Exploring Wildfire Plumes in the Paris region during Summer 2022: Integrating ACTRIS and ICOS Observations

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LSCE

SIRTA Scientific Day 2024

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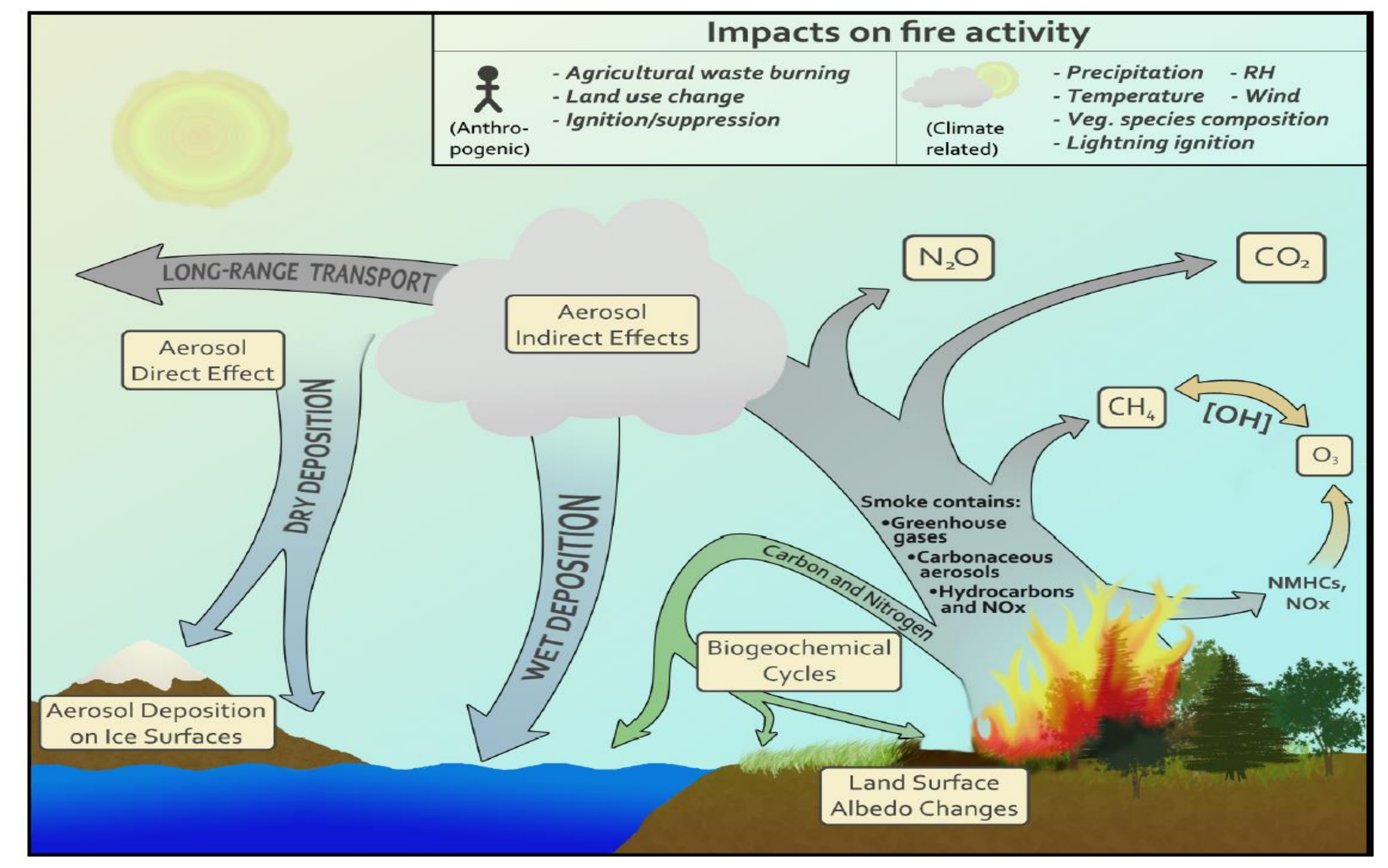
Wildfires have a large influence on atmospheric composition

❖ Wildfire smoke can rise many kilometres into the upper atmosphere, and can spread on a continental scale.



(Ward et al., 2012)

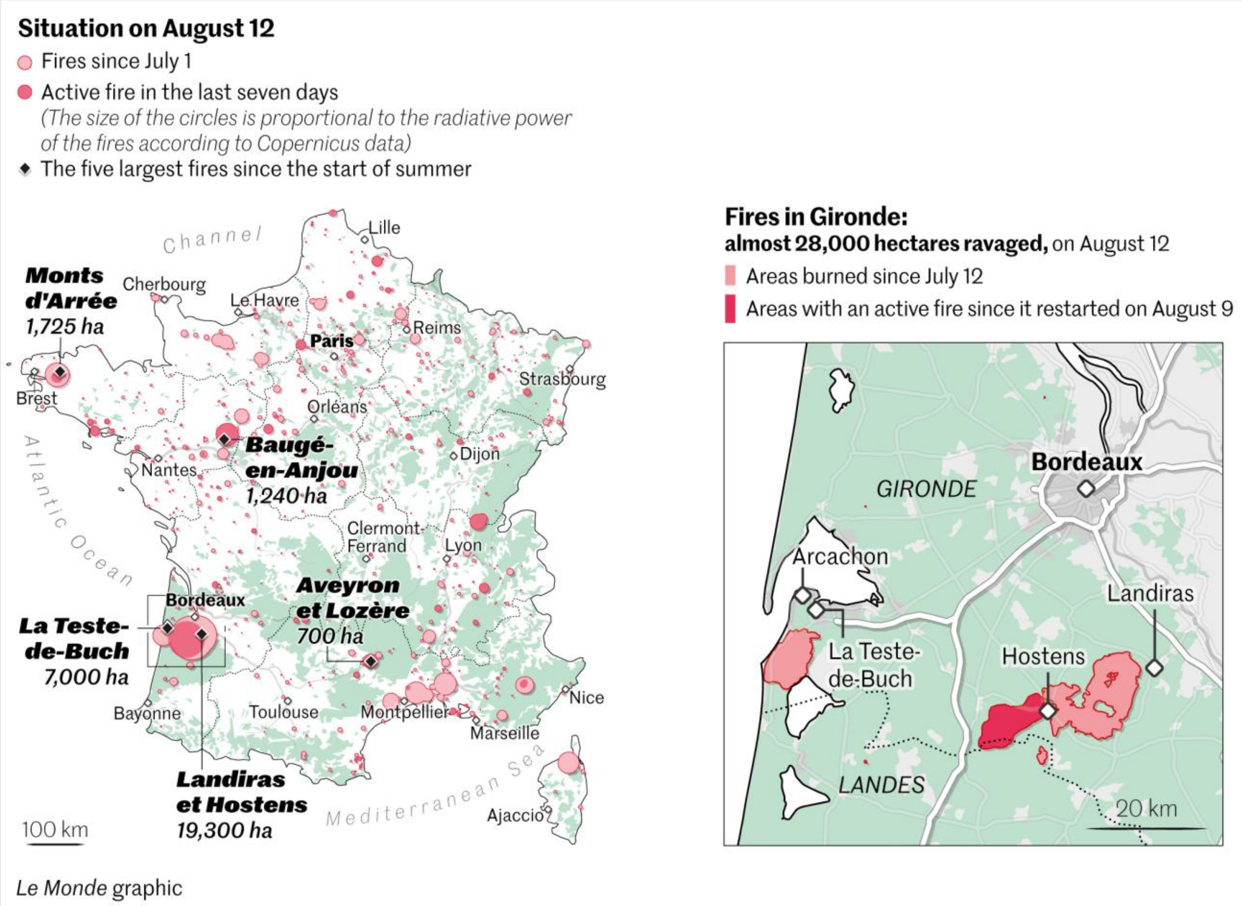
Aerosols injected into the upper atmosphere from extreme wildfires take longer to be removed from the system.

Wildfire emissions shape future climate in changing scenarios..

How well do we understand their atmospheric impacts?

France’s unprecedented summer of wildfires

- ❖ Enhanced by intense drought
  unprecedented heatwave
  record-breaking fire season in France in 2022 (10x higher than average)



- ❖ Wildfires everywhere!

- ❖ Air pollution knows no boundaries..

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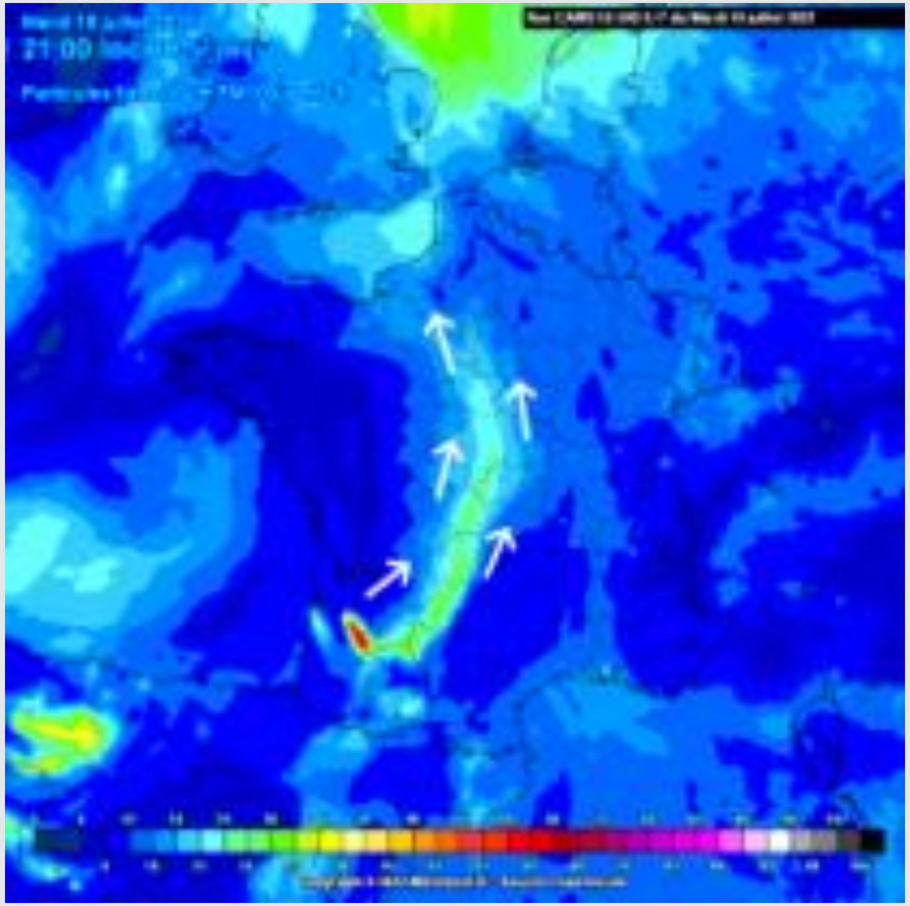
France’s unprecedented summer of wildfires

- On July 19th 2022, remarkable plume from Landes forest travelling throughout France

Impacted large urban areas, such as Paris



Source: ECMWF

- **What are the physical, chemical, and optical characteristics of the plumes..?**

- **What are their impact when they mix with urban atmosphere..?**

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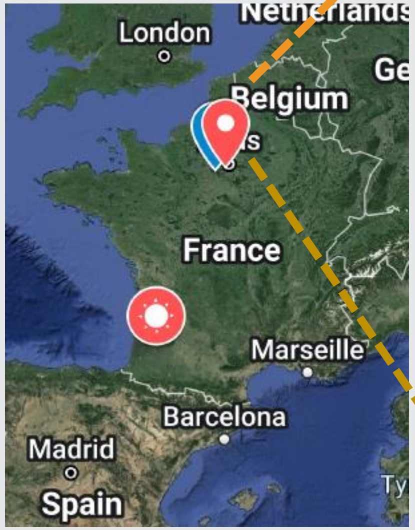
In-situ observations in the Paris region during summer 2022



Rambouillet
Forest site

Chatelet
Urban site

SIRTA
Sub-urban site

❖ Impact of wildfire plume on different kinds of observational sites: like forest, sub-urban, and urban

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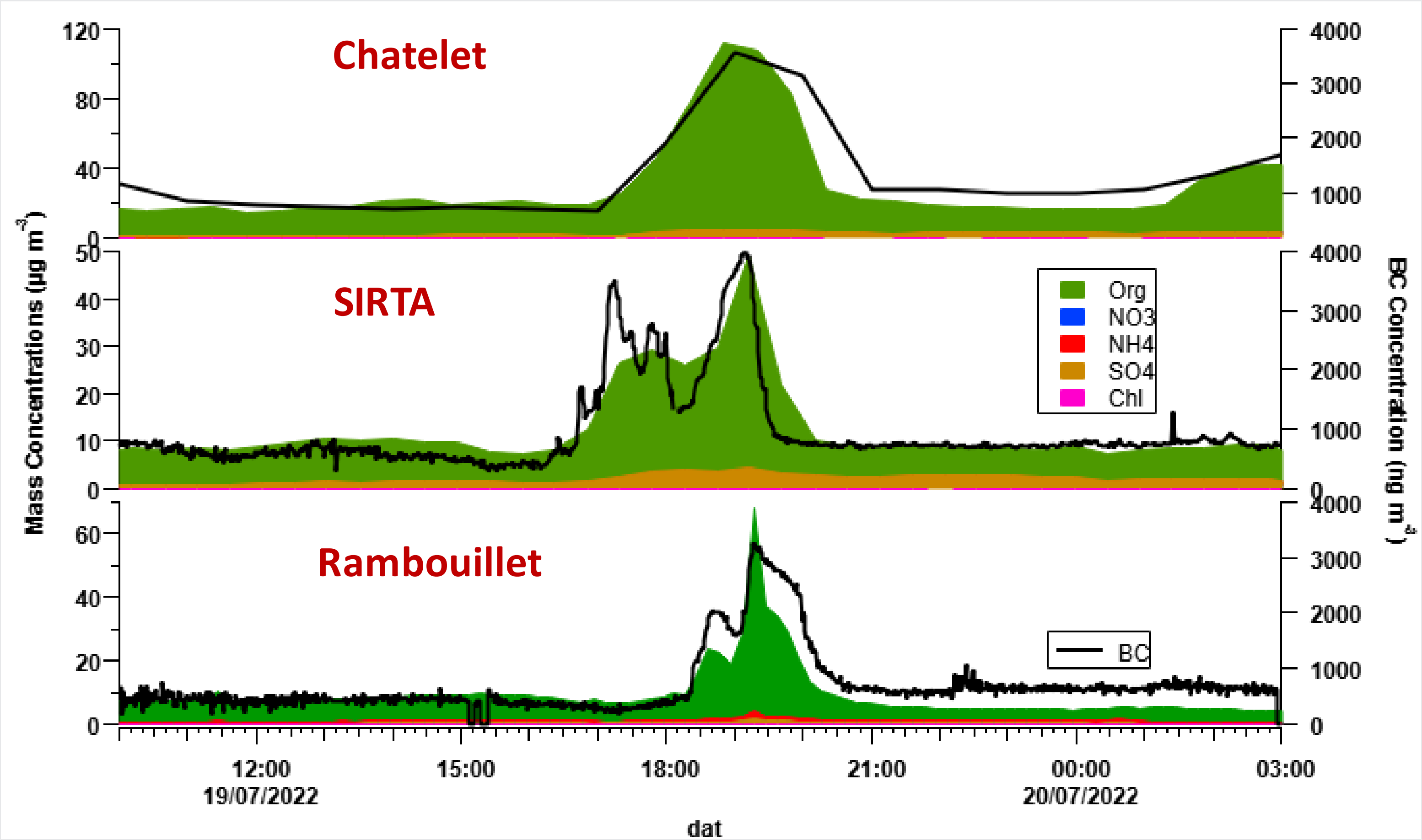
Chemical compositions & evolution of the fire plumes

❖ Substantial increase in PM concentrations

PM_1 reaching 60-80 µg/m^3 at SIRTA, Rambouillet, and Chatelet



PM_1 composition dominated by OM & BC

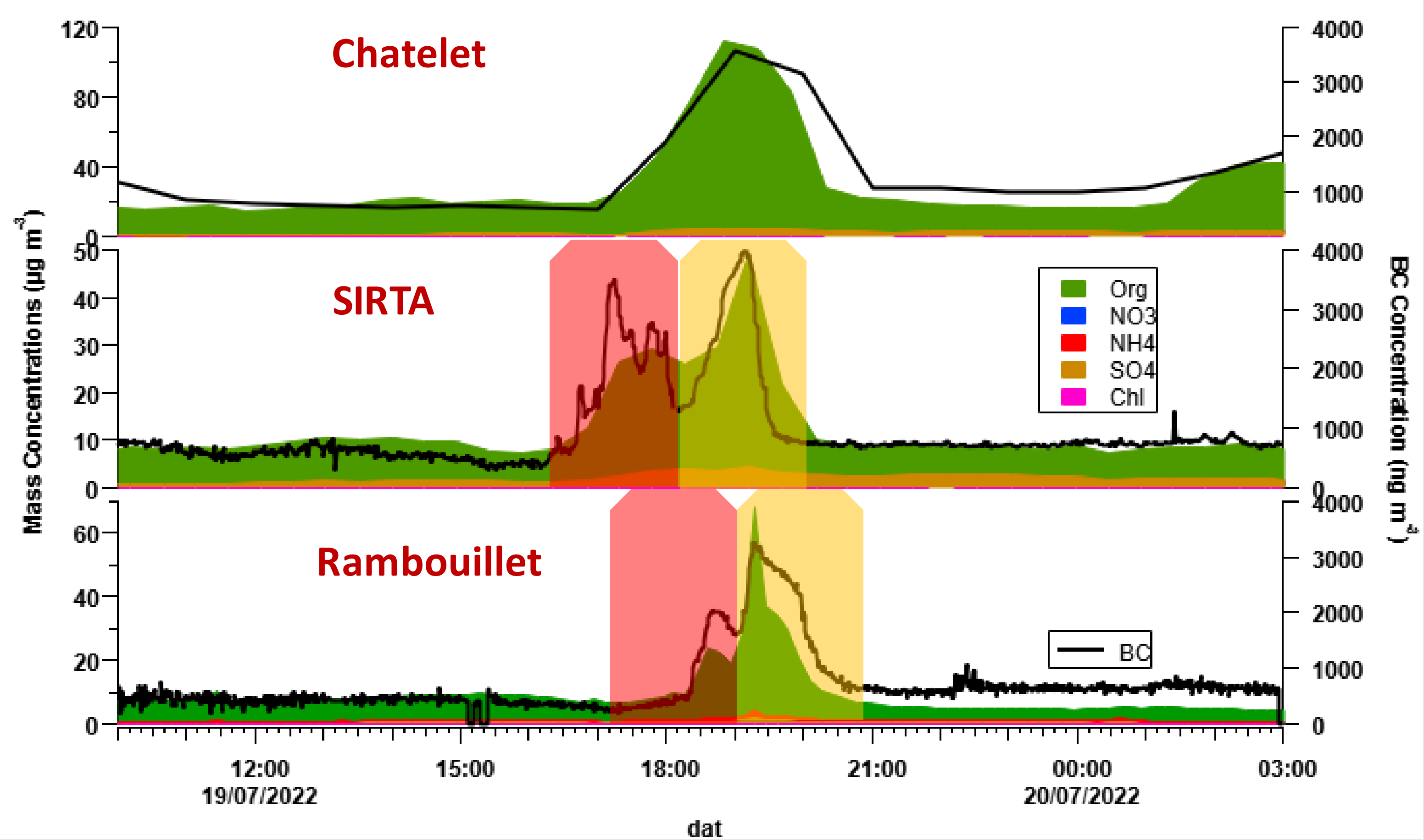
OM and BC impacts in cooling or warming of the planet

Clear response of biomass burning markers (f60, acetonitrile)

Instruments: ACSM + Aethalometer (AE33)

Chemical compositions & evolution of the fire plumes

- Substantial increase in PM concentrations
  PM_1 reaching 60-80 µg/m^3 at SIRTA, Rambouillet, and Chatelet



PM_1 composition dominated by OM & BC

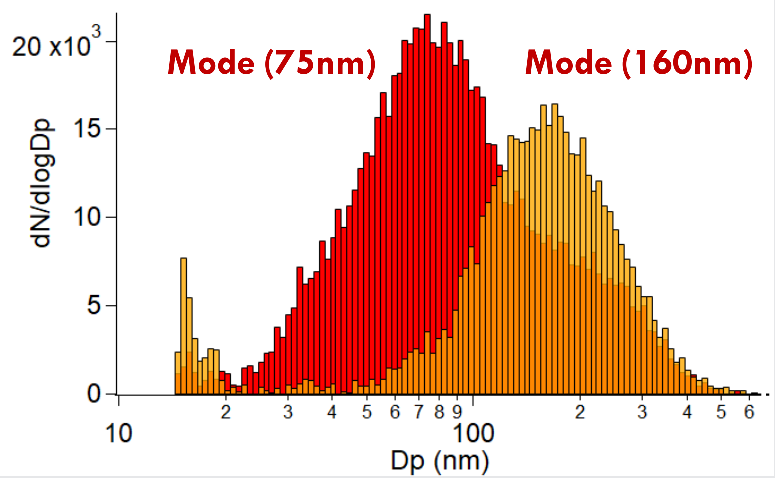
OM and BC impacts in cooling or warming of the planet

2 sub-events in **Rambouillet** and **SIRTA ?**

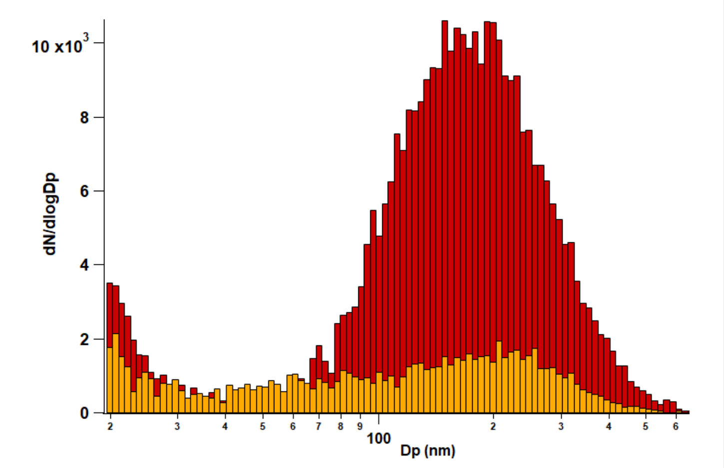
E1 **E2**

Size Distribution of Aerosols in Fire Plumes

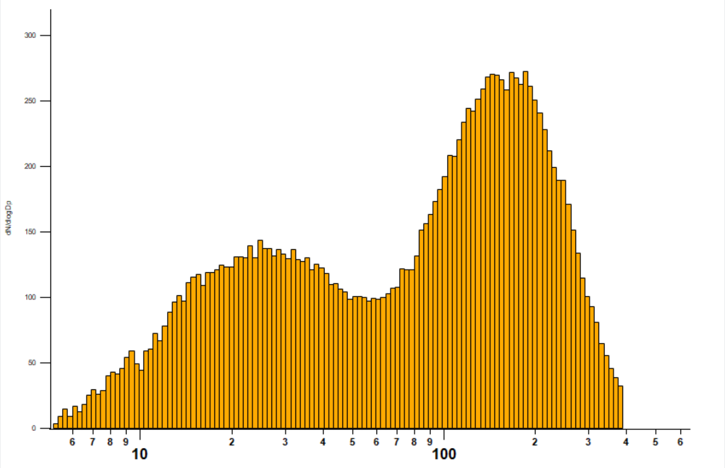
SIRTA



Rambouillet



Chatelet



Clear PNSD difference at SIRTA between E1 & E2

Two distincts events ?

No clear PNSD difference at Rambouillet between E1 & E2

But clear PN difference may underline a local influence

Same mode of E2 (~160nm) at all sites

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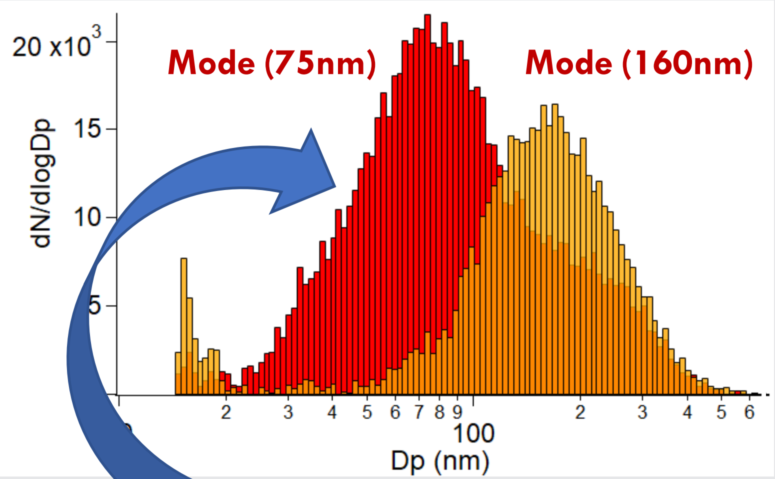
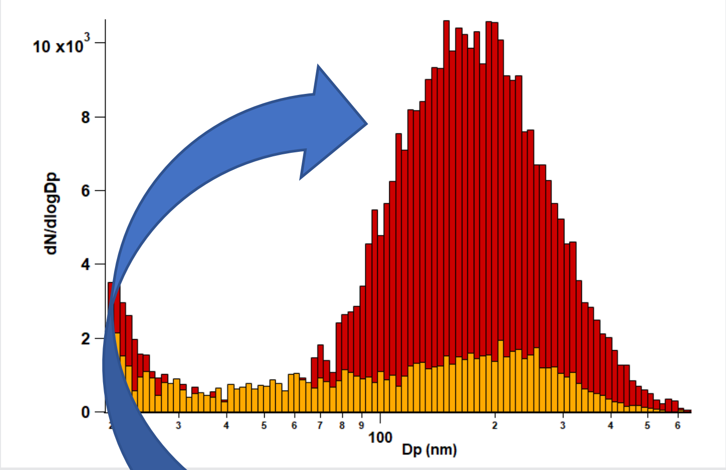
Size Distribution of Aerosols in Fire Plumes

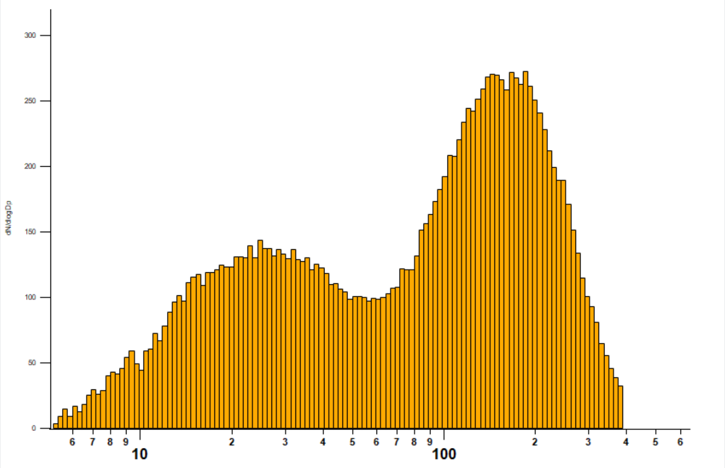
SIRTA



Rambouillet

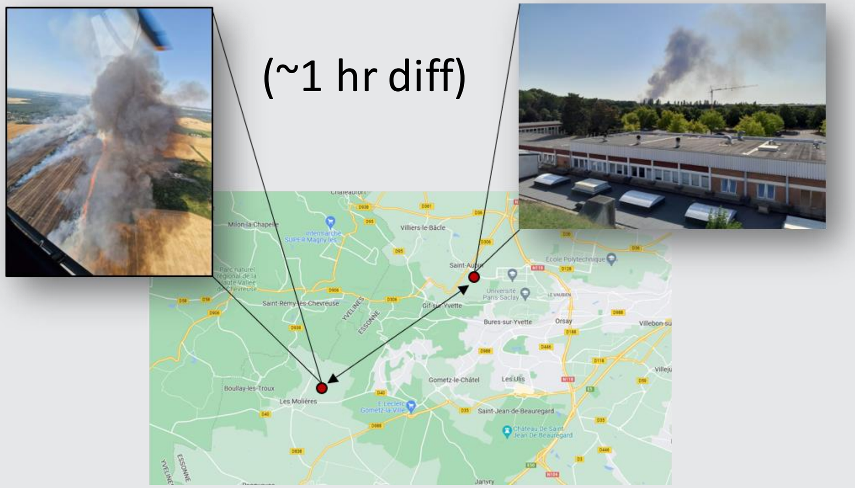


Chatelet



❖ **E1 SIRTA**: local stubble field fire 10km away from SI

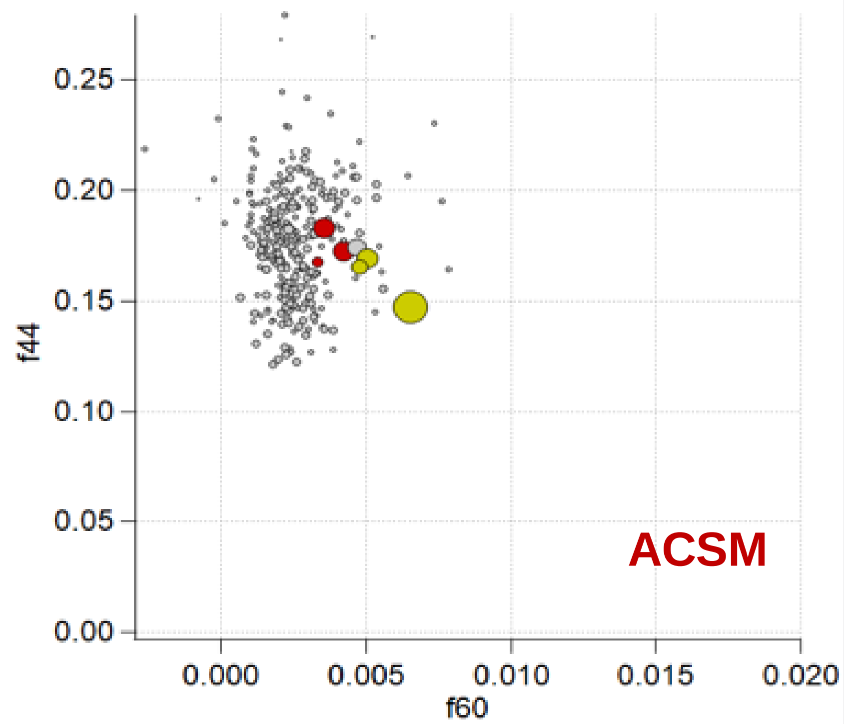
❖ **E1 Rambouillet**: local pine fire within Rambouillet forest ?



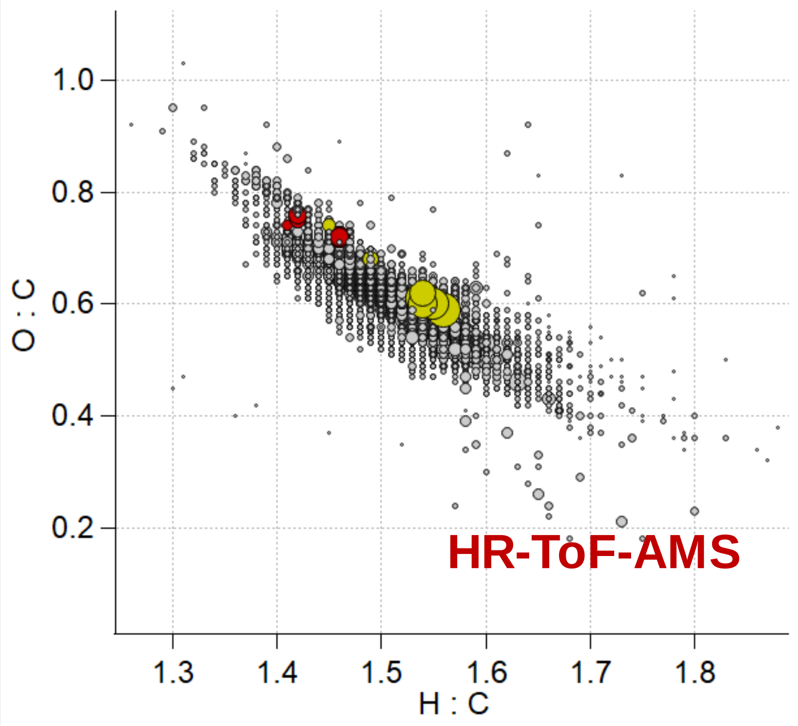
E2: advected plume from Landes forest, Gironde

Oxidation properties of aerosols in wildfire plumes

SIRTA



Rambouillet



E2 has higher f60 than E1

E2 higher H:C than E1, although it is advected..!

Two sites, two different instruments & same trend

atmospheric relevance (but counter-intuitive)

- **How can we further characterize the events other than advected or local plumes?**

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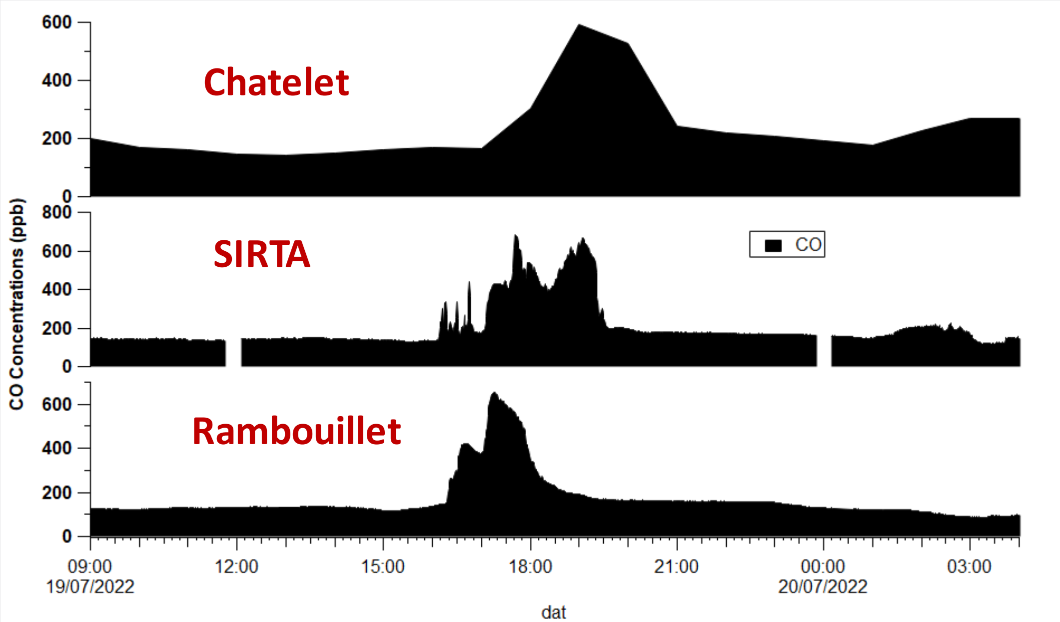
Added value of ICOS observations

ICOS | INTEGRATED CARBON OBSERVATION SYSTEM

ICOS: Integrated Carbon Observation System

Modified Combustion Efficiency (MCE):

$$\mathrm{MCE} = \frac{\Delta[CO2]}{\Delta[CO2] + \Delta[CO]}$$



Monitoring Site	E1	E2
SIRTA	0.947	0.827
Rambouillet	0.959	0.849
Chatelet	-	0.841

MCE ≥ 0.9 : Flaming

MCE ≤ 0.9 : Smouldering

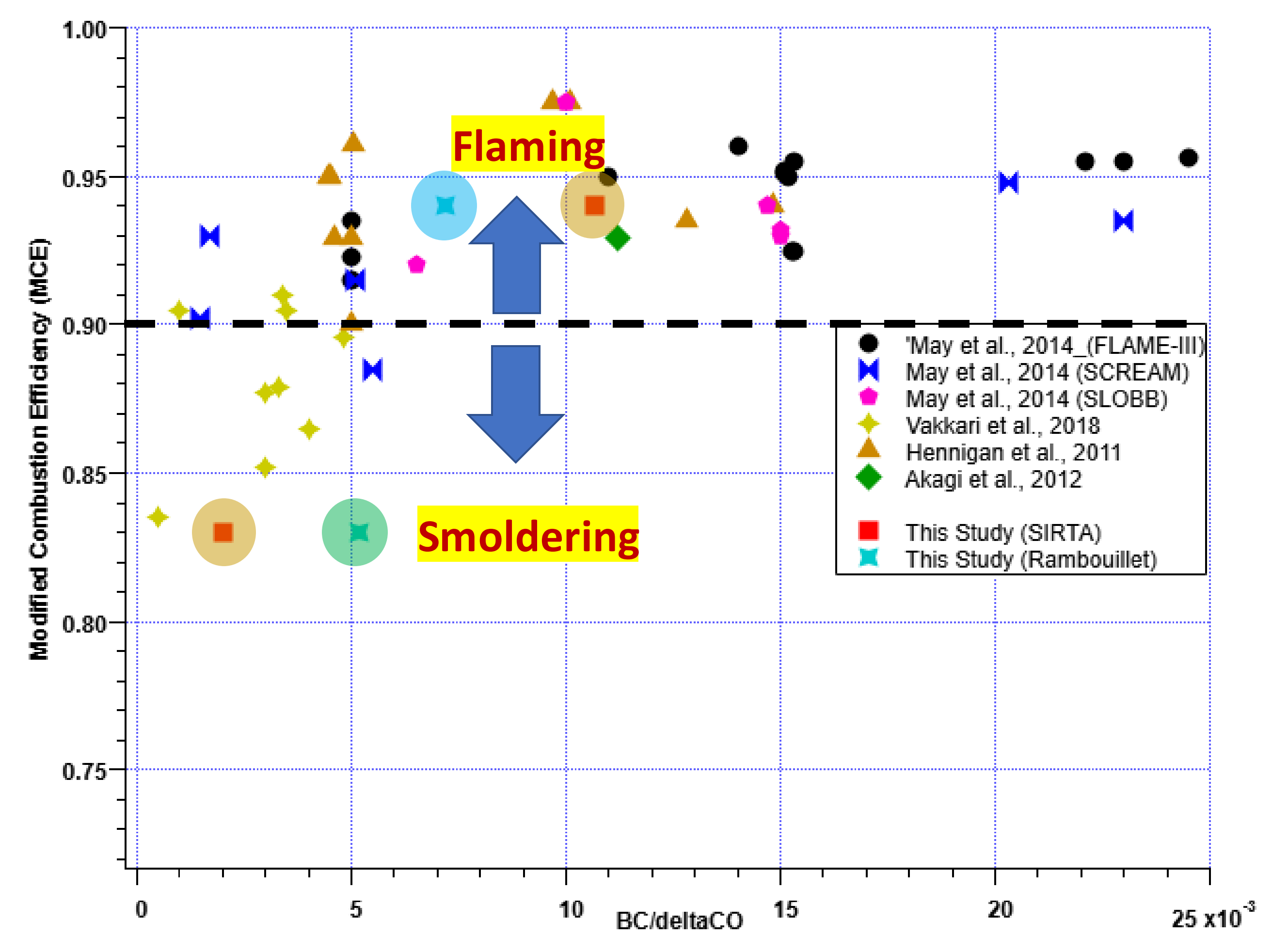
E1 → **Flaming**

E2 → **Smouldering**

- Flaming and smouldering fires emit different kinds of pollutants so it is crucial to investigate wildfire type

Comparison: Wildfires around the World

- ΔBC/ΔCO to be more reliable than MCE for combustion characterization (Vakkari et al., 2018; Nature Geos)



- Enhanced ratio of BC to CO (ΔBC/ΔCO): Lifetime of CO is approximately 1 month,

  ΔBC/ΔCO removes the effect of diffusion.

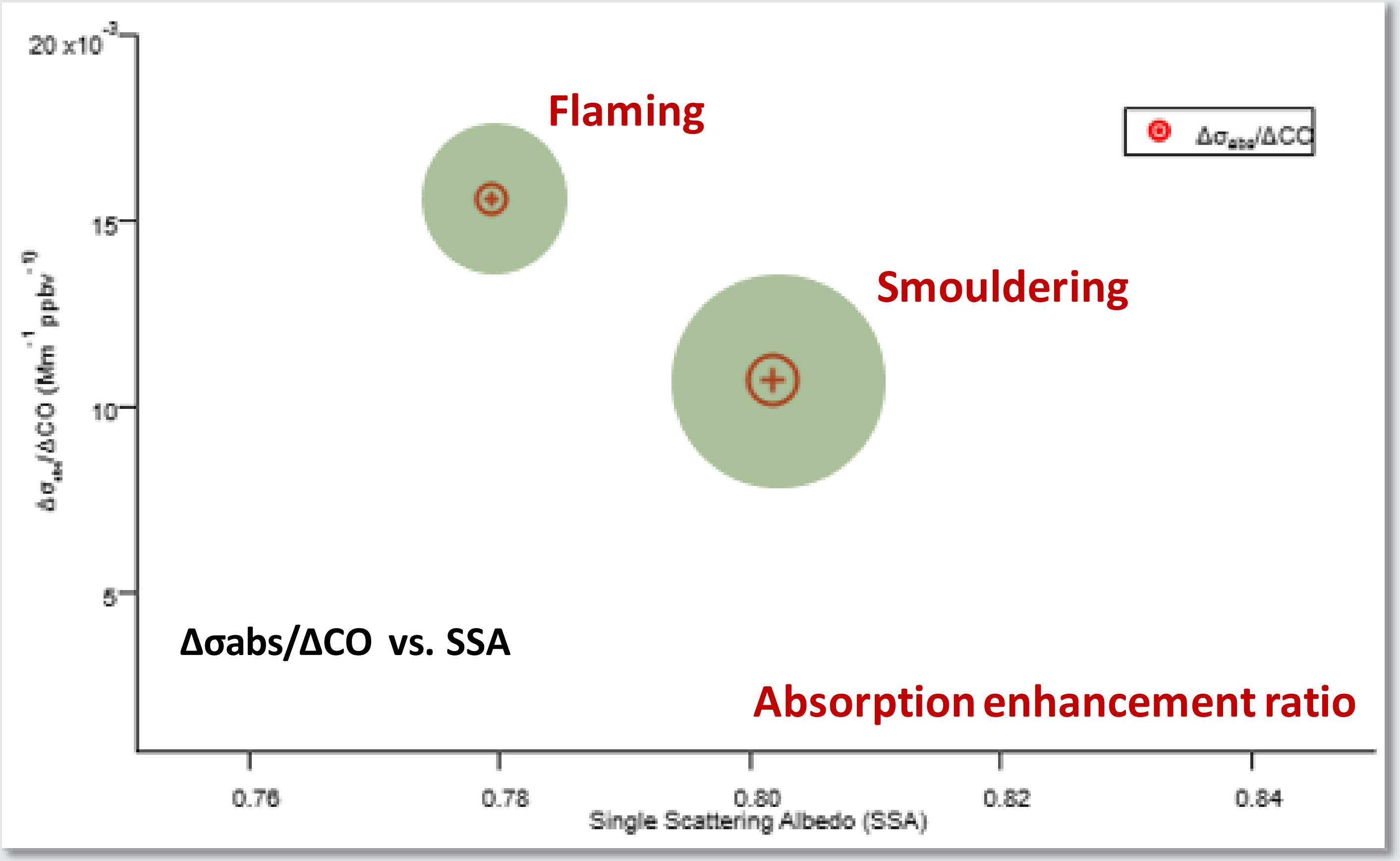
- MCE increases with ΔBC/ΔCO,

  Higher ΔBC/ΔCO: Higher flaming combustion.

- Smoldering Fires in France shows one of the lowest MCEs observed around the world

Merge ACTRIS + ICOS Observations to characterize plumes

- The optical properties shows the presence of two distinct fire events peaks:
  - Scattering (σ_{scat}) co-efficients (450, 525, 635 nm)
  - Absorbing (σ_{abs}) co-efficients (520 nm)



Single Scattering Albedo (SSA)

$$SSA = \frac{\text{Scattering efficiency}}{\text{Total extinction efficiency}}$$

Higher absorption enhancement ratio
lower SSA
in flaming combustion

To conclude:

- ❖ Wildfire Plume observed in the Paris region for the 1st time
- ❖ Characterization revealed unexpected complexity (local events near an advected plume)
- ❖ PM chemical composition (Org, BC) and biomass burning tracers showed presence of fire plumes in Paris
- ❖ The PNSD at SIRTA and Rambouillet showed characterization of two kinds of plumes
- ❖ MCE offered additional insights into plumes properties, like flaming or smouldering
- ❖ Merging ACTRIS + ICOS (ΔBC/ΔCO) offered a better understanding in comparison with wildfires around the world

❖ Instead of wildfire; we should specifically find out the nature of the plumes..!

Manuscript:

Wildfire plumes in the Paris region (France) during 2022 showcase the much-needed interconnections between ACTRIS and ICOS observations (Acharja et al., Under Preparation)

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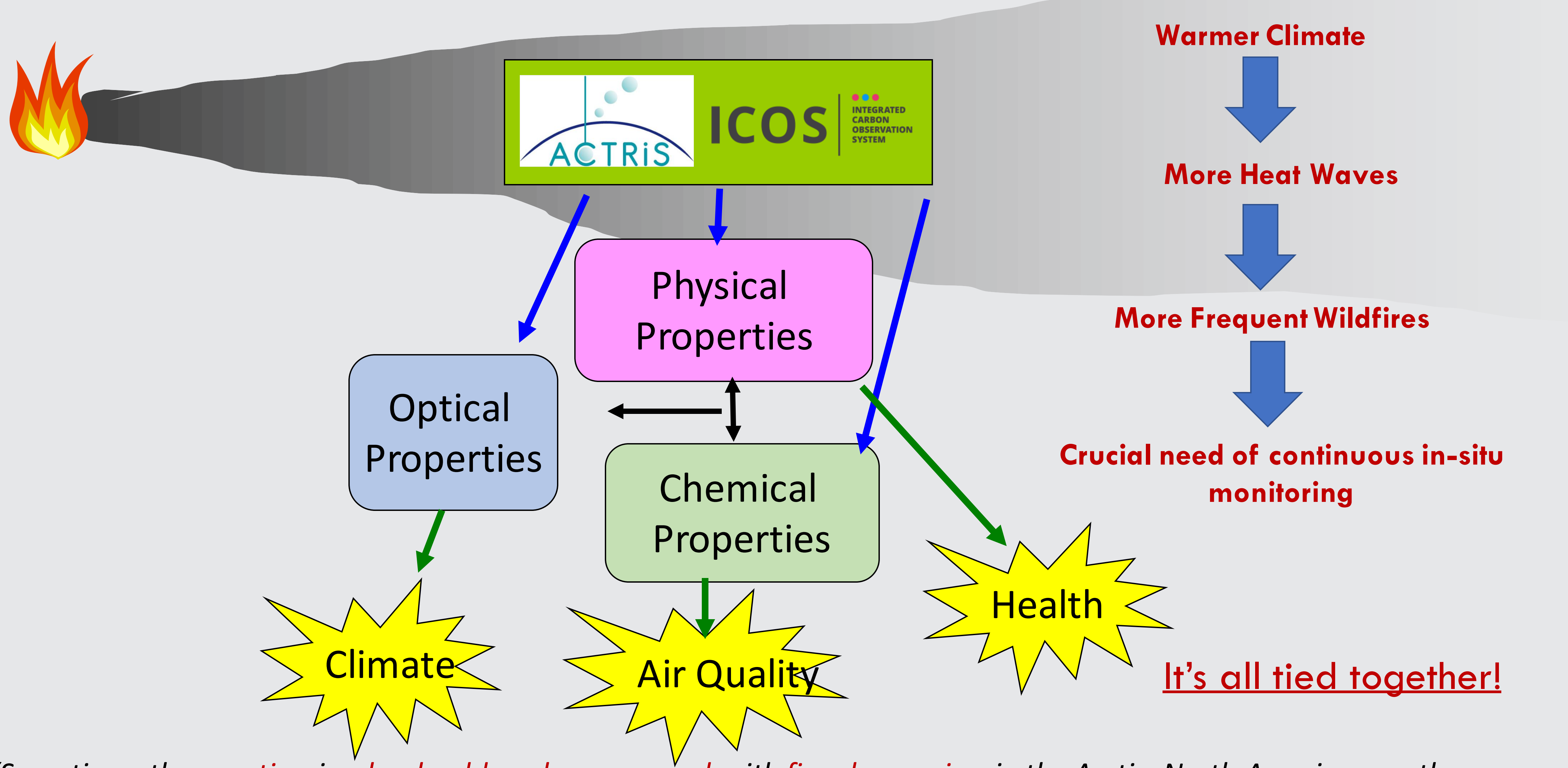
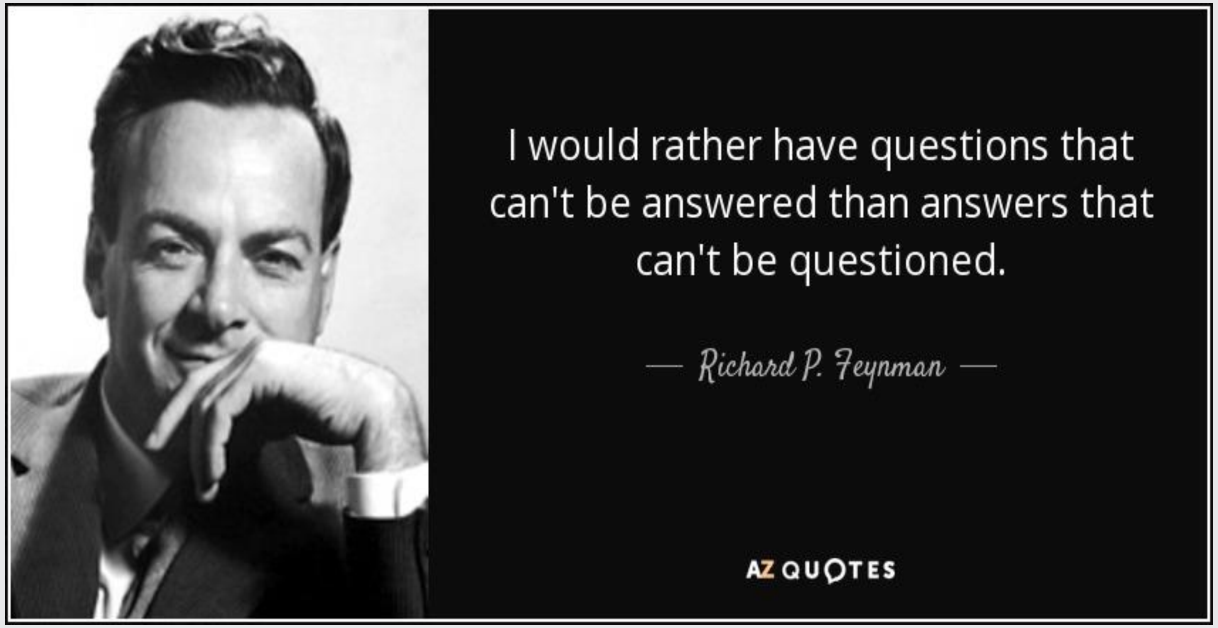
Take-Home Messages:



"Sometimes the question is why should we be concerned with fires happening in the Arctic, North America, or other places? But, under those conditions where we see an increase in fires, then that smoke transport basically links everybody together.."

Acknowledgement



Thank You..!!

CNRS LSCE cea AIRPARIF INERIS IMT Nord Europe École Mines-Télécom IMT-Université de Lille lisa SIRTA ACTRIS

THE CHEMISTRY OF WILDFIRES

From Jan. 1 to Dec. 22, 2017, there were 66,131 wildfires in the U.S. In this graphic, we look at wildfire combustion, the compounds produced, and the effects those molecules can have on health.

WILDFIRE COMBUSTION

Lightning strikes can spark wildfires. But between 1992 and 2013, people—either accidentally or deliberately—started 84% of wildfires in the contiguous U.S.

The principal combustible components of vegetation that fuel wildfires are cellulose and hemicelluloses (50–65%), lignin (15–35%), and other organic compounds not part of the cellular structure (0.2–15%).

WILDFIRE STAGES

1. <400 K — Polysaccharides and functional groups decompose.
2. >450 K — The polymer structure of wood breaks down.
3. 1,400 K — Flaming combustion produces highly oxidized gases.
4. 800 K to 1,000 K — Smoldering combustion takes over once most volatiles are released from fuel.

FLAMING VERSUS SMOLDERING

FLAMING	SMOLDERING
Combustion of volatile compounds released from fuel	Flameless, low temperature form of combustion.
PRODUCTS	**PRODUCTS**
Carbon dioxide Nitrogen oxides Sulfur dioxide Particulates Water vapor	Amines Ammonia Carbon monoxide Methane Organics

Compared with flaming combustion, smoldering converts fuel to more toxic compounds, but it occurs more slowly.

HEALTH & ENVIRONMENT

Wildfire smoke consists mainly of particulate matter, carbon monoxide, volatile organic compounds, nitrogen oxides, and other trace gases.

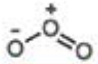
People can inhale particles smaller than 2.5 μm ($PM_{2.5}$) deep into their lungs, aggravating asthma and decreasing lung function. $PM_{2.5}$ also causes haze.

BENZ[a]ANTHRACENE

An example of a PAH found in $PM_{2.5}$

Exposure to polycyclic aromatic hydrocarbons (PAHs) increases risk of cancer and cardiovascular disease. The compounds also persist in the environment.

NITROGEN DIOXIDE + HYDROCARBONS → OZONE



Gases emitted during wildfires can undergo reactions that create ozone. Tropospheric ozone is a major component of smog and also causes respiratory problems.