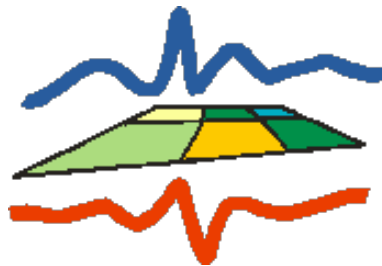


Transregio SFB 32
Subproject D2
Aircraft data from FluxPat campaigns



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Figure 1: Dimona research aircraft above a barley crop in the Selhausen area.

1 FluxPat Campaigns

Idea of the 'fluxes and pattern campaigns' (FluxPat) was to investigate how spatial patterns at the surface propagate into the boundary layer (BL), how temporal patterns develop in the BL and to provide airborne data of the BL for modelers within the TR32 (fig.1). For that purpose flights were performed in the Jülicher Börde around site Selhausen at $50^{\circ}52'9.48''\text{N}$, $6^{\circ}27'3.60''\text{E}$ / 105 m above sea level (ASL) during five campaigns with several flight days in 2008 and 2009 (see Table 1). Campaigns were in spring and late summer (large contrast between wheat and sugar beet fields) and summer (active vegetation). Desired meteorological conditions were fair weather with no clouds and easterly winds. During each flight day many parallel measurements were performed at the ground (turbulent fluxes, soil fluxes, plant physiology). In 2009 additionally radio soundings were performed every hour.

So far three papers have been published that used the airplane data from FluxPat: [Graf et al. (2010)] showed that temperature and humidity fluctuations observed at the surface are related to the respective profiles in the BL. [Reyers et al. (2010)] implemented a photosynthesis model in a regional circulation model and validated it with these aircraft

Table 1: Dates and basic conditions of the three campaigns

Campaign	Days	flights/hours	Conditions
2008 I	22 Apr – 26 Apr	4 / 14	developing winter wheat
2008 II	24 Jun – 2 Jul	6 / 21	wheat in harvest - develop- ing sugar beet
2008 III	9 Aug - 17 Aug	6 / 19	sugar beet to be harvested
2009 I	20 Apr - 24 Apr	5 / 20	developing winter wheat and barley, just seeded sugar beet
2009 II	4 Aug - 19 Aug	6 / 24	senescent or harvested wheat and barley, active sugar beet

data. [Zacharias et al. (2012)] used the aircraft data to investigate the advection term of the heat and moisture budget of the boundary layer in a regional circulation model. A fourth paper [Liu et al. (submitted)] has been submitted and is under review. It uses the data to validate a LES model.

When using the data the following acknowledgement should be used:

Aircraft data presented here stem from the FluxPat campaign from within the TR32 research collaborative. Measurements were made by MetAir Ag (Switzerland). We thank B. Neininger and J.H. Schween for postprocessing and providing the data. The SFB/TR 32 "Pattern in Soil-Vegetation-Atmosphere Systems: Monitoring, Modelling, and Data Assimilation" was funded by the Deutsche Forschungsgemeinschaft (DFG).

2 airplane

Data described here come from the Dimona research aircraft of company MetAir AG under Bruno Neininger. The aircraft is equipped to measure turbulent fluxes of momentum, sensible heat, water vapor and carbon dioxide. Several others parameters are recorded as well (see the the `MetAir_docu_<YYYY>.pdf` files or the netcdf header in the appendix). The airplane flies at a speed over ground of 180km/h , turbulence data are recorded at 10Hz giving a spatial resolution of 5m. Some additional parameters are recorded at 1Hz only giving a spatial resolution of 50m. Recorded raw data were processed by MetAir and delivered as

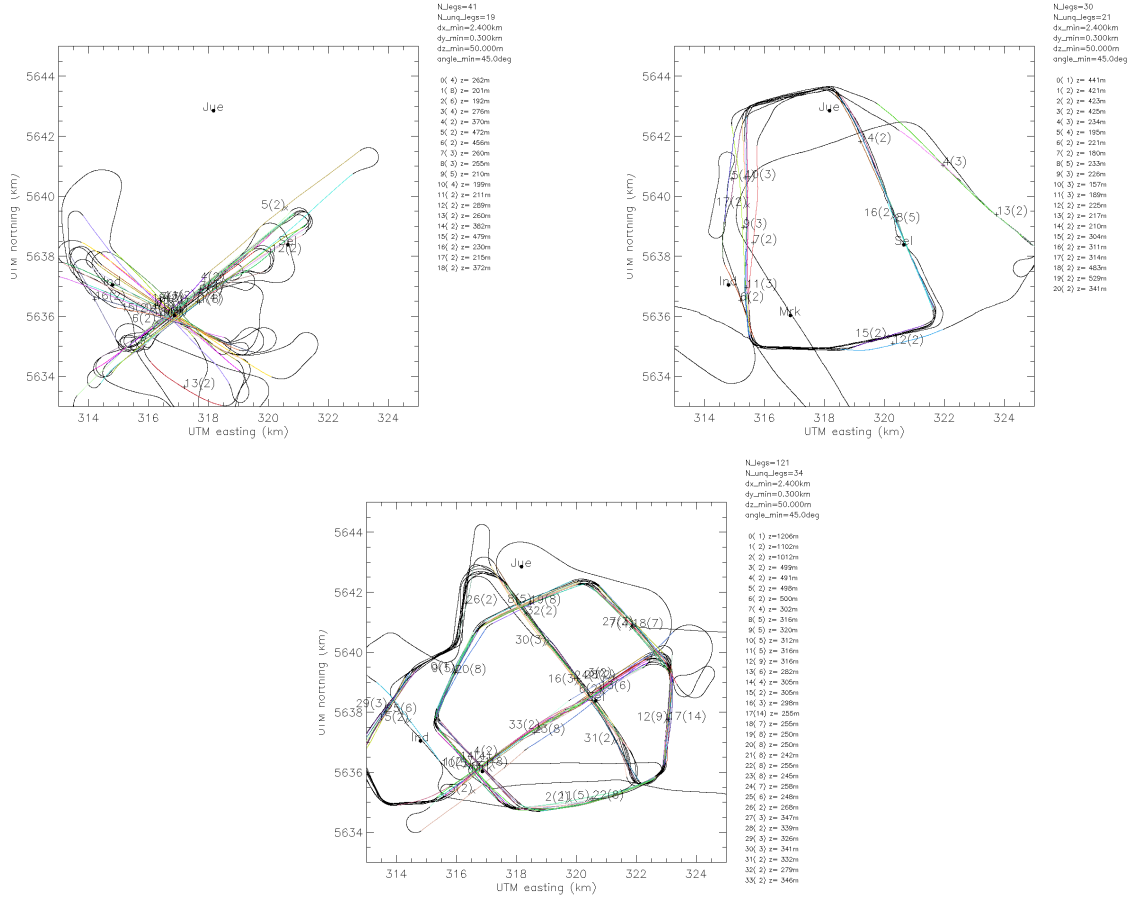


Figure 2: Exemplary flight tracks of type A (top left), B (top right) and C (bottom) from July 1, 2008, April 26, 2008 and August 5, 2009 respectively. Numbers on the track line indicate identified legs together with the number of repetitions (in brackets).

standard ASCII tables. A description of the measured turbulence data is given below, a more detailed description can be found in the documentation files `MetAir_docu_2008.pdf` and `MetAir_docu_2008.pdf` provided by MetAir.

3 flight patterns

Basic idea for the flight patterns was to fly on two levels: one as low as possible and a second around 250m above ground. As there are many restrictions (obstacles like power lines on the flight path, turbulent movement, regulations for low level flights in populated areas, etc.) the lowest flight level was around 70m above ground which could be achieved only for a few seconds. With longer horizontal flight legs with constant level the lowest achievable flight



Figure 3: Five hole probe and LI7500 at the pod below the right wing.

level was 120m above ground.

In 2008 different flight patterns were tested (see fig. 2), most of them consisted of straight legs along and perpendicular to the prevailing wind crossing above the measuring site Selhausen (type A) or Boxes with one side oriented along the wind (type B). It was tried to have the lower flight level as low as possible leading to strongly varying heights.

In 2009 a more or less fix polygonal pattern was flown between the research center in the north, the A4 highway in the south, and the two open pit mines Inden to the west, and Hambach to the east (type C, see 2). Flight levels were fixed to 220m and 350m above sea level i.e. in average 120m and 250m above ground respectively. On August 17, 2008 long legs (type LL) were flown between the TR32 site Selhausen in the Jülicher Börde and the Wüstebach catchment in the Eifel mountains about 70km to the south. The second half of the last flight on August 19, 2009 was used for a map pattern at 1200m ASL during which also aerial photographs of the region were taken.

The airplane started usually in Hangelar 20km NE of Bonn. The transfer from Hangelar to the Selhausen area and back at the end of each flight was used for a profile flight up to the top of the current boundary layer. Thus every flight should have 4 profiles: one ascending from Hangelar, one descending to Selhausen on the way towards Selhausen and two on the way back to Hangelar. In table 2 all flights are listed together with a classification of the flight pattern and a information about the weather situation.

4 measured quantities

The three components of the true air speed vector relative to the airplane are measured with a classical five-hole probe at the nose of a boom on the right-hand under-wing pod (Fig. 3). The movement of the platform (position, 3-d speed, and attitude angles) is measured by a phase sensitive GPS with four antennas (TANS Vector), assisted by 3-axis accelerometers in the boom. The 3D wind components are derived similar to [Crawford and Dobosy (1991)]

Table 2: Time table of dimona flights. N_P and N_R are number of profile flights and radiosondes. Pattern identifier are A for legs crossing over Selhausen, B for boxes, C for a polygon and LL for long legs between Selhausen and Wüstebach.

Date Time [UTC]	N_P/N_R	Pattern	Clouds, Wind, etc.
2008 I			
22.04.2008 12:24 - 15:17	4 / -	B	7/8; N, NE
23.04.2008 08:34 - 12:22	4 / -	B	3/8; SE
26.04.2008 08:09 - 10:30	4 / -	B	7/8; SW
26.04.2008 11:51 - 16:48	4 / -	A+B	6/8; SW
2008 II			
24.06.2008 11:22 - 15:32	4 / -	A	1/8, afternoon increasing Cu; NE
30.06.2008 07:33 - 10:13	4 / -	A	3/8 Cu; weak winds
30.06.2008 11:32 - 16:02	4 / -	A	3/8 Cu; weak winds
01.07.2008 07:27 - 10:26	4 / -	A	0/8; SE
01.07.2008 11:43 - 16:06	4 / -	A	0/8; SE
02.07.2008 07:46 - 12:17	4 / -	A	from 13UTC Cu increasing from 1/8 to 3/8; S,SE
2008 III			
09.08.2008 13:49 - 17:26	4 / -	A	3-5/8 CuCon; not ideal
14.08.2008 07:14 - 10:06	4 / -	A	0/8; SW
14.08.2008 12:23 - 14:26	4 / -	A	3/8 Cu ; S, SW
16.08.2008 07:26 - 10:28	4 / -	A	3/8 Cu and dense Ci; SE
16.08.2008 11:42 - 16:09	6 / -	A	3/8 Cu and dense Ci; SE
17.08.2008 08:15 - 10:46	1 / -	LL	1-6/8 Ac, 0-7/8 Cu; S; destabilization, arriving front
2009 I			
20.04.2009 09:33 - 14:13	4 / 7	C	0/8; NE
21.04.2009 10:01 - 14:36	4 / 6	C	0/8; NE
23.04.2009 11:39 - 15:52	6 / 5	C	6/8; NW
24.04.2009 09:11 - 13:41	5 / 6	C	1/8; SE
24.04.2009 14:57 - 16:57	5 / -	C	1/8; SE
2009 II			
04.08.2009 11:52 - 15:27	4 / 6	C	0/8; weak winds (different directions)
05.08.2009 09:17 - 14:11	4 / 6	C	0/8, in afternoon thin Cirrus; weak SE
06.08.2009 09:17 - 14:17	4 / 6	C	Morning 4/8 Ci , after 12 UTC 0/8 ; morning 1-2 and after 12 UTC 4 m/s E
18.08.2009 10:04 - 14:43	4 / 5	C	max 1/8 small Cu stationary ; 1-2m/s SE-E
19.08.2009 08:48 - 12:19	2 / 5	C	0/8; SE-S 1.5m/s
19.08.2009 13:05 - 14:54	2 / 2	C+Map	0/8; SE-S 1.5m/s

and adjusted in order to overcome the difficulties discussed by [Garman (2006)] and [Garman (2008)], by minimizing the turbulent kinetic energy TKE during the post-processing. Accuracy is 1.0 ms^{-1} and precision $0.2\text{-}0.5 \text{ ms}^{-1}$.

Temperature is measured by a copper-constantan thermocouple with the reference temperature measured by a thermistor in an Aluminum block (Meteolabor, Switzerland). Both sensors are exposed to the airflow below the boom about 25 cm from the nose of the 5-hole-probe. The kinetic correction is derived from ascents and descents in the same air mass. The overall accuracy is about 0.5 K and the precision better than 0.1 K.

Humidity is measured by two sensors: i) a dew point mirror at 1Hz (TP3, Metolab, Switzerland) for an absolute reference; and ii) an infrared open path gas analyzer (LI-7500, Li-Cor, USA) for fast measurements at 10 Hz. The instrument is mounted with its main axis in flight direction on the right side of the right pod, about 50 cm from the five-hole probe (see fig. 3). The instrument is surrounded by a perforated cylinder in order to achieve a homogenous density distribution in the optical path, which is measured and corrected for second order effects. The water vapor mixing ratios from the LI-7500 are then adjusted to the dew point measurements. The accuracy and precision is better than 0.2 gkg^{-1} , and 0.05 gkg^{-1} respectively.

To achieve maximum accuracy for CO₂ measurements a cascade of three measurements is used: i) Air is sampled approximately every 30 minutes in flasks to be analyzed with gas chromatography in the lab for a highly accurate absolute reference, ii) a modified Li-Cor LI-6262 closed path gas analyzer for a continuous slow reference, and iii) for the fast fluctuations at 10 Hz the LI-7500 as described above for the H₂O measurements. Both instruments (LI-7500, and LI-6262) are actively flushed with N₂ in order to avoid hysteresis of the signals (the internal scrubbers which are not sufficient for this purpose were removed). The accuracy of the combined result is better than 0.2 ppm.

A detailed description of the instrumentation can be found in Neininger et al. (2001) and Schmitgen et al. (2004).

5 data files

Data come in separate zip files one for every campaign containing data for every single flight in a subdirectory with the date as name (see table 3). Data for one flight day consist of the original ASCII data files received from MetAir with a temporal resolution of 10Hz (***.10h**) and 1Hz (***.1hz**), a netcdf file processed from the 10hz data (***.10h.nc**, see below) and two plots of the track of the respective flight. Plot **track.png** shows the whole track from start in Hangelar with the identified start- and end-points of legs marked with the individual leg number. The second plot **track_Legs.png** shows the flight track around Selhausen with the identified repeatedly flown legs marked with the leg number.

Original data files from MetAir are ASCII tables with columns separated by TAB characters (ASCII 9). In 2008 filenames start with an uppercase F followed by the date of the

flight in the form YYMMDD and an uppercase A or B for the first or second flight of the day respectively. In 2009 filenames start with the two uppercase letters FR the date and an lowercase a or b for the first or second flight of the day. First two lines form the header containing information about variables and their units in the data table (see table 4).

The files vary from flight to flight with different number-, order- and names of variables. Most of the files from 2008 contain position coordinates from the combined GPS and inertia navigation system as longitude and latitude (names `long` and `lat`) as well as universal transverse Mercator (UTM) coordinates (names `UTMx` and `UTMy`), i.e. km from the equator and a reference meridian. In most of the 2009 data files coordinates come only as longitude and latitude (names `Rlong` and `Rlat`). Coordinates of the first flight 080422a are missing most of the time due to a failure of the GPS. Vertical coordinate is provided in variable `zInt`, integrated from pressure, temperature and GPS measurements. File FR090806a.10h does not contain `zInt` but a height `Ralt` from the GPS measurement. Files F080630A.10h, F080630B.10h and F080701A.10h contain an erroneous file header with one column too much. File FR090804a.10h contains a transfer flight from Switzerland to Hangelar.

For a better data handling the 10Hz files were converted to netcdf format (see the appendix for the content). These files contain those variables which are contained in all *.10h files. If data are missing or of bad quality in the original ASCII files, they were replaced by, or calculated from other variables. Especially Coordinates `UTMx` and `UTMy` in these files where calculated from `Rlong` and `Rlat` if no UTM coordinates where in the original file. Roll angle `rol` is in the two first data files from 2008 rather noisy. In this case an theoretical roll angle was calculated from the second derivative of the UTM coordinates over 1 second time periods to make the leg identification more reliable.

Fluxes should be calculated only when the airplane is in stable orientation and experiences minor accelerations, especially during curves flux calculations are not recommended. For that reason the flight path is split into legs, i.e. straight lines at roughly the same height. These legs were identified by restricting the absolute roll angle to less than 10 degrees, a minimum length of 2.4km and a maximum height interval of 100m during a leg. Indices of start- and end-points of these individual legs can be found in the first two elements of array `i_Leg` inside the netcdf files. Repeatedly flown legs are identified from legs which center position deviates by less than 2.4km along the direction of the leg, 300m perpendicular in the horizontal and 50m in the vertical. The average center point position of these identified legs is given in fields `Leg_UTMx`, `Leg_UTMy` and `Leg_zInt`. The third member of Field `i_Leg` contains the index to this leg fields.

Table 3: Basic structure of the zip files in the database.

```

fluxpat_aircraft_<YYYY>_<i>.zip
  <YYMMDD>[a|b]/
    F[R]<YYMMDD>[A|B|a|b].1hz
    F[R]<YYMMDD>[A|B|a|b].10h
    F[R]<YYMMDD>[A|B|a|b].10h.nc
    plots/
      track.png
      track_Legs.png
  <YYMMDD>[a|b]/
    ...

```

Table 4: First columns of header of two original MetAir data files.

```

fluxpat2008_I/080422a/F080422A.10h
  "stime" "long" "lat" "UTMx" "UTMy" "zInt" "TAS0" "rol" ...
  "[s UTC]" "[]" "[]" "[km]" "[km]" "[mMSL]" "[m/s]" "[]" ...
  ...

fluxpat2009_I/090423a/FR090423a.10h
  "stime" "trig" "Rlong" "Rlat" "zInt" "TAS0" "Rrol" "zGND" ...
  "[s UTC]" "[V]" "[]" "[]" "[mMSL]" "[m/s]" "[]" "[mGND]" ...
  ...

```

6 appendix

netcdf header

Header of one of the netcdf files as received by `ncdump -h`

```
netcdf F080423A.10h {
dimensions:
    N_time = 136966 ;
    N_Legs = 15 ;
    N_Leg_idx = 3 ;
    N_unq_Leg = 12 ;

variables:
    double time(N_time) ;
        time:units = "julian day" ;
    double UTMx(N_time) ;
        UTMx:units = "km" ;
        UTMx:long_name = "UTM easting" ;
        UTMx:missing_value = nan ;
    double UTM_y(N_time) ;
        UTM_y:units = "km" ;
        UTM_y:long_name = "UTM northing" ;
        UTM_y:missing_value = nan ;
    float zInt(N_time) ;
        zInt:units = "m ASL" ;
        zInt:long_name = "height above mean sea level" ;
        zInt:missing_value = nanf ;
    float zGnd(N_time) ;
        zGnd:units = "m above Ground" ;
        zGnd:long_name = "height above ground" ;
        zGnd:missing_value = nanf ;
    float u_wind(N_time) ;
        u_wind:units = "m/s" ;
        u_wind:long_name = "zonal wind speed" ;
        u_wind:missing_value = nanf ;
    float v_wind(N_time) ;
        v_wind:units = "m/s" ;
        v_wind:long_name = "merdional wind speed" ;
        v_wind:missing_value = nanf ;
    float w_wind(N_time) ;
```

```

        w_wind:units = "m/s" ;
        w_wind:long_name = "vertical wind speed" ;
        w_wind:missing_value = nanf ;
float rol(N_time) ;
        rol:units = "deg" ;
        rol:long_name = "roll angle" ;
        rol:missing_value = nanf ;
float T_pot(N_time) ;
        T_pot:units = "degC" ;
        T_pot:long_name = "potential temperature" ;
        T_pot:missing_value = nanf ;
float q_vap(N_time) ;
        q_vap:units = "g/kg" ;
        q_vap:long_name = "water vapor mass mixing ratio" ;
        q_vap:missing_value = nanf ;
float CO2(N_time) ;
        CO2:units = "ppmV" ;
        CO2:long_name = "CO2 concentration" ;
        CO2:missing_value = nanf ;
float press(N_time) ;
        press:units = "hPa" ;
        press:long_name = "air pressure" ;
        press:missing_value = nanf ;
float Tsurf(N_time) ;
        Tsurf:units = "degC" ;
        Tsurf:long_name = "surface Temperature" ;
        Tsurf:missing_value = nanf ;
float aer03(N_time) ;
        aer03:units = "n/ml" ;
        aer03:long_name = "aerosol number concentration for particles > 0.3mi
        aer03:missing_value = nanf ;
float NO2(N_time) ;
        NO2:units = "ppb" ;
        NO2:long_name = "NO2 concentration" ;
        NO2:missing_value = nanf ;
float CO(N_time) ;
        CO:units = "ppb" ;
        CO:long_name = "CO concentration" ;
        CO:missing_value = nanf ;
long i_Leg(N_Leg_idx, N_Legs) ;
        i_Leg:units = "index" ;

```

```

        i_Leg:long_name = "index to begin and end of leg and number of unq le
        i_Leg:missing_value = -1s ;
float Leg_UTMx(N_unq_Leg) ;
        Leg_UTMx:long_name = "UTMx coordinate centered on Leg" ;
        Leg_UTMx:units = "km" ;
float Leg_UTMy(N_unq_Leg) ;
        Leg_UTMy:long_name = "UTMy coordinate centered on Leg" ;
        Leg_UTMy:units = "km" ;
float Leg_zInt(N_unq_Leg) ;
        Leg_zInt:long_name = "z coordinate centered on Leg" ;
        Leg_zInt:units = "m ASL" ;

// global attributes:
        :Creator = "Jan Schween" ;
        :creation_date = "Fri Jul 20 15:27:26 2012" ;
        :Description = "Airborne data from Metair Dimona during TR32 FLUXPAT
                        legs identified, curves excluded." ;
        :original_data_from = "/data/TR32/D2/data/fluxpat/dimona/fluxpat2008_
}

```

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