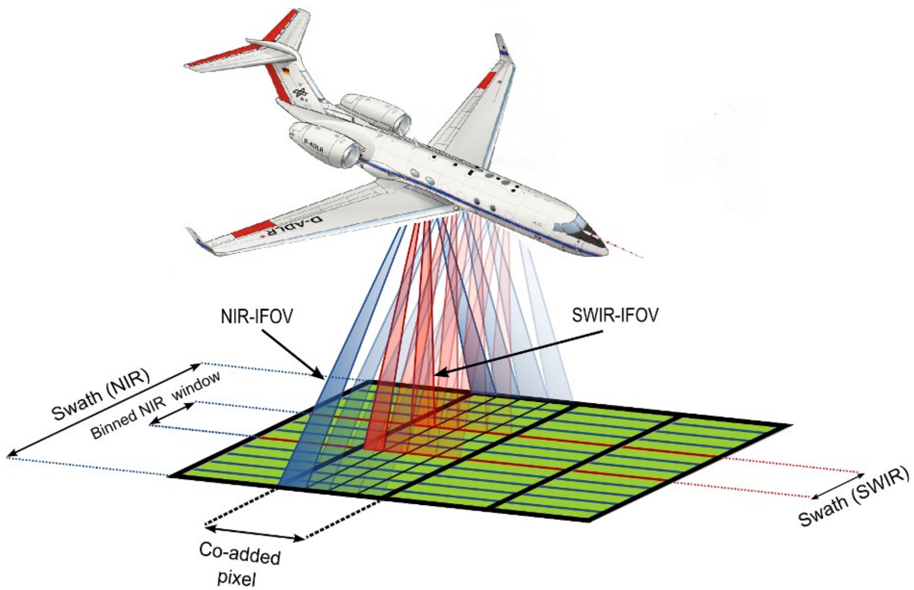
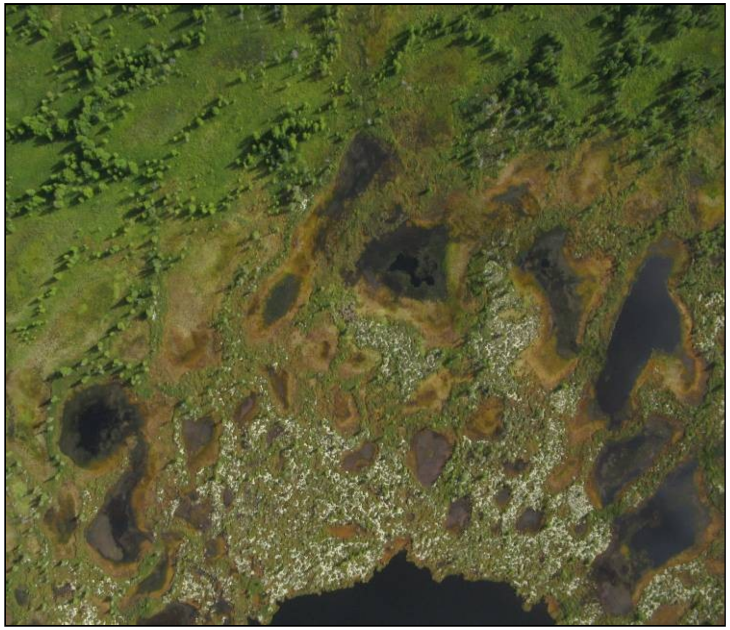
EO-HALO





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[3]Institut für Umweltphysik, Universität Bremen

Frankfurt, Okt. 2009

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Mission Overview

Topic :

Quantification of GHG emissions from natural sources in high-latitude regions by a closure of top-down and bottom-up approaches

Time frame :

Late Summer 2011 (2012 ??)

Mission Areas :

Preferably Russian permafrost, wetlands and boreal forest

Alternatives: Canadian / Alaskan permafrost wetlands and boreal forest

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The case for high latitudes

Global Warming Feedback Loop Caused by Methane, Scientists Say

Elizabeth Svoboda
for National Geographic News

Melting permafrost spews out more methane

Agençe France-Presse Thursday, 7 September 2006

Exclusive: The methane time bomb

By Steve Connor, Science Editor

Warming hits 'tipping point'

Siberia feels the heat It's a frozen peat bog the size of France and Germany combined, contains billions of tonnes of greenhouse gas and, for the first time since the ice age, it is melting

Arctic scientists discover new global warming threat as melting permafrost releases millions of tons of a gas 20 times more damaging than carbon dioxide

Renewed growth of atmospheric methane

M. Rigby,[1] R. G. Prinn,[1] P. J. Fraser,[2] P. G. Simmonds,[3] R. L. Langenfelds,[2] J. Huang,[1] D. M. Cunnold,[4] L. P. Steele,[2] P. B. Krummel,[2] R. F. Weiss,[5] S. O'Doherty,[3] P. K. Salameh,[5] H. J. Wang,[4] C. M. Harth,[5] J. Mühle,[5] and L. W. Porter[6,7]

Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming

K. M. Walter[1], S. A. Zimov[2], J. P. Chanton[3], D. Verbyla[4] & F. S. Chapin III[1]

Global Methane Emissions from Terrestrial Plants

CHRISTOPHER L. BUTENHOFF* AND M. ASLAM KHAN KHALIL
Department of Physics, Portland State University, P.O. Box 751, Portland, Oregon 97207

The case for high latitudes

- Tundra alone: 7.3 – 10.5 Mio km²
  - 5 – 7 % of the land surface
- Tight coupling between:
  - Soil / vegetation
  - Hydrosphere
  - Atmosphere
- Dependence on 0 °C (< or >?)
  - Extremely sensitive
- Arctic = climate relevant
- Stronger warming than average

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The case for high latitudes

- Soil / sediment / rock
  - ≥ 2 consecutive years at < 0 °C
- ~24 % of northern hemisphere
  - N-America: ~ 6,2 Mio km²
  - Eurasia: ~ 16,7 Mio km²
- Thickness up to > 1500 m
  - Seasonal active layer
  - Few decimeters to meters
  - Up to 1700 Gt organic C !!
- Warming since 1960s
  - East Siberia: ~ 1,3 °C
  - Alaska: ~ 2-3 °C (since 1980)

Source: International Permafrost Association, 1998. Circumpolar Active-Layer Permafrost System (CAPS), version 1.0.

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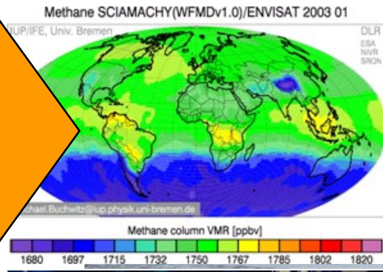
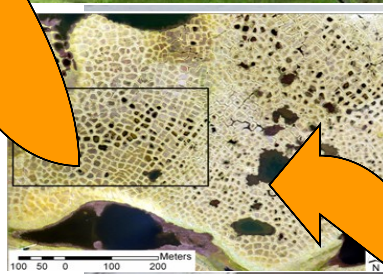
Scaling problems

Scaling top-down (inverse modelling)





Large uncertainties in scaling from points to globe

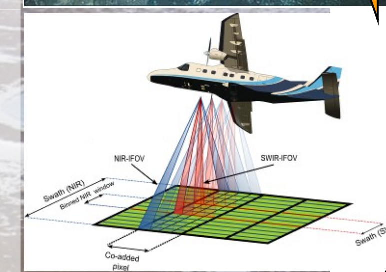
→ Closing the gap: EO-HALO

Strong heterogeneity within and between peatlands / wetlands

→ affects upscaling from points to larger scales:

→ requires high-res classification + many ground measurements

→ not feasible in large remote areas



Scaling bottom-up in small steps

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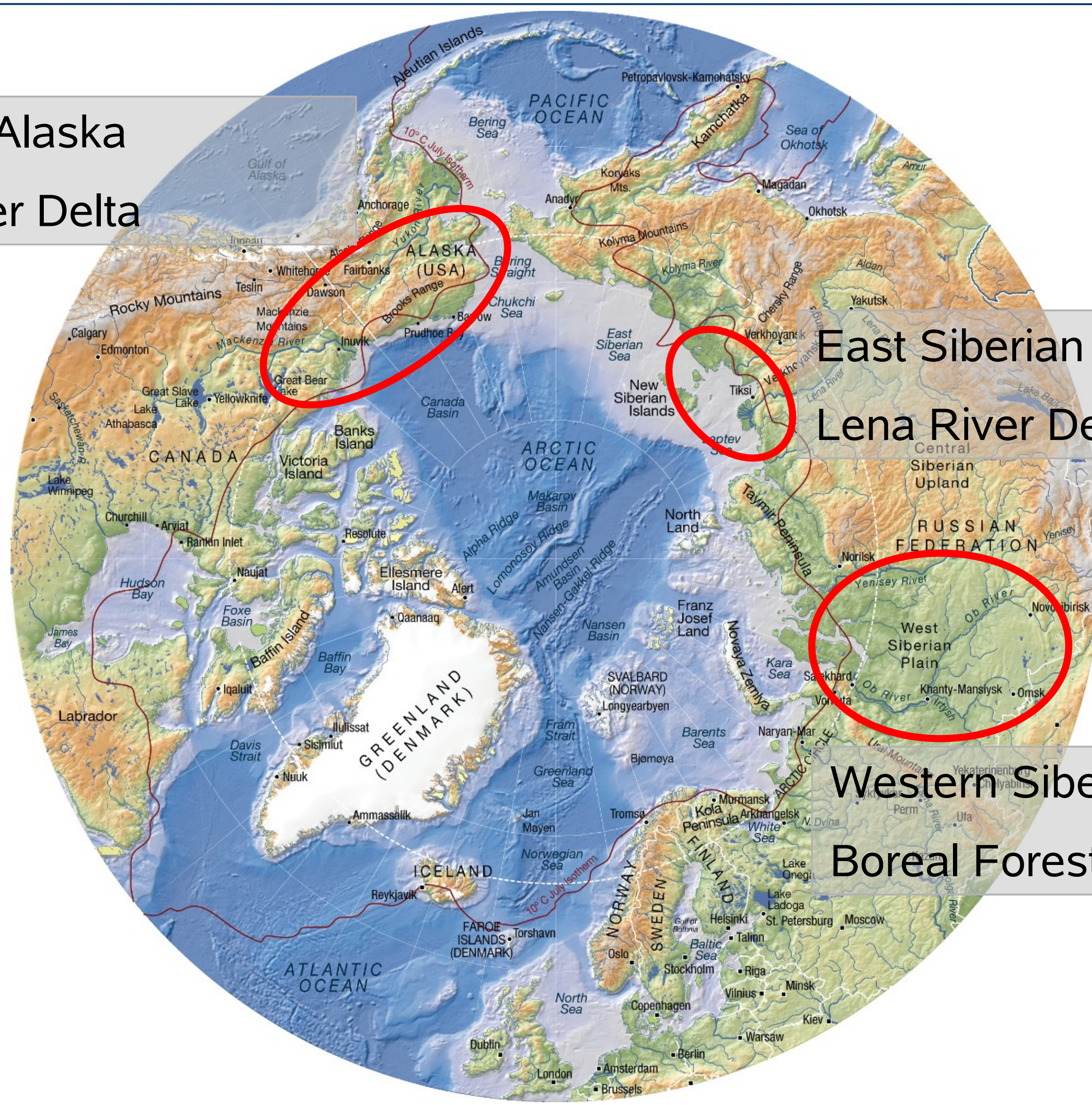
Measurement Areas

North Slope of Alaska

Mackenzie River Delta



East Siberian Arctic Shelf

Lena River Delta

Western Siberian Wetlands

Boreal Forest (ZOTTO tower)

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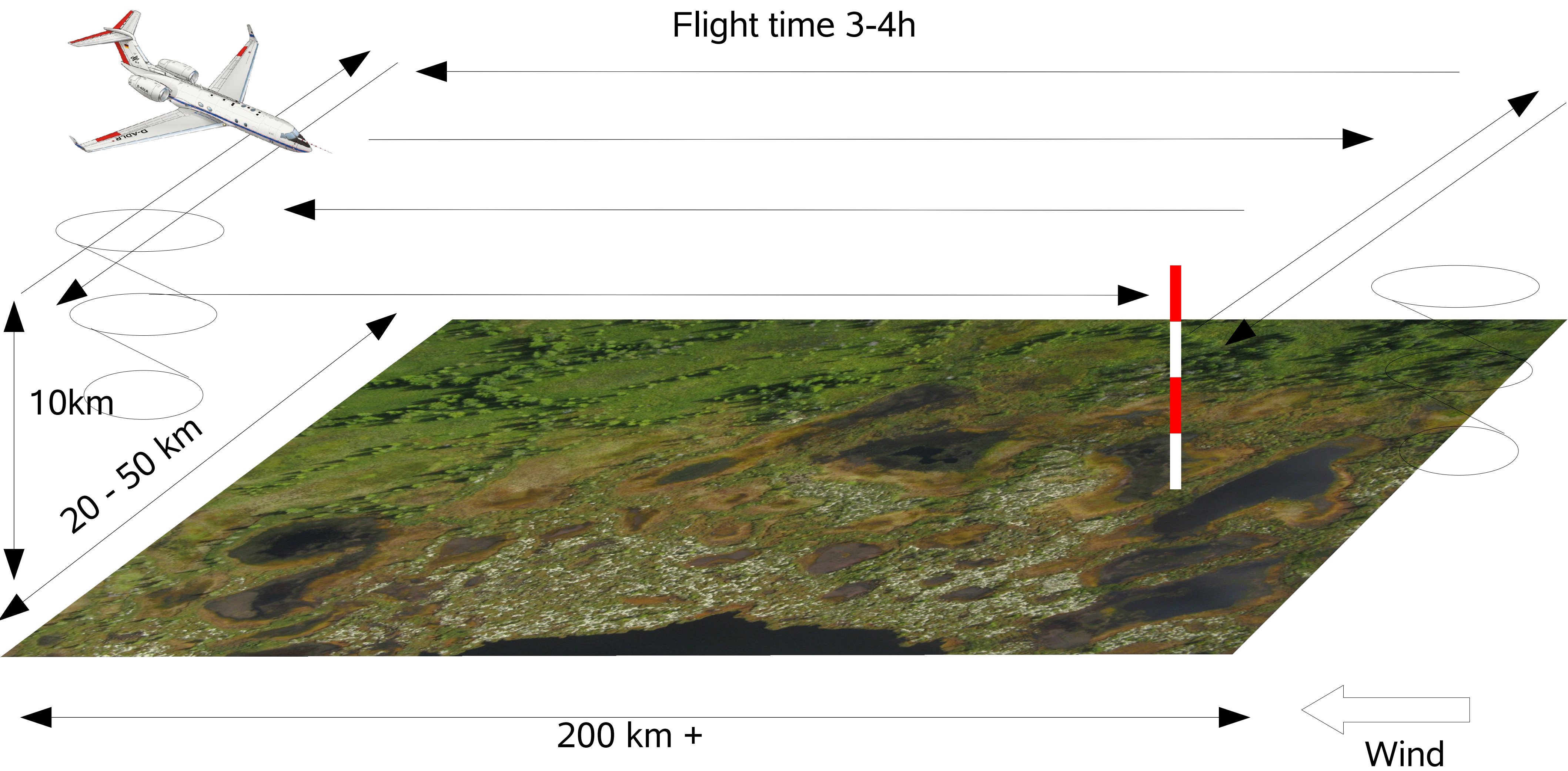
Flight pattern



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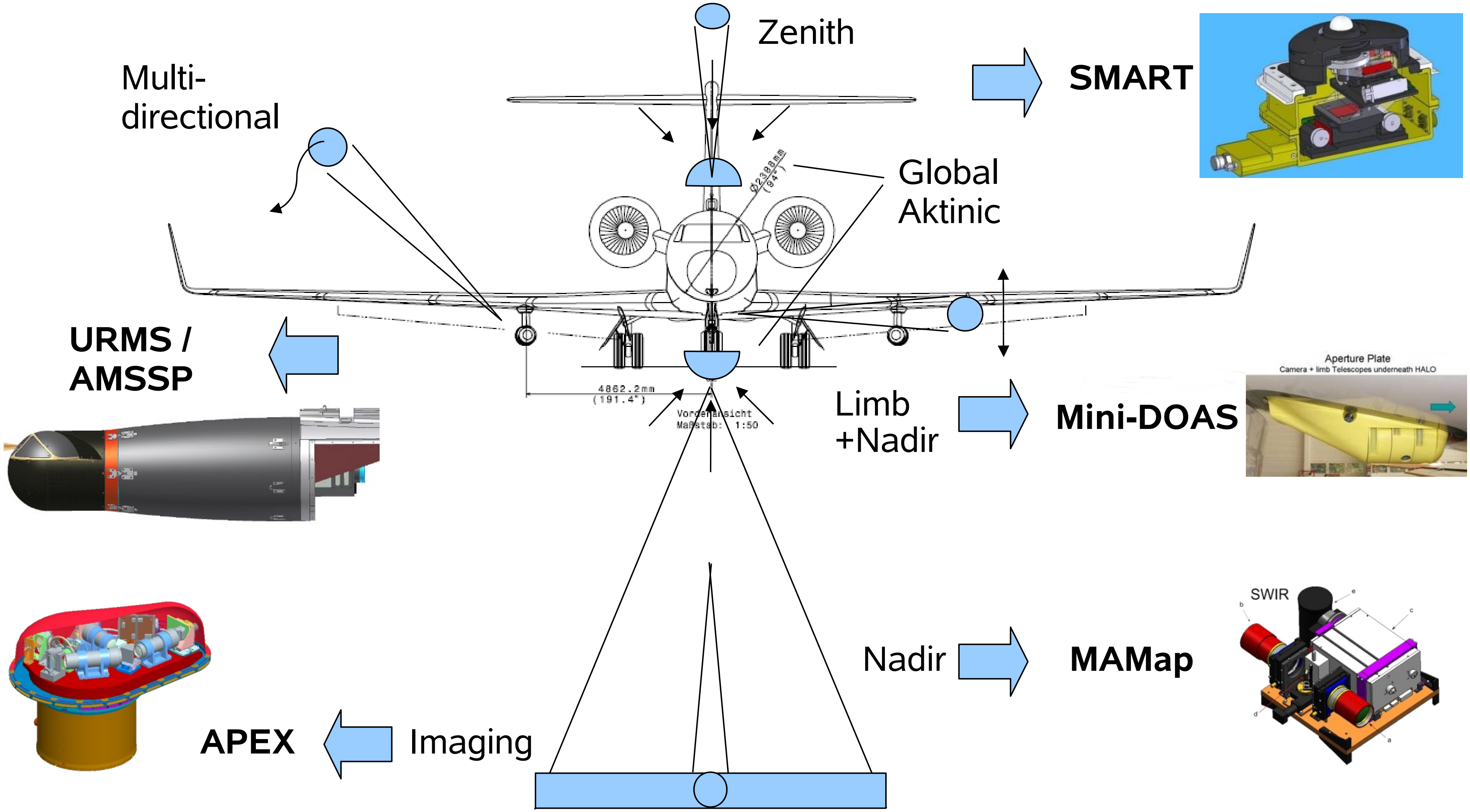
Instrument setup



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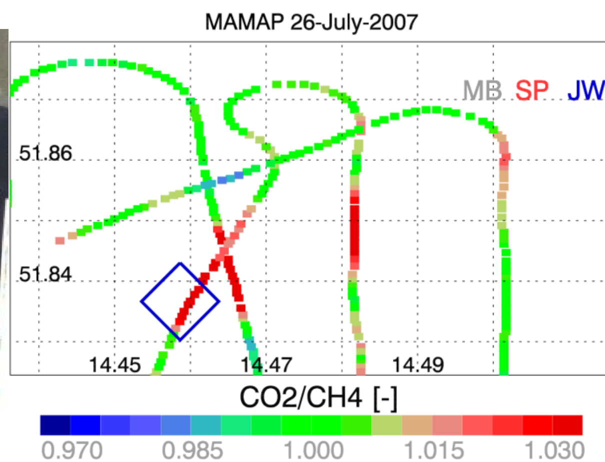
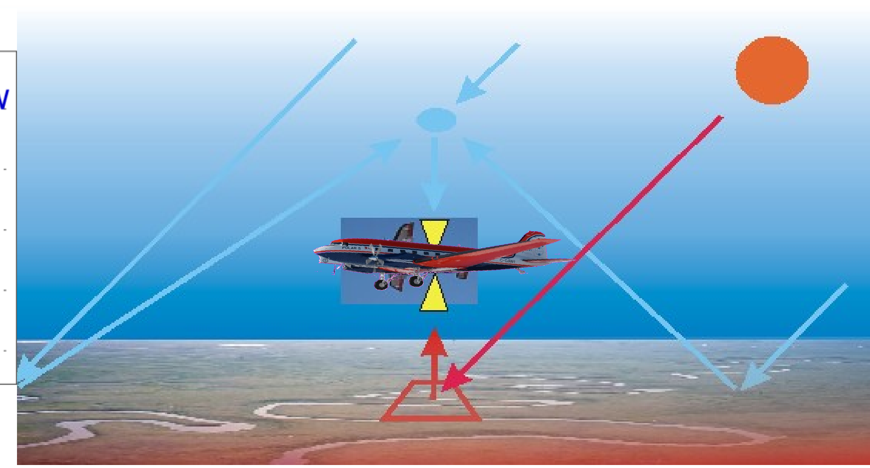
Methane Airborne Mapper (MAMap)

- Goal: mapping of CH4 and CO2 column averaged mixing ratios below the aircraft down to the surface with precisions of 1% or better, with spatial resolution < 100 m over land
- Constraint for regional scale GHG budgets (inverse modelling)
- Airborne 2 channel NIR/SWIR grating spectrometer system for simultaneous remote measurements of tropospheric methane (CH4), carbon dioxide (CO2) and oxygen (O2) to indentify and quantify terrestrial carbon sources and for satellite validation
- Successful test flights of the sensor with FU-Berlin Cessna and AWI Polar 5





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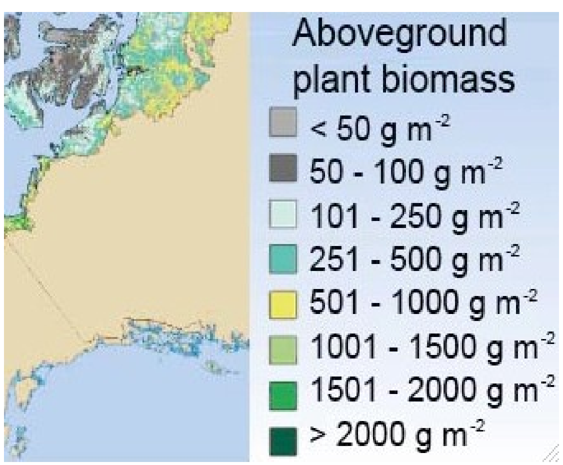
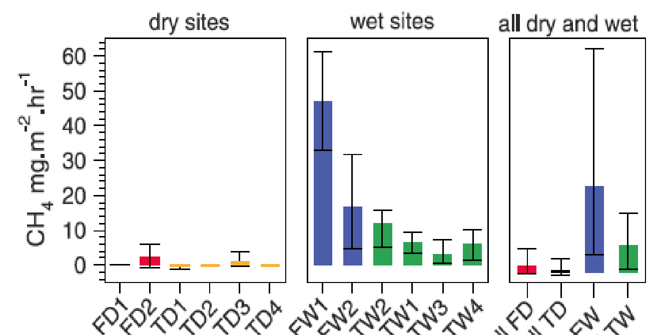
Airborne Prism Experiment

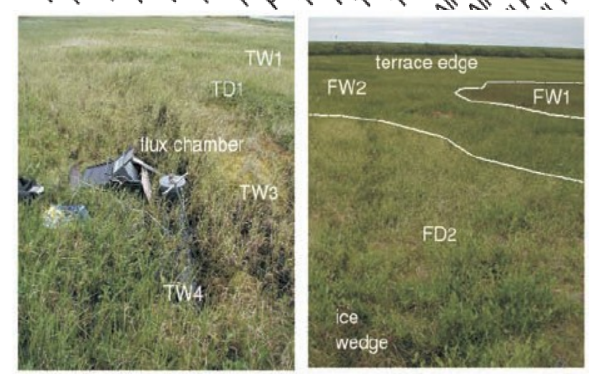
- High spatial resolution thematic maps of landscape indicators (e.g., Vegetation Indices (VI), LAI, fcover, plant functional type (PFT)) to represent dynamic vegetation at seasonal time scales
- Small-scale landscape features (variability) critical for methane emission estimation to assess systematic landscape-scale differences in the carbon balance
- Linking of APEX imaging spectrometer data with spatial and temporal variability of soil carbon fluxes



[Van Huissteden, J., et al., JGR 2005]

Linking APEX Landcover Products with in-situ carbon data





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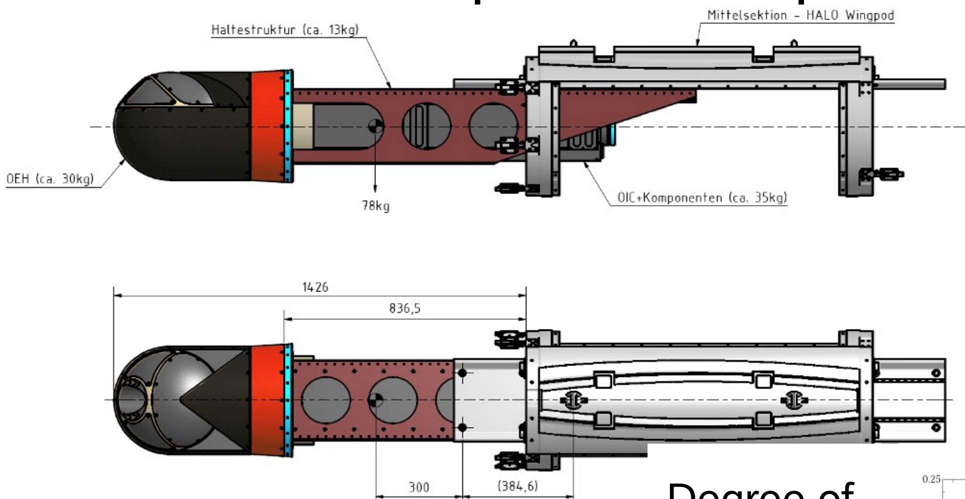
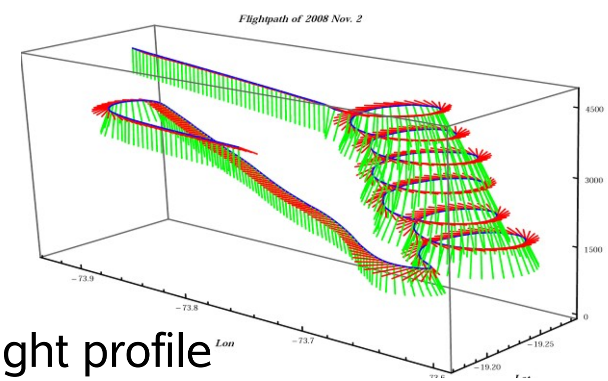
Universal Radiation Measurement System / Airborne Multi-Spectral Sunphoto- & Polarimeter



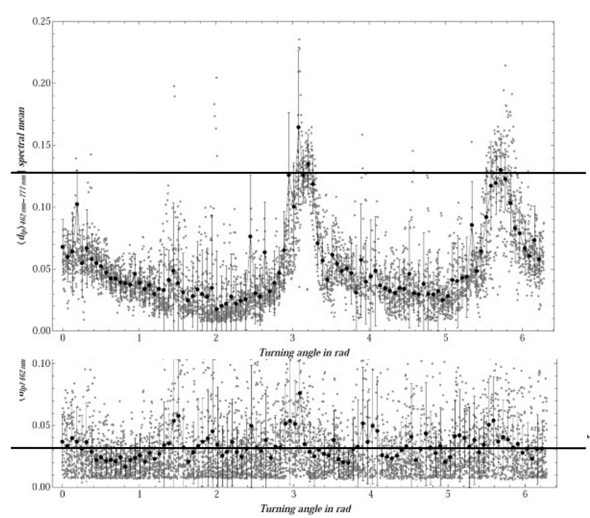
- Aerosol characterization
- Multi- directional polarized ground reflectance
- Cloud and Cirrus detection (for CH_4 and CO_2 retrieval)

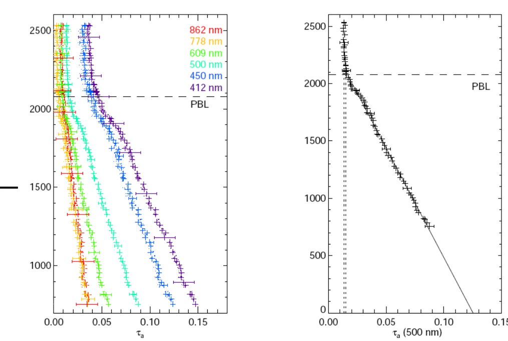


Flight profile
(Vocals 2008)

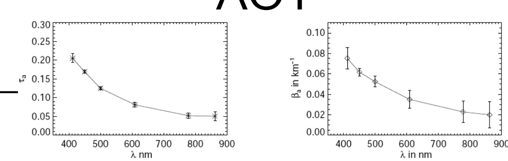
Degree of linear Polarization (10 – 15 %)

Degree of circular Polarization (2- 5 %)





AOT



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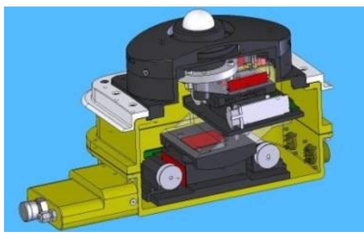
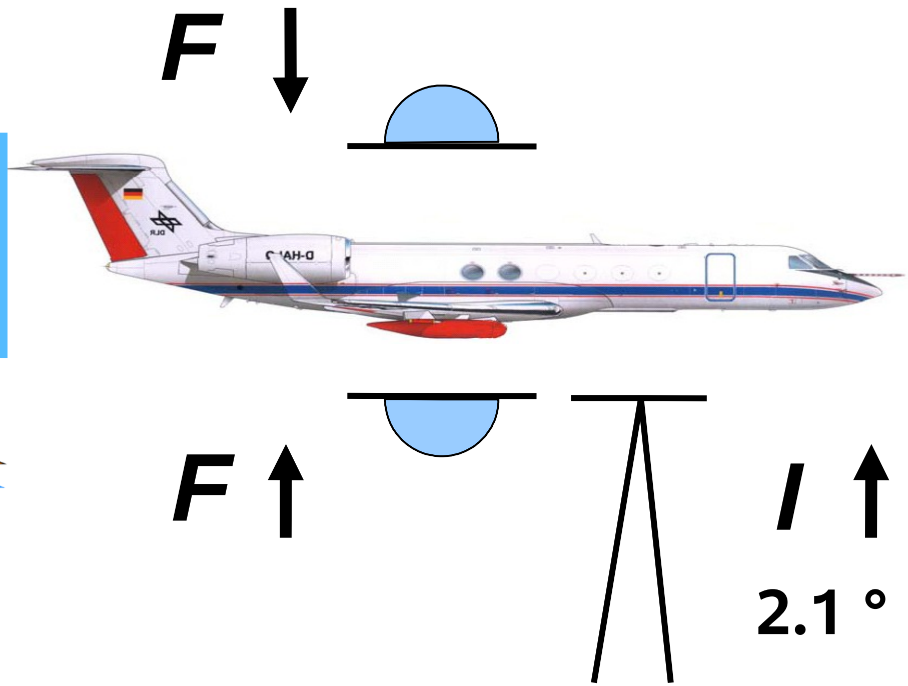
Spectral Modular Airborne Radiation measurement system

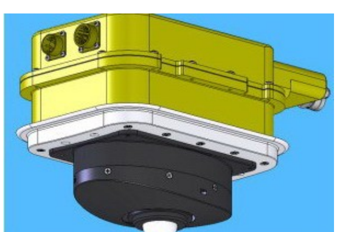
downwelling irradiance
[W m^{-2} nm^{-1}]





Surface Albedo
Energy Budget

upwelling irradiance
[W m^{-2} nm^{-1}]



upwelling radiance
[W sr^{-1} m^{-2} nm^{-1}]

Spectral Range
(350 – 2200 nm)

2-3 nm FWHM (0.35 -1.0 µm)
9-16 nm FWHM (1.0-2.2 µm)

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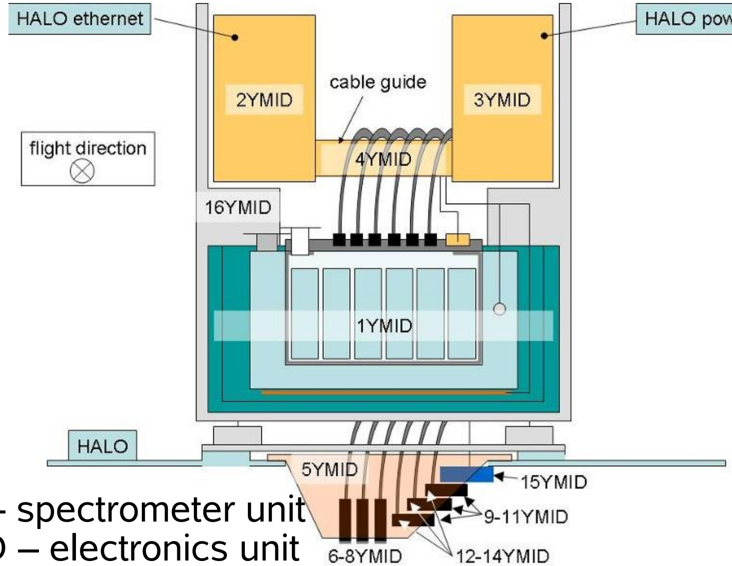
Mini-DOAS (Uni Heidelberg)

Miniature - Differential Optical Absorbtion Spectrometer

Components of the mini-DOAS instrument

Aperture Plate
Camera + limb Telescopes underneath HALO

Scattered sunlight DOAS combined with RT modelling
Detectable species:
(1) BrO, ClO OClO, IO, O_3, HCHO, HONO, SO_2 in the UV
(2) I_2, IO, OIO, OBrO, NO_2, O_3, O_4, $C_2H_2O_2$ in the visible; (3) H_2O (g, l, s), O_4, (CO_2, CH_4) in the near-IR



1YMID – spectrometer unit
2-4YMID – electronics unit
5-15YMID – aperture plate
16YMID – mini rack

Technical specification:
Total weight: 47 kg, excl. water 40 kg
Dimensions: (mini rack) 43x43x49 cm, (aperture pl.) 10x7" = 25x18 cm
Power: 100 W, 28 VDC

6 optical spectrometers (2x UV/vis/near-IR in nadir direction and limb scanning) immersed in a pressurized spectrom. housing, ice/water tank for T-control

Electronics (PC, T-controller, motor controllers, spectrometer readout electronics)

Aperture plate: (1) limb obs. webcam, (2) motors for limb scanning and (3) 6 telescopes

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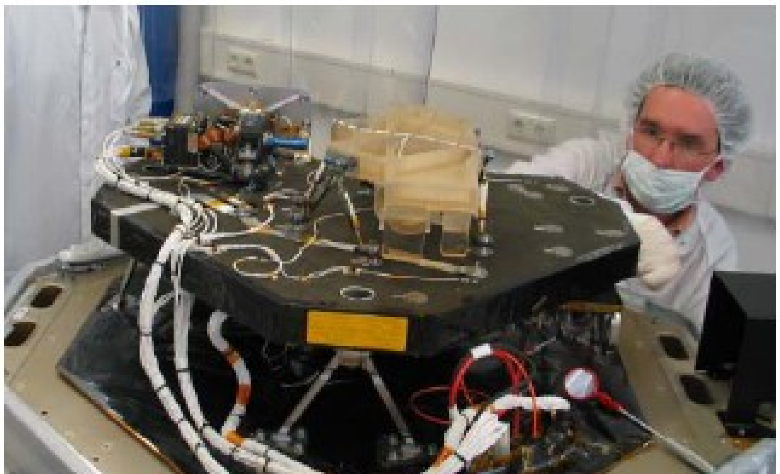
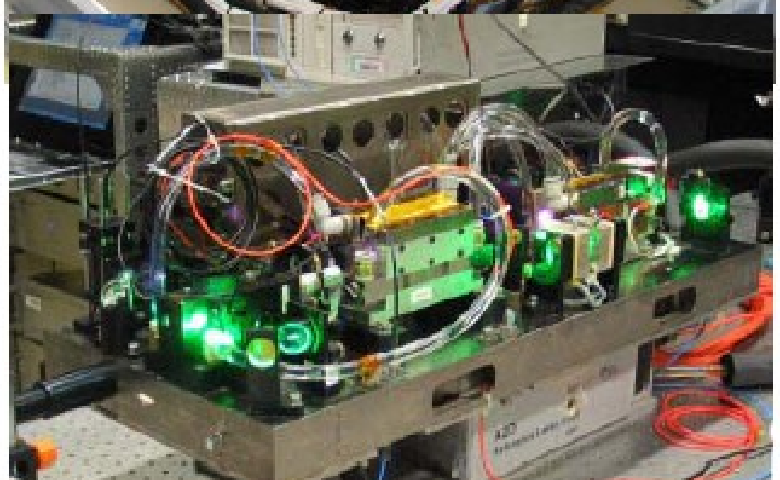
Der ALADIN Airborne Demonstrator A2D

A2D and 2-µm Wind-Lidar auf der Falcon im November 2007





in der Helmholtz-Gemeinschaft

Zielstellung der Entwicklung des ALADIN-Demonstrator

- Im Gegensatz zu kohärentem Wind-Lidar wurden kein Direkt-Empfangs-Doppler Lidar vom Flugzeug mit Messungen in Nadirgeometrie eingesetzt
- Entwicklung des ALADIN Empfänger bei EADS-Astrium Toulouse seit 2000
=> Tests ausschließlich im Labor ohne Signale aus der Atmosphäre
- ALADIN benutzt neue Technologien, die bei Doppler-Lidar Systemen noch nicht zum Einsatz kamen, z. B. Fizeau-Interferometer, akkumulierende CCD-Detektoren
=> Erfahrung mit Auswerte-Algorithmen fehlt

Development is going on !

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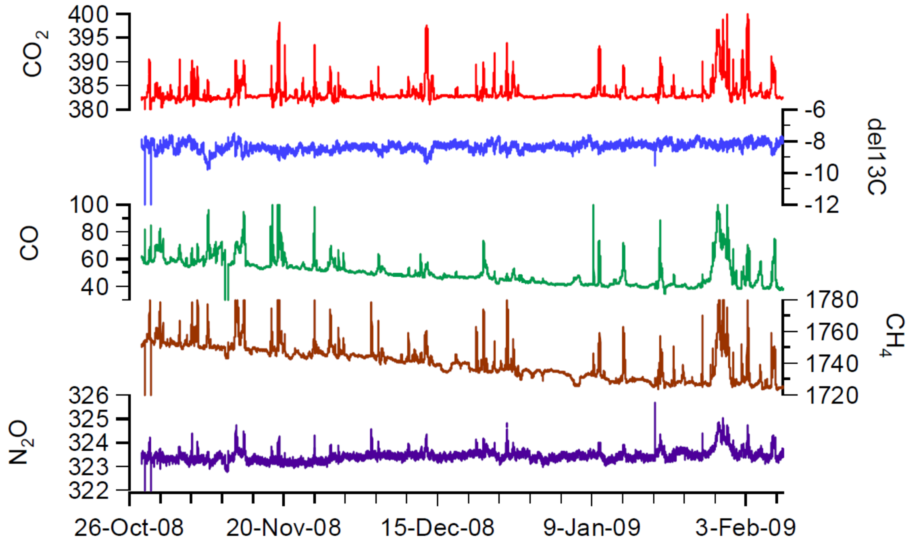
In-situ FTIR (Uni Bremen)

- Use of (existing) automated in-situ low-resolution FTIR-spectrometer on HALO **or** taking samples for measurements of trace gases and isotopic fractionation
  - determination of sources and sinks of trace gases (with isotopic information)
  - distribution of trace gases in the free troposphere and lower stratosphere
  - satellite validation (both instruments use same spectroscopy)



Species	precision (1σ)
CO_2/ppmv	0.1 - 0.2
CH_4/ppbv	<1
N_2O/ppbv	0.1 - 0.3
CO/ppbv	0.3 - 0.5
$\delta^{13}C-CO_2$/‰	0.1 - 0.2
δD in H_2O/‰	<1

(D. Griffiths, Uni Wollongong)

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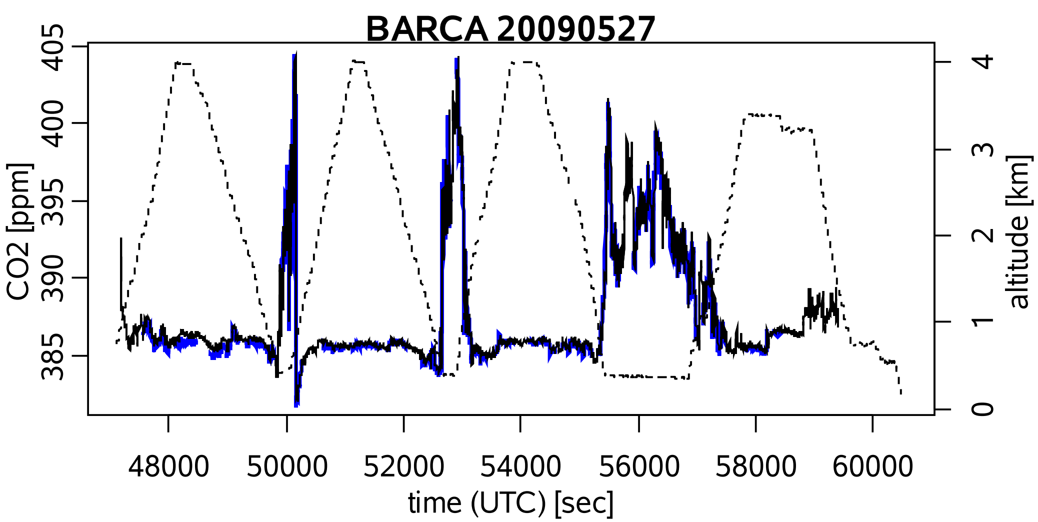
Cavity Ringdown Spectroscopy

- Constraint for regional scale GHG budgets (inverse modelling)
- Constraint on atmospheric transport from CO2 Profiles (Convection, Strat-Trop exchange, PBL dynamics)
- „Ground troothing“ of remote sensing
- Fully automated, CO2 and CH4 (Picarro Inc., Model G1301m)
- Future potential for Mid-IR (N2O, CO2 Isotopes, expected by end of 2010)



Specifications	
CO_2 Precision@2 s	0.1 ppm
CH_4 Precision@2 s	1 ppb
H_2O Precision@2 s	100 ppm
Dimensions + Weights	19”, 5 HU 25 kg

Frankfurt, Okt. 2009
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- Russian Academy of Science, Siberian Branch, Institute of Biophysics, Krasnojarsk
  - A. Shevyrnogov
- Yugra State University, UNESCO Chair of Environmental Dynamics and Climate Change
  - E. D. Lapshina, M. Glagolev (also Moscow State University)

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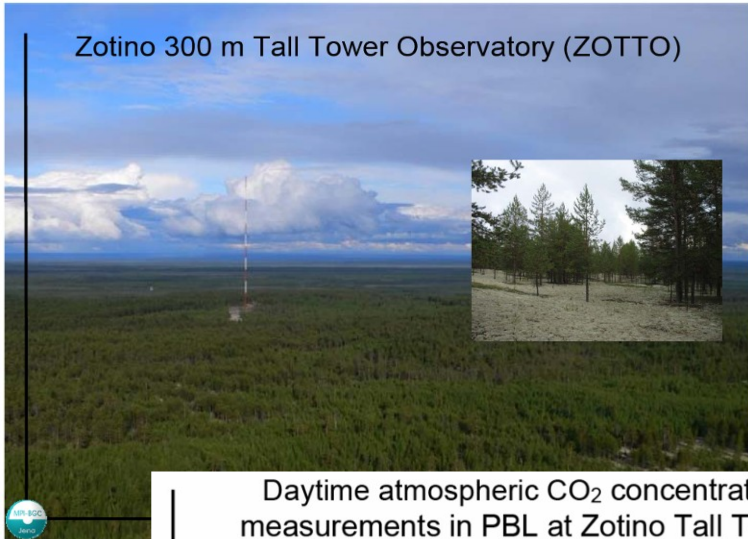
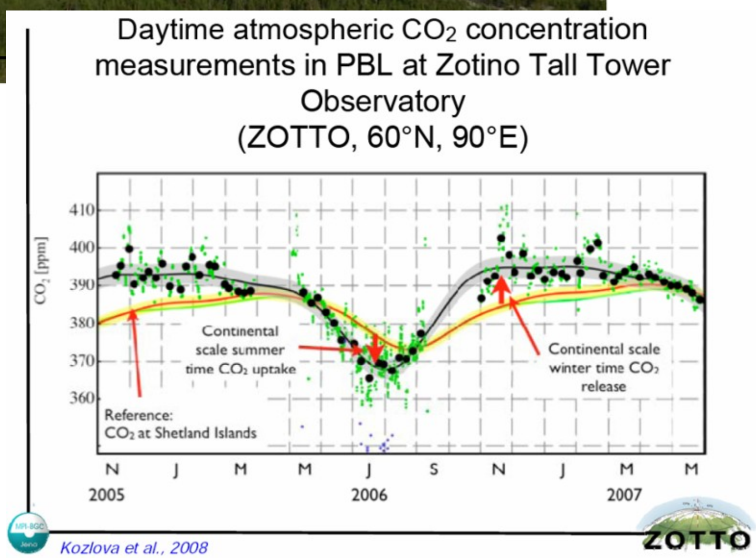
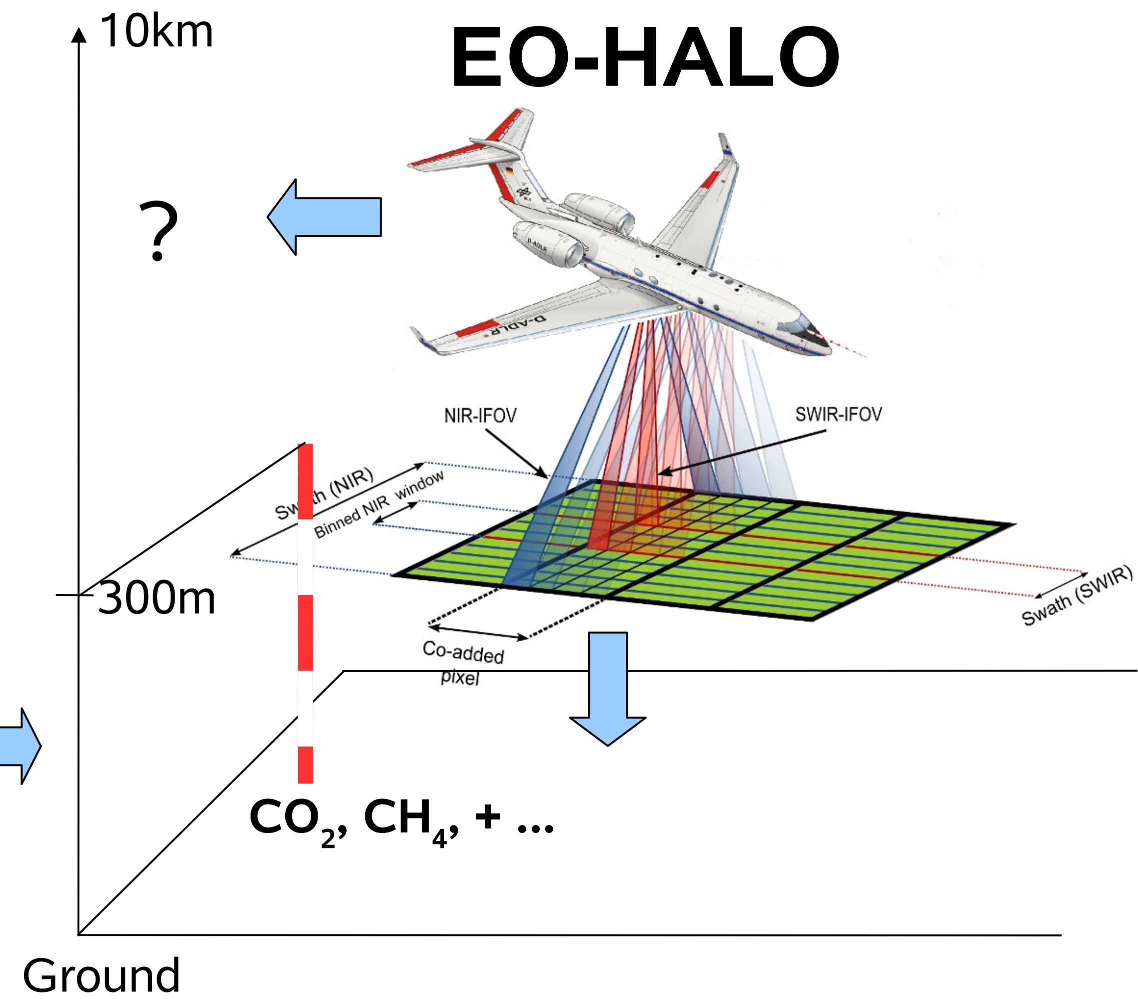
Summary







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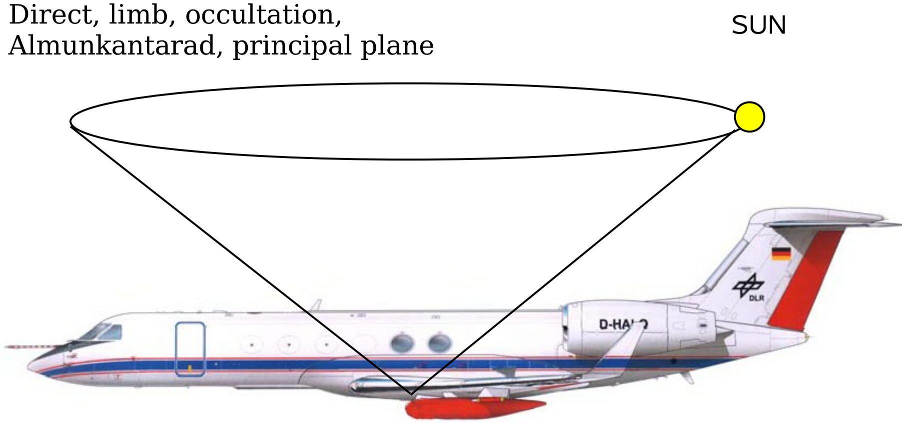
GFZ Helmholtz-Zentrum Potsdam · Freie Universität Berlin · University of Zurich · Universität Bremen · Universität Leipzig · Max-Planck-Gesellschaft

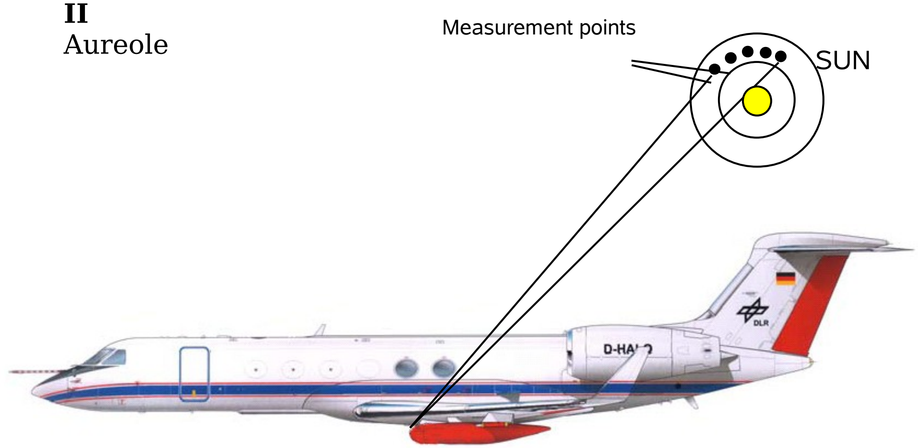
URMS Measurement geometries

Rene Preusker, Thomas Ruhtz, Freie Universität Berlin

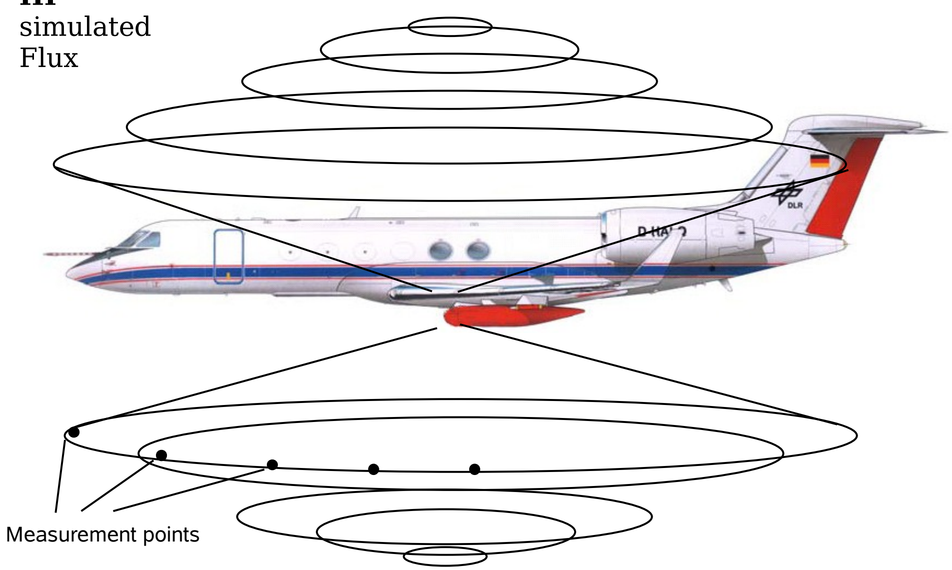
I
Direct, limb, occultation,
Almunkantarad, principal plane



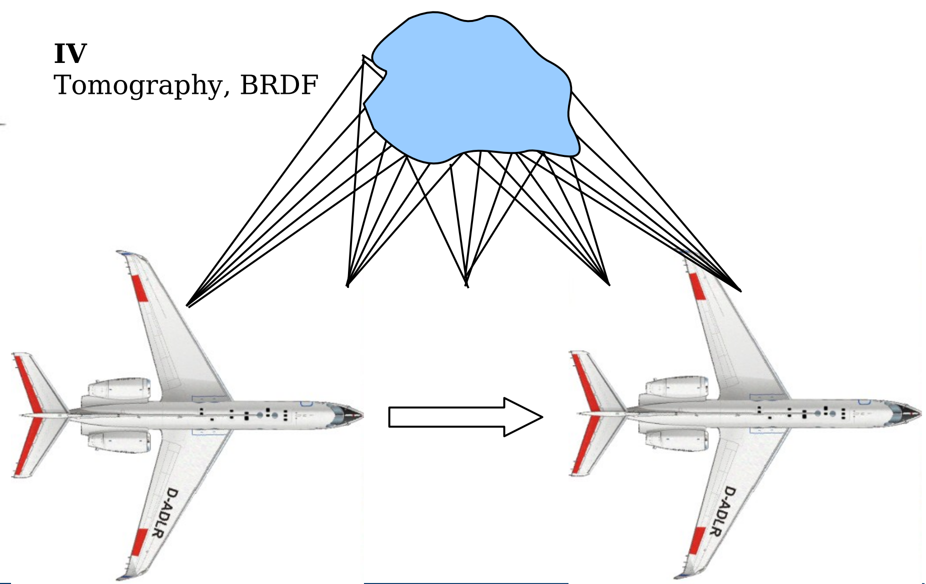
II
Aureole



III
simulated
Flux



IV
Tomography, BRDF



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Deutsche Forschungsgemeinschaft DFG · DLR · HALO

4-Wellenlängen DIAL für CO2 und CH4

(Demonstrator für die Weltraummissionen A-SCOPE (CO2) und SPACE-CHARM (CH4)

Instrument Features:

- Säulenmessung unterhalb des Flugzeugs bei vier Wellenlängen simultan
- Datenprodukte: Säulenintegrierte Mischungsverhältnisse XCO_2 und XCH_4 , Teilsäulen im Falle von Wolkenreflexen, Wolkenbedeckung längs des Flugwegs, Detektion erhöhter Aerosolschichten
- Hocheffizientes gepulstes Festkörperlasersystem bei 1.57 µm (CO2) und 1.64 µm (CH4)
- keine Querempfindlichkeit gegenüber Aerosolen und opt dünnen Wolken
- Angestrebte Messempfindlichkeit bei CO_2: 0.4 ppm über Wasser (über land Faktor 2 empfindlicher), horizontale Auflösung 1 km @ 200 m/s, Instrumenten-BIAS < 0.1 ppmv, Footprint 50 m
- Angestrebte Messempfindlichkeit bei CH4: 8 ppb über Wasser , horizontale Auflösung 1 km @ 200 m/s, Instrumenten-BIAS < 0.2 ppb, Footprint 50 m
- kompakter Aufbau in der Nähe eines der Fensters (< 200 kg, + zwei Racks)
- Fertigstellung (inkl. Zertifizierung) Ende 2011

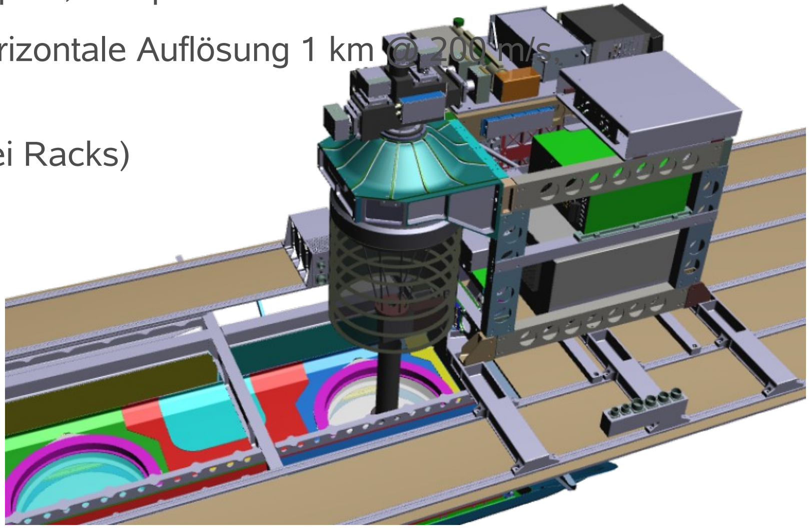

Bild: H2O-DIAL auf HALO,

ähnlicher Einbau für CHARM-F geplant

Frankfurt, Okt. 2009
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Airborne Scanning 2-µm Doppler-Wind-Lidar

Transceiver Specs:

wavelength 2.022 µm
repetition rate 500 Hz
pulse energy 1.0 mJ
pulse length 0.5 µs
range gate 100 m
first range gate 400 m

Off-axis telescope:
aperture 10 cm

Double Wedge Scanner:
elevation sector +/- 30 °
scan speed variable

Data acquisition:
early digitising 500 MHz
with quick-look

Specification for PBL:

Accuracy of horizontal wind:	0,5 m/s
Vertical resolution in the:	100 m
Along track integration:	5 km
Spin-off product:	PBL height

Status

Viele erfolgreiche Einsätze auf der Falcon

Portierung auf HALO in 2010 durch DLR/IPA geplant

Komponenten des 2 µm Doppler Wind Lidars für die Windprofilmessung auf der Falcon (ca. 170 kg)

2-µm Transceiver auf der Falcon

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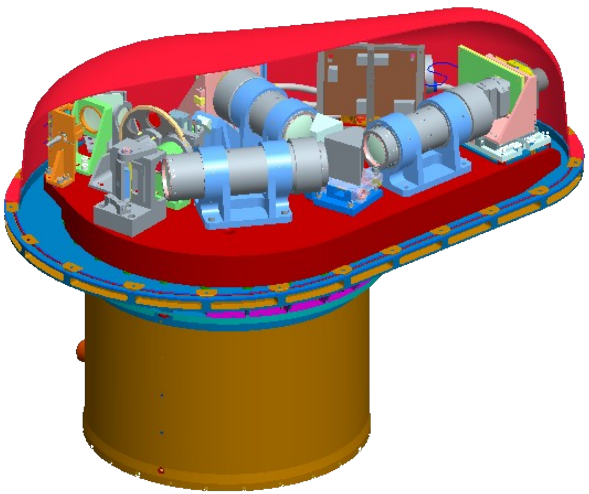
APEX (Universität Zürich)

Airborne Prism EXperiment

Spectral Performance	VNIR	SWIR
Spectral Range	380 – 970 nm	940 – 2500 nm
Spectral Bands	Up to 334 (default: 114) (number of VNIR spectral rows programmable via bi pattern upload)	199
Spectral Sampling Interval	0.5 ÷ 8 nm (default: 11 ÷ 8 nm)	5 ÷ 10 nm
FWHM	0.6 ÷ 6.3 nm	6.2 ÷ 11 nm
Spatial Performance		
Spatial Pixels (acrosstrack)	1000	
FOV	28°	
IFOV	0.028° (ca 0.5 mrad)	
Spatial Sampling Interval (across track)	1.75 m @3500 m AGL	
Sensor Characteristics		
Dynamic Range	CCD, 14 bit encoding	CMOS, 13 bit encoding
Pixel Size	22.5 µm x 22.5 µm	30 µm x 30 µm
Other Information		
Data Capacity	500 GB on SSD	
Data Transfer	Spectral frames Housekeeping Data	30 MB/s via Optical Link 20 kB/s via SR
Flight mission in default configuration	0.4 GB/km (approx. 1250 km over target, max)	
Operators	1 operator	



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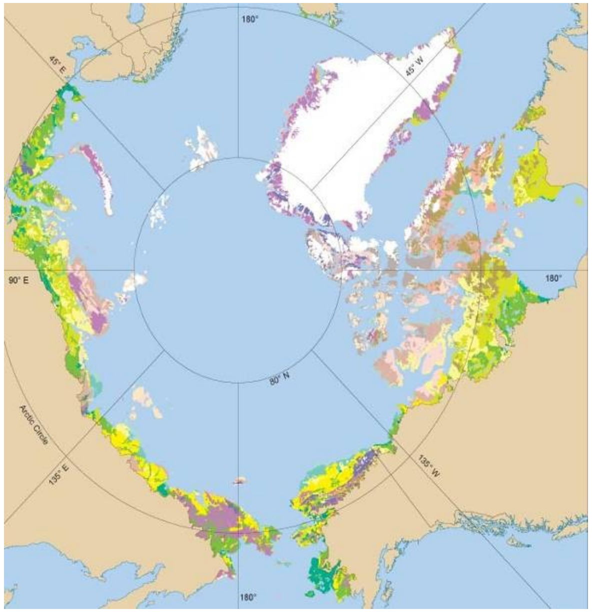
Airborne Prism EXperiment

- Spectral Data:
  - Georeferenced Ground Hemispherical Conical Reflectance Factor (HCRF), "imaging spectrometer data cube"
- Level 3 Products:
  - *For quantification and upscaling of the carbon balance, improved data on land cover and vegetation are indispensable*



Derived land cover classes from APEX data will be based on those of the Circumpolar Arctic Vegetation Map Initiative (CAVM)

[CAVM team, 2003]

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