

Supplement of

Ice nucleators have shorter persistence in the atmosphere than other airborne bacteria

Emiliano Stopelli¹, Franz Conen¹, Caroline Guilbaud², Jakob Zopfi³, Christine Alewell¹, Cindy E. Morris²

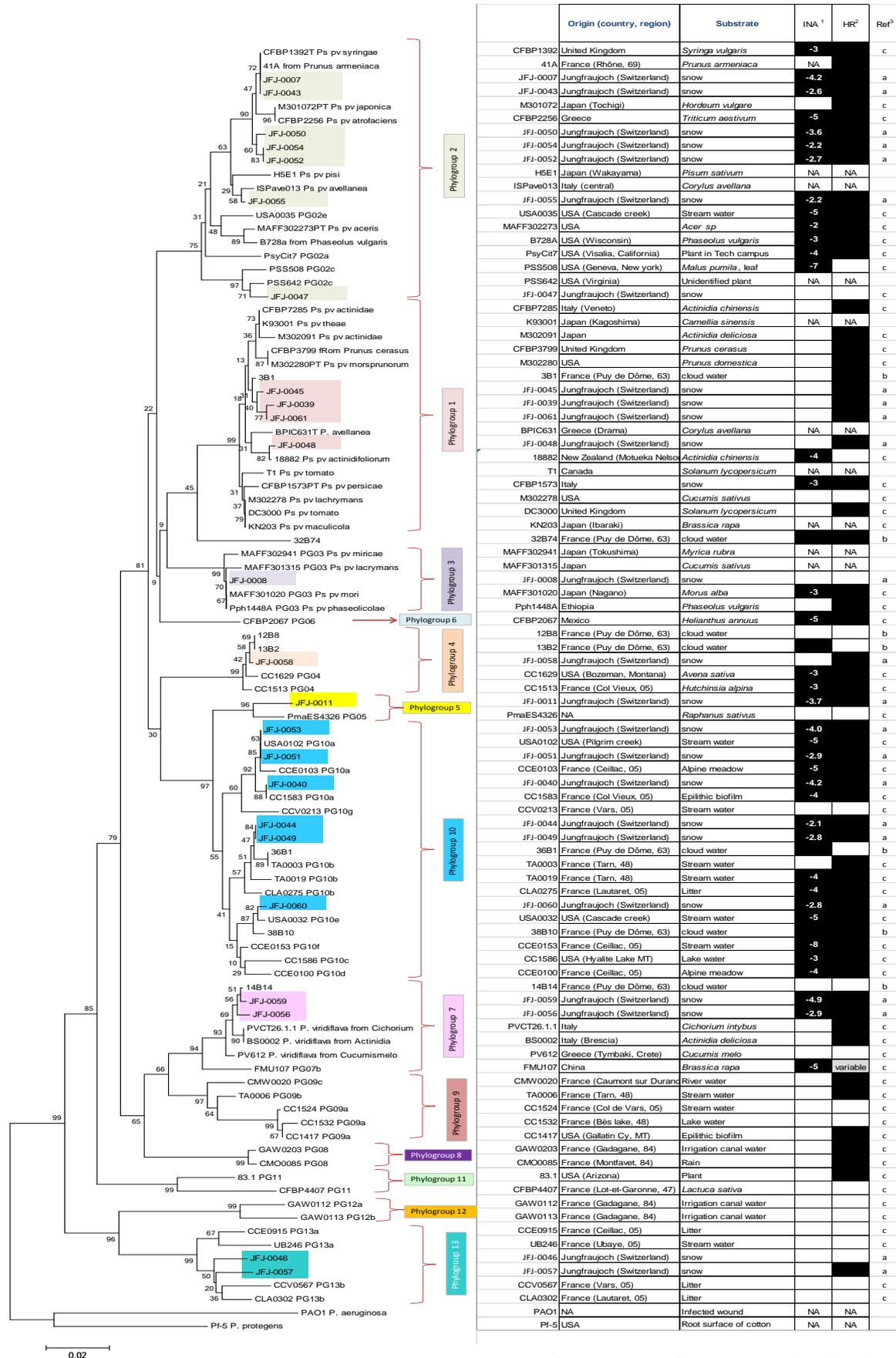
¹Environmental Geosciences, University of Basel, 4056 Basel, Switzerland

²INRA PACA, UR 0407 Plant Pathology Research Unit, 84143 Montfavet, France

³Acquatic and Stable Isotope Biogeochemistry, University of Basel, 4056 Basel, Switzerland

Correspondence to: Emiliano Stopelli (emiliano.stopelli@unibas.ch) and Franz Conen (franz.conen@unibas.ch)

Supplemental Figure 1. Neighbour joining phylogenetic tree of the strains of *P. syringae* isolated from Jungfrauoch, constructed on the basis of partial sequences of the citrate synthase housekeeping gene (*cts*) and comparison with *P. syringae* reference strains. More information is provided in section 2.2 of the article.



	Origin (country, region)	Substrate	INA ¹	HR ²	Ref ³
CFBP1392	United Kingdom	<i>Syringa vulgaris</i>	-3		c
41A	France (Rhône, 69)	<i>Prunus armeniaca</i>	NA		
JFJ-0007	Jungfrauoch (Switzerland)	snow	-4.2		a
JFJ-0043	Jungfrauoch (Switzerland)	snow	-2.6		a
M301072	Japan (Tochigi)	<i>Hordeum vulgare</i>			c
CFBP2256	Greece	<i>Triticum aestivum</i>	-5		c
JFJ-0050	Jungfrauoch (Switzerland)	snow	-3.6		a
JFJ-0054	Jungfrauoch (Switzerland)	snow	-2.2		a
JFJ-0052	Jungfrauoch (Switzerland)	snow	-2.7		a
H5E1	Japan (Wakayama)	<i>Pisum sativum</i>	NA	NA	
ISPave013	Italy (central)	<i>Corylus avellana</i>	NA	NA	
JFJ-0055	Jungfrauoch (Switzerland)	snow	-2.2		a
USA0035	USA (Cascade creek)	Stream water	-5		c
MAFF302273	USA	<i>Acer sp</i>	-2		c
B728A	USA (Wisconsin)	<i>Phaseolus vulgaris</i>	-3		c
PsyCit7	USA (Visalia, California)	Plant in Tech campus	-4		c
PSS508	USA (Geneva, New York)	<i>Malus pumila</i> , leaf	-7		c
PSS642	USA (Virginia)	Unidentified plant	NA	NA	
JFJ-0047	Jungfrauoch (Switzerland)	snow			c
CFBP7285	Italy (Veneto)	<i>Actinidia chinensis</i>			c
K93001	Japan (Kagoshima)	<i>Camellia sinensis</i>	NA	NA	
M302091	Japan	<i>Actinidia deliciosa</i>			c
CFBP3799	United Kingdom	<i>Prunus cerasus</i>			c
M302280	USA	<i>Prunus domestica</i>			c
381	France (Puy de Dôme, 63)	cloud water			b
JFJ-0045	Jungfrauoch (Switzerland)	snow			a
JFJ-0039	Jungfrauoch (Switzerland)	snow			a
JFJ-0061	Jungfrauoch (Switzerland)	snow			a
BPIC631	Greece (Drama)	<i>Corylus avellana</i>	NA	NA	
JFJ-0048	Jungfrauoch (Switzerland)	snow			a
18882	New Zealand (Motueka Nelson)	<i>Actinidia chinensis</i>	-4		c
T1	Canada	<i>Solanum lycopersicum</i>	NA	NA	
CFBP1573	Italy	snow	-3		c
M302278	USA	<i>Cucumis sativus</i>			c
DC3000	United Kingdom	<i>Solanum lycopersicum</i>			c
KN203	Japan (Ibaraki)	<i>Brassica rapa</i>	NA	NA	
32B74	France (Puy de Dôme, 63)	cloud water			b
MAFF302941	Japan (Tokushima)	<i>Myrica rubra</i>	NA	NA	
MAFF301315	Japan	<i>Cucumis sativus</i>	NA	NA	
JFJ-0008	Jungfrauoch (Switzerland)	snow			a
MAFF301020	Japan (Nagano)	<i>Morus alba</i>	-3		c
Pph1448A	Ethiopia	<i>Phaseolus vulgaris</i>			c
CFBP2067	Mexico	<i>Helianthus annuus</i>	-5		c
12B8	France (Puy de Dôme, 63)	cloud water			b
13B2	France (Puy de Dôme, 63)	cloud water			b
JFJ-0058	Jungfrauoch (Switzerland)	snow			a
CC1629	USA (Bozeman, Montana)	<i>Avena sativa</i>	-3		c
CC1513	France (Col Vieux, 05)	<i>Hutchinsia alpina</i>	-3		c
JFJ-0011	Jungfrauoch (Switzerland)	snow	-3.7		a
PmaES4326	NA	<i>Raphanus sativus</i>			c
JFJ-0053	Jungfrauoch (Switzerland)	snow	-4.0		a
USA0102	USA (Pilgrim creek)	Stream water	-5		c
JFJ-0051	Jungfrauoch (Switzerland)	snow	-2.9		a
CCE0103	France (Ceillac, 05)	Alpine meadow	-5		c
JFJ-0040	Jungfrauoch (Switzerland)	snow	-4.2		a
CC1583	France (Col Vieux, 05)	Epilithic biofilm	-4		c
CCV0213	France (Vars, 05)	Stream water			c
JFJ-0044	Jungfrauoch (Switzerland)	snow	-2.1		a
JFJ-0049	Jungfrauoch (Switzerland)	snow	-2.8		a
36B1	France (Puy de Dôme, 63)	cloud water			b
TA0003	France (Tarn, 48)	Stream water			c
TA0019	France (Tarn, 48)	Stream water	-4		c
CLA0275	France (Lautaret, 05)	Litter	-4		c
JFJ-0060	Jungfrauoch (Switzerland)	snow	-2.8		a
USA0032	USA (Cascade creek)	Stream water	-5		c
38B10	France (Puy de Dôme, 63)	cloud water			b
CCE0153	France (Ceillac, 05)	Stream water	-8		c
CC1586	USA (Hyalite Lake MT)	Lake water	-3		c
CCE0100	France (Ceillac, 05)	Alpine meadow	-4		c
14B14	France (Puy de Dôme, 63)	cloud water			b
JFJ-0059	Jungfrauoch (Switzerland)	snow	-4.9		a
JFJ-0056	Jungfrauoch (Switzerland)	snow	-2.9		a
PVCT26.1.1	Italy	<i>Cichorium intybus</i>			c
BS0002	Italy (Brescia)	<i>Actinidia deliciosa</i>			c
PV612	Greece (Tymbaki, Crete)	<i>Cucumis melo</i>			c
FMU107	China	<i>Brassica rapa</i>	-5	variable	c
CMW0020	France (Caumont sur Duranc)	River water			c
TA0006	France (Tarn, 48)	Stream water			c
CC1524	France (Col de Vars, 05)	Stream water			c
CC1532	France (Bés lake, 48)	Lake water			c
CC1417	USA (Gallatin Cy., MT)	Epilithic biofilm			c
GAW0203	France (Gadagane, 84)	Irrigation canal water			c
CMO0085	France (Montfavet, 84)	Rain			c
83.1	USA (Arizona)	Plant			c
CFBP4407	France (Lot-et-Garonne, 47)	<i>Lactuca sativa</i>			c
GAW0112	France (Gadagane, 84)	Irrigation canal water			c
GAW0113	France (Gadagane, 84)	Irrigation canal water			c
CCE0915	France (Ceillac, 05)	Litter			c
UB246	France (Libaye, 05)	Stream water			c
JFJ-0046	Jungfrauoch (Switzerland)	snow			a
JFJ-0057	Jungfrauoch (Switzerland)	snow			a
CCV0567	France (Vars, 05)	Litter			c
CLA0302	France (Lautaret, 05)	Litter			c
PA01	NA	Infected wound	NA	NA	
PF-5	USA	Root surface of cotton	NA	NA	

positive reaction	
negative reaction	
No data	NA
variable	variable

¹⁻³INA refers to ice nucleation activity of suspensions of cells via immersion freezing. The reported values are the freezing onset temperature. INA is considered positive when the onset of freezing occurred at temperatures $\geq -8^{\circ}\text{C}$. According to the reference:

- a- This study, 10^8 cells per mL in 0,9 % NaCl, 200 μL per unit analysed, corresponding to $\sim 2 \cdot 10^7$ cells.
- b- 10^7 cells per reaction in water, References:
 - Amato, P., Parazols, M., Sancelme, M., Laj, P., Mailhot, G., and Delort, A. M.: Microorganisms isolated from the water phase of tropospheric clouds at the Puy de Dôme: major groups and growth abilities at low temperatures, *FEMS Microbiol. Ecol.*, 59, 242-254, doi:10.1111/j.1574-6941.2006.00199.x, 2007;
 - Joly, M., Attard, E., Sancelme, M., Deguillaume, L., Guilbaud, C., Morris, C. E., Amato, P., and Delort, A. M.: Ice nucleation activity of bacteria isolated from cloud water, *Atmos. Environ.*, 70, 392-400, doi:10.1016/j.atmosenv.2013.01.027, 2013;
 - Vaïtilingom, M., Attard, E., Gaiani, N., Sancelme, M., Deguillaume, L., Flossmann, A. I., Amato, P., and Delort, A. M.: Long-term features of cloud microbiology at the Puy de Dôme (France), *Atmos. Environ.*, 58, 88-100, doi:10.1016/j.atmosenv.2012.03.072, 2012.
- c- 10^6 cells per reaction in water, Reference:
 - Berge, O., Monteil, C. L., Bartoli, C., Chandeysson, C., Guilbaud, C., Sands, D. C., and Morris, C. E.: A user's guide to a data base of the diversity of *Pseudomonas syringae* and its application to classifying strains in this phylogenetic complex, *PloS one*, 9, e105547, doi: 10.1371/journal.pone.0105547, 2014.

²Capacity to induce a hypersensitive reaction (HR) in tobacco indicative of the presence of a functional type III secretion system that is one of the fundamental traits usually required for pathogenicity of *P. syringae* to plants.

Supplemental Table 1. This table contains all most relevant field data collected at Jungfraujoch and reported in the paper. f_v represents the fraction of residual water vapour in a precipitating air mass. More details on the calculation of all these parameters are reported at the Methods section in the article.

Date of start sampling	Start sampling (UTC)	End sampling (UTC)	Total bacteria (cells mL ⁻¹)	fraction living	INPs ₈ mL ⁻¹	f_v	Wind speed (km h ⁻¹)	Temperature (°C)	<i>Pseudomonas syringae</i> (CFU L ⁻¹)
10.03.2013	23.00 h	06.00 h	5285		0.21	0.27	13.0	-13.6	
11.03.2013	07.00 h	11.00 h	7689	0.78	0.21	0.25	10.3	-12.7	
12.03.2013	06.00 h	09.30 h	22817		0.21	0.16	6.7	-13.1	
12.03.2013	16.00 h	18.00 h	10383	0.74	2.35	0.22	11.7	-14.1	
13.03.2103	21.00 h	05.00 h	9326	0.52	1.35	0.10	23.8	-22.4	
14.03.2013	05.00 h	08.00 h	7461	0.54	2.09	0.09	38.7	-24.3	
19.04.2013	11.40 h	13.40 h	8082	0.69	1.59	0.47	19.1	-6.2	
19.04.2013	13.40 h	15.30 h	7772	0.48	0.21	0.35	13.7	-7.1	
19.04.2013	15.30 h	18.00 h	4974	0.56	3.16	0.28	21.6	-10.9	
19.04.2013	21.30 h	04.00 h	9948	0.56	0.21	0.32	14.4	-11.6	
20.04.2013	04.30 h	10.30 h	10258	0.52	8.06	0.33	56.2	-10.0	
20.04.2013	10.30 h	14.30 h	9637	0.61	0.65	0.28	48.6	-8.5	
20.04.2013	14.30 h	17.30 h	10258	0.61	1.35	0.27	40.7	-8.1	
22.05.2013	13.45 h	15.30 h	7927	0.61	0.65	0.30	31.3	-9.3	
22.05.2013	15.30 h	17.15 h	4197	0.63	1.35	0.32	33.7	-9.9	
22.05.2013	21.00 h	01.00 h	4507	0.55	1.11	0.29	28.0	-11.3	
23.05.2013	12.30 h	15.15 h	12124		18.14	0.38	15.8	-11.1	
23.05.2013	16.15 h	17.45 h	5595	0.64	0.65	0.30	19.4	-11.5	
23.05.2013	20.45 h	04.00 h	4974	0.75	1.35	0.26	27.7	-16.3	
24.05.2013	04.00 h	06.00h	6528	0.64	0.88	0.21	29.5	-17.2	
20.06.2013	01.00 h	04.00 h	67301	0.66	113.92	0.67	66.3	0.3	
20.06.2103	04.00 h	08.00 h	66679	0.55	68.09	0.55	61.9	-0.1	
20.06.2013	11.00 h	13.30 h	34972	0.67	182.55	0.46	75.2	-0.8	
20.06.2013	15.30 h	17.30 h	23081	0.35	72.09	0.48	74.8	-1.5	
20.06.2013	19.30 h	02.00 h	22460	0.45	16.13	0.53	40.2	-1.0	
07.08.2013	12.00 h	14.00 h	53312	0.63	122.98	0.78	59.8	0.4	
07.08.2013	14.00 h	16.10 h	67612	0.59	68.09	0.63	65.7	0.1	
07.08.2013	16.10 h	19.20 h	43365	0.56	434.64	0.63	76.3	-0.2	
07.08.2013	20.30 h	04.00 h	32174	0.63	37.44	0.54	60.0	0.2	
08.08.2013	06.30 h	09.30 h	7772	0.40	7.21	0.47	30.3	0.4	
08.08.2013	11.00 h	15.00 h	13989	0.51	7.21	0.43	33.6	-0.4	
08.08.2013	15.00 h	17.00 h	5751	0.70	4.04	0.52	21.0	0.2	
08.09.2013	02.00h	05.00 h	3264	0.55	2.35	0.47	42.4	-0.8	
08.09.2013	12.00 h	14.00 h	3109	0.58	6.39	0.52	27.6	-0.1	
08.09.2013	14.00 h	15.15 h	3886	0.48	3.86	0.49	16.0	-0.4	

08.09.2013	15.15 h	16.45 h	4041	0.54	32.16	0.49	11.6	-0.5	
08.09.2013	18.30 h	04.00 h	2953	0.63	3.96	0.26	16.0	-3.2	
12.09.2013	10.50 h	13.50 h	3264	0.62	1.84	0.48	17.1	-7.7	
12.09.2013	13.50 h	15.40 h	2642	0.65	2.09	0.39	14.0	-7.5	
12.09.2013	15.40 h	17.00 h	2953	0.63	1.59	0.33	17.1	-7.6	
12.09.2013	19.30 h	01.00 h	2875	0.54	2.89	0.34	19.8	-9.2	
22.05.2014	4.00h	12.00h	52691	0.74	44.48	0.72	65.8	-3.2	under 2
22.05.2014	12.00 h	20.00 h	17874	0.69	12.01	0.49	55.3	-2.8	2
22.05.2014	20.00h	4.00h	15388	0.60	31.51	0.52	58.7	-5.1	4
28.06.2014	20.00h	4.00h	5285	0.53	5.00	0.47	26.2	-1.1	under 2
29.06.2014	4.00h	10.00h	3109	0.70	0.21	0.32	19.6	-1.8	under 2
29.06.2014	10.00h	16.00h	5595	0.56	6.29	0.36	14.6	-2.8	under 2
29.06.2014	18.00h	4.00h	2642	0.76	2.35	0.29	34.3	-7.4	under 2
29.07.2014	4.00h	10.00h	5751	0.70	0.43	0.23	26.2	-2.0	under 2
29.07.2014	11.00h	15.30h	4041	0.77	1.59	0.31	28.6	-1.6	under 2
30.07.2014	4.00h	12.00h	29998	0.55	0.88	0.34	33.0	-0.4	under 2
30.07.2014	17.00h	01.00h	7305	0.55	0.88	0.30	5.4	3.2	under 2
30.09.2014	13.00h	13.45h	3575		0.21	0.41	7.6	-1.2	
01.10.2014	5.00h	6.30h	2409	0.45	1.59	0.38	17.0	-2.5	
21.10.2014	20.00h	4.00h	9948	0.61	60.51	0.39	68.0	-12.8	45
22.10.2014	6.00h	13.00h	6839	0.48	29.02	0.29	60.4	-17.0	under 2