U.S. West Coast Versus the U.K. Atmospheric Rivers: Difference in Future Climate Projections

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NCAR

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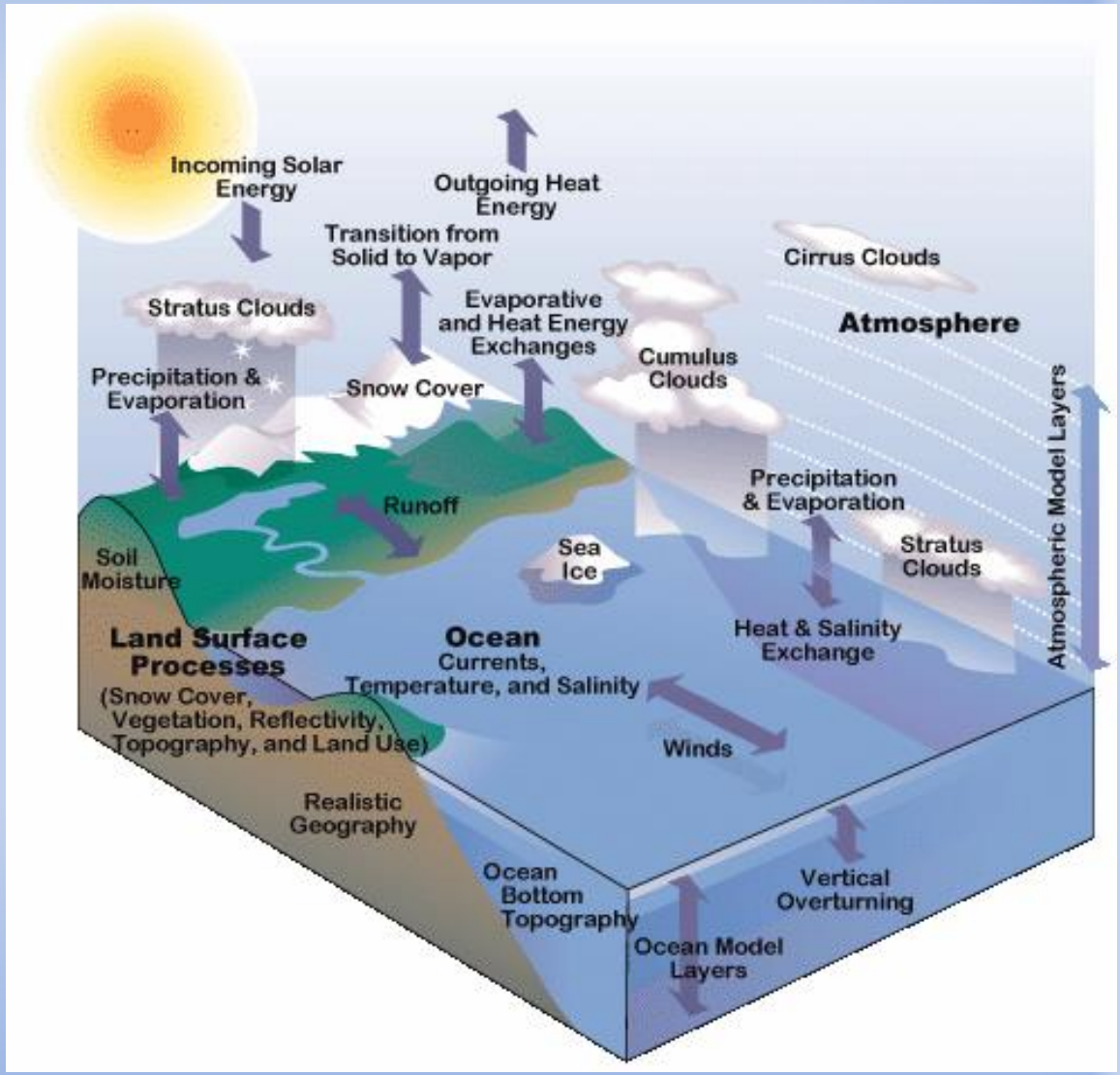
OUTLINE

- Definitions
- Metrics: validation, climatology, duration
- Dynamics: Jetstreams and climate change
- Extreme Precipitation by Latitude
- Climate Variability
- Next steps…

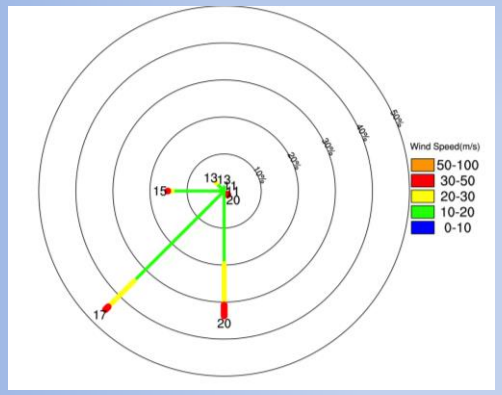
Hdeg CCSM4 Ensemble Suite

- Fully Coupled Climate Model: CAM4, CLM4 (RTM), POP2, CICE4
- Atmos/Land ~FV 0.47° x 0.63°
- Ocean/Ice ~x1°
- Historical and RCP8.5 Simulations
- 5 members (3 with high frequency tracking output)



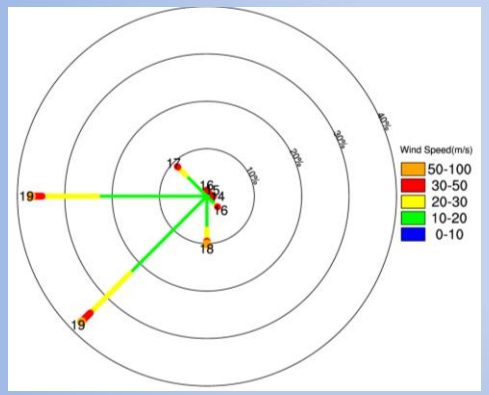
AR Definitions

U.S. West Coast



850 mb Wind Speed >= 10 m/s
270^{o} > Wind Direction > 180^{o}
DY/DX >= 2 (minimum DY= 4 grid points)
Moisture Thresholds "ZN"

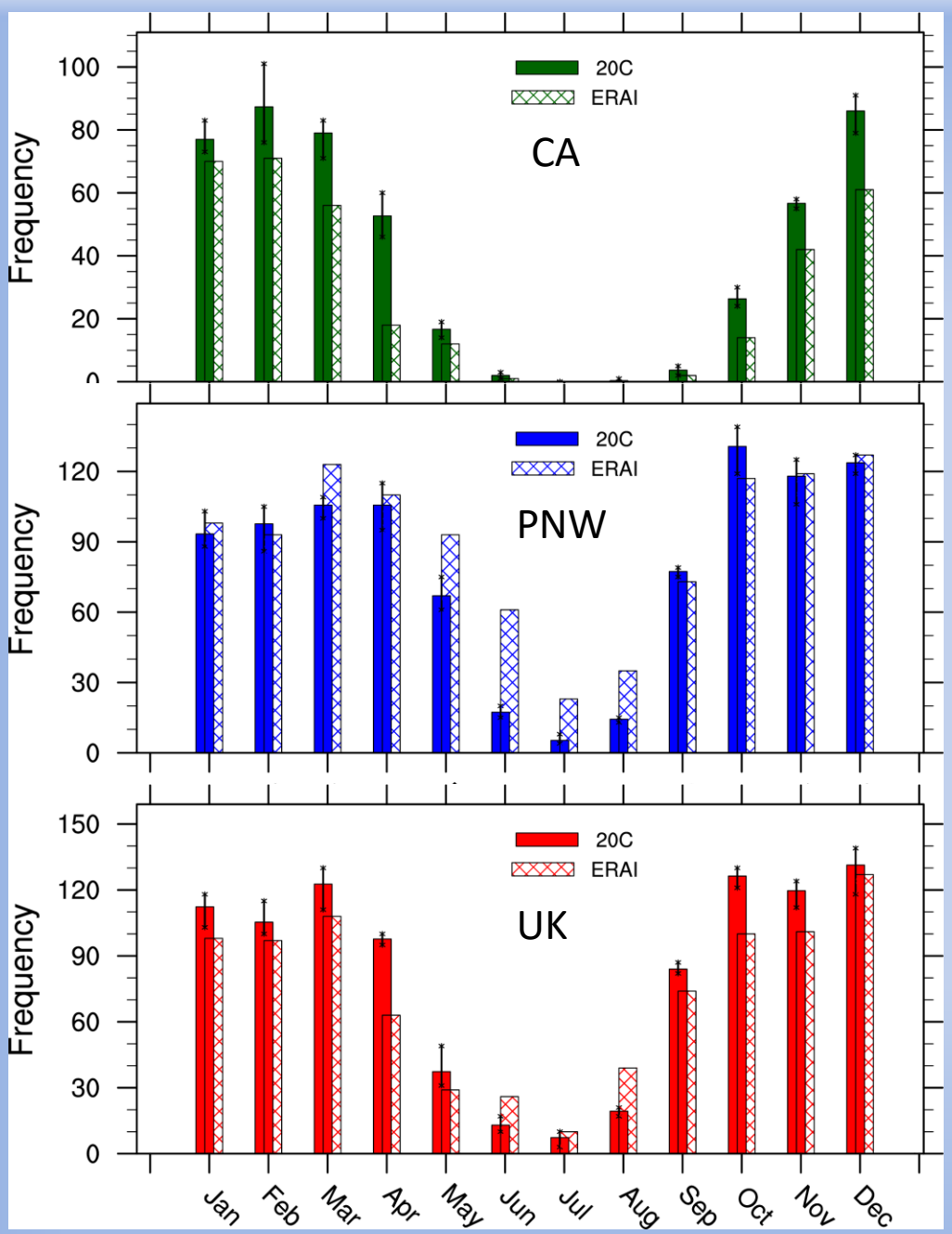
UK



850 mb Wind Speed >= 25 m/s (85th ptile)
360^{o} > Wind Direction > 180^{o}
DY/DX >= 2 (minimum DY= 4 grid points)
Moisture Thresholds "ZN"

$$ZN == |Q_{threshold}| >= |Q_{mean}| + 0.3(|Q_{max} - Q_{mean}|)$$

Mean = zonal mean and Max = zonal maximum



ERA-I 1980-2005 vs. Hdeg CCSM4 Historical Simulations

Climatology PDFs of storm frequency simulates seasonal cycle realistically.

California and UK storms are over-predicted. This improves with increasing resolution.

PNW storms are w/in ensemble spread except May-Aug. (Also improves with resolution).

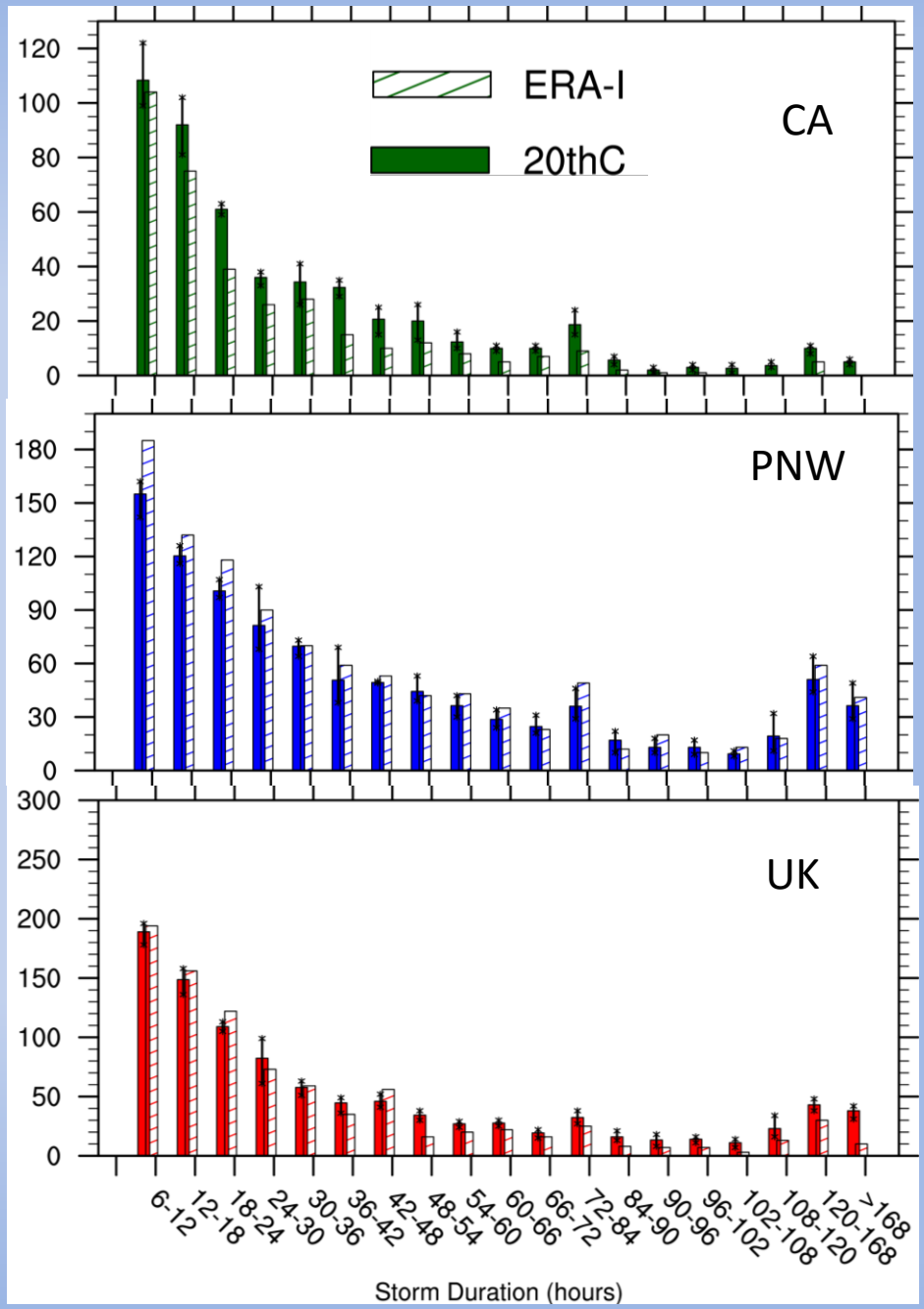
STORM DURATION

1980-2005 corresponding to ERA-I data

CA storms tend to be too long but do better with longer lived storms, i.e. > 3 days.

PNW ensemble spread is close to ERA for all periods except short storms.

UK ensemble spread is close to ERA for all periods except longer lived storms.



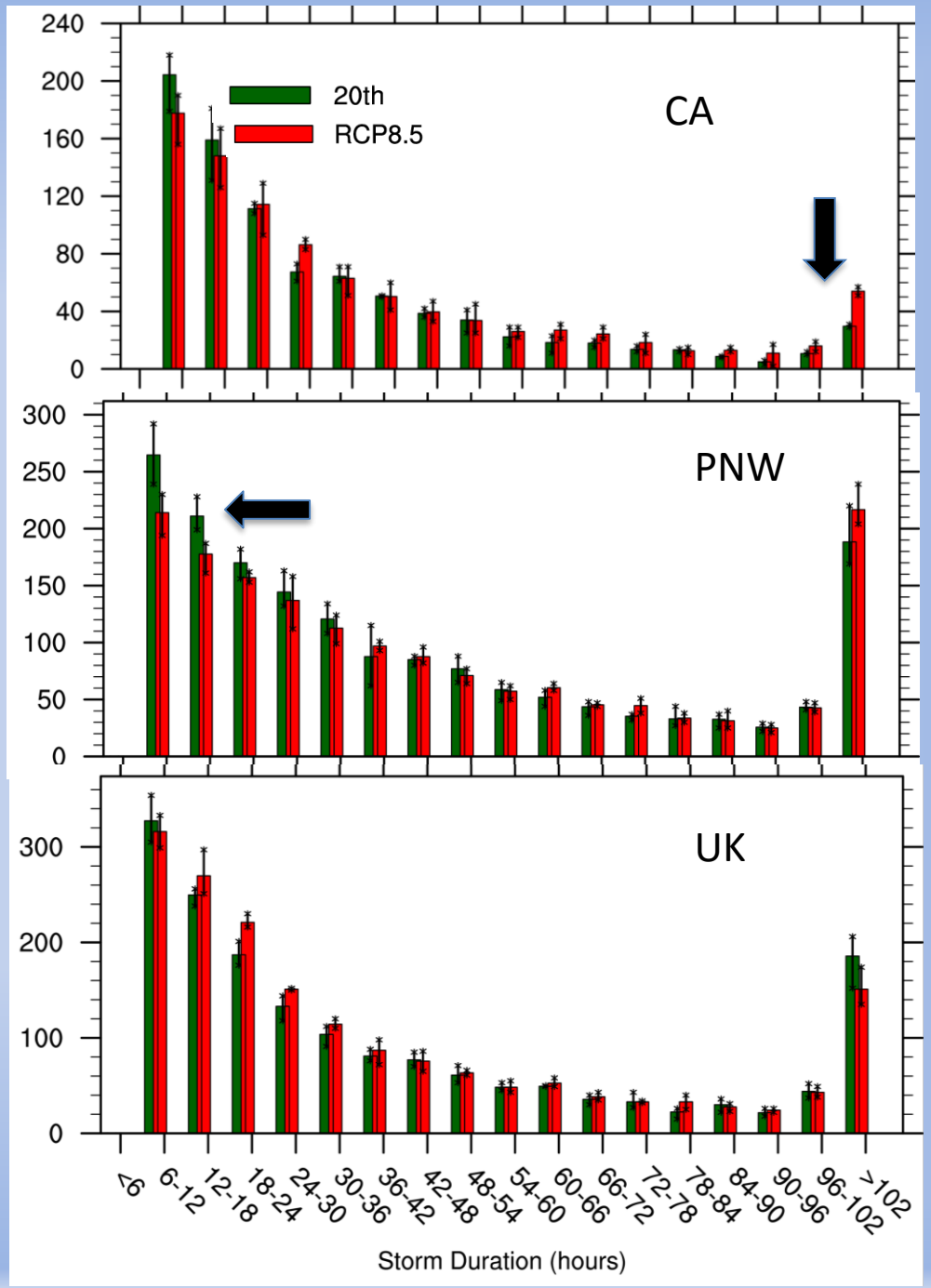
STORM DURATION Trends, Last 45yrs

Both California regions are projected to see longer-lived storms and a decrease in short storms < 1day.

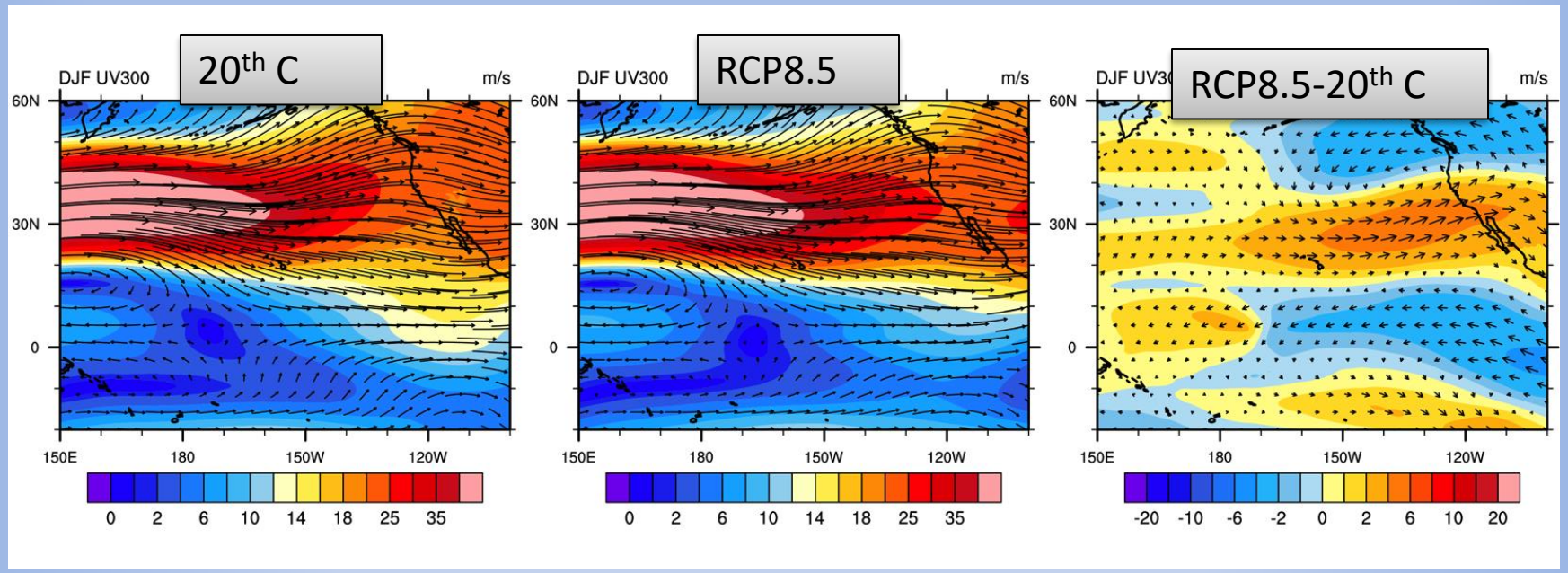
CA signal is robust for longer storms. PNW signal is robust for short storms.

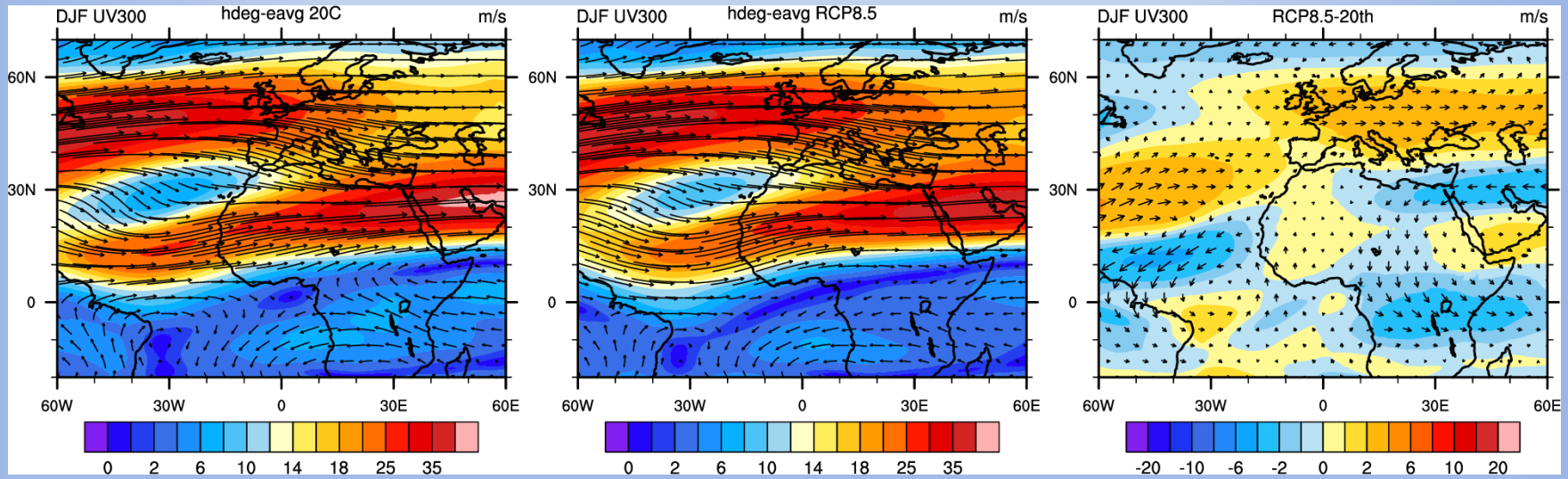
UK project a small increase for ~1day storms and decrease for longer lived storms, but signal is not robust.

However all these metrics are summed across entire region. How do things change by latitude and position relative to the jet?



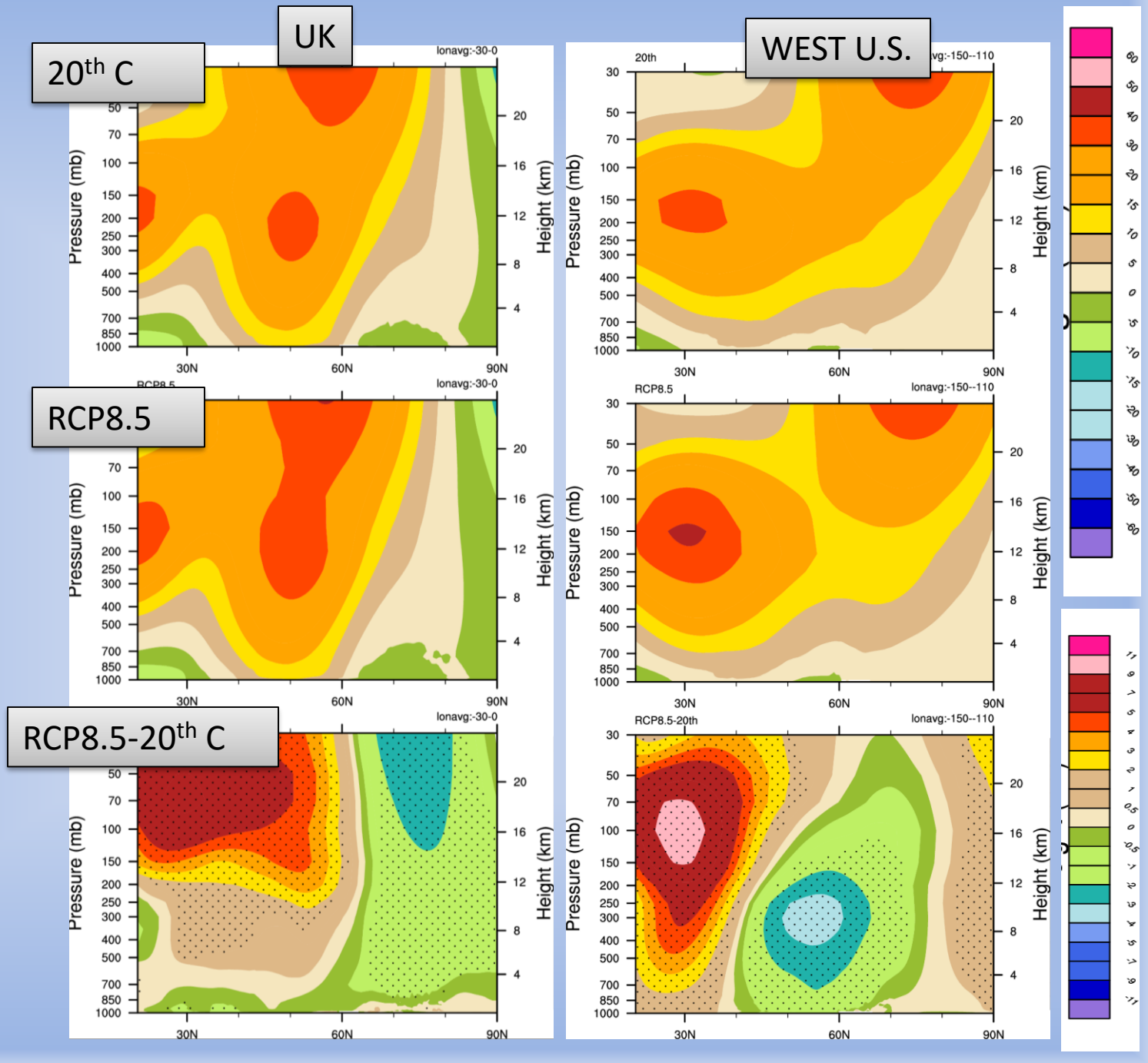
DJF 300mb Jetstream Climate Change





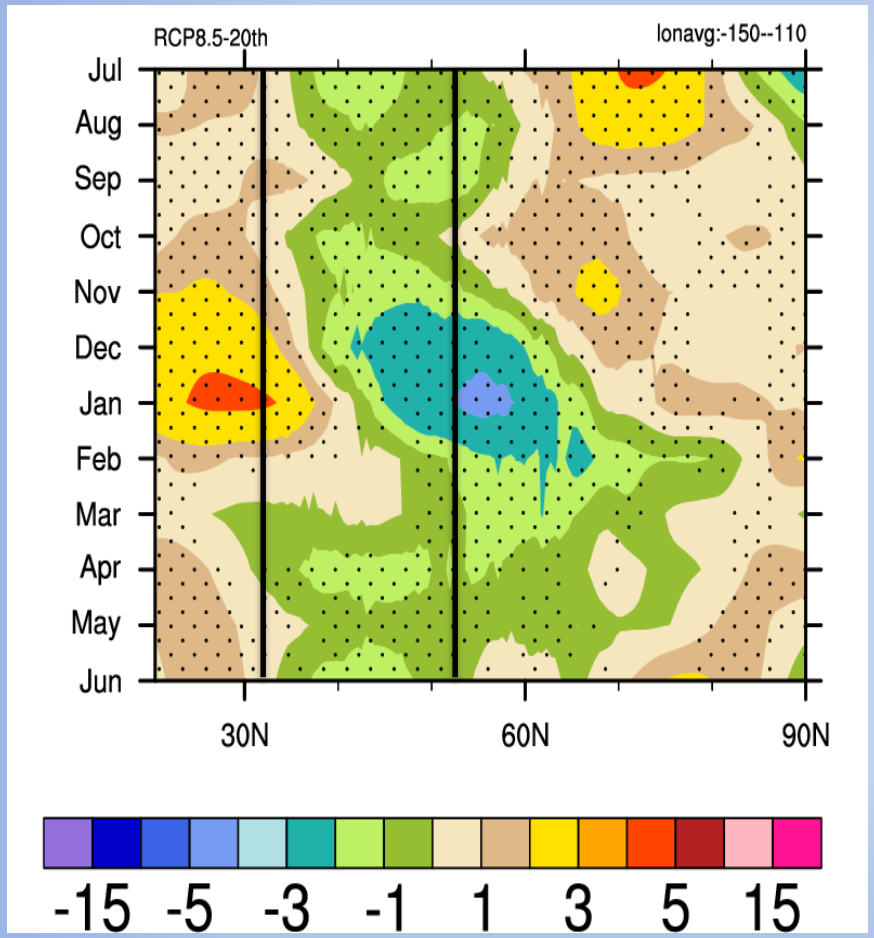
Subtropical jet over the Western U.S. significantly increases throughout the entire layer, as seen in many global warming studies.

Lower level jet changes over UK domain are relatively small.

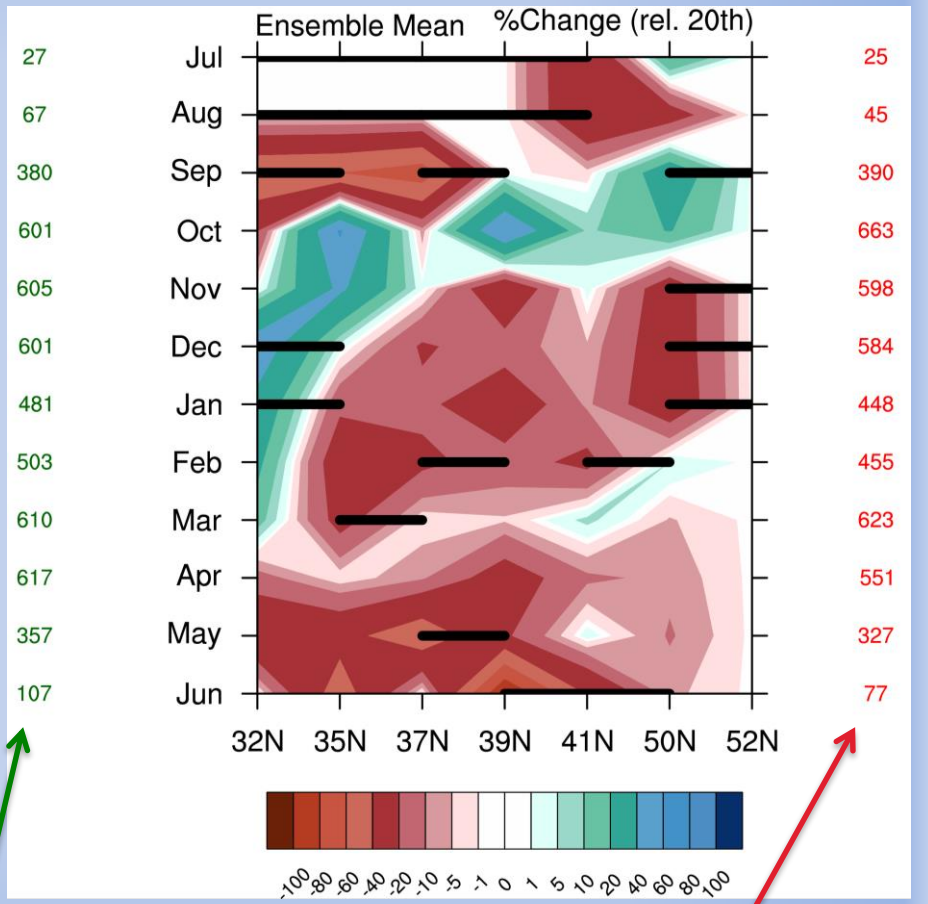


Western U.S Zonal Wind Change vs. AR frequency change

Zonal Wind



AR Storm Events



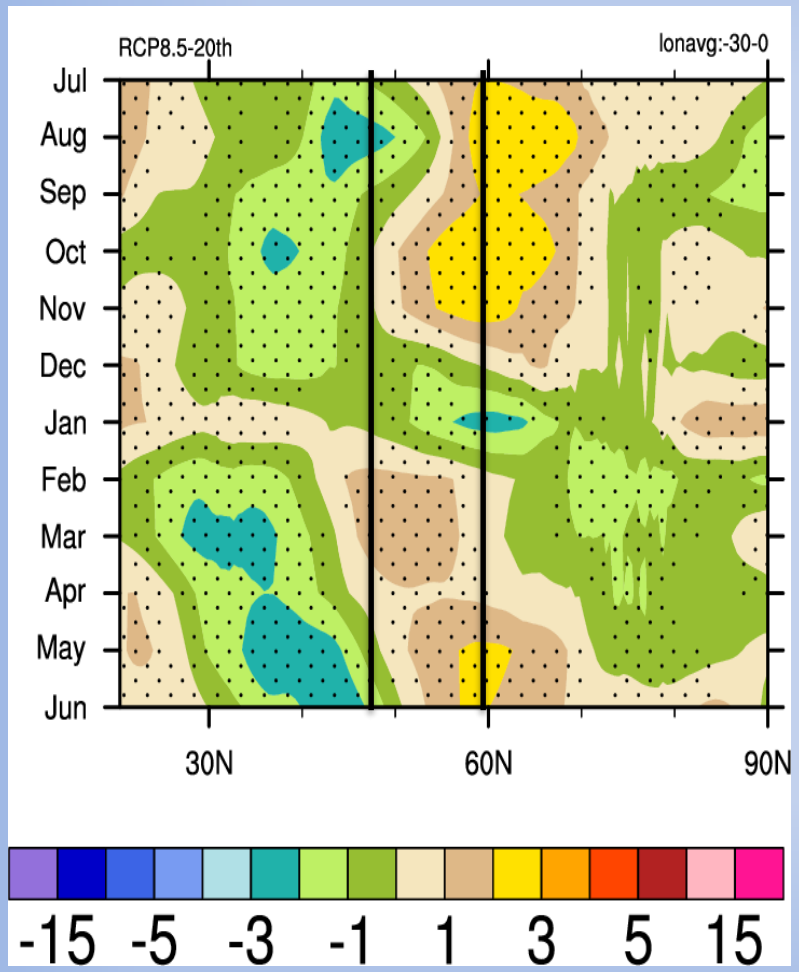
Total ensemble sum for 20th Century

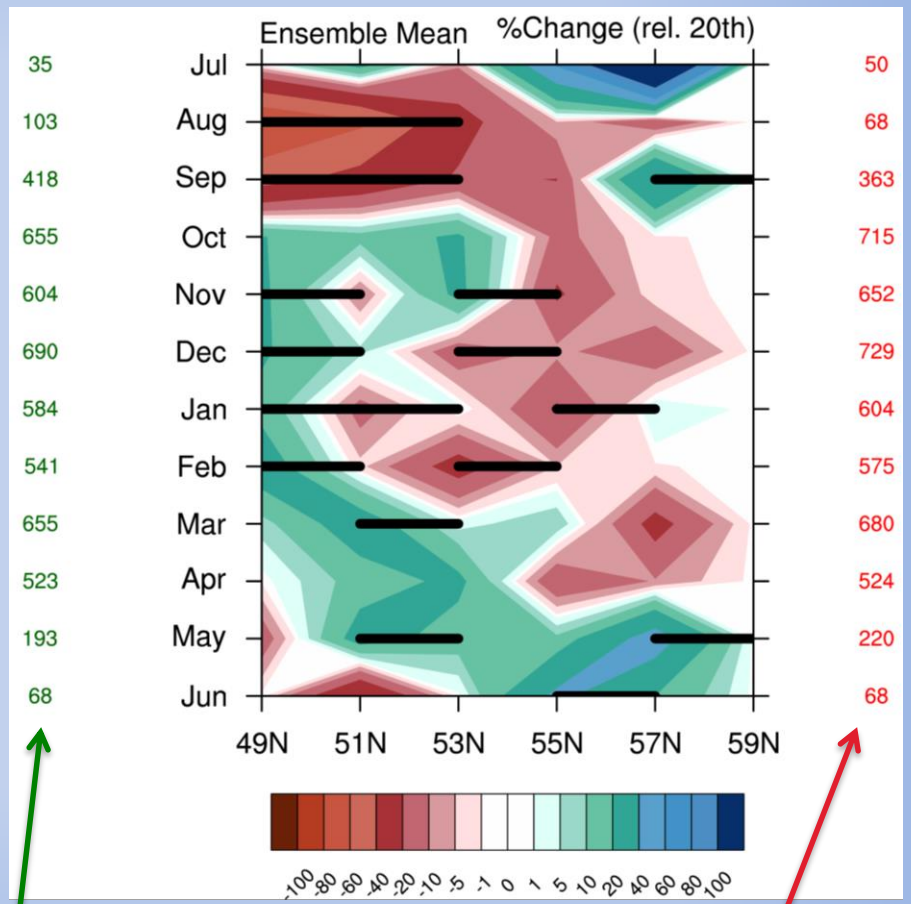
Total ensemble sum for RCP8.5

UK U.S Zonal Wind Change vs. AR frequency change

Zonal Wind

AR Storm Events

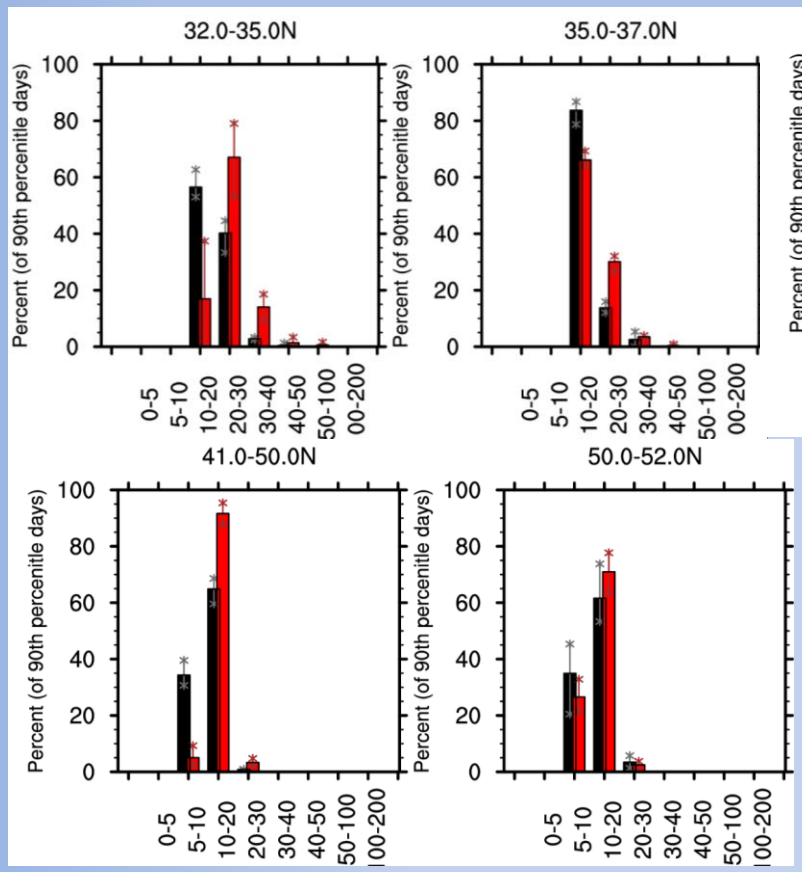




Total ensemble sum for 20th Century

Total ensemble sum for RCP8.5

West U.S. Precipitation AR 90th %tile days



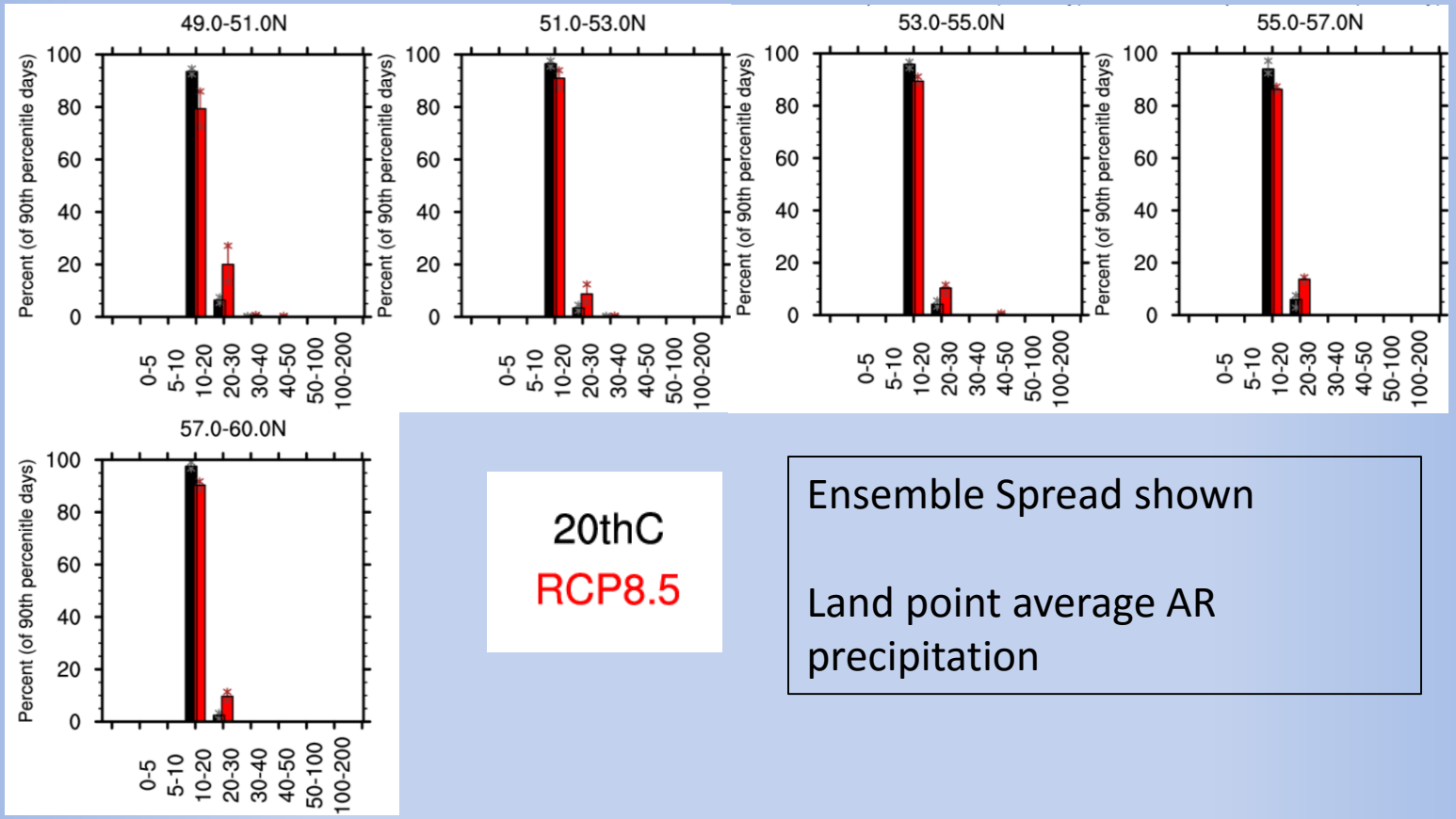
20thC
RCP8.5

Ensemble Spread shown

Land point average AR precipitation

Southern CA latitudes shift to more extremes but as increase in latitude the signal becomes less robust.

UK AR Precipitation 90th %tile days



20thC

RCP8.5

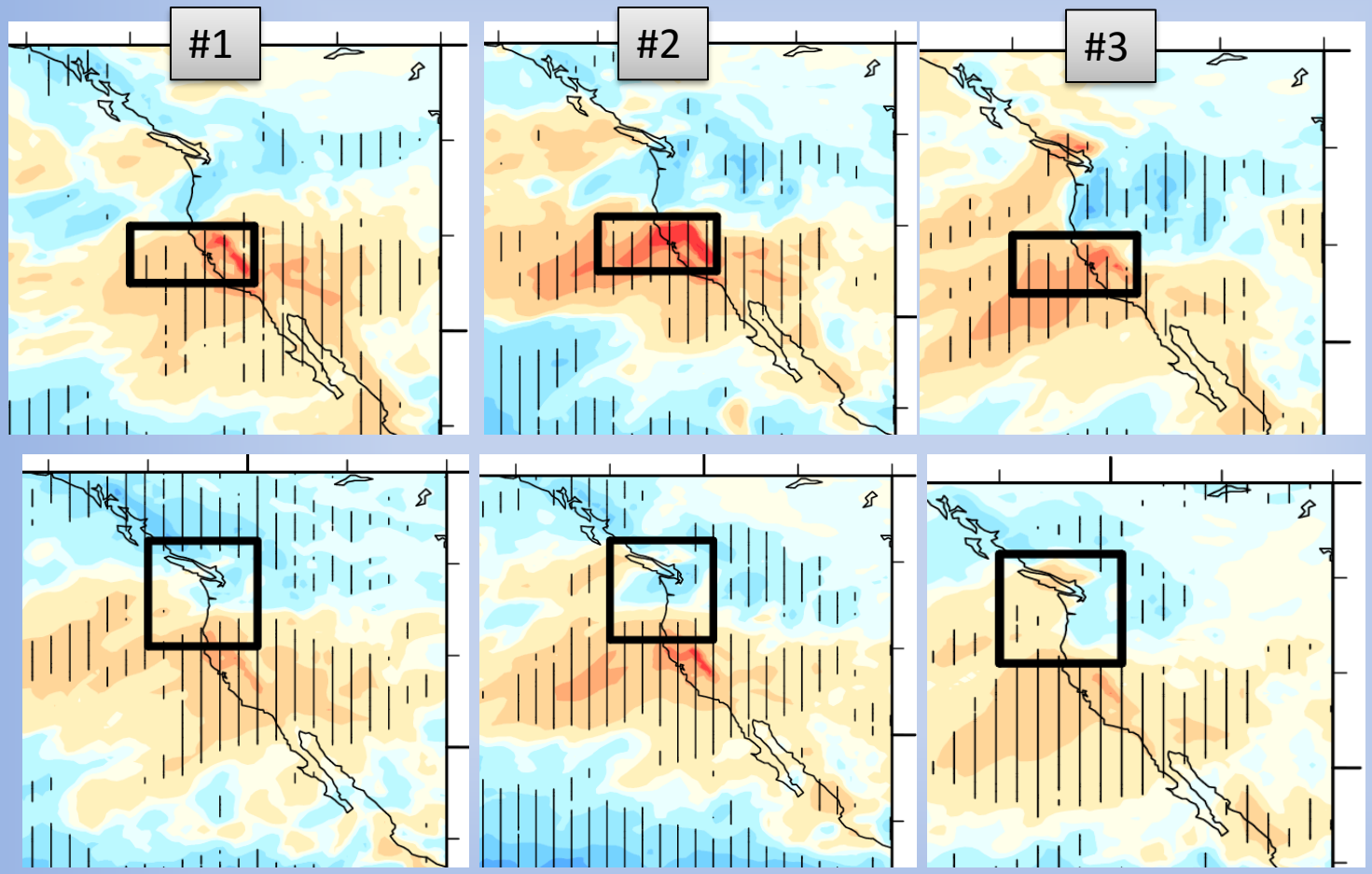
Ensemble Spread shown

Land point average AR precipitation

Extreme precipitation across latitude bands in the UK only slightly shifts into higher rainfall rate bins.

Climate Variability : ENSO

Regression Nino43 vs AR Precipitation (Historical, Individual ensemble members)



CA
Strong
Positive

PNW
Weak
Negative

Hatching at 95% significance

Take Away Points…

- CCSM4 Hdeg simulates realistic AR climatology for Western U.S. and UK.
- CCSM4 Hdeg projects for California and PNW longer-lived AR events under global warming.
- **Southern California is projected to experience an increase in winter AR events under global warming due to the strengthening of the subtropical jet over the Pacific Basin.**
- **Landfall changes in the UK are seasonally dependent and are influenced by the eddy-driven jet.**
- CCSM4 simulates a strong correlation with ENSO and AR precipitation over California
- CCSM4 also captures the PNA and NAO related AR events.

Next steps…

- Characterize ARs and their climate change by jet type: subtropical or eddy-driven. (Iberian Peninsula, Andes, New Zealand, Arctic/Antarctic (ice sheet impacts).
- Modes of variability effect on ARs with climate change
- Increase in model resolution (~0.25 degree); upgrade to latest version of CESM (Updated atmosphere component which includes better clouds, aerosols, and radiation).
- Ocean role in AR development
- CLIVAR: ARTMip (AR Tracking algorithm Intercomparison Project)

Thank You

Climate Variability : PNA for West AR months

Composite average DJF Precipitation (Historical, Individual ensemble members)

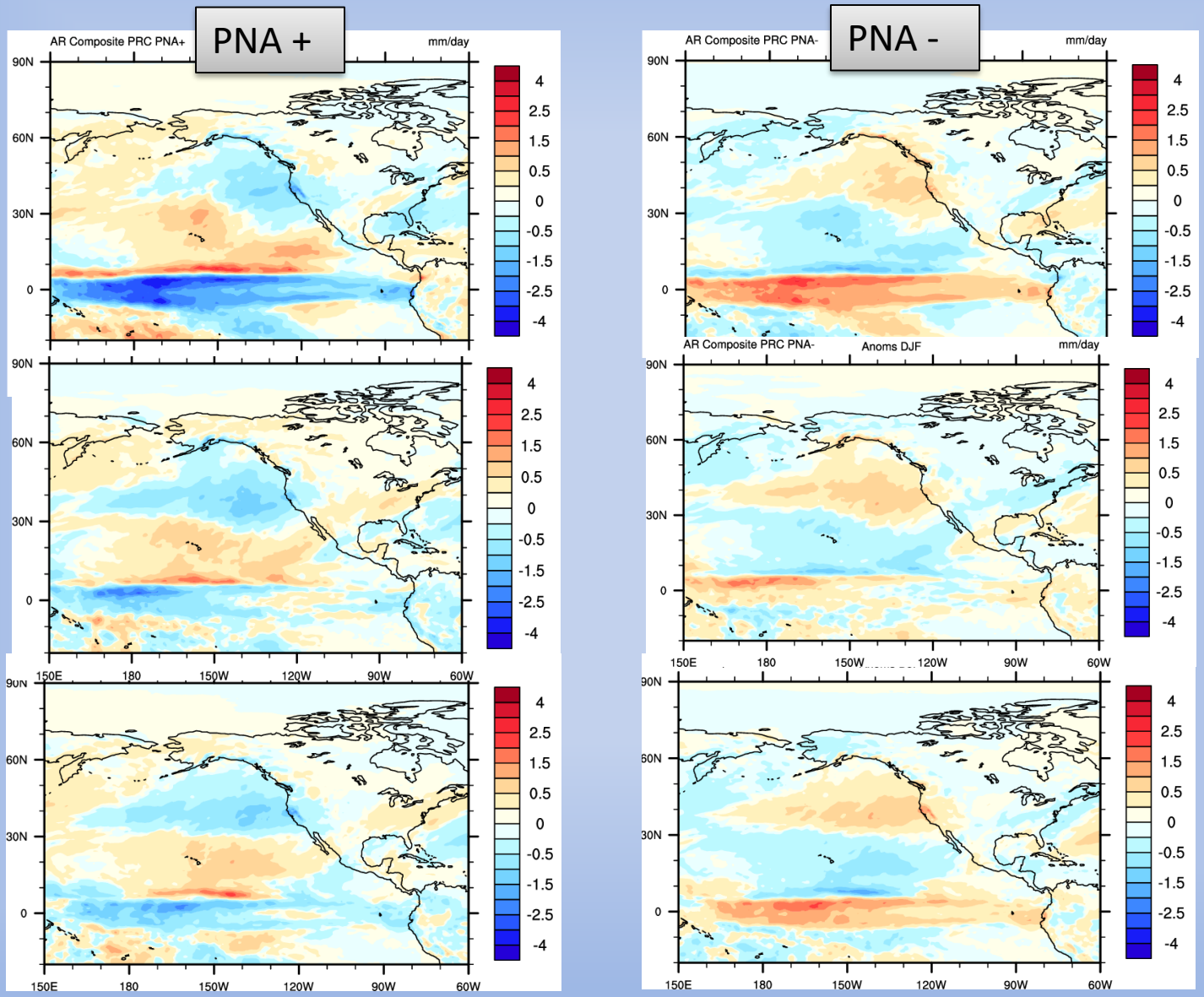
PNA +

PNA -

#1

#2

#3



Climate Variability : NAO for UK AR months

Composite average DJF Precipitation (Historical, Individual ensemble members)

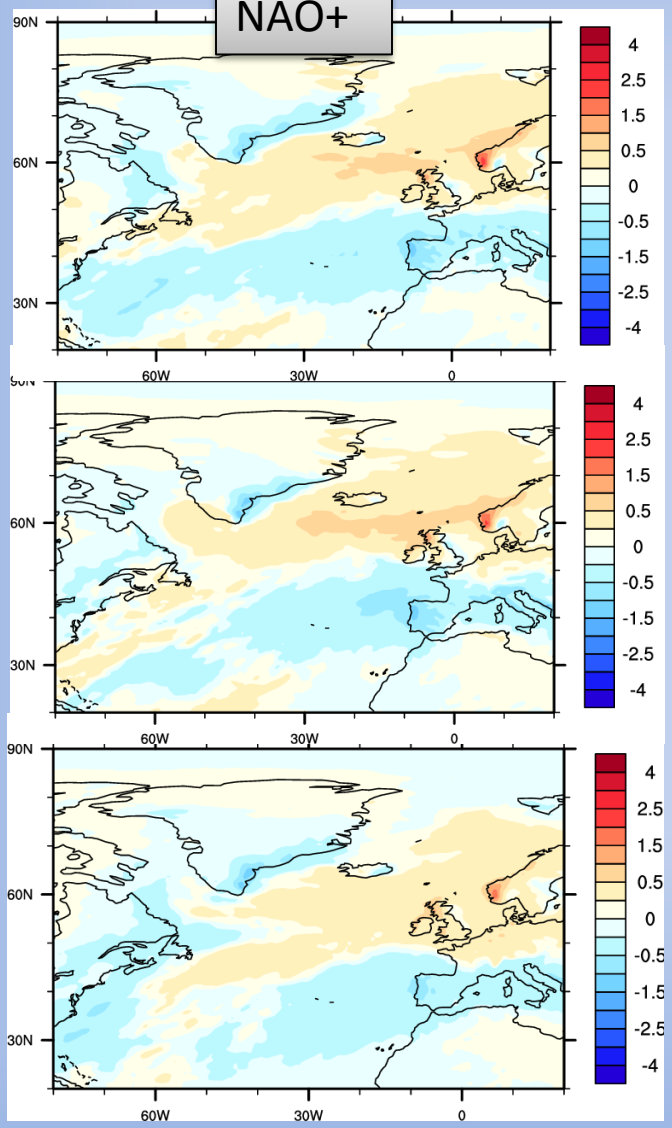
NAO+

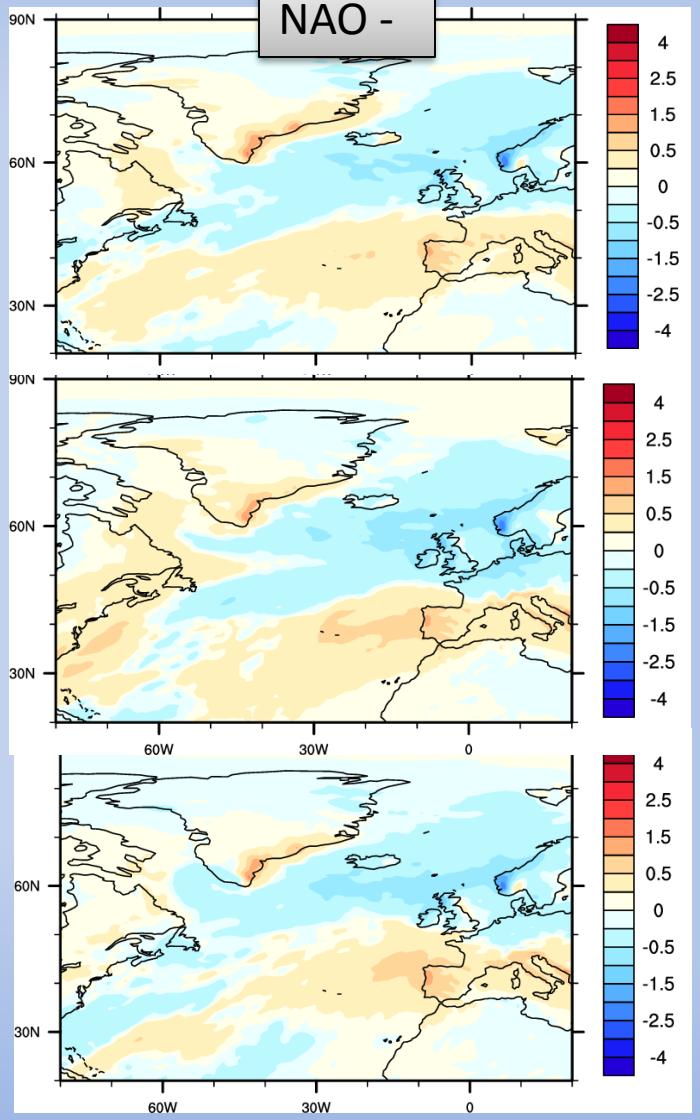
NAO -

#1

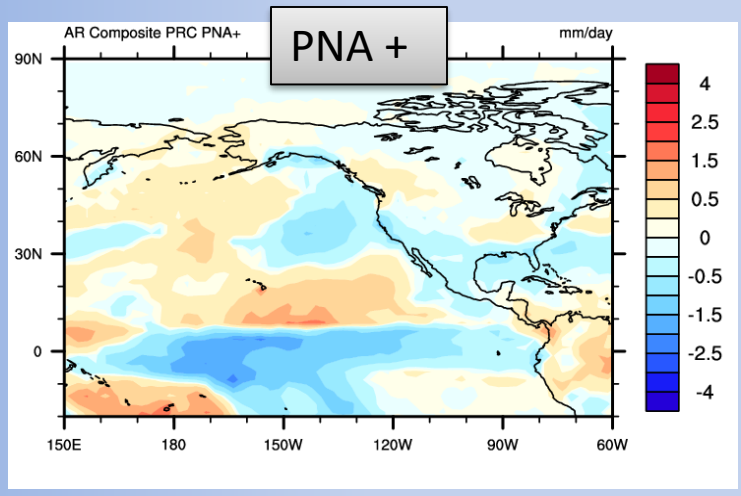
#2

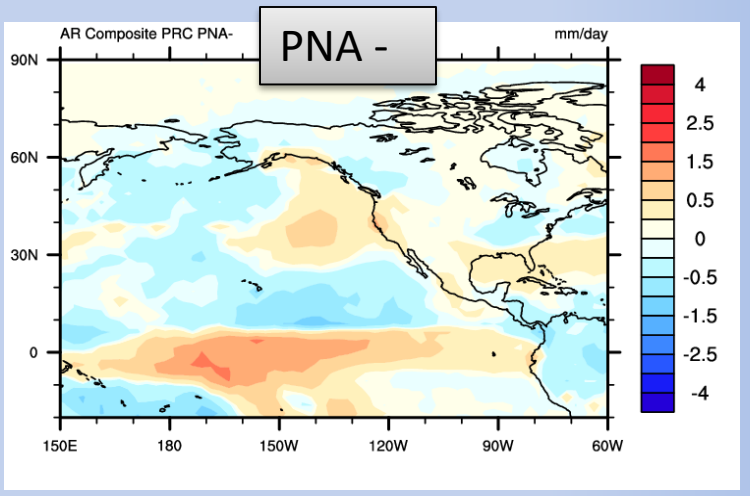
#3

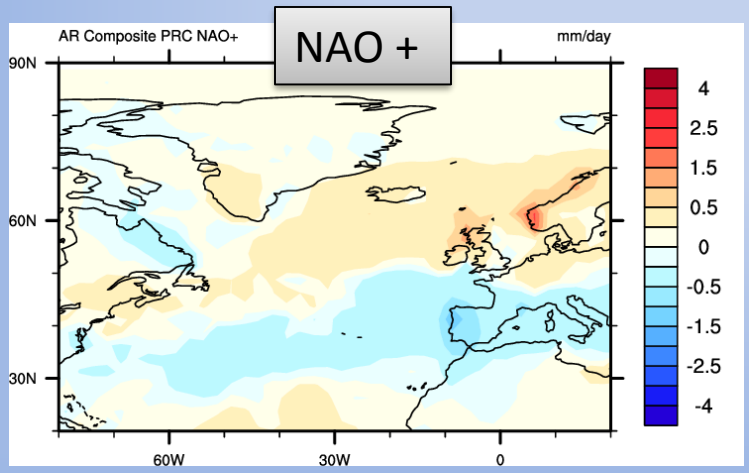


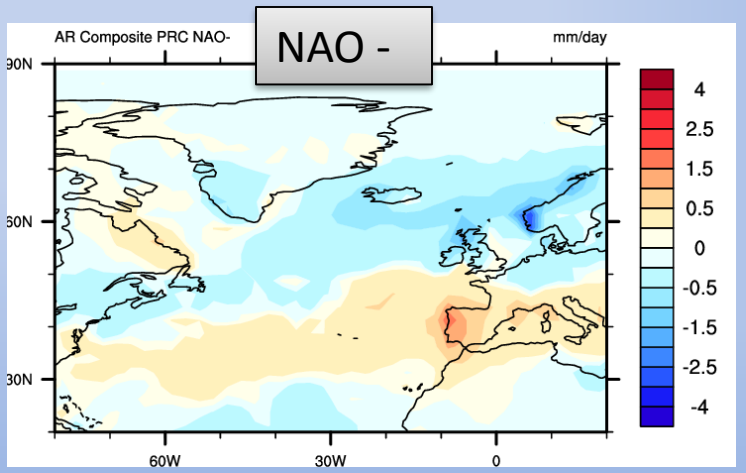


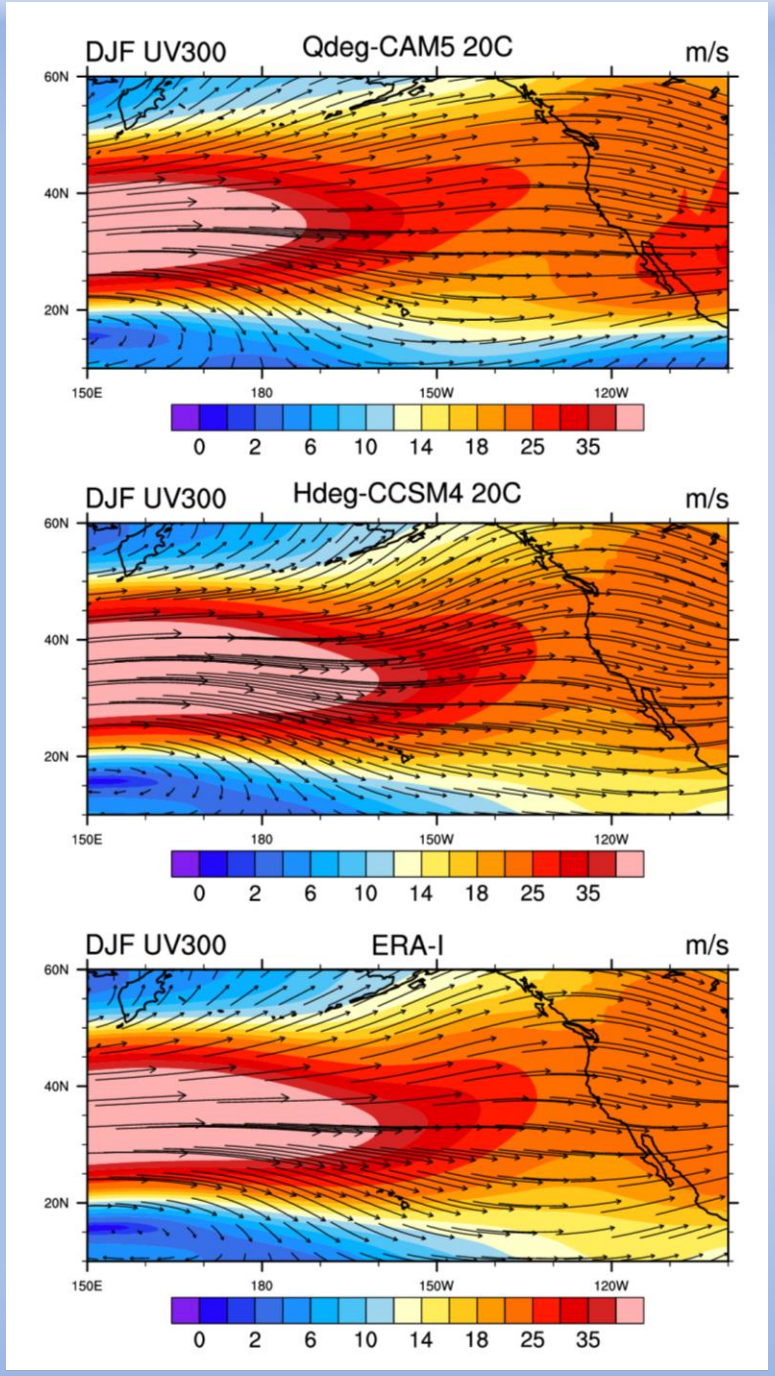
Climate Variability : PNA and NAO for AR months
“Observations”
ERA-I, Reanalysis, GPCP










DJF UV300
Qdeg-CAM5 20C
m/s
60N
40N
20N
150E
180
150W
120W
0 2 6 10 14 18 25 35
DJF UV300
Hdeg-CCSM4 20C
m/s
60N
40N
20N
150E
180
150W
120W
0 2 6 10 14 18 25 35
DJF UV300
ERA-I
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150E
180
150W
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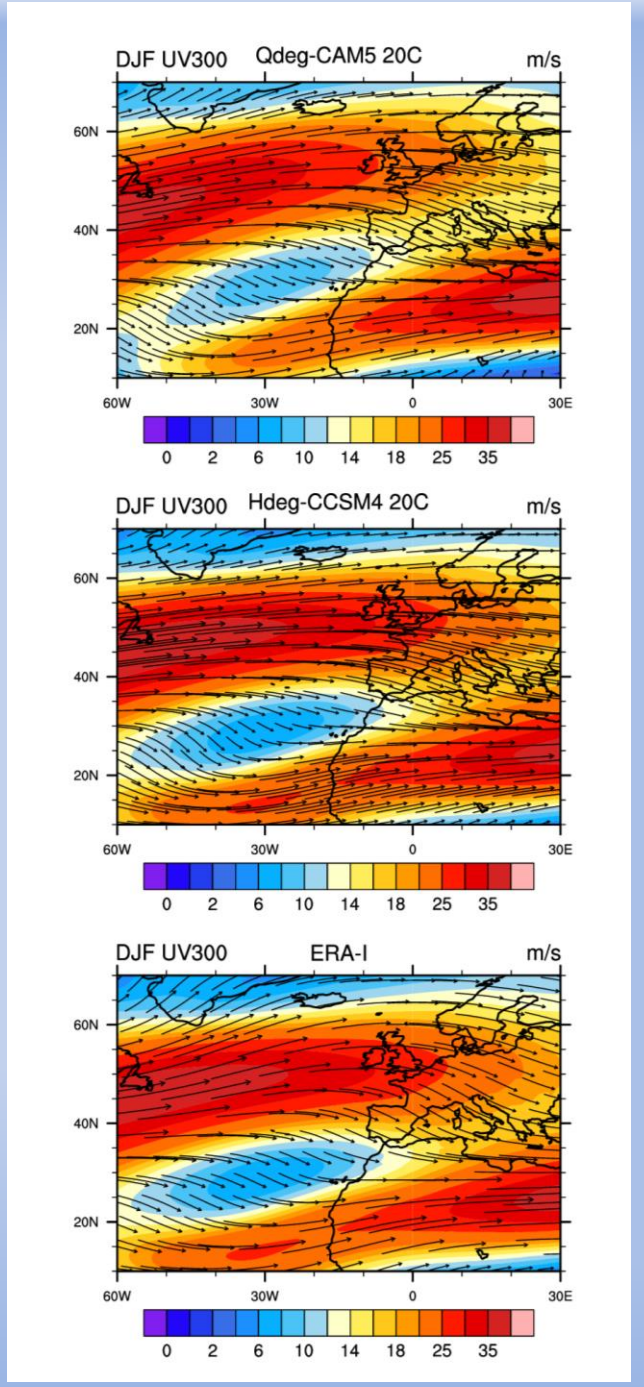
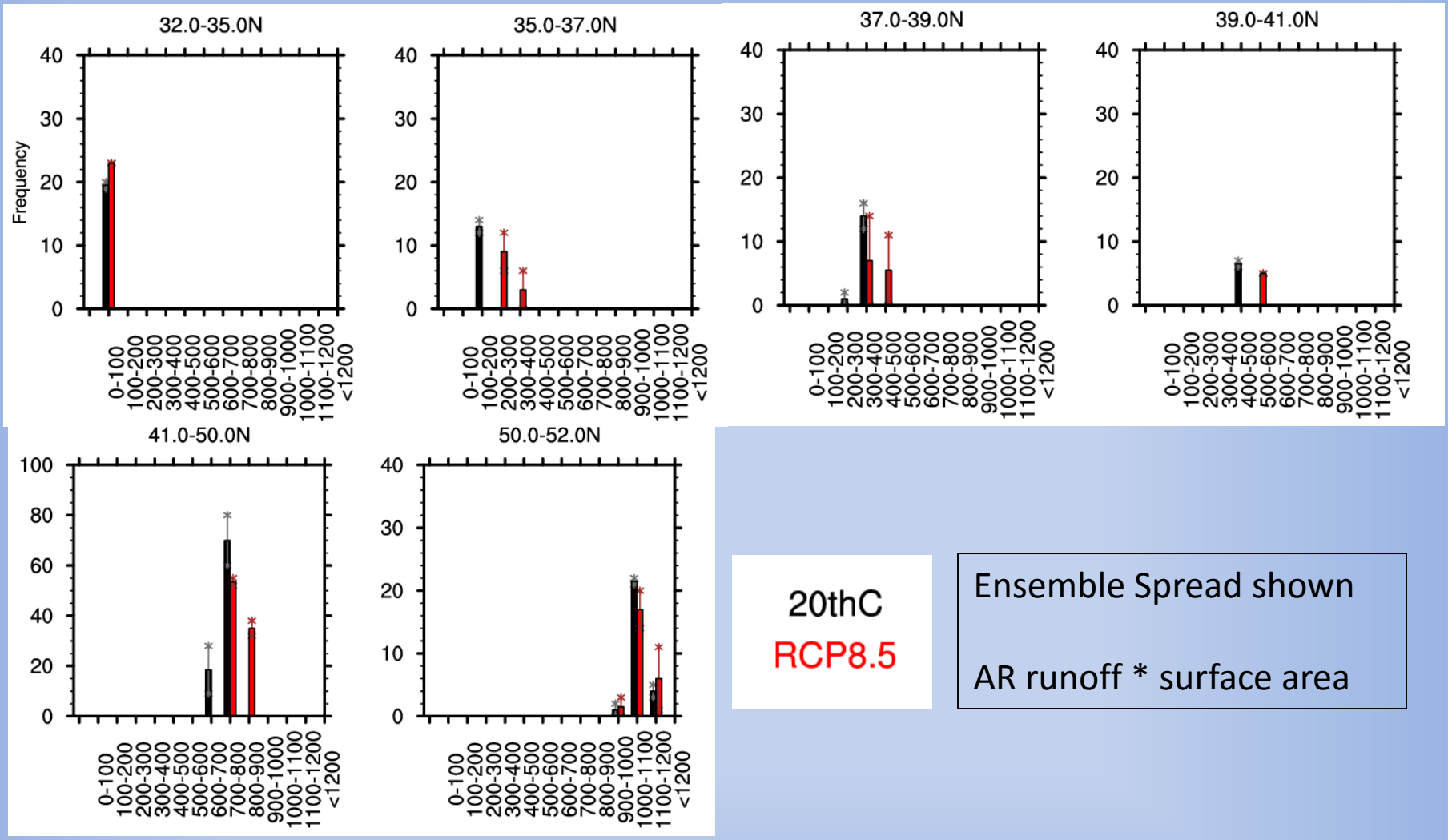

DJF UV300
Qdeg-CAM5 20C
m/s
60N
40N
20N
60W
30W
0
30E
0 2 6 10 14 18 25 35
DJF UV300
Hdeg-CCSM4 20C
m/s
60N
40N
20N
60W
30W
0
30E
0 2 6 10 14 18 25 35
DJF UV300
ERA-I
m/s
60N
40N
20N
60W
30W
0
30E
0 2 6 10 14 18 25 35

West U.S. AR Streamflow 90th %tile days



20thC

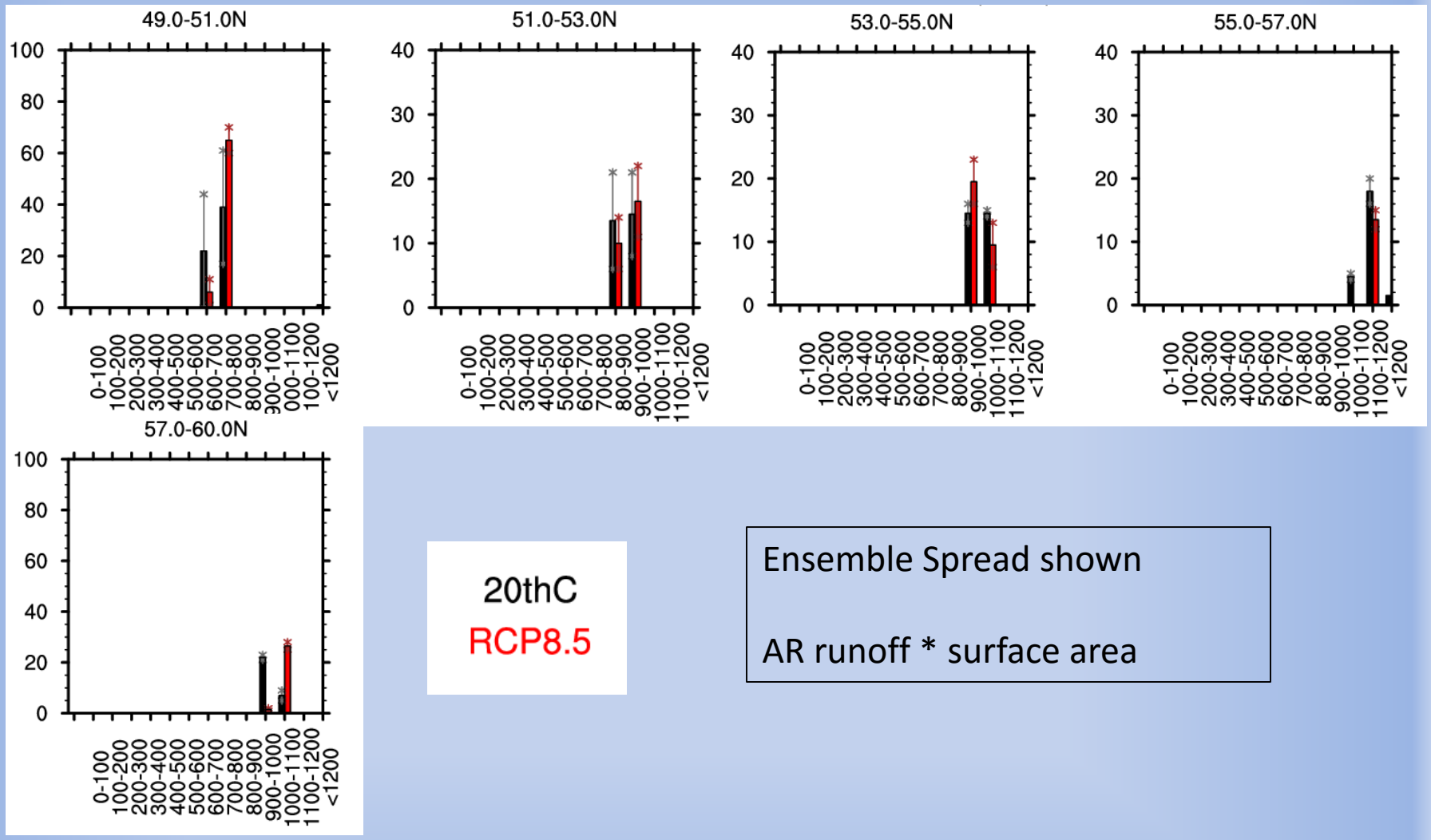
RCP8.5

Ensemble Spread shown

AR runoff * surface area

Southern CA latitudes shift to more extremes but as increase in latitude the signal becomes less robust.

UK AR Streamflow 90th %tile days



20thC

RCP8.5

Ensemble Spread shown

AR runoff * surface area

Storm Total Streamflow (m^3/hr)

Large ensemble spreads mean high uncertainty for most streamflow rate bins.

Figs 5 and 6

Deser et al. 2014, Journal of Climate

CCSM4/CAM4

Zonal mean response to Arctic sea ice loss.