Fluxes of Heat, Water Vapour and CO2 over the Northern Territory from airborne measurements during the TIPPEX Campaign

Jorg M. Hacker
Flinders University
Airborne Research Australia
2 research aircraft, based at Tipperary Station
- Team of ~10 people
- VH-EOS: 41:05 mission hours; VH-OBS: 55:40 mission hours; both: 96:45 mission hours
- VH-EOS: 34:30 ferry hours; VH-OBS: 34:30 ferry hours; both: 69:00 ferry hours
- Grand total: 165:45 hours flown
- Total amount of raw data: ~1TB

- Atmospheric parameters (BAT with FUST, LiCor 7500, Meteolabor TP3)
  - temperature, humidity, CO2, 3D-wind, turbulence, pressure
- Laser altimeters (Riegl LD90)
- IR surface temperature (Heimann KT15)
- Incoming and outgoing short- and long-wave radiation – radiation balance (Eppley PIR, PSP)
- Flux parameters (H, E, Cm)
- High accuracy CO2 (modified LiCor 6262)

- Full waveform lidar (Riegl Q560)
- Tri-spectral line scanner (AWI/ARA)
- Hyper-spectral scanner (SPECIM AISA+)
- 12Mpix camera (Canon EOS 1Ds)
- PLMR – soil moisture
- PodCams

- Aircraft position and attitude (3 x OXTS RT4003/RT3120 GPS/IMU)
- GPS Base Station (Novatel)
TIPPEX/SIOP
Airborne Flux Measurements
September 2008

Northern Transect
Middle Transect
Southern Transect

Howard Springs Grid
Daly Comparison Transects
Daly Grids
Budget Circles
Dry River Grid
Sturt Plains Grid

FLINDERS UNIVERSITY
ADELAIDE • AUSTRALIA
## OVERVIEW of ARA activities (by day)

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<thead>
<tr>
<th>DATE</th>
<th>EOS</th>
<th>OBS</th>
<th>FLUXES</th>
<th>BUDGET</th>
<th>LIDAR</th>
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<th>CANON</th>
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**OS:** Owen Springs / Alice Springs  
**TP:** Tipperary Station  
**MT:** Middle Transect  
**NT:** Northern Transect  
**ST:** Southern Transect  
**DD:** Douglas Daly area  
**FC:** Flux Comparison runs  
**DUC:** Daly Uncleared Grid  
**MN:** Mount Nancar area  
**RW:** Richard Weinman’s area  
**CO2:** Darwin CO2 profiles  
**BUDGET:** Budget/flux circles near TP  
**HSG:** Howard Springs Grid  
**DRG:** Dry River Grid  
**STG:** Sturt Plains Grid  
**DR:** Daly River  
**AR:** Adelaide River  

**VH-EOS:** “Flux”-Dimona  
**VH-OBS:** “Remote Sensing” and “Budget”-Dimona
Fluxes …… what fluxes?

How does one estimate fluxes from such a data set?
• purpose?
• validity?
• diurnal course?
• cloud?
• other? (“steps”)
• on what scale?

In any case – one needs to process the data first (not the fluxes yet….) -
• tested two independent processing procedures – BN (10Hz) / JMH (20Hz) – very similar results

Then one can start to compute fluxes – and that’s where it becomes difficult -
• averaging length?  Steps?  Filtering?  - no established method (perhaps there is none…)

Then one might want to attempt an intercomparison with “something” -
• flux towers – “dumb” comparison normally not very useful, but one can start with that
• model estimates ?? What does it mean if there are large differences – or if it fits ??
• other estimates ??

Visualisation of fluxes is useful (except perhaps if flux estimates are only used for “dumb” model input) —
(“simple” and probably not necessary for towers, because there are far less variables)

• why visualisation?
  • to be able to link the estimates to features in the landscape
  • to pick up problems
  • to find interesting features
  • more…..

• how to visualise?
  • Google Earth is an attractive and relatively simple framework
  • transect plots showing all parameters measured, including landscape parameters
  • “re-fly” the transects – human eye and brain is most powerful tool to “see things”
Middle Transect
6 Sep – MT1&2
NW-SE: 12:30-13:30LT
SE-NW: 14:00-15:00LT

175km each way

Flying altitude: 25m AGL

Wind:
At first ~4m/s Easterlies, later nearly no mean wind
6 Sep – MT1&2  175km

12:30-13:30LT

Giving way to flock of birds...

14:00-15:00LT

H: 379 W/m²  E: 104 W/m²

Fluxes averaged over 1000m

sensible heat flux  mean: 379.8 W/m²

latent heat flux  mean: 104.0 W/m²

Fluxes averaged over 1km

14:00-15:00LT

H: 316 W/m²  E: 35 W/m²
5 Sep – ST

Sensible Heat Flux (W/m²)

10km averages
Southern Transect
5 Sep – ST1&2
NW-SE: 12:00-13:30LT
SE-NW: 13:30-15:00LT

275km each way

Flying altitude: 25m AGL

Low wind conditions
(~2m/s Easterlies)
6 Sep – ST1&2  275km

**12:00-13:30LT**

- Laser altitude in m AGL: mean: 25.38m
- Canopy in m
- Veg in m
- Bare ground (vegetation removed) in m
- DTM (from SRTM) in m AGL: mean: ??? m

**Flying height (GPS)**

- Distance from start of run in km

**13:30-15:00LT**

- Sensible heat flux: mean: 369.1 W/m²
- Latent heat flux: mean: 60.5 W/m²

**Fluxes averaged over 1000m**

- Fluxes averaged over 1000m

**What's that? A spike in the data messing up the flux?**

**12:00-13:30LT**

- H: 399 W/m²
- E: 61 W/m²

**13:30-15:00LT**

- H: 336 W/m²
- E: 21 W/m²
6 Sep – MT

Sensible Heat Flux (W/m²)

10km averages

SE-NW: 14:00-15:00LT

NW-SE: 12:30-13:30LT
Southern Transect
Having a closer look…
90km section
45km section
TIPPEX - Sep08  0905E_ST1x (12:45:50LT)

- Air temperature (ta) mean: 29.03 degC
- Specific humidity (q) mean: 8.04 g/kg
- CO2 (ppm) mean: 376.8 ppm
- Vertical wind (wair) mean: 0.00 m/s
- Horizontal wind (wair:air) mean: -2.94 m/s; 0.80 m/s

Fluxes averaged over 1000m
- Sensible heat flux mean: 393.1 W/m²
- Latent heat flux mean: 6 W/m²
- CO2 flux mean: 11.9 umol/(m² * s)
- Surface temperature (TsKT) mean: 74.33 degC
- Laser altitude in m AGL mean: 27.54 m

Flying height (GPS) and DTM (from srtm) in m AMSL (mean: ??? m)
7km section
2km section

Very strong thermal – more than 3-times higher vertical velocity than second strongest one;
max \( w = 9 \text{ m/s} \) (at \( z = 30 \text{ m AGL} \));
horizontal gust >10 m/s;
diameter ~70 m;
delta T: >3 deg
2km section

“it was quite a bump….”
Tower Comparison
“dumb” ones at this stage
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<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
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**Daly Uncleared Grid 6 Sep**

6/09/2008

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Aircraft: averages over individual transects of grid (10km – 2.5km lateral spacing),
averages over 1km around tower site and average over all transects.
## Dry River Grid 6 Sep

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<th>Tower</th>
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Aircraft: averages over individual transects of grid (10km – 2.5km lateral spacing), averages over 1km around tower site and average over all transects

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[Map Image]
### Daly 25Yr Intercomparison Transects 6 Sep

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</table>

**Aircraft:** averages over individual transects along same track (5km), averages over 1km around tower site and average over all transects
1km averaged sensible heat flux for successive transects at 10m AGL
DALY 25yr

Tower (296 W/m²)
Grids
1km averaged sensible heat flux for DALY GRID (6 Sep – 11:50-12:30LT)

H in W/m²

ndvi
1 km averaged latent heat flux for DALY GRID (6 Sep – 11:50-12:30LT)

E in W/m²

ndvi
1km averaged CO2 flux for DALY GRID (6 Sep – 11:50-12:30LT)

Cm in 10umol/m2/s

ndvi
Budget Circles
“Re-flying” the patterns
“Re-flying” the pattern using a combination of:

- Google Earth and
- StrePla (gliding software) –
  to be modified to display measured and derived parameters, such as fluxes (currently only showing altitude); also use lidar/tri-spectral/hyper-spectral/other as background maps

Non-aircraft-derived parameters could also be included
RASP

Data from less than 5 mins of flight in Sep 09 over the Daly River:

• wLIDAR
• Tri-spectral scanner
• hyper-spectral scanner
• hi-res digital photography
RASP

Open Source

Written in Free Pascal

Runs under Windows, Linux, MacOS, others

Paired with ARA’s two other opens source packages (RAMF/R12 and PPREP)
It offers a totally integrated system to process and combine all ARA aircraft data
To a stage, where “scientific” processing can start (and beyond)

Batch/script-driven
Rudimentary GUI
Conclusions
• Aircraft-derived flux measurements are very different to tower-based ones

• need to inspect every transect and make subjective decision about validity

• there is no “standard” method to compute fluxes

• needs to be tied to landscape parameters – visualisation essential – interactive process

• great potential to study “convective processes in the landscape”

• no other flux tool can do that

• especially in combination with other measurements derived simultaneously
  • laser altimeter; lidar; tri/hyper-spectral scanners; micro-wave scanners
  • complex processing – no standards available

• change of turbulence structure depending on landscape parameters

In summary: There is a lot more that **CAN** be done with this data than is being done !!