Advanced in-situ Measurements

Ulrich Corsmeier

Institut für Meteorologie und Klimaforschung (IMK)
Forschungszentrum Karlsruhe/Universität Karlsruhe

1st COPS Workshop

September 13 – September 14, 2004

University of Hohenheim

ulrich.corsmeier@imk.fzk.de

A presentation with contributions of:

- ✓ **Christoph Kottmeier,** Forschungszentrum/Universität Karlsruhe
- ✓ **Andreas Wieser,** Forschungszentrum/Universität Karlsruhe
- ✓ **Peter Vörsmann,** University of Braunschweig
- ✓ **Jens Bange,** University of Braunschweig
- ✓ **Andreas Wahner,** Forschungszentrum Jülich
- ✓ **Andreas Hofzumahaus,** Forschungszentrum Jülich

PIs of the measurement systems shown.

ulrich.corsmeier@imk.fzk.de

In-situ measurement systems available or under development for COPS

ulrich.corsmeier@imk.fzk.de

In-situ Equipment at IMK for Field Research

- ✓ **research aircraft DO 128 (meteorological and chemical parameters)**
- ✓ **drop-sondes (30 pieces per mission)**
- ✓ **drop-up-sondes (30 pieces per mission)**
- ✓ **radiosonde stations (2, mobile)**
- ✓ **tethered balloons (2, mobile but tethered)**
- ✓ **energy balance stations (several)**
- ✓ **meteorological surface stations (several)**

ulrich.corsmeier@imk.fzk.de

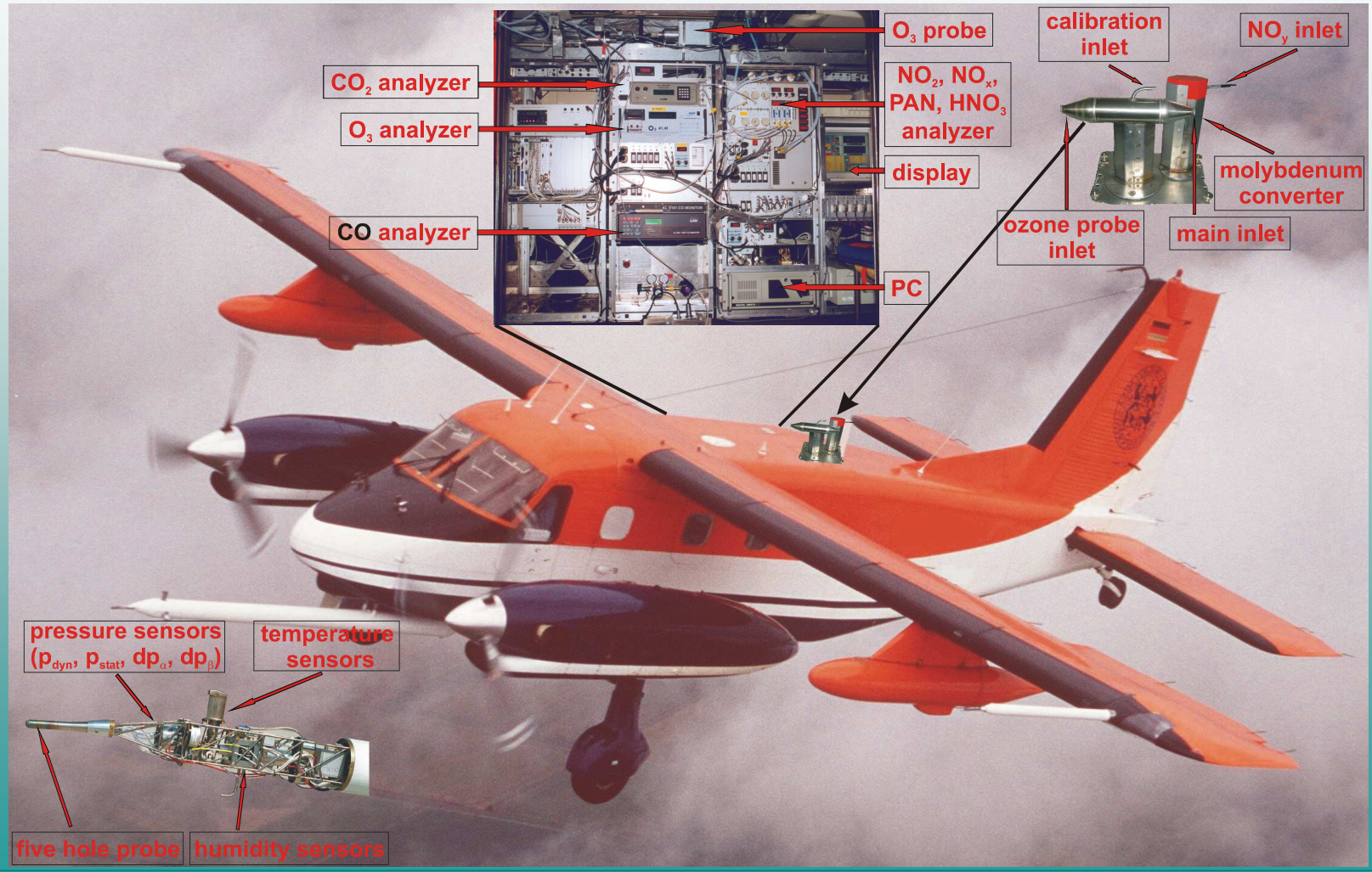
The DO 128 research aircraft

- **The DO 128 measures meteorological parameters (wind speed, temperature, humidity, solar and infrared radiation), surface temperature and turbulent fluxes with high resolution down to 100 ft. Additionally, dropsondes are available over land surfaces.**
- **Maximum altitude: 7000 m**
- **Endurance: 4 h.**
- **Research flight speed: 65 m s^{-1}.**
- **Flight range: 1000 km.**
- **Sampling rate: 100 Hz.**

CORSMEIER, U.; HANKERS, R.; WIESER, A.
Airborne turbulence measurements in the lower troposphere onboard the research aircraft Dornier 128-6, D-IBUF.
Meteorologische Zeitschrift, 10(2001) S.315-29.

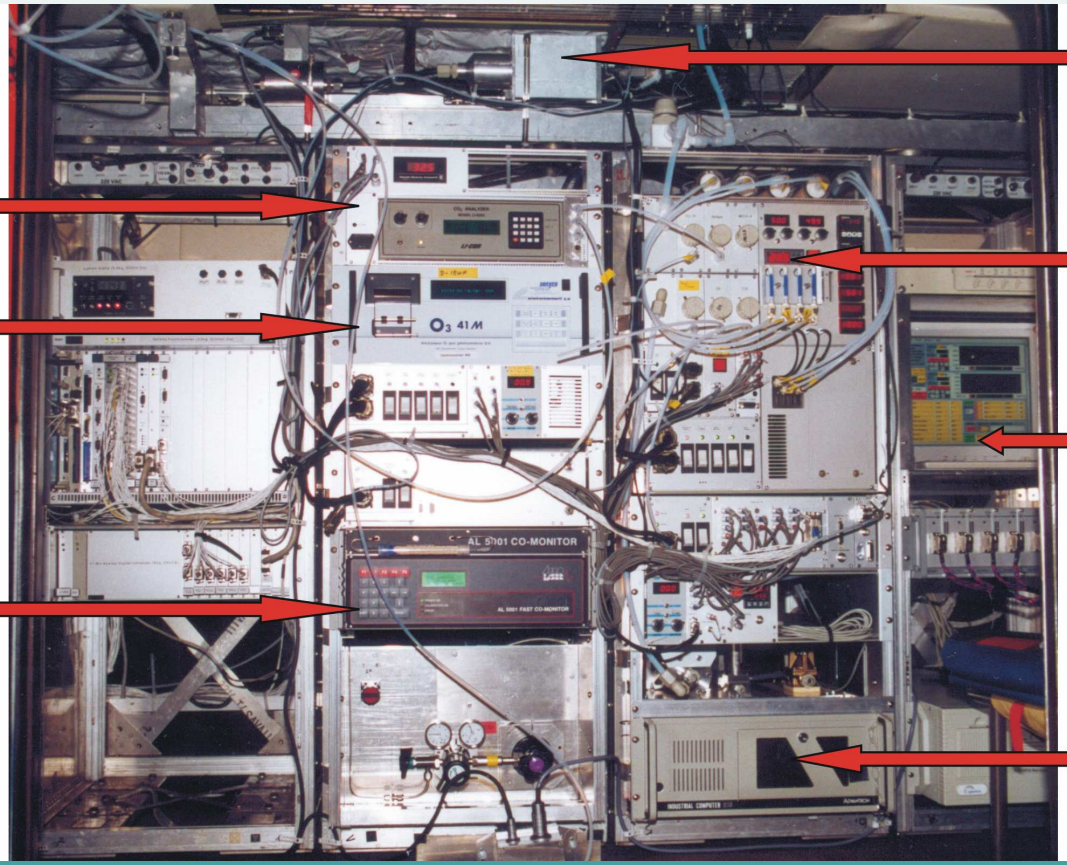
ulrich.corsmeier@imk.fzk.de

Equipment



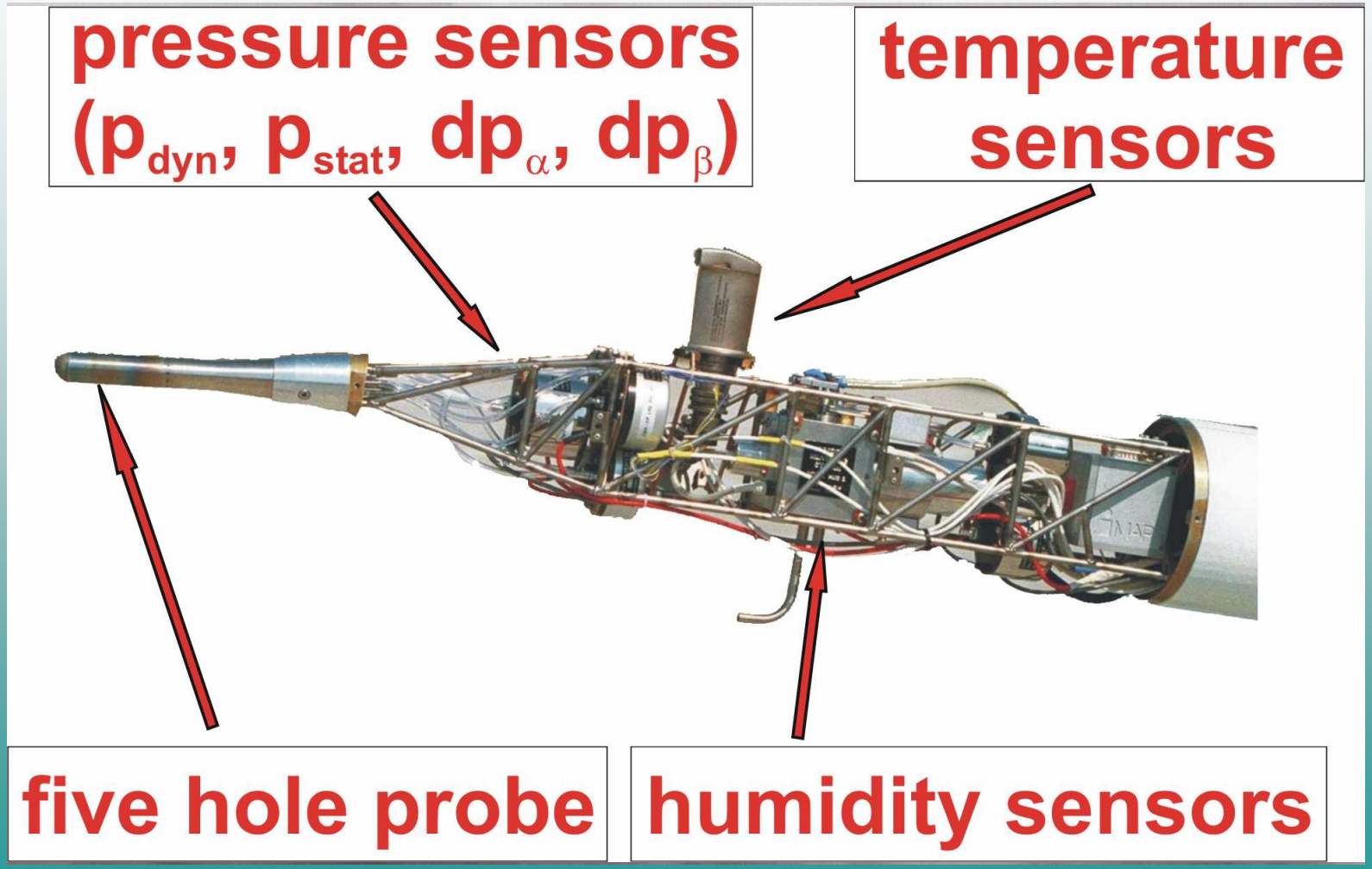
ulrich.corsmeier@imk.fzk.de

Equipment



ulrich.corsmeier@imk.fzk.de

Equipment



ulrich.corsmeier@imk.fzk.de

System Properties

Parameter	Accuracy	Delay time	Recovery time	Sampling freq.
u, v, w	0.3, 0.3, 0.15 m s^{-1}	< 0.01 s	< 0.01 s	20 Hz
T	0.4 ℃	< 0.11 s	< 0.01 s	20 Hz
O_3	3.4 %	0.16 s	0.05 s / 0.05 s ****	20 Hz
NO_2	8.8 % / 8.7 % *	2.72 s	0.28 s / 0.29 s ****	7 Hz
NO_x	11.6 % / 10.0 % *	2.75 s	0.21 s / 0.55 s ****	5 Hz
NO_x + PAN	12.5 % / 12.6 % *	4.57 s	0.20 s / 0.74 s ****	5 Hz
NO_y	n /a	4.24 s	0.41 s / 0.88 s ****	1 Hz
CO	7.8 % **	n/a	n/a	< 0.2 Hz
CO_2	2.5 % ***	0.77 s	0.30 s / .030 s ****	2 Hz

* 2 / 12 ppb; ** 170 ppb; *** 386 ppb ; **** Anstieg / Abfall

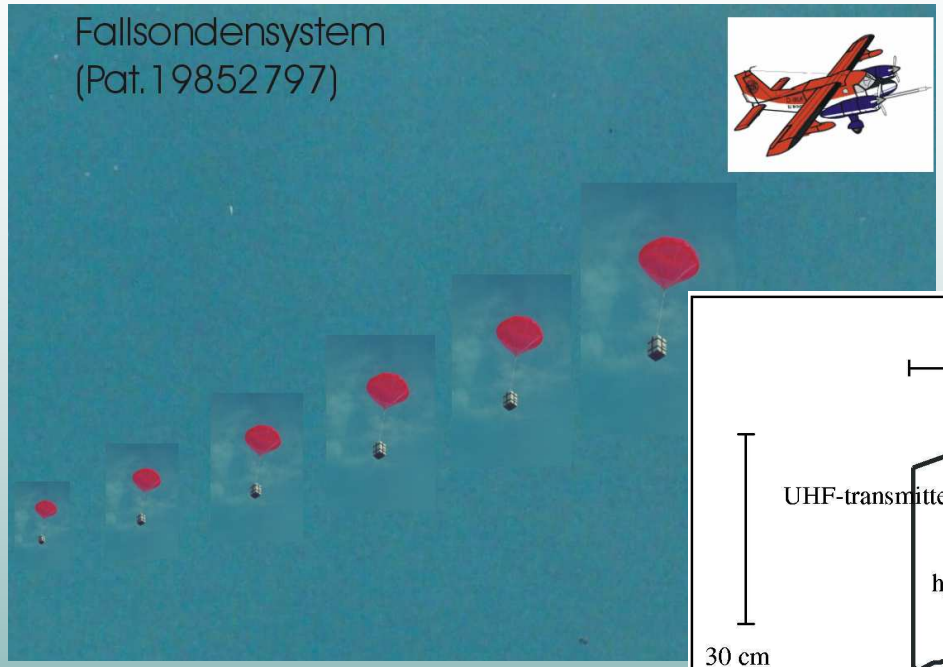
ulrich.corsmeier@imk.fzk.de

The Dornier 128 and its Standard Research Equipment

No. (Fig.)	Parameter	Probe, Sensor, Equipment	Unit	Explanations
1	Static, dynamic and differential pressure	Rosemount 5-Hole Probe	hPa	
2	Static, dynamic and differential pressure	Rosemount 1221, 1201 Pressure Transducers	hPa	
5	Position and speed	Novatel Differential GPS-Receiver	Degrees, mph	
6	Height	Optech 501 Laser Altimeter	m	
7	Pitch, bank, yaw, angular velocities, acceleration, INS-position, ground speed	Honeywell Lasernav	Degrees, mph, ms^{-2},	
8	Radar height	Sperry Radar Altimeter	m	
9	Data acquisition and processing computer	VME-Bus Computer		
15	Surface temperature of the earth	KT19 sensor	° C	Scanning device
19		Air inlet for trace gas measurements		replaceable
21	GPS signals	GPS-Antenna	Degrees, time	
22	Humidity of air (fast sensor)	Lyman-Alpha Sensor	Mixing ratio	
23	Temperature of air	Slow Rosemount Temperature Sensor PT 100	° C	
24	Temperature of air	Open wire Rosemount Temperature Sensor Pt 100	° C	
25	Humidity of air	Aerodata-Humicap	% rel. humidity	
26	Humidity of air	Meteolabor Dew Point Mirror TP 3	° C dewpoint	
1, 2, 9	Wind (horizontal)	5-hole-probe; GPS	ms^{-1}	
1, 2, 9	Wind (vertical)	5-hole-probe	ms^{-1}	
1, 2, 9	Turbulence	As “wind”, 100 Hz sampling		
19, 15	Radiation	Kipp & Zonen Pyranometer CM 22	Wm^{-2}	up and down
19, 15	Radiation	Kipp & Zonen Pyrgeometer CG 4	Wm^{-2}	up and down
11	O_3	Environment O_3 41M (UV-Absorption)	ppb	mean value
11	O_3	Fast ozone sensor (Chemiluminescence)	ppb	fluctuations
11	NO	NO_xTO_y with CrO3 (Luminol-Chemilum.)	ppb	
11	NO_2	NO_xTO_y (Luminol-Chemilum.)	ppb	
11	NO_y	NO_xTO_y Mo/CrO3 at heated intake (Luminol-Chemilum.)	ppb	
11	PAN	NO_xTO_y (CrO3/heat) (Luminol-Chemilum.)	ppb	
11	CO	AL 5001 (Resonance fluorescence)	ppb	
11	CO_2	LI-COR 6252 (IR-Absorption)	ppm	

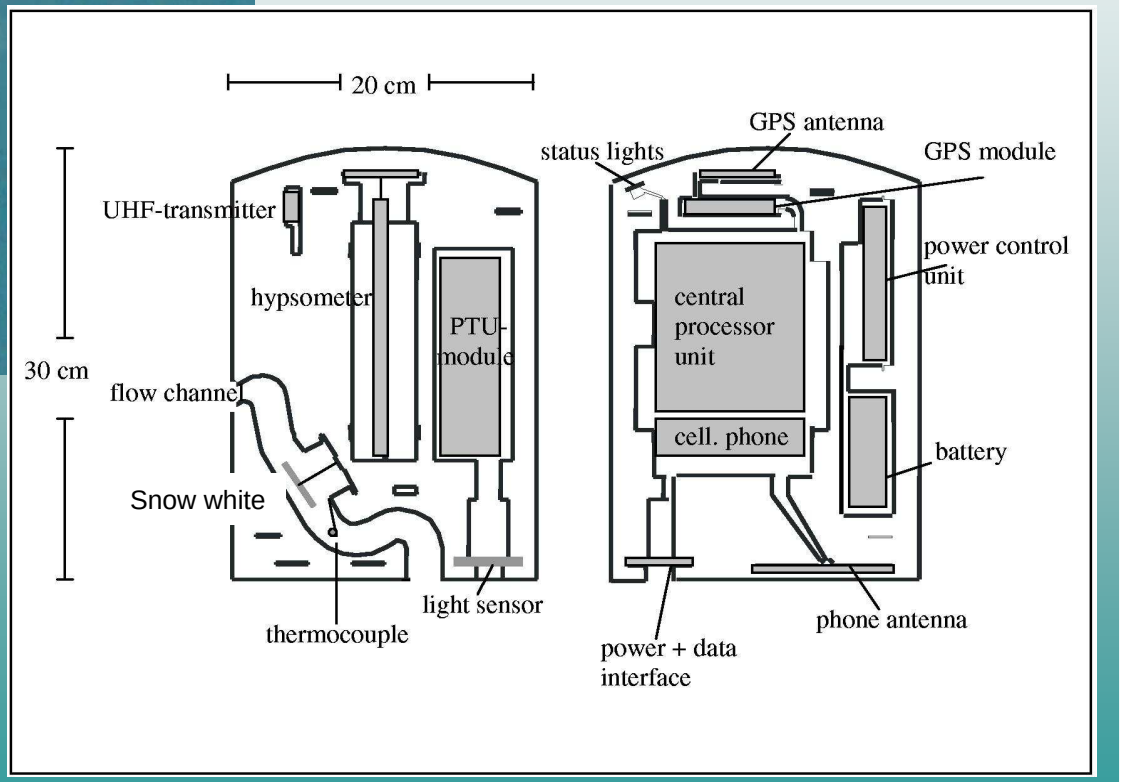
ulrich.corsmeier@imk.fzk.de

Forschungszentrum Karlsruhe /Universität Karlsruhe
Institut für Meteorologie und Klimaforschung



The IMK-dropsonde

Dropping 30 sondes within 15 minutes



Additional features:

- **light sensor**
- **particle/droplet counter (under development)**

KOTTMEIER, C.; REETZ, T.; RUPPERT, P.; KALTHOFF, N.:
A new aerological sonde for dense meteorological soundings.
Journal of Atmospheric and Oceanic Technology, 18(2001) S.1495-1502

ulrich.corsmeier@imk.fzk.de

Flexible launching strategy:

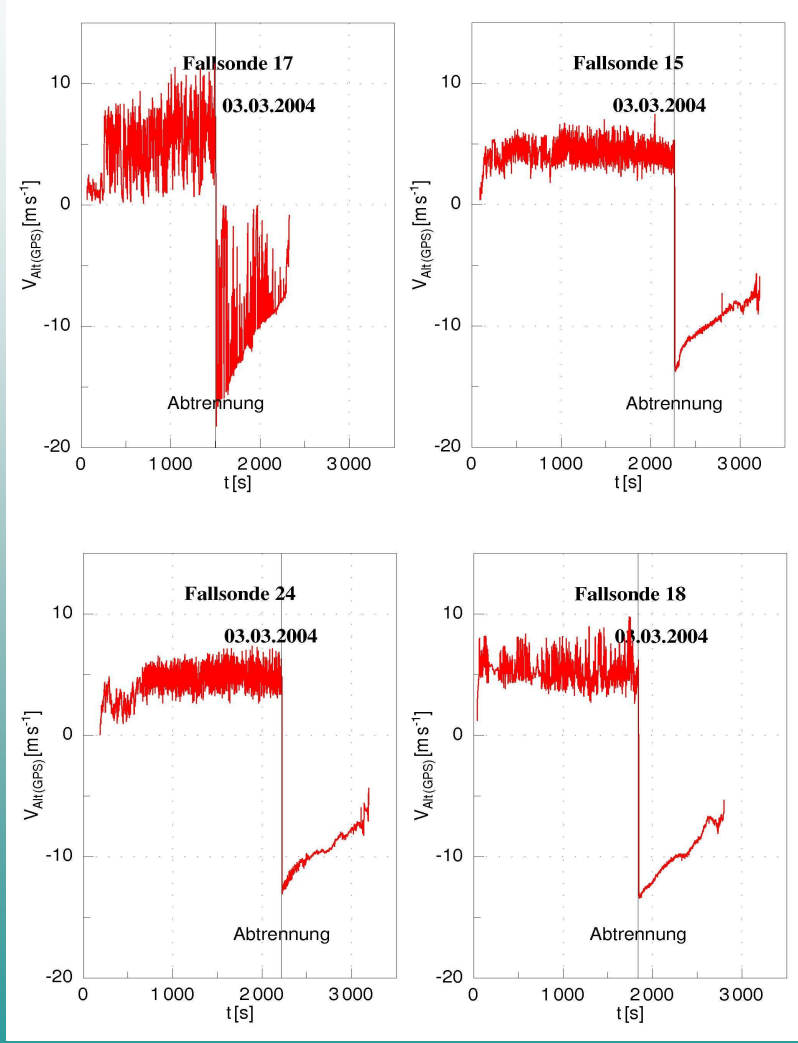
Selecting sites depending on convection development.

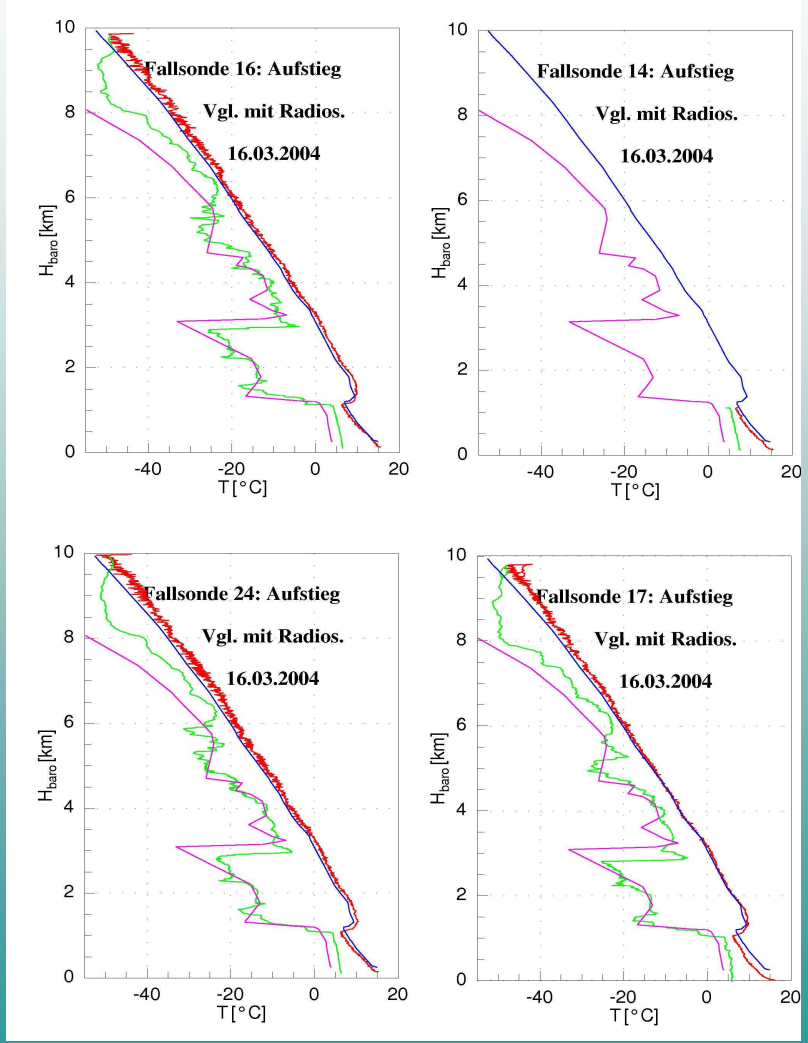
Launching of 30 sondes within 90 minutes at 5 different sites.

5 launching modules with 6 sondes each.

ulrich.corsmeier@imk.fzk.de

Drop-up-sonde Intercomparison

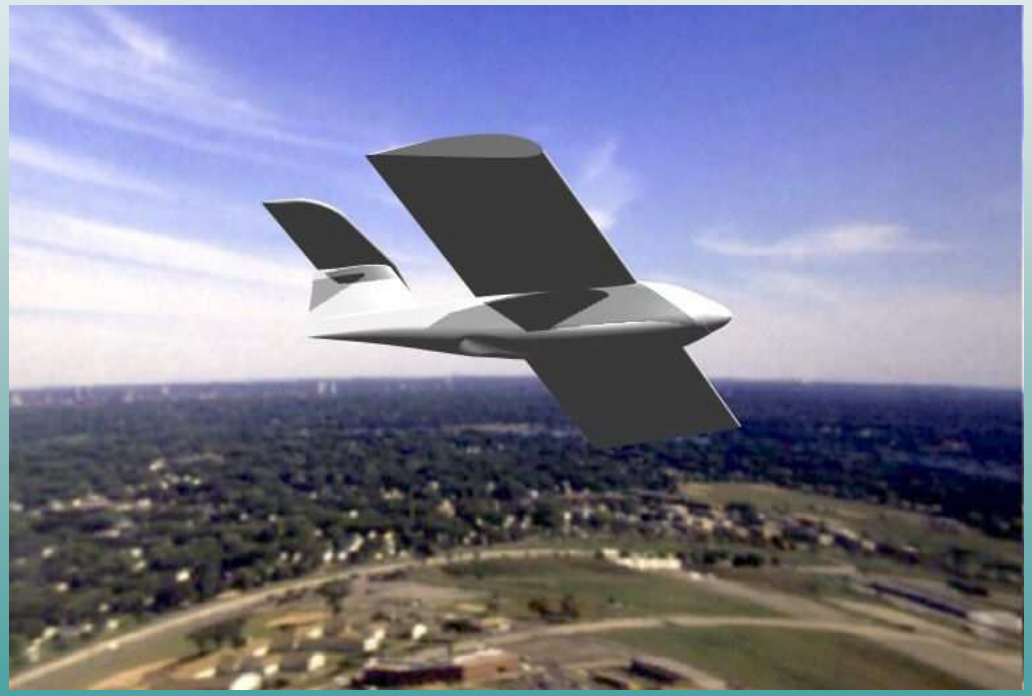




ulrich.corsmeier@imk.fzk.de

The Meteorological MAV “Carolo”

A fully autonomous aeroplane with very small dimensions



Applications:

- ✓ civil protection
- ✓ fire suppression
- ✓ road traffic control
- ✓ meteorological measurements

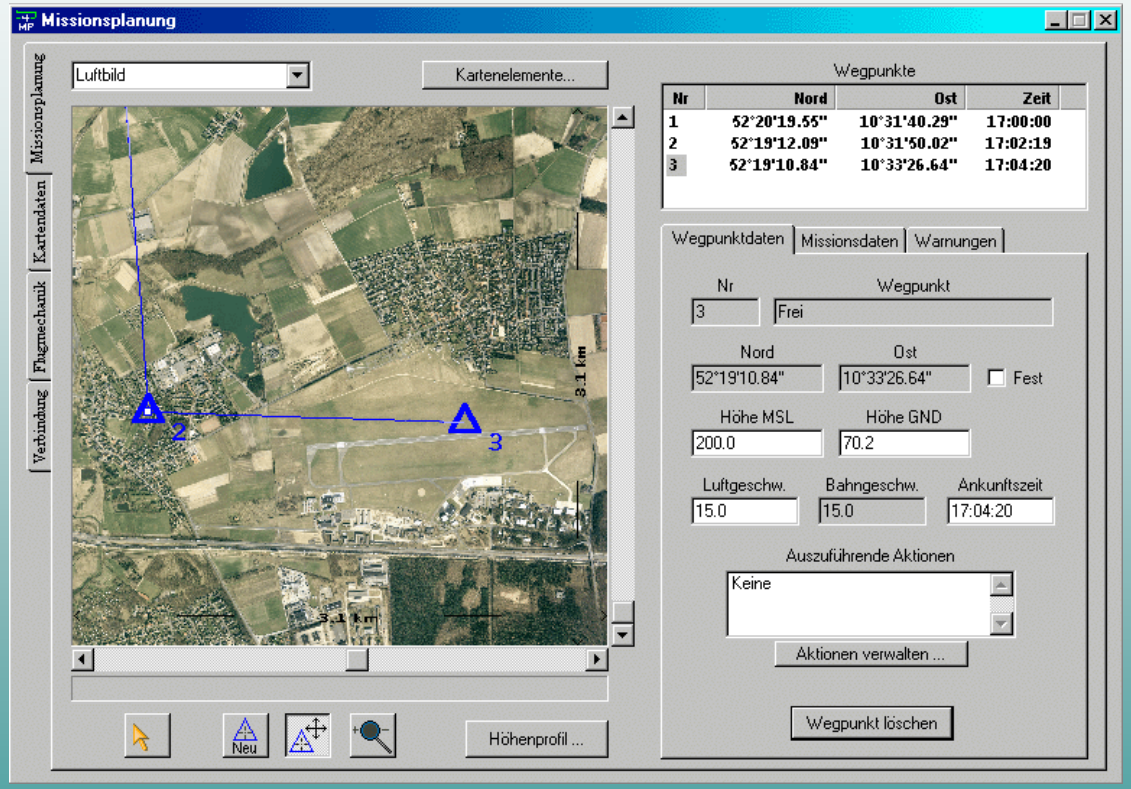
ulrich.corsmeier@imk.fzk.de

Universität Braunschweig
Institut für Luft- und Raumfahrtsysteme

The Meteorological MAV “Carolo”

Carolo T140

wingspan:	140 cm
mass:	1850 g
payload:	300 g
cruising speed:	15 m/s
endurance:	> 30 min
telemetry range:	1000 m



Flight planning and flight execution by PC ground station

ulrich.corsmeier@imk.fzk.de

The Meteorological MAV “Carolo”

Open temperature element:

- ✓ custom-made
- ✓ fast response (<< 1 s)
- ✓ low long-term accuracy
- ✓ fragile design

Sealed PT 100 element:

- ✓ standard component
- ✓ low response time (~ 10 s)
- ✓ high long-term accuracy
- ✓ robust mechanical design

➔ complementary filtering used

Humidity

- ✓ range: 0 .. 100 % rel. humidity
- ✓ response time: ~ 5 s
- ✓ accuracy: 2 %

(c) Dantec Dynamics

(c) Vaisala

ulrich.corsmeier@imk.fzk.de

The Meteorological MAV “Carolo”

5-Hole Probe

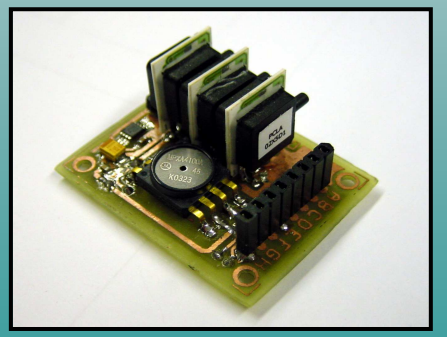
weight:	22 g
diameter:	6 mm
angle of attack:	-45° .. +45° (planned)
sideslip:	-45° .. +45° (planned)

Pressure Sensors

1 x dynamic pressure:	0 .. +1250 Pa
4 x relative pressure:	-250 .. +250 Pa
1 x static pressure:	20 kPa .. 105 kPa

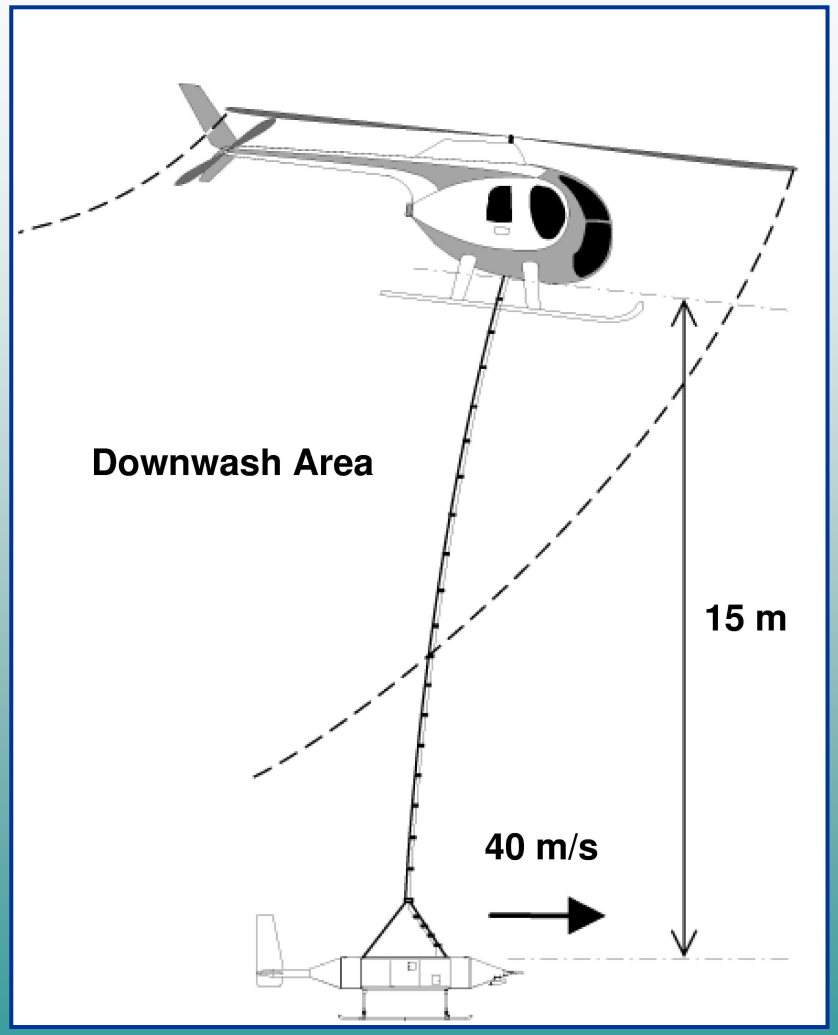
overall accuracy:	2 % over temp.
sampling rate:	100 Hz (raw data)
sampling resolution:	18 bit

weight:	50 g
power consumption:	< 800 mW



➔ low absolute accuracy but high relative accuracy (turbulence)

ulrich.corsmeier@imk.fzk.de



Helipod design

- ✓ Autonomous turbulence measuring system operated with a Helicopter
- ✓ Operation altitude: 50 m to 2000 m agl
- ✓ Operation in urbanized areas
- ✓ Speed of operation 40 m s^{-1} (TAS)
- ✓ Endurance: 4 hours
- ✓ High frequency measurement of wind components, temperature, surface temperature, humidity and CO_2
- ✓ Measurement of particulate matter (0,3 - 49 µm) by GKSS-probes

ulrich.corsmeier@imk.fzk.de

Helipod capabilities

- ✓ Measurement of turbulent fluxes of sensible and latent heat (areal average, statistics, spectral estimations)
- ✓ Evaluation and initialisation of numerical models, remote sensing and ground based measurements

ulrich.corsmeier@imk.fzk.de

Helipod advantages

- ✓Operation with different helicopters
- ✓Operation very close to the earth surface
- ✓Operation in complex terrain

- ✓Closing the gap of measurements between earth surface, remote sensing and research aircraft

The Institut für Luft- und Raumfahrtsysteme is certified according to ISO 9001-2000

ulrich.corsmeier@imk.fzk.de

Zeppelin NT

ulrich.corsmeier@imk.fzk.de

Zeppelin NT – Technical Data

Dimensions	length	75.0 m
	max. width	19.5 m
	height	17.4 m
	envelope volume	8225 m^3
Gondola	no. of seats	2 + 12
	cabin volume	26.0 m^3
	cabin length	10.7 m
Mass	take off weight	8040 kg
	payload	1900 kg
Performance	max. speed	125 km h^{-1}
	range	900 km
	ceiling	2600 m
	max. endurance	24 hours

ulrich.corsmeier@imk.fzk.de

Zeppelin NT – Scientific Equipment

- ✓**Meteorological basic equipment:** not yet available
  funding open
- ✓**Aerosol equipment:** under development by IfT Leipzig
  (instrumented gondola under cabin)
- ✓**A scientific challenge:** horizontally scanning wind lidar
  under the cabin for detecting wind
  at the basis of convective clouds.

ulrich.corsmeier@imk.fzk.de