Aeromon
Airborne Emission Monitoring

RPAS-assisted detecting and monitoring of gaseous compounds

1.11.2016
UAV Arctic, Kuopio

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- RPAS Finland, member of the board

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Aeromon - IoT measurement service

- **Aeromon Ltd.** utilizes readily available UAV/RPAS platforms and sensor technologies together with open data sources. **We are an integrator**.
- Aeromon delivers **verified and real-time results** from airborne, mobile and fixed measurement environments. We provide multidimensional and multisource measurements with **accurate location information**.
- **Point-of-source, 2D- and 3D-mapping of different gas concentrations**.
- Aeromon solution can be used e.g. in naval vessel, industry, power or recycling plant emission monitoring to ensure regulation compliance and to identify different sources of leaks and pollution.
- Aeromon solution is **highly cost-effective**.

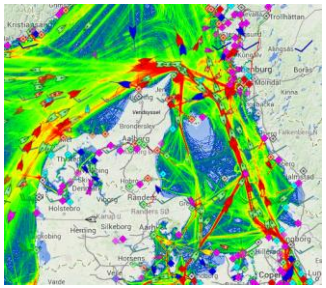
BH-8, Ultra light gas sensor package

+

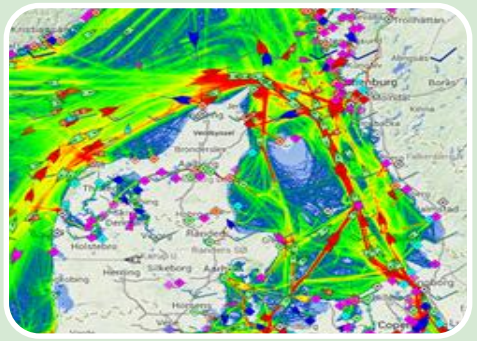
Mobile transportation platform

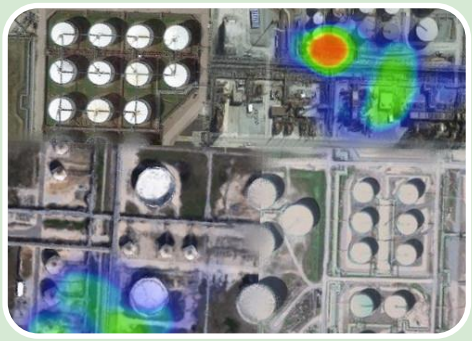
+

Data platform using open data sources



CORE MARKETS





Maritime

- Vessel emission monitoring and validation
- Surveying gas emissions from tank purging operations
- Fixed monitoring stations on vessels
- **Ongoing measurement project onboard R/V Aranda**

Industrial and Environmental

- Process leaks
- Gas pipeline leakages
- Enhancing environmental awareness and third party audit
- **Several ongoing measurement pilots at customer locations**

Health and Safety

- Mapping of accident areas for toxic gases – **real time situation awareness**
- Monitoring large areas for secondary leakages
- Reducing risk of biomass storage by mapping combustion gases from storage heaps

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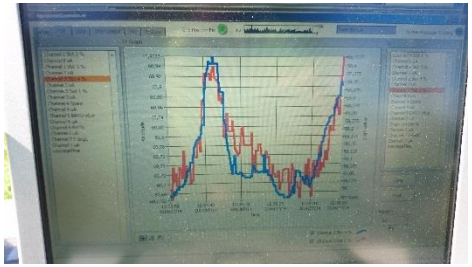
What it takes to measure gases with UAV's?

- **Weight of the payload**
  - The most crucial parameter
- **Operational conditions**
  - Vibrations and exposure to weather and chemicals
- **Data transfer**
  - Should be real-time, reliable and flexible



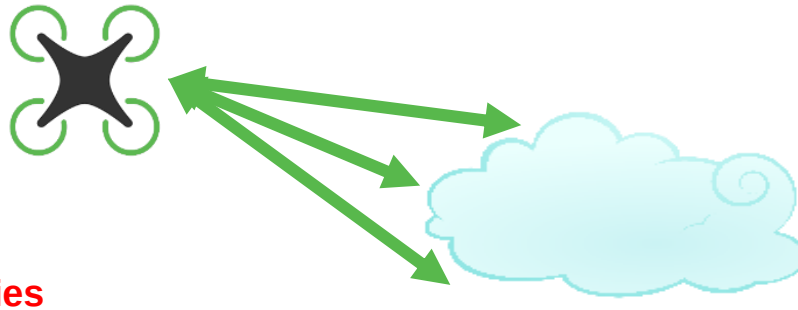
"This is why we can't have nice things"

- **Visualization and UI**
  - According to the user requirements

Two different approaches

1. **Direct measurement** (sensors etc.)
   - Measurement
     - Relatively high accuracy
     - Wide selection of target gases
     - Sample capture for further analysis
     - Slow spatial resolution (usually)
     - **Demand for advanced ultra-light technologies**
   - Operational profile
     - Might be easy…
     - …but not always.
     - **Demand for advanced robotics**

2. **Remote sensing** (LIDAR, Hyperspectral, etc.)
   - Operational profile
     - Easy to map and monitor large areas quickly
   - Measurement
     - Detection limit vs. distance
     - Selection of target gases
     - Price is relatively high
     - **Demand for advanced ultra-light technologies**



Concept ideas for chemical accident emergency personnel

Emergency personnel has an onboard drone with a wide selection of different gas sensors.

- Requires someone to use the drone
- Requires knowledge on the possible target gases

Emergency personnel calls in the gas measuring drone from a service provider.

- If the service provider has to arrive to the site, the price of the service might be relatively high.
- Price of a such service can decrease dramatically if the drone can be operated remotely. However, this requires BVLOS operation permits and e.g. MALE (or similar) platforms.

Kuopio, test range, 1.11.2016

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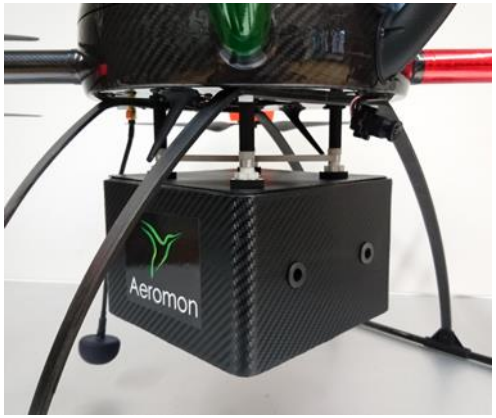
Aeromon sensor module BH-8

Size	168 mm – 168 mm – 107 mm
Weight	0,85 kg (fully equipped)
Gas sensor ports	8 pcs
Datalink	e.g. radio or GSM modem
Datalink range	Adjustable, from 1 km to global
Sampling frequency	Adjustable, typically 0,5 – 5 Hz
Data storage	Local storage and Aeromon Cloud Service database
GPS	Internal, 10Hz update
Sampling method	Free-flow (adjustable) and/or sample capture
Sample filter	Quartz wool membrane
Mechanical interface	Customized for each platform



Measurement + GPS + AIS + Weather…

Data link: Radio, GSM, Satellite

Aeromon GasMon Software

Internet: GSM, Satellite, Land line

Aeromon Cloud Service

Results and visualization

User interface via web app

Reporting

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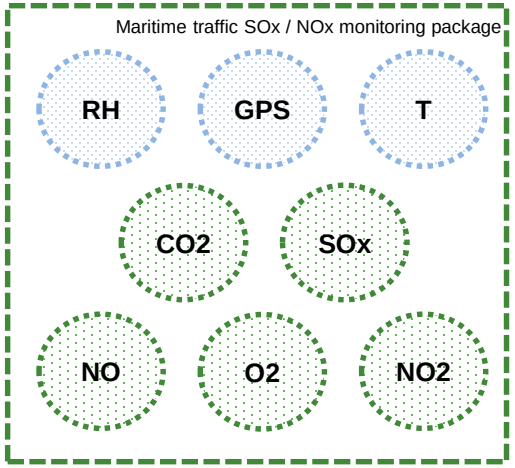
TECHNOLOGY BASE

SENSORS

AEROMON CLOUD SERVICE

PLATFORM

Currently Aeromon provides various combinations of gas monitoring addition to other parameters – up to **8 different gases monitored simultaneously** (per standard BH-8 module). Sensor integrations and algorithms are developed and validated together with our **partner network of companies and universities**.



Most common gases to monitor:

- combustible gases
- toxic gases
- explosive gases
- oxygen deficiency gases (danger of asphyxiation)
- refrigerants
- VOC emissions (Volatile Organic Compound)

Different measuring technologies:

1. Electrochemical EC
2. Sensor which absorb infrared light IR
3. Catalytic sensor CAT
4. Semiconductor sensor SS

+ Other commercially available technologies

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TECHNOLOGY BASE

Readily available sensors (organized by gas) for current mechanical and electrical design of **Aeromon sensor module BH-8**

- Acetaldehyde
- Acetic Acid
- Acetone
- Acetonitrile
- Acetylene
- Ammonia
- Benzene
- Buta- 1,3-diene
- Butyl Acrylate (n-)
- Carbon Dioxide
- Carbon Monoxide
- Chlorine
- Chlorine Dioxide
- Cyclohexane
- Dimethyl Ether
- Ethanol
- Ethene
- Ethene Oxide
- Ethyl Acetate
- Formaldehyde
- Formic Acid
- Gasoline
- Heptane (n-)
- Hexane (n-)
- Hydrocarbons in General
- Hydrogen
- Hydrogen Chloride
- Hydrogen Cyanide
- Hydrogen Sulphide
- Kerosene
- LNG (Liquefied Natural Gas)
- LPG Butane (n-)
- LPG Propane
- Methacrylic Acid
- Methane
- Methanol
- Methyl Ethyl Ketone
- Methyl Metacrylate
- Nitric Oxide
- Nitrogen
- Nitrogen Dioxide
- Octane (n-)
- Oxygen
- Ozone
- Pentane (n-)
- Phenole
- Phosgene
- Propanol (iso-)
- R113
- R134a
- R21
- R22
- R401A
- R404A
- R407C
- Radon
- Styrene
- Sulphur Dioxide
- Toluene
- Turpentine
- Vinyl Chloride
- VOC (Volatile Organic Compounds)
- Xylene

There are numerous possible sensors per gas where response time, operating range, sensitivity and type of sensor (Electro-Chemical, Catalytic, Optical, Semiconducting) vary.

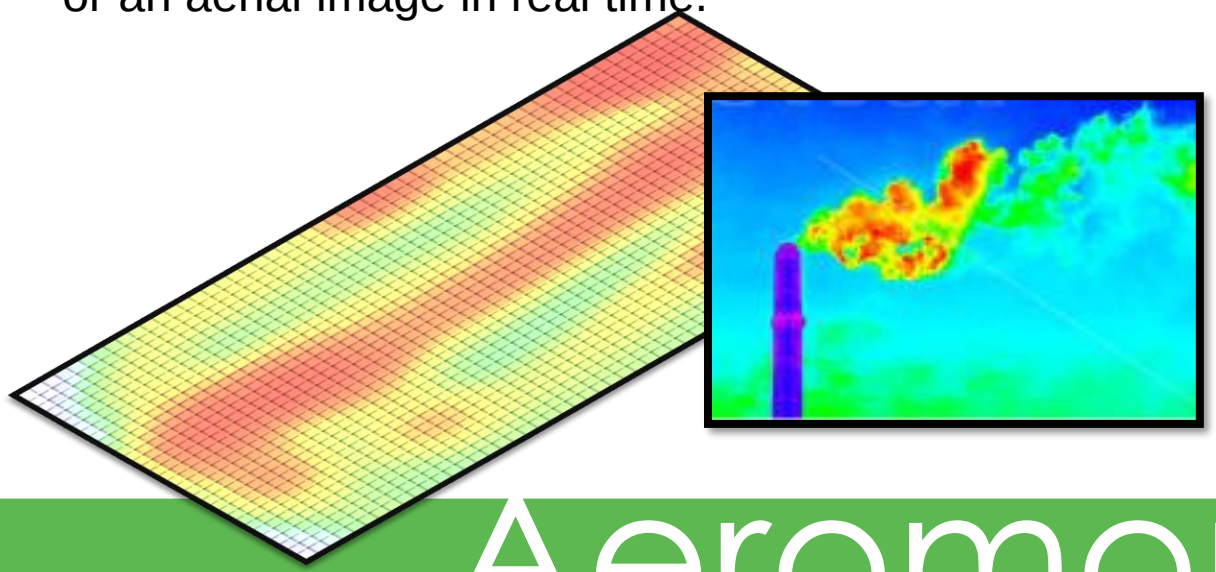
TECHNOLOGY BASE

SENSORS

AEROMON CLOUD SERVICE

PLATFORM

- Aeromon cloud service collects and stores all sensor data together with user ID and provides **automated analysing and reporting** through web interface.
- A versatile **signal processing, algorithms and cross-effect compensations generate high quality results** even from budget sensor technology.
- Visualization of the results can be provided on top of a map or an aerial image in real time.



TECHNOLOGY BASE

SENSORS

AEROMON CLOUD SERVICE

PLATFORM

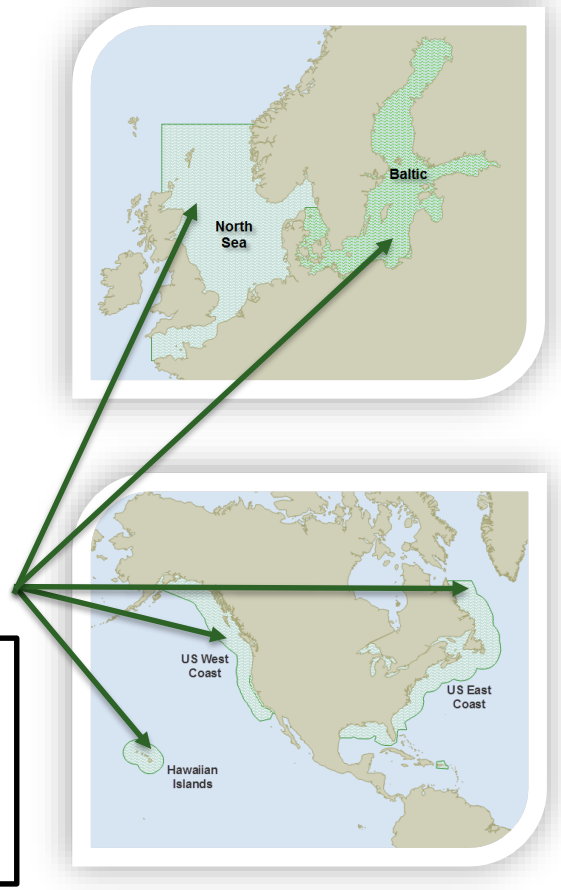
Aeromon selects the best monitoring platform for each monitoring situation. There are various monitoring platforms available:

- Unmanned Aerial Systems UAS
  - Rotary
  - Fixed wing
  - Balloon
- Other possibilities
  - Onboard a vessel or a vehicle
  - Network of stationary analyzers
  - Combinations

Aeromon Ltd. – 2015

During 2015 our R&D focus was in the marine emission monitoring service.

- Technological feasibility study ”**MeriSOx**” in collaboration with Finnish Meteorological Institute (FMI) and VTT Technical Research Centre of Finland
  - Sensor module BH-8 with CO_2, NO, NO_2, SO_2, O_2, RH%, temperature and pressure sensors.
  - The sensors were tested by the FMI in their environmentally controlled laboratory as well as field conditions
  - Field tests were made in collaboration with VTT test engine laboratory, Neste Ltd. and the Port of Helsinki.
  - **Aeromon system showed 30 % uncertainty for fuel sulphur content (FSC) determination in the 0,1 % FSC with 95 % confidence interval!**



- 0.1% SOx limits on SECA areas from 2015 onwards.
- 0.1 % sulphur content not reachable with heavy fuel oil (HFO)→ marine gas oil (MGO) must be used or exhaust gases must be washed (scrubbers)
- MGO is about 2x the price of HFO → benefit from non-compliance at the magnitude of 10 000 €/day
- States must have a credible method for emission monitoring to enforce the regulation and prevent the market from being distorted by non-complying companies.

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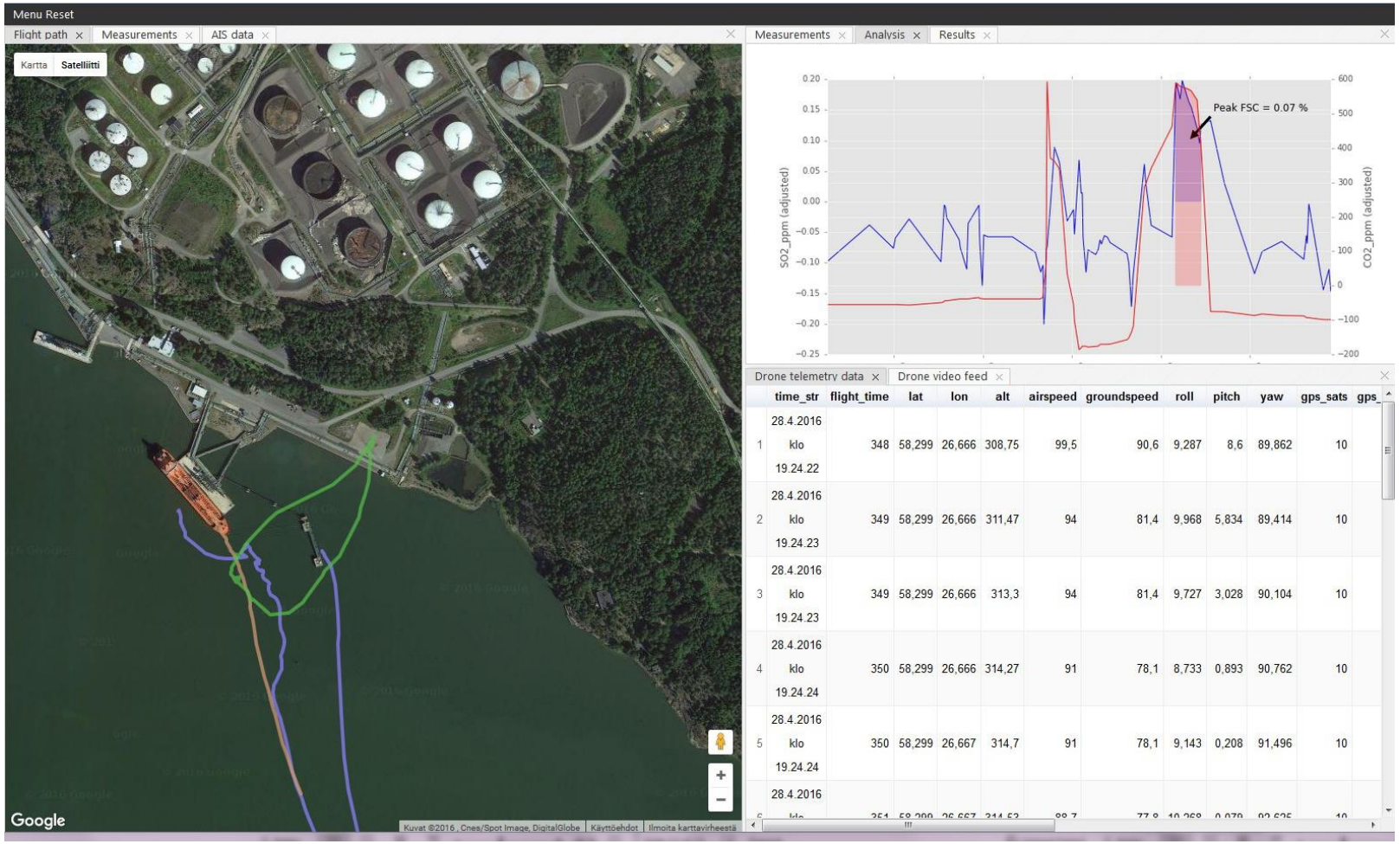
Vessel emission example in Aeromon Cloud Service



	time_str	flight_time	lat	lon	alt	airspeed	groundspeed	roll	pitch	yaw	gps_sats	gps_
1	28.4.2016 klo 19.24.22	348	58,299	26,666	308,75	99,5	90,6	9,287	8,6	89,862	10	
2	28.4.2016 klo 19.24.23	349	58,299	26,666	311,47	94	81,4	9,968	5,834	89,414	10	
3	28.4.2016 klo 19.24.23	349	58,299	26,666	313,3	94	81,4	9,727	3,028	90,104	10	
4	28.4.2016 klo 19.24.24	350	58,299	26,666	314,27	91	78,1	8,733	0,893	90,762	10	
5	28.4.2016 klo 19.24.24	350	58,299	26,667	314,7	91	78,1	9,143	0,208	91,496	10	
6	28.4.2016 klo	351	58,299	26,667	314,53	88,7	77,8	10,269	0,079	92,626	10	

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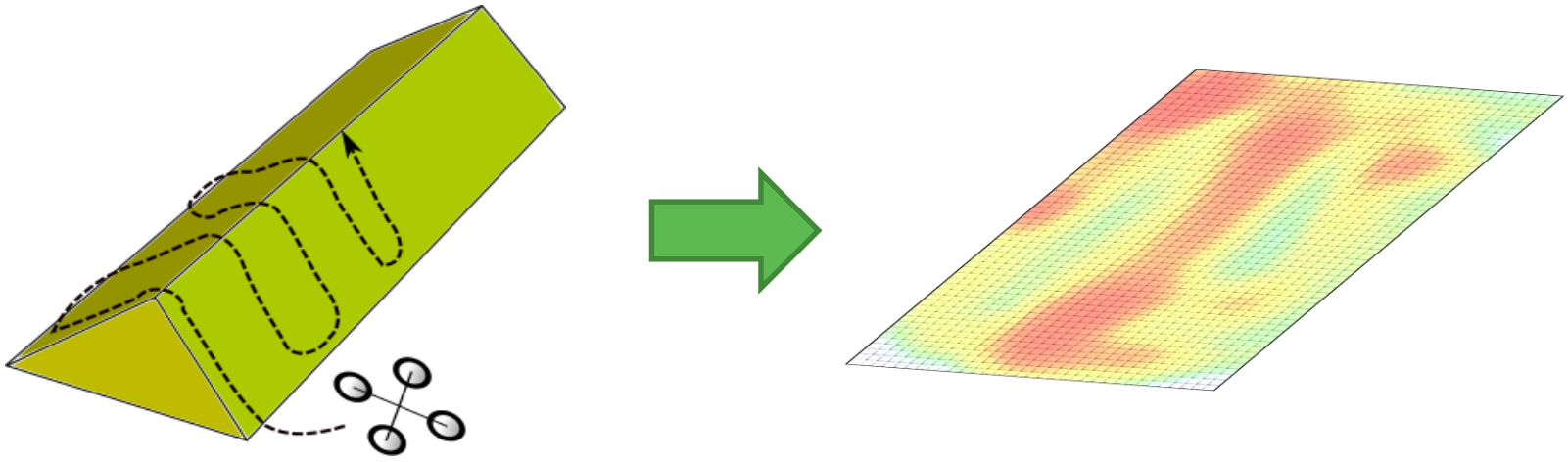
Aeromon Ltd. - BioSeCo 2015

- Project ”**BioSeCo**” (UAS-assisted **Bio**mass **Se**curity and self-**Co**mbustion prevention) was a measurement pilot in collaboration with the Finnish Natural Resources Centre (LUKE) and Aeromon used airborne monitoring to test for signals of spontaneous combustion of biomass.



https://www.youtube.com/watch?v=Ag0EZ9QwXz8

Aeromon Ltd. – 2016

AeroMap – Industrial emission monitoring application

- Fugitive emissions monitoring
- Leak detection
- Environmental mapping of TRS (Total Reduced Sulphur Compounds) compounds

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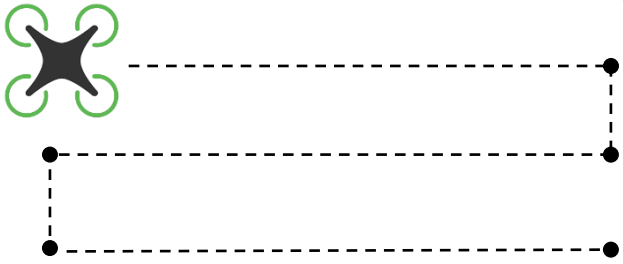
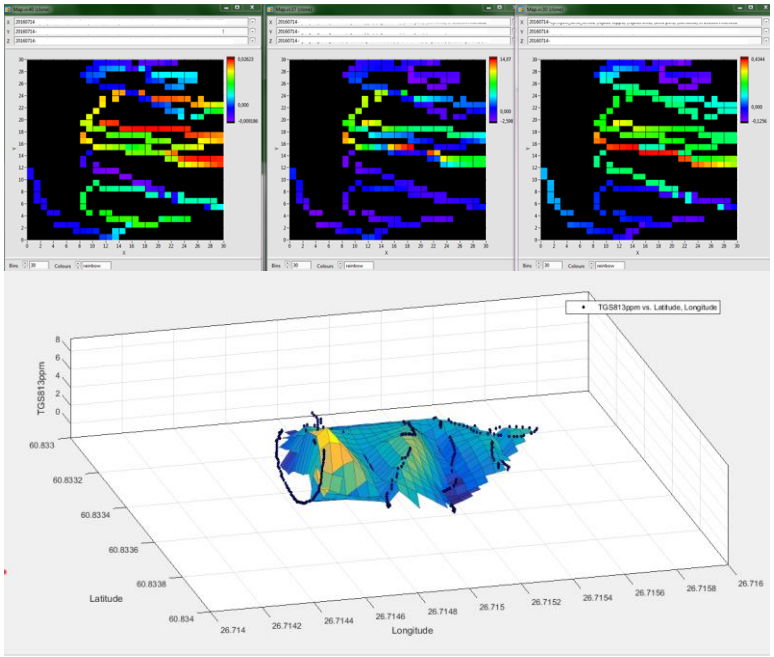
Diffuse emission mapping

- Aeromon BH-8 sensor module is used to **covers the desired area**.
- Aeromon BH-8 collects gas concentration **data tagged with exact location** information (GPS) throughout the entire measurement period
- Desired gases are measured with **calibrated sensors**.
- The raw measurement data is processed into gas concentration map in the Aeromon Cloud service **in real-time**
- **Automatic reporting for high efficiency** of measurement crews
- Detected **emissions can be pinpointed and quantified** with our **diffusion model**.





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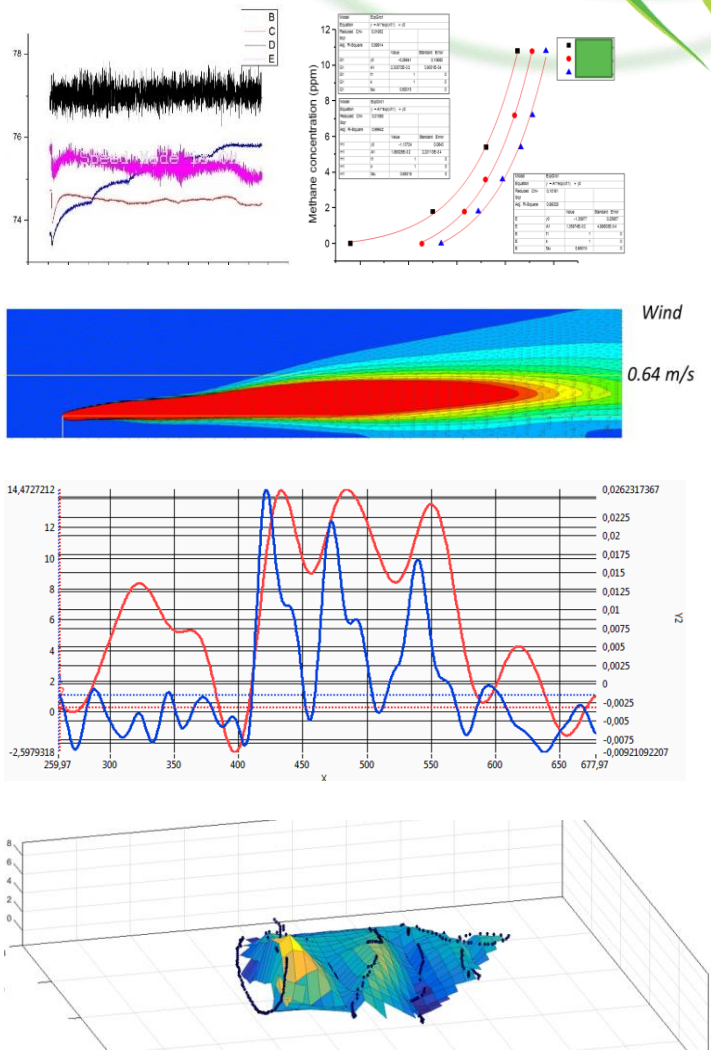
Workflow in diffuse emissions

- The behavior of the target molecules is analyzed in order to predict their diffusion pattern
- All sensors are verified to perform in the measurement conditions
- All field measurements are calibrated
- All data is refined, goes through the Aeromon Quality Assurance process and is stored (for future use)
- Reverse modeling is used to determine the mass flows of emissions
- Data analysis and Reporting



Conclusions

- The overall potential of UAV's as a gas safety tool for emergency staff is there and it's usable.

- The ultra-light and robust magic box of gas sensing doesn't exist – yet!
  - Technology is not yet mature for "plug-and-play" operations.
  - **However, there's already a lot we can do, if we want to.**

- With collaboration and good user requirement specifications, the right solution for emergency and response services is already possible.

Aeromon Ltd. – In collaboration

Tekes

Trafi
Liikenteen turvallisuusvirasto
Trafiksäkerhetsverket
Finnish Transport Safety Agency

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

SYKE

VTT

Luke
LUONNONVARAKESKUS

HSY

Turun yliopisto
University of Turku

Gasum

The Biofore Company
UPM

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