IKP2 Data Processing, Cayenne 2015

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Summary of Data

- Flights 9-26 were flown in Cayenne (18 flights)
  - Flight 9 is a Radar Calibration – no in cloud data, didn't process
  - IKP2 processed for 17 flights (10-26)

- Version 3 IKP2 data distributed to LaMP on 19-Oct-15, and deposited on NCAR archive on 23-Oct-15.
  - Draft data set, not for publication
  - Uses SAFIRE state parameter data distributed during the flight program – waiting for quality controlled data set to produce official IKP2 data set.
  - Initial climb and final descent excluded (due to background humidity, explained later in this presentation)

- IKP2 functioned well during program – only a few periods of blanked out data, mostly due to a few periods of loss of flow control
  - Most of flight # 19 needs further discussion

Periods of bad flight-level IKP2 data

	IKP Data Problem				
Flight #	Stim	Etime	D t (min)	D t @ alt (min)	Problem Description
10	20:03:11	20:03:29	0.30	327	IKP flow valve problem (out of cloud)
	20:10:50	20:11:15	0.42		IKP flow valve problem (out of cloud)
11	20:42:33	20:42:42	0.15	95	IKP flow valve problem (in IWC >~0.7 gm-3 during blanked period, inside a HIWC region peaking outside blanked period at 2.8 gm-3)
12-16				714	OK
17	15:49:24	15:49:33	0.15	135	IKP flow valve problem (in cloud, IWC in blanked period ~ 0.6 gm-3; cloud peaks outside blanked period ~2.5 gm-3); EAT drops 4 C, re-establishes after ~ 5 minutes
18				160	OK
19	18:23:10	18:24:14	1.07	177	IKP flow valve problem (in low IWC cloud in blanked period ~0.25 gm-3) – V1 for F#19
	15:41:00	18:38:00	177.00		**Tip temperature bad, drops 17:08-18:23, Stage 1 Evaporative powers low and unusual, but EAT OK – V2 for F#19**
20-21				312	OK
22	10:43:30	10:53:27	9.95	166	IKP flow valve problem (in moderate IWC in blanked period ~ 0.4 gm-3, peak ~ 1 gm-3 in blank period) , Alfons' robust data only data for 10:50:10-10:53:29 during restart M300, still in cloud
23-26				624	
					V1 and V2 are for different assumptions about F#19
Totals		V1	12.03	2710	
		V2	187.97		
		pctv1	99.56		Percentage of time at altitude with good data
		pctv2	93.06		

Conclusions:

- IKP failure frequency low
- Need to look carefully at flight 19 – need Alfons' F19 robust data to verify IKP is OK

Performance of new background humidity system

- In Darwin-2014, the background humidity (part of the calculation of IKP TWC) was found to be compromised due to the following primary issues:
    - Wetting of ceiling inlet by rain before takeoff (sometimes did not dry out until half way through flight)
    - Ingestion of ice crystals – elevated and contaminated background humidity
    - A secondary issue was the synchronization of the IKP humidity measurement and the background humidity measurement; sampling time and synchronization differences led to substantial 'noise' in the computed IKP TWC baseline outside of cloud.
- A new inlet system was designed for the Falcon-20 for Cayenne-2015. Ready just before Cayenne, limited testing
- Features:
    - Relatively high speed main flow with tap-offs for background Licor and WVSS-2; flowmeter/valve for setting flows of each
    - Desiccant cartridge for purging lines with dry air (after takeoff primarily), and possibly for 'zero' level of Licors at altitude
    - Reverse-flow inlet on belly of aircraft to help mitigate ingestion of ice crystals

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Results of new background humidity system – keeping inlets dry

- Efforts to keep lines dry with belly-mounted inlet and desiccant-purge on initial climb successful:
  - On each flight, lines were dry and ready to sample when at altitude

- New problem was found with deep descents into boundary layer:
  - Higher flow through lines of new system led to chilling of lines and condensation in lines on the deep descents (did not affect descents between -50 and -10 C during data collection)
  - Using dry-air purge during final descent, able to keep lines dry for next flight
  - Dry-air purge was adopted for final descent on all flights.

Results of new background humidity system – desiccant zero at altitude

- Efforts to use desiccant cartridges as source of dry air for ‘zero’ reading at altitude were unsuccessful:
  - Licor readings sometimes increased when air supplied through cartridges: possibly desiccant de-gassed H_2O at very low humidity at altitude and low pressure
  - Disruption of flows in background system sometimes led to small step changes in Licor readings at altitude.
- Decision to abandon use of desiccant cartridges for ‘zero’ readings at altitude – needs more testing and possible use of N_2 rather than desiccant air source.
- minimum disruption of flight data by testing in the air during Cayenne

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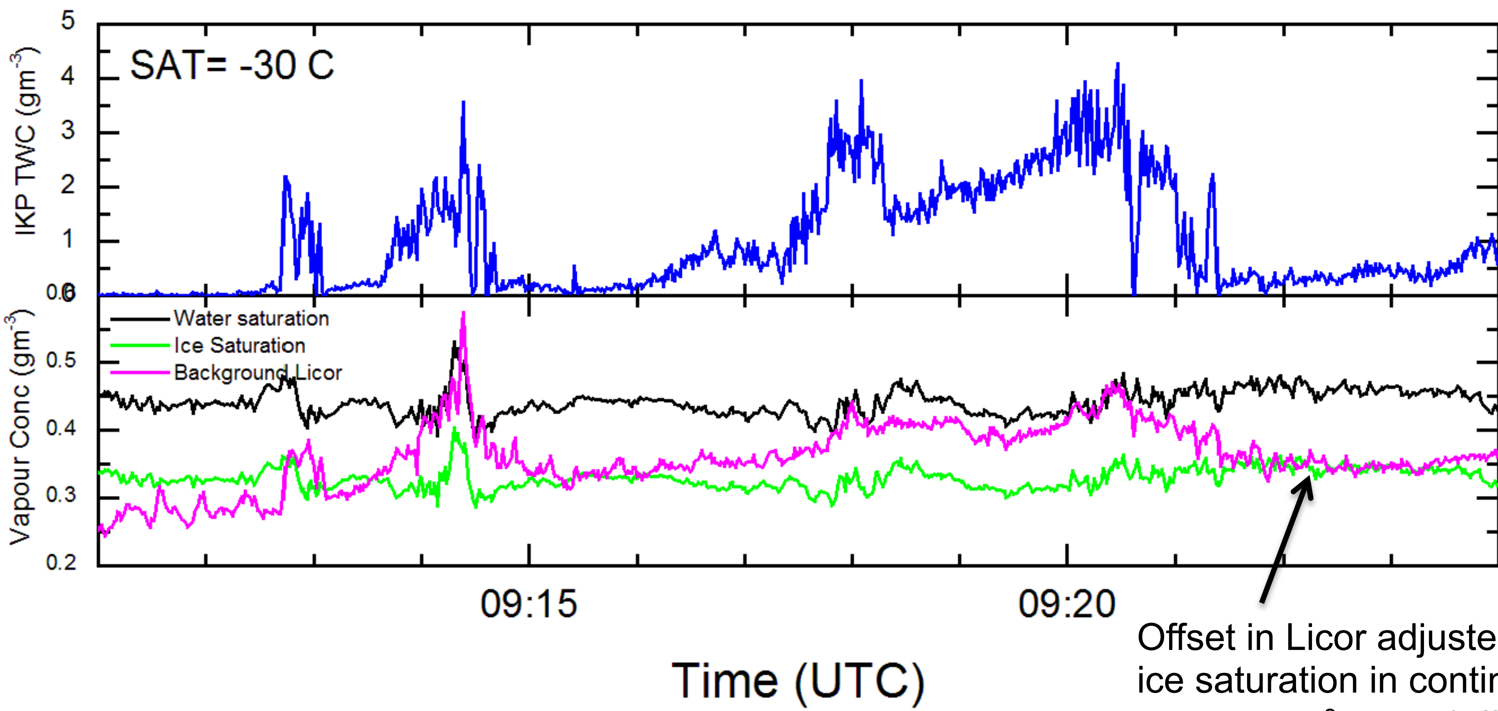
Results of new background humidity system – ice crystal ingestion

- Ice crystal ingestion through the reverse-flow inlet appears to have been improved, but probably not eliminated
- Very often looks like below

Flight #C24, 27-May-15, Background humidity in cloud

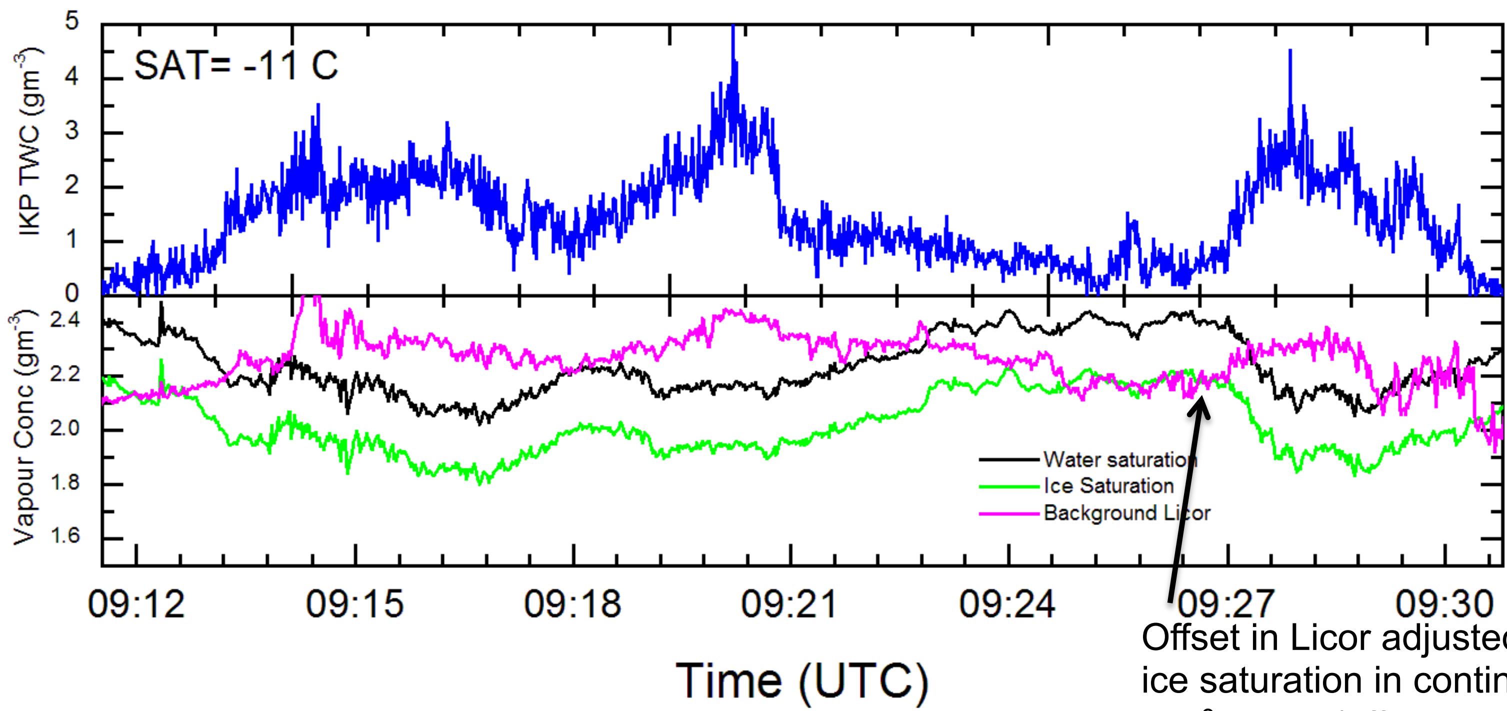


Offset in Licor adjusted to give ice saturation in continuous 0.1-0.2 gm^{-3} cloud (offset=0.08 gm^{-3})

Results of new background humidity system – ice crystal ingestion (cntd)

- Example where background Licor appears to significantly exceed even water saturation in cloud
- Still are cases where background humidity on cloud climbs to unreasonably high values, especially for -10 C runs

Flight #C22, 26-May-15, Background humidity in cloud



Offset in Licor adjusted to give ice saturation in continuous ~0.5 gm^{-3} cloud (offset=0.07 gm^{-3})

Results of new background humidity system – ice crystal ingestion (cntd)

Conclusions about ice crystal ingestion:

- Better than Darwin-2014, but still some evidence, especially in warmer HIWC runs, of background humidity rising well above water saturation (i.e. probably ice ingestion into air lines)
- Decision: use ice saturation for in-cloud humidity as in the case of Darwin-2014
- Basic uncertainty in TWC due to the fact that humidity may be between ice saturation and water saturation

Primary level	e_s (gm^{-3})	e_i (gm^{-3})	e_s-e_i (gm^{-3}) (uncertainty)
-10 C	2.37	2.15	0.22
-30 C	0.45	0.34	0.11
-40 C	0.18	0.12	0.06
-50 C		0.038	

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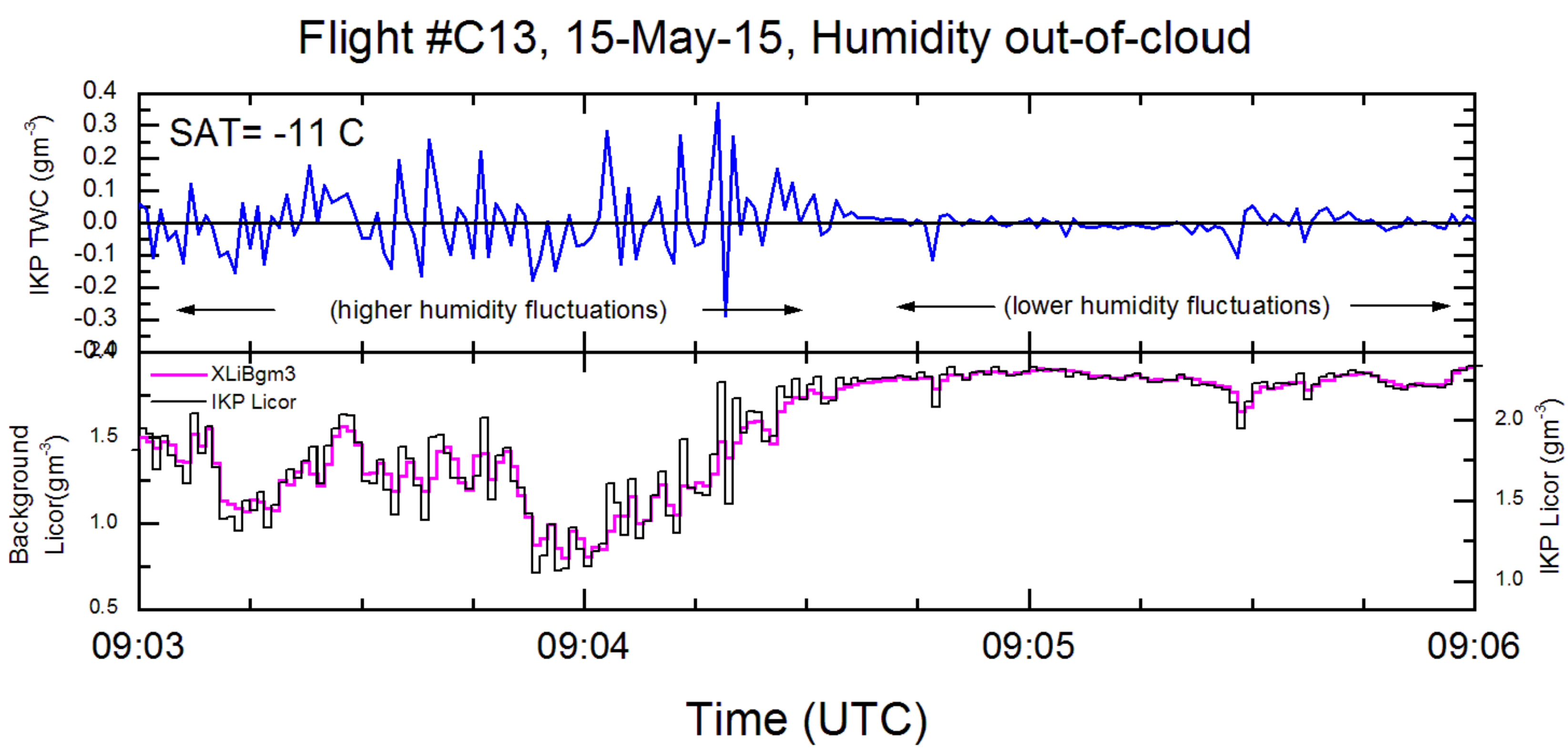
Results of new background humidity system – humidity synchronization

- In turbulent conditions, and high humidity, subtraction of background Licor from IKP Licor can lead to noisy baseline in clear-air conditions
- Below is a case of a bad fluctuation case from Cayenne, at -11 C (±0.3 gm^{-3})
- Background Licor (magenta) trace is very similar to an average of the current IKP Licor point and the next (i.e. fluctuations are smoothed out on background Licor)



Results of new background humidity system – humidity synchronization

- The noisy baseline appears to be independent of which Licor unit is used, and my subjective impression is that it is worse in Cayenne than it was in Darwin

- Current leading explanation of why worse than Darwin:

  - New inlet system has ‘reservoir’, or capacitive effect due to expanded volumes in flow valve and manifold in lines before the Licor. Tends to average out fluctuations
  - Size of these reservoirs is being investigated to determine if they are adequate to explain observations.

- This behaviour mainly affects out-of-cloud measurements, as ice saturation is assumed for in-cloud TWC calculations, and humidity variations in cloud are smaller than out of cloud. Uncertainty in cloud TWCs is then determined by possible variations between ice and water saturation as described in earlier slide (rather than differences between the two Licors).

Flow diagram of inlet system

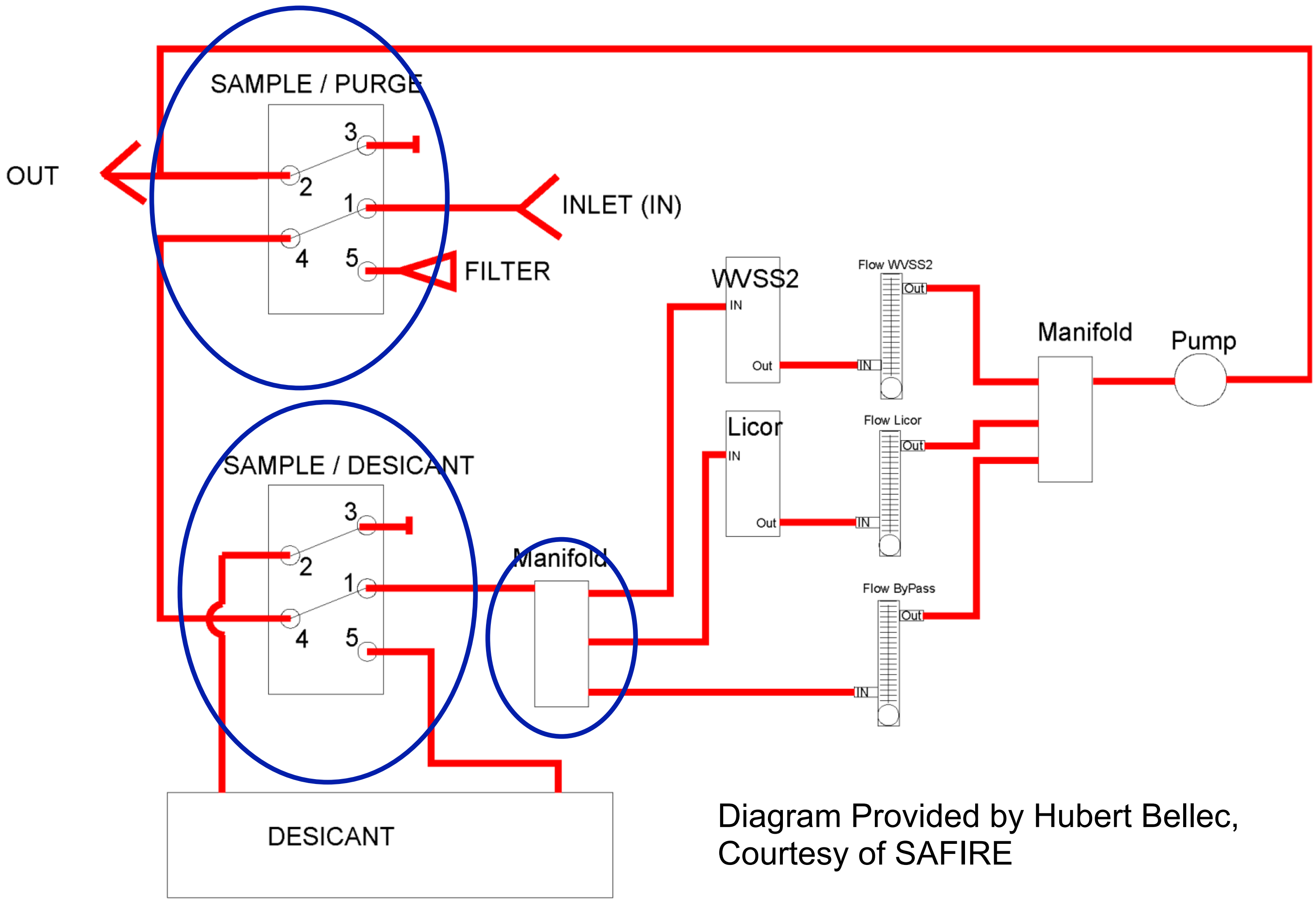
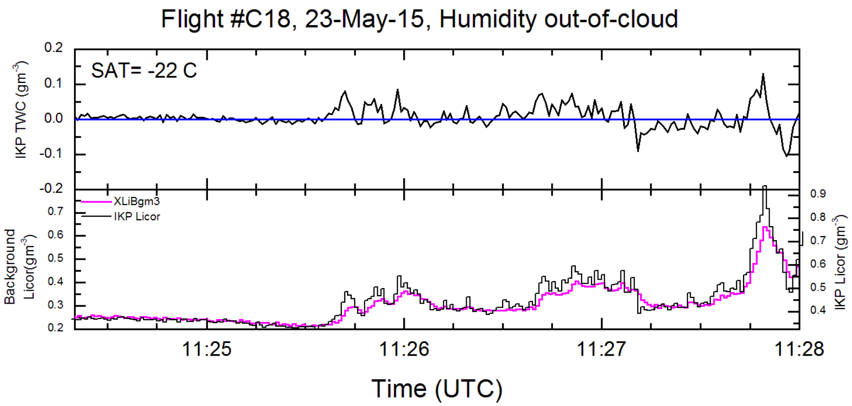
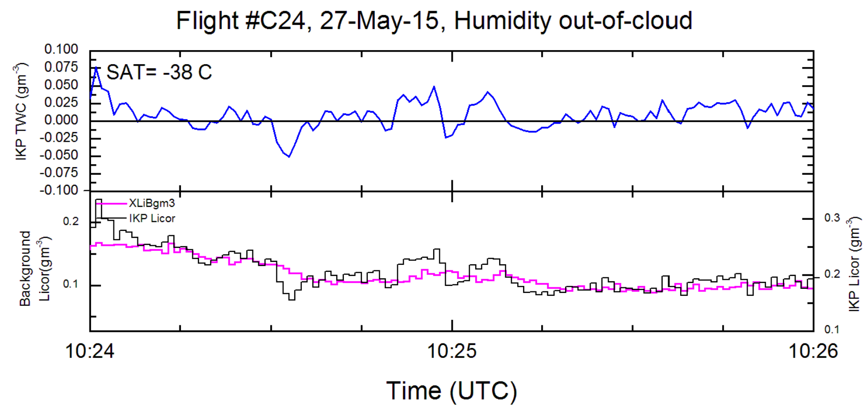
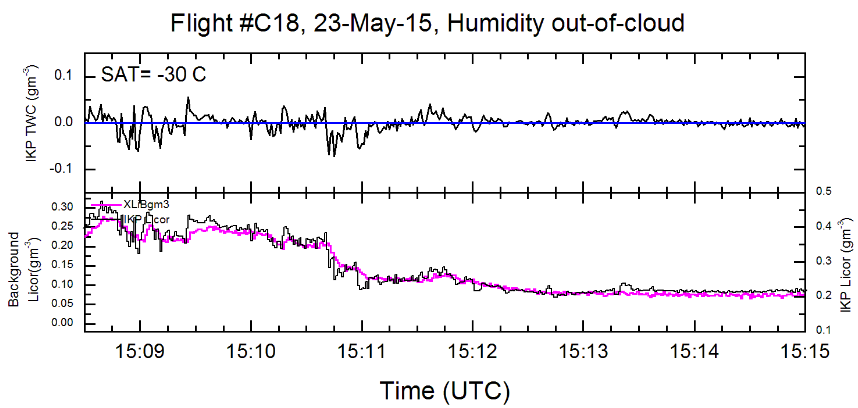


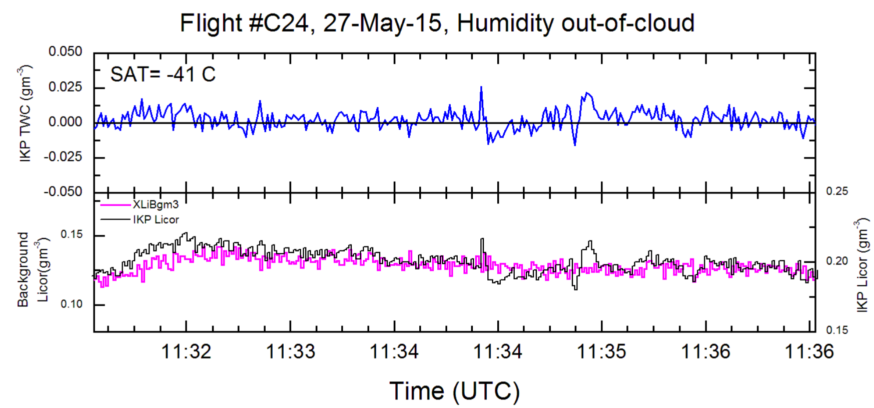
Diagram Provided by Hubert Bellec,
Courtesy of SAFIRE

Some example noise out-of-cloud TWC baselines:



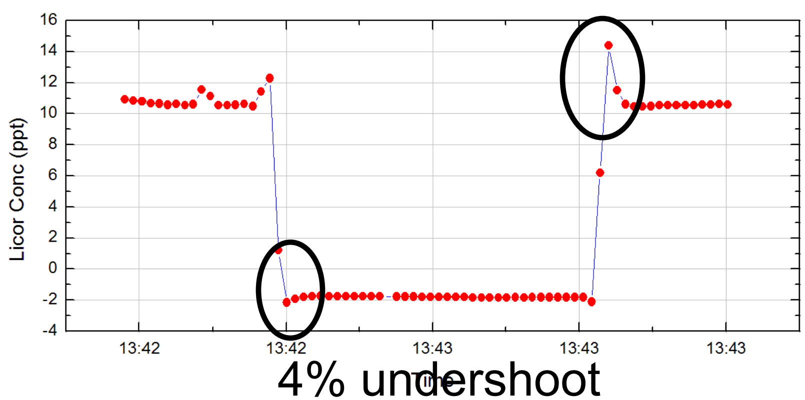


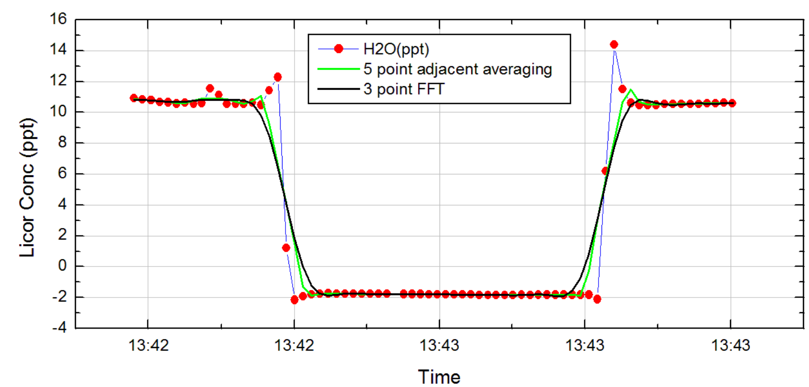




IKP Licor overshoots and undershoots during step changes in humidity

- Undershoots noticed in tunnel testing, and overshoots brought to our attention by Tom Ratvasky during NASA testing of Licors in October 2015
- Humidity overshoots during both positive and negative humidity step changes;
  - overshoot appears to be proportional to step change amount
  - In raw adsorption data, not just Licor processed ppm values
- Appears to be on all Licors (IKP, and all the background versions)
- Not noticed in Darwin-2014, but probably there based on wind tunnel measurements around that time.





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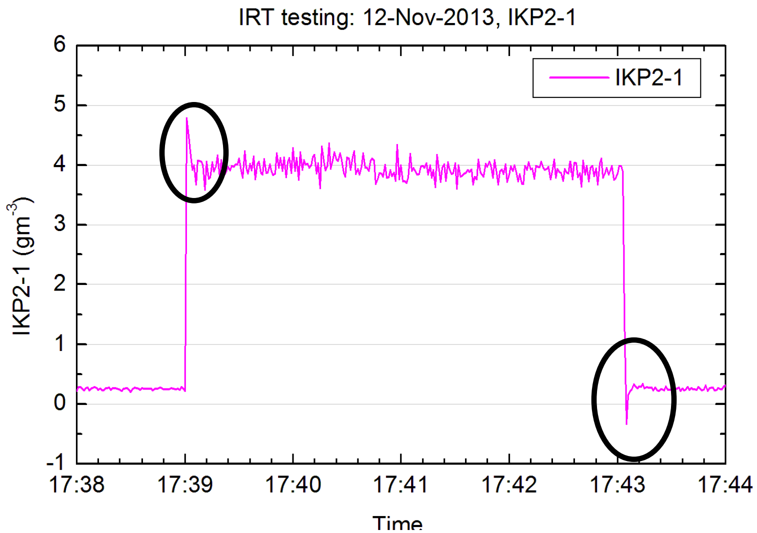
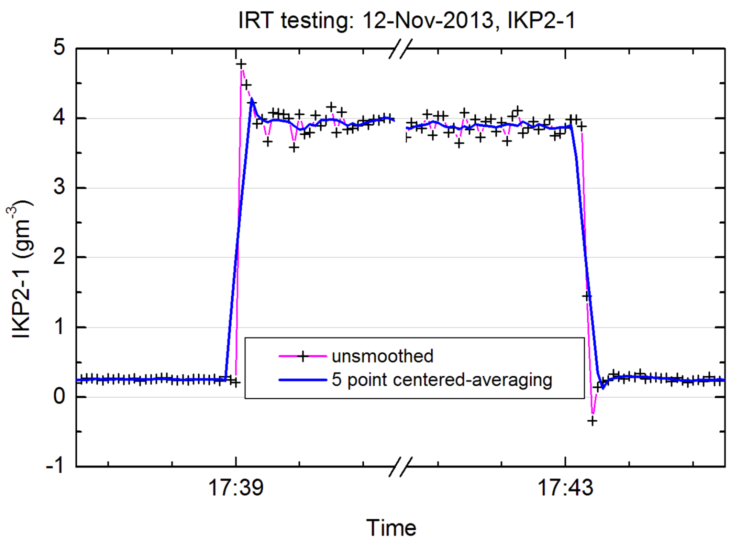
IKP Licor overshoots and undershoots evidence from IRT tests 2013 (before Darwin) – IKP2-1



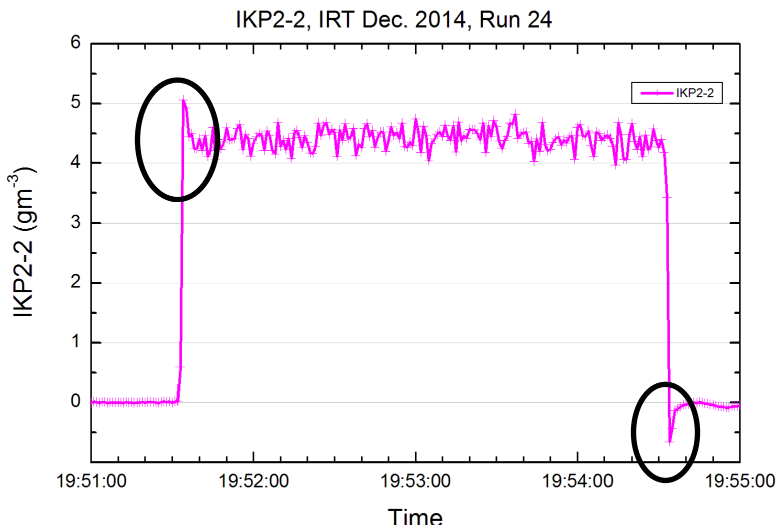
- ~24% overshoot
- ~16% undershoot

- This one was used on Falcon-20

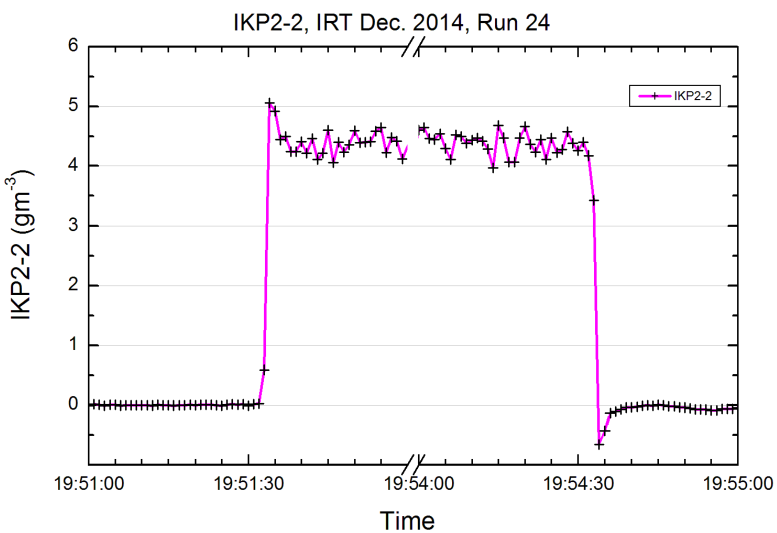


- Same data as above, but with break in X axis, and individual 1-second points
- Affects about 4 seconds of data after overshoot
- 5 point centered-averaging also shown (blue)

IKP Licor overshoots and undershoots evidence from IRT tests 2014 (before Cayenne)- IKP2-2

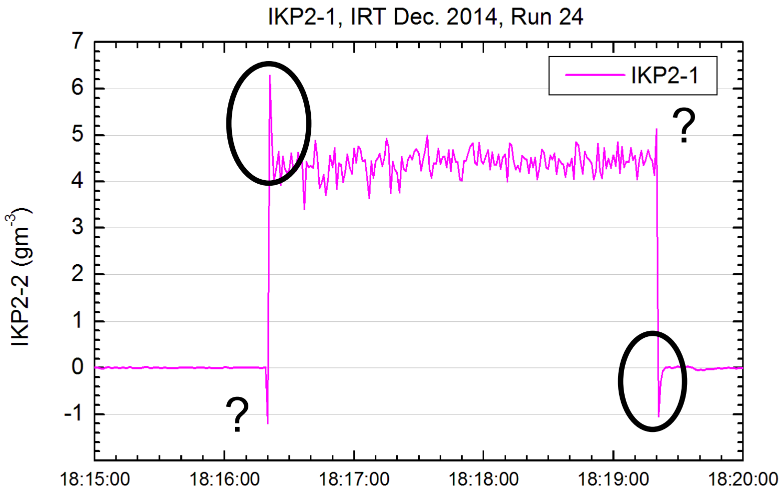


- ~15% overshoot
- ~15% undershoot

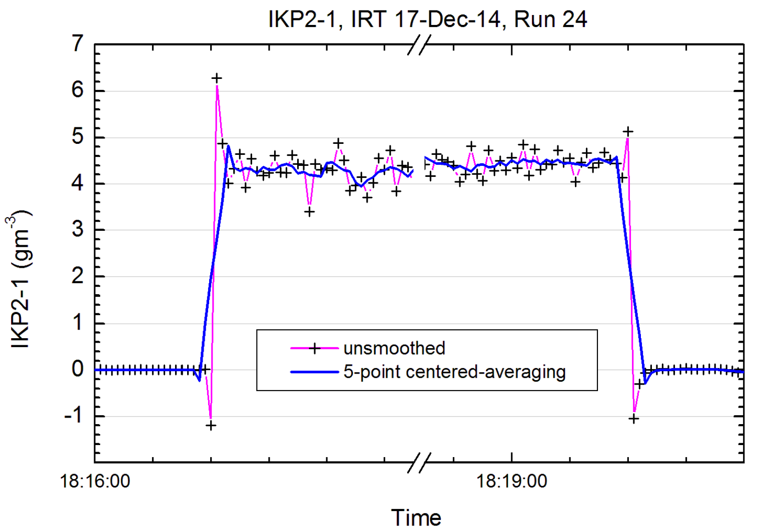


- Same data as above, but with break in X axis, and individual 1-second points
- Affects after about 5 seconds of data

IKP Licor overshoots and undershoots evidence from IRT tests 2014 (before Cayenne) – IKP2-1

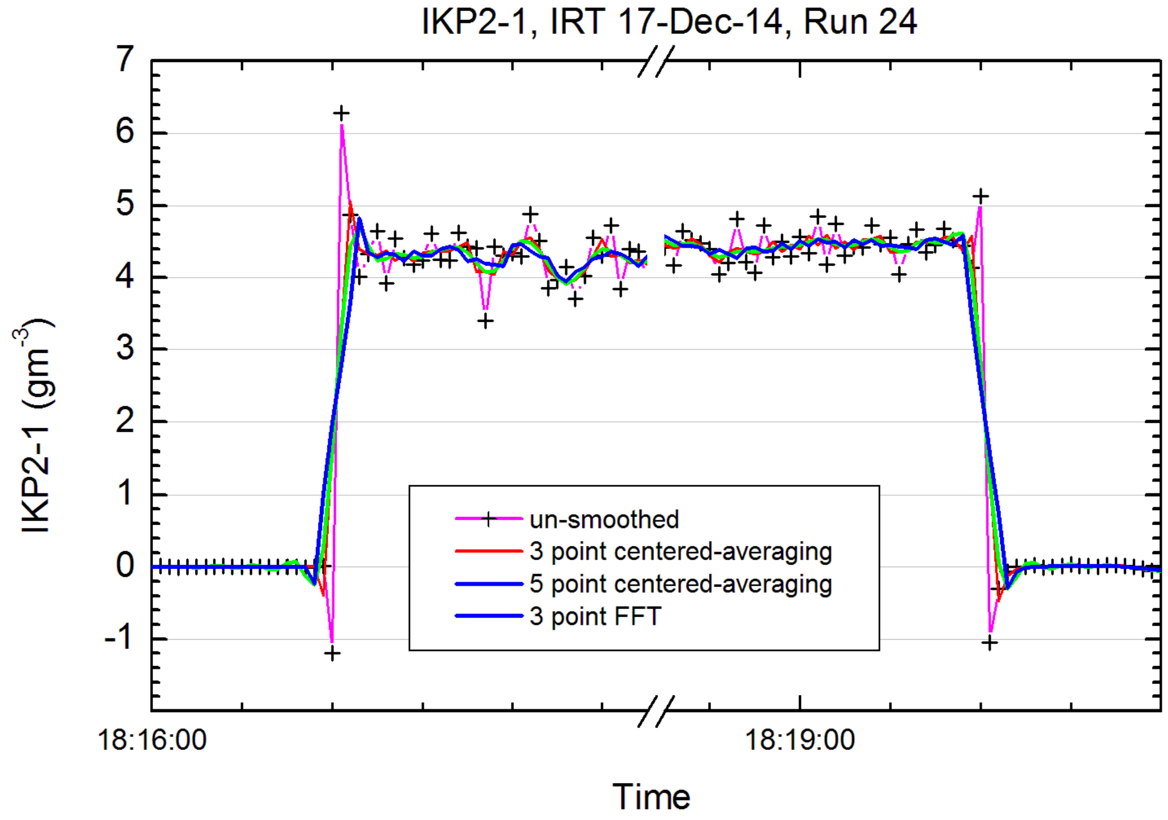


- ~30% overshoot
- ~25% undershoot
- This one was used on Falcon-20

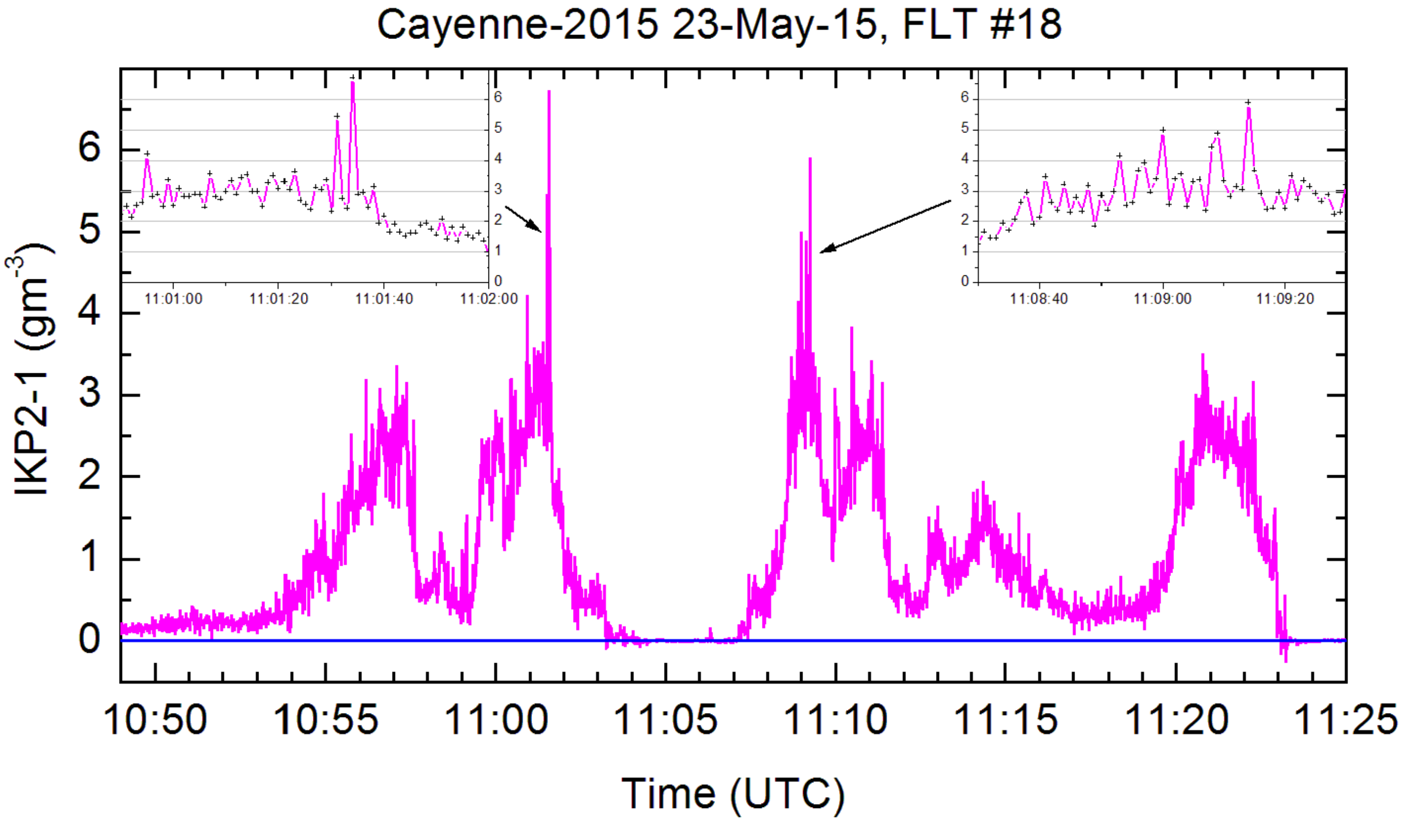


- Same data as above, but with break in X axis, and individual 1-second points
- Affects after about 3-4 seconds of data
- 5 point filter centered-averaging also shown

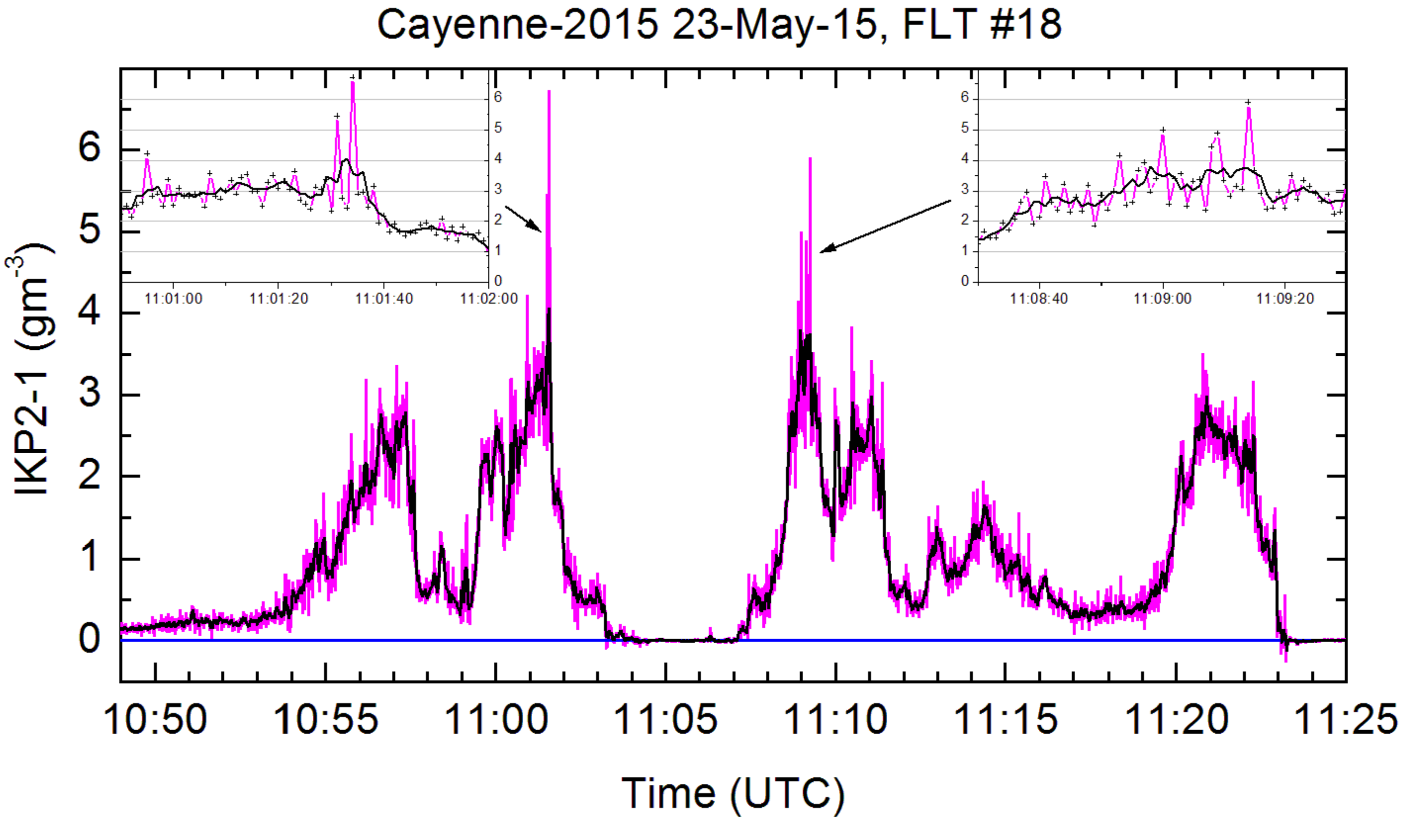
More smoothing examples



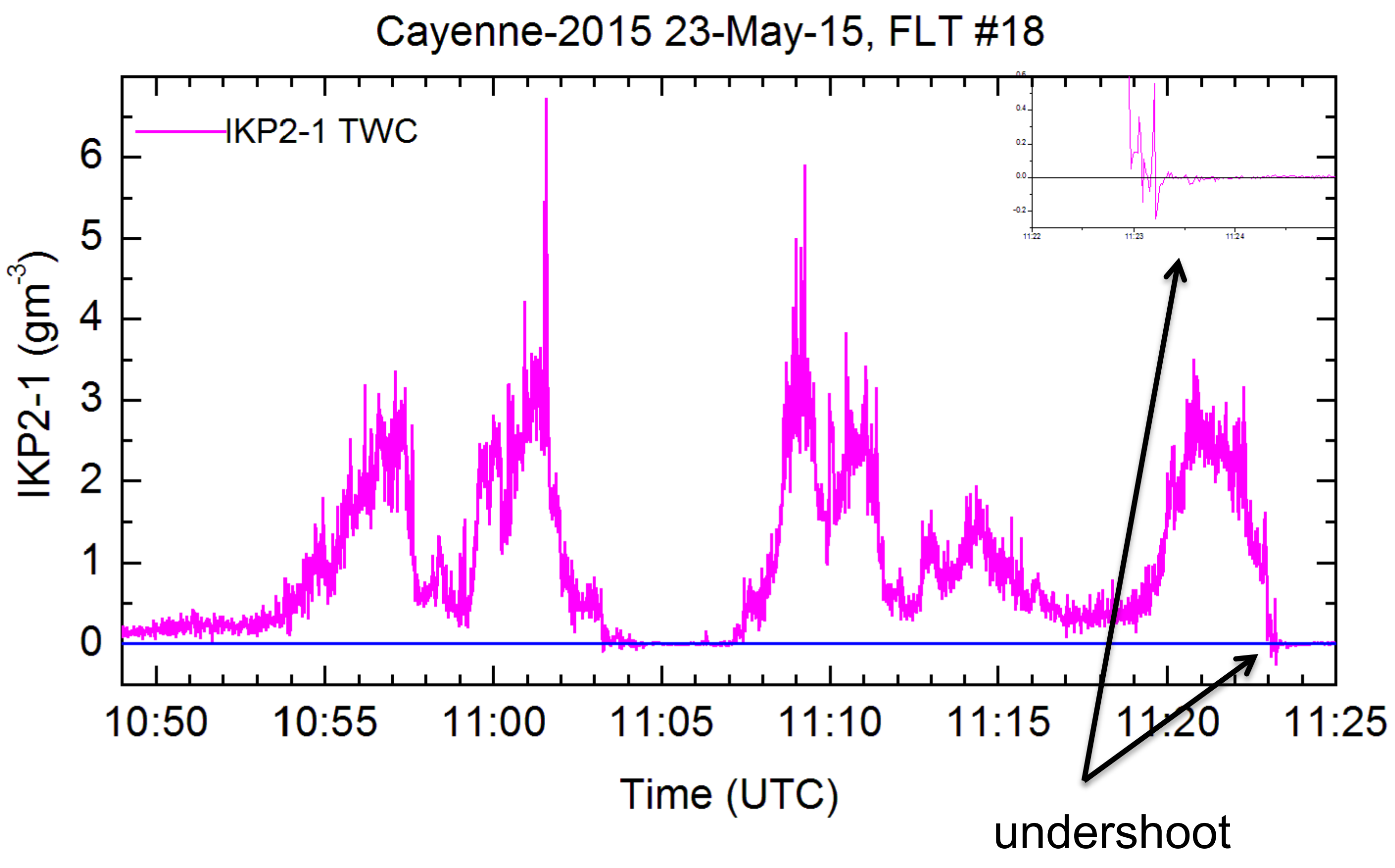
HIWC Case from Cayenne-2015(CAY15)



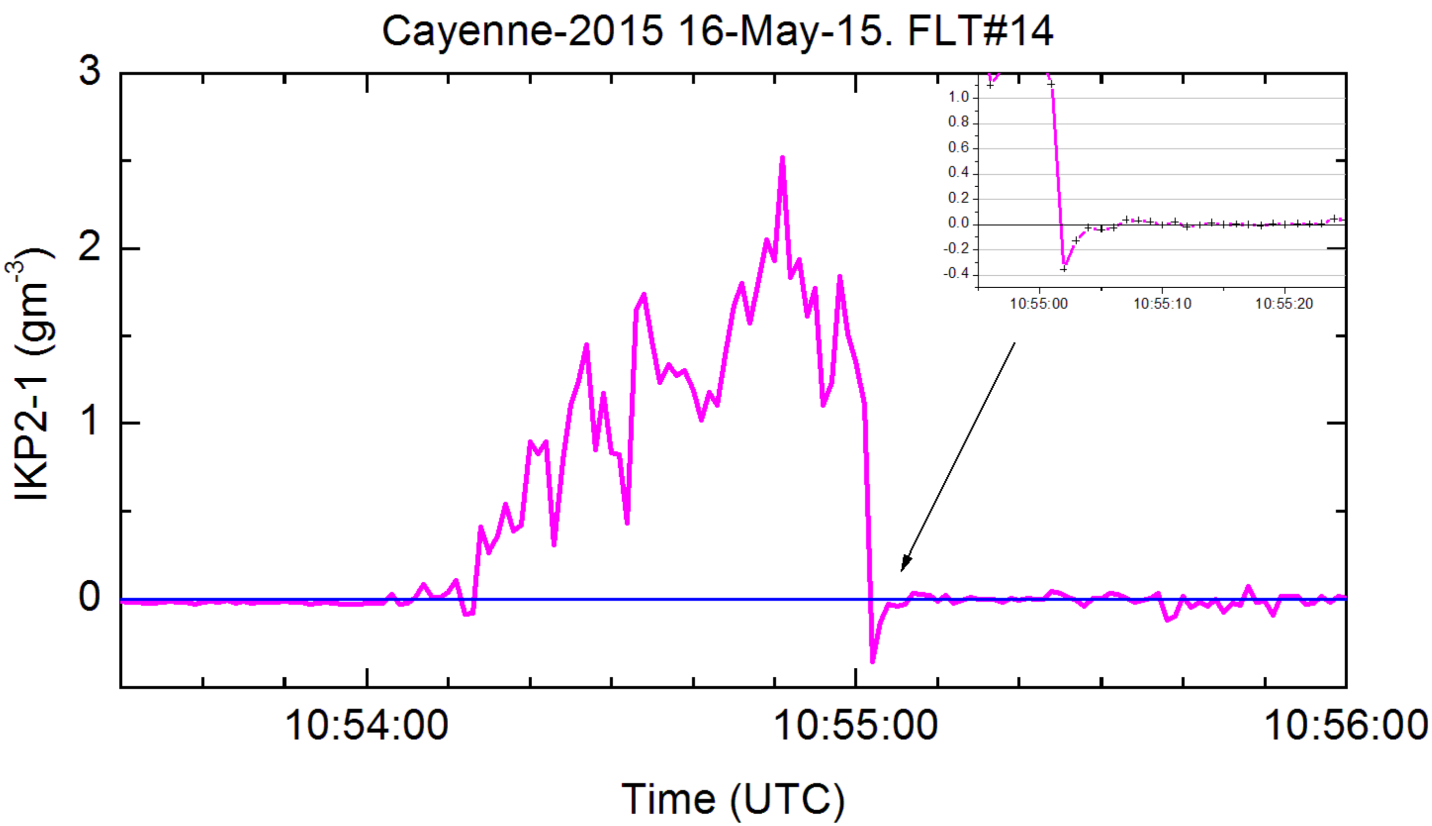
HIWC Case from Cayenne-2015(CAY15); with 5-point centered average (black)



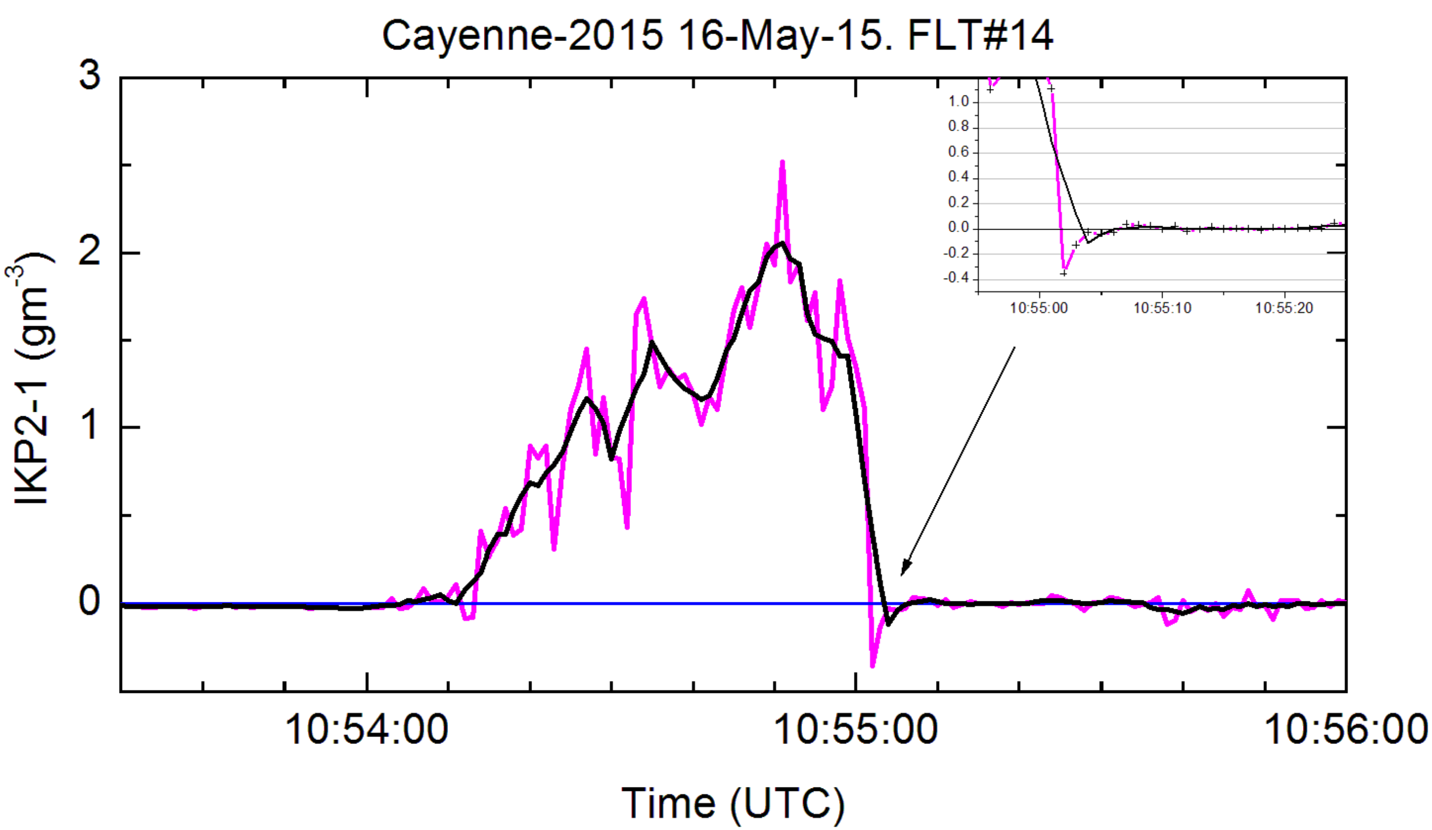
HIWC Case from Cayenne-2015(CAY15)



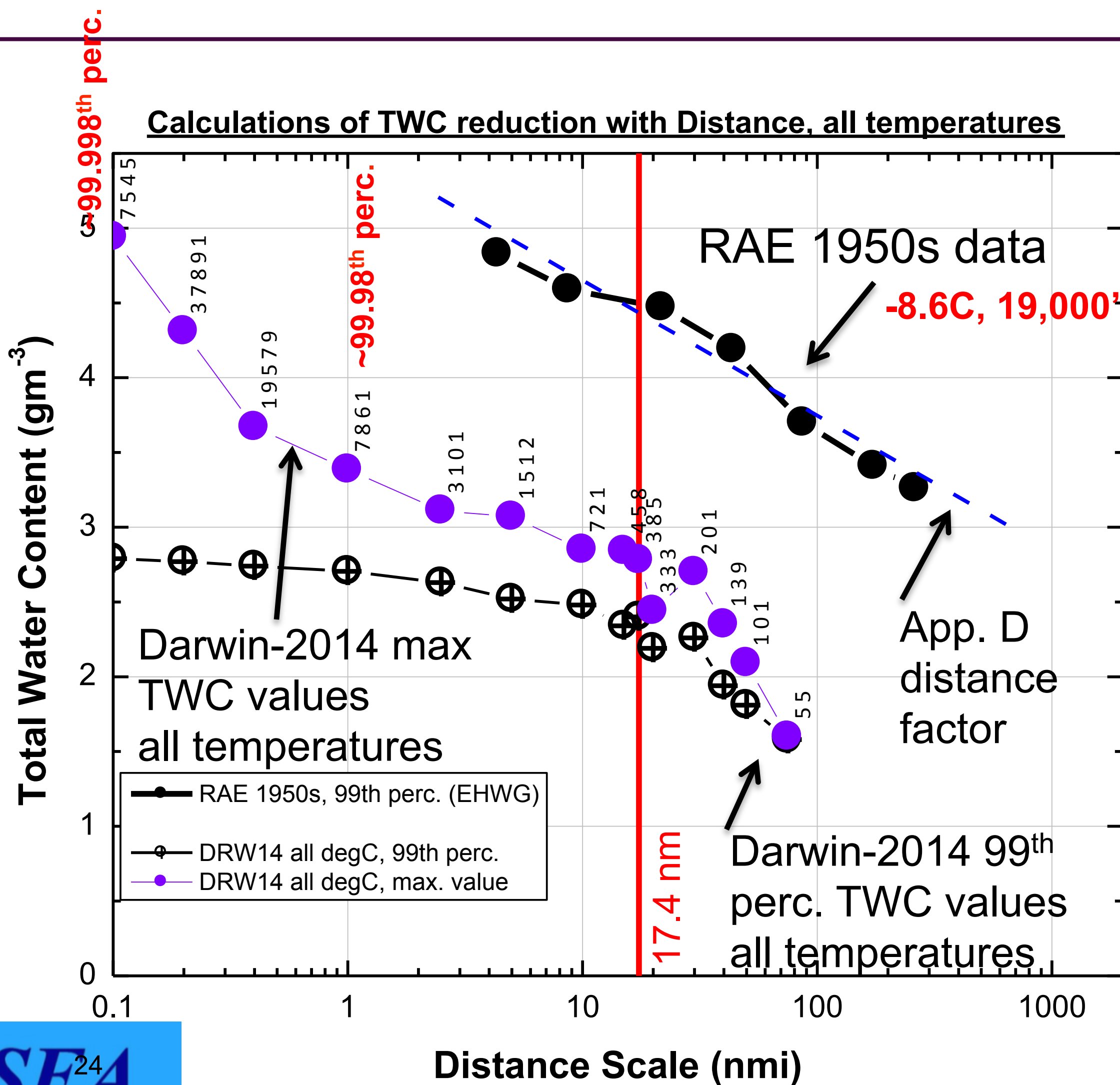
HIWC undershoot Case from Cayenne-2015



HIWC undershoot Case from Cayenne-2015 with 5-second centered averaging



Appendix D TWC Darwin-2014 :
TWC roll-off with distance scale– all temperatures



SUMMARY (p1)

- Draft IKP2 Cayenne data distributed 18-Oct-15; new release after completion of SAFIRE state parameter data
- Basic functionality of IKP2 good; fewer cases of lost data than Darwin

- New background humidity system a mixed success
  - Purge system kept lines dry so background humidity always ready at altitude (better than Darwin)
  - New inlet appears to be better at eliminating ice ingestion, but still problem in high IWC, especially at -10 C
    - Draft IKP2 data uses ice saturation for background humidity
    - Basic uncertainty in TWC is e_s (gm^{-3}) – e_i (gm^{-3})
  - For clear-air, synchronization errors between IKP and background Licors leads to noisy baseline out-of-cloud – impression that it may be worse than Darwin
    - Doesn't affect in-cloud TWCs because ice saturation used

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SUMMARY (p2)

- New problem identified with overshoot and undershoots of IKP2 signal
  - In raw data and cannot be recovered by re-processing from raw signals
  - In both Darwin and Cayenne data, but significantly worse in Cayenne (function of Licor used?)
  - Will lead to over-estimation of extreme values by ~30% (Dec. 2014 IRT testing) for 1 Hz data
  - Filtering (5 second) appears to mitigate most of problem, need to investigate low-pass filter to see if any advantage
  - Undershoots of up to ~0.3 gm^{-3} common when exiting cloud.
    - Should I leave these in the data or artificially remove them?
    - 5-second filtering minimizes the undershoots.

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End of Presentation

Merci, Thank You

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Effect of 1 C change in SAT on ice saturation

Assuming: $SAT_{meas} - SAT_{true} = 1$ C

Primary Level SAT_{meas} (C)	Ei change (gm^{-3})
-10	0.176
-30	0.032
-40	0.012
-50	0.004