Average spatial distributions of oxygen charge states in the global magnetosphere, as observed by POLAR

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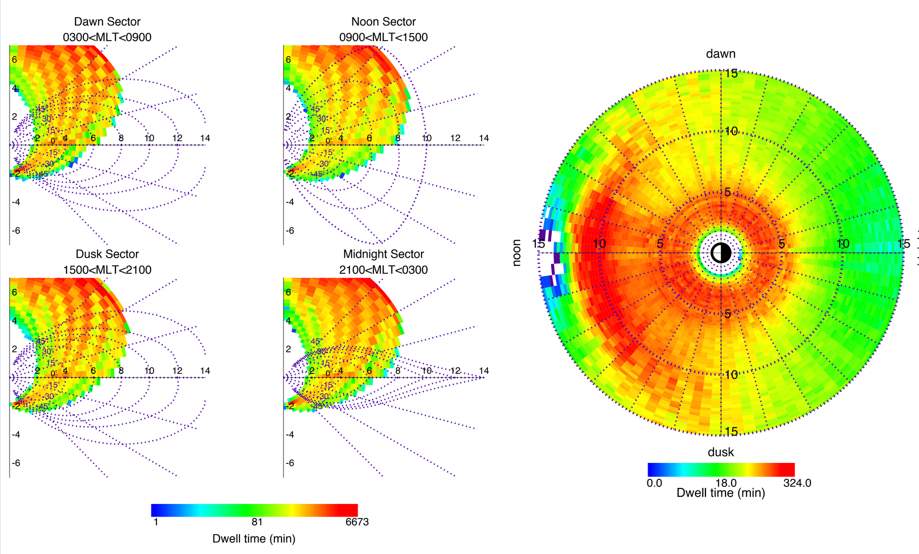
Abstract:

Geomagnetically trapped oxygen ions, of solar and ionospheric origin, have previously been observed in the Earth's magnetosphere. Early observations from AMPTE/CCE have studied this distribution within a limited spatial range of L-shell for all magnetic local times (MLT). This study expands on these early results using observations from the POLAR spacecraft. These distributions show O^{6+}, from the solar wind, charge exchanging into O^{5+}, O^{4+}, and O^{3+} as the ion populations drift to lower L-shells. Meanwhile, ionospheric O^{+} and O^{2+} are primarily seen at low L-shells and may also play a role in O^{3+} populations. Here we will investigate the L-shell, MLT, K_p, Bz, and AE dependencies of these oxygen charge states within the Earth's magnetosphere.

Motivation:

1. To better characterize the distribution and evolution of different charge states of oxygen.
2. To expand on the studies of *Kremser et al.* [1987; 1988].
3. To investigate amount of and dependencies of mass loading of solar O^{6+} into the Earth's magnetosphere.
4. Serve as broad study to launch more pointed case study investigations of Oxygen charge exchange.

POLAR CAMMICE:



Dwell times over the duration of this study are shown to the left for both Distance vs MLAT and MLT vs L-shell.

All L-shells are calculated using the Tsyganenko T96 model.

The CAMMICE instrument onboard POLAR is capable of measuring the counts of heavy ions as well as distinguishing between charge states. This allows for a study of the distribution of counts for different charge states of Oxygen. Due to the cadence of counts with this m/q resolution being lower than the steps of ESA voltage, we are unable to extract energy information. Thus, a study of flux is not possible for this study.

Background:

- The primary charge state of Oxygen in the solar wind is O^{6+}.
- Work done by *Kremser et al.* [1987; 1988] showed the inner magnetospheric oxygen is largely comprised of low charge states, likely originating from the ionosphere.
- The work of *Kremser et al.* [1987; 1988] also investigated how these distributions changed with Kp.
- In a study by *Fritz et al.* [2003], they found a strong correlation between the 30 minute average of phase density of Fe ions observed at ACE with those observed by POLAR.
- We would like to further parameterize the injection of solar wind ions into the magnetosphere, as well as use there ions as a tracer for plasma evolution.

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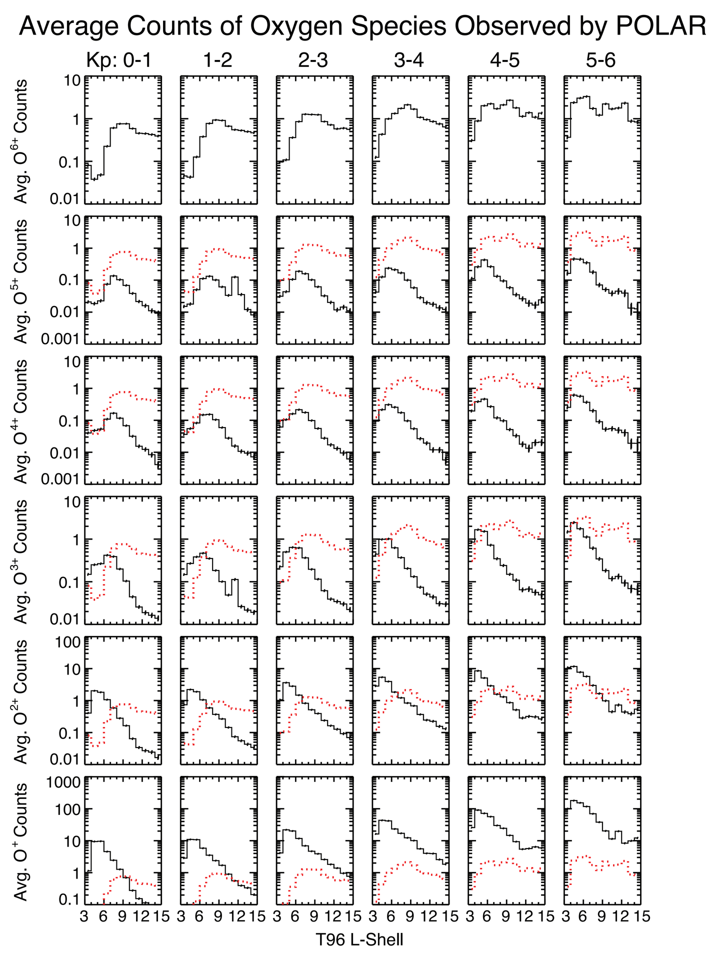
Counts vs. L-shell by Kp:



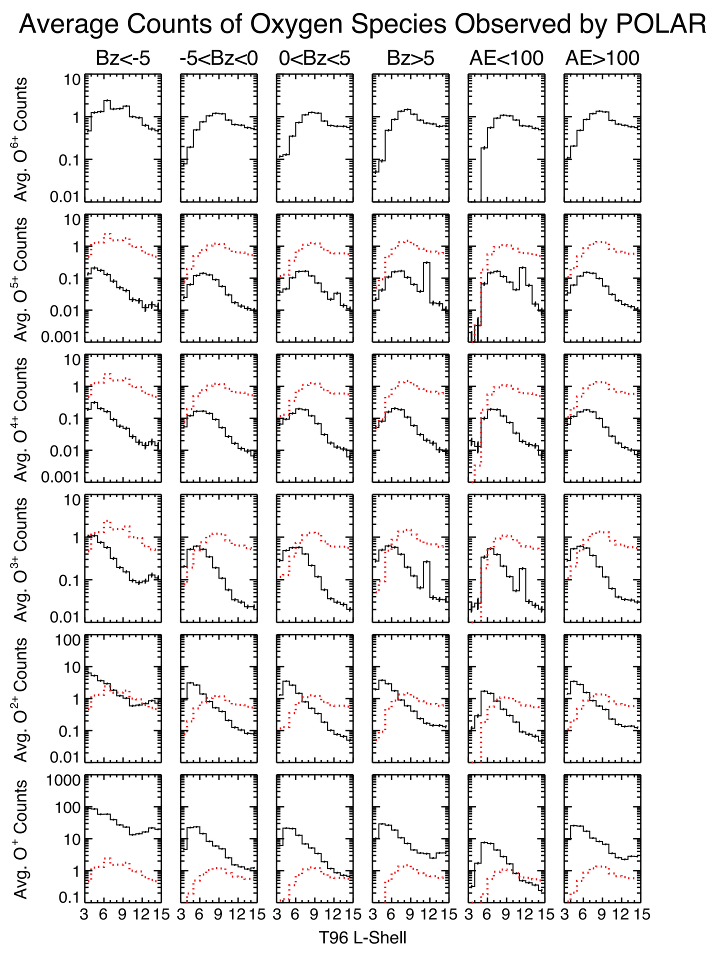
Shown on the left is a plot of counts of different oxygen charge states vs L-shell for different values of Kp for a larger range of L-shells than observed by *Kremser et al.* [1987; 1988].

The value of Kp represents the half hour average of Kp prior to observation.

For all values of Kp, the peak of counts between the different charge states moves inward with lowering charge state.

This illustrates the charge exchange of oxygen as it drifts inward.

Counts vs. L-shell by Bz and AE:



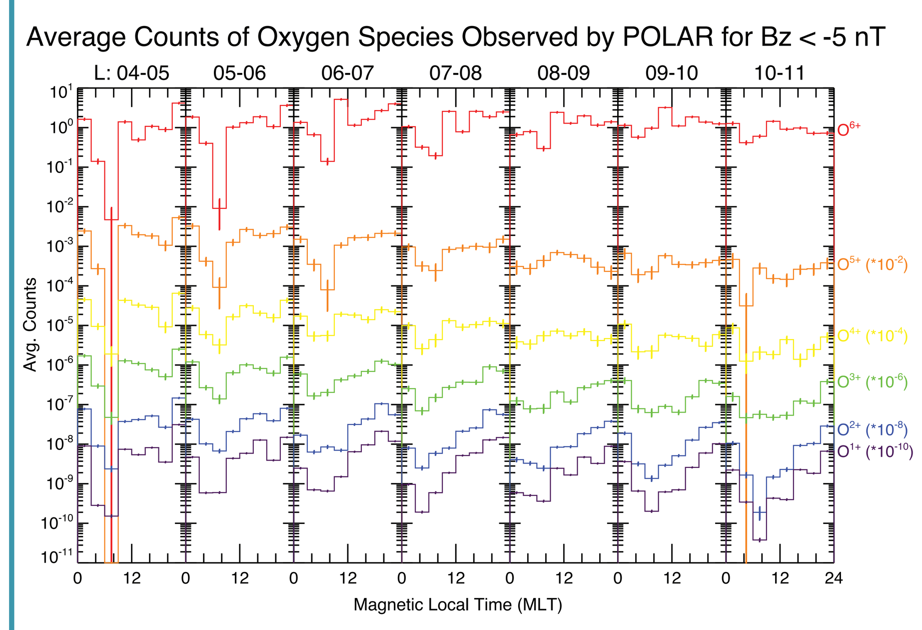
To the left is the distribution of counts vs L-shell for different half an hour averages of Bz and AE.

This shows that for strong southward Bz there is a higher amount of oxygen transport into the magnetosphere from the solar wind.

Additionally, the same change in relative peaks of charge states is seen as in the Kp plot.

There is little difference in the distributions for slight southward Bz and slight/strong northward Bz as well as between small vs large AE indices.

Counts vs. MLT by Bz:

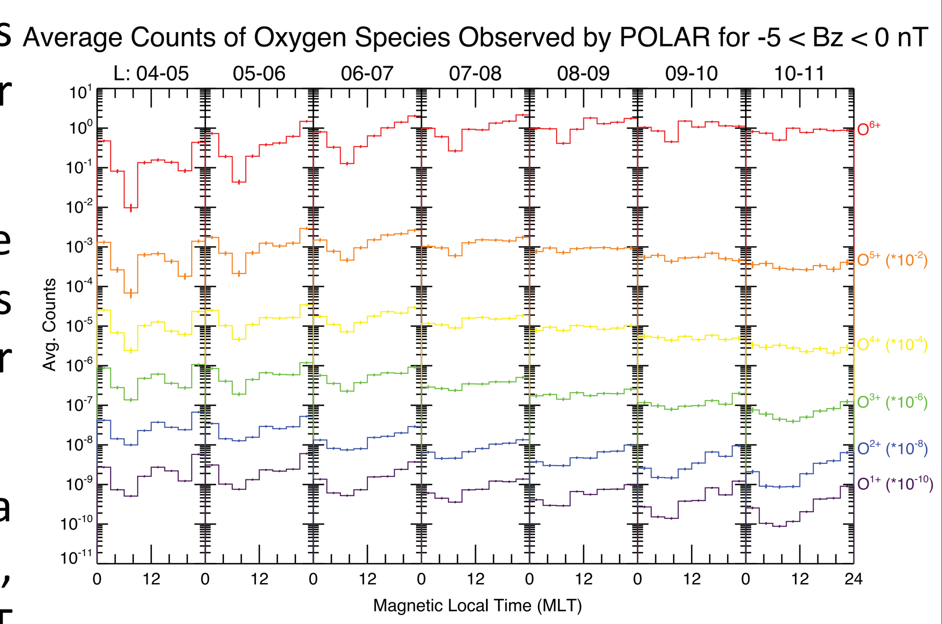


Distribution of counts vs MLT by different L-shells for times of half-hour average Bz < -5 nT.

Higher L-shells become more flat with slightly less counts at dawn for higher charge states.

Lower charge states see a peak in the dusk sector.

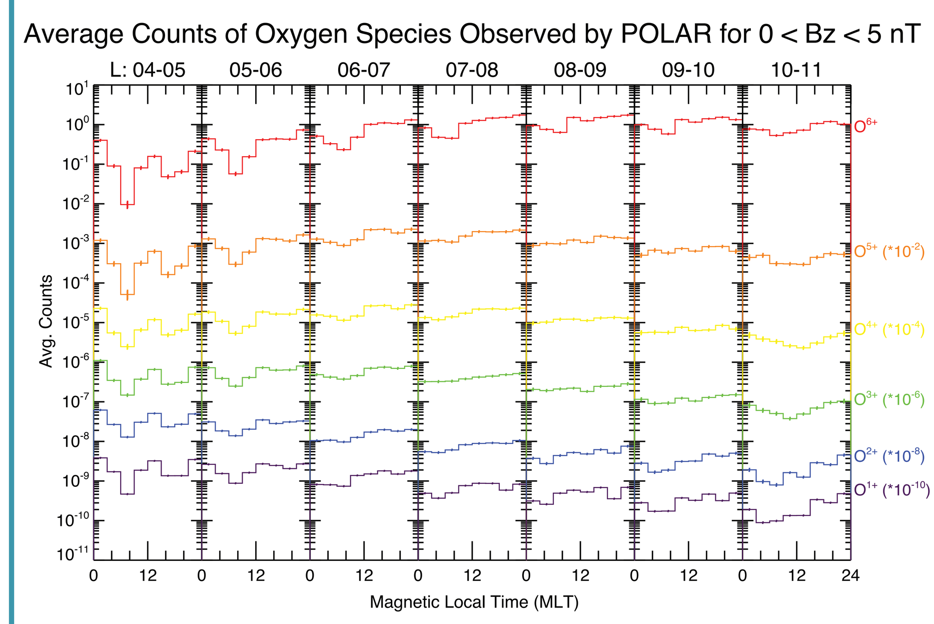
Distribution of counts vs MLT by different L-shells for times of half-hour average -5 < Bz < 0 nT.



Higher L-shells become more flat with slightly less counts at dawn for higher charge states.

Lower charge states see a peak in the dusk sector, but flatter than Bz < -5 nT case.

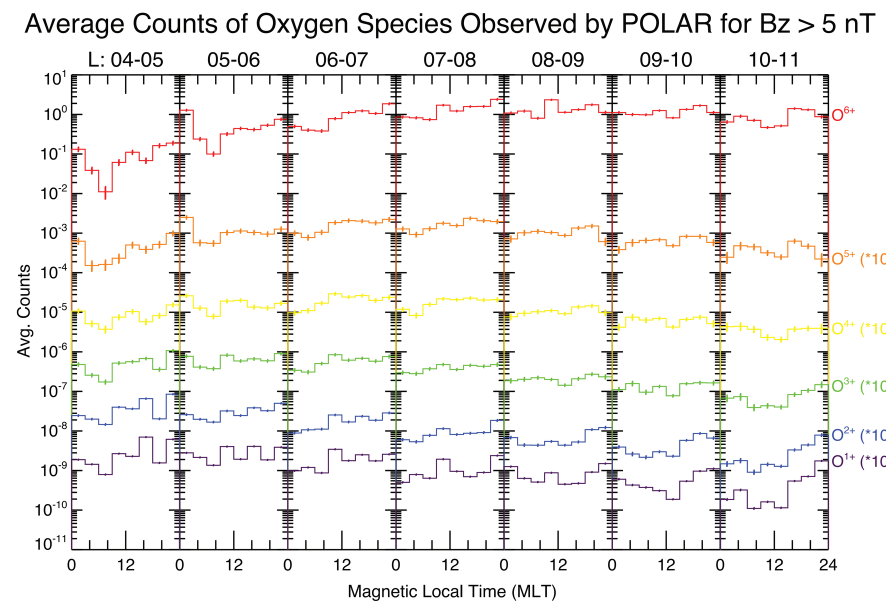
Counts vs. MLT by Bz (cont.):



Distribution of counts vs MLT by different L-shells for times of half-hour average 0 < Bz < 5 nT.

Distributions are flatter than for southward Bz.

Distribution of counts vs MLT by different L-shells for times of half-hour average Bz > 5 nT.



The distributions for higher charge states are flat.

Lower charge states observe an MLT asymmetry for L > 9.

Discussions & Conclusions:

Counts vs. L-shell by Kp	As Kp increases, the peak count rates increase.
	Distribution of O^{6+} becomes flat for higher L-shells with increasing Kp.
	The L-shell of peak counts for different change states becomes lower with lower ionization.
	O^{3+}, O^{4+}, and O^{5+} could be O^{6+} ions that have charge exchanged while drifting inwards.
Counts vs. L-shell by Bz	Strong southward Bz results in increased O^{6+}.
	Slightly southward and northward Bz distributions have little different.
	O^{6+} ions are likely from the solar wind.
Counts vs. L-shell by AE	Higher AE only increases the peak of low charge states.
	Higher charge states are not a result of substorms.
Counts vs. MLT by Bz	Higher charge states see less variation over MLT for most L-shells than lower charge states.
	All charge states see lower counts in the dawn sector for southward Bz.
	Little variation over MLT is seen for northward Bz.

References:

Fritz et al. (2003), The use of iron charge state charges as a tracer for solar wind entry and energization within the magnetosphere, *Ann. Geophys.*, 21, 2155-2164, doi: 10.5194/angeo-21-2155-2003

Kremser et al. (1987), Average spacial distributions of energetic O+, O2+, O6+, and C6+ ions in the Magnetosphere observed by AMPTE CCE, J. Geophys. Res., 92, 4459-4466, doi:10.1029/JA092iA05p04459

Kremser et al. (1988), Observations of energetic oxygen and carbon ions with charge states between 3 and 6 in the magnetosphere, *Ann. Geophys.*, 6, 325-334