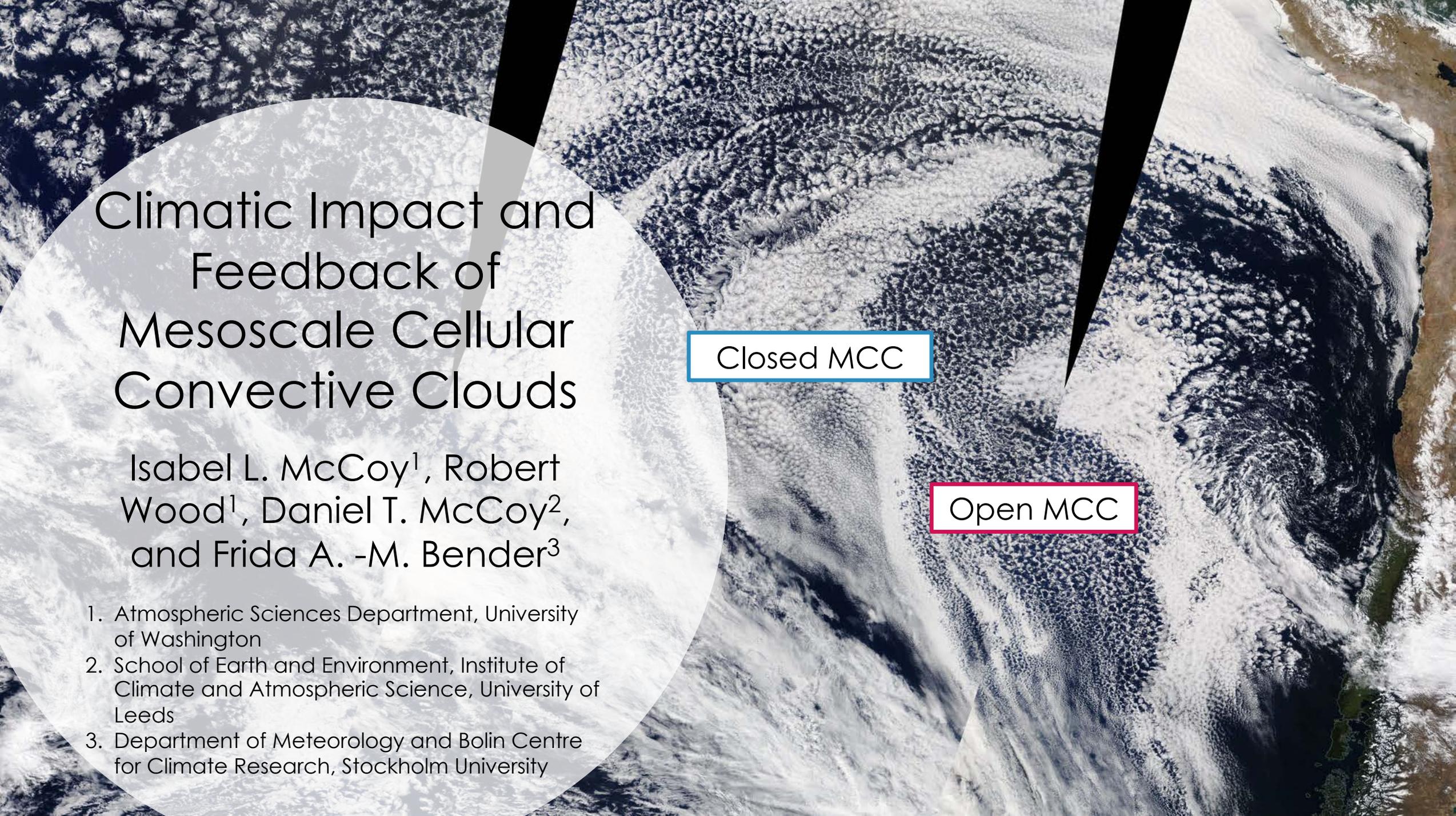
A satellite image of Earth showing cloud patterns over the ocean. The image is dominated by a large, circular white area that serves as a background for the text. The background image shows a vast expanse of the ocean with intricate cloud formations, including a large, dark, swirling cloud mass on the right side. Two black, triangular shapes point towards the center of the image, one from the top and one from the right.

Climatic Impact and Feedback of Mesoscale Cellular Convective Clouds

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Wood¹, Daniel T. McCoy²,
and Frida A. -M. Bender³

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2. School of Earth and Environment, Institute of Climate and Atmospheric Science, University of Leeds
3. Department of Meteorology and Bolin Centre for Climate Research, Stockholm University



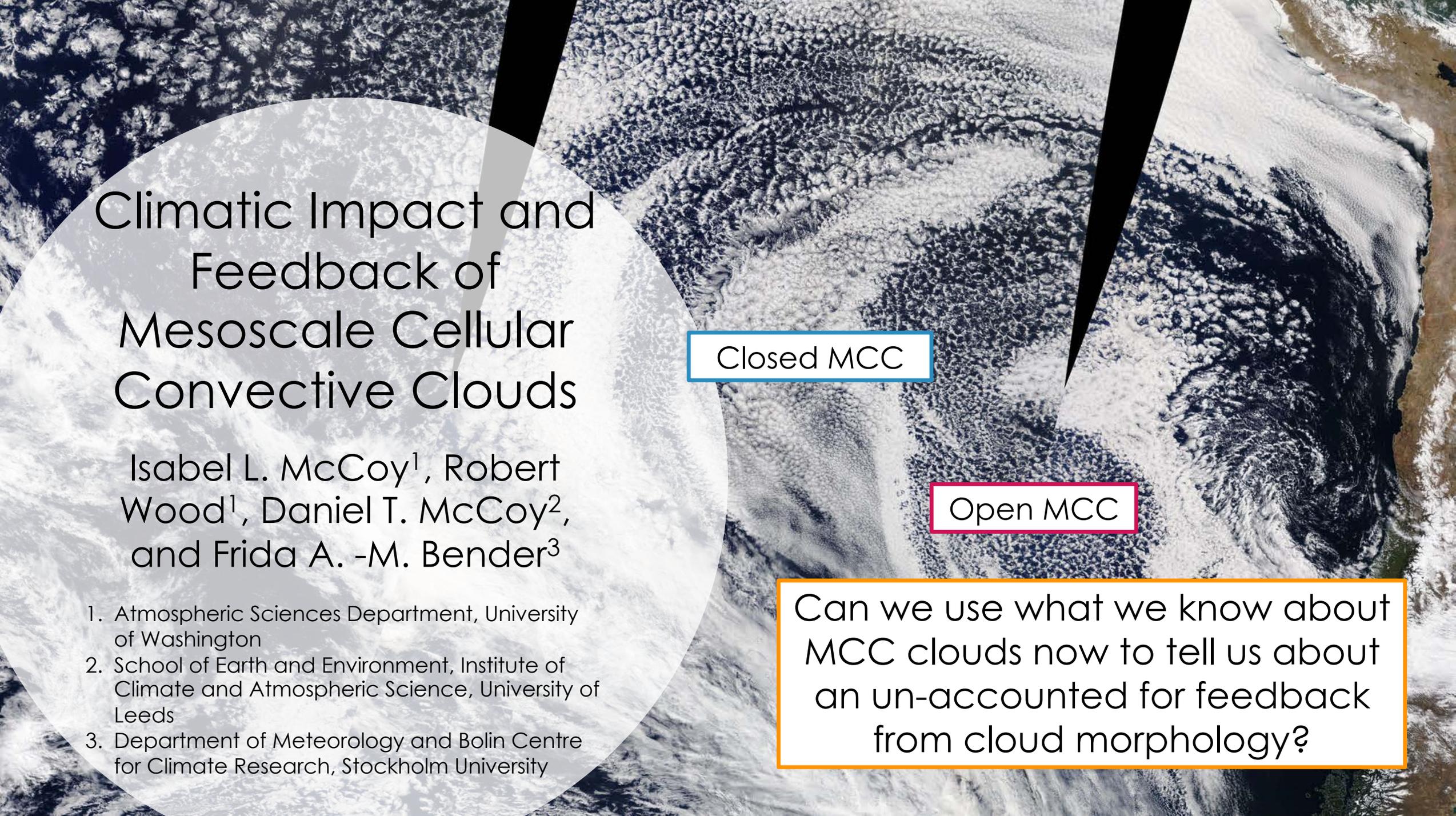
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Closed MCC

Open MCC



Climatic Impact and Feedback of Mesoscale Cellular Convective Clouds

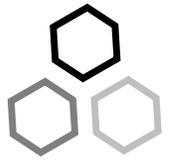
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Closed MCC

Open MCC

Can we use what we know about MCC clouds now to tell us about an un-accounted for feedback from cloud morphology?



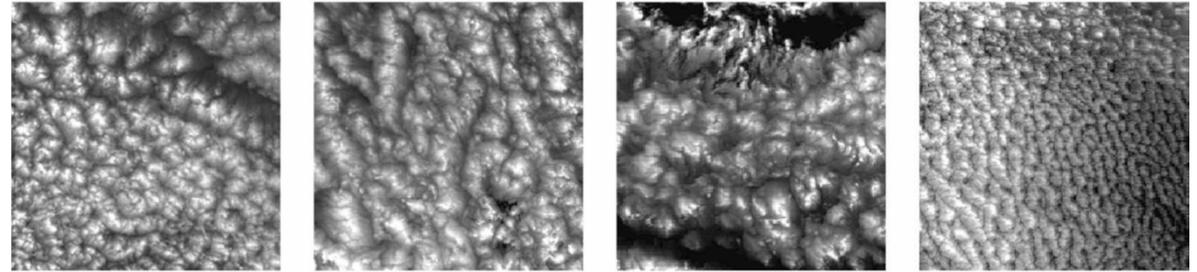
MCC Dataset

Mesoscale cellular convection (MCC) identifications derived using neural network algorithm from Wood and Hartmann (2006).

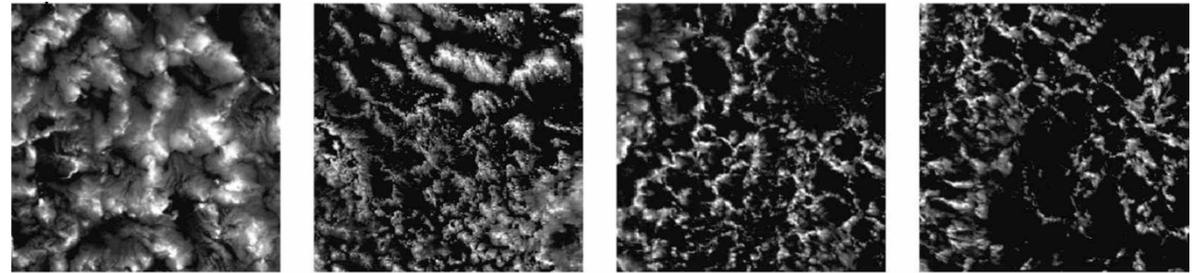
Algorithm applied to scenes of 256x256 km² LWP from MODIS Collection 6 data for years 2003-2011.

Expansion from identifications used in McCoy et al. (2017) for MODIS Collection 5.1 data for 2008.

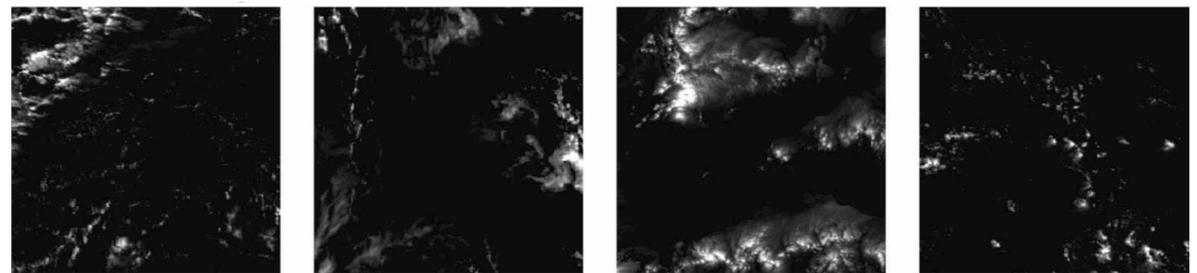
Closed MCC



Open MCC



Cellular but Disorganized

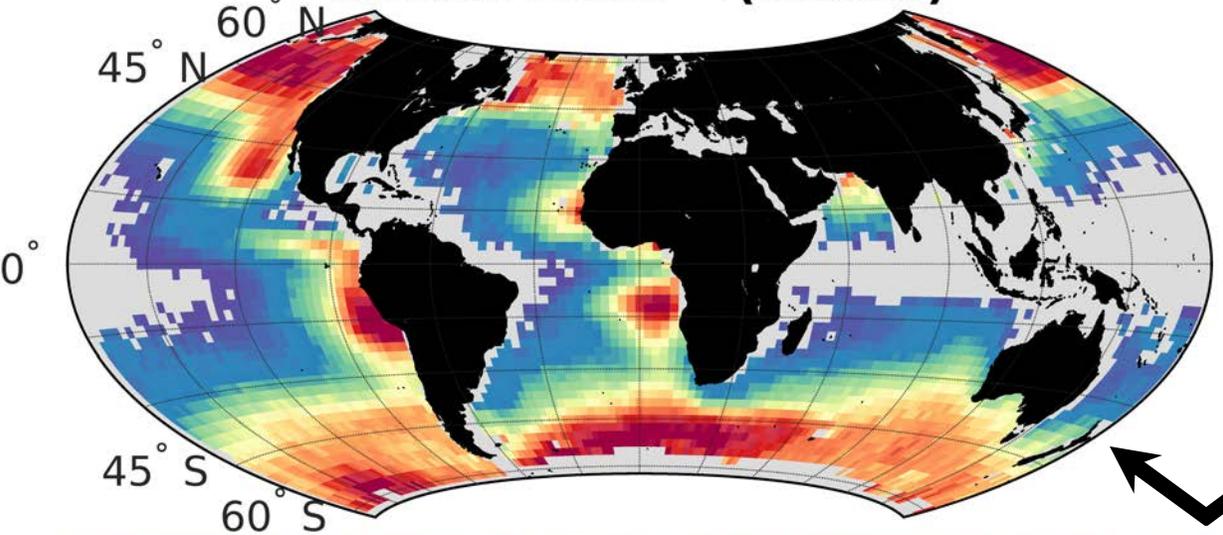


LWP (g m⁻²)

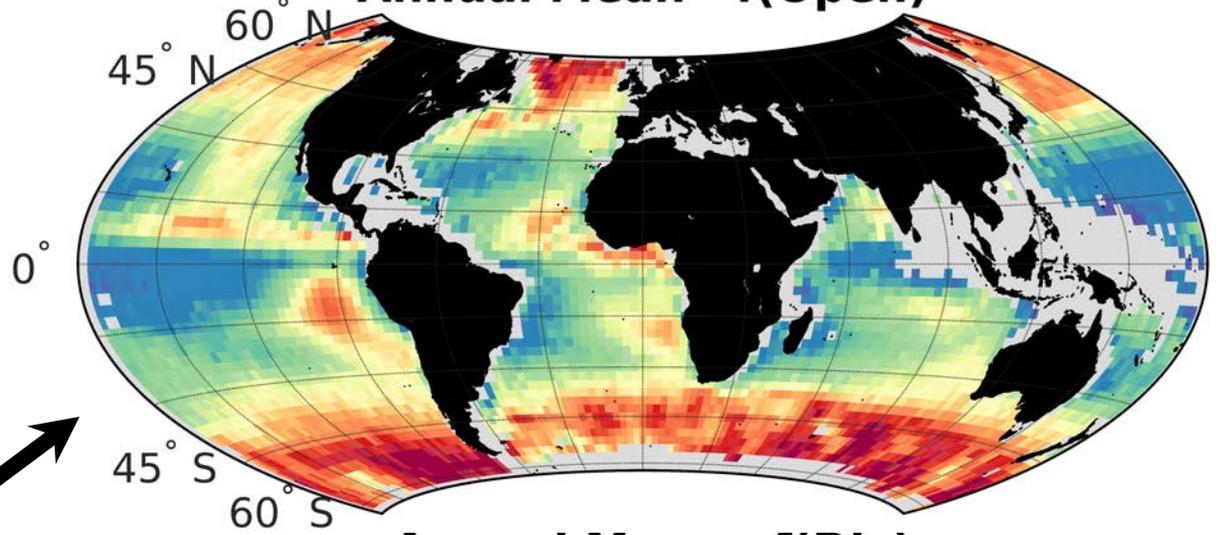


MCC Climatology

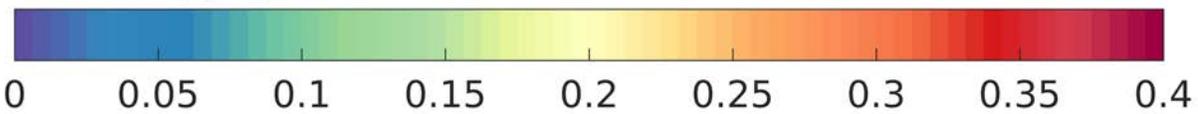
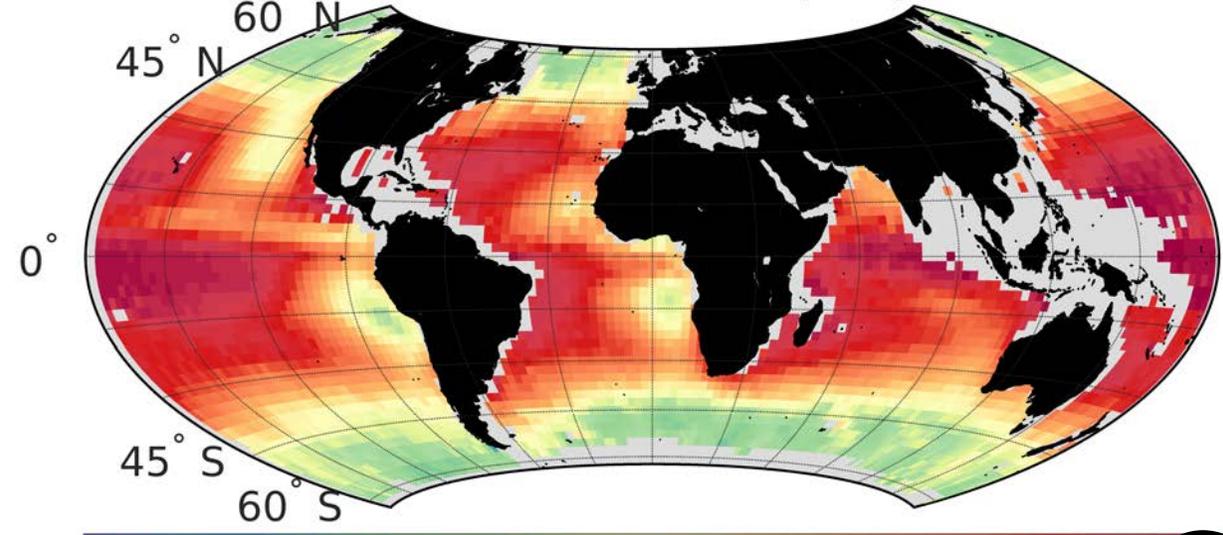
Annual Mean - f(Closed)



Annual Mean - f(Open)



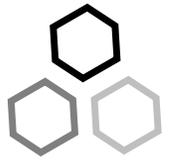
Annual Mean - f(Dis)



Relative Frequency of Occurrence of Low Cloud Types Identified by NNA

— Insignificant Number of Identifications





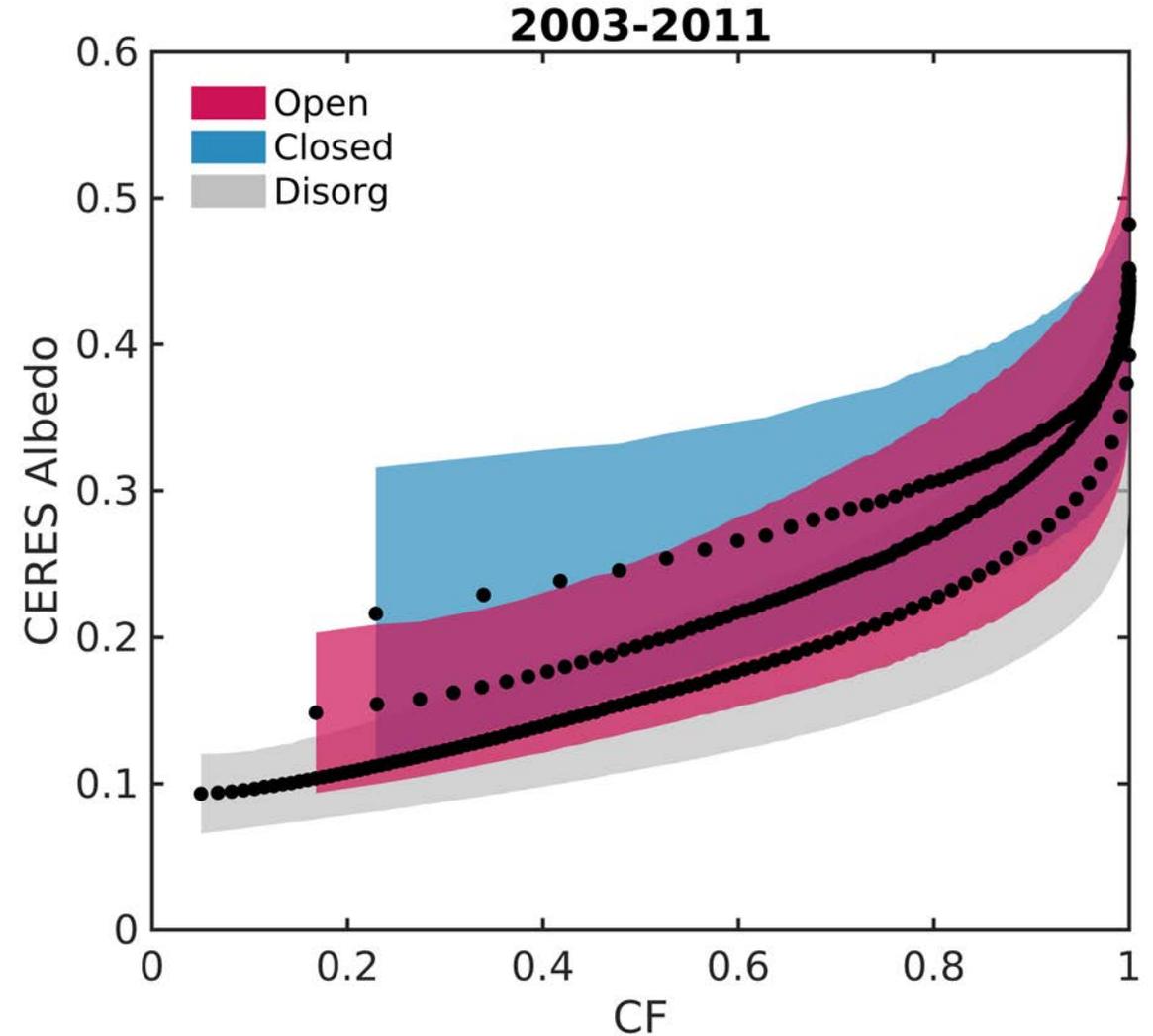
MCC Radiative Properties

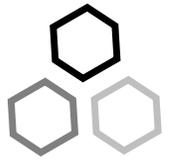
Closed MCC clouds have a higher scene albedo than Open MCC for the same cloud fraction.

Disorganized clouds have even lower albedo for same cloud fraction.

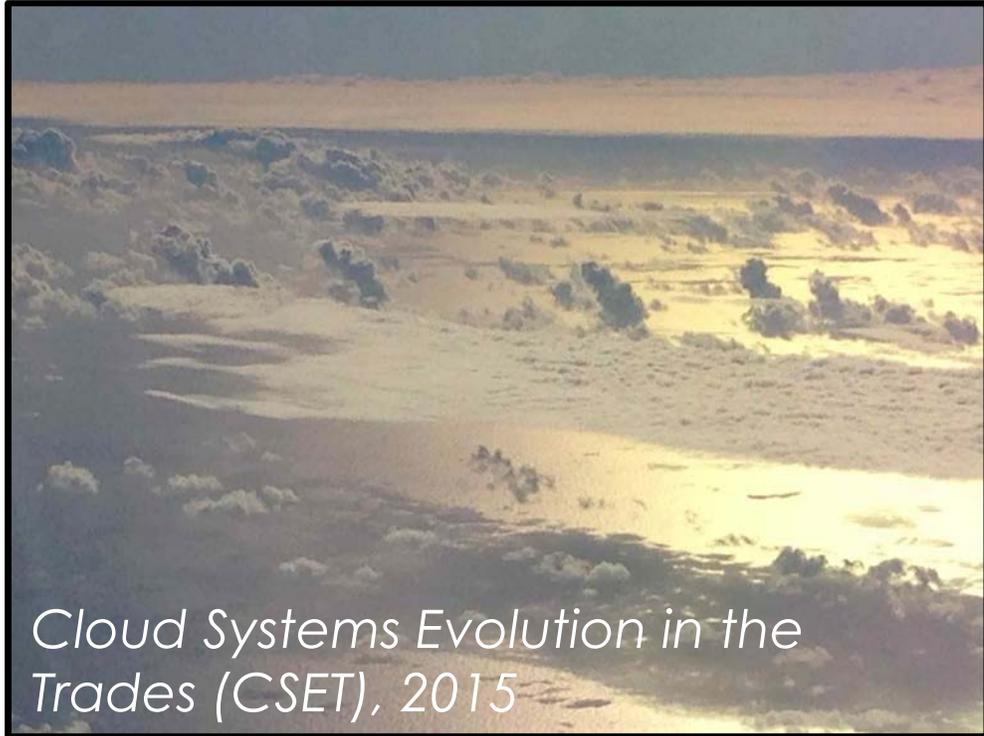
Points are for mean albedo within each cloud fraction quantile bin. Shading is one standard deviation and indicates range of data.

Consistent with McCoy et al. (2017)



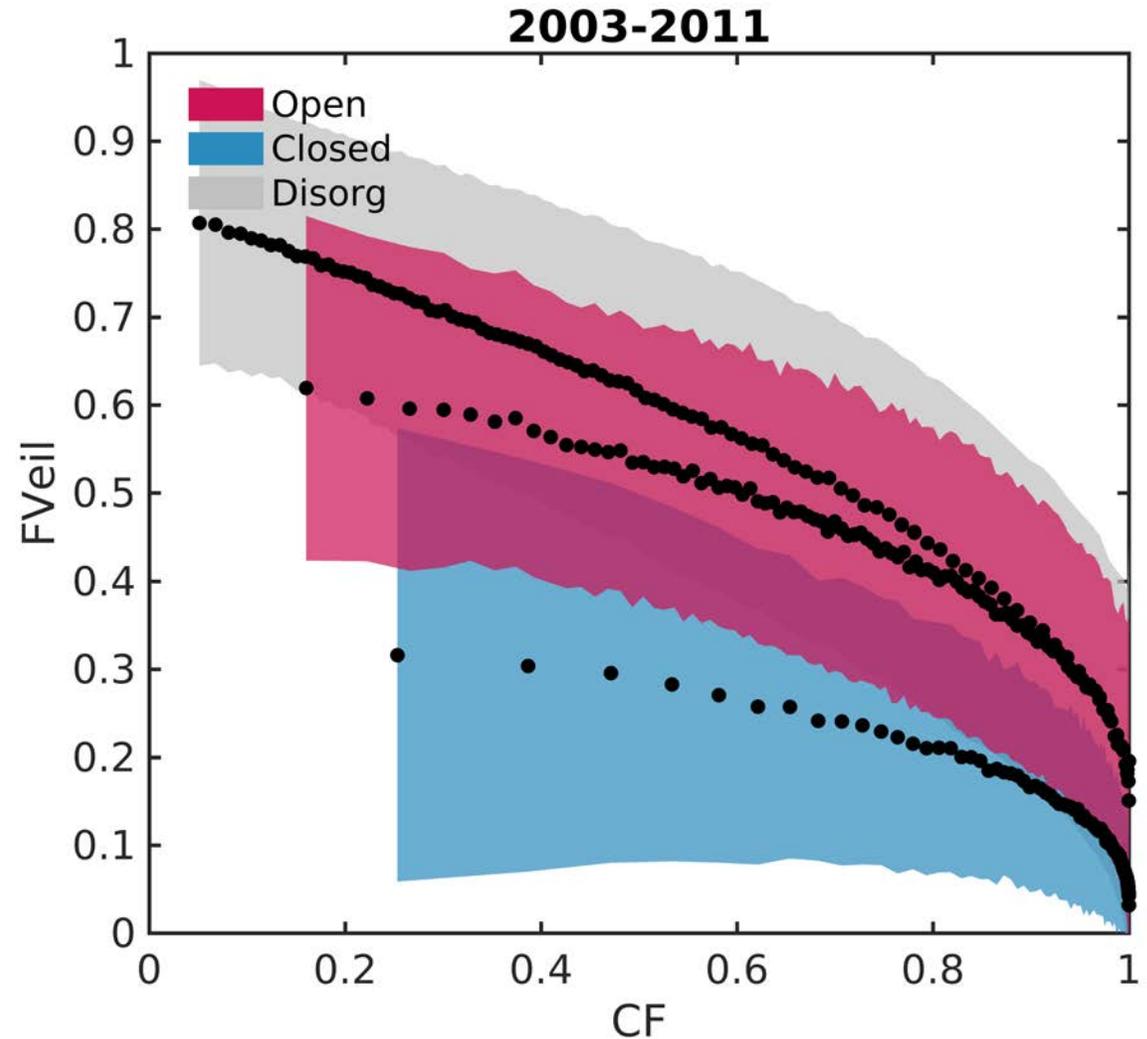


MCC Radiative Properties



Points are for mean veil cloud frequency ($\tau < 3$, as in O et al. 2018) within each cloud fraction quantile bin. Shading is one standard deviation and indicates range of data.

Closed MCC clouds have fewer veil clouds ($\tau < 3$) than Open MCC and Disorganized clouds for the same cloud fraction.





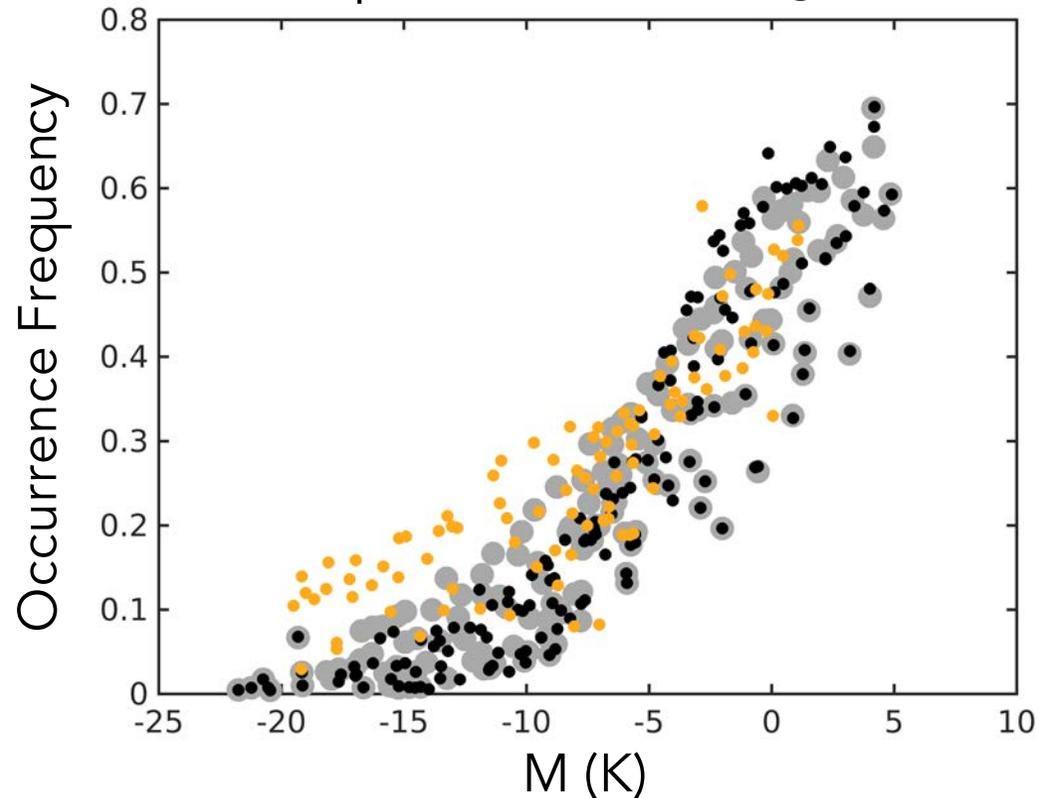
MCC Prediction

MCC Occurrence frequency can be predicted by the Marine Cold Air Outbreak (MCAO) Index, M :

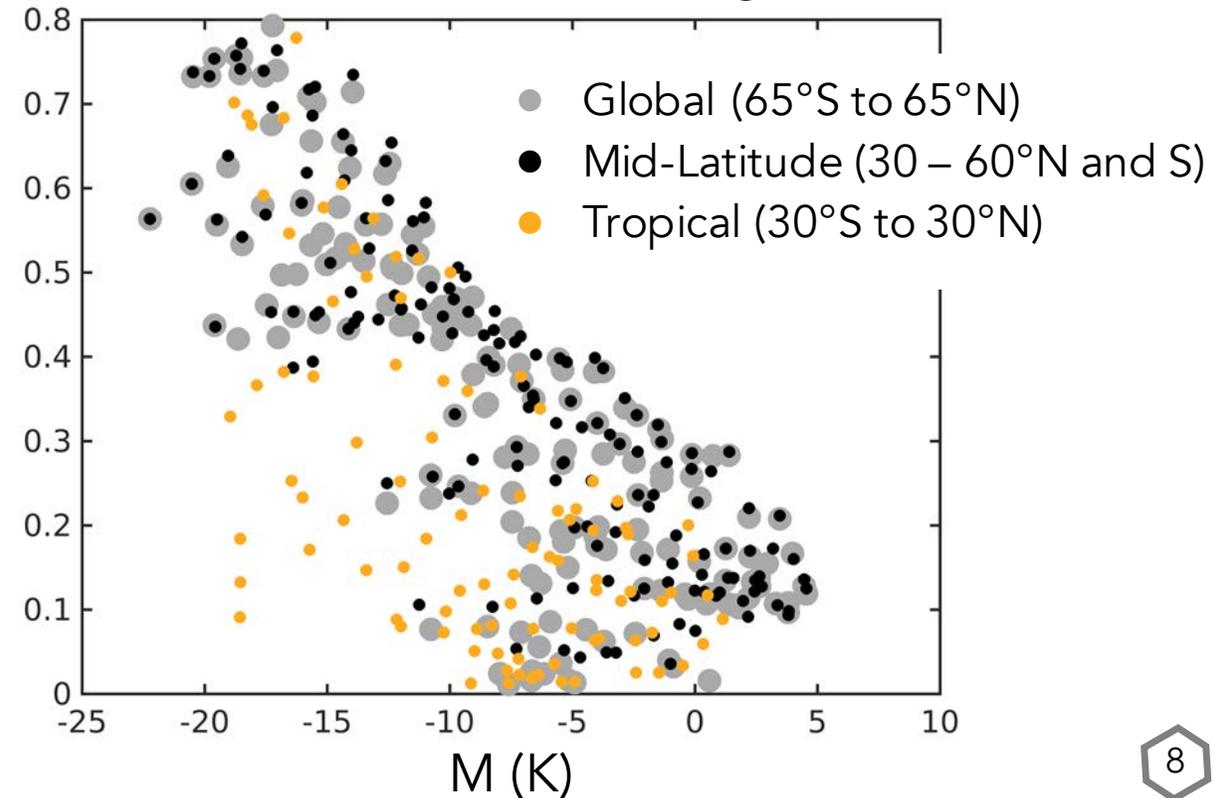
$$M = \theta_{\text{SST}} - \theta_{800\text{hPa}} \cong \Delta T - \text{EIS}$$

Points are for data binned by EIS , ΔT where EIS is estimated inversion strength and ΔT is sea-air temperature difference (McCoy et al. (2017))

(c) Open MCC — Regional



(d) Closed MCC — Regional

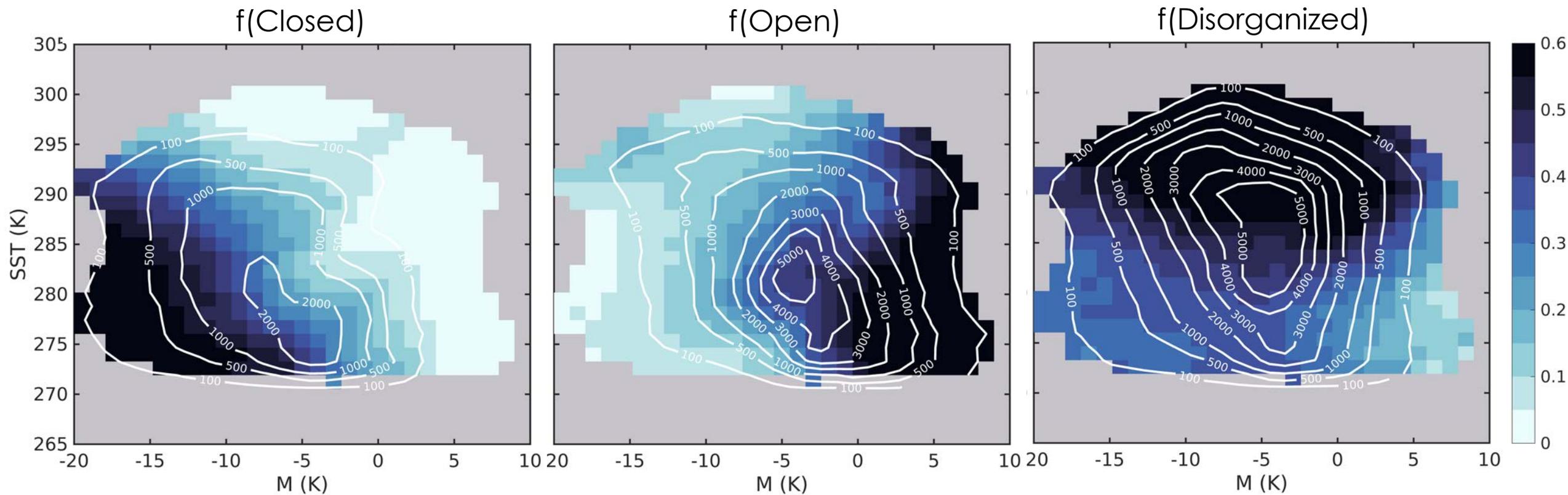




MCC Prediction

MCC occurrence depends on both M and SST in the present day.

Example shown for multi-year MCC dataset binned by M and SST in mid-latitudes (30-60°S, N)



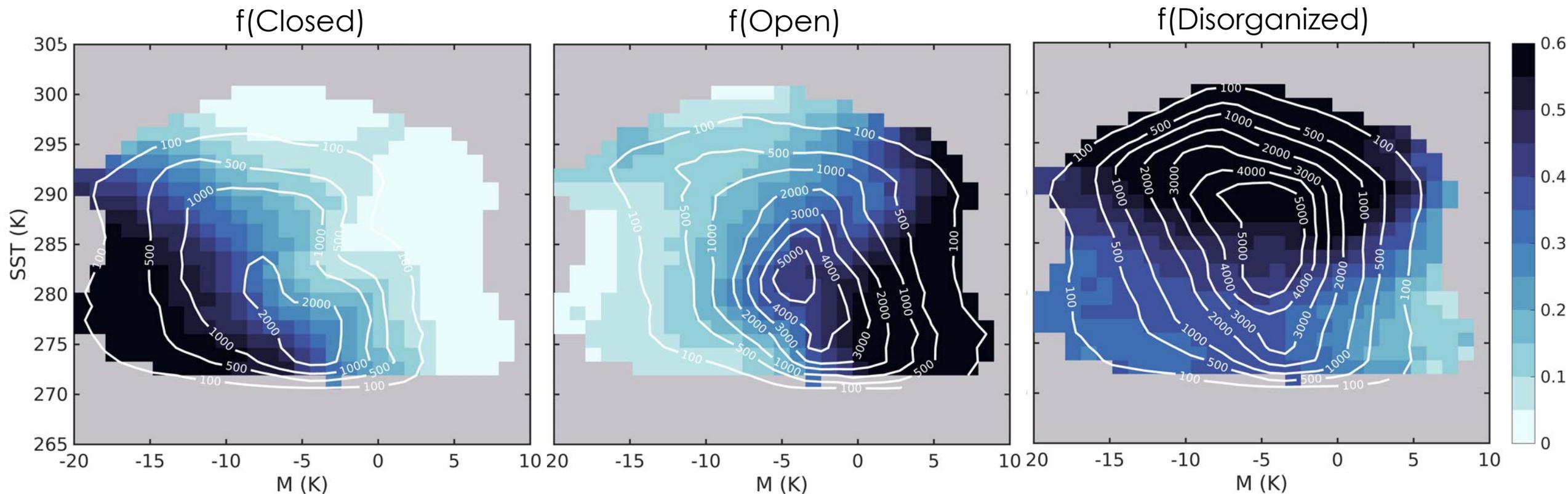


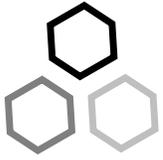
MCC Prediction

Example shown for multi-year MCC dataset binned by M and SST in mid-latitudes (30-60°S, N)

MCC occurrence depends on both M and SST in the present day.

Assuming relationships hold under warming, we can use analysis analogous to Qu et al. (2015) for calculating morphology changes.



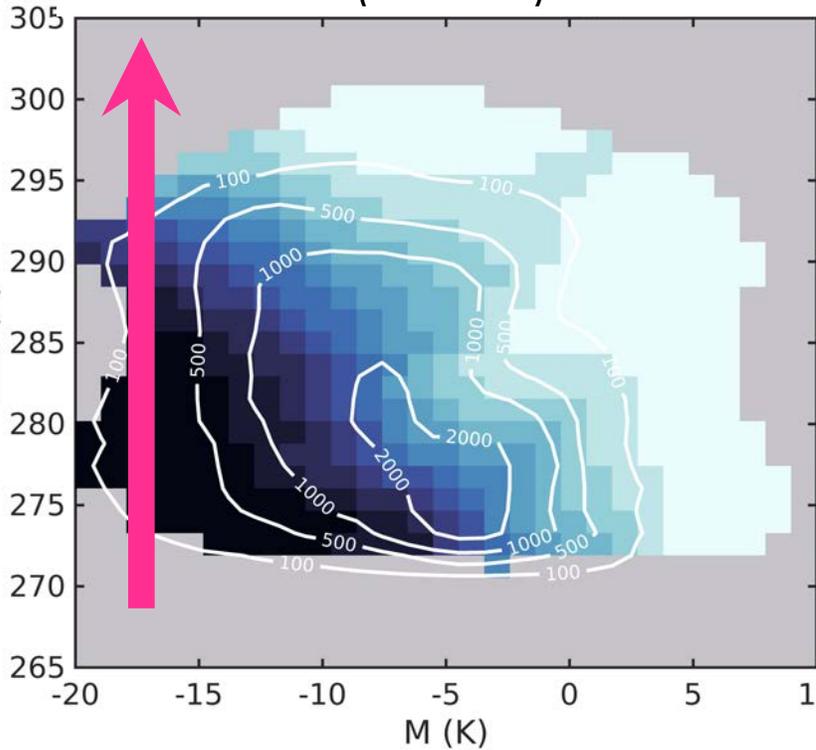


How will MCC occurrence change in the future?

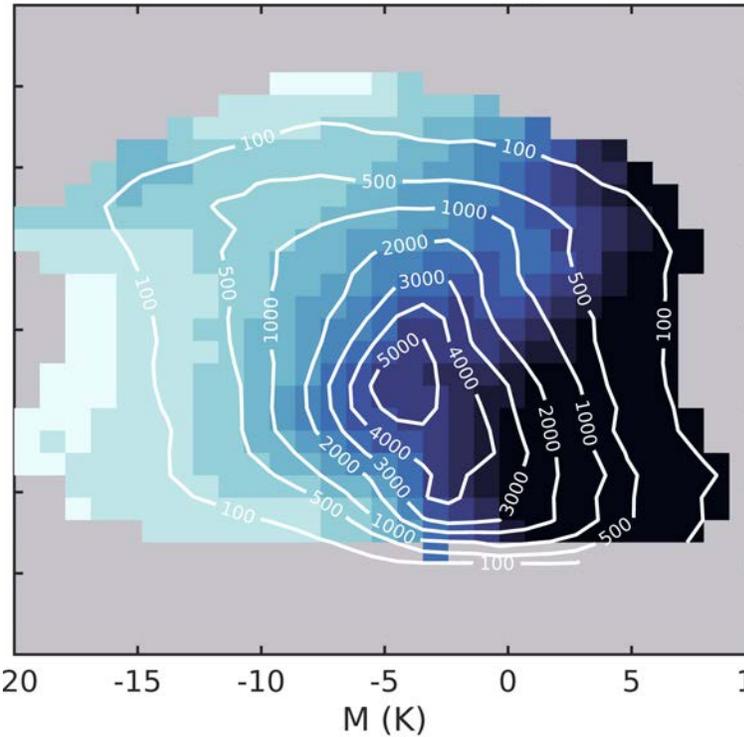
Depending on how M and SST change, you can gain Closed MCC, Open MCC, or Disorganized clouds.

SST increases

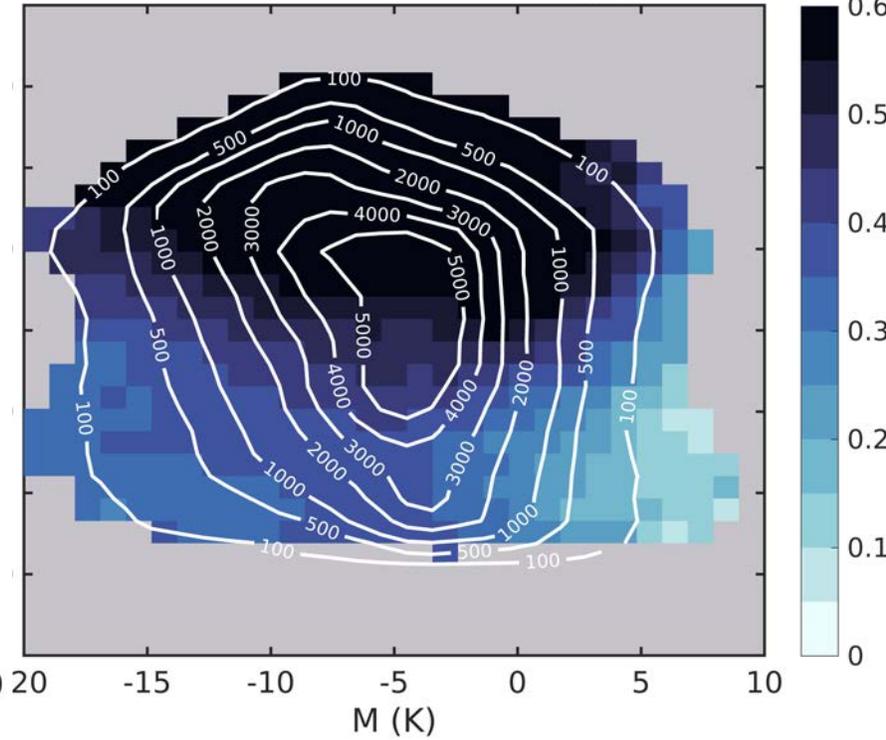
f(Closed)



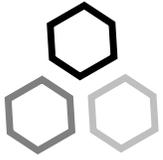
f(Open)



f(Disorganized)



M decreases



How will MCC occurrence change in the future?

Depending on how M and SST change, you can gain Closed MCC, Open MCC, or Disorganized clouds.

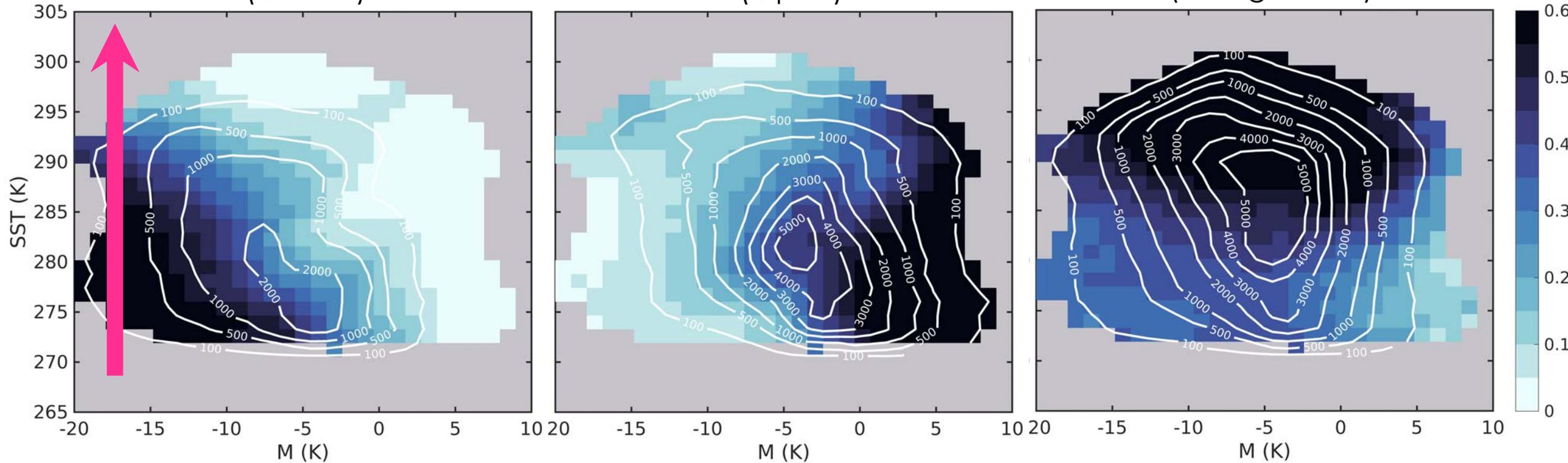
A change in cloud type will change the albedo, even with no change in cloud fraction.

SST increases

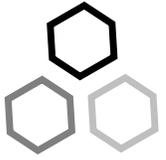
f(Closed)

f(Open)

f(Disorganized)



M decreases



Preliminary Morphology Feedback Estimate

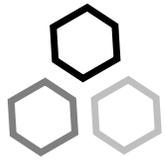
$$f(\text{closed}) = (\partial f(\text{closed}) / \partial M)_{\text{SST}} \Delta M + (\partial f(\text{closed}) / \partial \text{SST})_M \Delta \text{SST}$$

$$\Delta \alpha_{\text{MCC}} = (f(\text{closed})_{\text{future}} - f(\text{closed})_{\text{present}}) \times (\alpha_{\text{open MCC}} - \alpha_{\text{closed MCC}})$$

$$\Delta F = \text{SW}\downarrow \times \Delta \alpha_{\text{MCC}}$$

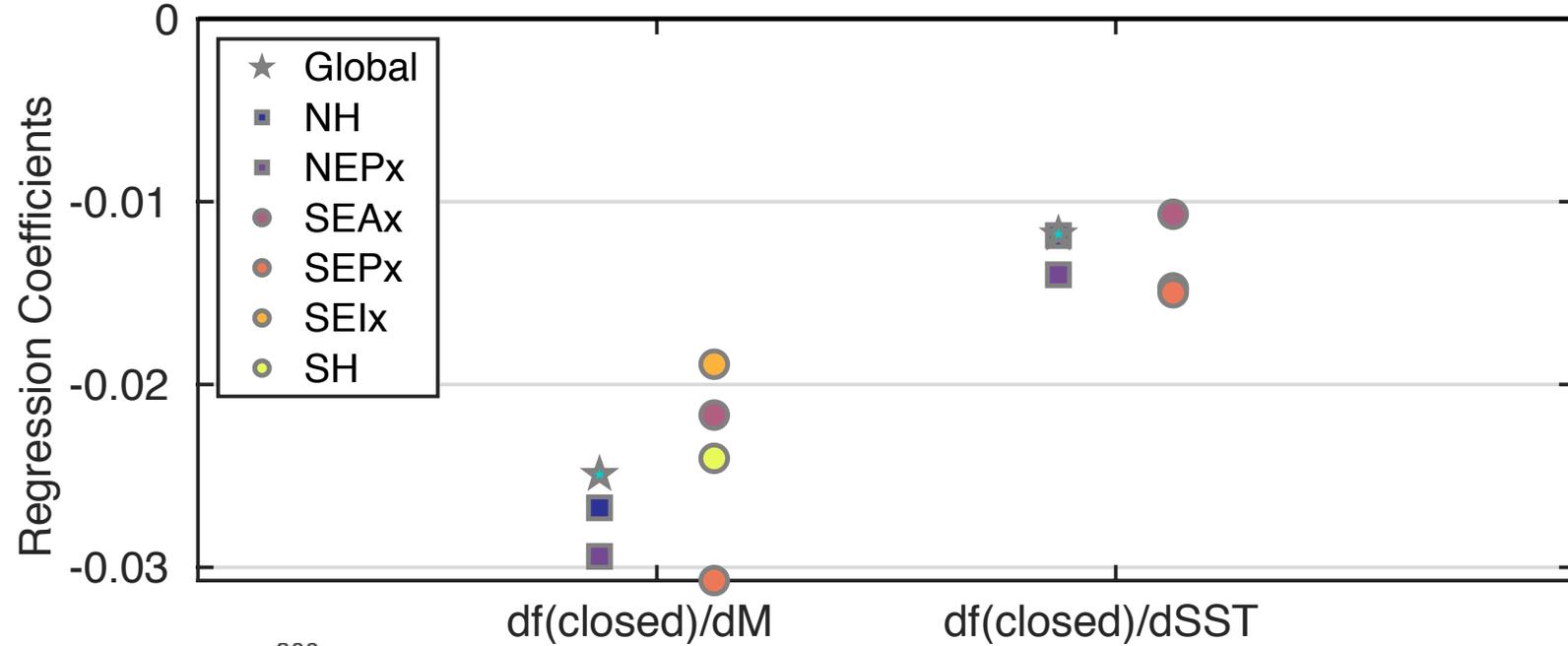
Data:

- MIROC5 amip, amip+4K
- M-SST-f(closed) Multiple Linear Regression (for Klein-Hartmann expanded regional boxes, 30-60° N and S bands, and global)
- α -CF MCC relationships

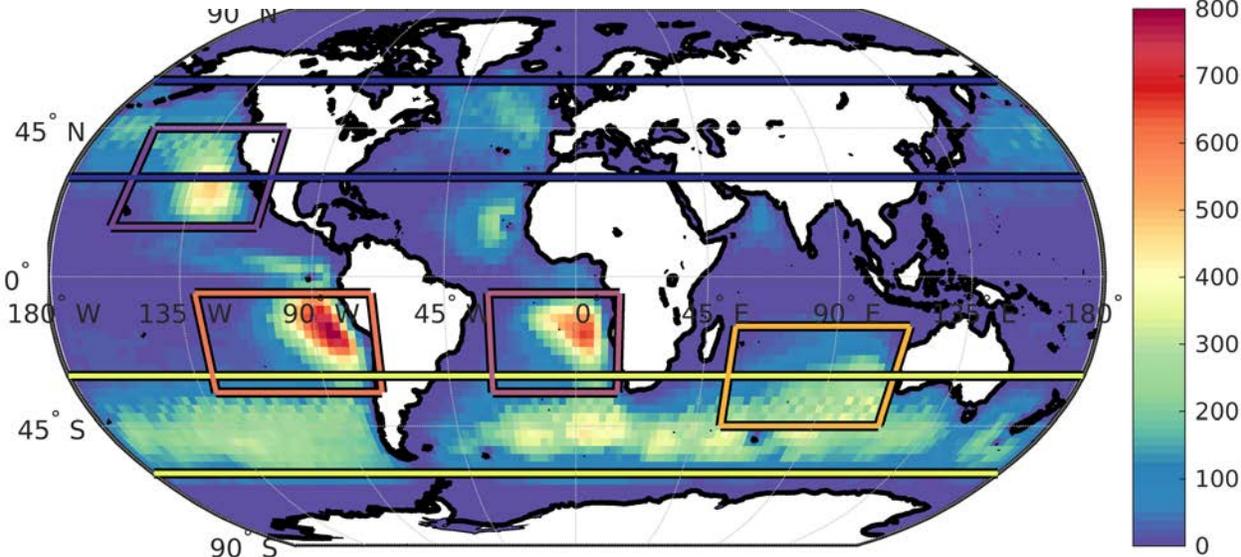


Preliminary Morphology Feedback Estimate

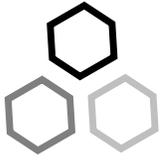
Consistency in regression coefficients across regions gives confidence in $f(\text{closed})$ prediction.



Closed Observation Number



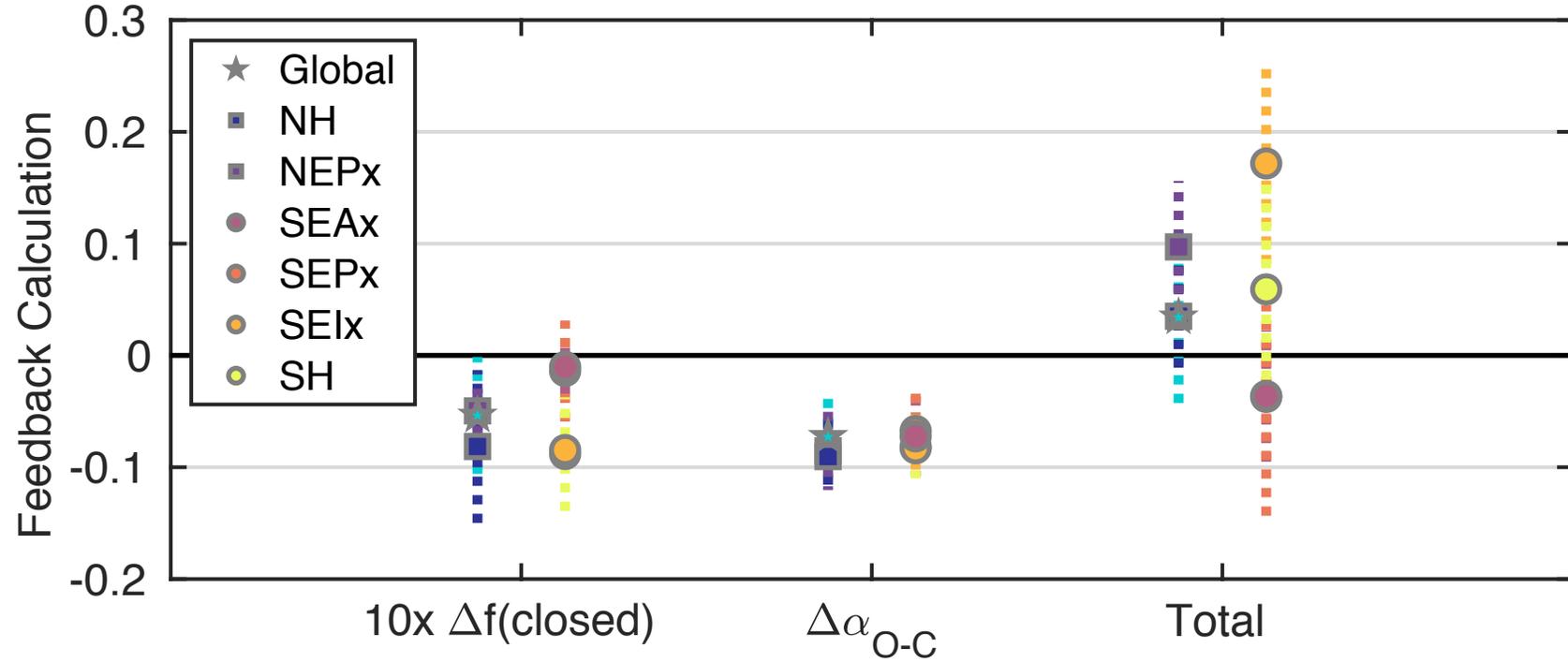
(above) Northern and global points on left, Southern on right.
(left) Corresponding regions of analysis.



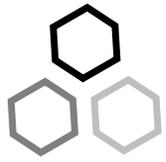
Preliminary Morphology Feedback Estimate

Changes in $f(\text{closed})$ vary across regions.

Resulting feedback (from shifting Closed MCC to Open MCC) is similarly diverse and potentially significant.

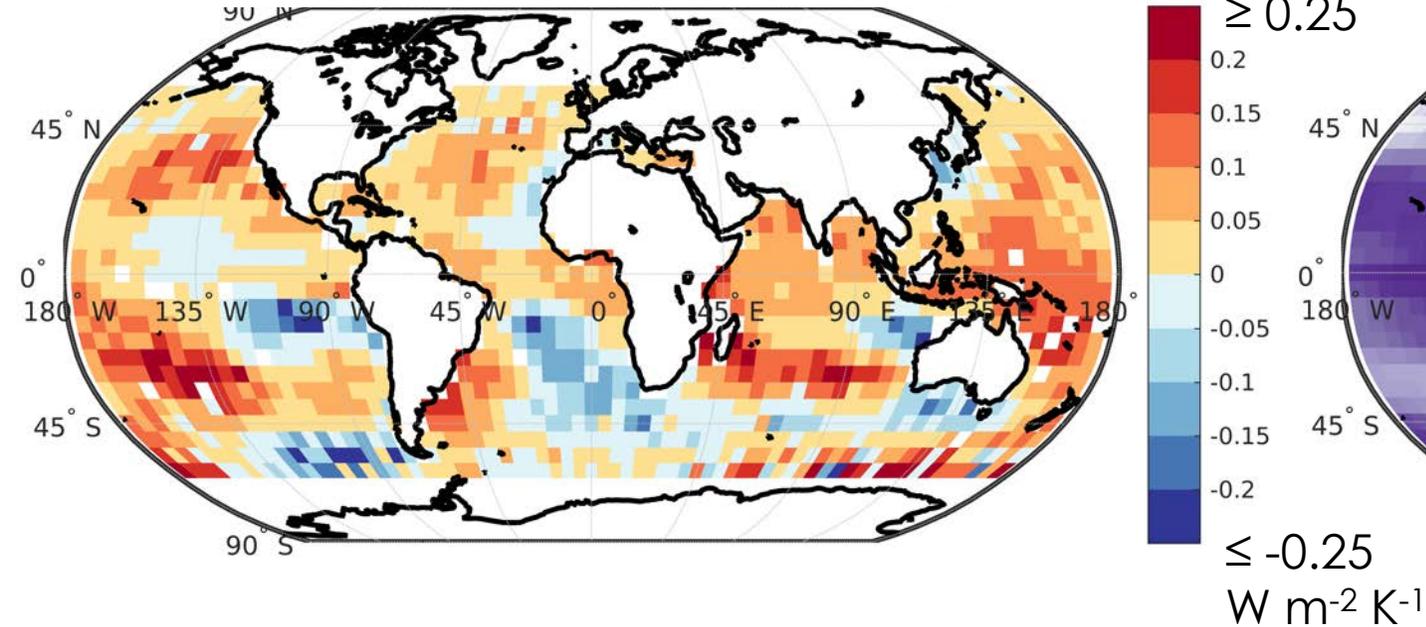


Points indicate mean, dashed lines indicate standard deviation and demonstrate regional spread in feedback. Northern and global points on left, Southern on right.

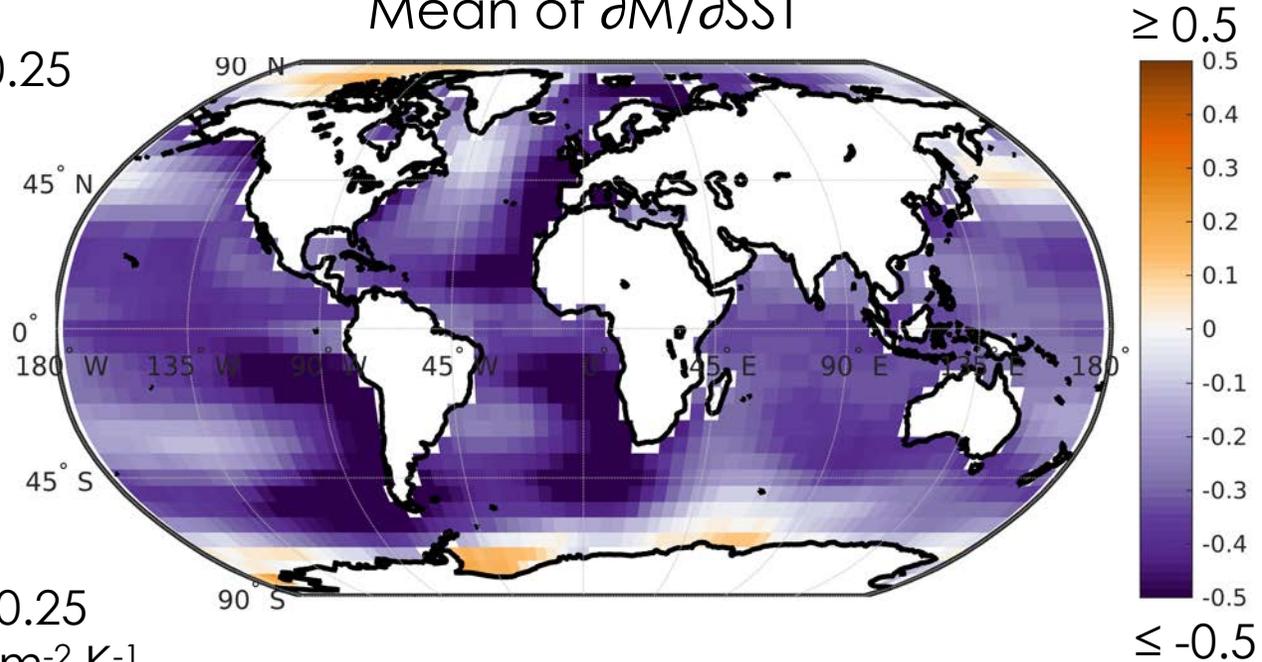


Preliminary Morphology Feedback Estimate

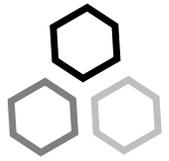
Mean Morphology Feedback – Closed to Open



Mean of $\partial M / \partial SST$



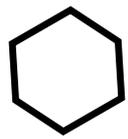
When examined globally, the pattern of the Morphology Feedback is connected to the pattern of $\partial M / \partial SST$, indicating the importance of large scale circulation in modulating the shift in cloud type occurrence.



Conclusions

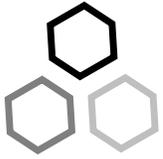
- Different cloud morphologies have significantly different in-cloud albedos on average: $\alpha(\text{Closed}) > \alpha(\text{Open}) > \alpha(\text{Disorganized})$
- Under climate change, we predict a shift in cloud morphology which will produce a negative or positive feedback depending on M and SST changes
- Morphology Feedback is estimated assuming Closed to Open > this will be an underestimate as Closed MCC could shift to Disorganized
- The Morphology Feedback is not included in GCMs currently. The pattern of the feedback may help to reduce currently observed model bias.
- Investigating different cloud types and understanding their connection to large scale circulation will help us to predict morphology changes in the future

Questions? imccoy@uw.edu



Extra Slides

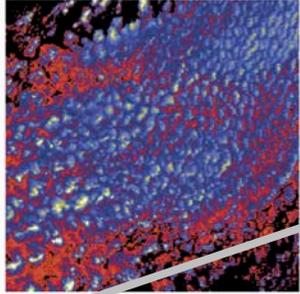
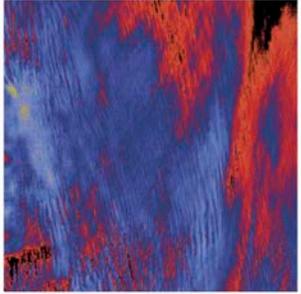




MCC Identifications — Wood and Hartmann (2006)

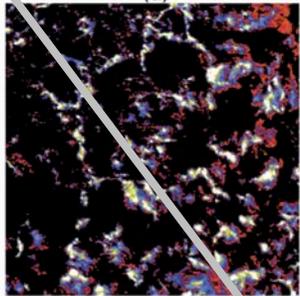
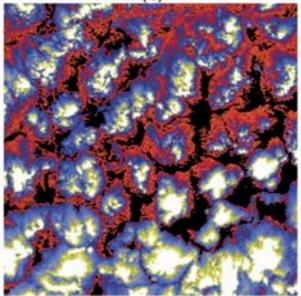
(a)

(b)



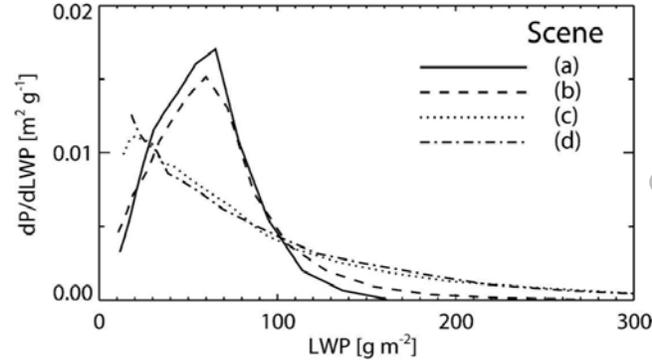
(c)

(d)

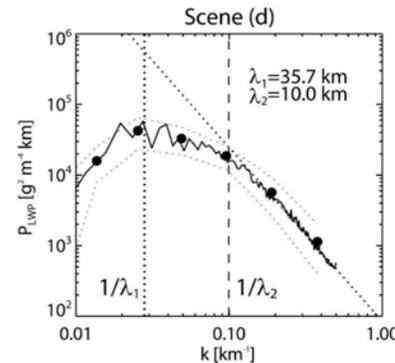
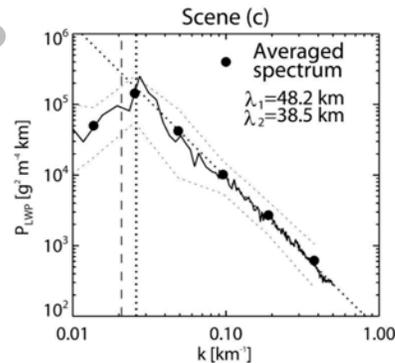
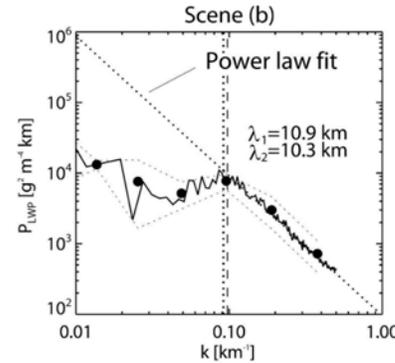
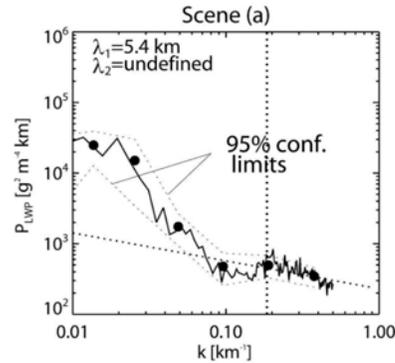


Liquid Water Path (LWP)
from MODIS
(256 x 256 km² Scenes)

PDF of LWP

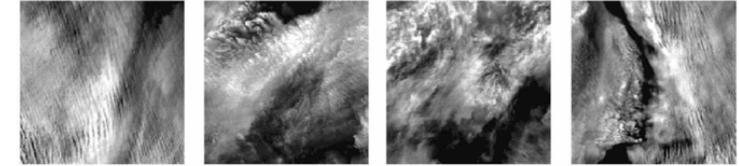


Power Spectrum of LWP

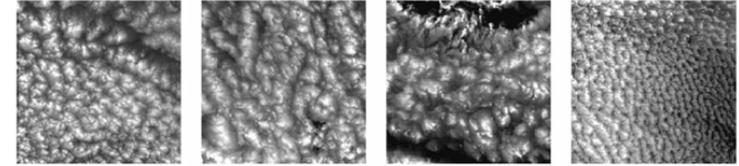


Resulting MCC Identifications

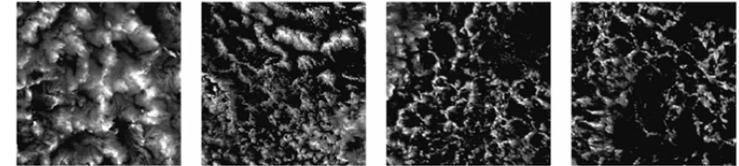
No MCC (a)



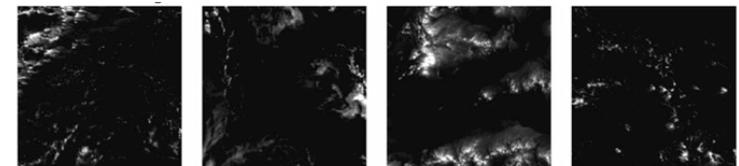
Closed MCC (b, c)



Open MCC (d)

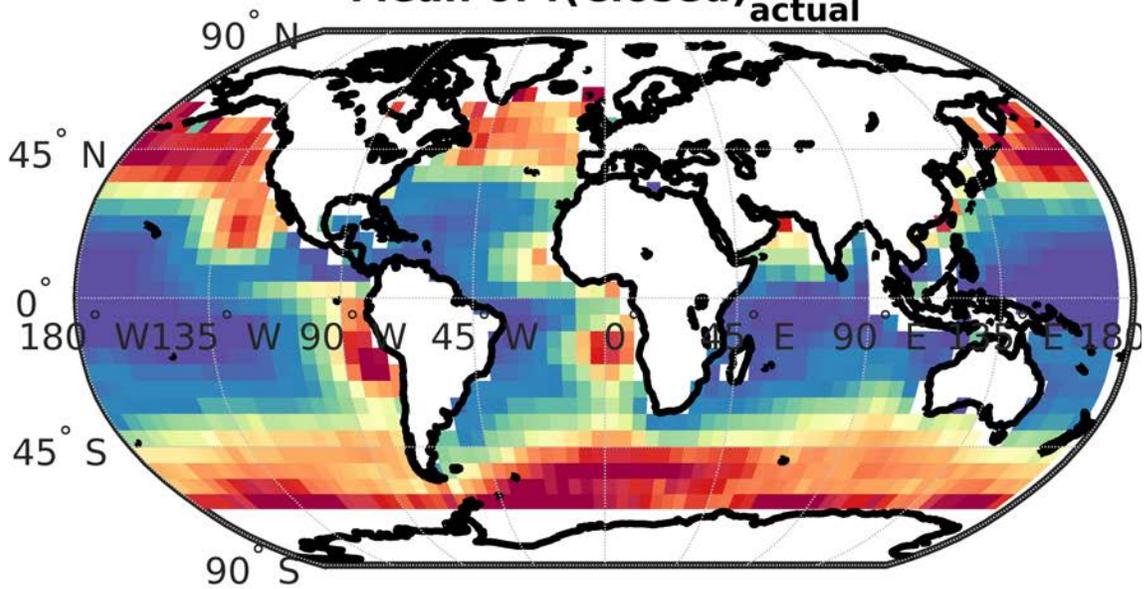


Cellular but Disorganized

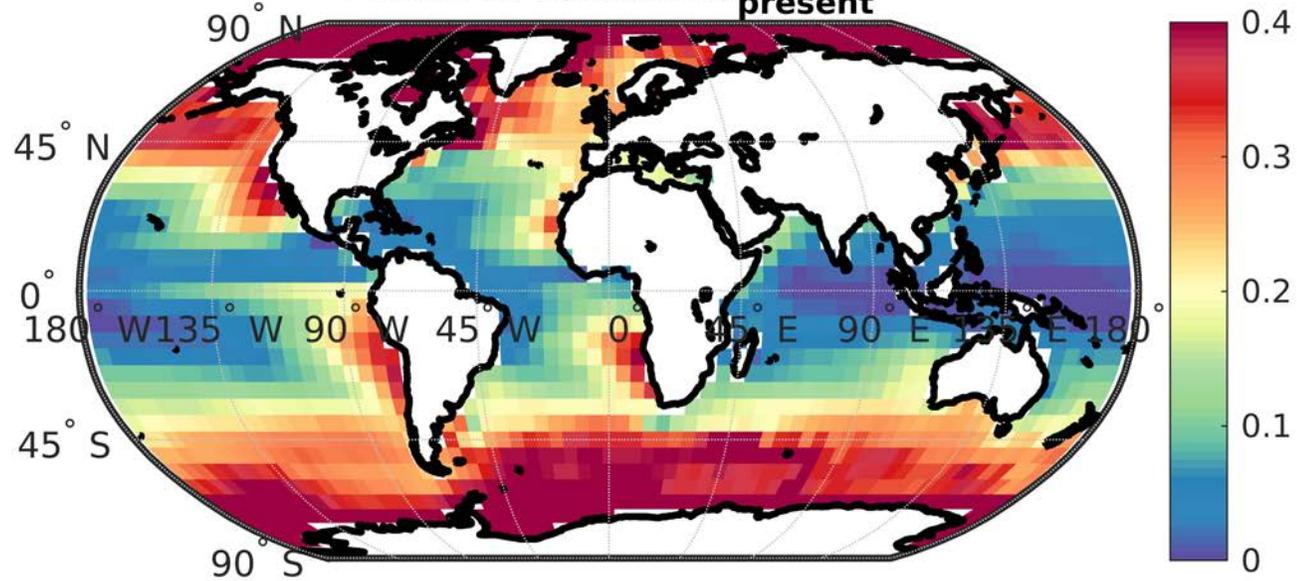


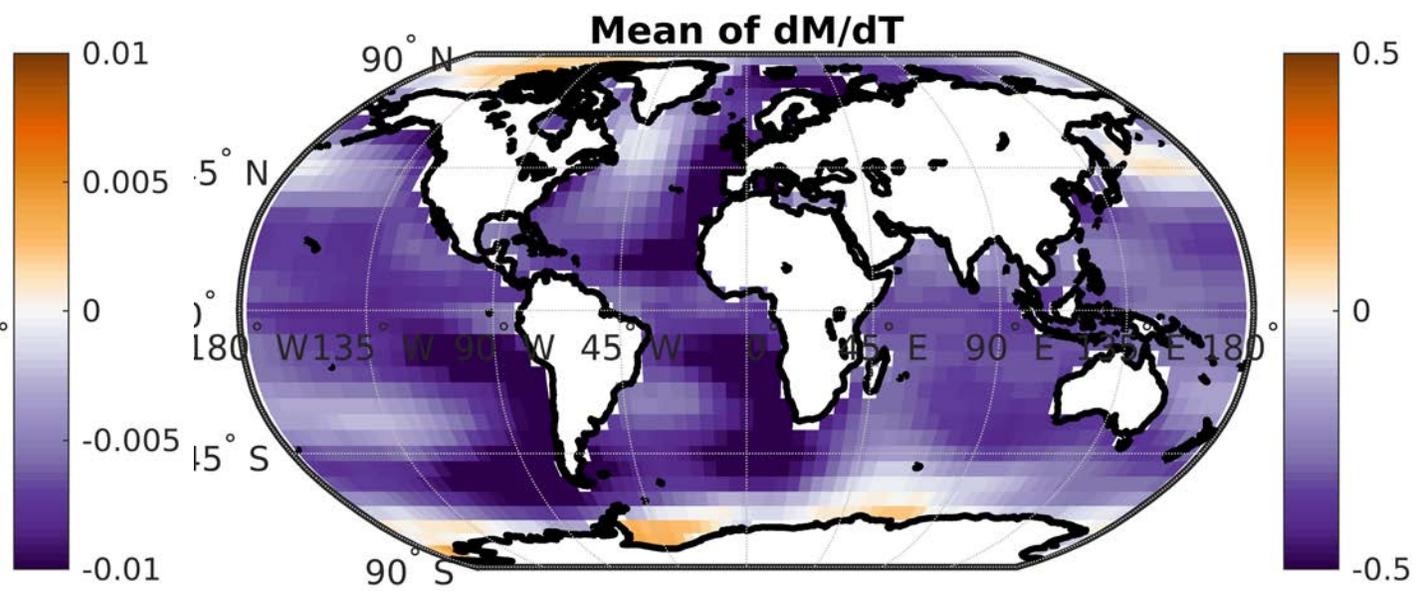
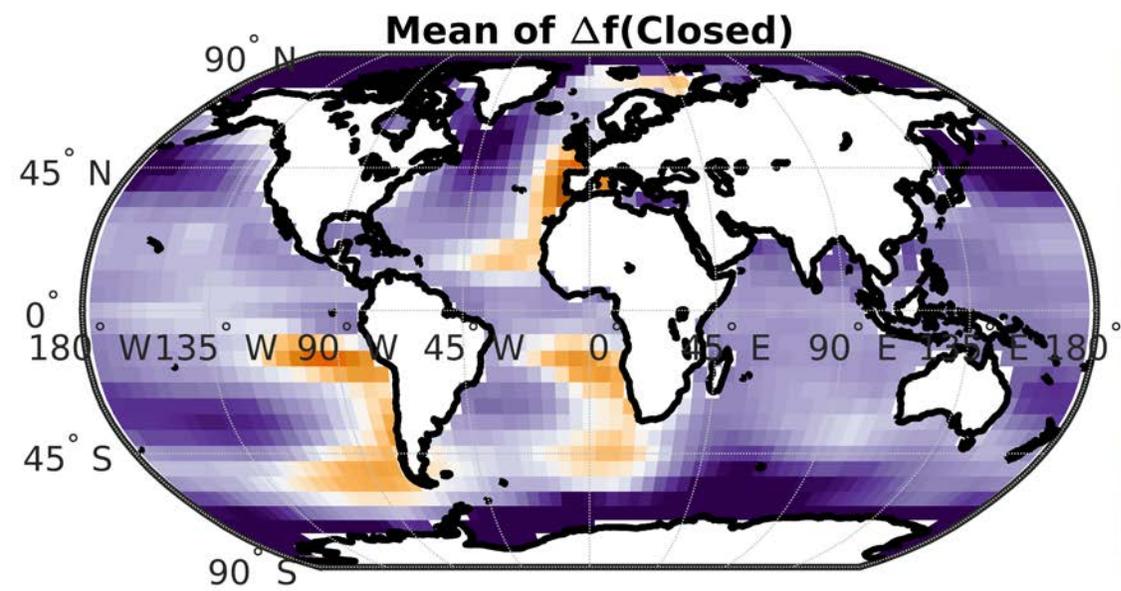
LWP (g m⁻²)

Mean of $f(\text{Closed})_{\text{actual}}$

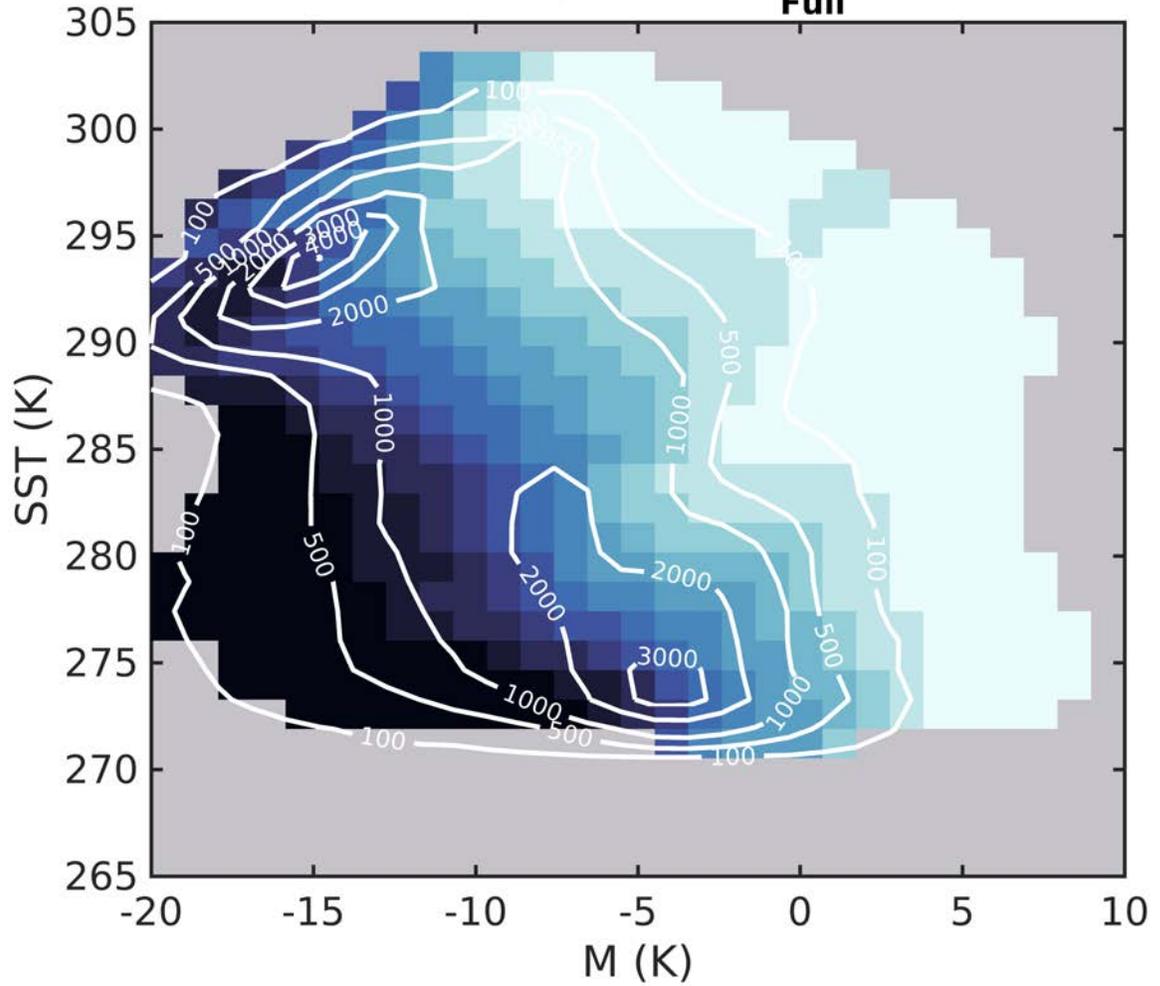


Mean of $f(\text{Closed})_{\text{present}}$

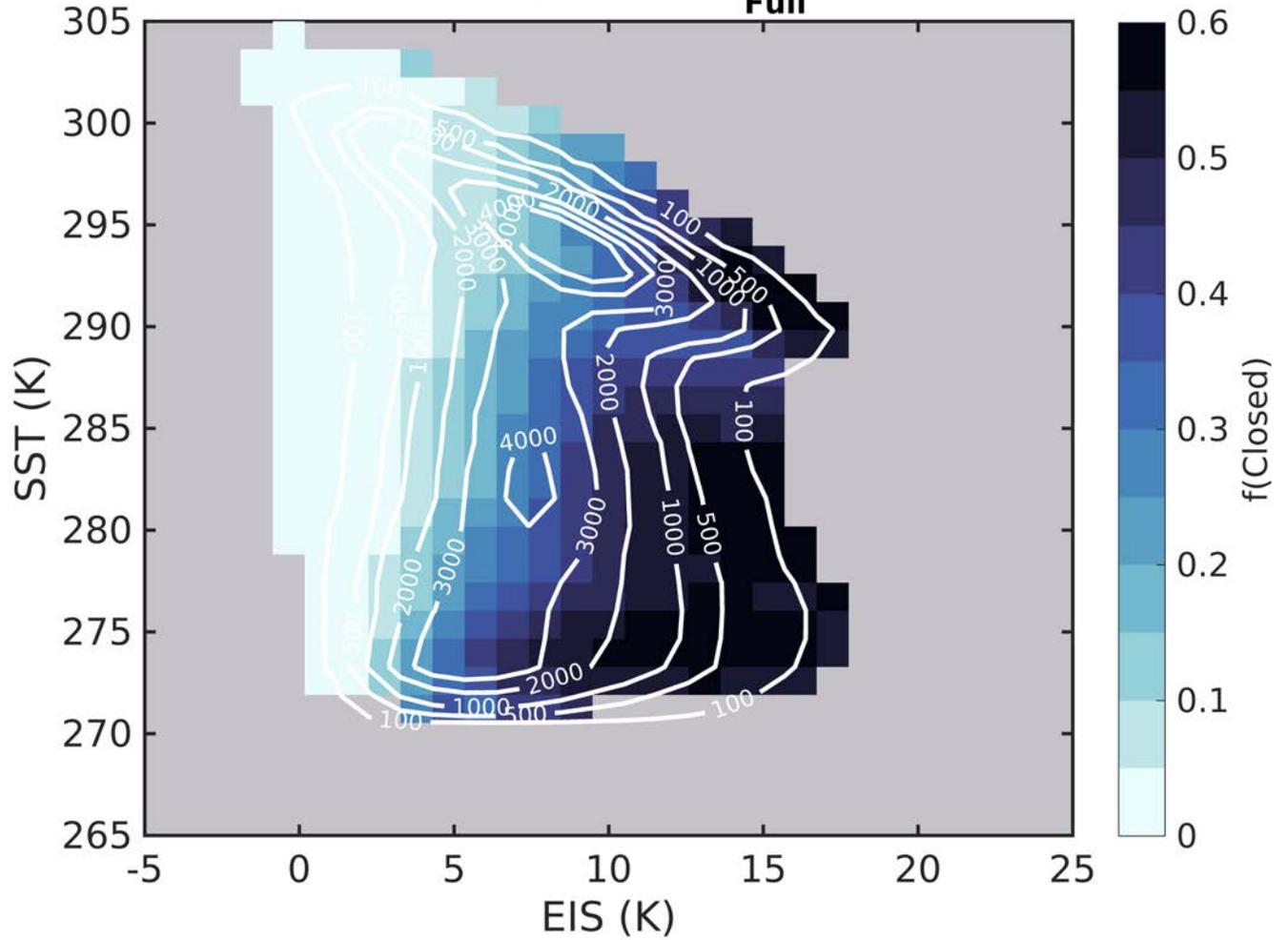


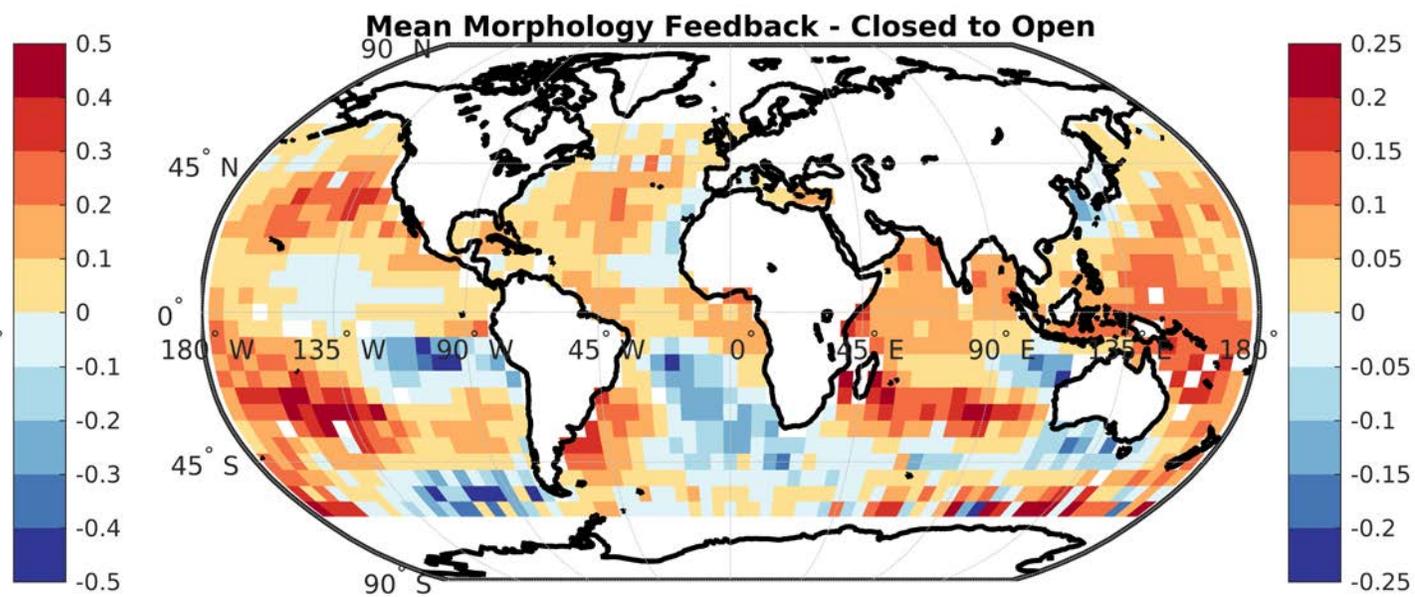
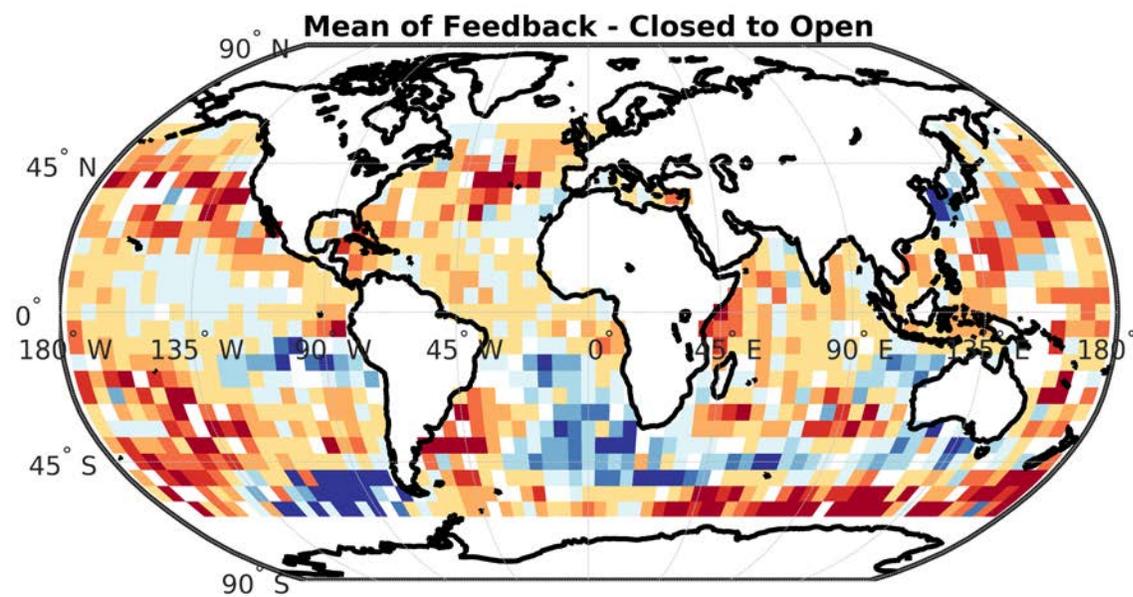


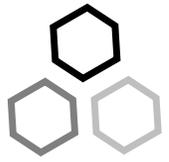
Closed - Global_{Full}



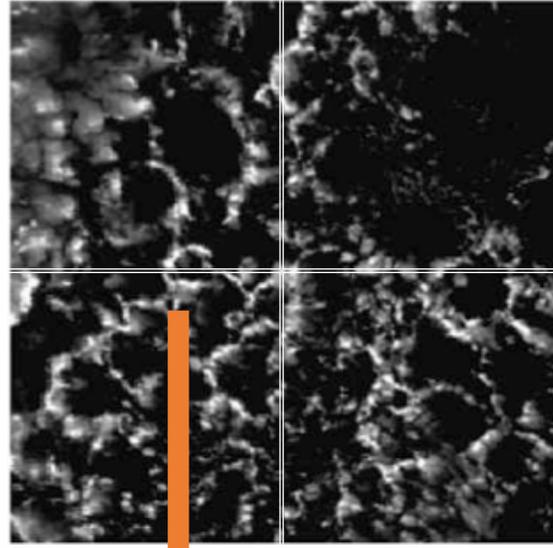
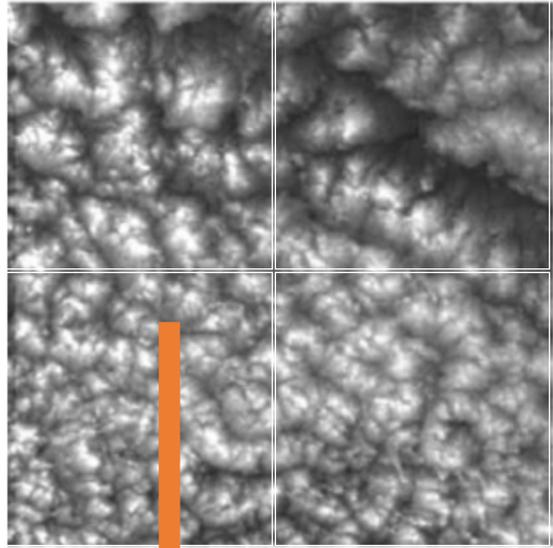
Closed - Global_{Full}



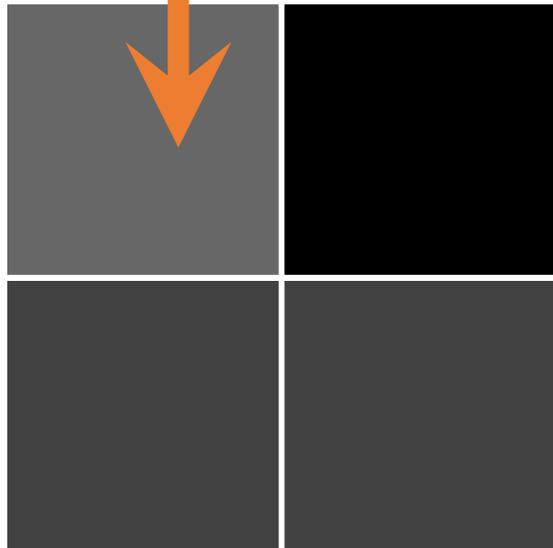
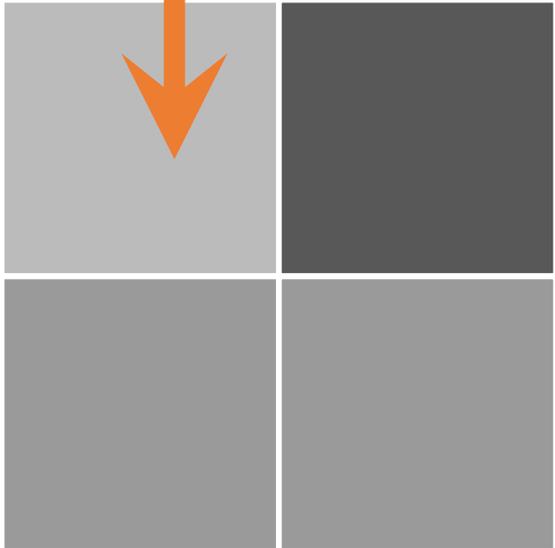




MCC Dataset



} $\sim 1^\circ = 111 \text{ km}$



}