
Dear Audience
I regret not being with you!
Many thanks to the presenter!
0.2'

Credits to

all freelance pilots @MetAir and all colleagues and customers we were interacting since 1990, such as from FZJ, PSI, ETH, ESA, Uni Bremen, etc.; others will be mentioned on specific slides.

0.3'

My main message will be:

MetAir

There is more out there than large research aircraft and big consortiums on the one hand, and UAV's for small groups on the other hand.
There is something in between, which is combining the "two worlds".
All three will stay important for future atmospheric research.
However, the focus might change.

0.7'

EMS Annual Meeting Abstracts
Vol. 14, EMS2017-**PREVIEW**, 2017

Trends in airborne atmospheric observations

Already when I prepared the talk still thinking that I will present it personally, I have decided to follow the abstract statement by statement. Therefore you will find these statements on top of the slides that are introducing these topics.

Two affiliations during the last 11 years (now retired from ZHAW):

Teaching & Research at the Zurich University of Applied Sciences (ZHAW) in Winterthur, School of Engineering, with about 1000 students; 250 enrolled in the Bachelor course of aviation (where UMARS was developed), and in another faculty on energy and environment.

METAIR AG: An SME which was founded as a spin-off of ETH Zurich in 1990, operating small aircraft for atmospheric research, involved in about 70 international field campaigns. After the retirement from ZHAW we have new capacities for new projects …

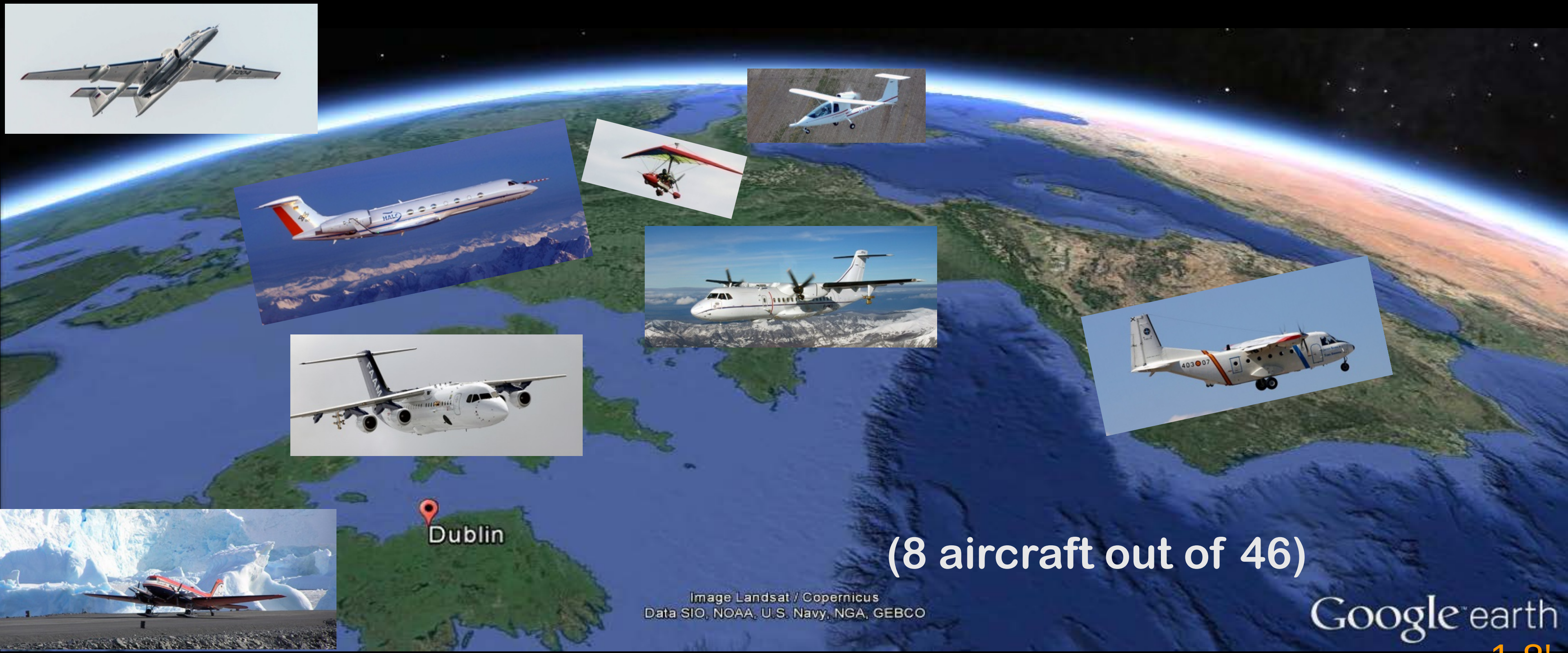
Two joint project: The RPAS 'UMARS' (2011), and the 'airborne wind LiDAR' (2016)

zh aw School of Engineering
ZAV Centre for Aviation

MetAir

1.4' (skip if late)

However, before becoming too specific, I will discuss a few general aspects of airborne atmospheric observations from a European perspective.



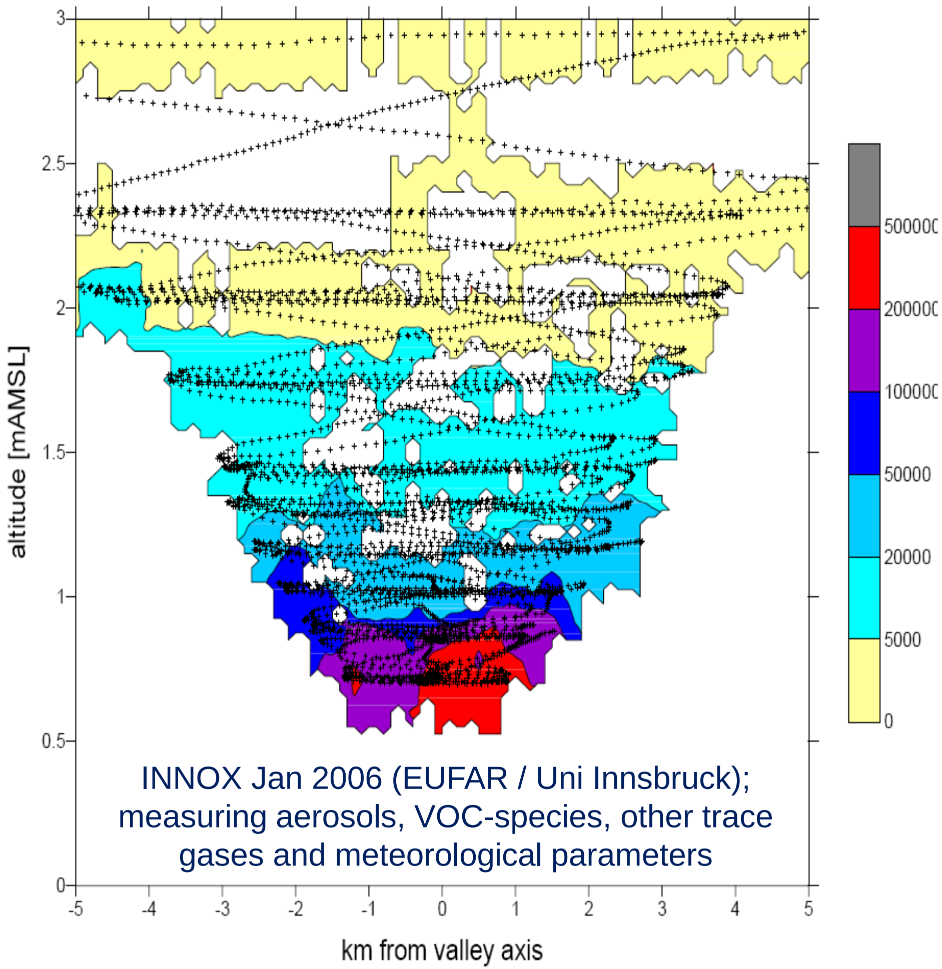
From the abstract: The atmosphere is a very dynamic three-dimensional subject and the underlying earth surface is full of relevant details. Only platforms able to either probe the atmosphere on different altitudes (in-situ), or observing the surface and the atmosphere by remote sensing methods, are able to provide enough information for process studies, or to feed and verify numerical models.

This is a trivial statement for the audience of this session, i.e. all know the necessity of 4-d-observations both for research and for operational purposes. The question is, where the main gaps in the observation system are, and with what kind of airborne measurements they can be filled now, or could be filled in the near future.

From the abstract: The list of standard methods for such four-dimensional observations is well known (satellites, precipitation radars, wind profilers, LIDAR for wind, aerosols and other constituents, balloon soundings, etc.). Also the use of aircraft of different sizes for such observations is known since more than 100 years *(e.g. celebrated in Lindenberg, Germany, in 2011)*.

The interpolated in-situ data (particles > 0.3 µm)

MetAir



INNOX Jan 2006 (EUFAR / Uni Innsbruck); measuring aerosols, VOC-species, other trace gases and meteorological parameters

The main advantage of airborne measurements is, that they are covering at least two dimensions in a flexible way:

- **mapping (horizontal plane)**
- **cross sections like in this example (vertical plane)**
- **combinations of them**
- **single or several trajectories along a certain distance**
- **several vertical soundings**

Of course all is depending from the type and performance of the aircraft, the air space and other possible restrictions for safety.

The main problem is time:
One cannot be everywhere at the same time, which is a problem for the observation of instationary processes.

3.3'

Other opinions about observations by aircraft:

- expensive (not necessarily)
- has to be planned years in advance (no, a few months is fine, and a campaign can remain very flexible in time and space)
- strongly depending from the availability and the preferences of the aircraft operators (true for large aircraft, less for small teams)
- all instruments have to be certified for the use on board of an aircraft (yes, however, also here, there are large differences between the different types of aircraft and operators)
- additional efforts needed for planning and permissions (yes, this seems to be increasingly the case, because almost everything is becoming more bureaucratic these days)
- logistics (yes, that's true for any field work)
- ??? (from the audience?)

The operators are knowing best what is possible, which are the main obstacles and what are the most robust approaches for your scientific questions. Therefore: Speak with several of them if you have any plans!

When speaking about trends, this full service (not just flying around) is certainly a key point that is gaining importance for the users.

From the abstract: When looking into the fleet of research aircraft in Europe (e.g. via EUFAR), or worldwide, we see an enormous variability of platforms, sensors and topics for which these platforms are used.

46 aircraft in total !	access via TA	direct access
large	6	7
medium	11	11
small	4	7
total	21	25

http://www.eufar.net

4 slides in 60"

DO228-101 - DLR

Deutsches Zentrum für Luft- und Raumfahrt e.V.

Land/Sea surface properties, Troposphere

D-CODE

Dornier Flugzeugwerke, Do 228 - 101

DO228-212 - DLR

Deutsches Zentrum für Luft- und Raumfahrt e.V.

Land/Sea surface properties, Troposphere

D-CFFU

Dornier Flugzeugwerke, Do 228 - 212

ECO Dimona - UEDIN

University of Edinburgh Airborne GeoSciences

Troposphere

G-GEOS

Diamond Aircraft, HK36 TTC ECO Dimona

ENDURO - KIT

Karlsruhe Institute of Technology

Troposphere

D-MIFU

Ultraleichtflug Schmidtler, Enduro

ERA - CNR - ISAFOM

Istituto per i Sistemi Agricoli e Forestali del Mediterraneo

Troposphere

I-AMMO

3I / Magnaghi Aeronautica, Sky Arrow 650 TCNS

FA20 - DLR

Deutsches Zentrum für Luft- und Raumfahrt e.V.

Land/Sea surface properties, Troposphere

D-CMET

Dassault Aviation, Mystere / Falcon 20 E-5

FA20 - SAFIRE

Service des Avions Francais Instrumentés pour la Recherche en Environnement

Troposphere

F-GBTM

Dassault Aviation, Mystere / Falcon 20 GF

Learjet - Enviscope

Enviscope GmbH

Land/Sea surface properties, Troposphere, UTLS (Upper Troposphere, Lower Stratosphere)

D-CGFD

Learjet / Bombardier Aerospace, 35A

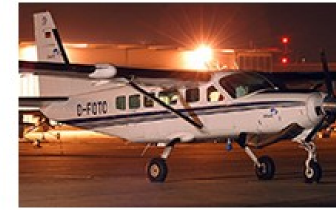
http://www.eufar.net/aircrafts/list-matrix

Aircraft not open to Transnational Access

ASK16 - FUB
Freie Universität Berlin, Institut für Weltraumwissenschaften
Troposphere
D-KMET
Alexander Schleicher GmbH & Co, ASK 16

BN Defender
Institute for Environmental Solutions
Land/Sea surface properties
YL-FBI
BN-2T-4S Defender

BNI - MUMM
Management Unit of the Mathematical Model of the North Sea, Royal Belgian Institute of Natural Sciences
Troposphere
OO-MMM
Britten-Norman, Islander BN-2A 21



C 208 - Enviscope
Enviscope GmbH
Troposphere
D-FOTO
Cessna Aircraft Company, C-208 B Grand Caravan

C 310 - DUTH
Democritus University of Thrace
Troposphere
SX-AJQ
Cessna Aircraft Company, C 310Q

C 402B - MUNICIPIA
Municipia, SA
Land/Sea surface properties
CS-DPS
Cessna Aircraft Company, C 402B

CITATION - NLR
Netherlands Aerospace Centre
PH-LAB
Cessna Aircraft Company, Citation II

DIMO - METAIR
MetAir AG, Switzerland
Troposphere
HB-2335
Diamond Aircraft, HK36 TTC ECO Dimona

King Air - TAU
Tel Aviv University
Troposphere
4X-DZT
Hawker Beechcraft, King Air C90

M55 - Geophysica
Myasishchev Design Bureau
Land/Sea surface properties, Stratospheric , Troposphere
55204
Myasishchev Design Bureau, M-55

Seneca - IBIMET
Institute of Biometeorology
Troposphere
I-VEIC
Piper Aircraft, PA34-200T Seneca II

Seneca - OGS
National Institute for Oceanography and Experimental Geophysics
Troposphere
S5-DGL
Piper Aircraft, PA34-200T Seneca II

STEMME S15 - INTA
Instituto Nacional de Tecnica Aeroespacial
Troposphere
EC-LOT
Stemme, S-15

TU 154 - GFRI
Gromov Flight Research Institute
Troposphere, UTLS (Upper Troposphere, Lower Stratosphere)
RA85317
Tupolev, Tu-154M

WB-57F - NASA
National Aeronautics and Space Administration
Land/Sea surface properties, Stratospheric , Troposphere
N926NA N927NA N928NA
Glenn L. Martin Company, Martin WB-57F

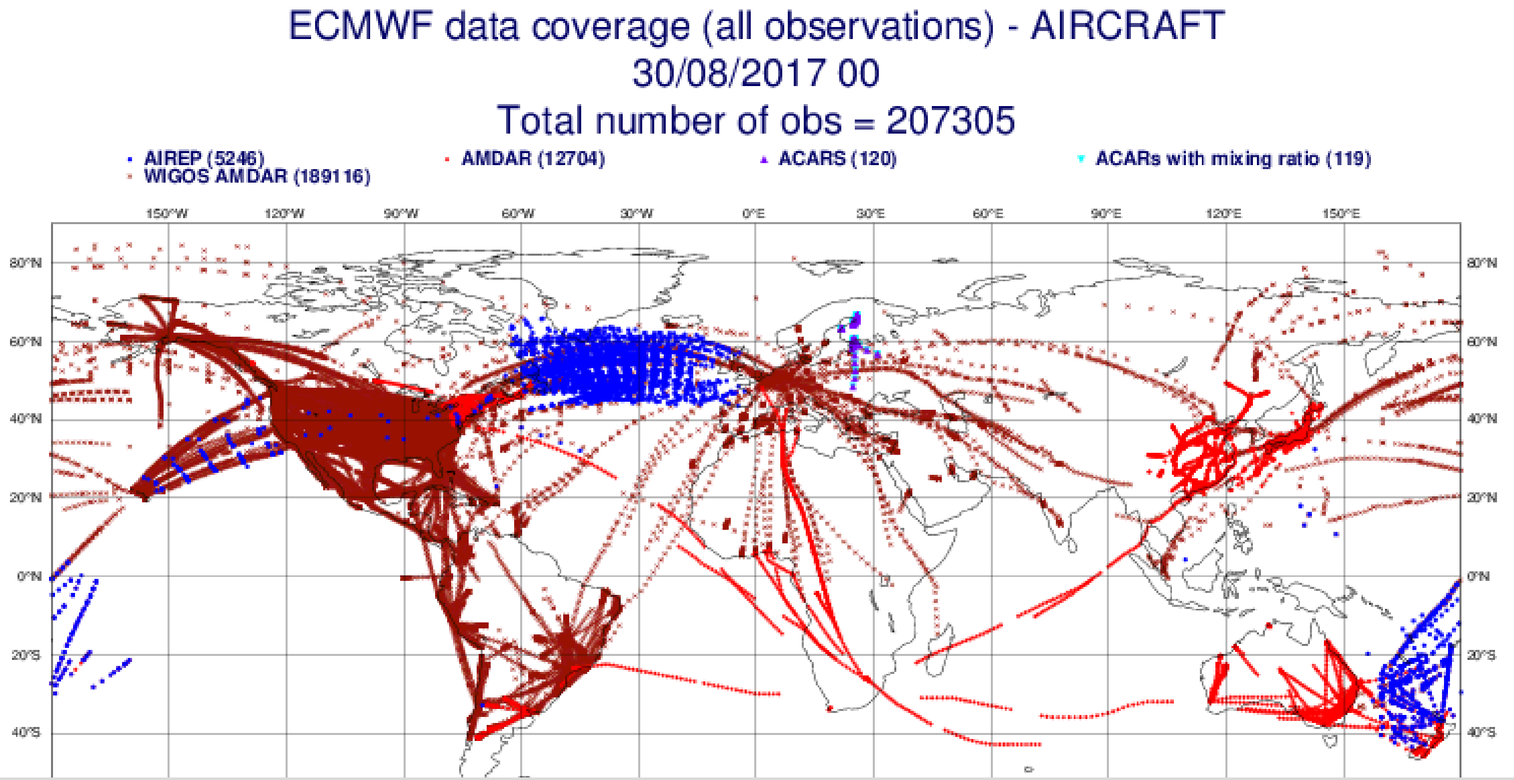
Zeppelin LZ N07-100
Zeppelin Luftschifftechnik GmbH
Atmospheric boundary layer, Land/Sea surface properties, Troposphere
D-LZZF
ZLT Zeppelin Luftschifftechnik LZ N07-100

5.2'

As indicated, having an aircraft is certainly not enough!
You need, suitable to your scientific question:

- ✓ the instrumentation
- ✓ more or less specific weather conditions
- ✓ an experienced team for the campaign
- ✓ methods for the data processing
- ✓ a mixture of competence and luck that everything is working when you need it – including logistics and perhaps special permissions

From the abstract: Most applications are for episodic process studies. However, some of them are serving for systematic observations such as AMDAR, daily drop sondes, or frequent observations of the earth's surface.



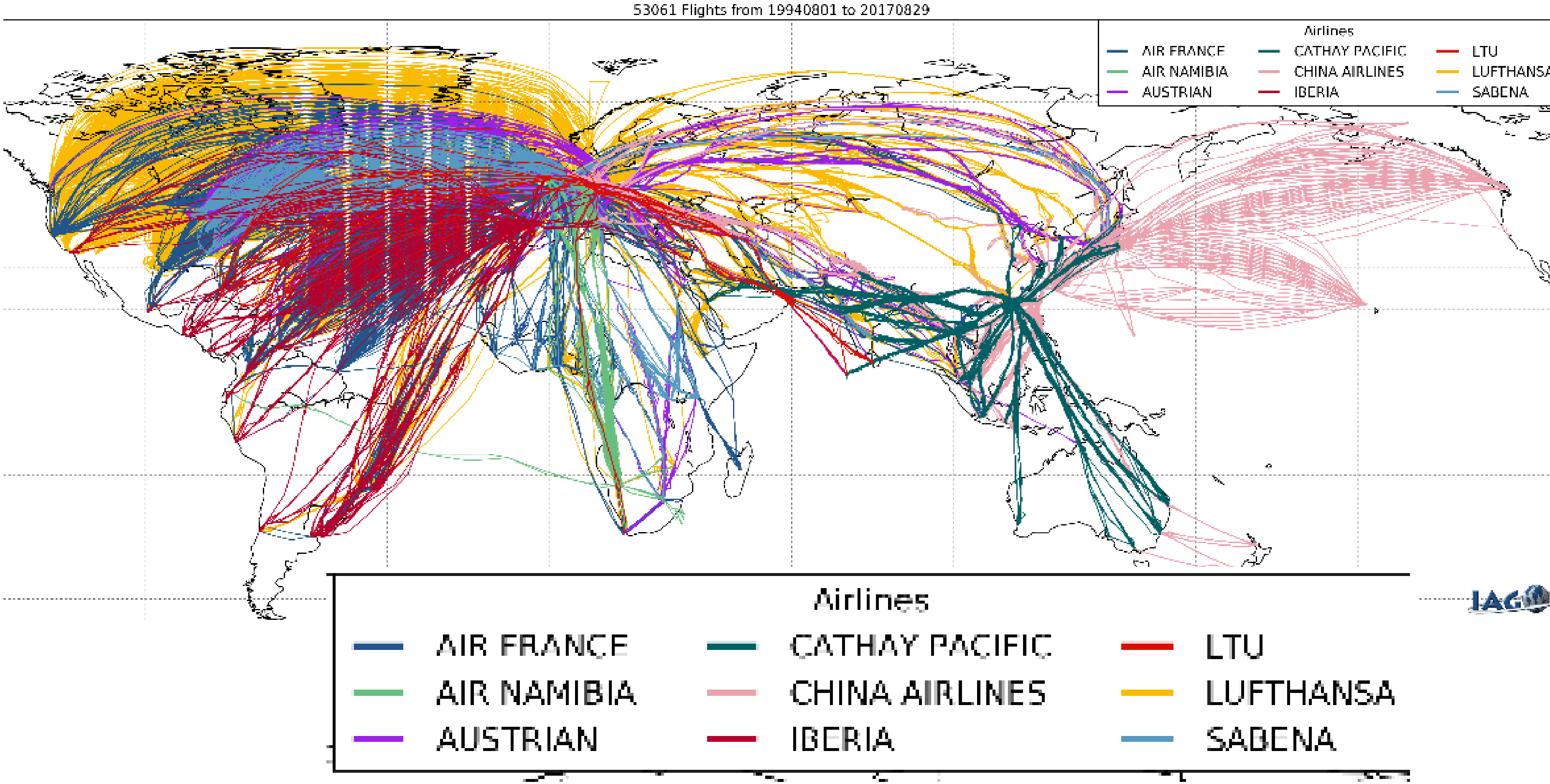
These are all airline flights providing data to ECMWF on a specific day (e.g. today)

6.1'

https://www.ecmwf.int/en/forecasts/charts/monitoring/dcover?time=2017083000,0,2017083000&obs=aircraft&Flag=all

http://www.iagos.org/

data coverage from 1994 to 2017



Very subjective answers, maybe supplemented by the audience:

- EUFAR was established as an overarching platform for the use of aircraft in atmospheric research and earth observation
- With this, the awareness about the options and the networking was improved
- More robust and accurate instruments for atmospheric trace gases are available (such as Picarro or Los Gatos ring-down lasers for GHG including CH_4)
- Airborne remote sensing methods have evolved considerably
- Some groups have acquired and equipped their own small research aircraft
- Some groups are making use of RPAS (UAV's, 'drones') as platforms (organised since 2009 in a COST-Action, now in ISARRA)
- ??? (from the audience?)

Many new aspects were recently presented and discussed at ICARE 2017 at DLR in Oberpfaffenhofen, and last week at the 'drone days' in Lausanne, showing that in the RPAS sector, a very fast (disruptive) development is happening, especially in the field of regulation (less restrictive regulations envisaged already for 2019 !)

However, at this point (not only at the very end) I wish to list a few critical comments from my personal point of view:

- **EUFAR and other large infrastructure projects like HALO or Zeppelin-NT costed a lot of money that is now missing for "small research"**
- **Despite EUFAR, the heterogeneity in platforms, quality of service and applied methods is still very big – maybe almost intransparent for users without long-standing experience (e.g. for PhD students).**
- **The institution of "Transnational Access" is distorting a market to the benefit of large national facilities (with public funding already) and to the disadvantage of smaller ones (both private and public). The idea behind was, that a research group from country B could use a funded aircraft from a facility in country A, which sounds good at a first glance. However, the national thinking behind this is paradox. An open market, with EUFAR as a "market place", enabler and supporter for trans-national cooperation (e.g. for getting flight permissions in different countries) would be a better solution. Perhaps this can be achieved in the follow-up of EUFAR.**
- **Plans for using RPAS (UAV's, 'drones') are sometimes not realistic, i.e. ignoring that a small manned aircraft would be better and cheaper for the purpose.**
- **??? (from the audience?)**

From the abstract: Which applications might be replaced by satellites or RPAS (Remotely Piloted Airborne Systems, also known as UAV or 'drones') in the near future?

8.9'

All copied from the ISARRA page

Let me answer with some considerations already presented earlier within the COST-Action ES0802.The basic questions, when dealing with a scientific question in our field of atmospheric research (including interaction with the earth‘s surface), are:

1st Is the focus on modelling or observing?

2nd When observing:

	stationary	airborne	satellite
remote sensing	**?**	✓	**?**
in-situ	**?**	✓	**?**

when airborne: Existing systems like free or tethered balloons, or do we need an aircraft?

9.5'

When an A/C is needed, the next question should be:
Is it possible to do the job with a (small) manned A/C?

YES

Then go for it and be sure that it's cheaper than a complicated UAV-solution (ask for an offer from any operator), unless …

NO

…you could use one of the small UAV's, or

- **during night close to terrain**
- **closer than 50 m to terrain anytime**
- **more than 5 h endurance needed**
- **"3D" and maybe other criteria**

My impressions or credo:

- **Satellite observations like microwave topography missions will substitute many applications of manned and unmanned airborne observations**
- **Observations on a scale of a few km^2 will be substituted by RPAS**
- **Repeated observations along the same tracks (including operational monitoring similar to AMDAR in order to supplement the radio-soundings by balloons)**
- **Tethered balloons might be replaced by drones (less sensitive for wind)**
- **On the other end, very large scale & long endurance missions might be replaced by RPAS. They might be complemented by "passenger flights" for involved scientists and students in order to experience the environment, and to keep contact with and control over the RPAS. It is possible, that data collected with one or several RPAS are transmitted to such a mission aircraft which can return to a base, while the unmanned platforms are continuing to measure.**
- **The research groups will need help for finding optimum solutions.**
  Again: A "market-place", where scientists could deposit their needs, and operators of manned and unmanned aircraft could offer solutions would be the most effective way
- **??? (from the audience?)**

From the abstract: Which might be the remaining strong applications, where neither satellites, ground based remote sensing nor RPAS could cope with?

- ✓ all observations which need ad-hoc decisions during flights
- ✓ operations with instrumentation that is not yet fully automatic and might need maintenance during flights
- ✓ flying prototypes of instrumentation which is foreseen for unattended operation in RPAS later
- ✓ research projects with less than about 10 flights in a certain area

From the abstract: What are the new options we would have when combining classical airborne observations using manned aircraft with autonomous systems?

MetAir

Combining different platforms air/ground is not new:

In 2011, we combined surface stations, bycicle, aircraft …

ETH zürich
Department of Environmental Systems Science

... and a tethered balloon system ...

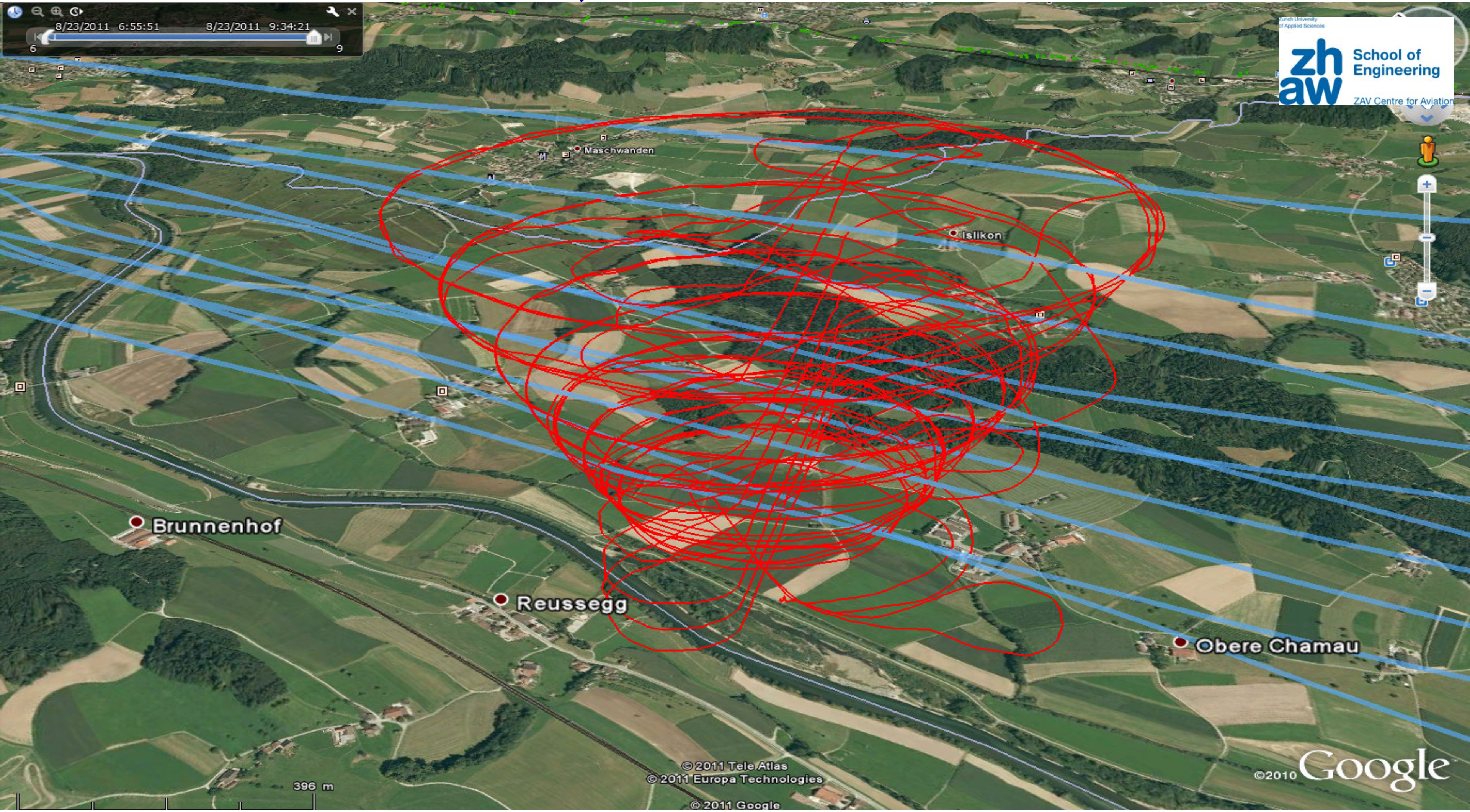
ETH
ZHAW
MetAir

Having three systems in the sky:
aircraft, tethered balloon, and an RPAS (UMARS with 5 m wing span, 30 kg mass).
FOCA confirmed, that our procedures were safe, mainly by «see and avoid»

12.3'

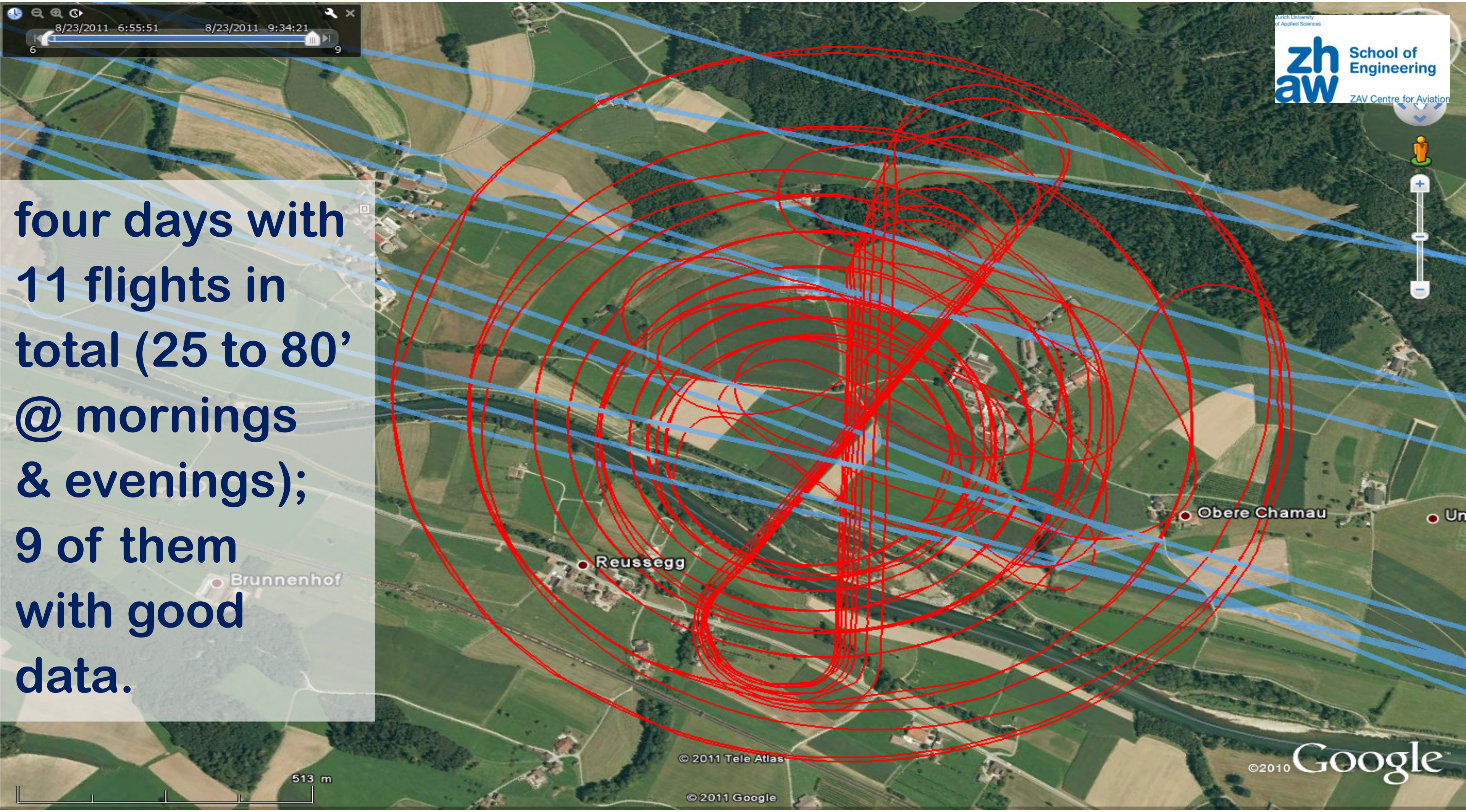
red track unmanned UMARS; blue tracks manned DIMO

MetAir



zh aw School of Engineering ZAV Centre for Aviation

12.5'



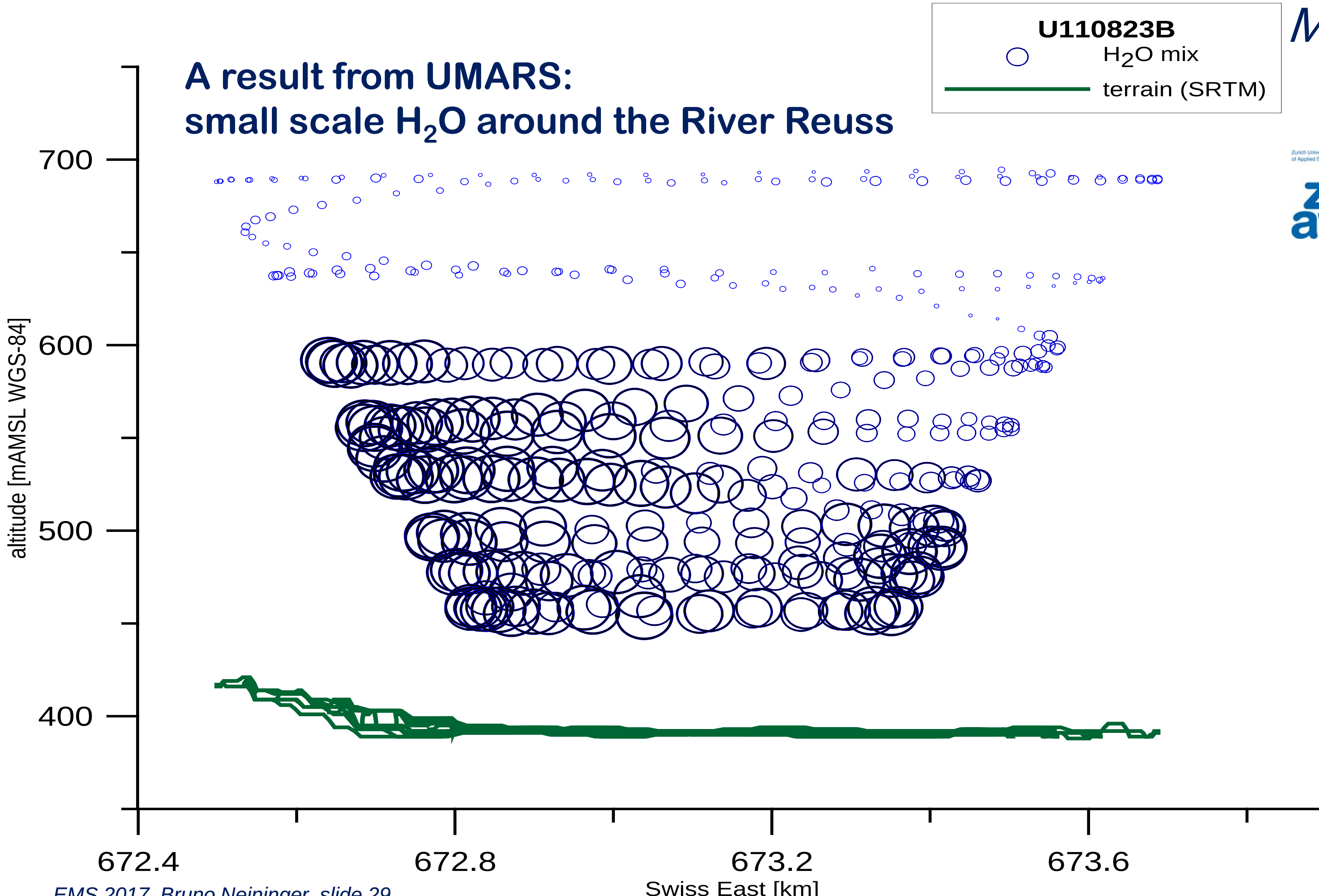
four days with 11 flights in total (25 to 80’ @ mornings & evenings); 9 of them with good data.

12.8'

A result from UMARS: small scale H_2O around the River Reuss

MetAir

zhaw School of Engineering
ZAV Centre for Aviation



13'

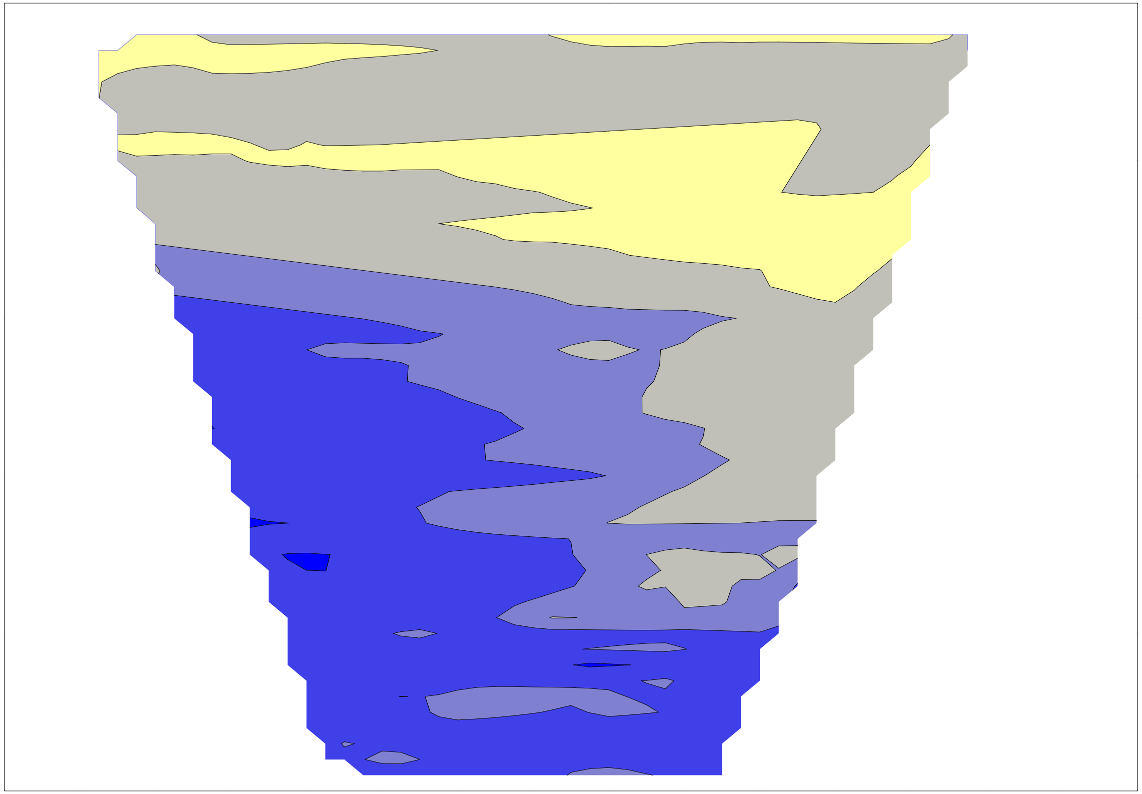
… here as an interpolated cross section

MetAir

Zurich University of Applied Sciences

zh aw School of Engineering

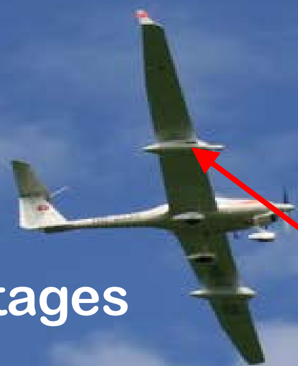
ZAV Centre for Aviation



g/kg H_2O

13.3'

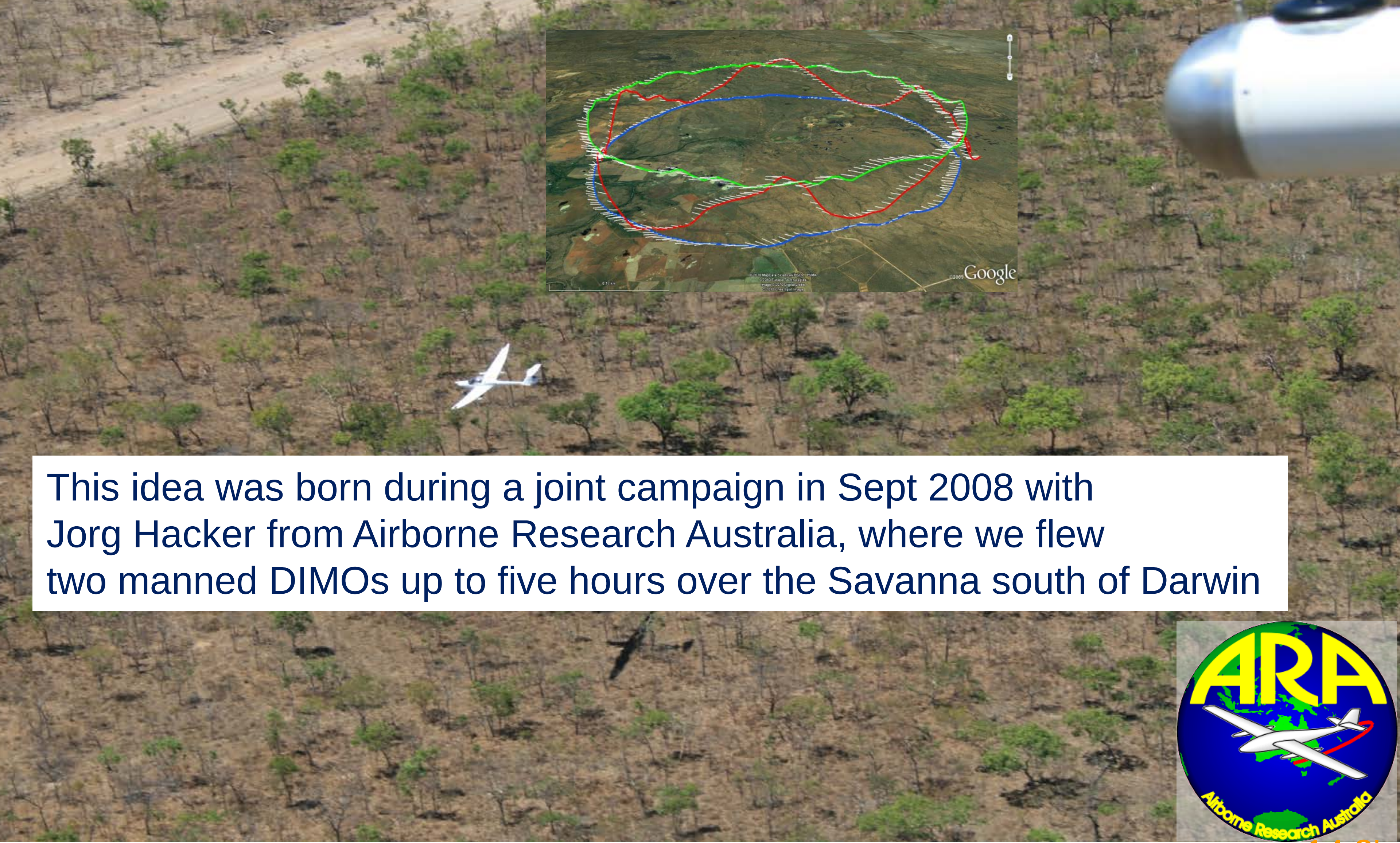
A next step could be combining a small & slow manned aircraft with a 'drone', following the aircraft, e.g. performing DOAS or other spectroscopy between the two platforms.



Some operational advantages are evident:

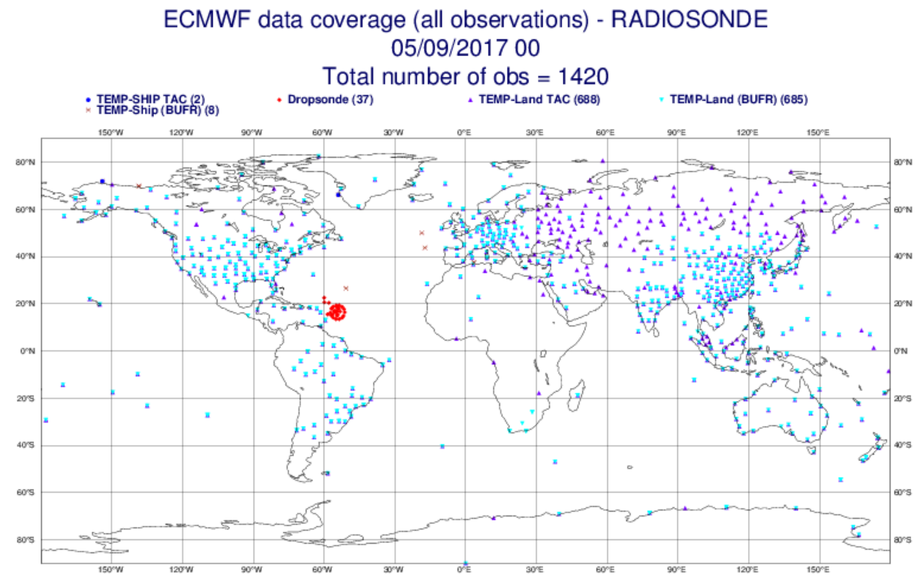
- it's in line of sight
- the communication with ATC is as a 'formation'
- the crew can watch and interact

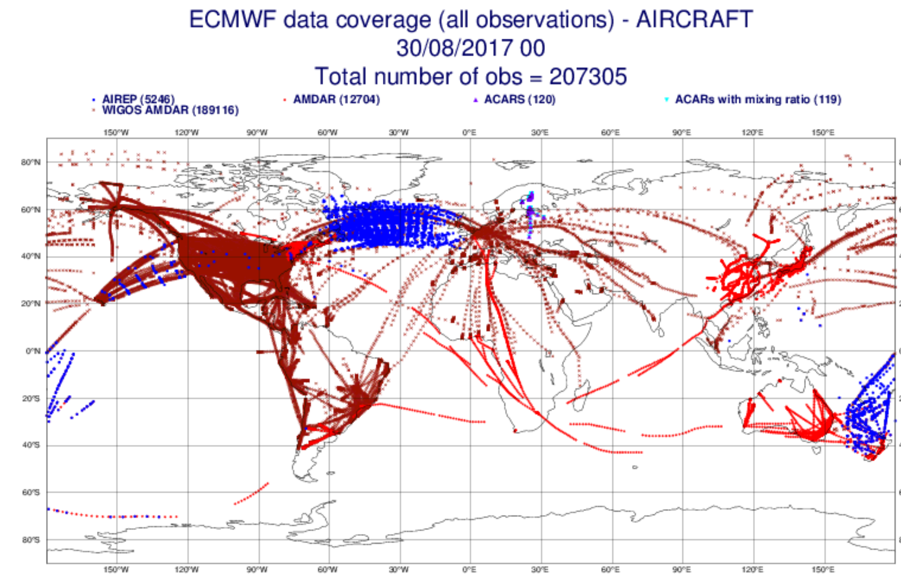
Another optical application could be a «flying reference» for hyperspectral sensing of the earth’s surface.
In-situ, gradients could be measured directly.



This idea was born during a joint campaign in Sept 2008 with
Jorg Hacker from Airborne Research Australia, where we flew
two manned DIMOs up to five hours over the Savanna south of Darwin

From the abstract: The progress in numerical analysis and forecasting, with increasing resolution on a widening spacial and temporal scale has further increased the need for precise data.
This might even be the trigger for new automated observation systems based on RPAS.





Even when combining daily balloon soundings (TEMP) and operational aircraft measurements, there are big data gaps especially on the southern hemisphere.
They could be closed by long-range RPAS, and the network for soundings in the boundary layer could be enriched by smaller 'drones'
(see what Meteomatics is doing with their Meteodrones).
This development could be regarded as a **trend**.

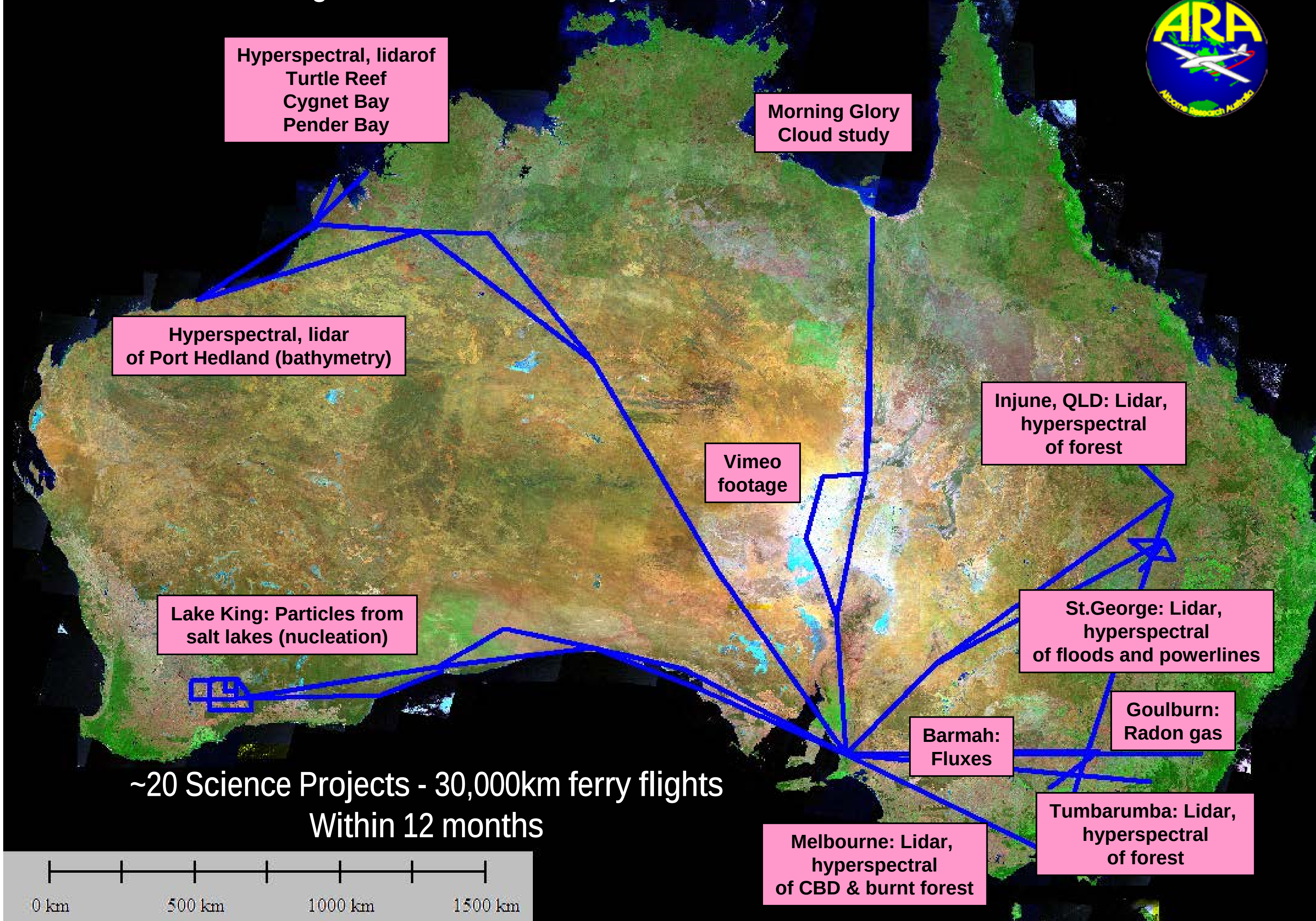
From the abstract: This talk will give an overview from the perspective of a group of scientists operating small research aircraft since more than 30 years.

MetAir

You know already METAIR-DIMO and ARA-DIMO. Additionally, I would like to show you some applications of the University of Wyoming (credits to Jeff French), and KIT (Wolfgang Junkermann)

15.3'

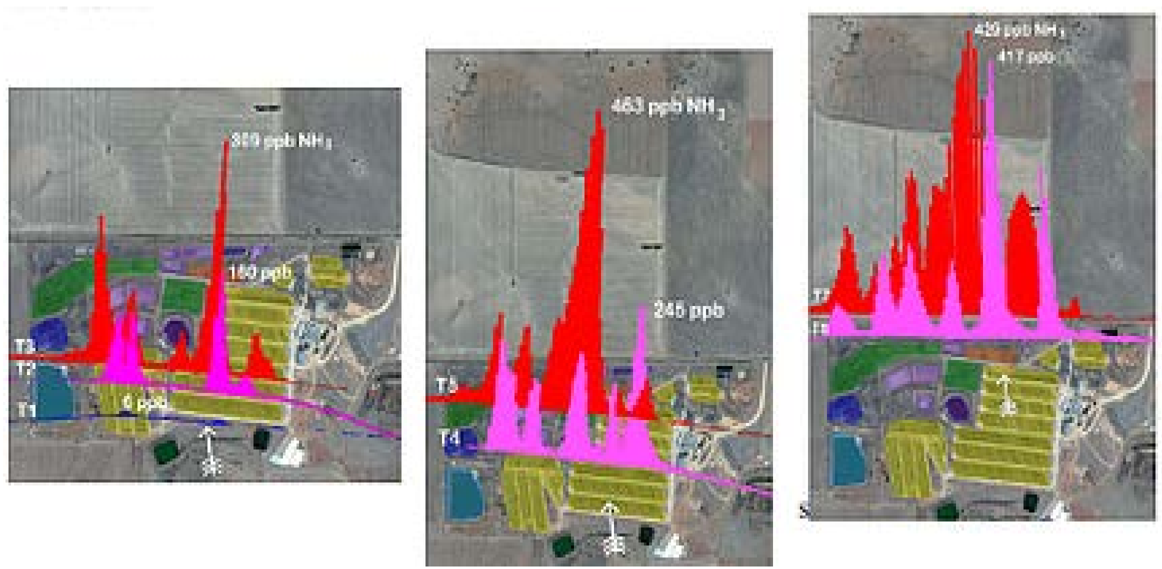
Small aircraft, but, long endurance and a very versatile instrumentation!



This was a project, where MetAir helped to digest the data from a flux study:

Greenhouse Gas Emissions from Cattle Feedlot

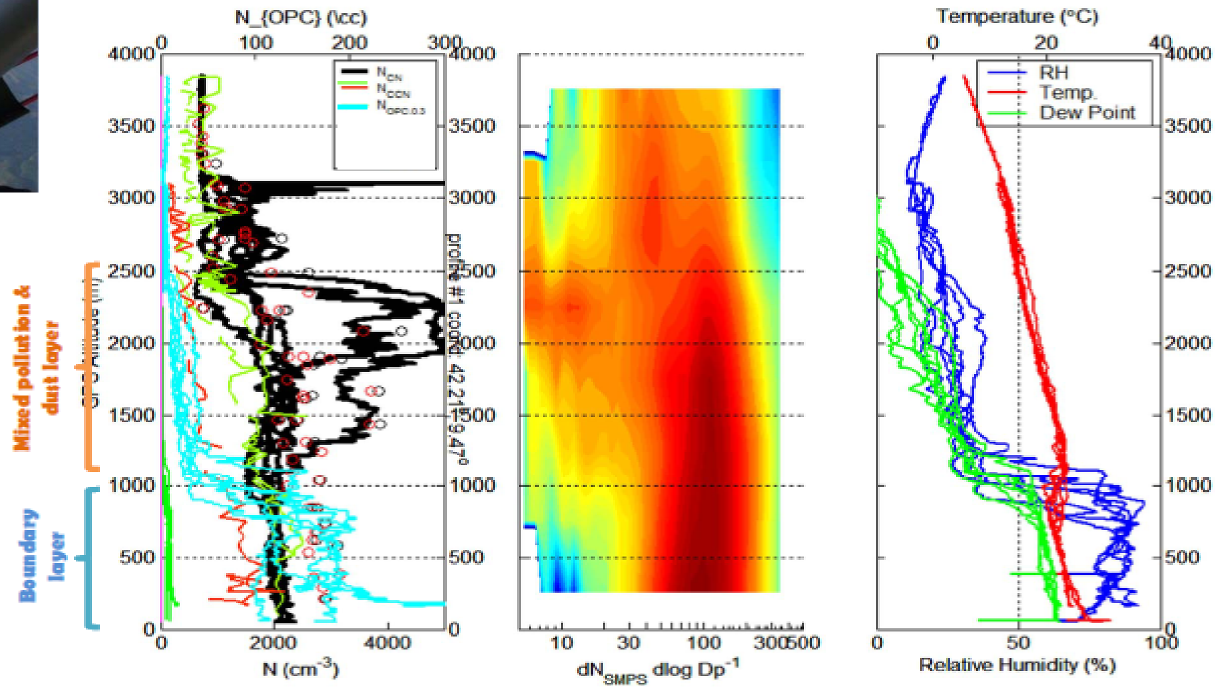
First results from a collaborative study to quantify Greenhouse Gas Emissions from a 17,000+ cattle feedlot near Charlton, VIC. using airborne technologies



A comprehensive paper has just been accepted by the ***Animal Production Sciences*** and will soon become available as: Hacker et al., 2016: **Using airborne technology to quantify and apportion emissions of CH4 and NH3 from feedlots**.

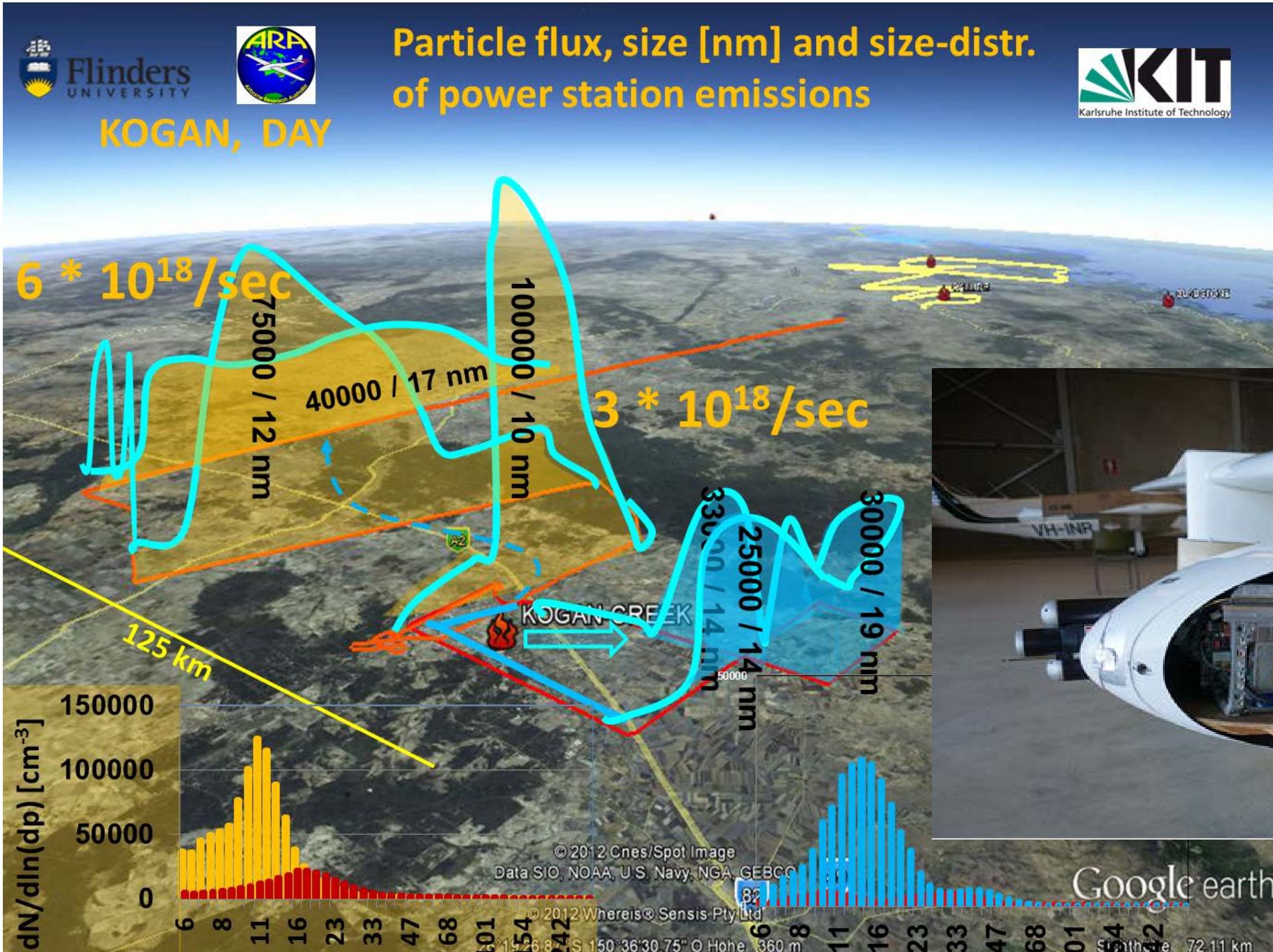
Wolfgang's Ultralight aircraft has a very specialized instrumentation for aerosols, including ultrafine:

ADVECTION FROM AJACCIO (POWER STATION) ->

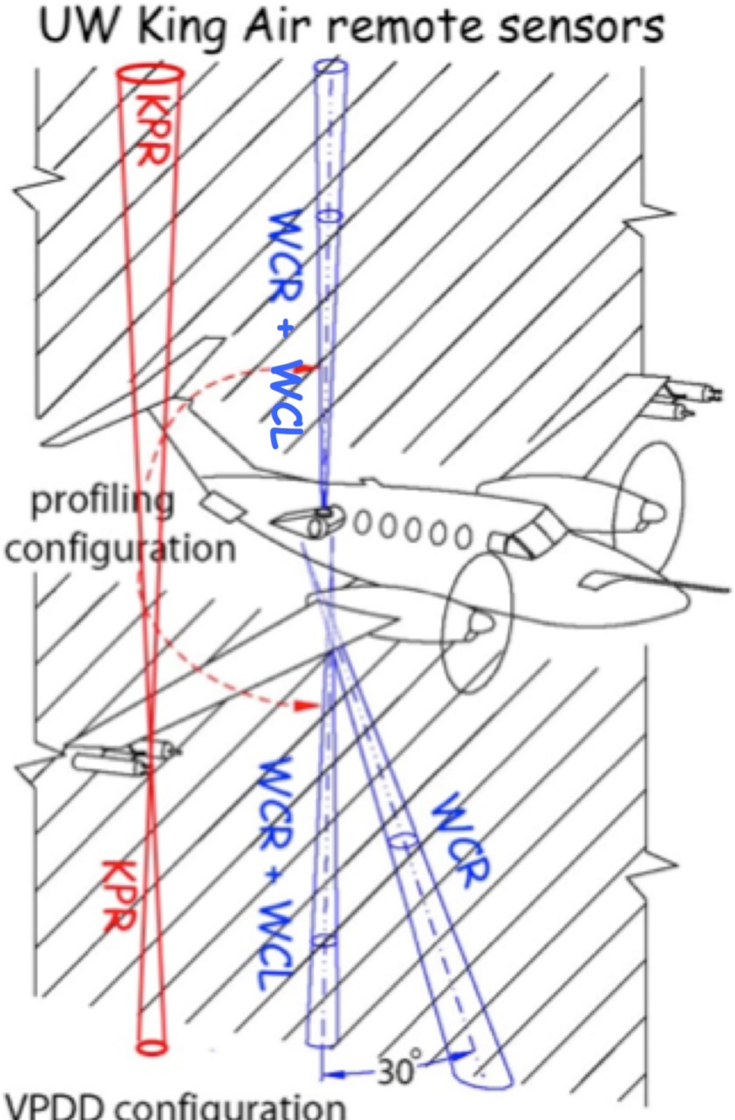


AEROSOL VERTICAL PROFILES OVER CORSICA, JULY 2012
HIGH NUMBER CONCENTRATION OF ULTRAFINE (UF) PARTICLES IN ELEVATED LAYERS, NEARLY ALL UF-PARTICLES ARE CCN

And this was a joint project with Wolfgang Junkermann's Instrumentation in Jorg Hackers DIMO-pods in Australia:

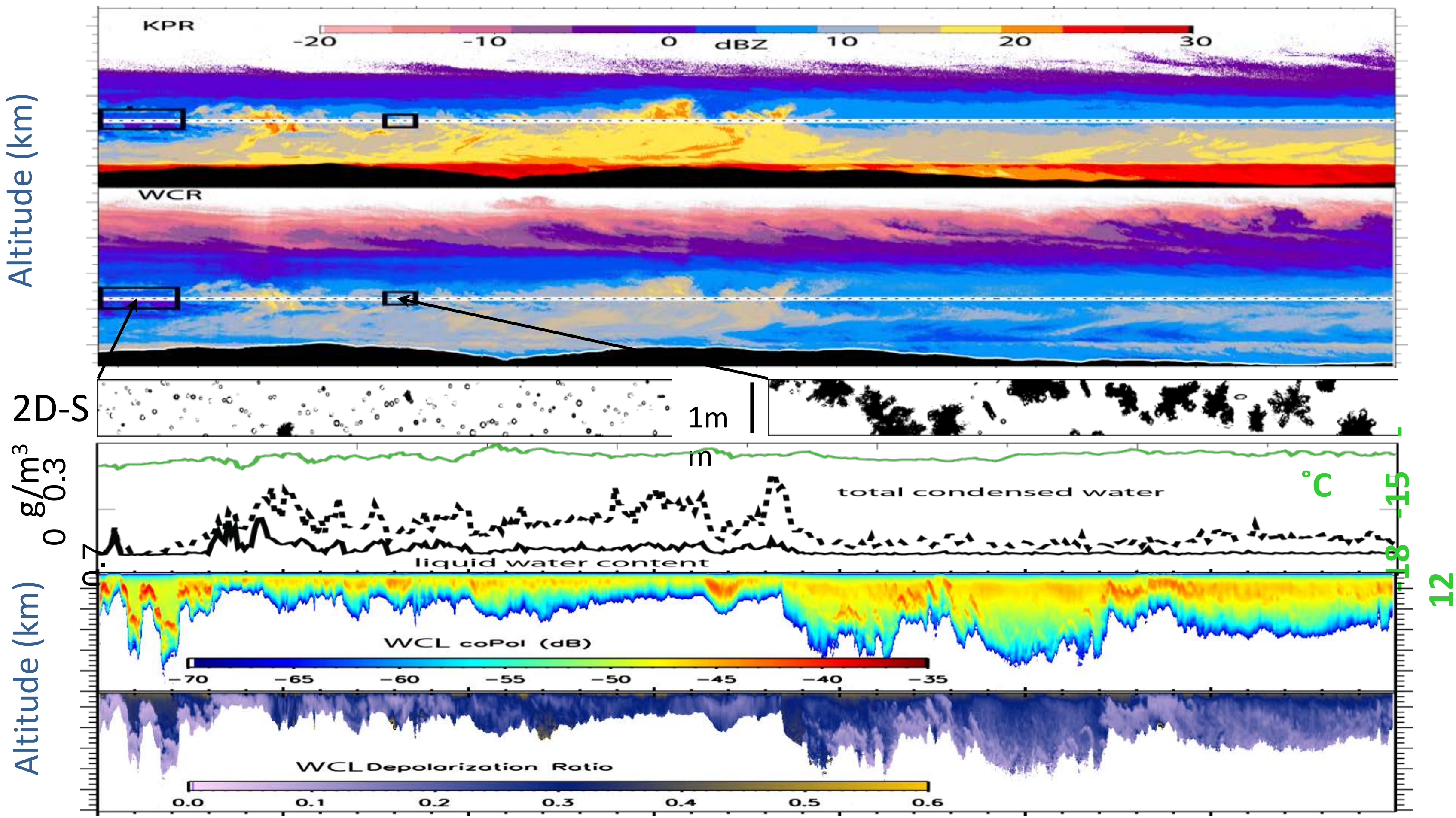


17.5'



Finally, the Wyoming 'King Air' is perhaps the best equipped cloud research platform with three different types of radar (each up- and downwards), able to document cloud physics in almost any conditions including icing (no CB's with hail of course). Doing more high-quality remote sensing from aircraft could certainly be a trend.

KPR (top), WCR (top/mid), Cloud Particle Images (mid) Cloud/Ice Content (mid/bottom), WCL



18.5'

Bottom line:
You do not need large aircraft for front-edge science; however, the examples shown might still be too difficult for RPAS (drones)

18.8'

From the abstract: One of the advantages of small environmental research aircraft (or some other classical airborne platforms) are the high flexibility and short reaction time, which became evident, when successful measurements were possible within the volcanic ash cloud spreading over Europe in April 2010.

MetAir

Between the news, the model output and the first take off at April-17, 2010, it took us only 26 hours, then documenting the particles and trace gases

Kein Schwenker in der Sicherheitspolitik

Bundesrat setzt auf Kooperation

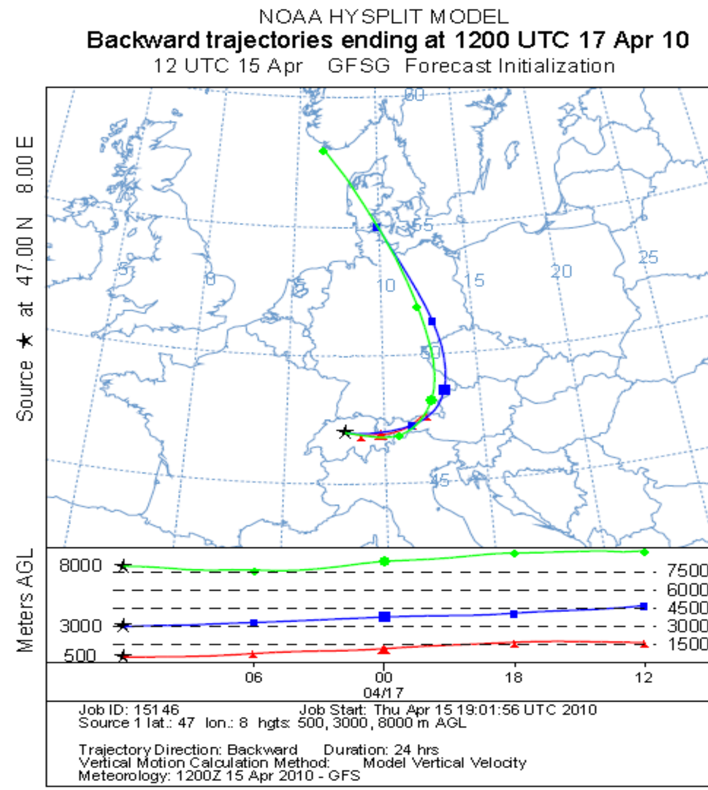
Villiger will keine UBS-«Schauprozesse»

Klage nicht im Interesse der Bank

NZZ und Tamedia tauschen Zeitungen

Mehr Spielraum für beide Häuser

Vulkanasche aus Island gefährdet Flugzeuge in Nordeuropa



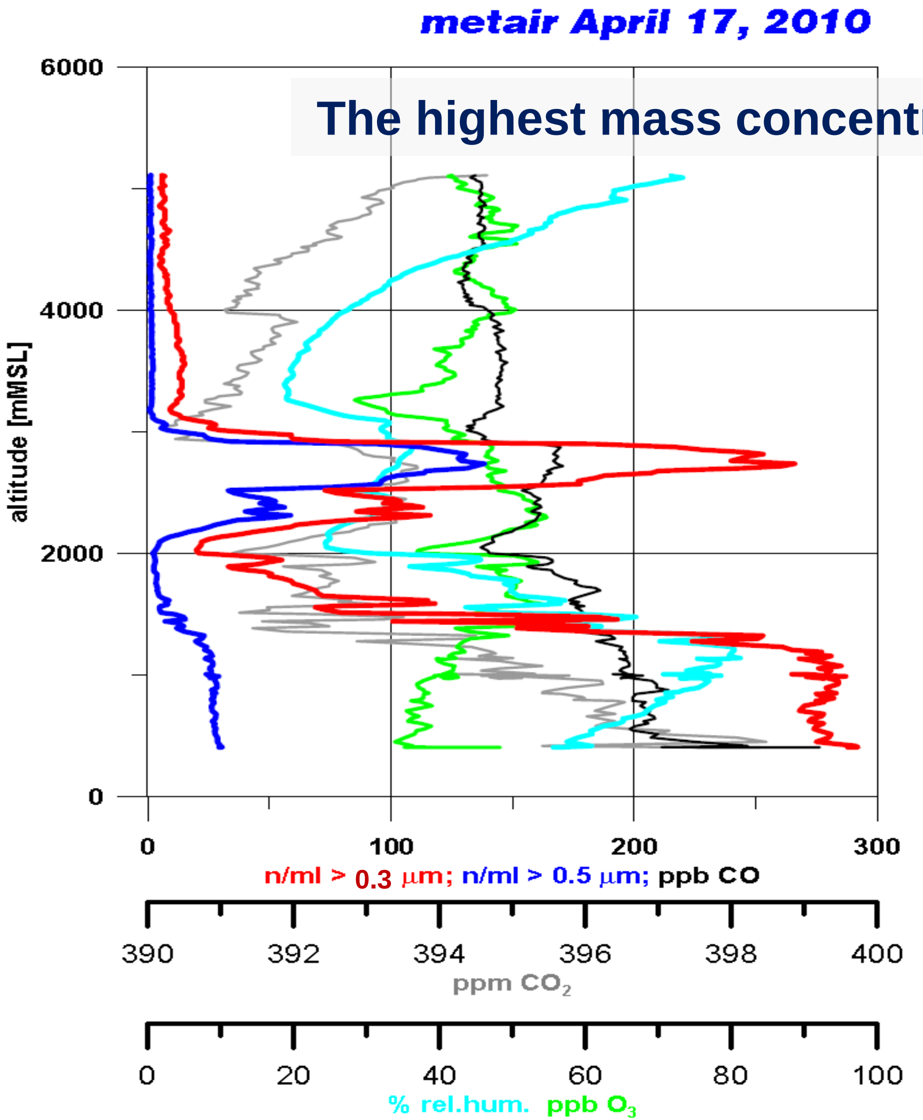
19.4'

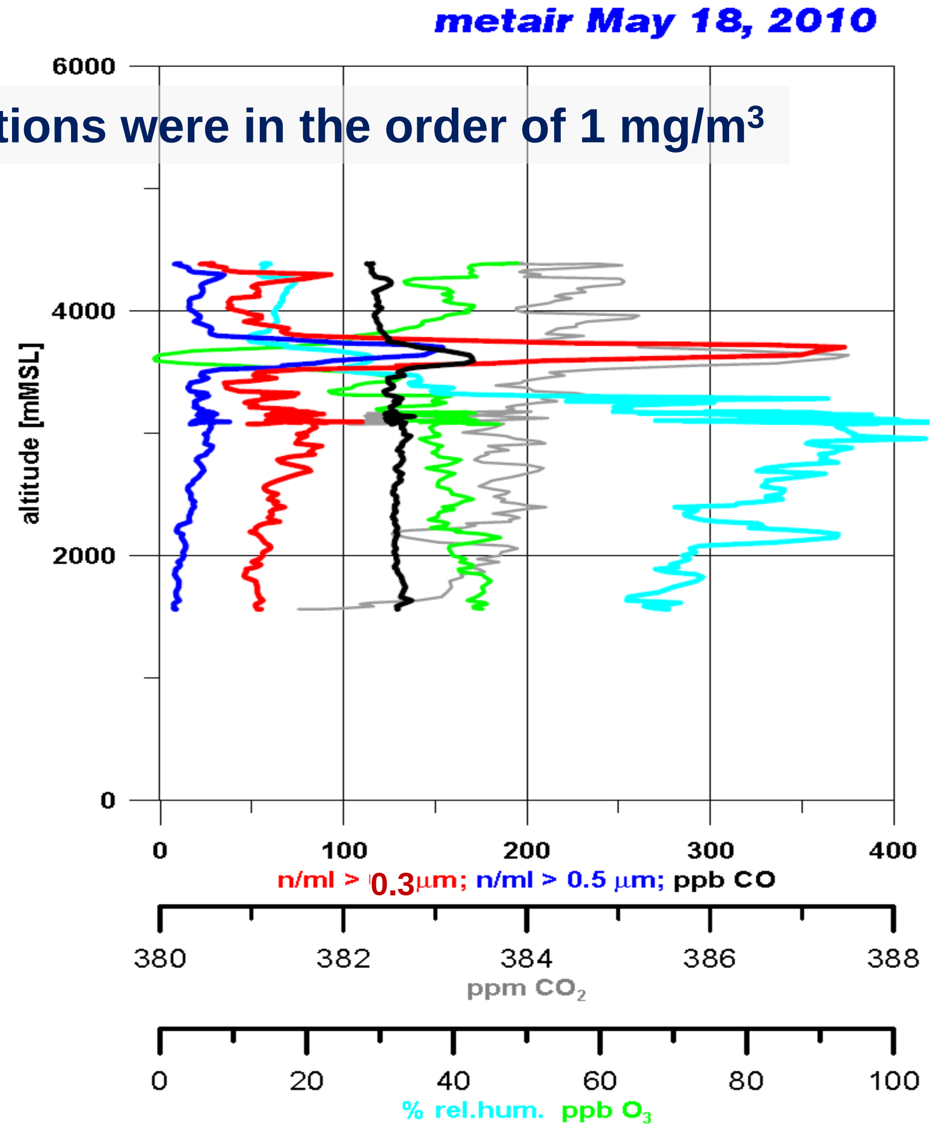
With the data on the display in front of the operator seat
(yellow profile is showing particle number concentration in the haze and in the ash at 2.7 km altitude).
Some flights reached up to 6 km.

MetAir

20'

The highest mass concentrations were in the order of 1 mg/m³

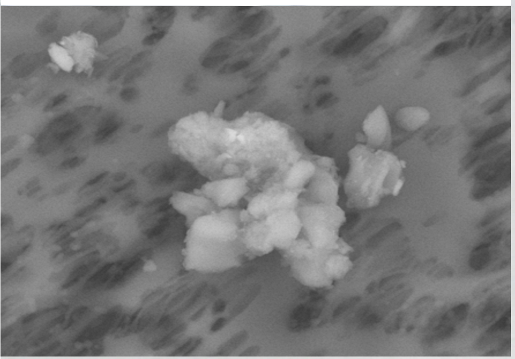




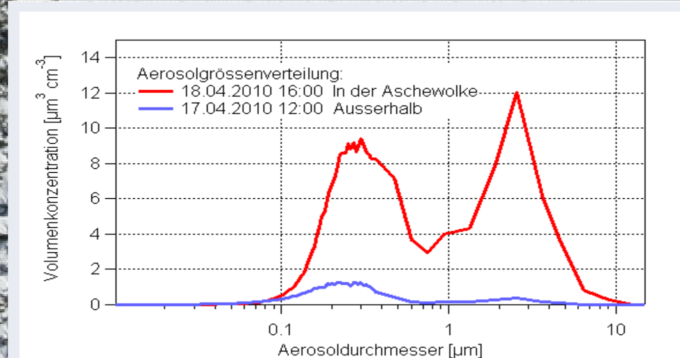
20.7'

Connecting the airborne measurements with the high (3600 mAMSL) Alpine research station on Jungfraujoch where the plume was detected as well, and more detailed analyses were made (full size spectrum, identification of particles)

PAUL SCHERRER INSTITUT PSI



21.3'

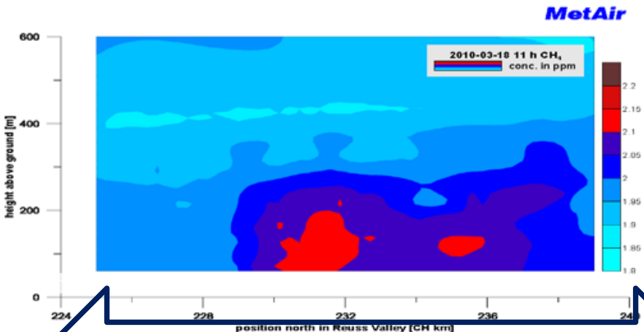


Die Grössenverteilung der Vulkanasche auf dem Jungfraujoch, im Vergleich zum Hintergrundsaerosol am Tag vorher.

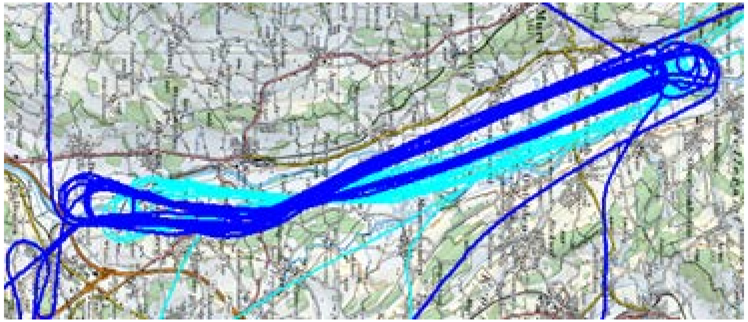
From the abstract: Another strong application with relevance for society is estimating the emissions of Green House Gases (GHG) from individual sources, or regions.

MetAir

You have already seen the example of measuring the emission of CH_4 from a feedlot in Australia. Here we measured the more diffuse CH_4 emissions from fertilized acres (cross section and map) and a wetland (map only). This was the project, where on the surface, CH_4 was also measured by bycicle.

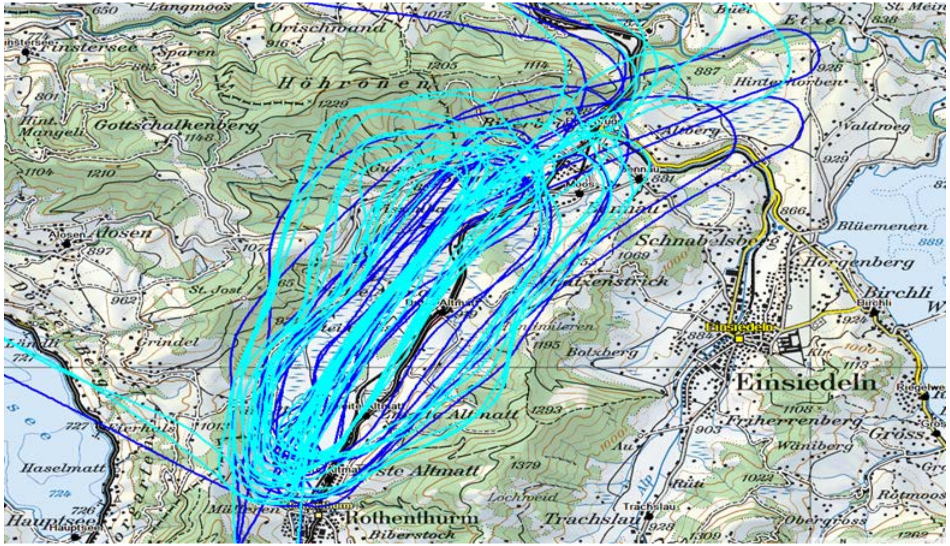


about 20 km



ETH zürich

Department of Environmental Systems Science



... or anthropogenic CO_2 from power plants ...

MetAir

C-MapExp (2012 with ESA / Uni Bremen / FU Berlin):

http://blogs.esa.int/campaignearth/2012/08/21/nothing-but-blue-skies/

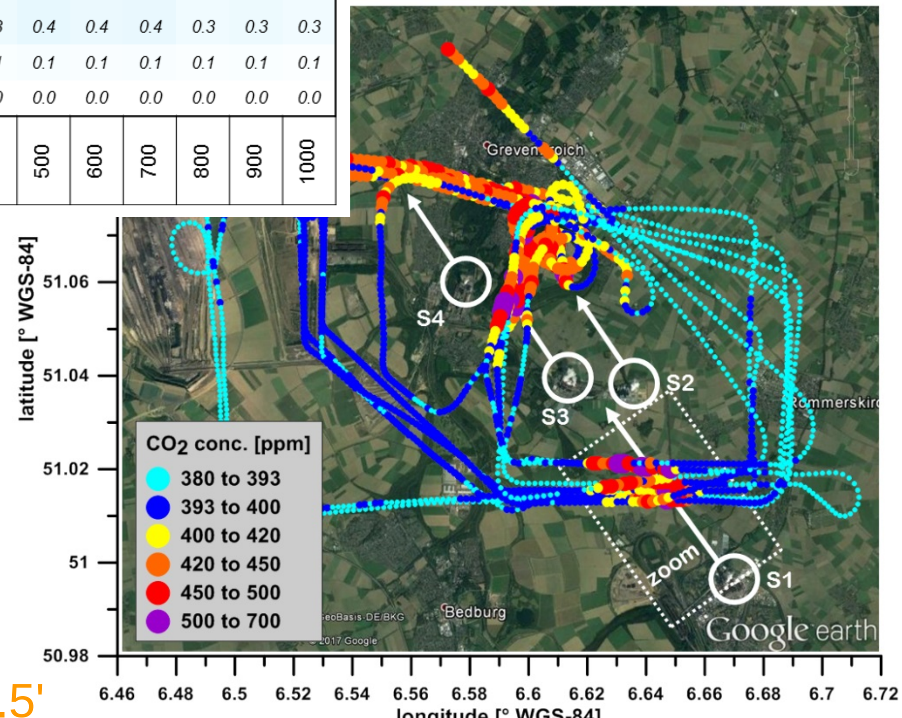
http://blogs.esa.int/campaignearth/2012/08/22/reflecting-on-the-c-mapexp-campaign/

an open publication is in revision: https://www.atmos-meas-tech-discuss.net/amt-2016-362/

MetAir with Uni Bremen FU Berlin under contract of ESA

z [mAMSL]	Niederaussem: direct CO_2 flux [kg/s] above background in the grid cells (sums and linear interpolations & extrapolations)																					
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	3.4	3.2	5.7	7.1	6.6	0.6	0.1	0.1	0.1
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.6**	**3.9**	**6.8**	**6.5**	**11.4**	**14.2**	**13.1**	**1.2**	**0.3**	**0.3**	**0.1**
1000	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.5**	**4.7**	**3.8**	**5.3**	**3.9**	**0.5**	**4.0**	**11.3**	**9.7**	**2.9**	**2.4**	**0.1**	**0.0**	**0.0**	**0.0**
900	0.3	0.1	2.0	**0.3**	**0.3**	**5.0**	**3.6**	**1.3**	**6.3**	**11.2**	**15.9**	**15.4**	**5.1**	**0.1**	**0.0**	7.8	5.8	1.5	1.2	0.1	0.0	0.0	0.0
800	**0.6**	**0.2**	**4.1**	**10.2**	**9.4**	**7.2**	**5.0**	**4.6**	**19.2**	**5.6**	**7.7**	**2.0**	**1.2**	**8.1**	**9.8**	**4.3**	**1.8**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
700	0.5	0.4	2.4	5.4	4.9	4.2	3.6	3.3	10.6	5.5	9.5	0.3	**6.4**	**16.1**	**7.7**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**	**0.1**	**0.1**
600	**0.4**	**0.6**	**0.8**	**0.5**	**0.3**	**1.2**	**2.2**	**2.0**	**2.1**	**5.4**	**11.3**	**5.2**	**8.9**	**23.7**	**14.0**	**7.7**	**1.3**	**7.0**	**26.5**	**3.0**	**1.1**	**0.1**	**0.2**
500	**0.5**	**0.2**	**0.5**	**1.0**	**0.9**	**1.8**	**0.9**	**2.6**	**8.4**	**9.7**	**8.2**	**7.9**	**1.4**	**7.7**	**5.8**	**2.8**	**0.9**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**
400	**1.0**	**0.7**	**0.6**	**1.0**	**5.8**	**4.8**	**2.5**	**0.8**	**1.3**	**1.0**	**1.9**	**2.6**	**1.7**	**3.0**	**18.6**	**31.3**	**18.3**	**16.5**	**11.2**	**6.2**	**0.8**	**1.5**	**0.3**
300	**0.5**	**1.1**	**1.3**	**1.0**	**0.3**	**0.4**	**1.3**	**1.0**	**3.0**	**7.2**	**12.5**	0.0	0.0	0.0	**1.6**	**0.7**	**0.3**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.3**
200	0.5	1.1	1.3	1.0	0.3	0.4	1.3	1.0	3.0	7.2	12.5	0.0	0.0	0.0	1.6	0.7	0.3	0.4	0.4	0.4	0.3	0.3	0.3
100	0.2	0.5	0.5	0.4	0.1	0.1	0.4	0.3	0.9	2.2	4.1	0.0	0.0	0.0	0.5	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
x [m] >	-1200	-1100	-1000	-900	-800	-700	-600	-500	-400	-300	-200	-100	0	100	200	300	400	500	600	700	800	900	1000

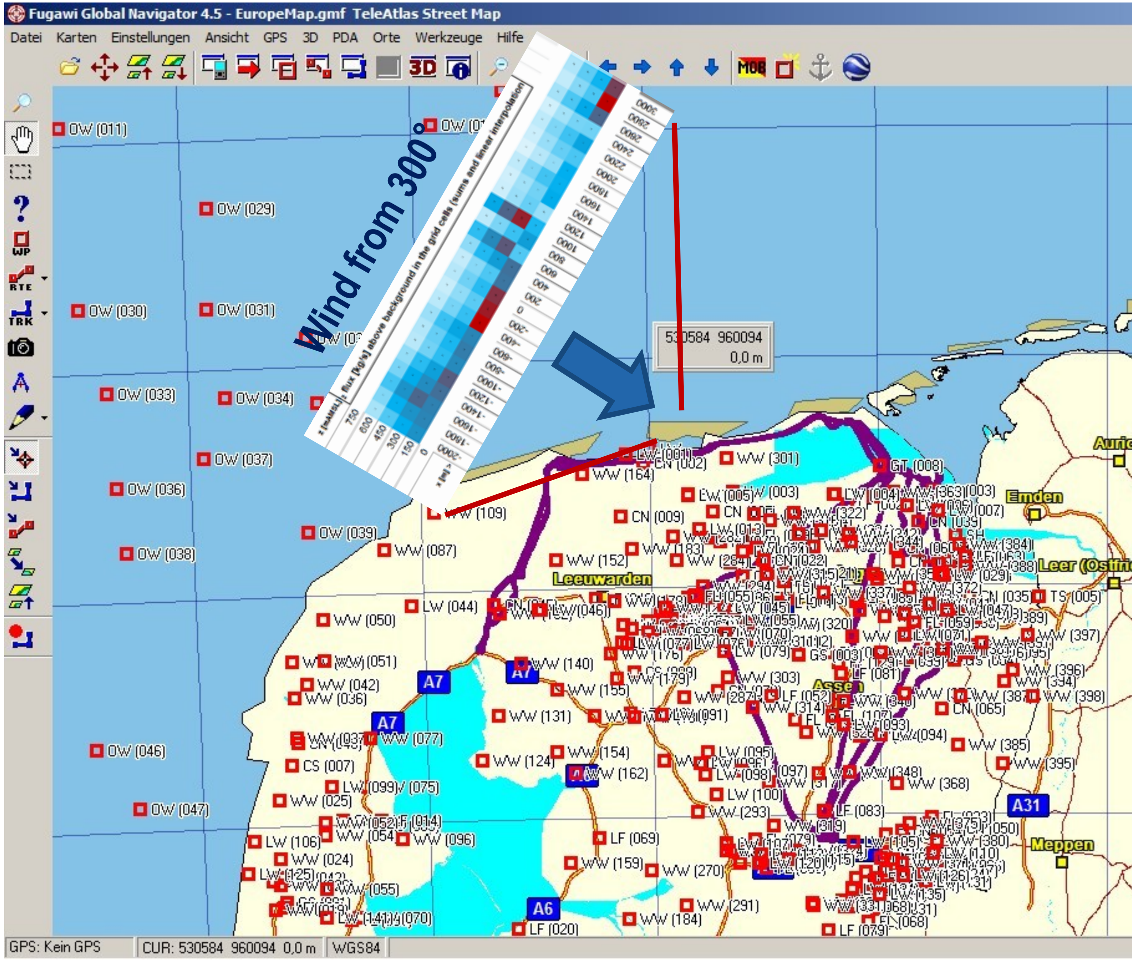
The complex situation with four major sources, and the calculated fluxes through the cross section in the South-East, for the source "Niederaussem". The numbers in the boxes are mass fluxes of CO_2 in kg/s;
bold for boxes with measurements (85 %),
the remaining 15 % are inter- and extrapolated.



23.5'

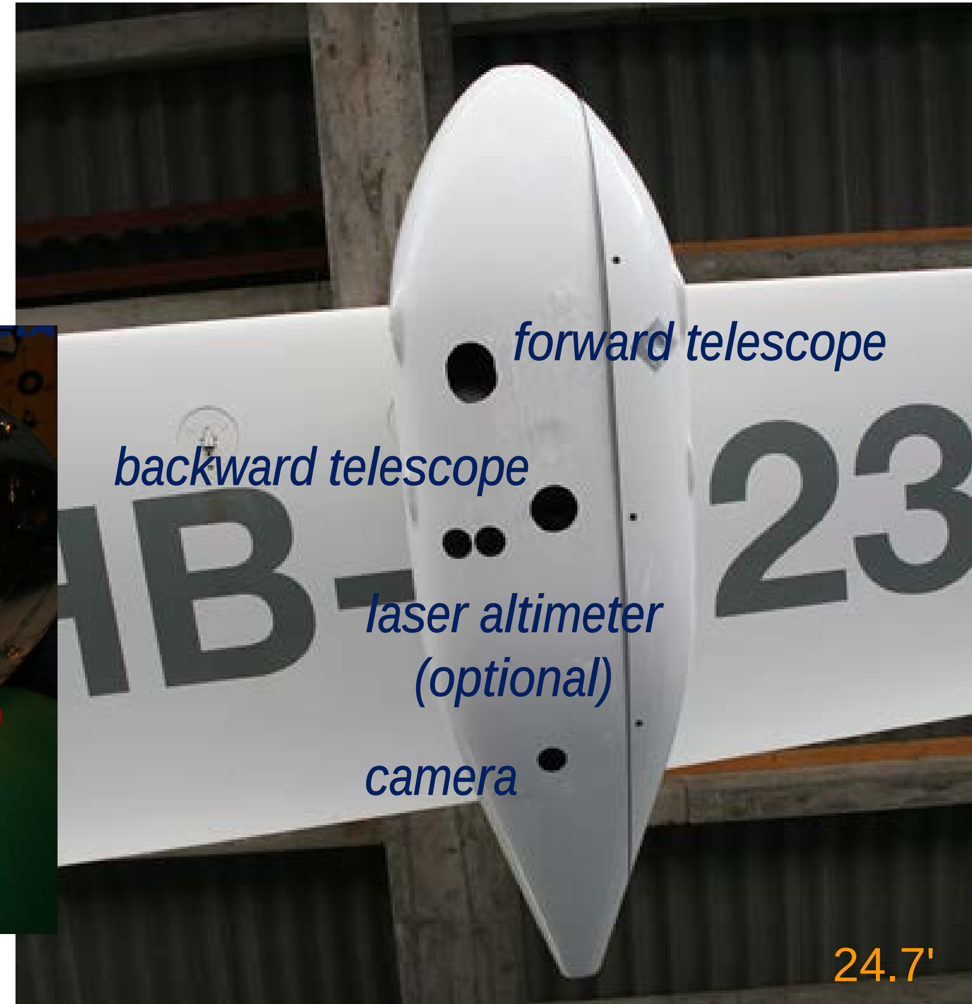
A similar project about CH_4 from the Groningen Gas Field followed in August 2016 (including an off-shore plume)

MetAir



24'

From the abstract: Finally, a new application realized with the small research aircraft METAIR-DIMO will be presented: An airborne wind LIDAR able to measure wind and turbulence (50 Hz) 50 m below the aircraft.



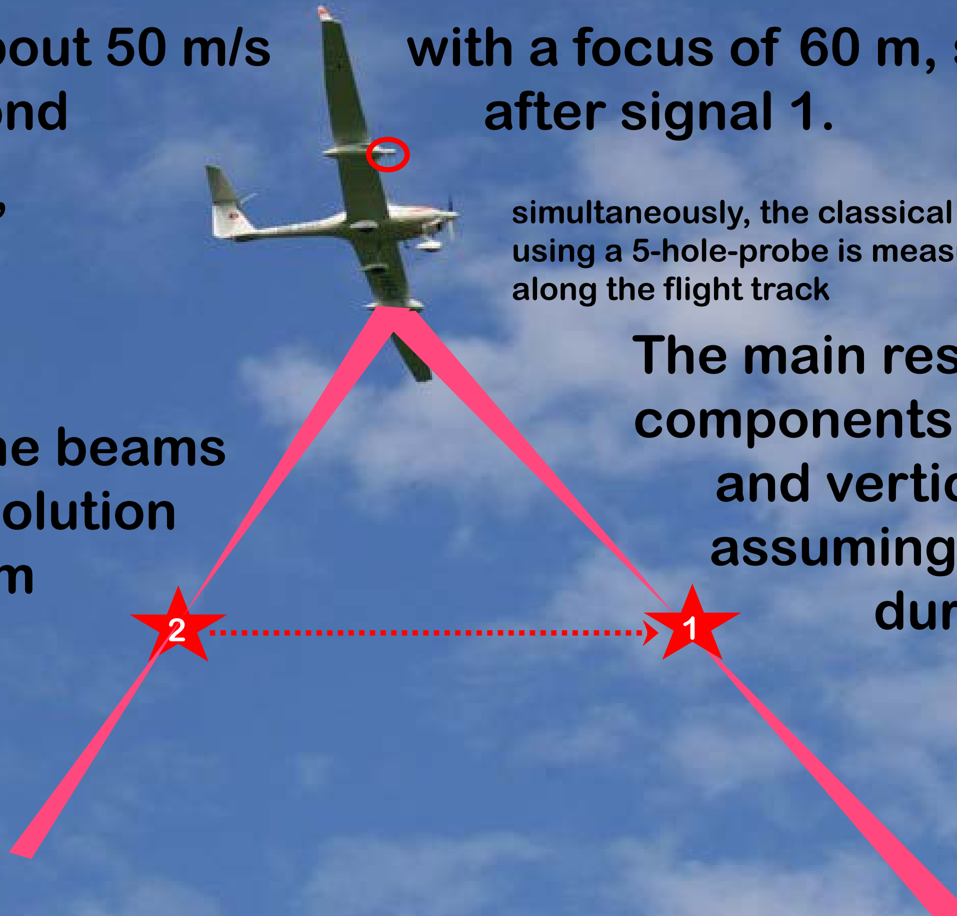
24.7'

The basic principle:

The CW LIDAR is detecting the Doppler shifts from aerosols in the foci of the two beams, delivering radial speeds in a known distance (adjustable between 5 and 90 m).

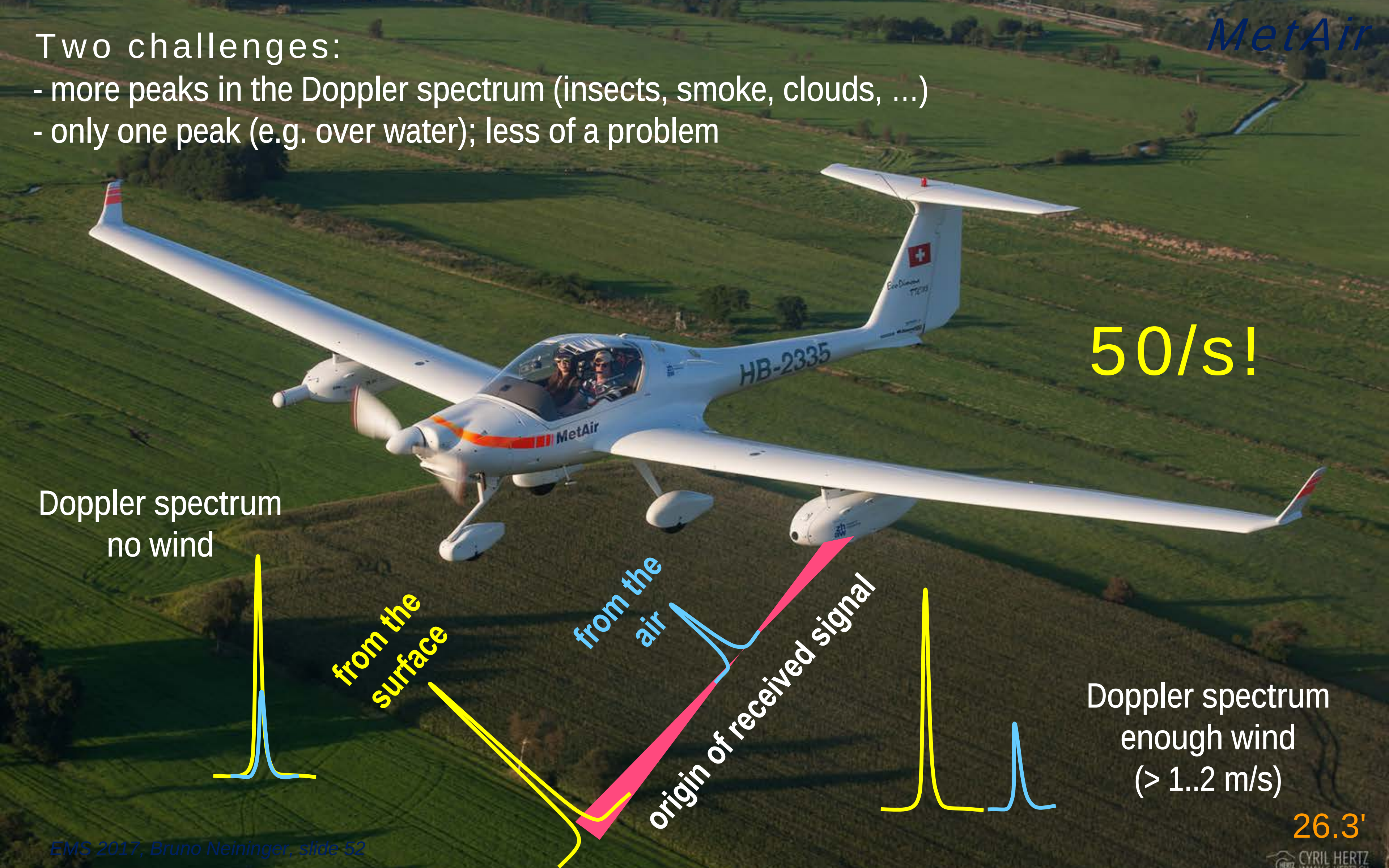
When flying with about 50 m/s with a focus of 60 m, signal 2 will follow about 1 second after signal 1.

During this second, 50 measurements are taken, which allows to analyse turbulence along the beams with a temporal resolution of 50 Hz, about 50 m below the aircraft.

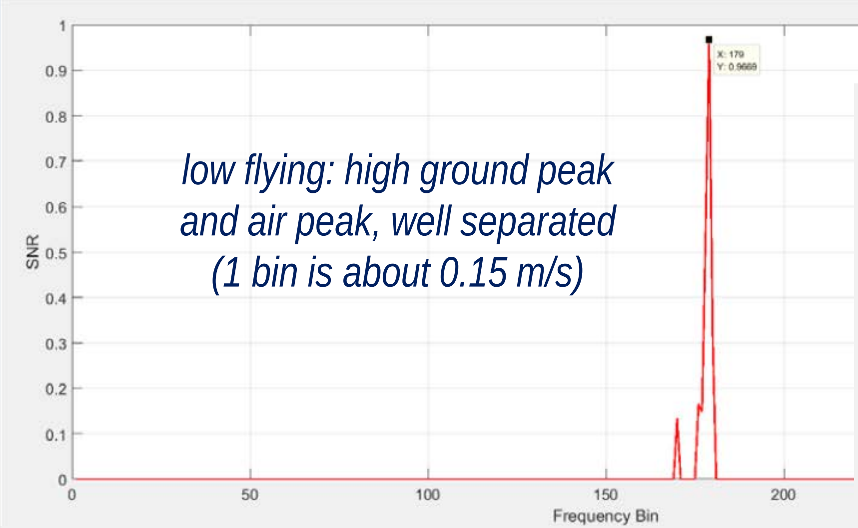


simultaneously, the classical wind sensing system using a 5-hole-probe is measuring the 3-d wind along the flight track

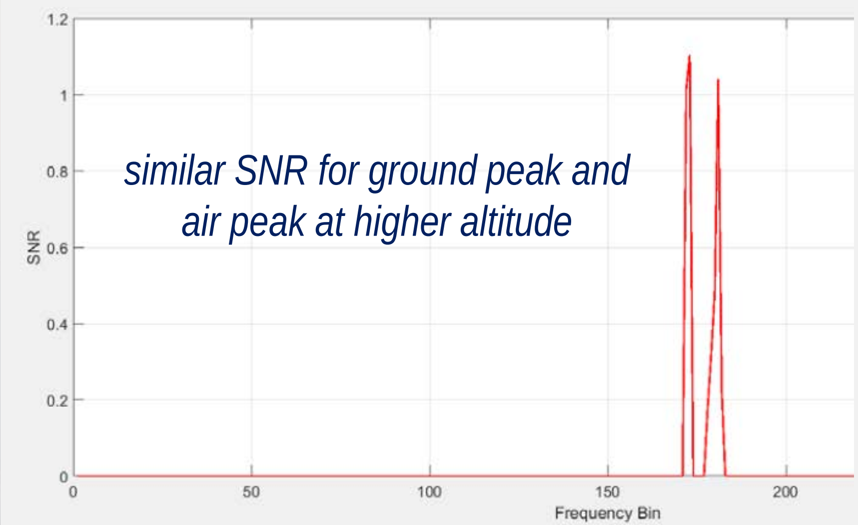
The main result are two wind components (along the flight and vertical) every meter, assuming "frozen eddies" during one second.


MetAir
Two challenges:
- more peaks in the Doppler spectrum (insects, smoke, clouds, ...)
- only one peak (e.g. over water); less of a problem
50/s!
HB-2335
MetAir
Doppler spectrum
no wind
from the surface
from the air
origin of received signal
Doppler spectrum
enough wind
(> 1..2 m/s)
26.3'
CYRIL HERTZ

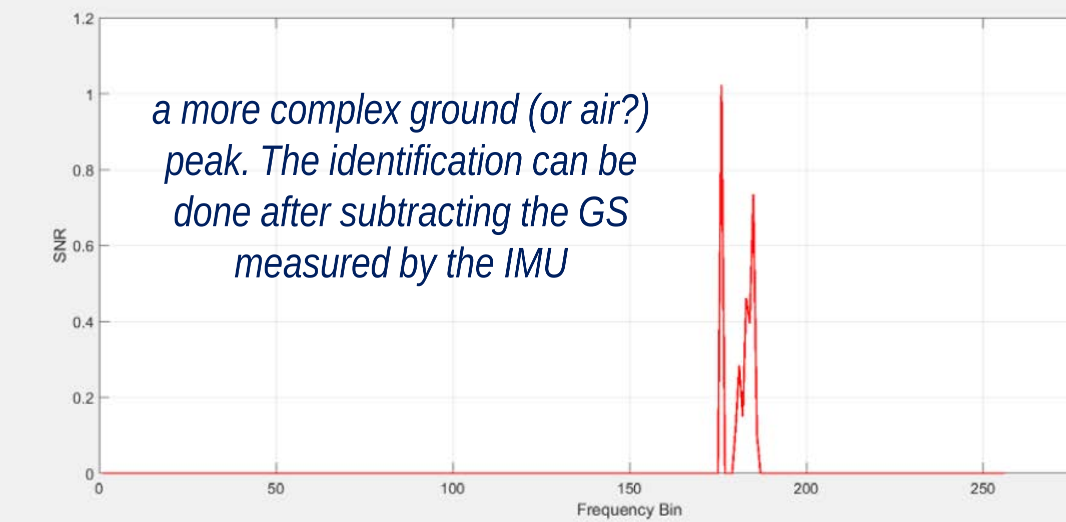
real Doppler spectra



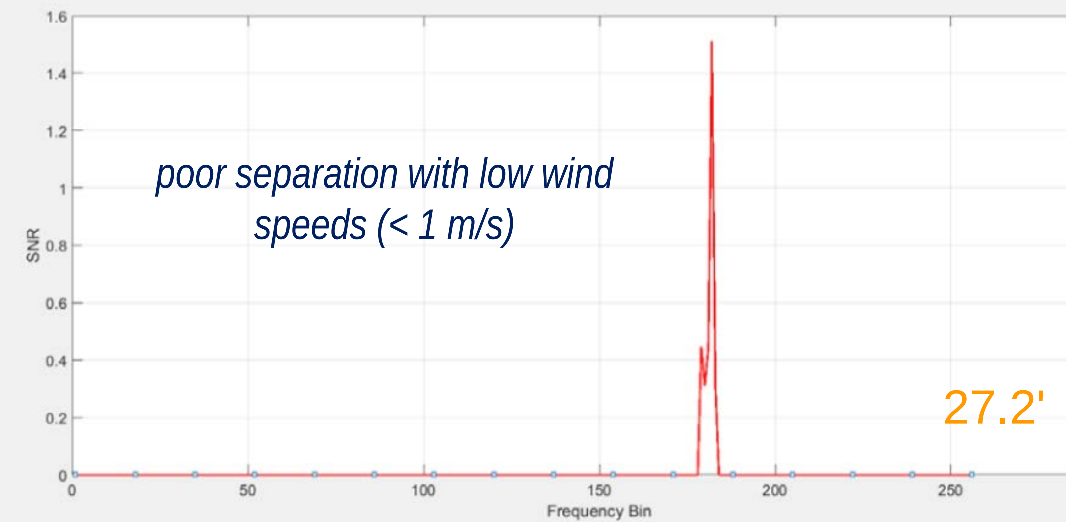
low flying: high ground peak and air peak, well separated (1 bin is about 0.15 m/s)



similar SNR for ground peak and air peak at higher altitude

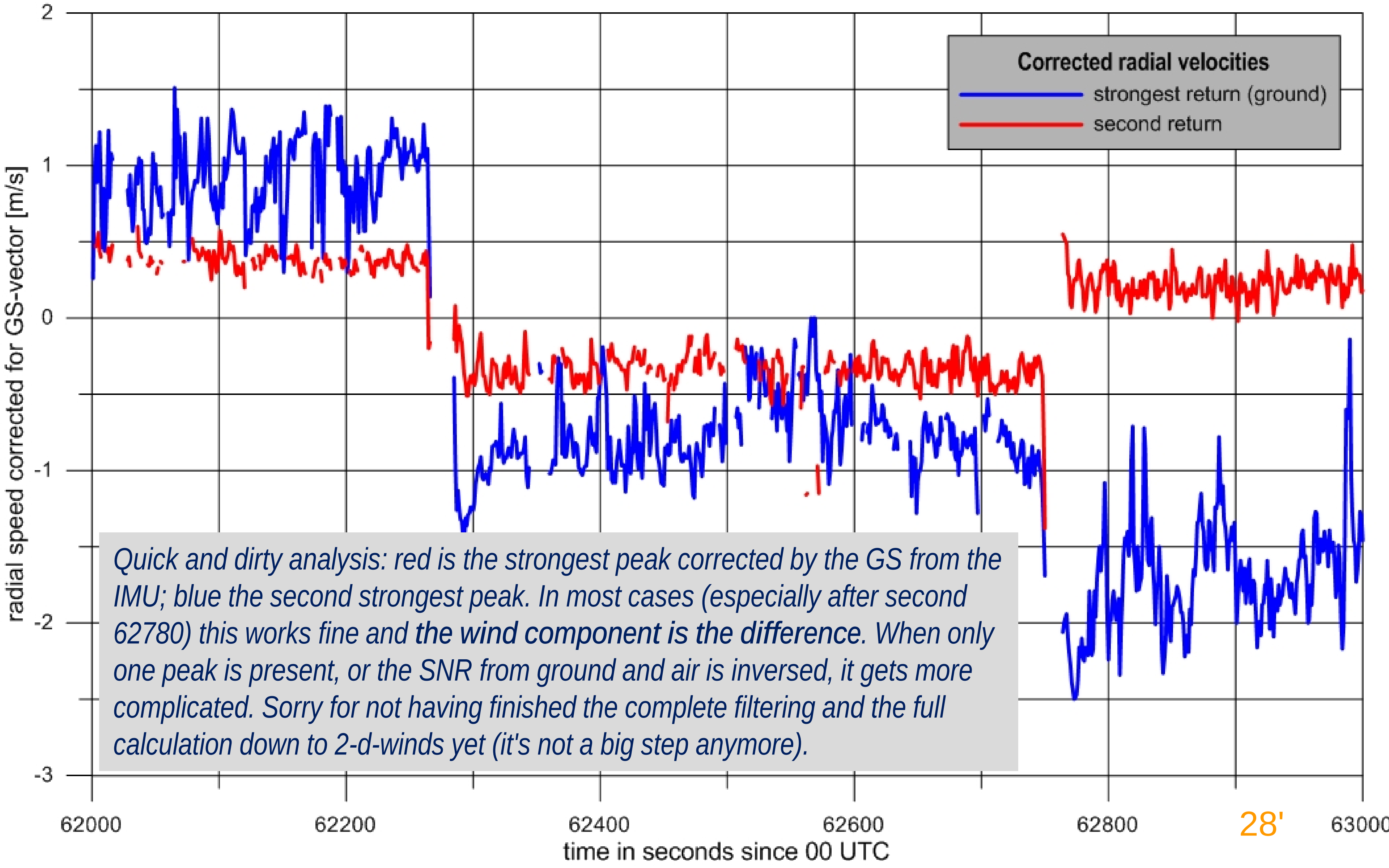


a more complex ground (or air?) peak. The identification can be done after subtracting the GS measured by the IMU



poor separation with low wind speeds (< 1 m/s)

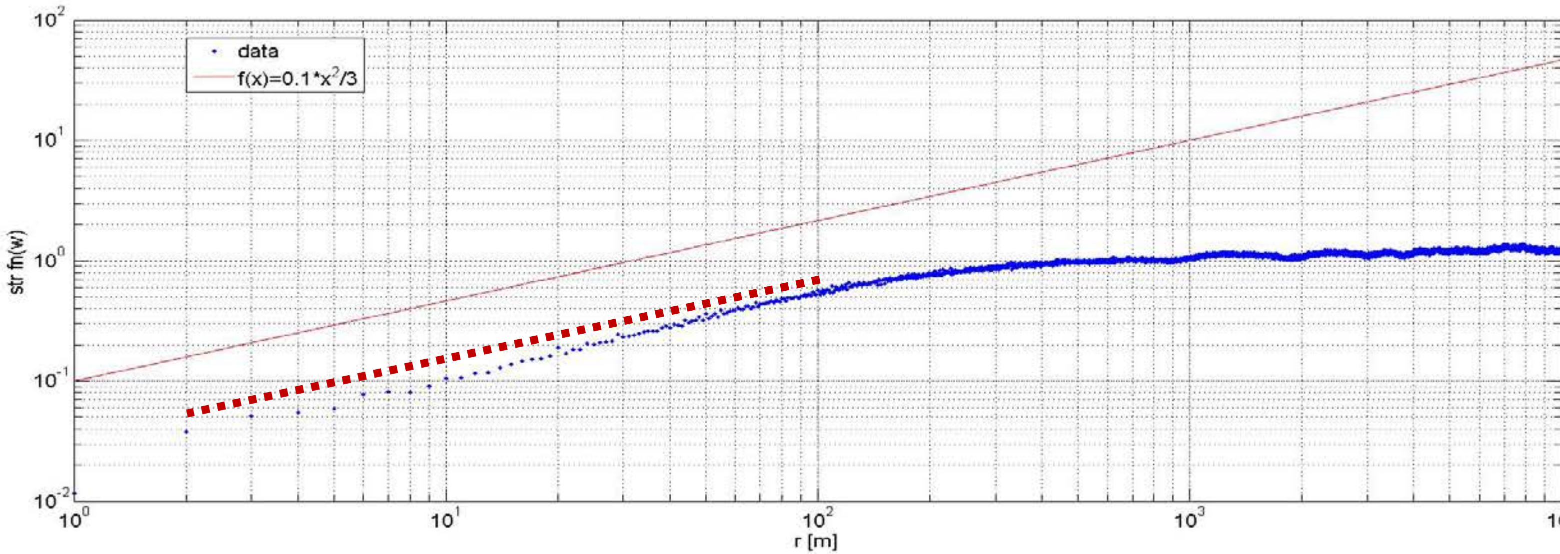
27.2'



*Quick and dirty analysis: red is the strongest peak corrected by the GS from the IMU; blue the second strongest peak. In most cases (especially after second 62780) this works fine and **the wind component is the difference**. When only one peak is present, or the SNR from ground and air is inversed, it gets more complicated. Sorry for not having finished the complete filtering and the full calculation down to 2-d-winds yet (it's not a big step anymore).*

MetAir

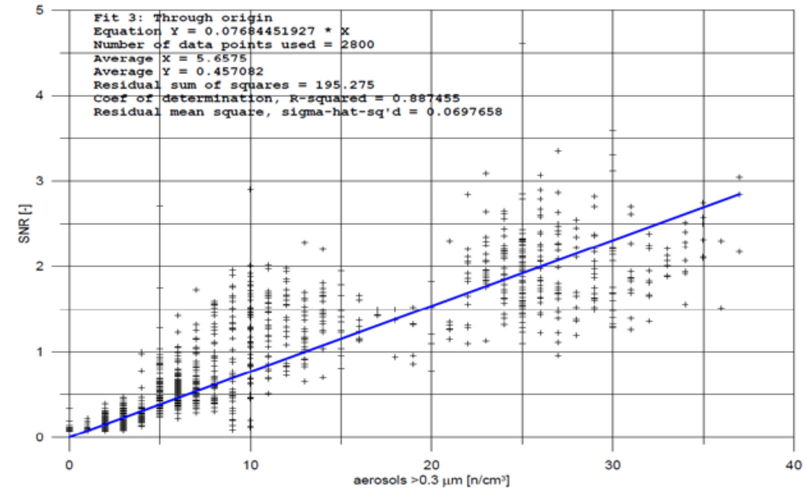
We got very nice spectra of the wind components from earlier tests using the car instead of the aircraft, proofing that there was no noise in the measurements, i.e. the compensation by the IMU is sufficient.
There are more vibrations and shaking in the car than in the DIMO-pod!
The only limitation is the resolution of the Doppler Speeds, which is about 0.15 m/s (bin size of the Fourier Transform). Shown here is the structure function of the vertical wind, with a perfect inertial subrange from about 100 m down to 2 m.

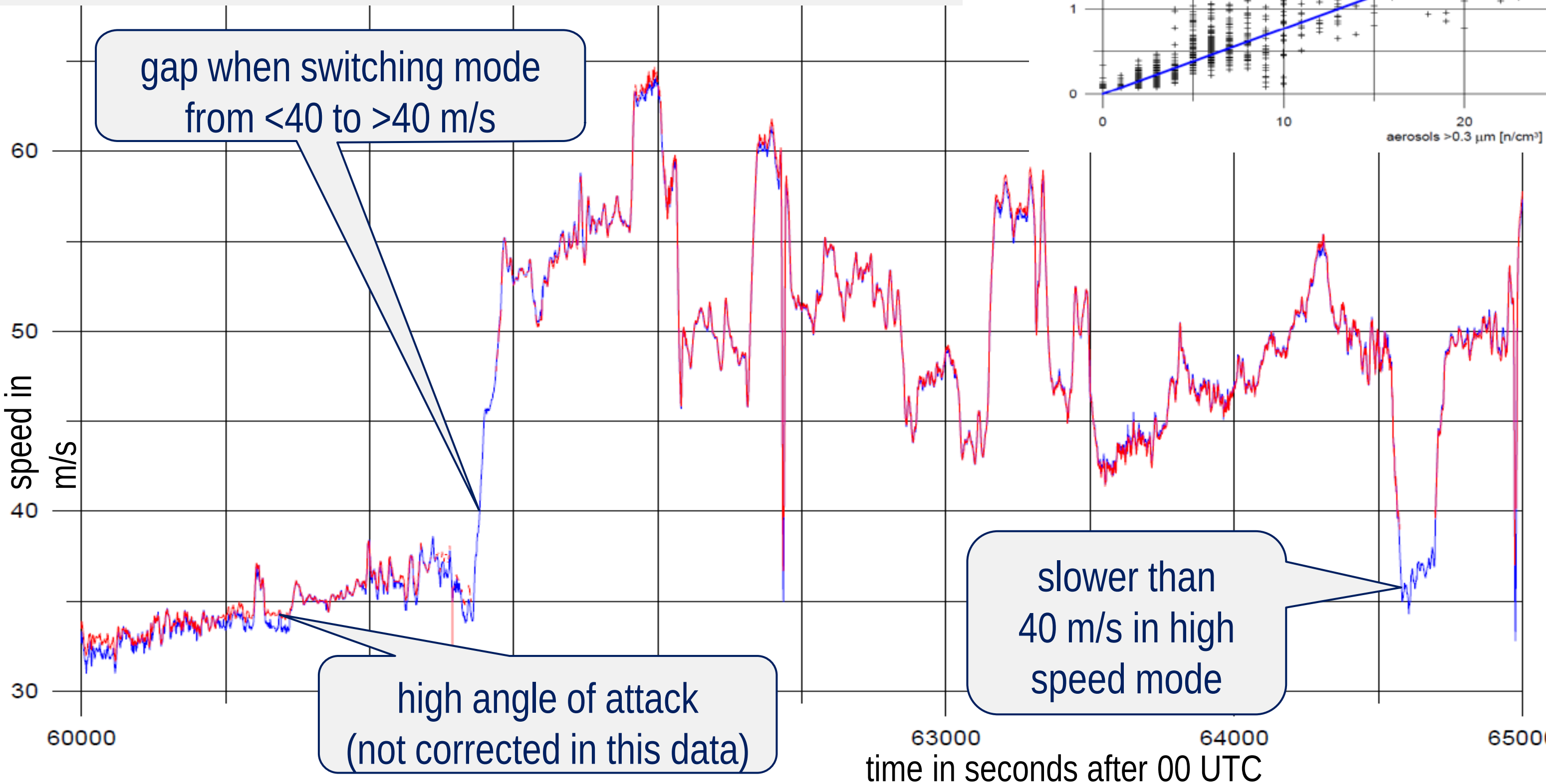


28.7'

Forward looking (60 m) TAS:

bottom: the direct comparison of the forward looking LIDAR radial speed in comparison with the TAS at the 5-hole-probe.
top, right: the correlation between signal/noise (SNR) of the LIDAR and the measured aerosol concentration (particle counter MetOne for particles >0.3 µm)





29.7' (skip when late)

proceed to the end

Finish with a fast series of pictures from 2010, 2013 and 2016
above the North Sea out of Cuxhaven, Germany
Photographer Cyril Hertz, a former student at ZHAW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Thank you!
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