Characteristics of the QBO-Stratospheric Polar Vortex Connection on Multi-decadal Time Scales?

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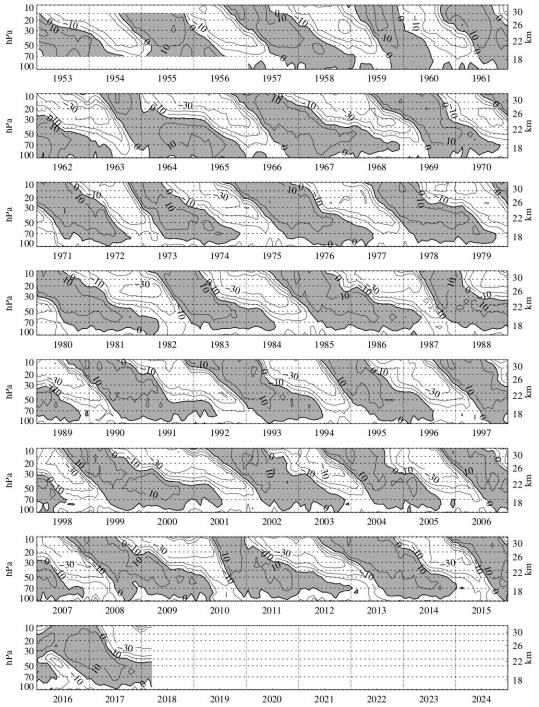
Tropical QBO is considered a potential atmospheric source of enhanced predictive skill of extratropical Northern Hemisphere circulation on subseasonal to interannual time scale due to:

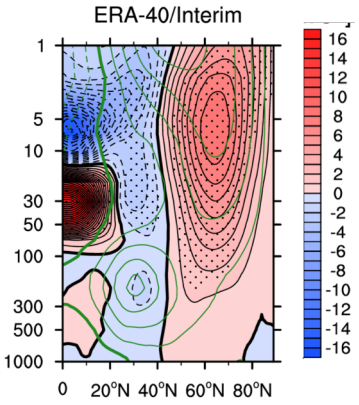
Its very large and quasi-regular interannual fluctuations



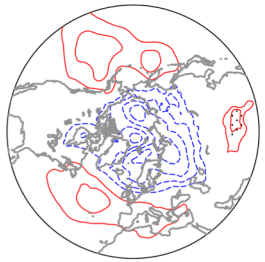
Its association with the extratropical circulation from the stratosphere to the surface

QBOw-QBOe

Zonal mean Zonal Wind [m/s]



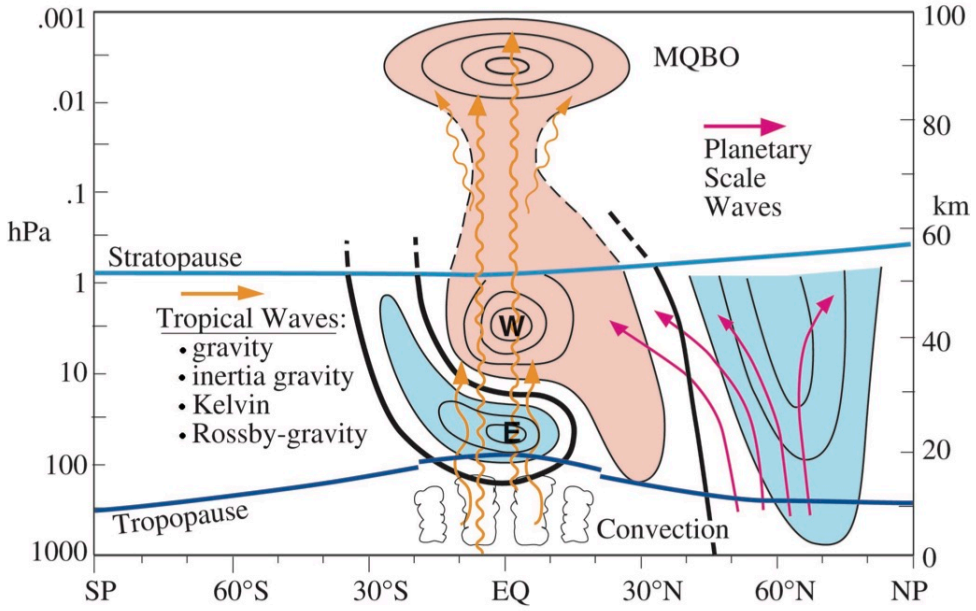
SLP [hPa]



Index: U 2S-2N at 30hPa (threshold |2.5|m/s)

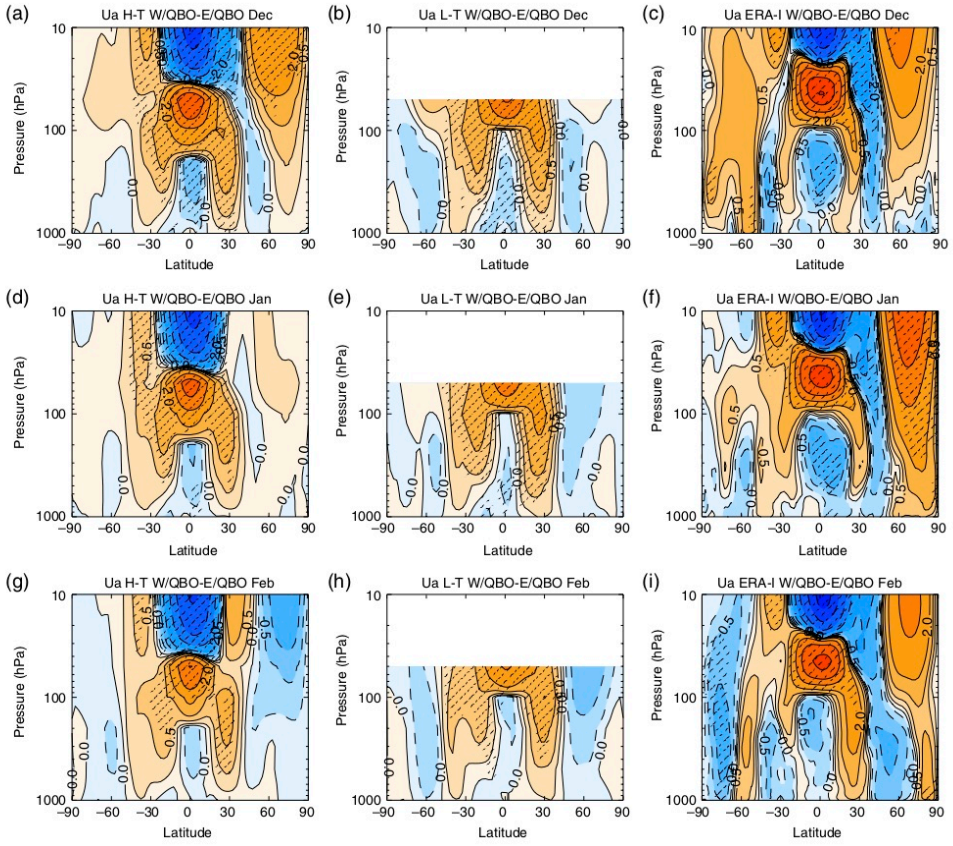
Quasi-biennial Oscillation-Stratospheric Polar Vortex Connection (Holton-Tan Effect)

- Indicates an impact of QBO on extratropical circulation
- QBO mainly driven by upward propagating tropospheric waves in the tropics and their interaction with the mean flow
- Modulates the position of subtropical zero-wind line with subsequent effects on upward wave propagation and stratospheric polar vortex conditions.



Motivation

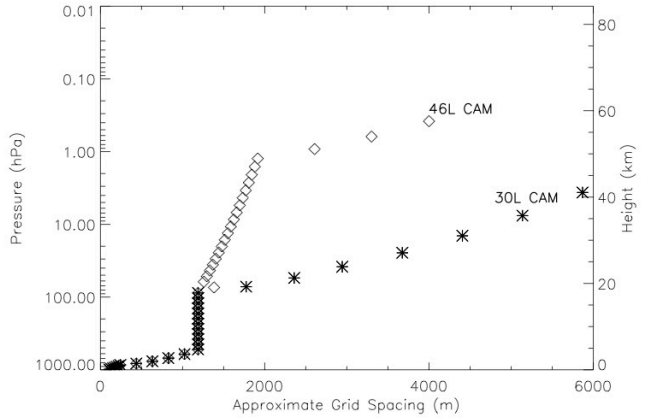
- Proper simulation of QBO-like behavior and its extratropical linkages in S2S forecast models is desirable
- Observed strength of H-T relationship important metric for model evaluation of global QBO - effects
- Models used for S2S prediction have difficulty simulating proper relationship (Butler et al.2016, Garfinkel et al. 2018)
- H-T relationship strongly varies on decadal time scale (weak in 1978-1997, compared to 1959-1976 and 1999-2011)

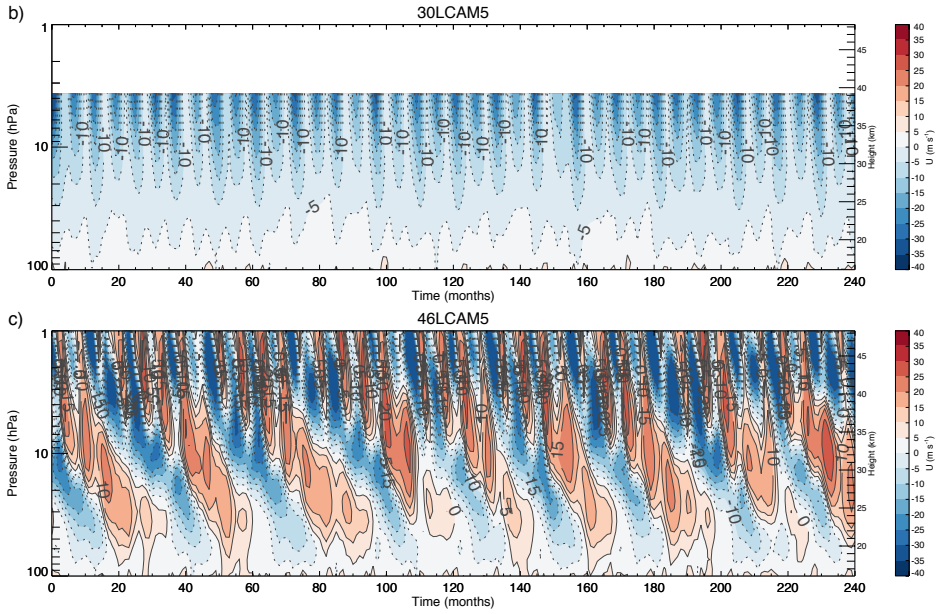


Butler et al. (2016)

What characterizes the strength of the QBO-Stratospheric Polar Vortex Connection on multi-decadal time scale?

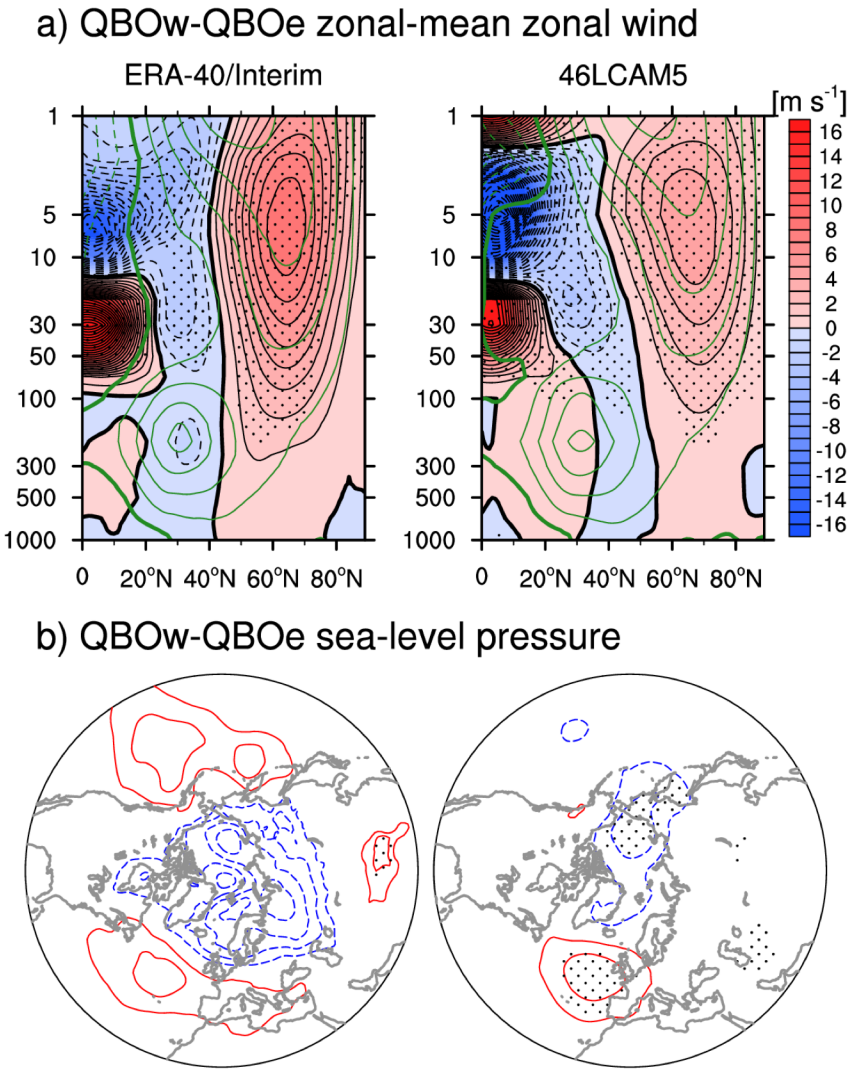
- Utilize a 10-member ensemble of historical climate model simulations 1957-2015 with 46LCAM5 (AMIP)
- Explore the robustness of the H-T relationship on multi-decadal time scale (~60 years)
- Identify possible causes for variations in the strength of the H-T relationship





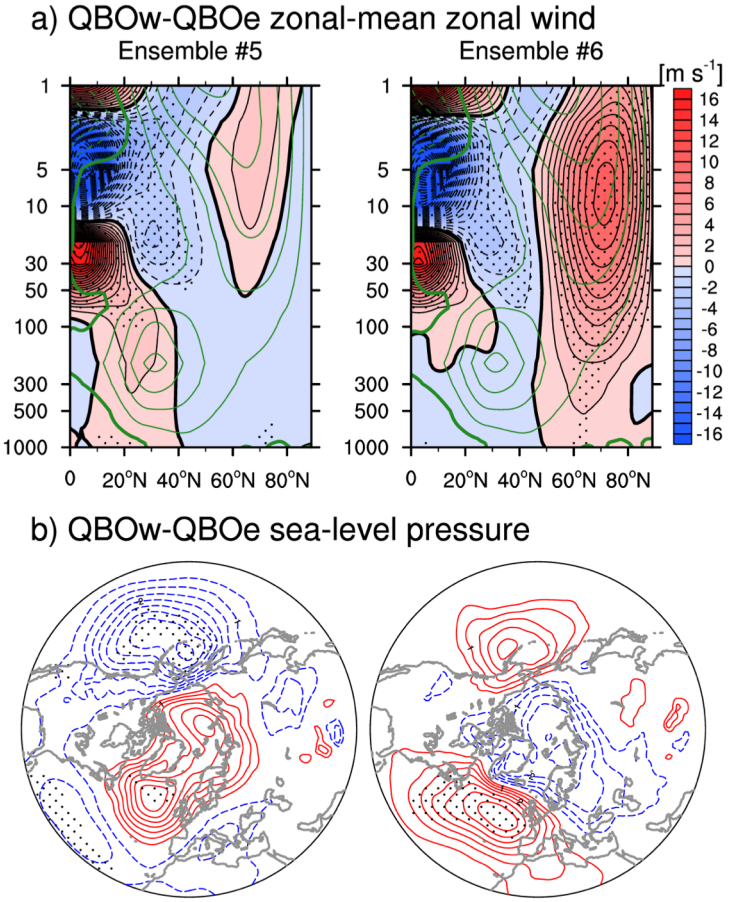
Comparison of H-T relationship between reanalysis and 46LCAM5

- Model average simulates features of the H-T relationship and tropospheric response but weaker

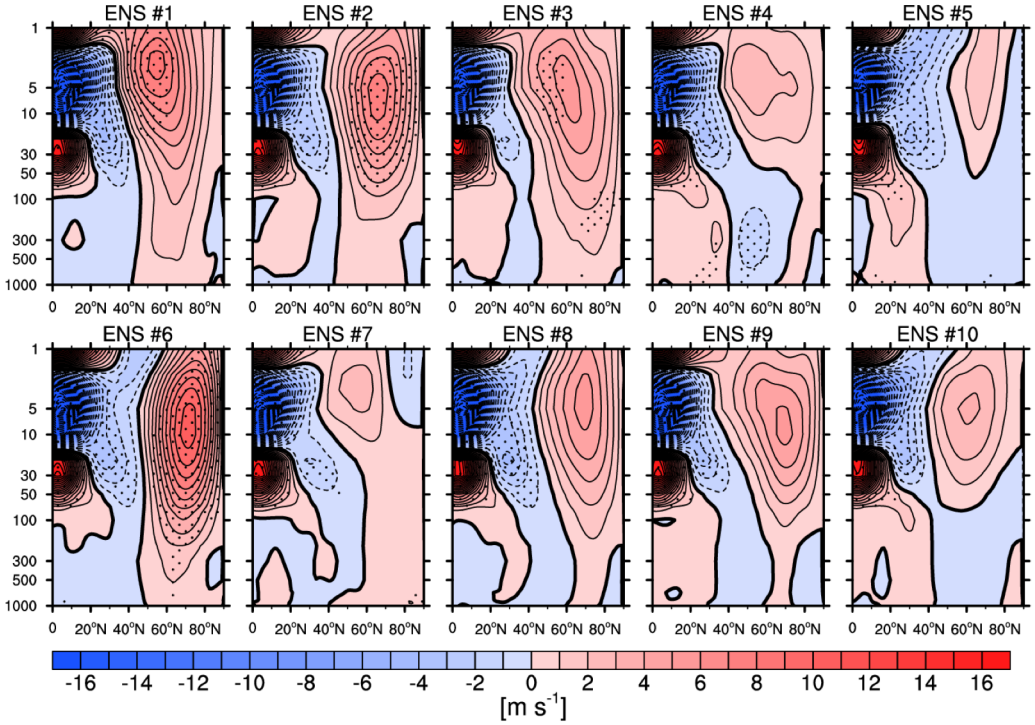


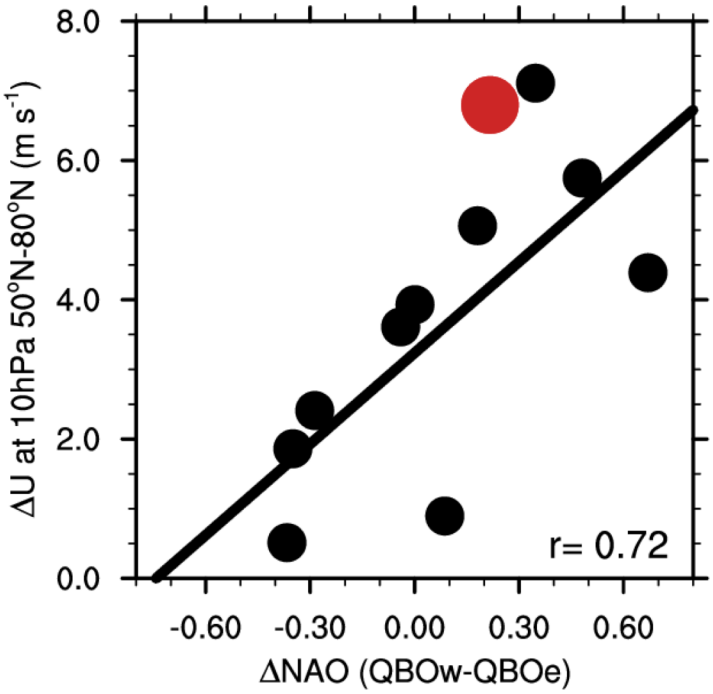
H-T relationship in individual model runs

- Strength of the H-T relationship can strongly vary based on 58-year periods in model
- Runs with strong and weak H-T relationship shows opposite effect in the troposphere
- Variation in strength of H-T relationship mainly an expression of internal atmospheric variability
  - is not due to sampling , ENSO conditions or solar cycle phase

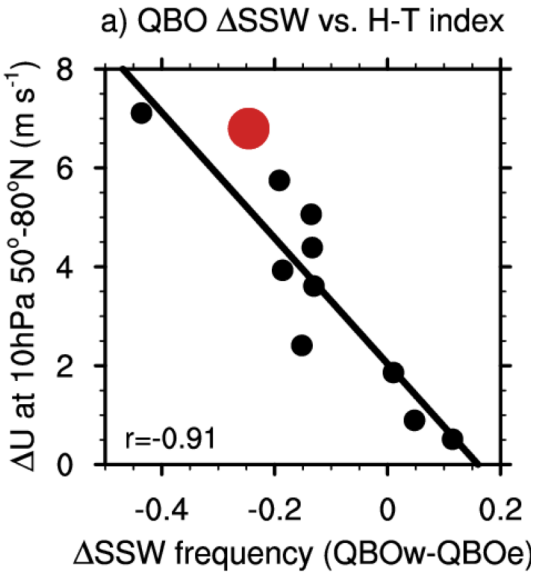


H-T relationship in individual model runs and linkage to North Atlantic Oscillation





Linkage between strength of H-T relationship and SSWs



- Strong correlation between index of H-T relationship and difference in SSW frequency between QBOw and QBOe
- Strong correlation results mainly from SSW frequency in QBOe
- SSW frequency in QBOw and index of H-T relationship are not significantly correlated

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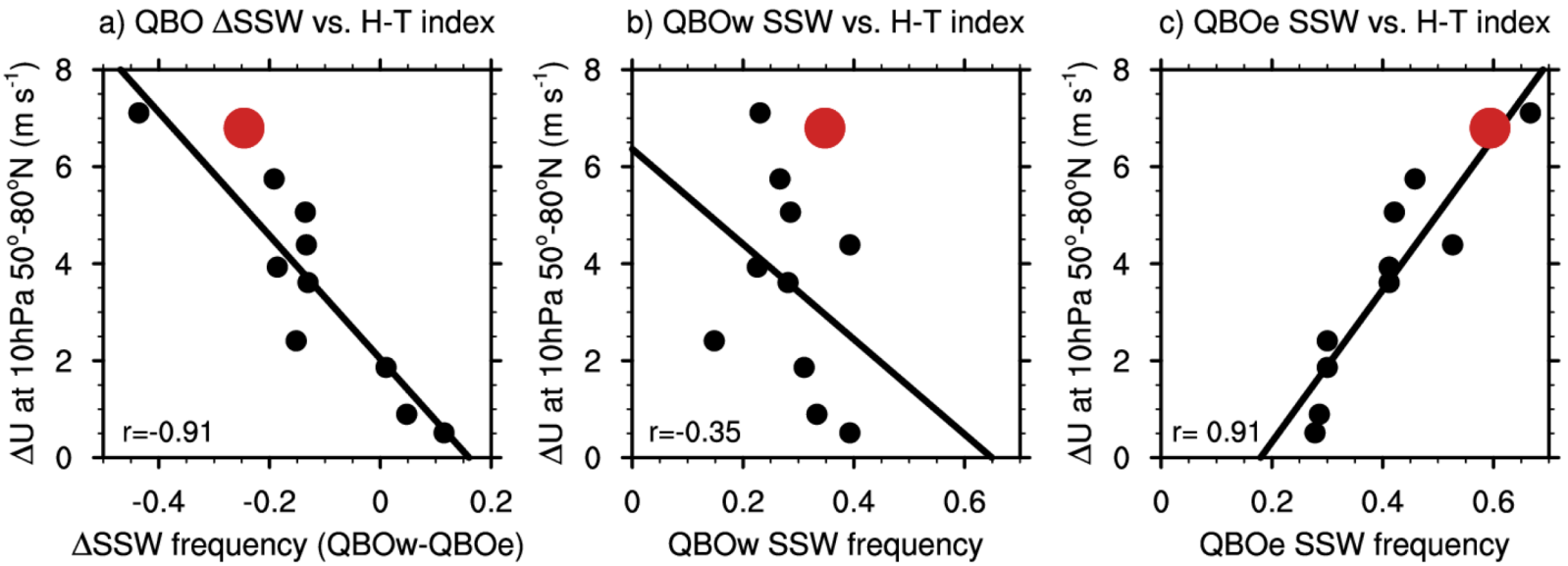

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- Strong correlation results mainly from SSW frequency in QBOe
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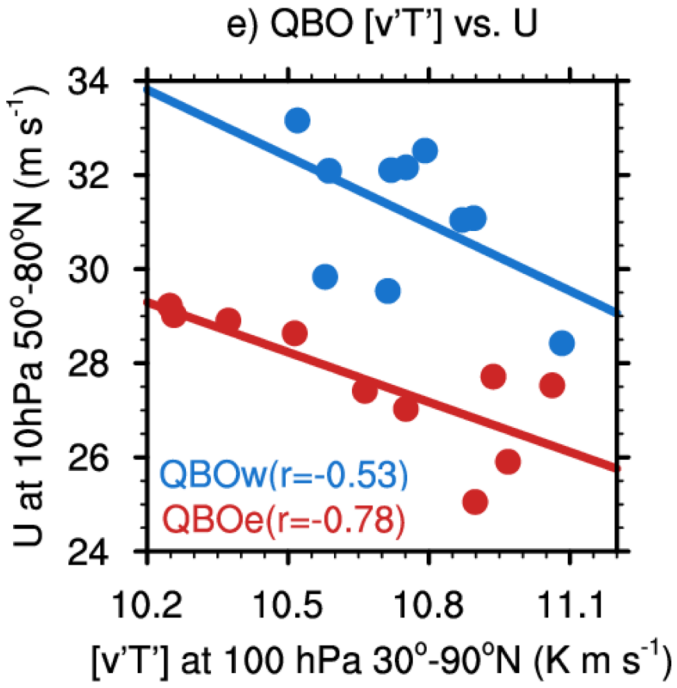
Linkage between tropospheric wave forcing and stratospheric vortex strength

- Similar tropospheric wave forcing affects more efficiently stratospheric polar vortex in QBOe than in QBOw due to different stratospheric basic state in relation to zero wind line location



What characterizes the strength of the QBO-Stratospheric Polar Vortex Connection on multi-decadal timescales?

- Model ensemble simulations suggest that there is substantial variability in this connection on ~60-year timescales mainly due to internal atmospheric variability.
- The strength of this connection is strongly related to the frequency of occurrence of major stratospheric sudden warming during QBO east phase.
- Results are consistent with our understanding on the role of QBO's modulation of zero wind line location and resulting effects
  - similar tropospheric wave forcing affects more efficiently stratospheric polar vortex in QBOe than in QBOw
  - enhances the probability of SSW occurrences in QBOe via the accumulated effect of wave forcing on the stratospheric circulation

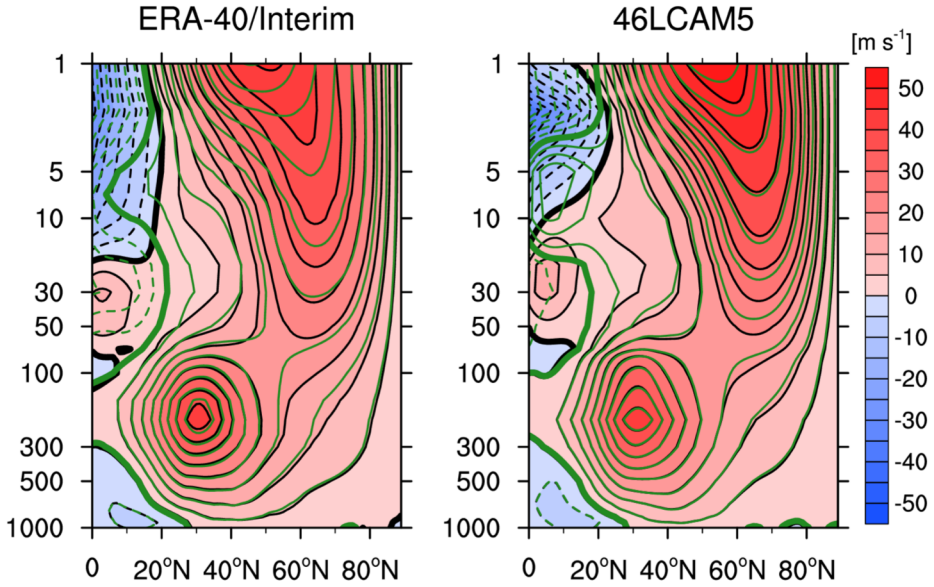
Implications

- A metric of the strength of the H-T relationship determined based on a ~60-year reanalysis record still inherits large uncertainties due to a potentially large role of internal atmospheric variability.
- Model evaluation of the strength of the H-T relationship should be combined with other metrics that diagnose sudden warming frequency and tropospheric wave forcing.
- The strong QBO-tropospheric NAO relationship and thus the QBO's role as source of predictive skill on subseasonal to interannual time scale identified in reanalysis may not be robust.

Backup slides

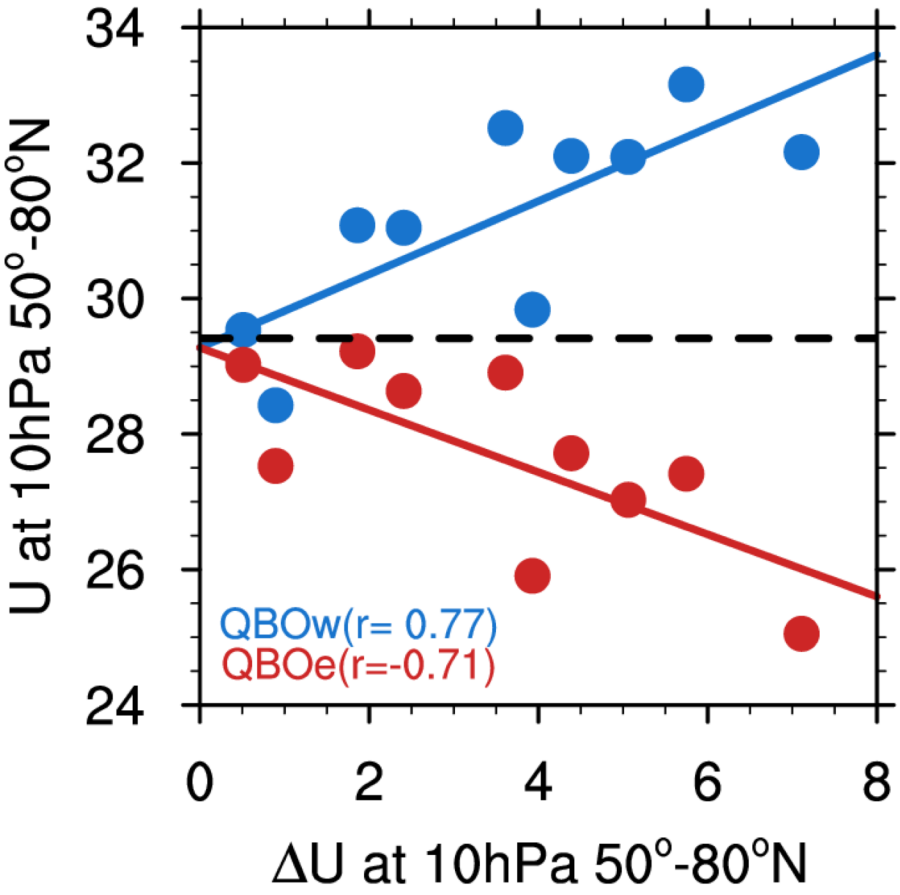
QBOw (shaded) and QBOe (isolines) zonal mean zonal wind

- Model simulates properly the modulation of zonal mean zonal wind response
- Important mechanism by which the QBO affects the stratospheric vortex strength
- QBOe: zero wind line is shifted towards subtropics, leading to a narrow wave guide and wave activity is reflected toward polar latitudes;
- QBOw: zero wind line is located in the summer hemisphere, leading to a wide waveguide where wave activity can more easily disperse towards the tropics



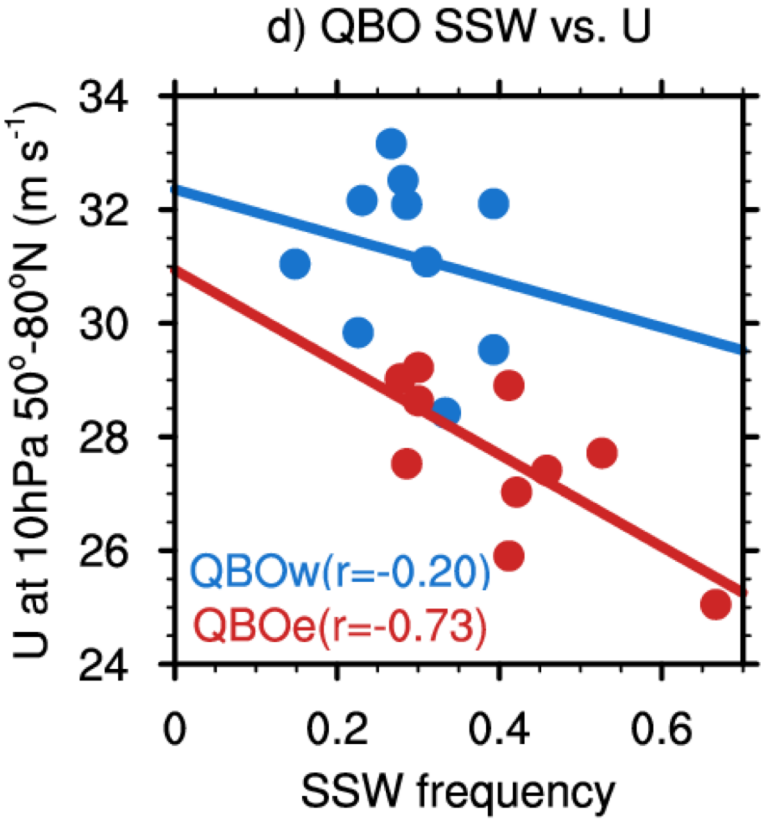
Linkage between strength of H-T relationship and zonal wind composites in QBOe (red) and QBOw (blue)

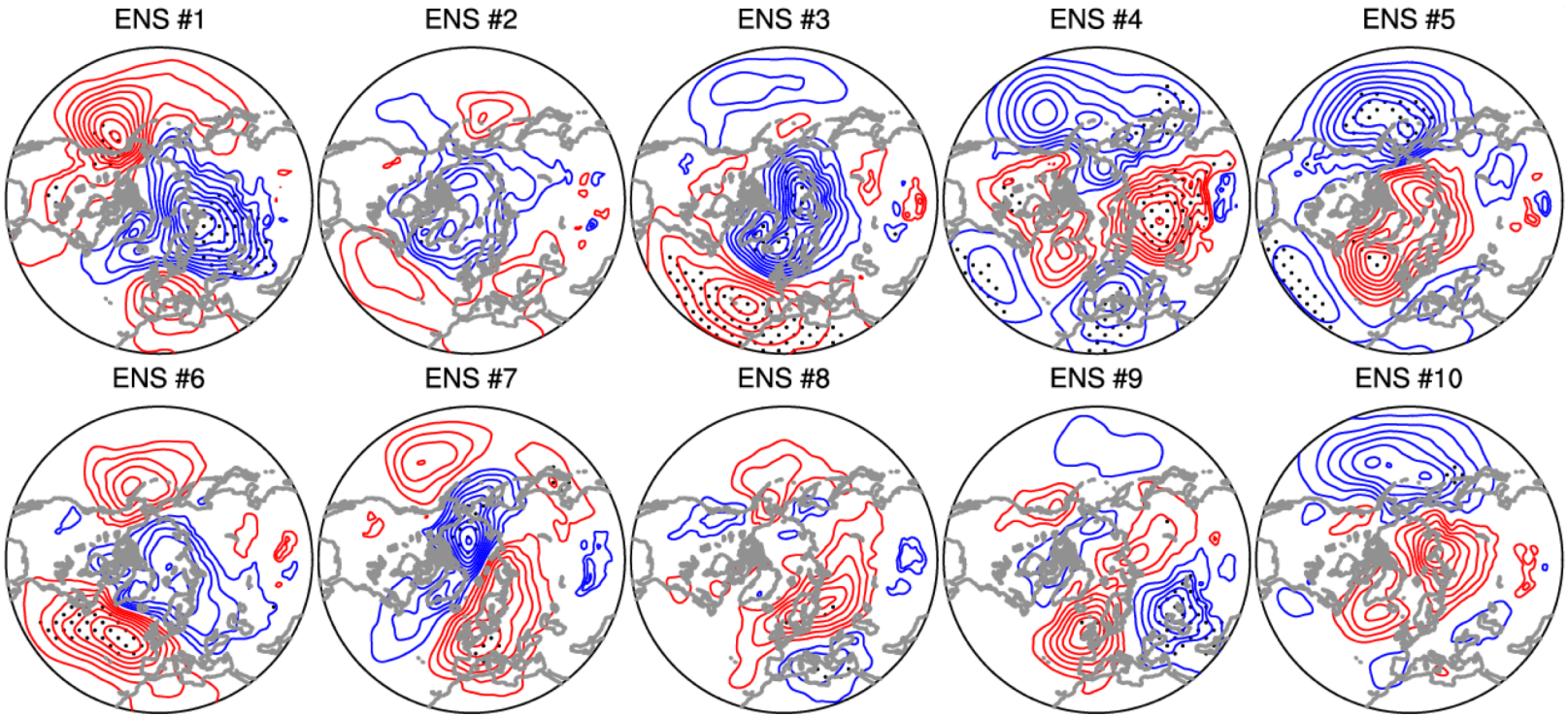
- Significant correlation of index of H-T relationship both with polar vortex strength in QBOe and QBOw



Linkage between SSW frequency and polar vortex strength in QBO composites

- Significant relationship between SSW frequency and polar vortex strength in QBOe
- No significant relationship in QBOw
- Result points to stronger feedback between tropospheric wave driving and stratospheric mean flow in QBOe than in QBOw

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