Using Microfluidic Biphasic Flows to Study Aqueous Atmospheric Aerosol Chemical Mimics

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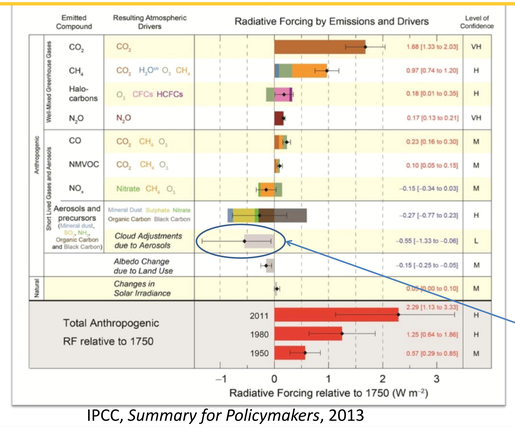
Project Scope

What are atmospheric aerosols?

- Liquid or solid particles suspended in the atmosphere
- Size range: 1 nm – 100 µm;
- Sources: natural (volcanoes) and anthropogenic (fossil fuel emission);
- Common water-soluble species found in aqueous phase: inorganic electrolytes (Na^+, NH_4^+, SO_4^{2-}, Cl^-) and organics (dicarboxylic acids);
- Impacts climate, human health, and cloud formation.

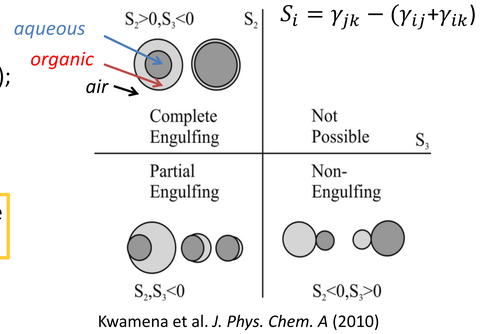
In this work, we studied the surface activity of organic acids, which are a key chemical component in **Aqueous Atmospheric Aerosols.**



IPCC, *Summary for Policymakers*, 2013

Spreading Coefficient

$$S_i = \gamma_{jk} - (\gamma_{ij}+\gamma_{ik})$$

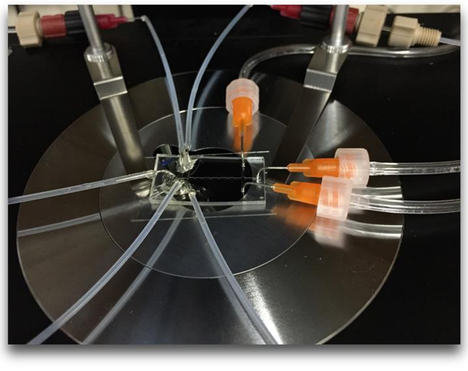


Kwamena et al. *J. Phys. Chem. A* (2010)

Why are we interested in their surface properties?

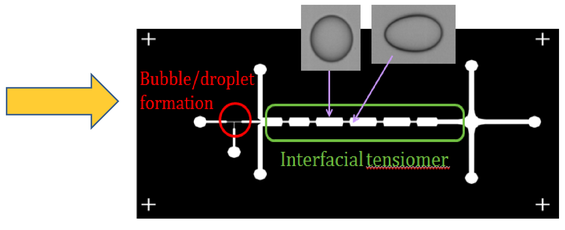
- *Surface tension* influences particle growth due to effect on vapor pressure of curved surfaces, (Kelvin effect);
- *Chemical bulk – surface partitioning* dictates available species for surface based heterogeneous chemistry;
- Surface composition affects their *optical properties* and thus changes the radiative energy budget of the Earth, known as *radiative forcing*;
- *Particle mixing state and morphology* are determined by interfacial tension and challenging to observe.

Methods



Biphasic Microfluidic Flows

- A novel method for studying aerosol micro-mimics: aqueous droplets (dispersed phase) and silicone oil (continuous phase);
- Key advantages: high throughput, non-contact, important length scale for interfacial processes.

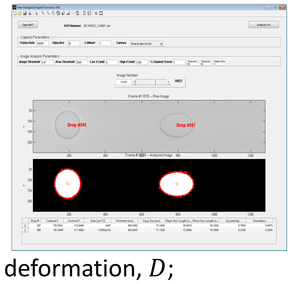


Matlab Analysis – Interfacial Tension (IFT) Measurements

- Two unknowns, viscosity, η_c, and interfacial tension, σ. We measured viscosity and calculated the interfacial tension.

$$\alpha\eta_c\left(\frac{5}{2\hat{\eta}+3}\dot{\varepsilon} - u\frac{\partial D}{\partial x}\right) = \gamma\frac{D}{a_0}$$

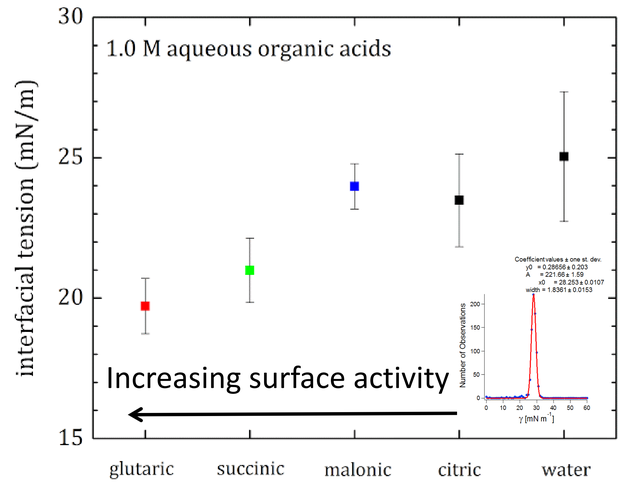
(Hudson et al., *Appl. Phys. Lett.*, 2005)

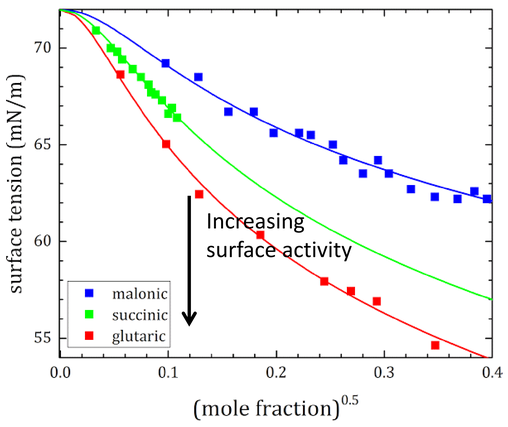


- Variables: Flow velocity, u; drop deformation, D; extension rate, $\dot{\varepsilon}$; undistorted drop radius, a_0; relative viscosity, $\hat{\eta}$, of which α is a function; viscosity, η_c; and interfacial tension, γ.

Results

Correlation of Interfacial Tension with Surface Activity





Boyer and Dutcher, *J. Phys. Chem. A,* (under review)

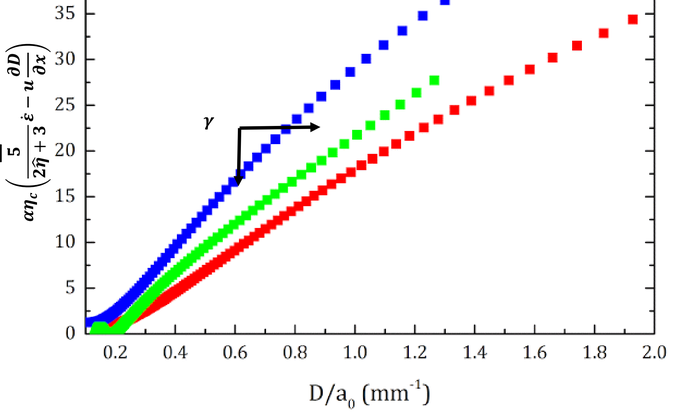
Depression of surface tension

- We measured IFT of dicarboxylic acids.
- IFT compared well with statistical models demonstrating the varying depression of surface tension for the dicarboxylic acids.
- Citric acid is a weak surfactant, so expected to have the least depression of surface tension.

Viscosity

- The effect of viscosity on IFT was minimal
- Found we could approximate viscosities as water with little effect on results

Species	Viscosity (mPa-s)	Statistical Error (mPa-s)
Glutaric	1.269	0.024
Succinic	1.4705	0.0085
Citric	1.4977	0.0158
Malonic	1.115	0.003



Conclusions

My research focused on various dicarboxylic acids because of their abundance in the atmosphere, solubility in water, and how they inform aerosol surface properties as they generally reside on aqueous surfaces. The data gathered agreed with predictions of interfacial tension for the variety of dicarboxylic acids that all experienced a decrease in interfacial surface tension compared to pure water. These preliminary results demonstrate using microfluidic devices to extrapolate surface property data on atmospheric aerosols.