Center for Western Weather and Water Extremes

Contrasting Local and Long-Range Transported Warm Ice-Nucleating Particles During an Atmospheric River in Coastal California

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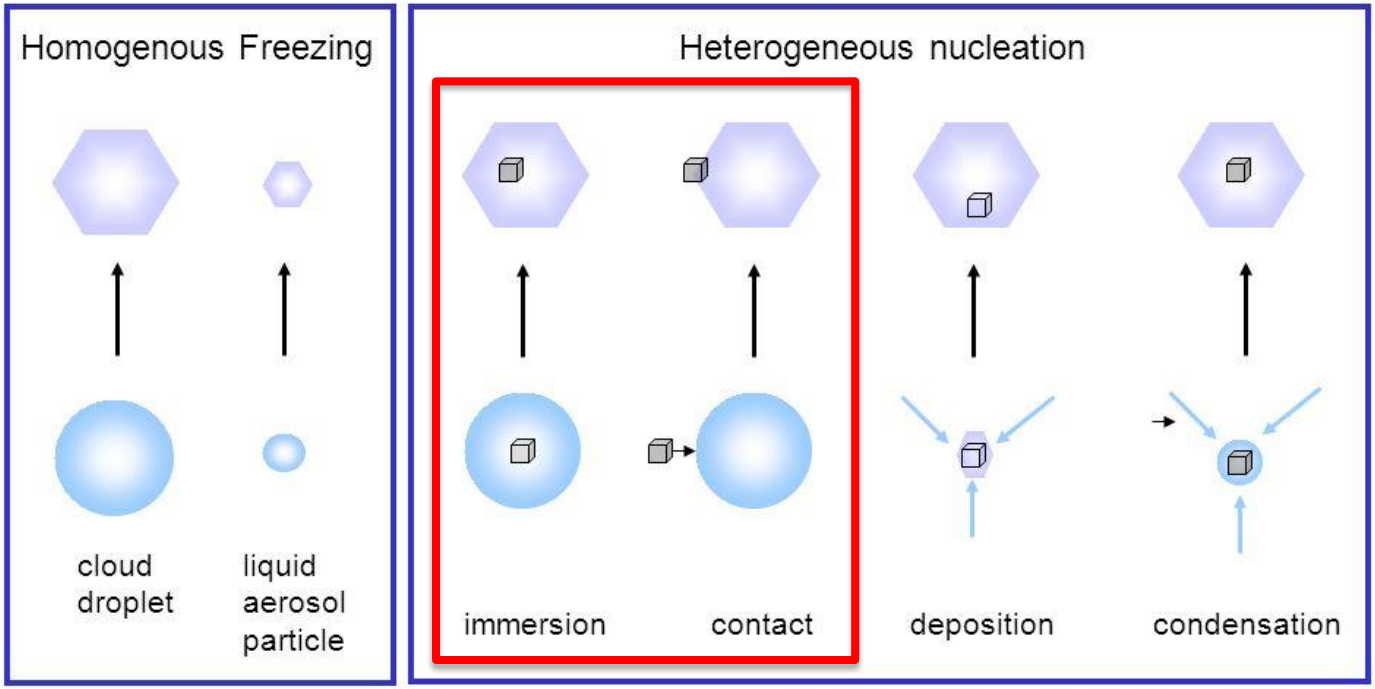
Outline

1. Background: What are “warm” ice nucleating particles (INP) and what are their sources?
2. Background: How are INP thought to modulate atmospheric rivers (ARs)?
3. Description of AR event and measurements
4. What are the warm INP sources in our AR?
5. How does meteorology modulate source presence?
6. What impact did the warm INP have on the clouds in this AR?
7. Review

Ice Nucleating Particles: What are They?



Credit: Thomas Leisner, DWD

Kanji et al., 2017

What are Warm INP?

Warmest temperature of activity for some ice nucleation-active materials †

Nucleating ma	
Kaolinite (clay r	
Birch pollen	
Ice⁺ insects	
AgI	
Pantoea agglor	
Pseudomonas	

† Temperatures
¥ The tempera

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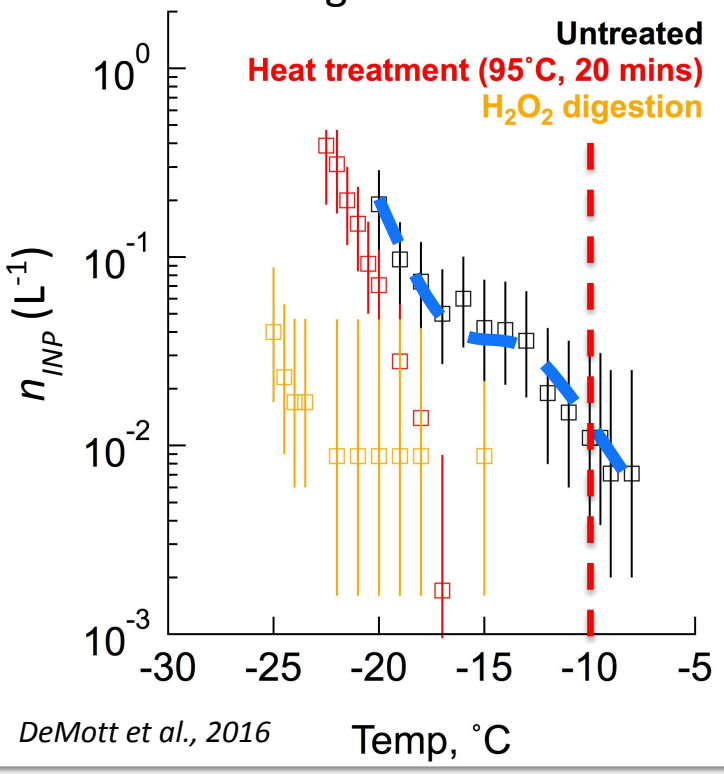
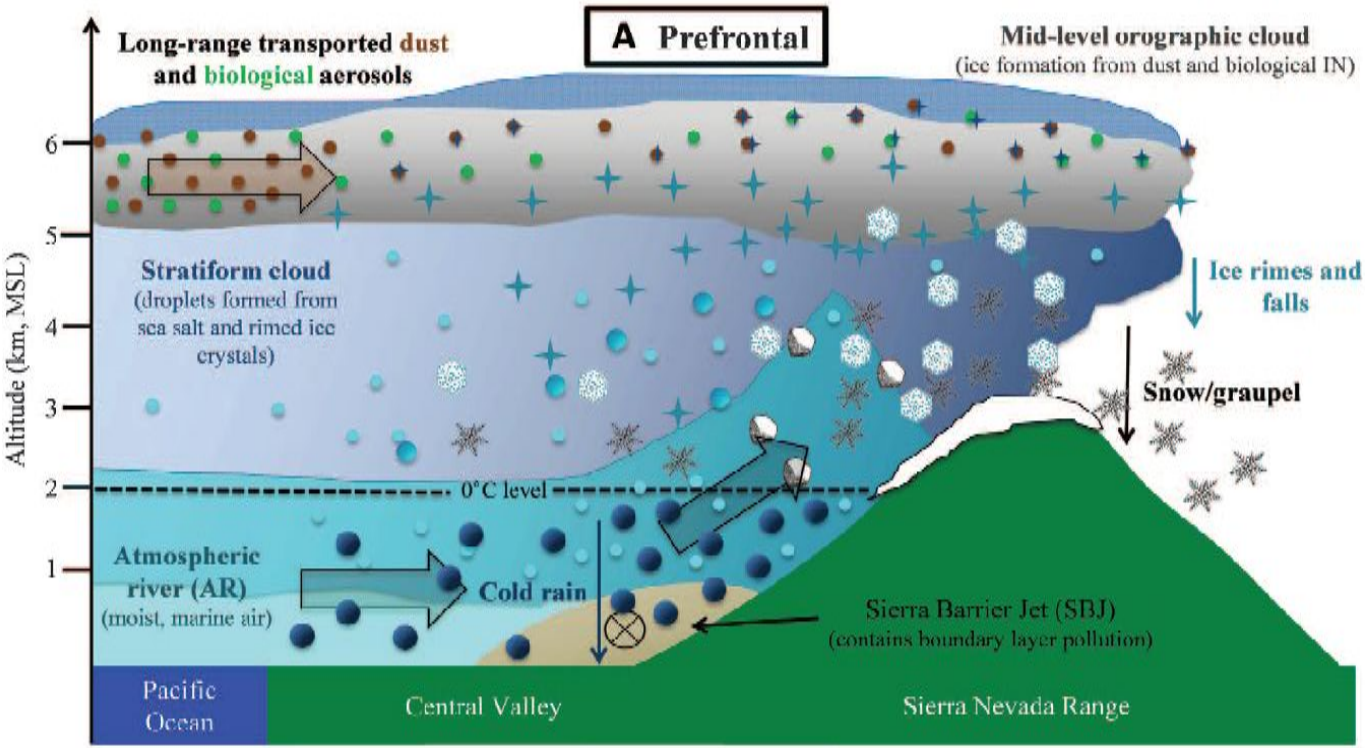
Biological:



DeMott et al., 2016

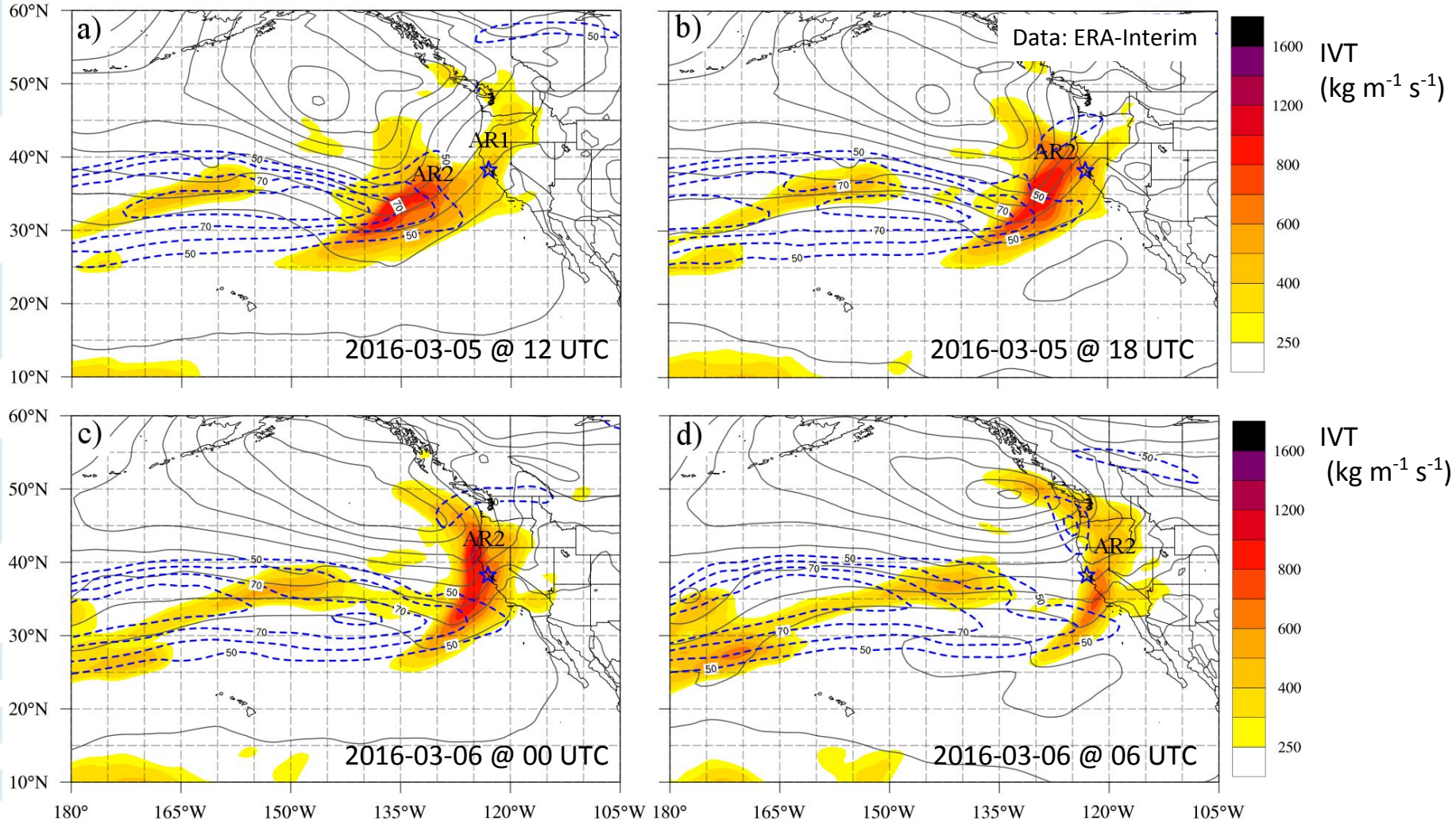
A Conceptual model for INP modulation of Atmospheric Rivers



- Long-range transported aerosol can influence the ice formation process
- Meteorological details like the transport pattern, freezing altitude, cloud depth and layering, are important.
- What about locally generated INP?
  - Marine and Terrestrial

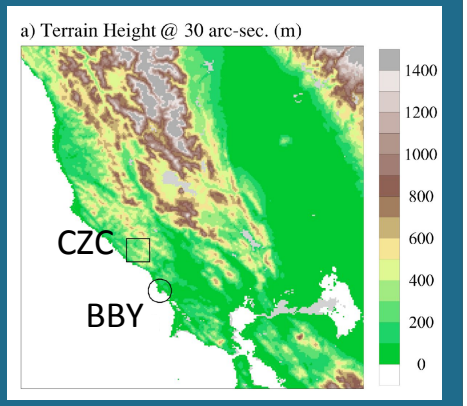
Creamean and Suski et al. (2013)

Overview of our atmospheric river: 5-6 March, 2016

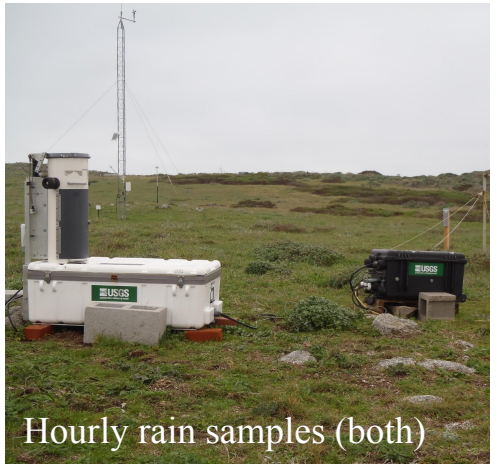


Colors: IVT (kg m^{-1} s^{-1}); Blue Dashed: 300 hPa Isotachs (m s^{-1}); Gray Solid: Sea-Level-Pressure (hPa)

Measurements

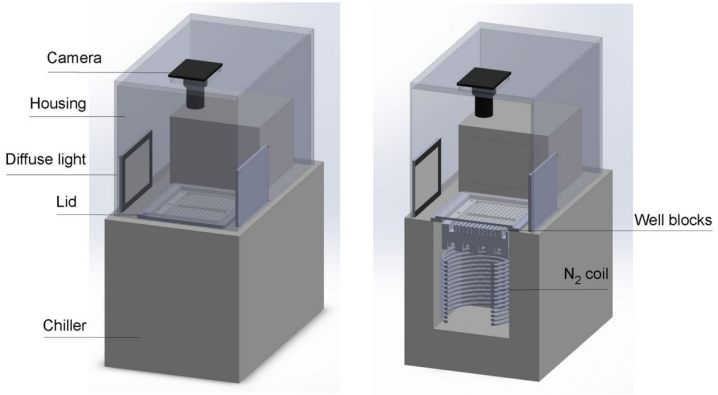


Coast (BBY)



Inland (CZC)

Laboratory

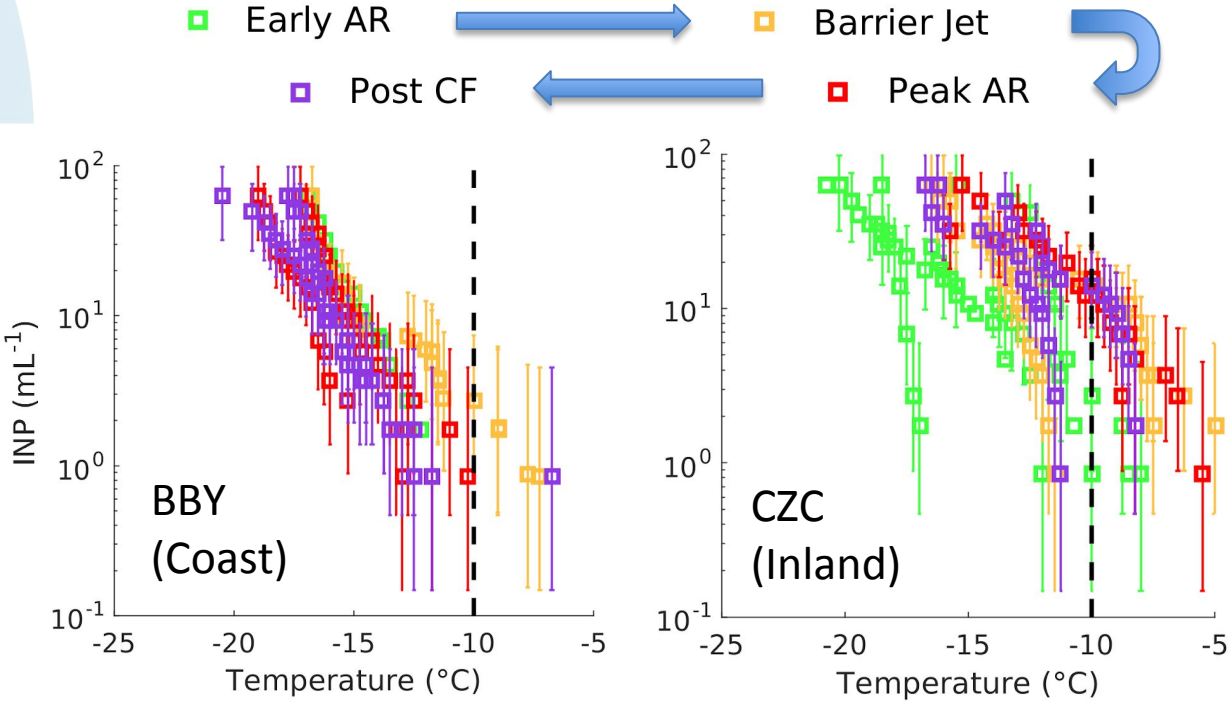


Automated Ice Spectrometer:
Counts the number of heterogeneous freezing events that occur as a rain sample is slowly cooled.

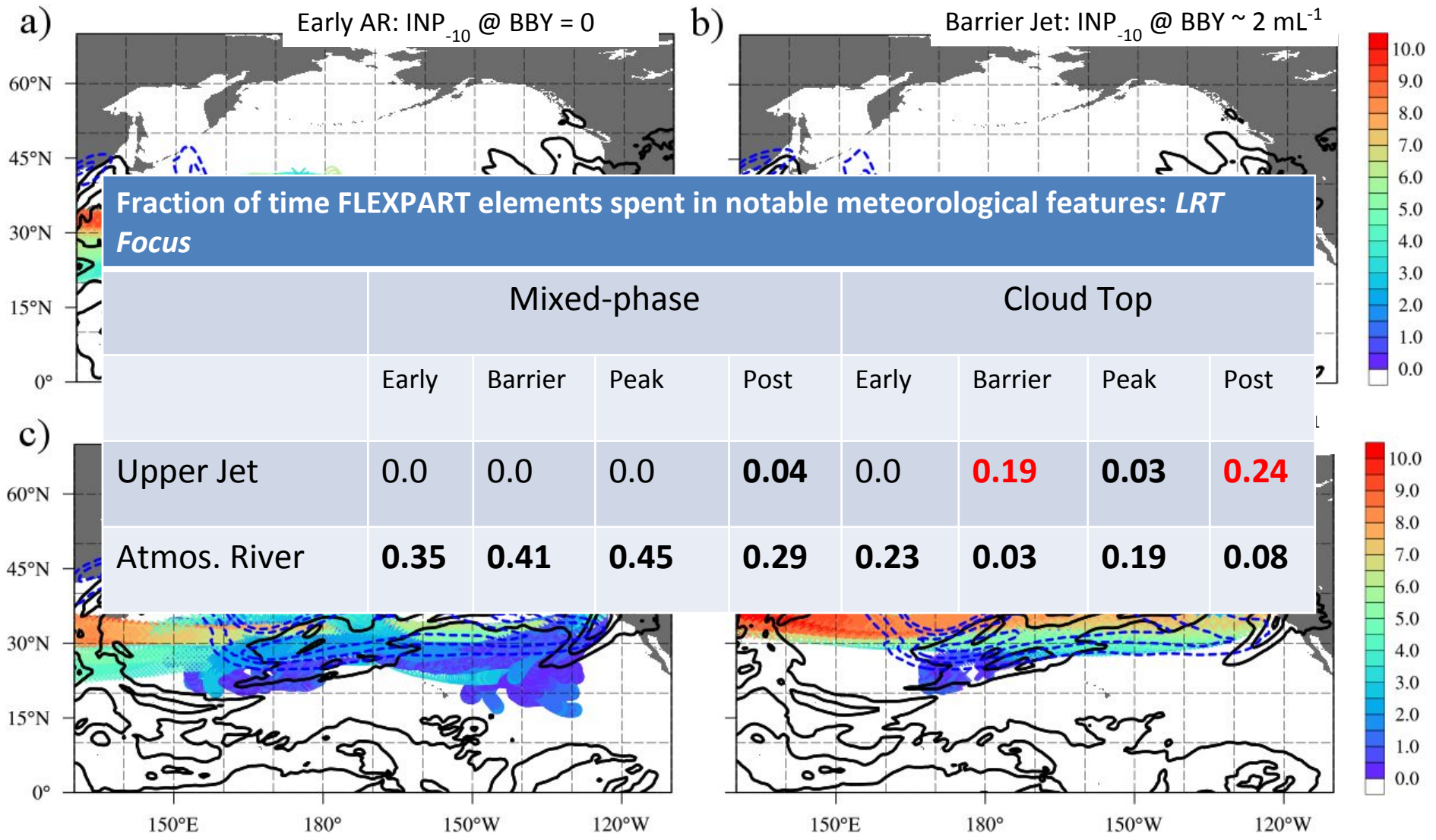
Freezing-Temperature spectra show vastly different INP at each site

- At most temperatures, BBY freezing chance follows dust-like curve.
- The chance of freezing in CZC samples is similar to tests with high concentration of known Ice^{+} biologicals.
- Even when warm INP appear in BBY samples, their concentration is order of magnitude lower than highest CZC.

Samples are assigned to periods separated by major kinematic features. Arrows show increasing time.



FLEXPART Element position and height, sorted by storm kinematics



Fraction of time FLEXPART elements spent in notable meteorological features: *LRT Focus*

	Mixed-phase				Cloud Top			
	Early	Barrier	Peak	Post	Early	Barrier	Peak	Post
Upper Jet	0.0	0.0	0.0	**0.04**	0.0	**0.19**	**0.03**	**0.24**
Atmos. River	**0.35**	**0.41**	**0.45**	**0.29**	**0.23**	**0.03**	**0.19**	**0.08**

FLEXPART Analysis of Local Airmass Sources

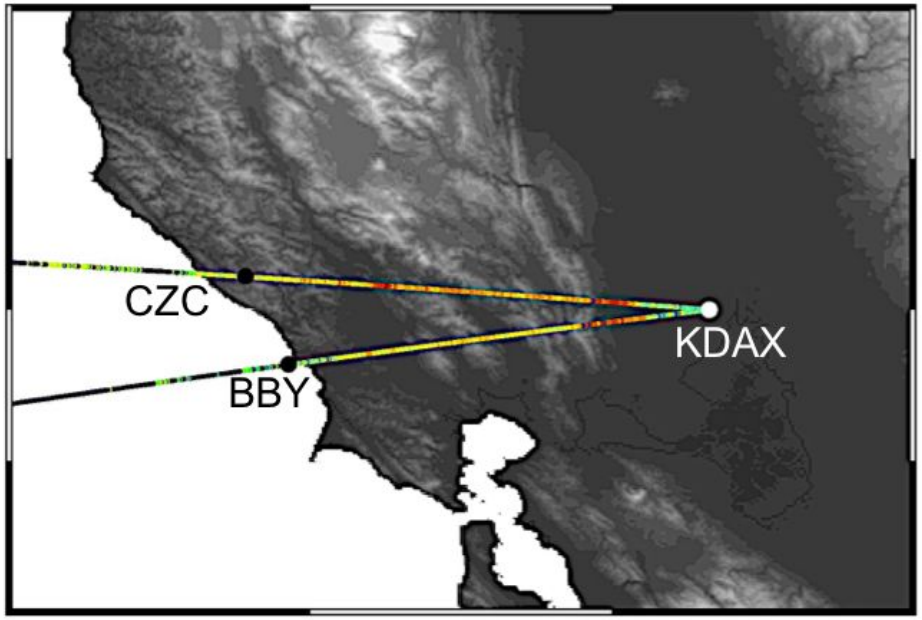
Fraction of time FLEXPART elements spent in notable meteorological features: *Local Focus*								
Mixed Phase Clouds	**BBY**				**CZC**			
	Early	Barrier	Peak	Post	Early	Barrier	Peak	Post
Terrestrial Boundary Layer	0.0	0.0	0.0	0.0	0.0	**0.06**	**0.08**	**0.04**
Marine Boundary Layer	**0.16**	**0.30**	**0.40**	**0.29**	**0.16**	**0.30**	**0.40**	**0.29**

Summary of FLEXPART findings regarding sources:

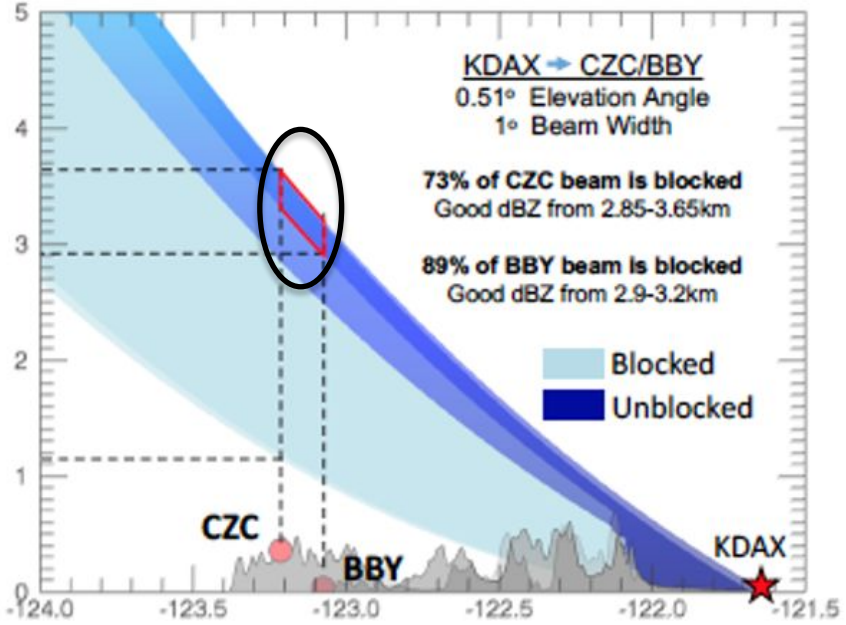
- Upper tropospheric transport in the UTJ is indicated when warm INP are found at BBY.
- Both sites have equivalent and consistent exposure to marine airmasses.
- Inland site, but not coastal site, shows exposure to terrestrial boundary layer airmasses.

WSR-88 Polarimetric Hydrometeor Retrievals

a)



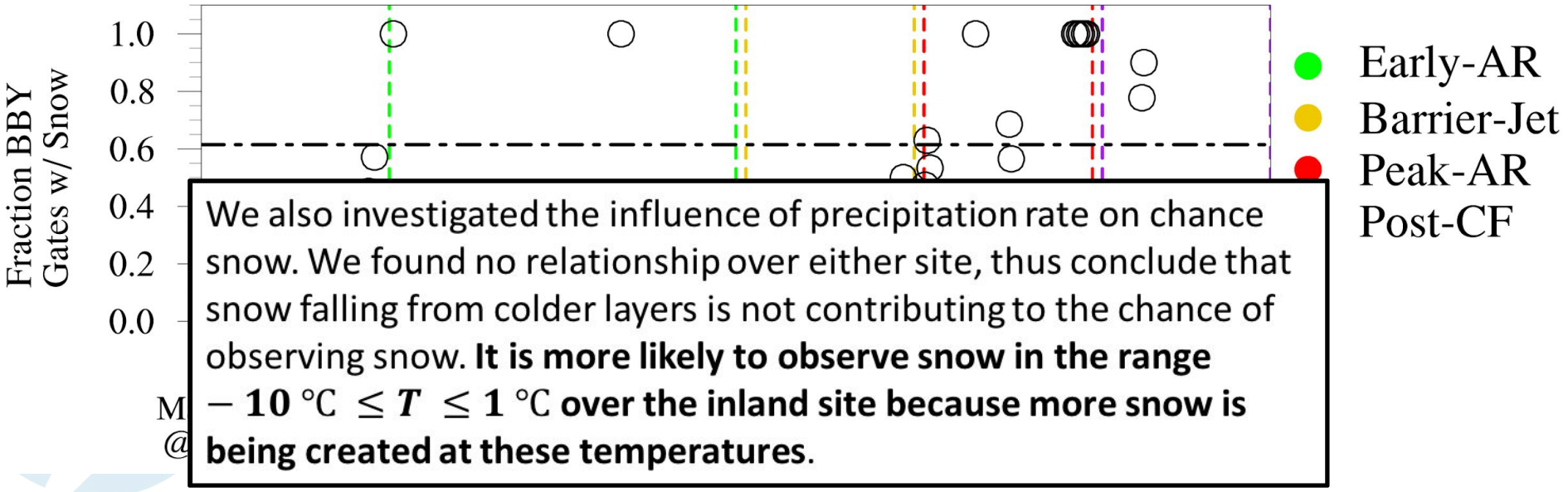
b)



The lowest KDAX scan is partially blocked by topography, but valid hydrometeor classifications are still available.

By matching the range gates in the red trapezoid from BBY azimuth to the CZC gate and azimuth, we ensured hydrometeors over both sites are in range $-10\ ^{\circ}\mathrm{C} \leq T \leq 1\ ^{\circ}\mathrm{C}$.

What is the chance of observing frozen hydrometeors in the mixed-phase clouds over each site?



We also investigated the influence of precipitation rate on chance snow. We found no relationship over either site, thus conclude that snow falling from colder layers is not contributing to the chance of observing snow. **It is more likely to observe snow in the range $-10\ ^{\circ}\mathrm{C} \leq T \leq 1\ ^{\circ}\mathrm{C}$ over the inland site because more snow is being created at these temperatures.**

The WSR retreivals contain 11 hydrometeor types; we define all frozen types as "snow" and all liquid types as "not snow".

P (snow | CZC) = 0.62; P (snow | BBY) = 0.17

Chi-Sq Probability that chance of snow is similar over both sites: 1×10^{-38}

Review

1. Strong, continual presence of biological warm INP in inland site (CZC) precipitation. Ephemeral and weaker biological warm INP concentrations at the coastal (BBY) site.
2. Both sites received equivalent influence from marine and long-range transported airmasses. Inland site received small, but non-zero influence from local terrestrial airmasses.
3. Upper tropospheric transport influence waxed and waned in-phase with concentration of warm INP at coastal site.

Finding 1: LRT warm INP occasionally become incorporated to coastal site precipitation. Both terrestrial and LRT warm INP become incorporated to inland site precipitation.

4. Terrestrial boundary layer air can become entrained into inland mixed-phase clouds.
5. In-situ microphysics is causing a difference in hydrometeor phase in inland mixed-phase clouds.

Finding 2: More numerous warm INP can become lofted into mixed phase clouds and impact ice-phase physics there.