Eddy Covariance, setup, site – design, instrument selection & calibration

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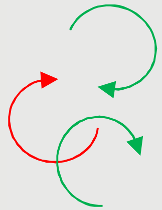
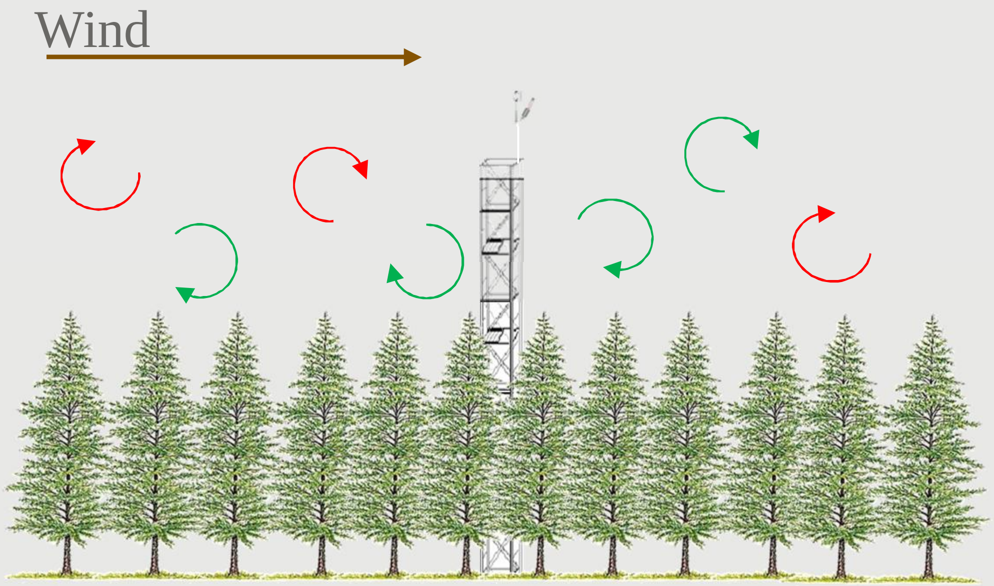
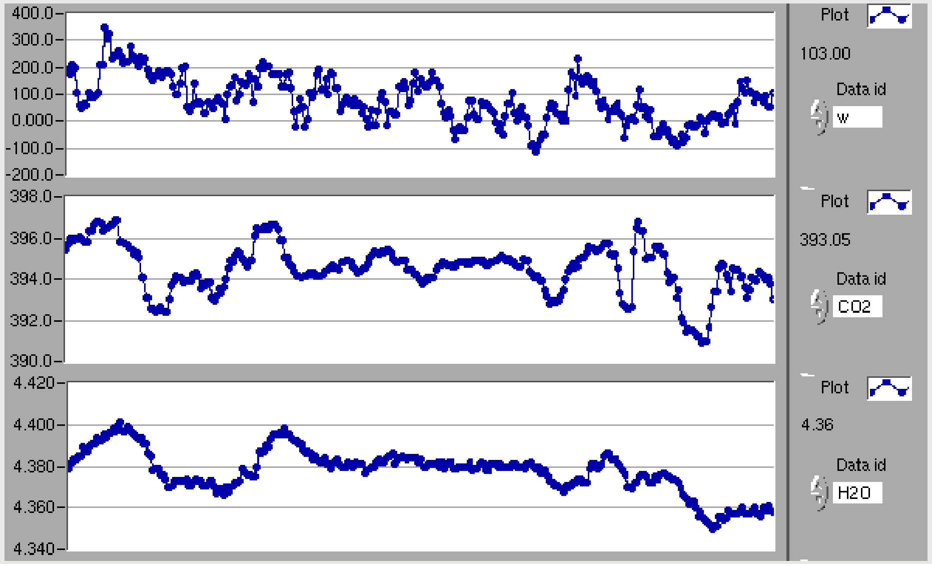
Overview

- How to catch eddies...
- Instrumentation types and their inner lives...
- Where to catch eddies?
- Are we using the right “catcher”?
- Are we catching the right eddies?
- How to clean and keep the catcher clean;
- ... and once we have finished catching eddies...



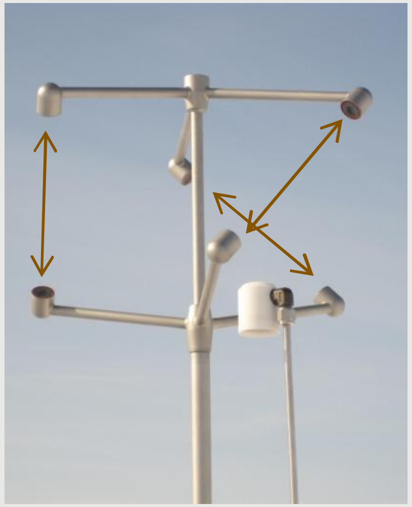
Why are we using eddy covariance?





The vertical component of wind velocity is derived from data provided by a three axis sonic anemometer, while the carbon dioxide (CO_2) and water vapour (H_2O) concentrations are measured with a gas analyser.

Ultrasonic anemometers



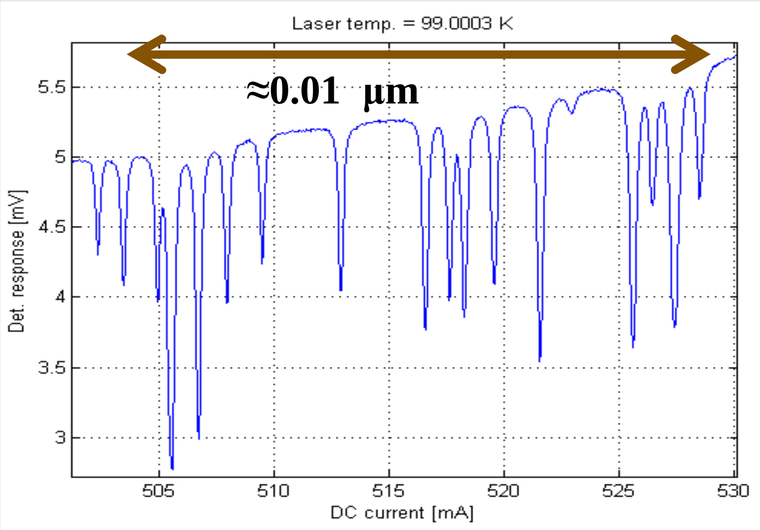
- short ultrasonic pulses sent between the transducers;
- velocity of air parcel summed to sound velocity;
- sound velocity in the air depends on temperature and humidity → sonic temperature (≈ virtual temperature);
- one pulse travels < 1 ms → full 3D wind vector solved within 10 ms (10 Hz);
- Several reliable anemometers (Campbell, Gill, Metek, etc)

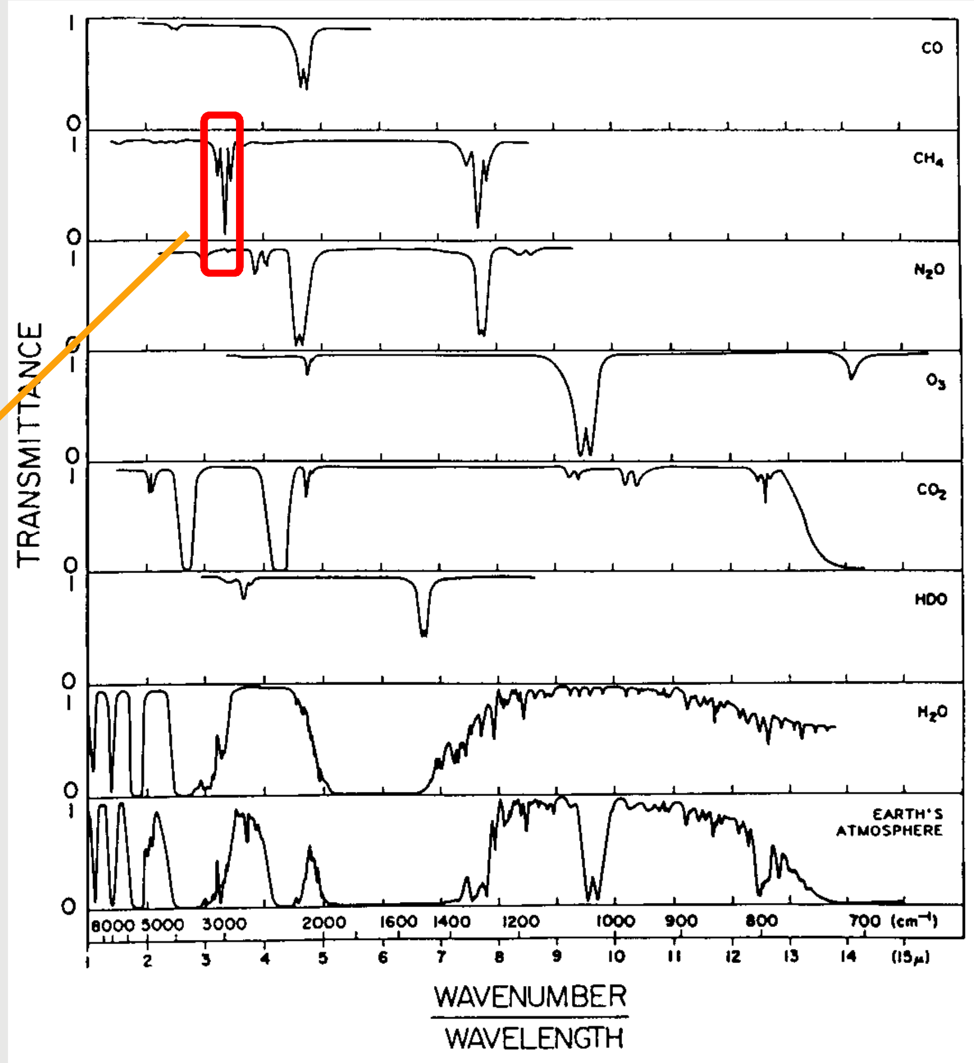
Ultrasonic anemometers:

- Campbell - CSAT3
  - user friendly;
  - needs to be orientated into main wind direction;
  - no need for “cross wind “ correction;
- Gill - R3 (3-axis), HS
  - does not need to be orientated towards North;
  - angle of attack corrections;
- METEK –USA1
  - no need to be orientated towards North but makes life easier;
  - “cross wind” correction;

Gas analysers

- absorption of electromagnetic radiation by gases;
- many useful bands within near to mid infrared region;

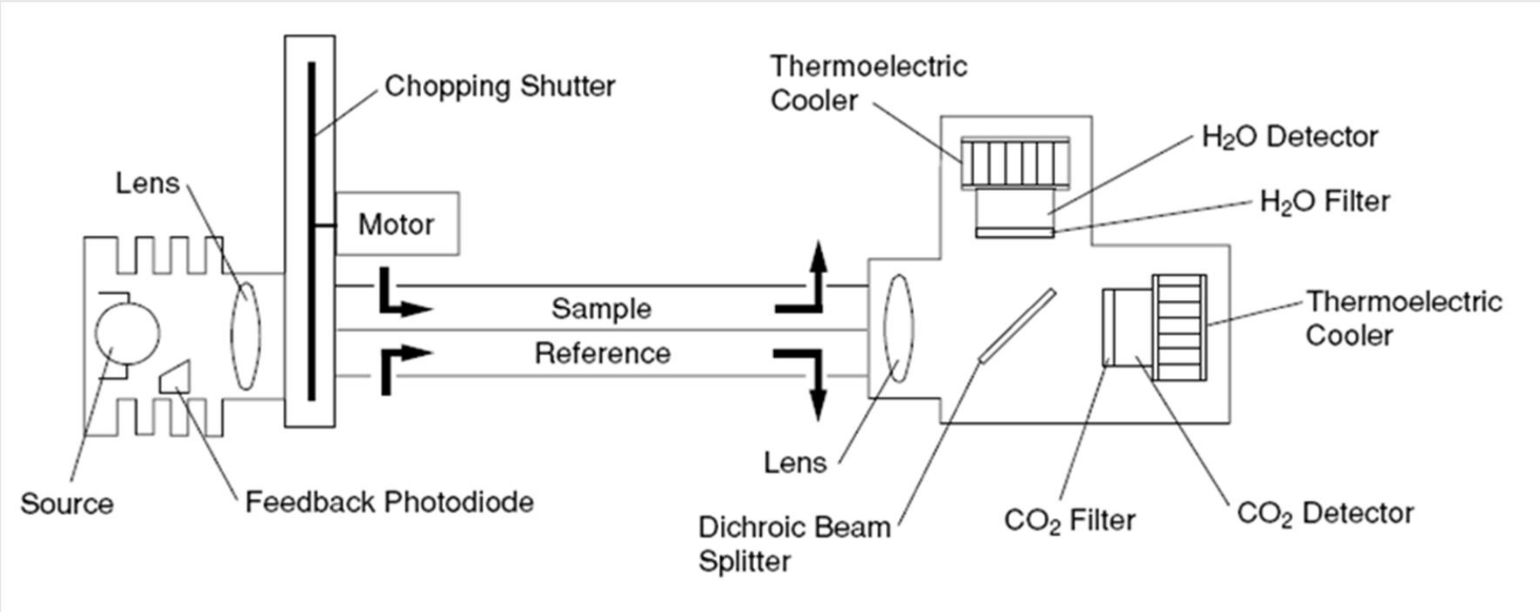




Kidder & Vonder Haar, 1995

InfraRed gas analysers (IRGA)

- measures light absorption within carefully selected absorption band of about 0.1 μm;
- sensitive to temperature, pressure, gas matrix… (but easy to correct);



LI-COR (1996)

InfraRed gas analysers (IRGA)

- Closed-path gas analyser:

  - LI-6262 (CO_2/H_2O)
    - requires an external pump;
    - requires constant reference gas supply;
    - frequent calibration checks/calibration needed;
    - tube attenuation; lag time;

  - LI-7000 (CO_2/H_2O)
    - requires an external pump(???);
    - requires constant reference gas supply;
    - frequent calibration checks/calibration needed;
    - tube attenuation; lag time;

InfraRed gas analysers (IRGA)

- Open-path gas analyser:
  - LI-7500 (CO_2/H_2O)
    - no need for external pump;
    - low power requirement;
    - no need for reference gas;
    - user friendly; light weight;
    - no time lag;

InfraRed gas analysers (IRGA)

- Closed-path (enclosed) gas analyser:
  - LI-7200 (CO_2/H_2O)

    - comes with its own pump;

    - low power requirement;

    - no need for reference gas;

    - user friendly;

    - own logging system;

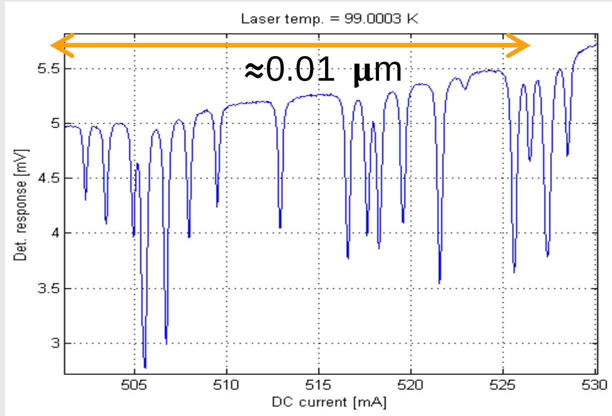
    - light weight;

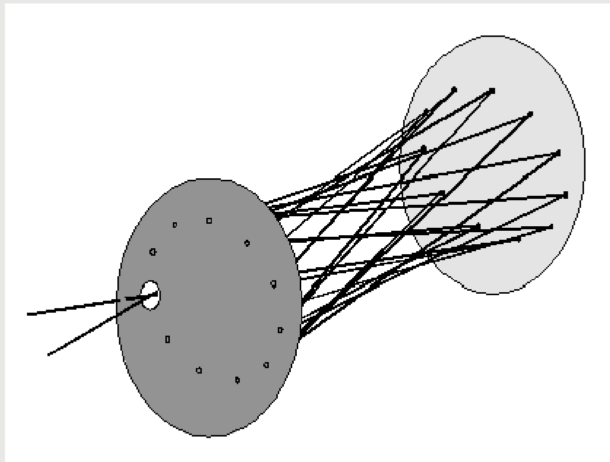
    - tube attenuation;

Laser spectroscopy

- measures light absorption within carefully selected, species specific absorption feature of about 0.0001 μm;
- sensitive to temperature and pressure (but easy to correct)

- several different implementations
  - absorption within single pass cell
  - absorption within multipass cell (effective pathlength increased for better sensitivity)
  - cavity ring down cell (less sensitive to laser power variation)
  - integrated cavity output spectroscopy (ICOS)





Laser spectroscopy

- Licor: open path multipass cell

  CH_4

- Campbell: closed path single pass cell

  CH_4, N_2O etc...

- Aerodyne: closed path multipass cell

  CH_4, CO, CO_2, N_2O, H_2O etc...

- Picarro: closed path cavity ring down

  CH_4, CO, CO_2, H_2O etc...

- Los Gatos: closed path ICOS

  CH_4, CO, CO_2, N_2O, H_2O etc...

Laser spectroscopy

- Open path multipass cell instrument

  - LI-7700 (CH_4)
    - no need for external pump;
    - low power requirement;
    - no need for reference gas;
    - user friendly; no time lag;
    - spectroscopic correction

Laser spectroscopy

- Closed path cavity ring down
  - Picarro (CO_2/H_2O/CH_4/CO, etc.)
    - requires an external pump;
    - needs mains power;
    - no need for reference gas (reference capsule inside);
    - tube attenuation; lag time;

Laser spectroscopy

- Closed path integrated cavity output ICOS

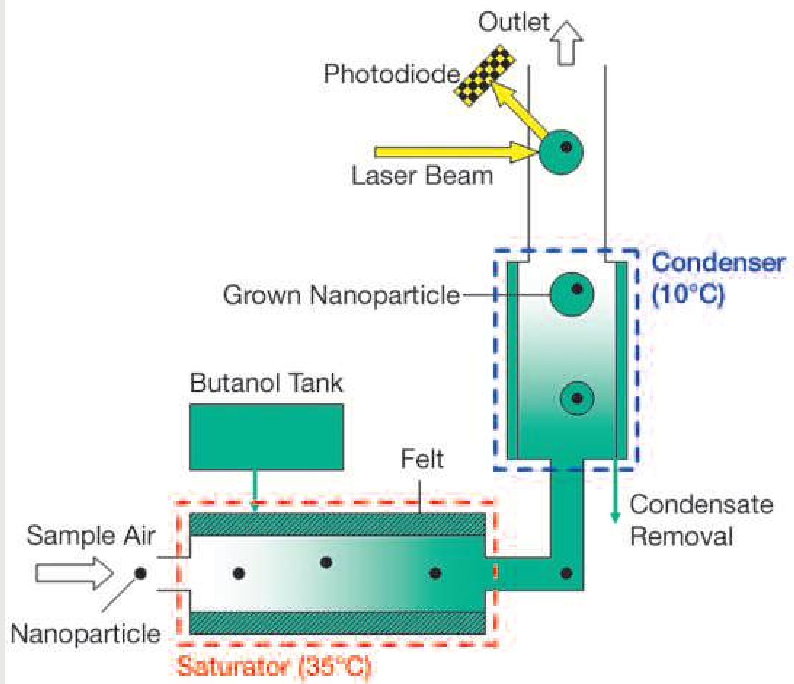
  - Los Gatos (CH_4, CO, CO_2, N_2O, H_2O etc.)

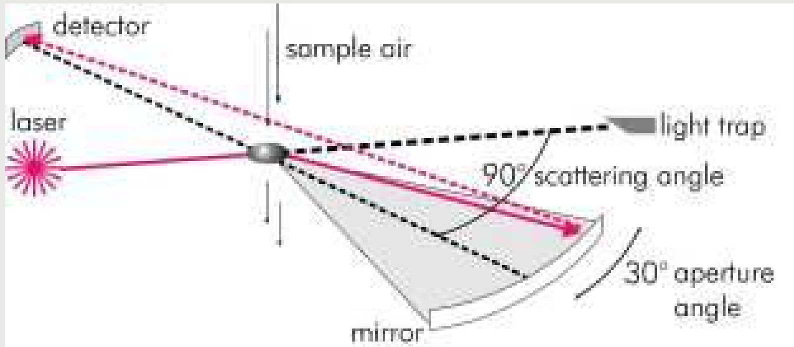
    - requires an external pump;
    - needs mains power (a massive generator does it too);
    - no need for reference gas;
    - tube attenuation;

Instruments for aerosol particle flux

- Condensation particle counter (CPC)
  - small particles magnified by growing with condensation
  - detects large particles by light scattering
- Optical particle counter (OPC)
  - detects large particles directly by light scattering
- Aerosol mass spectrometer (AMS)

sampling frequency typically slow ~ 1 Hz





Figures: Grimm Aerosol Technik

Other gas analysers

- Chemical ionization mass-spectrometers
    - PTR-quad-MS: slow detection of VOCs
    - PTR-ToF-MS: fast detection of VOCs
- Chemi-lumenenesence
- Photoacoustic spectroscopy (PAS)
- Fourier transform infrared spectroscopy (FTIR)
- Conventional chromatographical methods (GC-FID)

Power requirements and supply

(getting down to business...)

- Short-/long-term data collection;
- Continuous recording or sampling of data;
- 5 V, 12 V, 24 V, 220 V/110 V required?

- Car batteries, solar panels, wind energy, generator, mains power;

Power supply

- Car batteries (additional power source):
    - frequent replacement;
    - ideal for short term studies;
    - easy to use but bloody heavy if needs to be carried around;

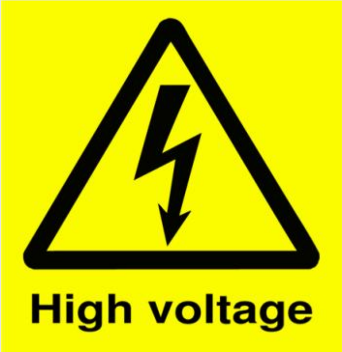
- Solar panels:
    - site location;
    - adequate supply all year round?
    - charge controller and battery units;
    - easy to use (once you know how it works);

Power supply

- Wind energy:
  - Site location;
  - adequate supply?
  - charge controller and battery units;
  - location (footprint location);
  - easy to use;
- Fuel generator:
  - location (footprint location);
  - frequent refuelling of petrol, hydrogen, diesel, etc.;
  - charge controller and battery units;

Power supply

- Mains power:
  - Site location;
  - distance to nearest transformer (Voltage drop);
  - easy to use (and convert to lower Voltage);
  - No limitation of supply to instruments all year round;
  - Expensive if newly established;
  - Running costs;
  - power surges(?)



Site establishment

(Quality Assessment/Quality Control)

- purpose of study and choice of ecosystem
    - end user of data;
- site location, land ownership and access
    - are we measuring in the right location? Pilot project;
- length of data collection (campaign/permanent)
    - end user of data; purpose of measurement;
- data expectations (flux magnitude)
    - why are the measurements carried out? Use of correct measurement protocols;

Site infrastructure

- Ecosystem relevant structure;
- Access;
- Safety;
- Protection;
- Housing;
- Data management;
- Set-up selection

Decision time

- Open- vs. closed-path analyser;
  - data quality (dry/wet);
  - power requirements (mains/batteries);
  - cleaning (filter/open window)
  - reference gas requirement (gas cylinders, synth. air);
  - necessity of a pump;
  - data storage
  - costs (purchase & running costs);

And what now???

- Once site is up and running…
  - Calibration checks;
  - frequent data control (to avoid instrument drift, power failure, filter clogging, pump failure, underestimated data storage, drop outs, etc.);
  - instrument and site maintenance;
  - (reference gas checks);

Calibration and calibration checks

- A calibration check refers to a procedure where instrument readings are compared to a set of well known concentrations (including zero)
- difference is quantified for correction during post processing
- A calibration refers to the re-adjustment of an instrument to read correct "zero" and "span" values, often 0 and 400/500 ppm CO_2.
- alternatively, the instrument can be tuned to show correct value on-site or taken to home institute for calibration (LI-7000); !!! LI-6262!!!
- Open path instruments need their respective "calibration shroud";
- A calibration should never be done in rainy weather!
- Time consuming;
- Always read manual prior to proceed;

Calibration and calibration checks

- EC not very sensitive to zero drift (offset error) but span drift (gain error) will bias your flux data;

- calibration intervals instrument specific

- IRGAs typically need calibration every 1 – 6 months

- laser spectroscopic instruments are more stable: calibration interval ~ 1 year

However, dirt accumulation, instrument failure etc. may lead severe drift any time!

Eddy system maintenance (cleaning)

- EC setup running 24/7 typically collects ~1-10 mio l air per year
- dirt load varies heavily depending on location:
  - urban / rural
  - pollen period
  - forest fires
  - agricultural activity
- Filters and inlet tubes: - capacity and filtering efficiency affects it's lifetime as filter areas cover 10 - 1000 cm^2 and pore sizes often vary between 0.1 - 10 µm;
- Depending on filter type and costs, they need to be exchanged up to 1/month…
- Gelman filter vs. Filter holder & paper;

Why all this cleaning?

- If filters are located downstream of the tubing, also the tube walls become dirty (often even sticky...);
- Dirt on tube walls affects heavily H_2O, potentially also other gases;
- Consider cleaning / changing tubes occasionally;

- Conclusion: the cleaner you keep your system and the better you maintain you system the higher quality data you will have (technical point of view)!

How communicative are these systems?

- Instruments give technical diagnostics (pressures, temperatures, indicators about the optical path condition (LI-7700/LI-7200);
- The measurement data itself often gives indication whether the data was good (spikes, outliers);
- In some cases only the post-processed data can indicate problems (lag time, spectra, instrument orientation, etc.)