Is a Low Cloud Signal in Response to CO_2 Forcing Observable?

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Introduction

Low stratocumulus clouds have a net cooling effect on the earth. This is due to their thickness that provides a high albedo to reflect solar radiation back to space as well as their weak greenhouse effect. Low-level clouds are an important factor to consider for global climate change, but much uncertainty remains regarding cloud feedback and climate sensitivity. This is in part due to cloud processes occurring at a smaller scale than models can account for and small changes in cloud amount can have climactic impacts.[1]

Objectives

We are interested to determine whether century-scale transient response is similar to equilibrium cloud response, and whether simulated cloud changes since ~1980 are similar to the transient cloud response. Although models produce various cloud responses, finding similar equilibrium and transient cloud change would indicate internal consistency of the model. Furthermore, if simulated cloud change since ~1980 resembles the transient cloud change, this would suggest that low-level cloud changes observed by satellites since 1984 may be in response to climate change rather than natural variability.

Methods

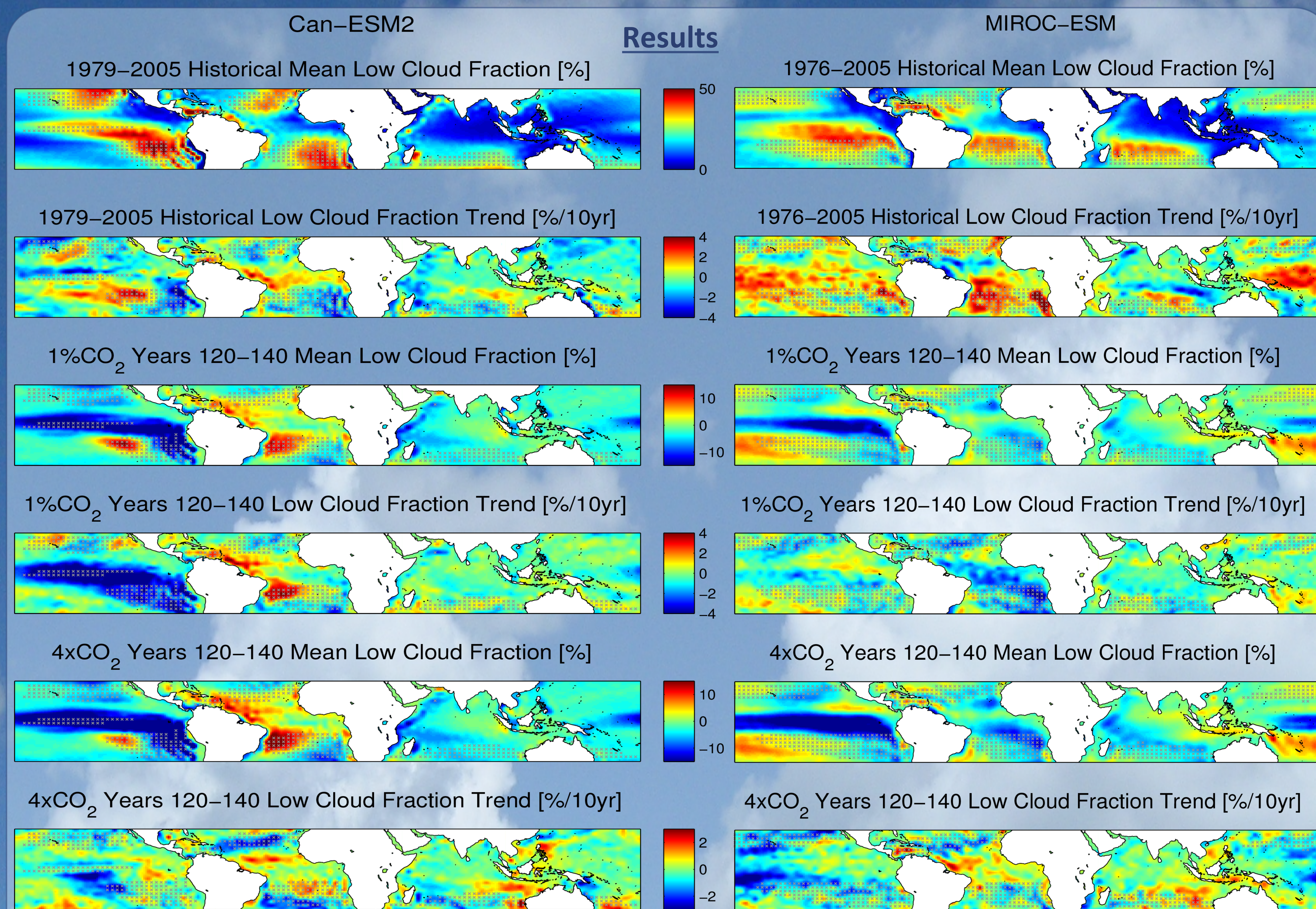
This study looks at the cloud fraction output from 6 different CMIP5[2] climate models (CanESM2, HadGEM2, MIROC5, MIROC-ESM, MRI-GCM, MPI-ESM) to investigate how low-level clouds may respond to increasing CO_2. The simulations that are examined are 1% CO_2 increase per year, 4 times CO_2 equilibrium change, and historical radiative forcing from ~1980-2005.

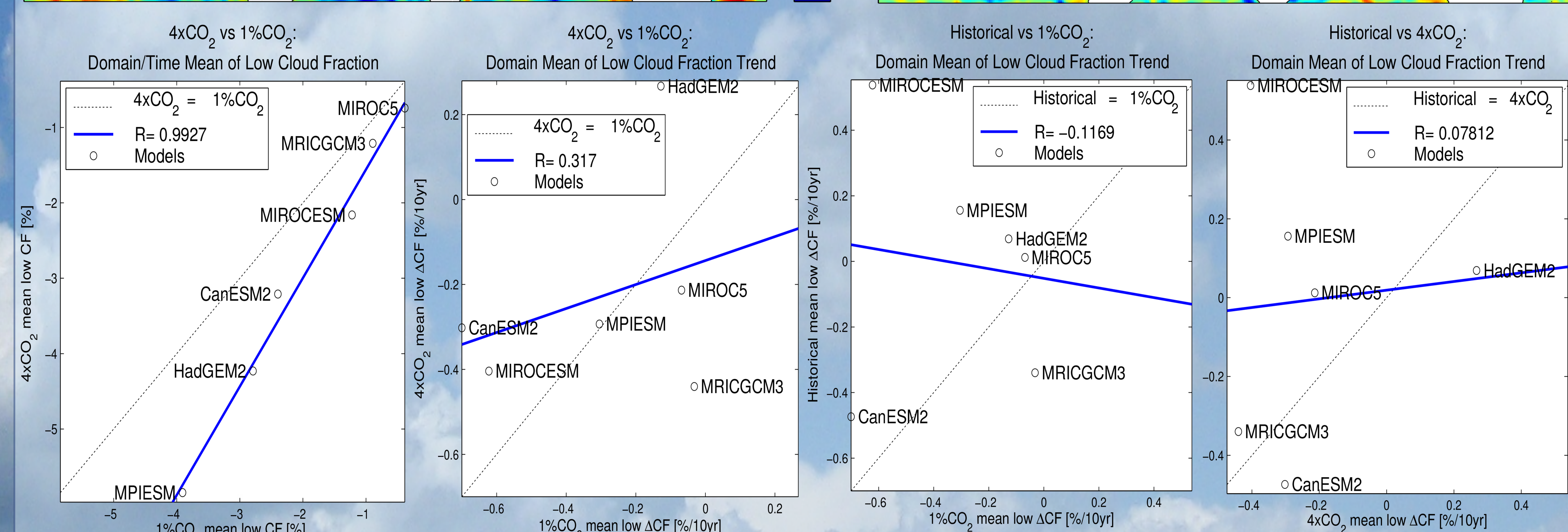
Low level cloud fraction data was obtained for cloud top pressure ≥ 680 hPa, and optical thickness ≥ 0.3. Metrics used were mean cloud fraction and cloud fraction change per decade. The domain studied contains subtropical oceans within 30°S-30°N latitude where subsidence occurs[3]. More specifically, grid boxes were selected for each model if the long term mean of vertical velocity at 700hPa was positive ($\omega_{700}>0$) for every month, and the monthly means were positive for at least 80% of the record.[4]

Mean cloud fraction and cloud fraction change from simulations for 1% CO_2 increase per year and 4 times CO_2 were correlated to see if a century-scale transient cloud response is similar to the equilibrium response. Both CO_2 simulations were then correlated with historical radiative forcing simulations.

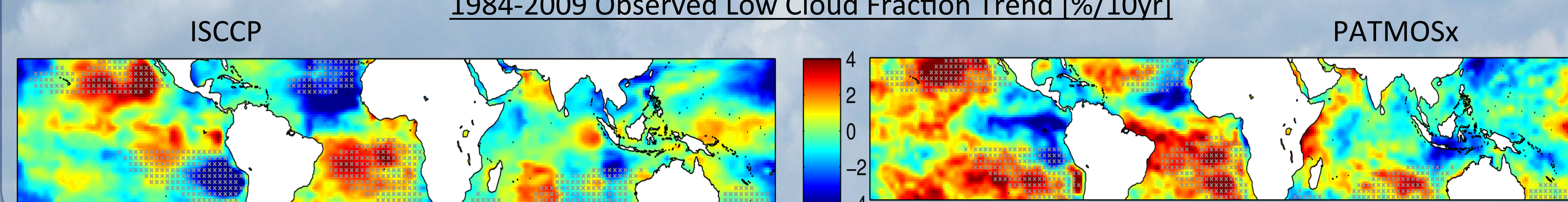
1%CO_2 and 4xCO_2 simulations run from an arbitrary year 0 to 140. Analysis is of the final 20 years.

Results





1984-2009 Observed Low Cloud Fraction Trend [%/10yr]



- The global maps shown are 2 of the 6 models and 2 satellite records.[5] X's on the maps indicate grid boxes used. The selection of grid boxes is in the Methods section.
- Can-ESM2 output is shown since it is the only model to show negative mean cloud fraction and negative cloud fraction change for all simulations.
- MIROC-ESM is shown as it had the biggest difference between the the historical and CO_2 simulations.

Conclusions

- Transient CO_2 response is similar to equilibrium response
- Historical radiative forcing simulations do not show the same response in transient or equilibrium CO_2 for most of the models. Therefore CO_2 alone is not responsible for low cloud change.
- CanESM2 is the most consistent model, showing decrease in low cloud fraction.
- Based on the inconsistency between the six models, a low cloud response to climate change observed by satellites (1984-2009) is unlikely and mostly due to natural variability.

Discussion and Further Research

- More models and realizations (different initial conditions) could provide a more accurate conclusion to cloud response due to CO_2 forcing.
- More models exist for total cloud amount. If low clouds are represented well enough by the dynamics of total cloud amount, then more data would be accessible for analysis.
- Analysis of each models' natural variability.

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References

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