Preliminary Appendix D/P Assessment Darwin-14 update

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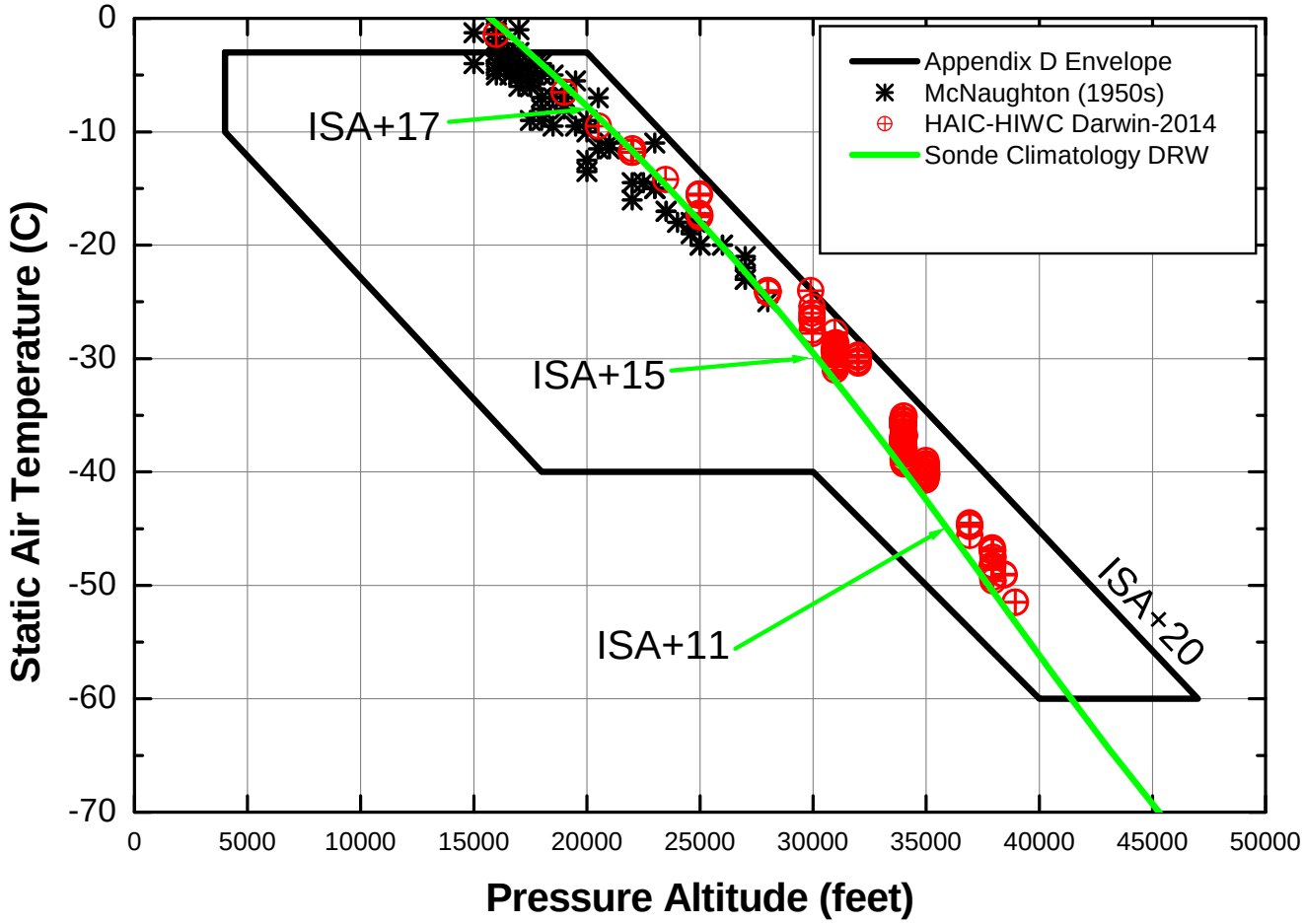
10-Mar-15
HAIC-HIWC Science Team meeting, NASA GISS Manhattan

** Work funded by the FAA through as subcontractor to Science Engineering Associates*

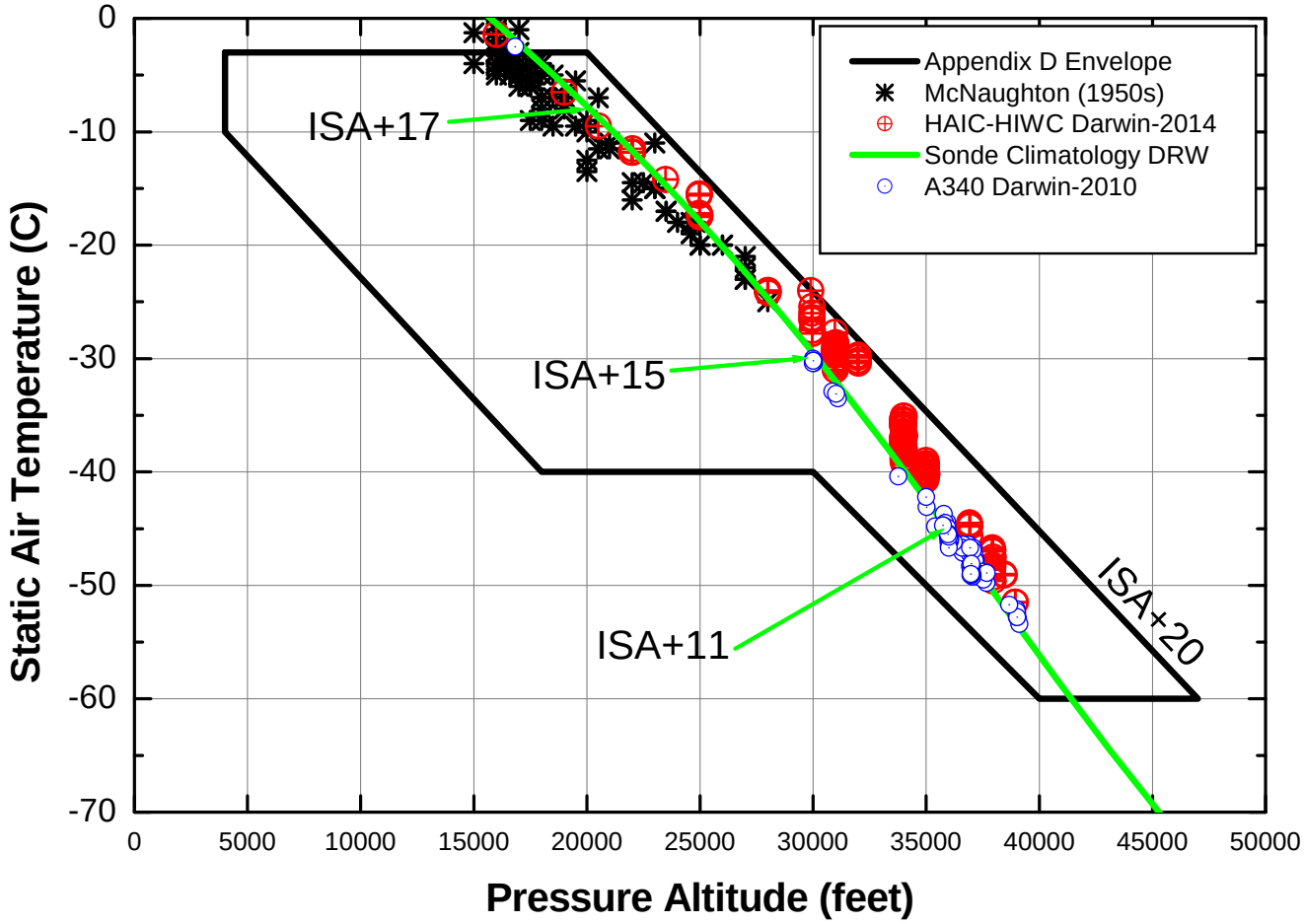
Darwin-14 General Statistics

Number of Flights:	23
Number of flights with Appendix D/P cloud measurements:	16
Number of Oceanic MCS flights:	14 (88%)
Number Continental MCS flights:	2 (22%)
Number Isolated Cumulonimbus:	0
Number of Segments:	157
Total Distance in Segments (nm):	7648
Avg. length of Segment (nm):	36.5

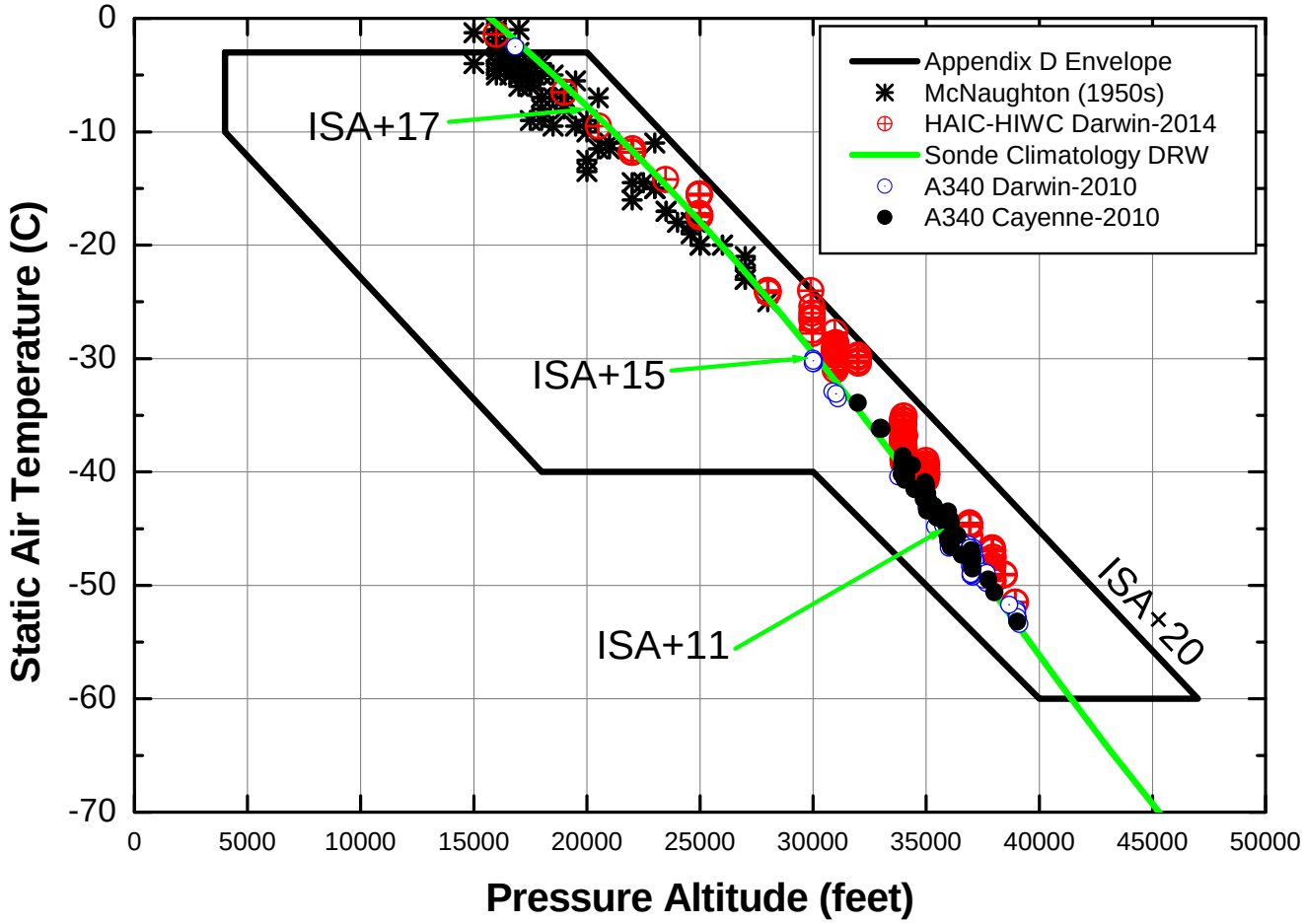
Appendix D Altitude-Temperature Envelope



Appendix D Altitude-Temperature Envelope: A340 Darwin 2010 added



Appendix D Altitude-Temperature Envelope: A340 Cayenne 2010 added



Temperature check F20 versus radiosonde

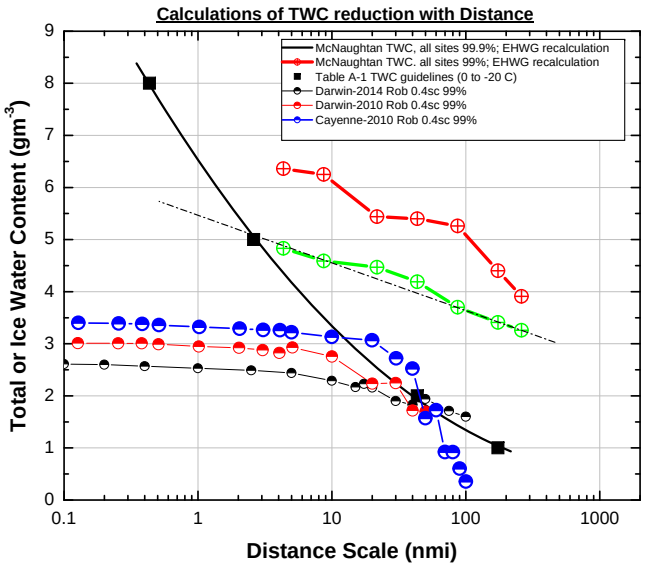
				climb		descent	
Pressure	Tclimat C	DRW14-Sonde C	dt-climat	F20 T C	F20-Sonde	F20 T C	F20-Sonde
850	18.7	18.6	-0.1	18.7	0.0	19.0	0.4
700	9.8	10.2	0.4	10.5	0.3	10.4	0.2
500	-4.7	-4.0	0.7	-3.7	0.4	-3.6	0.4
400	-15.0	-13.8	1.2	-13.2	0.6	-13.3	0.6
300	-29.8	-28.4	1.5	-27.6	0.8	-27.9	0.5
250	-39.9	-38.4	1.5	-37.5	1.0	-37.6	0.8
200	-52.5	-51.8	0.7	-50.0	1.8	-51.0	0.8
AVG					0.7		0.5

Strapp conclusion:

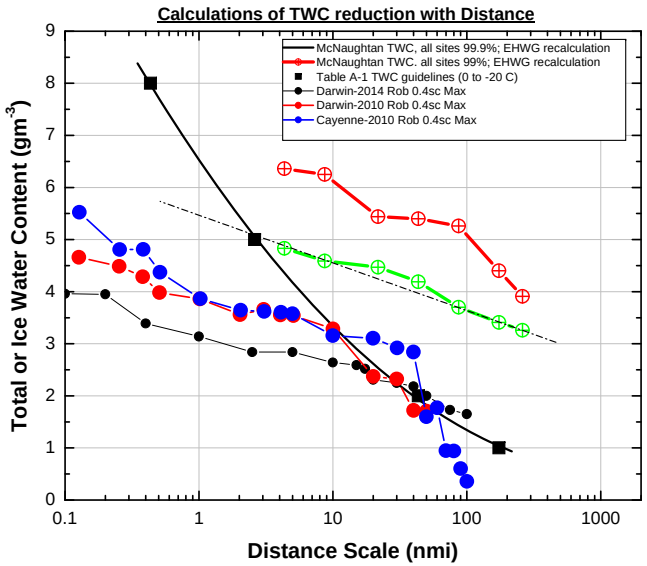
- F20 SAT values are OK
- F20 SAT values often increase in cloud by several degrees (updrafts?.. makes sense)
- Not sure why we saw different behaviour on A340

Appendix D TWC statistics $Robust_{0.4}$ Darwin-2014, Darwin-2010, Cayenne-2010

99th percentile



Maximum



$$\frac{Robust_{DRW10}}{Robust_{DRW14}} \approx 1.11$$

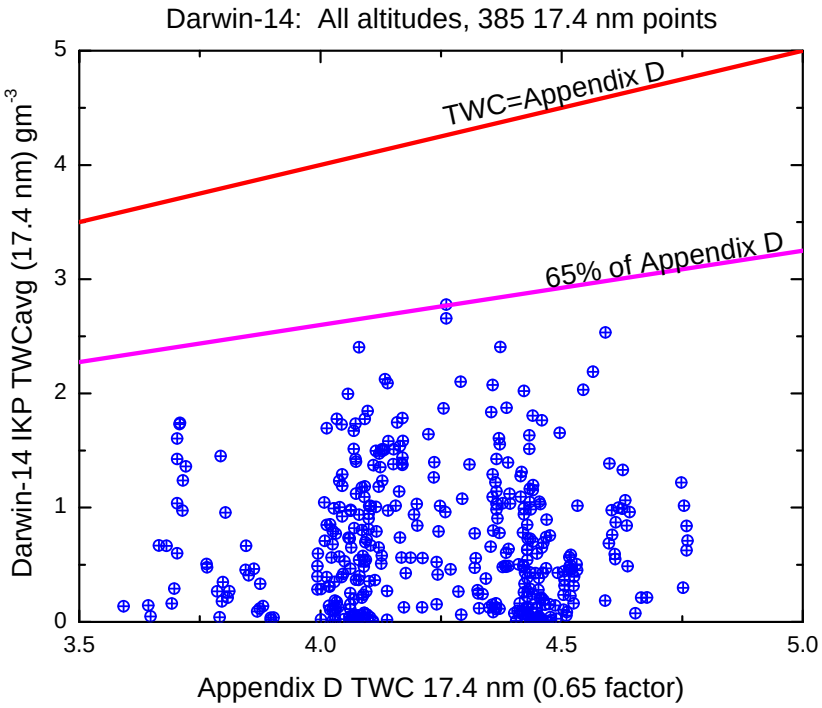
$$\frac{Robust_{CAY10}}{Robust_{DRW10}} \approx 1.12$$

Updates since Paris meeting

- discussed preliminary results with statisticians in November 2014
- now think that the flat rolloff of 99th percentile at short distance scales is due to high spatial correllation of neighboring points
- Statisticians are embarking on a parallel analysis to try to provde a more sophisticated 99th percentile and error estimates
    - Details not available at time of this meeting

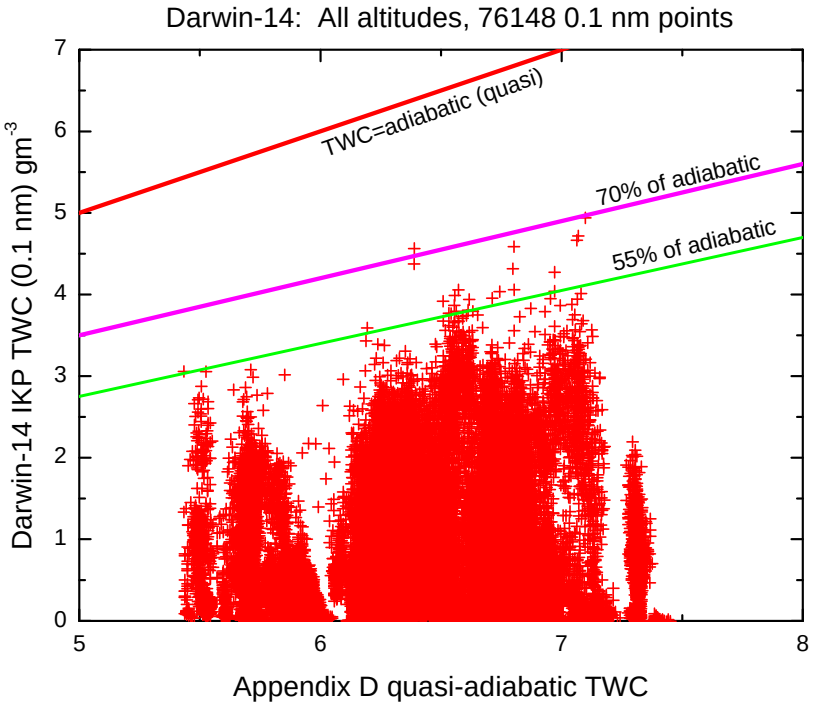
Another way of displaying the data

- Maximum IKP TWC values averaged over 17.4 nm are falling below about 65% of Appendix D
- 99th percentile TWC for all points on this graph is about 2.5 gm-3



Short distance scale vs. adiabatic

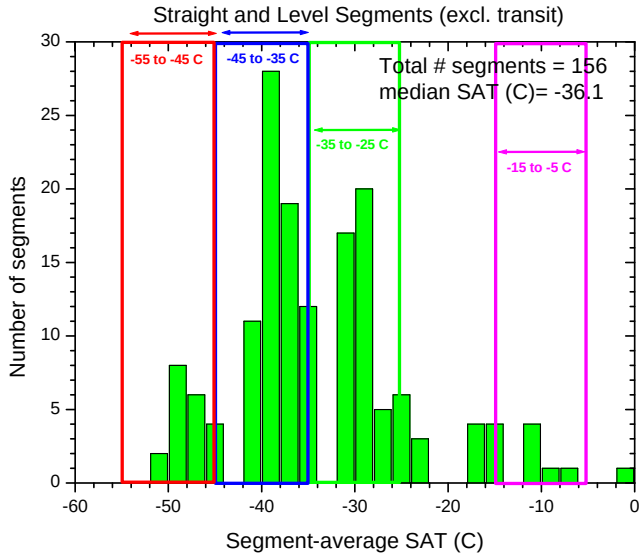
- Quasi-adiabatic value here assuming on pseudoadiabat, and integrate to cloud base (assuming 90% RH at surface)
- Extreme TWCs reach about 70% of adiabatic
- 55% of adiabatic may be better characterization of typical limit
- 99th percentile TWC for all points on this graph is about 2.8 gm-3
- Max of 4.94 gm-3 represents ~99.999th percentile



Final decision on new temperature intervals after polling EIWG

Add and new temperature level (-40 C) , and widen categories

Temp.	Planned 20-nm pts.	Collected 20-nm pts.	No. of segments
-10 ± 5 ºC	100	11	4
-30 ± 5 ºC	100	131	41
-40 ± 5 ºC	100	148	63
-50 ± 5 ºC	100	21	18



- How long does it take on the F20 to reach -45 C (top level)?
- My estimate is 60 minutes from Darwin-14 flights

Work still to do

- Continue work with statisticians from Boeing and Pratt and Whitney to assess the statistical nature of the TWC distributions, and strategy for best error estimates and 99th percentile determination

- Continue to try to assess (or at least document) bias due to overnight-maximum in convective intensity (another presentation)

- Refine straight and level runs and context of data
  - Use pilot's radar and distance from heavy rain below?
  - Use a new scheme based on satellite images?
  - Need to develop ideas some more after looking effectiveness of pilot's radar for this task

- Entrain PSD MMDs into the same analysis as has been done for IKP TWC.

- Started thinking with Alain Protat about use of W-band radar TWCs for Appendix D extension to other altitudes – Alain to lead

Thank you, merci

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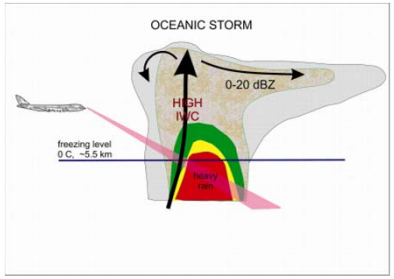
In General, for conditional statistics

- **We want to identify an active cell, and the main rain area below it associated with the cell.**
- **We want to fly over the main rain area, or pass within 20 nmi of this area**

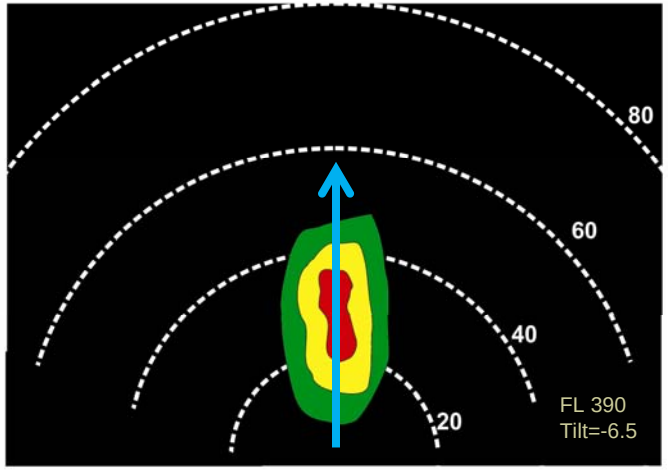
spare slides

Proposed solution to conduct Appendix D/P flight tracks (cntd)

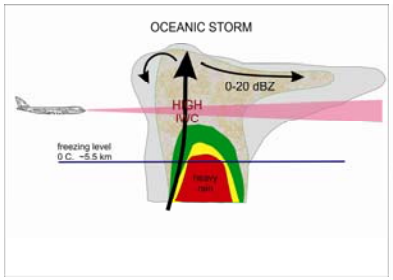
- **First approximation of run, tilting radar down on approach**



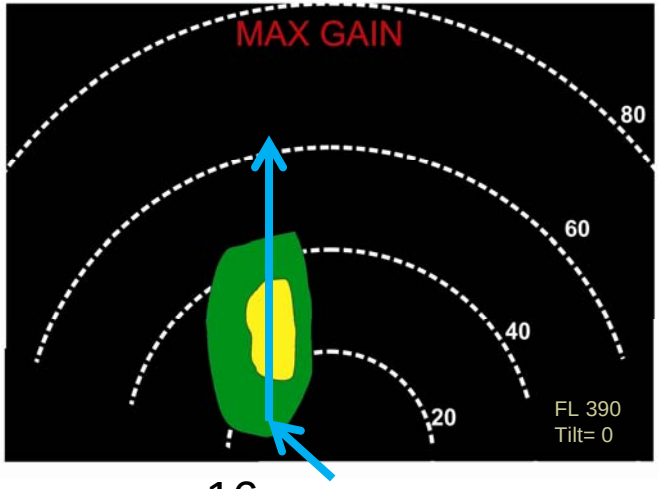
Tilt down, Normal gain



- **Tilting radar back up, and setting to max gain, fine-tune track if possible to go through area of maximum dbZ at flight altitude – otherwise use track in picture above**



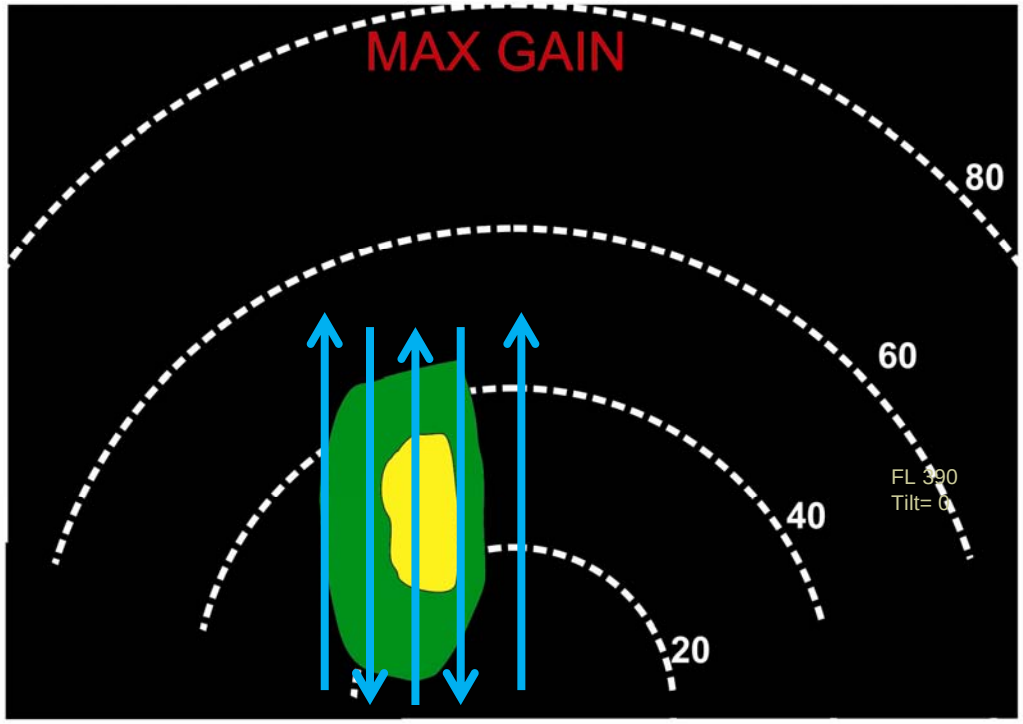
Tilt horizontal, Max gain



Proposed solution to conduct Appendix D/P flight tracks (cntd)

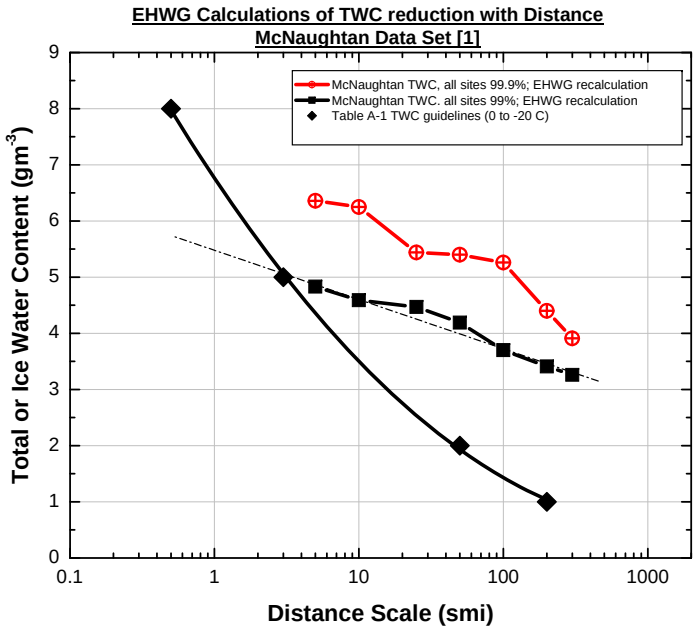
- **On-board IKP and RASTA operators monitor cloud on first run**
- **If conditions are good, pilots set up repeated runs with horizontal spacing of (nominally) 5 nmi (have been using larger)**
- **On-board flight director provides pilots with feedback after each run, and any other recommendations from the back**
- **Pilot occasionally tilts radar down to ensure aircraft is ideally within 20 nmi of rain area below.**

Tilt horizontal



Appendix D/P validation

- EHWG wants 99th percentile TWC and particle size at distance scale of 17.4 nmi
- Statistics would come mainly from ‘oceanic’ flights, where 17.4 nmi long legs could easily be accomplished

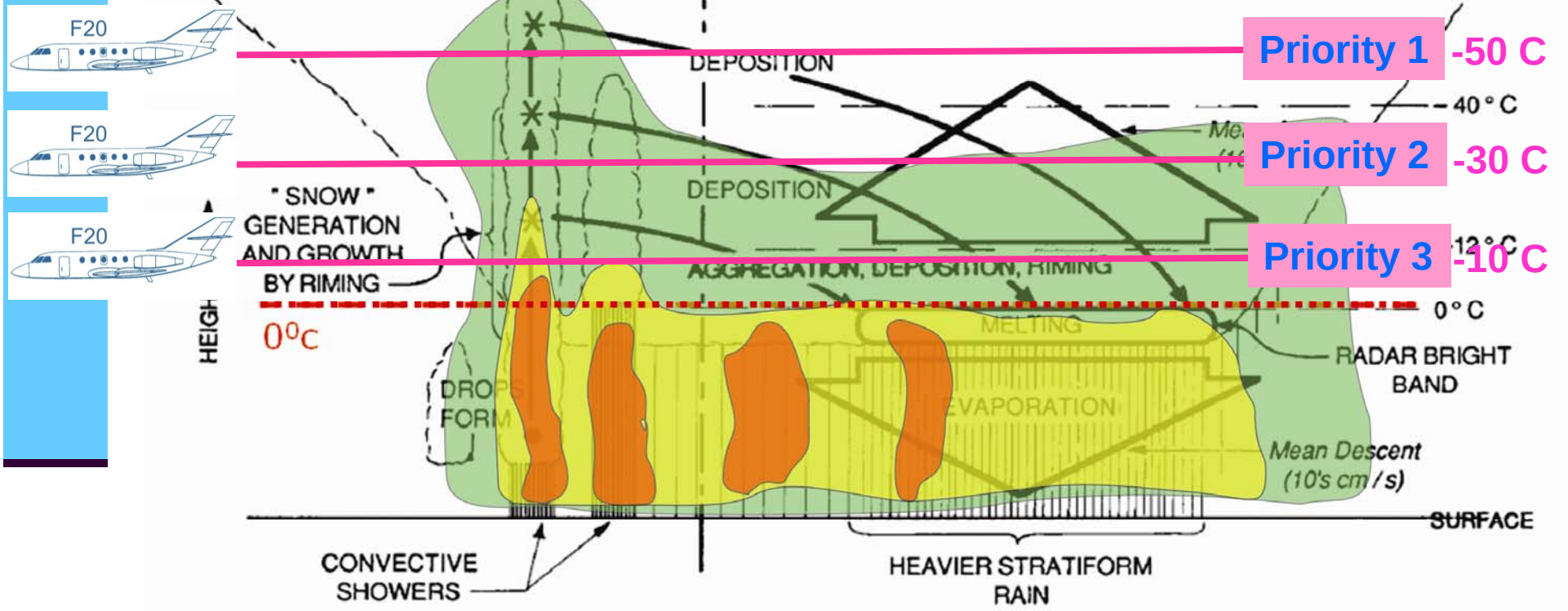


Suggested run selection approach

- **Falcon-20 pilots chose the flight tracks from their radar, after initial estimate from scientists on ground, as per following slides**
- **On-board flight director provides assessment of pilot's choices, advice based on instruments, and relays messages from ground**

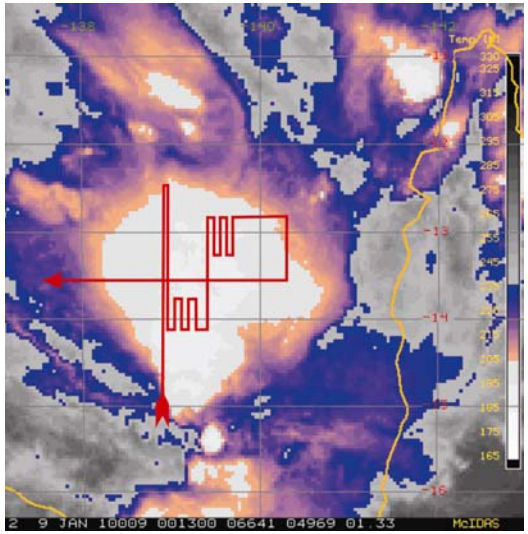
MCS Cross Section

**Monsoonal over water



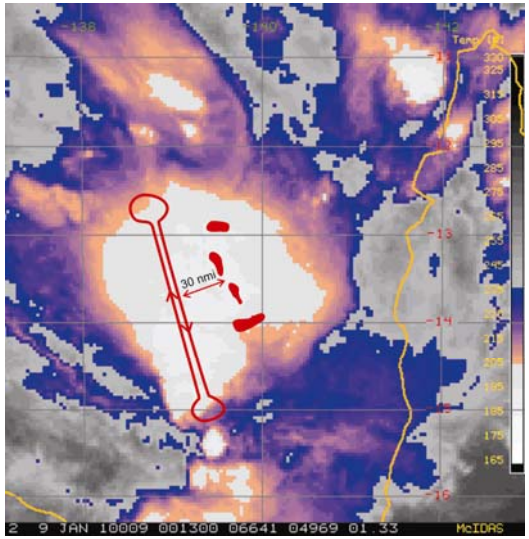
Review of Types of Cloud to Sample

Less vigorous Oceanic MCS



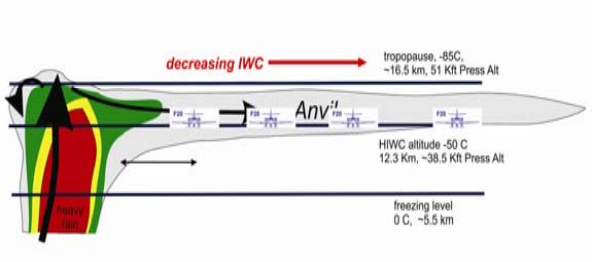
- 60% of flight hours
- Target MCS scale > 100 nm

More vigorous Continental MCS



- 25% of flight hours
- Target MCS scale > 100 nm

Isolated Continental Cumulonimbus



- 15% of flight hours

Review– altitudes/temperatures

In order of priority, 100 20 nm segments* at each of the following altitudes/temperatures:

- **-50 ±3 C,** 12.4 Km above ground, or approximately **38.5 Kft** pressure-altitude (ISA+6 °C).
- **-30 ±3 C,** 10.2 Km above ground, or approximately **31.4 Kft** pressure-altitude (ISA+21 °C).
- **-10 ±3 C** , 7 Km above ground, or approximately **21.8 Kft** pressure altitude (ISA+22 °C).

* Each segment ideally within 20 nm of a heavy rain area below, as per pilot's radar

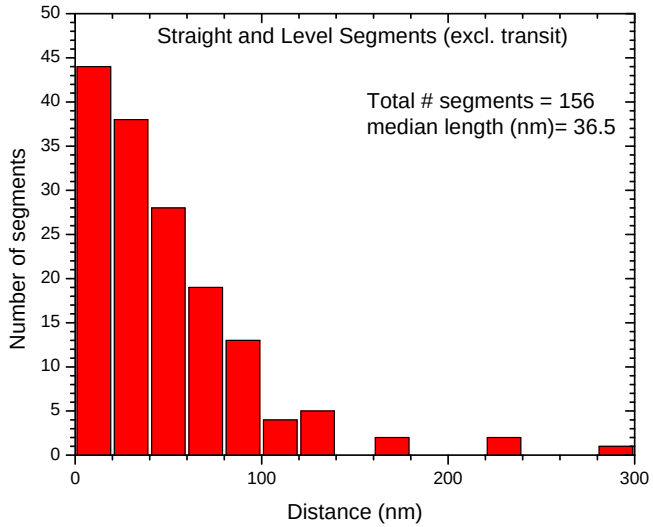
Choosing Segments and Analyzing for Appendix D/P Analysis: First cut for these meetings

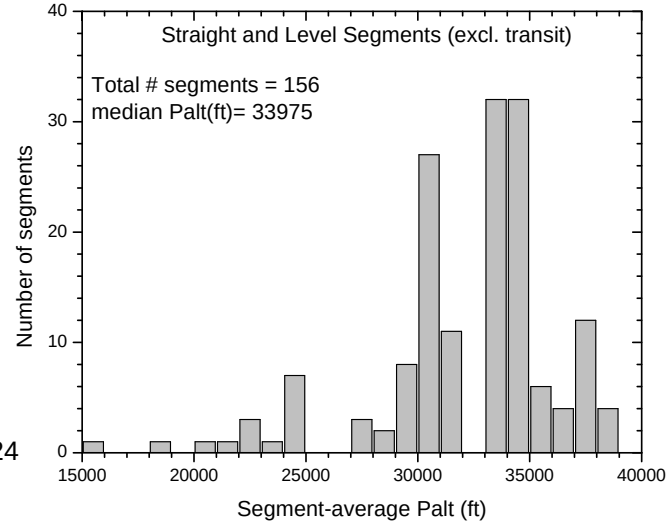
- Examine each flight and identify all regions of straight and level flight when the aircraft was not in transit (i.e. measuring a targeted cloud)
- Provide a unique segment number for each of these periods
  - Include even small repositioning segments if they were within targeted cloud – will refine later

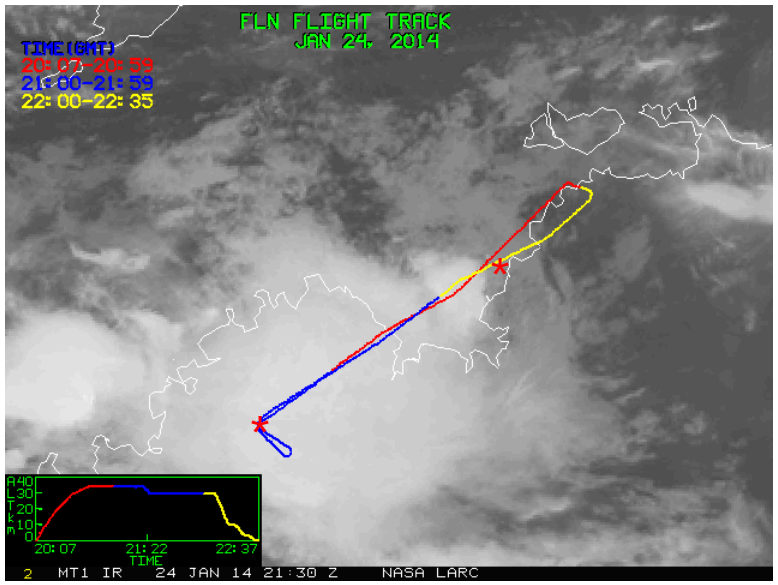
- Analyze the Falcon-20 data for each of these segments:
  - Calculate averages of IKP TWC for progressively larger distance scales, from 0.1 nm to 100 nm
  - Calculate general information on segment population (number of segments, length, TWC etc.)
  - Calculate statistics for a subset of distance scales (chose 15 distance scales for now) – average, 50th percentile, 99th percentile etc.

- Did not sub-divide into different temperature regimes at this stage. All data in next slides is for the entire temperature rage.

Segment Lengths and altitudes:

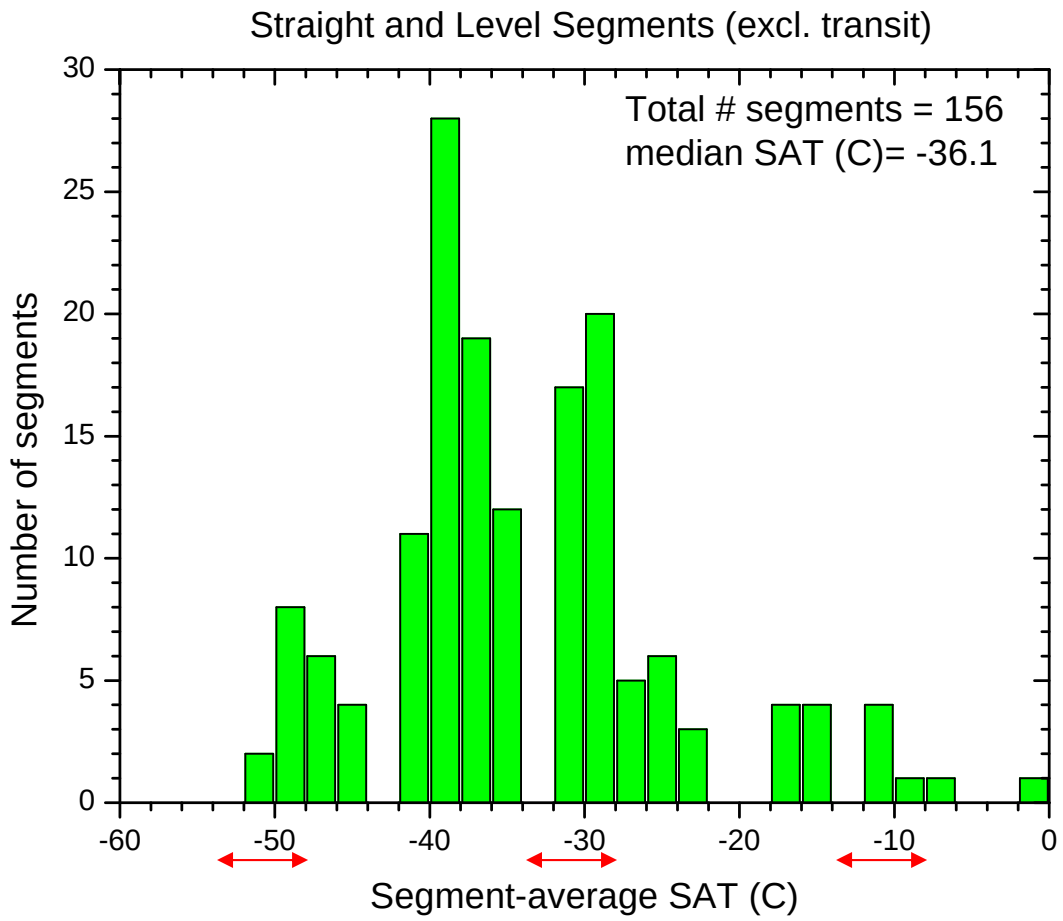






Example showing very long segment

Segment Temperatures:



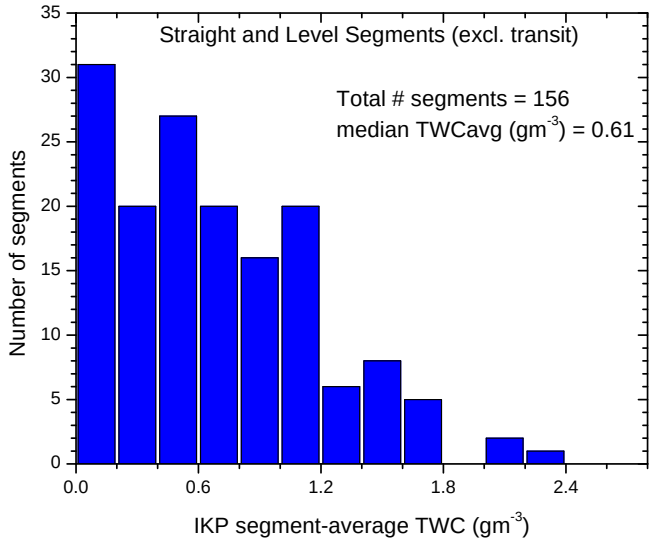
Question:

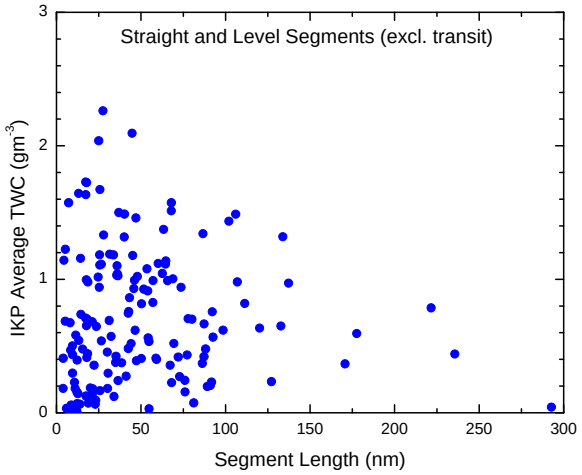
How to assign these data to the prescribed temperature intervals?

Pre-project levels shown by: ↔

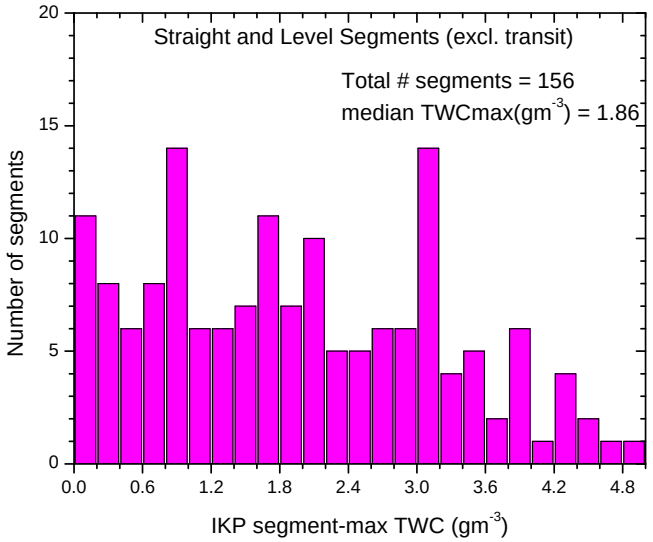
Segment IKP Average/Max TWC

Segment-Average

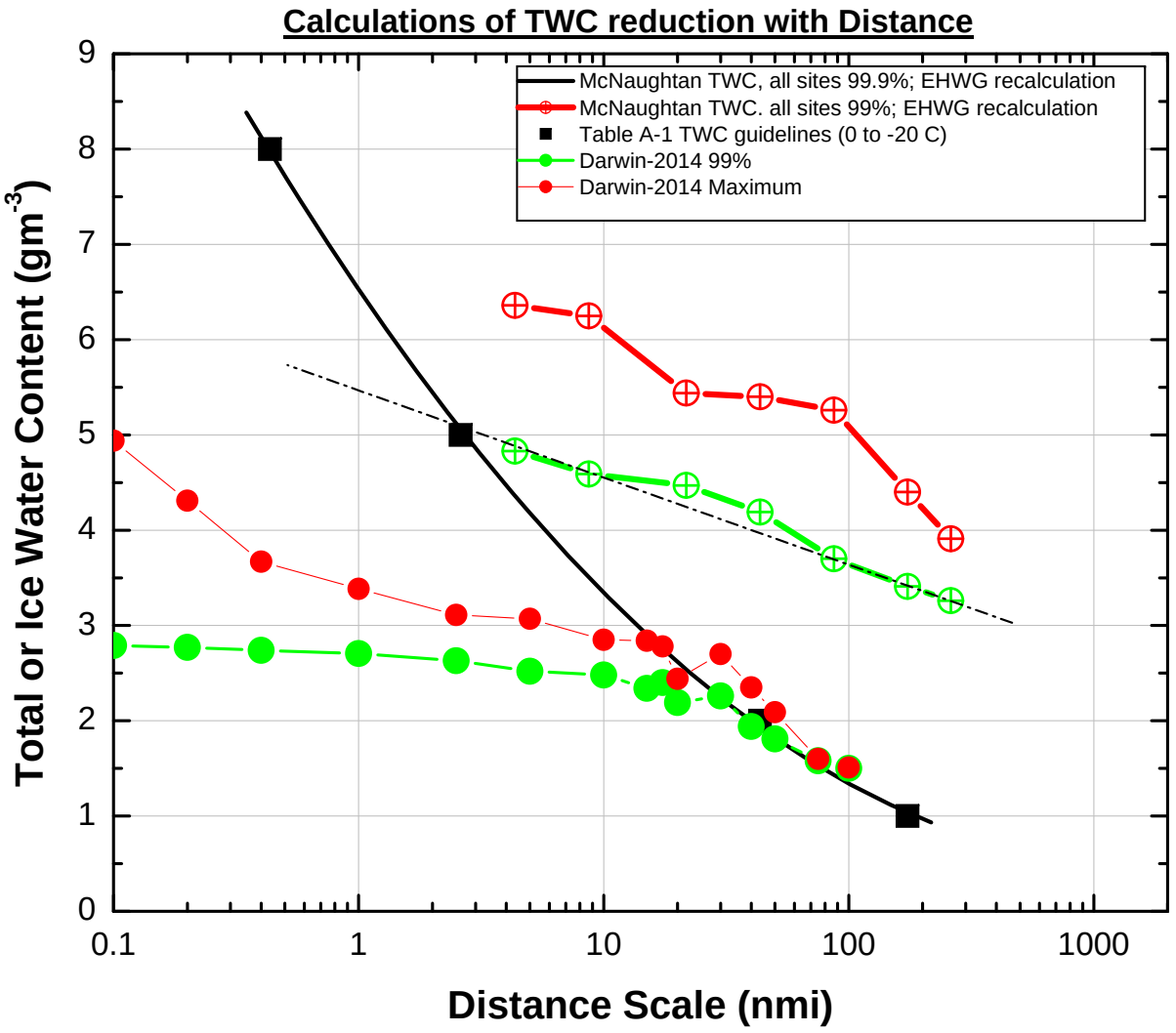




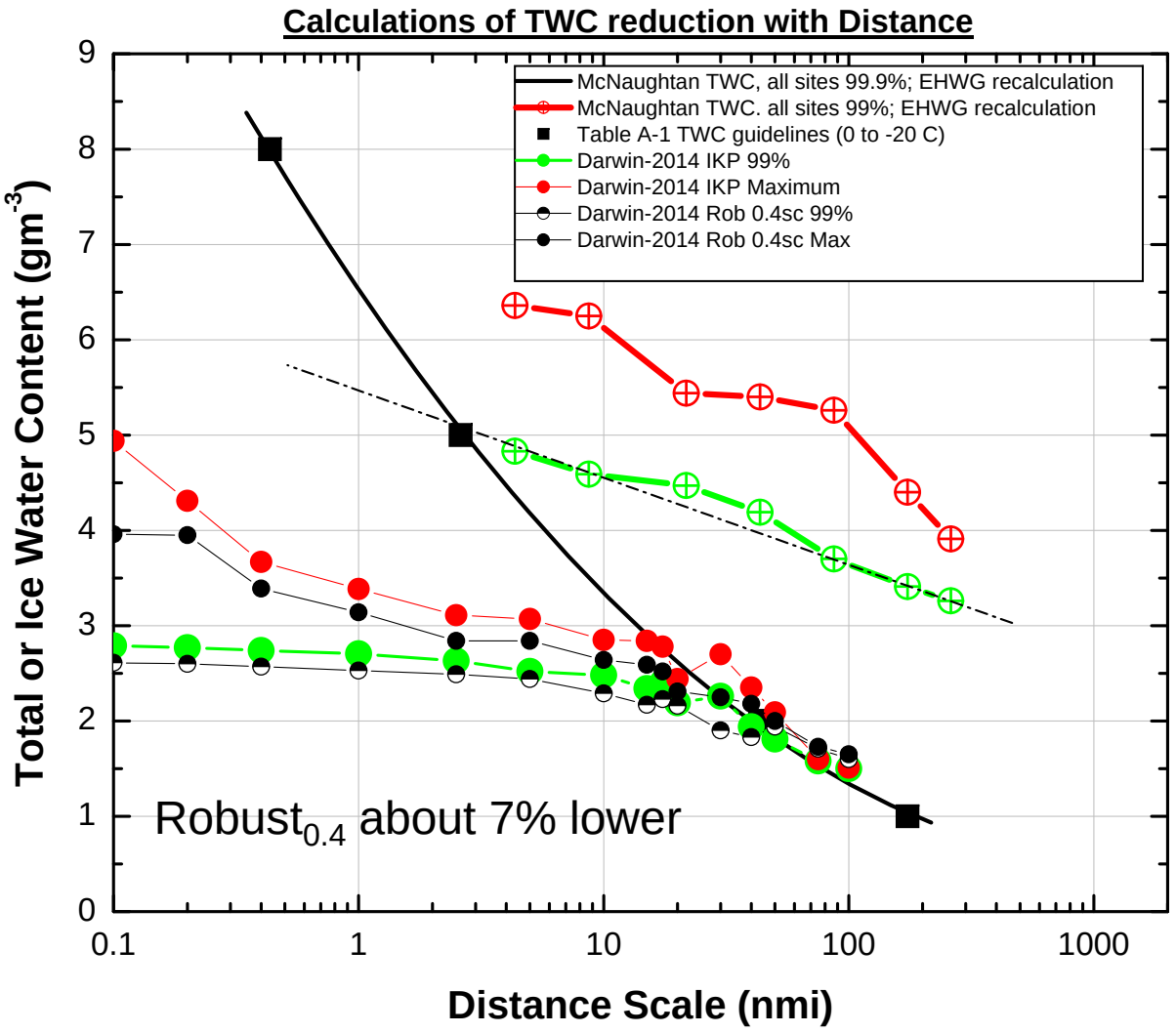
Segment 1 s Maximum



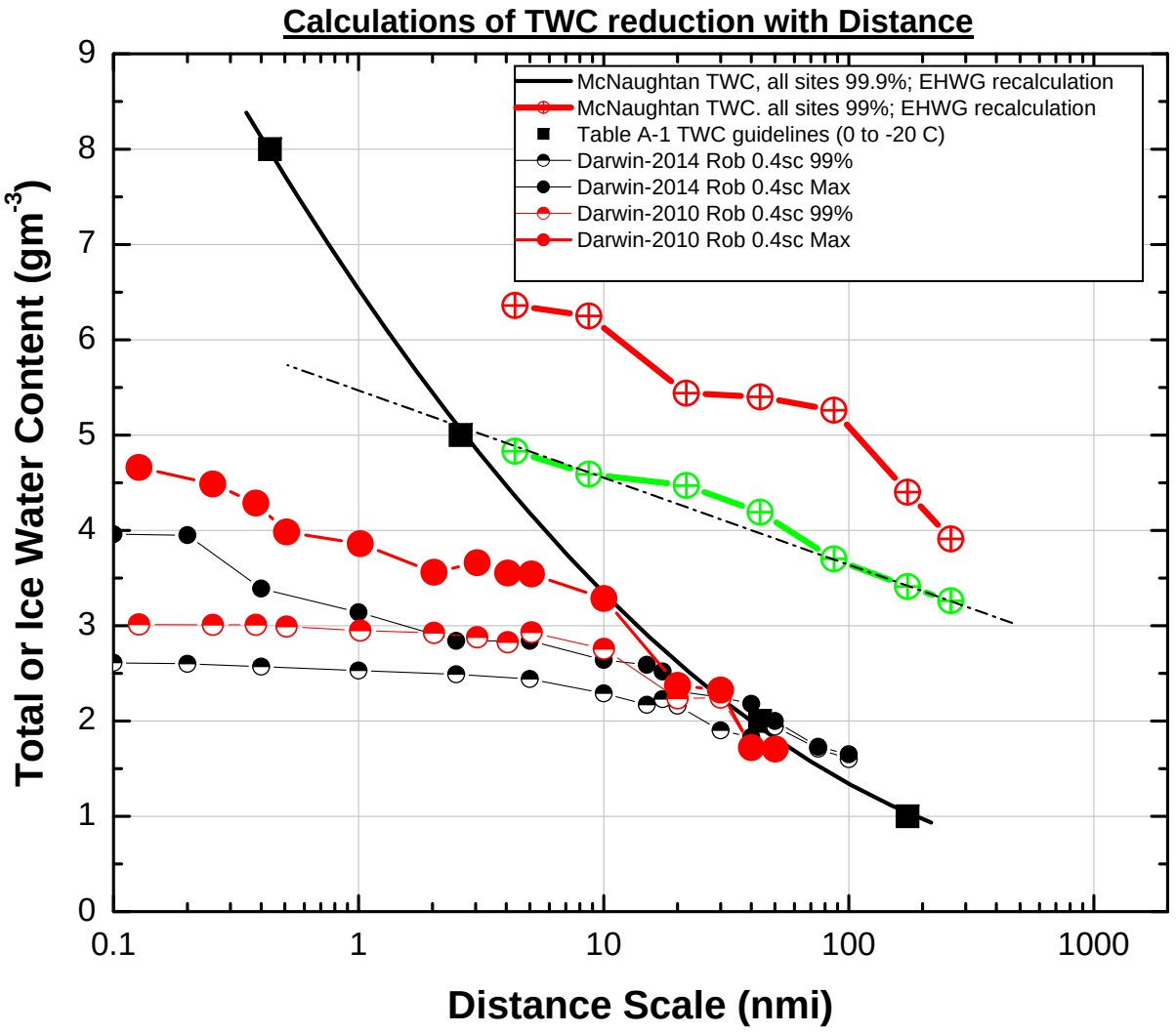
Preliminary Appendix D TWC statistics Darwin-2014 : IKP



Appendix D TWC statistics Darwin-2014 IKP and Robust (scale=0.4)



Appendix D TWC statistics Robust$_{0.4}$ Darwin-2014, Darwin-2010

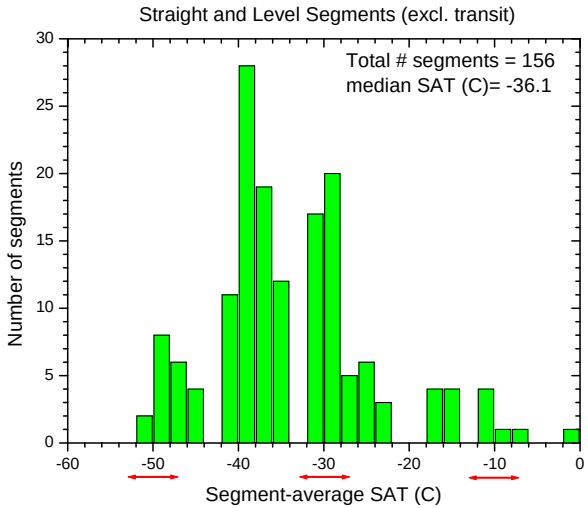


Assessment of where we are (cntd)

- Original plans were to collect 100 20-nmi data points at each of the three focus altitudes. A total of 335 20-nmi data points were collected, but not specifically at the focus temperatures.
  - Also, some of these 335 will be considered unsuitable after closer inspection using pilot's radar data, or for other reasons.

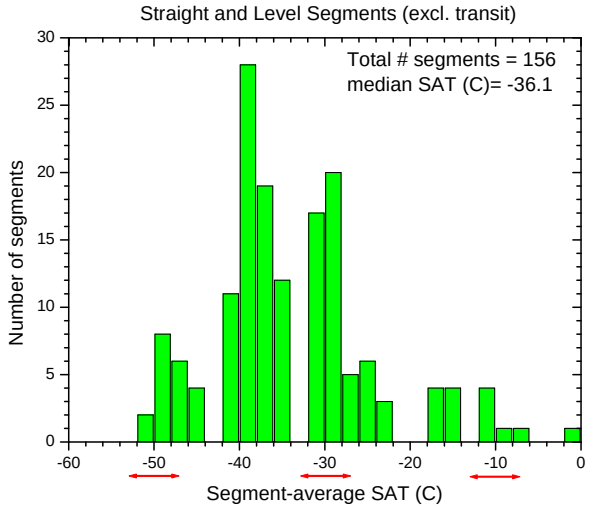
- Original plans, and actual data collected are as follows:

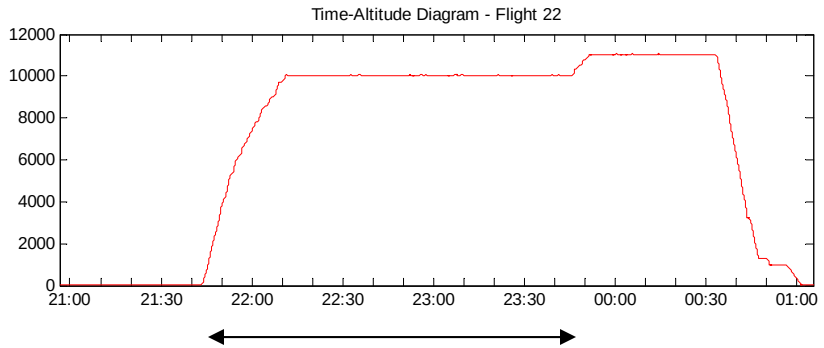
Temp.	Planned 20-nm pts.	Collected 20-nm pts.	No. of segments
-10 ± 3 ºC	100	11	3
-30 ± 3 ºC	100	140	44
-50 ± 3 ºC	100	17	8



Assessment of where we are (cntd)

- A large amount of data was collected between -34 C and -42 C, not in any of our altitude temperature thresholds
  - The F20 cannot reach -50 C immediately with full fuel (see time-height lower right).
  - 30 minutes to -30 C
  - 45 minutes to -40 C
  - 90 minutes to -50 C
  - Considering typical transit back base, this leaves <40 minutess capable for sampling at -50 C.
  - -50 C sampling has always bee at end of flight (bias?)

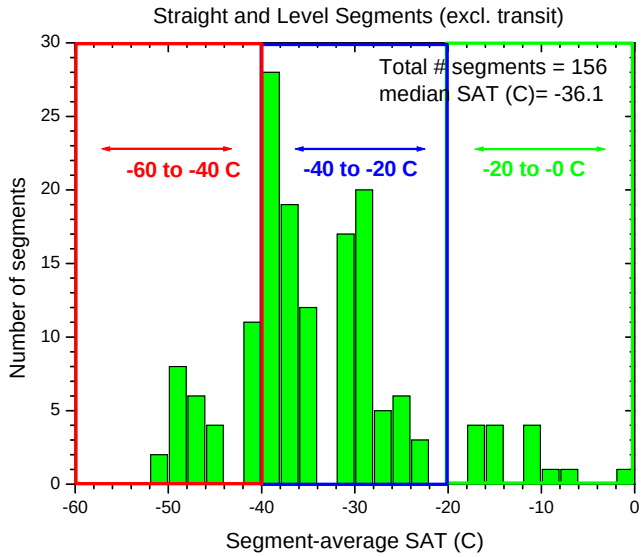




Suggestions for modifying ‘temperature’ levels

1. Widen temperature levels:

Temp.	Planned 20-nm pts.	Collected 20-nm pts.	No. of segments
-10 ± 10 ºC	100	21	9
-30 ± 10 ºC	100	264	98
-50 ± 10 ºC	100	37	23



Second flight program

- Darwin-14 was very successful, but its early termination resulted in insufficient data to meet the original objectives of the flight program
- A second flight program is in preparation, which will emphasize data that was not collected in Darwin
  - ~100 20-nm points at -10 C
  - ~100 20-nm points at -50 C
  - Some challenges due to the proximity to the melting layer (vertical distance to red-echo below) at -10 C
  - Some challenges in the time required to reach -50 C.
  - Is there a diurnal bias in convective intensity at next location?