天津大学 Tianjin University 表层地球系统科学研究院 Institute of Surface-Earth System Science

EGU 2020 AS 3.9 Atmospheric Surface Science and Ice Particles

Biological Ice Nucleation Particles in Urban Atmosphere of Two Megacities Beijing and Tianjin in North China

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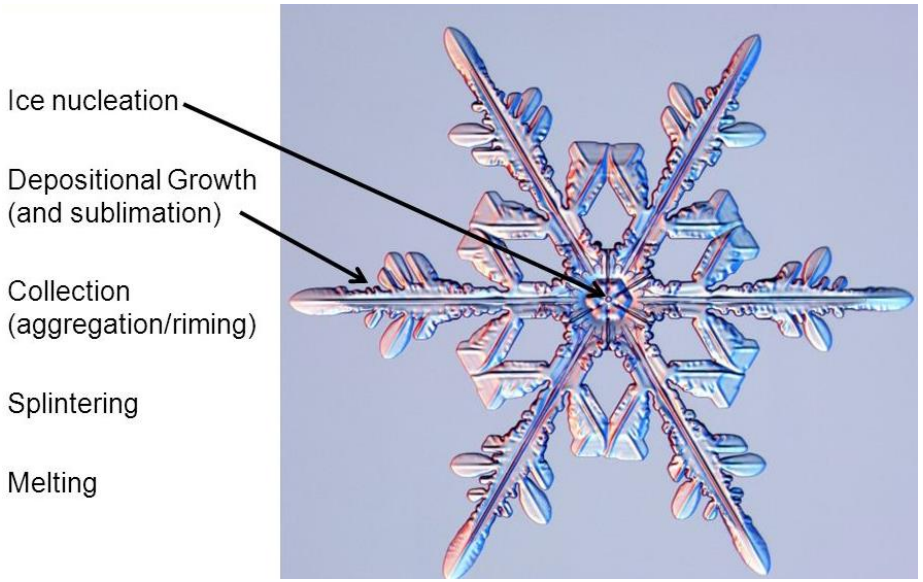
CONTENTS

Mechanisms of Ice Nucleation

- Ice Nucleation: the first step of the ice crystal's formation



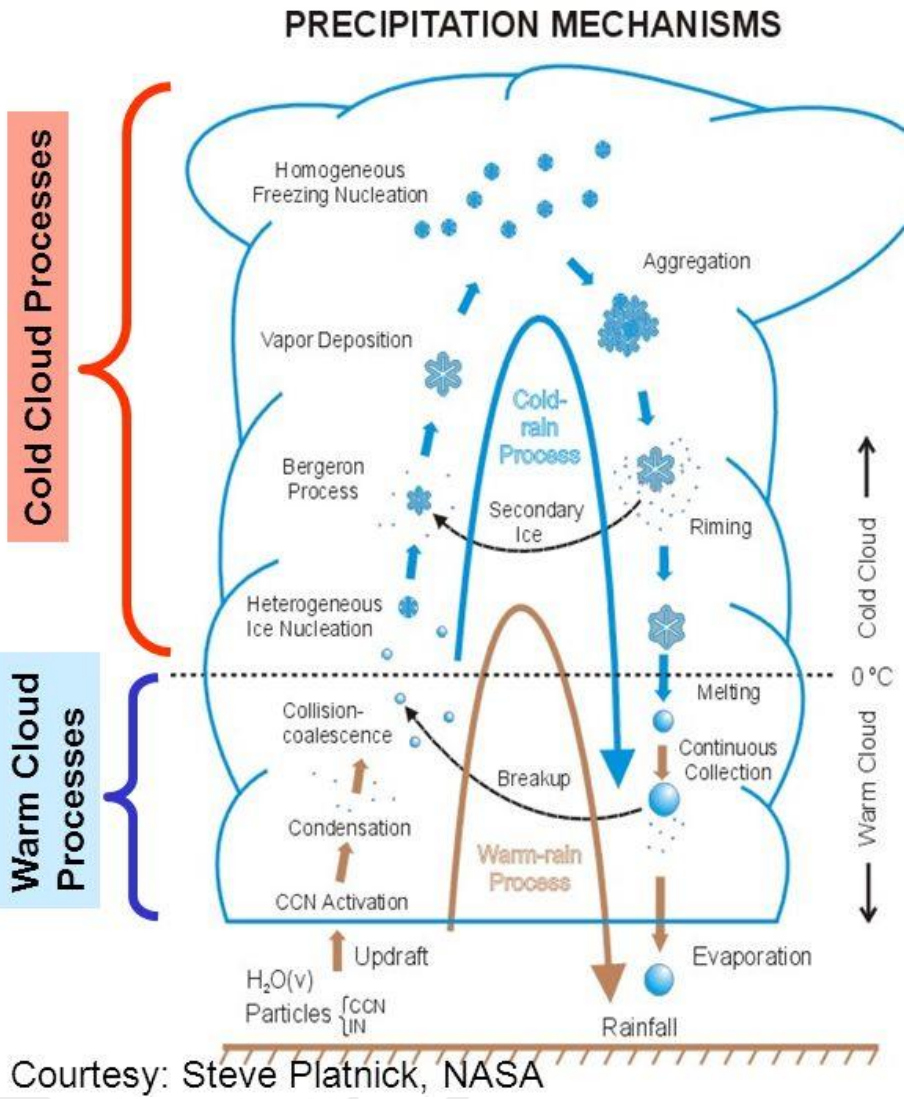
Ice Nucleation

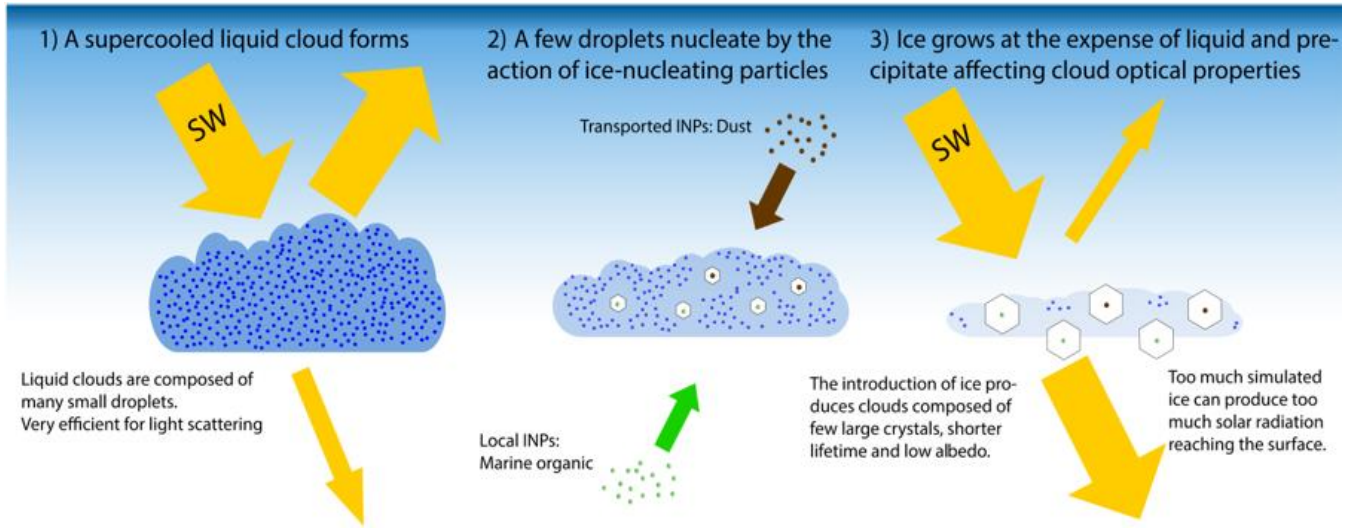
- Homogeneous nucleation → High clouds (< –38 °C , RH > 140%) → No other particles
- Heterogeneous nucleation → The origin of most of the ice → Foreign particles → Reduce the energy barrier

Ice nucleation particles **(INPs)**

Deposition nucleation | Immersion freezing | Condensation freezing | Contact freezing

Impacts on Troposphere





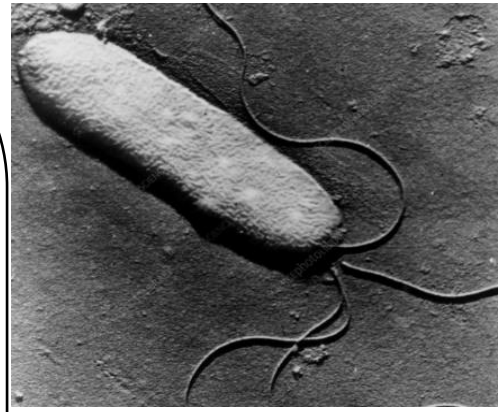
- Physical properties
- Chemical composition
- Radiative transfer
- Precipitation

(Vergara, *PNAS*, 2018)

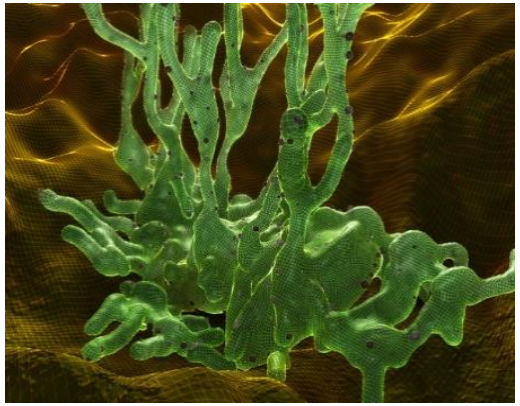
Types of Biological INPs

Biological INPs:

- Bacteria, fungi, plankton, pollen, leaf litter, fragments of them, etc.
- Most effective INPs
- Initiate ice clouds at warmer temperatures (> –15 °C)
- Major influence between –3 °C to – 8 °C
- *Pseudomonas syringae:* widespread, ~ – 2 °C



Bacteria



Fungi

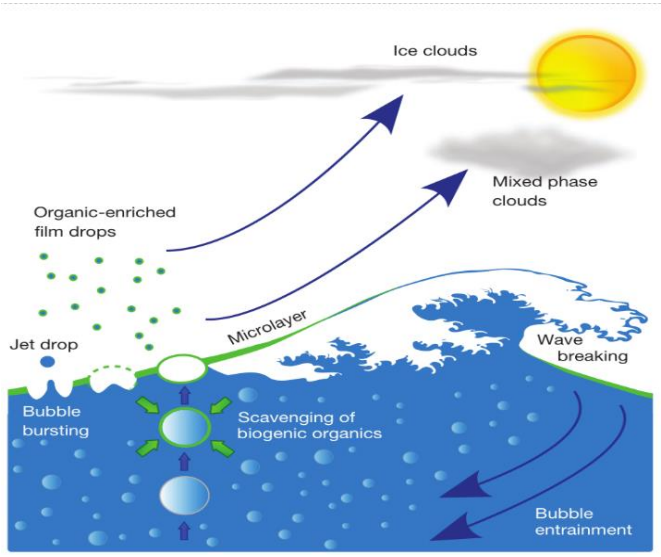
Plankton

Birch pollen

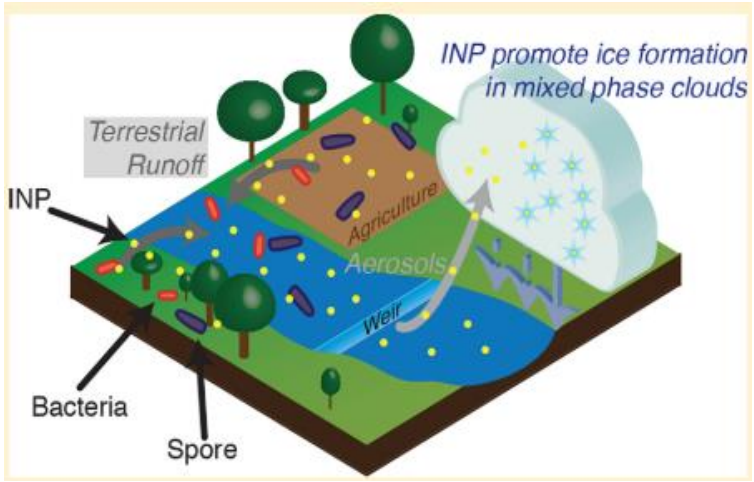
Sources of Biological INPs

Soil

Leaves



Sea spray (Wilson, *Nature*, 2015)



(Knackstedt, *ES & T*, 2018)

Fresh waters

Scientific Questions

Tianjin:

1. The biggest coastal megacity in North China
2. Influenced by both continental/anthropogenic pollution and marine air masses, especially in summer

Beijing:

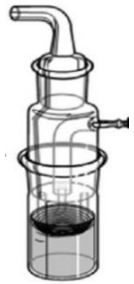
1. The biggest megacity in North China
2. Suffered from severe air pollution

Aims:

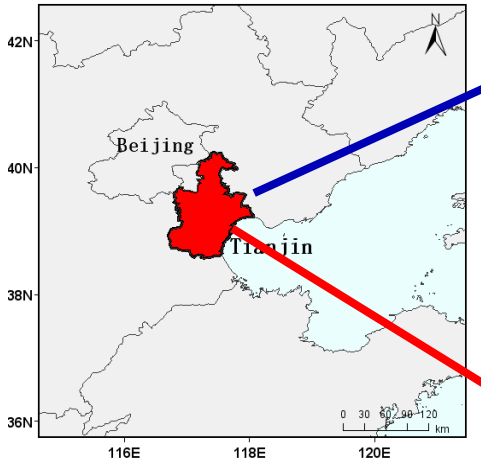
1. Dynamic variations in concentrations of atmospheric INPs in Tianjin & Beijing during summer
2. The contribution of different types of INPs in Tianjin & Beijing during summer
3. The impacts of meteorological factors on INPs

Sampling Information & INP Measurements

	Tianjin	Beijing
Sample site	Tianjin University	Peking University
Sample date	2019.07.01 – 07.08	2019.08.11 – 08.18
Sample time	Morning: 09:00 – 12:30 Afternoon: 17:00 – 19:30	
Sampler	SKC BioSampler (12.5 L/min)	



Liquid impinger bio-sampler

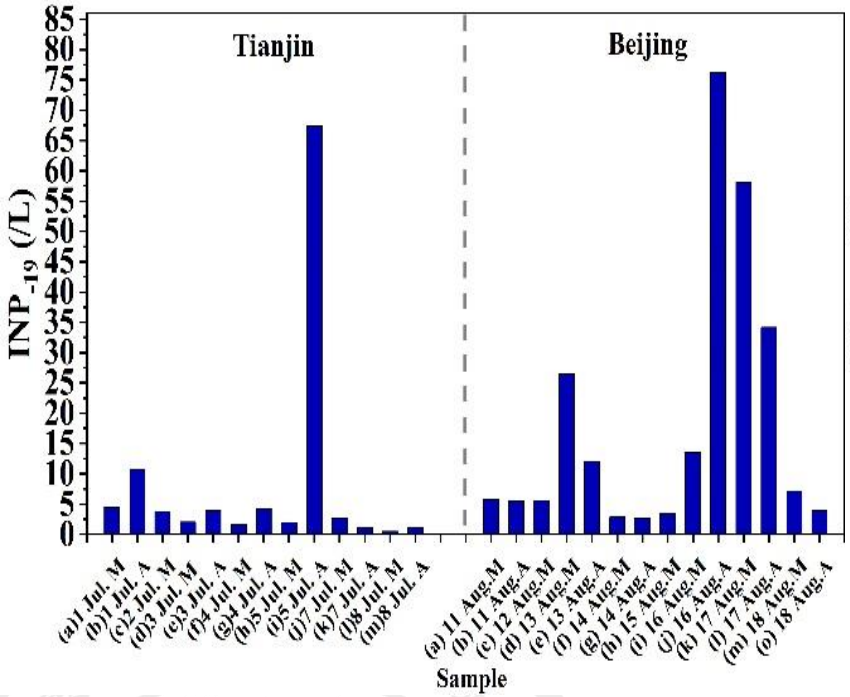


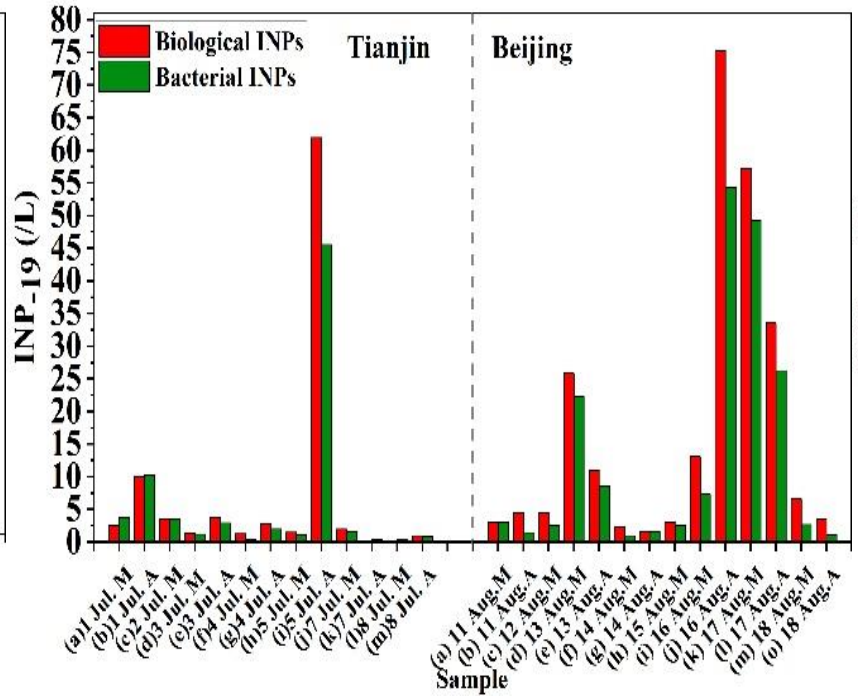
PKU-INA
(Chen et al, *Atmosphere*, 2018)

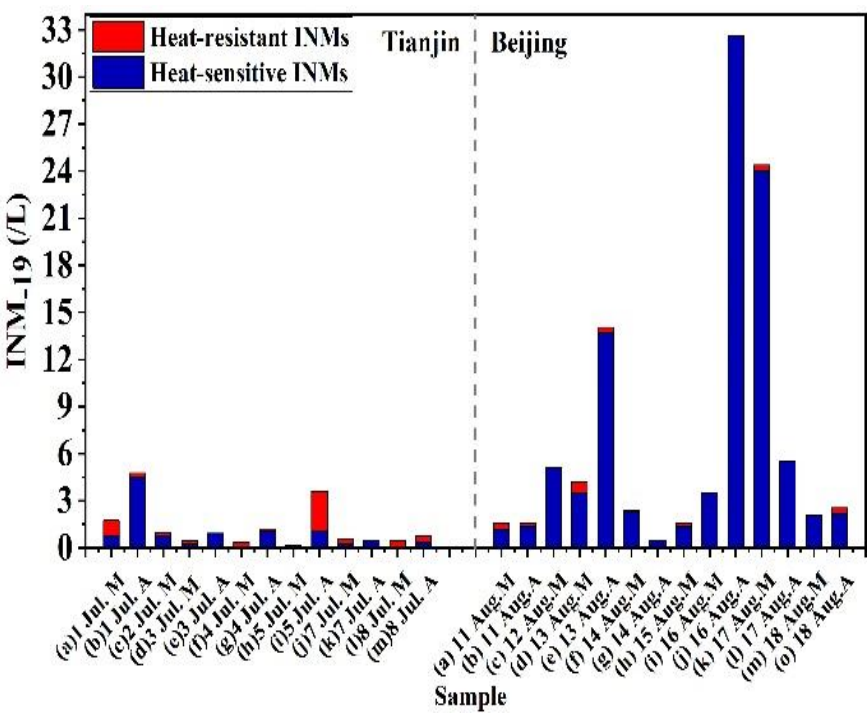
Bacteria counting

Methods	Mechanism	Type
Heat treatment 95 °C, 15 min	Protein heat-sensitivity	Most **biological INPs**
Lysozyme 72 h, 4 °C	The hydrolysis of peptidoglycan molecules in bacterial cell walls	Lysozyme-sensitive **Ice Nucleating Bacteria**
Filtration (0.22 μm)	Size difference	**Ice Nucleating Macromolecules (INMs)**

INP Concentration in Urban Area of Tianjin & Beijing







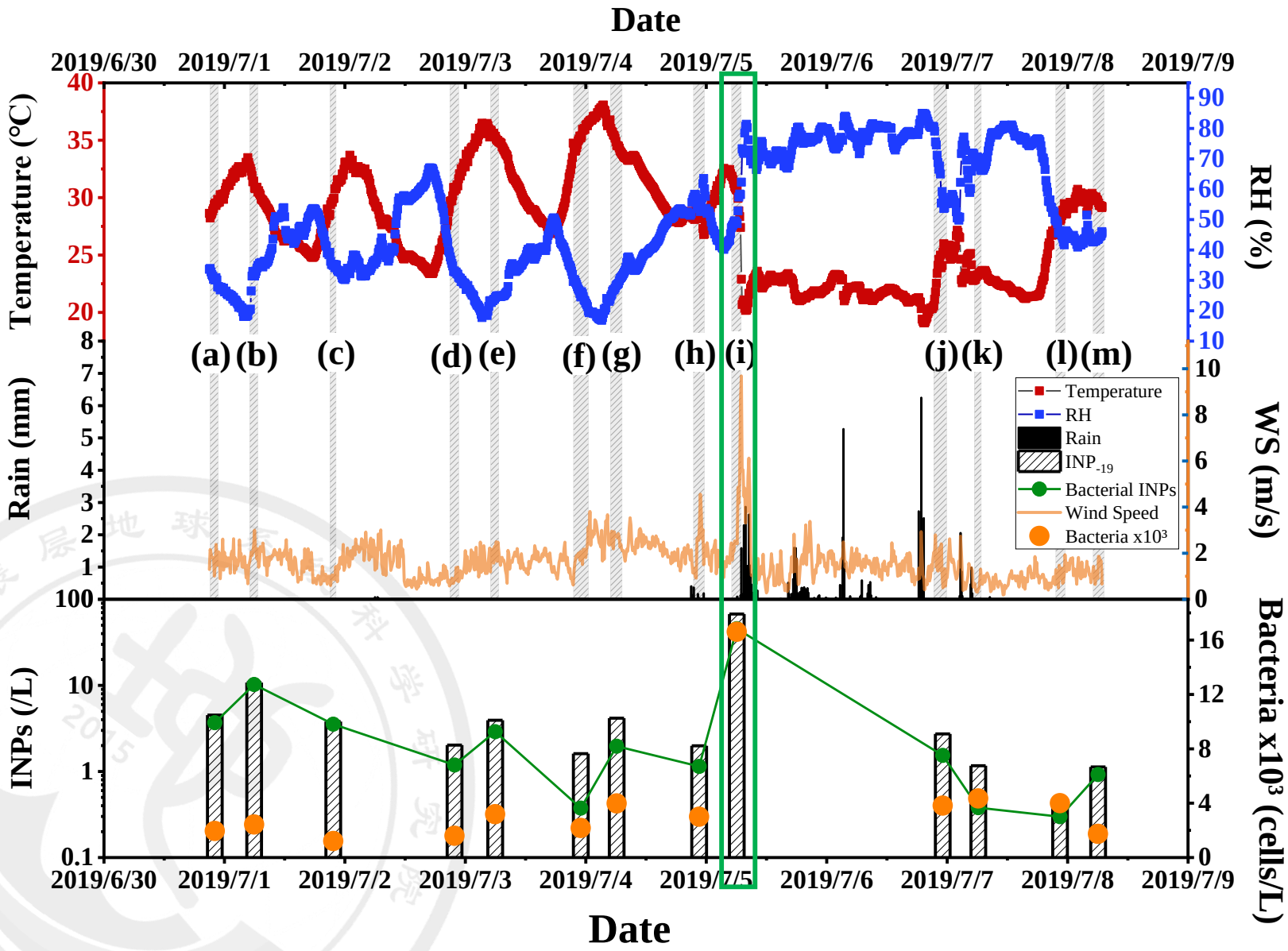
- ✓ N_{INP} (−19 °C): Beijing (18, 3–76 /L) > Tianjin (8, 0.5–68 /L)
- ✓ Fraction of biological N_{INP}: Beijing (86%, 52–99%) > Tianjin (65%, 0–94%)
- ✓ Fraction of bacterial N_{INP} : Beijing (57%, 27–85%) < Tianjin (64%, 23–95%)
- ✓ The abundance of heat-sensitive ice nucleating macromolecules (INMs) (7, 0.5–33 /L) in Beijing is higher than that in Tianjin(1, 0.4–5 /L), likely proteinaceous materials.

Comparison with Other Studies

ISESS

Sampling site	Date	Instruments	Temperature(°C)	Concentration (L^{-1})	Mode	Reference
Tai′an (urban)	Jun. 2018	Static vacuum vapor diffusion chamber	–20	1.57 (RH=95%) 4.82 (RH=101%)	All modes	(Jiang et al., 2019)
Beijing (urban)	27 Nov. – 22 Dec. 2016	INDA&LINA	–10 – –28	0.001–10	Immersion	(Chen et al., 2018)
Beijing (urban)	20 Mar. – 19 Apr. 2017	The Bigg's mixing cloud chamber	–10, –15, –20, –25, –30	0.18, 1.76, **26.89**, 203.31, 496.7	All modes	(Che et al., 2019)
Beijing (urban)	4 May. – 4 Jun. 2018	CFDC	–20, –25, –30	70, 230, 430	All modes	(Bi et al., 2019)
Leeds Farm, UK (rural)	19 Sep. – 2 Nov. 2019	μL-NIPI	–18 –20	0.1–10 0.2–22	Immersion	(O'Sullivan et al., 2018)
Tianjin (urban)	**1–8 Jul. 2019**	**PKU-INA**	**–19**	**8 (0.5–68)**	**Immersion**	**This work**
Beijing (urban)	**11–18 Aug. 2019**	**PKU-INA**	**–19**	**18 (3–76)**	**Immersion**	**This work**

Meteorological influence on Ice Nucleating Bacteria in Tianjin



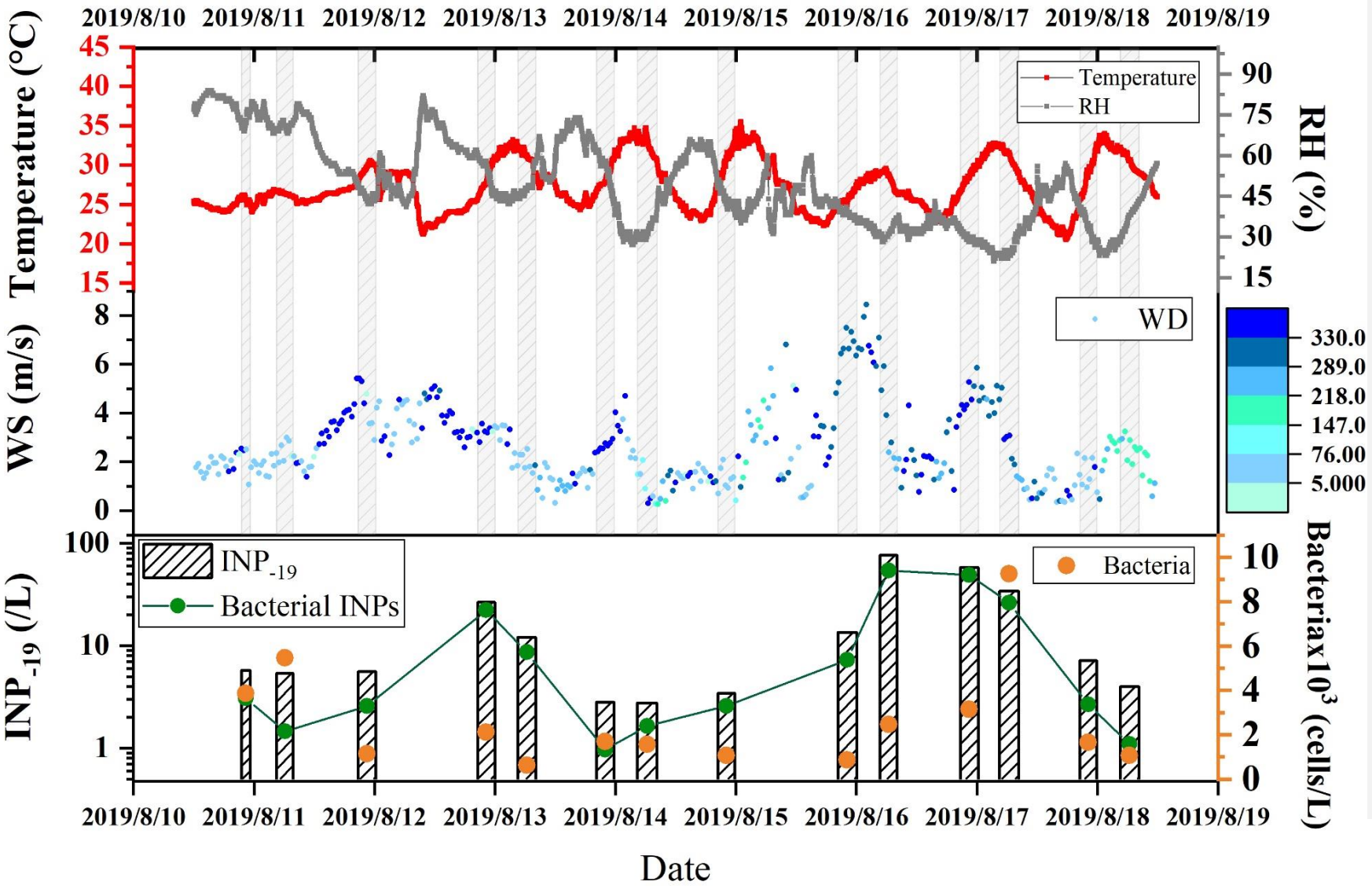
- Bacterial N_{INP}:

(1) Afternoon > Morning

(2) No correlation with T and RH

(3) Increased during rain with strong wind

Meteorological Influence on Ice Nucleating Bacteria in Beijing



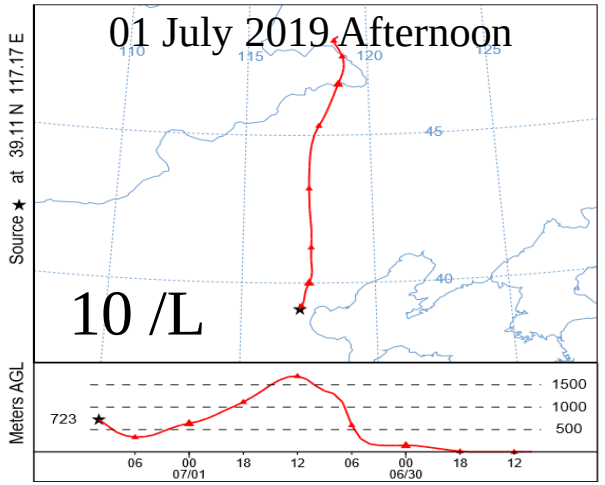
- No trend : Afternoon > Morning
- The effect of wind speed on INPs & bacteria was not significant in Beijing

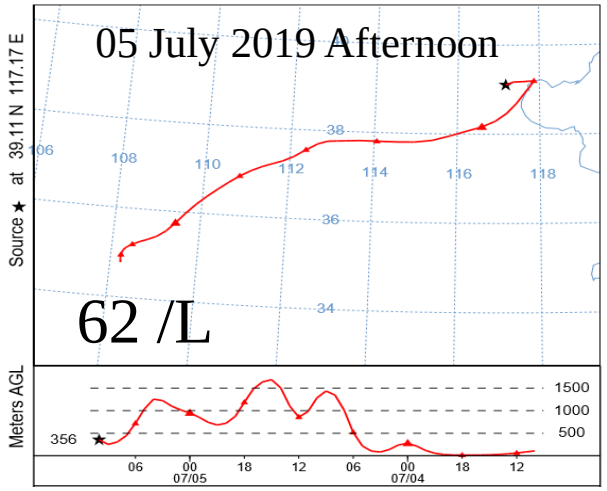
Continental air masses brought more biological INPs in Tianjin

ISESS

High INP concentration

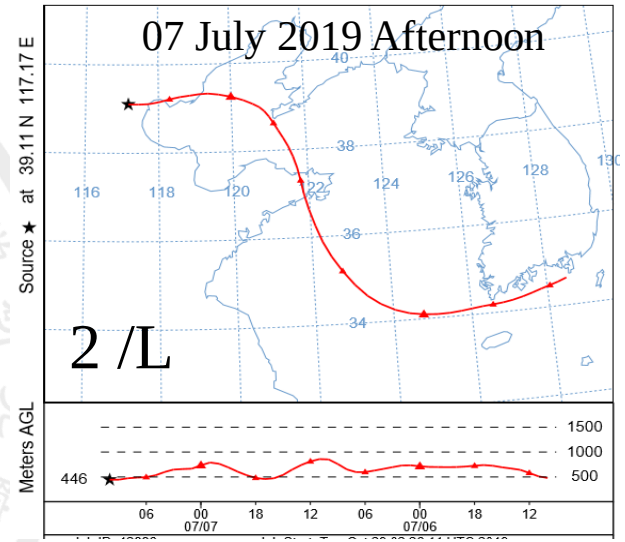
Continental air masses

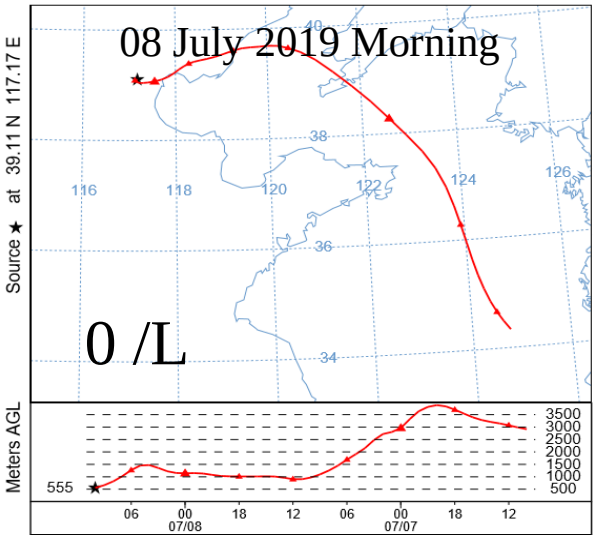


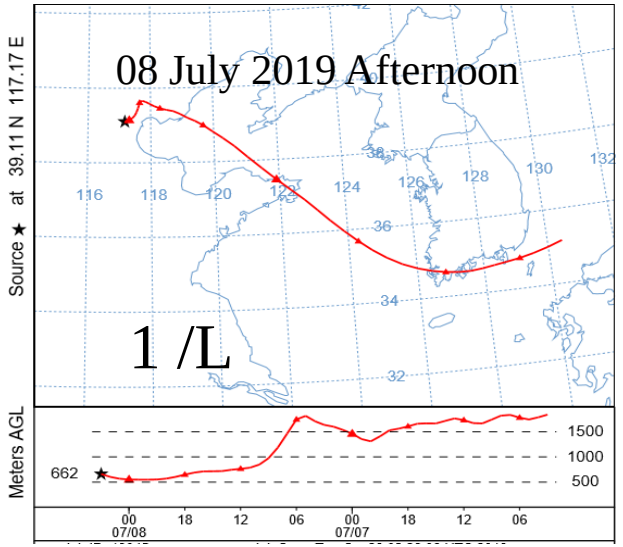


Low INP concentration

Marine air masses







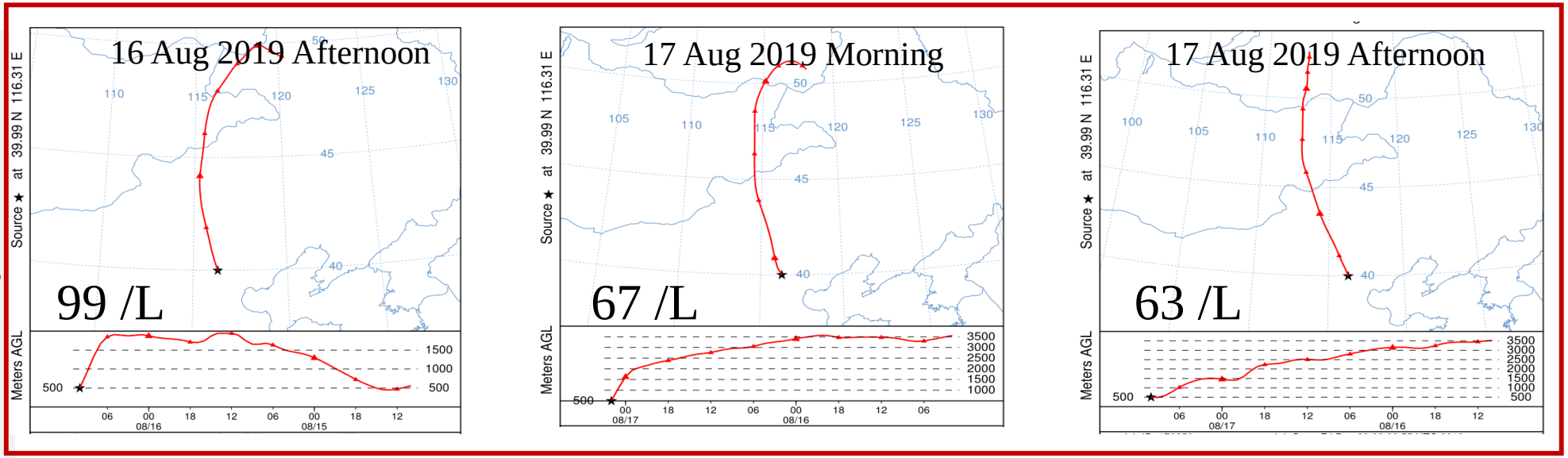
HYSPLIT Model

Continental air masses brought more biological INPs in Beijing

ISESS

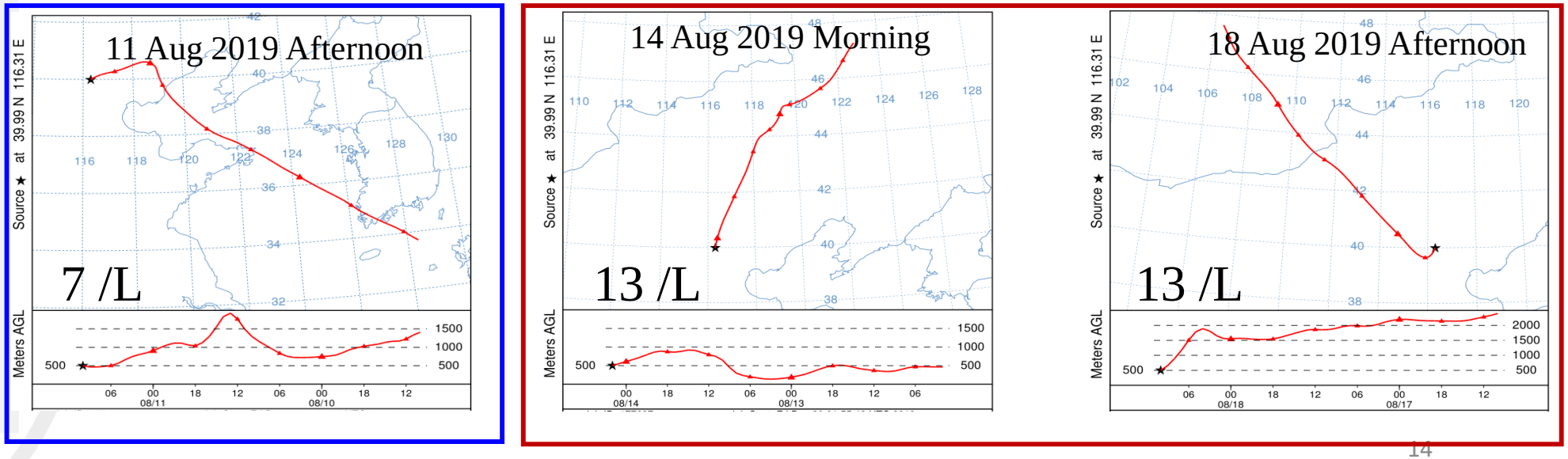
High INP concentration

Continental air masses



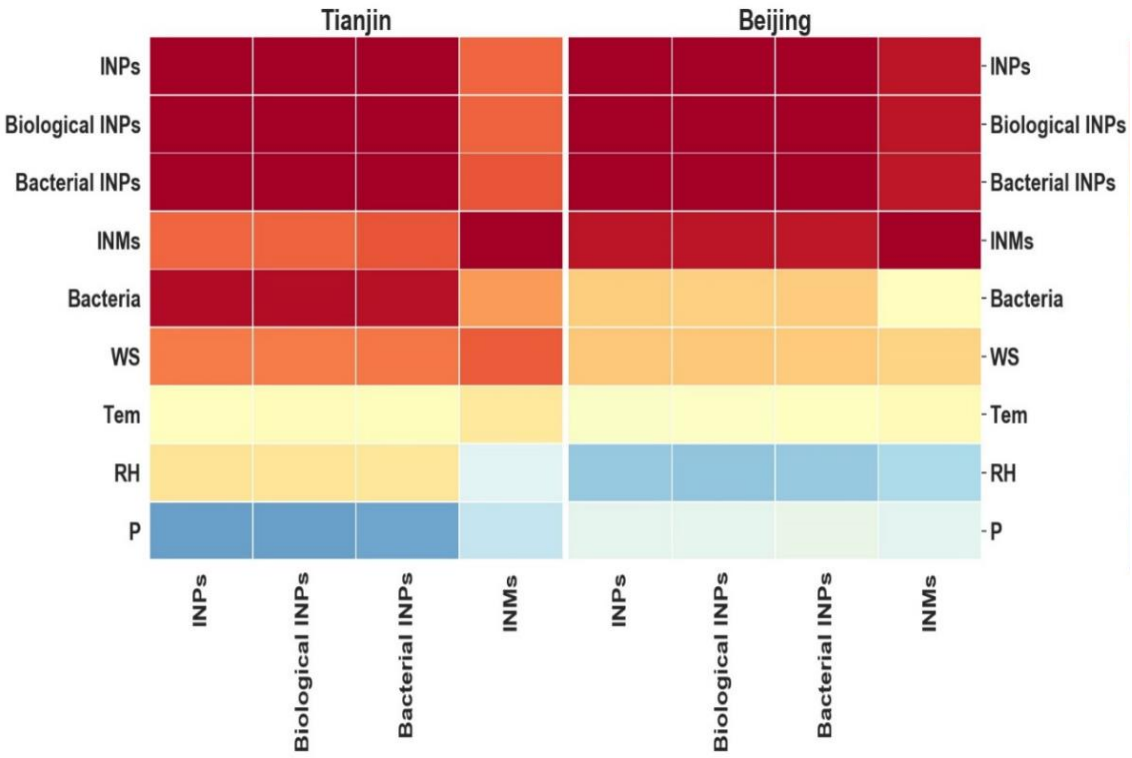
Low INP concentration

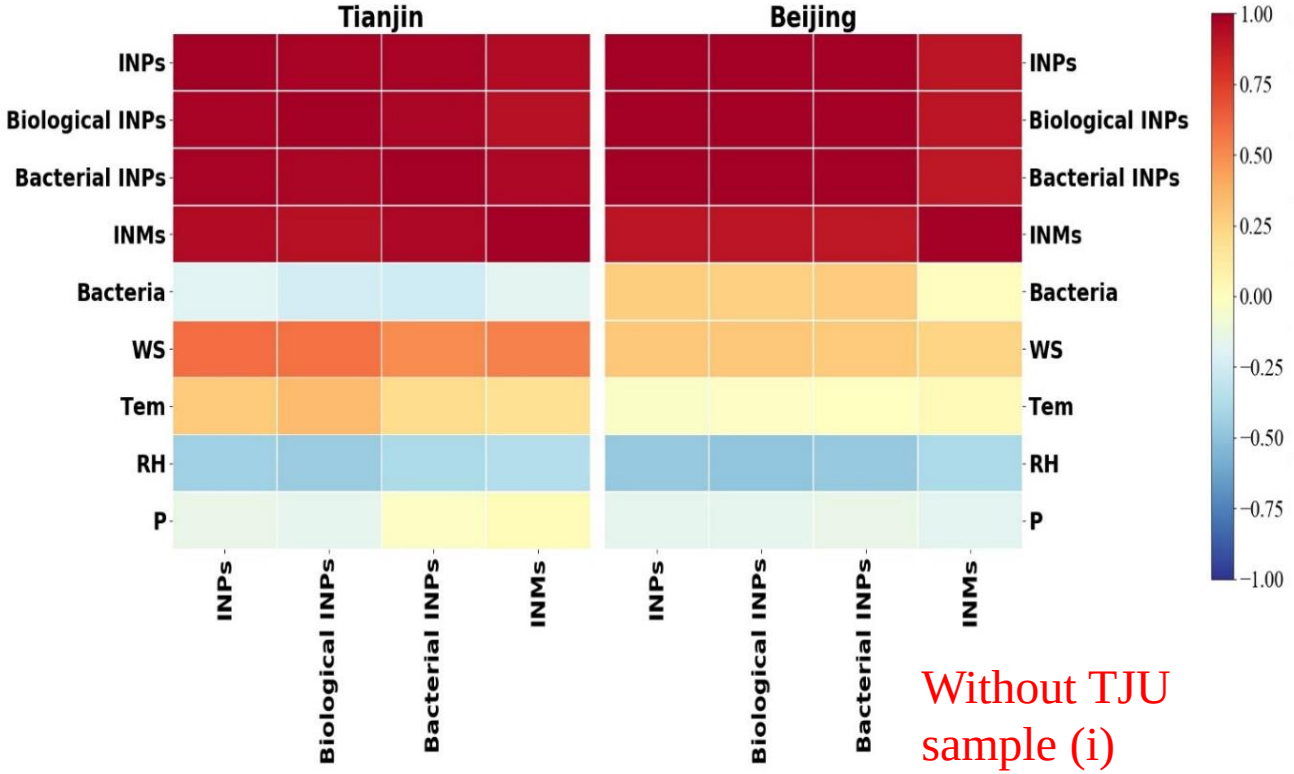
Marine air masses



HYSPLIT Model

Positive Correlation Between INPs and Wind Speed

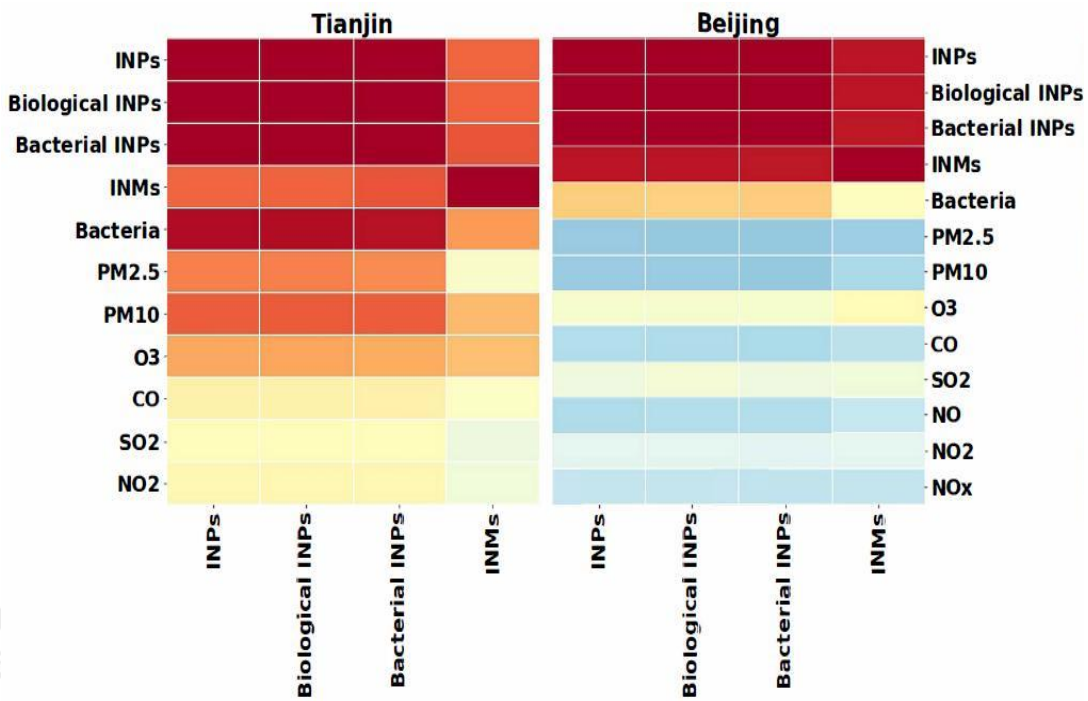


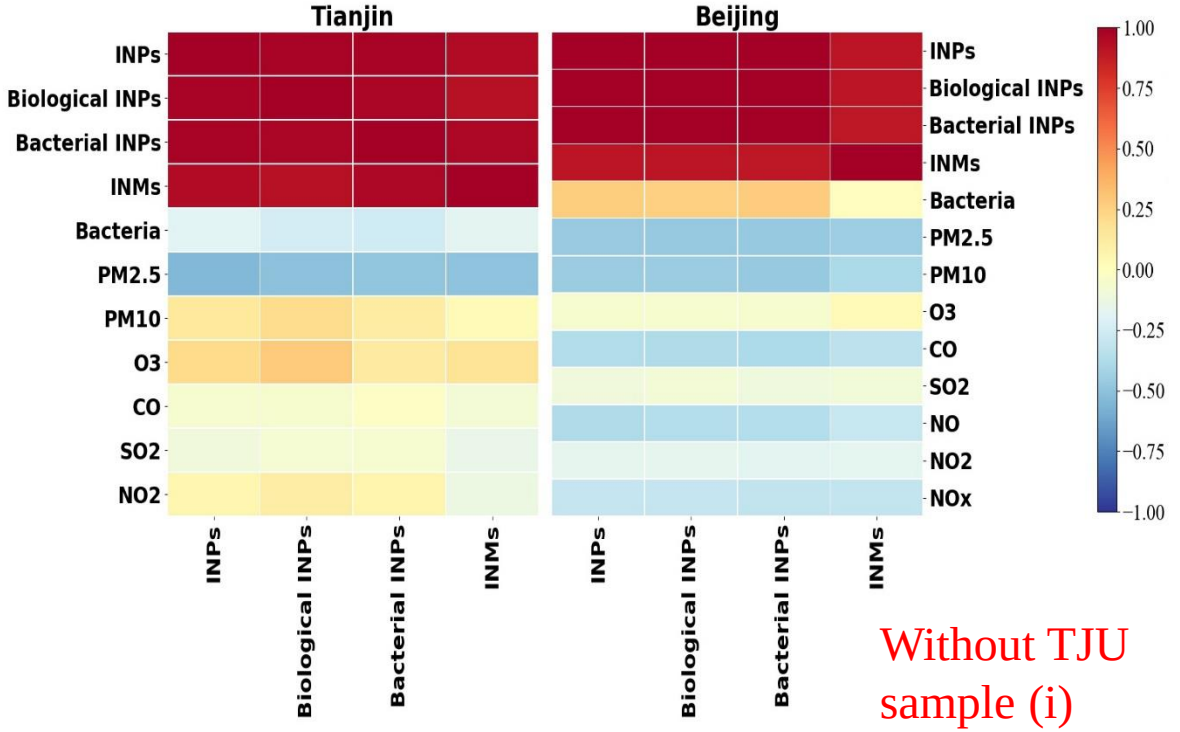


Without TJU sample (i)

- Positive correlation between INPs and wind speed
- No significant correlation between bacterial INPs and total bacteria
- Strong wind can probably lift INMs into the atmosphere

Biological INPs contributed more to total INPs than nonbiological INPs





Without TJU sample (i)

- INP_{-19}, biological INPs, bacterial INPs showed strong correlation
- Biological INPs contributed more to total INPs than non-biological INPs in both Tianjin & Beijing, especially bacterial INPs
- INMs in Beijing & Tianjin have strong correlation with biological & bacterial INPs, and INMs probably are related to ice nucleating protein
- Negative correlation between INPs and $PM_{2.5}$ & PM_{10} in Beijing

Conclusions

- **Biological sources may contribute more to atmospheric INPs than non-biological particles (≥ –19°C) in urban areas Tianjin & Beijing: Tianjin < Beijing.**
- **Heat-sensitive INMs can not be ignored in urban areas, and some of them may be related to biological origin.**
- **Wind speed and rainfall may influence the abundance of bacterial INP concentration in Tianjin. Continental air masses can bring more biological / bacterial INPs in Tianjin & Beijing**

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