The spring minimum in subseasonal 2-meter temperature forecast skill over North America

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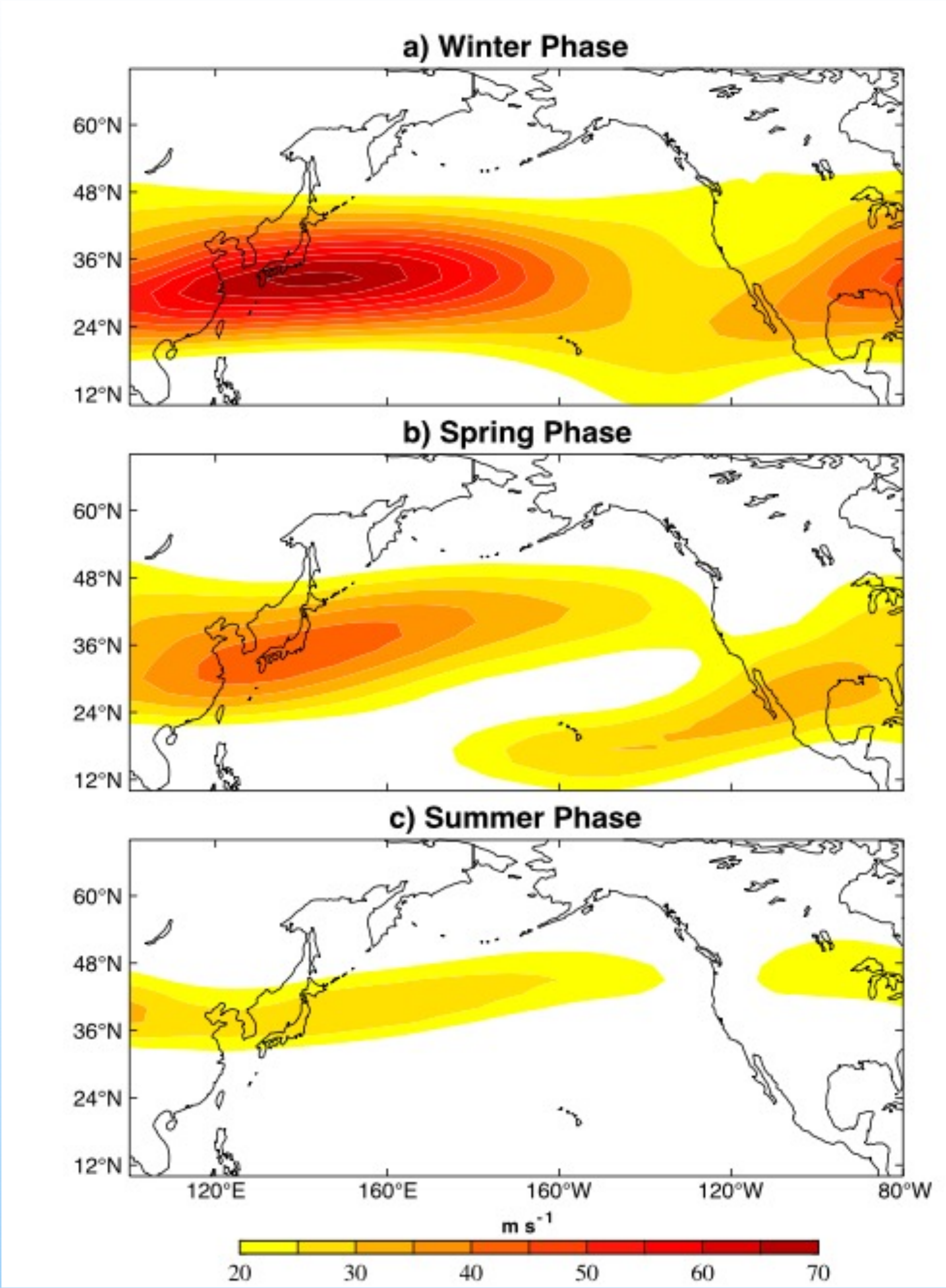
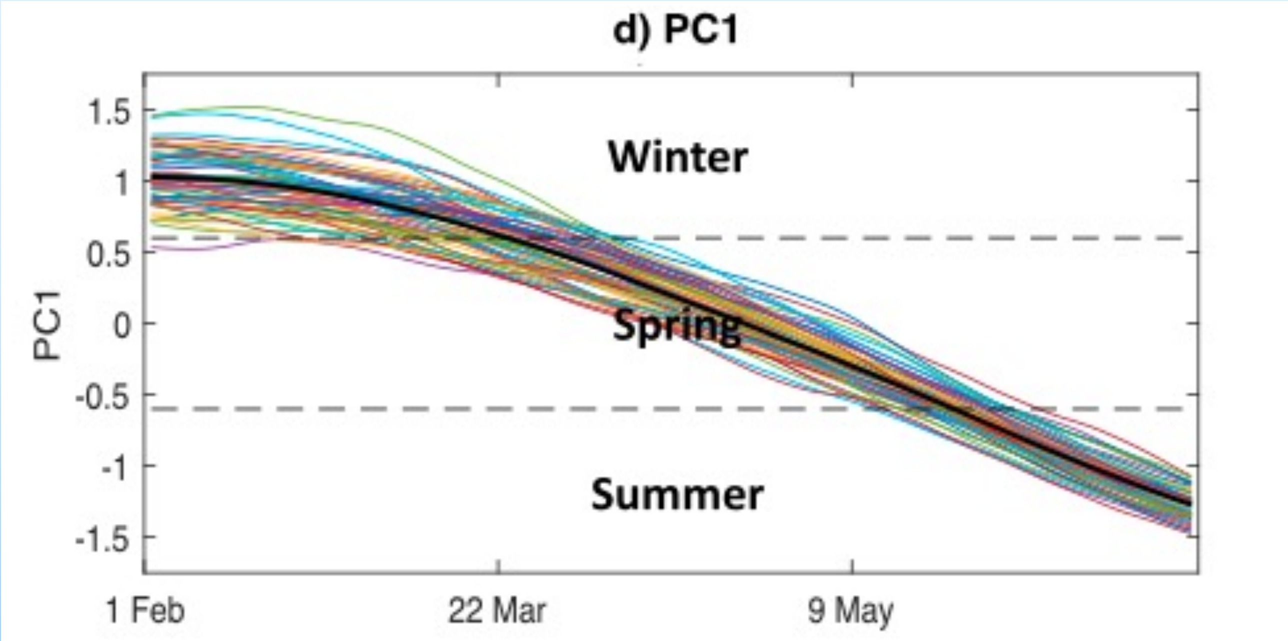
Background

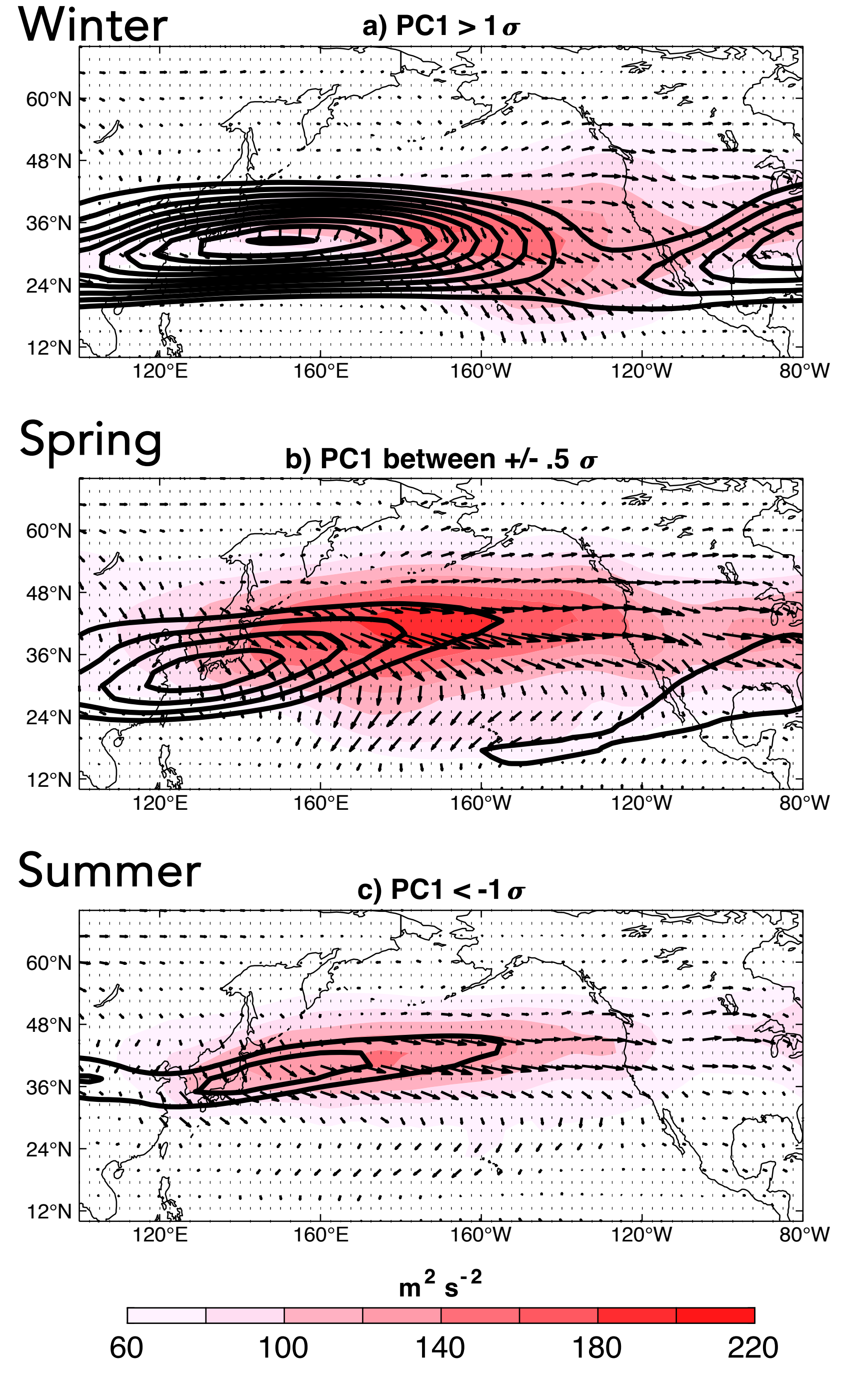
- Late winter / early spring North Pacific jet variability is high
- The leading EOF of U200 anomalies that include seasonality can capture seasonal transitions and their year-to-year timing





Breeden et al. 2022, MWR

More energetic storm track during spring phase



Contours: 200-hPa zonal wind
Color shading: high-frequency eddy kinetic energy
Arrows: **E**-vector

Breeden et al. 2021, ACP

Research Questions

- How does 2mT forecast skill compare in late winter, spring and early summer? Why?

- Can subseasonal forecasts of opportunity for 2mT be identified? When? What patterns are they associated with?

Past uses of Linear Inverse Models (LIMs)

- Can simulate the subseasonal evolution of wintertime North Pacific blocking (Breeden et al. 2020 MWR)
- Subseasonal forecasting and modeling (Winkler et al. 2001; 500Z - Albers and Newman 2019; PNA - Henderson et al. 2020; precip - Breeden et al. 2022)
- Identifying subseasonal forecasts of opportunity (SFO's) at time of forecast
- Identifying SFO's *in other models* including the IFS (North Atlantic Oscillation, Albers and Newman 2021 ERL)

Linear Inverse Model (LIM)

For state vector $\mathrm{X} = \{2\mathrm{mT}, \Psi_{200}, \Psi_{850}, \mathrm{OLR}_{\mathbf{trop}}\}$,

JRA55 7-day running mean daily anomalies Jan - Jul 1959-2018

{1} $$\frac{d\mathbf{X}}{dt} = \mathbf{Lx} + \boldsymbol{F_S}$$

Evolution of system

Slow, predictable

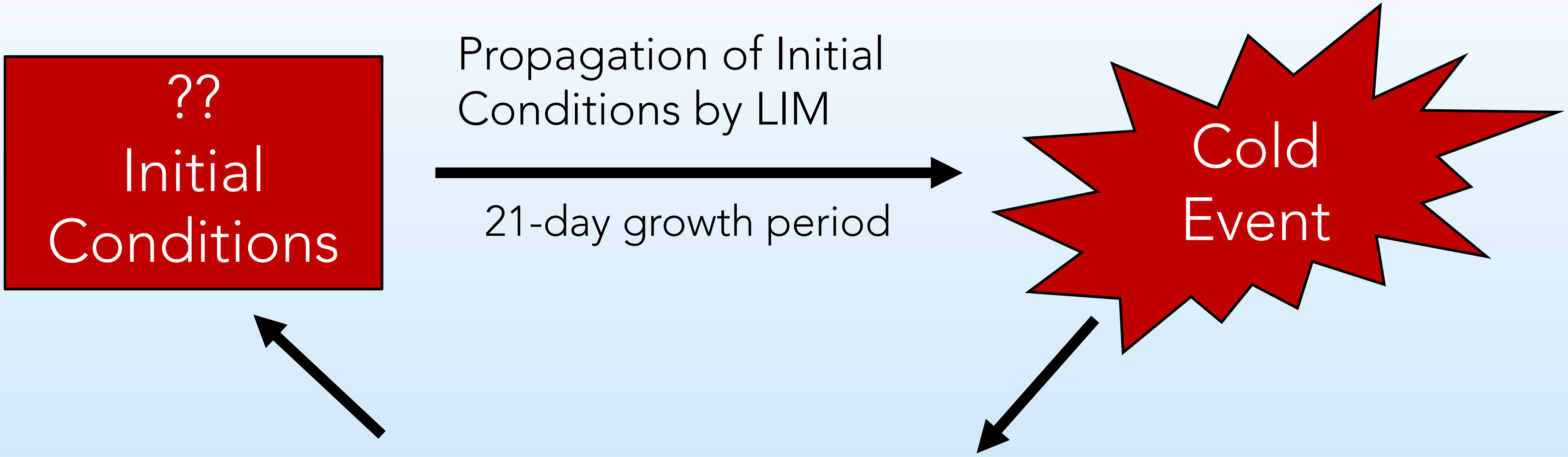
Fast, rapidly decorrelating, unpredictable

Dynamic Operator: $\mathbf{L} = \boldsymbol{logm}(\mathbb{C}\tau * \boldsymbol{inv}(\mathbb{C}_{\mathbf{0}}))/\tau$

LIM Forecast: x(t) = x(0) *exp(Lt) = x(0)G(t)

Penland and Sardeshmukh 1995

Optimizing 2mT growth



Eigenvalue Problem

$$[e^{Lt}Ne^{Lt}]p - \mu_t p = 0$$

norm (2mT, blocking)

Eigenvector (optimal initial conditions)

growth

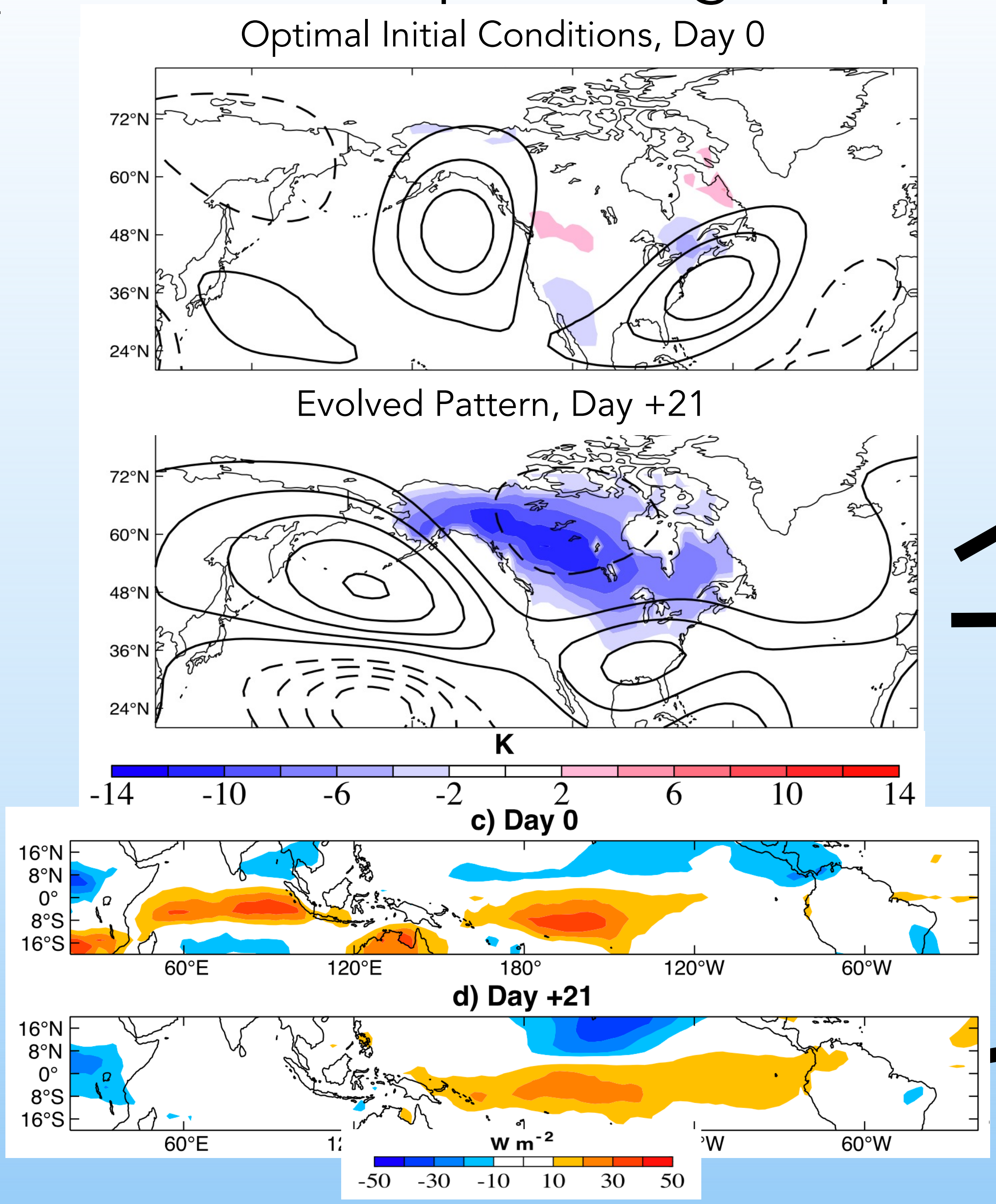
Penland and Sardeshmukh 1995

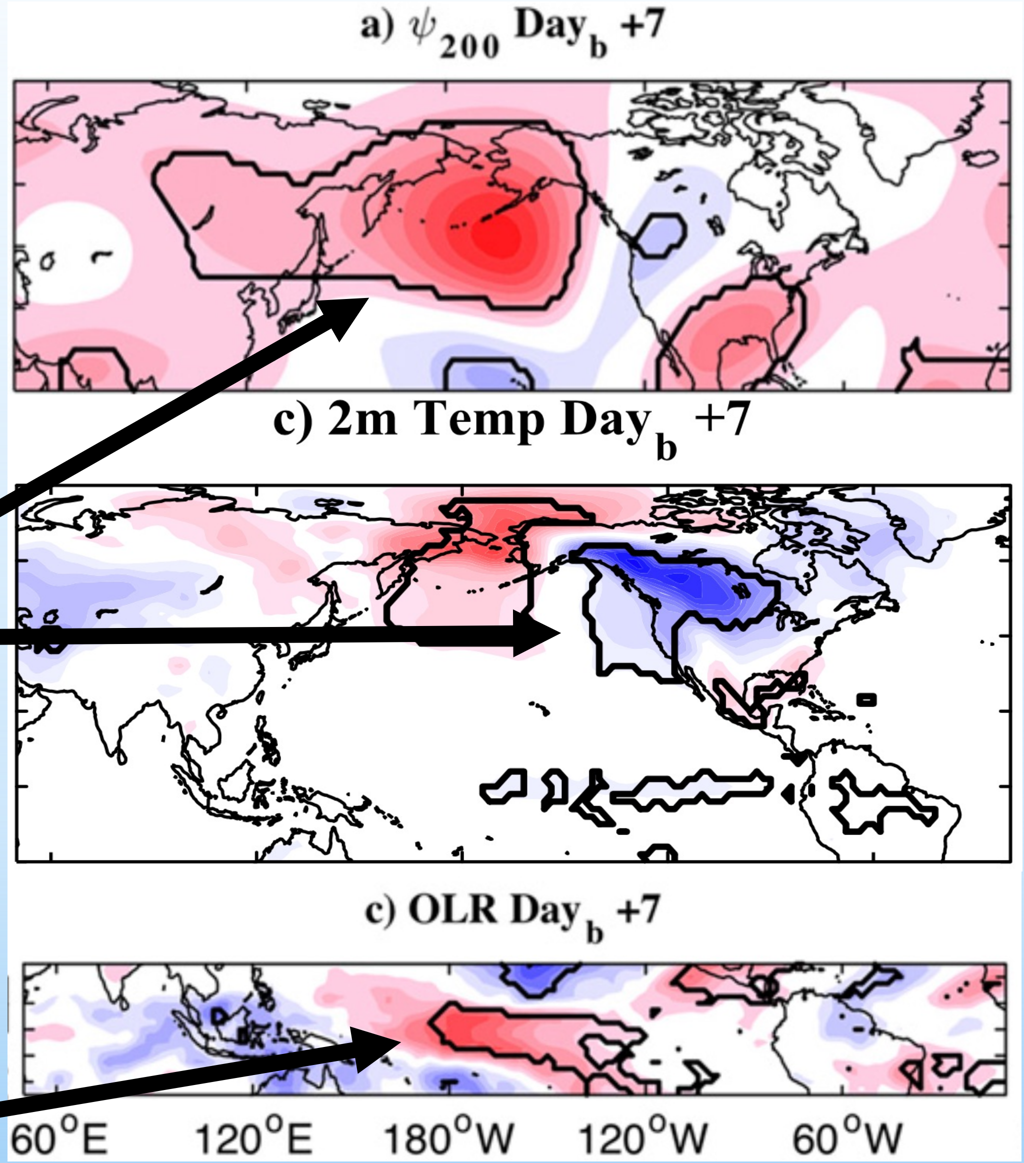
Optimizing temperature growth

Winter LIM

Contours: Ψ_{200}
Shading: 2mT

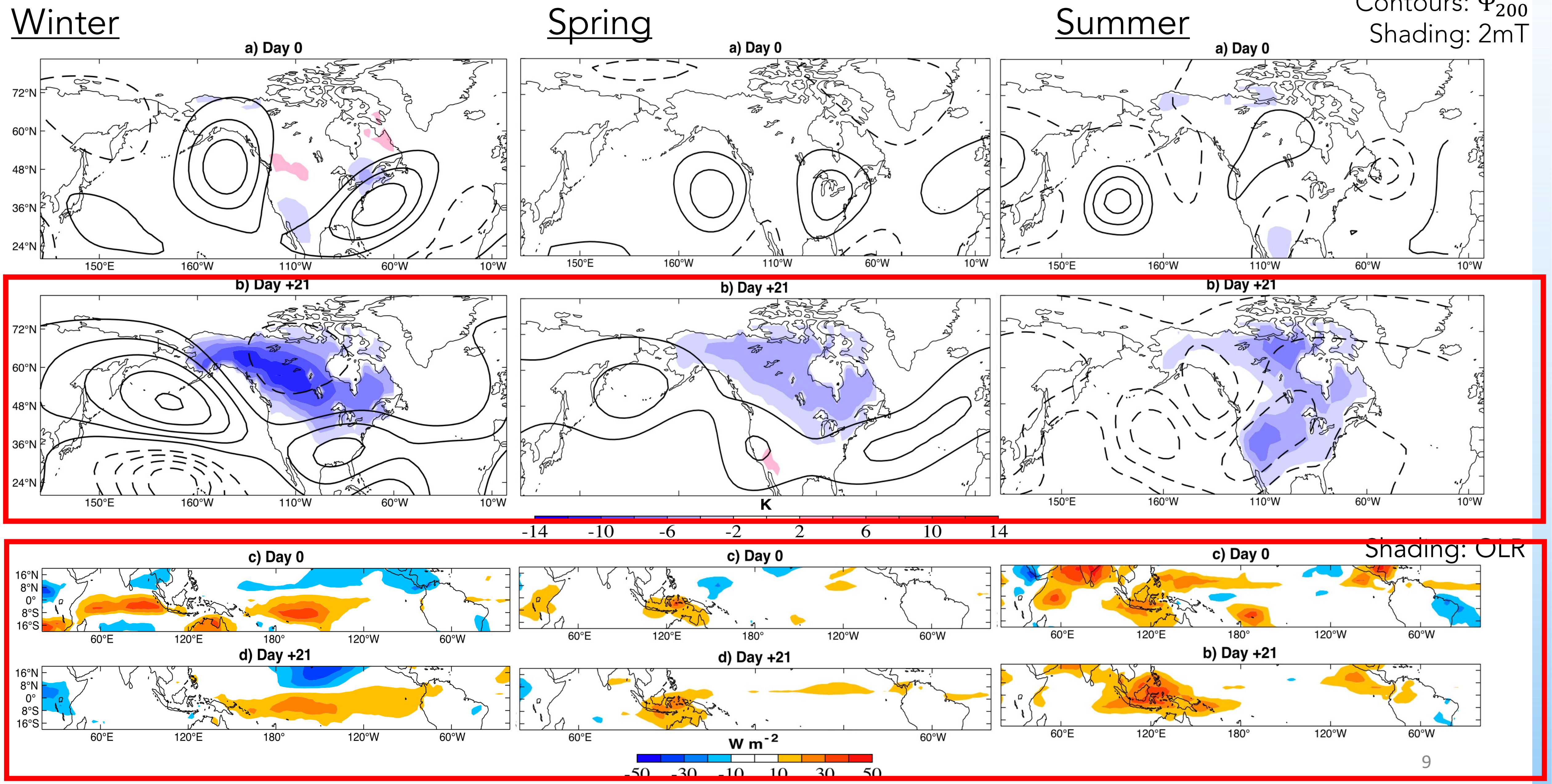
Shading: OLR





Breeden et al. 2020, MWR

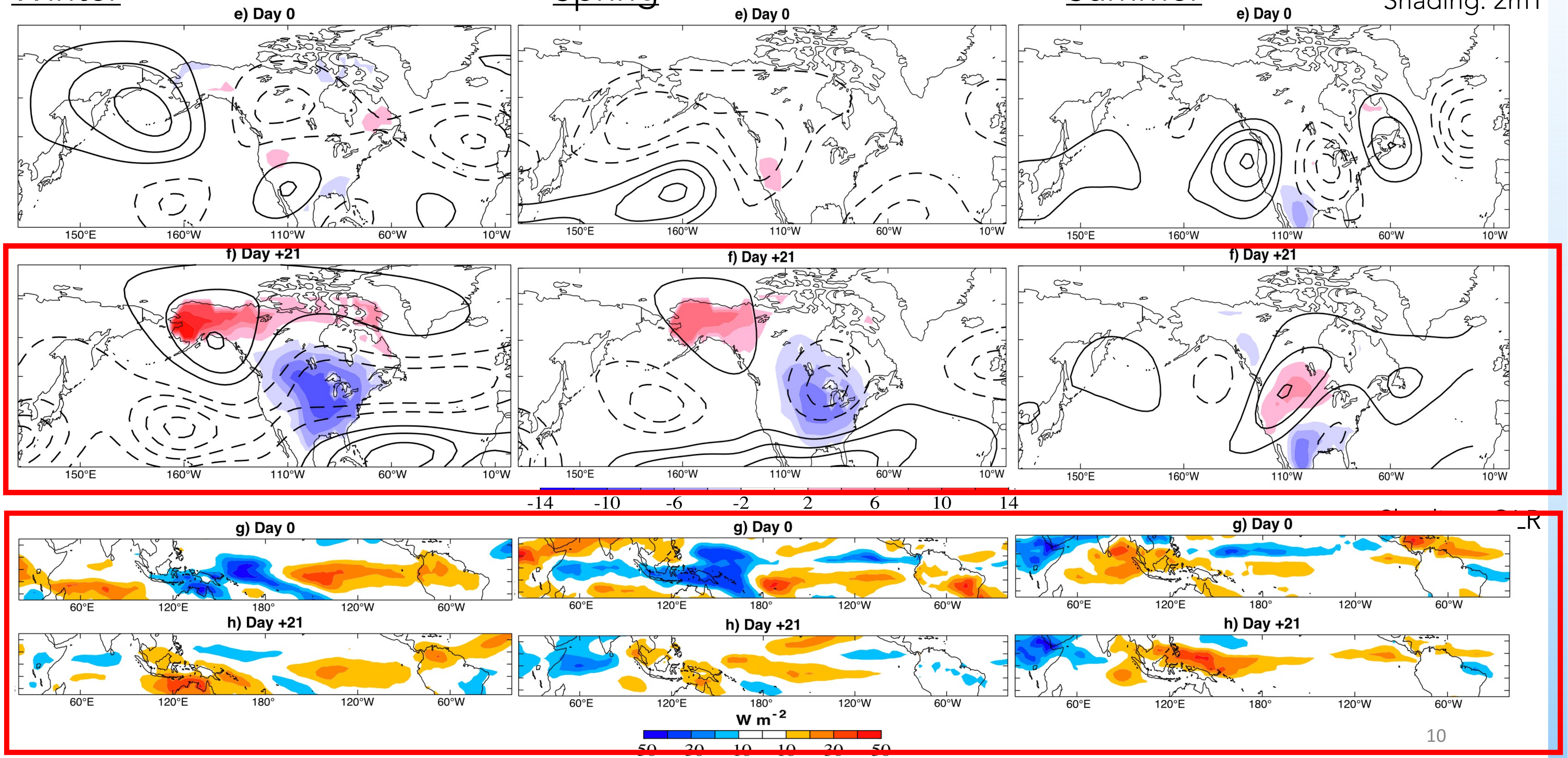
Leading pattern optimizing temperature growth (OP1)



Second pattern optimizing temperature growth (OP2)

Contours: Ψ_{200}
Shading: 2mT

Winter | Spring | Summer

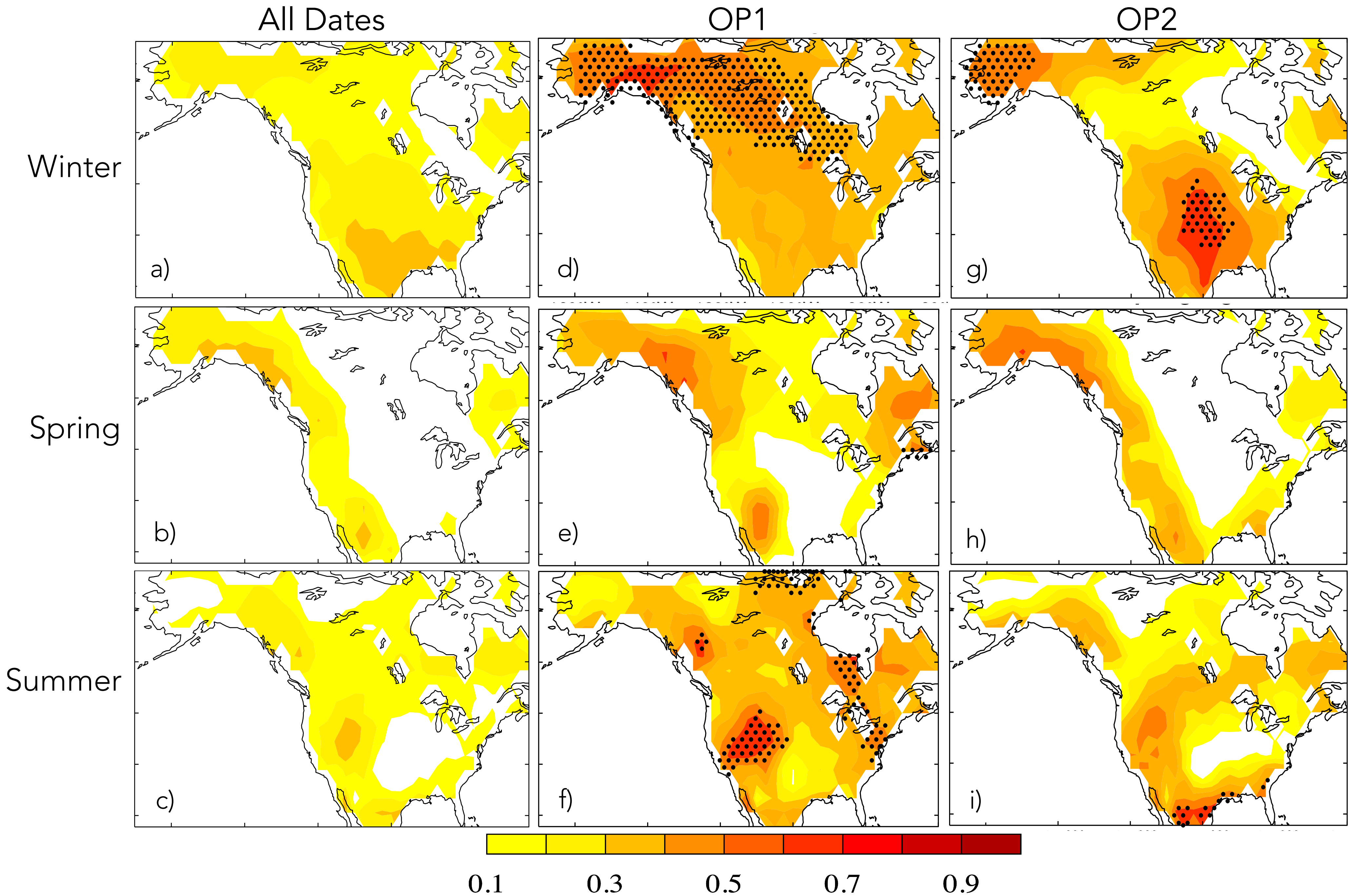


Can optimal initial conditions be used to anticipate forecasts of opportunity?

1. Find initializations that have the strongest projections onto optimal initial structures

2. Evaluate forecast skill of this subset of forecasts and compare to the skill of all forecasts

Weeks 3-4 Anomaly Correlation



ACC for all dates (left); 20% dates indicating a forecast of opportunity for OP1 (middle) and OP2 (right)

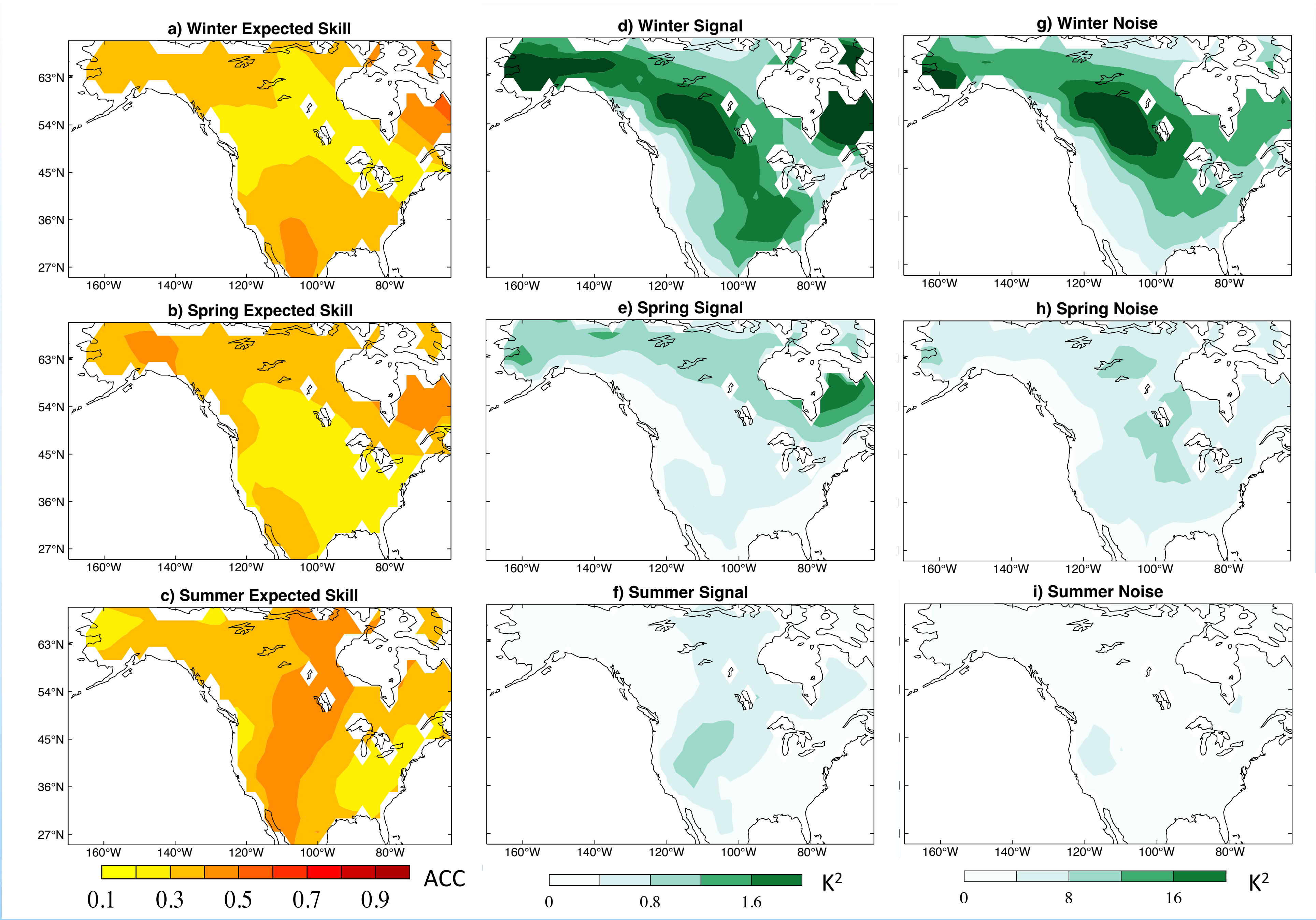
Is the spring minimum expected from theory?

Expected Skill: $\rho_\infty(\tau) = \frac{S^2(\tau)}{\{[S^2(\tau)+1]S^2(\tau)\}^{.5}}$

Signal-to-noise ratio: $S^2(\tau, i) = \frac{F(\tau)_{ii}}{E(\tau)_{ii}},$

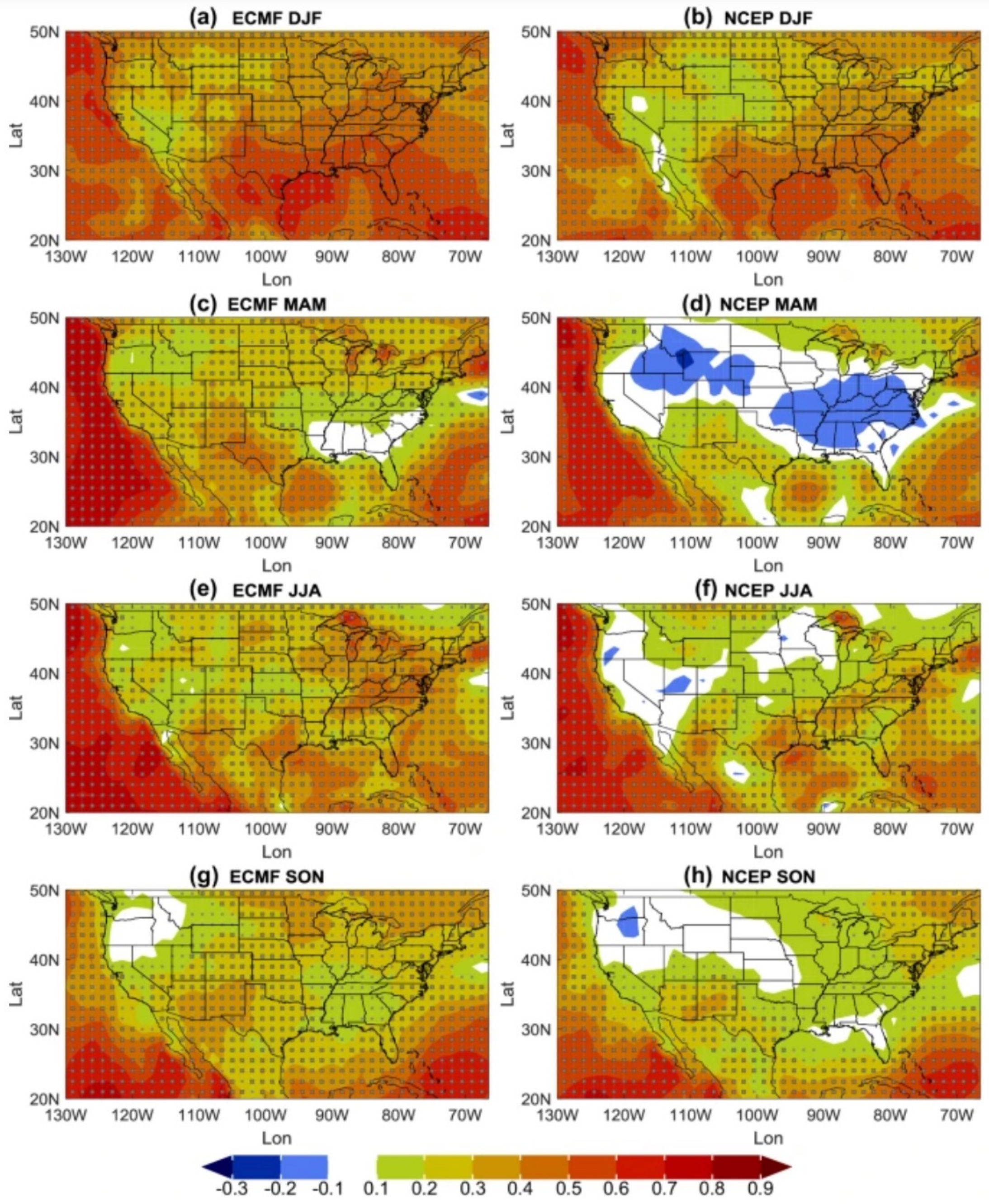
Forecast signal covariance: $F(\tau) =< x(t+\tau)x(t+\tau)' >$

Forecast error covariance: $E(\tau) = \mathbb{C}\boldsymbol{O}\boldsymbol{G}(\tau)\mathbb{C}\boldsymbol{O}\boldsymbol{G}(\tau)'$



Spring minimum is due to a minimum in signal coincident with relatively elevated noise

Skill comparison from other studies also shows a spring minimum



Week 3–4 CORA skill maps for 2 m temperature

Wang and Robertson 2018
Clim. Dyn.

LIM for CPC Weeks 3-4 2mT Guidance

Forecasted variables:

- Mean sea-level pressure (20˚-90˚N)
- Geopotential height (500 hPa, 20˚-90˚N)
- Tropical heating (-14˚S-14˚N)
- Tropospheric stream function (750 hPa, 20˚-90˚N)
- Upper troposphere-lower stratosphere geopotential height (100 hPa, 30˚-90˚N)
- Tropical sea surface temperature (-14˚S-14˚N)
- 2m temperature (North America-land only)
- “Root zone” soil wetness (first two layers - North America-land only)

$$x = \begin{bmatrix} p \\ \Phi \\ H \\ \psi_T \\ \psi_{UTLS} \\ SST \\ T_{2m} \\ S_w \end{bmatrix}$$

Courtesy of John Albers, Matt Newman
Yuan-Ming Cheng and Maria Gehne

Baseline forecast skill for United States (CONUS and Alaska)

(skill measured by HSS)

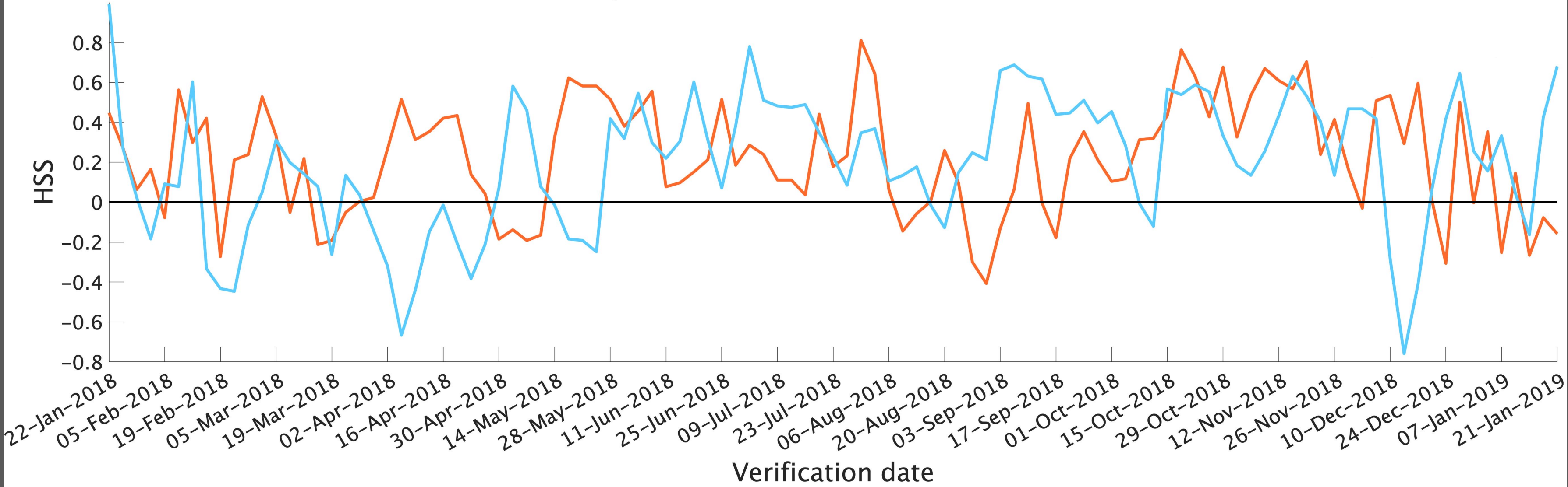
	2017	2018	2019	2020	2021	5-year average: (2017-2021)
CPC-PSL LIM	0.26	0.23	0.21	0.35	0.19	0.25
ECMWF IFS	0.23	0.22	0.31	0.32	0.27	0.27

Courtesy of John Albers, Matt Newman
Yuan-Ming Cheng and Maria Gehne

Week 3-4 2m temperature HSS
(CONUS + Alaska)

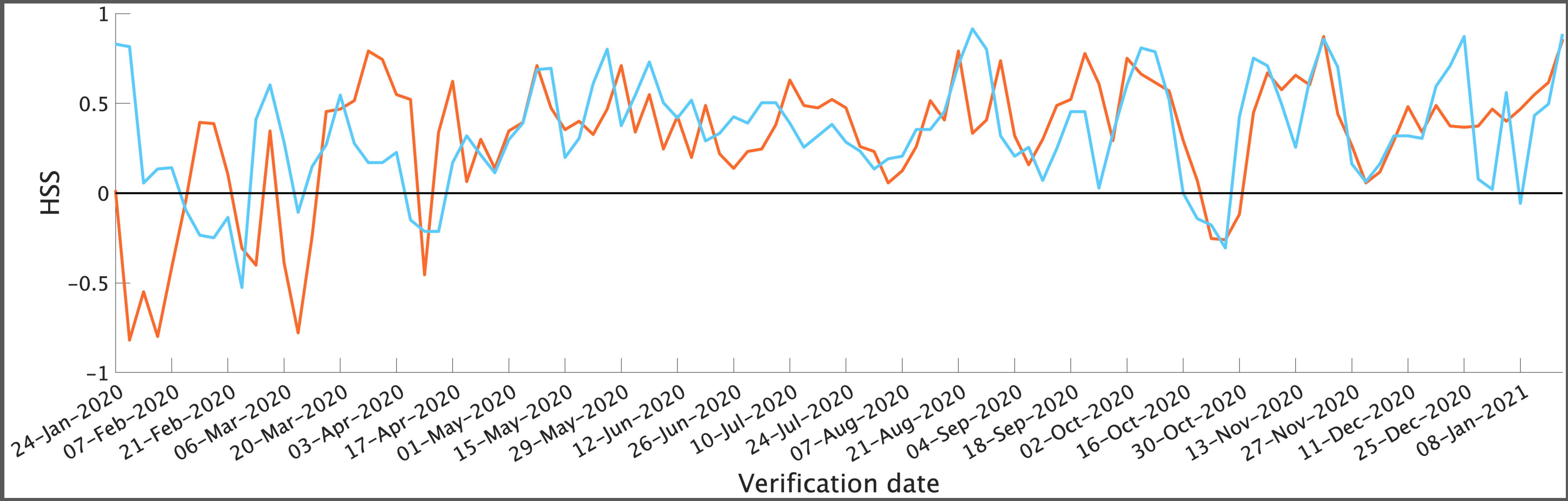
2018

ECMWF IFS (mean HSS: 0.224)
CPC LIM (mean HSS: 0.2)



2020

ECMWF IFS (mean HSS: 0.315)
CPC LIM (mean HSS: 0.334)



Conclusions, more information

- Spring is a notable predictability minimum in subseasonal 2mT skill due to a minimum in forecast signal coincident with elevated noise
- Spring skill remains low even during forecasts of opportunity, in contrast to winter and summer

Near realtime LIM 2mT forecasts are available for North America: https://psl.noaa.gov/forecasts/lim_s2s/

Near realtime LIM 2mT and precipitation forecasts are available for East Africa and southwest Asia: https://www.psl.noaa.gov/forecasts/s2s_international/

This talk: Breeden, M. L., Albers, J. R., Butler, A. H., and Newman, M.: The Spring Minimum in Subseasonal 2-m Temperature Forecast Skill over North America, *Monthly Weather Review*, *150*(10), 2617-2628, 2022.

Recent subseasonal application: Albers, J. R., Newman, M., Hoell, A., **Breeden, M. L.**, Wang, Y., and Lou, J.: The February 2021 Cold Air Outbreak in the United States: a Subseasonal Forecast of Opportunity, *Bulletin of the American Meteorological Society*, *103*(12), E2887-E2904, 2022.

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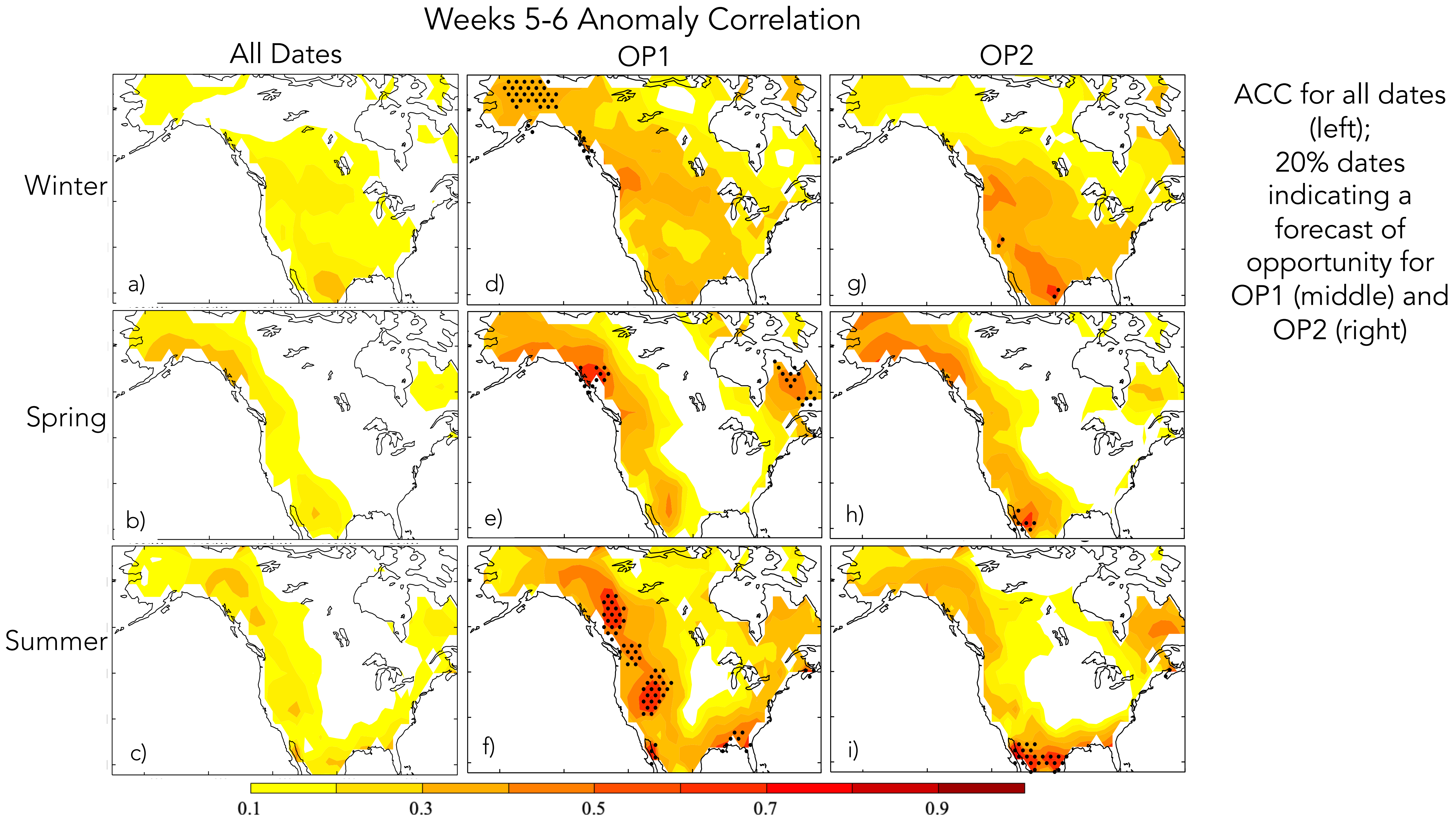

Weeks 5-6 Anomaly Correlation
All Dates
OP1
OP2
Winter
Spring
Summer
a)
b)
c)
d)
e)
f)
g)
h)
i)
0.1
0.3
0.5
0.7
0.9
ACC for all dates (left); 20% dates indicating a forecast of opportunity for OP1 (middle) and OP2 (right)