Water Adsorption on model atmospheric clay minerals as a function of RH: Application to Adsorption Activation Theory

Courtney D. Hatch, Kenneth J. Harris, Matthew J. Christie and Ann Greenaway

Hendrix College Department of Chemistry

Mineral Dust Aerosol

- Scattered and dispersed order (direct climate effect)
- Ather tropospheric gas phase budget, photochemistry and mineral surface composition
- Influence ocean bioproductivity by deposition of bioavailable minerals
- Impact human health and visibility
- Act as cloud condensation nuclei (CCN) in indirect climate forcing

Recent Advances

Adsorption Activation Theory

Water Adsorption affects CCN activation

\[ S_{100} = \exp \left( -\frac{A}{B} \right) \exp \left( 4\Gamma \frac{M}{RT_p D} \right) \]

- A & B MUST be determined experimentally

HATR-FTIR H₂O Adsorption Measurements

Application of FHH Adsorption Isotherm

The Frankel-Halsey-Hill (FHH) Isotherm:

- Promising isotherm for describing multilayer adsorption of water on insoluble particles.
- A term: Describes long-range van der Waals interactions between the surface of the clay and the first adsorbed monolayer.
- B term: Describes interactions between surface and successive monolayers

Water Adsorption affects CCN activation:

- Aerosol:
  - Experimentally shown
  - Theoretically illustrated

Water Adsorption and growth

Applications/Shortfalls of Köhler Theory

- Köhler Theory: Describes growth of completely soluble particles well
- Köhler effect: droplet size decreases the equilibrium vapor pressure above the particle.
- Result effective water activity term: equilibrium vapor pressure around the particle, which decreases with increasing particle size.
- Köhler Theory: Works well for insoluble aerosols, including freshly emitted mineral dust aerosol, that exhibit physical H₂O adsorption.
- Köhler Theory: Works well for describing growth of soluble and insoluble aerosols that contain >10% by mass soluble material.
- Köhler Theory: Works well for freshly emitted mineral dust aerosol, that exhibit physical H₂O adsorption.

Acknowledgements

Support: The National Science Foundation supports this work under Grant No. ATM-0928121.

Thanks: The Hatch group would like to thank Dr. Jonas Baltrusaitis for his assistance with FTIR spectroscopy work.

References


Conclusions

1. Experimental water adsorption measurements were used to extract FHH parameters to predict CCN activity of the three most abundant clays in the Earth’s atmosphere.
2. Results agree well with previously measured CCN activities.
3. Atmospheric models should account for contribution of freshly-emitted mineral dust aerosol to the #CCN available in the atmosphere.
4. More information about the exact method of water adsorption onto clays is needed, along with particle size-specific data, in order to provide a better model of CCN activation in these materials.