Decadal Observations of Polar Mesospheric Clouds Over McMurdo, Antarctica

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Introduction and Background

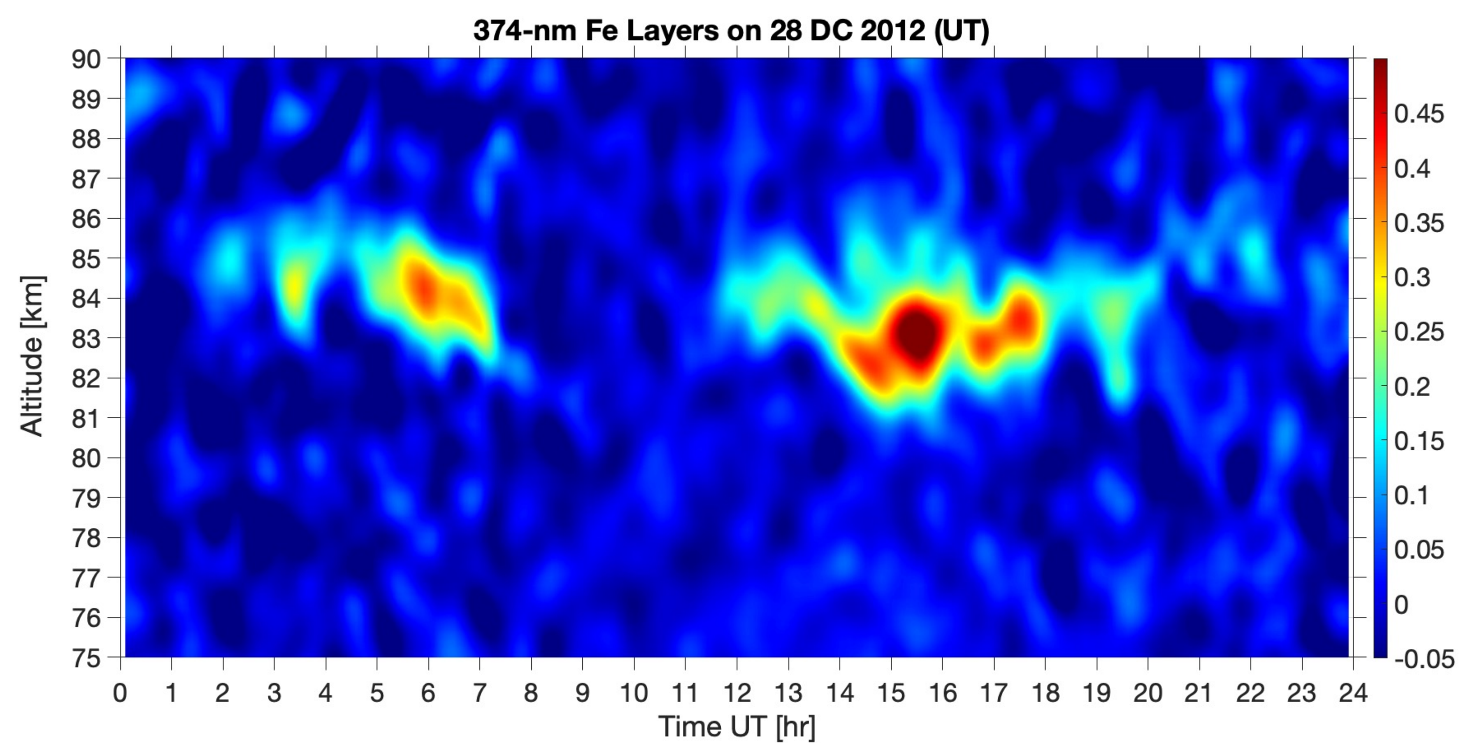
Polar Mesospheric clouds (PMCs) are water ice particles occurring in polar mesopause regions during summer. They are a "canary in the coal mine" – potential tracers of global climate change in the upper and middle atmosphere. An increase in greenhouse gases concentration lowers the mesospheric temperature and increases H_2O concentration which should result in brighter, more frequent PMCs occurring at lower latitudes.

Why do we need to study PMCs?

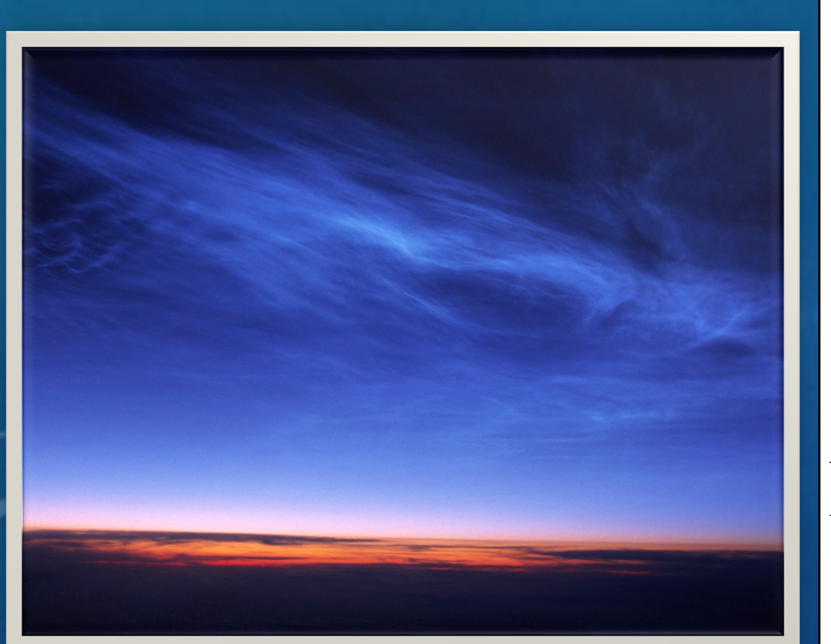
- **Tracers for climate change**: To use PMCs as tracers for climate change and atmospheric dynamics, it is important to derive the long-term trends in these clouds, their inter-annual and diurnal variations.
- **Natural Laboratory for MLT:** PMC formation is sensitive to mesospheric temperature, water vapor and meridional wind. Low saturation temperature leads to high water vapor saturation, which when accompanied by wave-induced temperature oscillations leads to a greater probability of ice particles.
- **Stable altitude:** PMCs are present at relatively stable altitudes, providing a good test bench for atmospheric models.

The Chu Research Group was first to report lidar observations of the PMCs at McMurdo in Antarctica on 21st December 2010, using a ground-based Fe Boltzmann temperature Lidar. Lidar observations in the past have significantly contributed to understanding and characterizing their altitude distribution, scattering properties such as brightness and thickness, seasonal variations as well as their formation. Lidar observations have revealed inter-hemispheric differences in PMC altitudes, the role of stratospheric gravity waves in different latitudes affecting the PMC brightness. A unique feature of lidar observations is ability to measure diurnal variations.

An example of PMC observation from Fe Lidar



The PMC can be observed in the 374 nm channel – low Fe contamination in this channel.



Polar Mesospheric Clouds as seen from ground.
Picture Credits: NASA

Diurnal PMC Brightness with T, U, V and H_2O

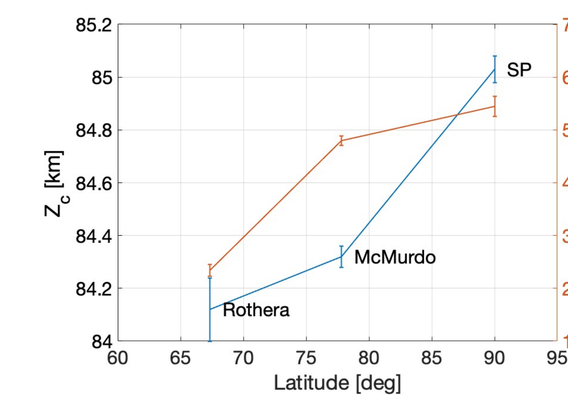
Using the HWM to get diurnal meridional and zonal wind shows strong anticorrelation between diurnal PMC brightness and meridional wind at 75 & 80 km, as well as zonal wind at 85 and 90 km.

We expect an anticorrelation between diurnal PMC brightness and mesospheric temperature and water vapor, but preliminary analysis with MLS and MERRRA2 data does not show this.

Mean Characteristics over 1 decade

PMC Feature	All Seasons 2010-2020
R_{max}	33.47 ± 0.52
$\beta_{max}\left[\frac{10^{-9}}{m \cdot sr}\right]$	2.28 ± 0.03
$\beta_{total}\left[\frac{10^{-6}}{m \cdot sr}\right]$	4.80 ± 0.09
Z_C [km]	84.32 ± 0.04
σ_{RMS} [km]	0.89 ± 0.01

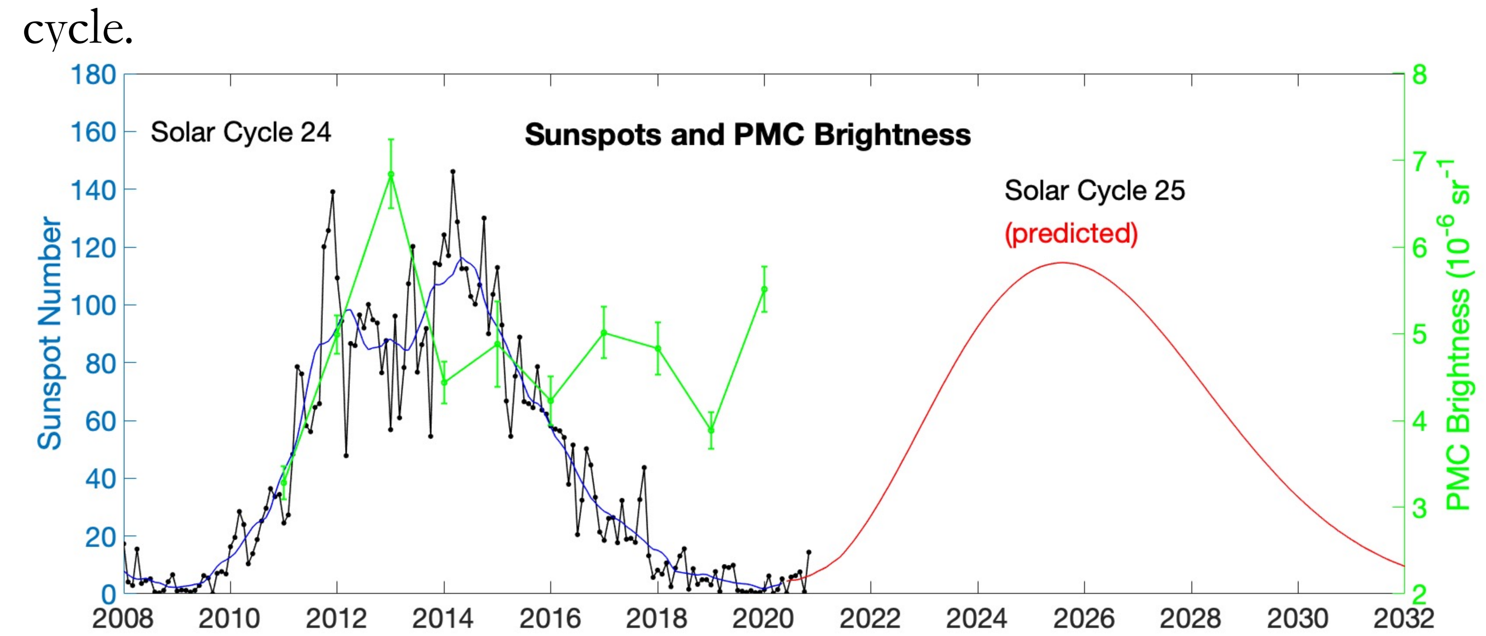
- The table presents the overall means 992 of observed PMCs hours for each PMC feature.
- Total lidar observations made is 3212 hours, yielding a PMC occurrence frequency of 30.8%

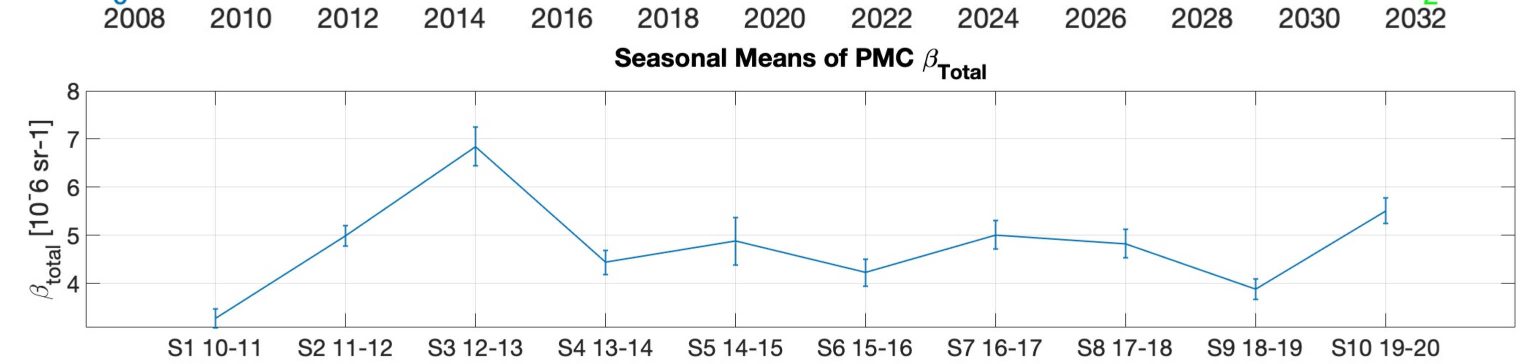


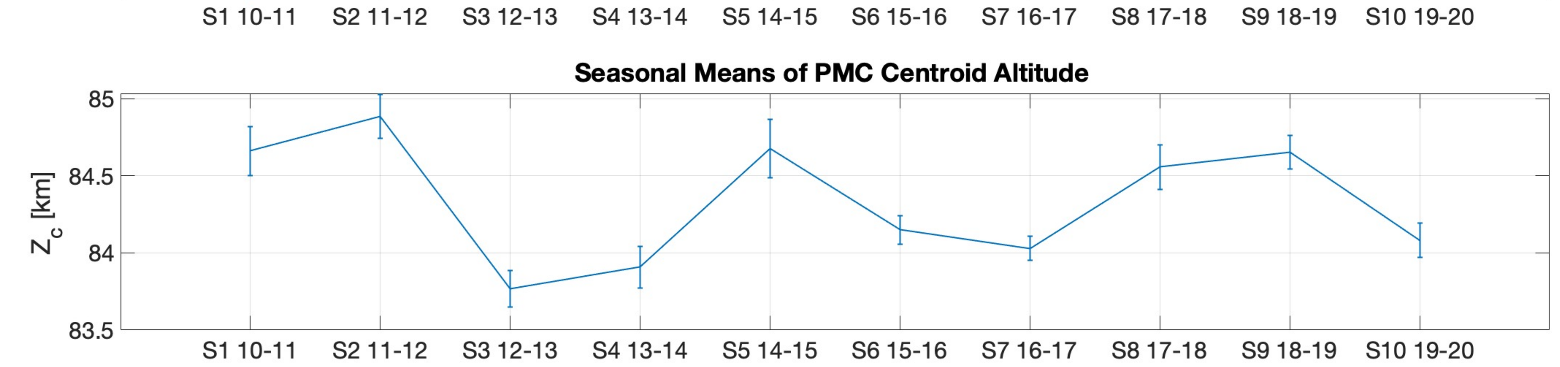
- **PMC latitudinal dependence re-established – Higher PMC at high latitude:** Possibly due to strong upwelling winds moving towards Poles during summer.

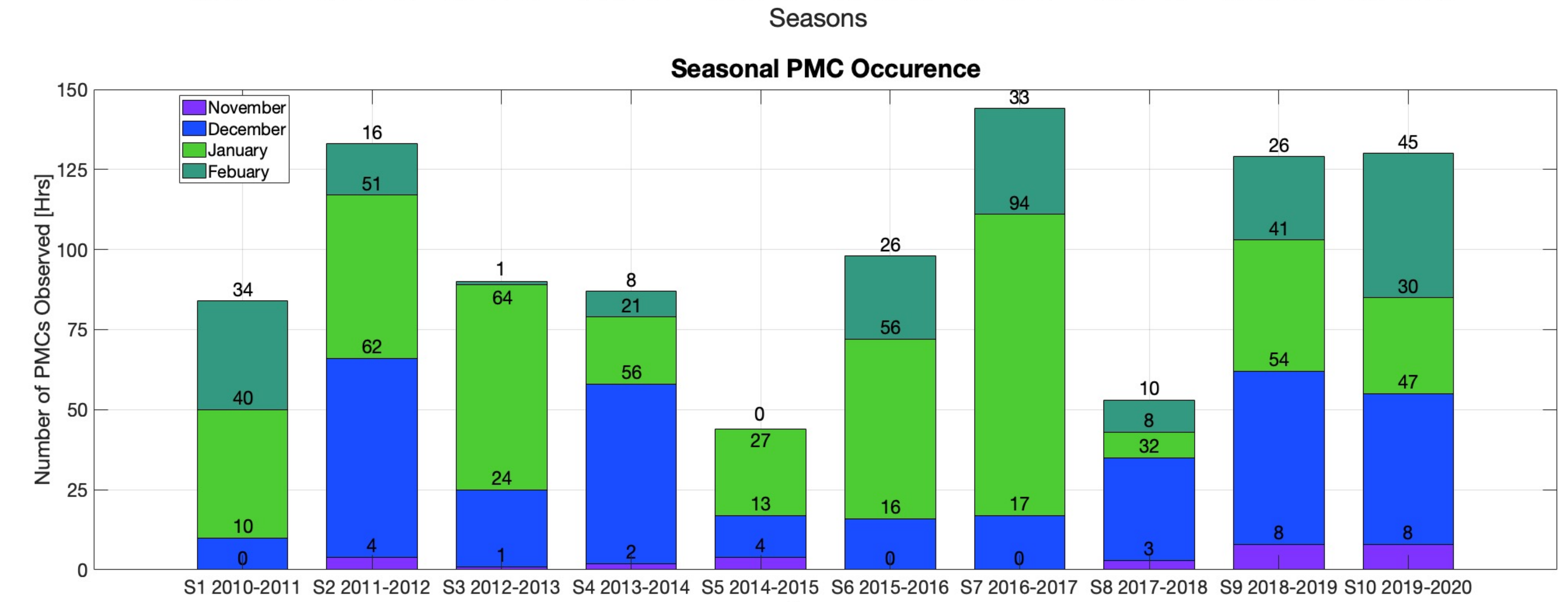
Inter-Annual Analysis

- **Solar Cycle** – An Open-ended question, since this is the smallest solar cycle and 10 years of PMC observations currently show a lack of solar cycle.





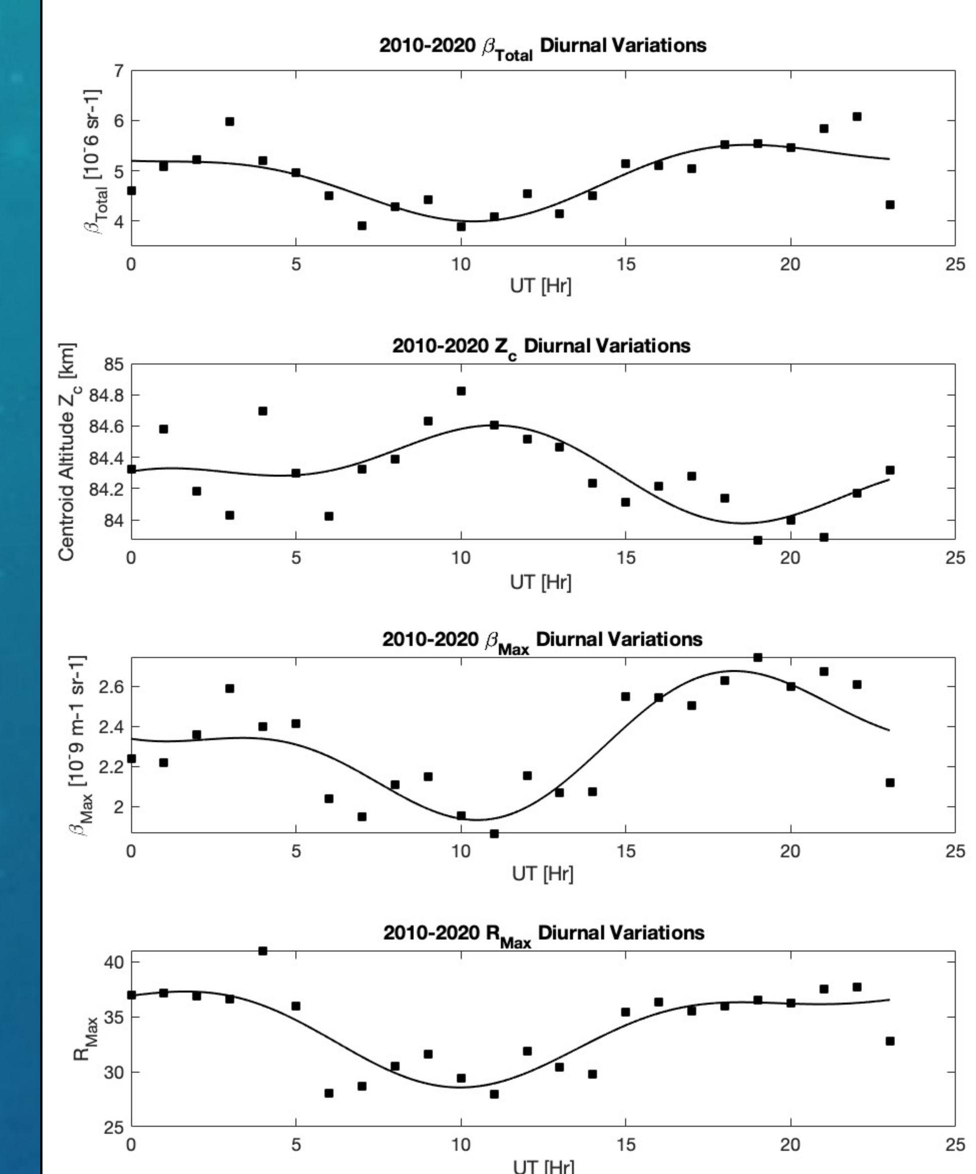




Diurnal Variations over 1 Decade

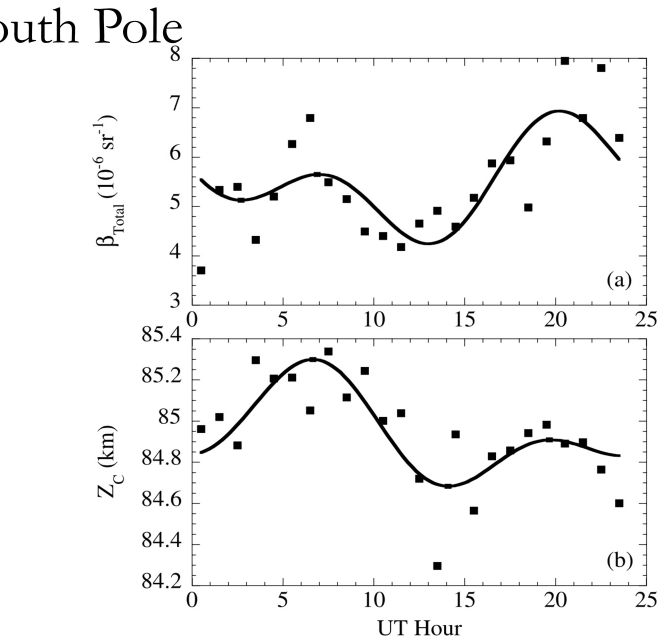
	R_{max}	$\beta_{max}\left[\frac{10^{-9}}{m \cdot sr}\right]$	$\beta_{total}\left[\frac{10^{-6}}{m \cdot sr}\right]$	Z_C [km]
A_0	34.05± 0.99	2.31± 0.06	4.89± 0.18	84.29± 0.08
A_{12}	1.64± 1.99	0.15± 0.12	0.26± 0.37	0.14± 0.16
A_{24}	3.86± 1.99	0.27± 0.12	0.65± 0.37	0.21± 0.16
UT_{12}	3.74± 1.5	5.30± 1.5	4.85± 1.5	11.82± 1.5
UT_{24}	22.34± 3	20.58± 3	21.60± 3	8.64± 3
R	81.94%	85.44%	78.67 %	73.43 %

- All fits have a confidence of 99.99% or more.



$$y = A_0 + A_{12}\cos\left[\frac{2\pi}{12}(t - UT_{12})\right] + A_{24}\cos\left[\frac{2\pi}{24}(t - UT_{24})\right]$$

South Pole



Comparison with South Pole (1999 – 2001) Diurnal Plots:

- South Pole shows strong diurnal and semi-diurnal phases wherein the local minima is at 12 UT.
- McMurdo plots show a strong diurnal and a weak semi-diurnal phases, with local minima at around 10 or 11 UT.

- There is a strong anticorrelation between diurnal PMC brightness and centroid altitude R = -0.63 and confidence = 99.99%.
- The first 5 seasons show a strong diurnal phases in both brightness and centroid altitude during solar maxima and the second five show both strong diurnal and semidiurnal phases during solar minima, hinting a possible relationship between the diurnal PMC phases with solar cycle.

Conclusion and Future Work

- PMC features depend on latitude
- Diurnal PMC brightness and centroid altitude are strongly anticorrelated as expected.
- Strong diurnal phase in PMC features observed at McMurdo over 10 years.

Currently, there is a lack of correlation/anticorrelation with solar cycle, thus we need to investigate the dependence of diurnal variability of PMCs on different phases of the solar cycle.

PMC formation depends on temperature, H_2O as well as meridional wind circulation. Next steps are to look into how these affect inter-annual as well as diurnal variations using MLS, MERRA2, WACCMx and SOFIE data, etc.. We will also be looking into possible teleconnection for interhemispheric studies.