Polar Cloud Opacity and Surface Pressure Responses to Atmospheric Electricity from Global Circuit and Solar Wind Sources: Electrical Modulation of Aerosol Scavenging Rates?

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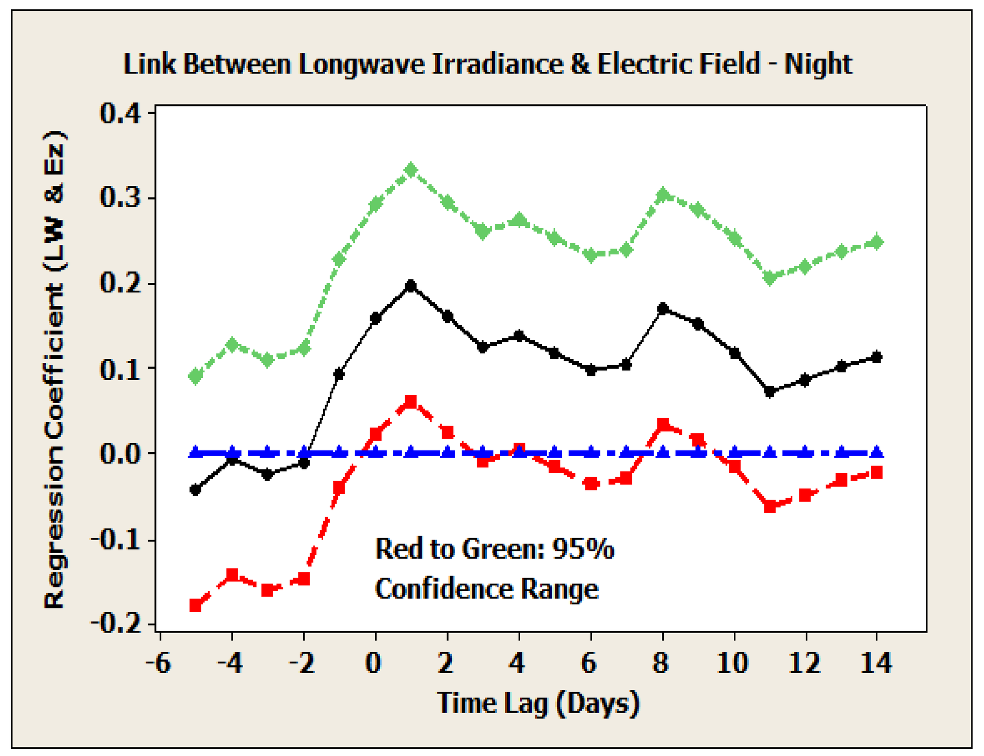
The effect of current flow in the global electric circuit on in-cloud scavenging, aerosol concentrations, and cloud radiative forcing is a phenomenon that is now being explored through both observational, theoretical and modeling work.

OBSERVATIONAL DATA

1 **Measured visible and downwelling infrared irradiances** at the South Pole and Summit, Greenland show statistically significant correlations with both internal and external drivers of downward ionosphere-Earth current density (Jz), using Vostok, Antarctica vertical electric field (Ez) measurements as a proxy for Jz

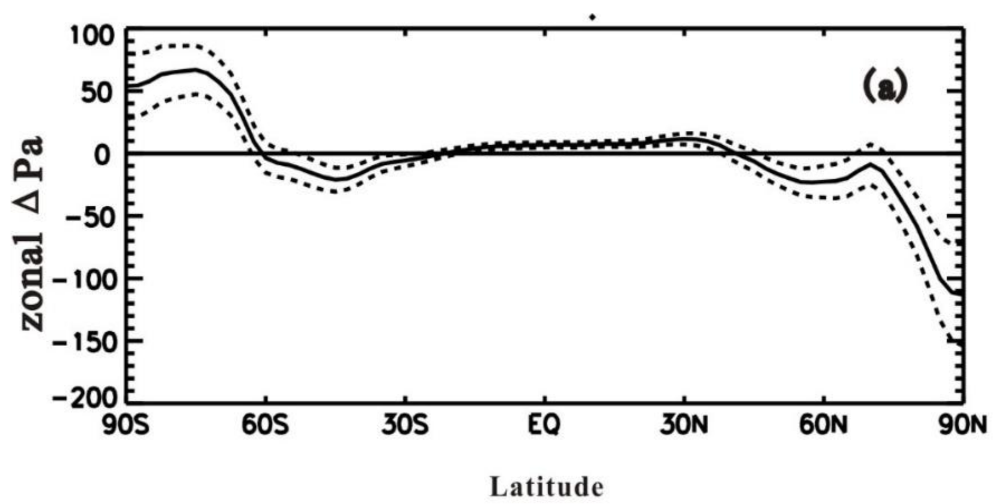


Lagged regression coefficient of local cloud opacity (longwave IR irradiance) vs vertical electric field at South Pole. Exceeds 95% Statistical significance.

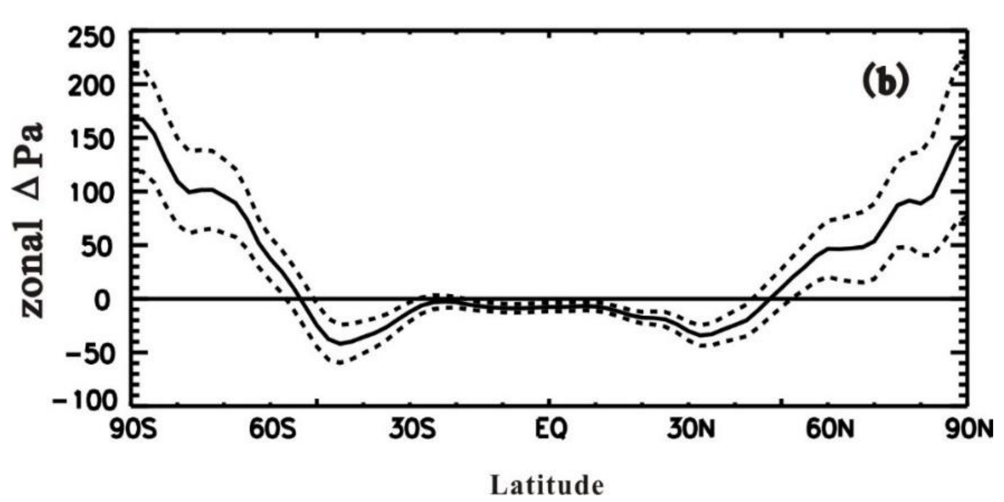
3% change in opacity at South Pole for 25 V/m in electric field change.

See refs. 1-4

2. Surface Pressure changes consistent with the cloud irradiance (opacity) and current density changes in persistent stratus-type clouds in the polar regions.



Annual average surface pressure (Pascals) responses to IMF By changes > 6 nT , (equivalent to > 4 V/m Ez change)



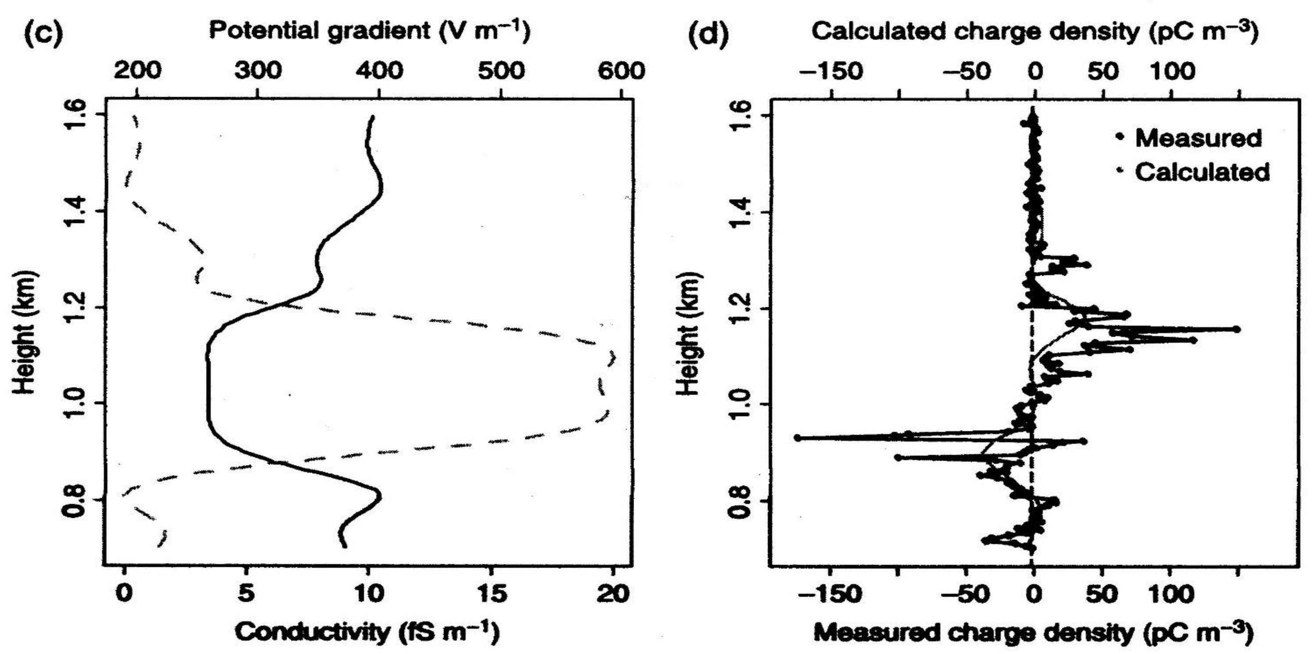
Annual average surface pressure responses to measured Ez changes >10 V/m

See refs 5-8

THEORY and MODELING

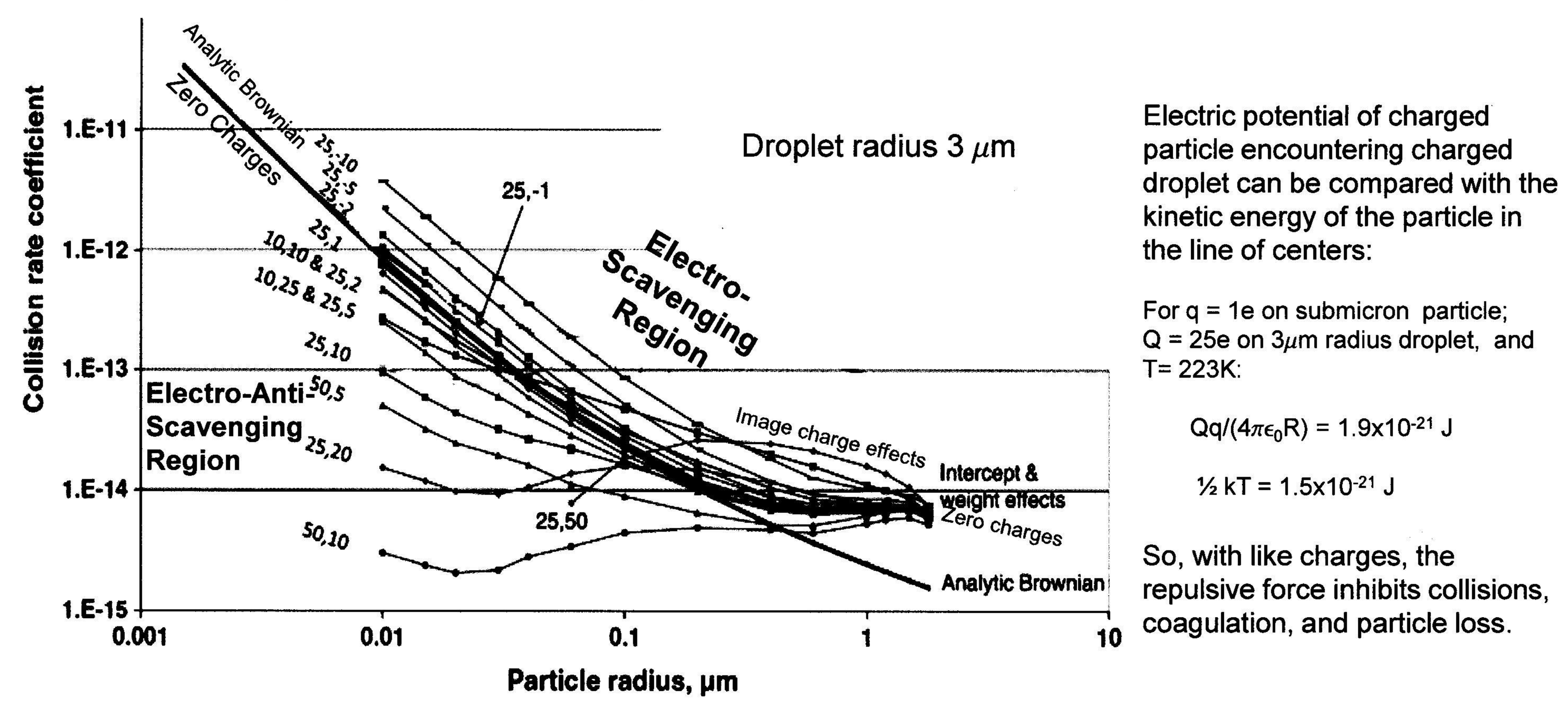
1 **Cosmic rays** produce ions in the global atmosphere. This allows **current flow** (Jz) in the global electric circuit, generated by thunderstorms and electrified shower clouds and by solar wind electric fields at high latitudes. The Vostok Ez measurements have been shown to be reliable proxies for diurnal varying and average day-to-day changes in the generators. See refs. 9-10.

2. **Aerosol particles and droplets** are quickly **charged** by ions: the majority charged either positively or negatively. Initially 'symmetric' charges (equal concentrations of positive and negative charges). Downward flow of current density (Jz) through gradients of conductivity at gradients of droplet concentration at cloud boundaries produces asymmetric **'space charge'** (excess charge of one sign on ions, particles and droplets) at **cloud boundaries** especially for stable stratus-type clouds. Refs. 11-15



Formation of Space Charge at Tops and Bases of Layer Clouds. Ref. 15. Potential gradient and conductivity model (left) compared with space charge measured by balloon and modeled (right)

3. **Collision and coagulation** rates for small aerosol particles (less than about 0.2 microns radius) are **reduced in space charge** regions, decreasing loss rates. This will cumulatively reduce the loss and increase the concentration of small CCN and small droplets, when eventually activated in weak updrafts. See refs 16 and 17.



4. Collision and collection rates for larger (above about 1 micron radius) aerosol particles are increased by image charge forces as a net effect of charge in space charge regions, and as the only effect of charge in symmetric charge regions. Refs. 12, 16 and 17.

These effects subsequently narrow CCN and droplet size distributions; increase concentration; reduce coagulation, and increase cloud opacity.

NEEDED WORK

Continuing observations of global circuit variations.

Modeling of charging process (dependent on positive and negative ion mobility, ion concentration, size distributions of aerosol particles, of droplets, and of mixing).

Modeling of time variations of aerosol number and size distributions; on ice nucleation, and on macroscopic cloud properties, resulting from of electric charge effects .

CONCLUSIONS

Electric current flow in the global atmospheric electric circuit influences in-cloud coagulation and scavenging processes.

Effects occur both in space charge regions, and symmetrically charged regions in cloud interiors. The effects are different for small aerosol particles (electro-anti-scavenging) and large particles (electro-scavenging). **These can account for observed changes in cloud opacity and atmospheric dynamics via cloud radiative forcing.**

References:

1. Frederick (2016). J. Atmos. Solar Terr. Phys., 147, 59-70
2. Frederick (2017). J. Atmos. Solar Terr. Phys., 164, 97-104
3. Kniveton et al. (2008). J. Atmos. Solar Terr. Phys., 70, 1633-1642
4. Frederick and Tinsley (2018). J. Atmos. Solar Terr. Phys., 70, under review
5. Burns et al. (2008). J. Geophys. Res., 113, D15112
6. Lam et al. (2013), Env. Res. Lett., 8, 045001
7. Lam et al, (2014), Geophys. Res. Lett., 41, 6509-6514
8. Zhou et al. (2018), J. Atmos. Solar Terr. Phys., 171, 111-118
9. Zhou and Tinsley (2010), J. Atmos. Sci., 67, 1143-1156
10. Burns et al. 2005, J. Geophys. Res., 110, D10106
11. Mironova et al., (2012), J. Adv. Space Res., 50, 783-790
12. Tinsley, (2012), J. Adv. Space Res., 50, 791-805
13. Beard et al., (2004), Geophys. Res. Lett, 31, L14111
14. Zhou and Tinsley, (2012), J. Adv. Space Res., 50, 828-842
15. Nicoll and Harrison, (2016), Q. J. Roy. Meteol. Soc. 142, 2679-2691
16 Tinsley and Leddon (2013), J. Geophys. Res., 118, 8612-8624
17. Tinsley and Zhou, (2015). J. Geophys. Res., 120, 8389-8410