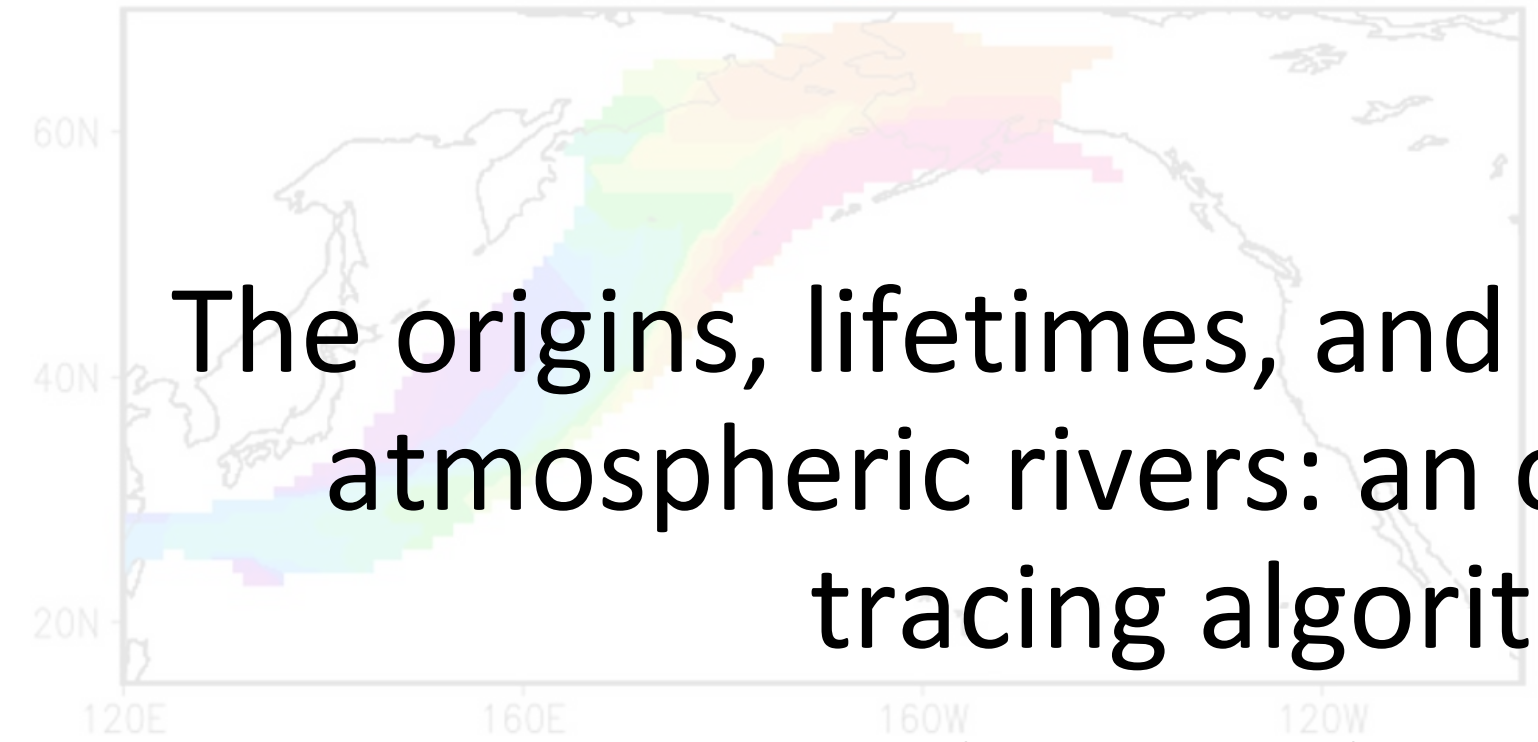


The origins, lifetimes, and terminations of atmospheric rivers: an object-based tracing algorithm

Yang Zhou[1], Hyemi Kim[1], and Bin Guan[2,3]

[1]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, New York, USA
[2]Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, California, USA
[3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

- Zhou, Y., H. M. Kim, and B. Guan: The Atmospheric Rivers Life Cycles: Identification and Climatological Characteristics *(submitted)*

Atmospheric rivers (ARs)

➢ Vertically-integrated vapor transport:

$$\overrightarrow{\mathrm{IVT}} = -\frac{1}{g}\int_{Ps}^{300} \vec{V} \cdot q \, dP$$

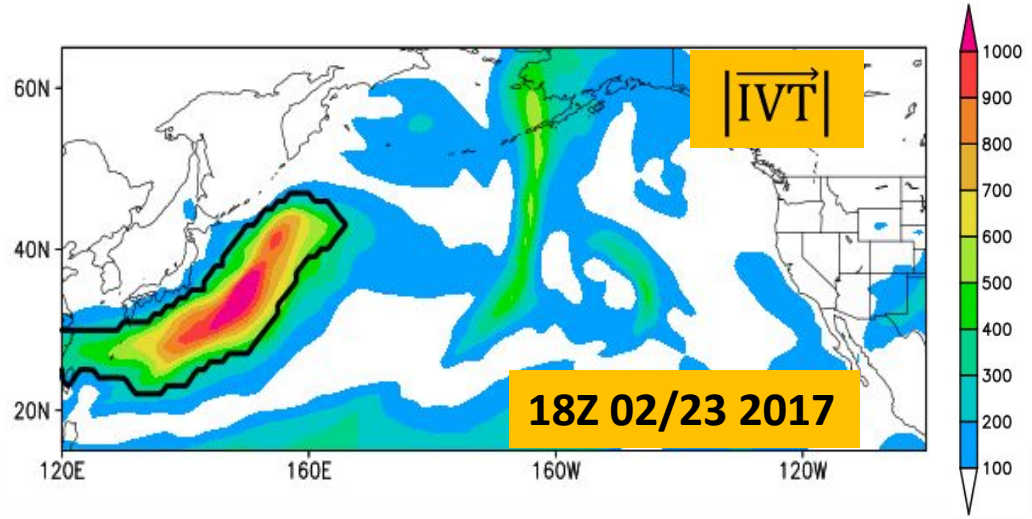
Ps: surface pressure
V: horizontal wind
q: specific humidity

- ERA-Interim, 1 degree 6hourly
- Nov. – Mar. 1979/80-2016/17

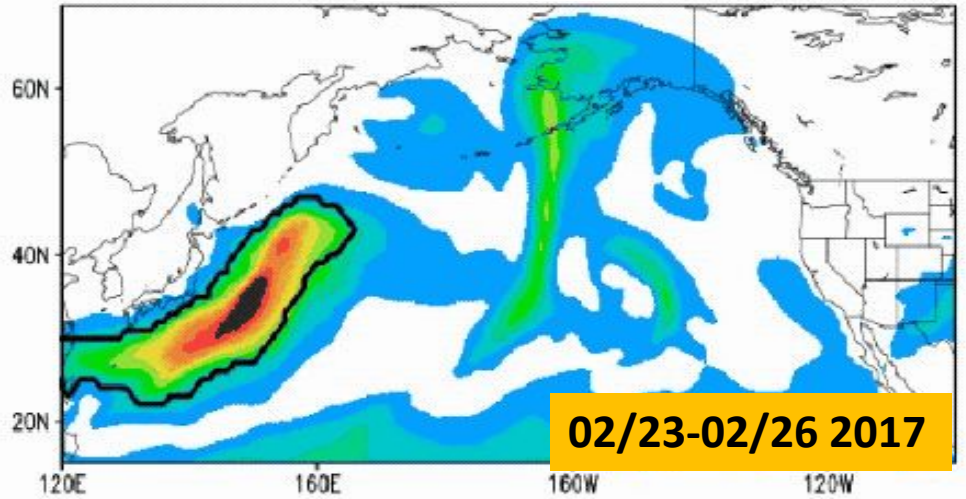
- **The detected ARs are time independent**

- A strong IVT event can last for a certain period

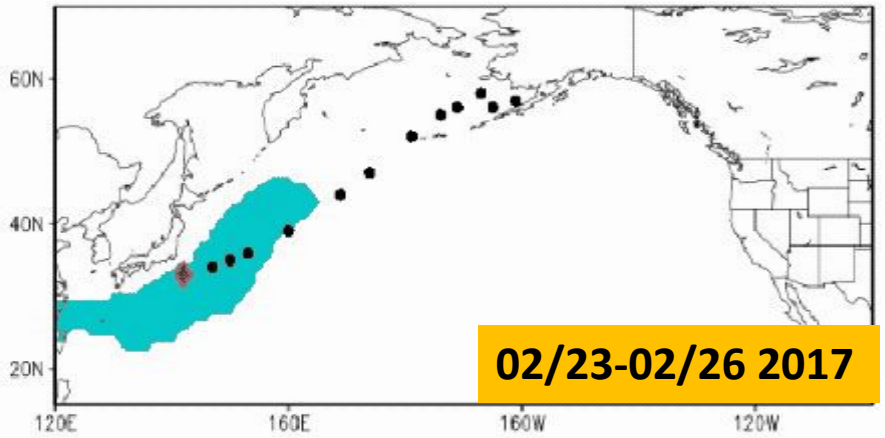
➔ The same IVT event can be detected as ARs during consecutive time steps

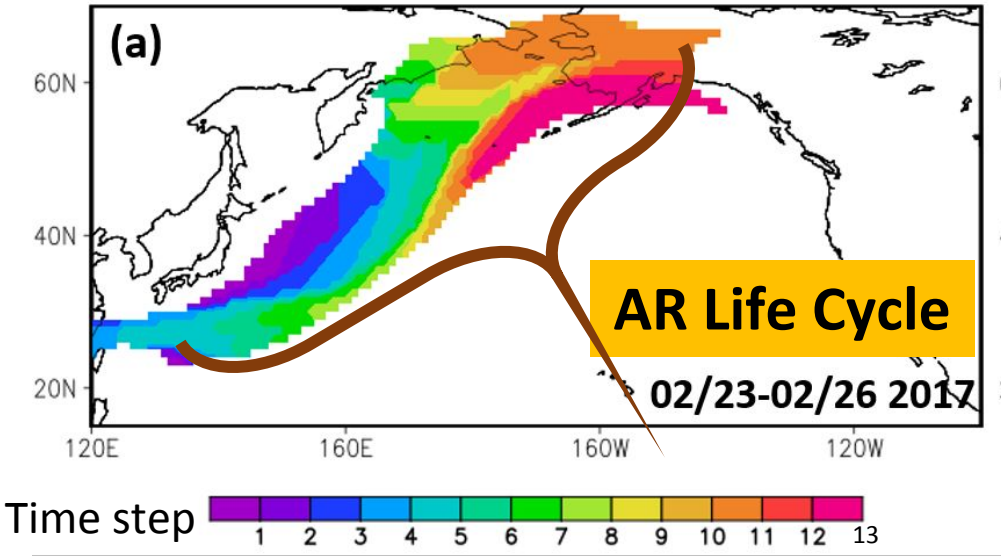


(Detection method: Guan and Waliser 2015)



ARs vs. AR Life Cycles (LCs)





ARs:

- 2D objects (LON, LAT),
- time independent

AR LCs:

- Series of spatiotemporally connected ARs (LON, LAT, **Time**)

Motivation

- To establish a link between the ARs through space and time
- A better understanding of strong moisture transport events

Tracing the AR LCs

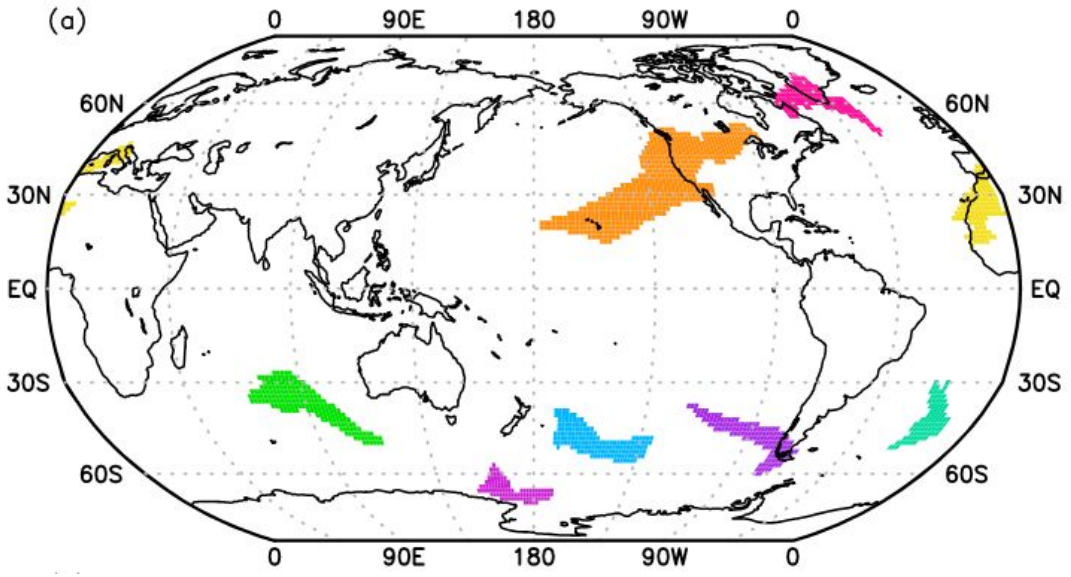
Step I:
AR detection

Step II:
Origin selection

Step III:
Recording the LCs

Step I

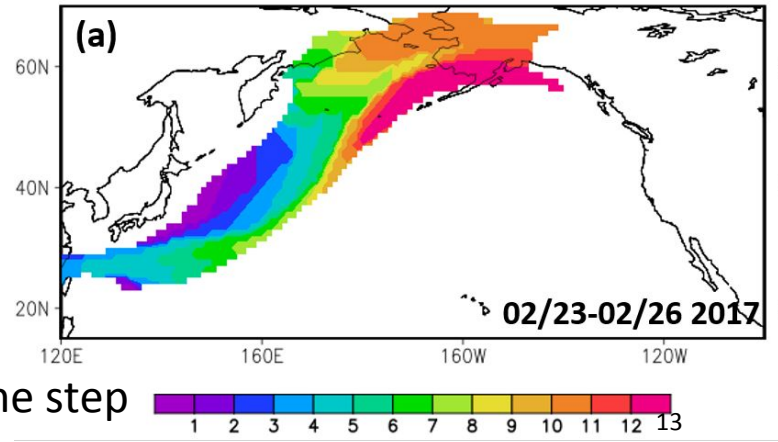
- ERA-Interim, 1 degree 6hourly
- Focus on North Pacific

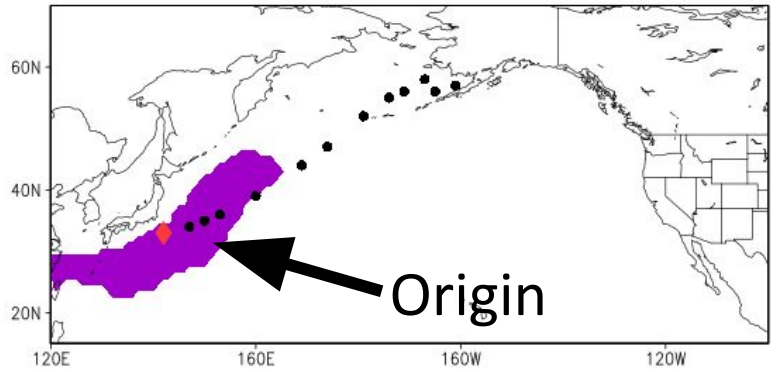


(Detection method: Guan and Waliser 2015)

Tracing the AR LCs

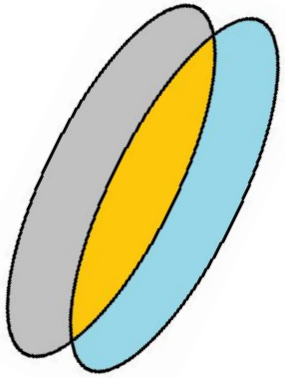
Step II: Origin selection





Overlapping ratio at step *t*:

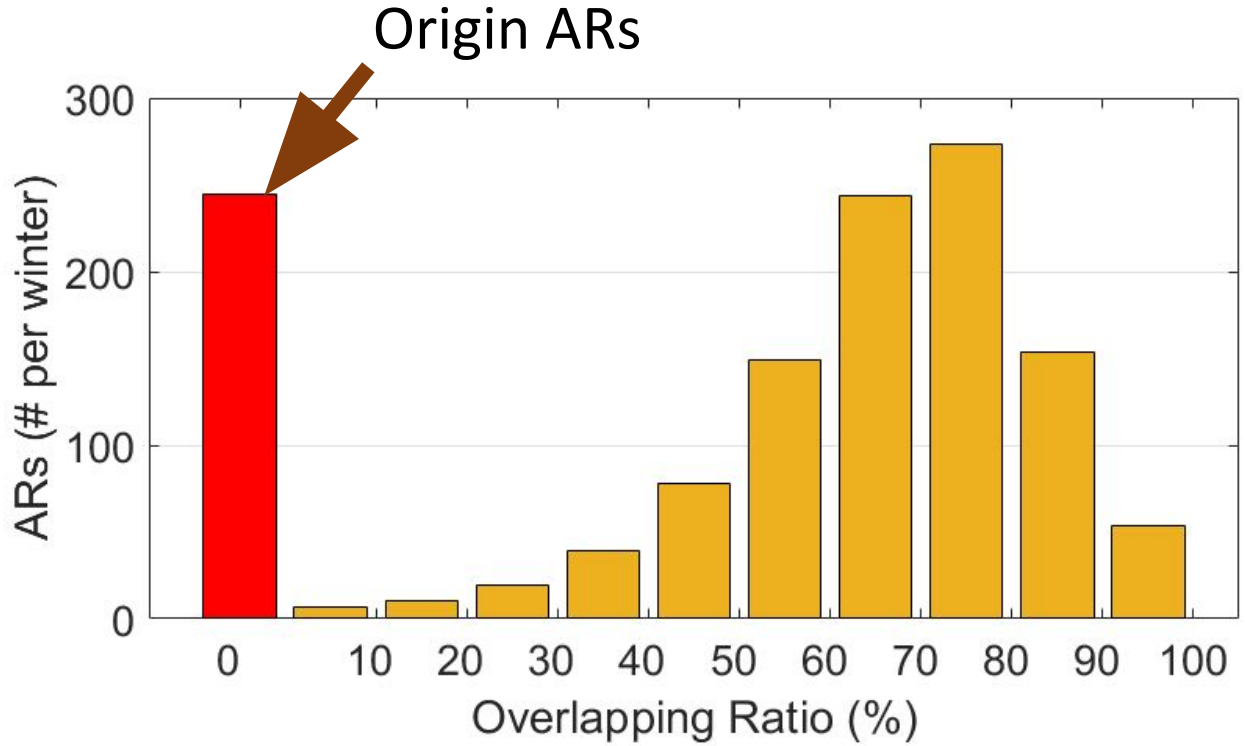
$$\frac{\mathrm{AR}'_t\ \mathrm{s\ overlapping\ area\ with\ AR}_{t-1}}{\mathrm{Total\ area\ of\ AR}_t} \times 100\ \%$$



: AR_{t-1}

: Overlapping area at time t with AR_{t-1}

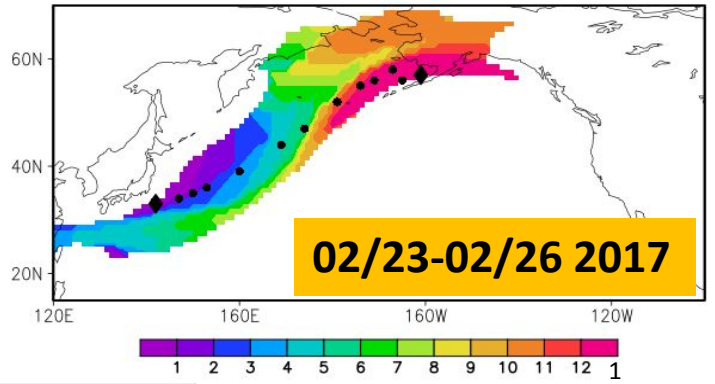
: AR_t

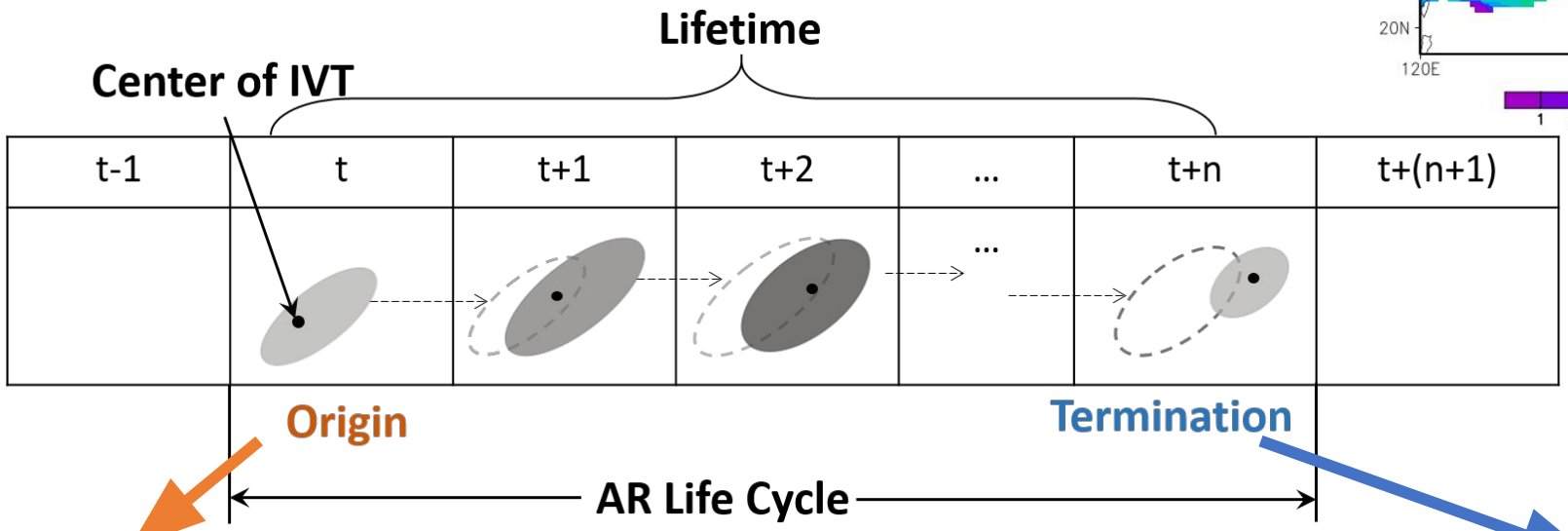


Origins & Terminations

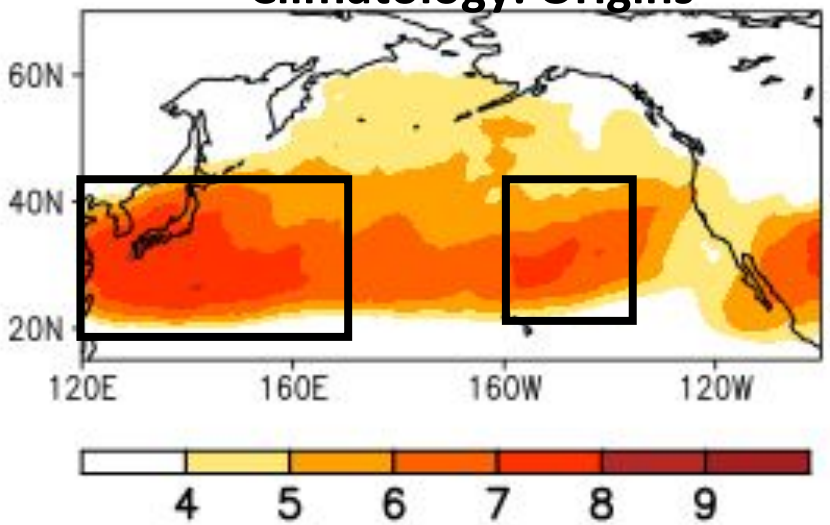
Step III: Recording the LCs

- On average **100** LCs over the North Pacific per winter





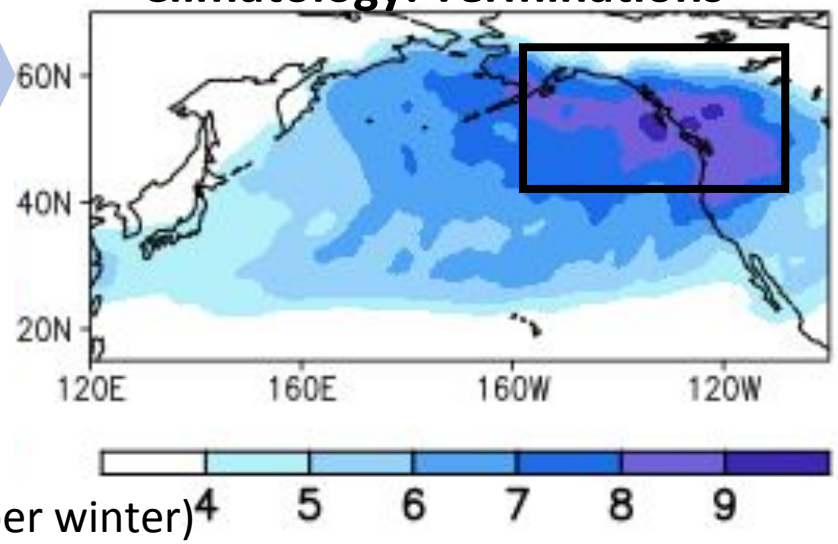
Climatology: Origins



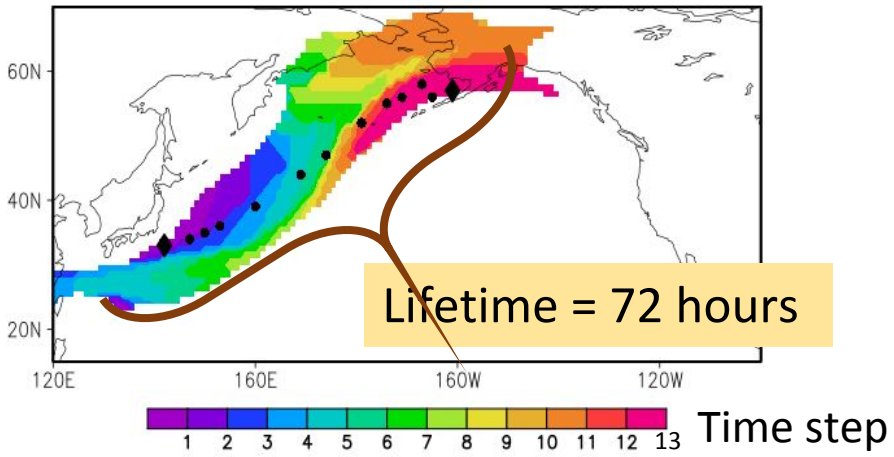
Packed in the subtropics

Locate over higher latitude

Climatology: Terminations



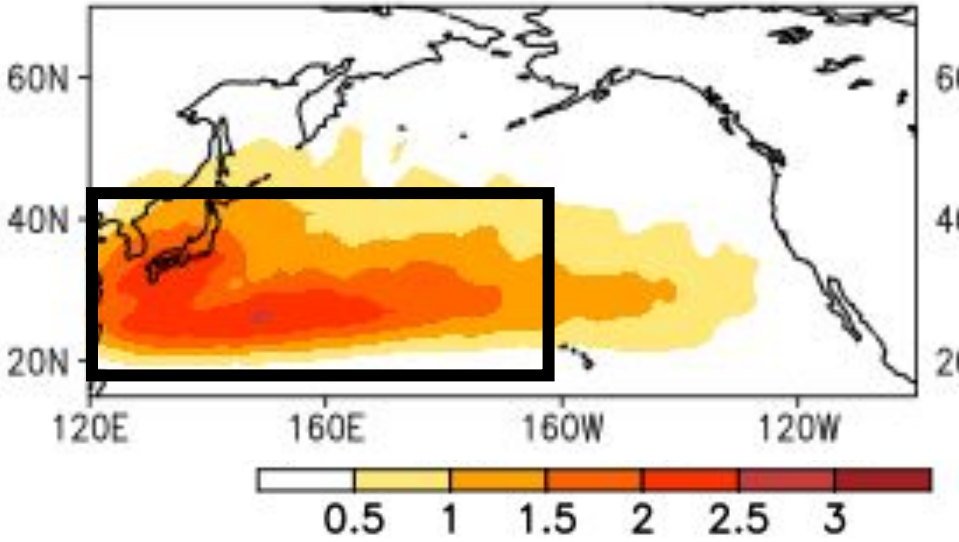
Lifetime



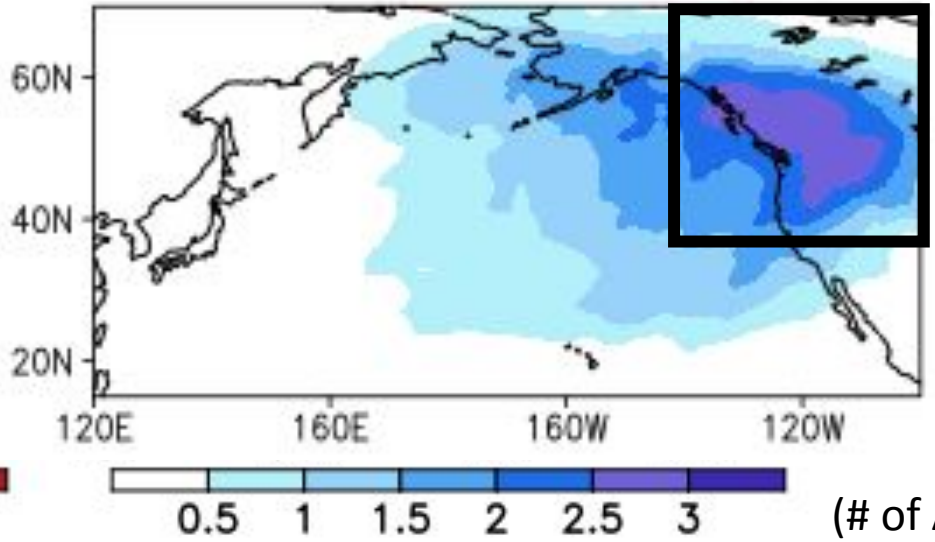
- Lifetime = (time step-1)×6 hourly

- Long LCs: >72 hours (85th percentile)
- Short LCs: <24 hours (30th percentile)

Long LCs: Origins



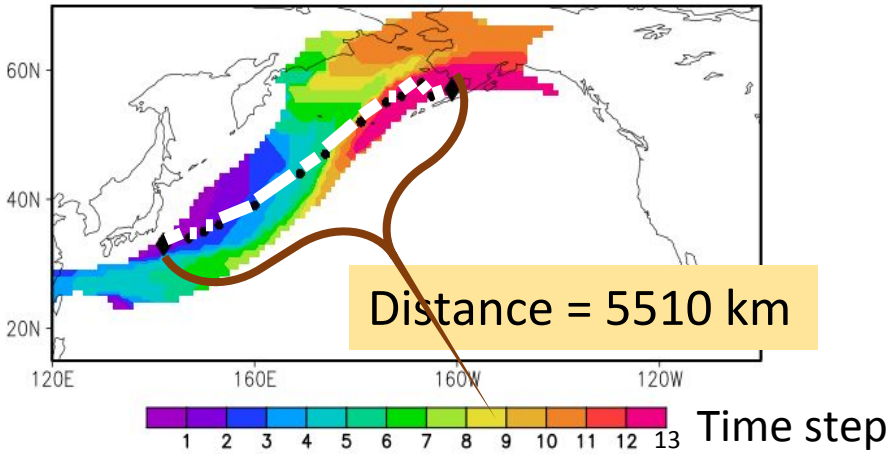
Long LCs: Terminations



- Explain 40% of total

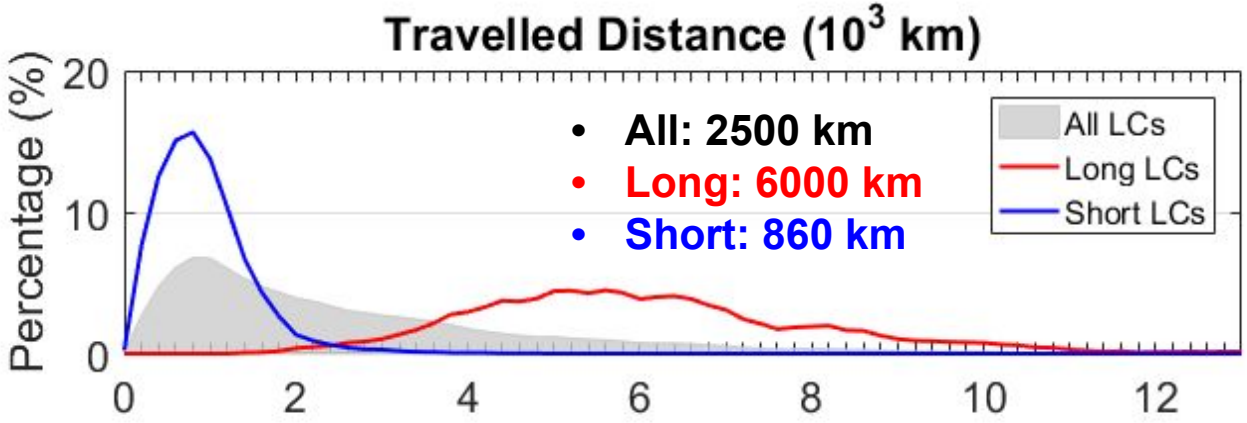
(# of ARs per winter)

Distance & Propagation Speed



- Long LCs travel seven times longer than short LCs
- Comparable mean propagation speed

- Long LCs: >72 hours
- Short LCs: <24 hours



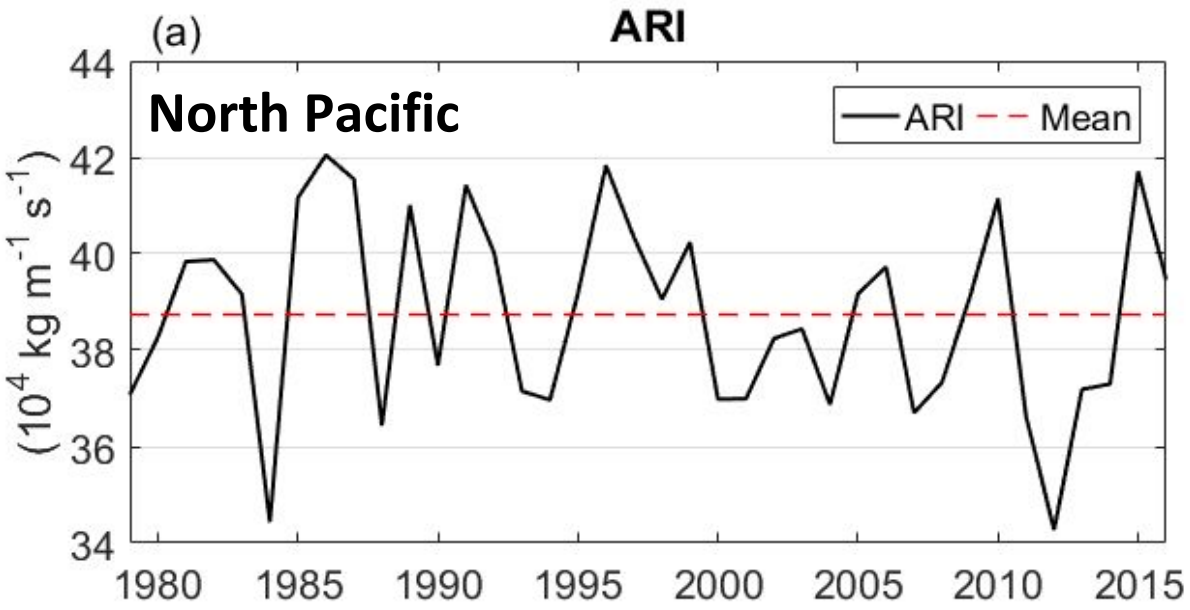
Accumulated AR Intensity

➢ Accumulated AR Intensity (ARI) index

$$\mathrm{ARI} = \sum_{i=1}^{i=N} \sum_{t=1}^{t=T_i} [\mathrm{IVT}\ (t)]_i$$

Number Lifetime Intensity

- Unit: 10^4 kg m^{-1} s^{-1}



➢ The ARI represents the overall AR activities of given period

➢ Year-to-year variability

- $|\mathrm{IVT}\ (t)|_i$: |IVT| of the AR at step t of the i^{th} LC
- T_i: the total time steps of the i^{th} LC
- N: the number of LCs of the given season

Model Simulations

➢ **ERA-Interim**

- Nov. – Mar., 1979-2016

➢ **ECMWF AMIP Runs* (Davini et al. 2017)**

- 1980-2000, 10 ensembles
- Horizontal resolution: ~60km

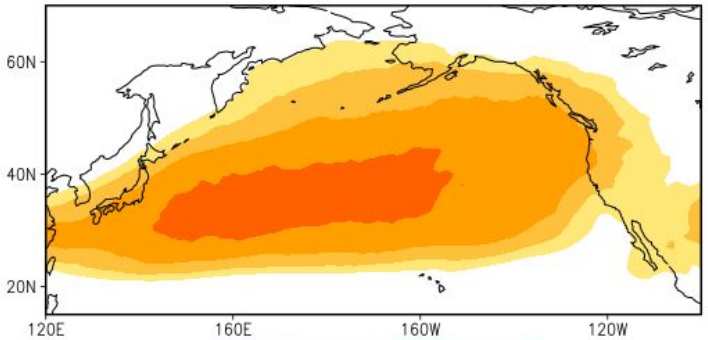
➢ **CESM1.2 AMIP Runs**

- 1979-2016, 10 ensembles
- Horizontal resolution: ~100km

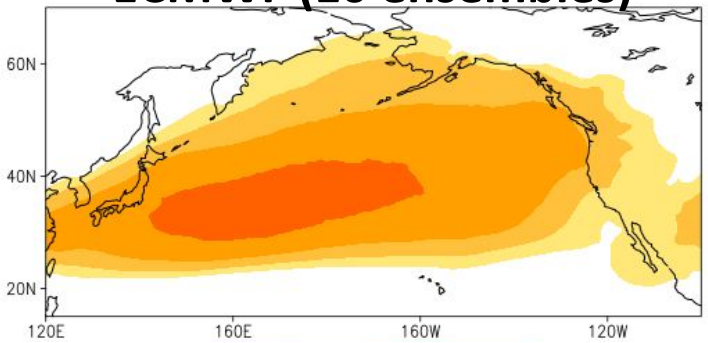
***The ECMWF runs are provided by Aneesh Subramanian**

Shading: AR frequency

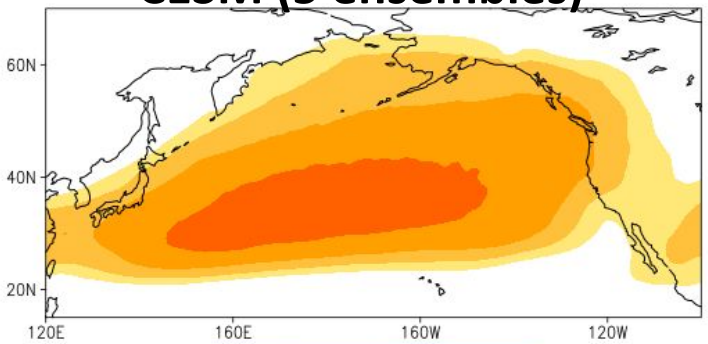
ERA-I

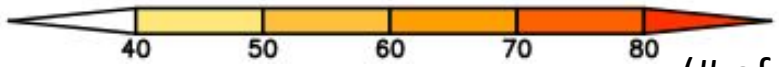


ECMWF (10 ensembles)



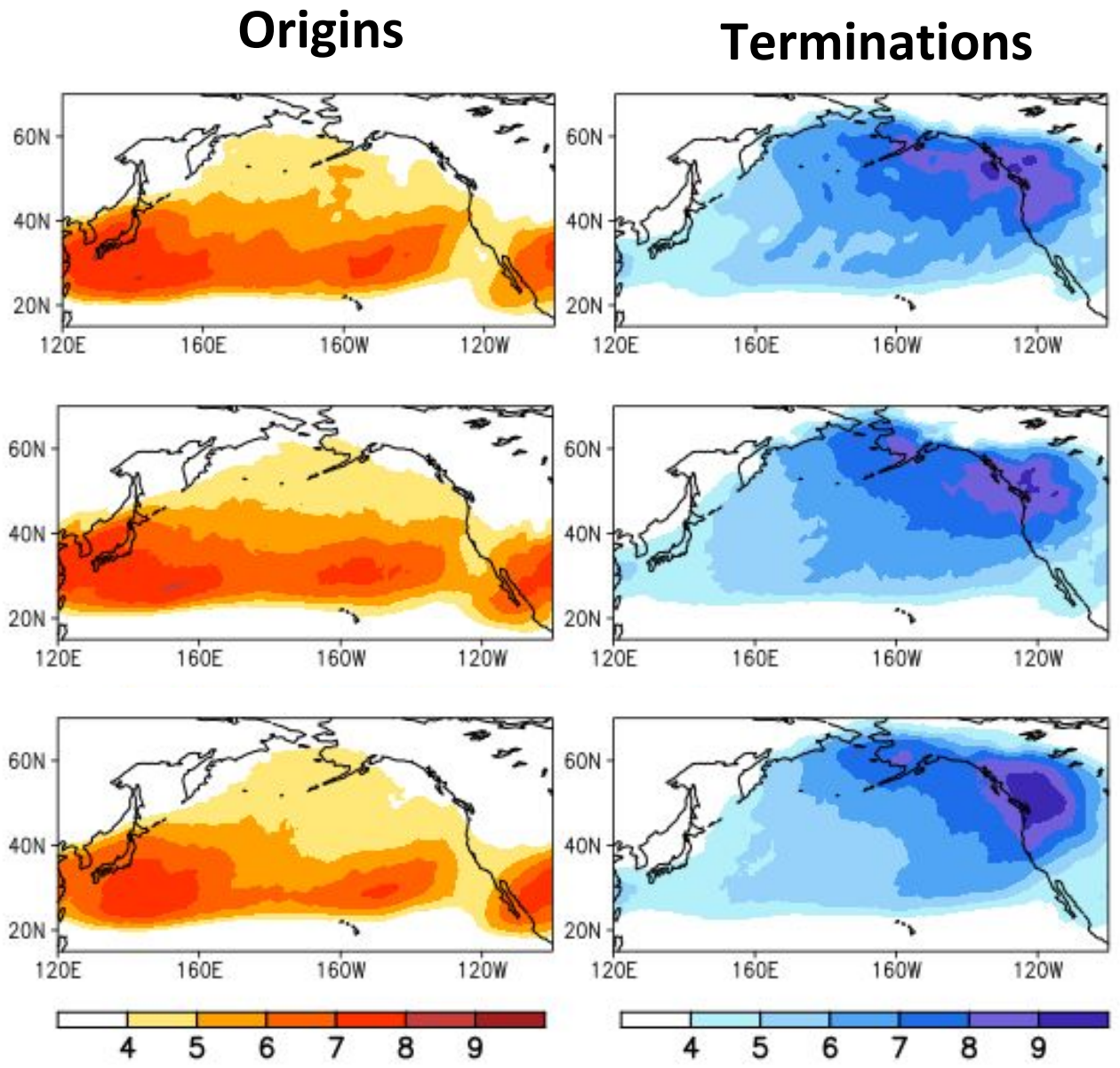
CESM (5 ensembles)





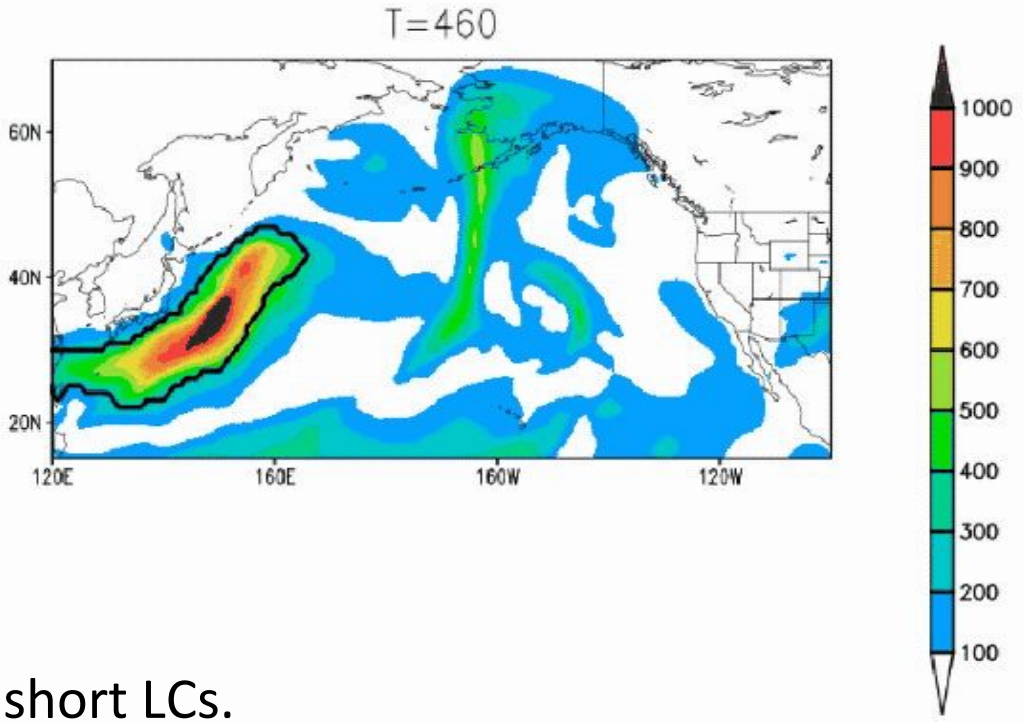
(# of ARs per winter)

Model Simulations



(# of ARs per winter)

Summary



1. **The Tracing Algorithm**
   - Applies to gridded reanalysis and model output
   - Generate subset of AR life cycles (LCs)
   - Suitable for various time scales

2. **Statistical Results**
   - The long LCs on average travel 7 times longer than the short LCs.
   - The accumulated AR intensity (ARI) index represents the overall LC activities of given period.

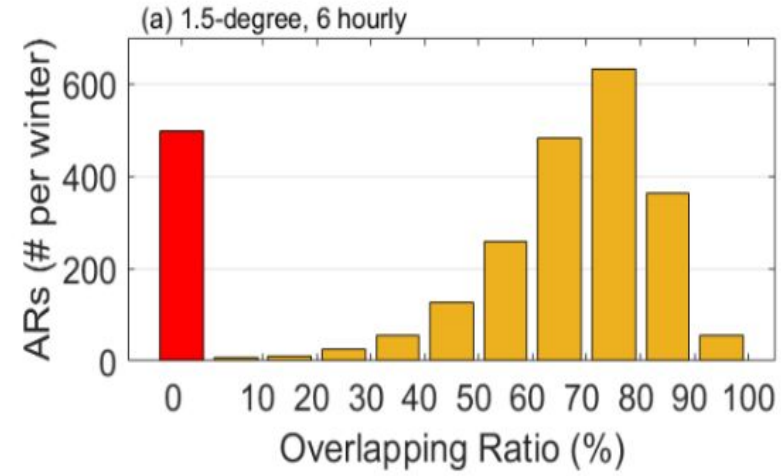
3. **Model Simulations**
   - The winter climatology patterns of AR frequency, origins and terminations are reproduced.

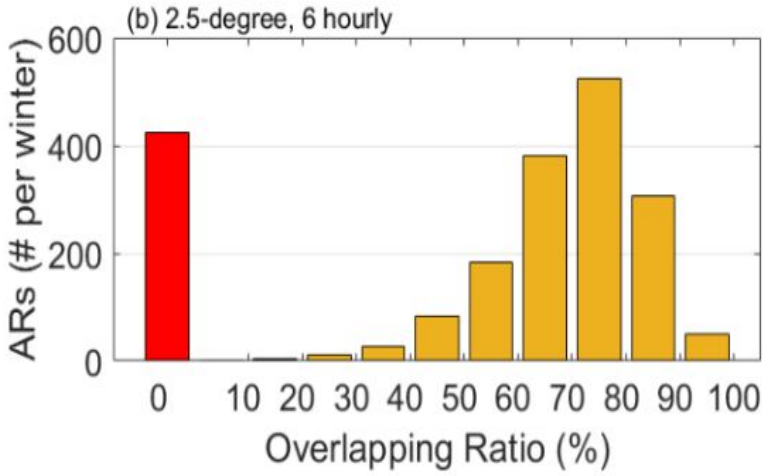
- Zhou, Y., H. M. Kim, and B. Guan: The Atmospheric Rivers Life Cycles: Identification and Climatological Characteristics *(submitted)*

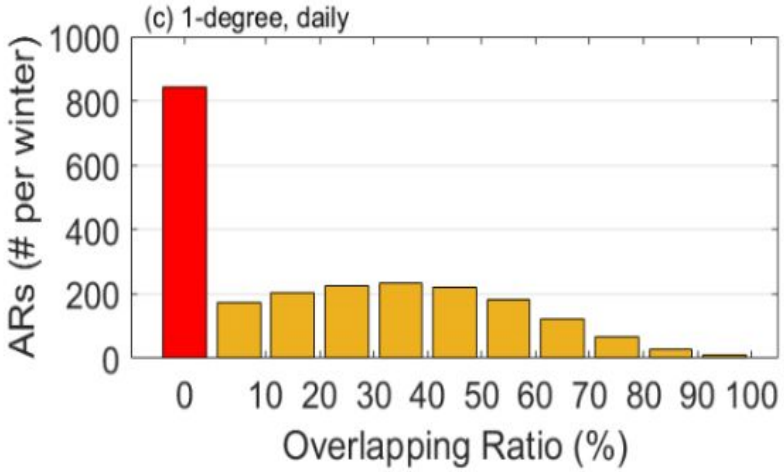
- Email: yang.zhou.1@stonybrook.edu

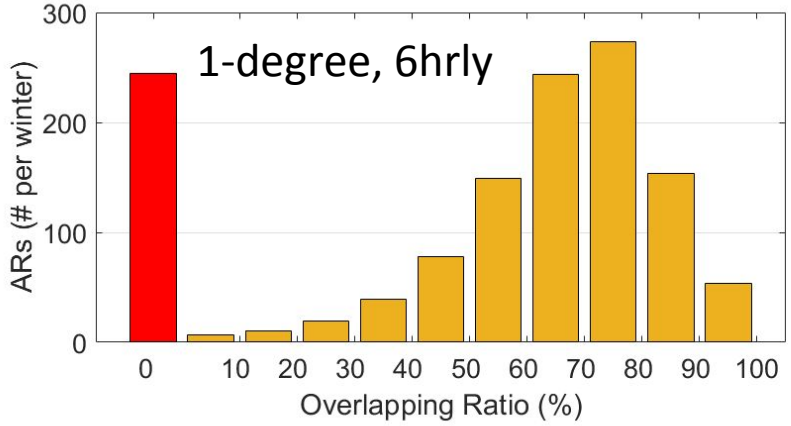
Thank you!

Sensitivity Test

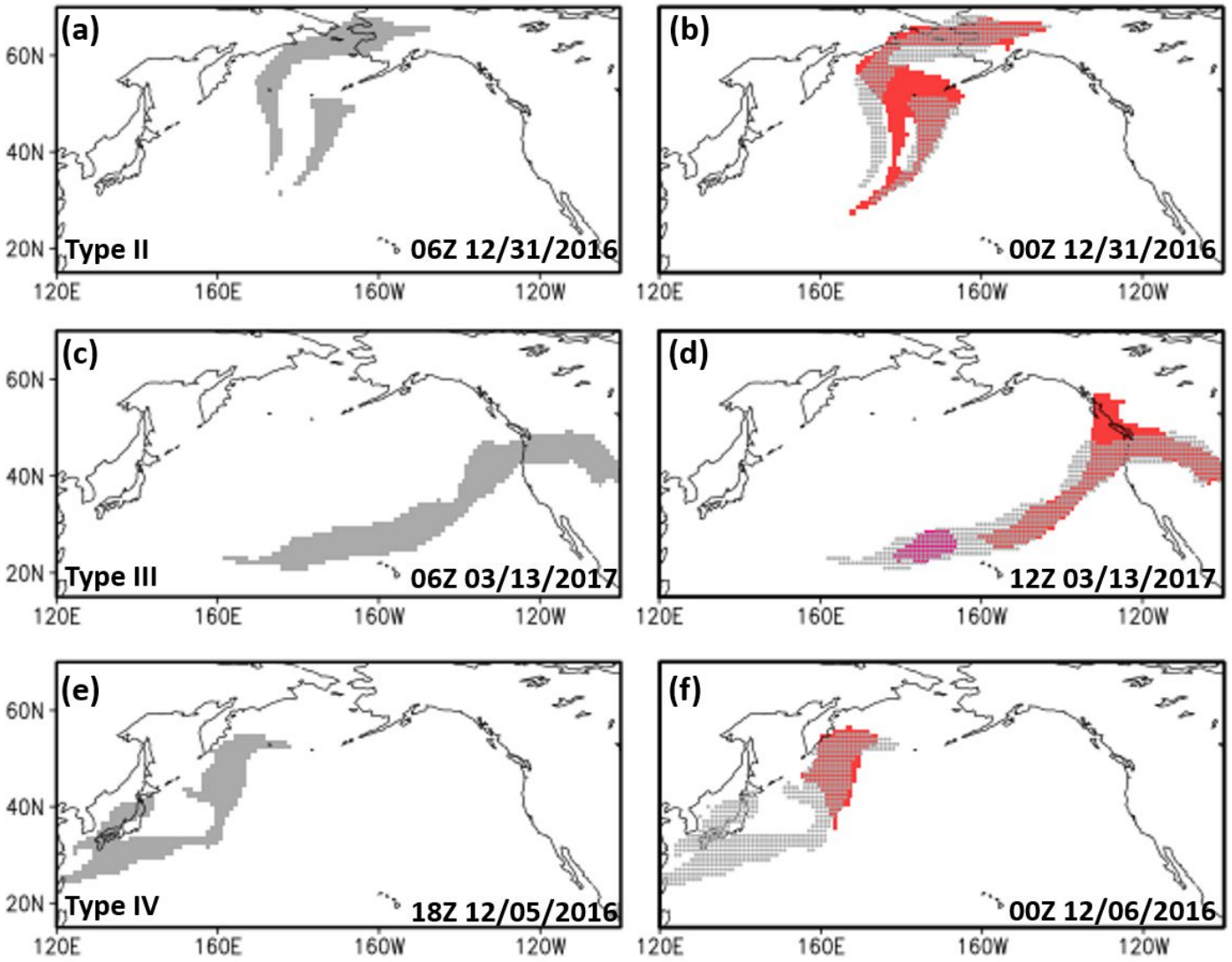








Four types of AR Origins

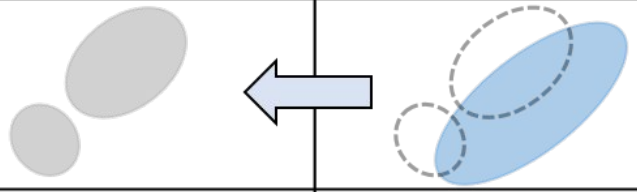
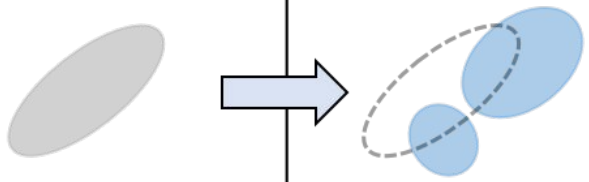
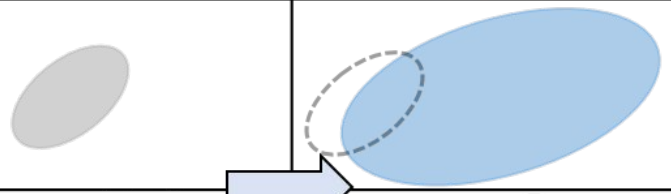
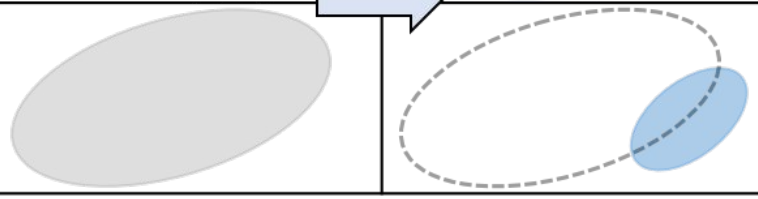


Type II: combination

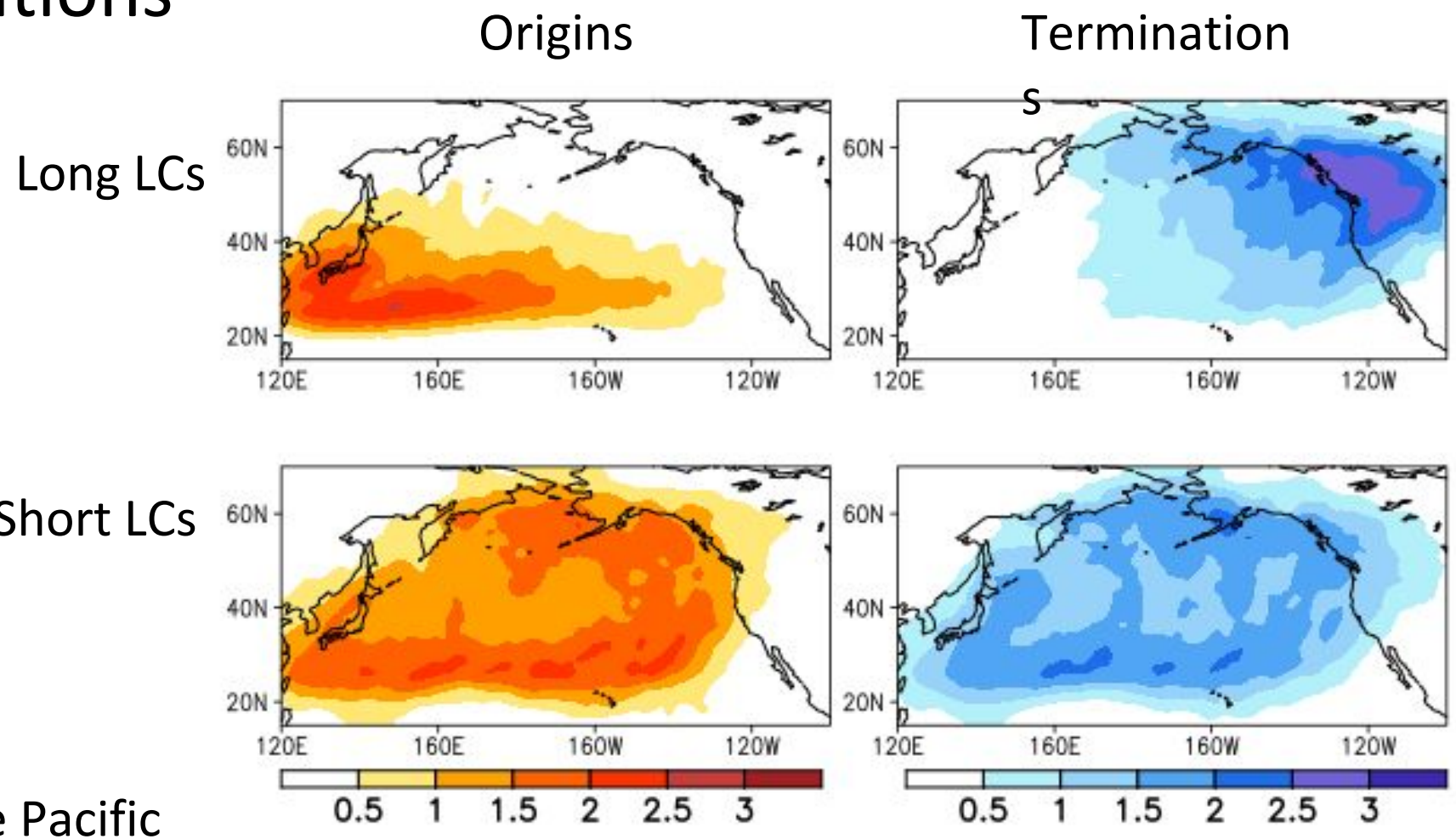
Type III: division

Type IV: deformation

Four types of AR Origins

	t-1	t	Conditions
Type I General			No overlapping
Type II Combination			Number of overlapping ARs ≥ 2
Type III Division			
Type IV Deformation			$\frac{\text{area}(\text{AR}_{t-1})}{\text{area}(\text{AR}_t)} < \frac{1}{2}$
			$\frac{\text{area}(\text{AR}_{t-1})}{\text{area}(\text{AR}_t)} > 2$

Origins and Terminations

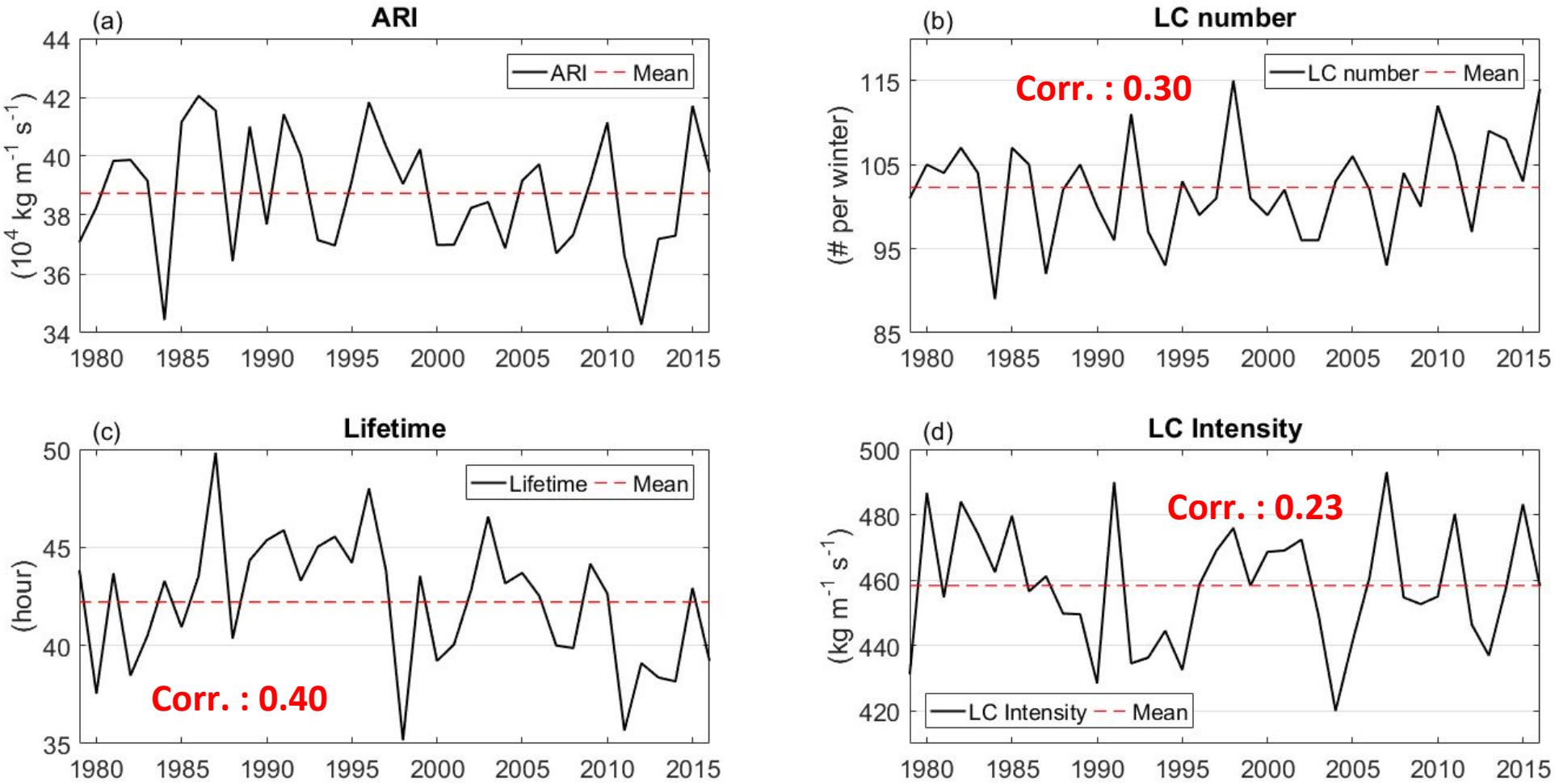


➢ Short LCs:

- Origin ARs scatter over the Pacific
- Termination ARs are close to origins due to short lifetime
- Terminate over North America (explain up to 20% of total)

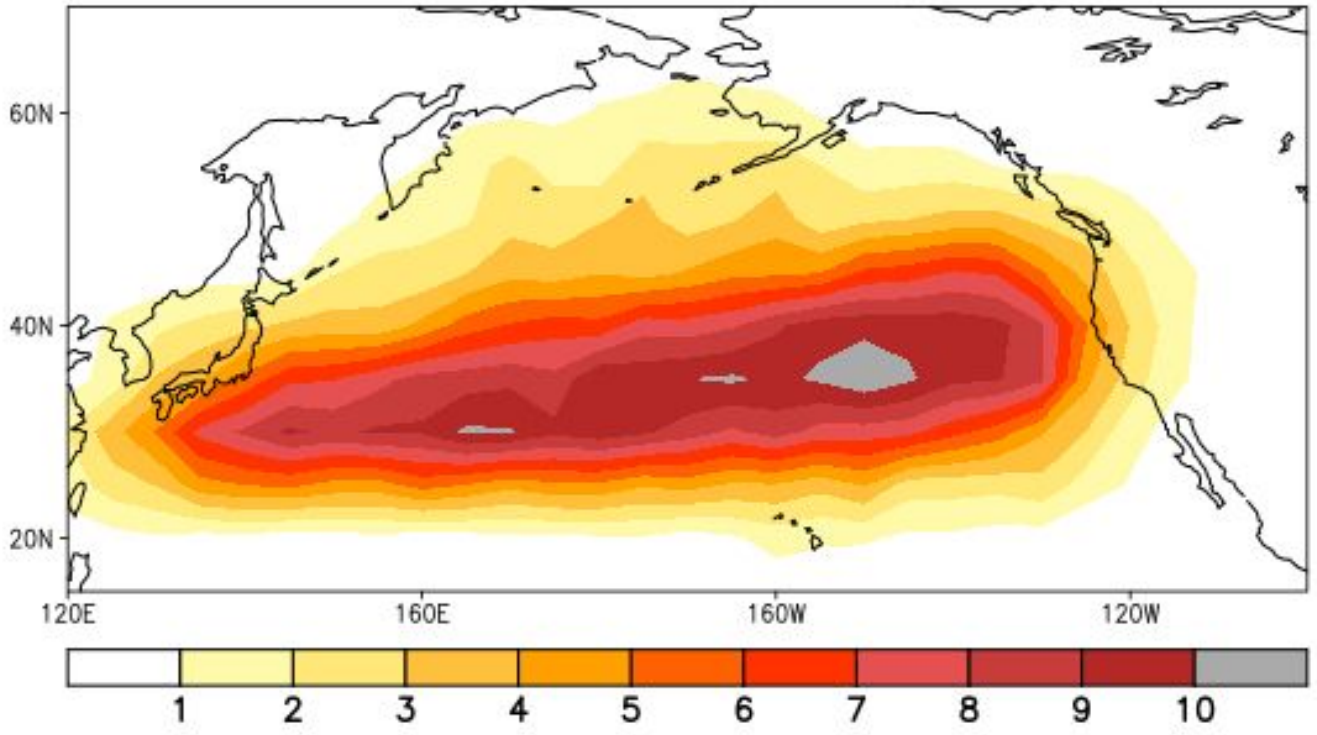
Accumulated AR Intensity (ARI) index

Contributors:
- Number of LCs
- Lifetime
- LC Intensity



➢ **Lifetime is the relatively stronger contributor to the magnitude of ARI**

AR
Tracks



- Interpolated into 5°×5° grid