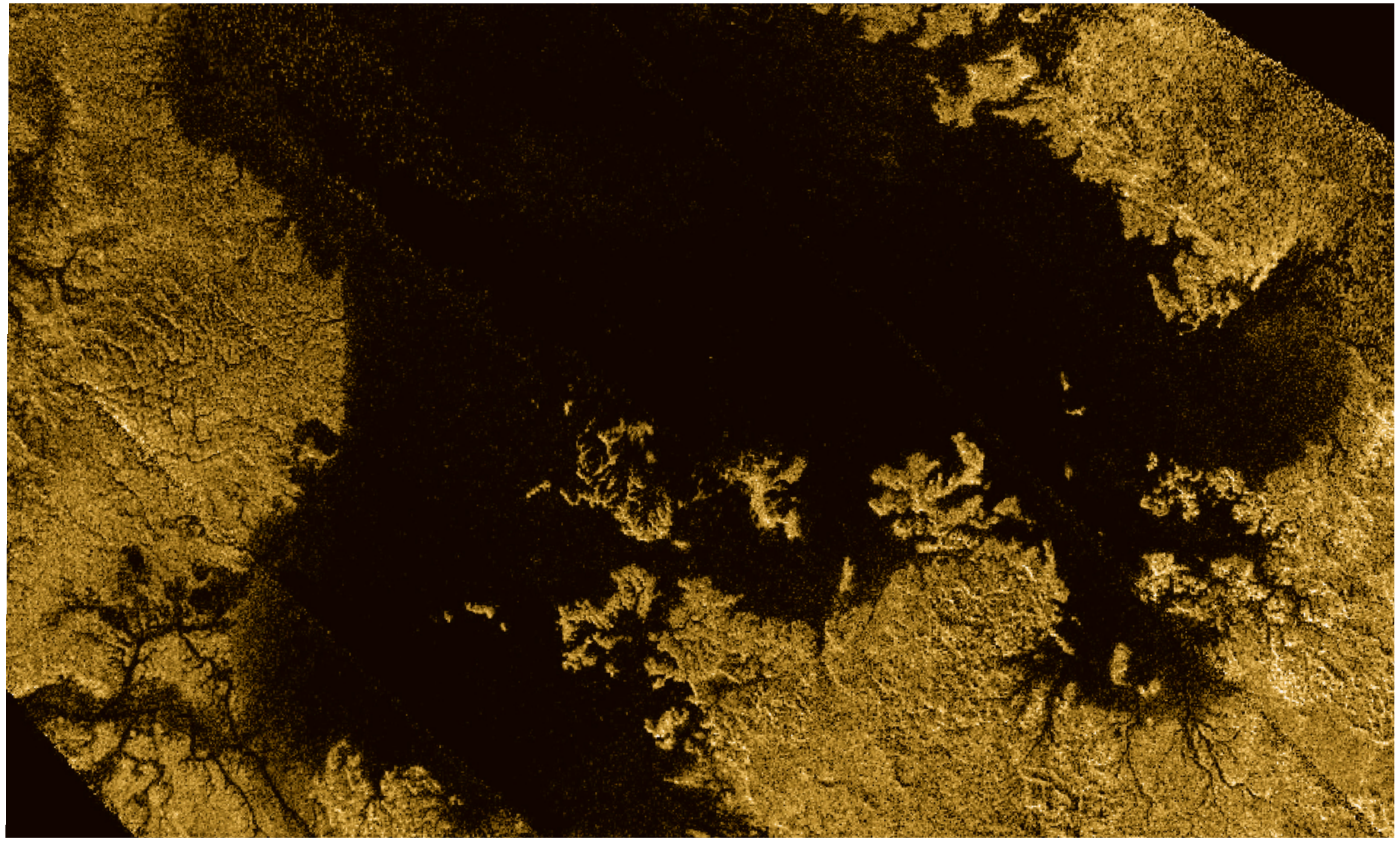
Uncovering the influence of surface and subsurface hydrology on Titan's climate system

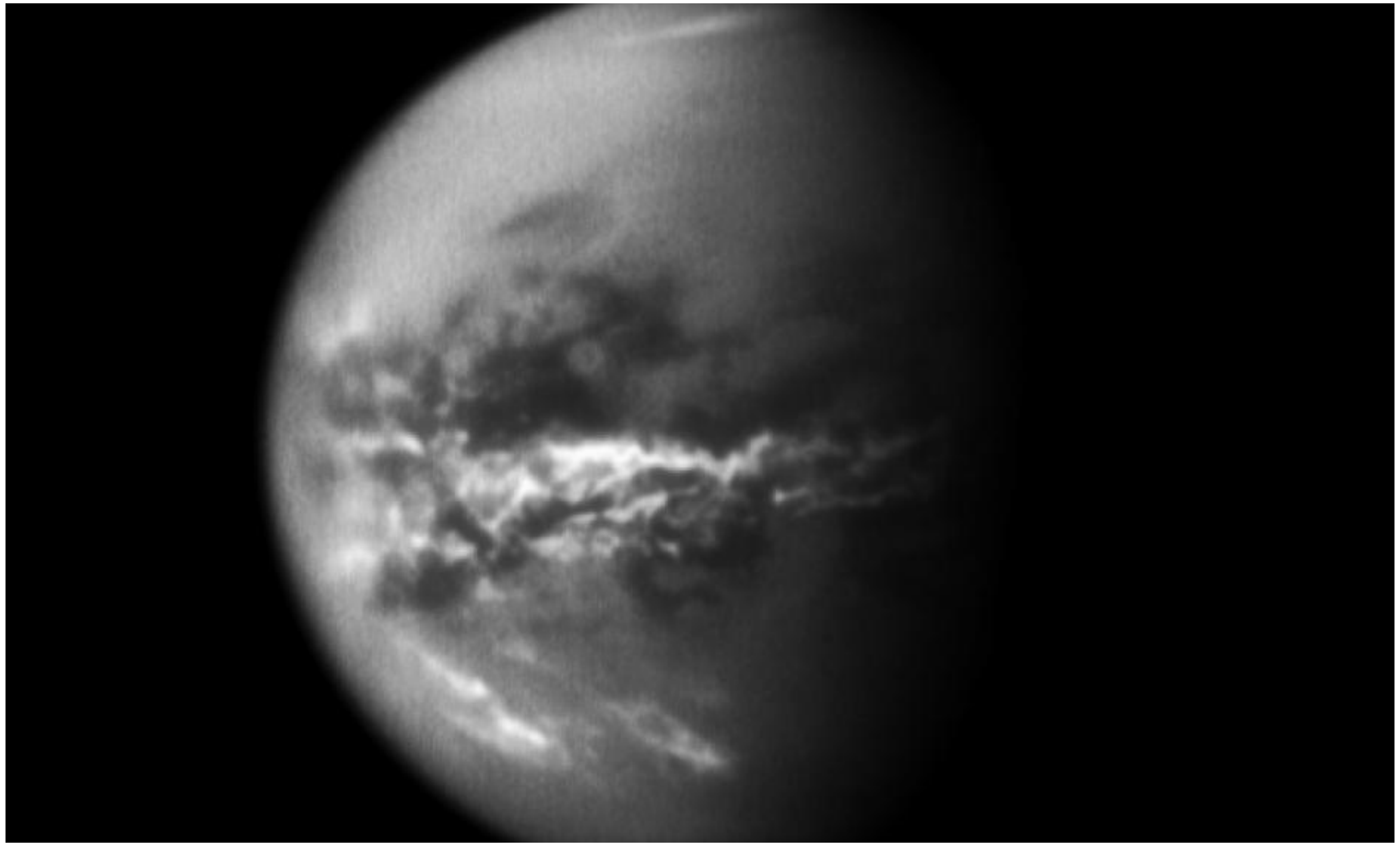
Juan M. Lora

Sean P. Faulk & Jonathan L. Mitchell, UCLA
P. Chris D. Milly, USGS

How Much Methane Is in Titan's Climate System?



~10^3–10^4 GT carbon

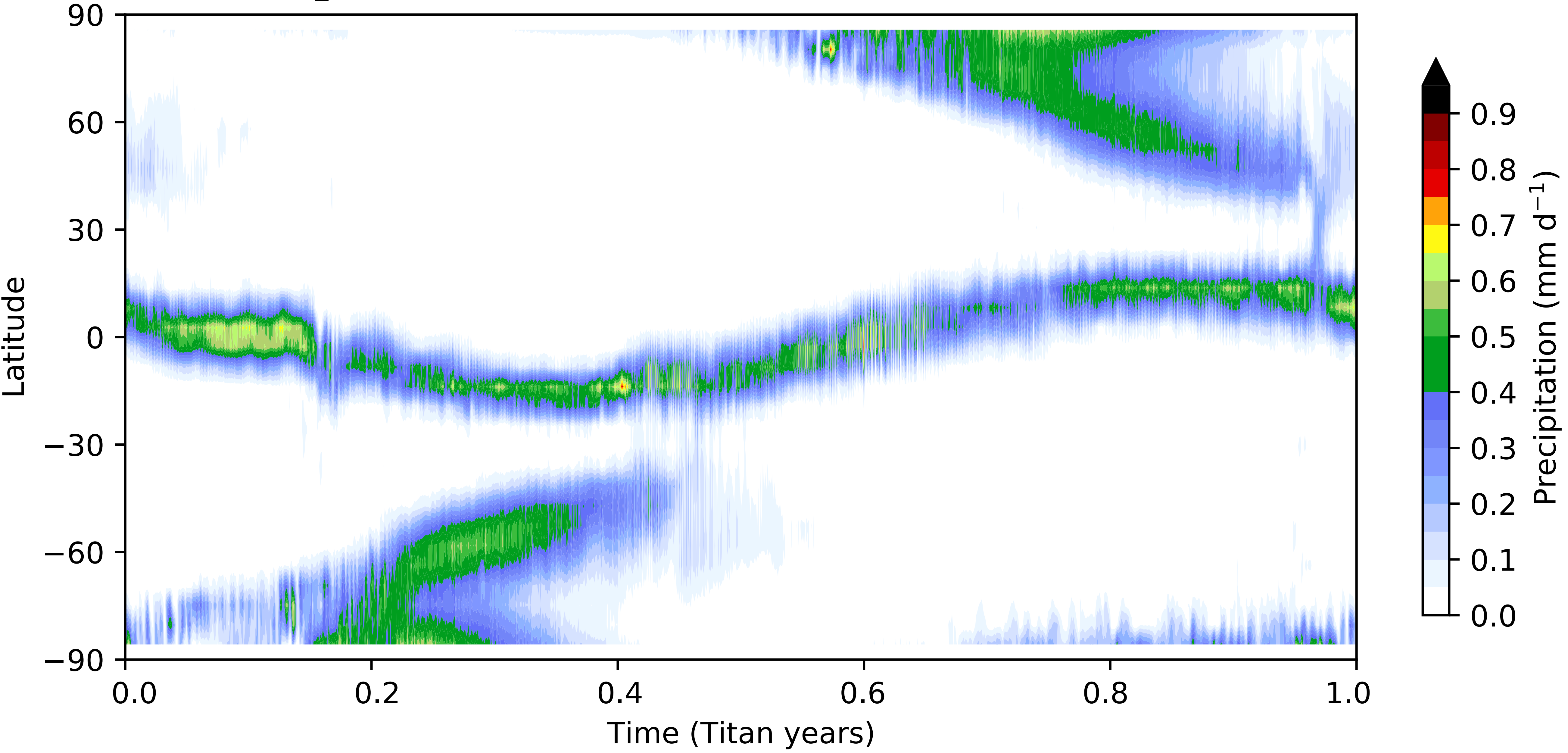


~4×10^4 GT carbon

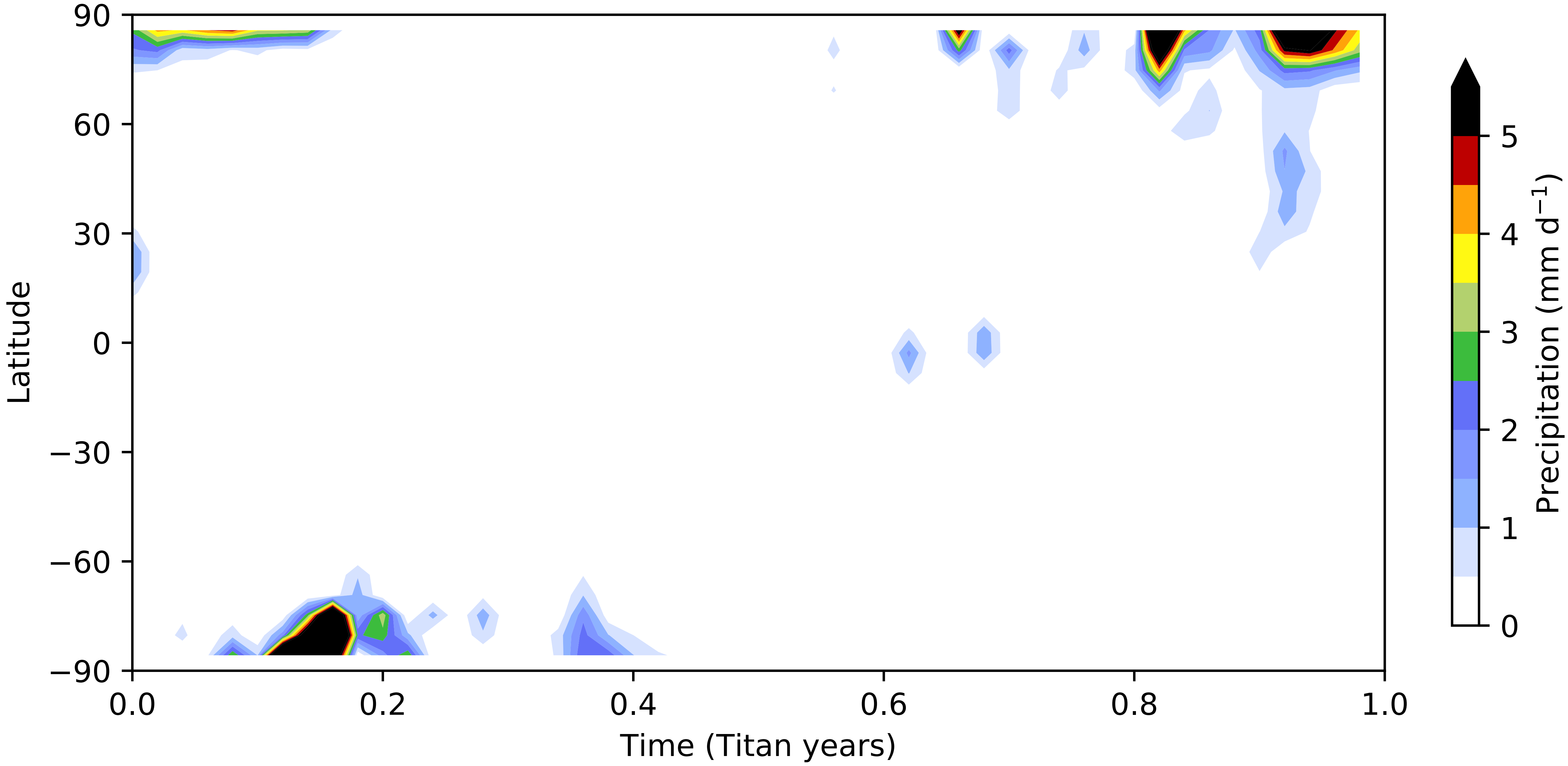
Lorenz et al. (2018)

The Methane Inventory in Contact with the Atmosphere Strongly Impacts the Climate

Globally moist surface



Seas only



- **Simulations with the Titan Atmospheric Model (TAM; Lora et al. 2015, Icarus 250)**
- **Agrees with 2D simulations of different total methane reservoirs (Mitchell 2008, JGR 113)**

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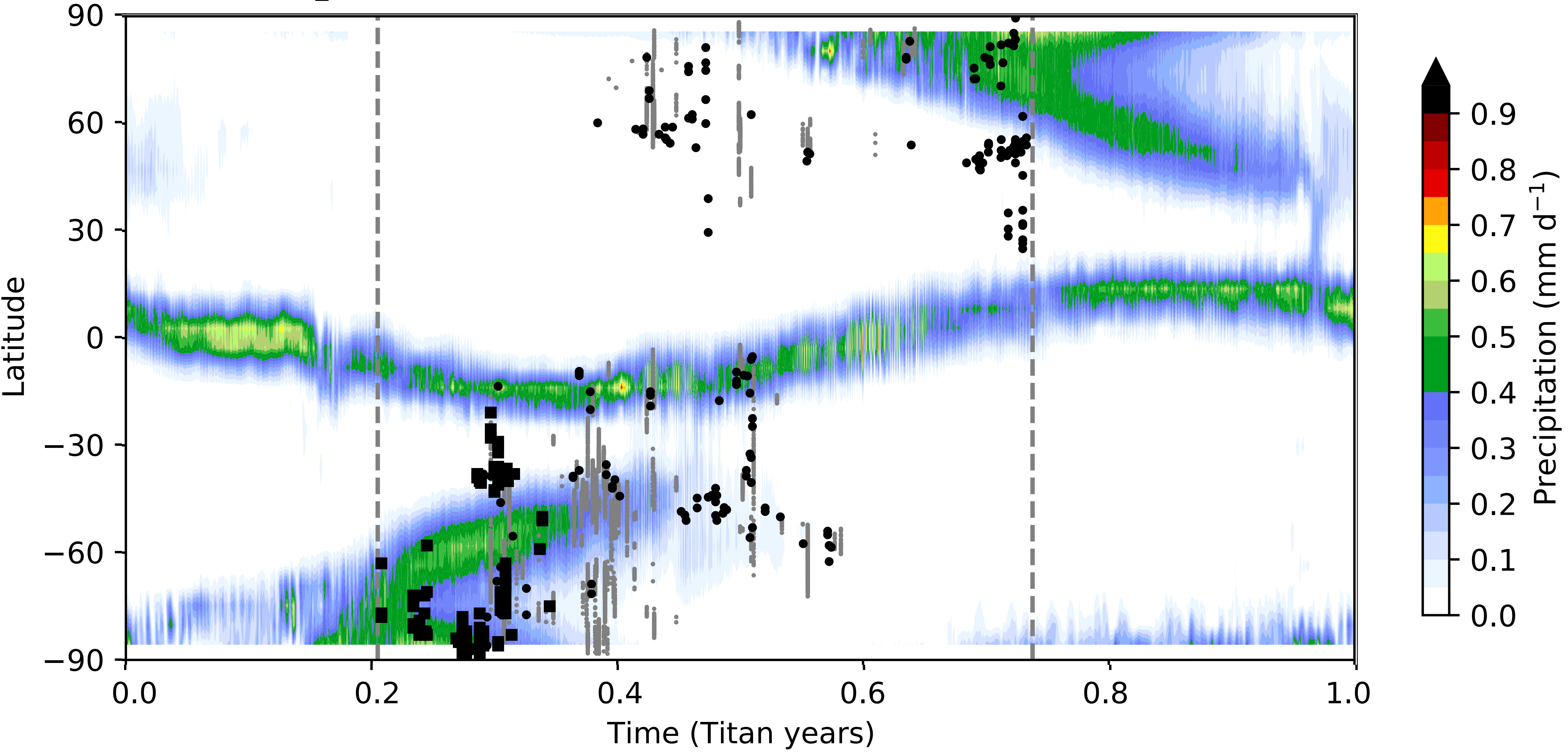

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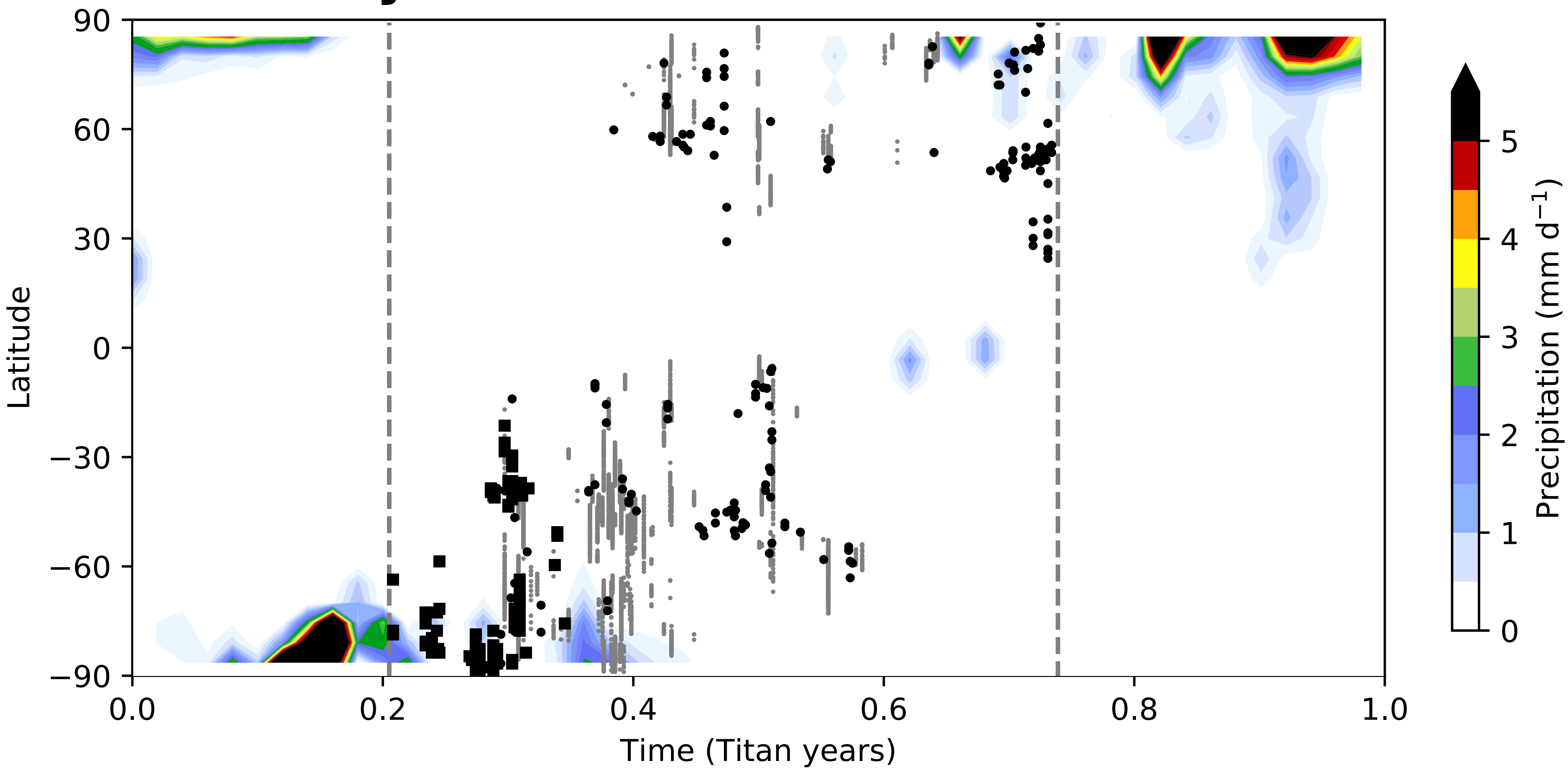
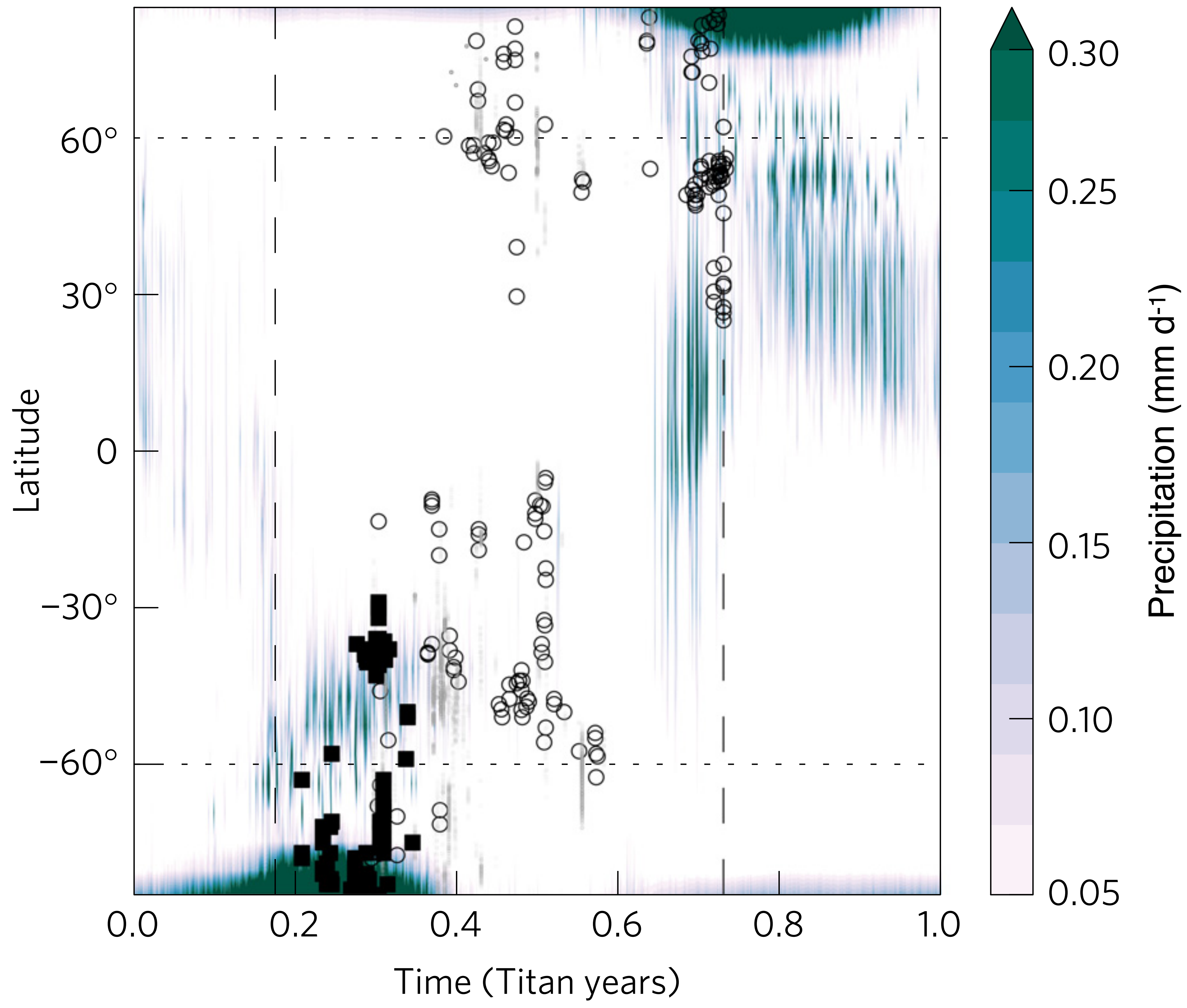


- **Cloud observations from Cassini and ground-based instruments**

The Most Successful **Idealized** Surface Methane Configuration Is One With Polar "Wetlands"…



Faulk et al. (2017)

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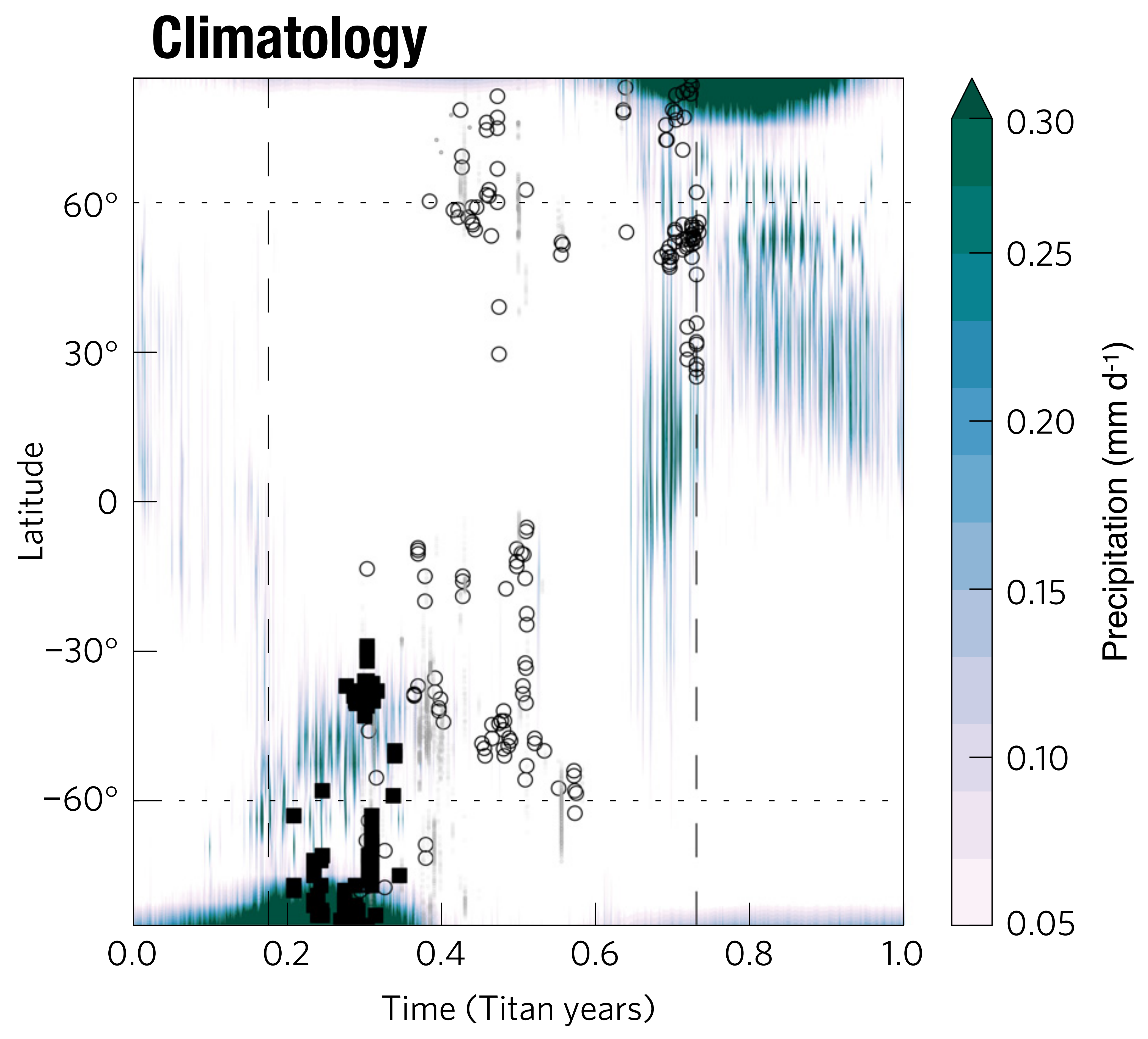
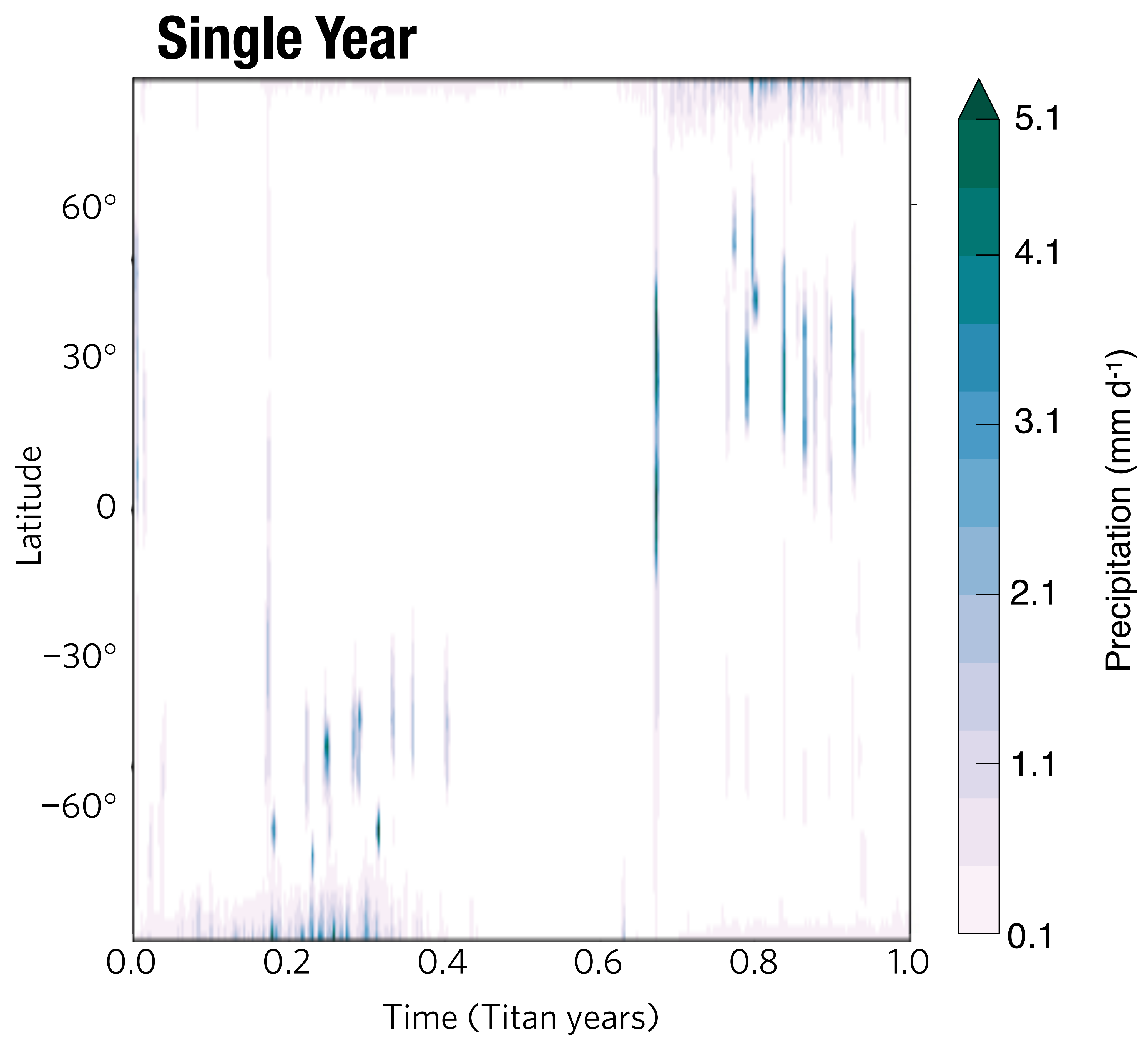
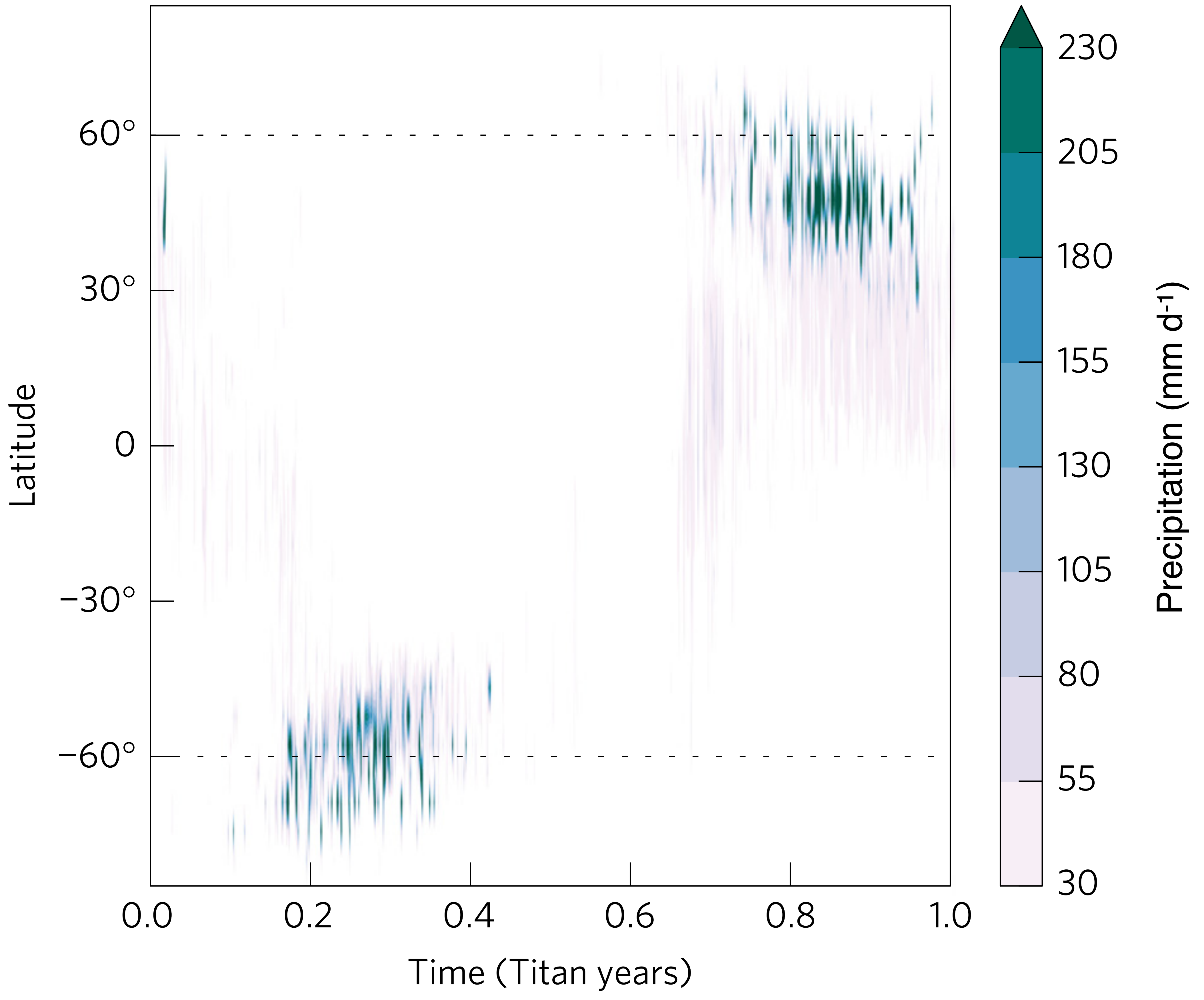
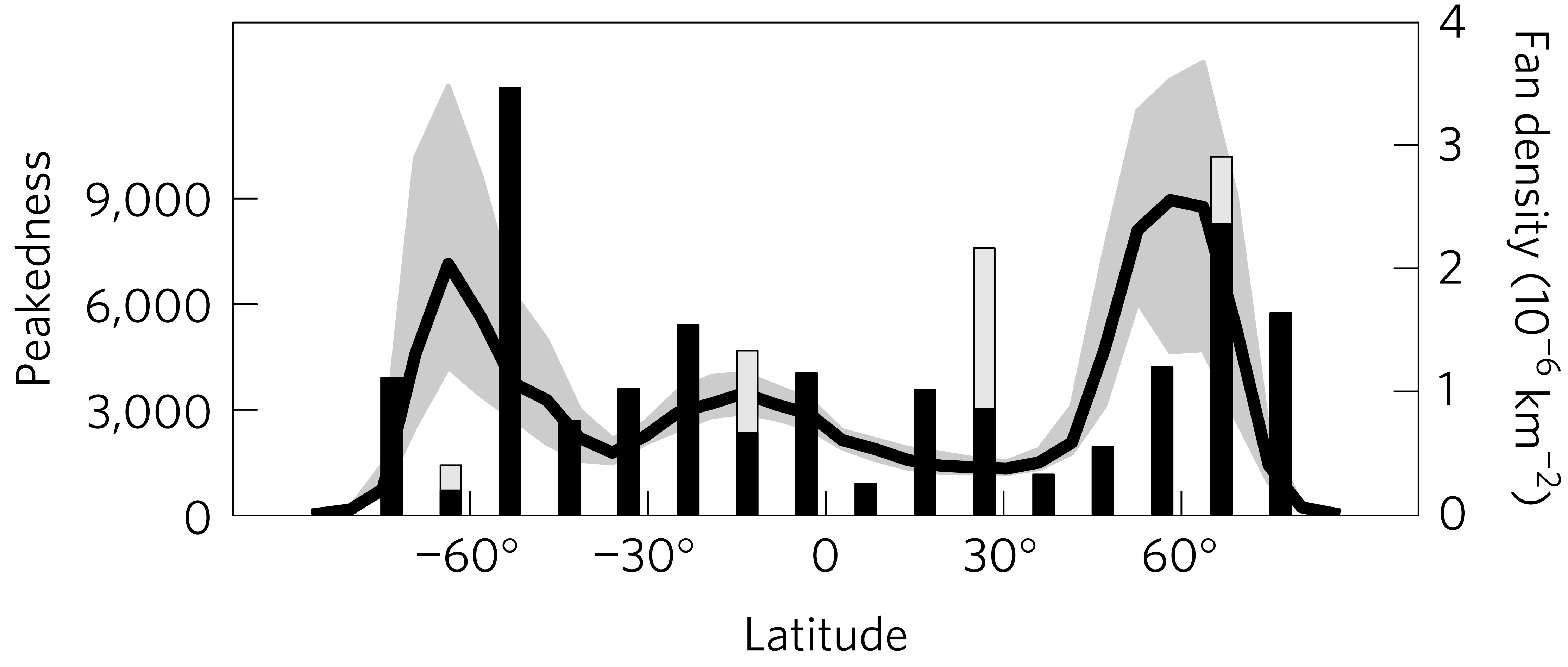


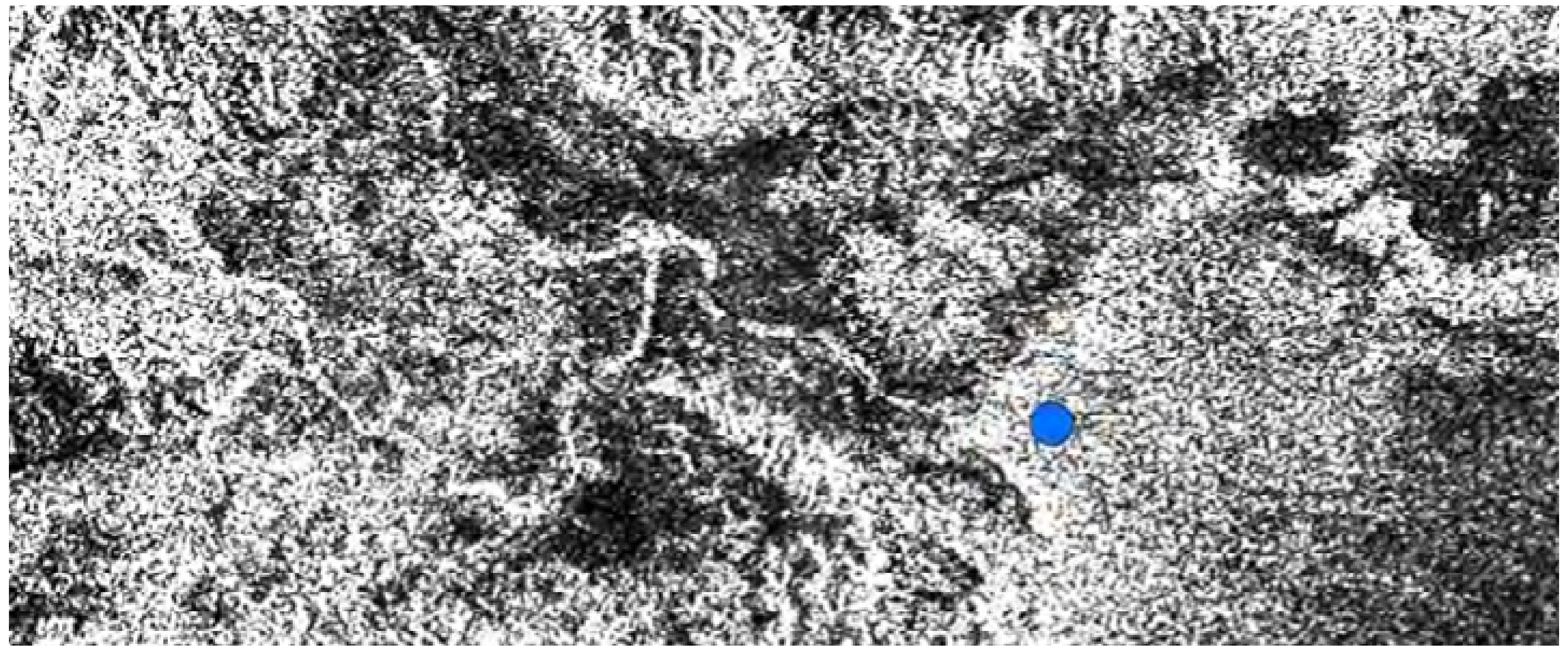


Faulk et al. (2017)

…Which Produces Intense High Mid-Latitude Storms that Correlate With Observed Geomorphic Features



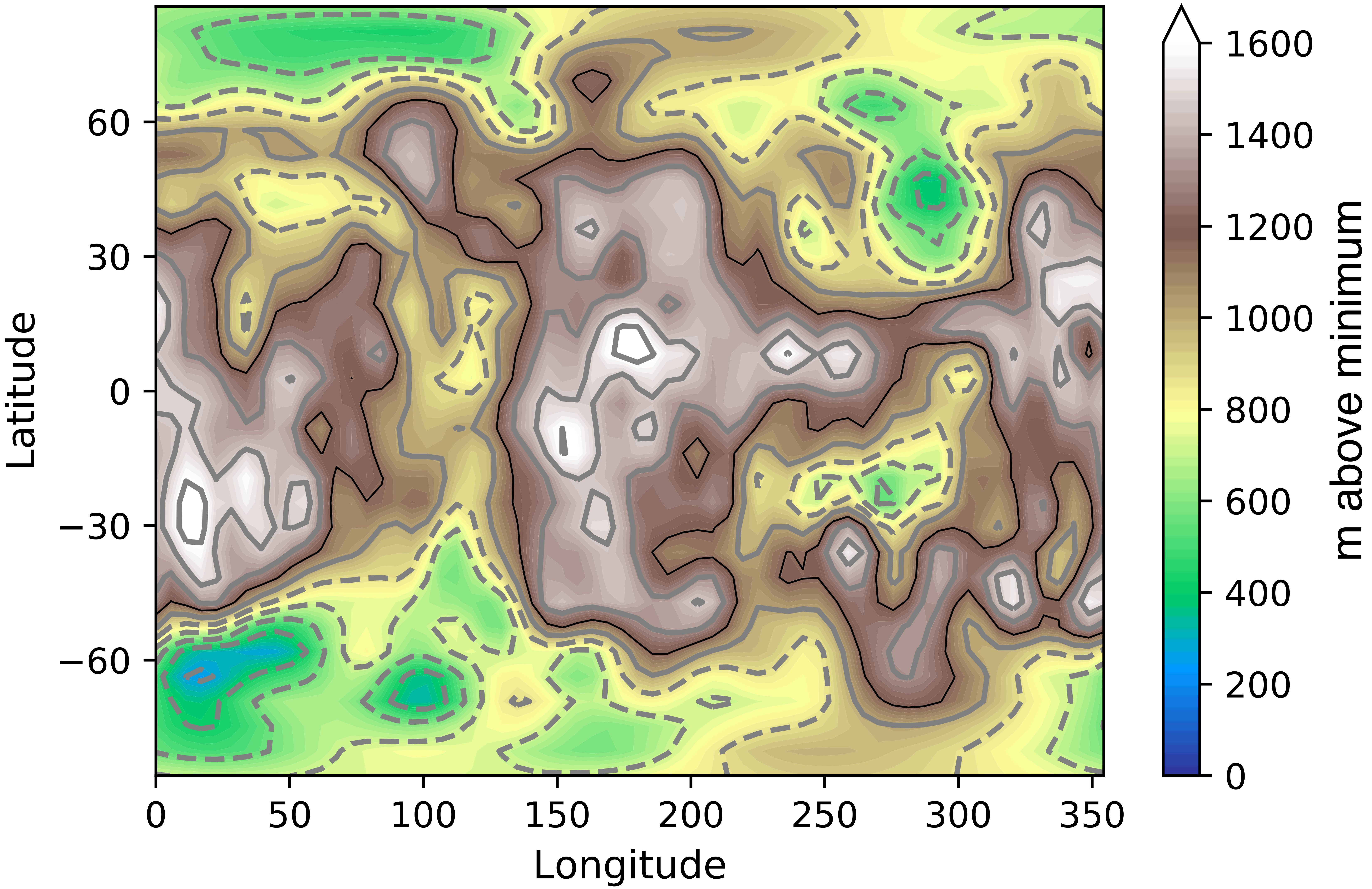




Birch et al. (2016)

Faulk et al. (2017)

Titan's Polar Regions Are Low-Lying; Equator Is Higher Elevation



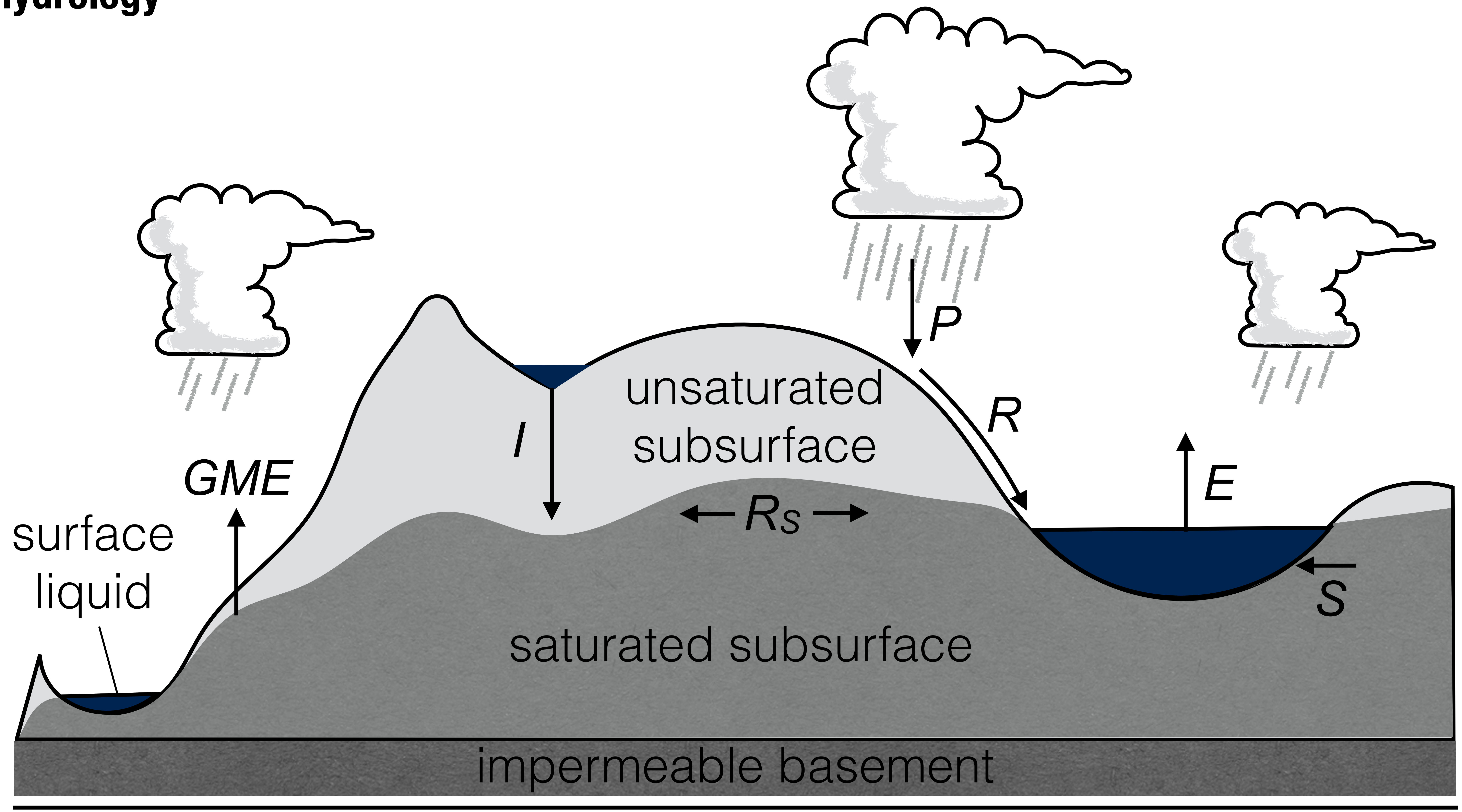
Corlies et al. (2017)

Does This Imply Poleward Surface/Subsurface Flow?
Need a Self-Consistent Hydrologic Model to Address Such Questions

- Development of a **coupled atmosphere–surface hydrology** climate model

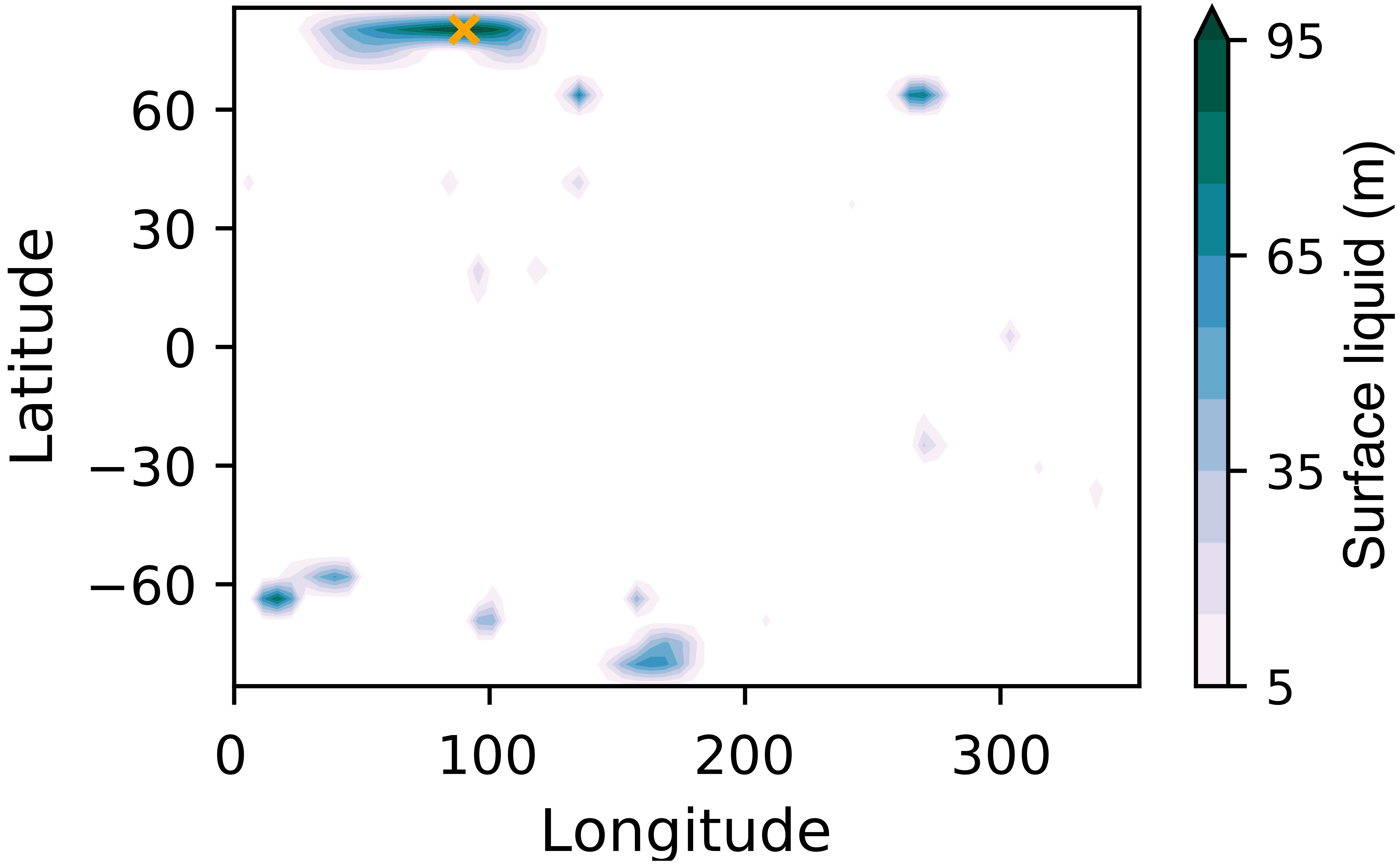
Does This Imply Poleward Surface/Subsurface Flow?
Need a Self-Consistent Hydrologic Model to Address Such Questions

- **TAM + hydrology**



Fully Coupled Simulations Quickly Reproduce a Moist-Poles, Dry-Equator Climate

- **Simulations initialized from spun-up atmosphere plus a dry surface and 1200 m methane table**



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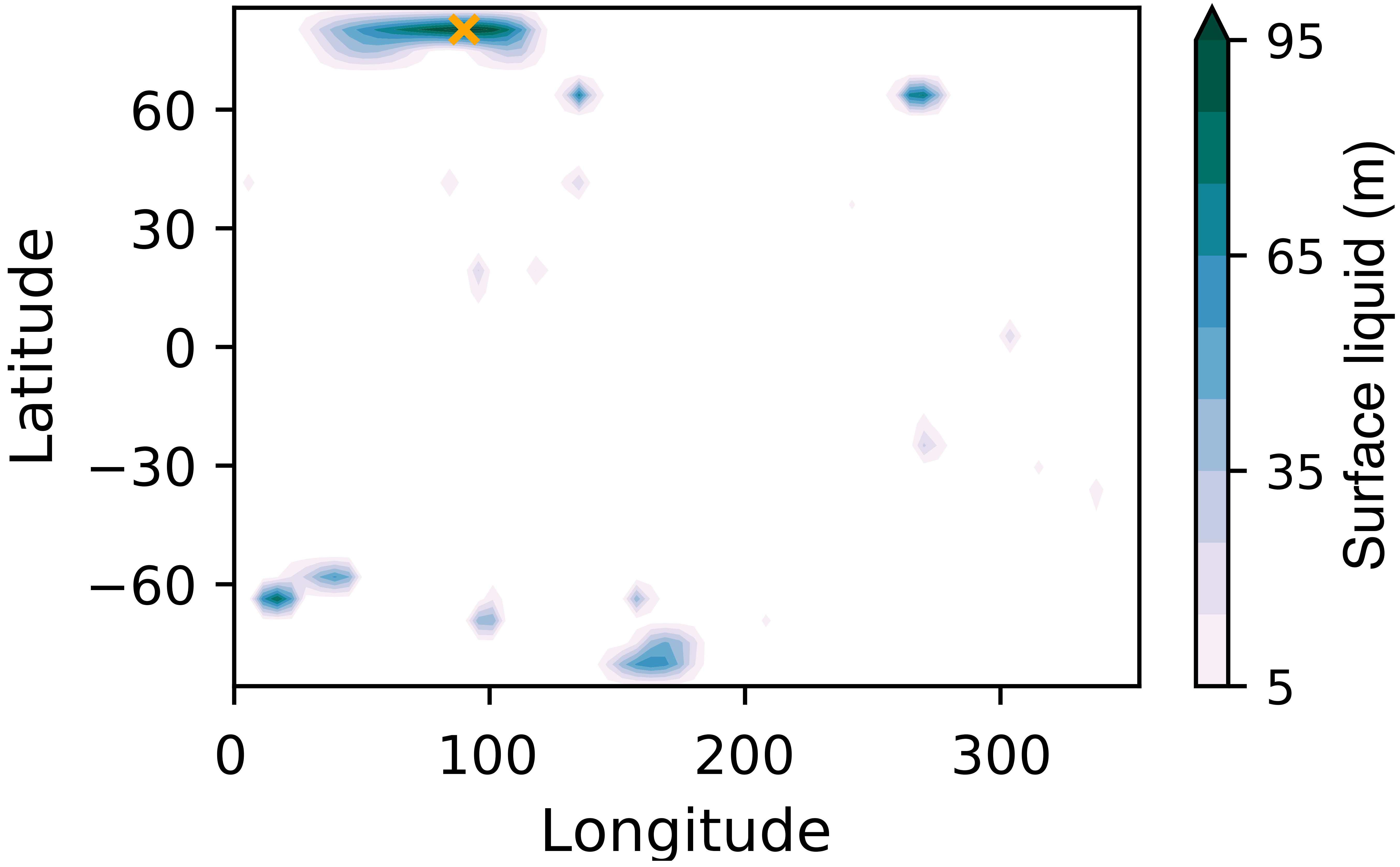

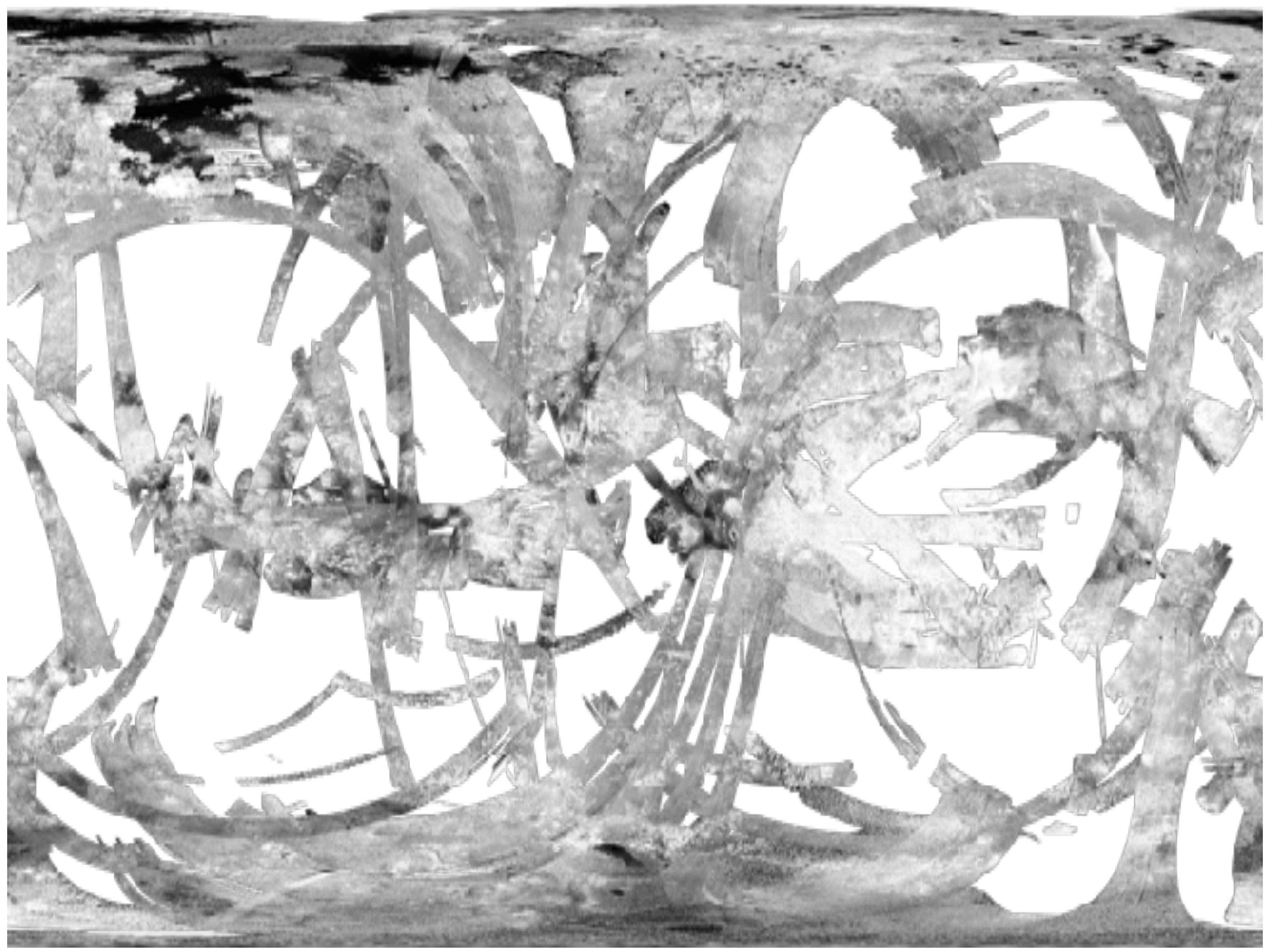

USGS/Cassini SAR

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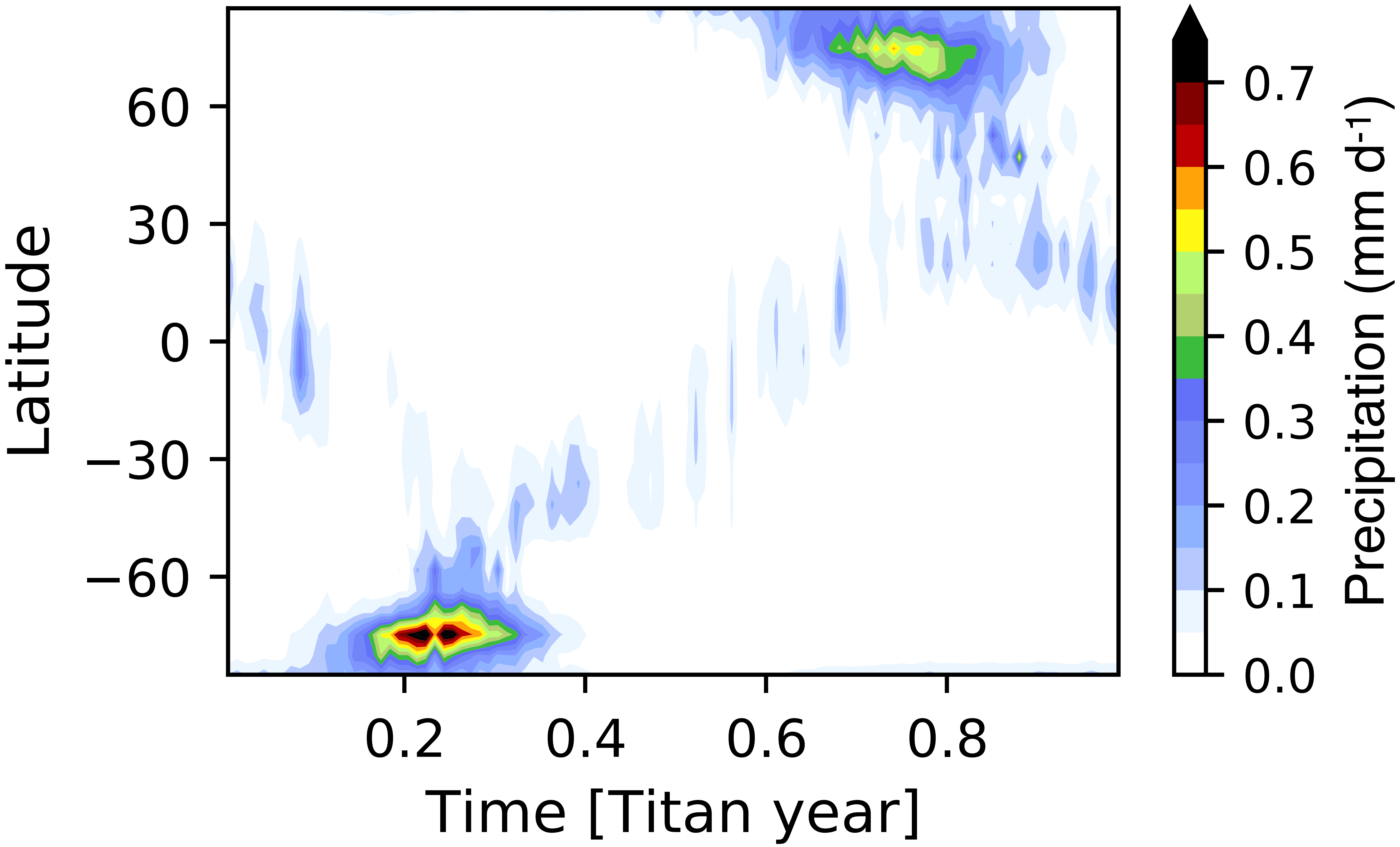

Infiltration, Runoff, and Subsurface Seepage Are Important Contributors to the Surface Moisture Budget

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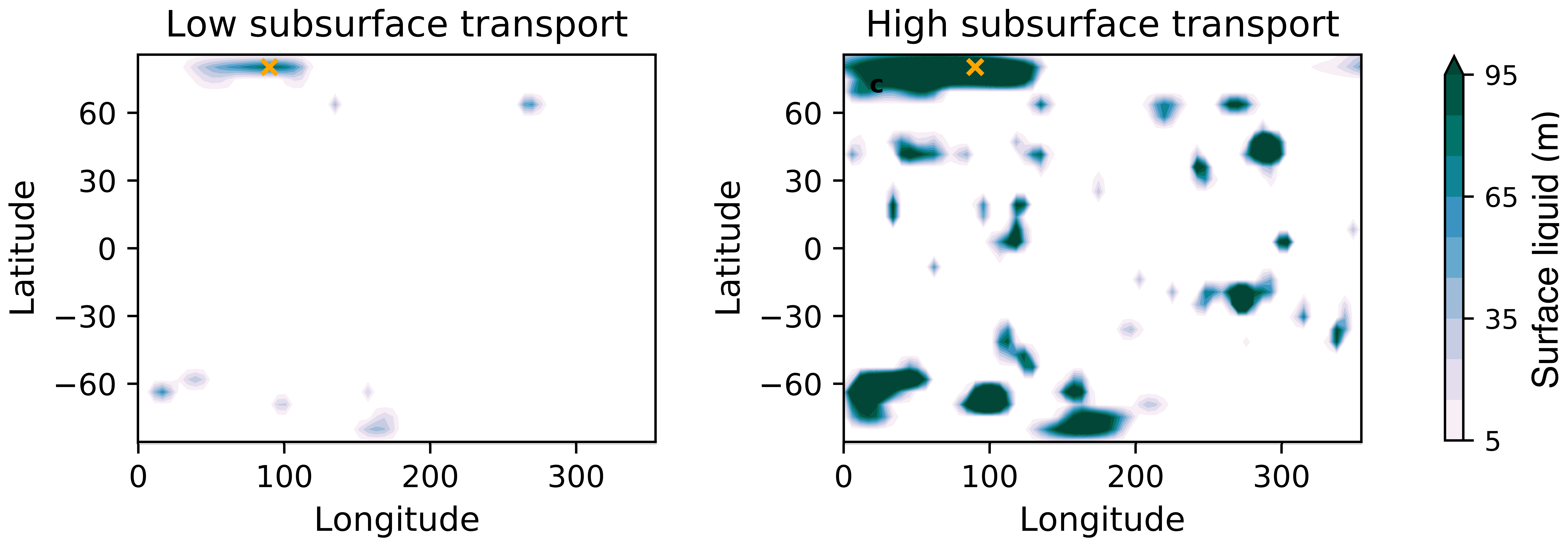
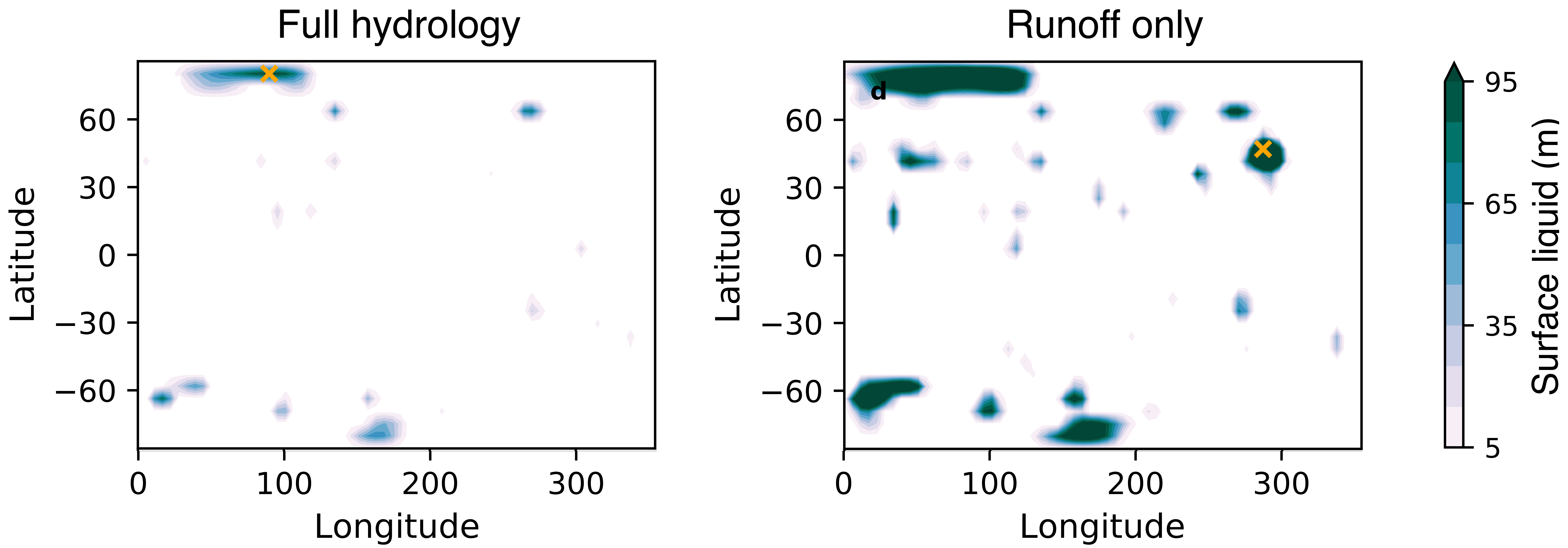
Sensitivity Simulations Indicate the Importance of Subsurface Methane Transport

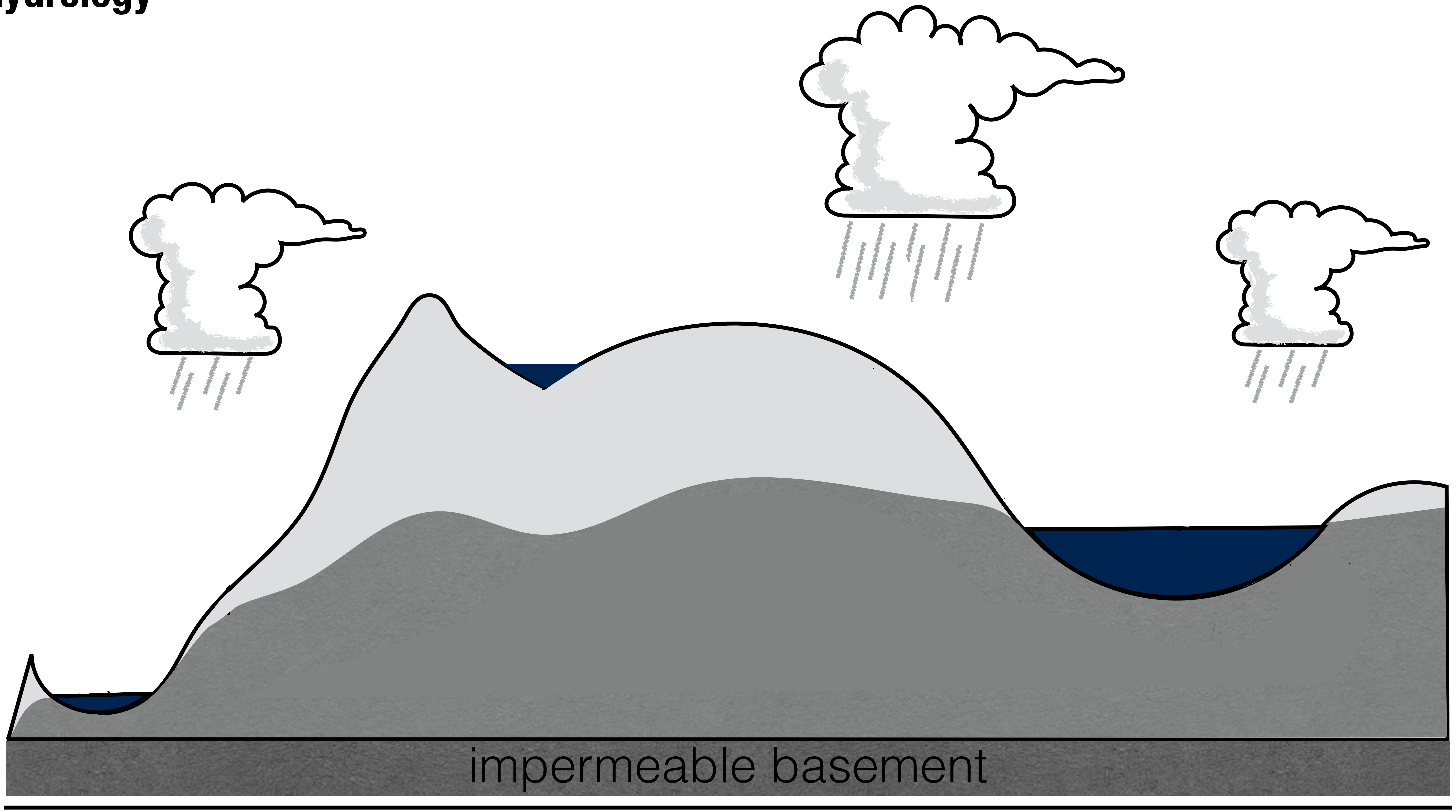


Sensitivity Simulations Indicate the Importance of Subsurface Methane Transport—Surface Runoff Alone Does Not Reproduce Obs.



Coupled Simulations Suggest a Methane Cycle Involving Transport in the Atmosphere, on the Surface, and in the Subsurface

- **TAM + hydrology**



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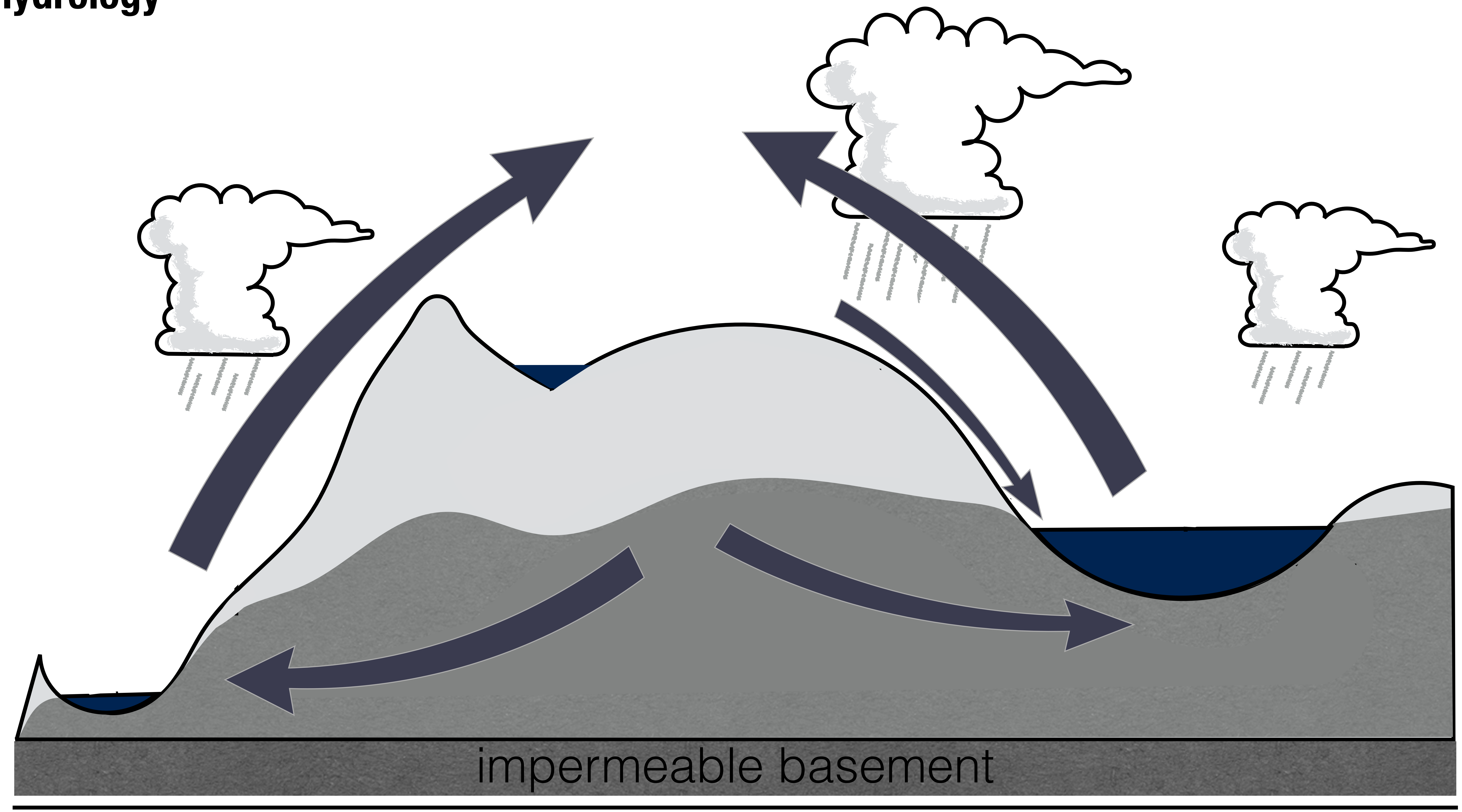

Conclusions

- Titan's topography and surface liquid distribution suggest a hydrology component to the methane hydrologic cycle
- We have developed a coupled surface–atmosphere model with **fully self-consistent** hydrology and net precipitation
- This coupled model quickly reproduces observed surface liquid distributions, as well as a moist-polar/dry-equatorial climate
- Methane infiltration, surface runoff, and seepage from the subsurface (as well as ground-methane evaporation) are important terms in the surface moisture budget
- Sensitivity simulations indicate an important role for the transport of liquid methane in the subsurface, which occurs globally in our model
- Ongoing and future work are needed to refine/constrain physical parameters of the hydrology model
- Future work will also include the orographic impact of topography on the atmosphere to address an additional potential feedback

Titan Atmospheric Model (TAM)

GCM simulations of Titan's middle and lower atmosphere and comparison to observations

Juan M. Lora [a,*], Jonathan I. Lunine [b], Joellen L. Russell [a]

Icarus 250 (2015) 516–528

Regional patterns of extreme precipitation on Titan consistent with observed alluvial fan distribution

S. P. Faulk*, J. L. Mitchell, S. Moon and J. M. Lora

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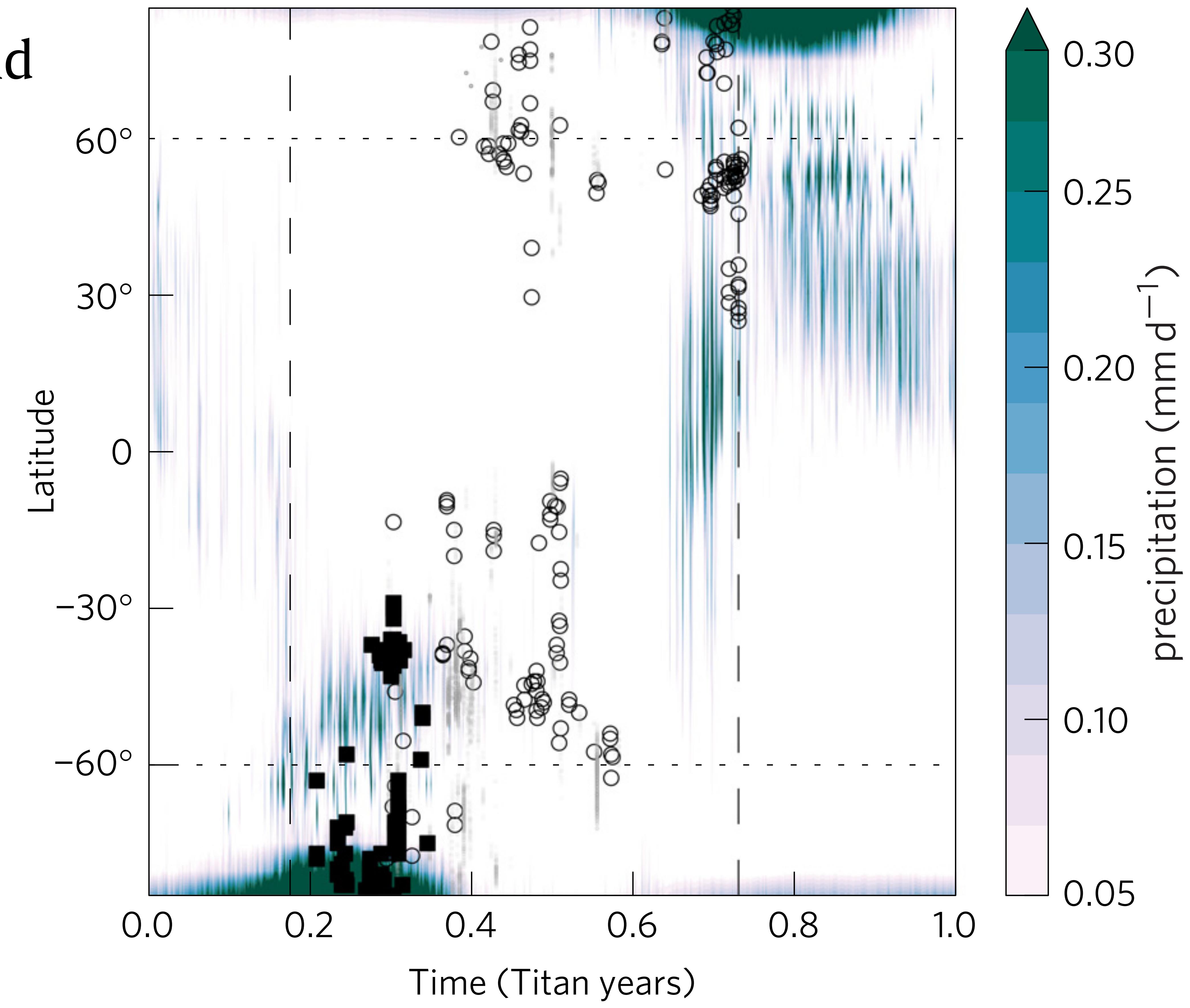

UCLA

Topography Coupled to the Atmosphere Impacts Average Precipitation