverse in last half century (generally positive trajectory)**

Solid line: Percent ICOADS (in situ) Coverage and Dashed line: Signal-to-Noise of remaining datasets

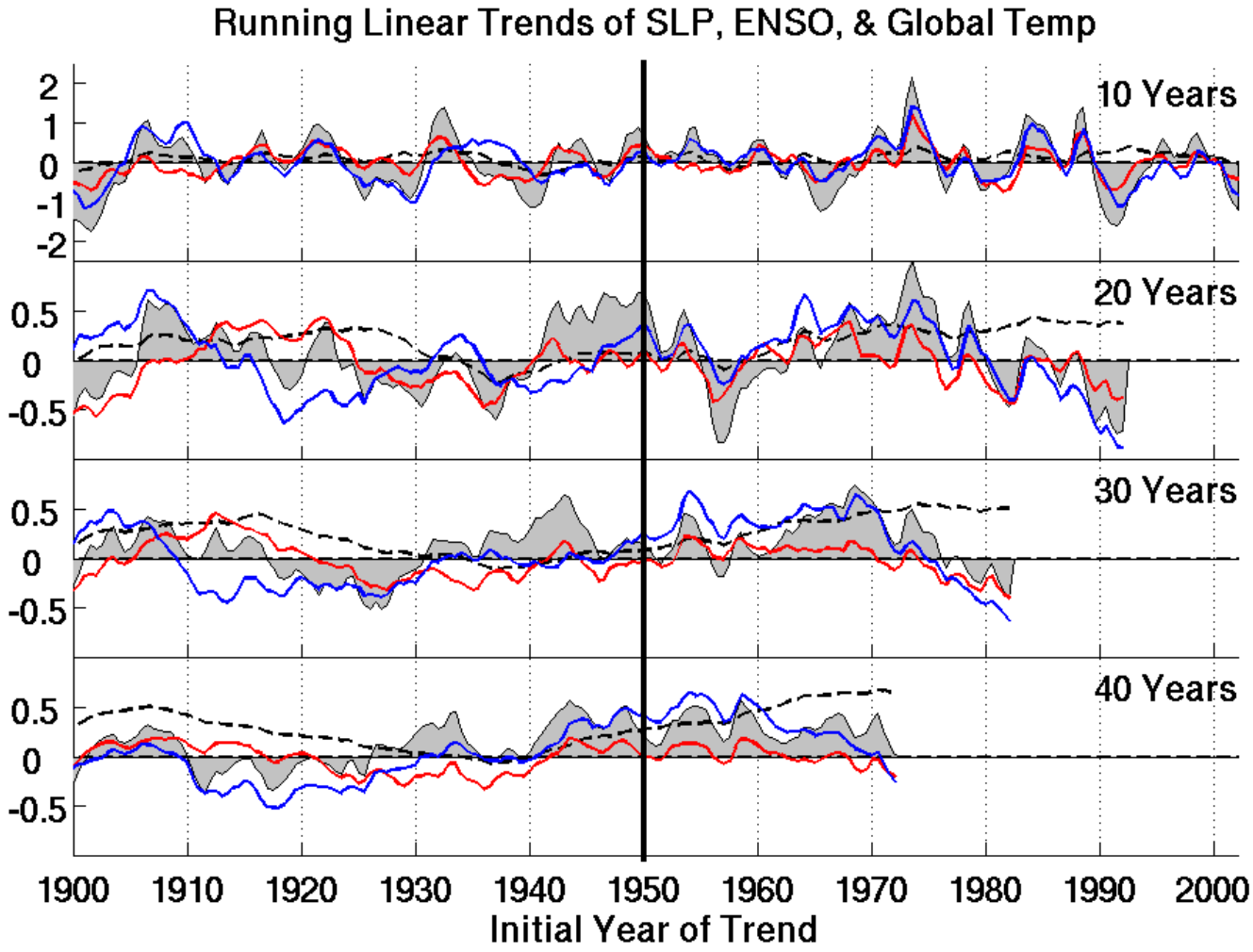








- **ICOADS (in situ only and component of other datasets) data coverage is lower where spread between remaining datasets is higher**

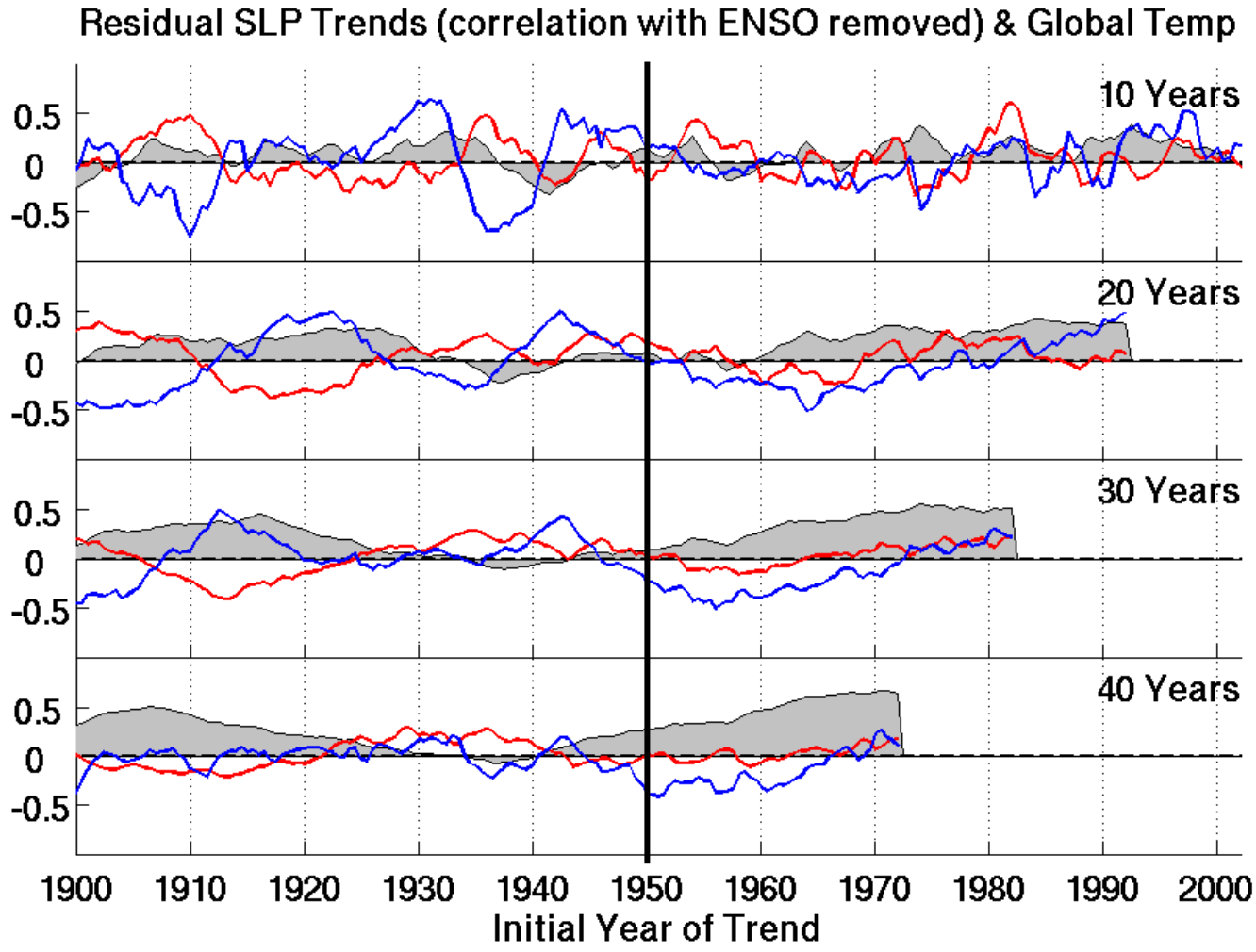


Gray Shading: Niño-3.4 SST index

Red: *inverted* or *flipped* East. Pac. SLP Index

Blue: Indonesia SLP Index

- **10-yr SLP trends strongly related to ENSO variability, whereas 20 to 40 yr trends indicate some divergence from ENSO**
- **Shift in behavior of Indonesia and E. Pacific SLP trends before/after 1950**



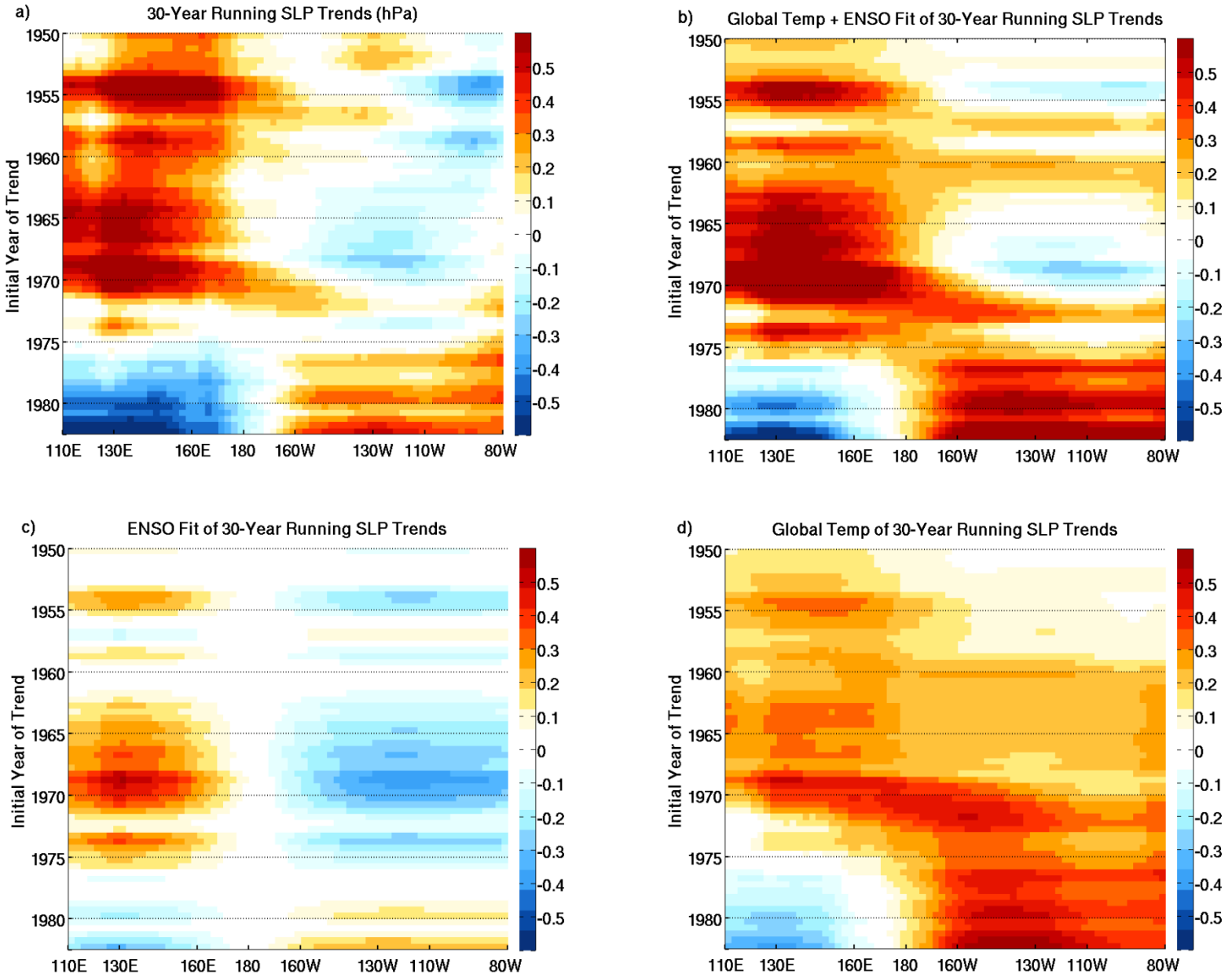
Gray Shading: Avg. Global Temperature

Red: East. Pac. SLP Index

Blue: *inverted* Indonesia SLP Index

- **After ENSO is linearly removed, 20-40 yr trends in the SLP indices indicate a tendency toward a stronger Walker Circulation, which nearly corresponds to the shift toward positive global temperatures**

30-Year Running SLP Trends (10S-10N) across the Indo-Pacific



Conclusions

- Infer that observed SLP trends indicate a strengthening Walker Circulation
- the reliability of trends are suspect prior to ~1950 due to low data coverage

- After ENSO-related trends are removed, the leftover residual suggests a nearly monotonic increase in the Walker Circulation starting in the late 1950s/early 1960s.

- This increase appears to mirror the shift toward positive trends in global mean temperatures.

Outstanding Scientific Issues:

-- Do these results imply the CMIP suite of models do not sufficiently capture the observed Walker circulation trends? [Rate of precipitation too low in models? Static stability too high?]

-- Could these findings be reflecting natural internal decadal and multi-decadal variability? [Anthropogenic forcing can't be clearly detected in obs.]

-- What are the related global impacts? [more La Niña-like?]