Surface tension and surfactant concentration in atmospheric aerosols: Completing the ecosystems-aerosol-cloud relationship

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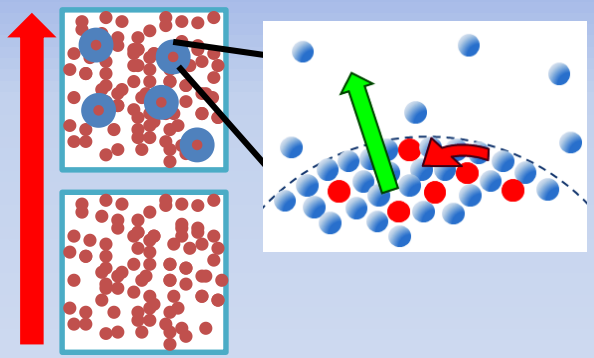
Context and scientific objectives

SOLAS Theme 4
"Interconnections between aerosols clouds and ecosystems"

Cloud formation not predicted by models:
computational & **fundamental challenges**



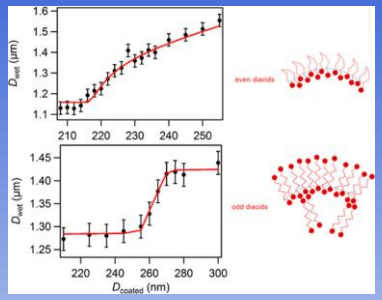
In Earth's atmosphere **clouds possible**
ONLY because chemicals in aerosols affect

- **Raoult's term ⇒ «hygroscopicity»**
- **Surface tension ⇒ surfactants**

Surfactant effects not detected by «on-line» instruments
⇒ hardly studied and excluded from models

Context and objectives *(continued)*

Yet many recent studies indicate a role of surfactants

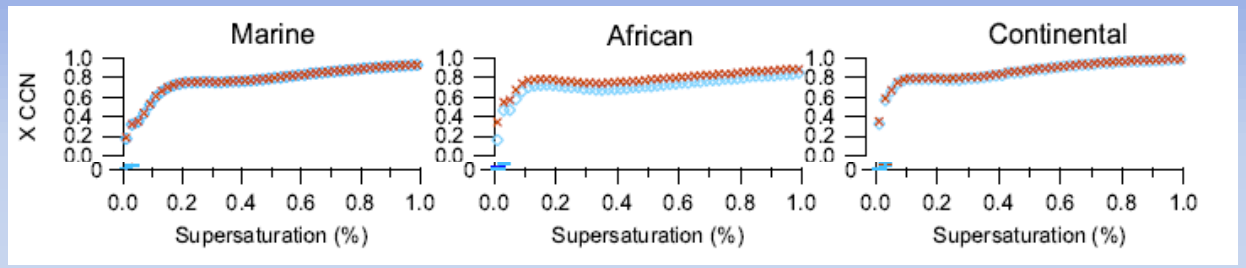


In laboratory

Ruehl et al. 2012; 2014…

In the atmosphere

Asa-Awuku et al. 2006, Good et al., 2010; Irvin et al., 2010



Long res. time instruments ⇒ CCN_{meas} ≥ 1000 cm^{-3} instead of 500

⇒ surfactants present (σ ~ 50 mN/m) & factor 2 on CCN numbers !!!!

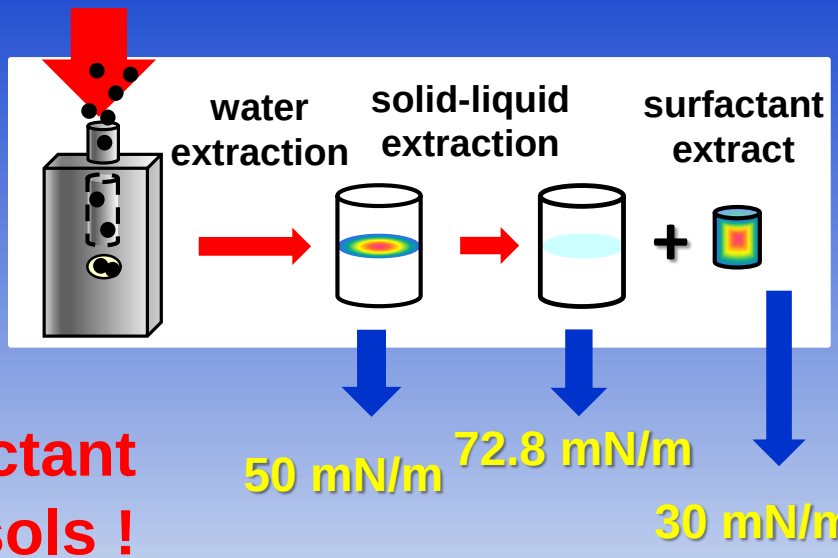
⇒ Objectives of our project

- Isolate & characterize aerosol surfactants directly
- Develop alternatives to “on-line” techniques
- Determine their role on cloud formation
- Determine sources and/or link with ecosystems

Methodology

- Collect aerosol samples on filters
- Isolate aerosol surfactants by targetted double extraction

Ekström et al. 2010, Baduel et al. 2012, Gérard et al., 2015

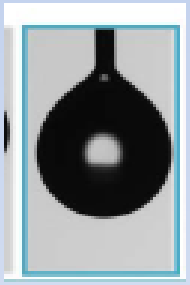


⇒ **Extracts total surfactant fraction of aerosols !**

Combine with investigation of the extracts by

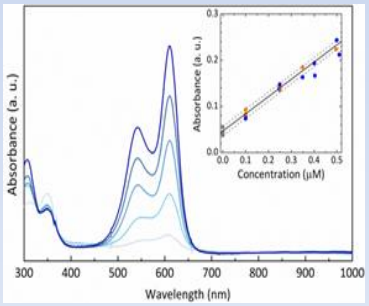
- **Surface tension measurements**

Hanging droplet technique (V_{min} = 40 µL, $\varnothing_{min}$ = 1 mm)



- **Concentration measurements**

Colorimetric methods: dyes specific for anionic, cationic or non-ionic surfactants



- **Chemical analysis (NMR, LC/MS…)**

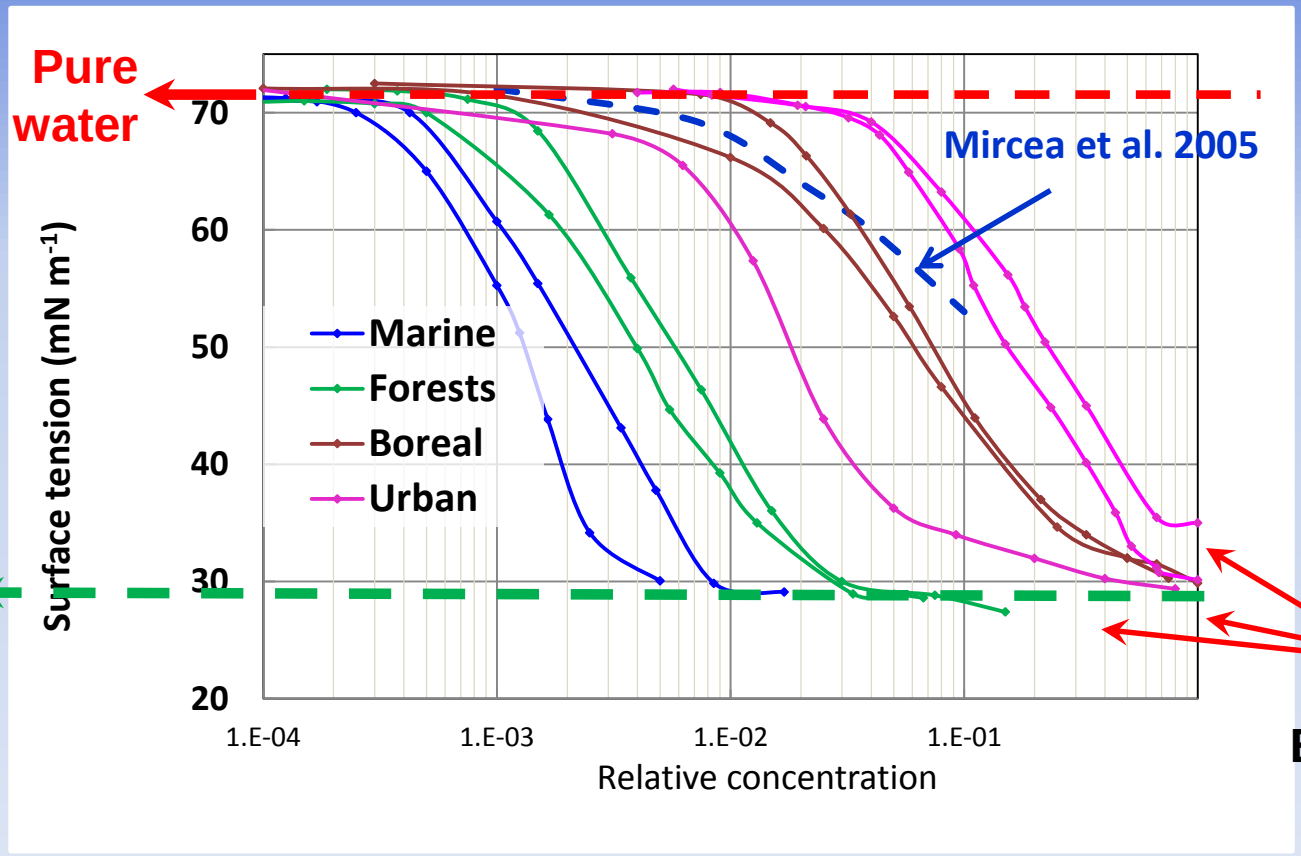
…

Main results

1. Relative surface tension curves:

Much stronger surfactants than expected present in PM1, PM2.5, PM10 aerosol fractions

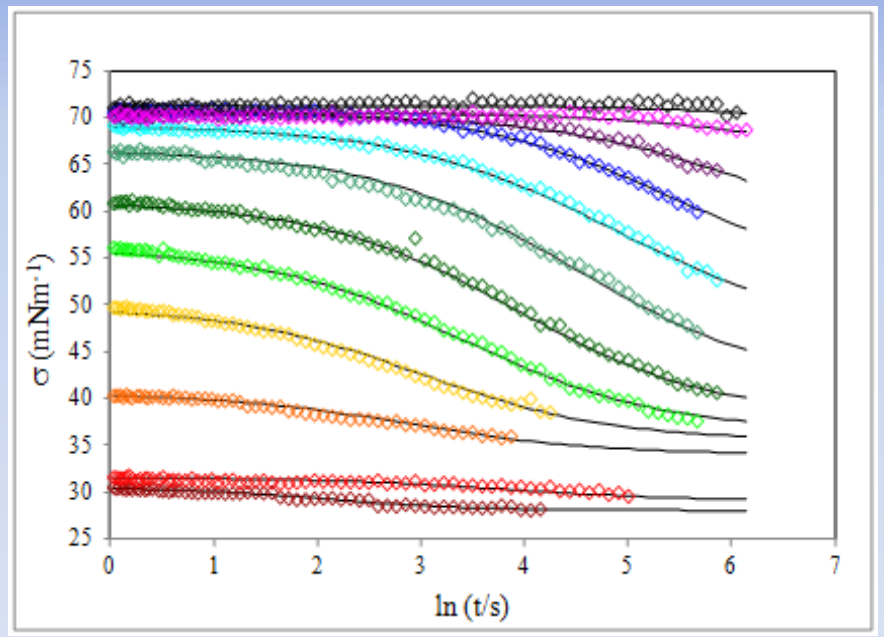
Ekström et al. 2010, Baduel et al. 2012, Gérard et al., 2015

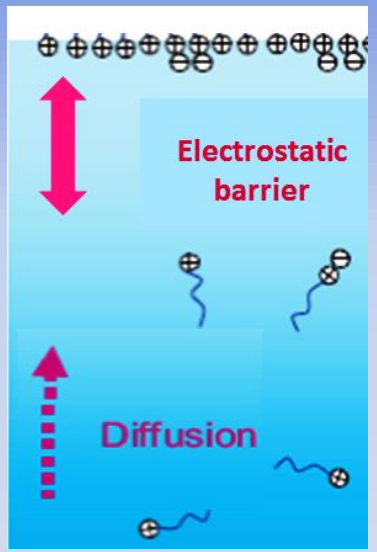


Main results *(continued)*

2. Dynamic surface tension study of atmospheric surfactants:

Atmospheric surfactants need ≥ 30 s to equilibrate in aerosol particles ⇒ explains why on-line instruments «blind» to them





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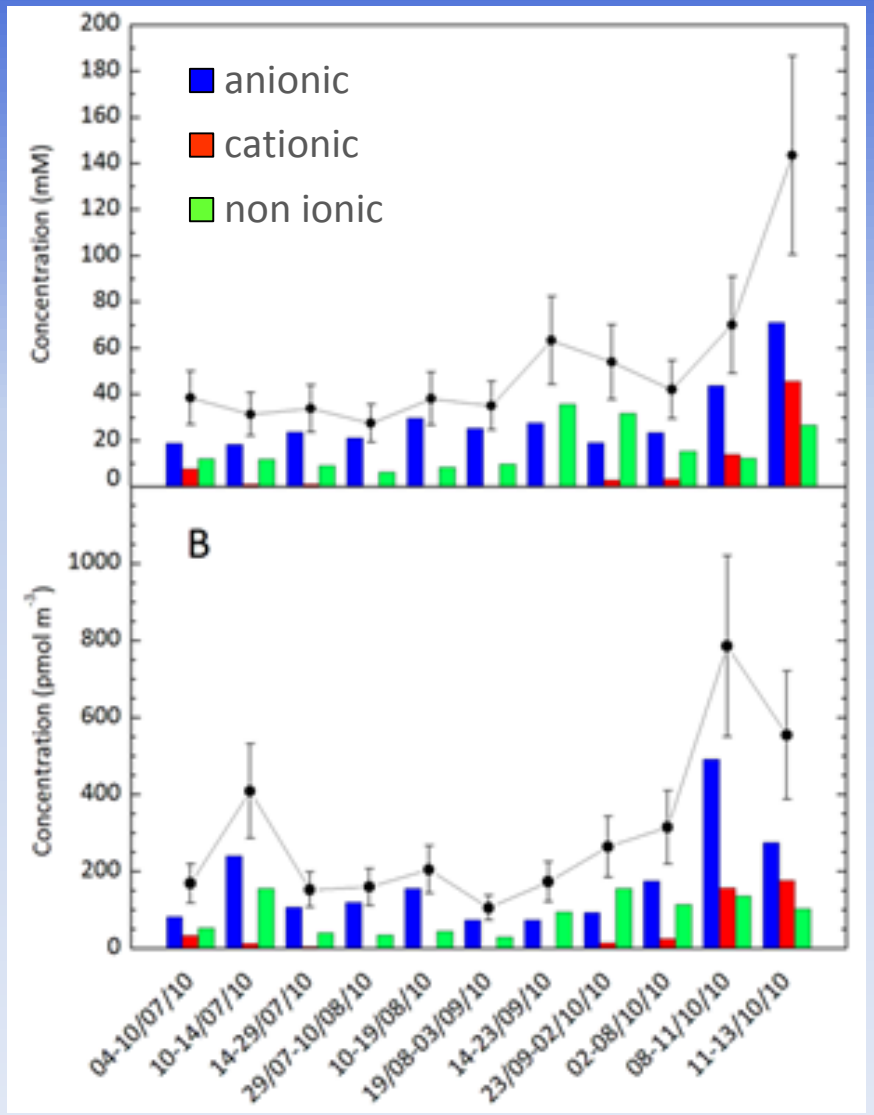
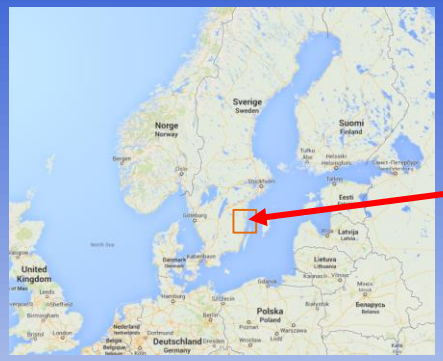
The dynamic surface tension of atmospheric aerosol surfactants reveals new aspects of cloud activation

Barbara Nozière[1,†], Christine Baduel[1,†] & Jean-Luc Jaffrezo[2]

Main results *(continued)*

3. Absolute concentrations & surface tension curves:





PM2.5 from Askö, Sweden

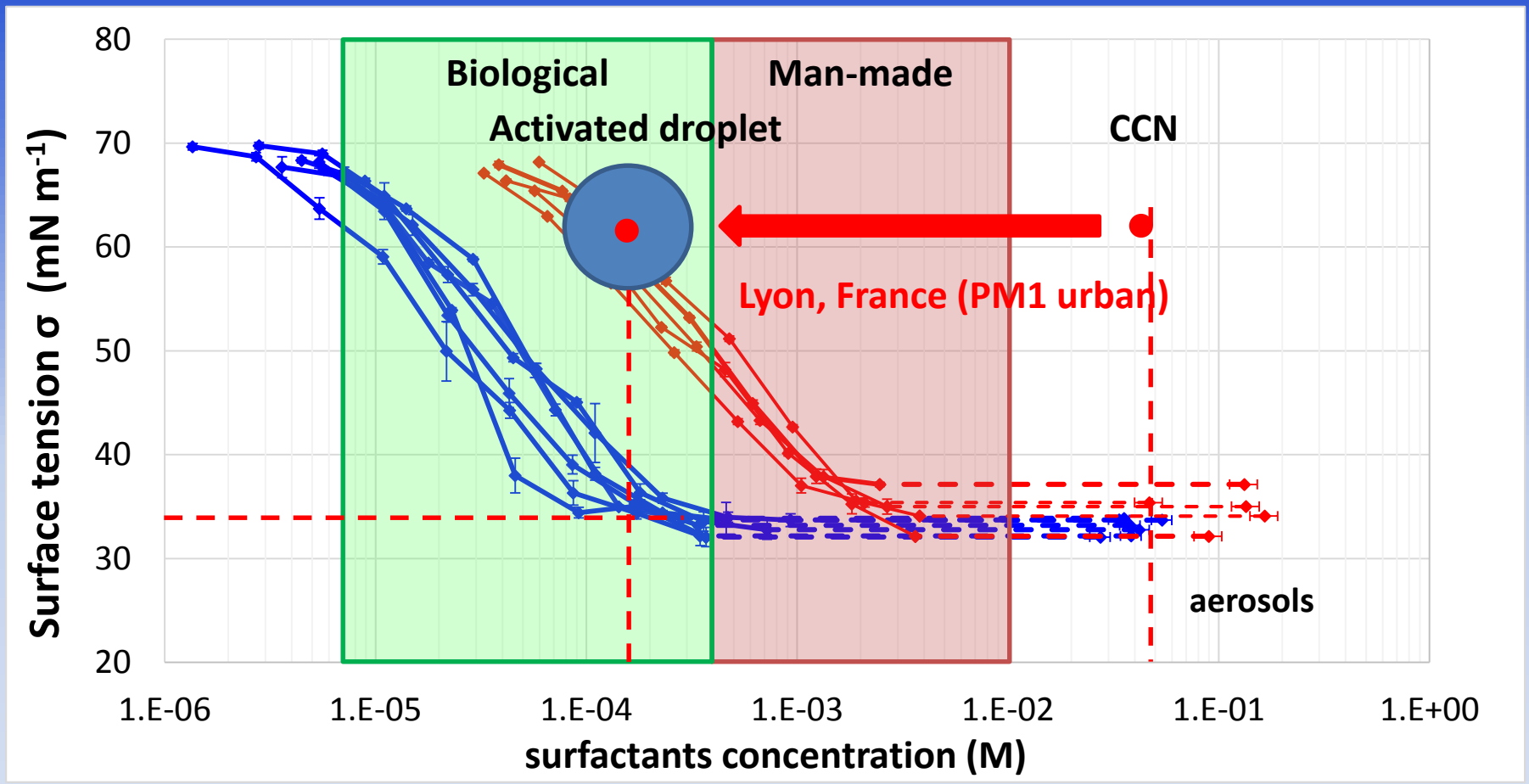
Seasonal evolution of anionic > non-ionic > cationic surfactants

Detection limits:
~ 50 nM anionic/cationic,
~ 300 nM non ionic

No correlation between surfactant types

⇒ no common sources

Absolute surface tension curves

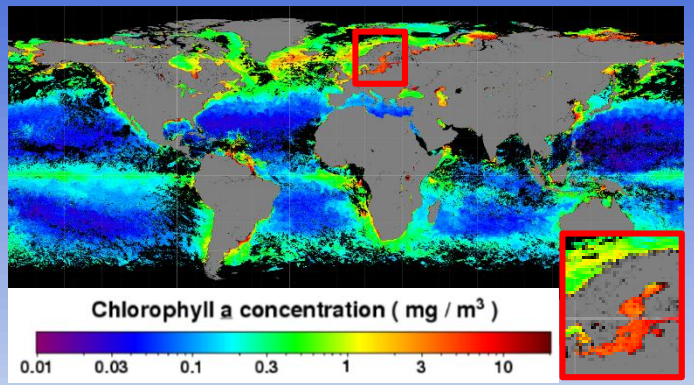


- Surfactants concentrated enough to affect complete activation
- Curves in typical range for microbial surfactants ⇒ biological origin ?

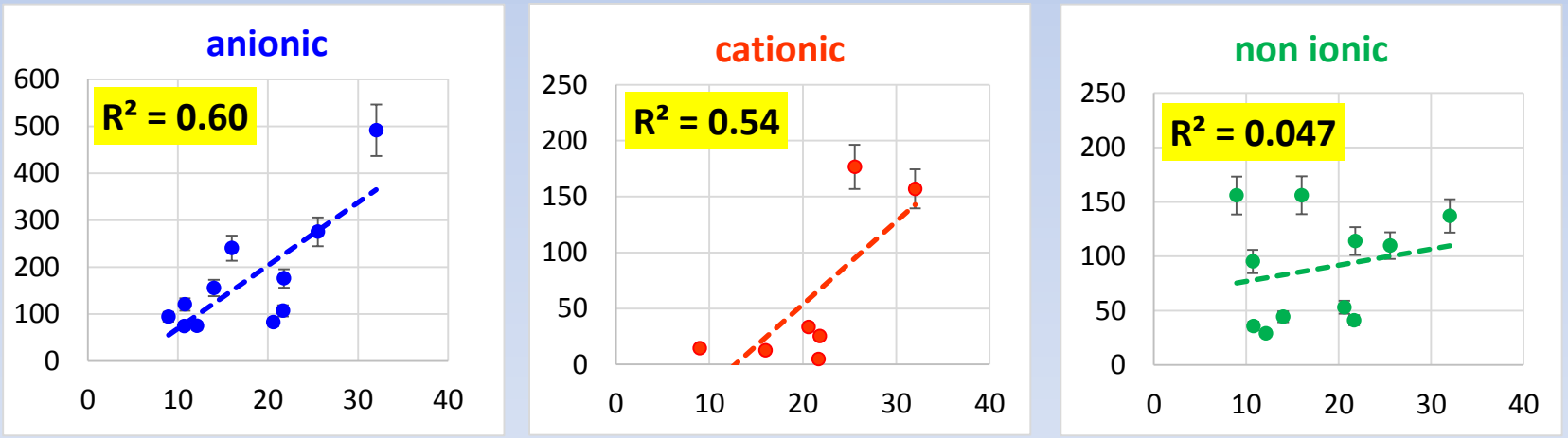
Main results *(continued)*

3. Source apportionment: Correlations with seawater chlorophyll

Chlorophyll a data from
MODIS aqua satellite, Level L3
Resolution: 15 km area around Askö



surfactant a concentration (pmol m^{-3})



⇒ **Possible marine & biological origin** *(Gerard et al. 2015)*

Conclusions

- Presence of strong surfactants ($\sigma \leq 40$ mN/m) in atmospheric aerosols now well established
- Concentrated enough to affect entire cloud droplet activation process
- Now possible to investigate sources and other properties (molecular structure…) $\Rightarrow$ large progress expected in near future
- Development of alternatives to on-line techniques essential for progress

Contributors

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Thank You !