

Introduction

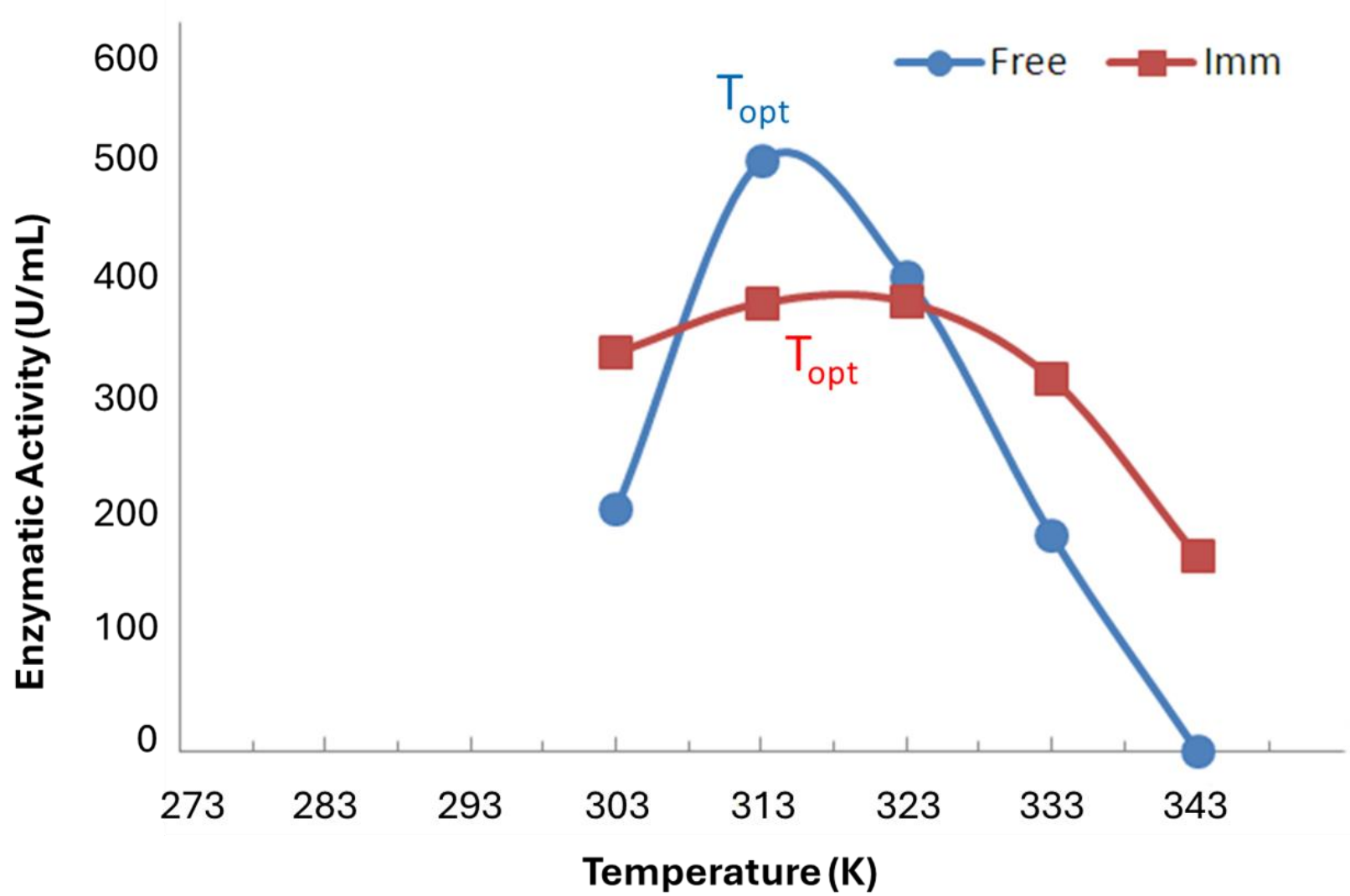


Figure 1: Optimum temperature profile of free and immobilized urease - which occurs following urease complexation with soil components -.^[5]

Agriculture's reliance on nitrogen fertilizers contributes significantly to atmospheric ammonia (NH₃) emissions, affecting the environment and public health.^[1,2] Urea contributes to 51% of global N-fertilizer consumption and is converted into NH₃ by soil urease.^[4] Soil urease's enzymatic activity is strongly influenced by soil temperature, peaking at an optimal temperature (T_{opt}) before declining sharply due to protein denaturation. This optimal temperature varies with soil composition, as urease complexation with clay minerals and/or organic matter can enhance the enzyme's thermal stability.^[3,5,6]

Soil type	Clay & Organic Matter Content	Amount of Complexation	Optimal Temperature (T _{opt})
Sandy soil	Low	Low	≈ 313K
Silty soil	Medium	Medium	≥ 313K
Clayey soil	High	High	313K ≤ T _{opt} ≤ 343K

Table 1: The effect of soil type and complexation on the optimal temperature of urease activity.^[3,5,6]

Objectives

- Temperature Influence:** Examining the relationship between NH₃ columns and surface temperature (T_{skin}), across agricultural zones.
- Fertilizer Type:** Comparing NH₃-T_{skin} correlations in regions predominantly consuming urea-based versus non-urea-based fertilizers.
- Soil Composition:** Analyzing the influence of various soil types (sandy, silty, clayey) in agricultural regions on NH₃-T_{skin} correlations.
- Moisture Interactions:** Investigating how soil moisture (SM) interacts with T_{skin} to affect NH₃ volatilization.

Methodology

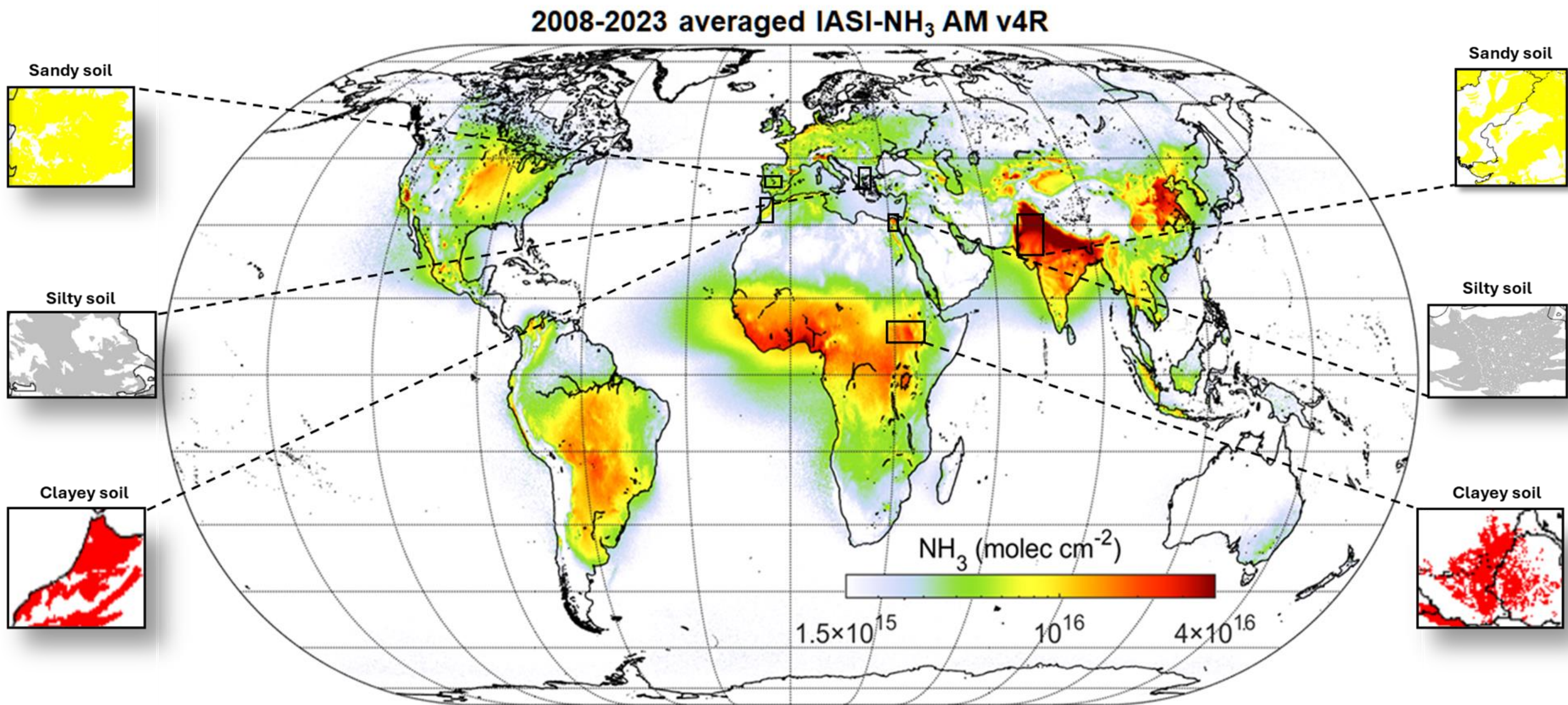


Figure 2: Global distribution of total atmospheric NH₃ columns (molec.cm²). The selected agricultural regions are framed, with the close-ups highlighting the dominant soil types: red for clay-rich, grey for silt-rich, and yellow for sand-rich areas.

- Data:** 15 years of atmospheric NH₃ total columns and T_{skin} data from the morning overpasses from the Infrared Atmospheric Sounding Interferometer (IASI) onboard the MetOp-A and MetOp-B satellites.^[10] Soil moisture data was obtained from the ESA's Soil Moisture Climate Change Initiative.^[7]
- Analysis:** NH₃, T_{skin} and SM data were spatially and temporally aligned, with T_{skin} grouped into 1K intervals. Median NH₃ and SM values were calculated per interval and were plotted for each region.
- Region Selection** based on cropland intensity, climate, N-fertilizer consumption^[8] and soil type^[9], which were then categorized into two main groups, namely extensive - (e.g., India, Egypt, Ethiopia) and limited urea consumption (e.g., Spain, Morocco, Greece), across all three major soil types (sandy, silty and clayey).

Results & Discussion

Extensive urea consumption

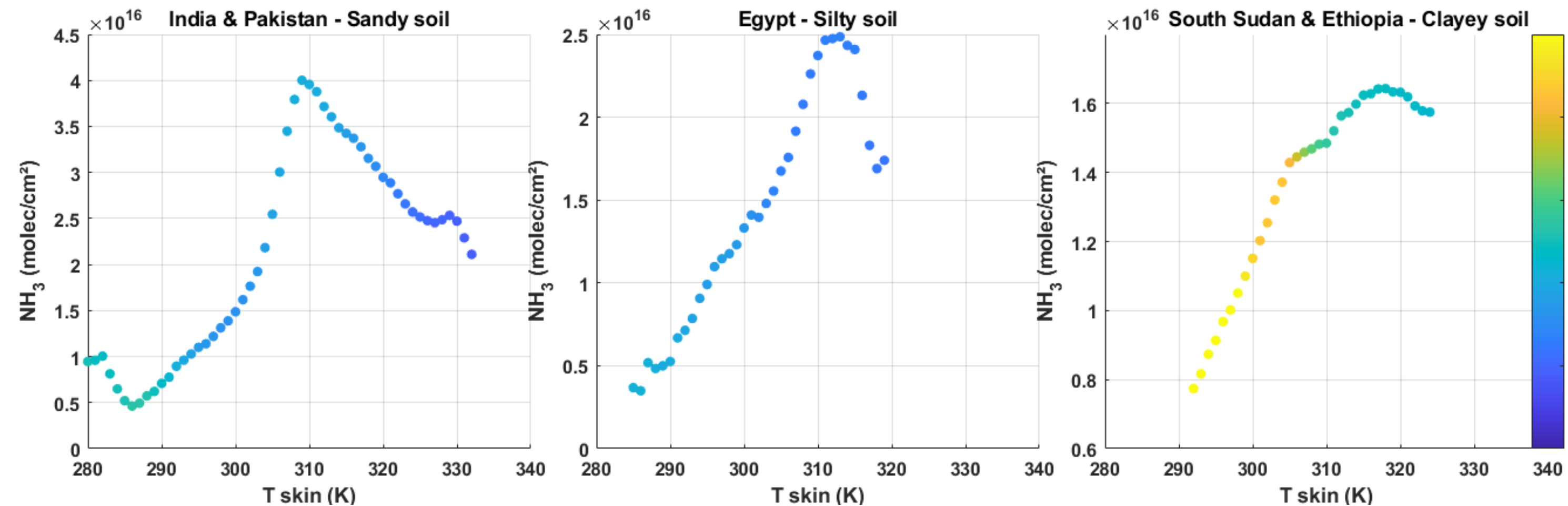


Figure 3: NH₃-T_{skin}-SM correlations in agricultural regions, known for their extensive urea consumption, across all three soil types.

Limited urea consumption

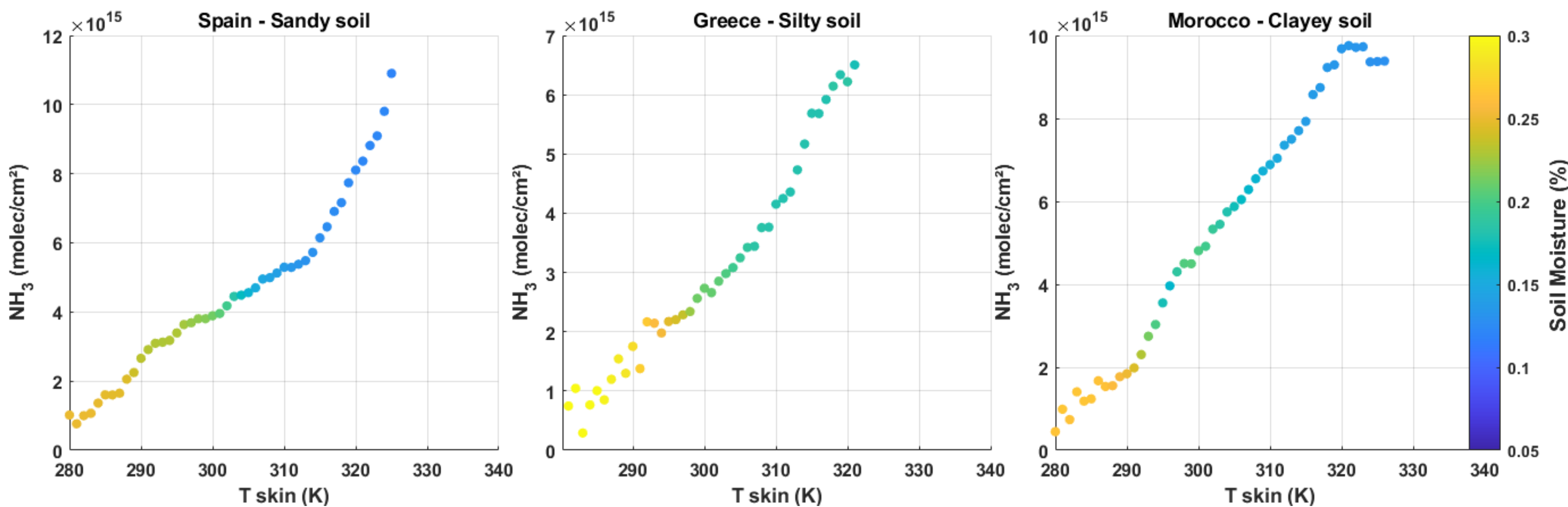


Figure 4: NH₃-T_{skin}-SM correlations in agricultural regions known for their limited urea-based fertilizer consumption, across all three soil types.

	Extensive urea consumption regions			Limited urea consumption regions		
	N-W India & Pakistan	Egypt	South Sudan & Ethiopia	Spain	Greece	Morocco
Soil type	Sandy	Silty	Clayey	Sandy	Silty	Clayey
NH ₃ drop observed?	Yes	Yes	Yes	No	No	Intermediate
Expected urease complexation	Low	Medium	High	Low	Medium	High
Temperature for max. atmospheric NH ₃ (T _{opt})	309K	313K	313K	≥ 325K	≥ 321K	(≥) 321K

Table 2: The relationship between T_{skin} and atmospheric NH₃ columns, relative to soil types and N-fertilizer consumption.

Extensive urea consumption regions: Sandy soils are characterized by increasing NH₃ emissions with increasing T_{skin}, up to a temperature of 313 ± 3 K, after which NH₃ columns abruptly decrease. For clayey soils - and to lesser extent silty soils – this breakpoint occurs at a higher temperature, mirroring the behavior of urease activity.

Limited urea consumption regions: A direct proportionality between atmospheric NH₃ columns and T_{skin} is observed, even well beyond the 313K threshold, consistent with literature. In these regions, soil type appears to have a minimal impact on NH₃ volatilization, likely due to the limited influence of soil urease activity.

Conclusion

This study highlights the significant influence of surface temperature and nitrogenous fertilizer type on atmospheric NH₃ columns. Regions with high reliance on urea-based fertilizers display temperature-dependent NH₃ emissions, with declines at elevated temperatures, likely due to reduced urease activity. Conversely, regions with limited urea consumption align with literature, exhibiting a direct proportionality between T_{skin} and NH₃ volatilization. These findings highlight the need to consider climate conditions, soil properties, and fertilizer practices in modelling NH₃ emissions and optimizing fertilizer management strategies.

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