What does the variability of Earth's Highest Clouds tell us?

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Polar Mesospheric Clouds – Earth's Highest Clouds

Polar Mesospheric clouds (PMCs) are water ice particles occurring in polar mesopause regions during summer.
These bluish ice clouds occur at 80-88 km in high latitudes, during a constant sunlit period, when the MLT (Mesosphere and Lower Thermosphere) is the coldest region between Sun and Mars!
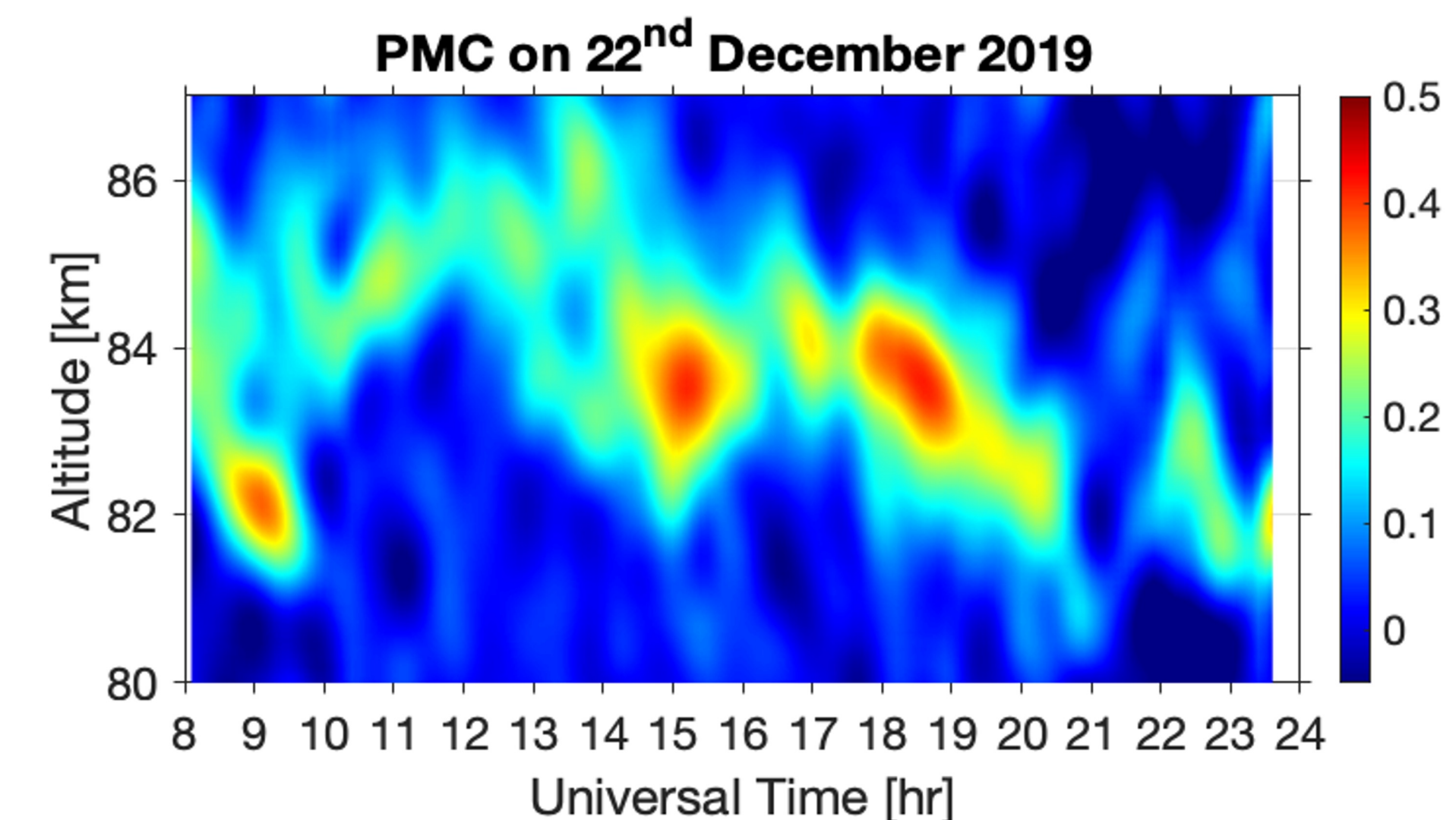
Why are PMCs important?
➤ They are a **Miner's Canary!**
➤ **Natural laboratory and tracer** for Polar MLT:
✓ Evidence of inter as well as intra hemispheric coupling in the polar atmosphere.
✓ Excellent indicators of the mean meridional circulation strength.
✓ Trackers of hemispheric differences in the atmosphere.
✓ Important indicators of dynamics and photochemistry in the MLT.
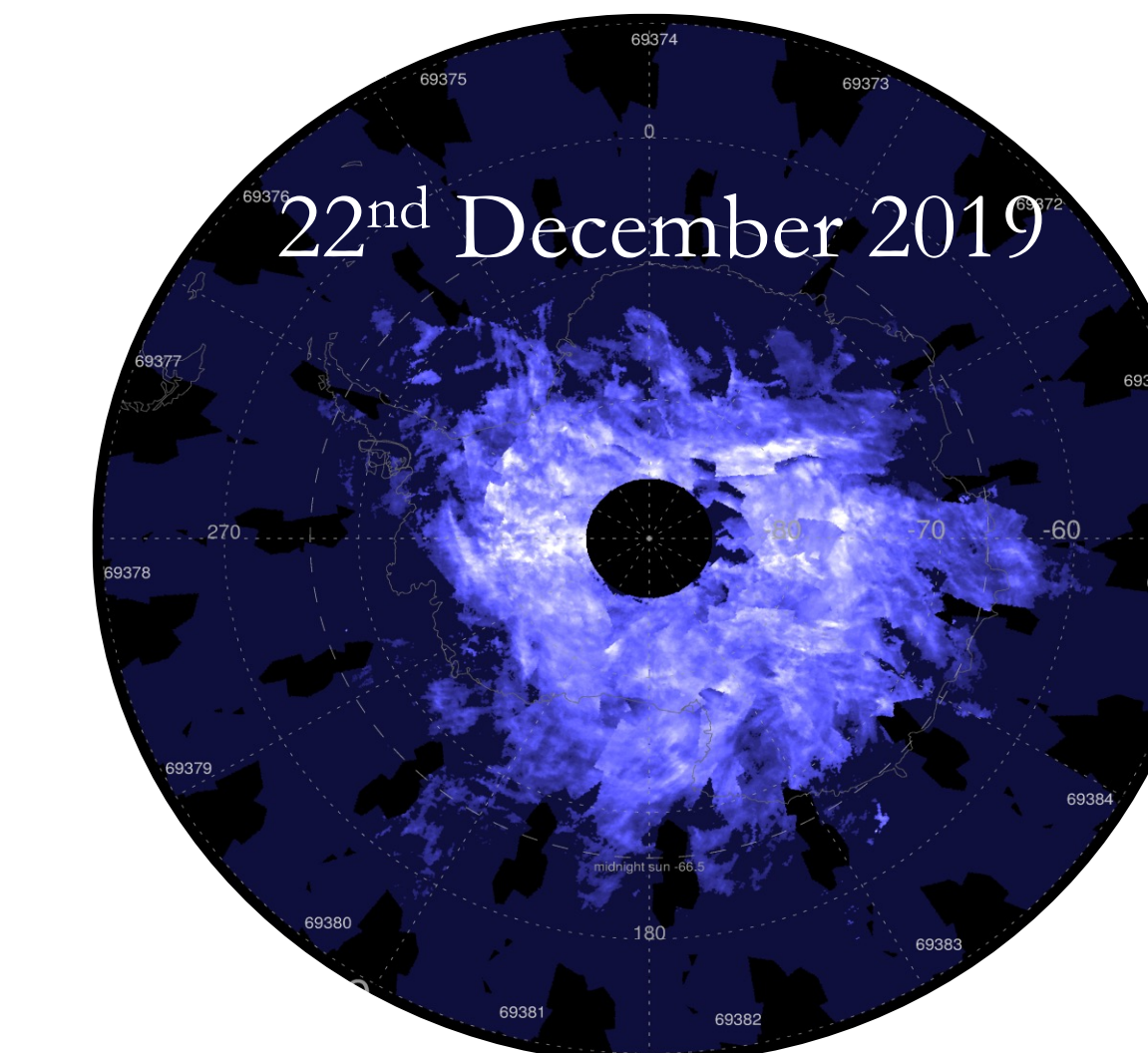
But there is so much we don't know about them yet!
➤ Could PMCs be the first harbinger of long-term climate change?
As climate change ↑ CO_2 cools down MLT → T ↓ and CH_4 → H_2O ↑ ➡ PMC ↑

➤ Mysteries revolving around the 11-year Solar Cycle: **A solar cycle signature is clearly seen from 1978-2002 but disappeared afterwards. Why?**
Solar flux ↑ causes photolysis → H_2O ↓ and radiative heating → T ↑ ➡ PMC ↓

The McMurdo Lidar Campaign aims to answer these questions and resolve theses mysteries!

Lidar Observations of PMCs at McMurdo

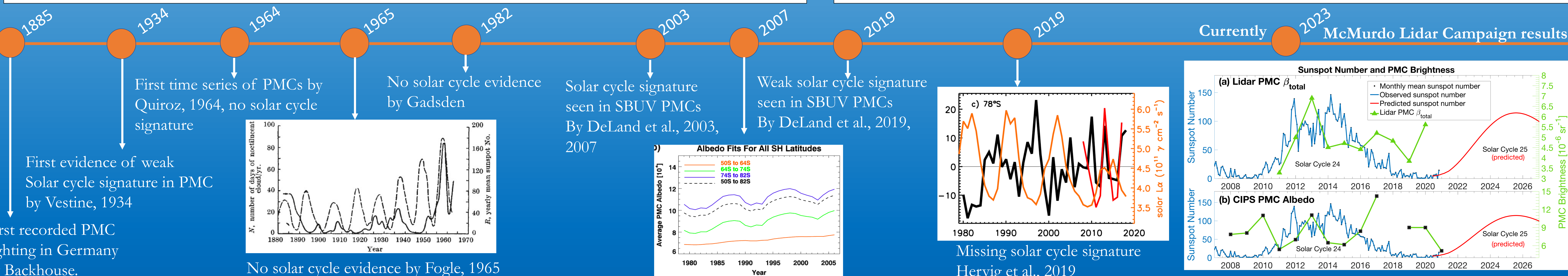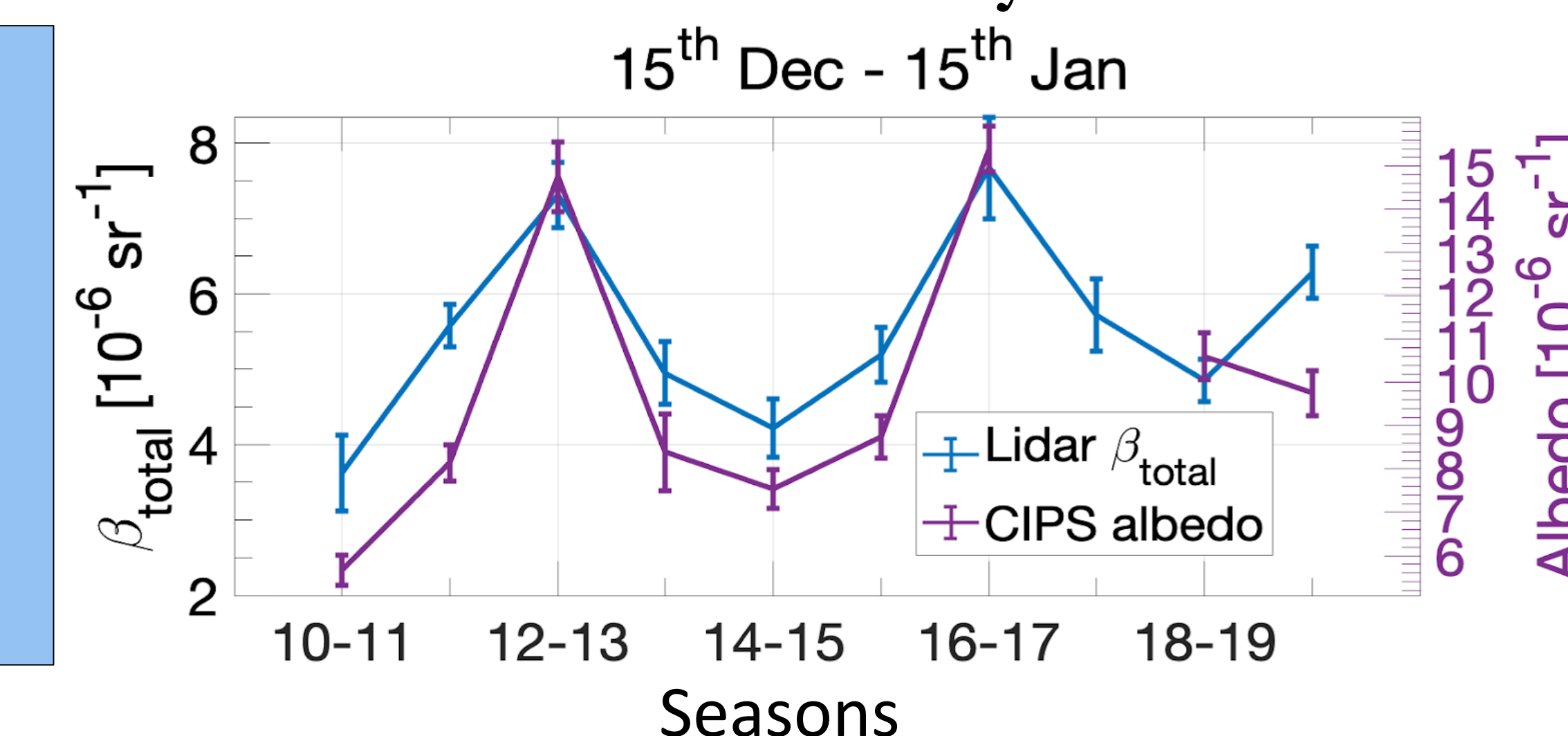**PMC on 22nd December 2019**

AIM satellite CIPS PMC observation over Antarctica

22nd December 2019

Interannual Variability of PMCs
15th Dec - 15th Jan

PMC Brightness correlation between lidar β_{total} and **CIPS albedo R = 0.92 (99.96%)** in the dominant PMC period (**15th Dec – 15th Jan for each season**).

Timeline

- **1885** – First recorded PMC sighting in Germany by Backhouse.
- **1934** – First evidence of weak Solar cycle signature in PMC by Vestine, 1934
- **1964** – First time series of PMCs by Quiroz, 1964, no solar cycle signature / No solar cycle evidence by Fogle, 1965
- **1965** – No solar cycle evidence by Gadsden
- **1982** – Solar cycle signature seen in SBUV PMCs By DeLand et al., 2003, 2007
- **2003**
- **2007** – Weak solar cycle signature seen in SBUV PMCs By DeLand et al., 2019,
- **2019** – Missing solar cycle signature Hervig et al., 2019
- **2019**
- **Currently**
- **2023** – McMurdo Lidar Campaign results

Albedo Fits For All SH Latitudes
- 50S to 64S
- 64S to 74S
- 74S to 82S
- 50S to 82S

c) 78°S

Sunspot Number and PMC Brightness
(a) Lidar PMC β_{total}
- Monthly mean sunspot number
- Observed sunspot number
- Predicted sunspot number
- Lidar PMC β_{total}
Solar Cycle 24 / Solar Cycle 25 (predicted)

(b) CIPS PMC Albedo
Solar Cycle 24 / Solar Cycle 25 (predicted)

Unraveling the mystery behind PMCs and Solar Cycle

Solar cycle is one of many factors affecting T and H_2O in the MLT and solar cycle 24 is one of the smallest cycles!

Late vortex break → PMC ↓
Early vortex break → PMC ↑

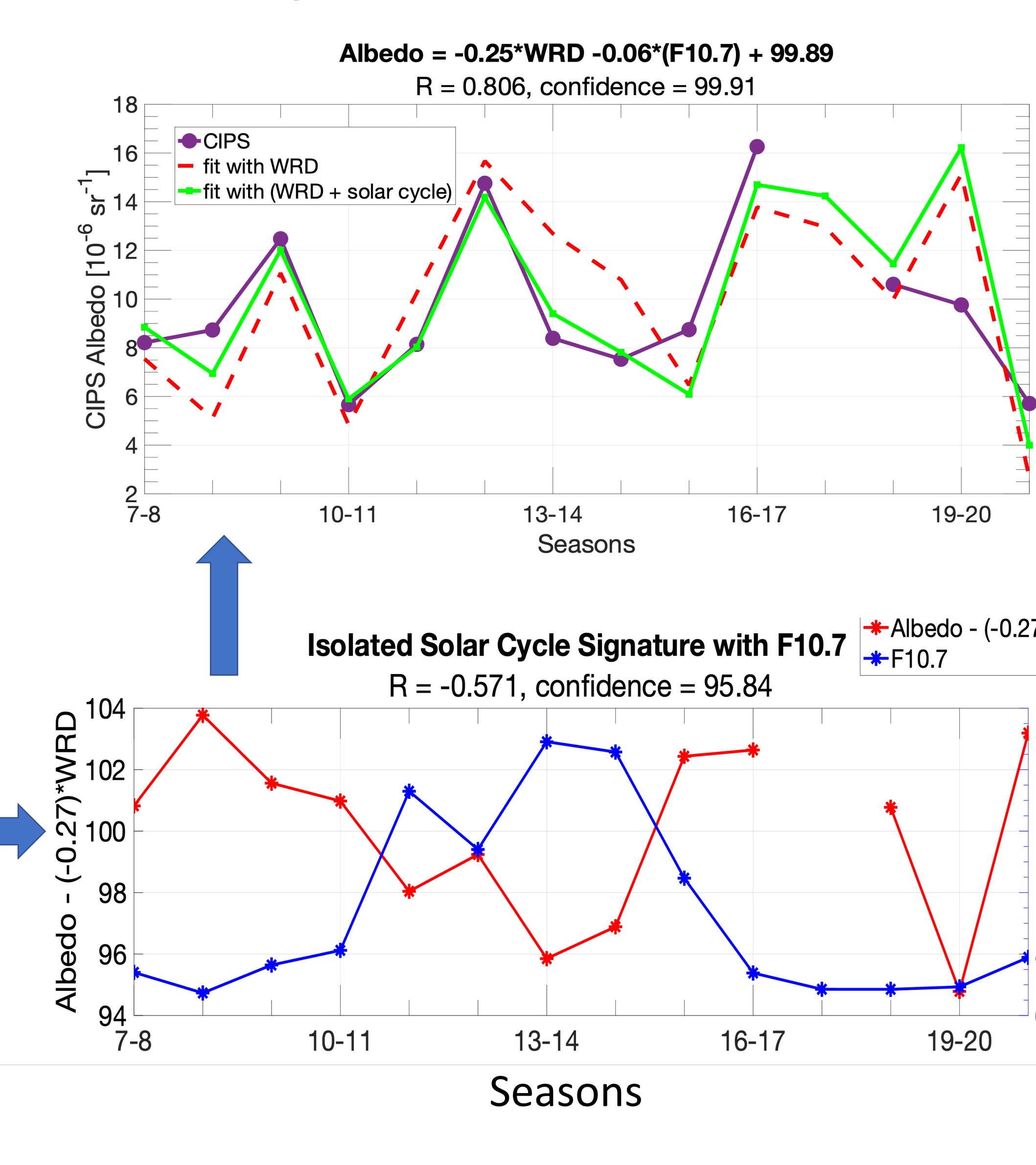Polar Vortex breakup (PVB) timing → Transitions from winter to summer → PMC formation

Could dynamical forcing of the polar vortex overshadow radiative forcing causing the solar cycle to take a back seat in PMC variability?

YES!

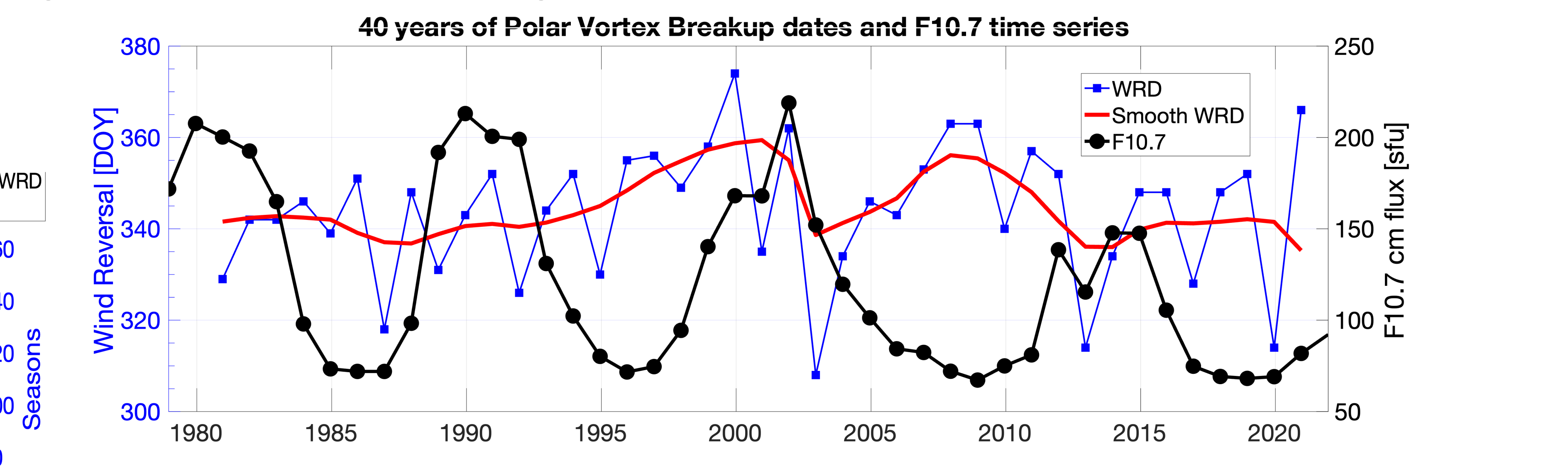**(a) Time series of Lidar PMC β_{total} and Wind Reversal Dates**
- WRD
- Lidar PMC β_{total}

(b) Time series of CIPS PMC Albedo and Wind Reversal Dates
- WRD
- CIPS PMC Albedo

Albedo = -0.25*WRD -0.06*(F10.7) + 99.89
R = 0.806, confidence = 99.91
- CIPS
- fit with WRD
- fit with (WRD + solar cycle)

Isolated Solar Cycle Signature with F10.7
R = -0.571, confidence = 95.84
- Albedo - (-0.27)*WRD
- F10.7

Improved correlation (by 44%) shows that there is a solar cycle signature in PMC brightness variability, although polar vortex is the major driver. Solar cycle is a secondary driver!

But in 1978-2002 what made the solar cycle overshadow polar vortex when polar vortex breakup timing showed similar variability?
PVB timing are averaged out with solar cycle during 1980-2001, so the solar cycle effects stand out. While PVB timing is out of phase with the solar cycle, concealing any solar cycle signatures in the total PMC brightness from 2007 to 2021.

40 years of Polar Vortex Breakup dates and F10.7 time series
- WRD
- Smooth WRD
- F10.7

With such dynamic variability in PMCs, can they really be a Miner's canary? Can PMCs really be the first harbinger of climate change when they have strong variability?