

Impacts of global greenhouse on albedo and local land surface temperature

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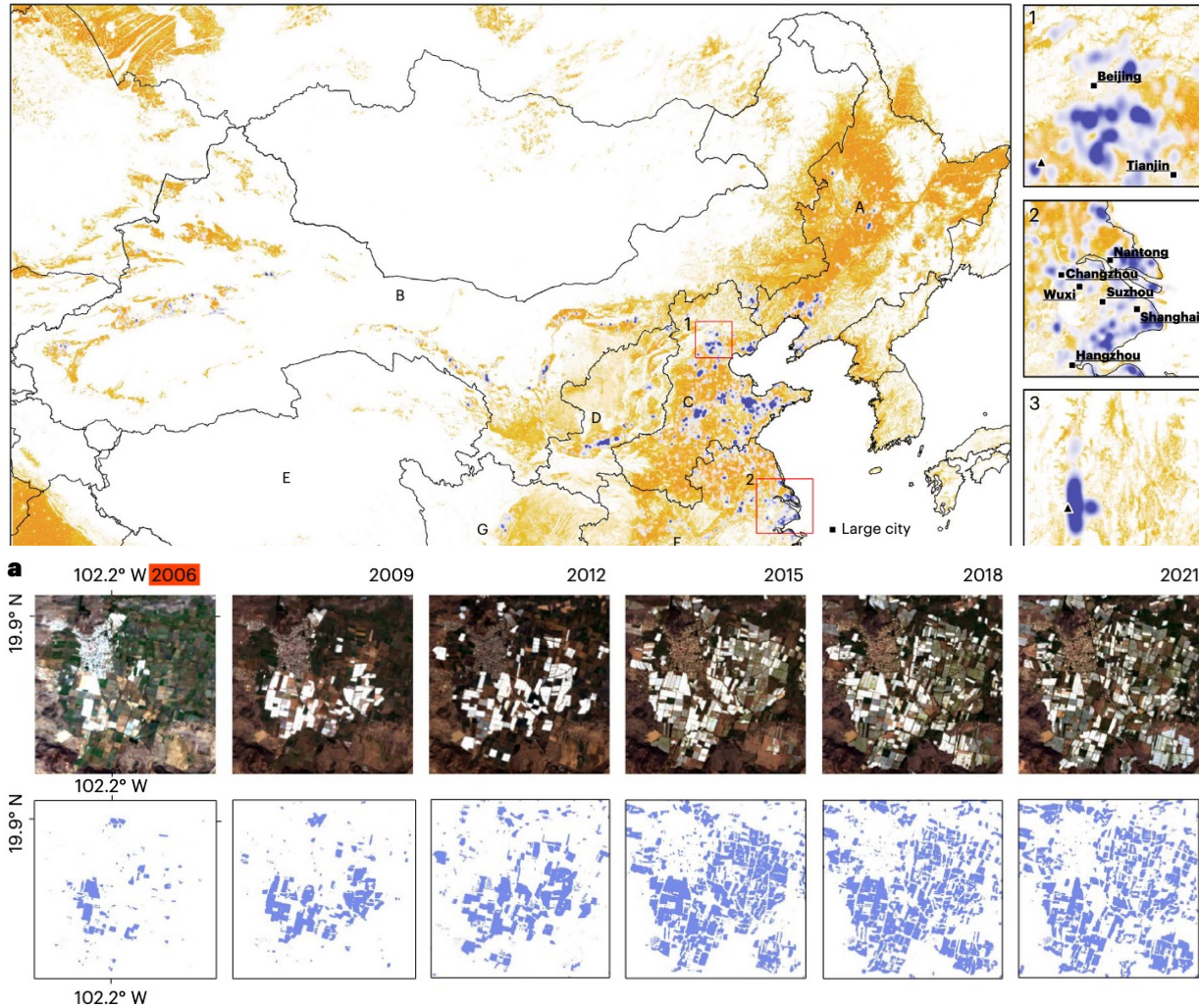
Xi'an

1. Background – Brighter land surface



IP: Almeria, Spain

1. Background - Why focus on agriculture greenhouse?



nature food

Analysis

<https://doi.org/10.1038/s43016-024-00985-0>

Global area boom for greenhouse cultivation revealed by satellite mapping

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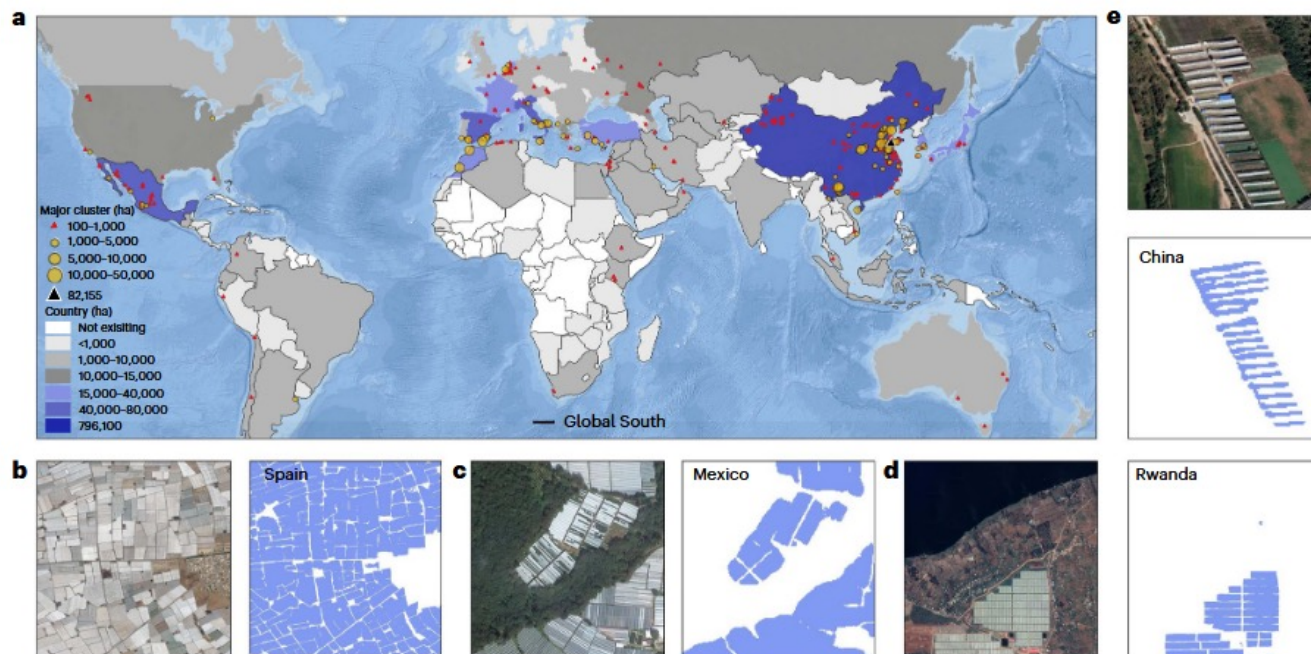
Xiaoye Tong¹, Xiaoxin Zhang¹, Rasmus Fensholt¹, Peter Rosendal Dau Jensen², Sizhuo Li^{1,3}, Marianne Nylandsted Larsen¹, Florian Reiner¹, Feng Tian⁴ & Martin Brandt¹

- Greenhouse area increased significantly worldwide since 2000.
- Global greenhouse area is 1.3 million ha in 2019 (1‰ cropland area; two times of 2022 solar panel area)

➤ **Research question: How do greenhouses modify surface albedo and land surface temperature?**

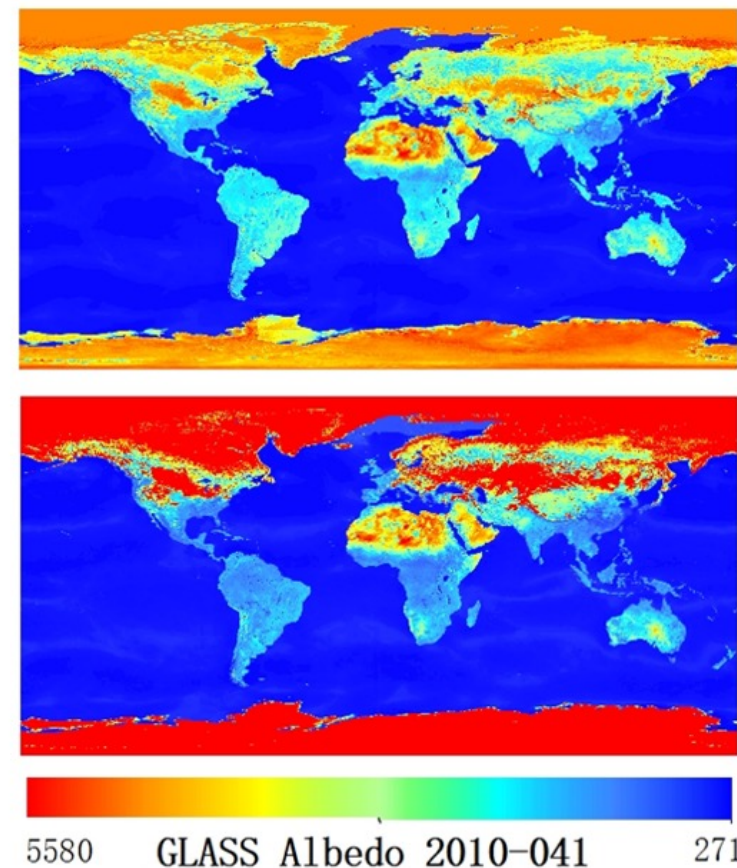
2.1 Data – greenhouses and albedo satellite data

- Global 3m-resolution greenhouse distribution data for 2019



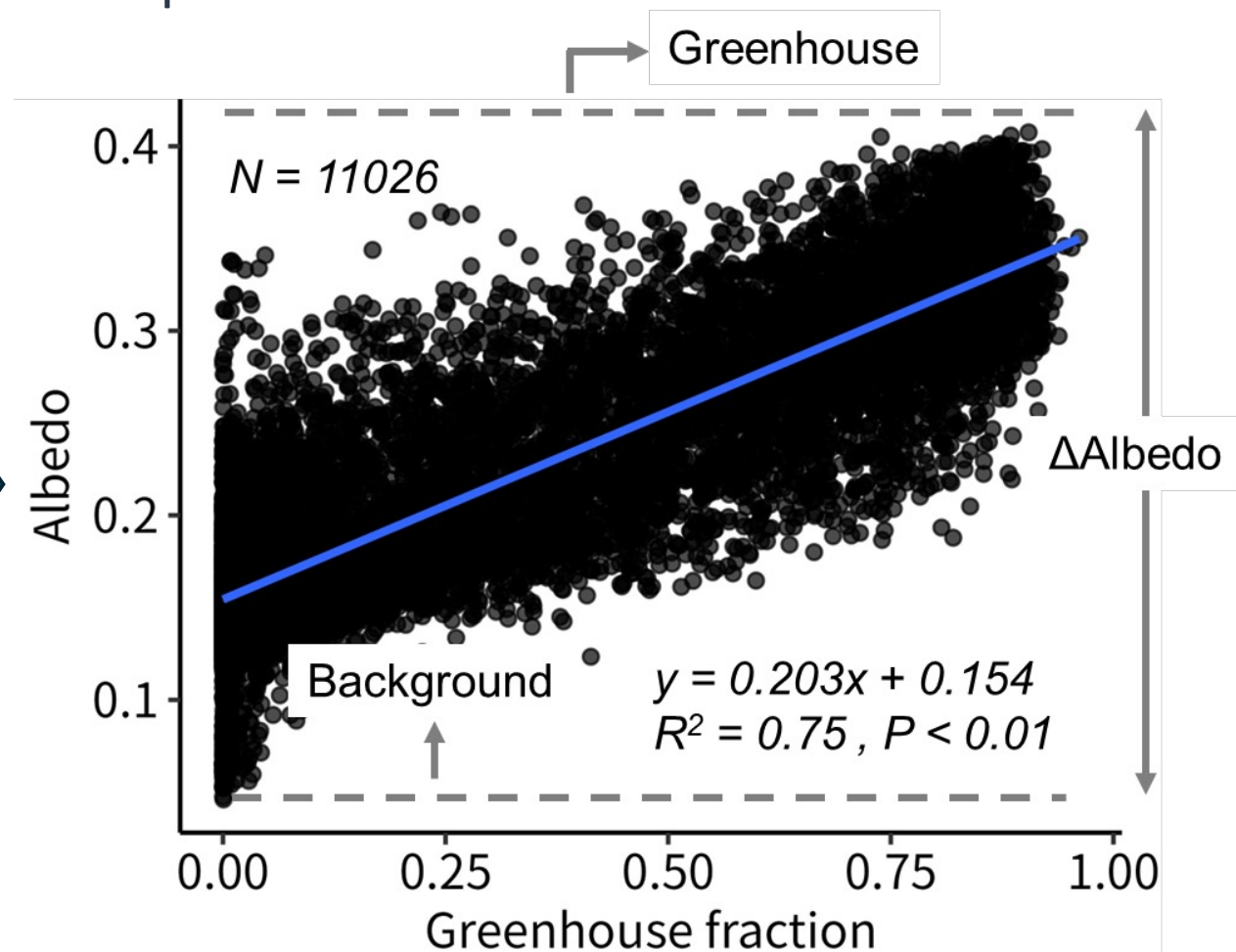
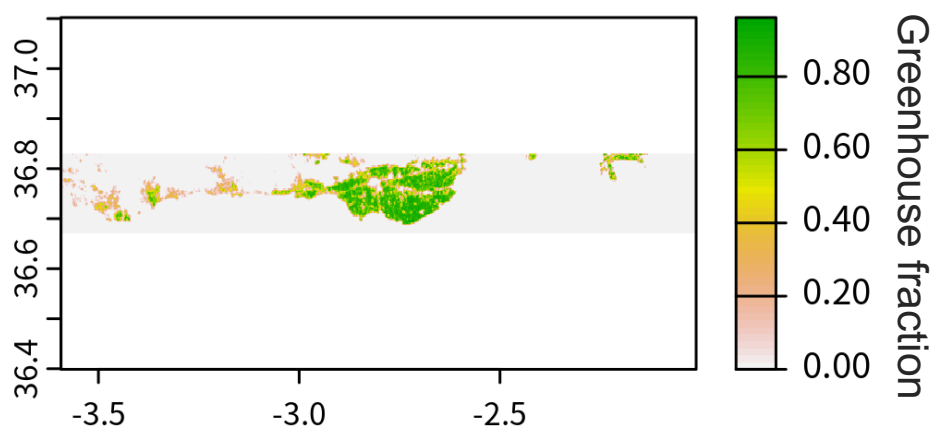
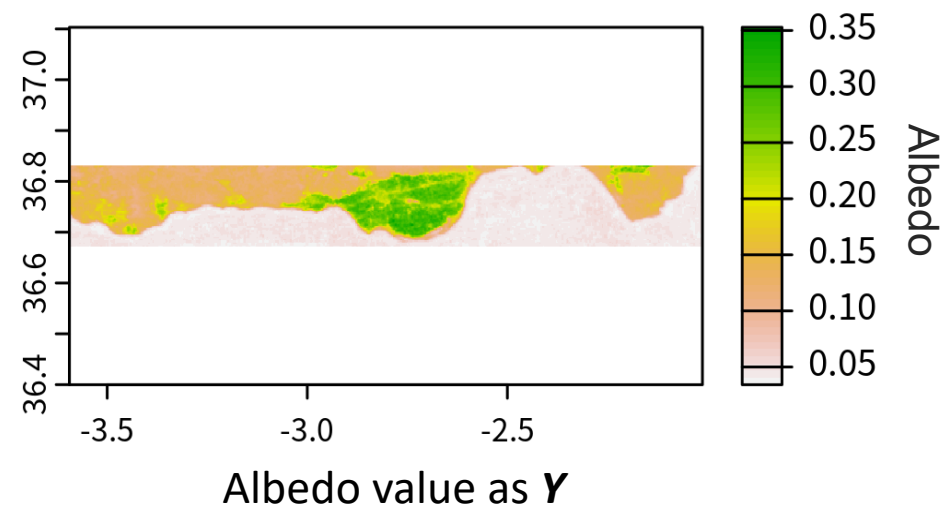
Tong et al., 2024

- GLASS Albedo of 2020-2022 at 250m



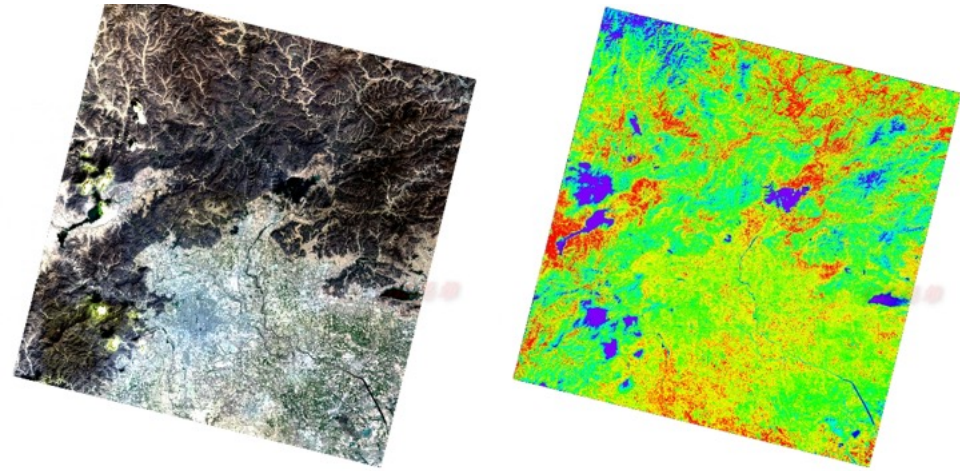
2.2 Method - quantify greenhouses impact on albedo

- Regression analysis to estimate greenhouse impact on albedo



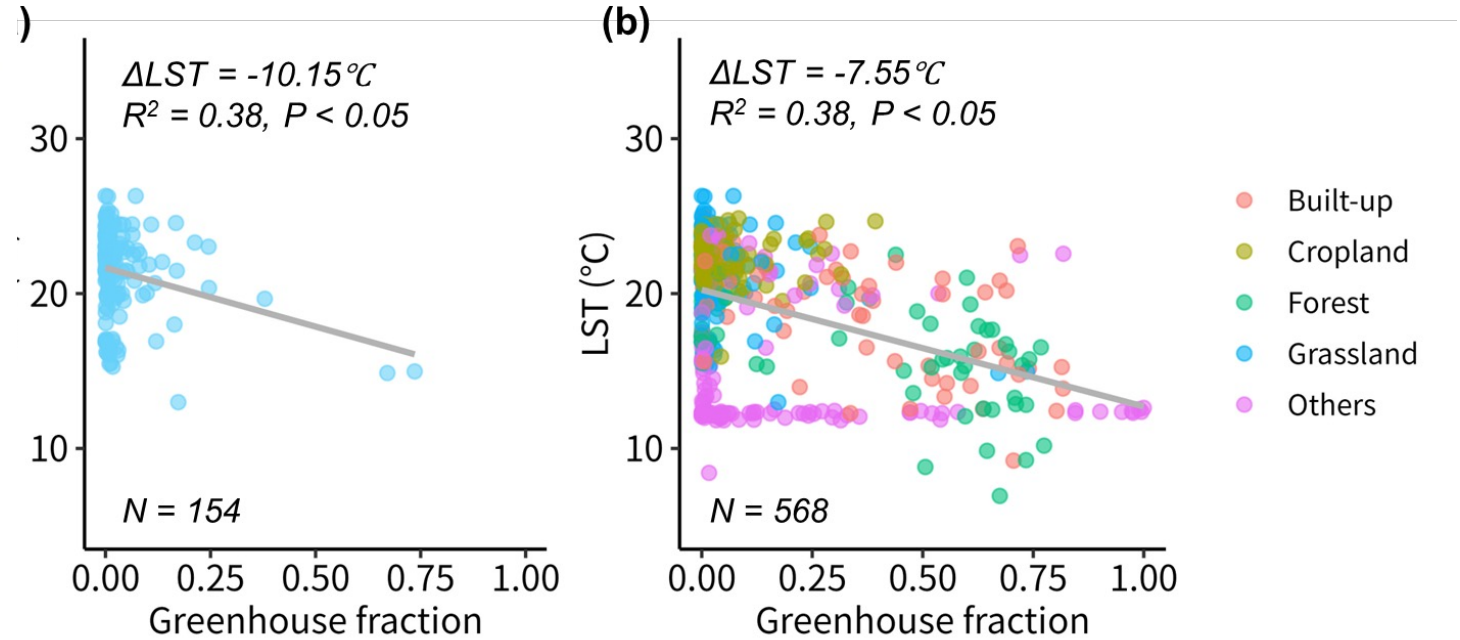
Δ Albedo: albedo changes induced by greenhouse

2.2 Method - quantify greenhouse impact on LST



$$(a) LST = -10.15 \times GF + 0.05 \times DEM + 1.47 \times LC + 17.93$$

$$(b) LST = -7.55 \times GF + 0.05 \times DEM + 2.38 \times LC + 16.91$$



- Landsat8 land surface temperature of 2020-2022 at 100m
- ESA WorldCover land cover in 2020 at 10m
- SRTM DEM at 90m

$$\overline{LST}_{act} = \beta_{GF} \times GF$$

$$\overline{LST}_{act} = \beta_{GF} \times GF + \beta_{DEM} \times DEM$$

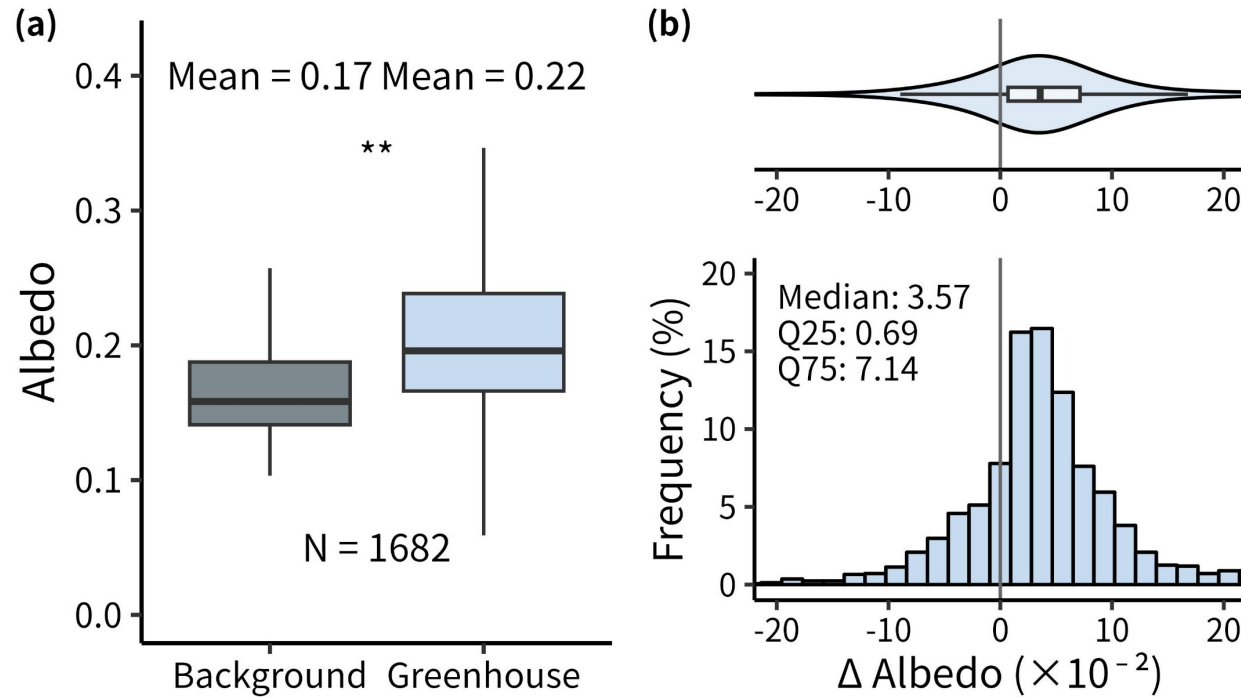
$$\overline{LST}_{act} = \beta_{GF} \times GF + \beta_{DEM} \times DEM + \beta_{LC} \times LC$$

$$\overline{LST}_{act} = \beta_{GF} \times GF + \beta_{DEM} \times DEM + \beta_{LC} \times LC + \beta_{lat} \times lat + \beta_{lon} \times lon$$

$$\overline{LST}_{act} = \beta_{GF} \times GF + \beta_{DEM} \times DEM + \beta_{LC} \times LC \text{ (Only dominant landcover)}$$

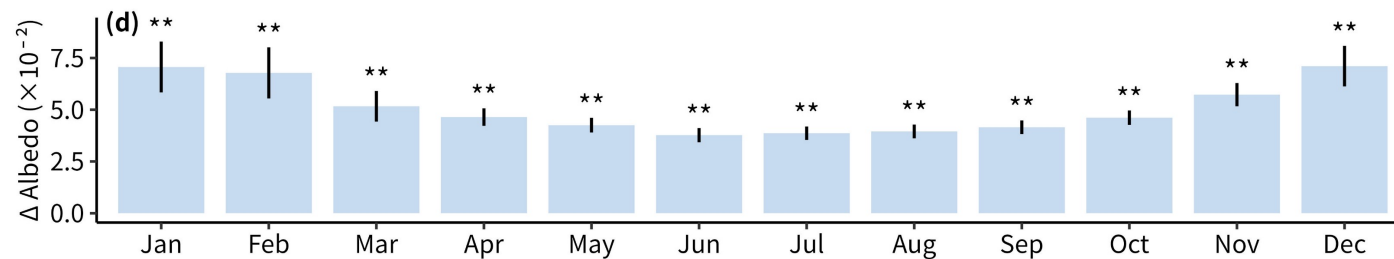
3.1 Results – global albedo impact

Annual mean albedo changes



- Global mean albedo: **0.22** (greenhouse) **0.17** (background)
- Greenhouses increase albedo by **0.0506 (+32%)** relative to background conditions

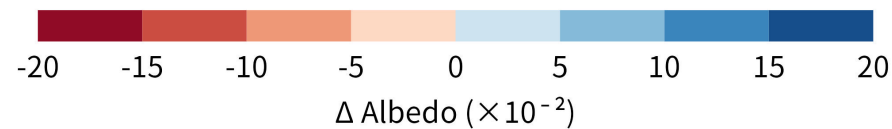
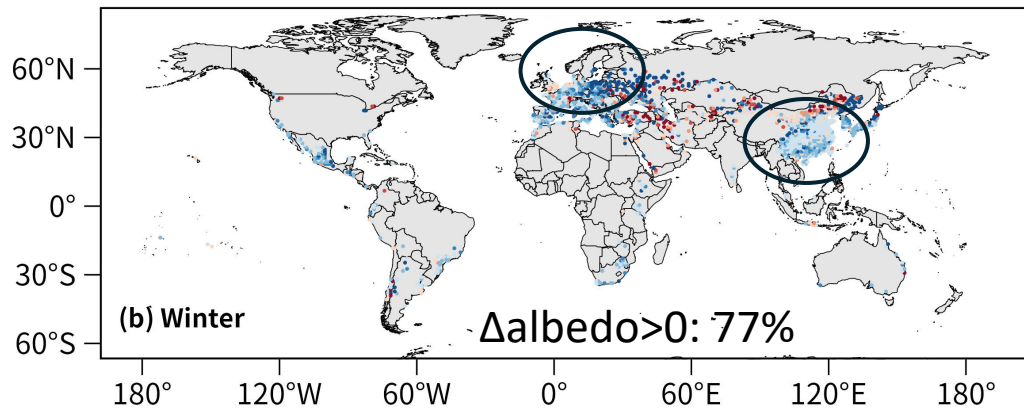
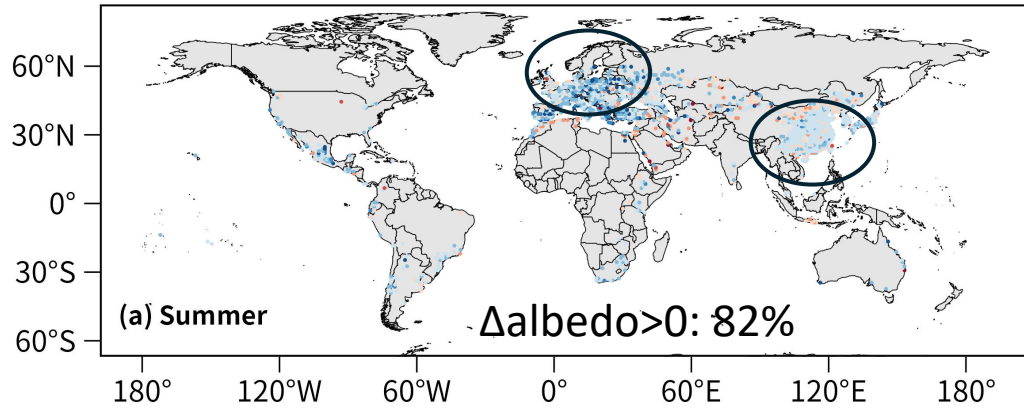
Monthly albedo changes



- Seasonally, albedo increase more in **winter (0.0698, +38%)** than in **summer (0.0386, +26%)**

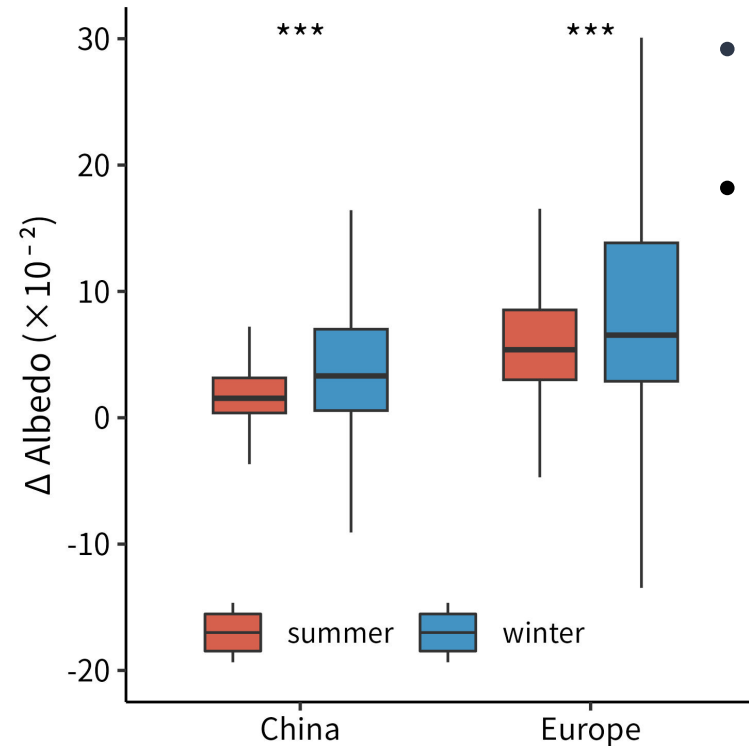
3.1 Results - spatial pattern of albedo impact

Albedo changes

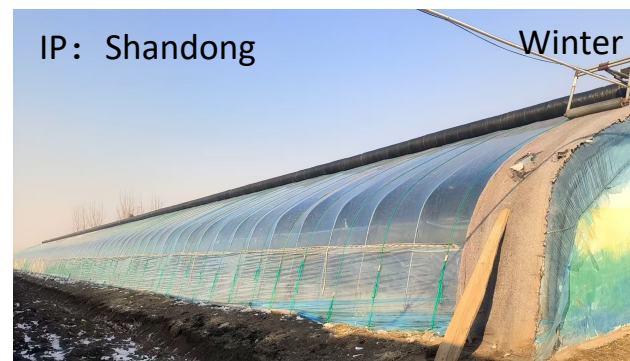
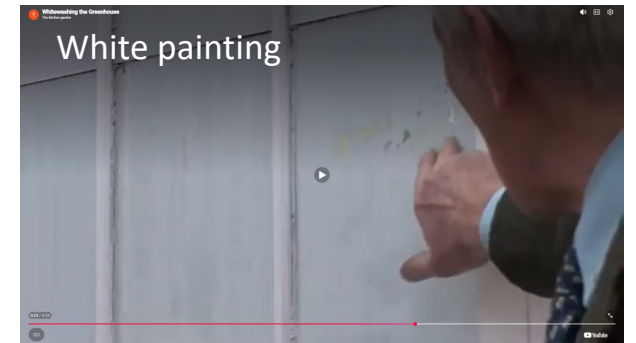


- Increased albedo in **78%** samples (82% summer and 77% winter)

Regional comparison: China vs Europe

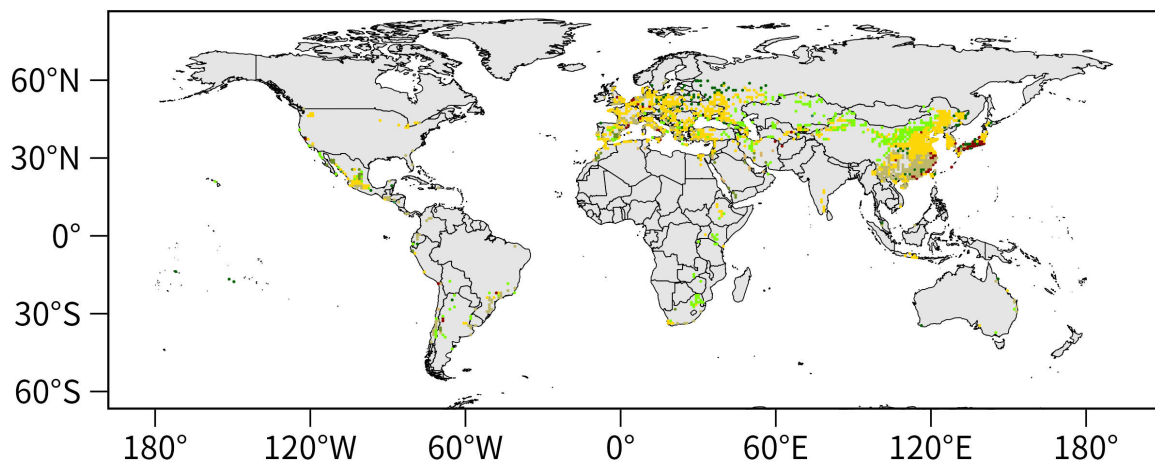


- Albedo increase is greater in **Europe** than in **China**
- Small summer albedo increase in China but very large increase in Europe due to management

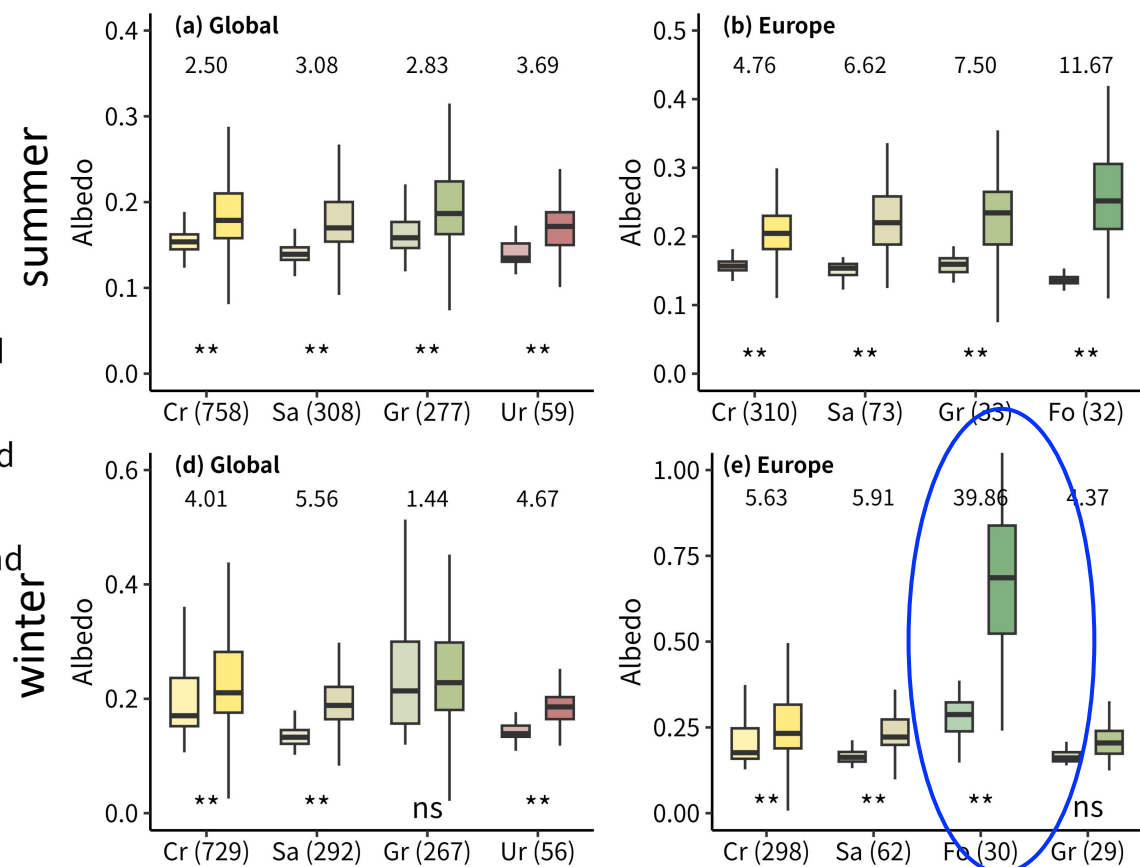


3.2 Results – albedo impact by land cover type

Greenhouses and their background land cover type



Albedo of greenhouse and land cover

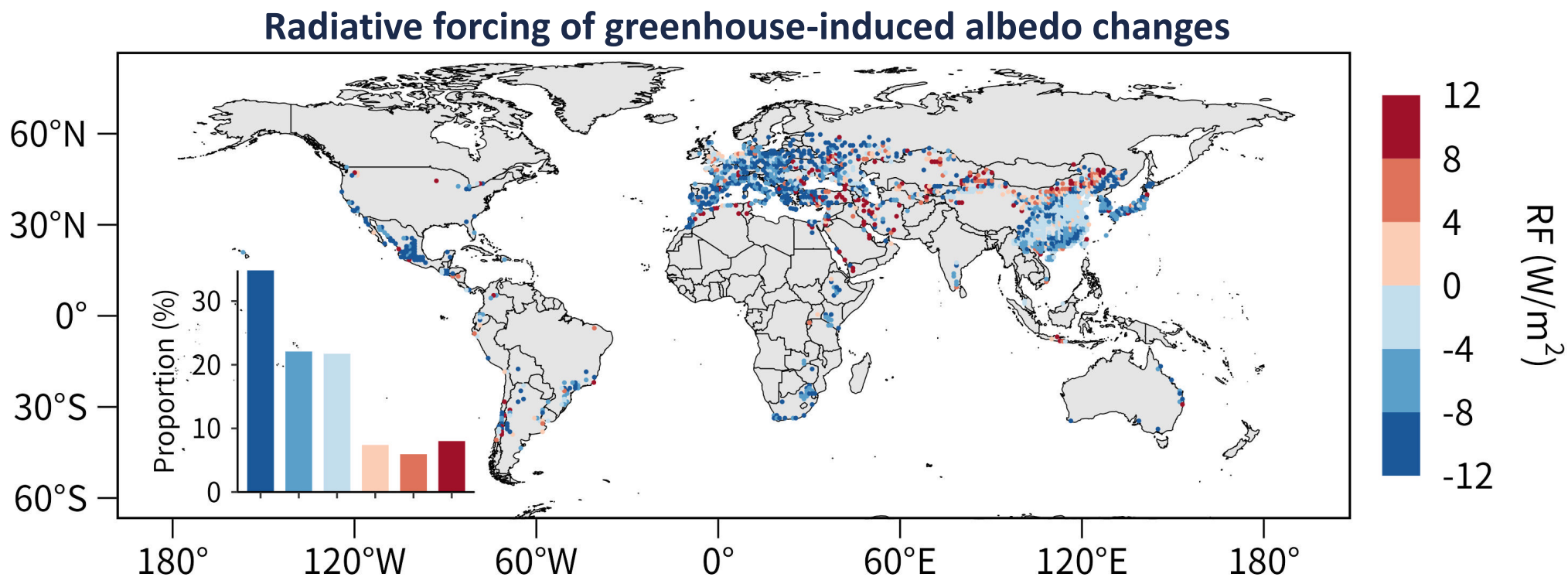


- Greenhouses are mainly located on croplands and grasslands, with a small fraction in forests and urban lands.

- Greenhouses in land cover with darker surface (e.g., forests), have most pronounced albedo increase, particularly in winter

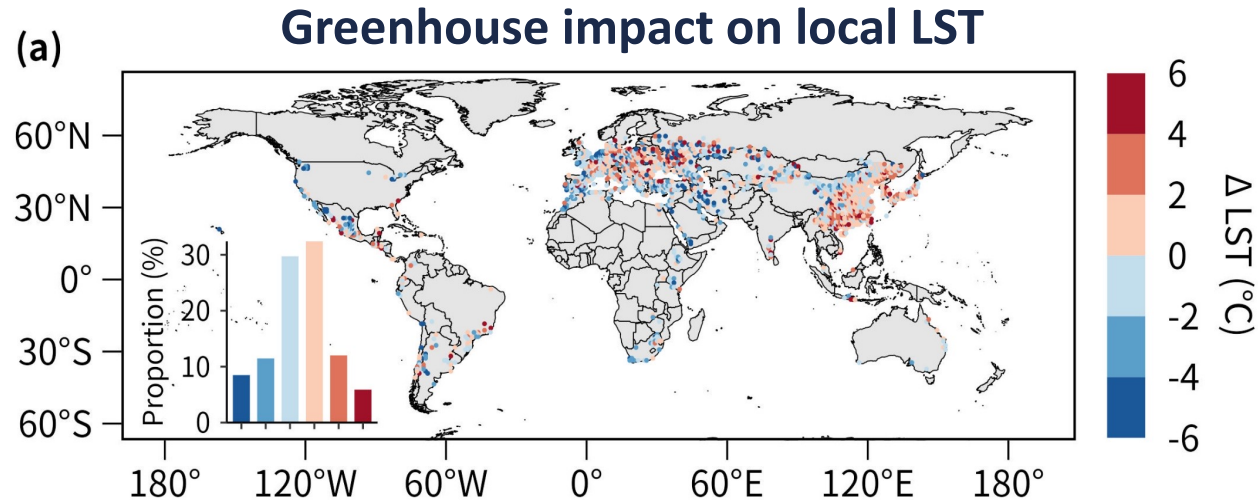
3.3 Results - radiative forcing induced by albedo changes

Local radiative forcing = $\Delta\text{Albedo} \cdot \text{downward shortwave radiation} \cdot \text{transmittance}$ ($T_a = 0.854$)

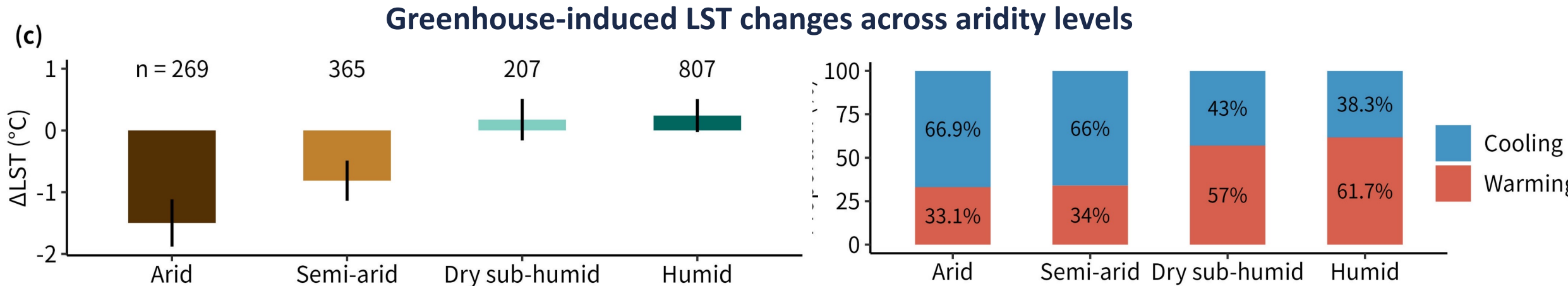


- For 78% greenhouses with increased albedo, they create a negative radiative forcing (-6.03W/m^2), suggesting potential cooling influence on climate.

3.4 Results – impact on land surface temperature



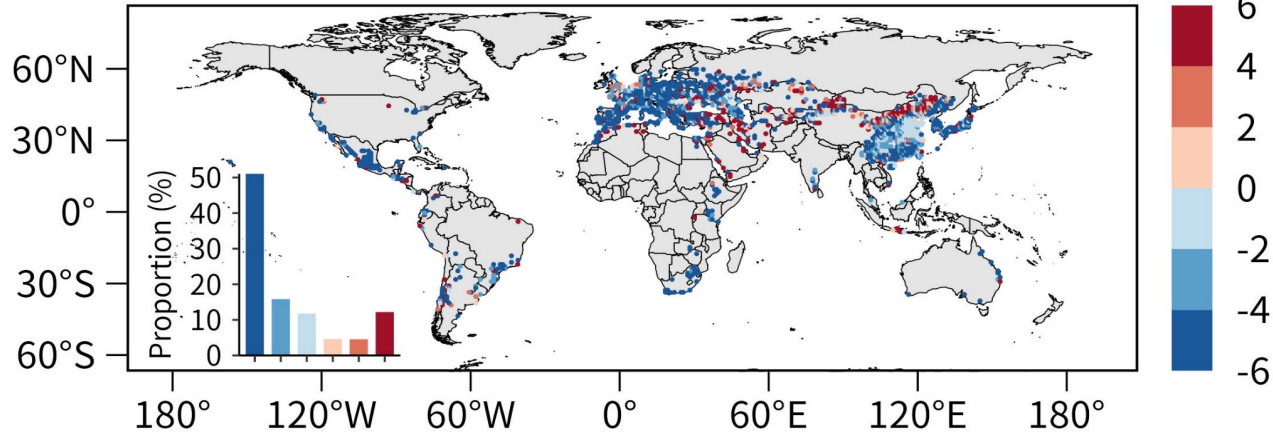
- Globally, greenhouses decrease land surface temperature (LST) by **0.28 °C**
- Mixed LST impacts: LST cooling or warming are roughly 50%



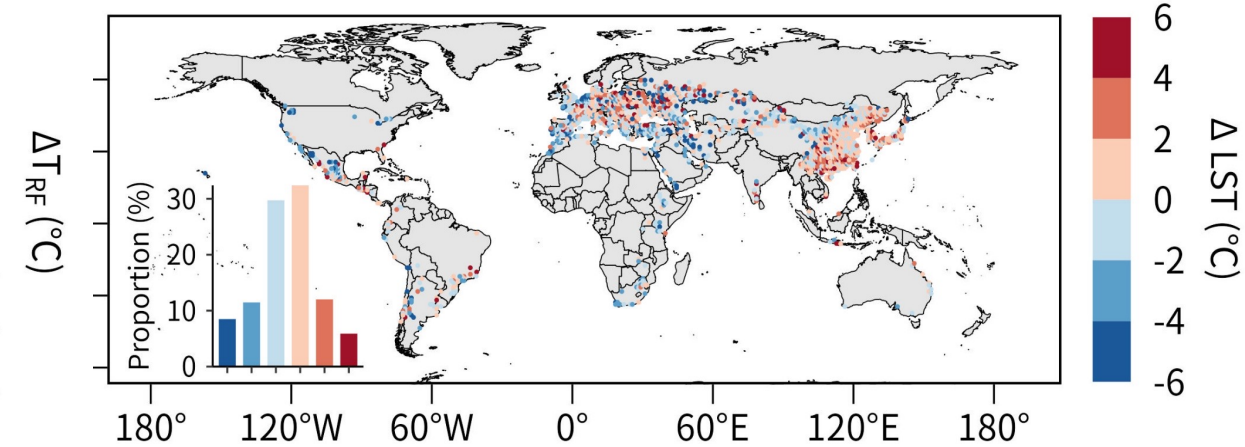
- The LST cooling induced by greenhouses is stronger toward drier regions, with more cooling proportion.

3.5 Results – compare radiative forcing-induced and local observed LST changes

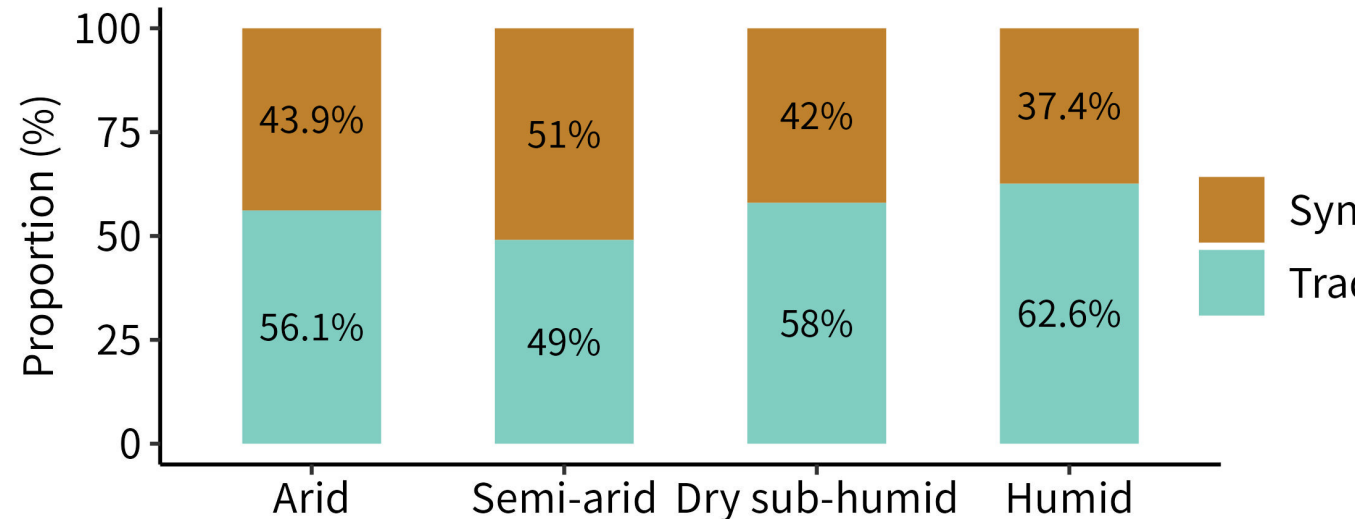
RF-induced equivalent LST changes $\Delta T_{RF} = \lambda \cdot RF$ ($\lambda = 0.8$)



Local LST changes



- The greenhouse-induced albedo change cause much **larger equivalent LST changes** (-4.83°C) than **observed local LST changes** (-0.28°C)
- In more arid regions, albedo-induced cooling tend to be **increasingly synergistic** (same sign) with observed LST cooling



Synergy: $\Delta LST \cdot \Delta T_{RF} > 0$; **Trade-off:** $\Delta LST \cdot \Delta T_{RF} < 0$

Take-home message

- Globally, greenhouse expansion leads to a **significant increase in surface albedo (0.0506), negative radiative forcing and local LST cooling of 0.28 °C.**
- This albedo increase is more pronounced **in winter than in summer**, and is generally stronger in **Europe than in China**, reflecting different greenhouse management practices and climatic conditions.
- The observed local LST responses exhibit substantial spatial heterogeneity, with the **albedo-driven global temperature response exceeding local LST changes.**
- The radiative cooling effect of greenhouses and local LST cooling become **more synergistic toward more arid regions.**



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Thank you!

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