IKP2 Data Processing, Status Review (Falcon-20) Darwin-2014 and Cayenne-2015

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16-May-2016

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Summary of Data – Darwin-2014

- 23 flights, 18-Jan. to 18-Feb. 2014, F-20 only
- Issues: inlet problems for background water vapour (BWV); wetting and ice crystal ingestion, bad inlet
  - Most data from -30 C and colder, so BWV is relatively low
  - Assumed ice saturation in cloud for current version of IKP2
    - Probably no way to improve BWV subtraction, no plans to change but will review given new experience with Cayenne
    - Will estimate uncertainties in ice saturation estimate, after discussions with Korolev
    - Expect only small effect on 99th percentiles
  - LICOR overshoot issue (discussed later), may affect high frequency data (> 5 second average data very small effect)
- Possible re-issue of new data set for attempted overshoot correction ????? ;

Summary of Data – Cayenne-2015

- 18 Falcon-20 flights (17 with in-situ cloud data), 10-29 May 2015,
- 12 Convair 580 flights (Convair IKP2 to be discussed separately by Korolev)
- Falcon-20 IKP2 functioned well during program – only a few periods of blanked out data, mostly due to a few periods of loss of flow control
- More runs at -10 C and -50 C than Darwin-2014
- Draft Version 3 of IKP2 data distributed Oct. 2015, not for publication
  - Background water vapour improved over Darwin, but not yet fully assessed for use in IKP2 calculation, especially at -10 C
  - Draft 3 uses ice saturation, consistent with Darwin-2014 data
  - Used SAFIRE data set produced during field project
- Remaining issues:
  - Flight 19 had some loss of control of tip temperature and general power management issues. Looks OK but need to compare with CNRS robust hot-wire data to confirm.
  - Currently proposing using ice saturation for BWV in official version, and comparing to second IKP2 TWC value using LICOR background as uncertainty estimate (TBD)
  - LICOR overshoot issue (discussed later), may affect high frequency data
- New version of data may be released after checking SAFIRE data set for changes, and after checking Flight 19.
- New version of data may be released with attempted overshoot correction ????? ; very small effect for > 5 second averages

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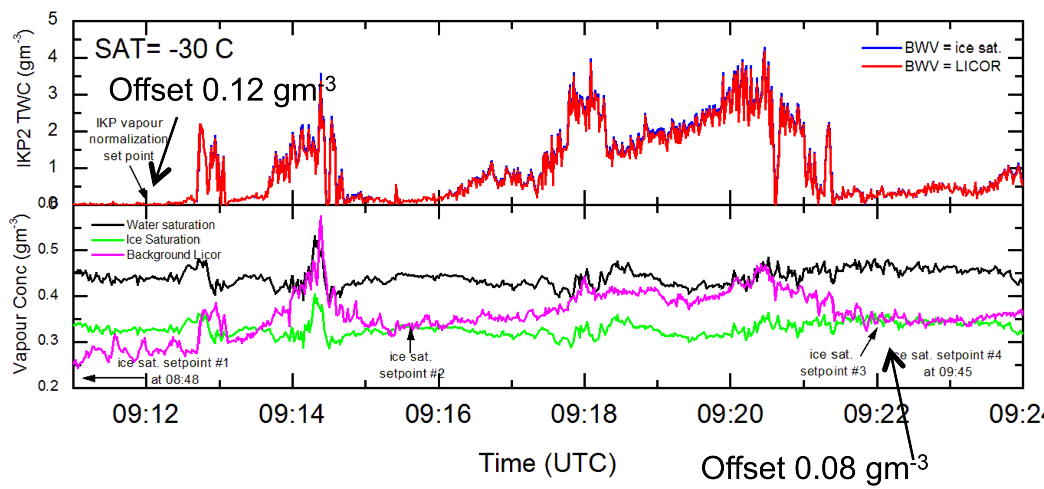
BWV Subtraction – Cayenne-2015

- All LICORS have drifting offsets (e.g. with pressure)
- LICORS usually cannot be used effectively for TWC calculation without compensating for offsets

- Method used:
    - Find area of broad and low IWC and assume at ice saturation
    - Apply offset to background LICOR to force it to ice saturation
    - Find an out-of-cloud period close to ice saturation region, and apply an offset to the IKP2 LICOR to force it to the same value as the BWV LICOR
    - Perform this procedure periodically, and time-interpolate the offsets between setpoints

Two options for BWV in TWC calculation

- Ice saturation (green line)
- BWV Licor (magenta line)
- Maximum difference ~0.3 gm-3 at max IWC
- Difference in TWCs top panel

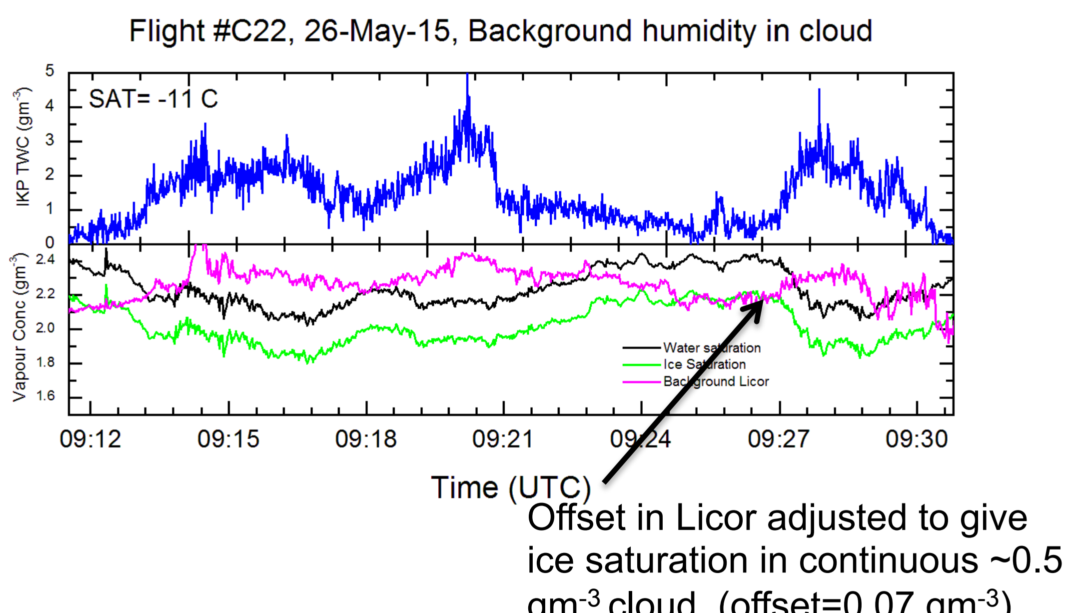


BUT IS THERE CONTAMINATION OF BWV SIGNAL LIKE DARWIN?

BWV Subtraction – Cayenne-2015

- Counter-example at -11 C
- Set BWV offset in 0.5 gm^{-3} steady cloud
- Adjust IKP LICOR out of cloud to BWV LICOR (not shown)
- In-cloud water vapour rises to well above water saturation
  - If real, should create a liquid cloud and limit BWV to ~ water saturation
  - BWV rise above ice saturation is proportional to IWC
  - Is this an indication of BWV contamination (ice crystal ingestion, sublimation?)

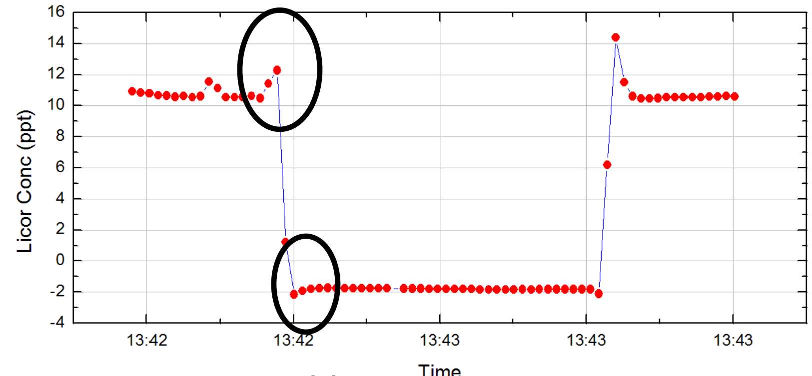
- Could be error in assumption of location of ice saturation
- But if we shift BWV down to limit to water saturation, there are substantial regions of cloud > 1 gm-3 TWC sub saturated with respect to ice



IKP Licor overshoots observed in step changes during calibrations

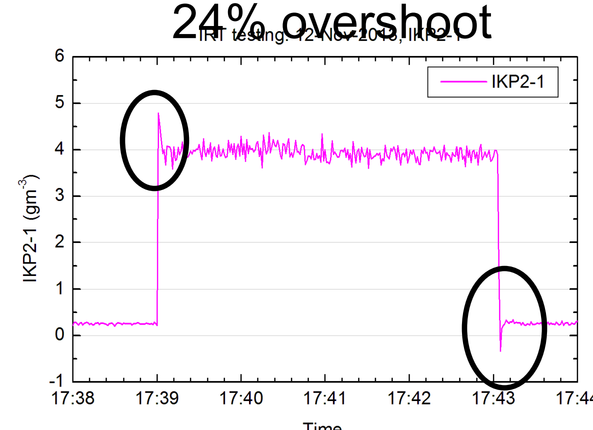
- brought to our attention by Tom Ratvasky during NASA testing of Licors in October 2015
- Humidity overshoots during both positive and negative humidity step changes;
  - In raw adsorption data, not just Licor processed ppm values
  - Affects about 4 seconds of data after overshoot/undershoot
  - Lilie discussions with LICOR: property of detector
- Appears to be on all Licors (IKP, and all the background versions)
- Observed in 2014 IRT testing before Darwin (IKP2-1), and 2014 IRT testing before Cayenne (both IKP2-1 and IKP2-2)
- CORRECTABLE?

35% overshoot



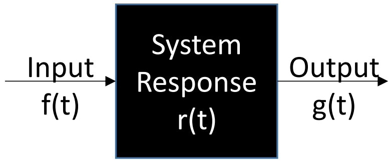
4% undershoot

24% overshoot

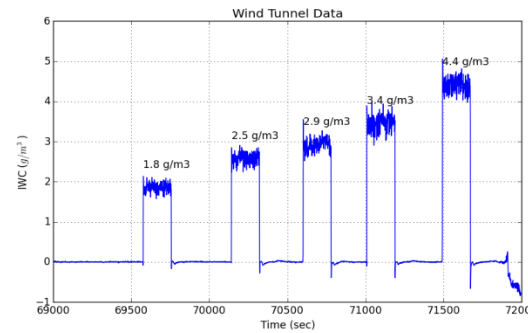


16% undershoot

NASA Langley (Steve Harrah group) proposed possible correction algorithm



$$f(t)*r(t) = g(t)$$



- Instrument output results from true input and a system response
- Approach:
  - Use IRT data to define system response function *r(t)*
  - Complete the correction in the frequency domain, and convert results back to time domain by the inverse Fourier Transform

$$f'(t) = \mathcal{F}^{-1}\left\{\frac{\mathcal{F}\{g'\}}{\mathcal{F}\{r\}}\right\}$$

  - Justin Stricklind (NASA Langley) has analyzed IRT data as a training data set, and proposed various options as to how to process the data
  - If an acceptable method is agreed upon, we would propose to re-process the Darwin and Cayenne data sets
  - Practical effect would be mainly in a reduction in the peak 1-second IKP2 values, and only during large step changes.
  - Private breakout meeting Thursday to discuss Justin's analysis.

Conclusions

- Darwin IKP2 data set unlikely to change except for possible IKP overshoot correction, that would mainly affect high Hz data (> 0.2 Hz)

- Cayenne IKP2 data still in draft form
  - Will check SAFIRE data and one problem flight against robust data, and re-issue new data set if required
  - May incorporate overshoot correction
  - Background water vapour TBD

- Darwin data has no option other than ice saturation BWV in cloud. Issue not fully resolved for Cayenne data.
  - I favour using ice saturation for both data sets to be consistent, and estimate uncertainties. Need to discuss this with Alexei, Alfons and others at this meeting for their input.
  - Propose a final Cayenne-2015 IKP2 data set for mid-July 2016, or earlier depending on amount of re-processing

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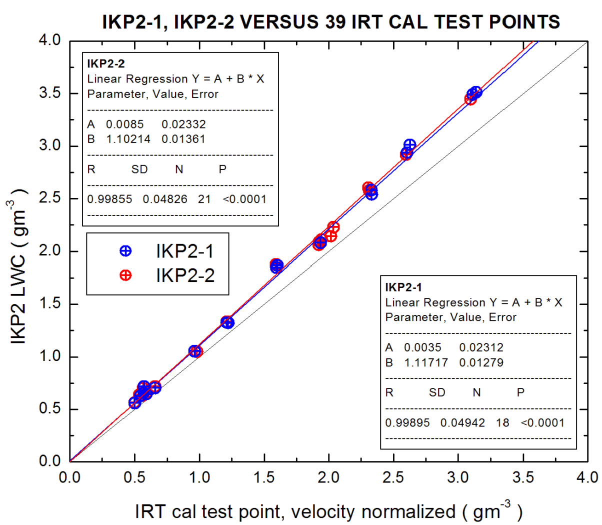
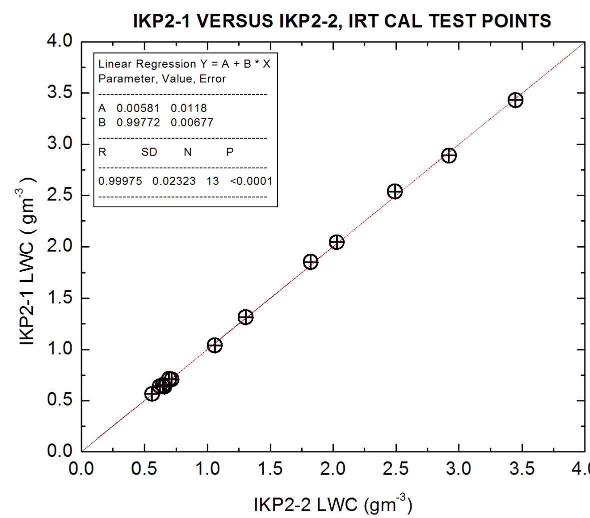
IKP2 Reference Material

Davison, C. R., Strapp, J. W., Lilie, L., Ratvasky, T. P., and Dumont, C., " Isokinetic TWC Evaporator Probe: Calculations and Systemic Error Analysis", 2016, *8th AIAA Atmospheric and Space Environments Conference,* June 17, 2016, Washington, DC. (to be submitted as written paper)

Strapp, J. W., Lilie, L., Ratvasky, T. P., Davison, C. R., and Dumont, C., "Isokinetic TWC Evaporator Probe Development and Performance Testing for the HAIC-HIWC Darwin 2014 and Cayenne 2015 Field Campaigns", 2016, Submitted for publication, 8th AIAA Atmospheric and Space Environments Conference, June 17, 2016, Washington, DC. (to be submitted as written paper)





End of Presentation

Merci, Thank You

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Spare slides

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

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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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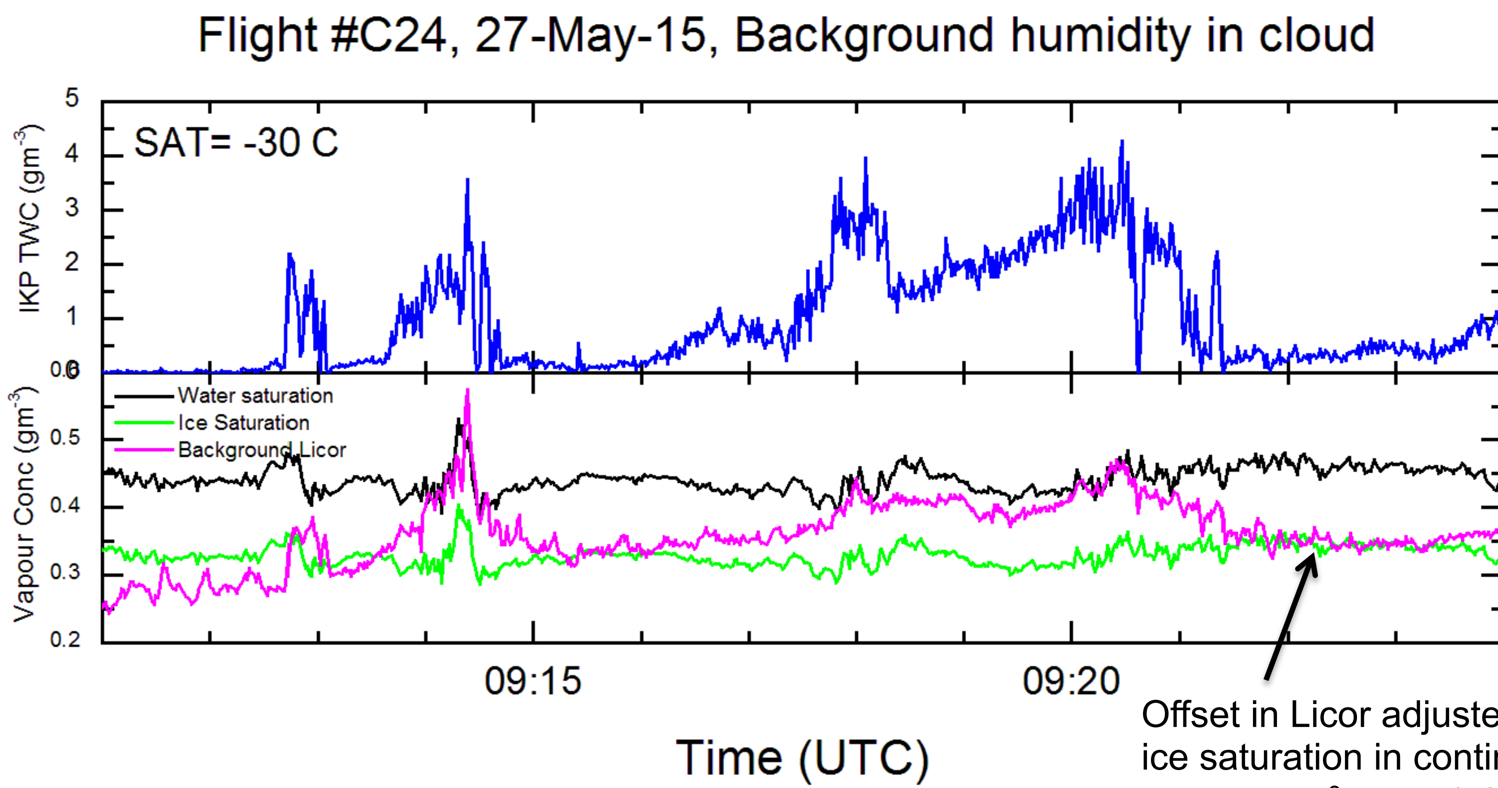
Results of new background humidity system – <u>ice crystal ingestion</u>

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

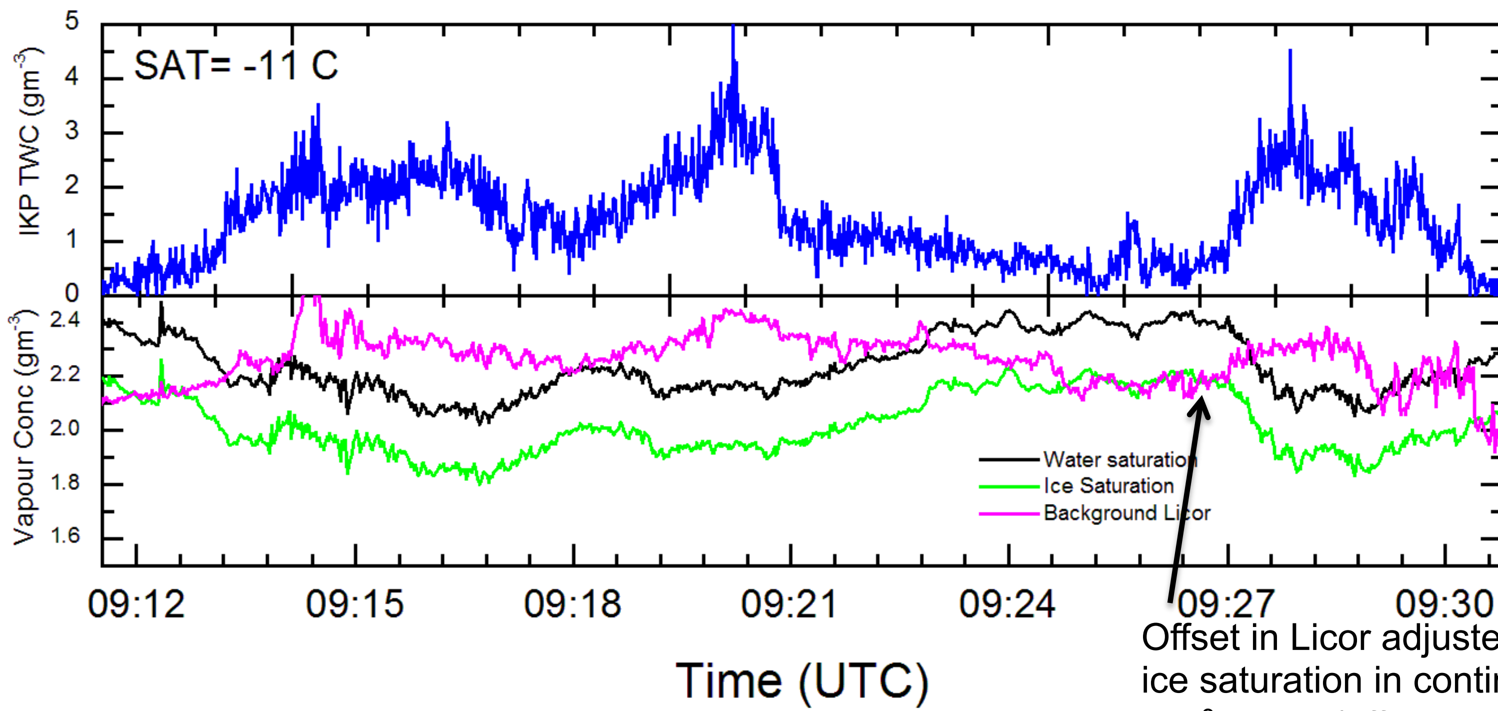


Offset in Licor adjusted to give ice saturation in continuous 0.1-0.2 gm^{-3} cloud (offset=0.08 gm^{-3})

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

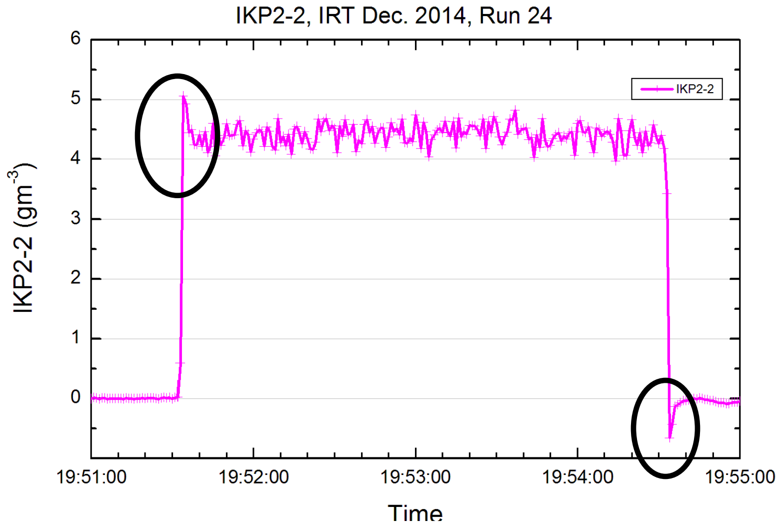
- Example where background Licor appears to significantly exceed even water saturation in cloud
- Still are cases where background humidity on cloud climbs to unreasonably high values, especially for -10 C runs

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

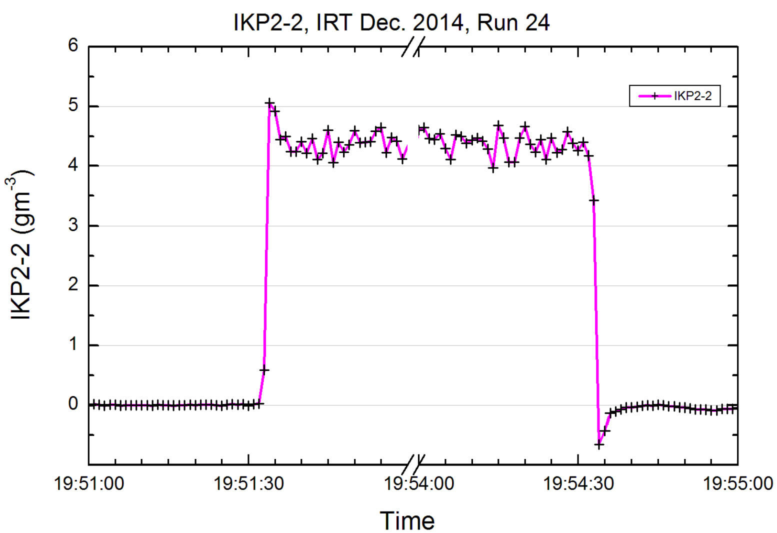


Offset in Licor adjusted to give ice saturation in continuous ~0.5 gm^{-3} cloud (offset=0.07 gm^{-3})

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

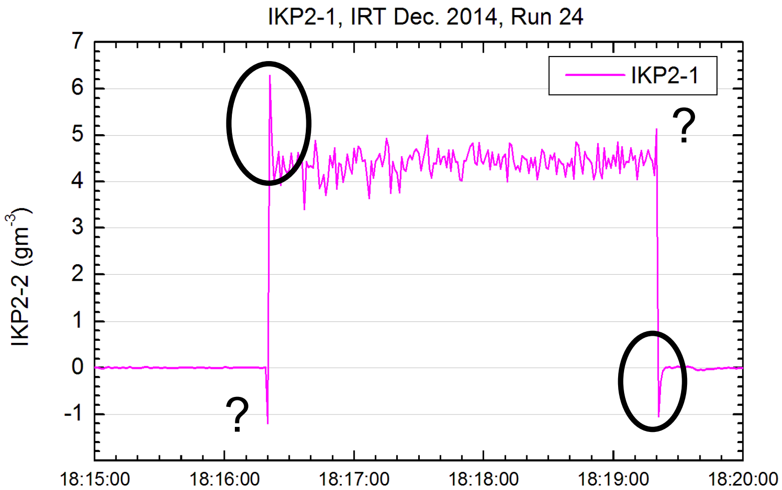


- ~15% overshoot
- ~15% undershoot

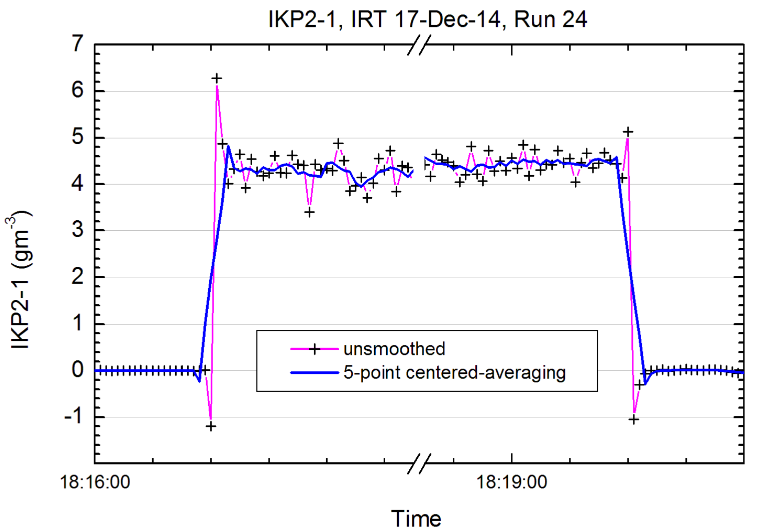


- Same data as above, but with break in X axis, and individual 1-second points
- Affects after about 5 seconds of data

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

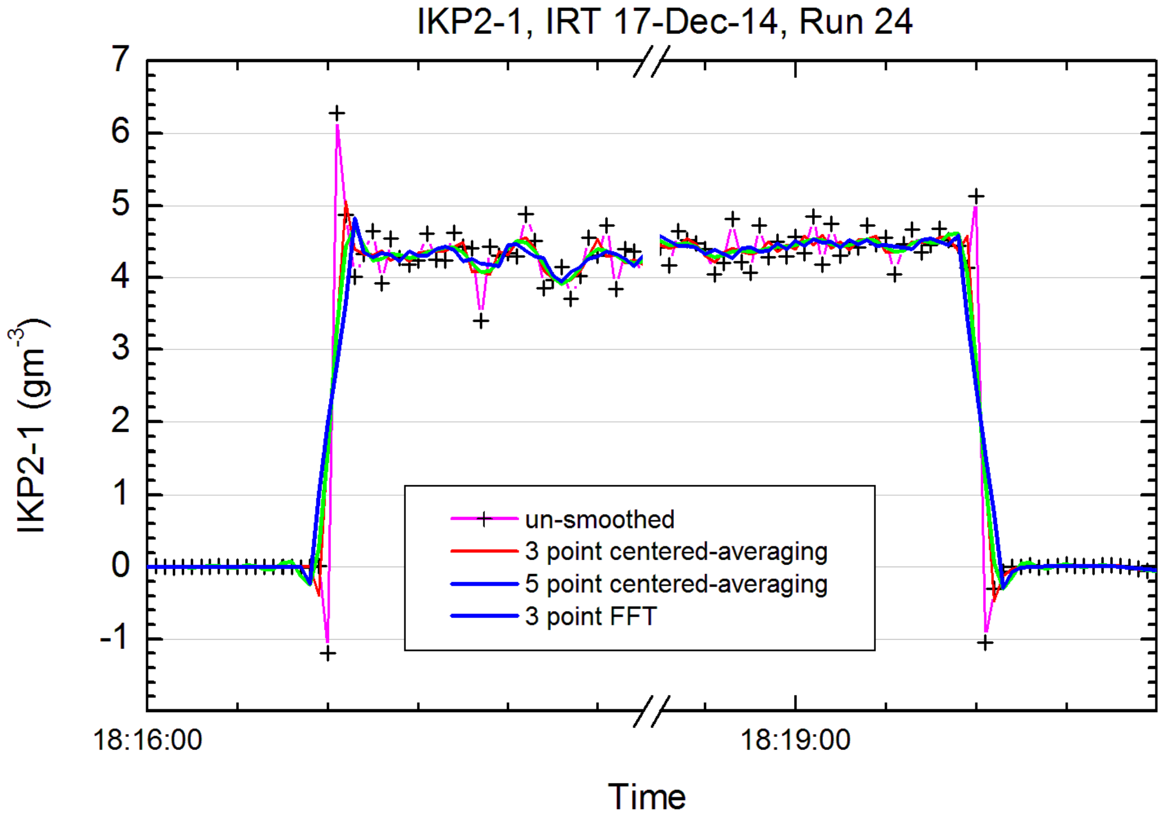


- ~30% overshoot
- ~25% undershoot
- This one was used on Falcon-20

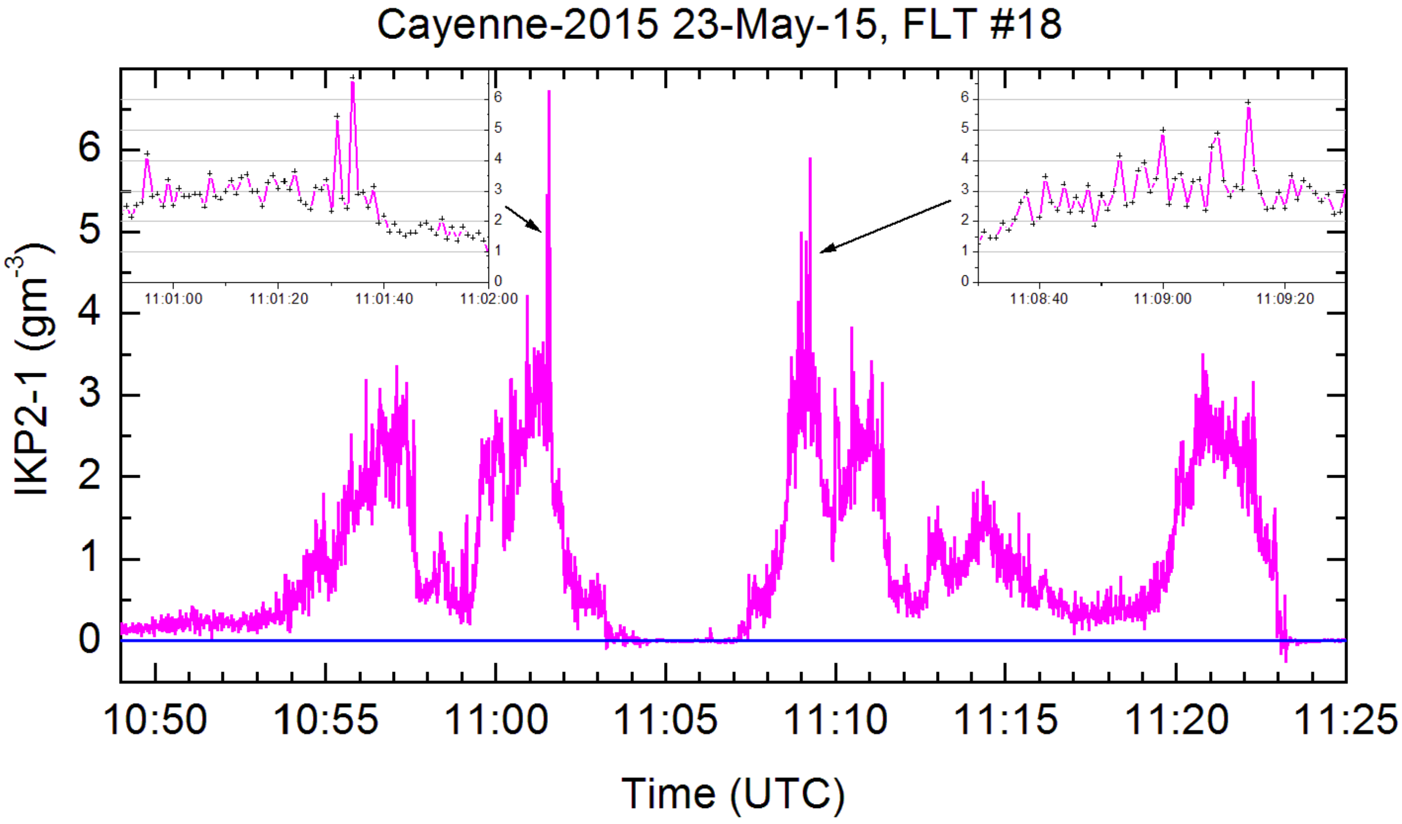


- Same data as above, but with break in X axis, and individual 1-second points
- Affects after about 3-4 seconds of data
- 5 point filter centered-averaging also shown

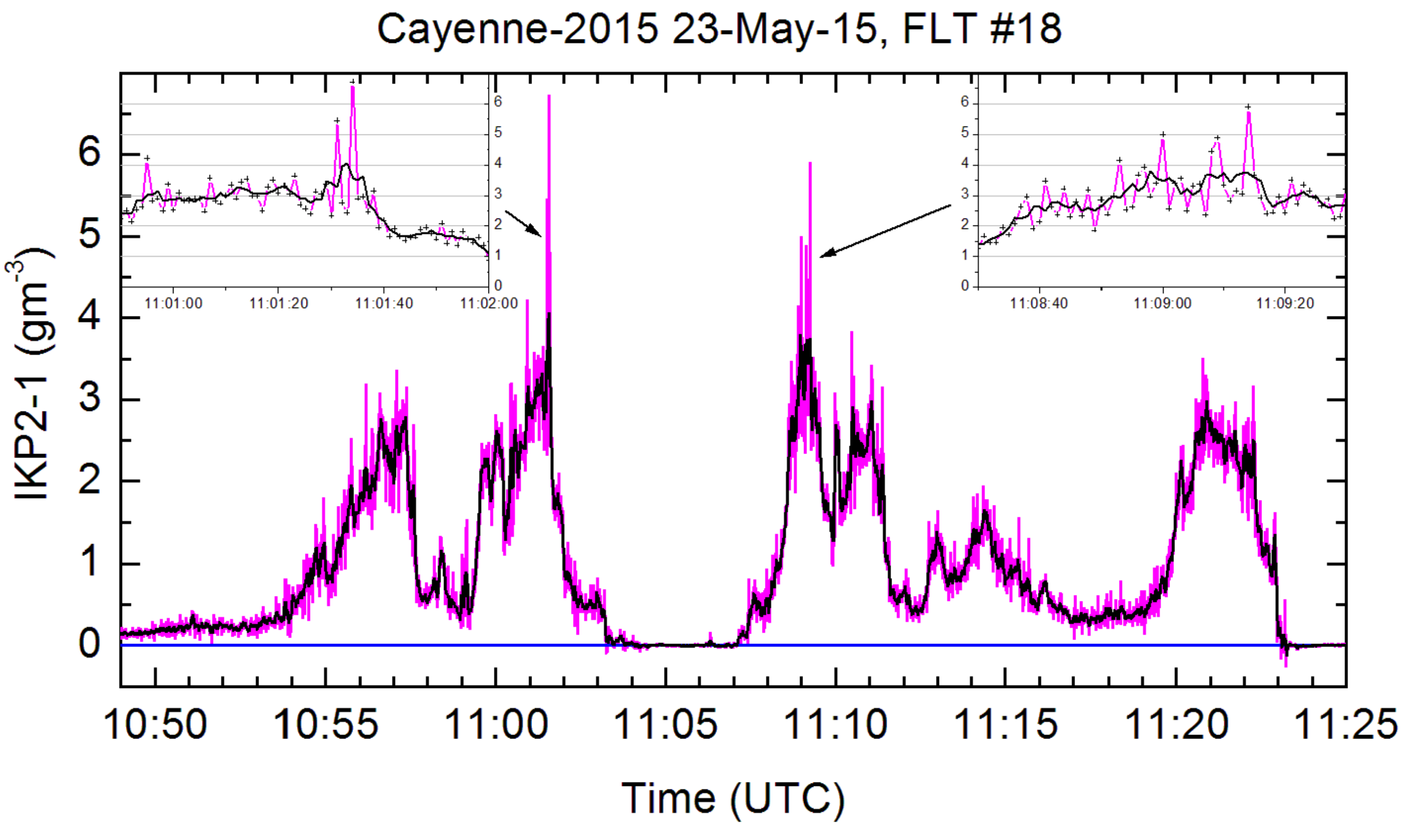
More smoothing examples



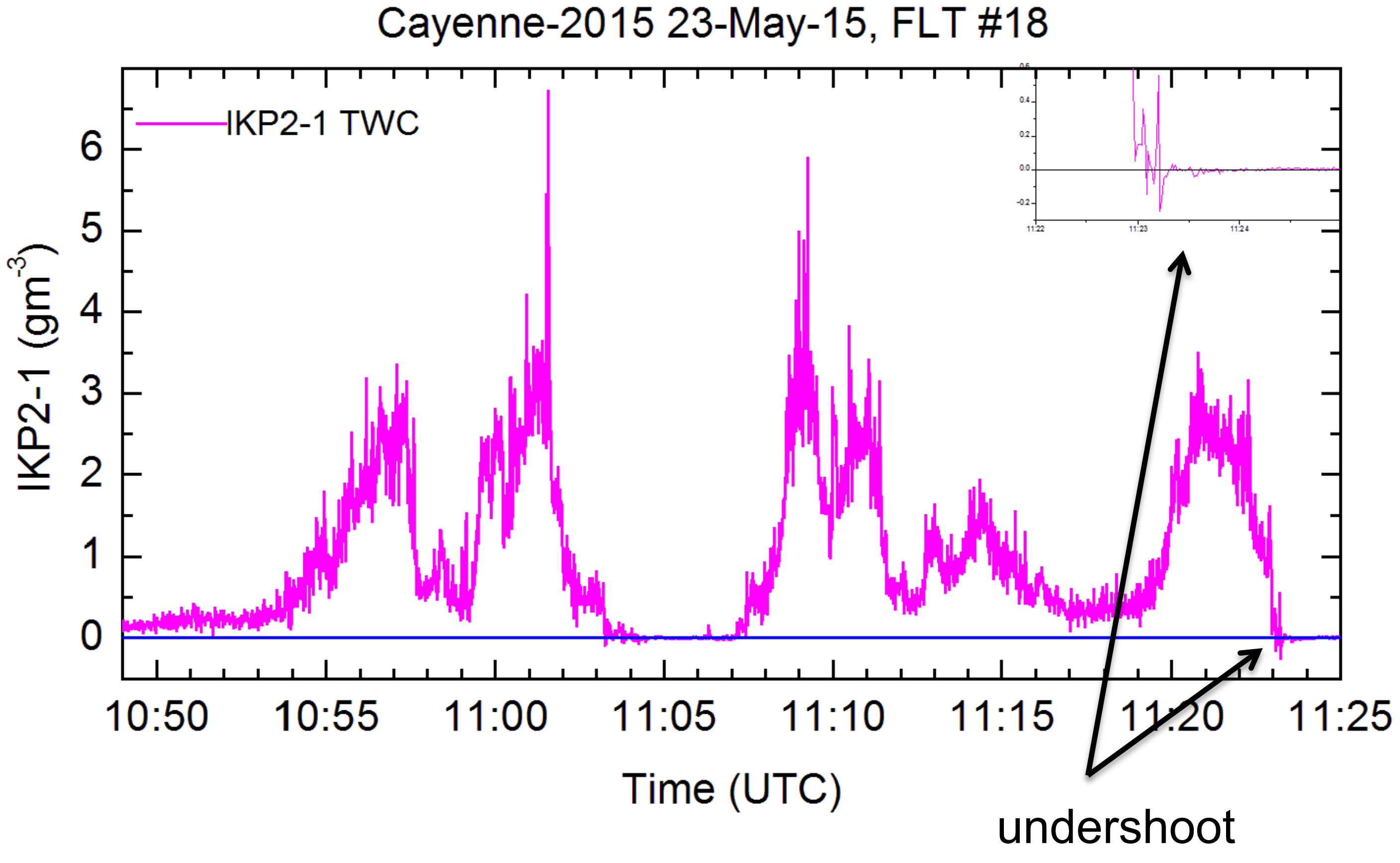
HIWC Case from Cayenne-2015(CAY15)



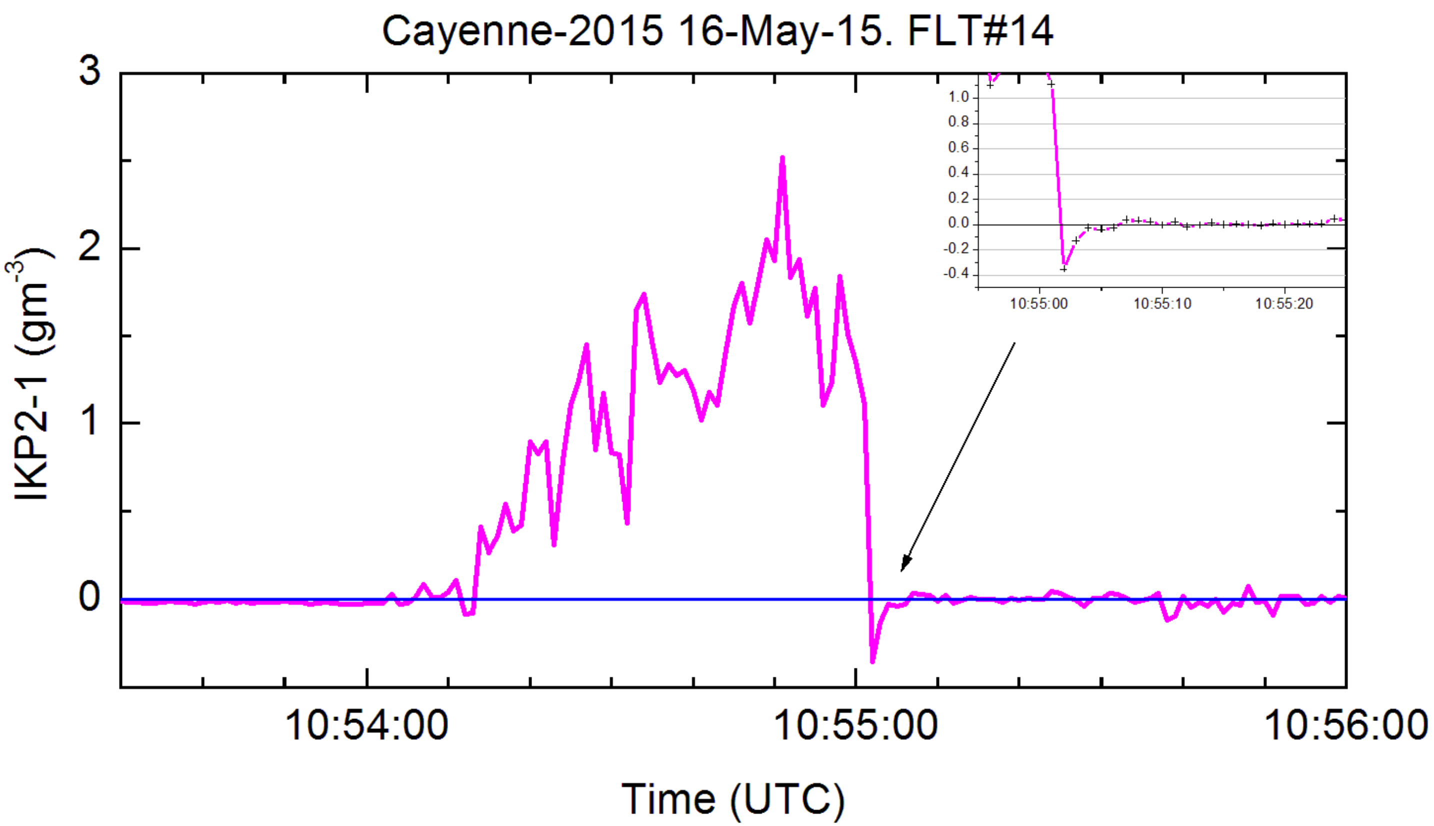
HIWC Case from Cayenne-2015(CAY15); with 5-point centered average (black)



HIWC Case from Cayenne-2015(CAY15)



HIWC undershoot Case from Cayenne-2015



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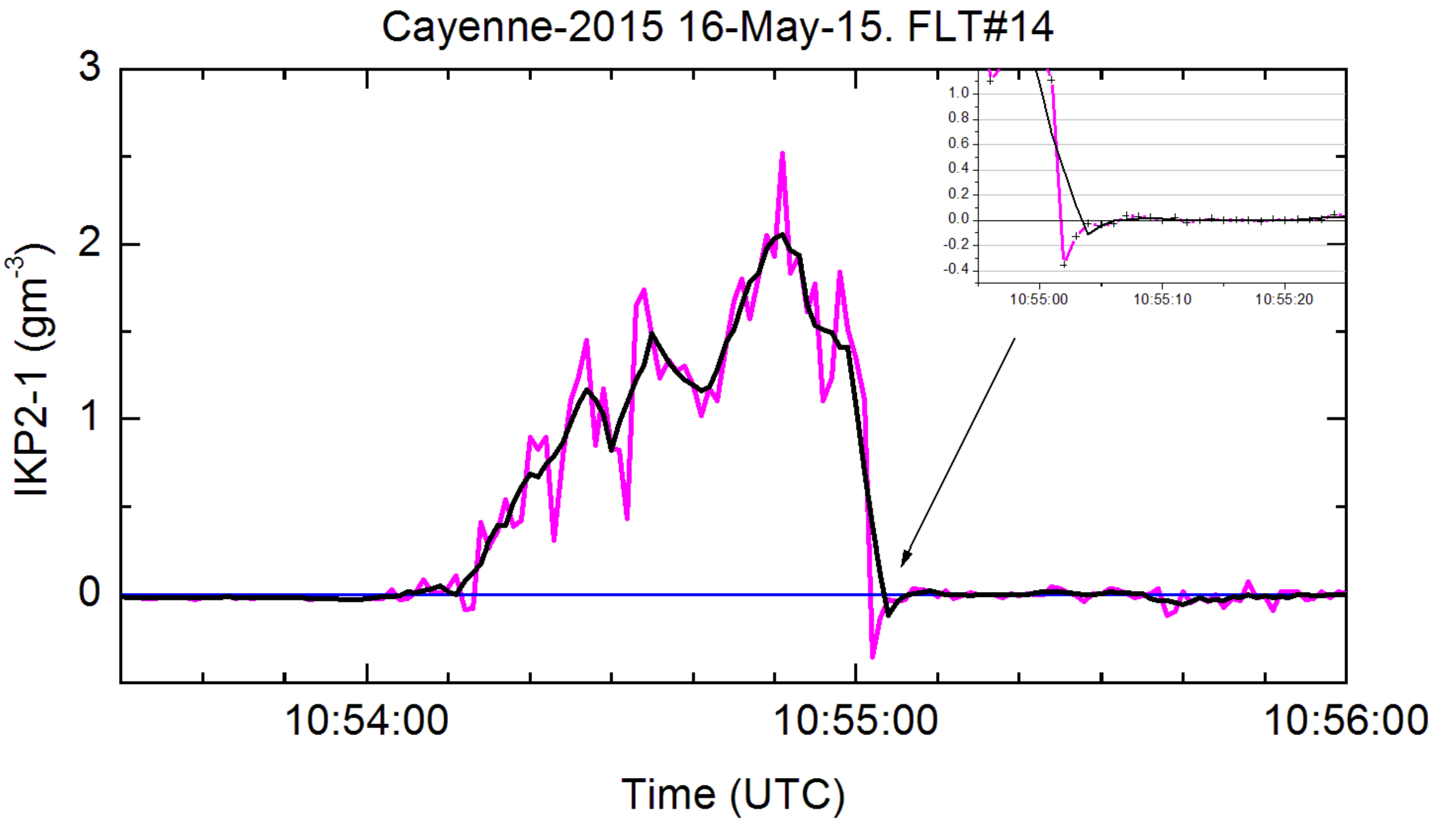
HIWC undershoot Case from Cayenne-2015 with 5-second centered averaging



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SUMMARY Melbourne (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

SUMMARY Melbourne (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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