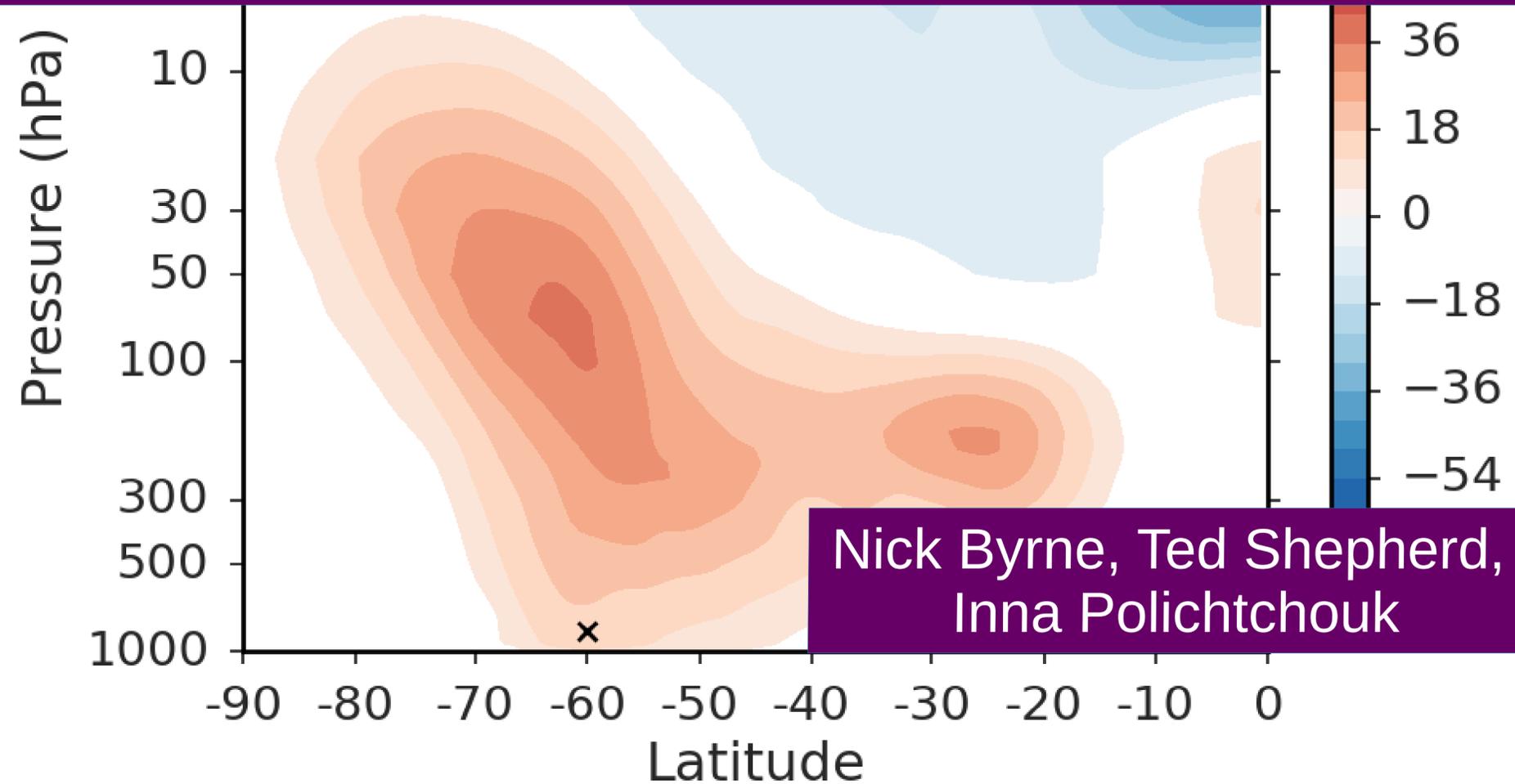
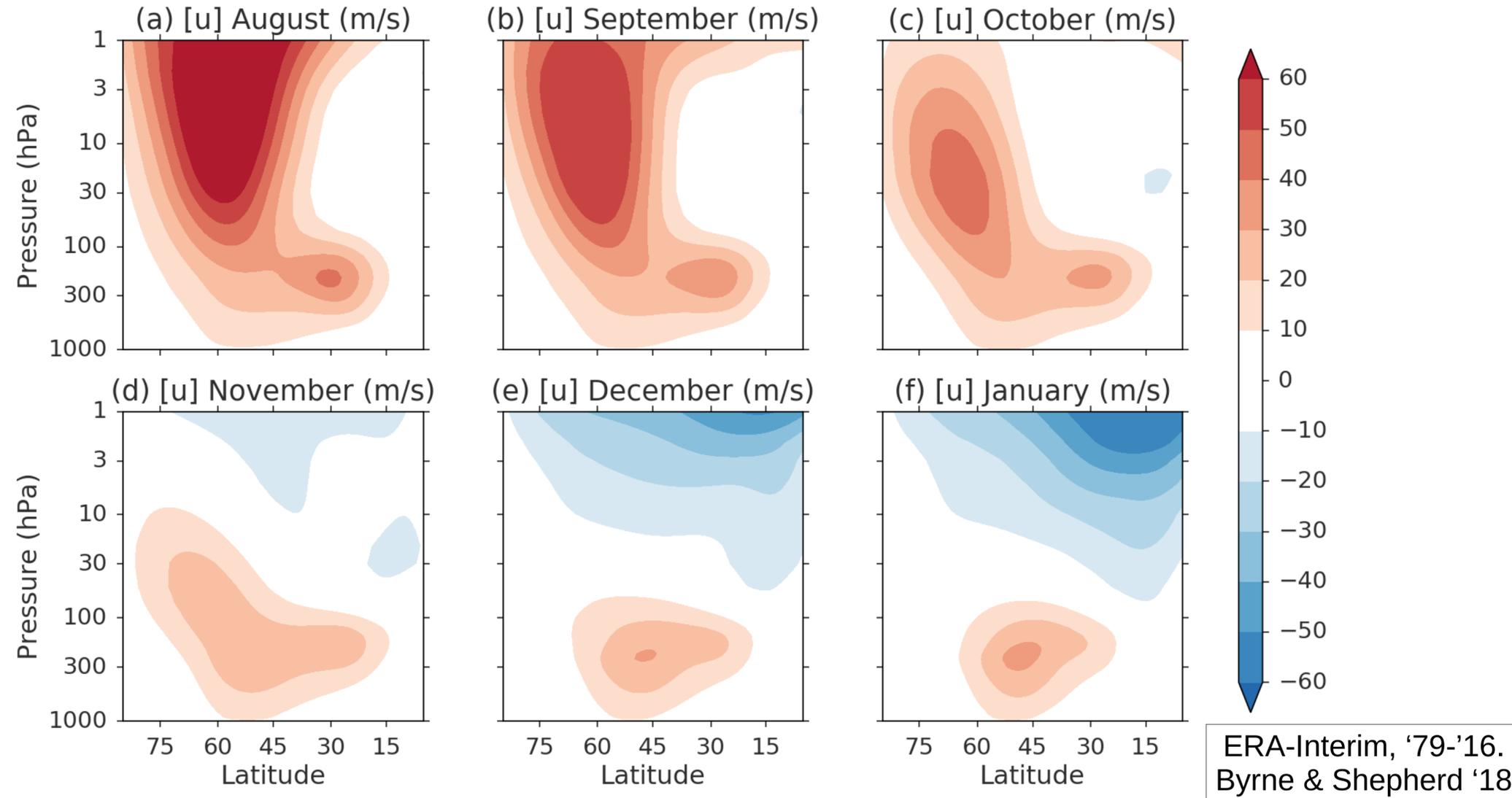


Subseasonal-to-seasonal predictability
of the Southern Hemisphere eddy-driven jet
during austral spring and early summer



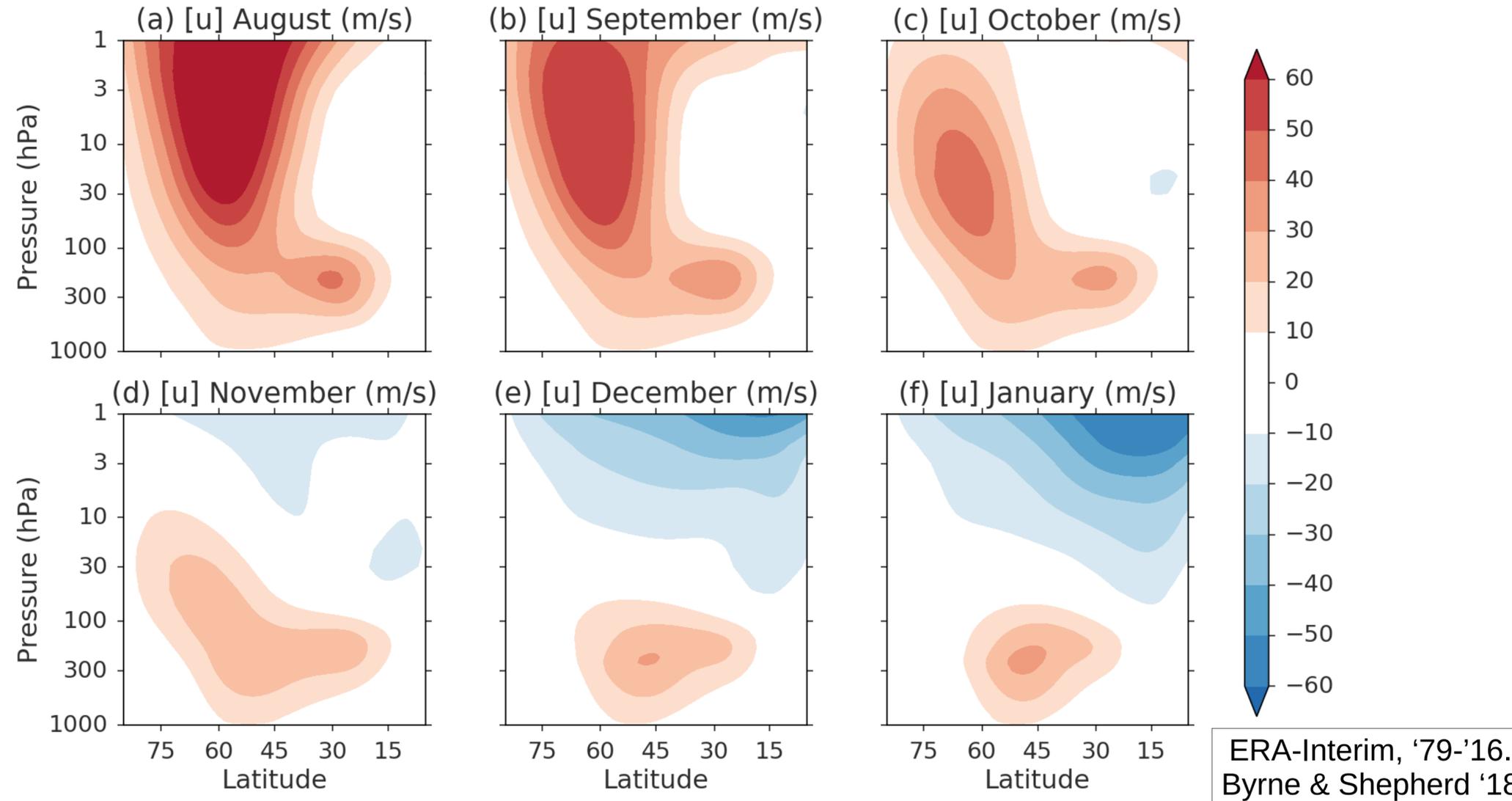
University of
Reading

The 'Downward Shift'



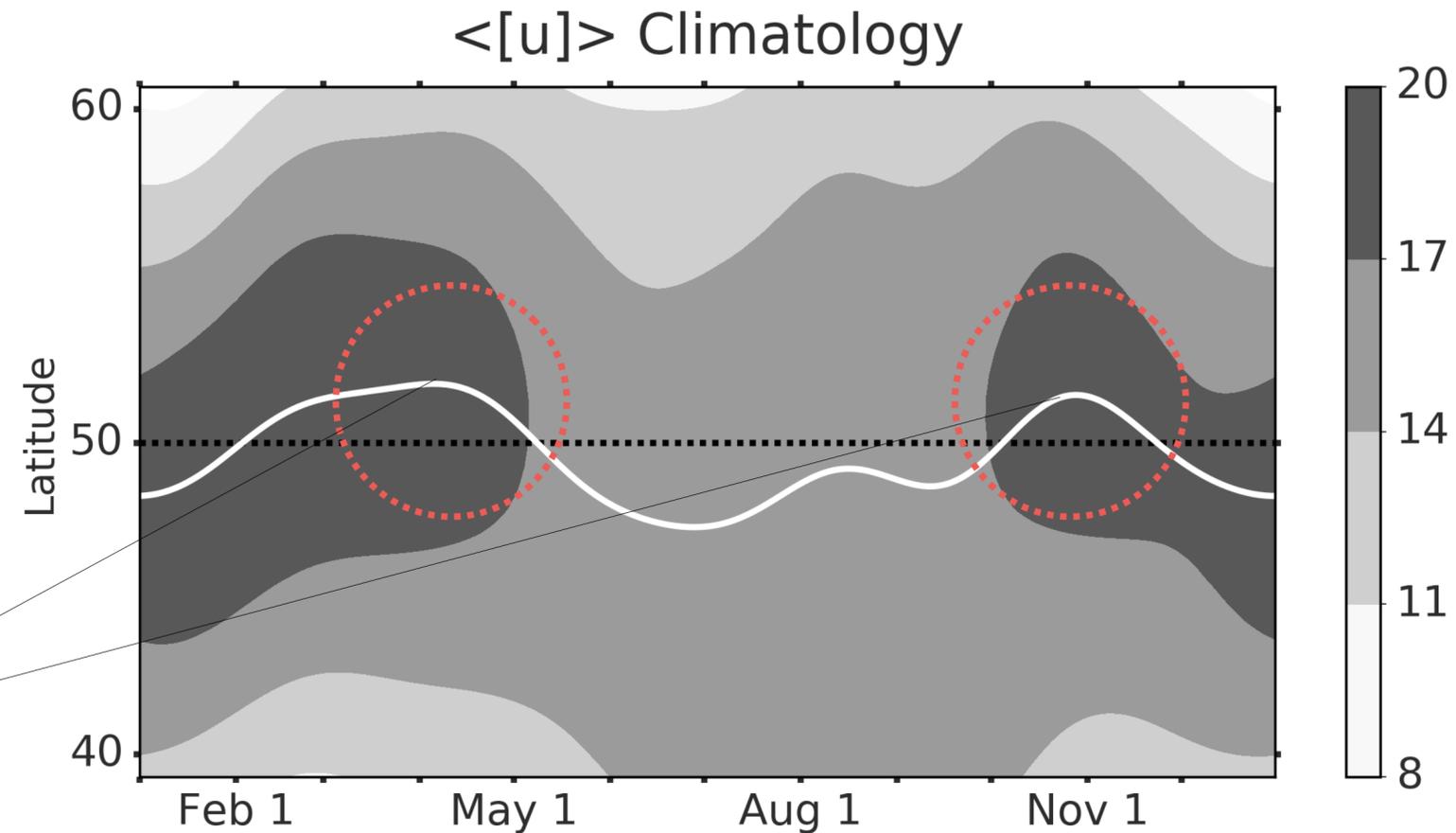
- **Region of strongest winds** in stratosphere shifts downward as part of seasonal cycle.
- Concludes with **stratospheric vortex breakdown event** between November – January.

The 'Downward Shift'



- Considerable **interannual variability** in timing of downward shift.
- **Key idea:** knowledge of timing also gives **information about circulation later in season.**

Semi-Annual Oscillation (SAO)



2 'crests' of oscillation

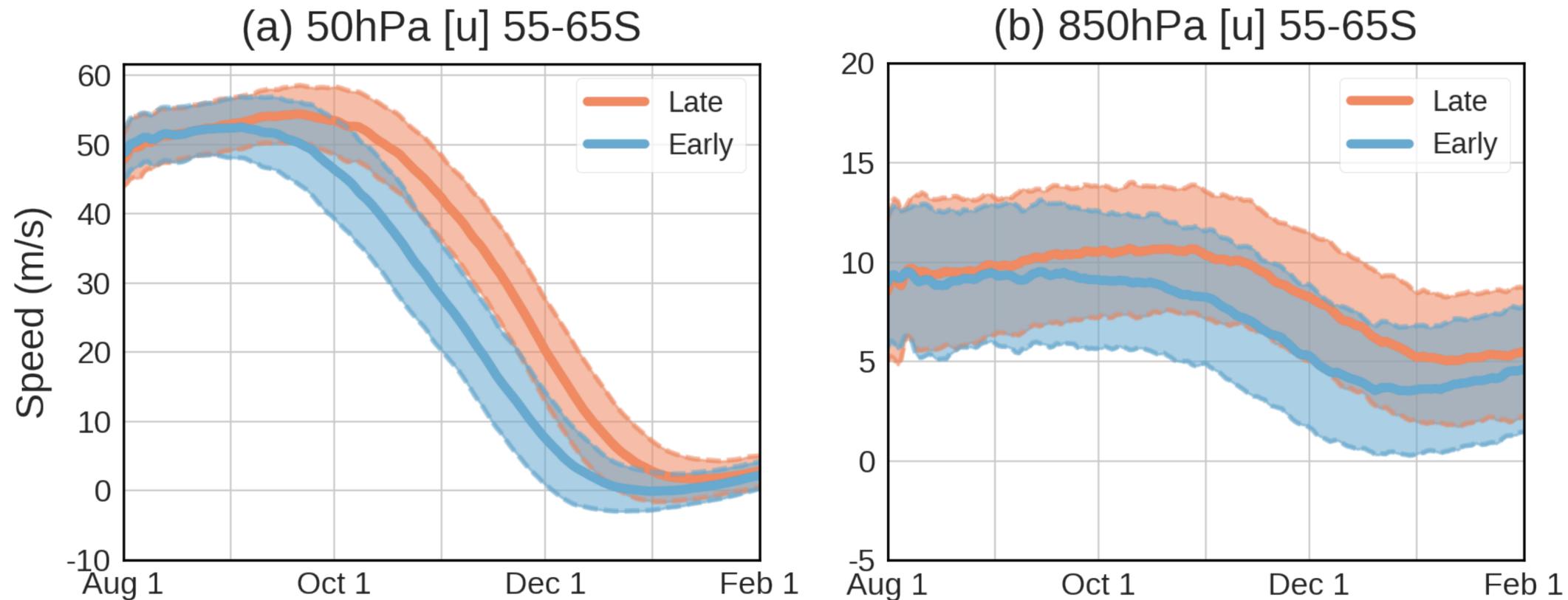
Climatology of tropospheric mid-latitude jet strength (shading) and latitude (white-line).
ERA-Interim, '79-'16. Byrne & Shepherd '18.

- **Hypothesis:** Interannual variability in downward shift will lead to interannual variability in SAO between August and January?

Outline

- Use **large ensemble** of hindcasts (ECMWF System 4, initialised on 1 August) to provide **baseline** for stratospheric impact on troposphere.
- Compare hindcasts against reanalysis to **determine subseasonal-to-seasonal (S2S) skill**. Also use hindcasts to investigate whether evidence of over-dispersive ensemble (**‘signal-to-noise paradox’**).
- Also: How important is **El-Nino Southern Oscillation (ENSO)** for S2S skill of SH mid-latitude jet?

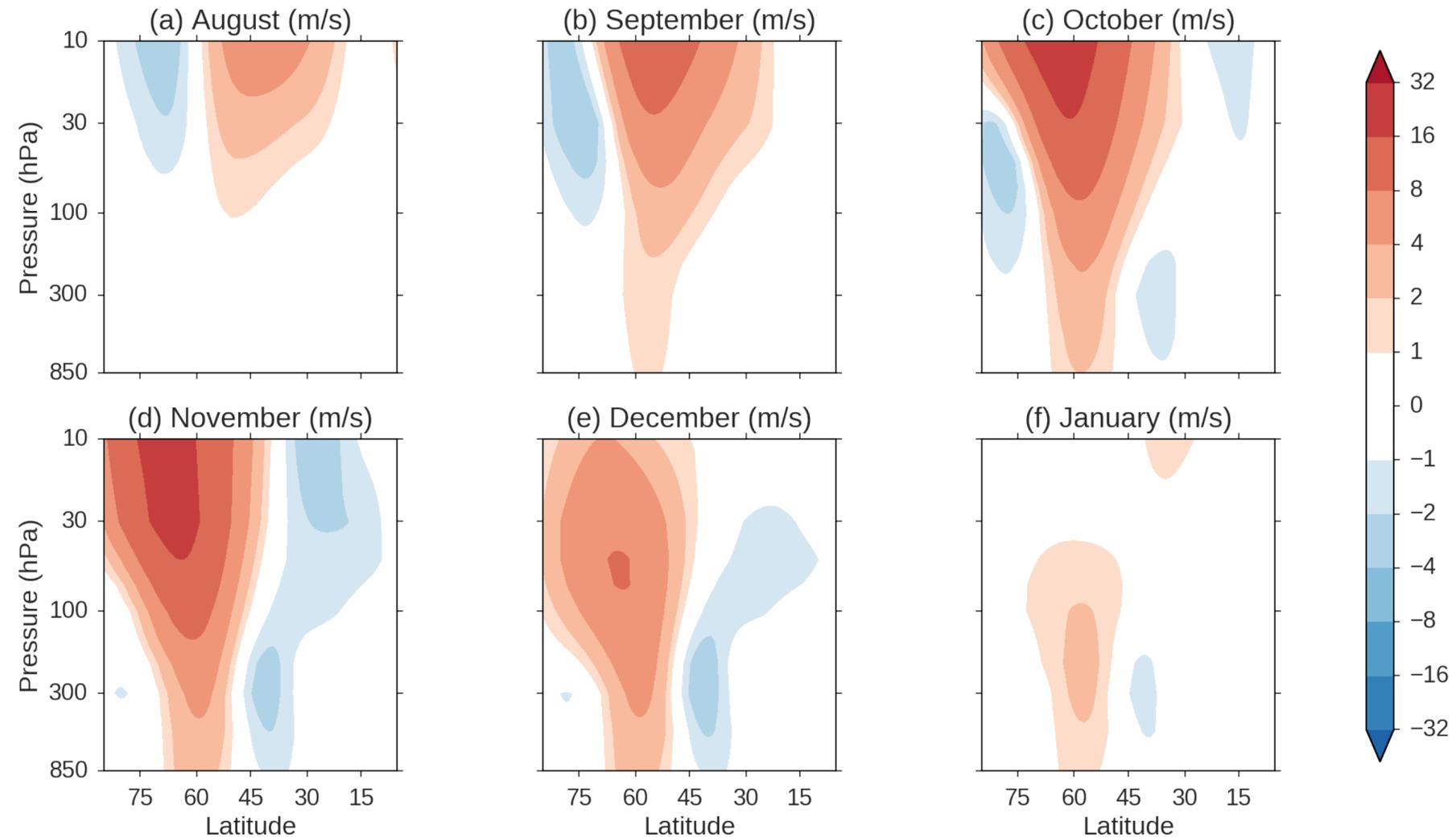
Downward Shift in System 4



(a) Mean (solid line) and mean ± 1 standard deviation (dashed lines) for 50hPa zonal-mean zonal wind 55-65S for late (red) and early (blue) years in ensemble for 1 August initializations. (b) Similar to panel (a) but for 850 hPa. Byrne et al '19

- Define index for early/late downward shift, **classify each year/member** (left panel).
- What is **impact in troposphere** in ensemble (right panel)?

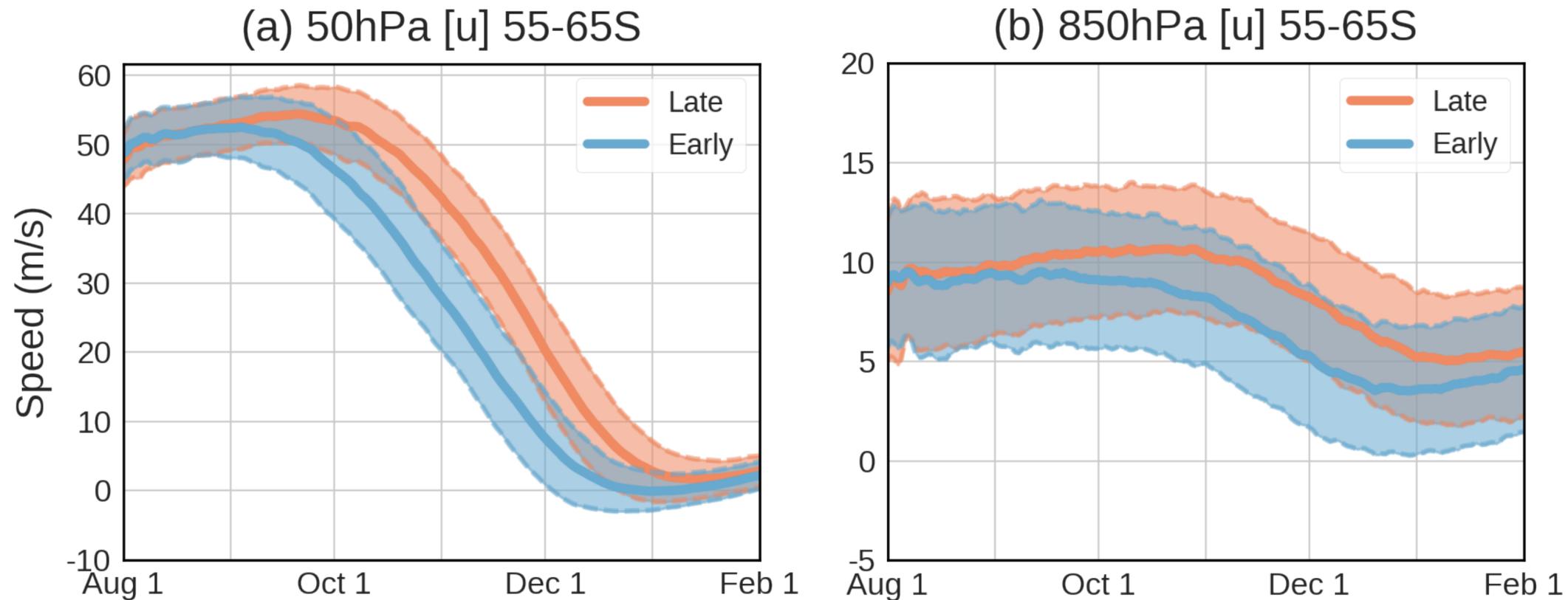
Downward Shift in System 4



Monthly mean differences in zonal-mean zonal wind between late and early years of ensemble for 1 August initializations. Byrne et al '19

- Strongest tropospheric signal in ensemble **from October - January** (September relatively weak).

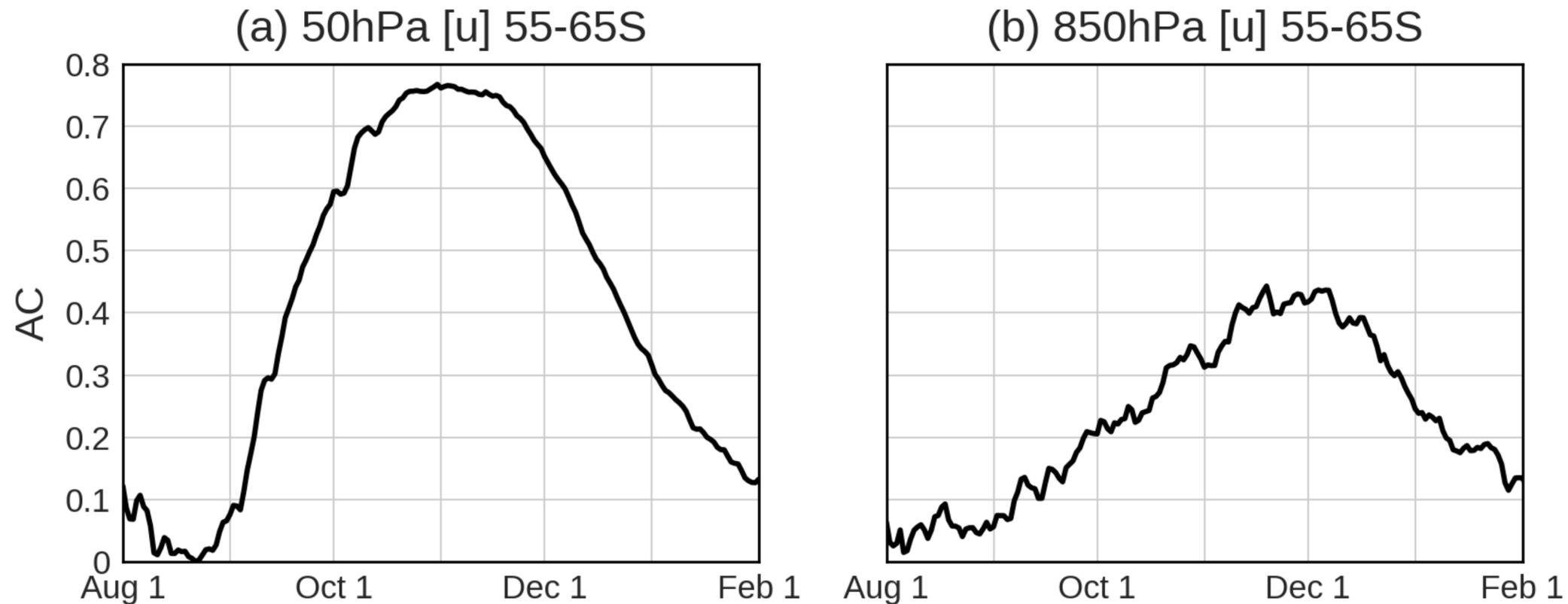
Downward Shift in System 4



(a) Mean (solid line) and mean ± 1 standard deviation (dashed lines) for 50hPa zonal-mean zonal wind 55-65S for late (red) and early (blue) years in ensemble for 1 August initializations. (b) Similar to panel (a) but for 850 hPa. Byrne et al '19

- What is expected skill (anomaly correlation; AC) if **we can correctly forecast early/late?**
- For sufficiently large ensemble, skill $\sim \Delta (\text{mean}) / (2 * \text{standard deviation})$ (Kumar 2009).

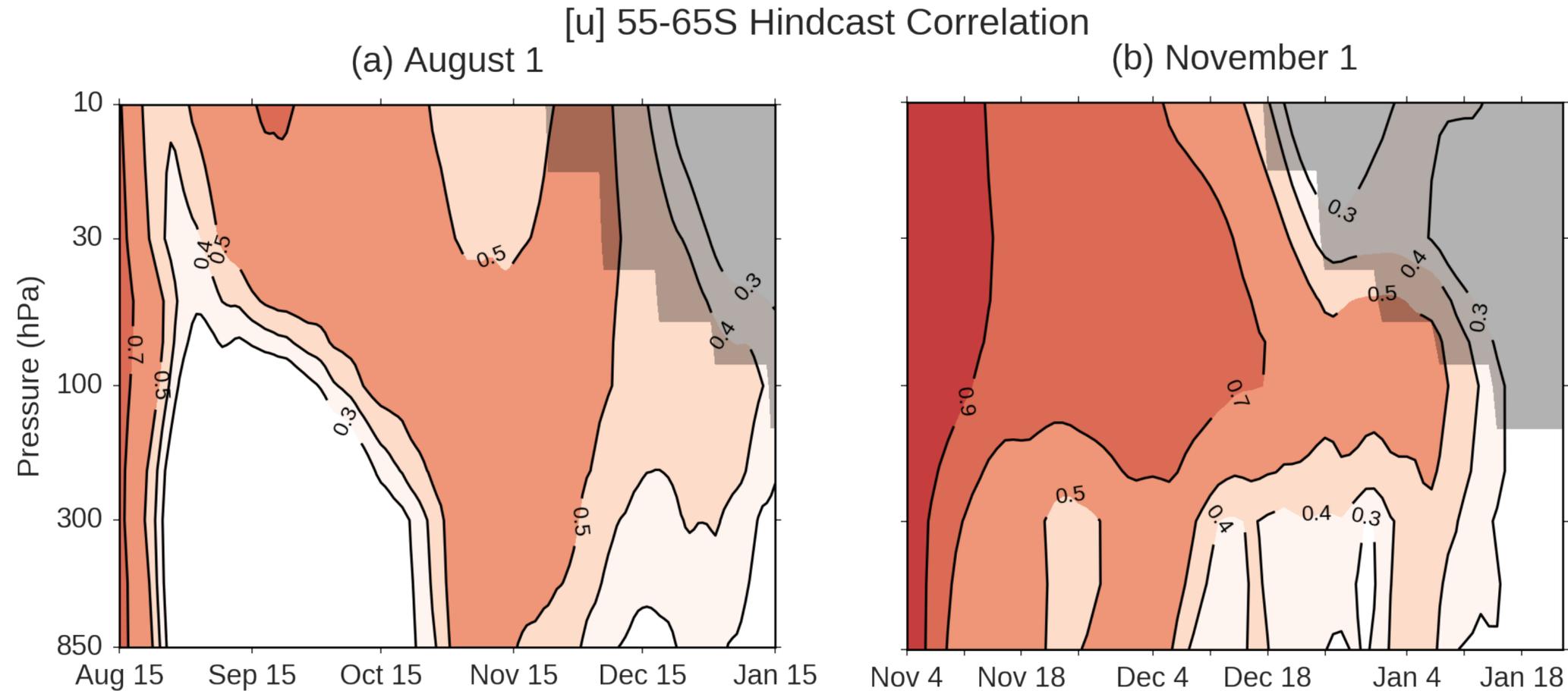
Baseline Estimate of Skill



Expected AC for early/late model for zonal-mean zonal wind 55-65S at (a) 50hPa and (b) 850 hPa. Byrne et al '19

- Tropospheric AC > 0.3 from mid-October (sampling variability dominant if AC < 0.3 ; Kumar 2009).
- Suggests impact of stratosphere on troposphere **difficult to detect** before this point.

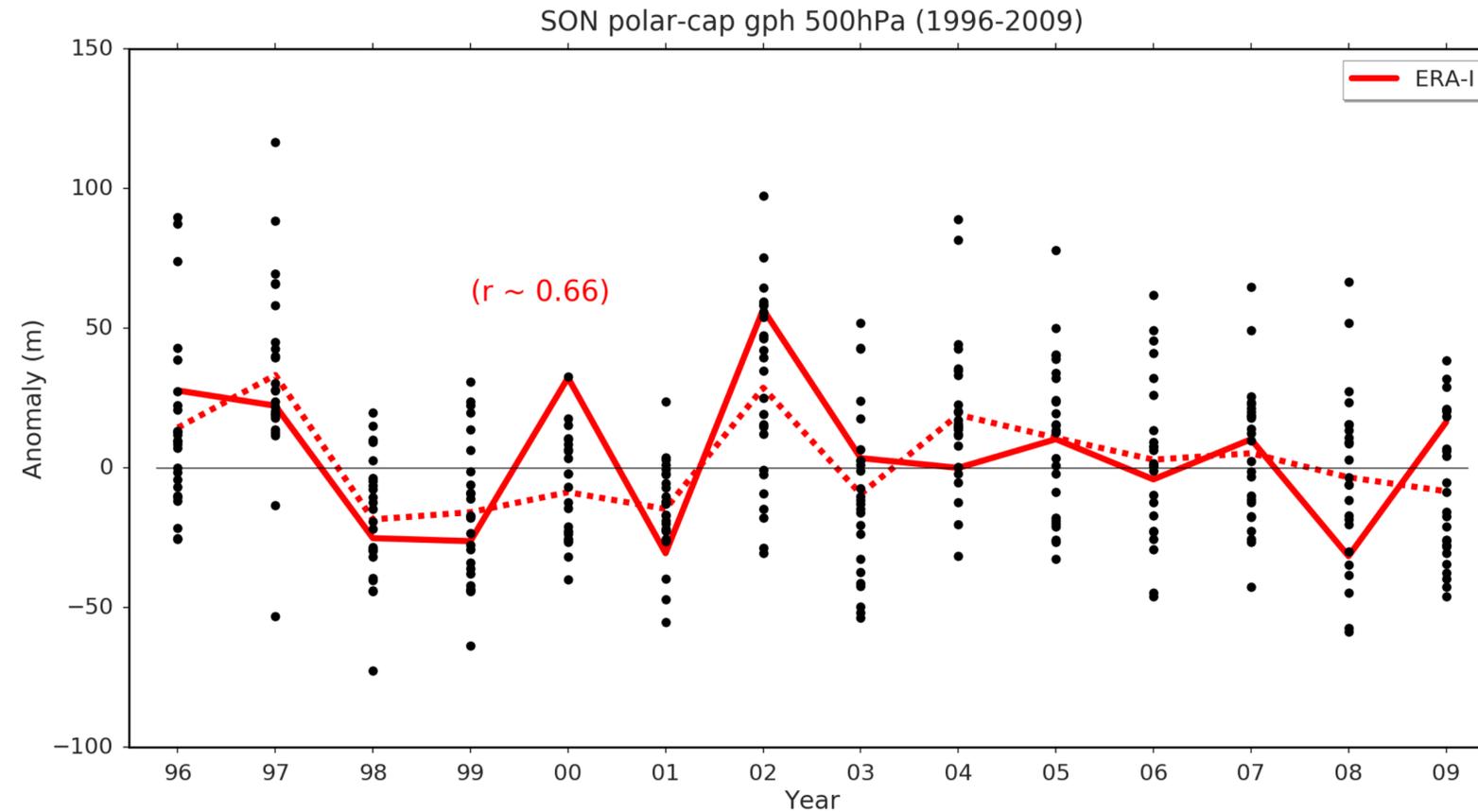
Hindcasts



(a) Correlation between 31-day mean ensemble mean zonal-mean zonal wind 55-65S and 31-day mean zonal-mean zonal wind 55-65S in ERA-Interim for 1 August initialization. (b) As in (a) but for 7-day means for 1 November initialization. Byrne et al '19

- Is **hindcast skill** in agreement with estimate from ensemble?
- Suggests **20-30% of monthly/weekly-mean variability** predictable at 3+ month/week lead time.

Signal-to-Noise Model



September-October-November forecast for polar-cap geopotential height at 500hPa for S4 ensemble members (black dots) and ensemble mean (dashed red line) for 1 August initialisation. Values from ERA-Interim also shown (solid red line).

- Can also define more general model of expected skill – **signal-to-noise model** (Kumar 2009).
- **Signal** ~ standard deviation of ensemble mean (dashed red line).
- **Noise** ~ standard deviation of ensemble members (black dots) about ensemble mean.

Signal-to-Noise Model

Month	AC - S/N	AC - ERA	RMSE/Spread
Aug	0.73 (0.59 , 0.84)	0.78	1.36
Sep	0.29 (-0.06 , 0.49)	-0.12	0.98
Oct	0.29 (-0.04 , 0.50)	0.23	1.23
Nov	0.32 (-0.01 , 0.52)	0.45	1.39
Dec	0.33 (0.02 , 0.53)	0.30	1.08
Jan	0.32 (0.01 , 0.52)	0.28	1.11

Table of values from signal-to-noise model for 1 August initialisation. Byrne et al '19

- Signal-to-noise model shows **no evidence of overdispersive ensemble** (RMSE/Spread $\ll 1$).
- No evidence model better predicts reality than itself (AC-ERA **outside** ensemble AC intervals).

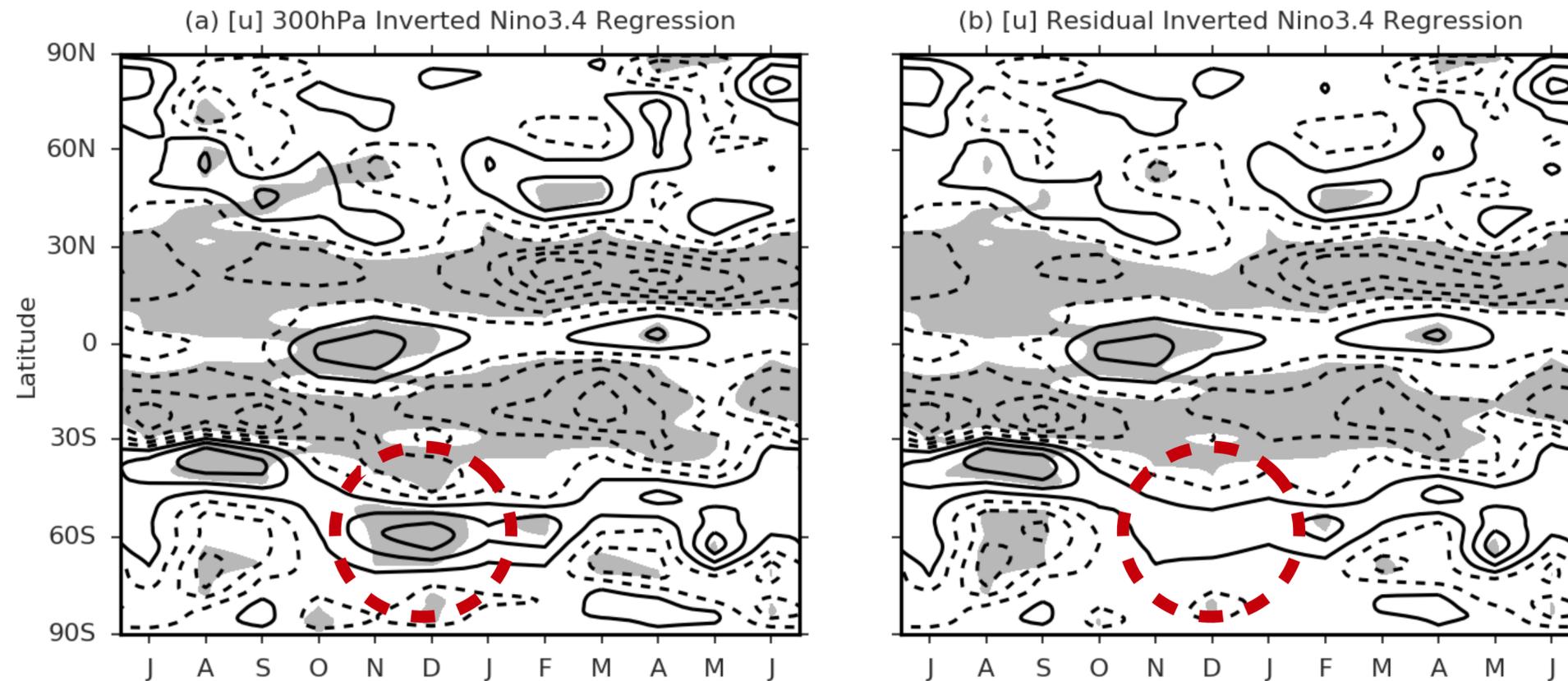
Signal-to-Noise Model

Month	AC - S/N	AC - ERA	RMSE/Spread
Nov	0.74 (0.62 , 0.83)	0.71	1.03
Dec	0.47 (0.20 , 0.65)	0.46	1.04
Jan	0.34 (0.02 , 0.55)	0.37	1.12

Table of values from signal-to-noise model for 1 November initialisation. Byrne et al '19

- Signal-to-noise model shows **no evidence of overdispersive ensemble** (RMSE/Spread $\ll 1$).
- No evidence model better at predicting reality than itself (AC-ERA **within** ensemble AC intervals).

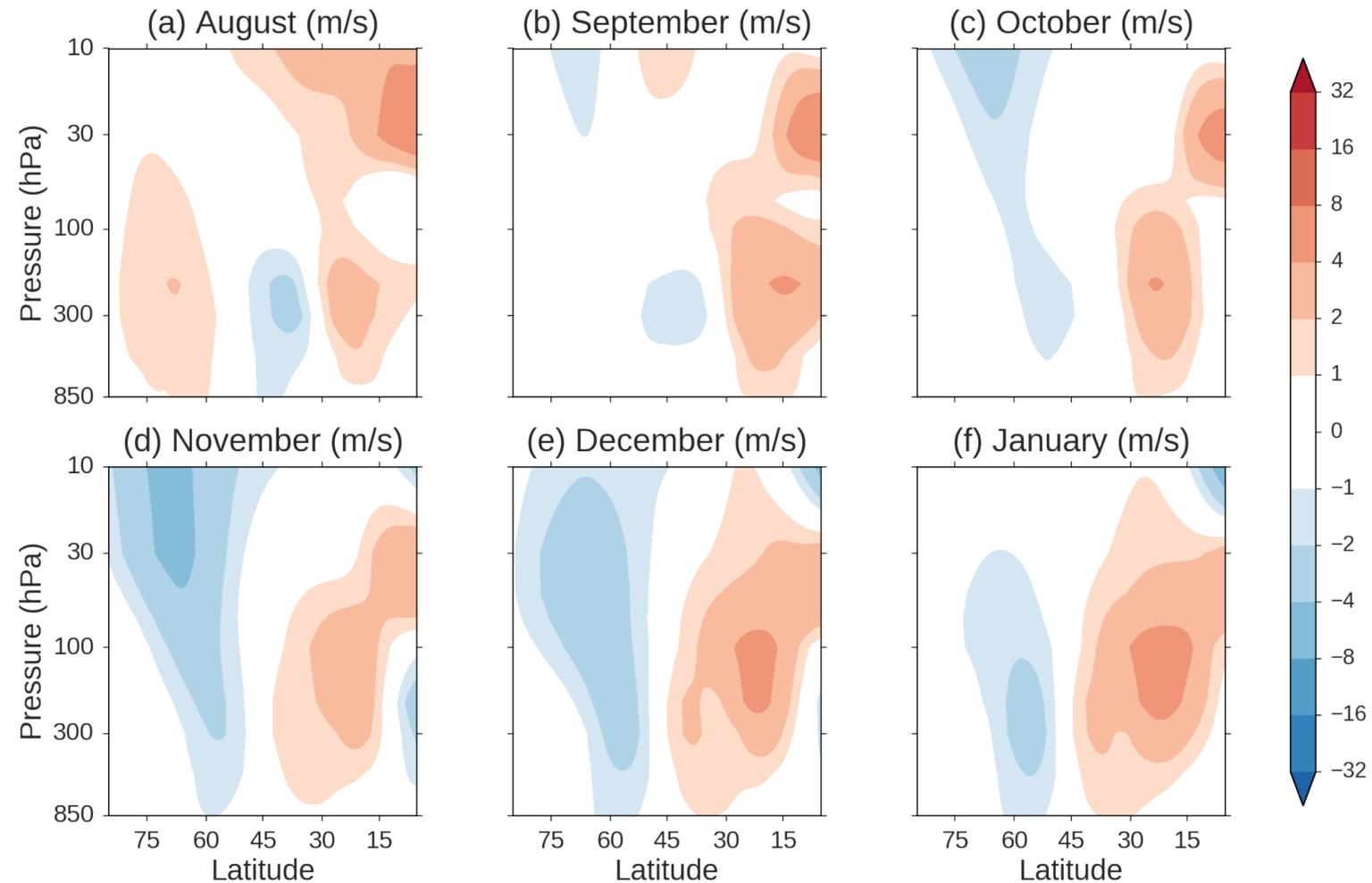
ENSO-Stratosphere Pathway



Regression of [u] 300hPa against ENSO for (left) raw and (right) residual time series. ERA-Interim '79-'16. Byrne et al '17

- Link (correlation) between ENSO/jet **documented for NDJF** (e.g. L'Heureux & Thompson 2006).
- Link **vanishes** when stratospheric pathway removed (multiple regression).

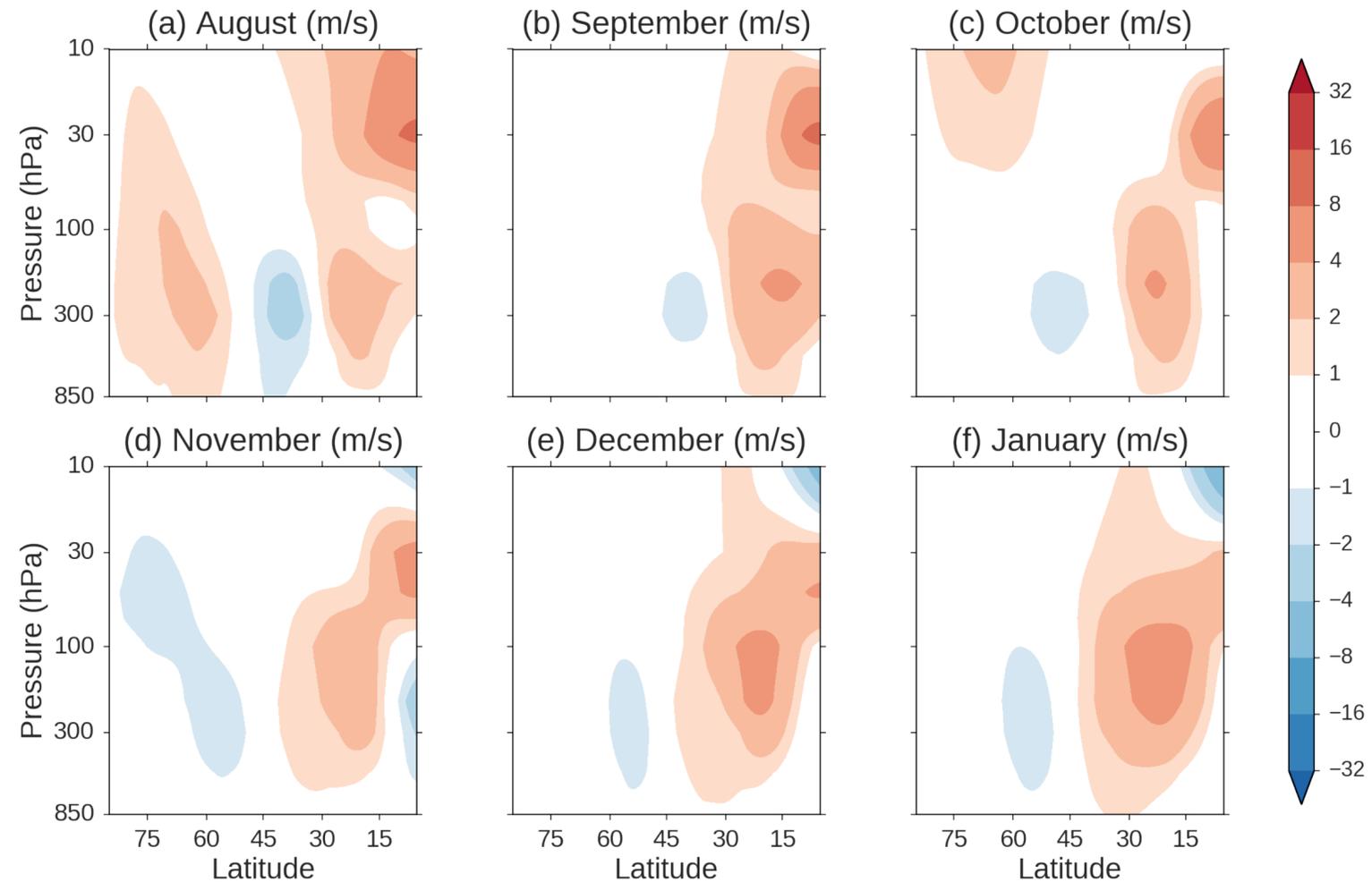
ENSO Teleconnection in S4



Differences in S4 [u] between El Niño and La Niña. Byrne et al '19

- Can **use ensemble** to probe ENSO-stratosphere-jet link.
- ENSO-jet relationship strongest from November onwards, **consistent with reanalysis**.

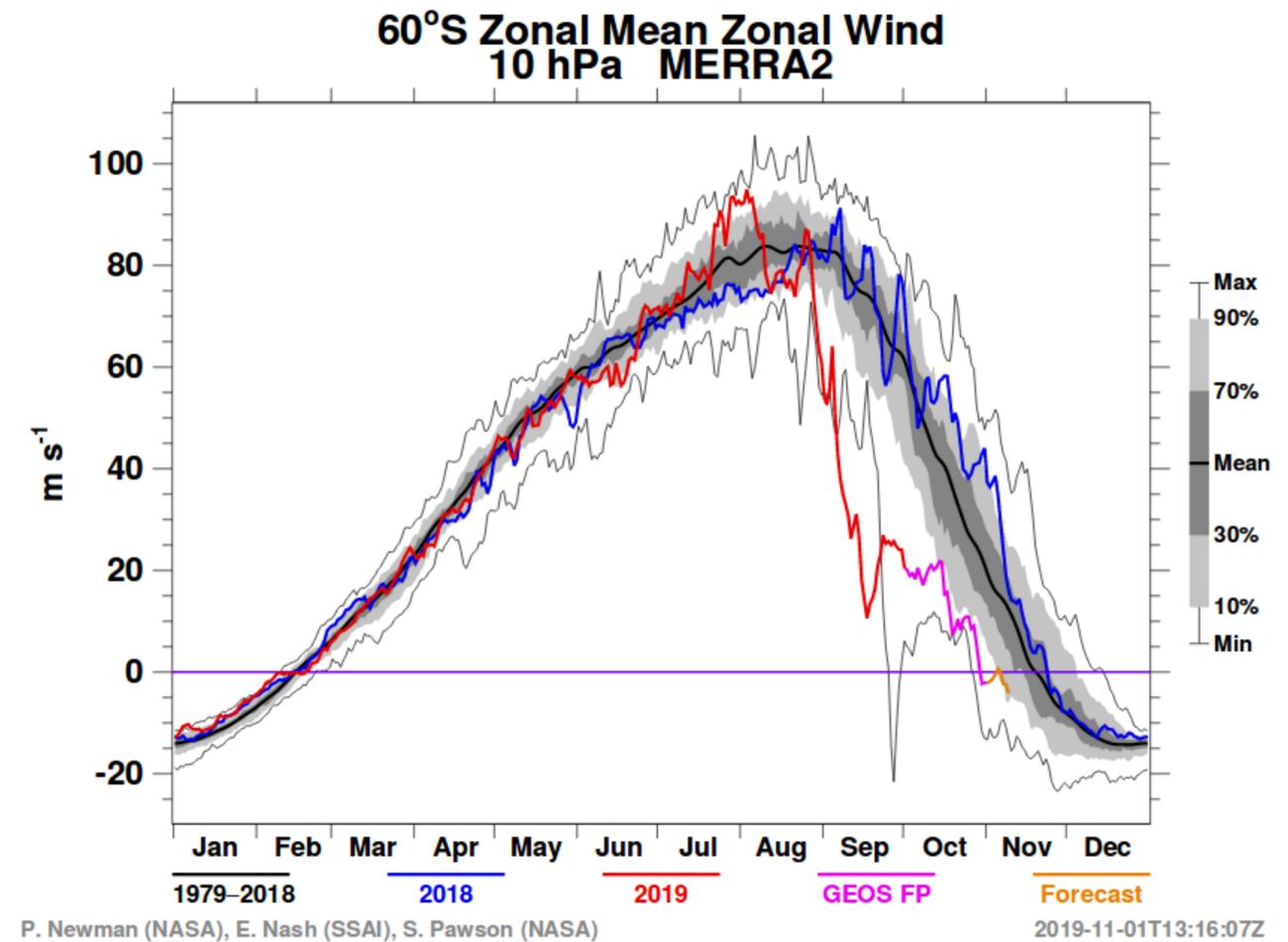
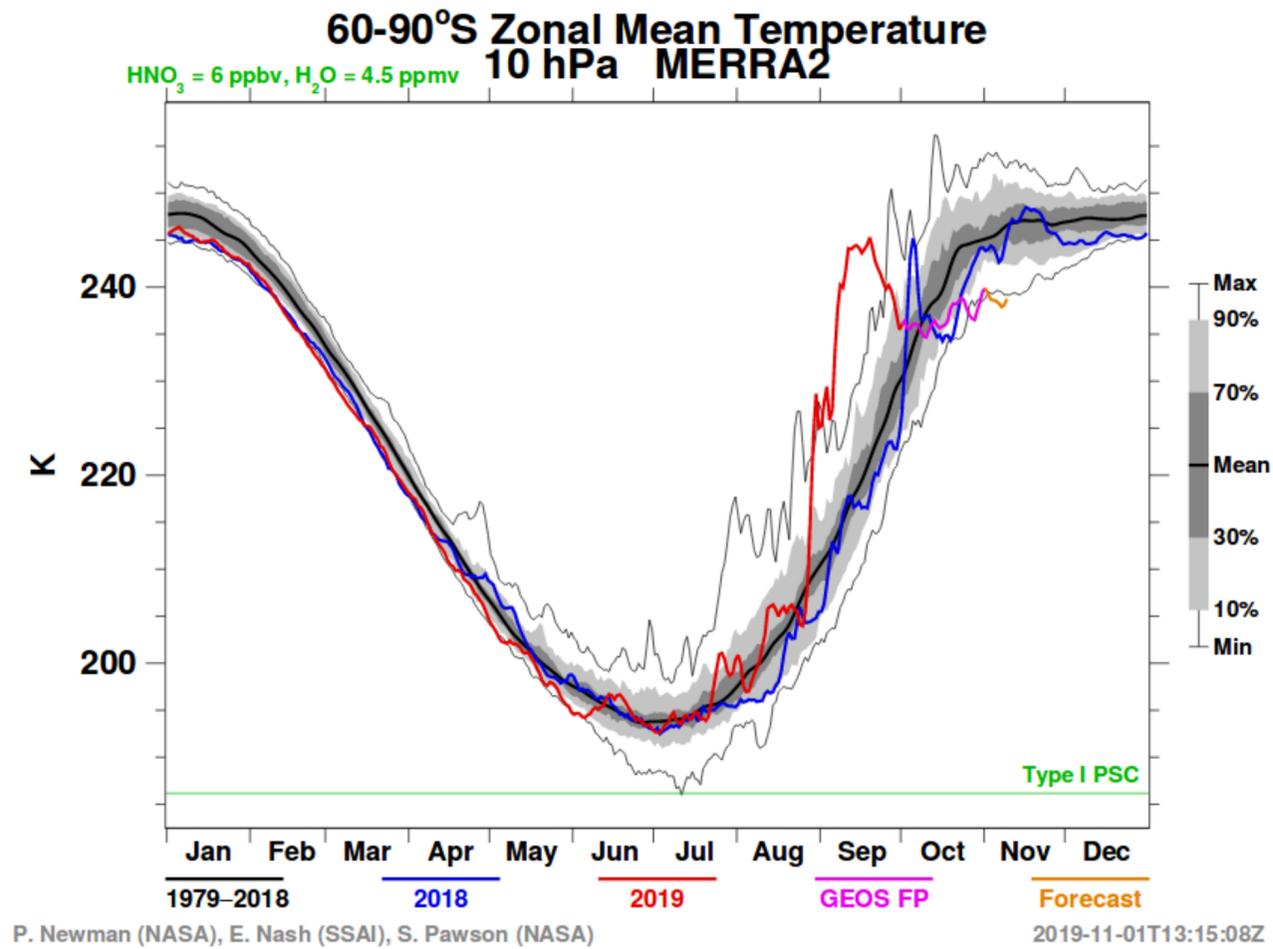
ENSO Teleconnection in S4



Differences in S4 [u] between El Niño and La Niña for early stratosphere years only. Byrne et al '19

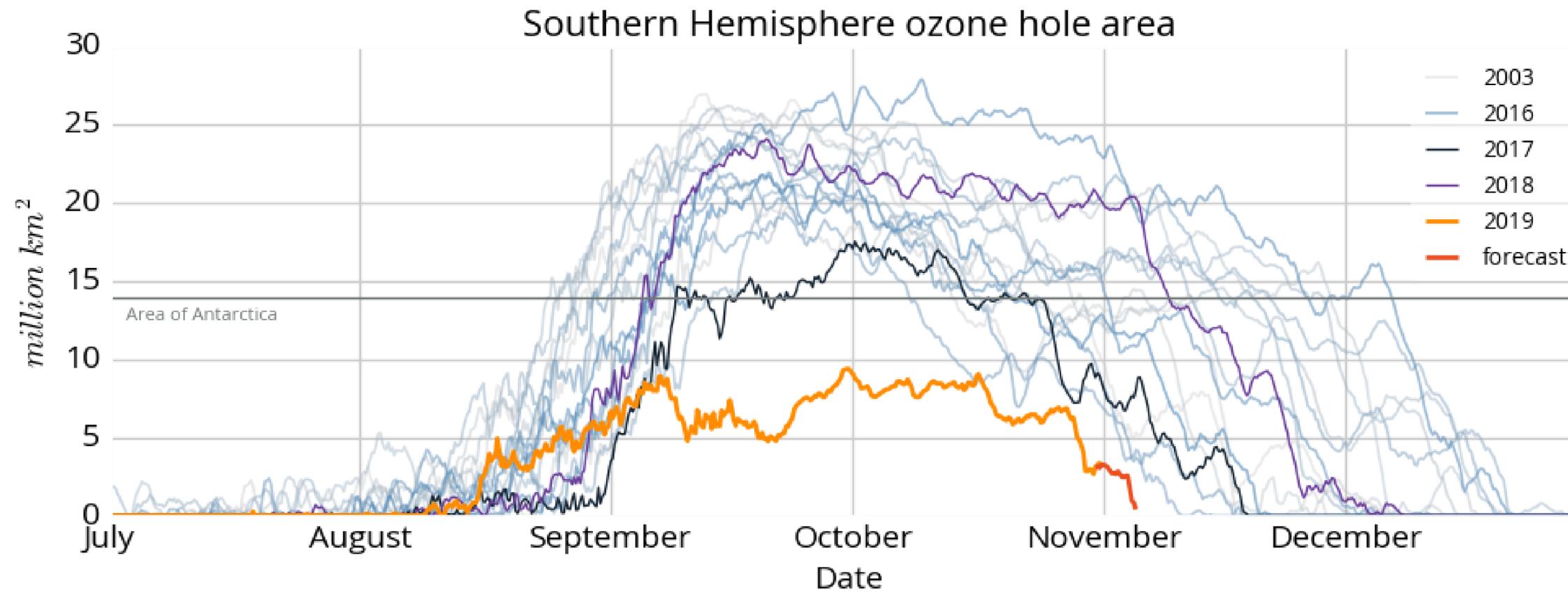
- Signal largely vanishes **after stratospheric pathway removed** (condition on early/late years).
- **Conclusion:** ENSO appears to impact stratosphere, which then impacts troposphere.

The Disturbance of 2019



Plots via webpage of Paul Newman
https://acd-ext.gsfc.nasa.gov/Data_services/met/ann_data.html

The Disturbance of 2019

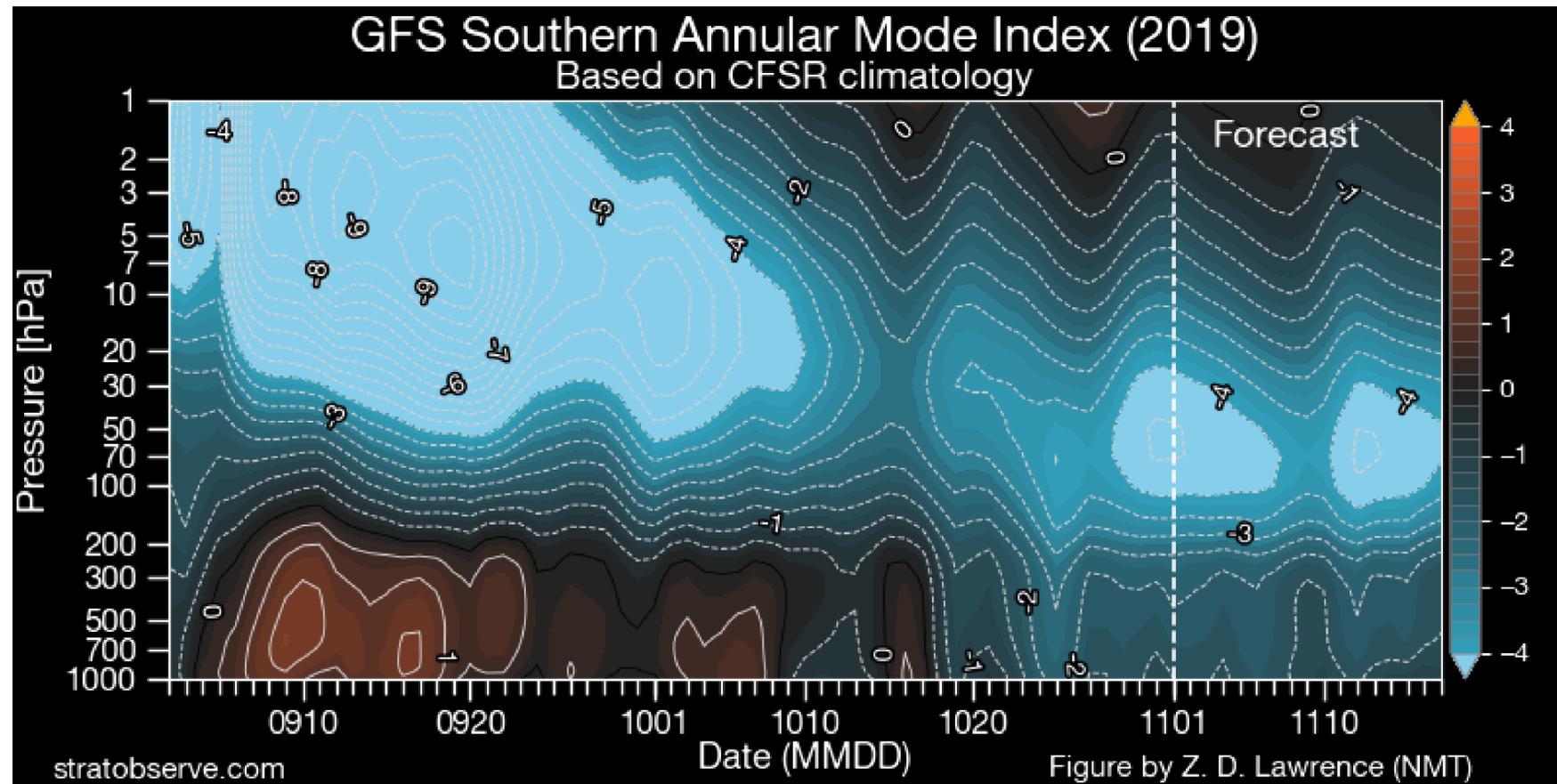


Last update: 2019-11-01T10:15Z

@CopernicusECMWF

Plot from Copernicus Atmosphere Monitoring Service, ECMWF

The Disturbance of 2019

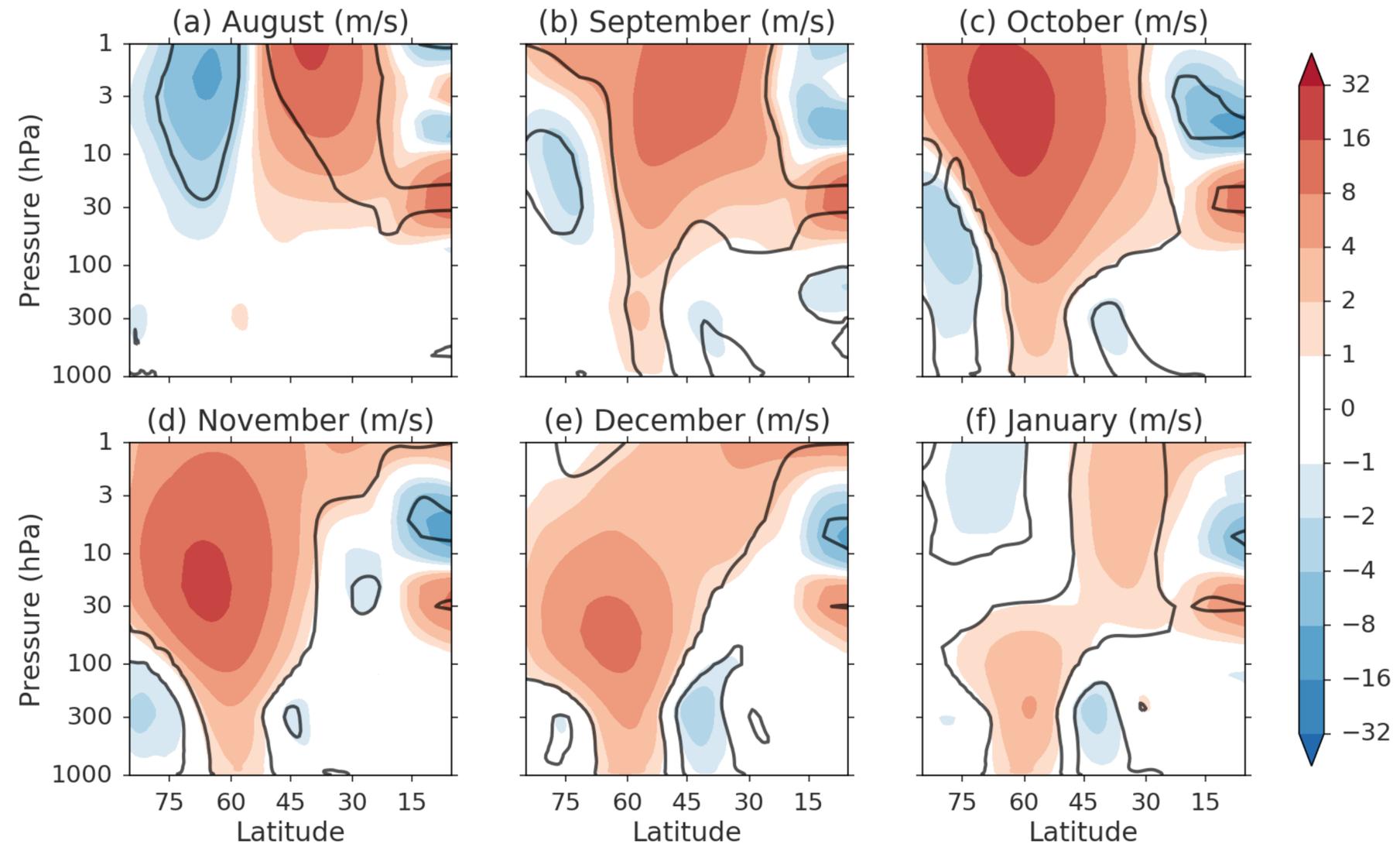


Plot via webpage of Zachary Lawrence
<https://www.stratobserve.com/>

Summary

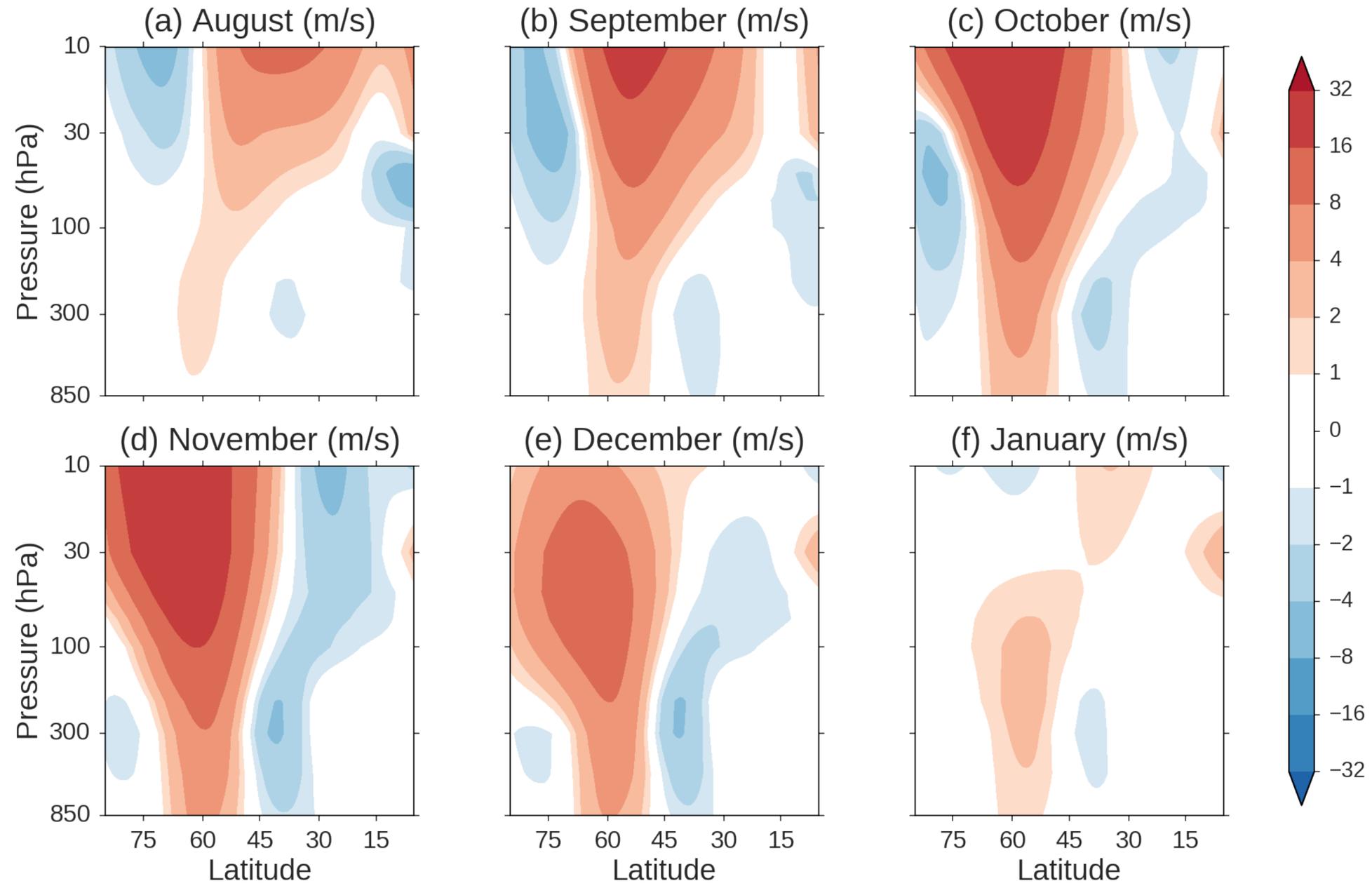
- Interannual variability in downward shift of stratospheric vortex **leads to** interannual variability in tropospheric SAO between August and January.
- Moderate S2S tropospheric skill associated with stratospheric disturbances:
 - **20-30% of monthly-mean variability** at 3+ month lead time, 1 Aug start date.
 - **20-30% of weekly-mean variability** at 3+ week lead time , 1 Nov start date.
- **No evidence** for overdispersive ensemble.
- ENSO-jet link appears to be almost entirely **via stratosphere.**

Additional Slides



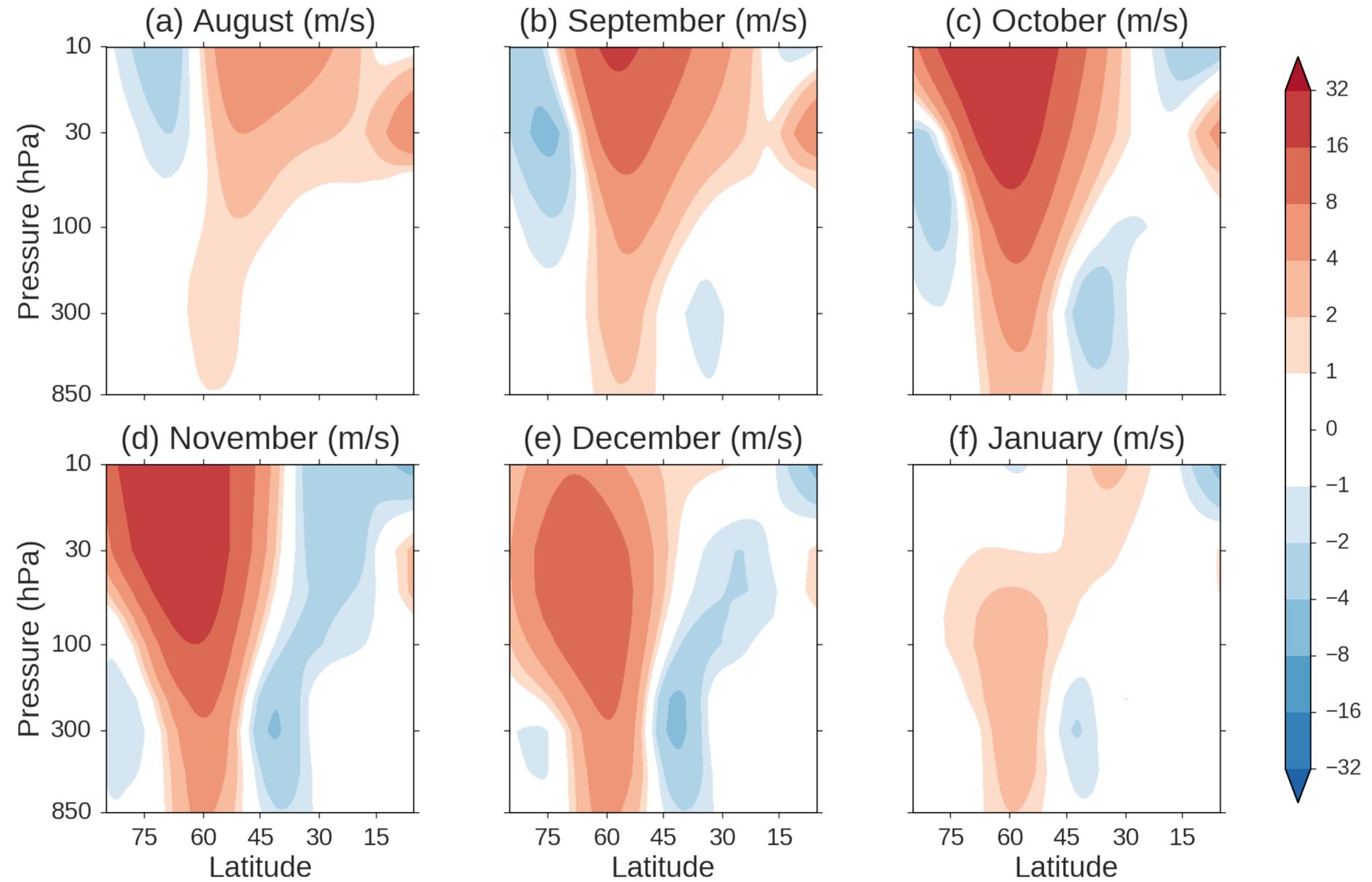
ERA-Interim

Additional Slides



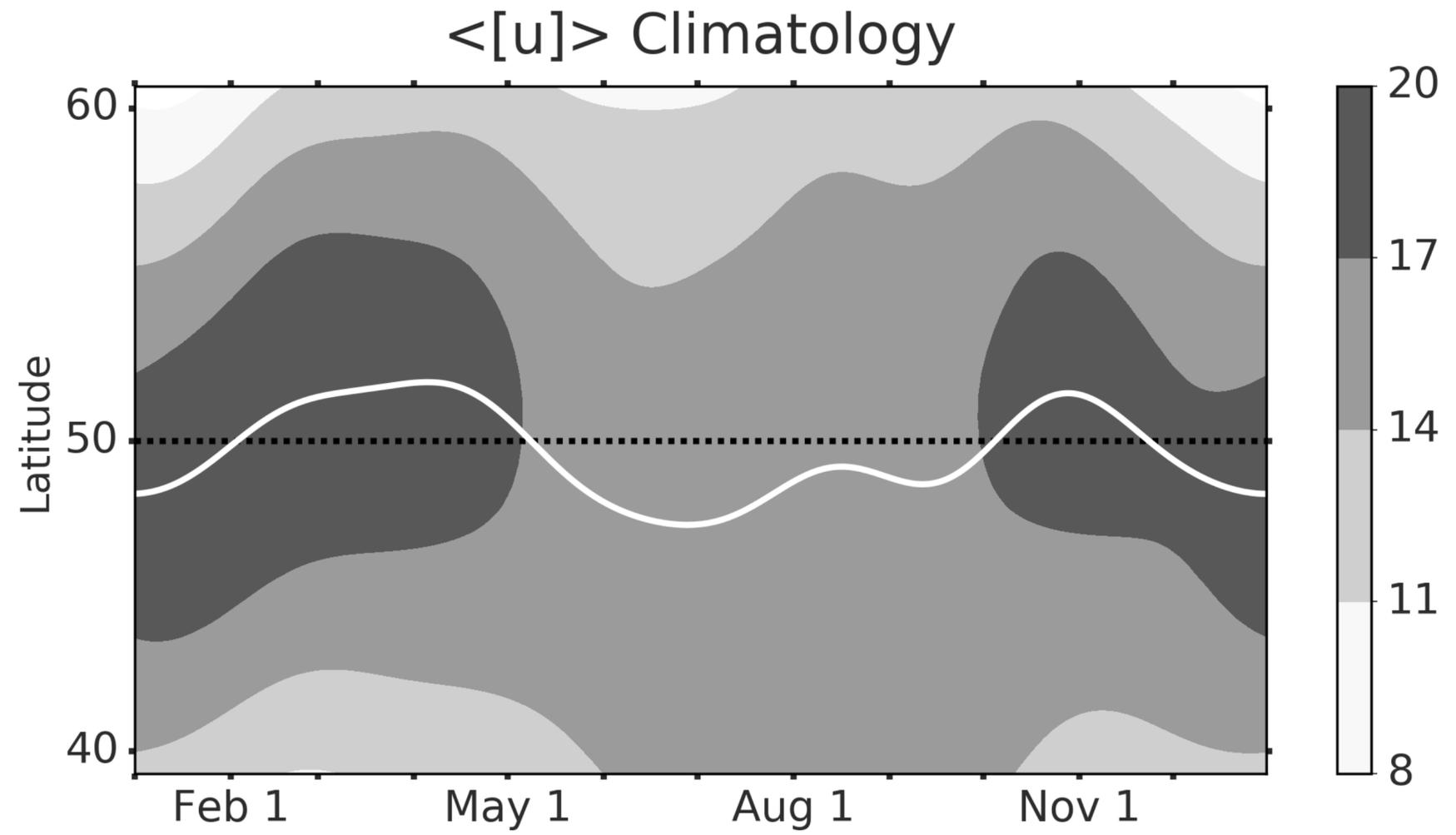
El Nino - S4

Additional Slides

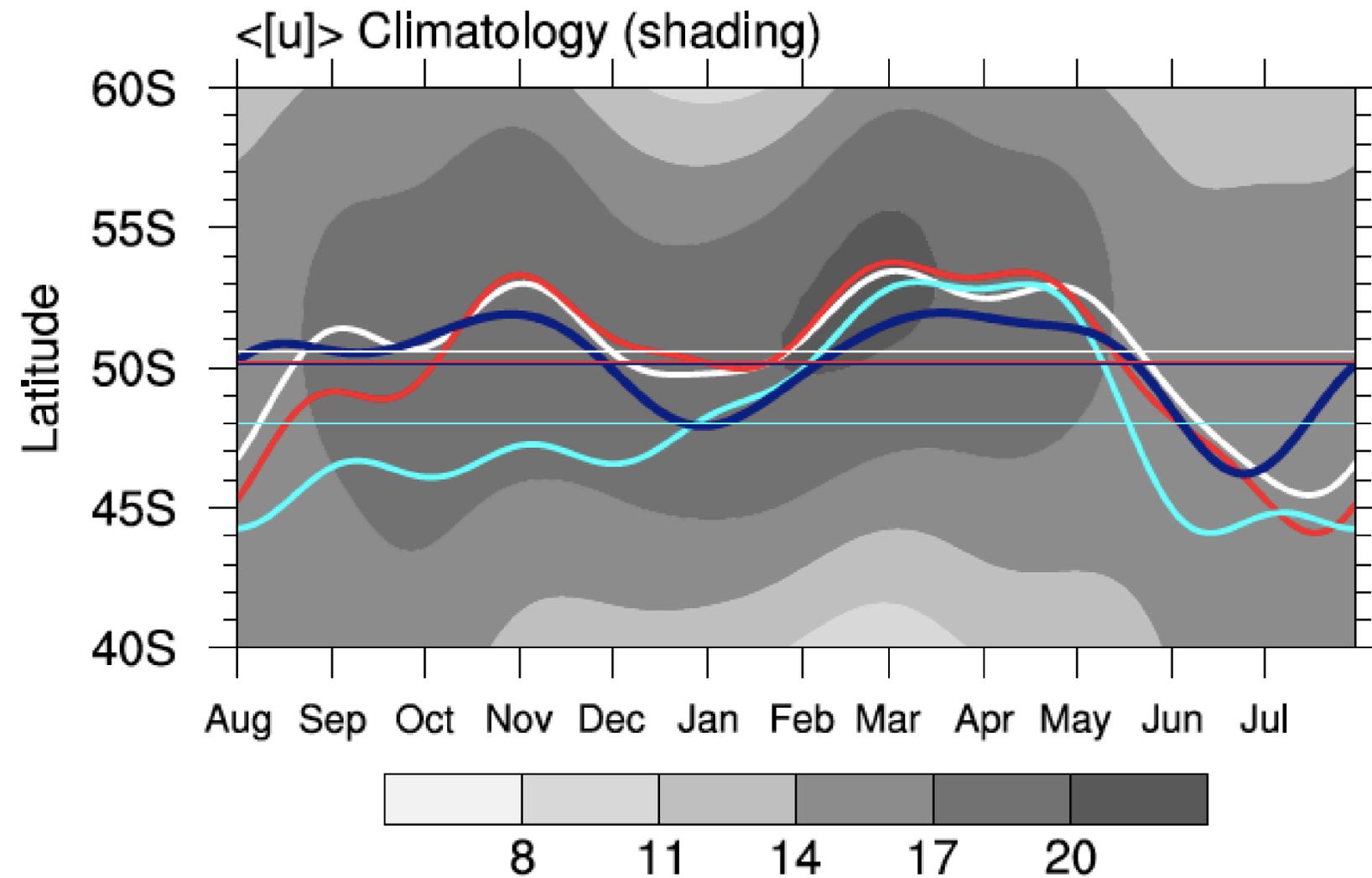


La Nina - S4

Additional Slides

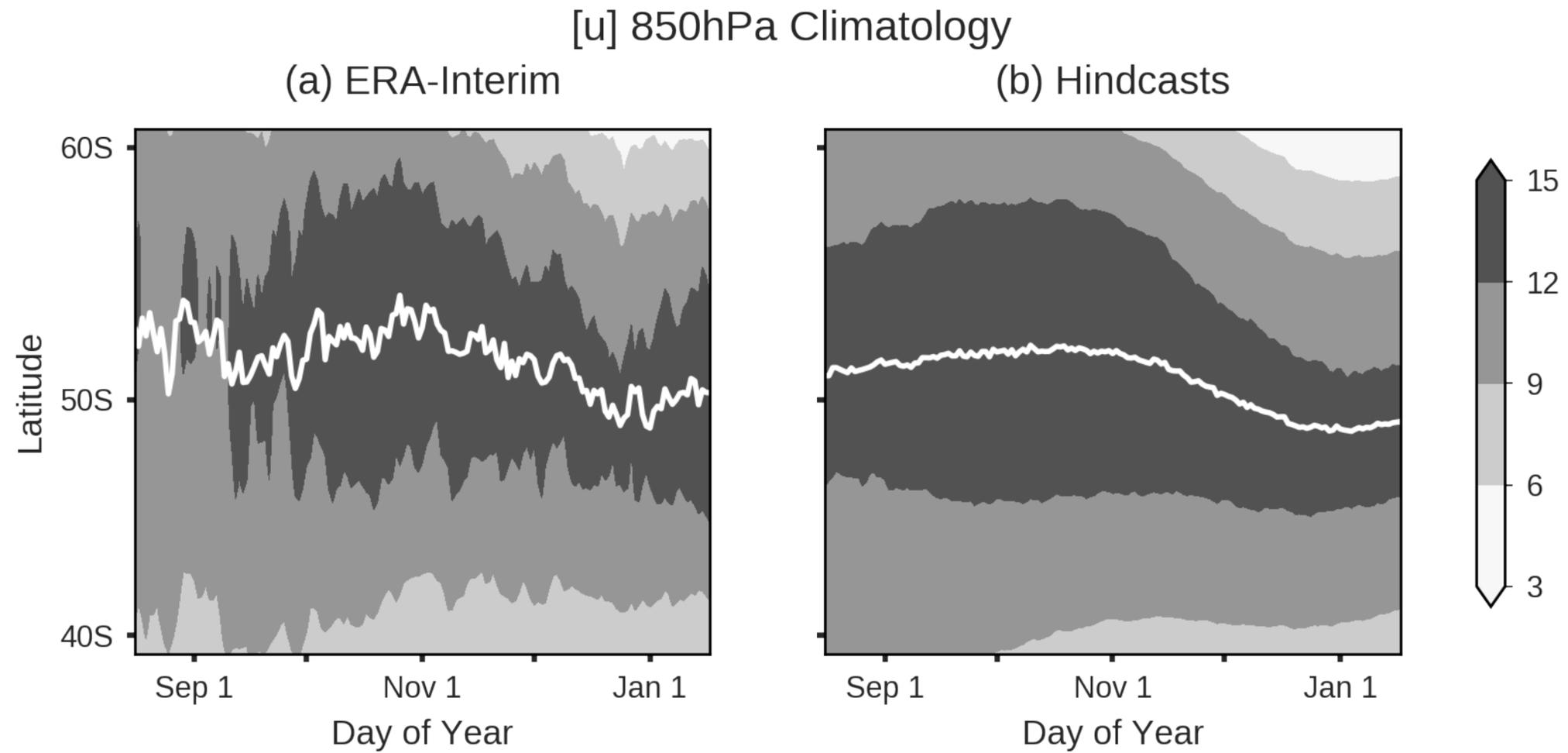


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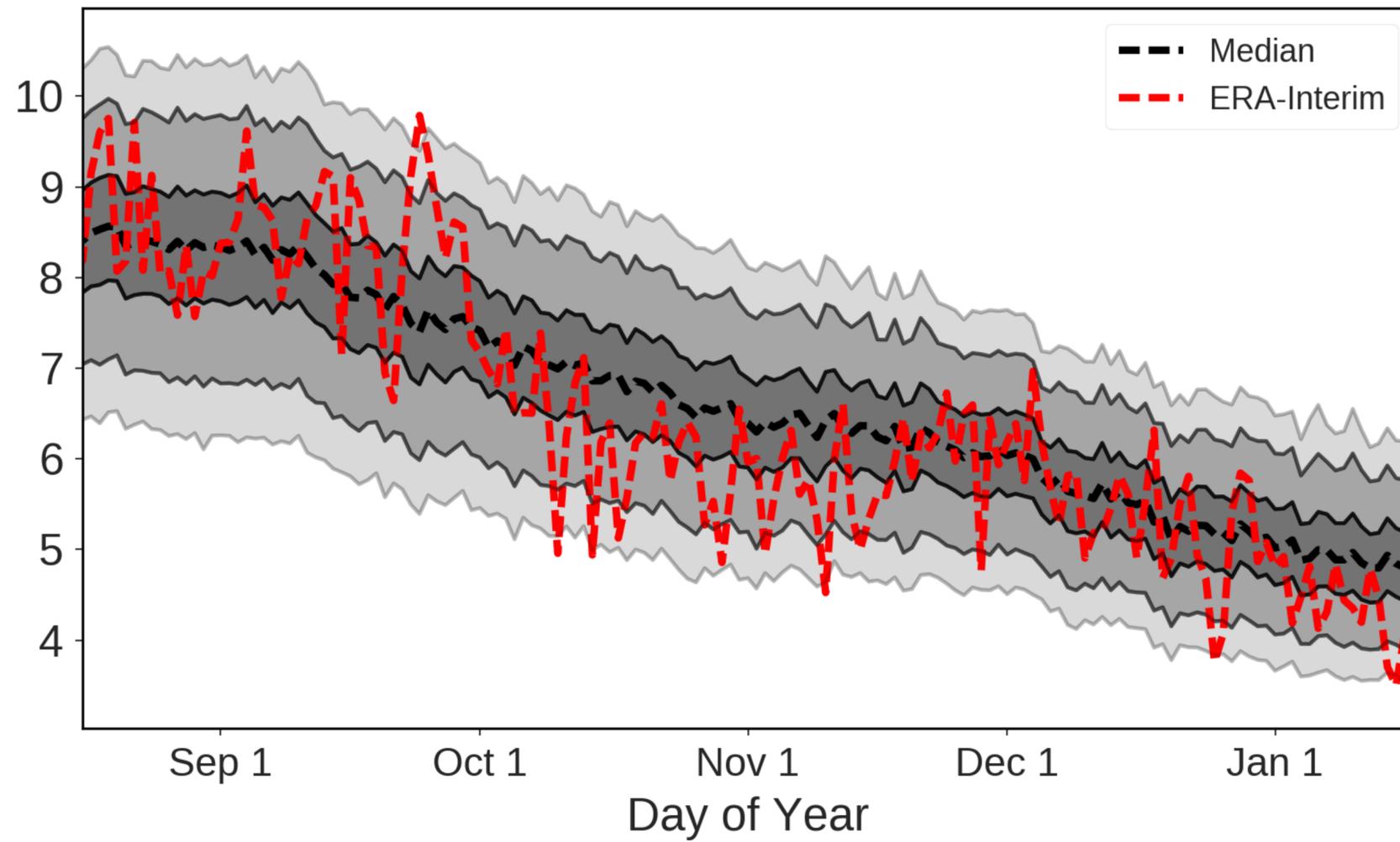
Polichtchouk et al 2018

Additional Slides

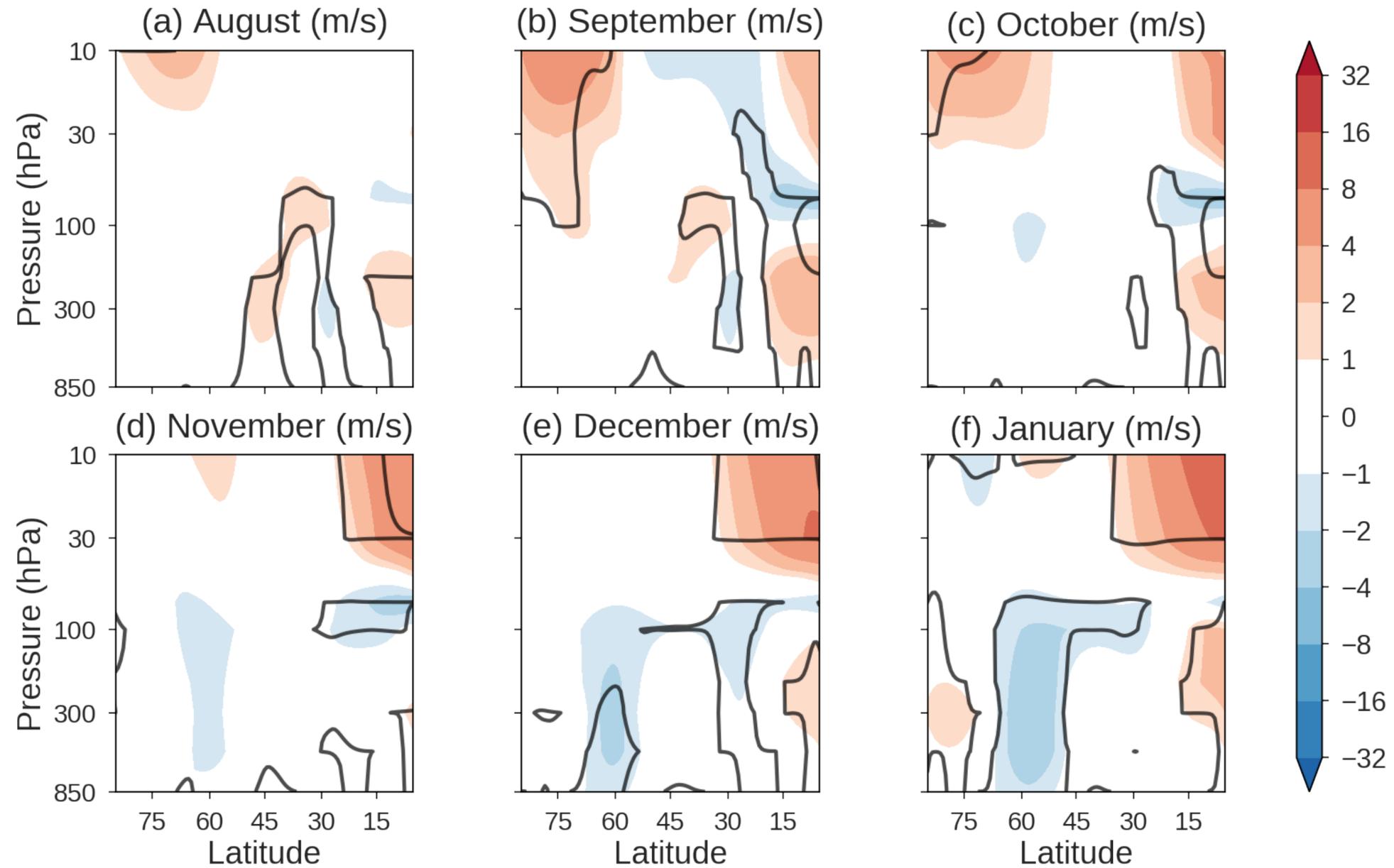


Additional Slides

Interannual SD Jet Latitude Index

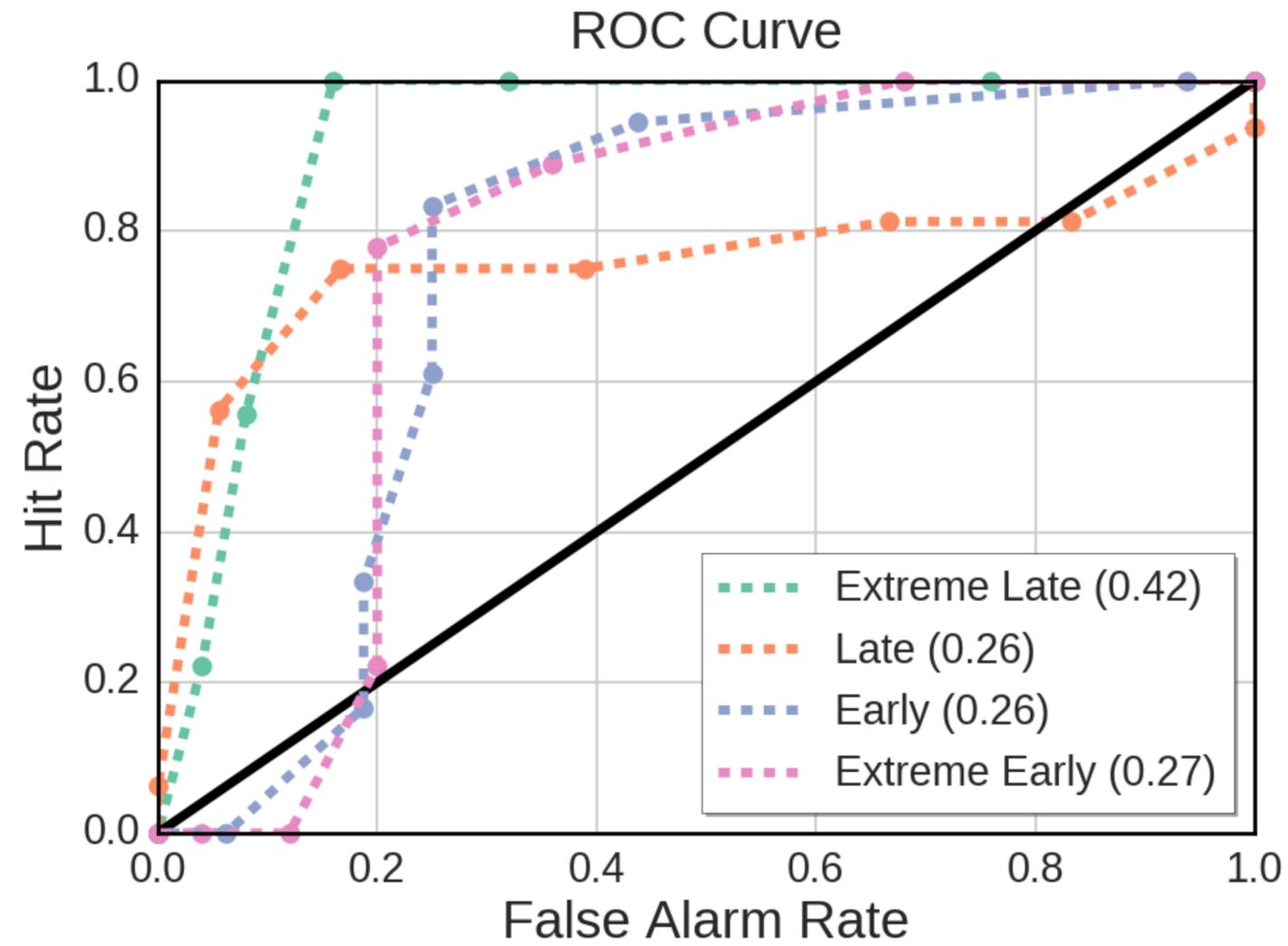


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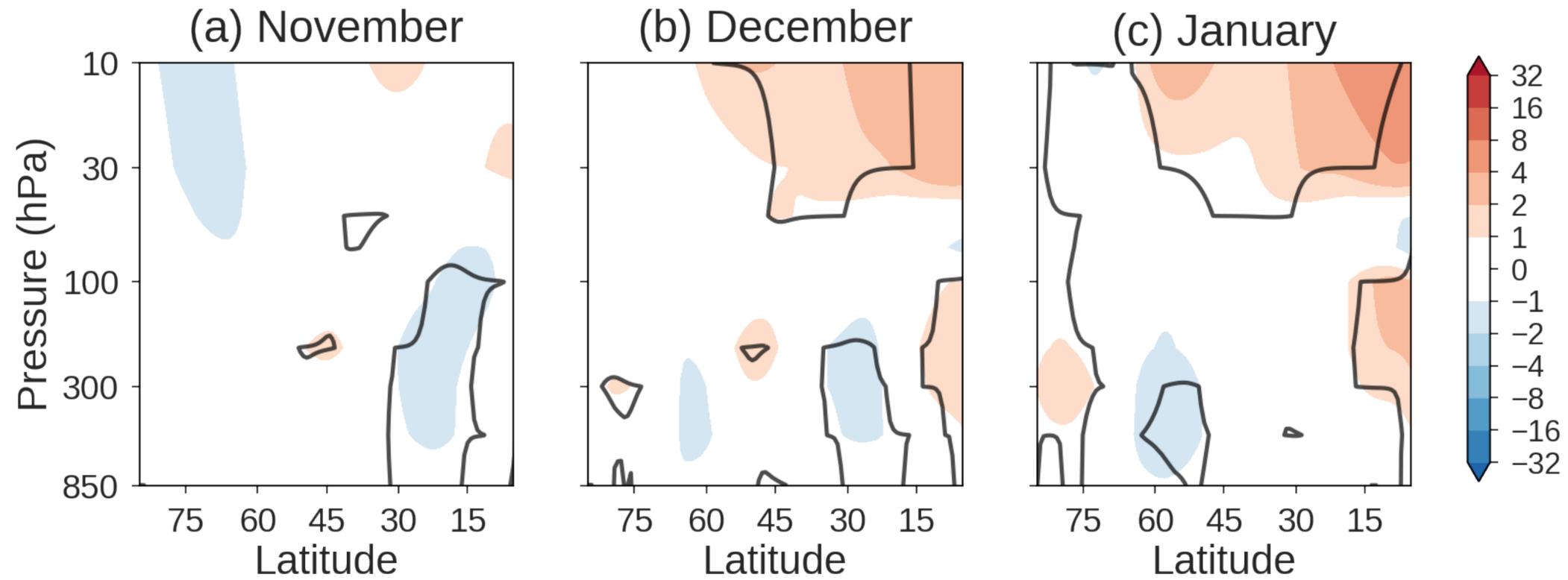
S4 Model Bias

Additional Slides



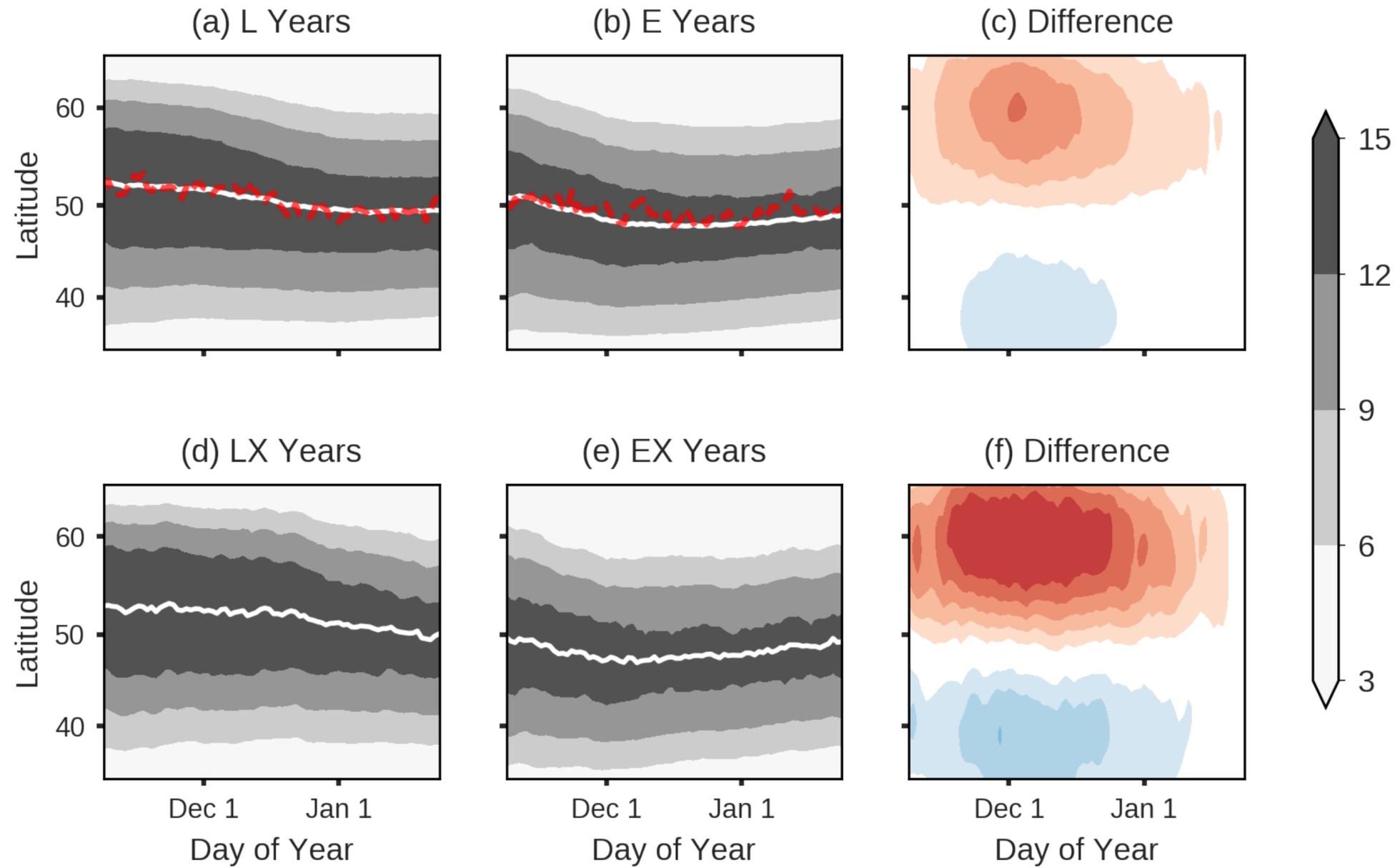
ROC Curve for 1 Aug Hindcasts

Additional Slides



S4 Model Bias

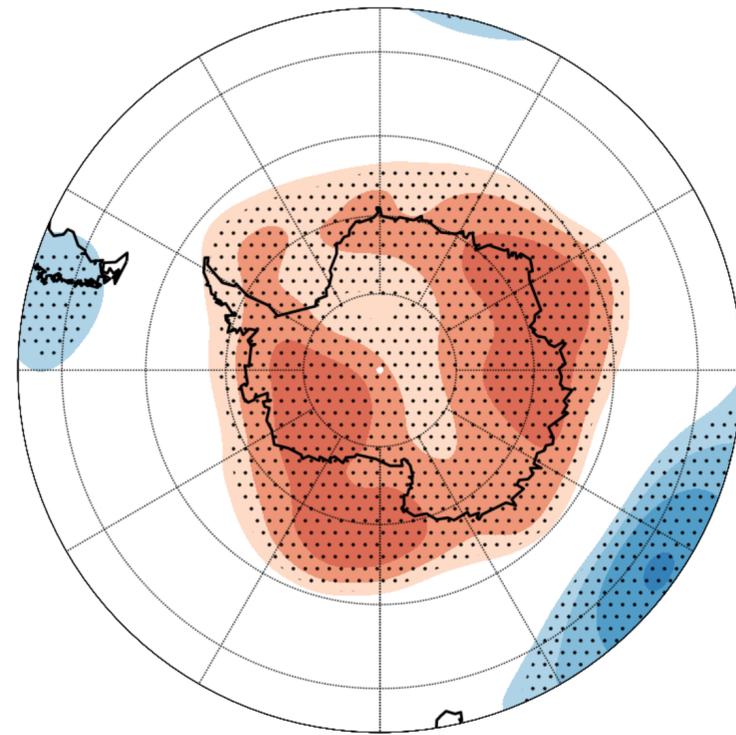
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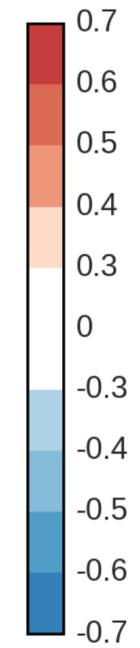
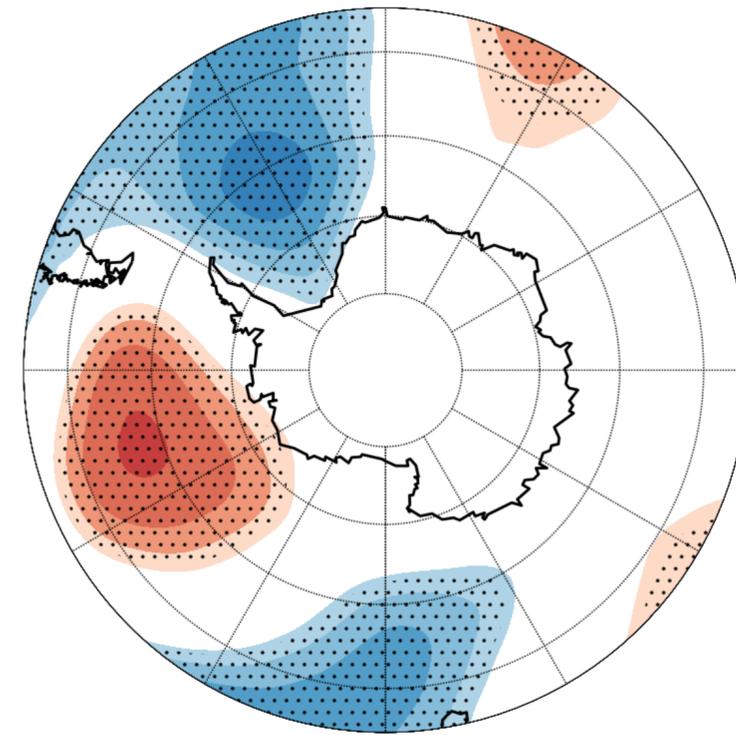
Additional Slides

ACC 500hPa Geopotential Height (SON 1981 - 2015)

(a) August 50hPa SAM

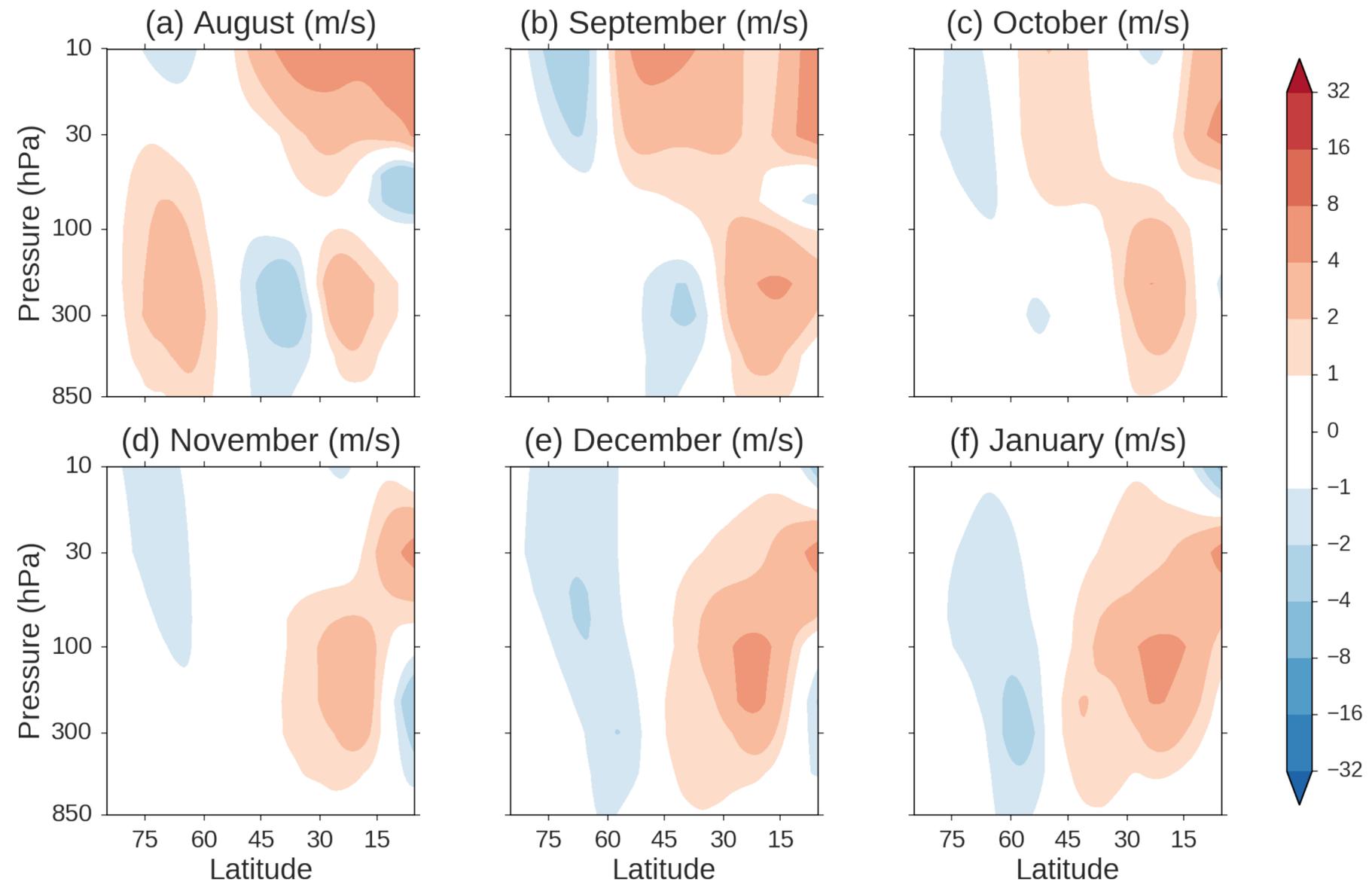


(b) August Nino 3.4



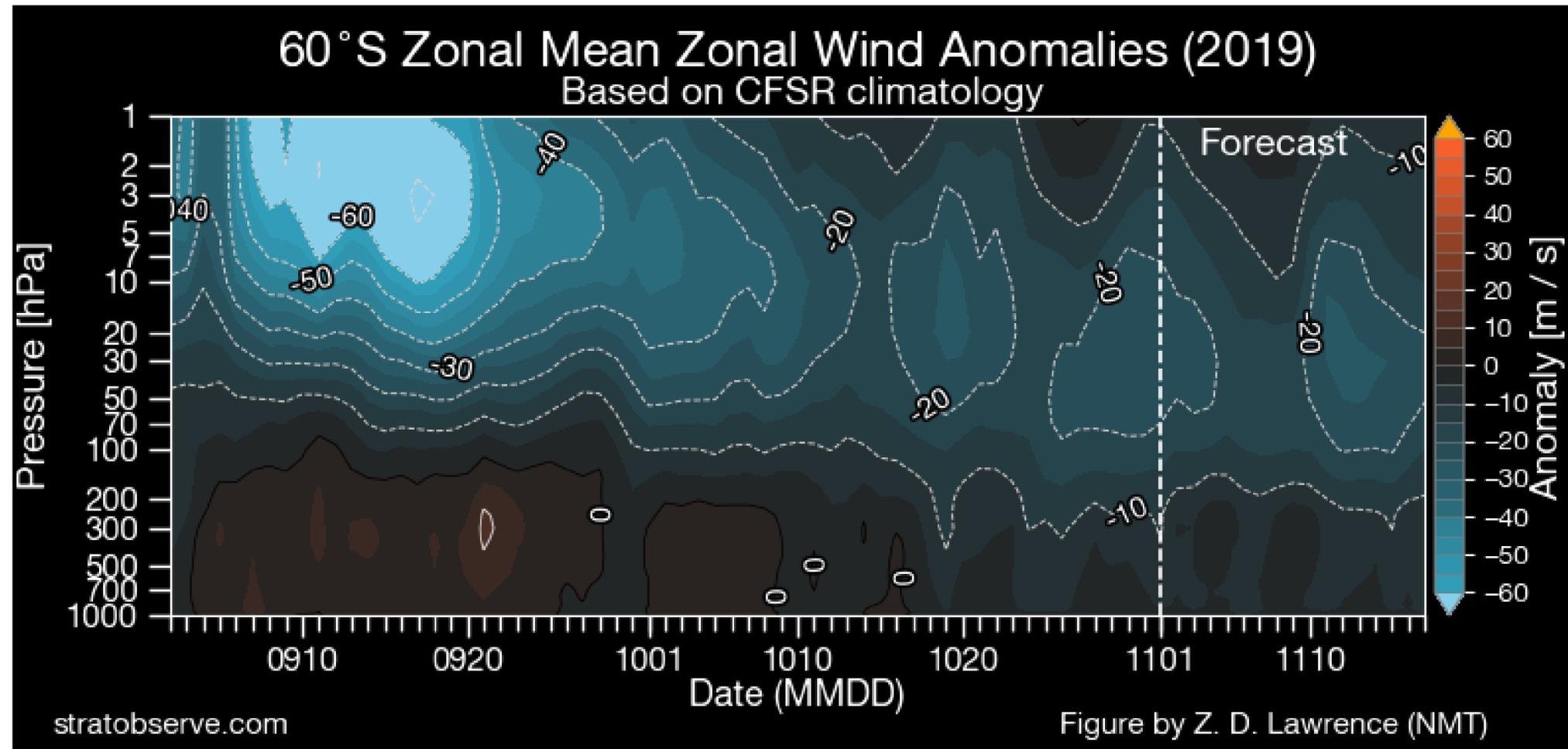
ERA-Interim

Additional Slides



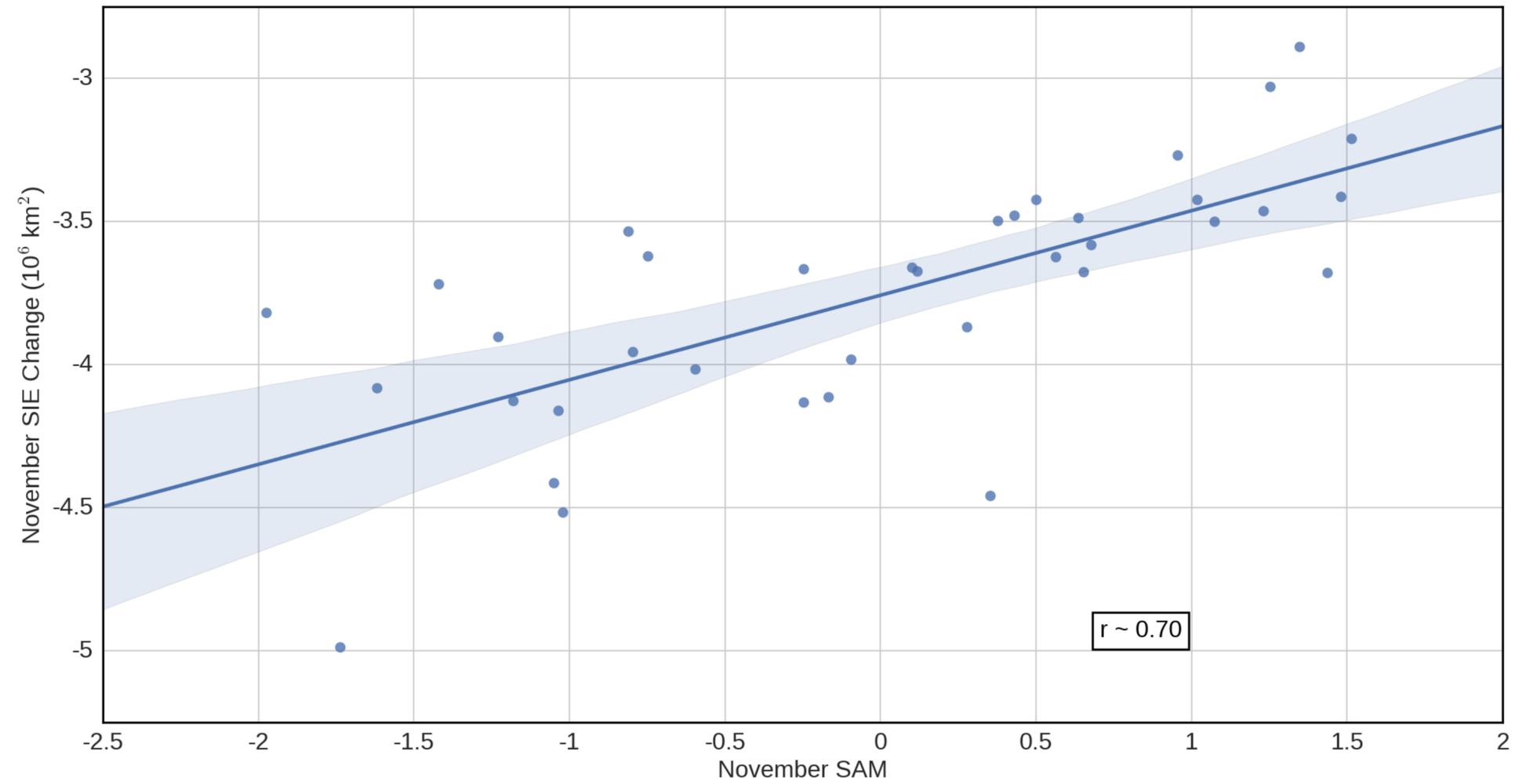
La Nina - S4

Additional Slides

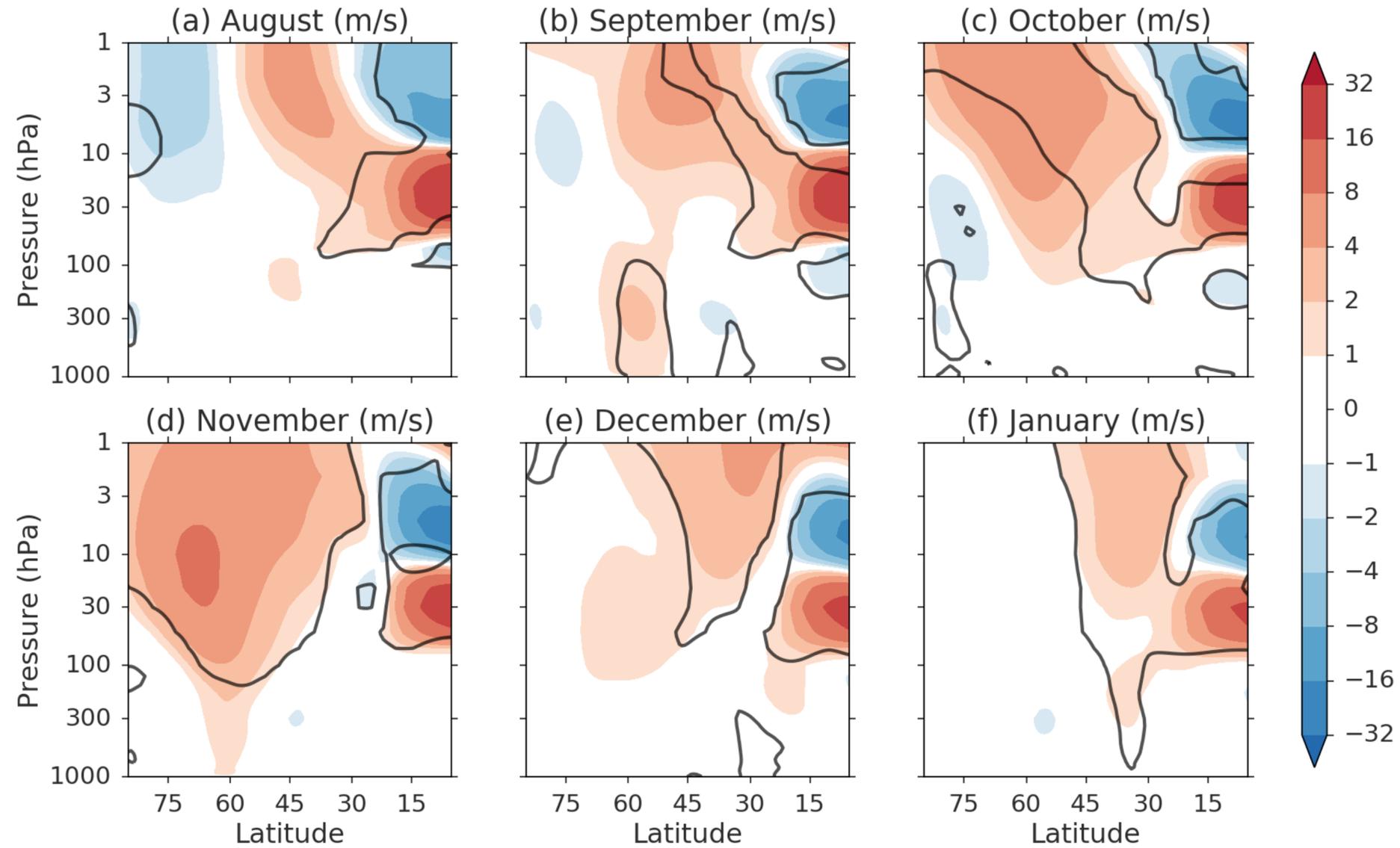


Plot via webpage of Zachary Lawrence
<https://www.stratobserve.com/>

Additional Slides

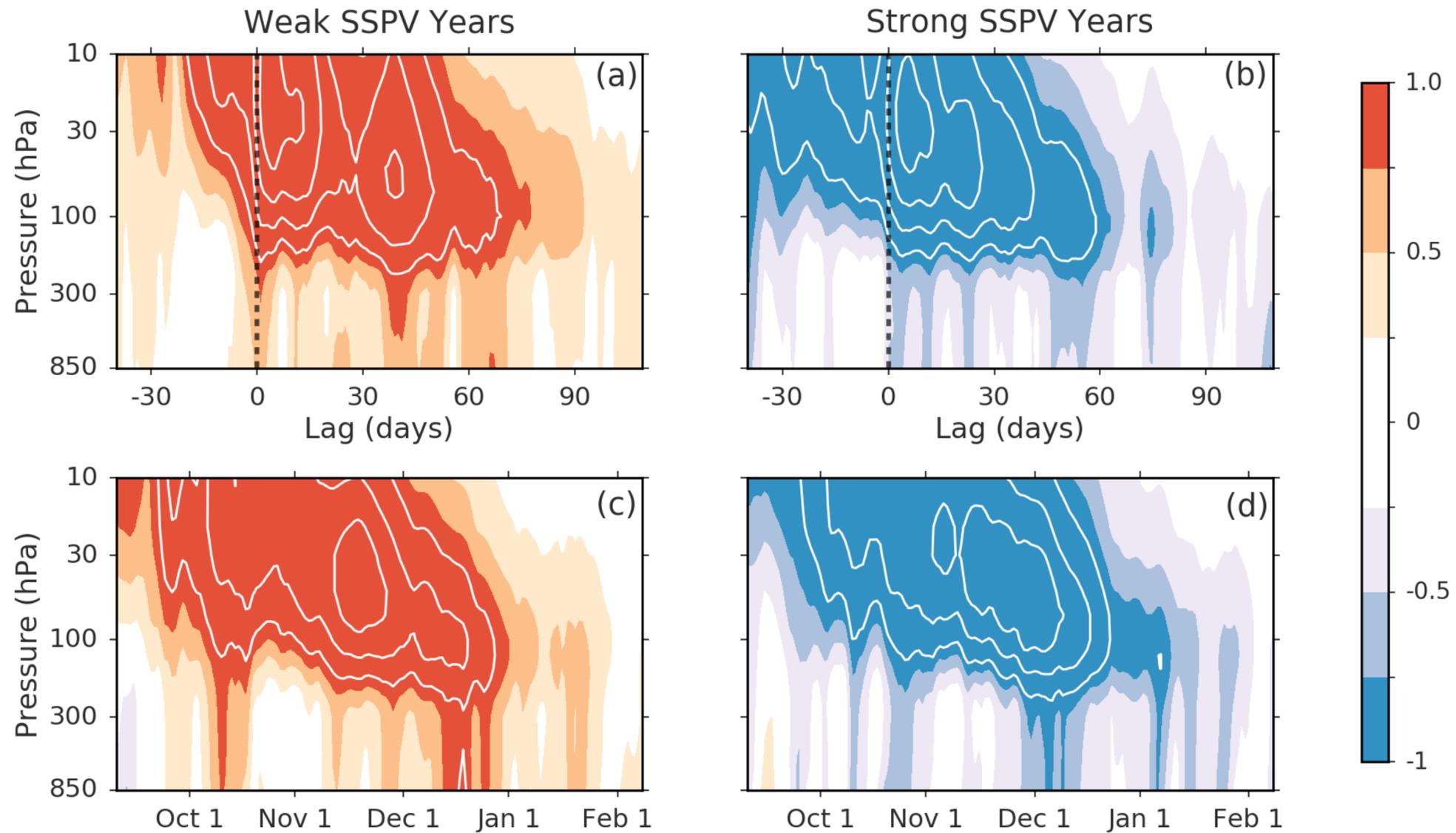


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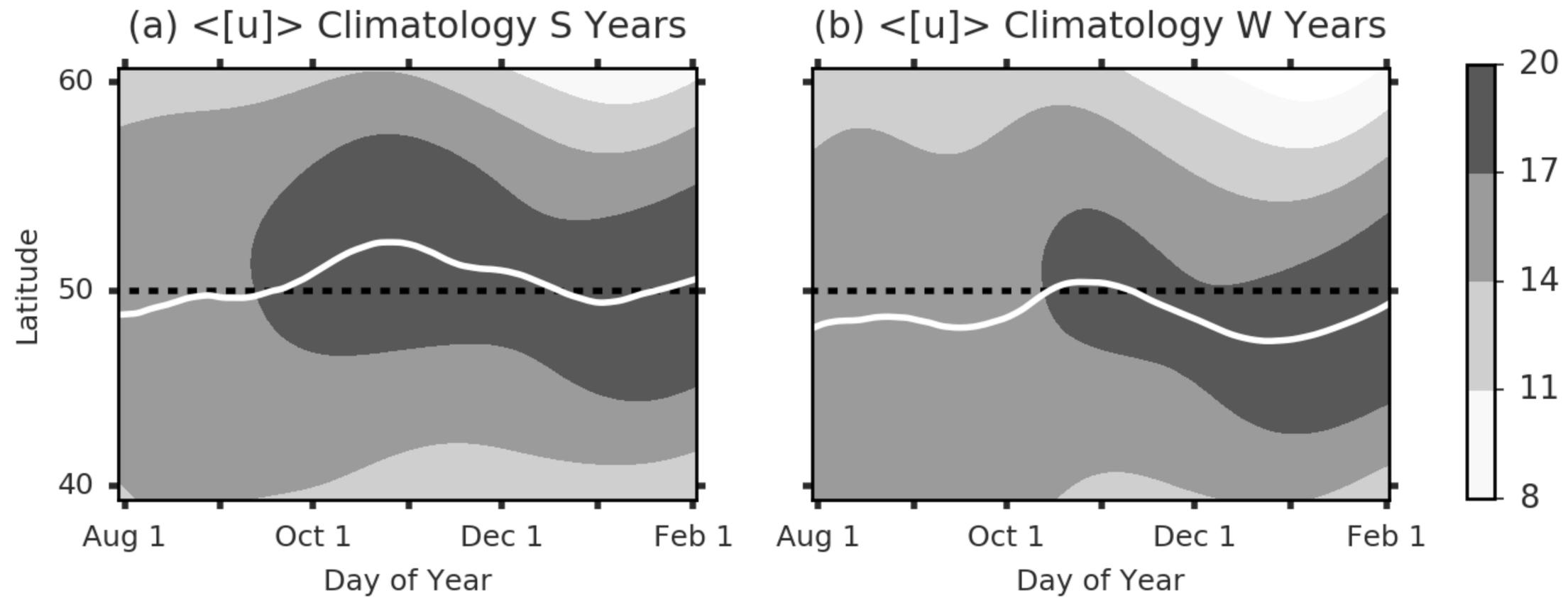
QBO ERA-Interim

Additional Slides



ERA-Interim

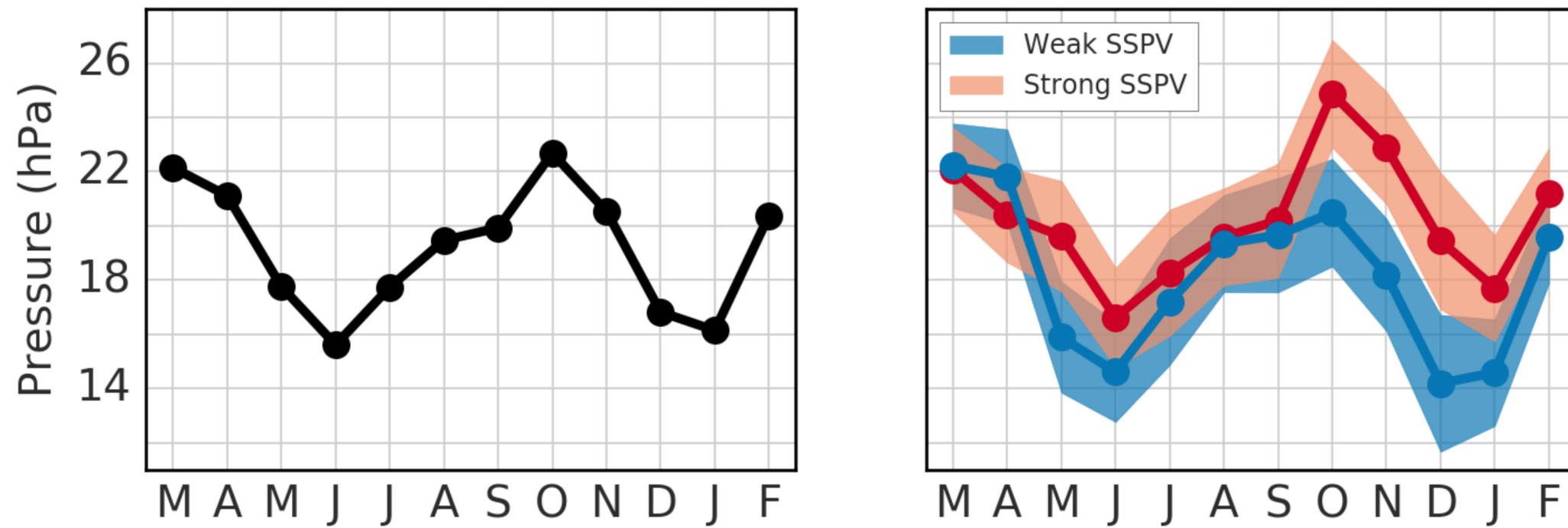
Additional Slides



ERA-Interim

Additional Slides

Zonal-Mean MSLP (50S - 65S)



ERA-Interim