MSS - Software for planning research aircraft missions
About me

Forschungszentrum Jülich GmbH

http://www.fz-juelich.de/
Atmospheric Research – WHAT?

Understand various individual processes and their interplay

Figure: NASA Earth Observatory
Sketch of Atmospheric Processes

- **Stratosphere**
  - Wave-driven circulation (Brewer-Dobson)
  - Planetary and gravity waves
  - Transport / Mixing

- **Troposphere**
  - Convection
  - NOx
  - CO, Organics
  - Biomass Burning

- **Tropics**

- **Mid-latitudes**
  - Urban Pollution

- **Poles**

Source: SPARC Report (check!)

12.07.2017 @ReimarBauer
Atmospheric Research – WHY?

Provide predictions for the atmosphere regarding

- Climate
- Global warming
- Ozone hole
- ... and many more
Atmospheric Research – HOW?

- Measurements of chemical trace gas composition and other parameters of interest that characterize these processes
  - Laboratory
  - Balloons
  - Aircrafts
  - Satellites

- Simulations of the atmosphere (composition, particles) by a variety of models
Atmospheric Research – AIM

- Improved **understanding** of the individual processes

- **Parametrize** these processes in atmospheric models, e.g. Chemistry climate models (CCMs) and Earth system models (ESMs)

- Quality improvement of models and **predictions** for ozone hole, climate, . . .
Atmospheric Research – Aircraft Measurements

- **Flexibility** to measure at locations of scientific interest
- **Cheap** compared to satellite measurements
- Research flight hours are **rare** and still very expensive
- **Collaboration** with various groups and institutions that are specialized for individual measurements
Example: The Geophysica Aircraft

Top altitude: 20 km, range: 3000 km
Example: The Geophysica Aircraft

Places for payload of scientific Instruments

12.07.2017

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Example: The Geophysica Aircraft

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameter</th>
<th>P.I.</th>
<th>Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOZAN</td>
<td>$O_3$</td>
<td>Ulanovsky, CAO</td>
<td>Bay 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fabrizio Ravegnani, CNR</td>
<td></td>
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<tr>
<td>FISH</td>
<td>$H_2O$ (total)</td>
<td>Martina Kraemer, JUELICH</td>
<td>Bay 4</td>
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<tr>
<td>FLASH</td>
<td>$H_2O$ (gas phase)</td>
<td>Alexey Lykov, CAO</td>
<td>Under Wing Pylon</td>
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<tr>
<td>SIOUX</td>
<td>$NO$, $NO_y$, Particle $NO_y$</td>
<td>Hans Schlager, DLR</td>
<td>Under Wing Pod</td>
</tr>
<tr>
<td>HALOX t.b.d.</td>
<td>ClO</td>
<td>Fred Stroh, JUELICH</td>
<td>Left Wing Pod</td>
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<tr>
<td>HAGAR</td>
<td>$N_2O$, CFC12, CFC11, CH$_4$, $H_2$, SF$_6$, Halon 1211, CO$_2$</td>
<td>Michael Volk, BUW</td>
<td>Bay 8</td>
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<tr>
<td>WAS</td>
<td>Long lived trace gases and isotopo-logues</td>
<td>Thomas Roeckmann, UTRECHT</td>
<td>Fuselage Bay</td>
</tr>
</tbody>
</table>

Many more instruments for measurements of different parameters
Example: The HALO Aircraft

Top altitude: 15 km, range: 10000 km

HALO leaving the Arena Arctica. Picture by Peter Preuße, FZJ.
Planning of Research Flights

- Typically, scientific campaigns with more flights from a base airport address one or more scientific questions.
- Model simulations provide related parameters of interest for the near future using meteorological forecast data.
- Optimization of the scientific outcome by finding the best flight path (in 4 dimensions time, latitude, longitude, altitude) in the “model world”.
- Consideration of various aircraft constraints (range, flight altitude, overflight permits...).
- Discussion and iteration of the proposed flight plans with pilots and aircraft representatives.
Mission Support System (MSS)

Software to aid scientific flight planning:
Marc Rautenhaus, formerly DLR, introduced MSS in 2012. It is since May 2016 a git FOSS project on bitbucket.

- Python 2.7.x and 3.6 Client / Server application
- OGC web map service based, version 1.1.1
- conda-forge - anaconda application
- License: Apache 2.0
- Docs: mss.rtfd.io
A web service based tool to plan atmospheric research flights

M. Rautenhaus, G. Bauer, and A. Dörnbrack
Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Correspondence to: M. Rautenhaus (marc.rautenhaus@dlr.de)

Received: 10 August 2011 – Published in Geosci. Model Dev. Discuss.: 1 September 2011
Revised: 13 January 2012 – Accepted: 13 January 2012 – Published: 17 January 2012

Abstract. We present a web service based tool for the planning of atmospheric research flights. The tool provides online access to horizontal maps and vertical cross-sections of numerical weather prediction data and in particular allows the interactive design of a flight route in direct relation to the Taylor's cascade of atmospheric research flight planning is to explore large amounts of atmospheric prediction and observation data in order to extract specific regions of interest. Subsequently, a flight route is designed considering the scientific objectives of the campaign, the predicted atmospheric situation, and ins-
Basic principle of the OGC Web Map Service standard

A client (left) sends a GetMap request, encoded as an HTTP URL to the server (right). The server creates an image file and sends it to the client.

Rautenhaus et al., GMD, 5, 55-71, 2012
Description MSS

- A data center can install the MSS server component and configure it to provide data.
- Already implemented methods for ECMWF, CLaMS, GWFC, EMAC, METEOSAT data.
- The client is a QT 4/5 GUI application which can access many MSS Servers.
- The client accesses the server and requests vertical, horizontal views and receives generated images.
- Scientists interactively design a flight route in direct relation to atmospheric prediction data.
- Way points of a proposed flight route are overlayed on any view of requested data.
- All the information could be exchanged and manipulated by others.
Architecture of MSS WMS Server

client request

WSGI

WMS core

data driver (CF-NetCDF)

file structure

horizontal sections

vertical sections

ECMWF

model 2

visualisation definitions

horizontal sections

temperature

good potential

cloud cover

vertical sections

temperature

horiz. wind

cloud cover

...
Architecture of MSS GUI

Server

Mission Support User Interface

Views

Addons

Result

- top view
- side view
- table view
- Sattelite Track Prediction
- Remote Sensing Tools
- KML Overlay
- aircraft performance hexagon control

flight track
Installing MSS and running Server and Client

$ conda config –add channels conda-forge
$ conda create -n mssenv python=2
$ source activate mssenv
$ conda install mss
$ #demodata and standalone server
$ demodata
$ export PYTHONPATH=~/mss
$ mswms
$ #GUI
$ mss
MSS User Configurations

All defaults can be changed by a json setting file.

- layout sizes of views, immutable sizes
- available map projections
- predefined waypoints
- import/export plugins
- lists of predefined web service URLs and login data
- optional proxy
Top View

A) map projection
B) zoom/pan
C) way points
D) appearance
E) open controls
F) layer / styles
G) time setup
H) new request
Table View and Vertical Flight Profile
Reviewing Data
Features

On Top View you could add different layers
- Satellite Tracks
- Remote Sensing
- KML Overlay

On Table View we have the possibility to add a hexagon flight pattern and to use aircraft performance data.
Example: HALO flight from Kiruna to Oberpfaffenhofen

Top view: Mixing ratios of $\text{N}_2\text{O}$ and $\text{O}_3$:
Example: HALO flight from Kiruna to Oberpfaffenhofen

Side view: Mixing ratios of N₂O and Ozone loss:

Source: POLSTRACC flight planning team
### Examples of campaigns using MSS

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Year</th>
<th>Location</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML-CIRRUS</td>
<td>2014</td>
<td>Oberpfaffenhofen</td>
<td><a href="http://www.pa.op.dlr.de/ML-CIRRUS/">http://www.pa.op.dlr.de/ML-CIRRUS/</a></td>
</tr>
<tr>
<td>POLSTRACC</td>
<td>2016</td>
<td>Kiruna</td>
<td><a href="https://www.polstracc.kit.edu/polstracc">https://www.polstracc.kit.edu/polstracc</a></td>
</tr>
<tr>
<td>NAWDEX</td>
<td>2016</td>
<td>Iceland</td>
<td><a href="http://www.pa.op.dlr.de/nawdex/">http://www.pa.op.dlr.de/nawdex/</a></td>
</tr>
<tr>
<td>WISE</td>
<td>2017</td>
<td>Ireland</td>
<td><a href="https://www.blogs.uni-mainz.de/fb08-ipa/wise/">https://www.blogs.uni-mainz.de/fb08-ipa/wise/</a></td>
</tr>
</tbody>
</table>
Documentation

- http://mss.rtfd.io
- https://bitbucket.org/wxmetvis/mss
- https://anaconda.org/conda-forge/mss
Ecosystem

- bitbucket, github
- pycharm
- quantified code
- py.test
- pypi, anaconda
- conda-forge community
- jenkins, travis, appveyor, circleci
- readthedocs
MSS - Mission Support System

Main Language: Python
Total Lines of Code: 19,580
Active Contributors: 8
Commit Activity

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more at Open Hub