



Modulations of Atmospheric River Climatology by the Stratospheric Quasi-Biennial Oscillation

CESM Workshop
Boulder, CO

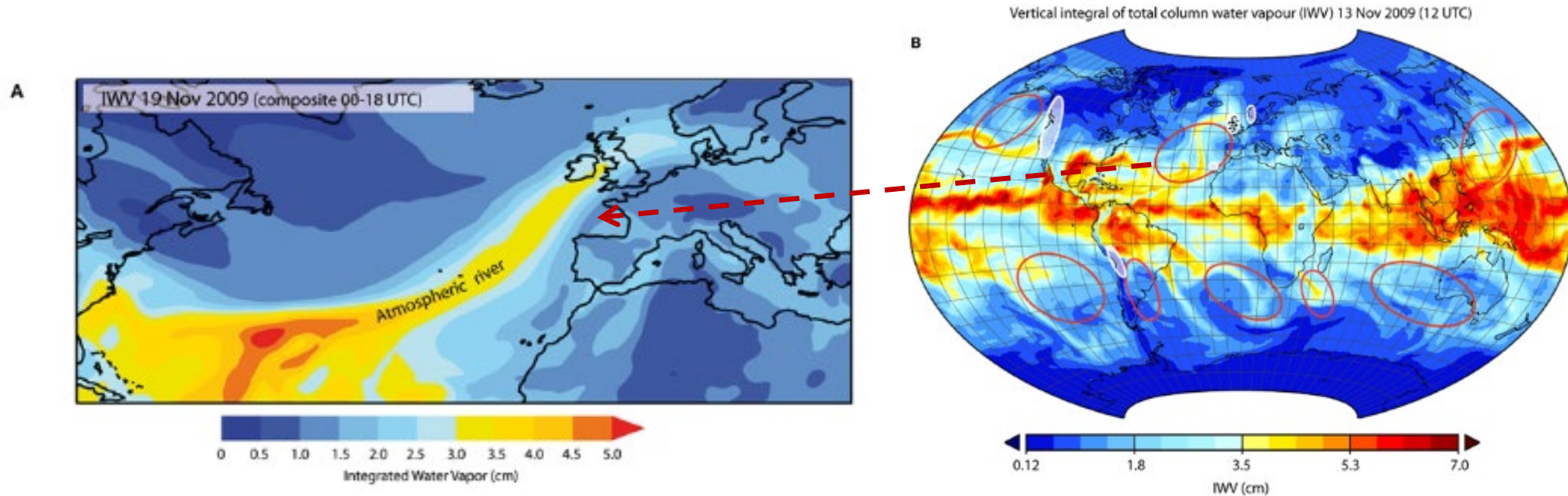
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June 12, 2024

I . Introduction *Atmospheric River*

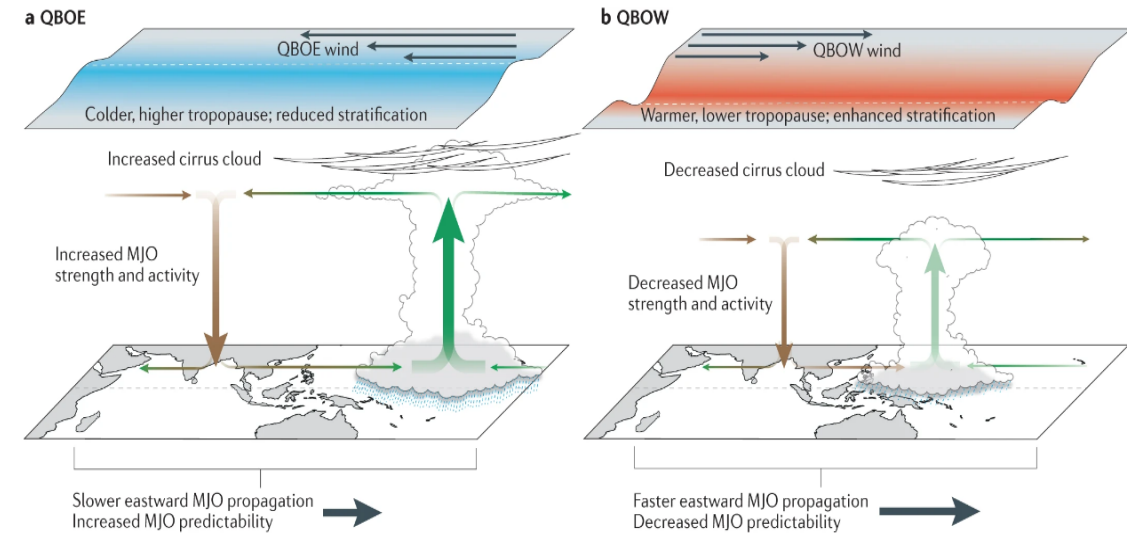


Giemeno et al., 2014

- Long, narrow bands of enhanced water vapor transport in the troposphere.
“Pineapple Express”
- Middle to higher latitudes.
- The main agents of water resources in many coastal regions.

Does the QBO's influences on the Northern Pacific AR **consistent among different AR detection algorithms? Any seasonality?** Also did the analysis for the **other regions.**

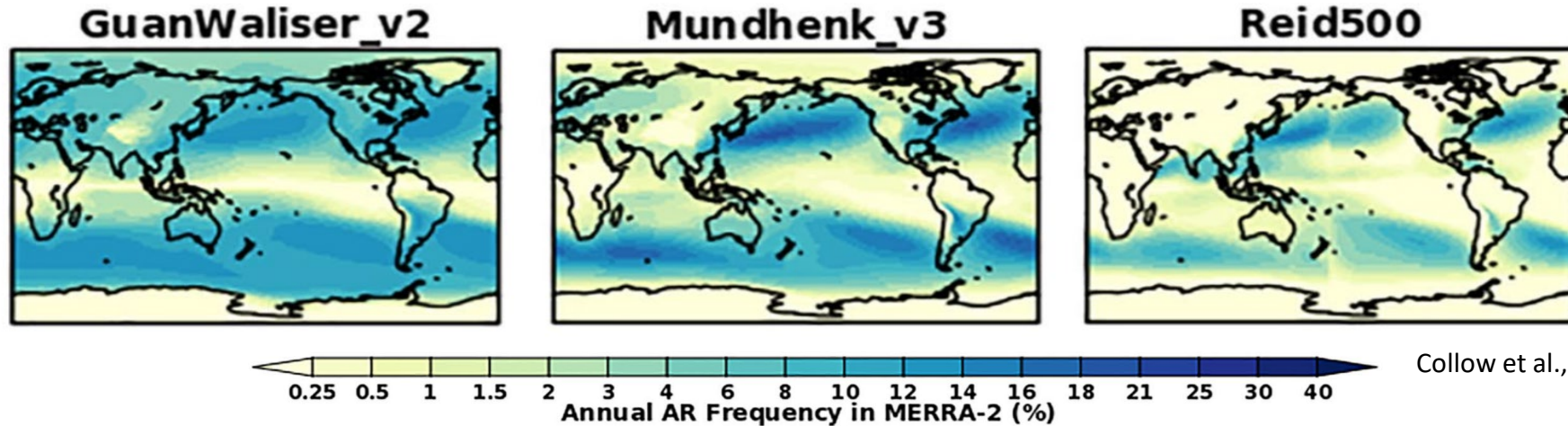
- The QBO-MJO connection (e.g., Yoo and Son 2016).
 - amplitude & propagation
 - teleconnection patterns
- The skillful predictions of **CA AR landings using QBO and MJO indices** (e.g., Castellano et al., 2022, Mundhenk et al., 2022).
 - only for the boreal winter season
- QBO's impacts on the **northern hemisphere winter storm tracks** (e.g., Wang et al., 2017).



Martin et al., 2021

single ARDT, single season, single region.

Annual mean of the AR frequency



➤ ERA5 reanalysis

- 1980 to 2017
- Hourly IVT and daily atmospheric variables
- 0.25 degrees by 0.25 degrees horizontally

➤ QBO phase

- 3-month average of the equatorial (10S-10N) zonal-mean U50
- above (below) half standard deviation of the mean for QBOW (QBOE)

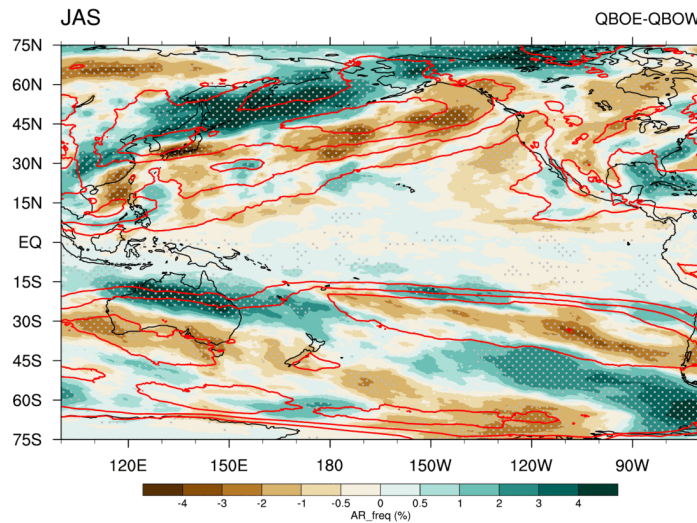
➤ 3 ARDTs

- GuanWaliser_v2 (lenient)
- Reid500 (strict)
- Mundhenk_v3 (medium, suitable for the MJO-induced AR events, **run by Dr. Kyle Nardi**)

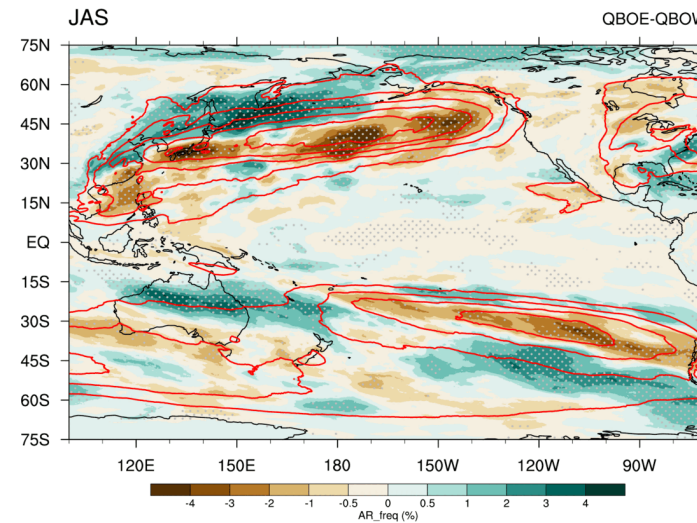
III. High Consistency among the Three ARDTs

AR frequency maps
Shading: QBOE-QBOW
Lines: QBOW seasonal mean

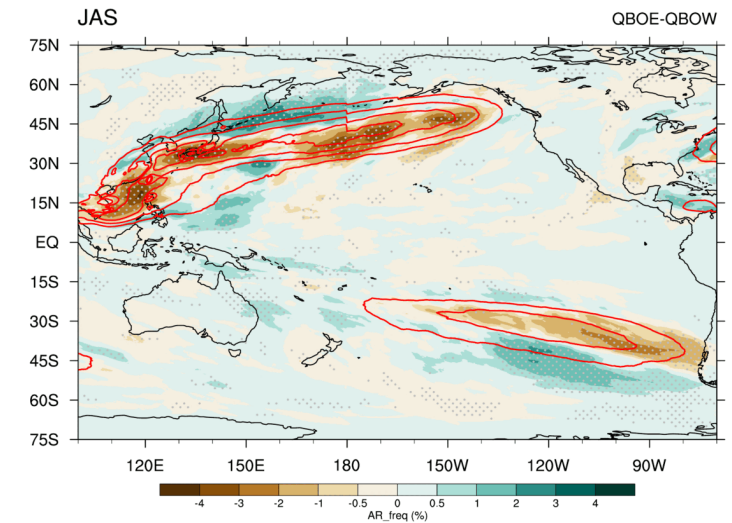
GuanWaliser_v2



Mundhenk_v3



Reid500

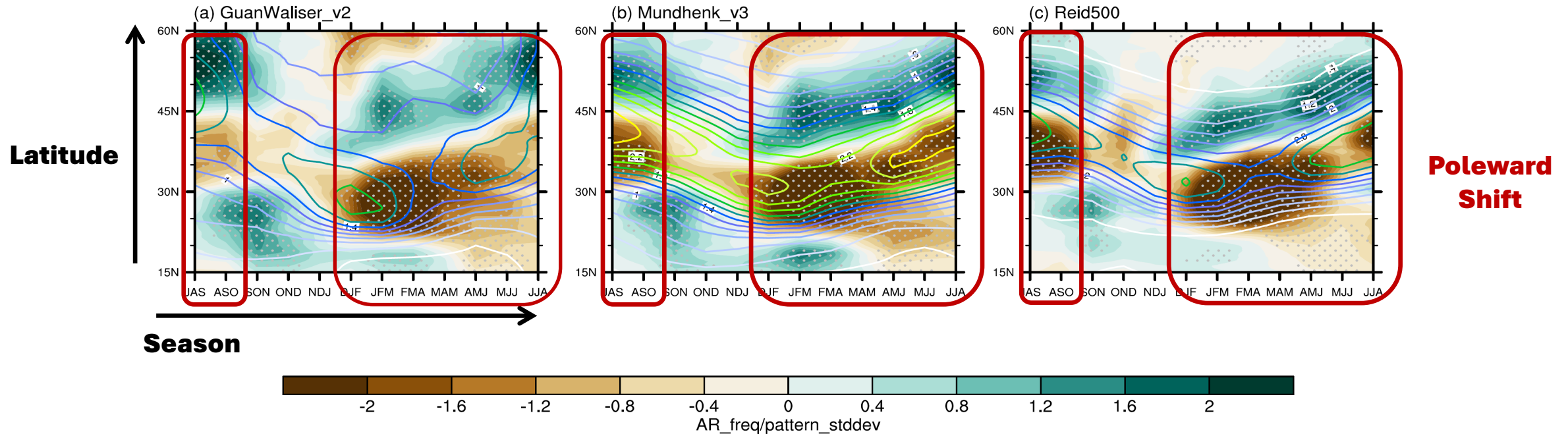


- Organized differences in certain seasons over the Northern Pacific.
- High consistency for the organized differences among three selected ARDTs.

III. AR Domain Changes over the Northern Pacific

Lines: all-season-mean AR frequency
Shadings: QBOE-QBOW differences

Northern Pacific (150E-150W)



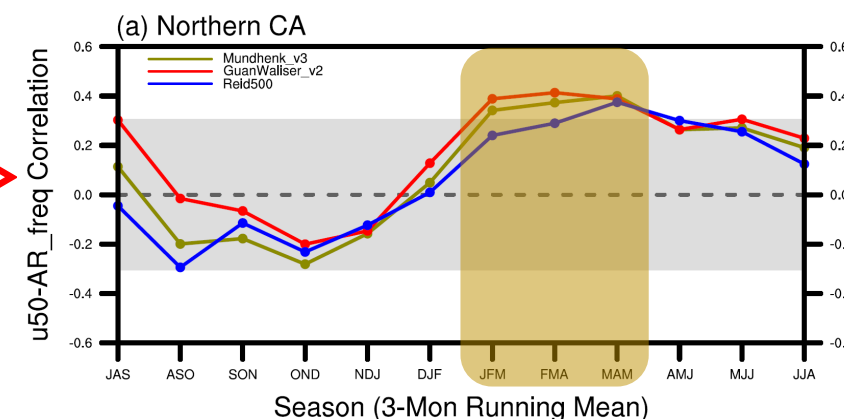
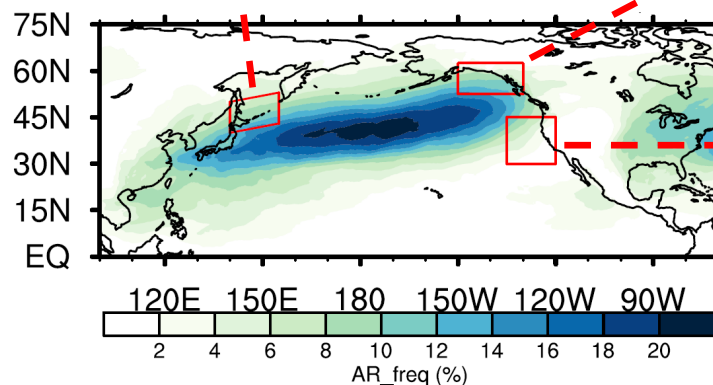
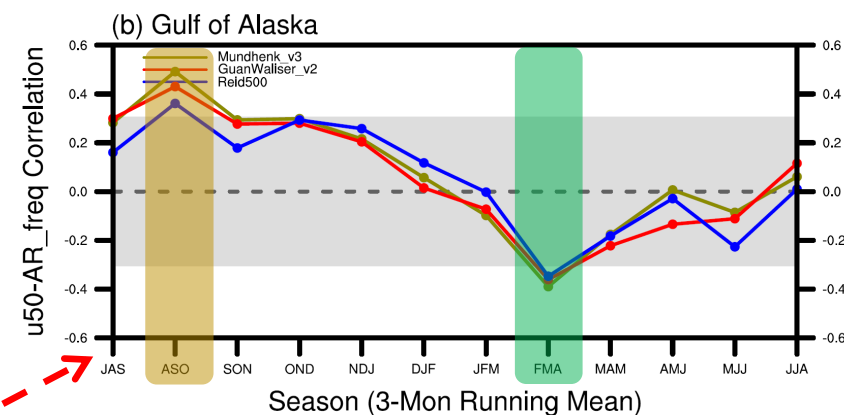
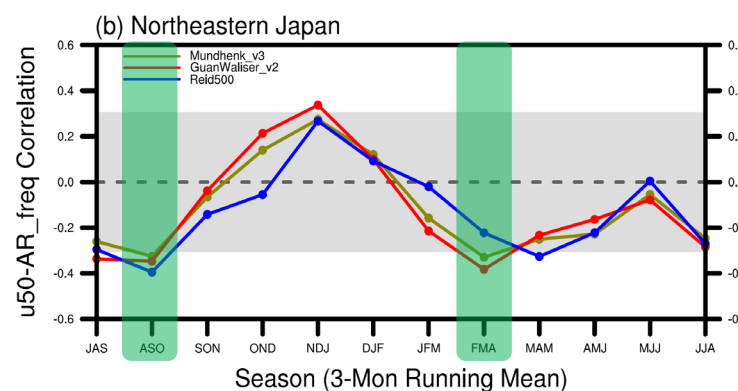
III. Local Impacts around the Northern Pacific Basin

Correlations between the seasonal-mean QBO index (u50) and the domain-averaged AR frequency

— Mundhenk_v3
— GuanWaliser_v2
— Reid500

lower (higher) QBO index means QBOE (QBOW)
 negative (positive) correlations means more (less) AR in the QBOE

- High agreement among the three ARDTs.
- The poleward shift around the ASO.
 - ✓ increased AR in the northern Japan
 - ✓ decreased AR in the gulf of Alaska
- The poleward shift around the FMA.
 - ✓ increased AR in the northern Japan and gulf of Alaska
 - ✓ decreased AR in the northern CA



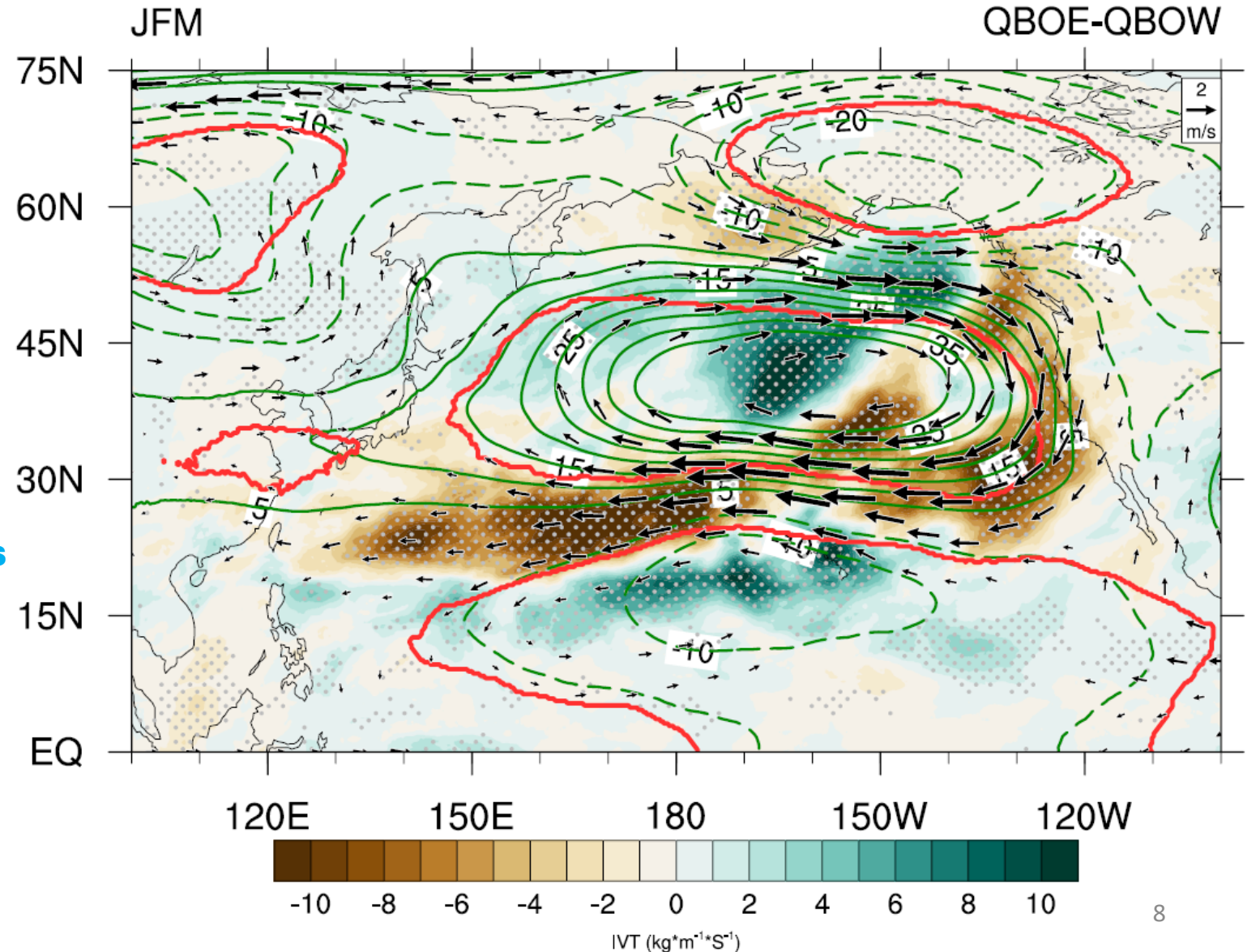
VI. Plausible Mechanisms *Background mean state changes*

The QBOE JFM-season-mean background is featured by

- an anomalous **z500 high** centered at the northeastern Pacific
- low-level **easterly (westerly)** anomalies in the **lower (higher)** latitudes

lower (higher) AR IVT over the anomalous easterly (westerly)

Mundhenk_v3 AR IVT (shading), z500 (lines), and 700hPa wind (vectors)



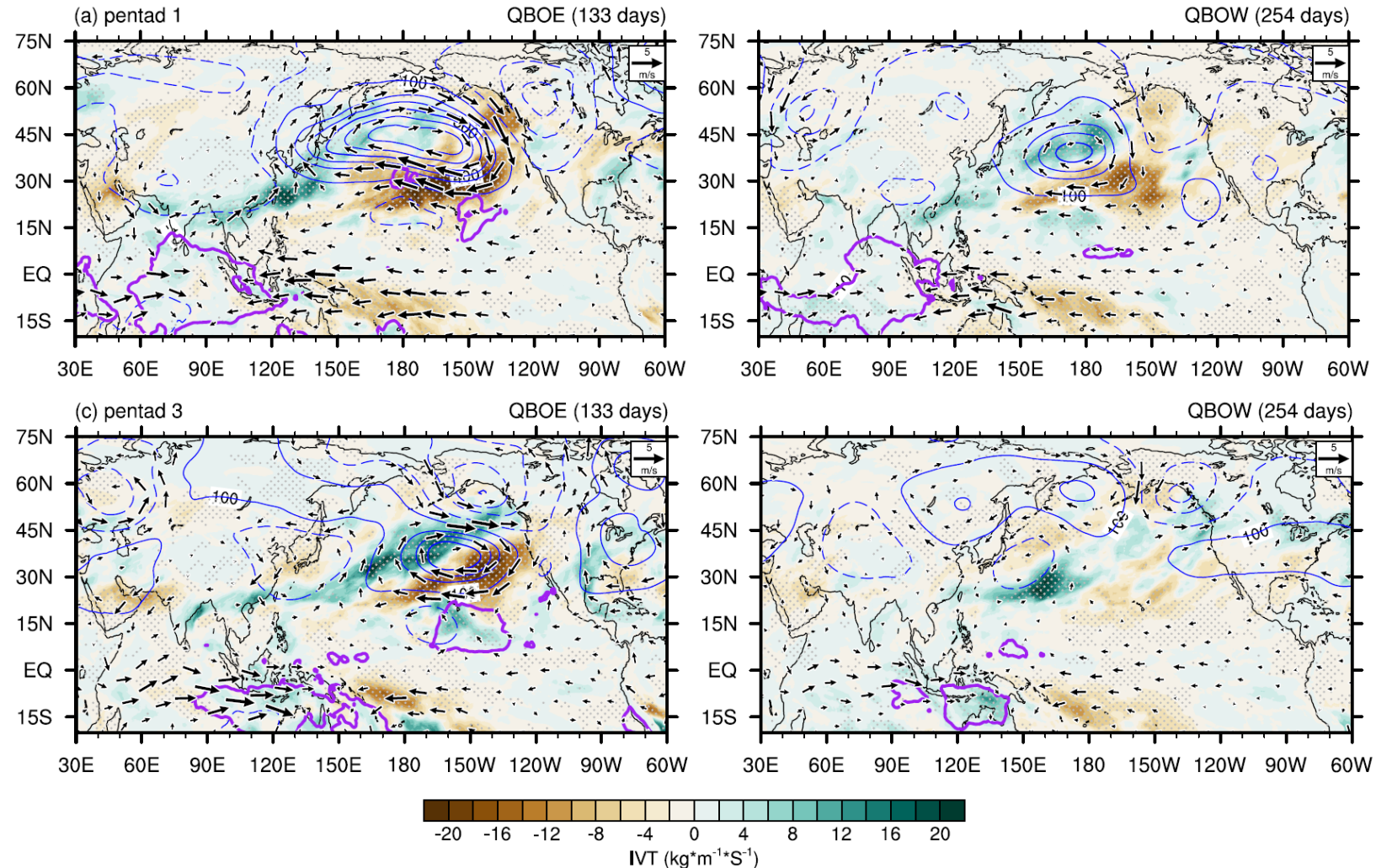
VI. Plausible Mechanisms *QBO-MJO teleconnection relationships*

JFM anomalous AR IVT (shading), z500 (blue lines), and wind at 700hPa (vectors) for RMM Phase 2/3
with the 120-day-running-mean removed

The JFM MJO teleconnections in the QBOE is featured by

- a stronger anomalous **z500 high** with a wider zonal range and longer persistence
- **anti-cyclonic gyre** in the lower troposphere

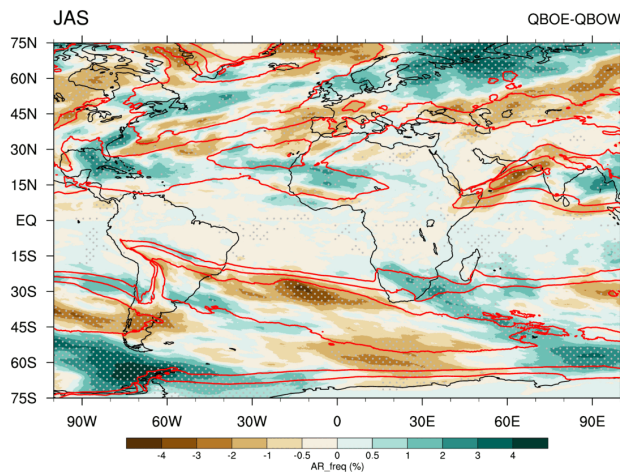
poleward shift of the AR path induced by the MJO teleconnections



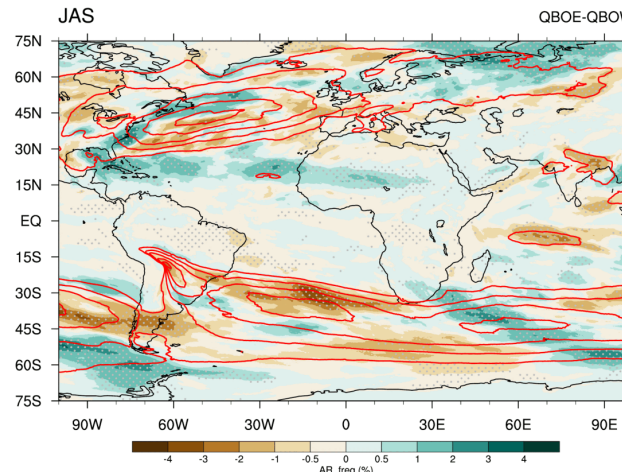
V. Takeaway Messages

- **High consistency** among the three ARDTs for the **QBO-AR connection** over the NP.
 - ✓ poleward shift in QBOE
 - ✓ zonal narrowing in QBOE
 - ✓ strong seasonality
 - *Highly agreed connections also found for other regions*
- **Significant impacts of the QBO on the local AR frequency** around the NP.
- Contributions from both the **season-mean background** and the **MJO teleconnection** changes.

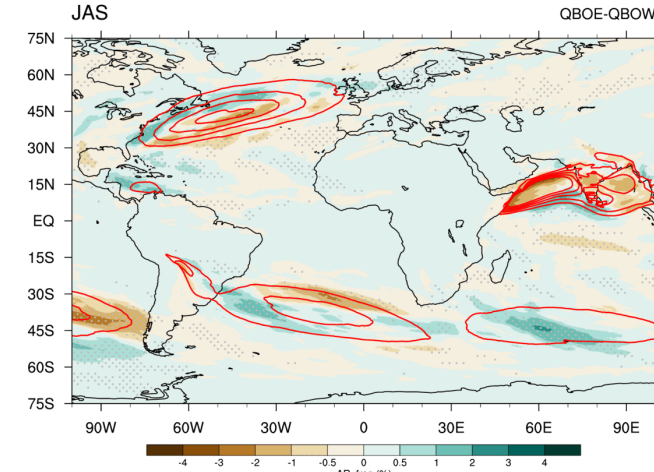
GuanWaliser_v2



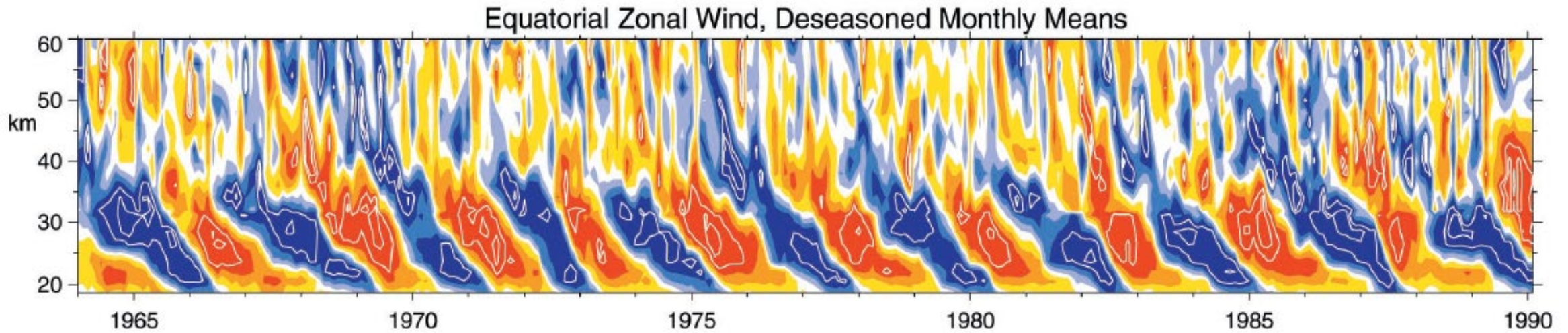
Mundhenk_v3



Reid500



I . Introduction *Quasi-Biennial Oscillation*



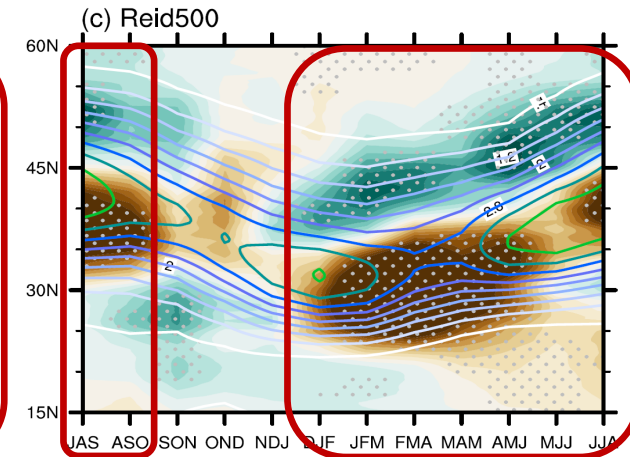
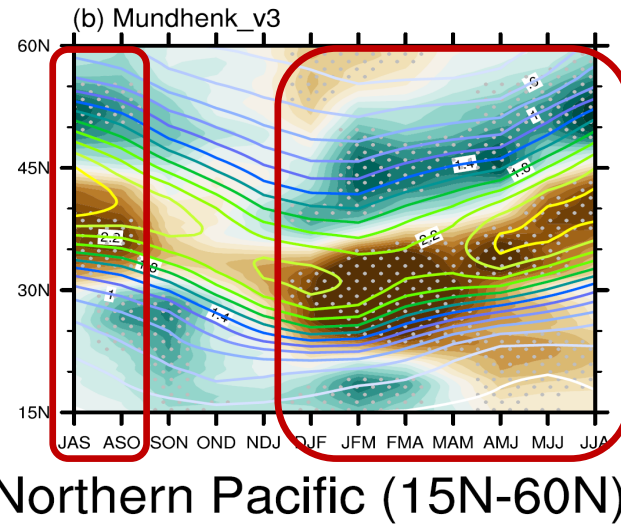
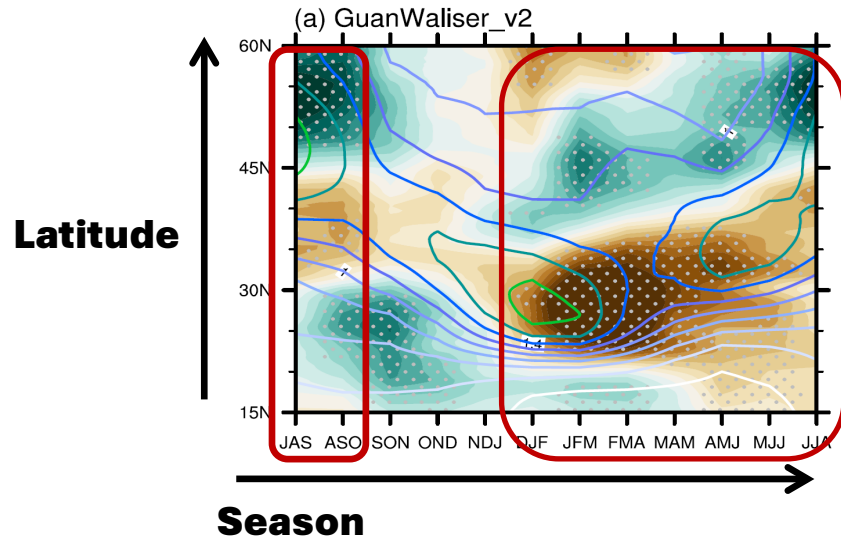
Baldwin et al., 2001

- Stratospheric regime of zonal-mean flow.
Easterly to westerly, back and forth.
- Downward propagation.
- ~28-month periodicity.

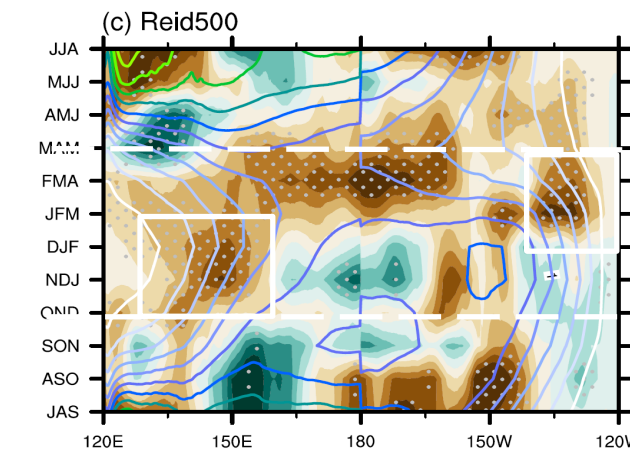
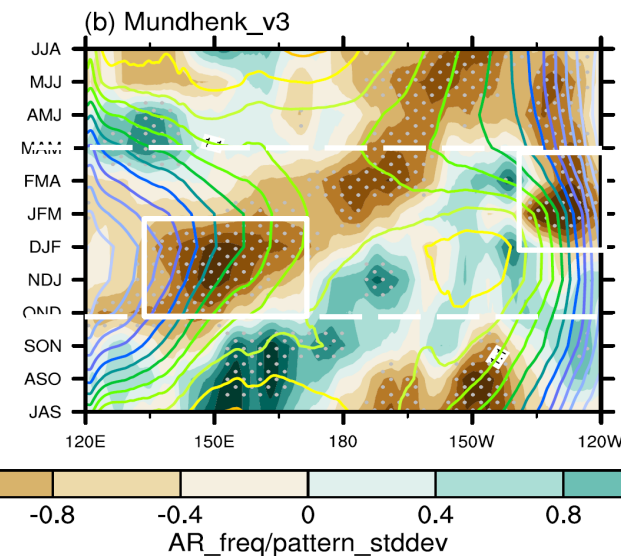
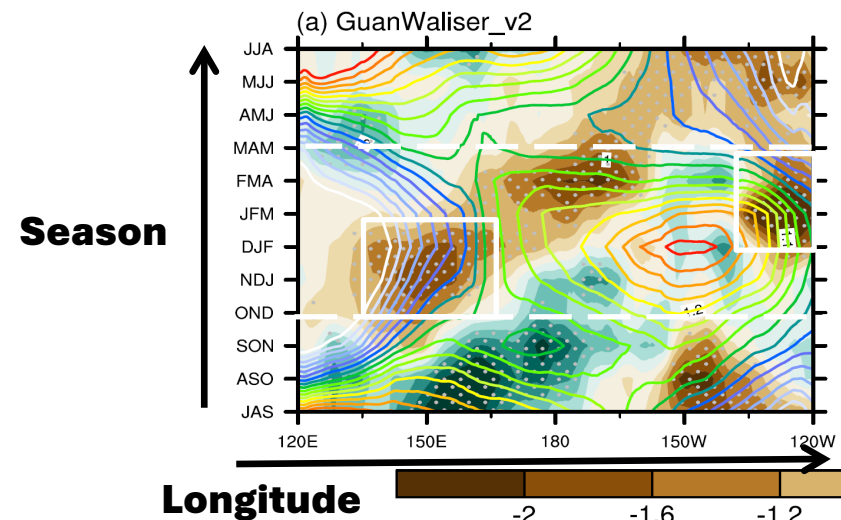
III. AR Domain Changes over the Northern Pacific

Northern Pacific (150E-150W)

Lines: all-season-mean AR frequency
Shadings: QBOE-QBOW differences



Poleward Shift



Zonal narrowing at both ends

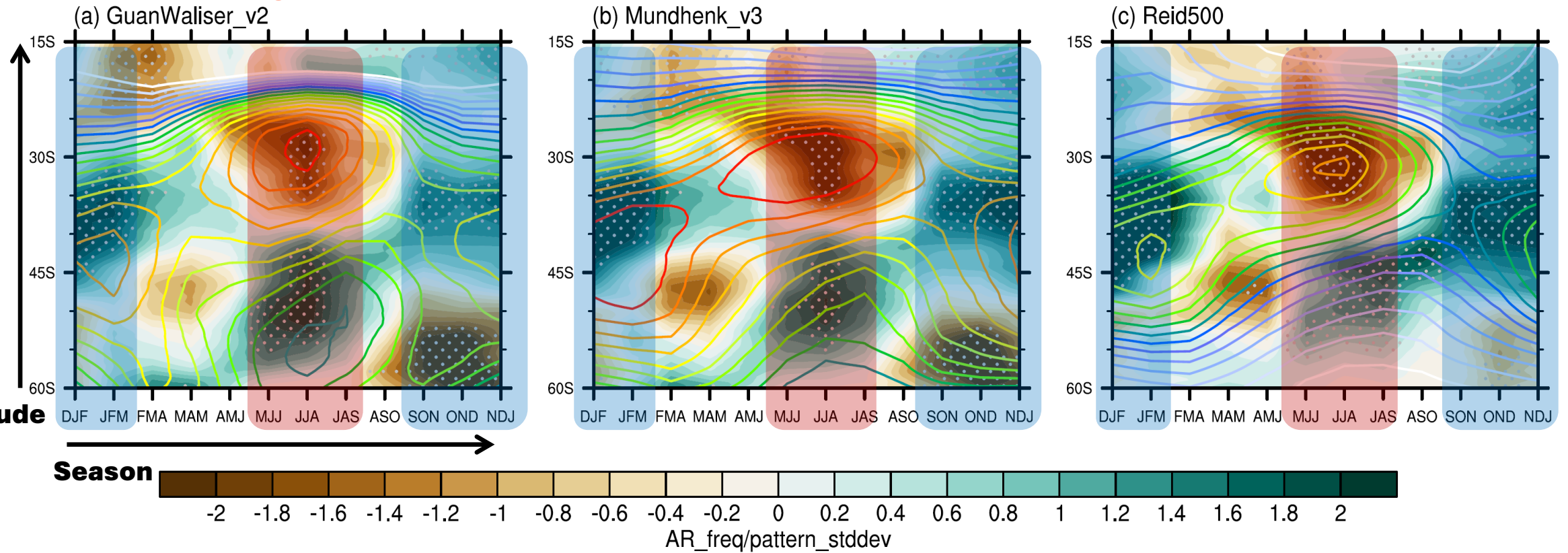
III. AR Domain Changes over the Southern Pacific

Hövmollor diagrams of the all-season-mean AR frequency (lines) and QBOE-QBOW differences (shadings)

Southern Pacific (180-90W)

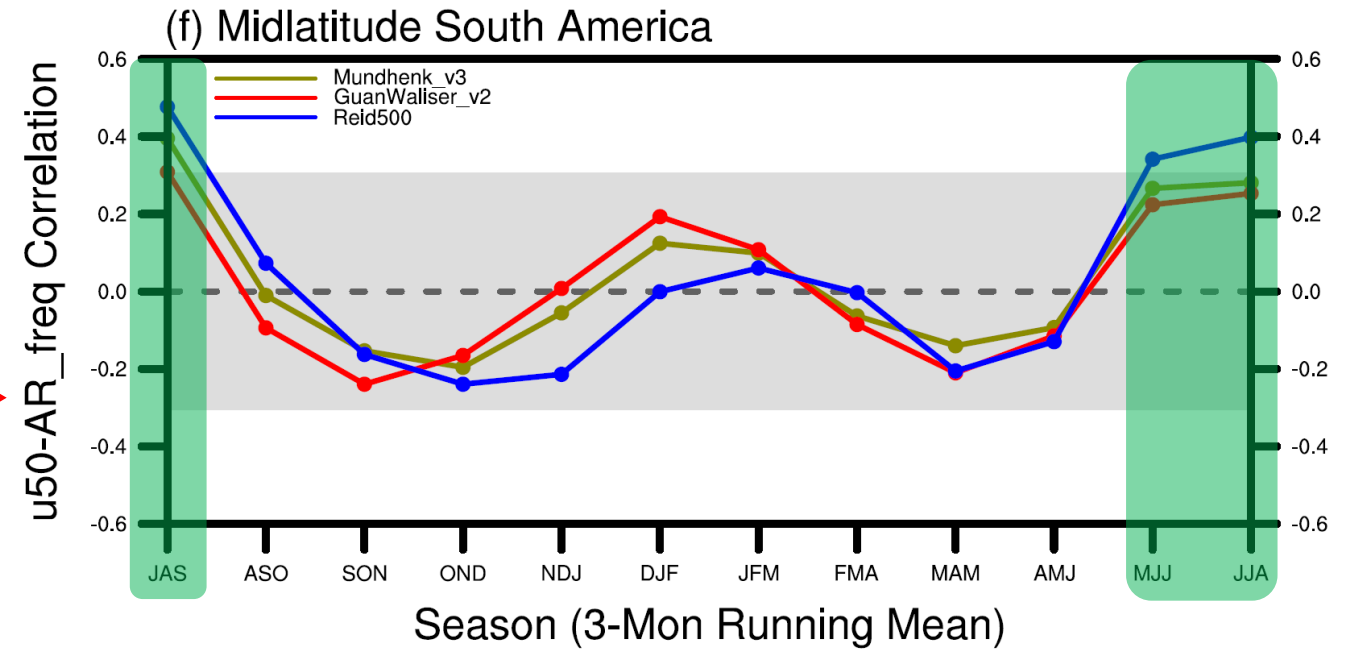
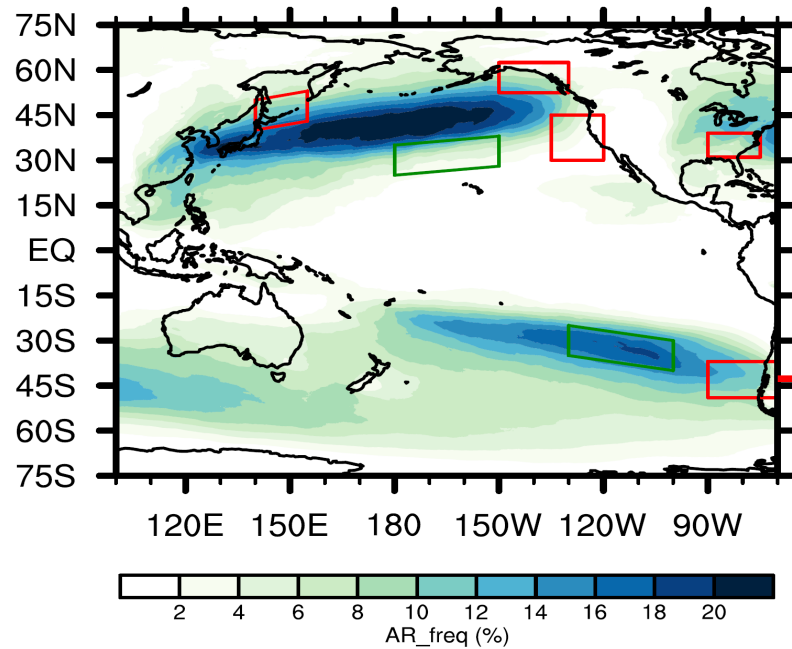
Poleward Shift

Amplification



III. Local Impacts around the Southern Pacific Basin

Correlations between seasonal means of the QBO index (u50) and the domain-averaged AR frequency



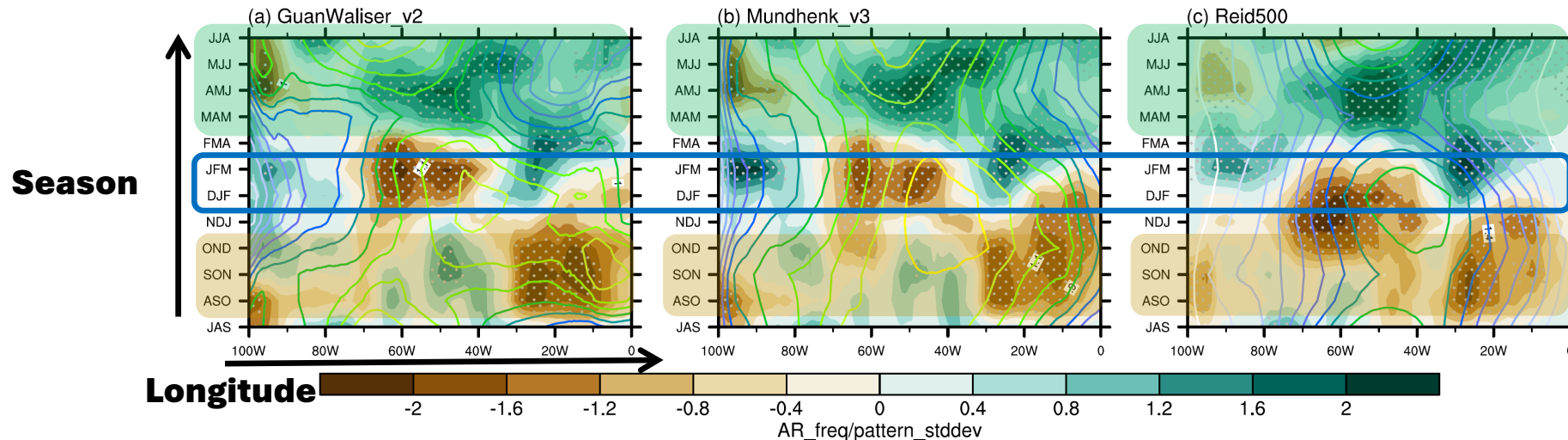
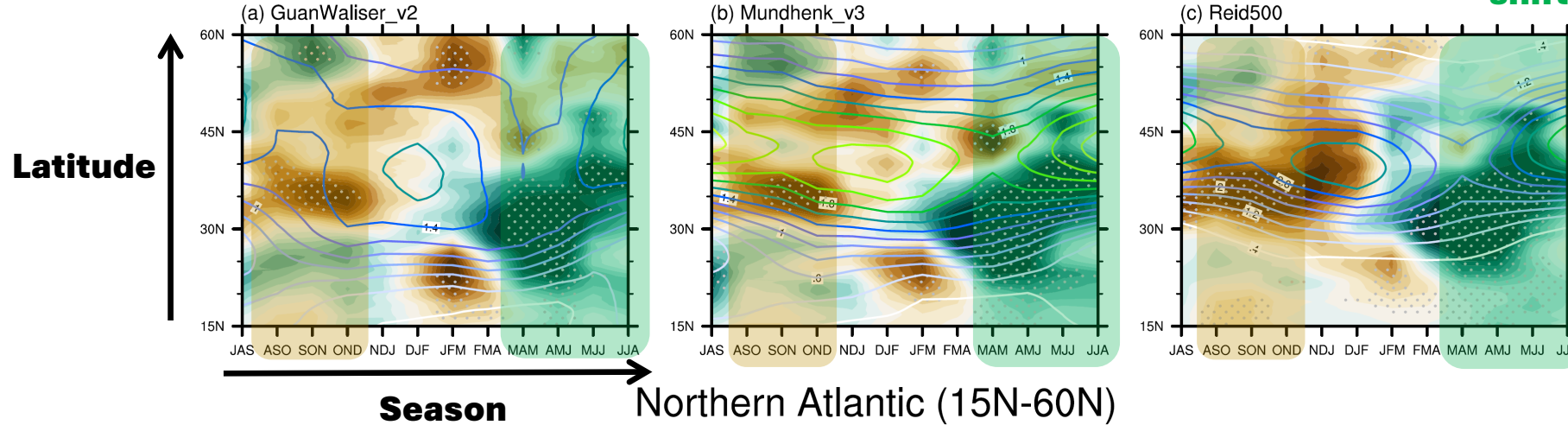
III. AR Domain Changes over the Northern Atlantic

Hövmollor diagrams of the all-season-mean AR frequency (lines) and QBOE-QBOW differences (shadings)

Northwestward extraction

Northern Atlantic (30W-20E)

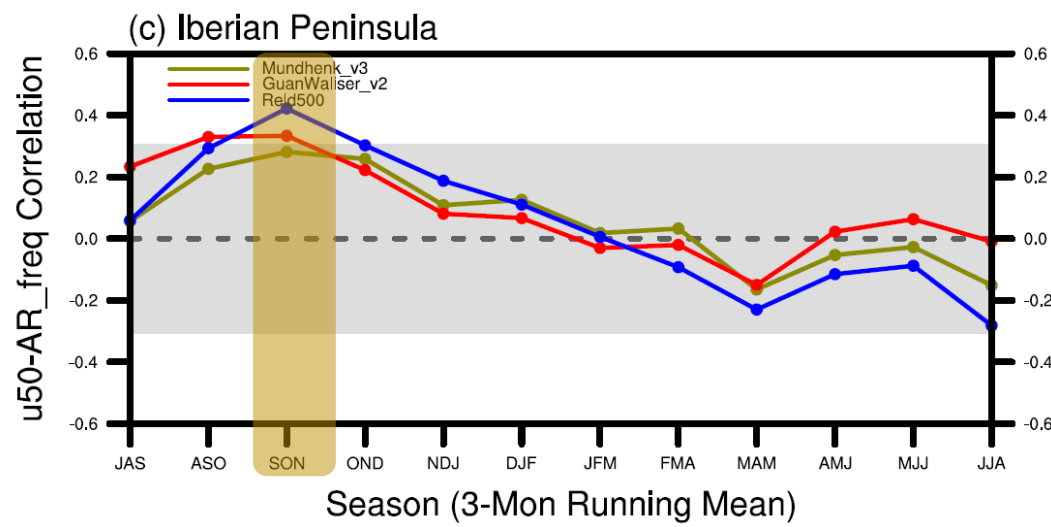
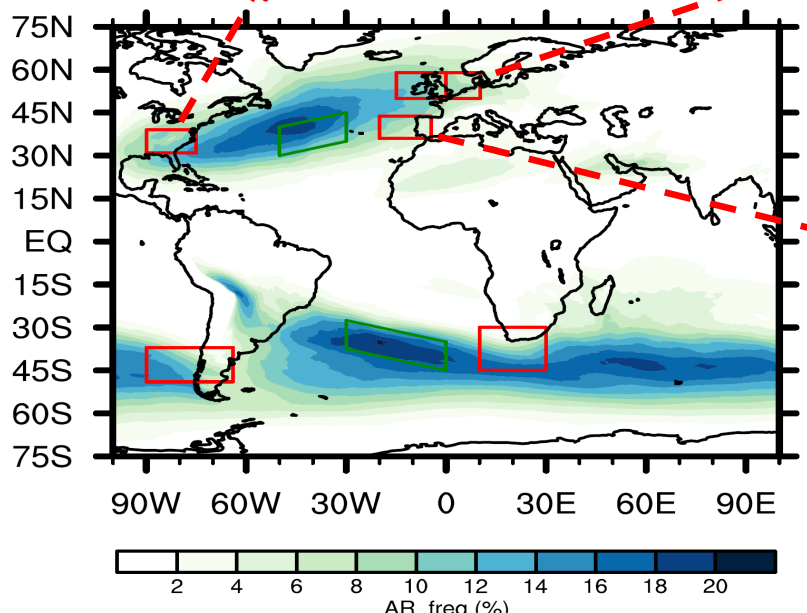
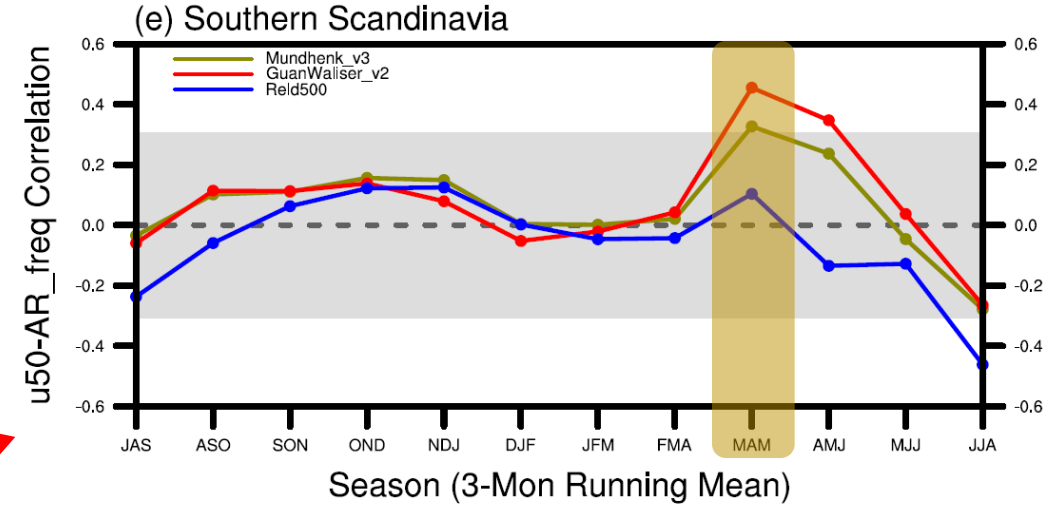
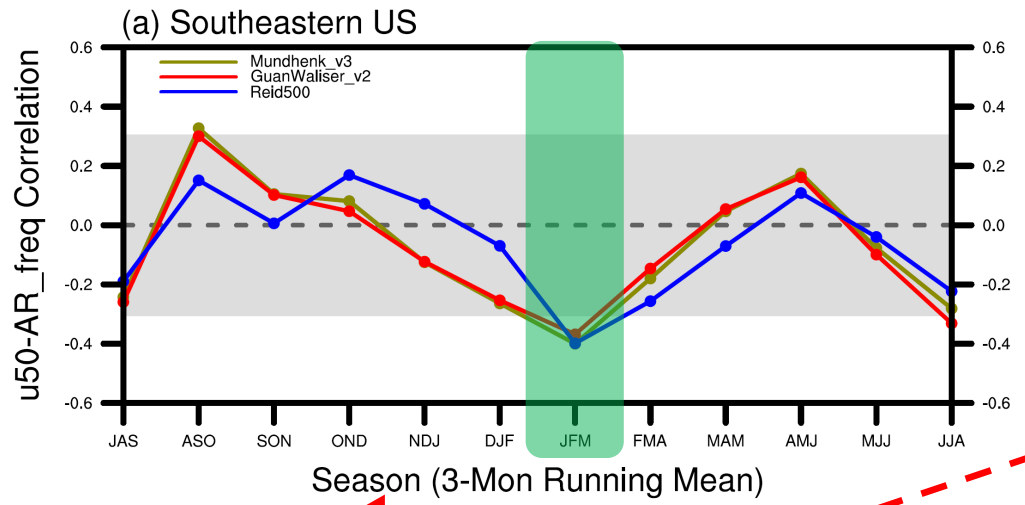
Southeastward shift



Extension at both zonal ends

III. Local Impacts around the Northern Atlantic Basin

Correlations between seasonal means of the QBO index (u50) and the domain-averaged AR frequency



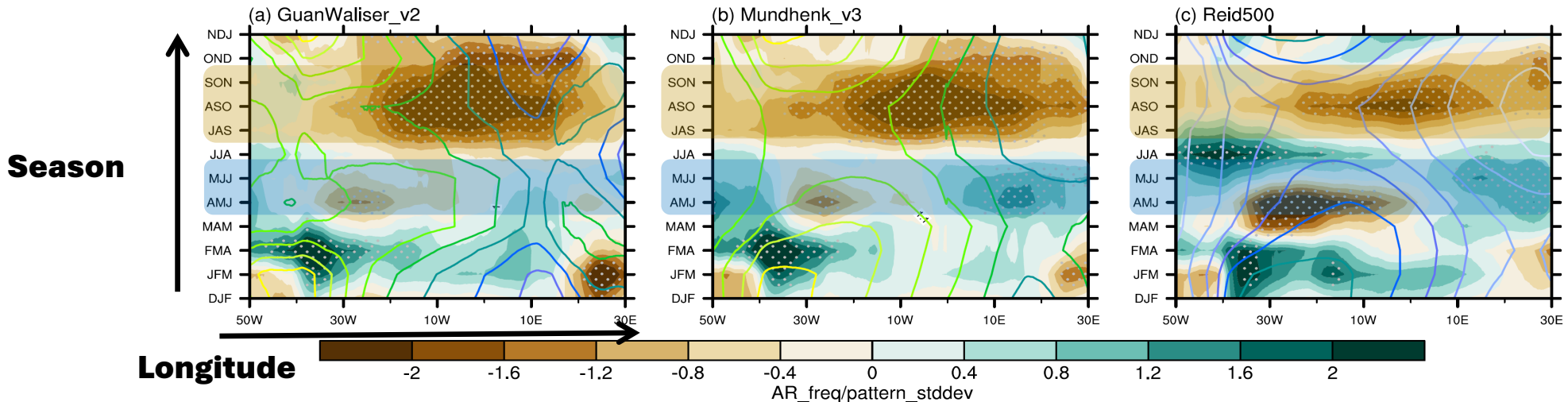
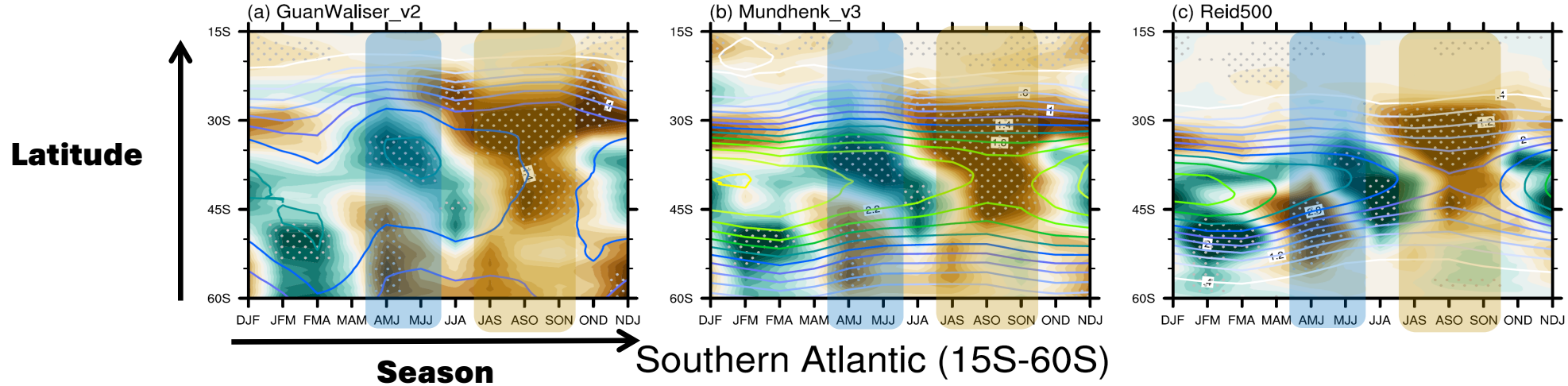
III. AR Domain Changes over the Southern Atlantic

Hövmollor diagrams of the all-season-mean AR frequency (lines) and QBOE-QBOW differences (shadings)

Northeastward shift

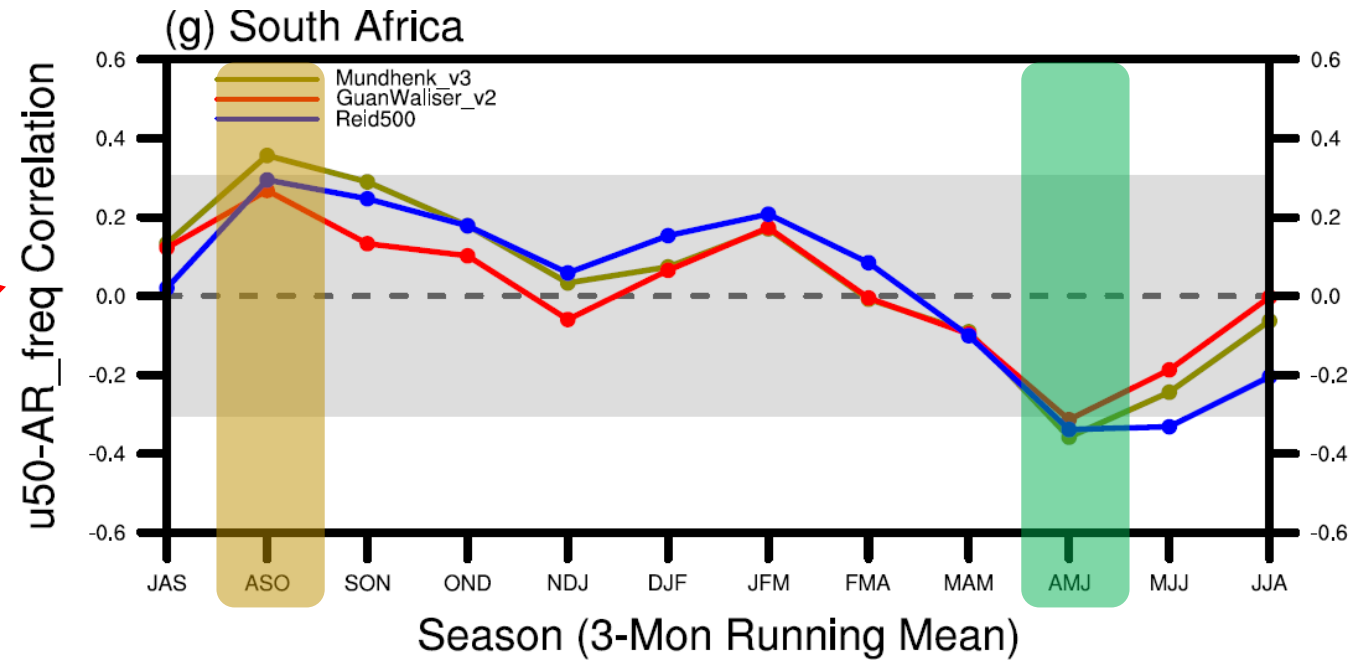
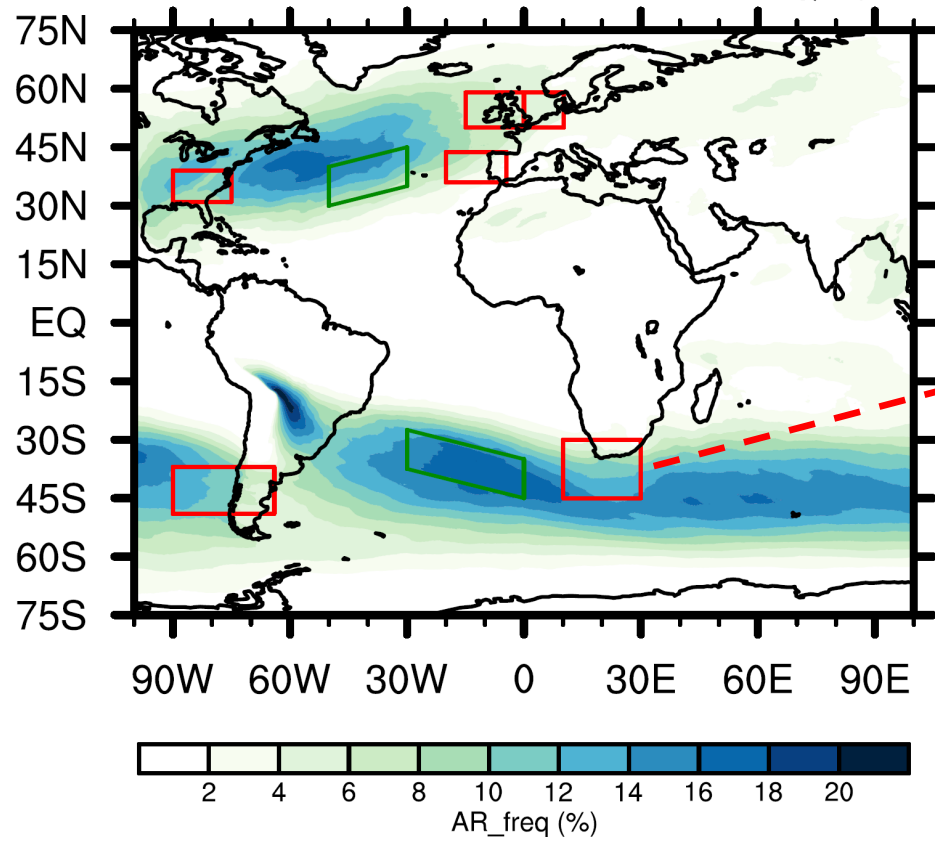
Southern Atlantic (30W-20E)

Universal weakening

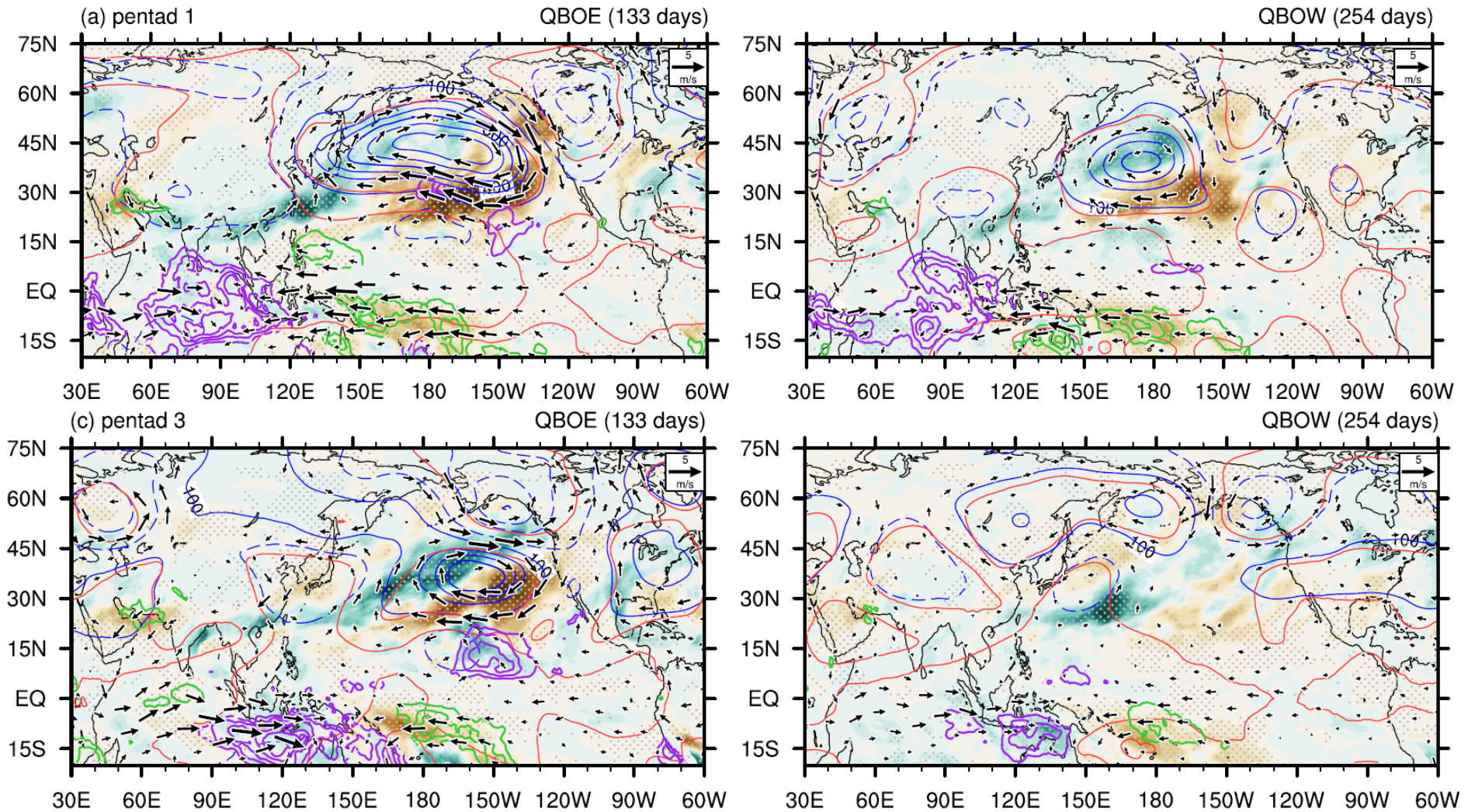


III. Local Impacts around the Southern Atlantic Basin

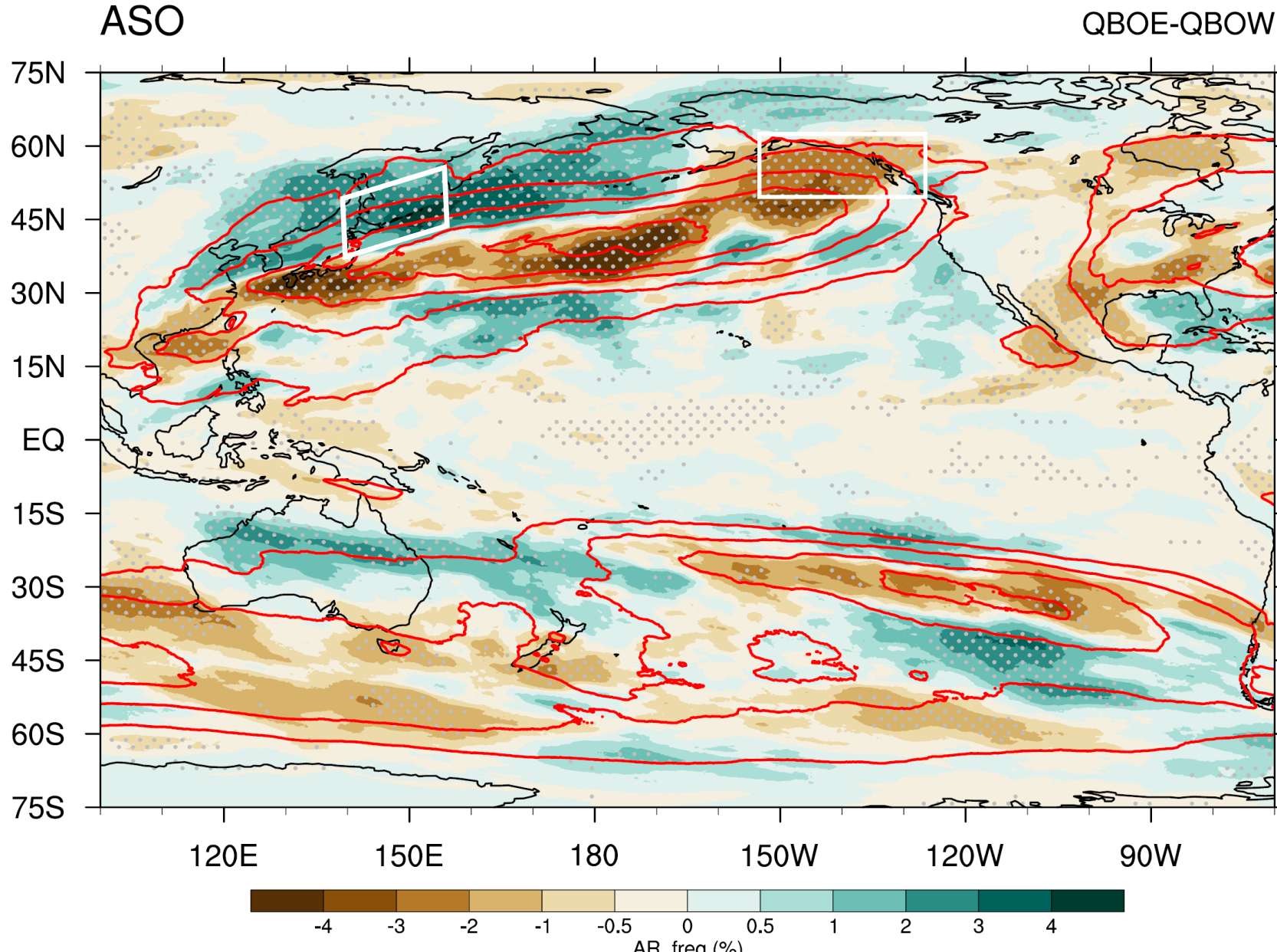
Correlations between seasonal means of the QBO index (u50) and the domain-averaged AR frequency



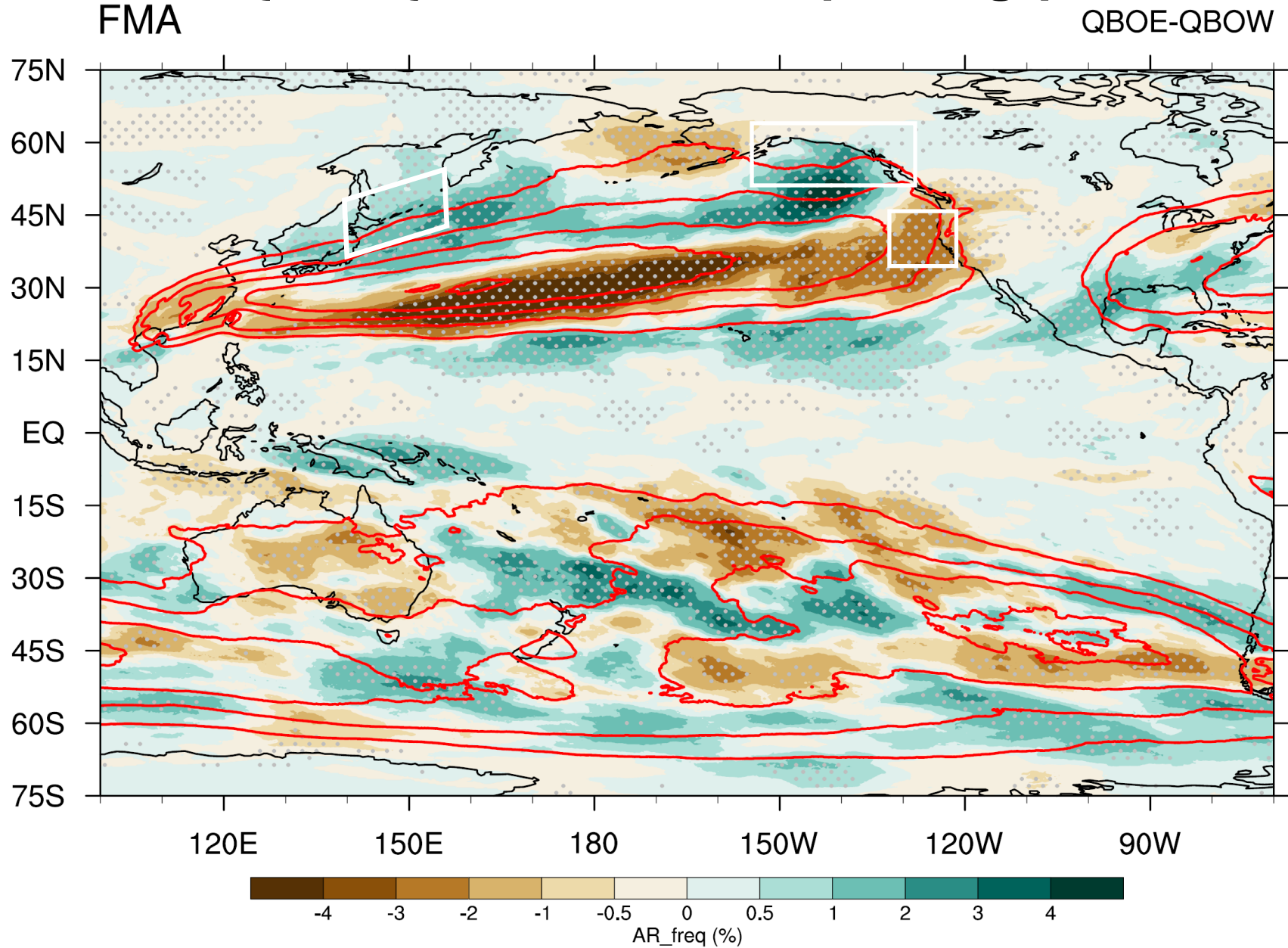
JFM anomalous AR IVT (shading), z500 (blue lines), and wind at 700hPa (vectors) for RMM Phase 2/3



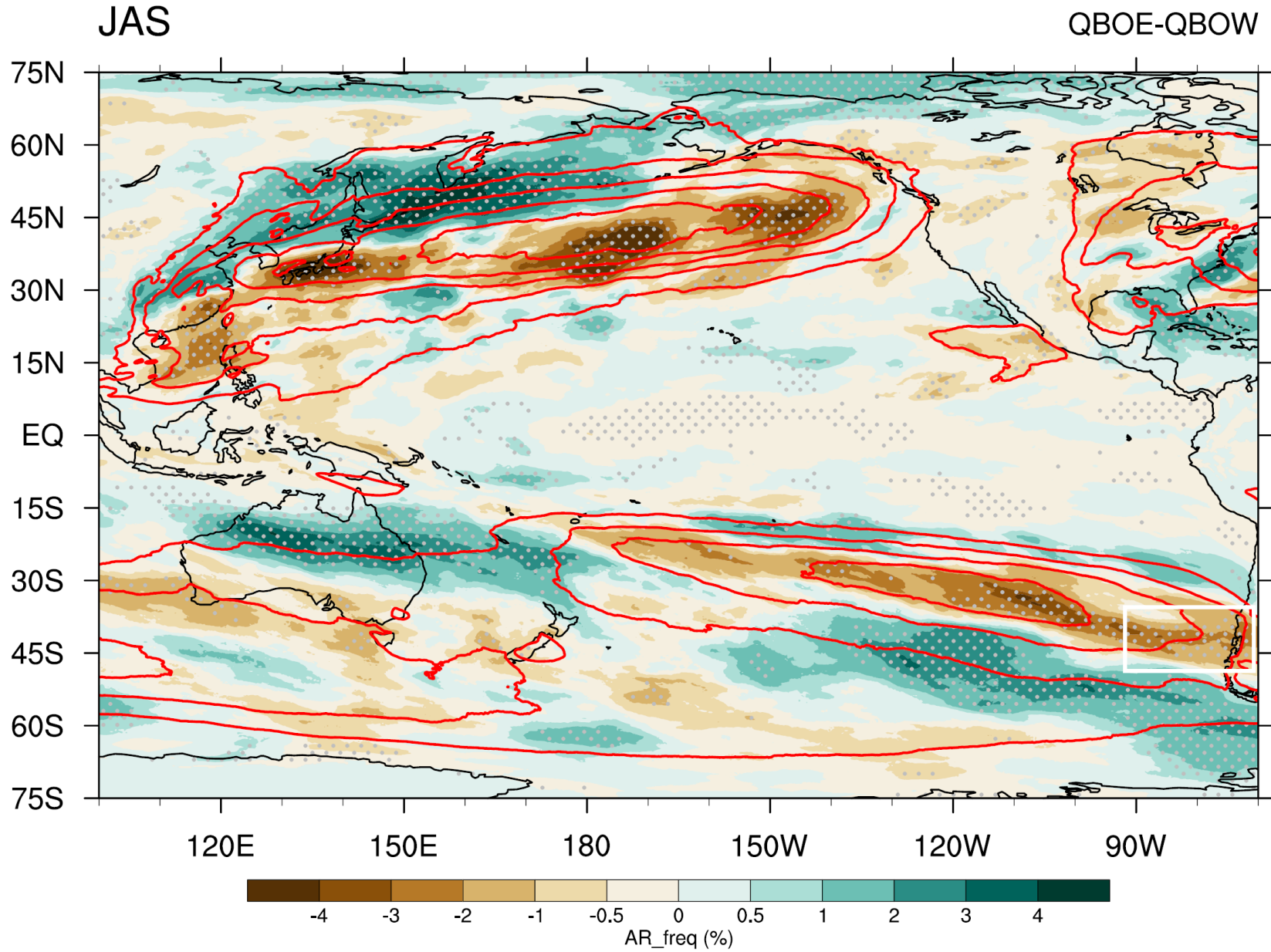
Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



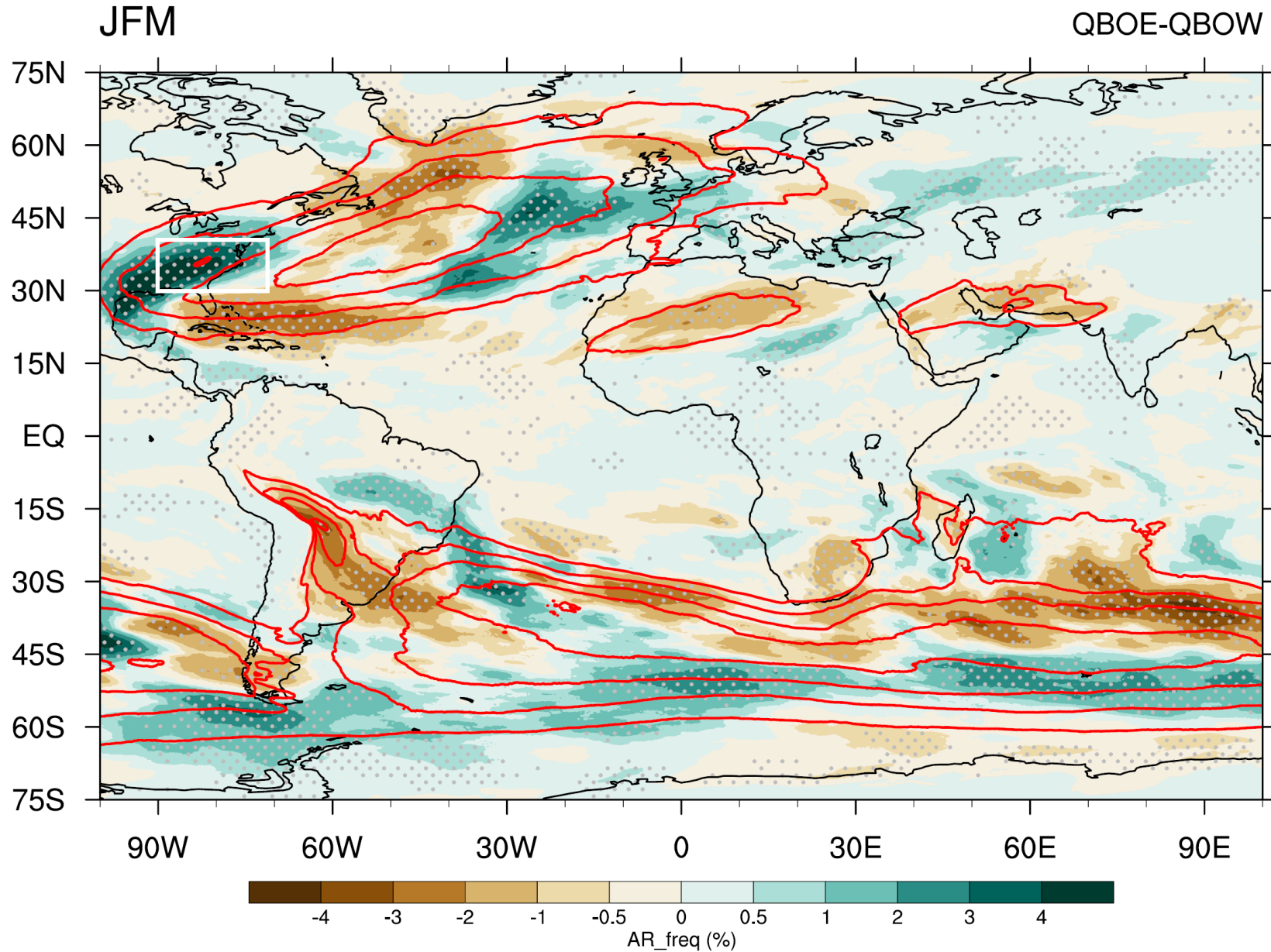
Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



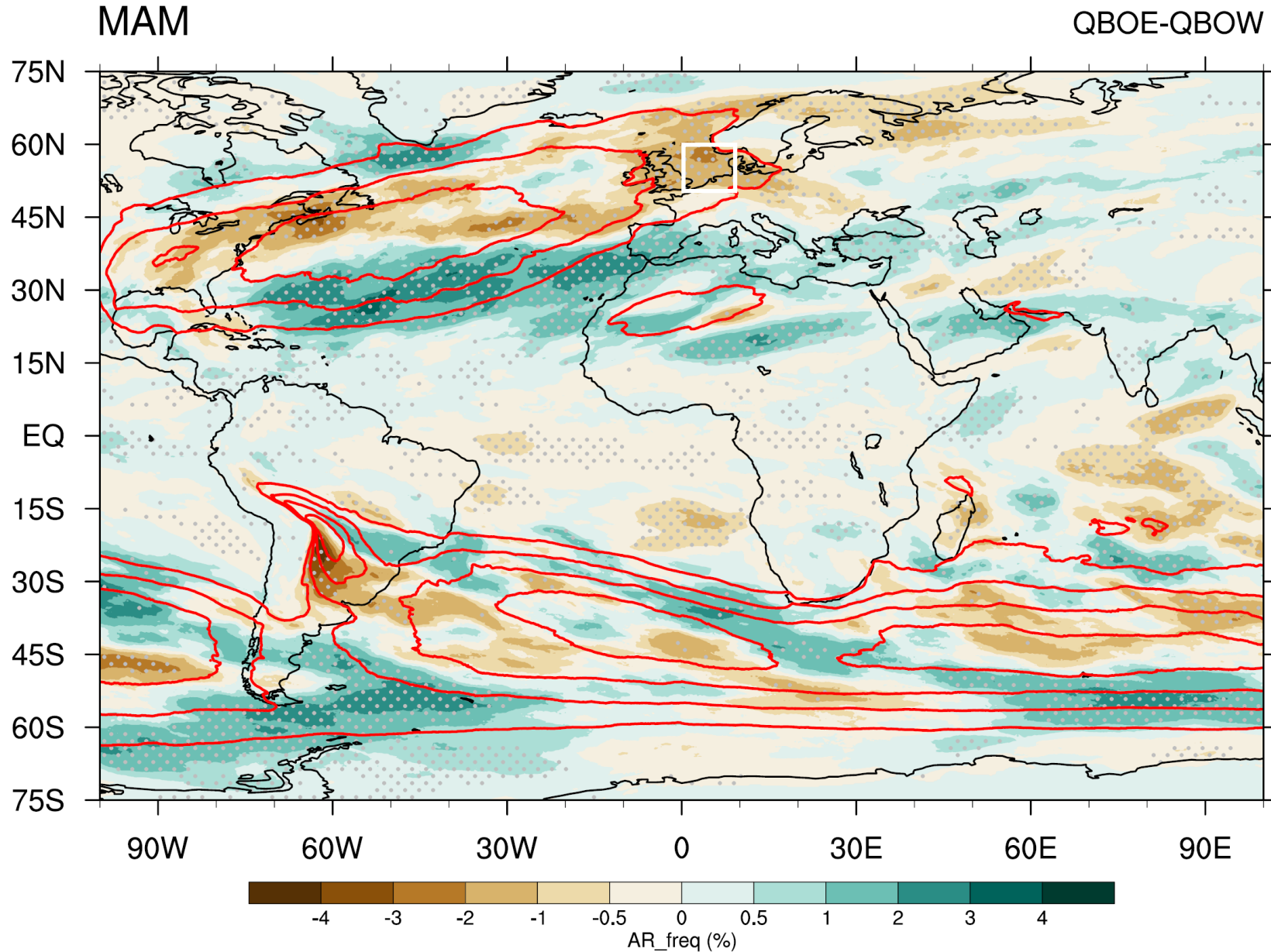
Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



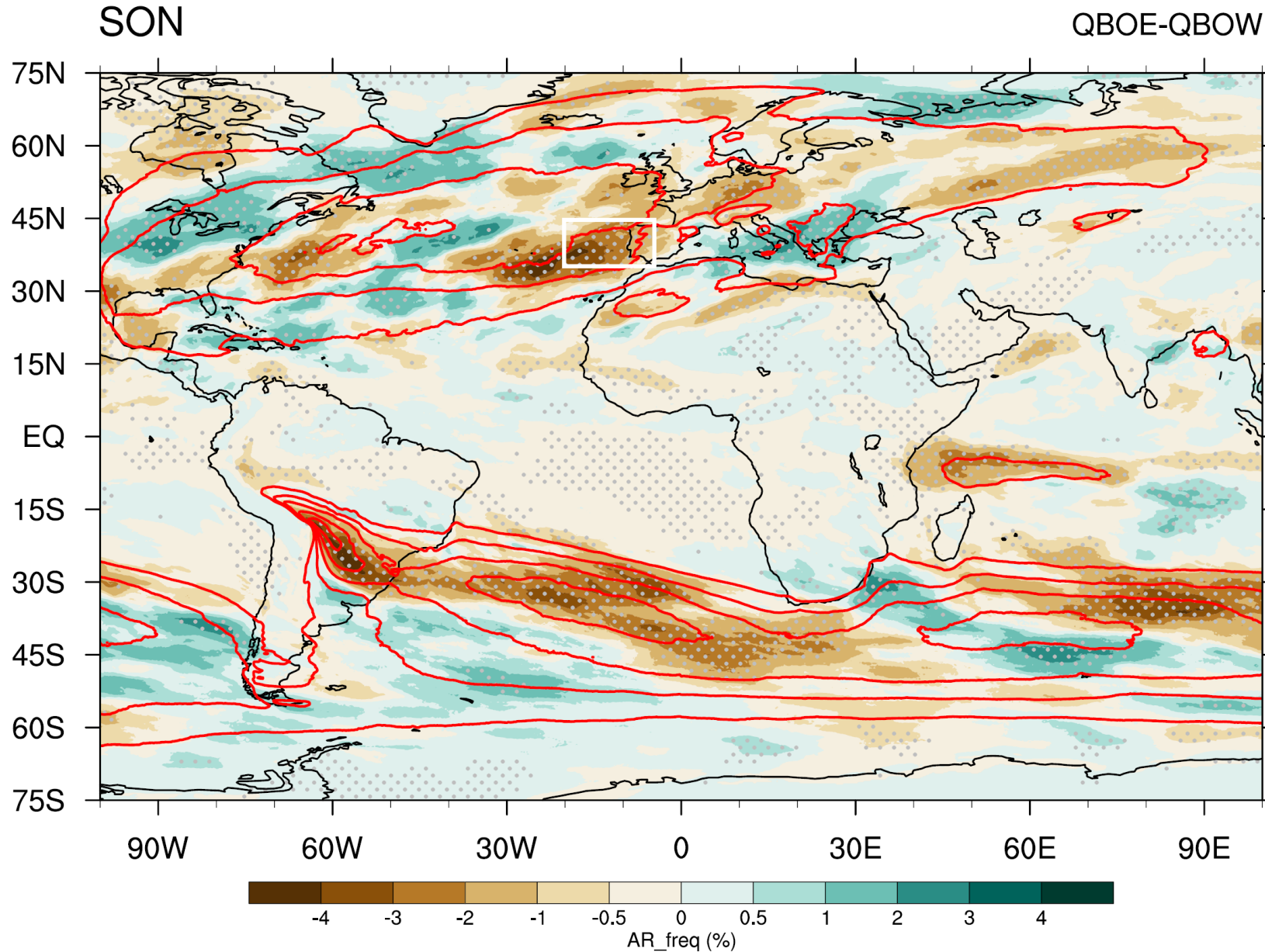
Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



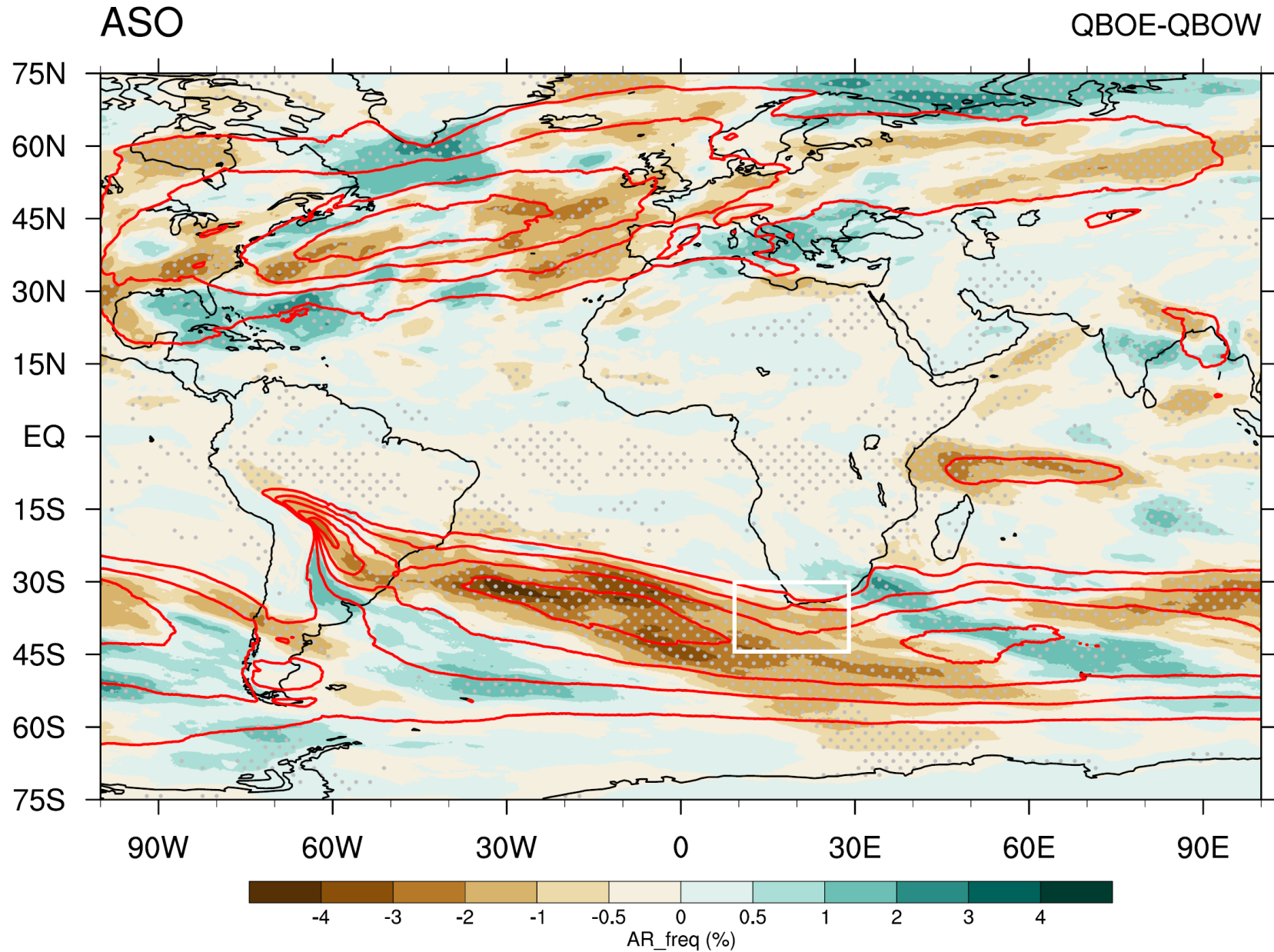
Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)



Seasonal-mean AR frequency for QBOW (lines) and QBOE-QBOW differences (shadings)

