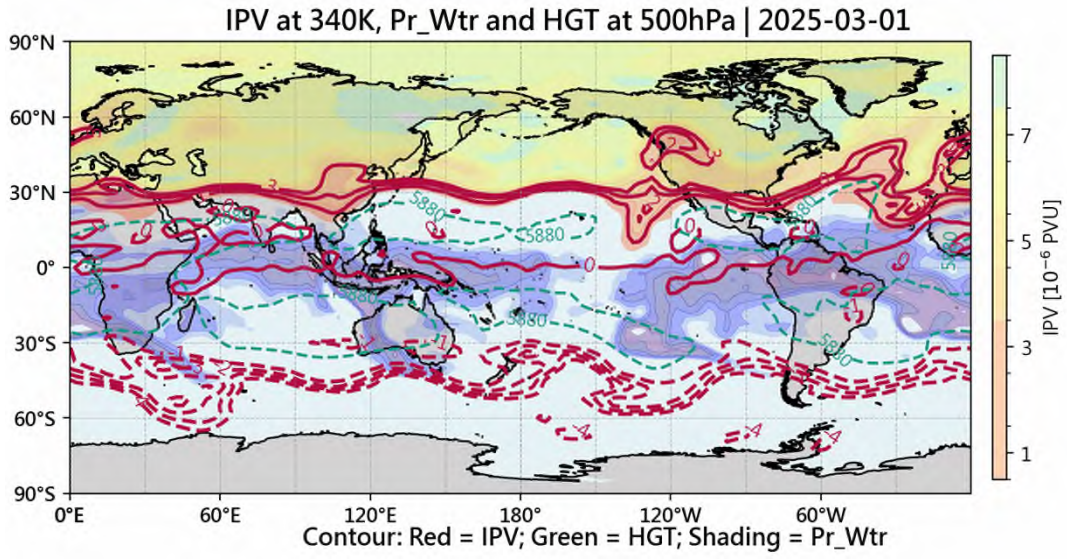
Seasonal Transition, Spring, Autumn, and Prediction



John C.-H. Tseng

Sep/04/2025

Objectives

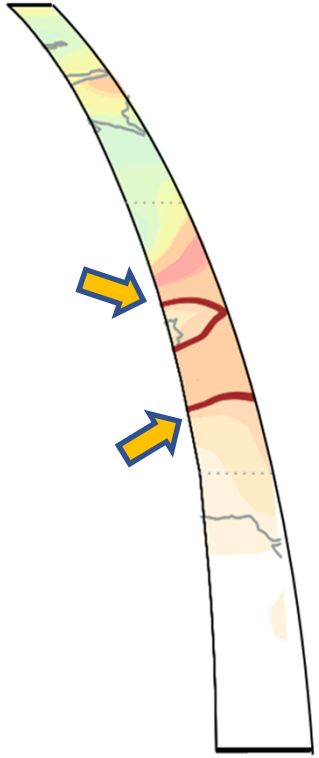
(1) identifying persistent circulation, Rossby waves propagation, breaking;

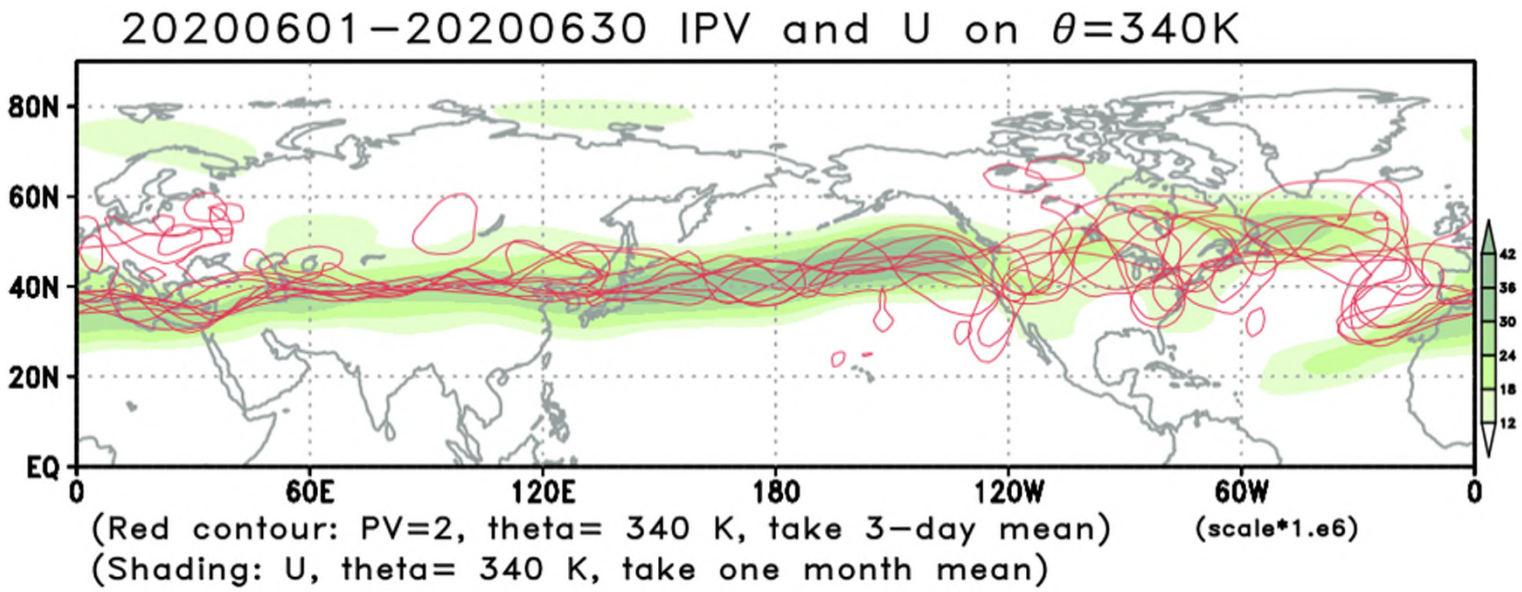
(2) demonstration the seasonal transition, monsoon, and wave interactions;

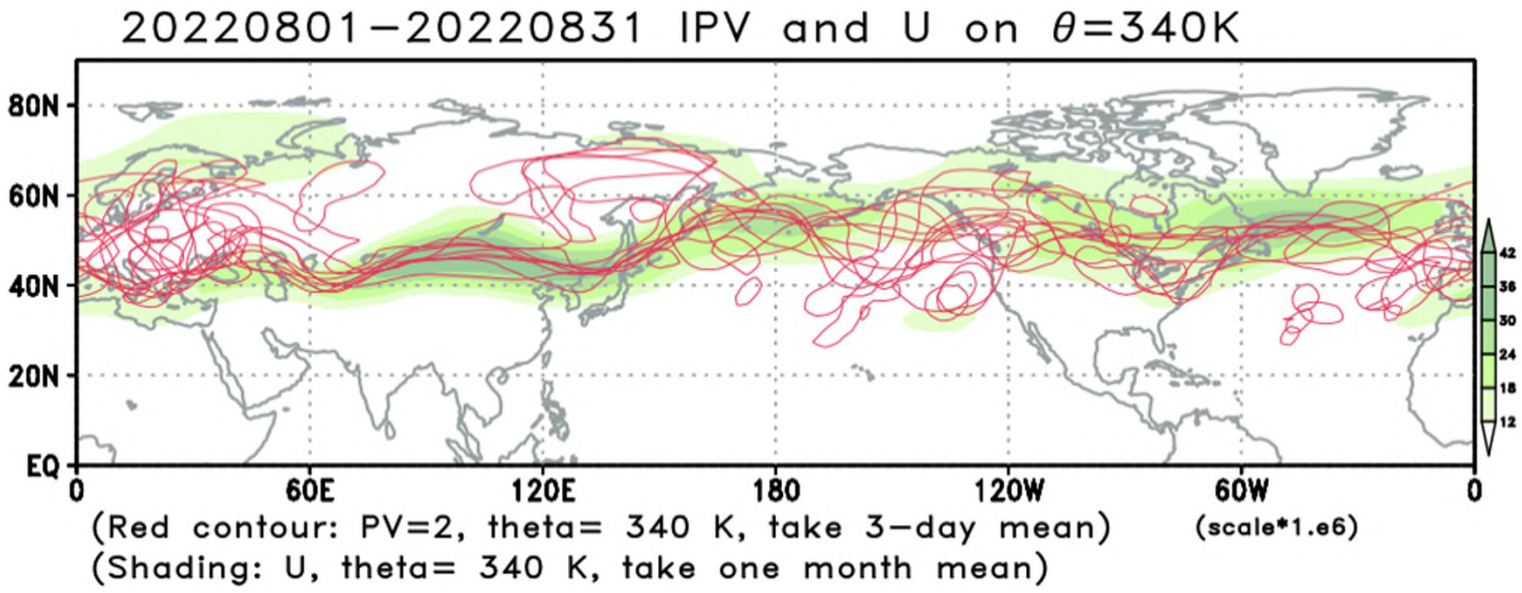
(3) classification or clustering; and

(4) applying ISOMAP on PV to establish sub-seasonal to seasonal neural network predictions.

evidences to support ...

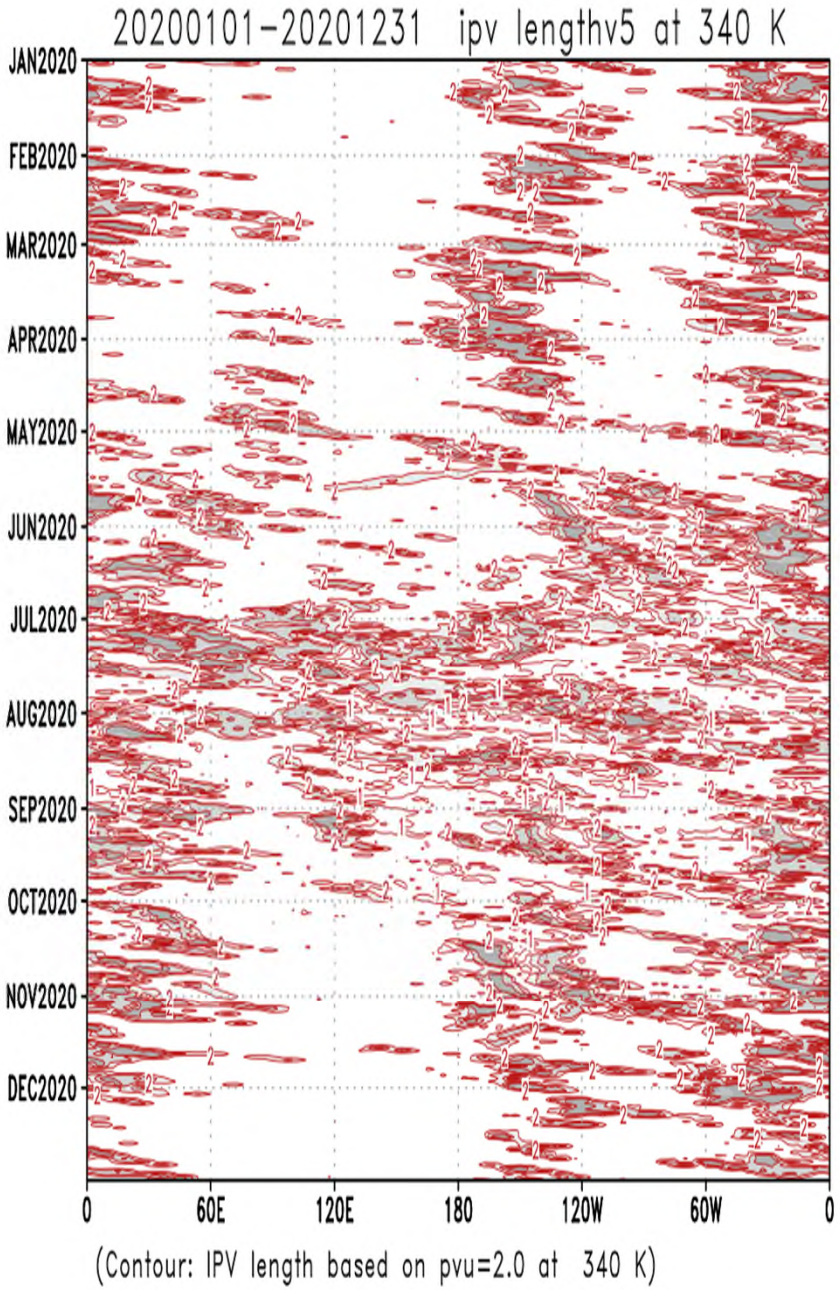


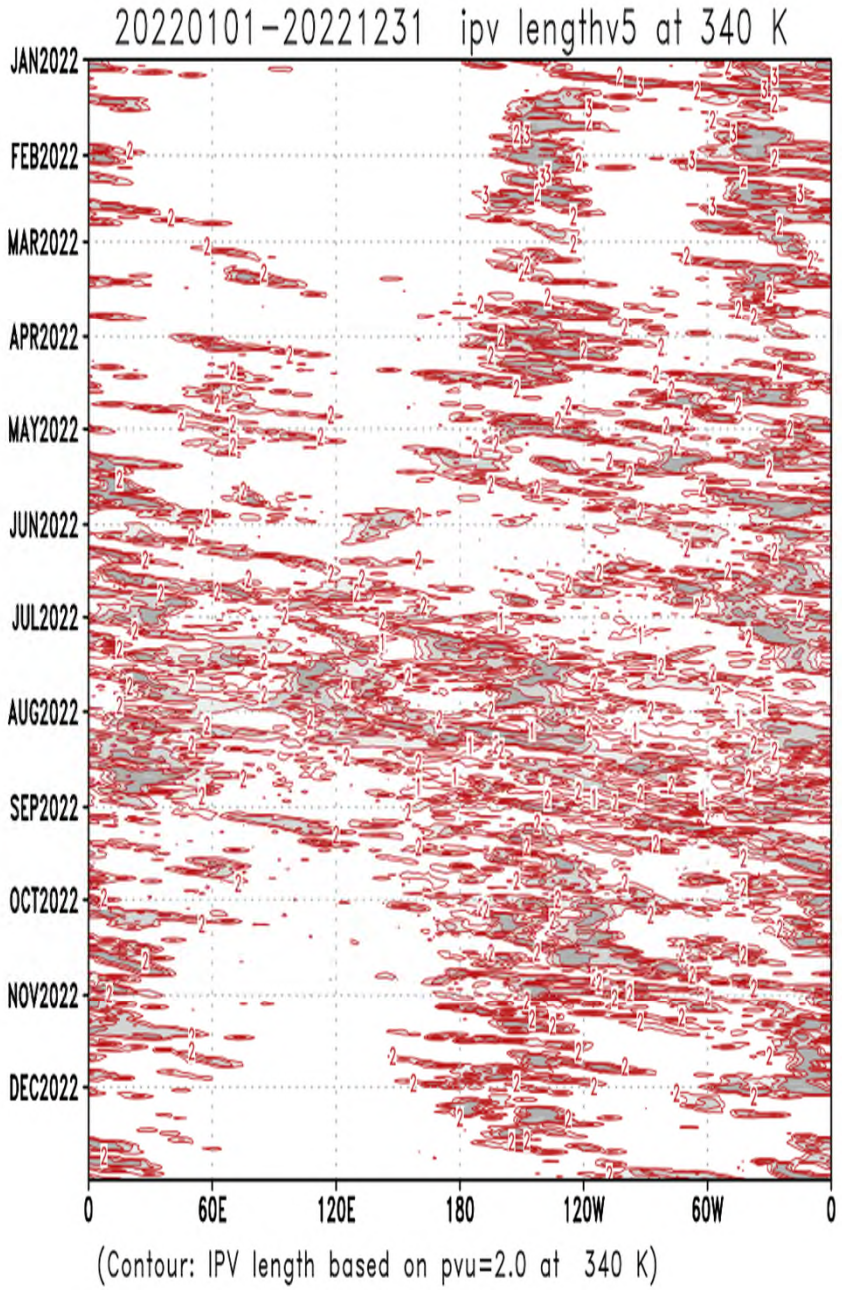




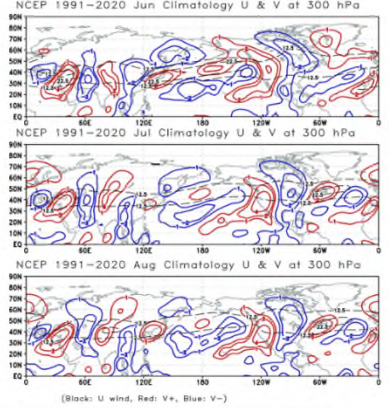
2020 vs 2022 Hovmöller plot of 2PVU contour lengths

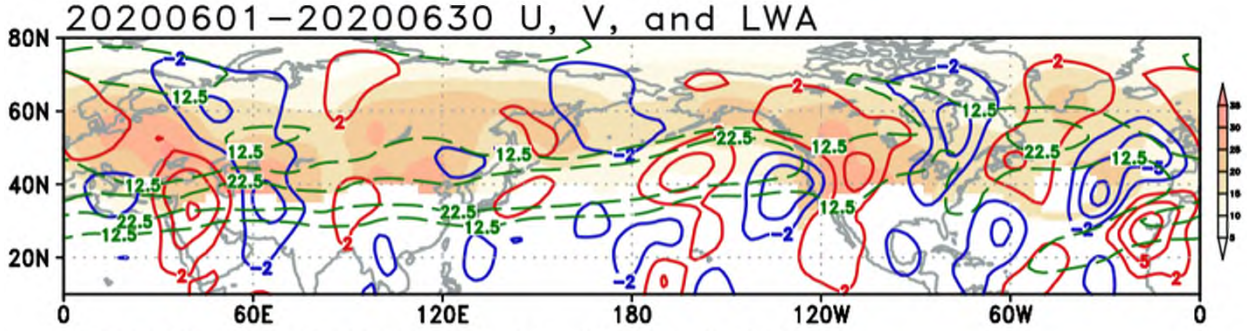
- Longer PV contour lengths correspond to greater meandering

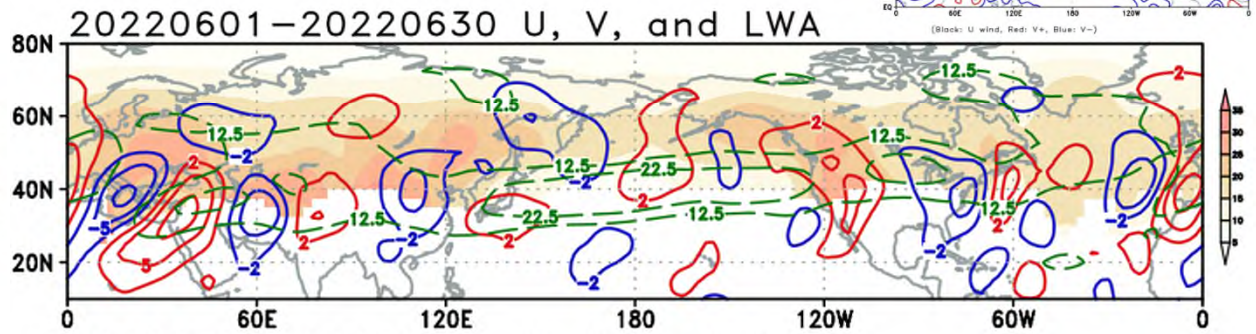


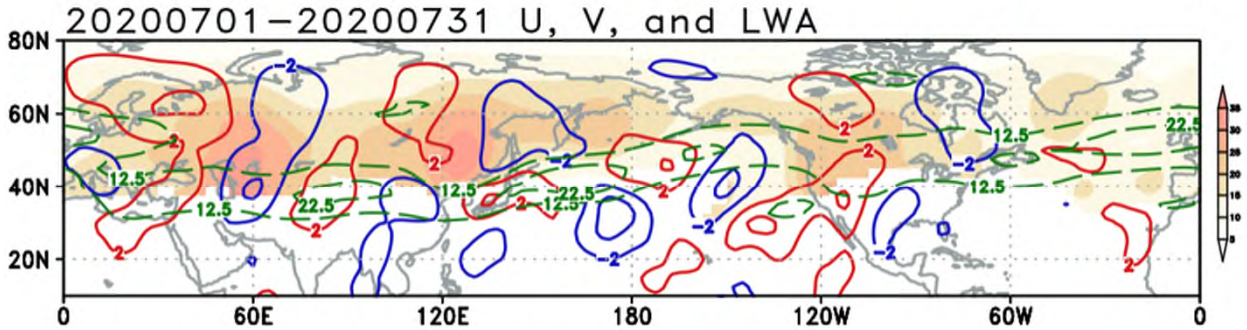


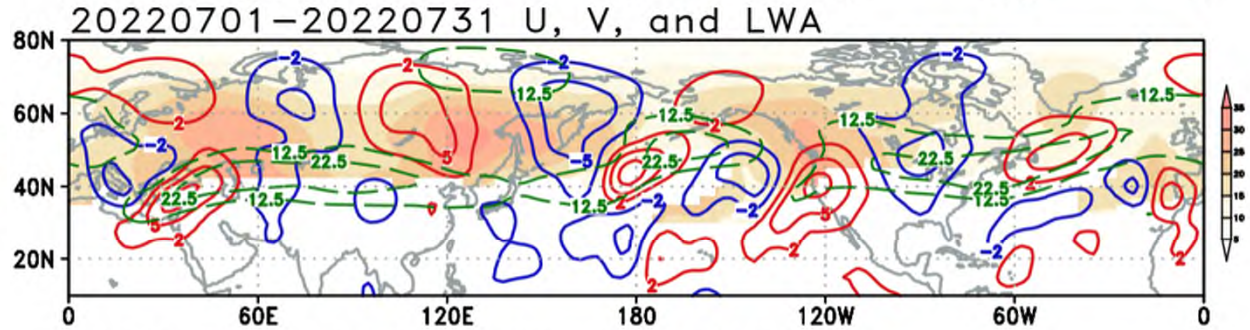
(Remark) As a phase-independent metric, Local wave activity (LWA) provides a more robust measure of the Rossby wave train

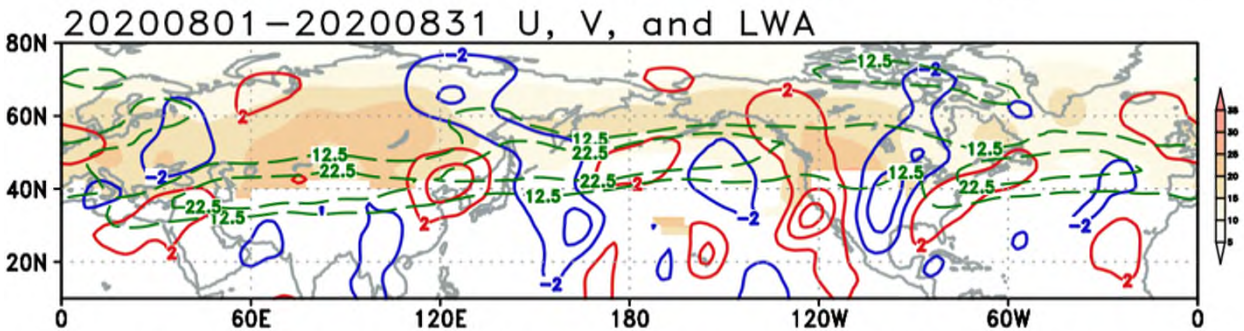




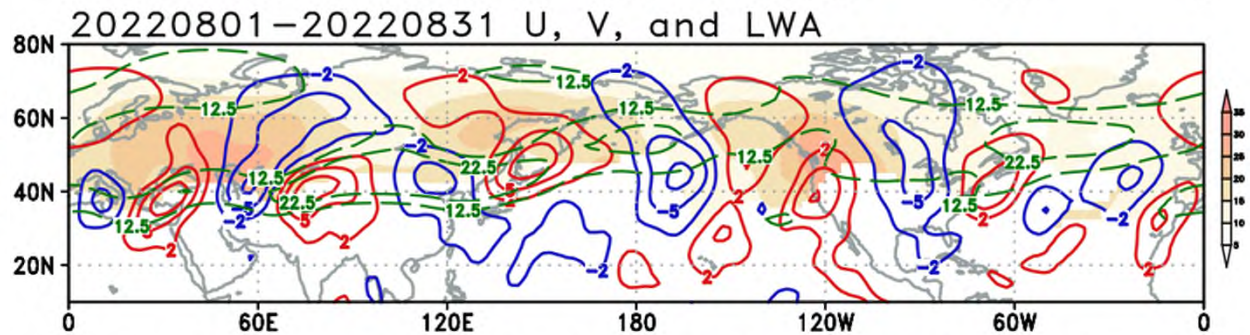








(Contour Green: U, Red: V+, Blue: V−, 300hPa; Shade: LWA, and 340K IPV>1.0)



(Contour Green: U, Red: V+, Blue: V−, 300hPa; Shade: LWA, and 340K IPV>1.0)

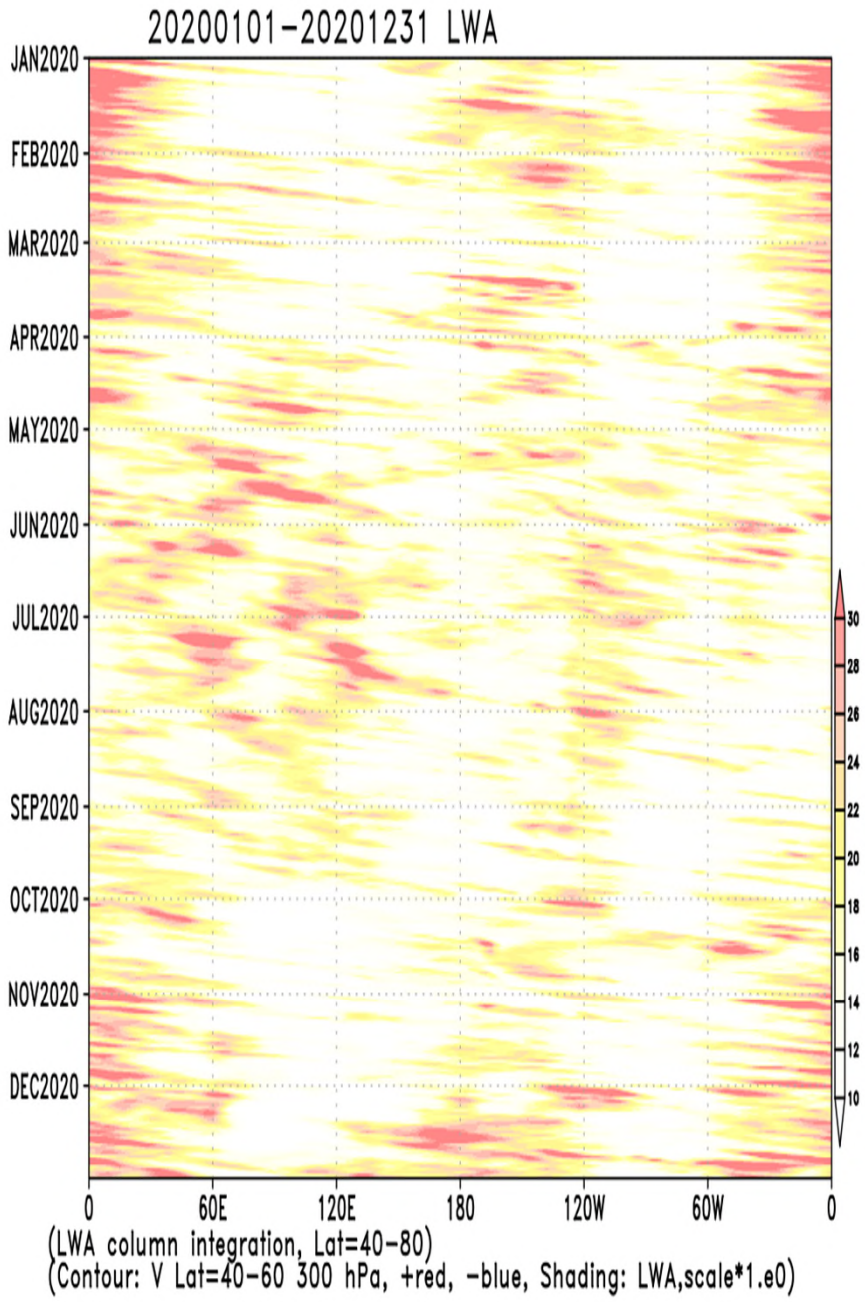
2020 vs 2022 Hovmöller plot of LWA

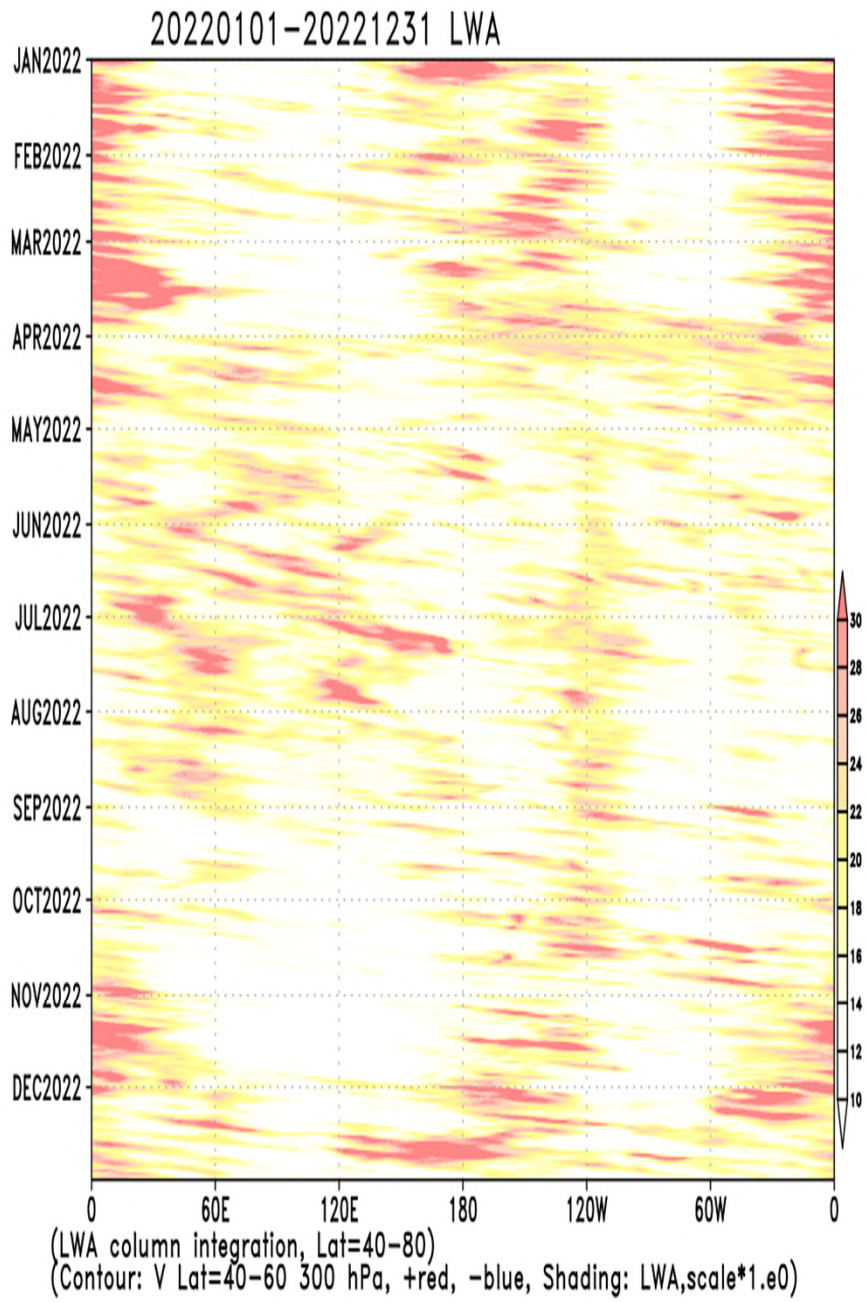
- LWA=local wave activity, the measurement of wave meandering

$$A(\lambda,\phi,z,t)\cos\phi \equiv -a\int_0^{\eta} q_e \cos(\phi+\phi')d\phi'$$

$$\mathrm{LWA} \equiv \langle A\cos\phi\rangle = \int_0^{\infty} (A\cos\phi)e^{-z/H}dz \;/\; H$$

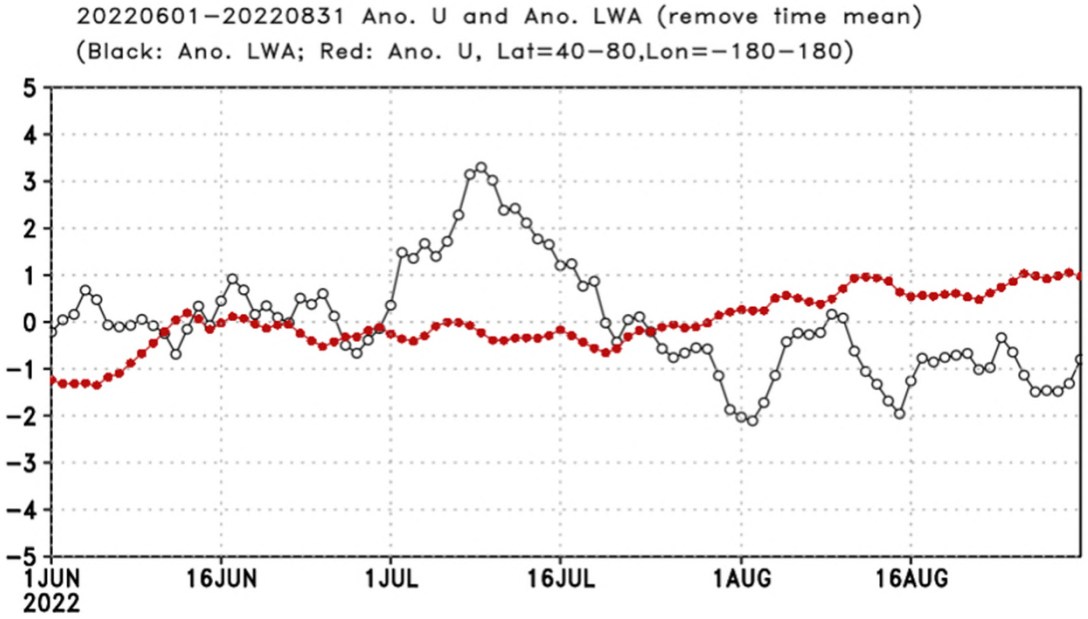
$$\frac{\partial}{\partial t}(\langle\overline{u}\rangle+\langle A\rangle)\approx 0$$



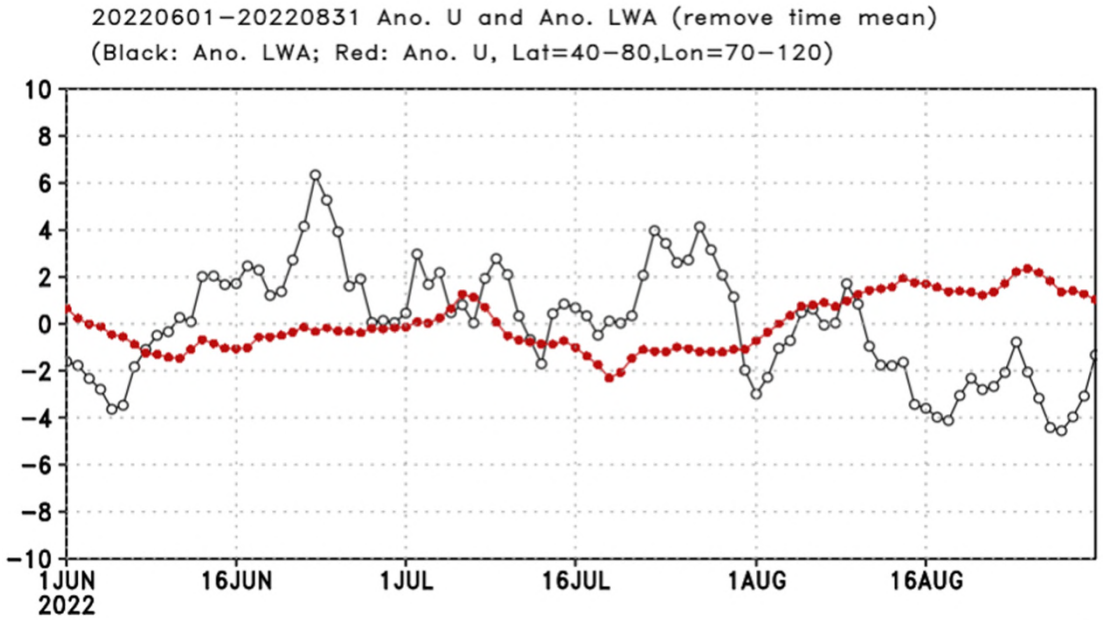


LWA is from Huang and Nakamura (2016)

Zonal wind (U) and LWA

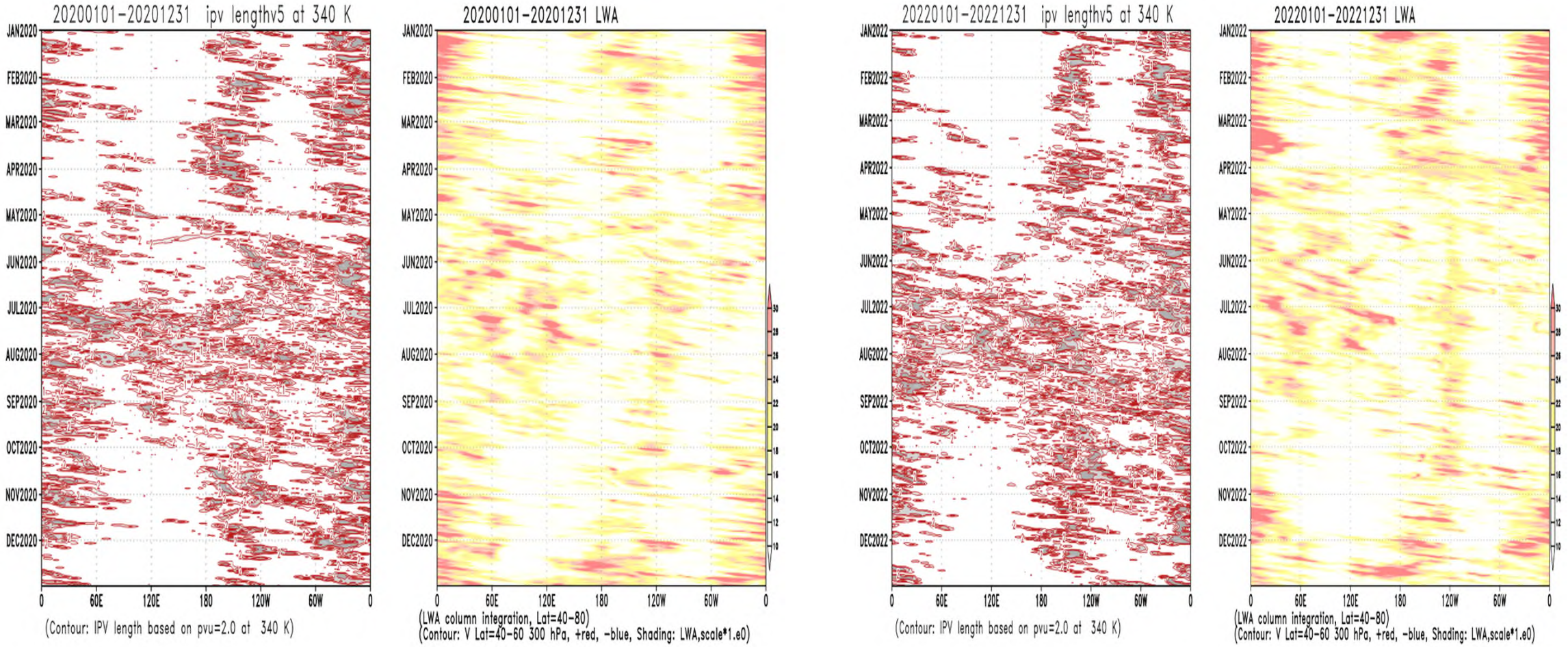


$$\frac{\partial}{\partial t}(\langle \overline{u} \rangle + \langle A \rangle) \approx 0$$



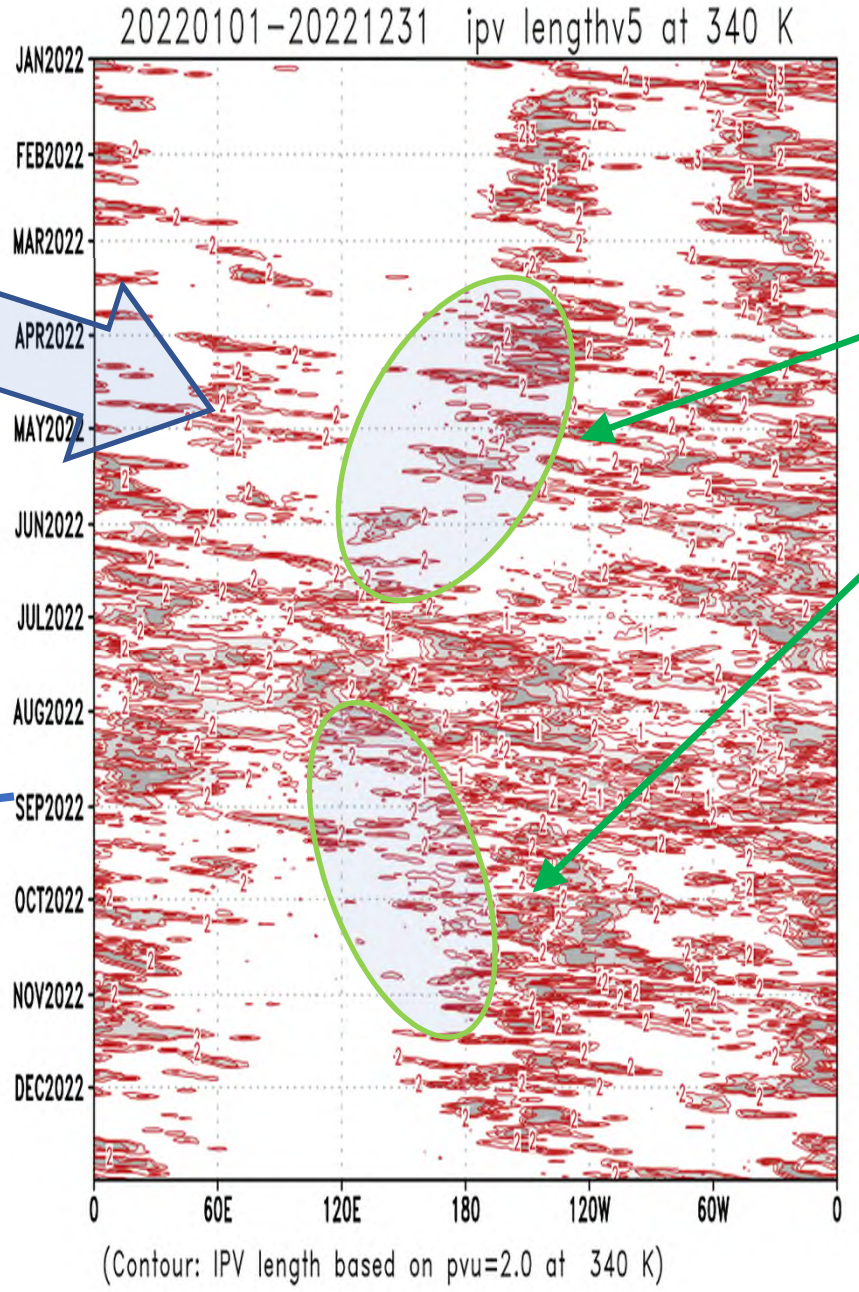
- Based on the previous slides, we found there are obvious transition signals, ***retreating westward waves*** in spring, and similar signals but ***gradually disappearing westward waves*** in end of summer. The summer had ***winding and meandering jet*** in contrast to the winter ***jet moving eastward steadily***.
- These two events were not special cases. The support evidences were

Both **PV contour lengths** and **LWA** highlight the **evolving** and **retreating** behavior of **westerly synoptic wave groups** in **spring** and **autumn**.



Transition period, spring rain? Mei-Yu?

What happens in this period?



What are they?

The westward retreat of wave groups coincides with the seasonal migration of quasi-stationary atmospheric rivers

- Hovmöller of column water vapor (CWV) at 30N in 2017

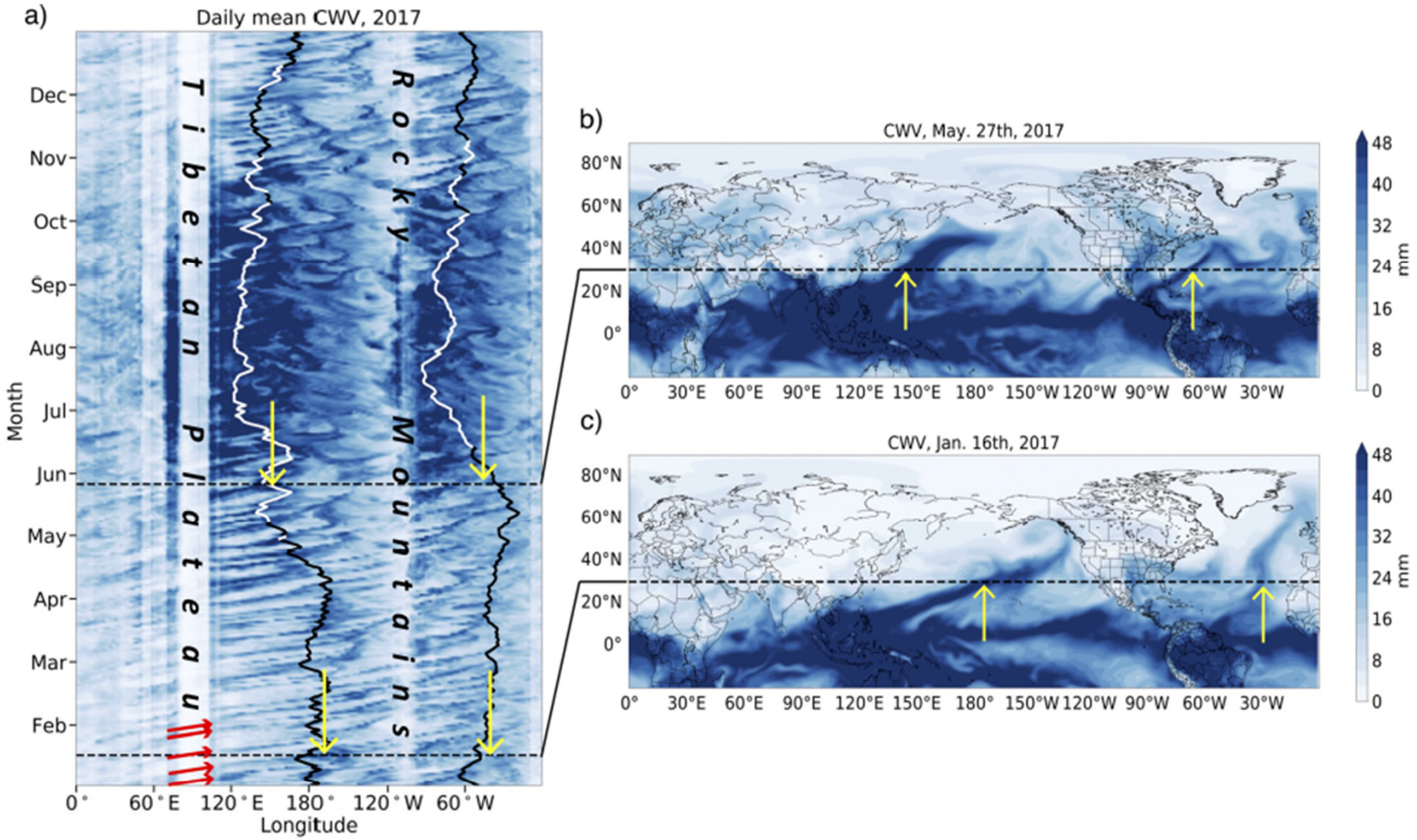
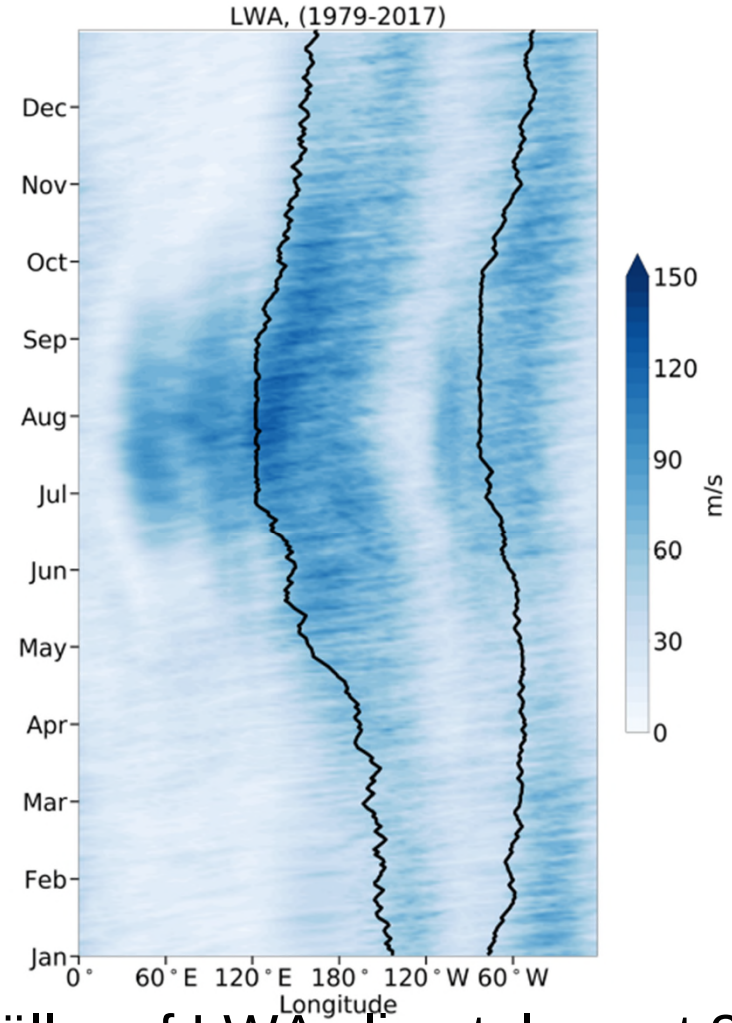


Figure 1. (a) Hovmöller diagram of CWV (2017) at 30° N with the addition of (1) QSAR pathways marked by white curves (with the amount of 7-day moving averaged CWV above 40 mm) and black curve (below 40 mm), (2) red arrows to illustrate synoptic westerly waves, and (3) two black dashed horizontal lines and yellow arrows to show the locations of QSARs on 27 May 2017 and 16 January 2017. (b) CWV map on 27 May 2017. The black dashed horizontal line shows 30° N, and two yellow arrows indicate the locations of QSAR observed in (a). (c) Same as (b) but on 16 January 2017. LWA = local wave activity; CWV = column water vapor; QSAR = quasi-stationary parts of atmospheric rivers.

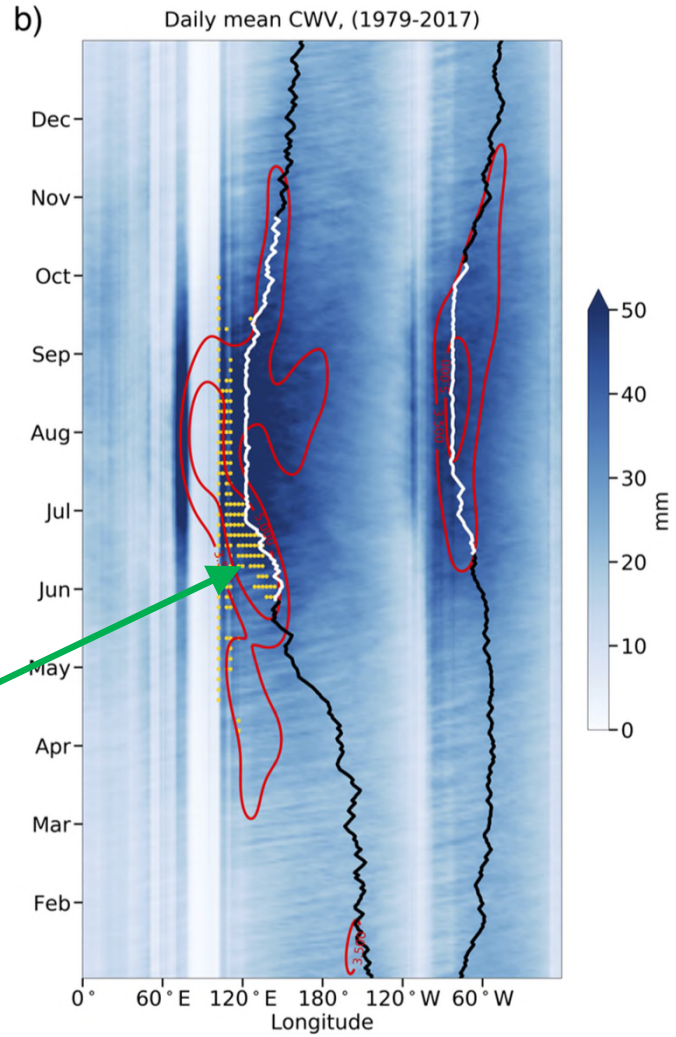
From Lee et al.(2019, GRL)

LWA is greatly enhanced downstream of quasi-stationary atmospheric rivers

Monsoon onsets when those rivers make landfall to Asia continent



Yellow stippling indicates monsoon regions (Wang Bin and LinHo 2002)



From Lee et al.(2019, GRL)

- Hovmöller of LWA climatology at 30N
- Hovmöller of CWV climatology at 30N

Figure 4. The Hovmöller diagram of daily mean climatology local wave activity (LWA), a measure of the nonlinearity of waves, at 30° N with the addition of quasi-stationary part of atmospheric rivers pathways (black curves).

(Proposal) This fact indicates that monsoon onsets can be predicted by “1” variable — PV!

- QG Equation

$$\frac{\partial \psi}{\partial t} + J(\psi, \nabla^2 \psi) + \beta \frac{\partial \psi}{\partial x} = 0$$

- QGPV

$$q = f_0 + \beta y + \nabla^2 \psi + \frac{\partial}{\partial p}\left(\frac{f_0^2}{(-R/p)(p/p_R)^{\kappa}(\partial \theta_R / \partial p)} \frac{\partial \psi}{\partial p}\right)$$

- IPV

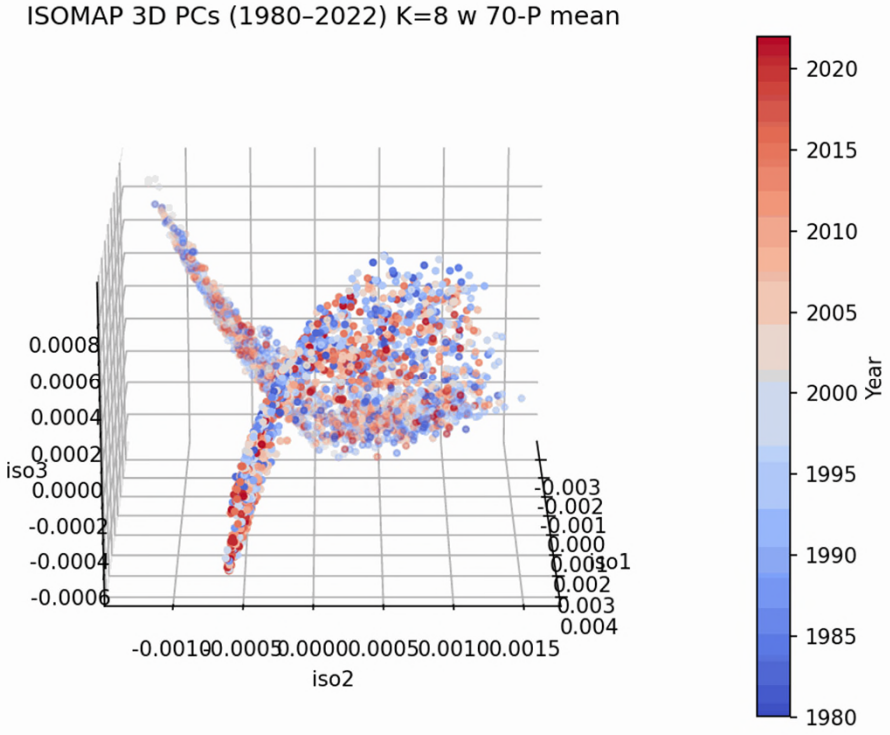
$$q = (\zeta + f)\left(-g \frac{\partial \theta}{\partial p}\right)$$

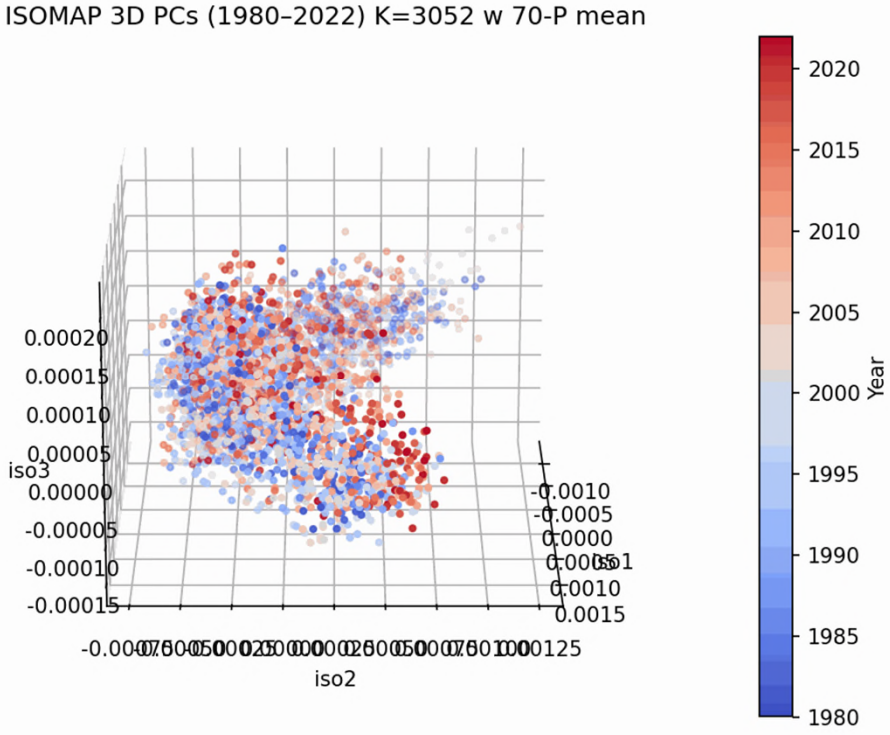
Goal

- To explore the internal dynamical processes
- Have any method to predict effectively and especially fulfill long-term, 1-3, 6-12 months, seasonal forecasts?

  -- We want to find ***a economical way*** to produce the long-term forecasts. We think about the ***dimensionality reduction (DR).*** Brunton et al. (2020) in Annual Reviews journal, Machine Learning (ML) for Fluid Mechanics, mentioned that **representation of a high-dimensional system in terms of a low-dimensional one, balancing accuracy and efficiency**. Their article gave us the direction and hint.
  -- DR candidate now is ISOMAP, … ,
- Apply ISOMAP on PV!

ISOMAP (K=8) and PCA on PV at 340K with removing 1980-2022 70-Pentad climatological mean PV



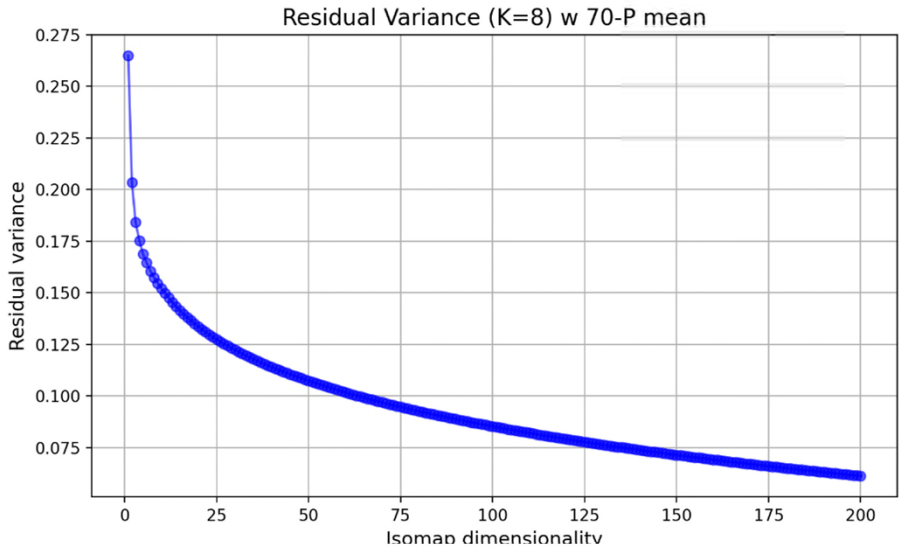


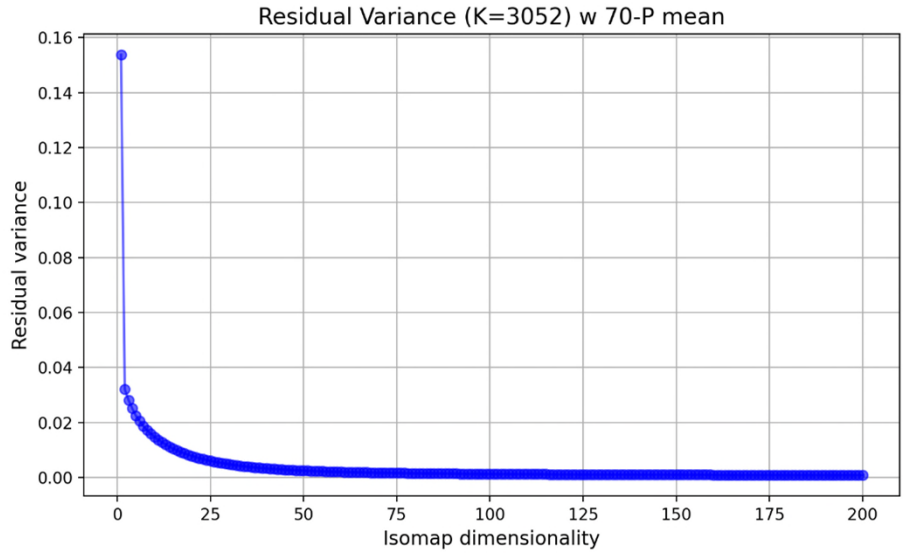
PC 1-3 from ISOMAP show 3D spiral structures

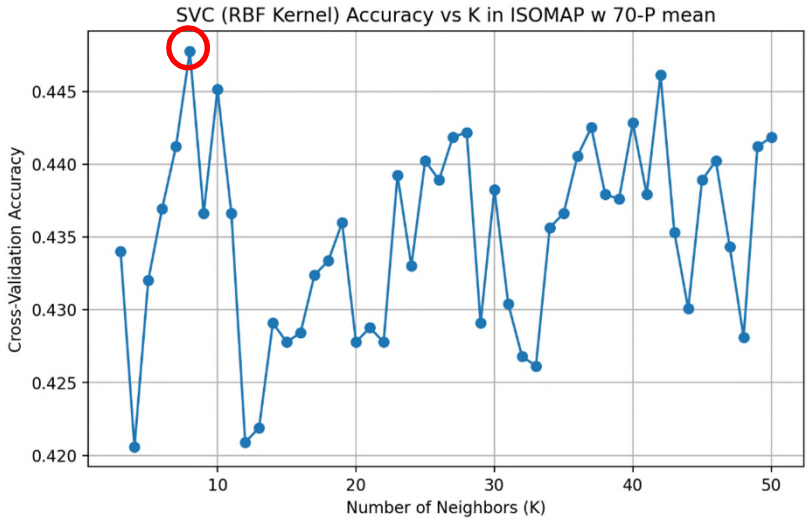
PC 1-3 from PCA form a 2D horseshoe pattern, with largely random variation in the vertical (3) direction.

ISOMAP (K=8) and PCA

with removing 1980-2022 70-Pentad climatological mean

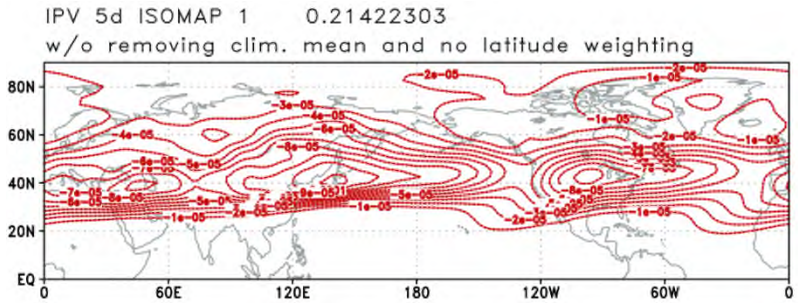


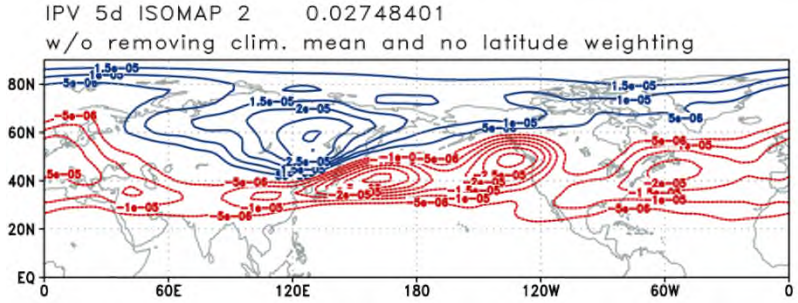


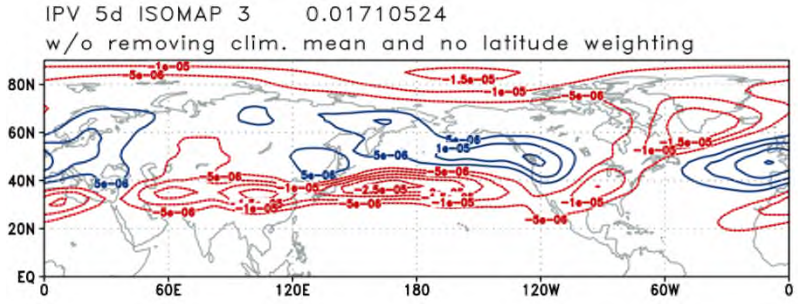


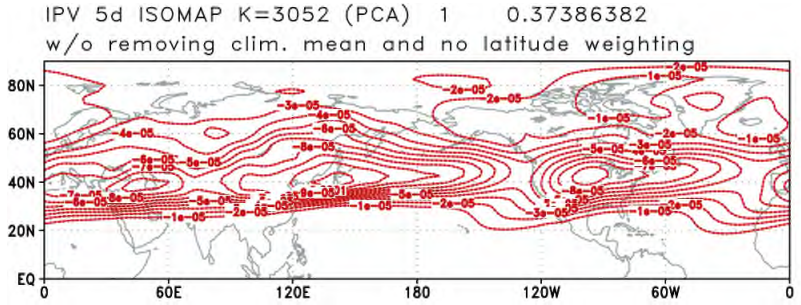
Based on checking Oceanic Niño Index (ONI) labels and IPV ISOMAP PCs SVM accuracy …

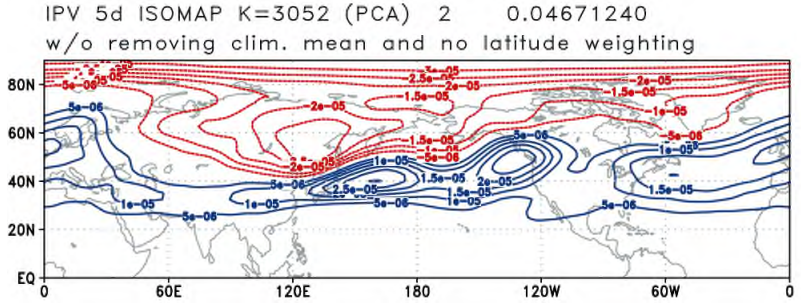
EOF1-3 from ISOMAP (K=8) and PCA (k=3052)

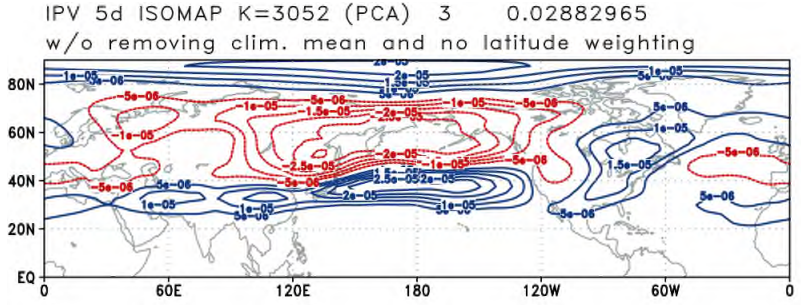










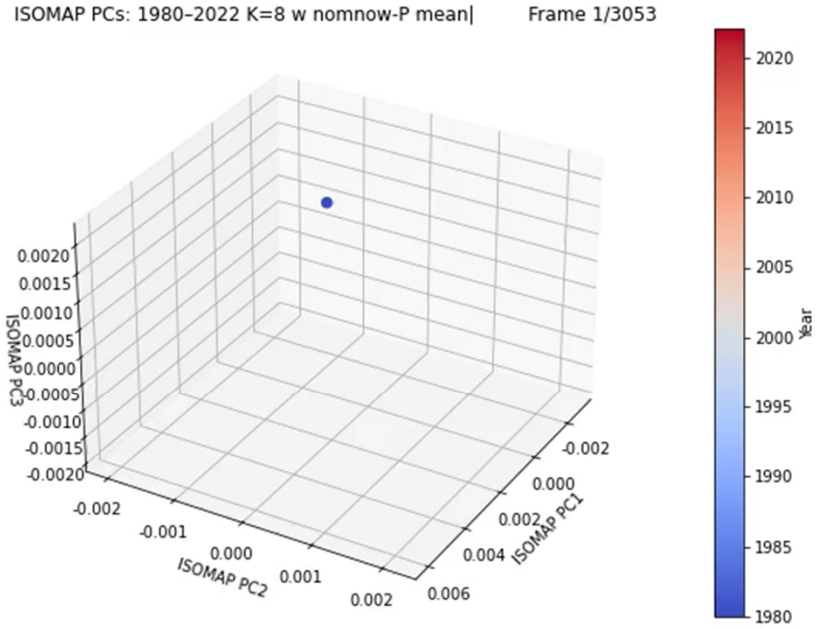


ISOMAP captures the mean, meridional, and zonal structures of enstrophy (variance of PV)

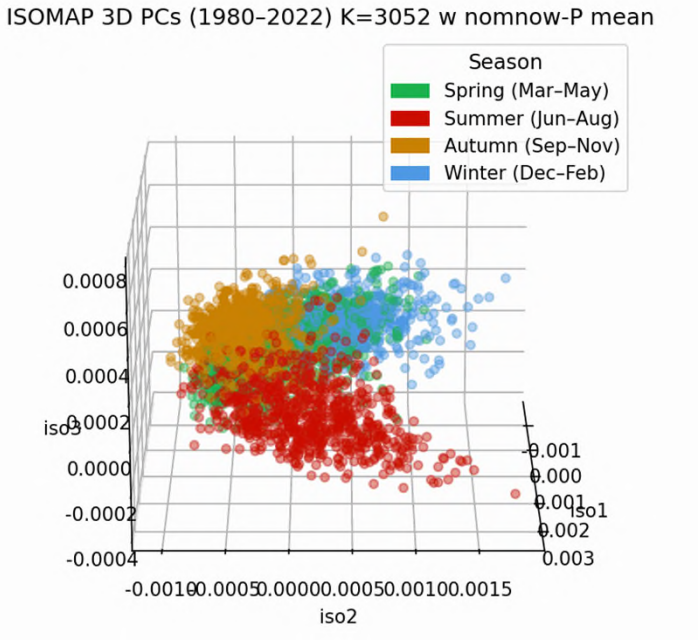
PCA results are similar to ISOMAP but ISOMAP EOF3 keeps slightly clear zonal structure.

animation

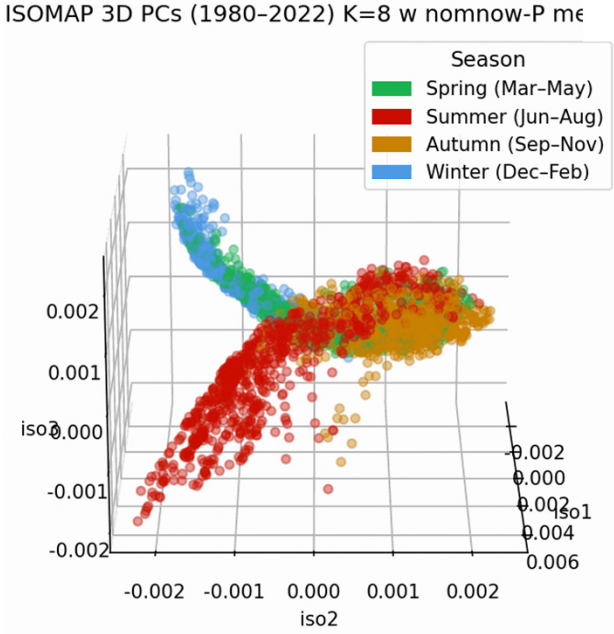
ISOMAP PCs follow the regular, well-controlled orbit to have movement.



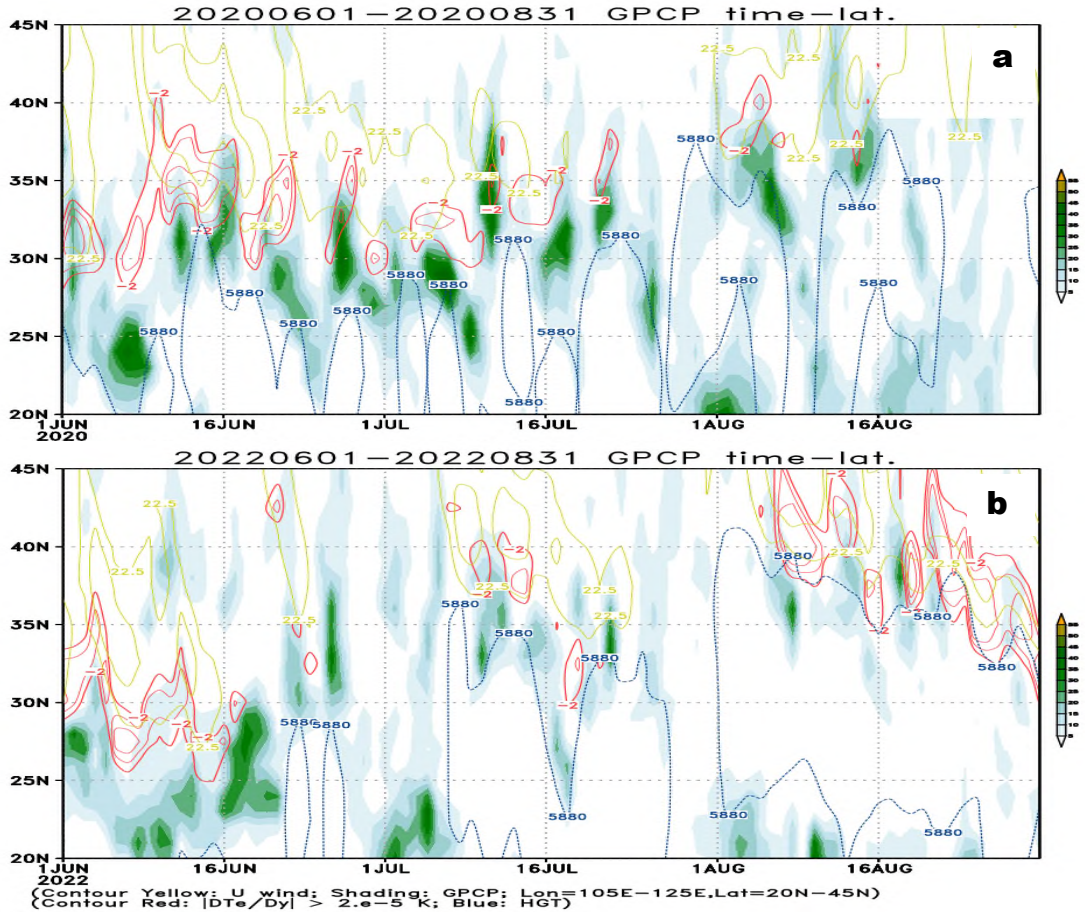
PCA

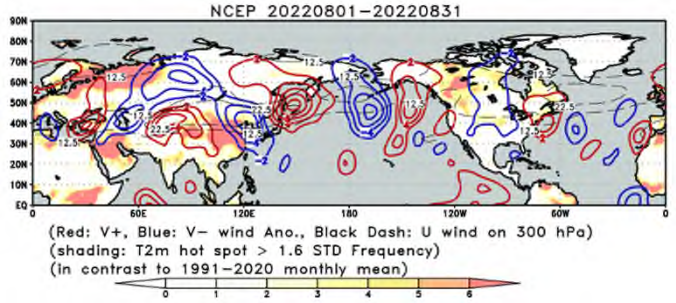


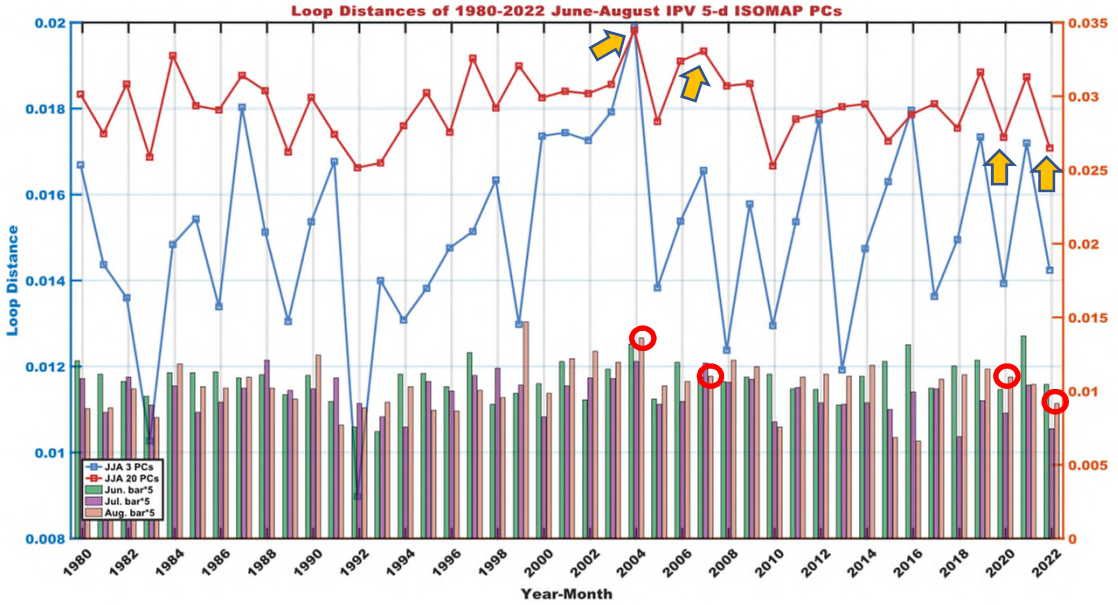
ISOMAP

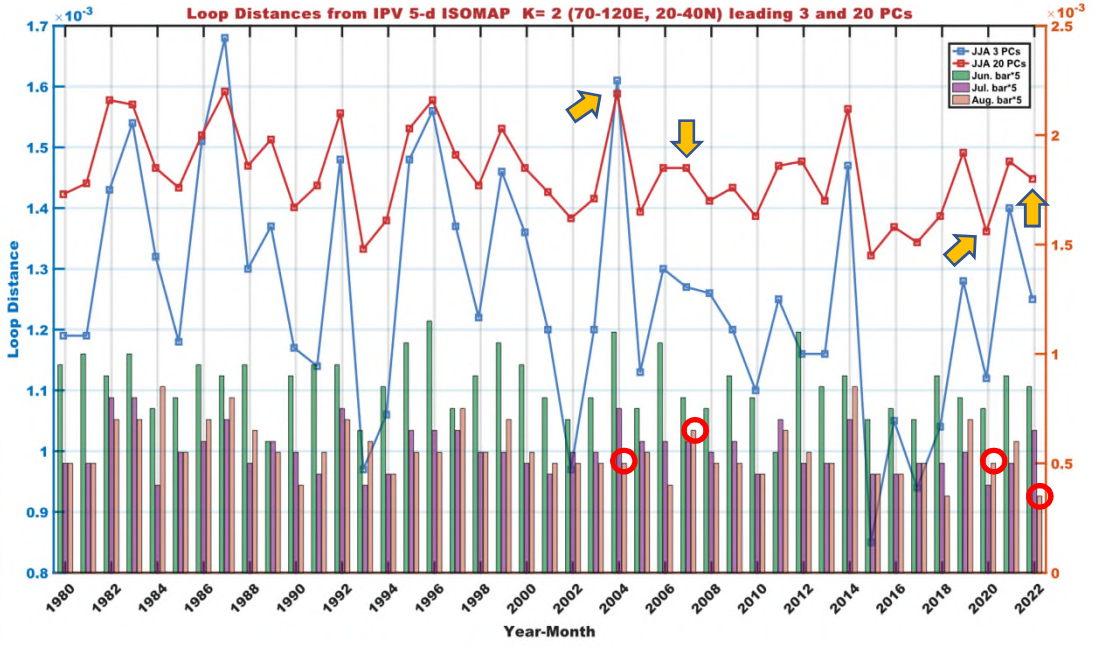


PCs Applications





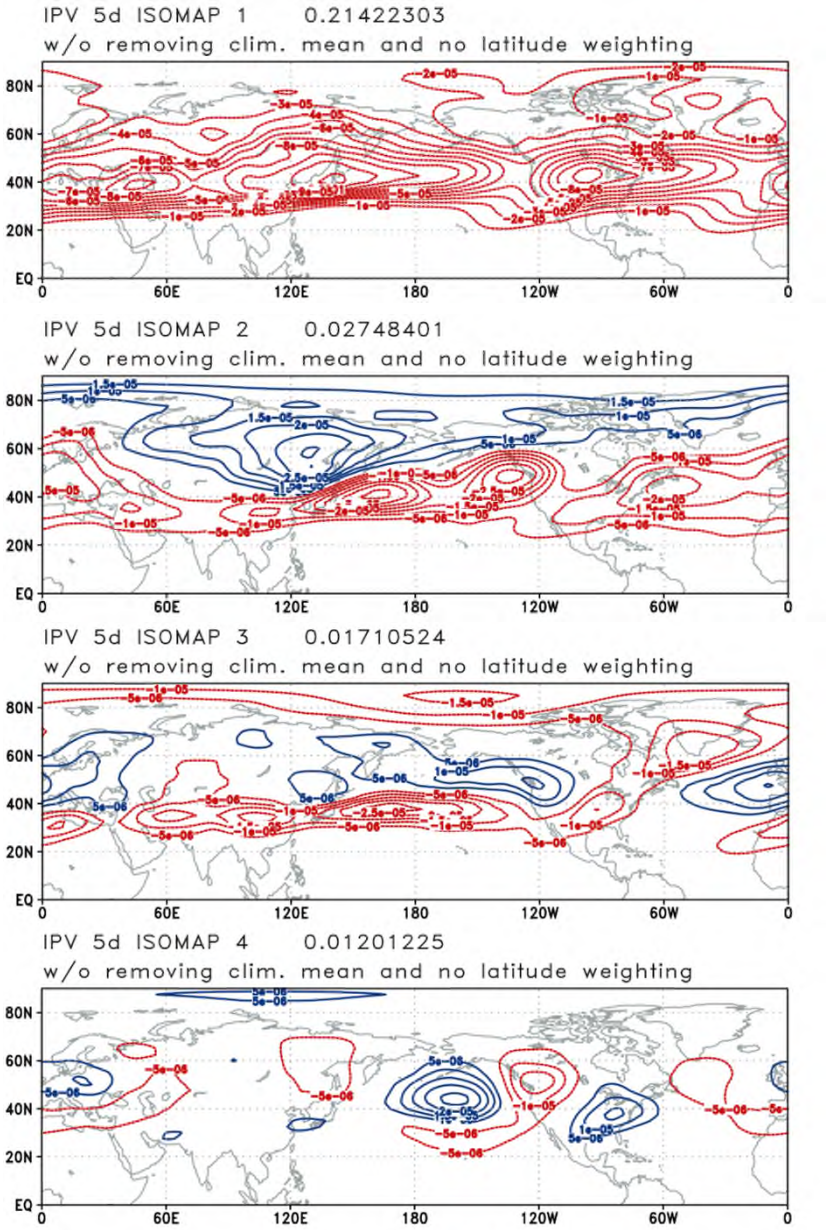




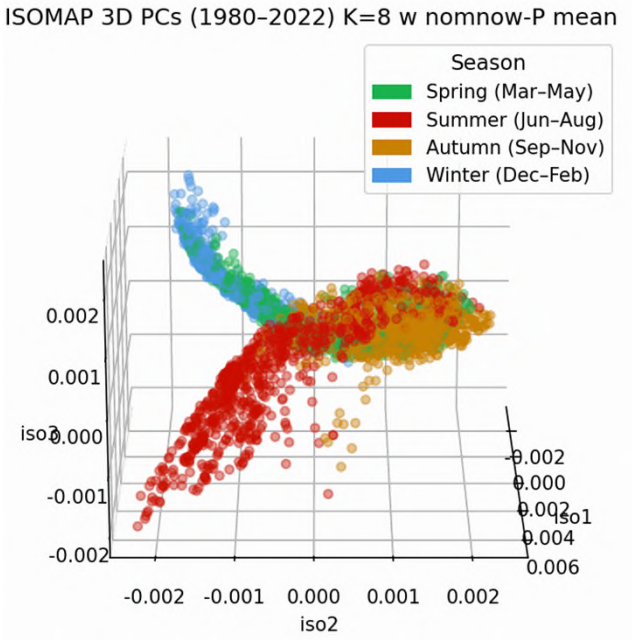
Neural Networks Prediction

- Based on the ***trajectories*** of ***IPV 340K ISOMAP PCs***, the ***neural networks*** (**NN**) can be built. The future PCs can be predicted. These PCs can multiply the spatial EOF of ISOMAP to ***retrieve*** physical space IPV, the future predicted IPV.
- When building NN, the different hidden layers, different NN activate functions, long-short term memory, different dimensionality reduction will be considered in the following researches …

EOFs x PCs



ISOMAP



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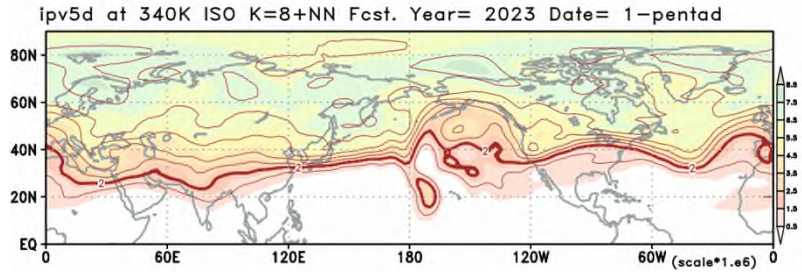
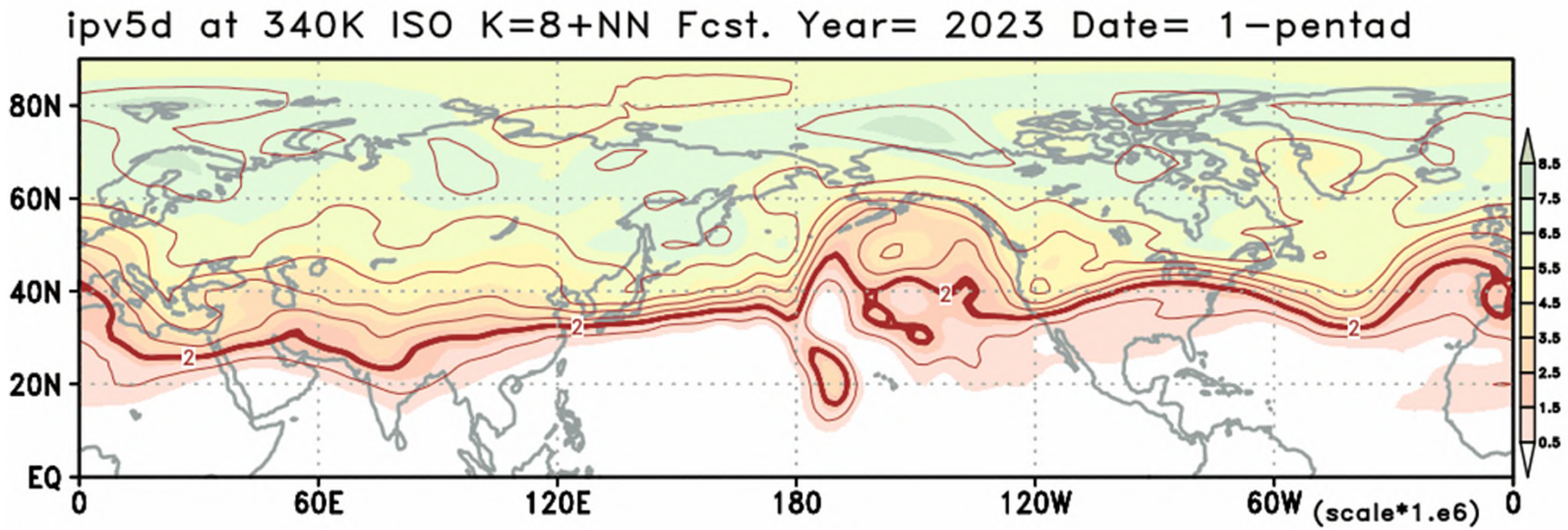
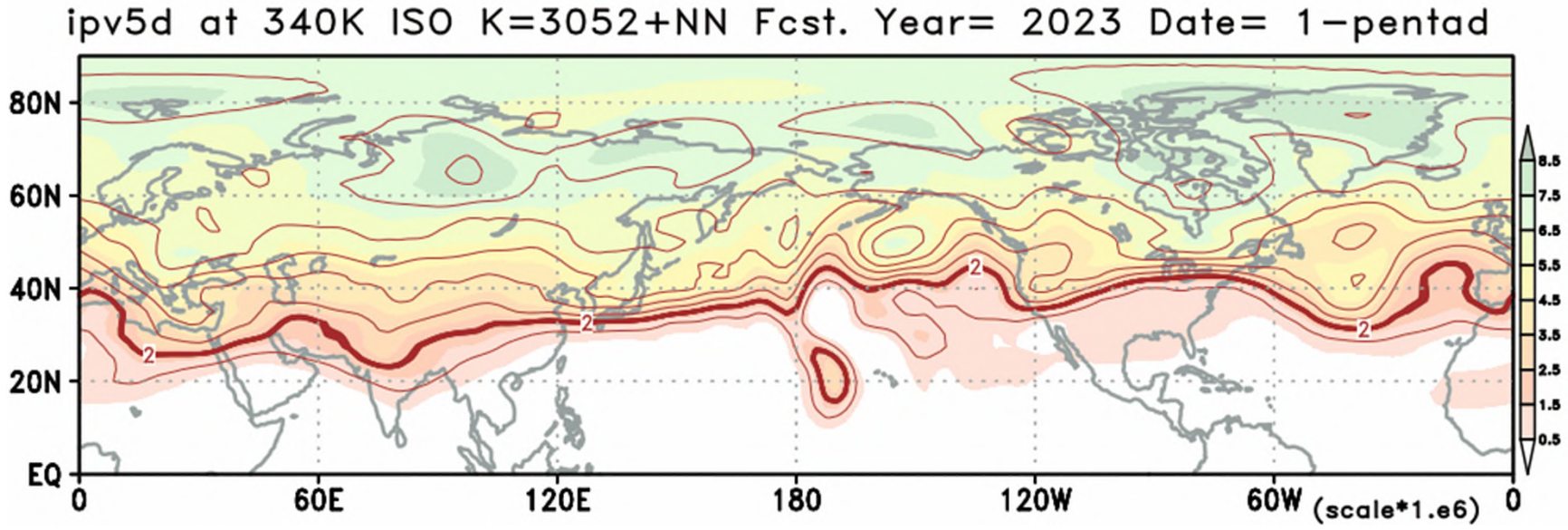


ISO + NN



Using leading 20 ISOMAP PCs…

Current NN, with 4 hidden layers, 128 nodes, and ReLU activation function



Next …

- Build seasonal NN inference model
- Identifying persistent circulations
- Construct early warning of monsoon onset prediction in Taiwan using the ISOMAP-based model
- Study the nonlinear structures of inter-annual variability

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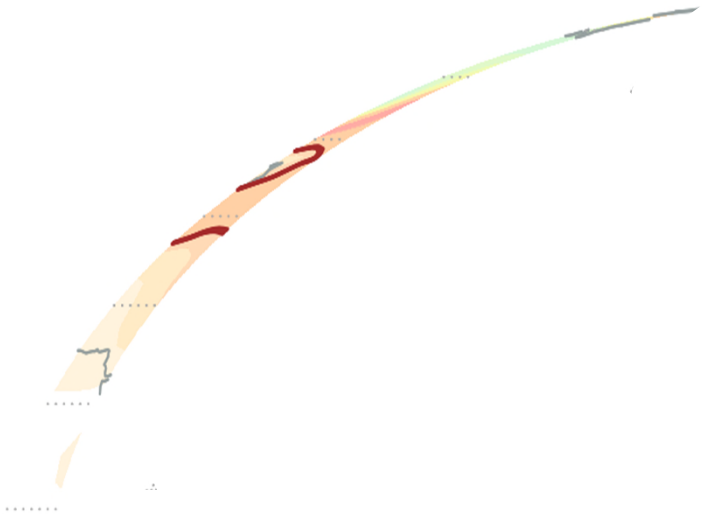
Tseng, J.C-H., Tsai, BA. & Chung, K. Sea surface temperature clustering and prediction in the Pacific Ocean based on isometric feature mapping analysis. *Geosci. Lett. 2023,* **10**, 42.

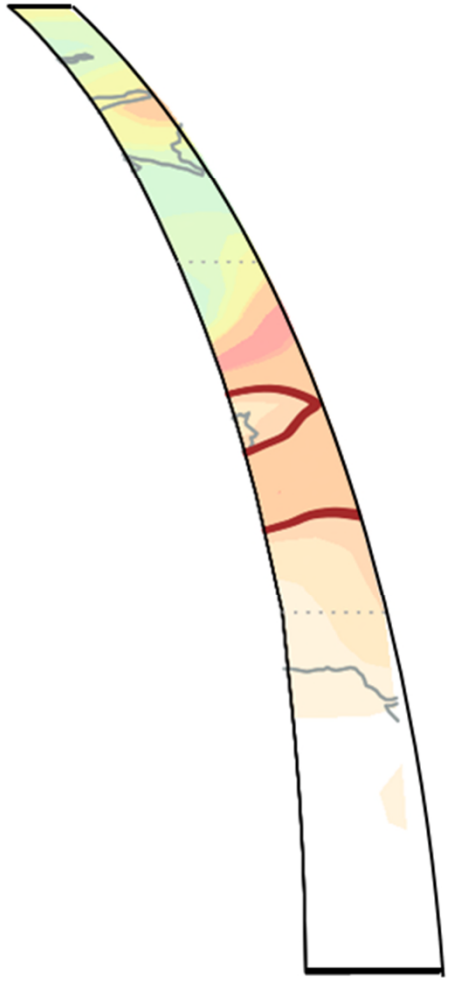
Thanks!

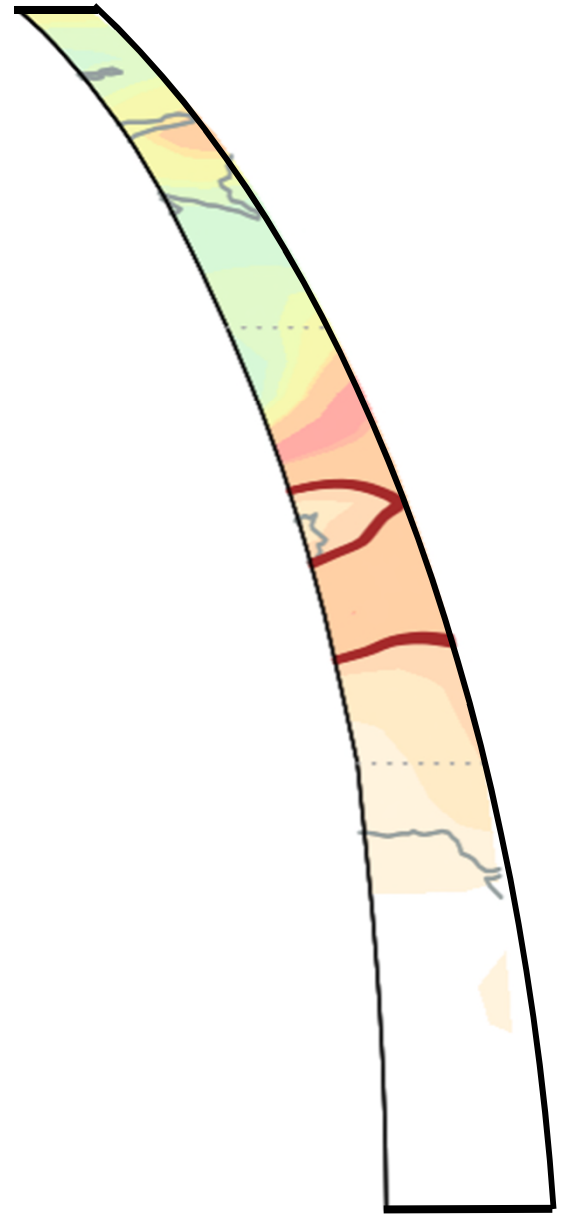
In memory of Confucius (孔子) and Tseng Zi (曾子).
Confucius edited 'Spring Autumn Annals (春秋)', which although short in words, has profound significance. Right, wrong, and judgement of this Annals were left to others or next generations.
Tseng Zi followed Confucius thought and lived by this philosophy …

I appreciate Prof. Linho's instructions. I am grateful to all teachers, friends, and colleagues who have taught me.

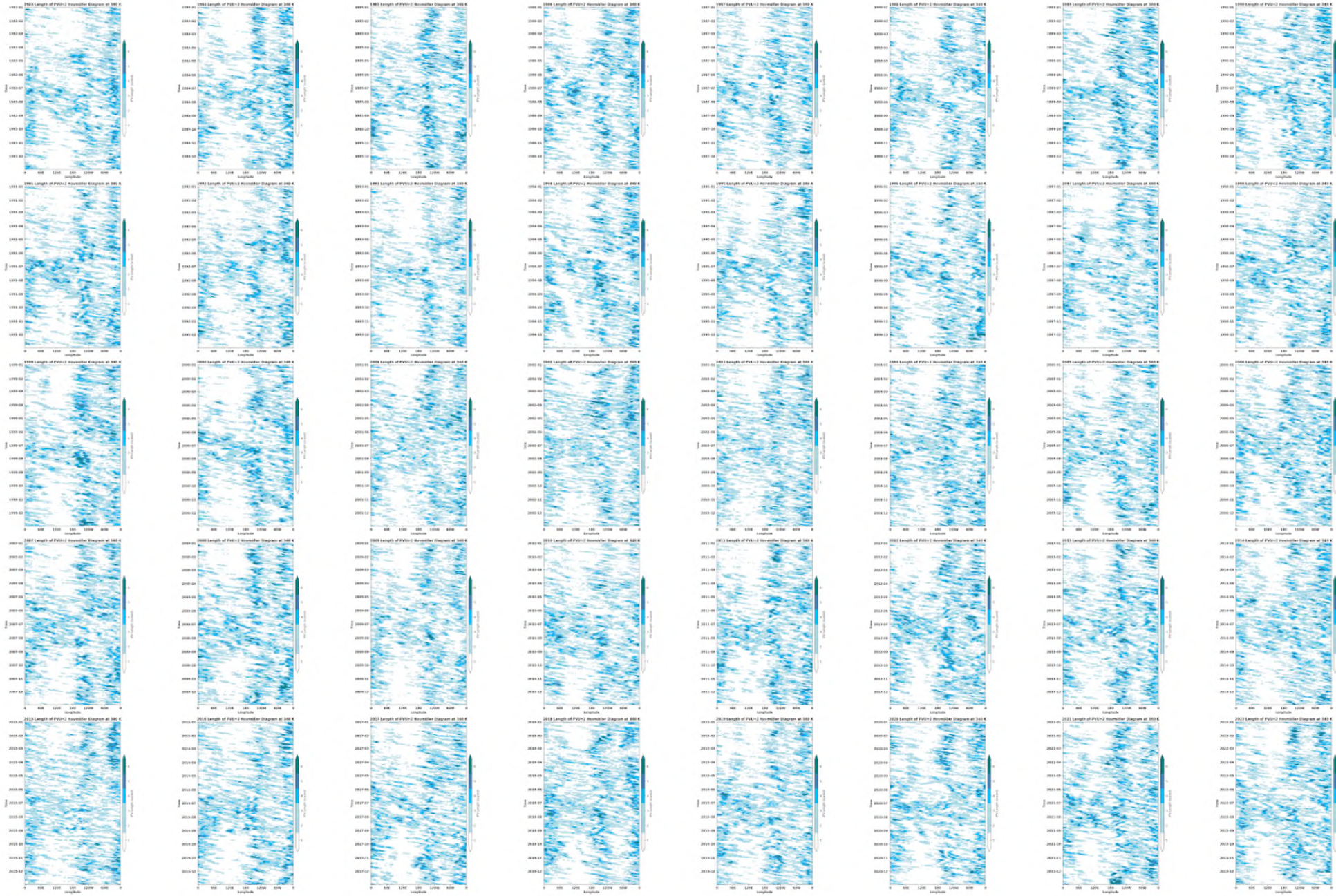
Miscellaneous





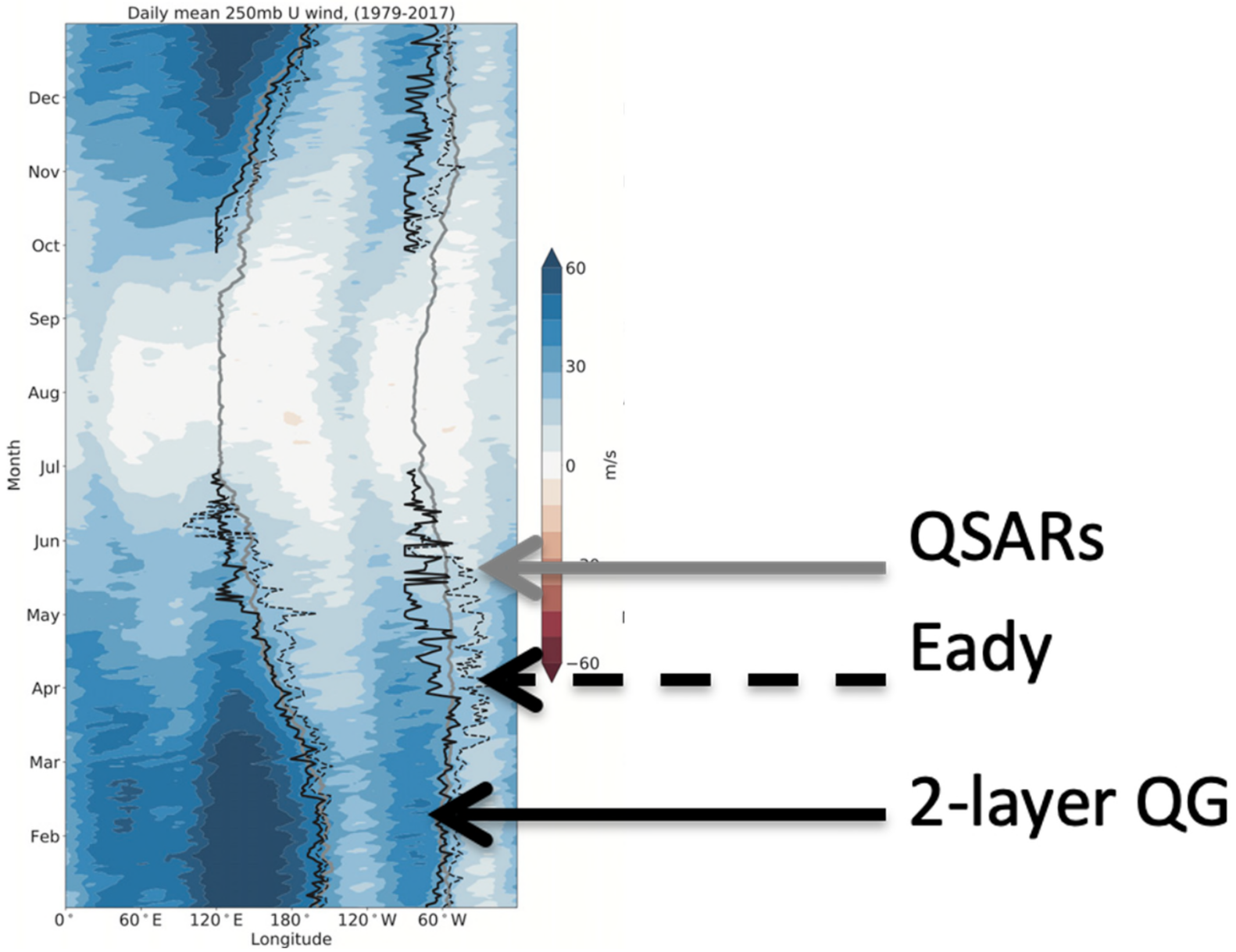


1983-2022
PV=2
contour length



1983-2022 LWA

Pathways are quasi-stationary wave fronts can be predicted semi-analytic QG model



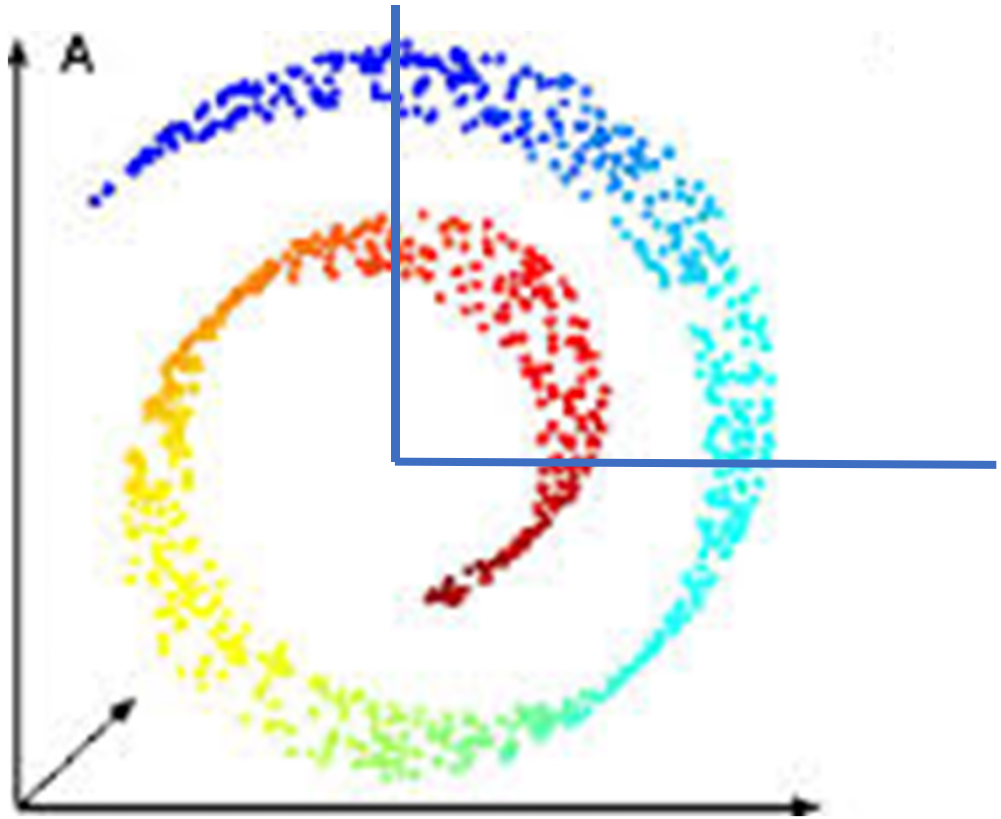
From Lee and Mitchell (2021, JAS)

ISOMAP (Why not PCA?)

- Considering a hypothetical nonlinear structure like Swiss Roll

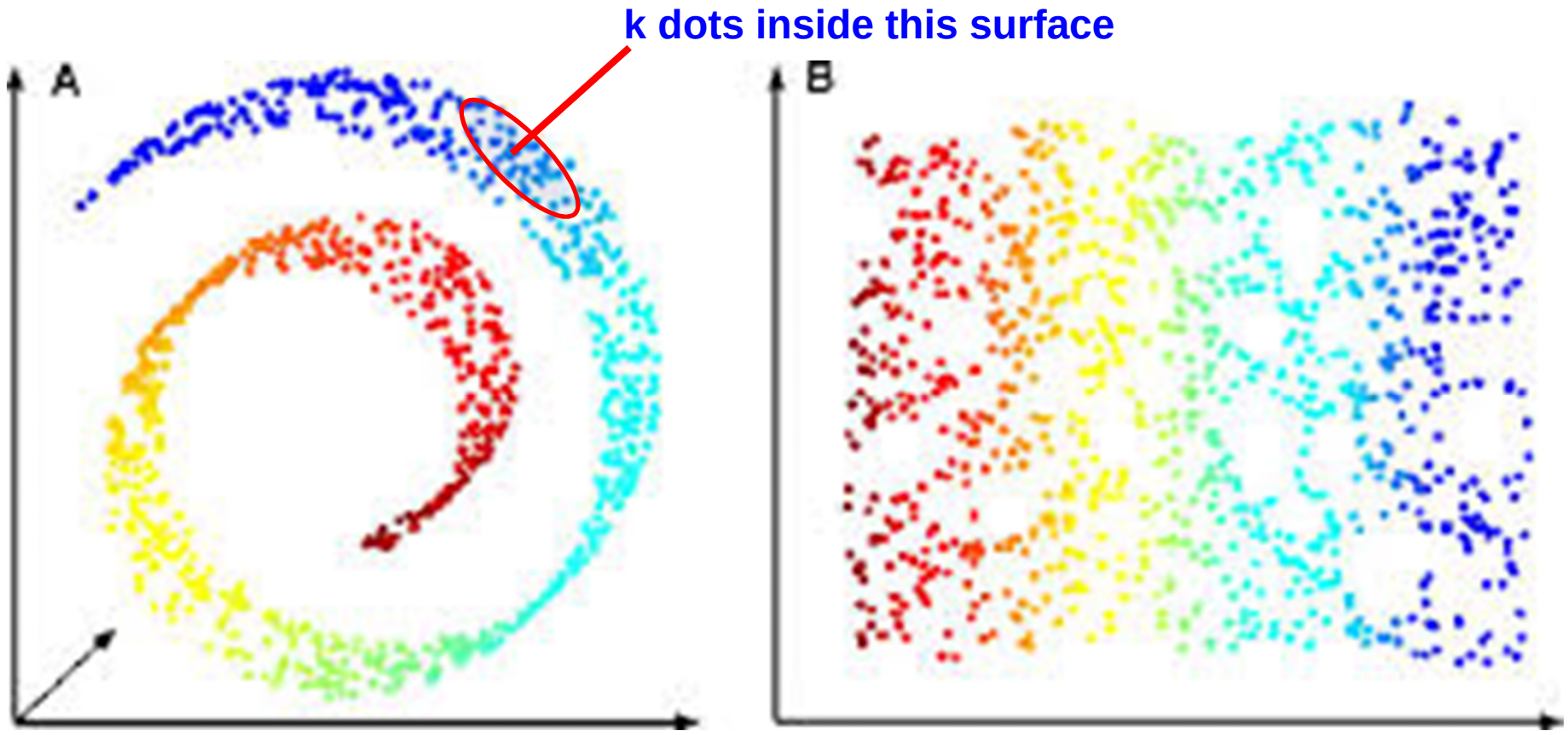
ISOMAP (Why not PCA?)

- PCA will just cut through the structures….

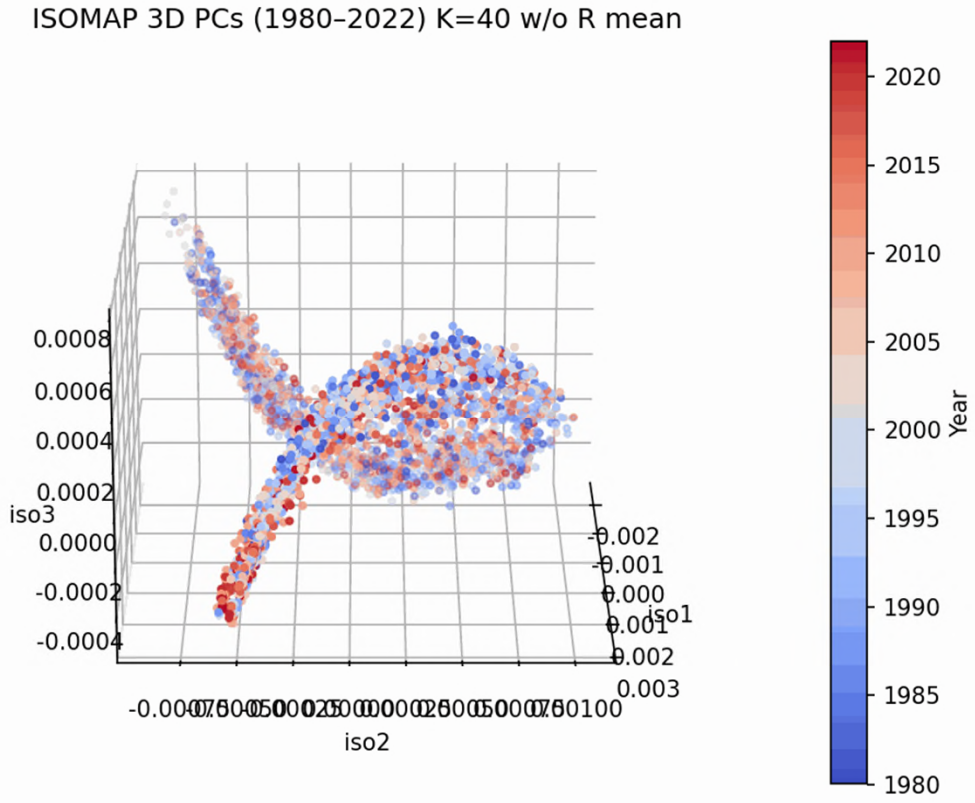


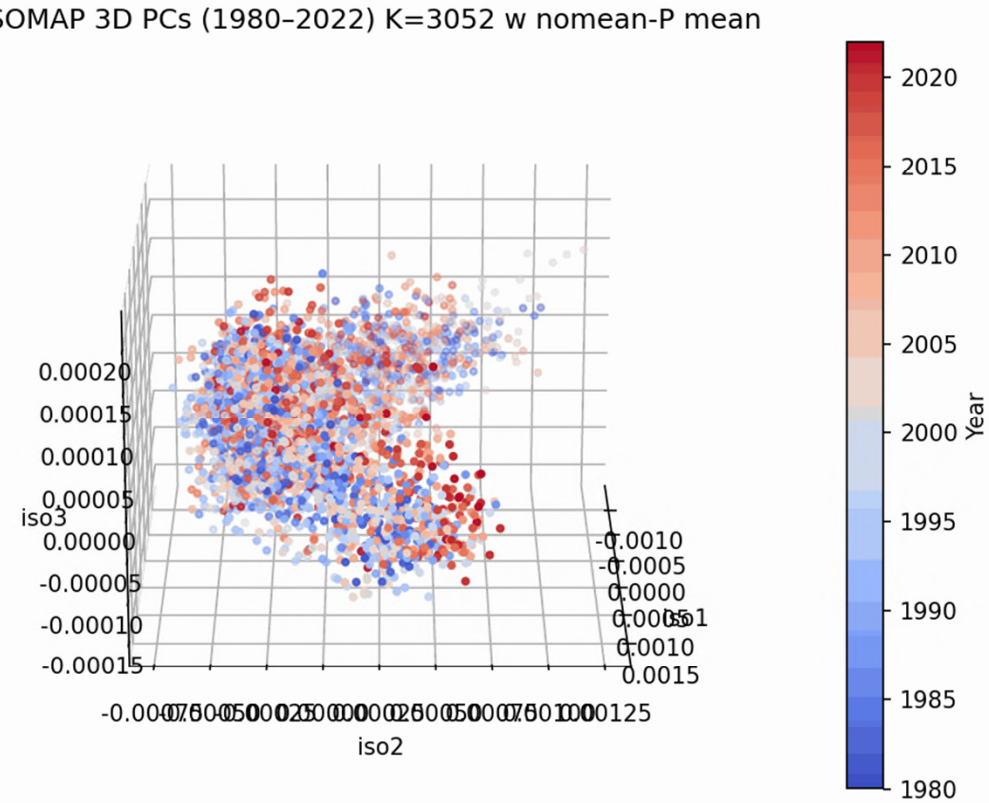
ISOMAP (Why not PCA?)

- The ISOMAP algorithm can unroll the Swiss roll by identifying the *k* nearest neighbors to approximate the manifold structure.



ISOMAP without removing climatological mean …

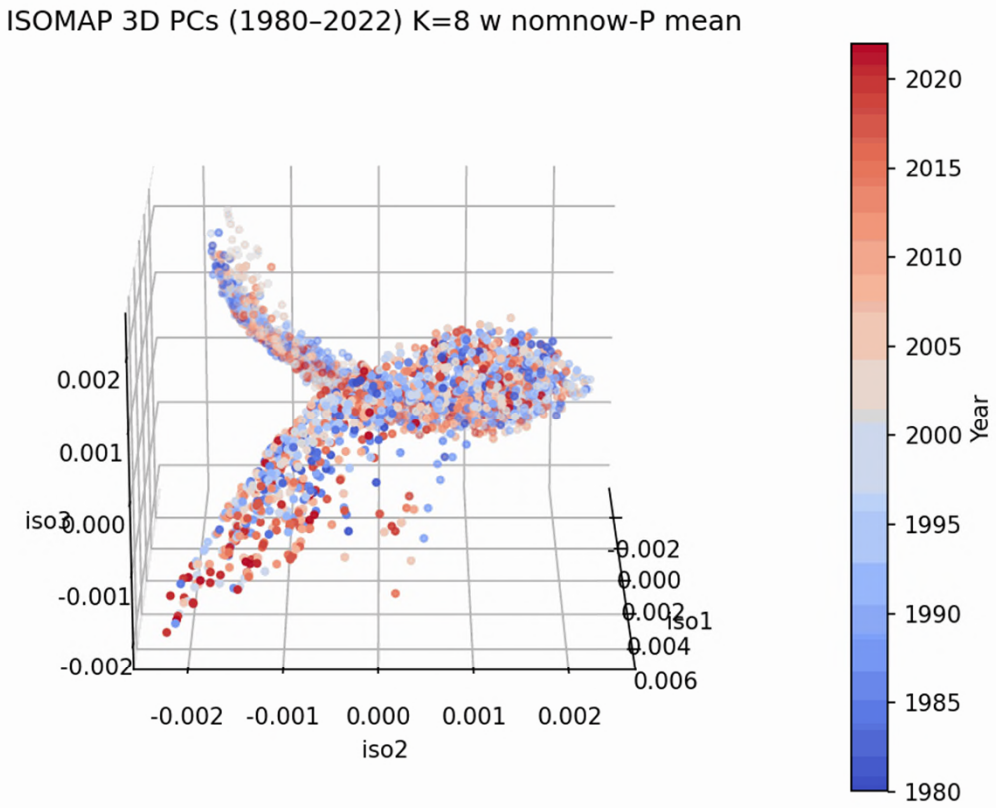


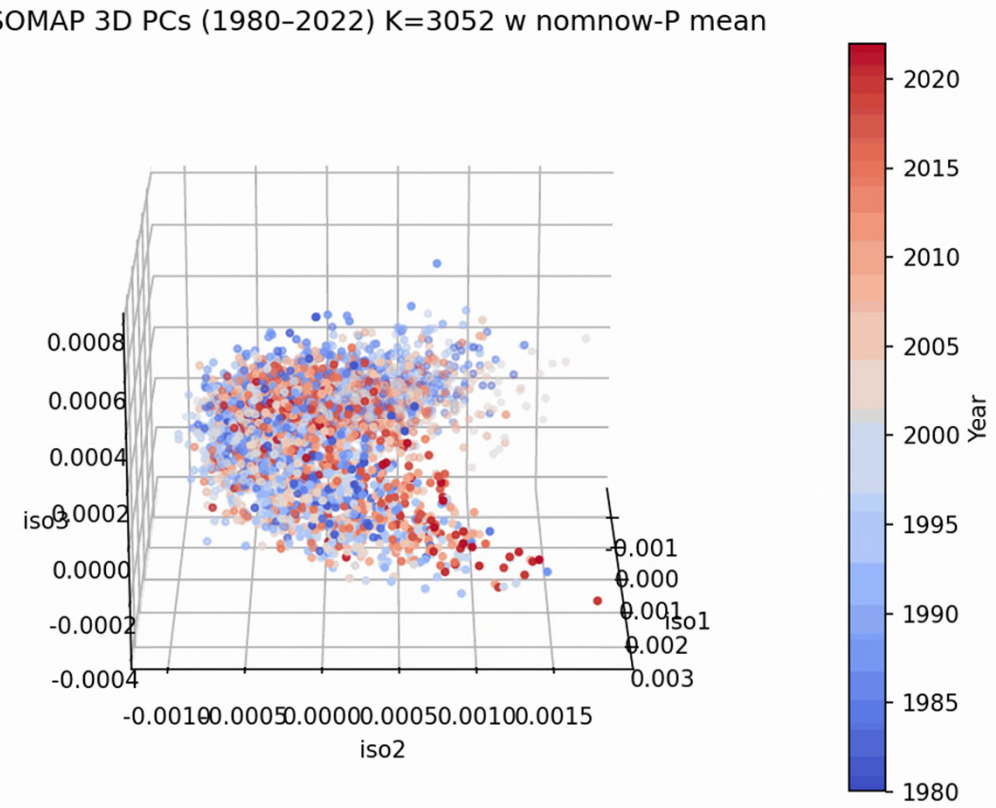


The results were similar to the 70-Pentad climatological mean removing !

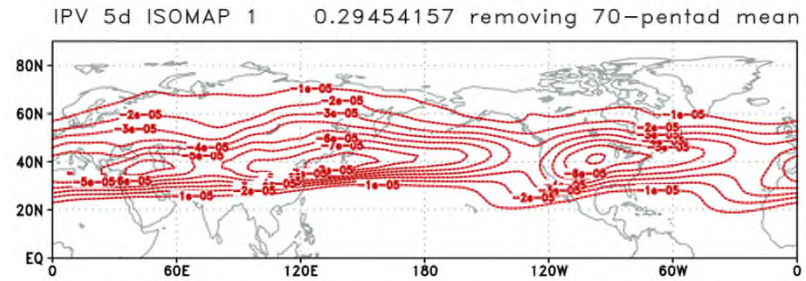
When doing PCA or ISOMAP, the variance definition …

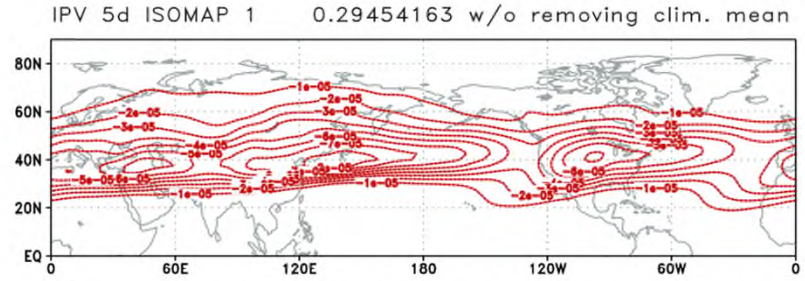
- The variance was always multiplied cosine latitude weighting …
- If we did not take cosine latitude weighting, …

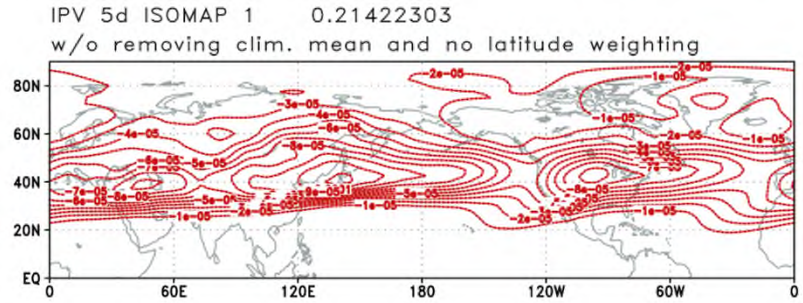


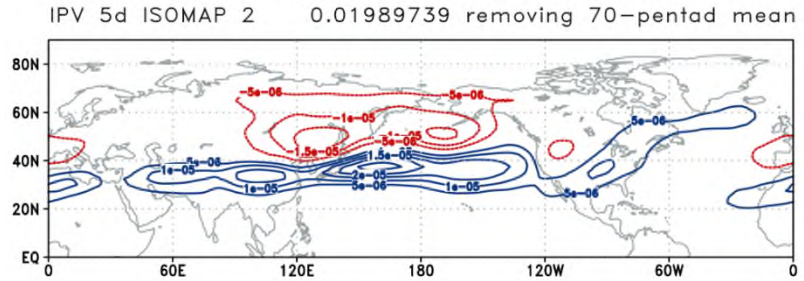


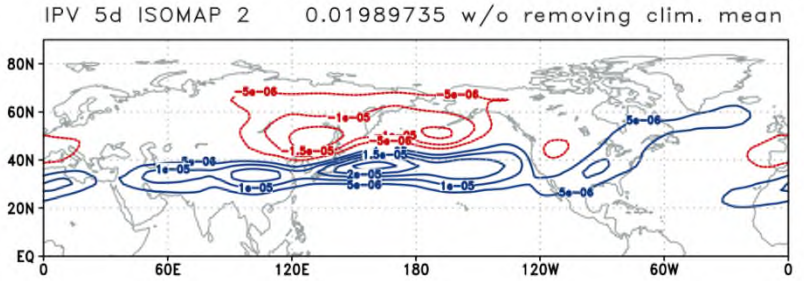
The EOFs differences by removing mean or not …

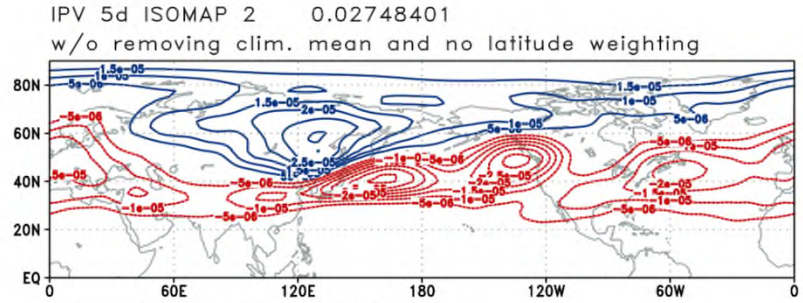


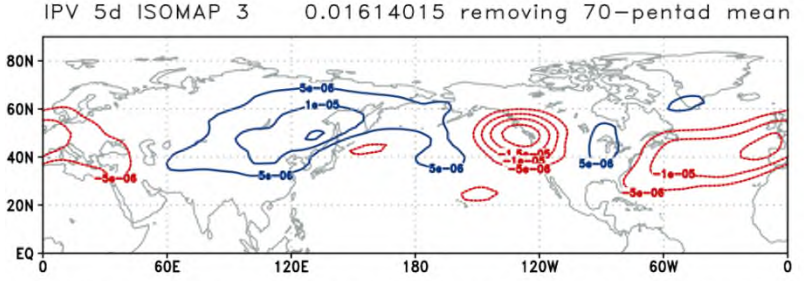


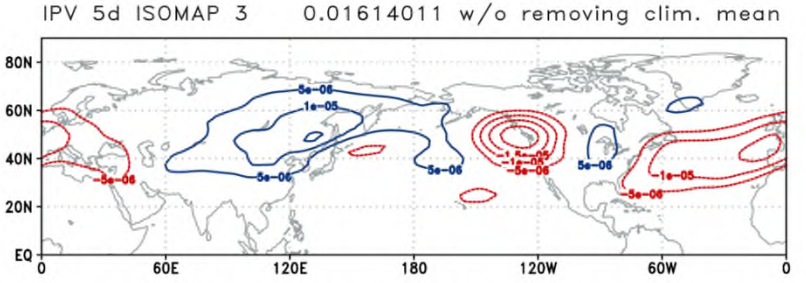


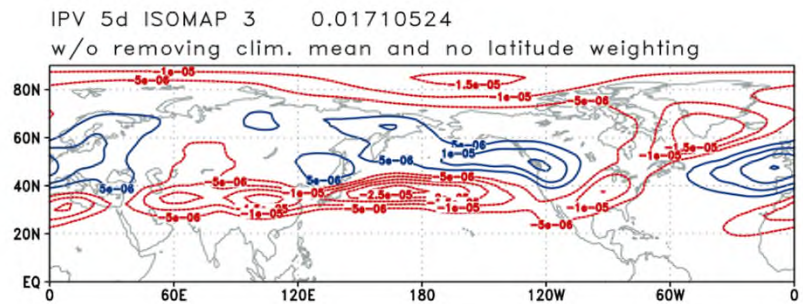


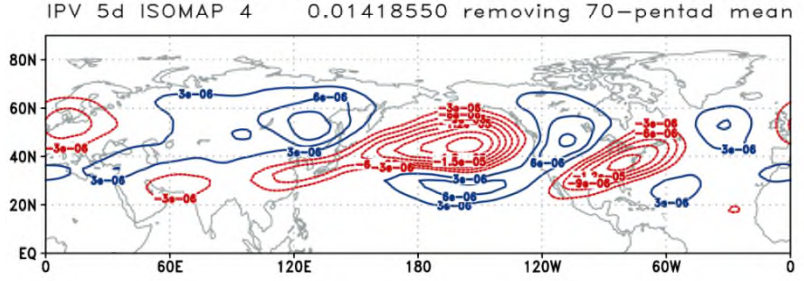


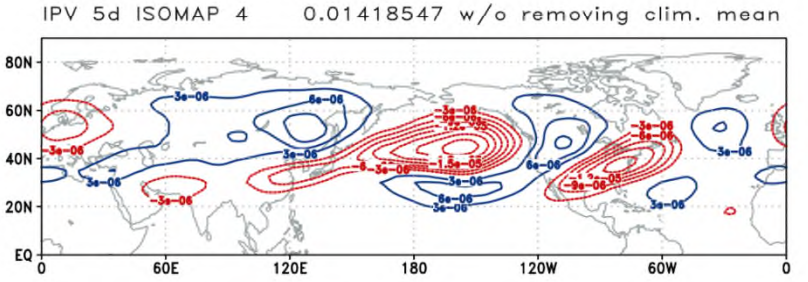


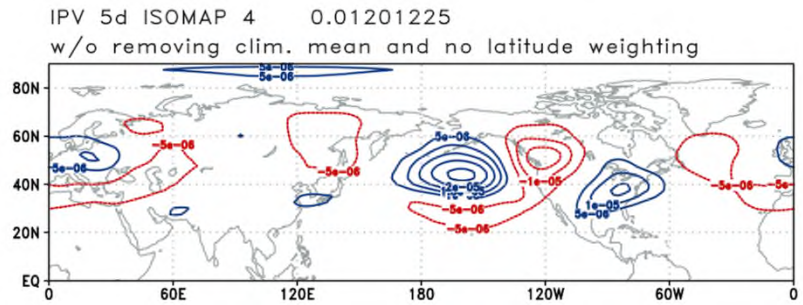












If the climatological mean keeps seasonal variation. That means every pentad data were subtracted by their corresponding pentad climatological mean …