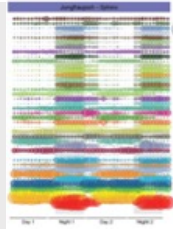


Impacts and implications of airborne microorganisms in a warming atmosphere

April 16th, 2024, EGU24, Vienna, Austria



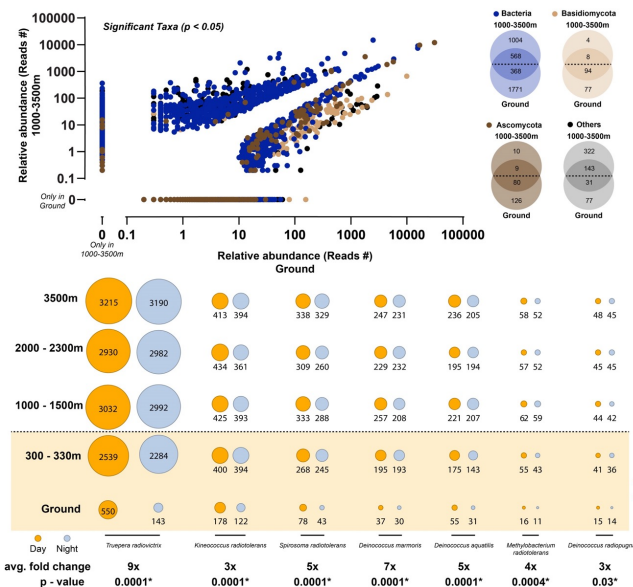
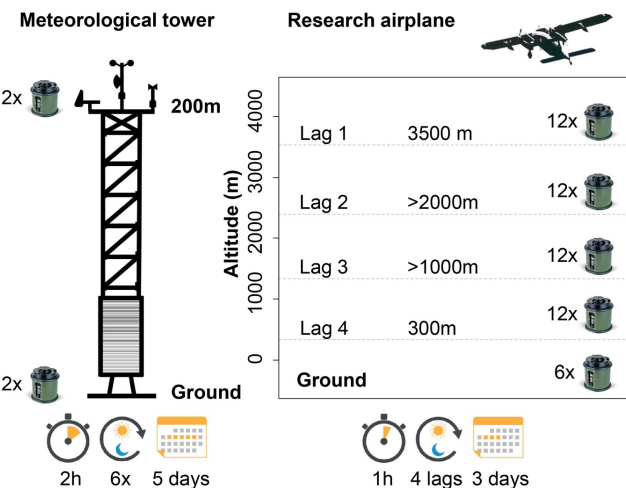
Stephan C. Schuster

Professor, Research Director, Nanyang Technological University

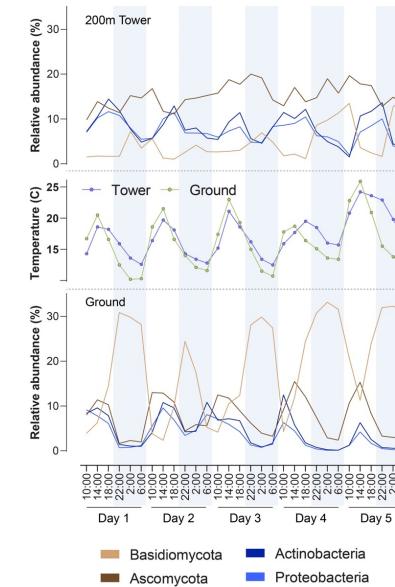
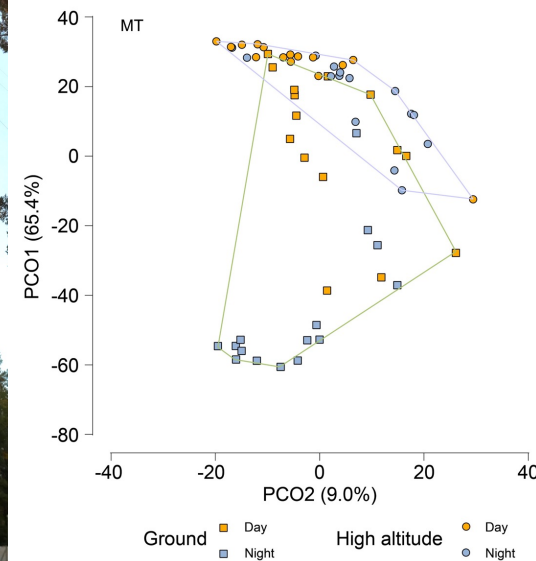
SCELSSE, Singapore Centre for Environmental Life Sciences Engineering, Singapore

Vertical Stratification of the Air Microbiome

Study Design



Meteorological Tower

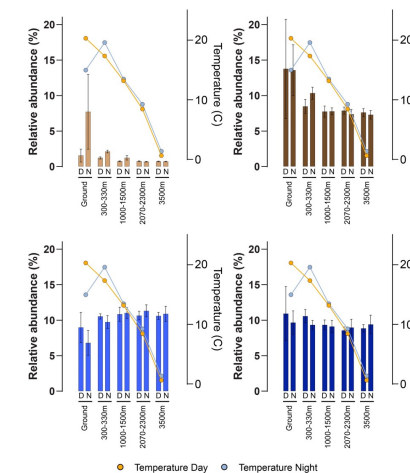
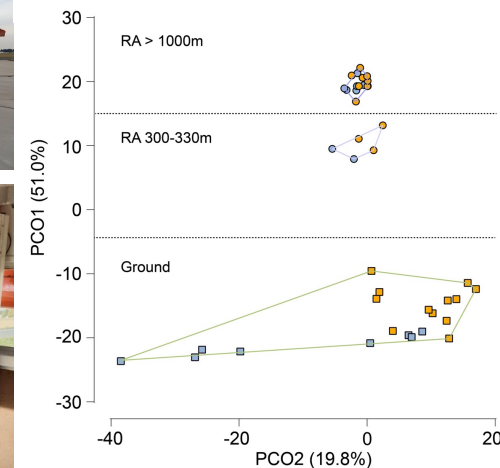


Major Outcomes

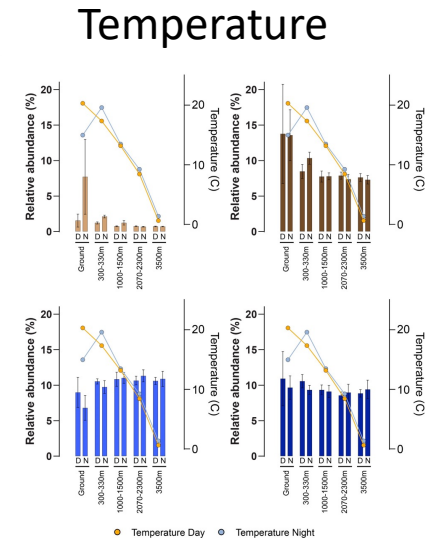
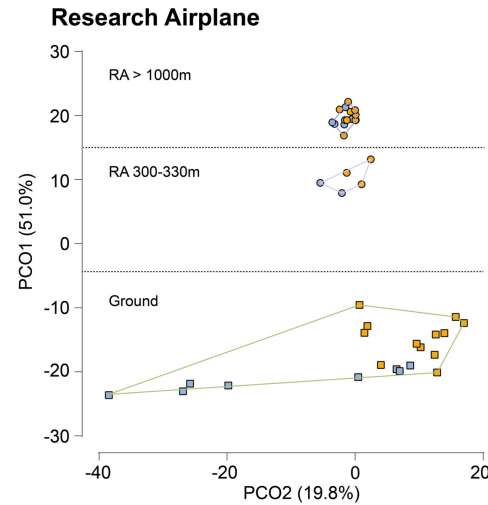
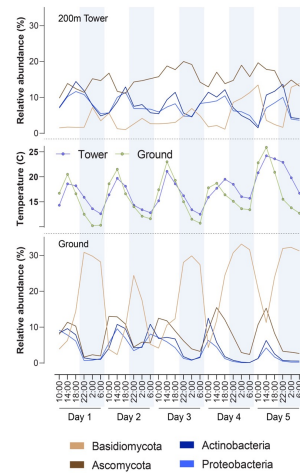
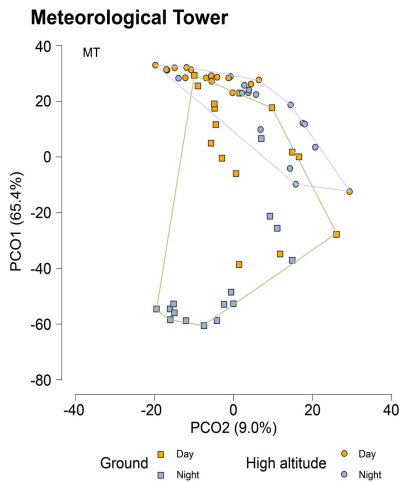
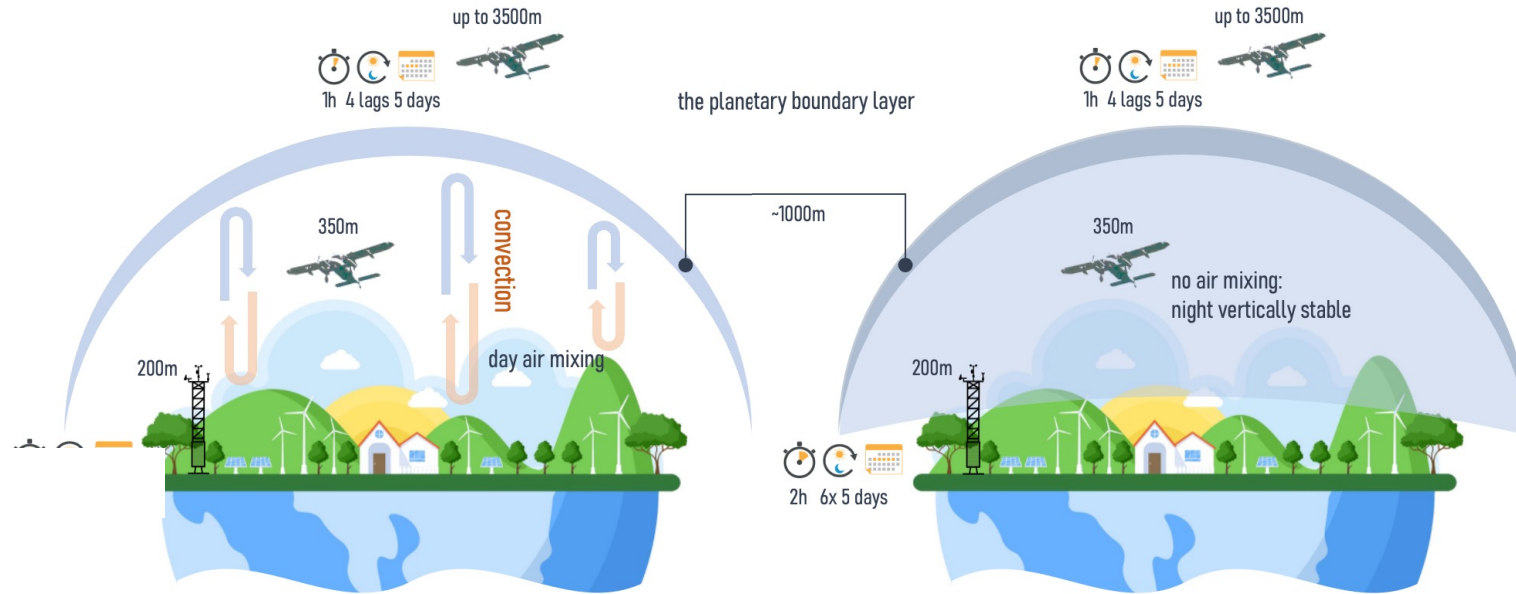
- ❖ **480** air samples collected across two locations and various heights of up to 3,500m with high temporal and large spatial resolution
- ❖ Synchronized measurements of meteorological parameters and airborne biomass in the vertical air column
- ❖ Stratification of the airborne biomass into ground- and height-associated taxonomic groups, mainly driven by atmospheric turbulence (e.g., temperature)
- ❖ The diel cycle of airborne microorganisms is a ground-based phenomenon and diminishes at heights >1,000m
- ❖ Unexpectedly large diversity of Ascomycota fungi and bacteria, including radiotolerant taxa at greater heights



Research Airplane



Dynamics of the air microbiome is driven by temperature !!!

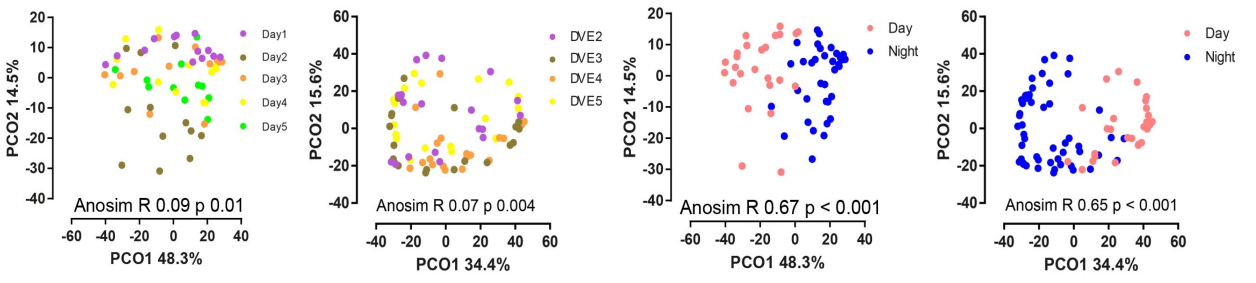
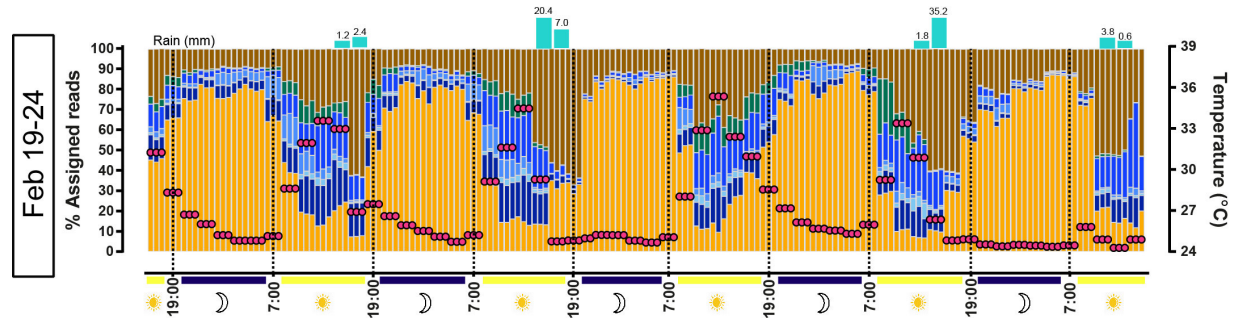
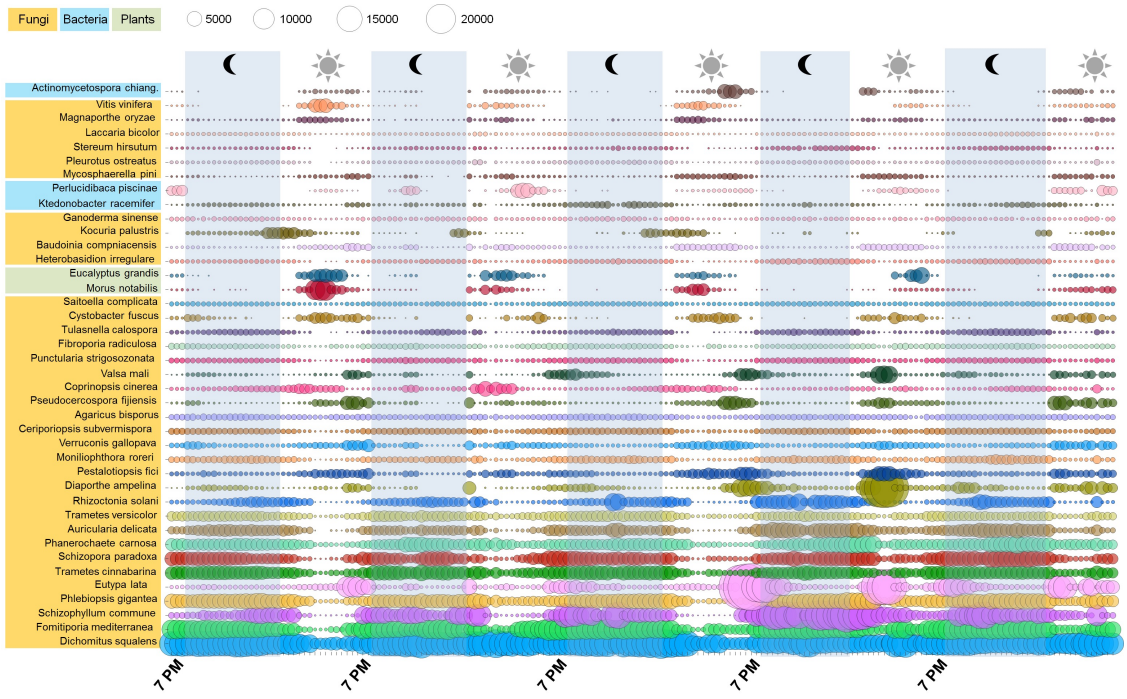


Microbial communities in the tropical air ecosystem follow a precise diel cycle

Elena S. Gusareva^{a,1}, Enzo Acerbi^{a,1}, Kenny J. X. Lau^a, Irvan Luhung^{a,1}, Balakrishnan N. V. Premkrishnan^a, Sandra Kolundžija^a, Rikky W. Purbojati^a, Anthony Wong^a, James N. I. Houghton^a, Dana Miller^a, Nicolas E. Gaultier^a, Cassie E. Heinle^a, Megan E. Clare^a, Vineeth Kodengil Vettath^a, Carmon Kee^a, Serene B. Y. Lim^a, Caroline Chénard^a, Wen Jia Phung^a, Kavita K. Kushwaha^a, Ang Poh Nee^a, Alexander Putra^a, Deepa Panicker^a, Koh Yangqing^a, Yap Zhei Hwee^a, Sachin R. Lohar^a, Mikinori Kuwata^b, Hie Lim Kim^{a,b}, Liang Yang^a, Akira Uchida^a, Daniela I. Drautz-Moses^a, Ana Carolina M. Junqueira^a, and Stephan C. Schuster^{a,2}

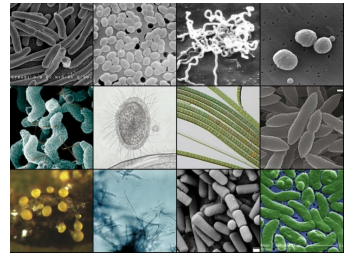
^aSingapore Centre for Environmental Life Sciences Engineering, Nanyang Technological University, 637551 Singapore; ¹Asian School of the Environment, Nanyang Technological University, 637459 Singapore; and ²Departamento de Genética, Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 21941-590 Brazil

Airborne microbial organisms follow a diel cycle

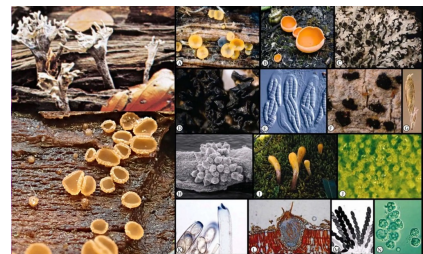


The outdoor air microbiome in Singapore

- 'The missing ecosystem'
- 5 consecutive days; 24 hours/day
- Deep sequencing (metagenomics)



Bacteria



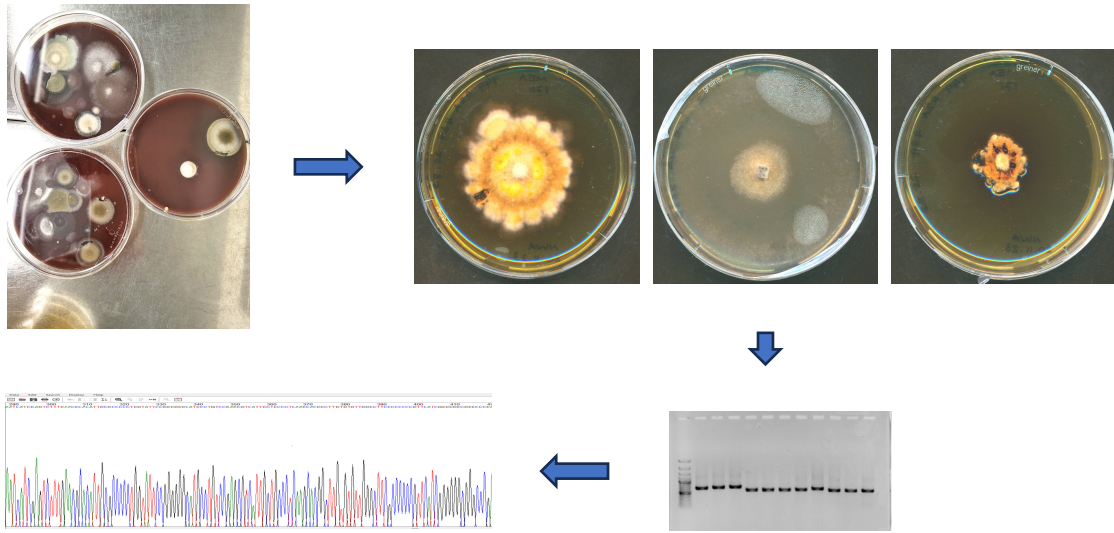
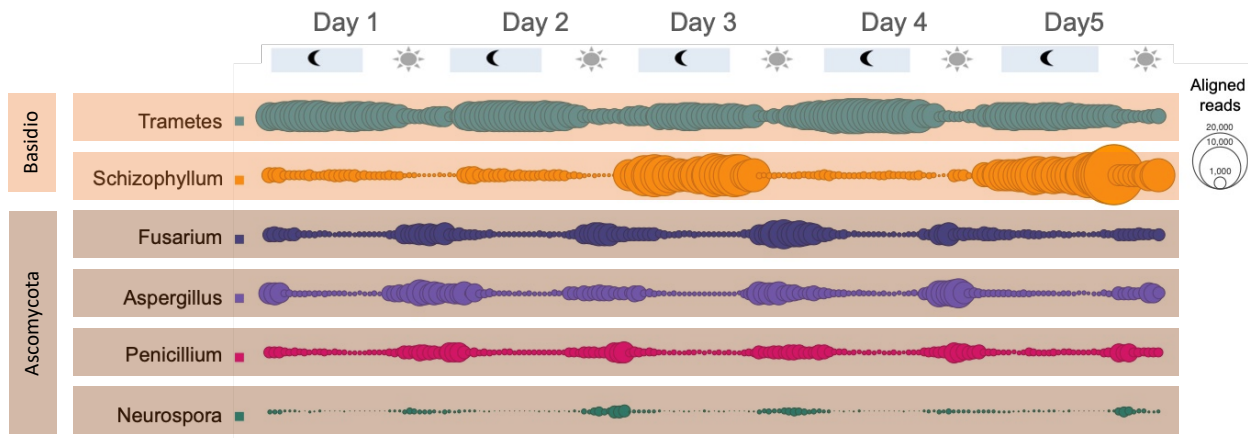
Ascomycota



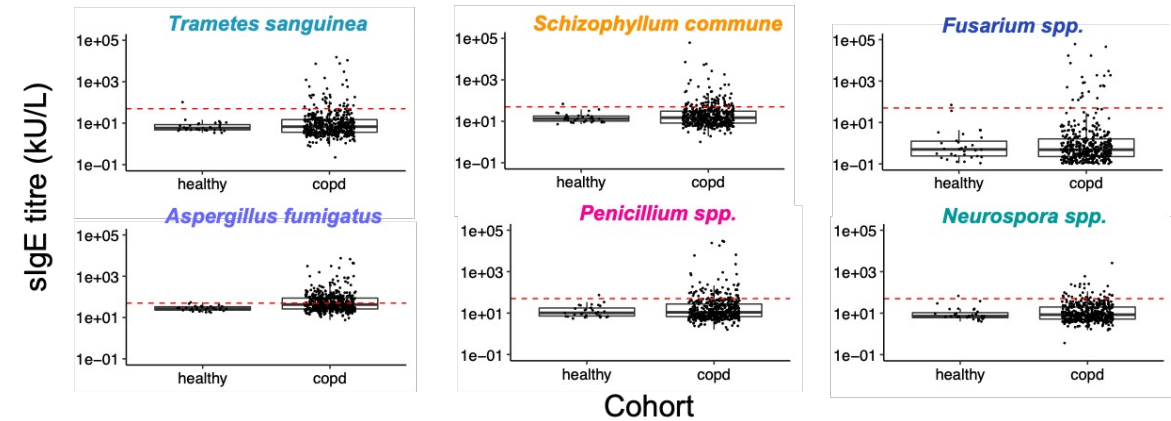
Basidiomycota

Temporal Variation of the Air Microbiome

Most abundant fungal taxa in Singapore outdoor air



Associations with clinical outcomes



Specific IgE antibody titers in healthy volunteers (N=31) and respiratory patients (N >400).
 (In collaboration with Sanjay Chotirmall & Chew Fook Tim)



Alpine



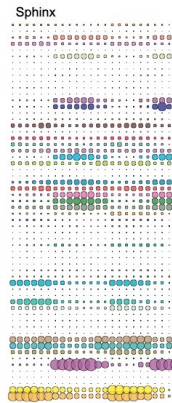
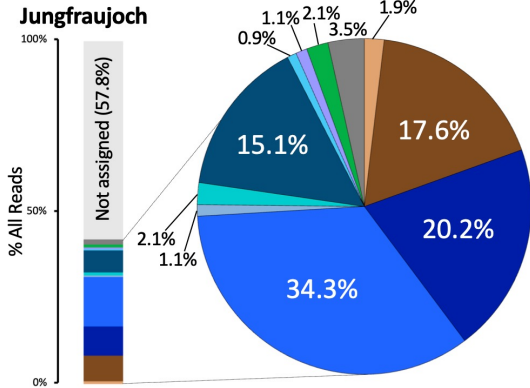
Metropolitan



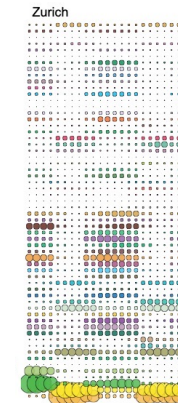
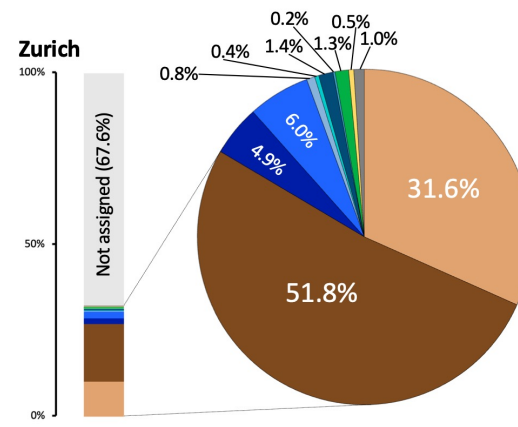
Metropolitan



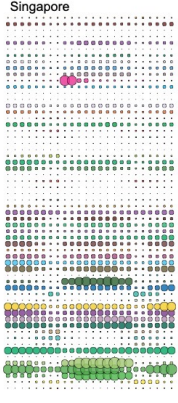
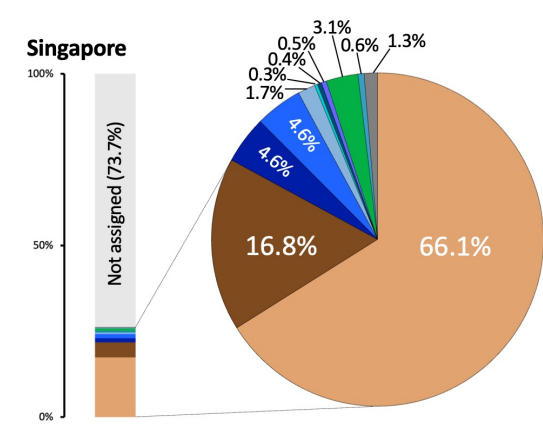
pristine



temperate



tropical



- Basidiomycota
- Ascomycota
- Proteobacteria
- Firmicutes
- Cyanobacteria
- Verrucomicrobi
- Streptophyta
- Others
- Oomycota
- Actinobacteria
- Acidobacteria
- Bacteroidetes
- Planctomycetes
- Chloroflexi

Physico-Chem

pm2.5: 4 $\mu\text{g}/\text{m}^3$
 pm10: 6 $\mu\text{g}/\text{m}^3$
 Omaot: 0.037 τ
 DNA: 0.25 ng/m^3

Physico-Chem

pm2.5: 8 $\mu\text{g}/\text{m}^3$
 pm10: 12 $\mu\text{g}/\text{m}^3$
 Omaot: 0.029 τ
 DNA: 1.3 ng/m^3

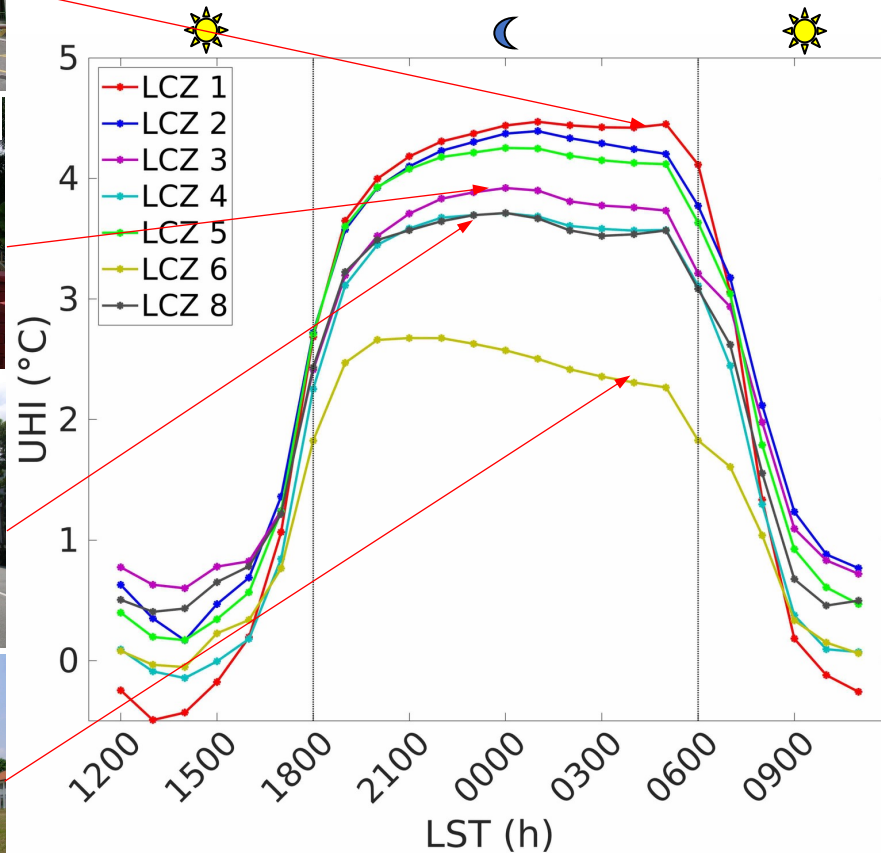
Physico-Chem

pm2.5: 15 $\mu\text{g}/\text{m}^3$
 pm10: 23 $\mu\text{g}/\text{m}^3$
 Omaot: 0.160 τ
 DNA: 1.5 ng/m^3

Locally produced climate change dominates Singapore's spatial air temperature distribution

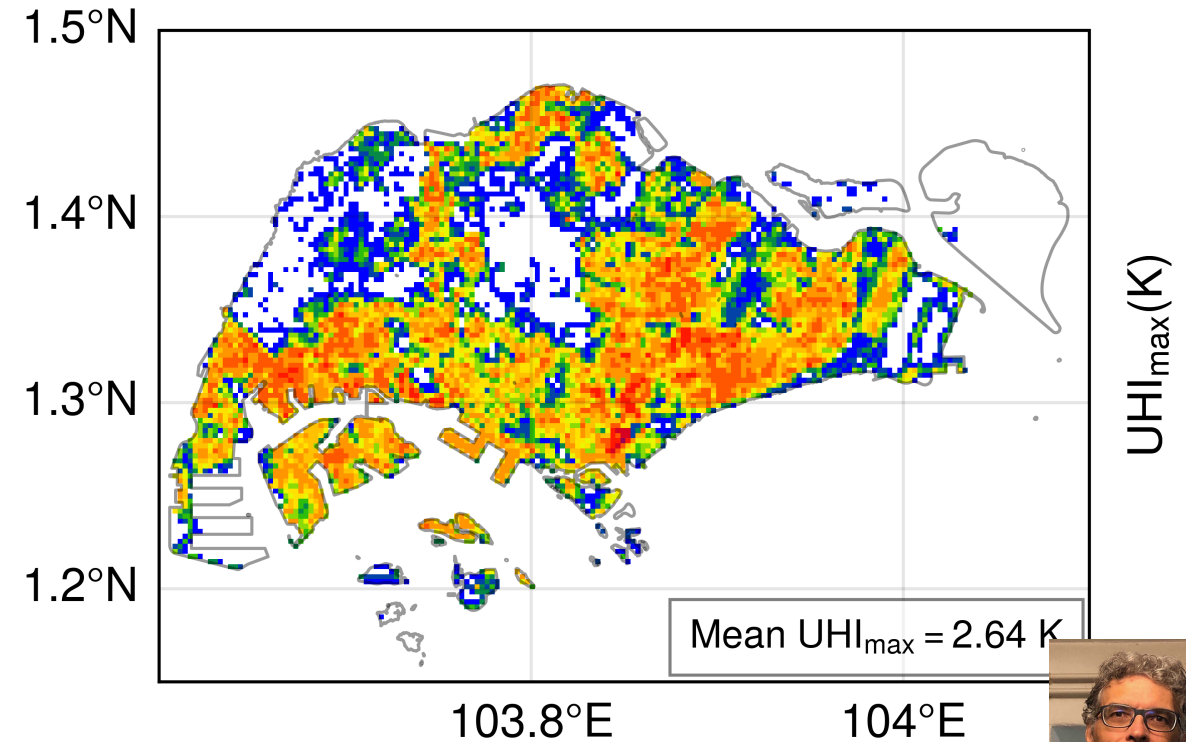
About half of the local warming in Singapore during the last ~60 years is due to the urban heat island (UHI) effect which has distinct diurnal, seasonal and spatial characteristics.

Temperature increment of built vs natural surfaces exceeds 4°C:



(Roth et al, 2022)

Simple statistical model predicts UHI under various weather conditions:



(Sanchez et al. 2023)



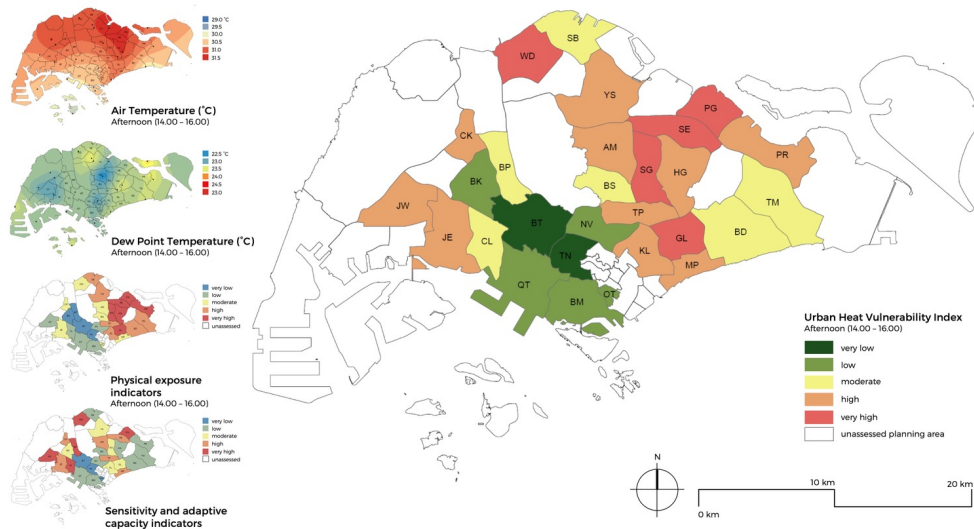
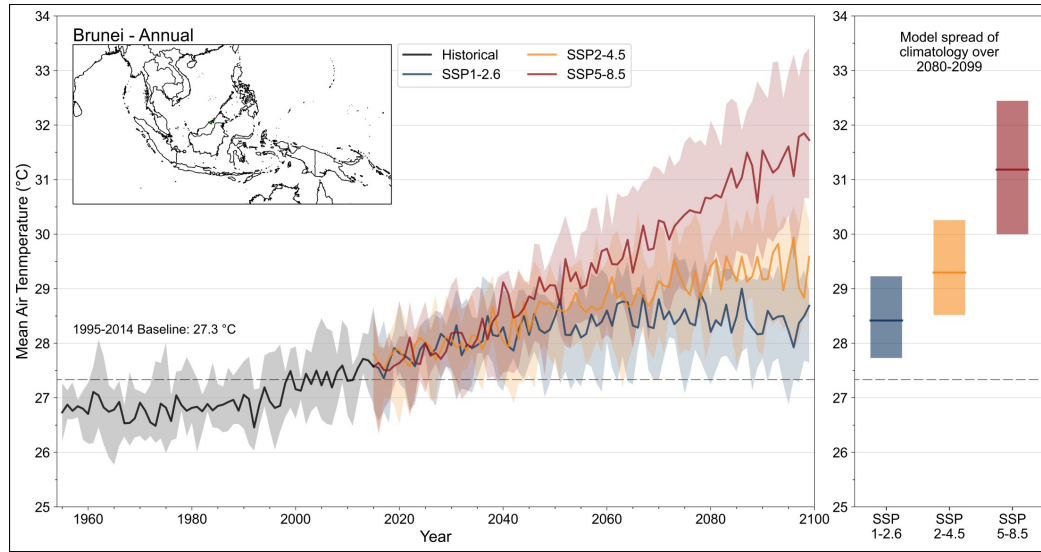
Matthias Roth, NUS



Judith Wong, NEA

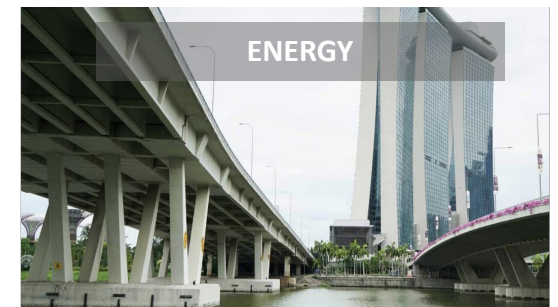
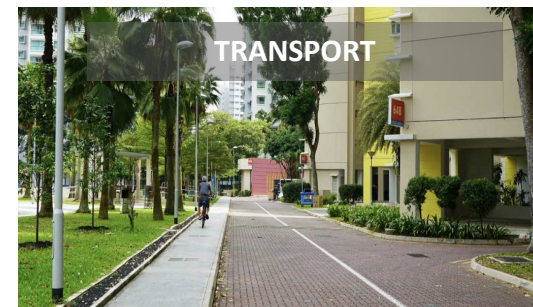
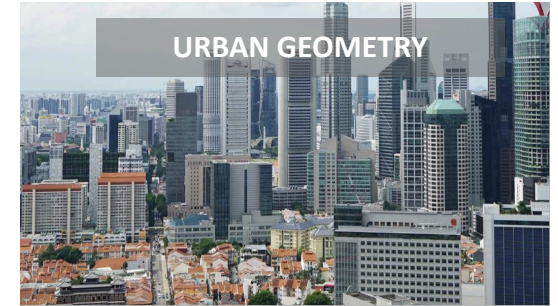
Singapore's Third National Climate Change Study

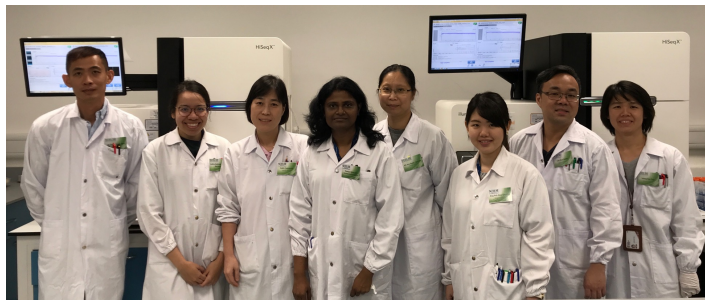
Access climatic data and projection models



Leveraging Synergies of Cooling Singapore Project

Impact of air microbiomes vis-à-vis proposed mitigating strategies





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 Vineeth K. Vettath
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Collaborators:



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MOE Research Fund Tier 3 Grant
(MOE2013-T3-1-013)

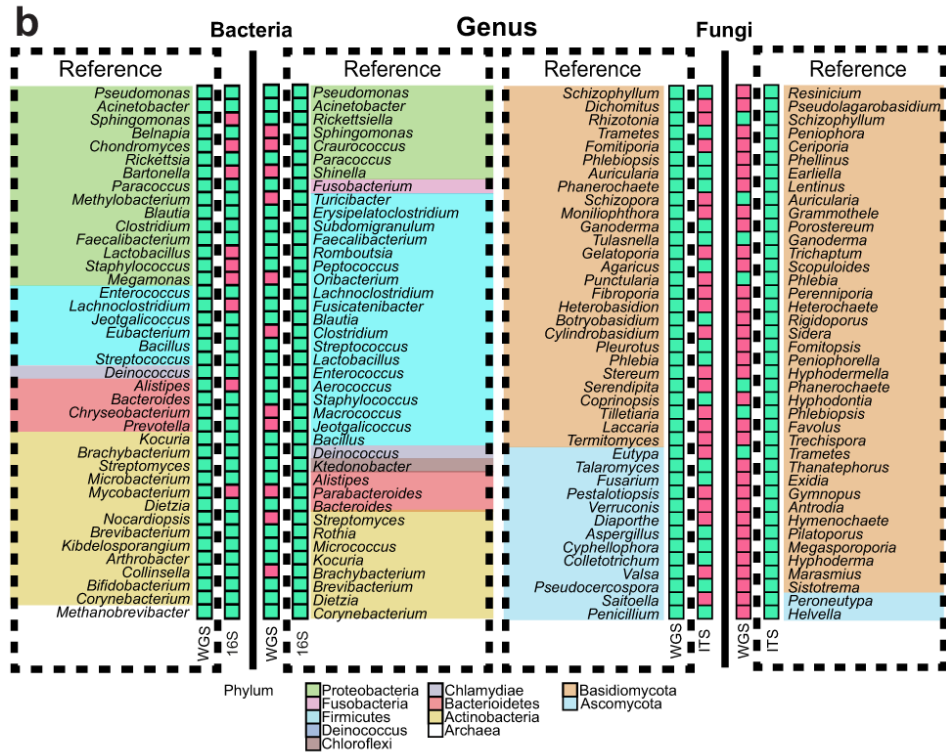


Ministry of Education
SINGAPORE

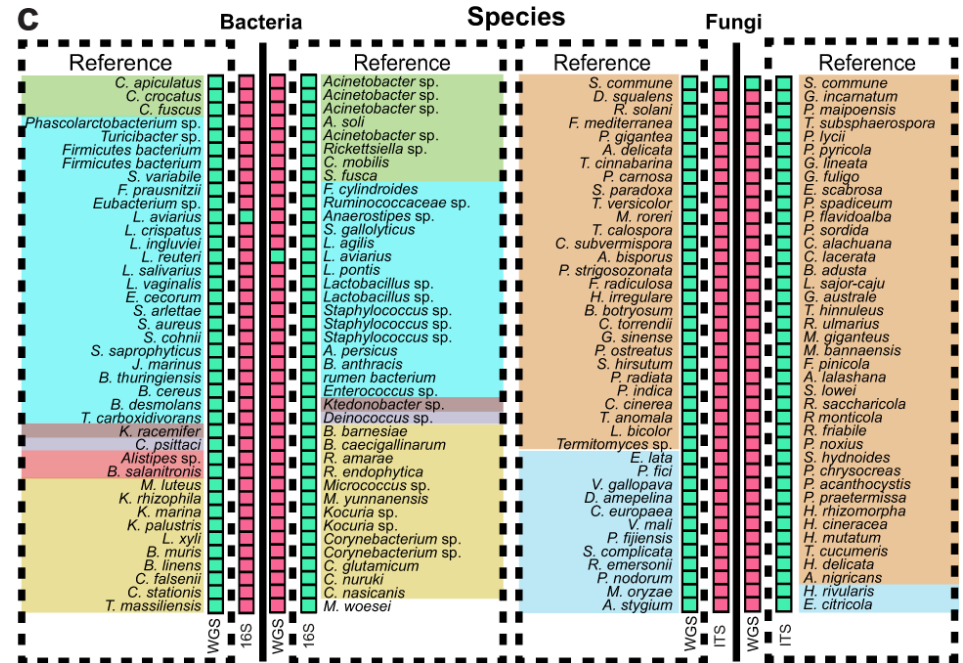
MOH COVID-19 Research Fund
(MOH-000411)



WGS metagenomics vs. Amplicon sequencing



Genus Level



Species Level

Thank you