A method for evaluating convective Impacts on the TTL, with some examples from ATTREX 3

Leonhard Pfister

Eliot Atlas

Maria Navarro

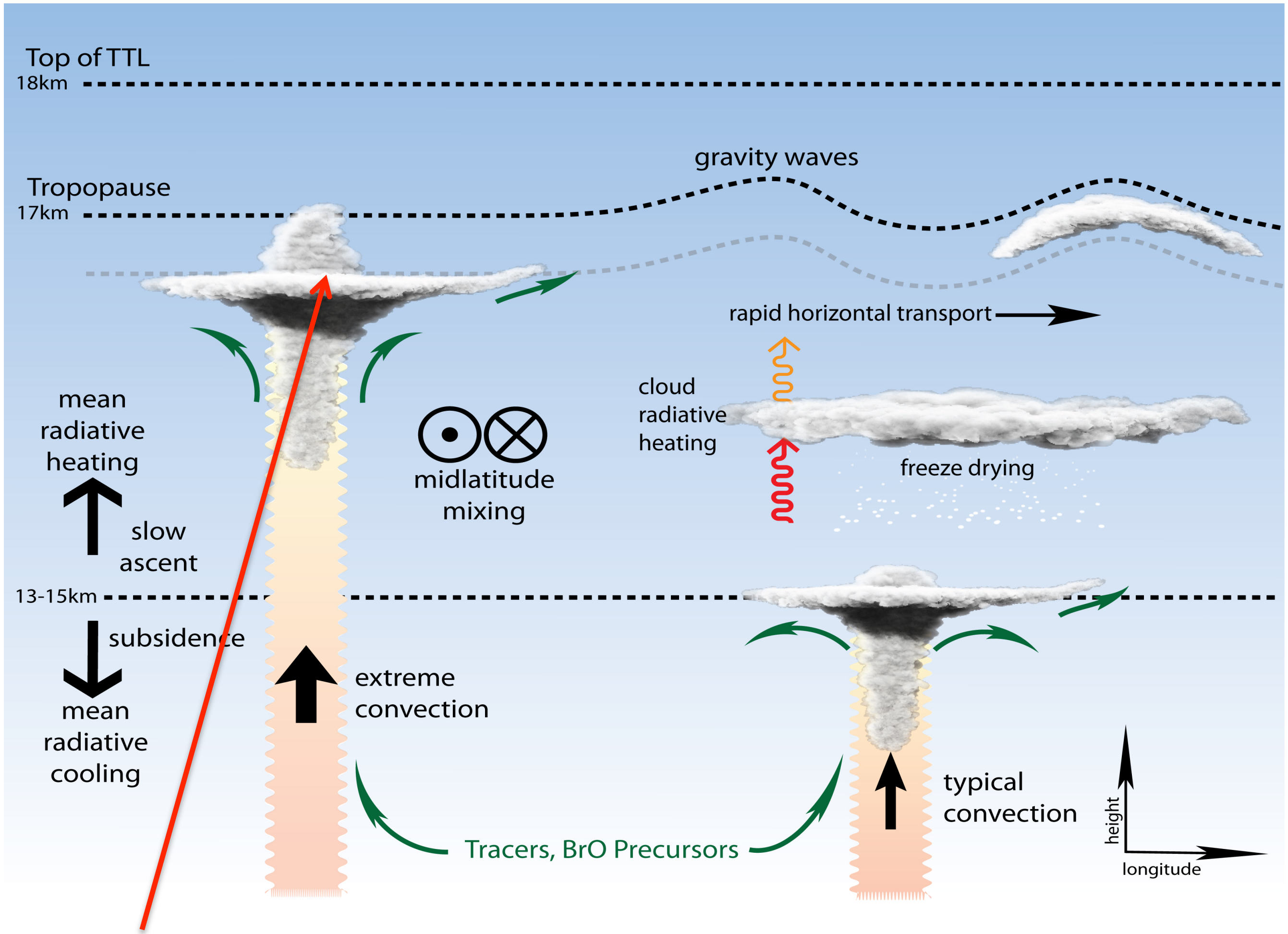
Rei Ueyama

Eric Jensen

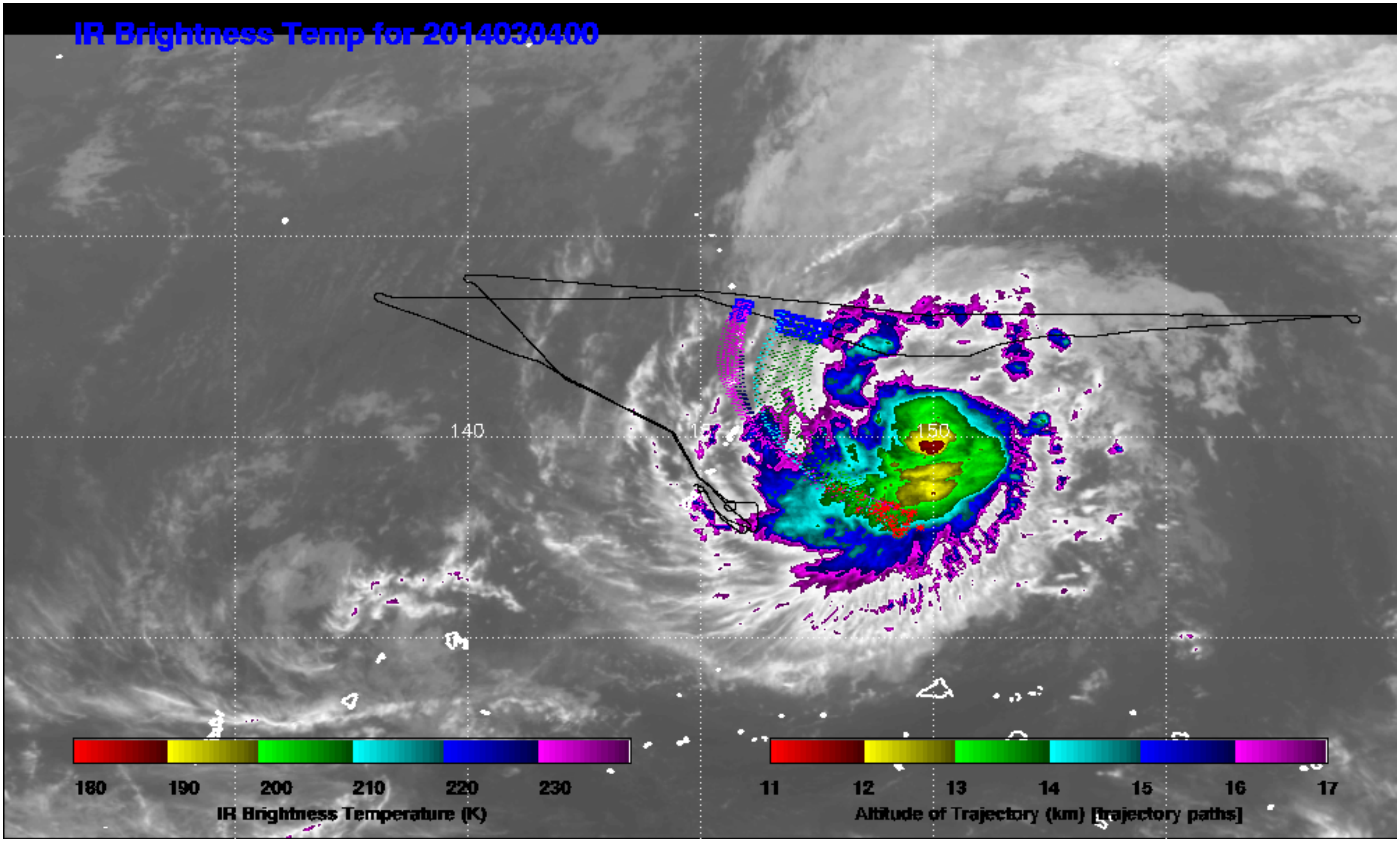
Troy Thornberry

Outline

- Motivation
- Description of convective method, some validation.
- Examples from global calculations (water vapor, CO)
- Example from ATTREX 3



Most convection has tops around 150 mb, some reaches the Cold Point Tropopause. Because the time scales of the other processes (slow ascent, midlatitude transport) are similar, getting cloud tops Right is important

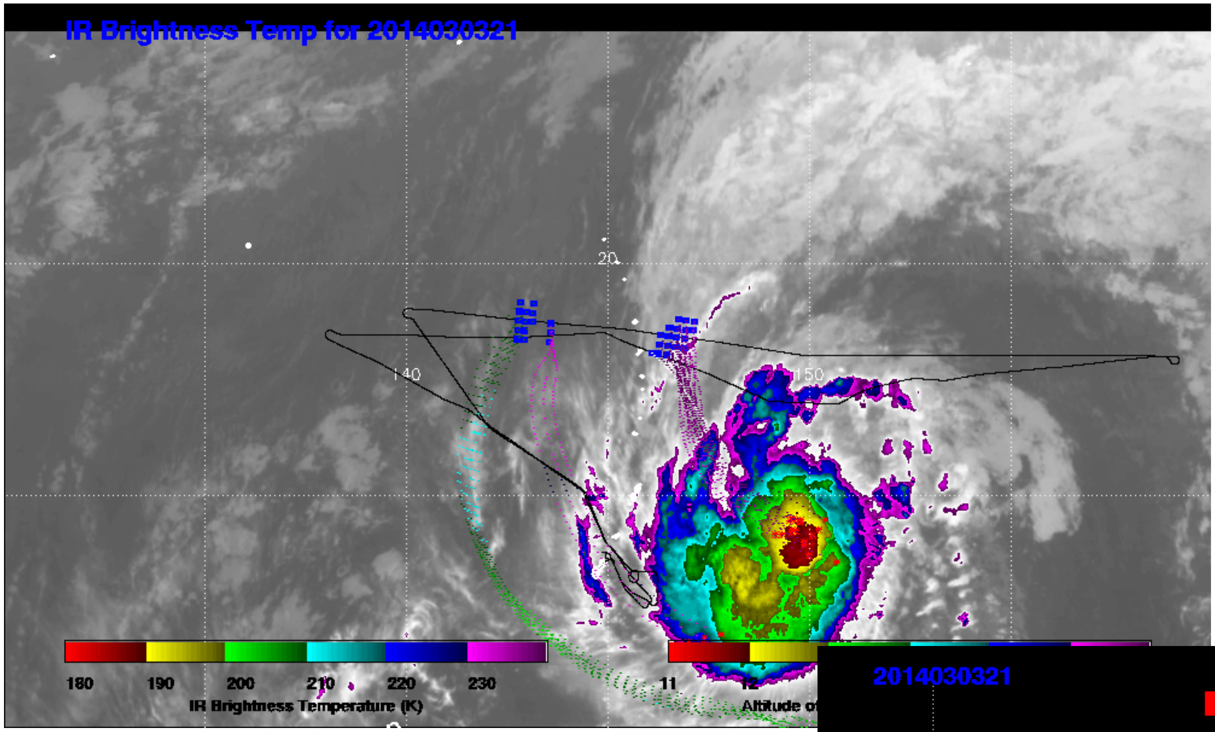


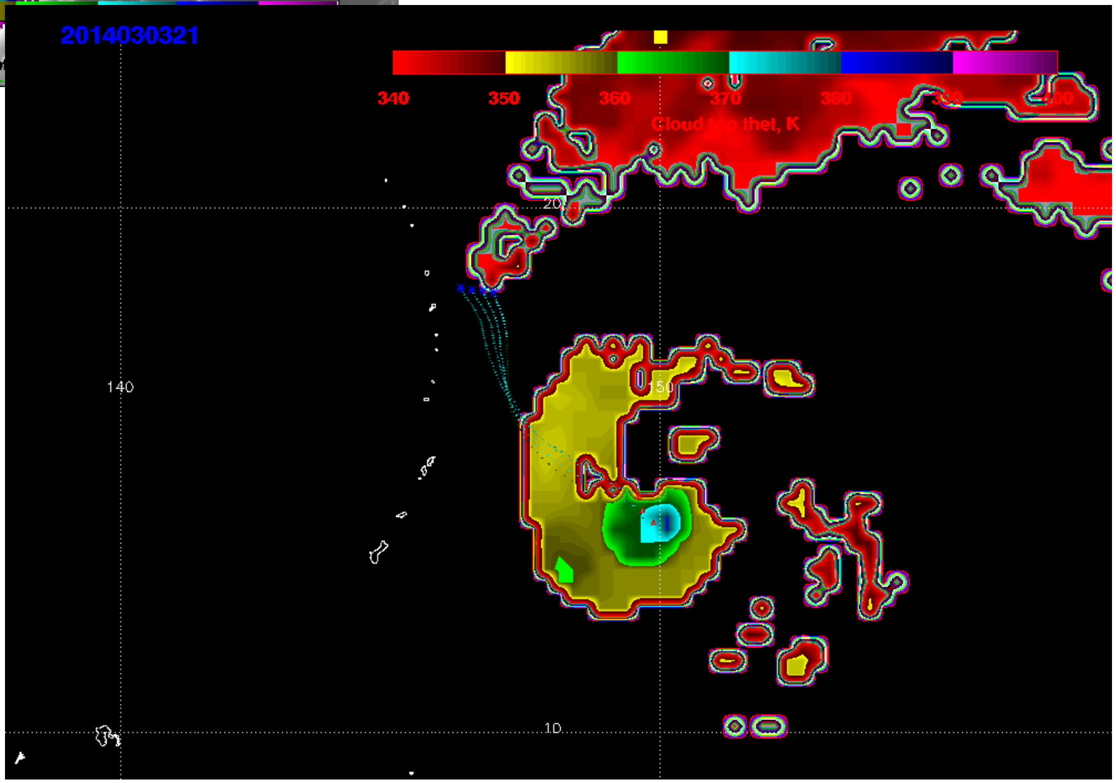
Three problems: (1) Models have trouble location convection and, especially, getting the altitude right. (2) Problem with satellite imagery is that a lot of what we see is anvil and not convection. (3) Cloudsat-Calipso get altitude, but only statistical sampling.

Solution: Use IR Satellite imagery and a rainfall threshold. Easily available, global, frequent.

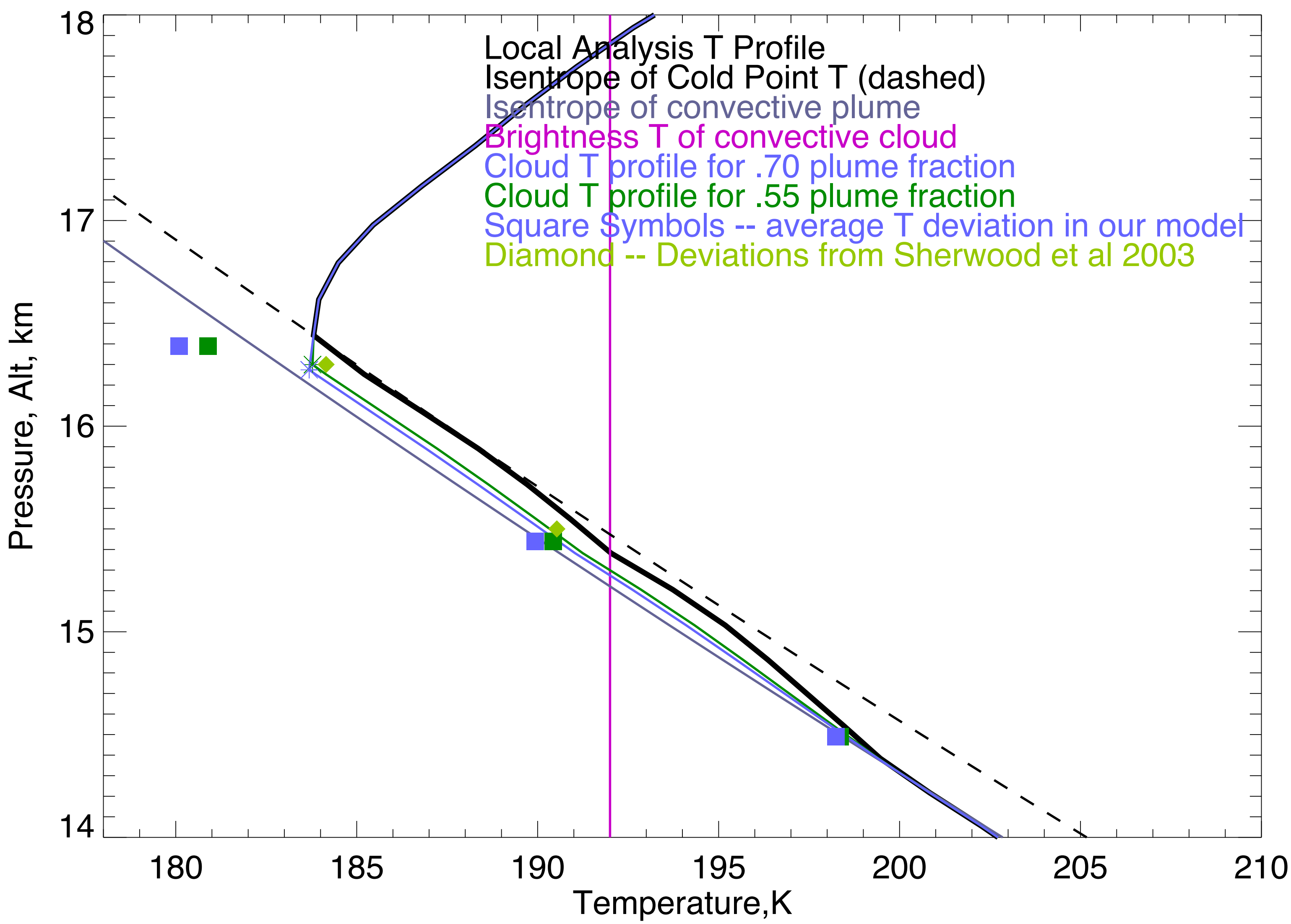
Outline of approach

- Threshold 3-hourly quarter degree global precip estimates (Huffman et al, 2007) (limits "anvil", focuses on core convection)
- Search for minimum IR-Brightness T within a specified radius of points meeting threshold.
- Calculate Cloud top altitude/theta using analyses (ERA-Interim in this case), plus a mixing scheme, to reflect cooling by convection (Biondi et al, 2012, Sherwood et al 2003, Selkirk et al 1993, Danielsen, 1982).
- Add about 1 km (IR vs actual shows this kind of deviation (Minnis et al, 2003).
- "Calibrate" with CLOUDSAT deep convective cloud product (which can actually define deep convective regions) "enhanced" by CALIPSO (Cloudsat cannot see cloud tops much of the time).

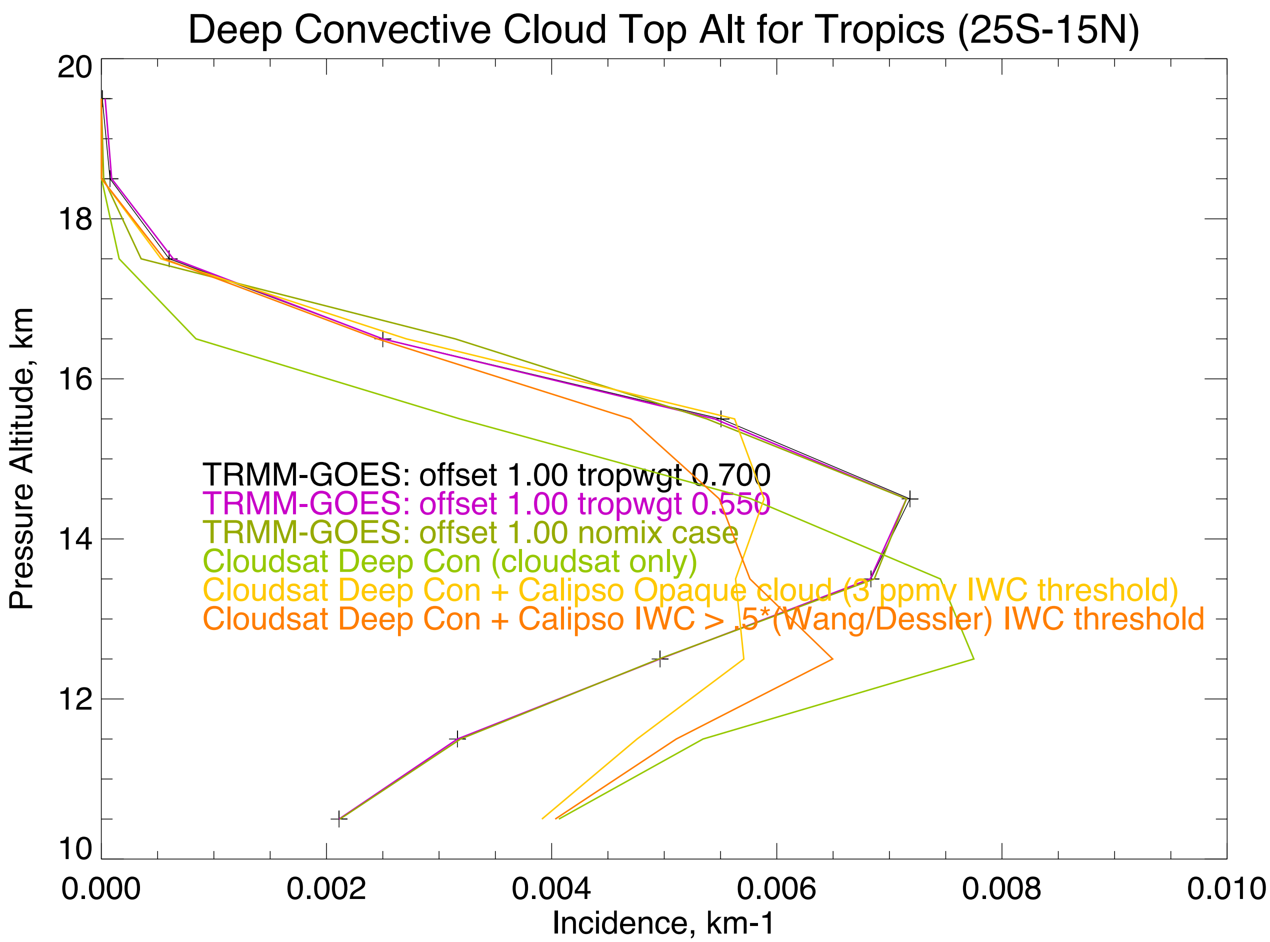

IR Brightness Temp for 2014030321
20
140
150
180
190
200
210
220
230
IR Brightness Temperature (K)
11
12
Altitude o


2014030321
340
350
360
370
380
20
140
150
10

Using mixing scheme lowers the calculated altitude a bit, but lowers cloud top theta significantly.

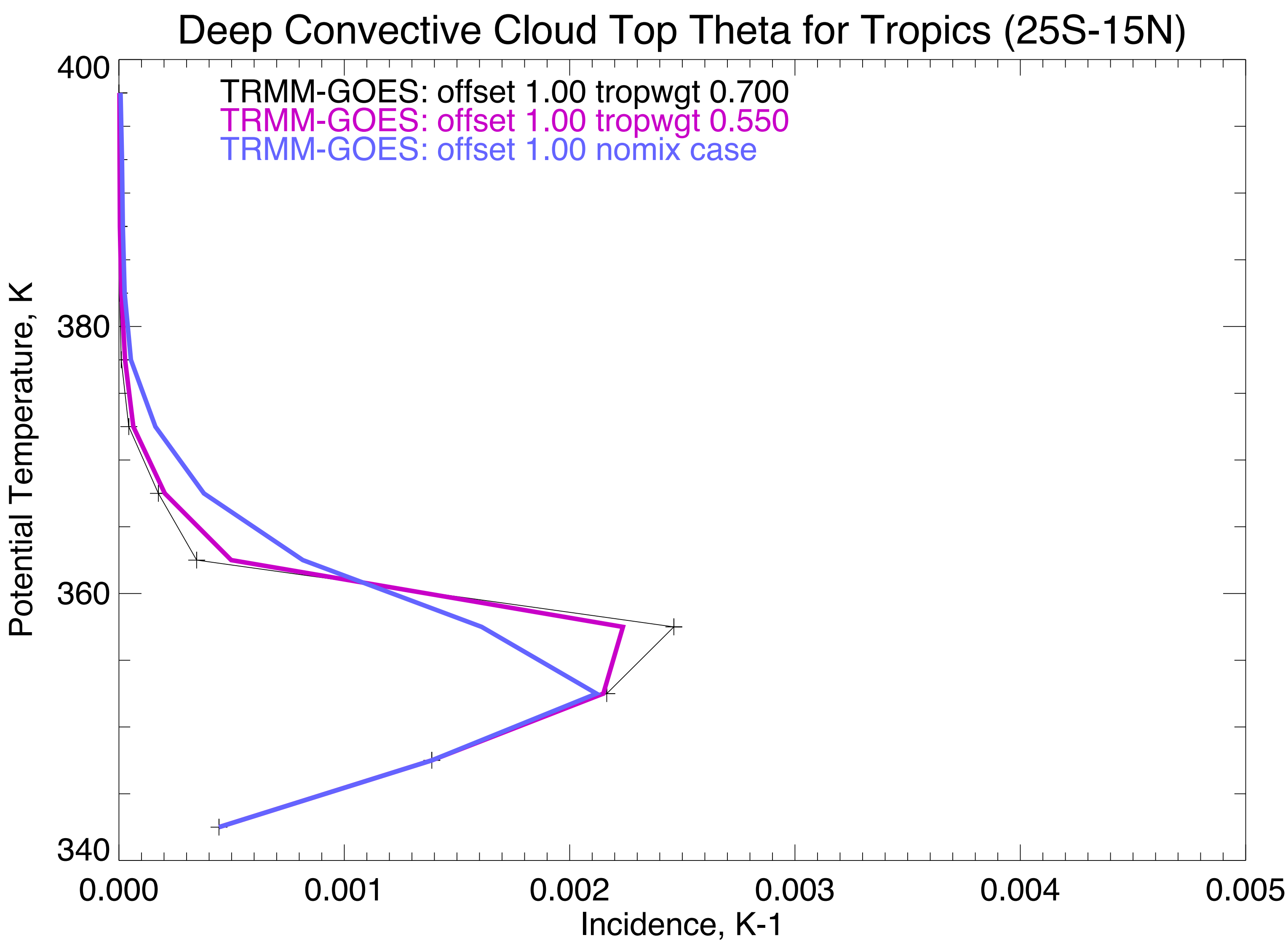


Comparison of our scheme (winter 2006-2007) with Cloudsat Calipso combination.

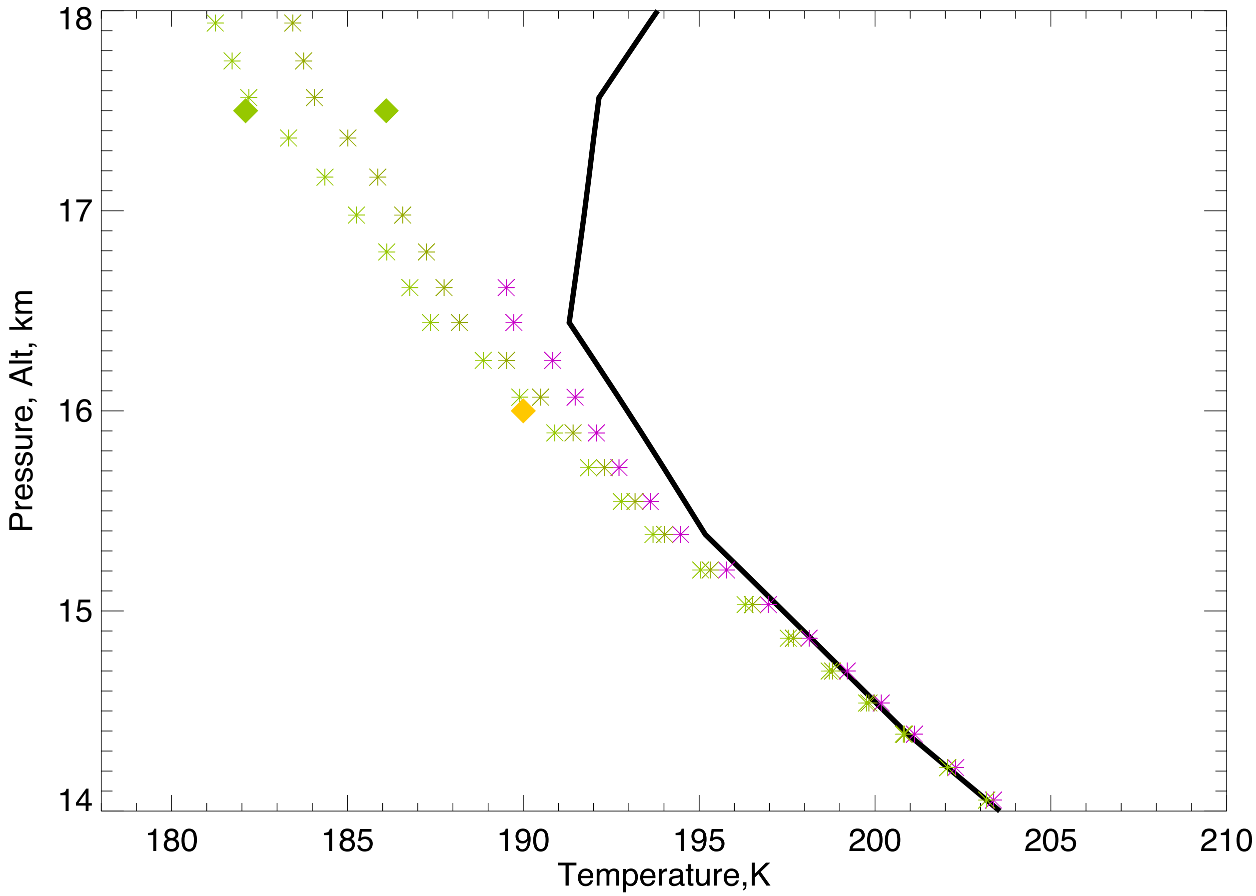


Good performance in the "tail" of convection up to and above the CPT. All mixing schemes are fairly similar FOR ALTITUDE.

Not so for Theta. This is actually what we really care about, and Cloudsat/Calipso cannot really tell us about cloud top theta directly.



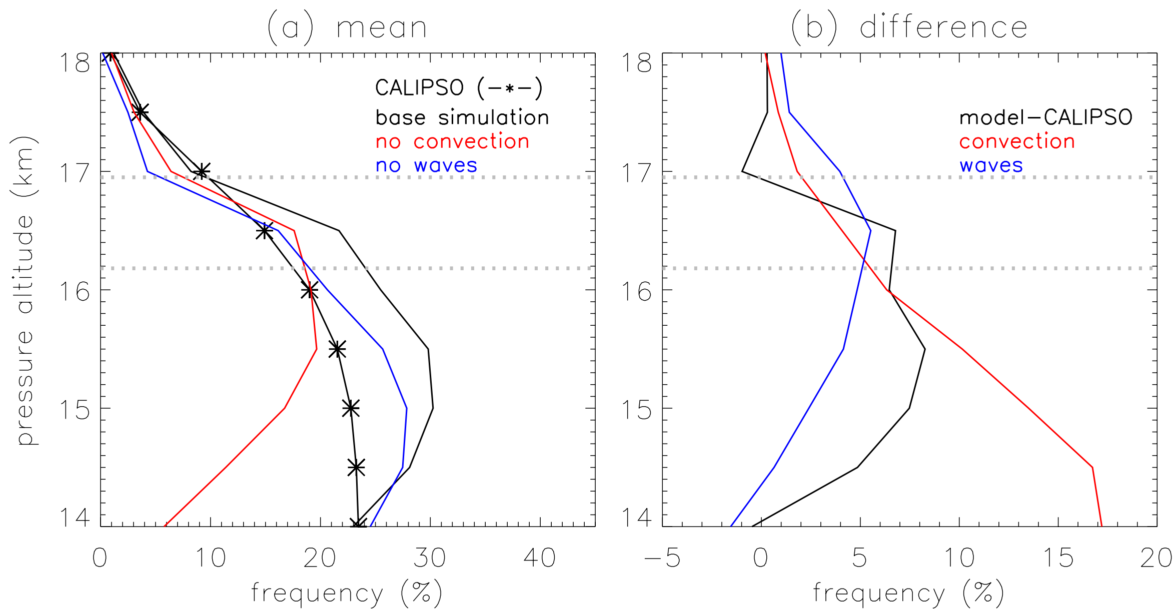
Mean tropical profile, with deviations due to mixing schemes (green Asterisks), Johnson and Kriete (1986) (green diamonds), Biondi et al (2012) (Orange Diamond), and Faxai (ATTREX-3, pink diamonds.



Suggestion is that our mixing approach is “not unreasonable.”

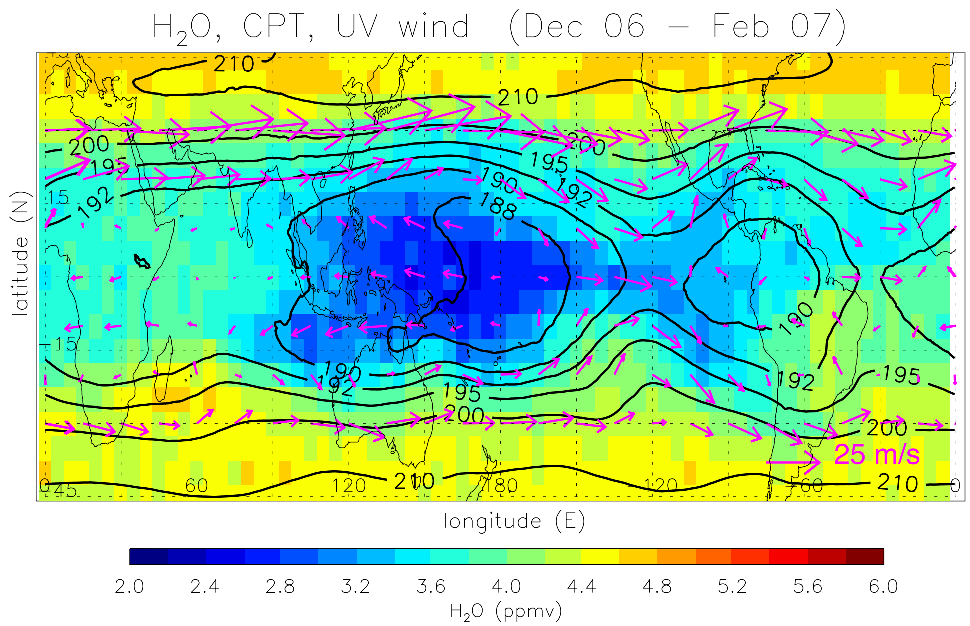
Examples of convective effect on TTL -- global

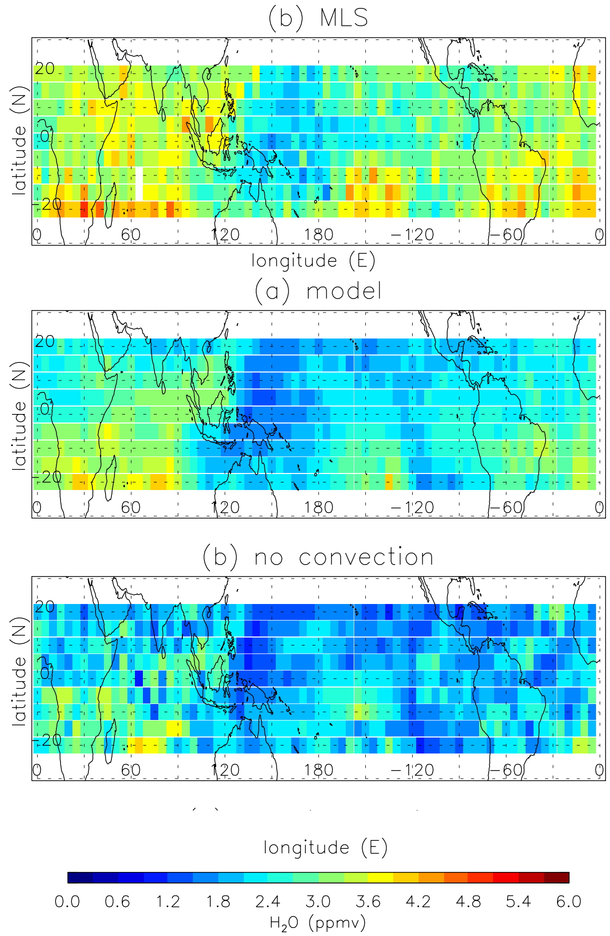
From Ueyama et al (2015 – in review)

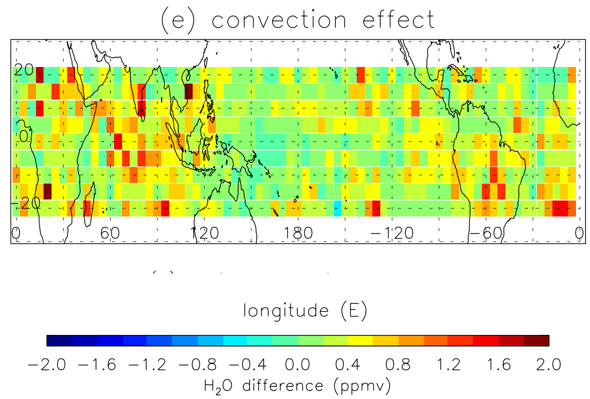


Convection is key to getting a reasonable estimate of TTL clouds.

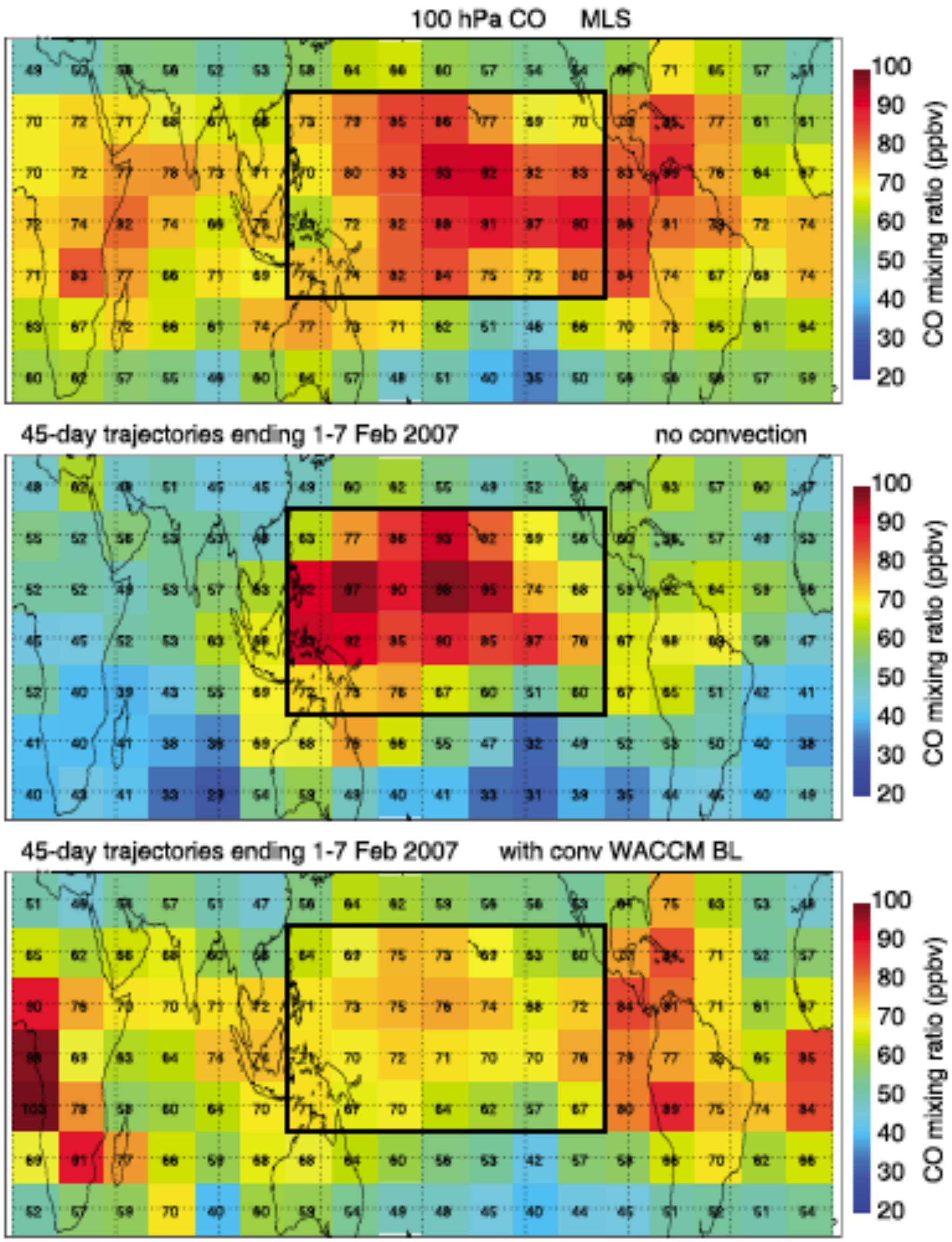
Also noted by Schoeberl et al, 2014 – Earth and Space Science





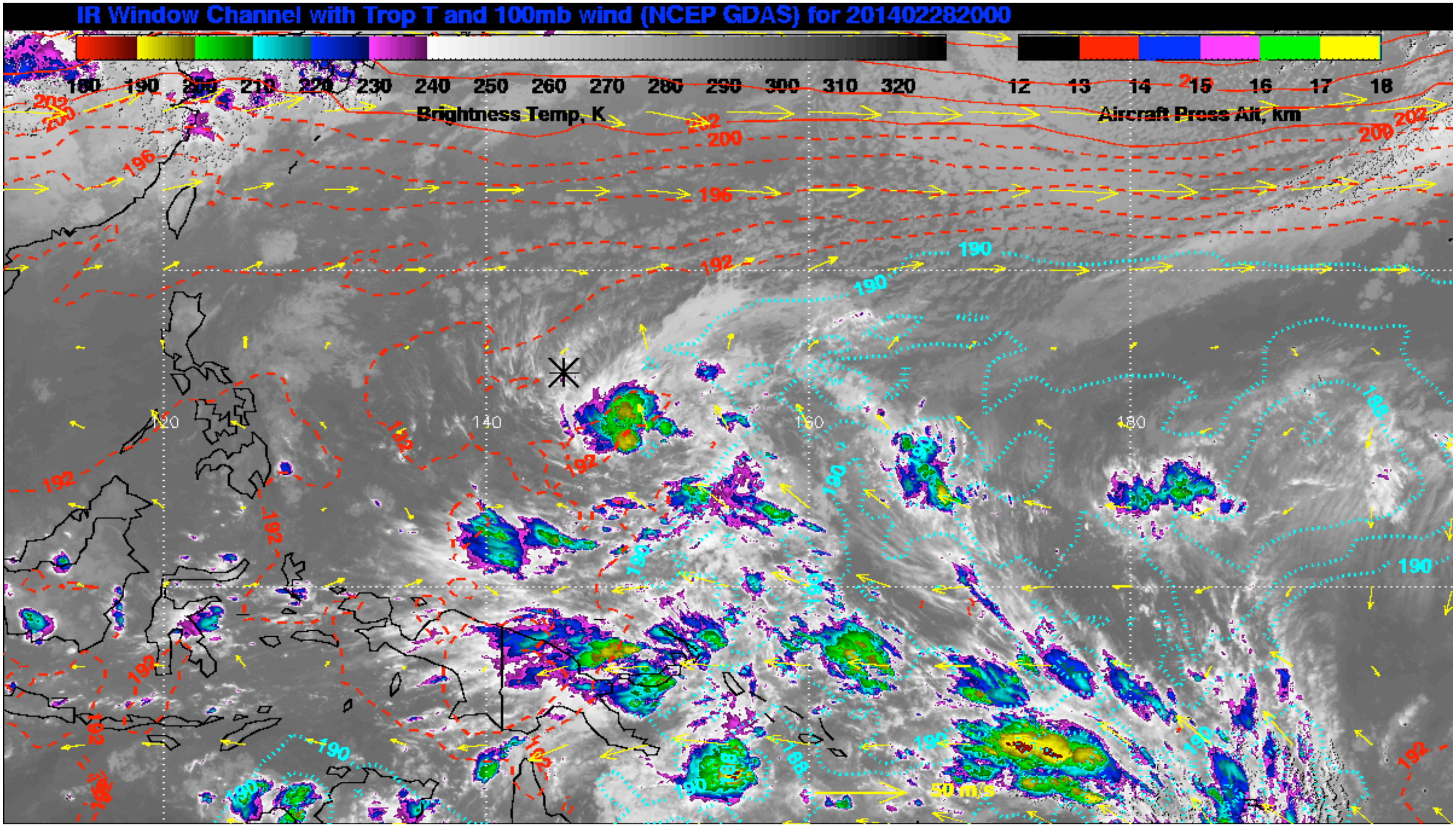


Convection effect on average TTL water is more subtle (.3 ppmv average tropics), but has an important impact on the structure. Without, convection, the cold pool dries up the whole TTL "swimming pool."© (OK, I exaggerate)

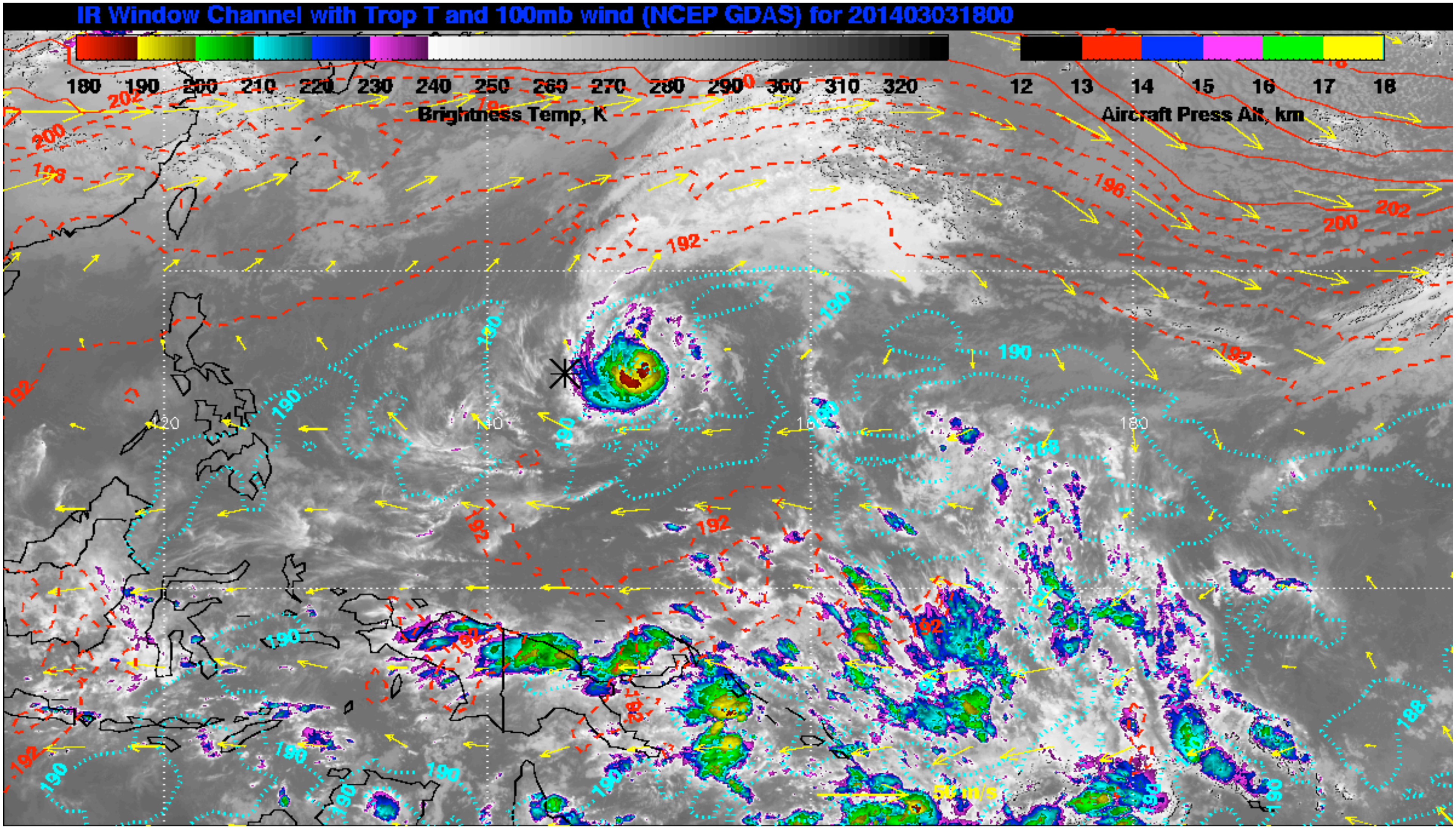


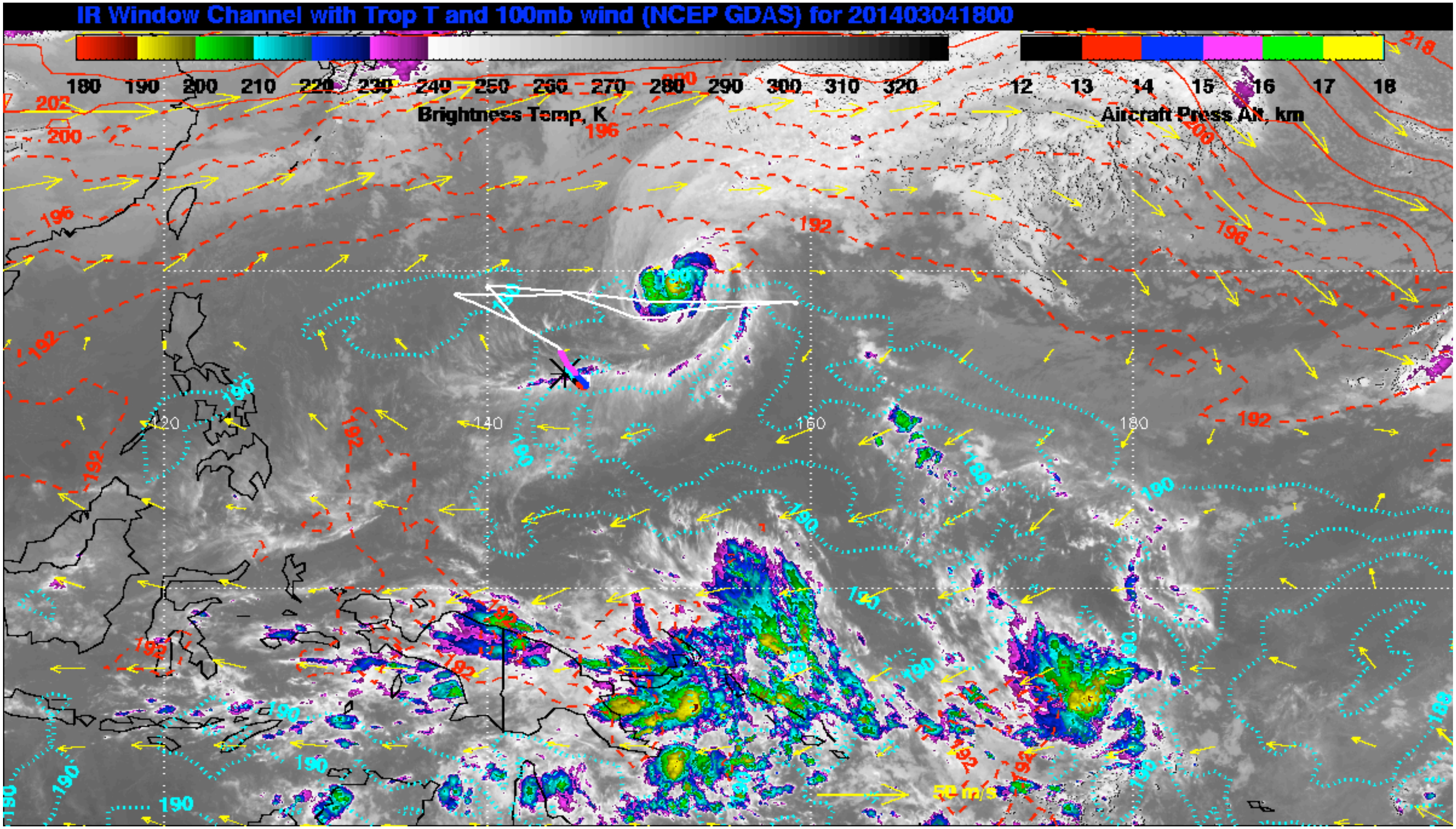
From Jensen et al, 2014:
Without convection, CO distribution is dominated by region of ascent near the cold pool.

Case Study from ATTREX3 – RF03 (Typhoon Faxai)

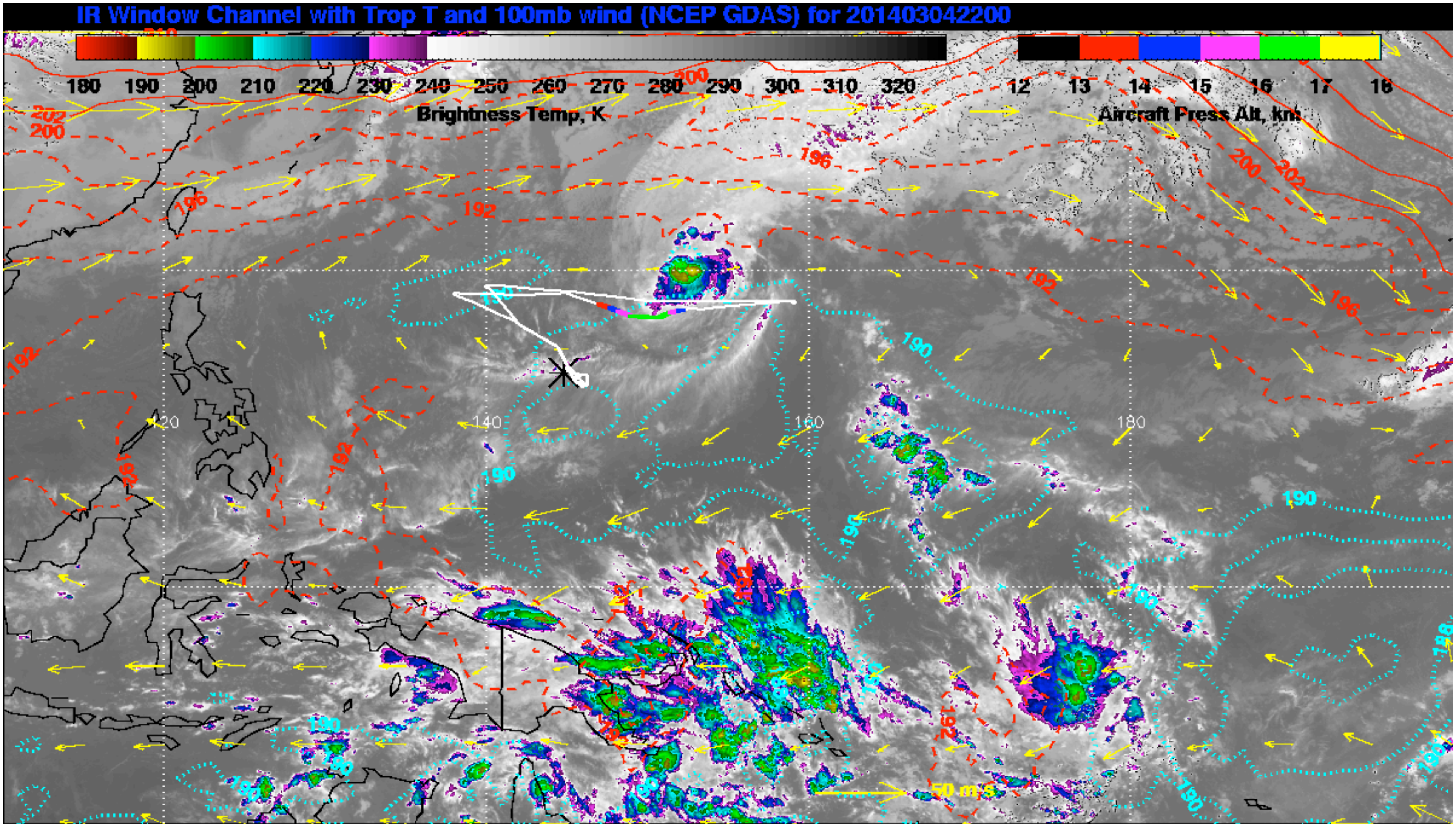


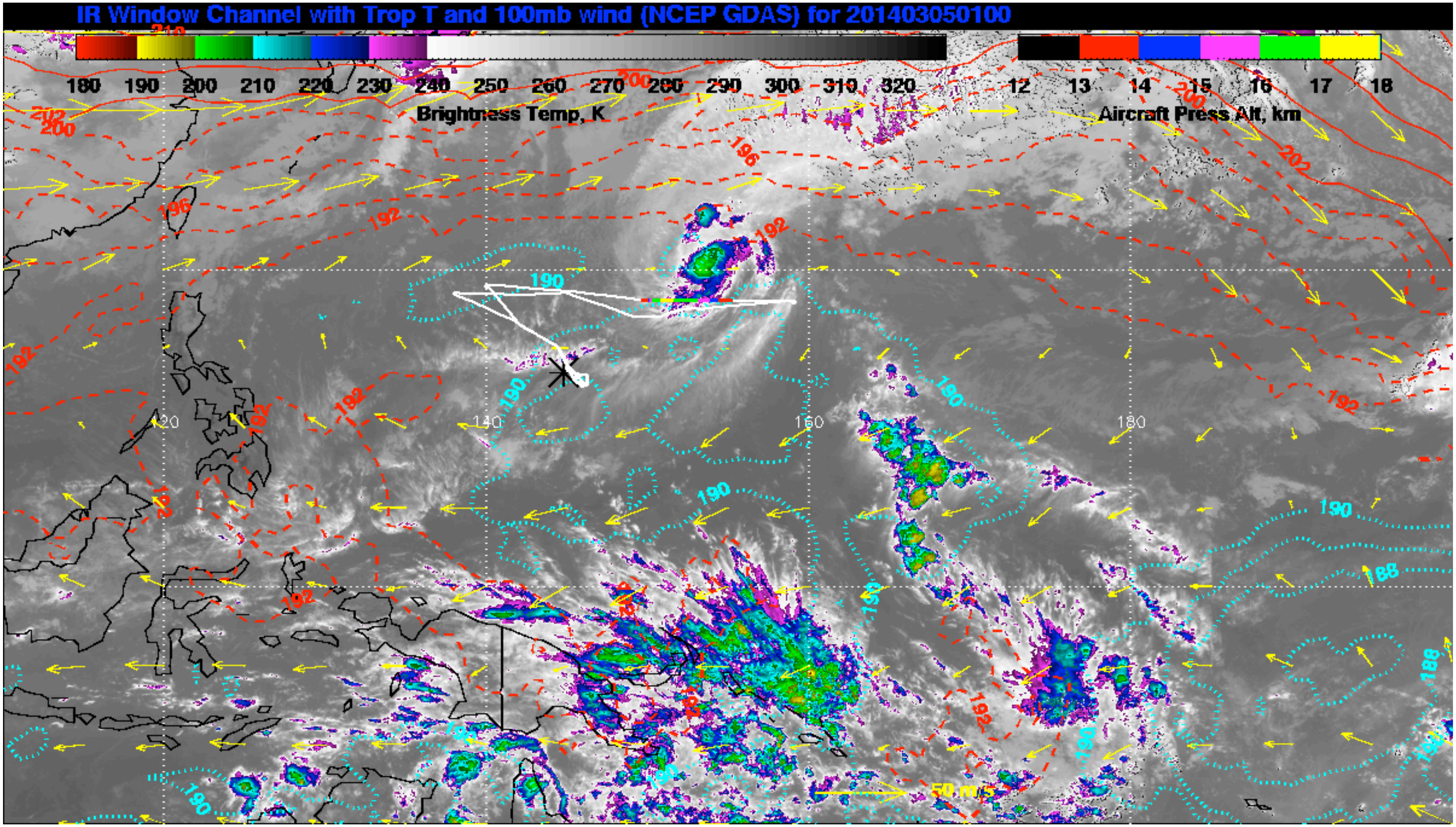
IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201402282000
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
12 13 14 15 16 17 18
Aircraft Press Alt, km
120
140
160
180
50 m/s

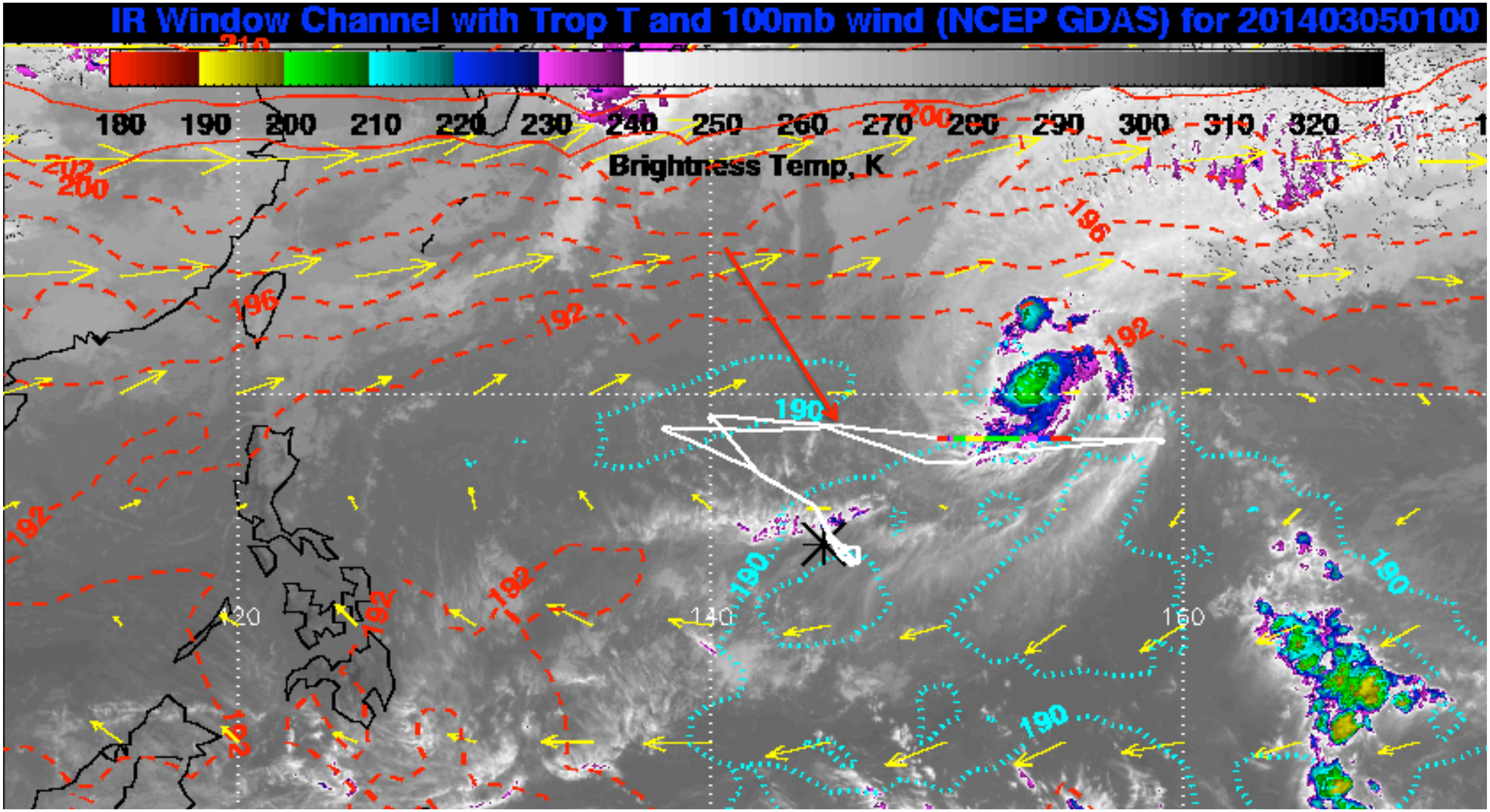

IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201403031800
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
12 13 14 15 16 17 18
Aircraft Press Alt, km
120
140
160
180
192
190
196
200
202
188
50 m/s



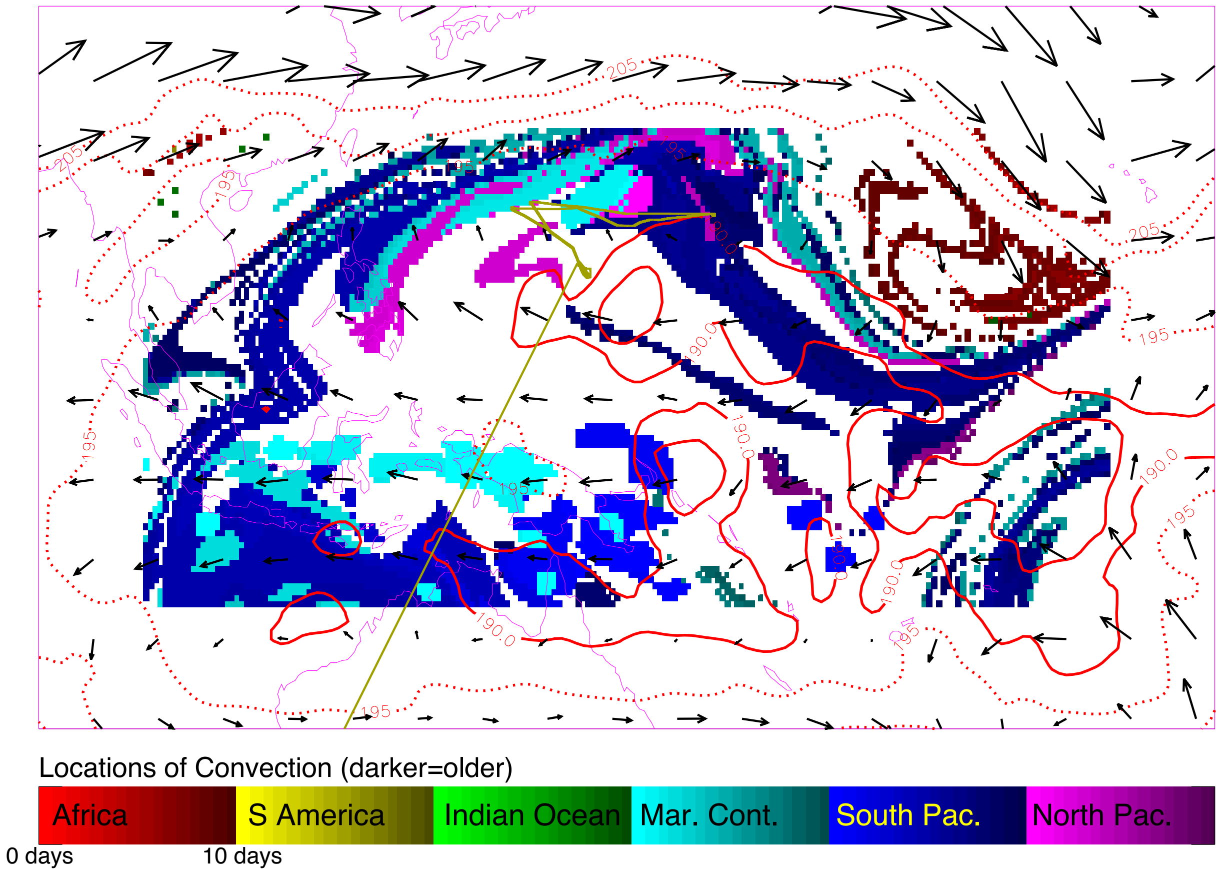
IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201403041800
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
12 13 14 15 16 17 18
Aircraft Press Alt, km
120
140
160
180
50 m/s

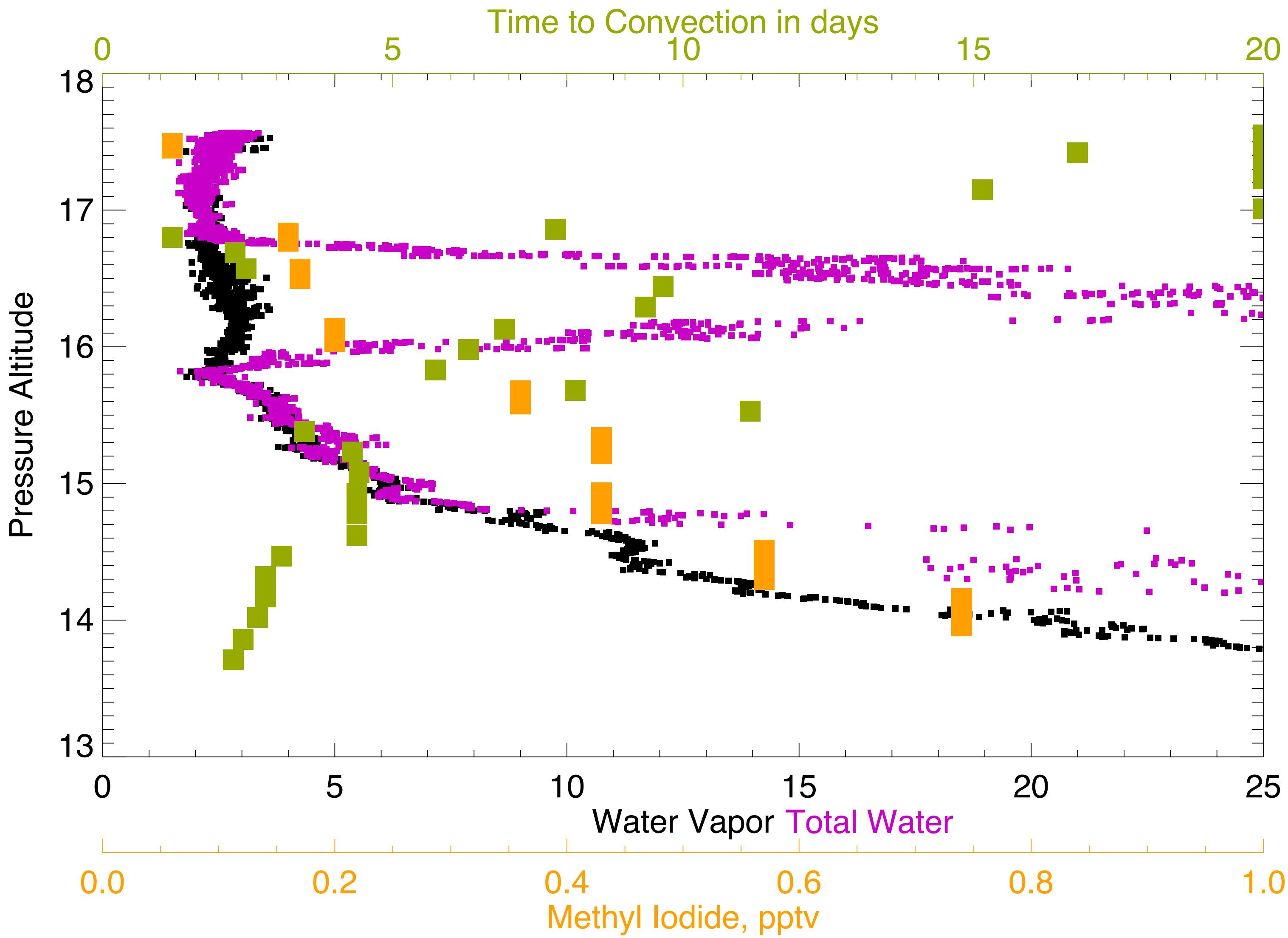

IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201403042200
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
12 13 14 15 16 17 18
Aircraft Press Alt, km
50 m/s


IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201403050100
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
12 13 14 15 16 17 18
Aircraft Press Alt, km
120
140
160
180
50 m/s


IR Window Channel with Trop T and 100mb wind (NCEP GDAS) for 201403050100
180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
Brightness Temp, K
120
140
160
190
192
196
200

Origin of Convectively Influenced Air at 14030418 on 365 surface





An ascent on the west bound flight leg.

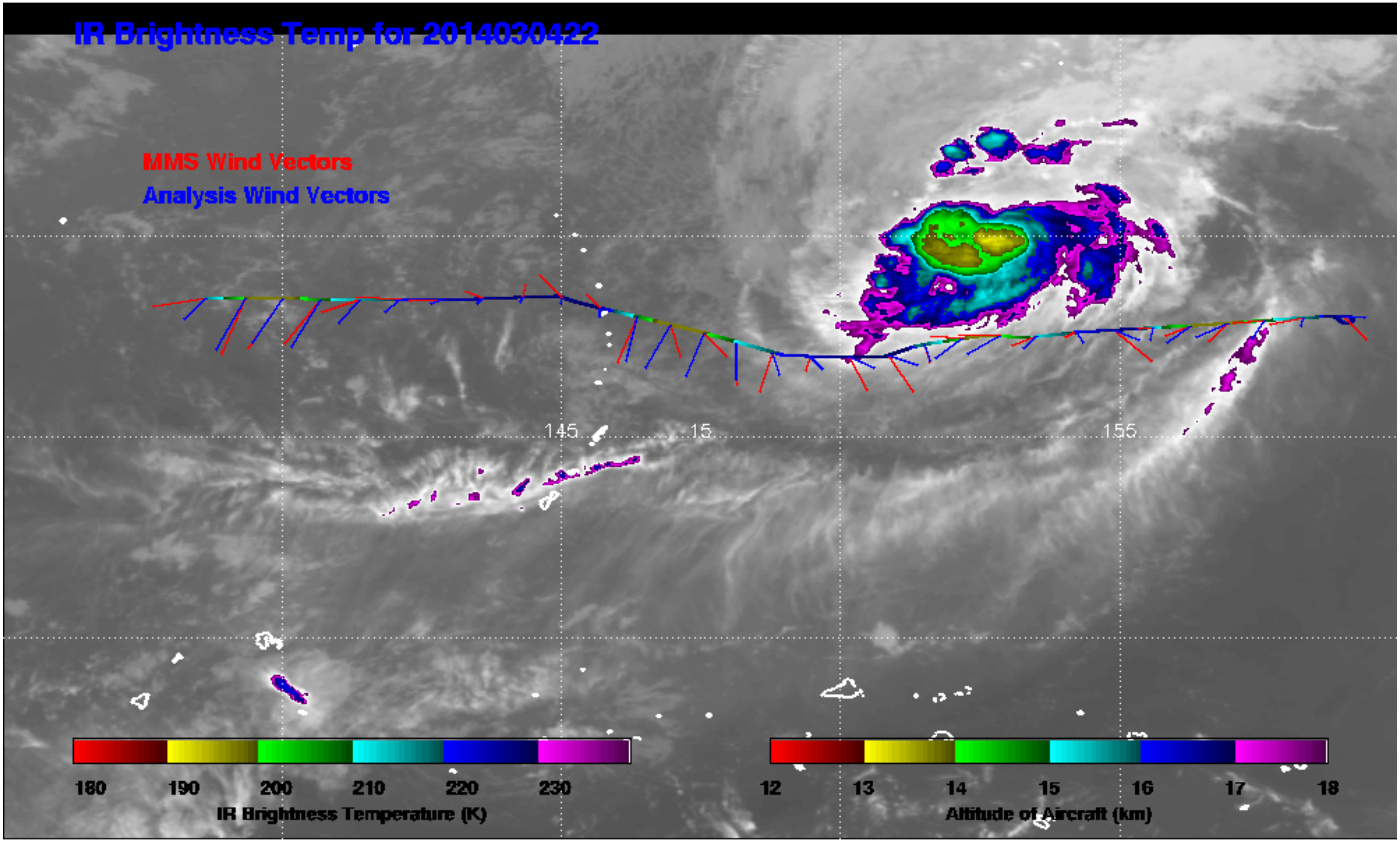
(1) No, or very old convective influence above cloud top (low Methyl Iodide also)

(2) Recent coninf near top of upper cloud, and some MeI (mixing?)

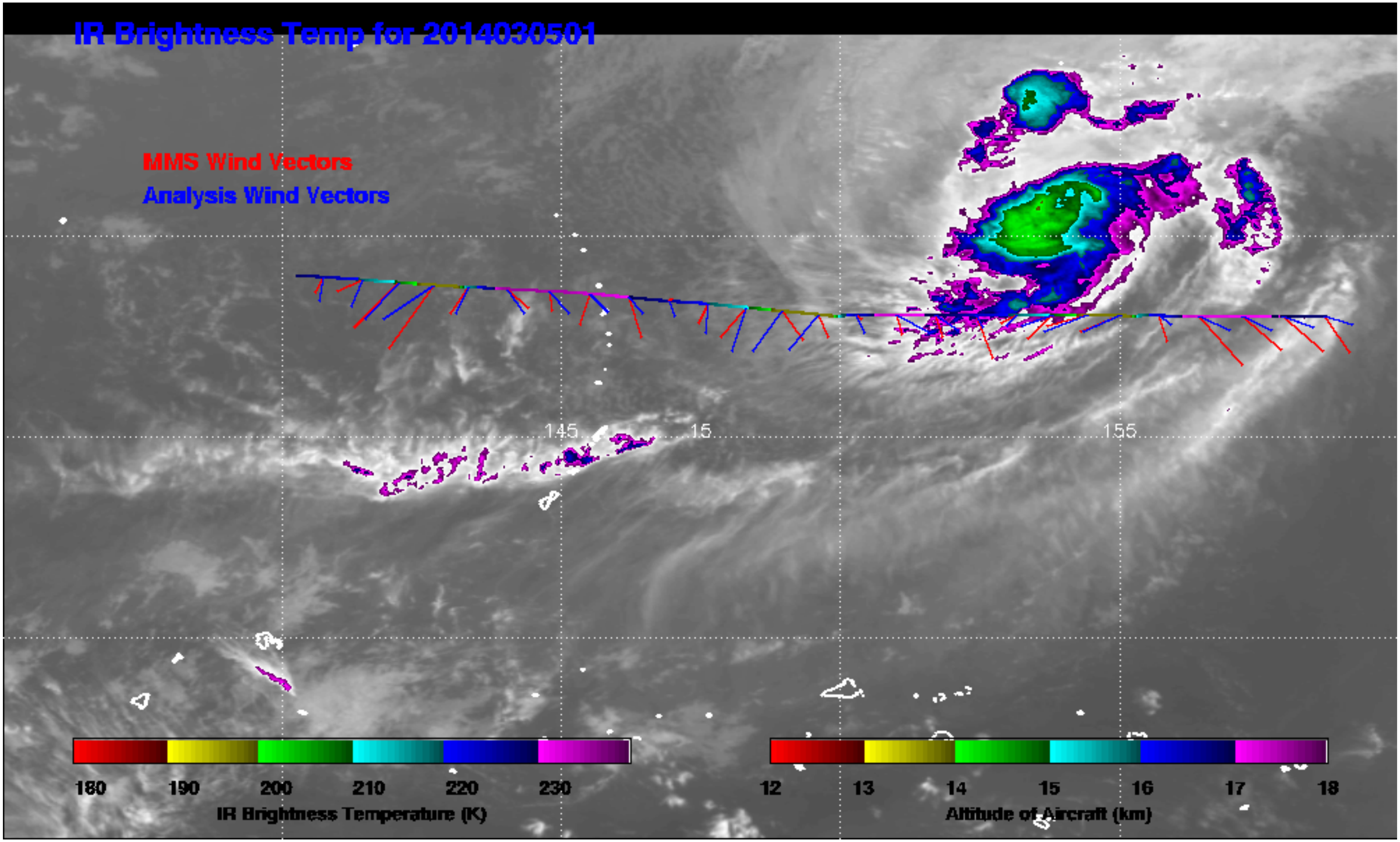
(3) Substantial MeI near 15-16 km, but NO CLOUD, coninf about 4 days old.

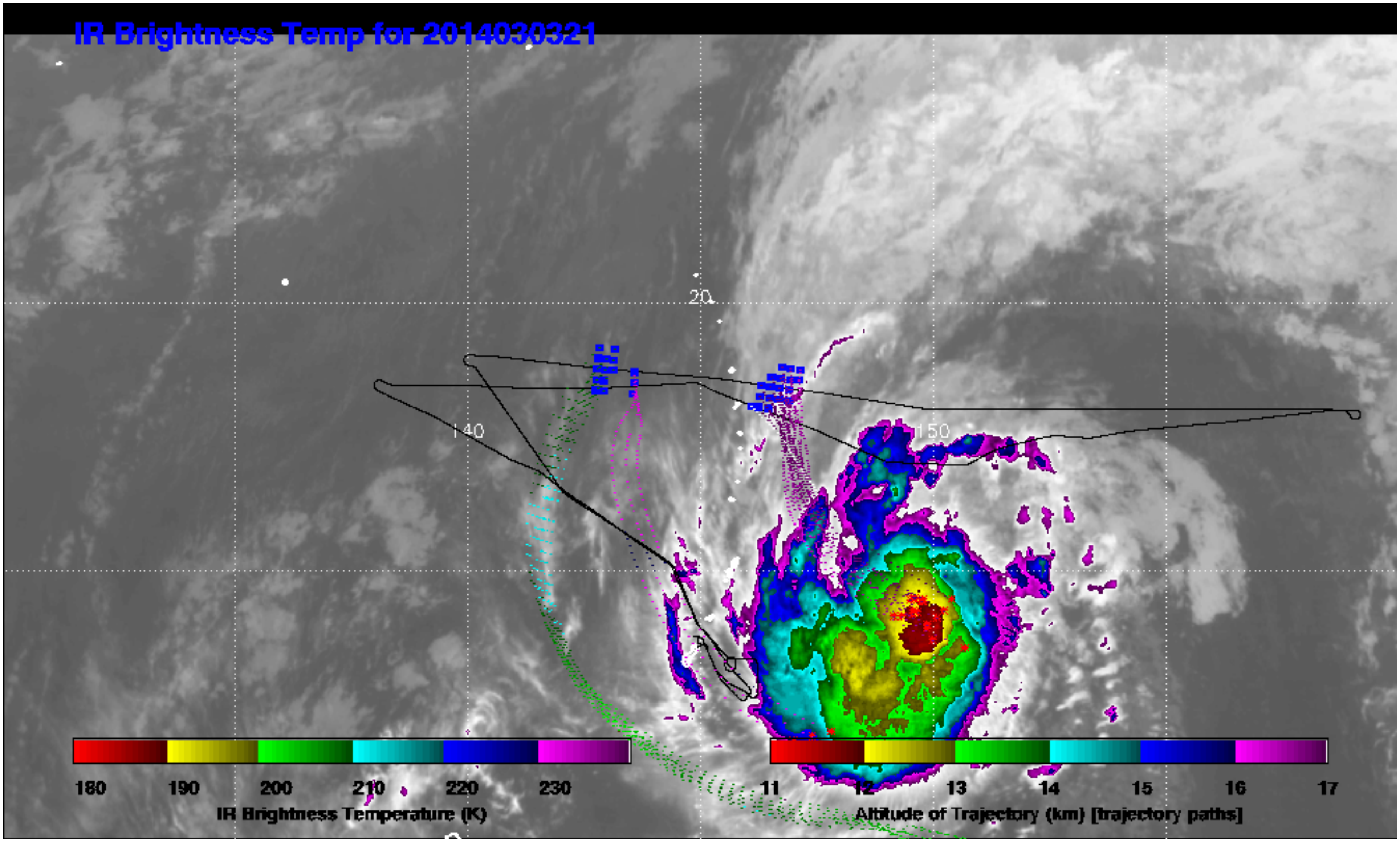
(4) Below 15 km, high MeI and cloud, coninf about 3 days old (should be more recent?).

Note challenge for trajectory model in getting these near field conditions right. For the most part, analysis winds and observed winds have a northward component, but there are significant differences.



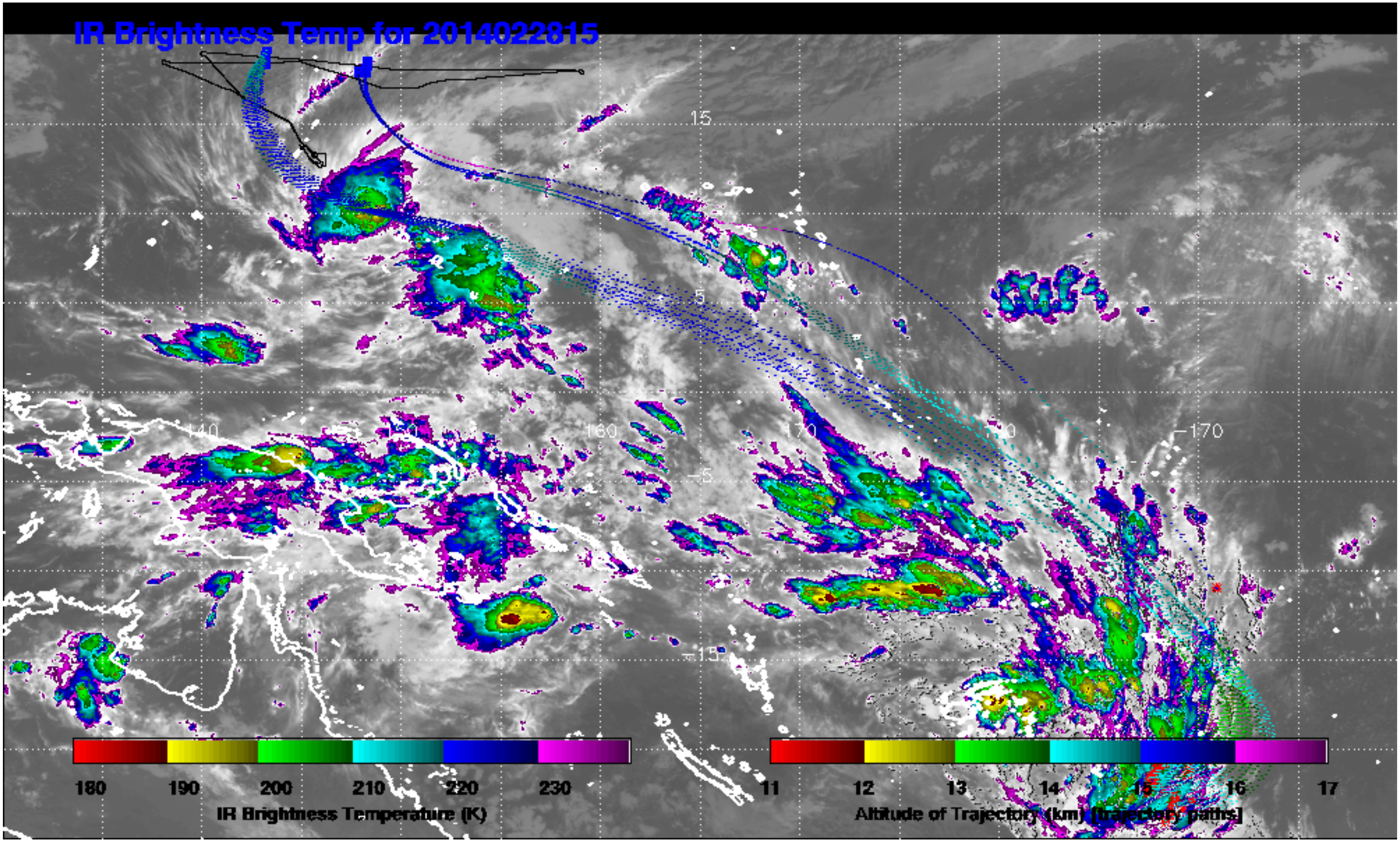
This return leg has better agreement (cyclone has moved a bit), but there are still discrepancies.

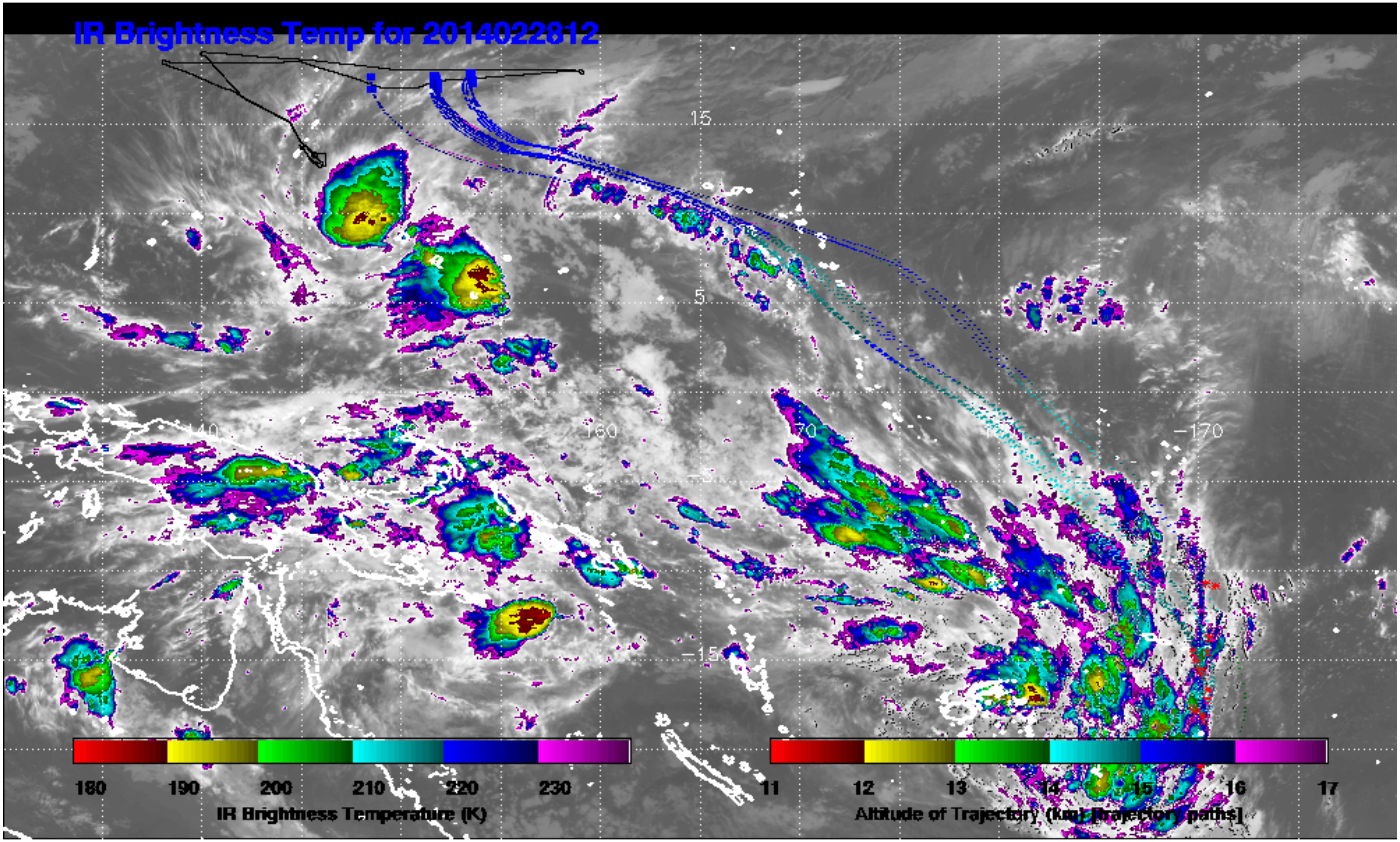




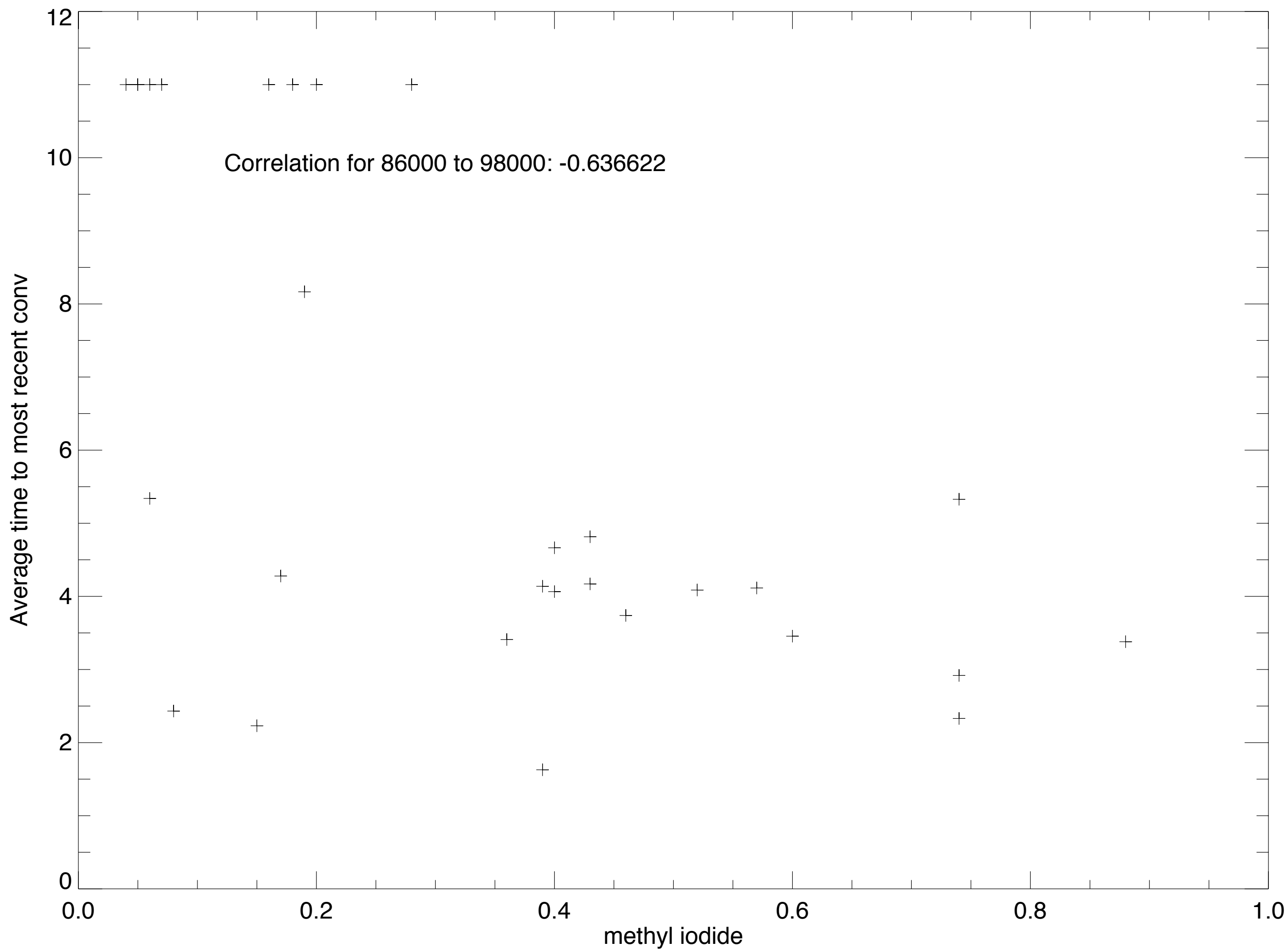
High altitude cloud traces back about 1.2 days to cyclone. Why is MeI not higher?
probably a lot of mixing with environmental air up top (theta is about 370K).
Presence of high TW clearly indicates convective influence, though.

Region around 15 km influenced by SH development about 4 days earlier ?





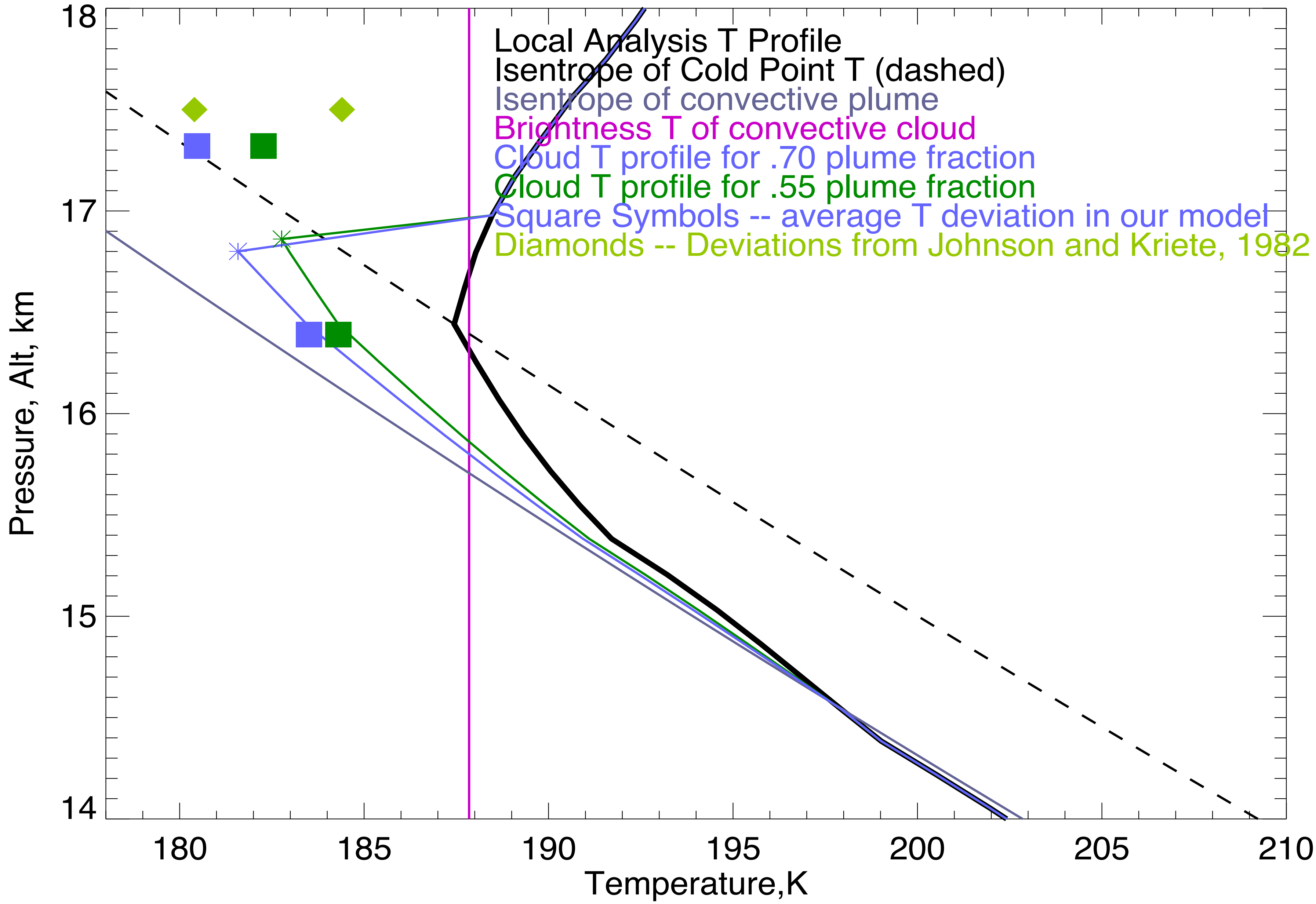
IR Brightness Temp for 2014022812
15
5
-5
-15
140
150
160
170
-170
180
190
200
210
220
230
IR Brightness Temperature (K)
11
12
13
14
15
16
17
Altitude of Trajectory (km) [trajectory paths]



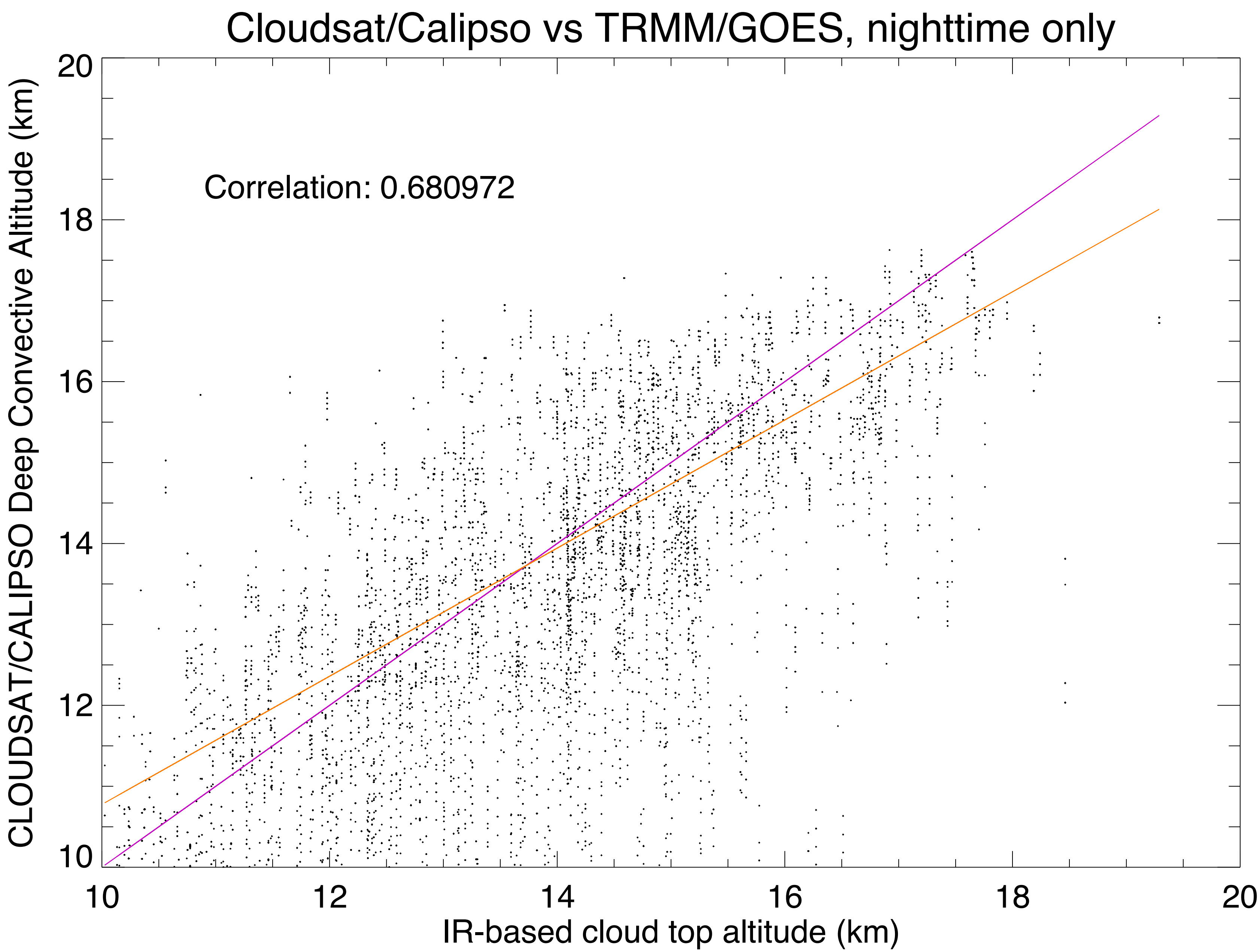
For entire east-west flight leg, have reasonable correlation between MeI and convective influence measure.

Summary

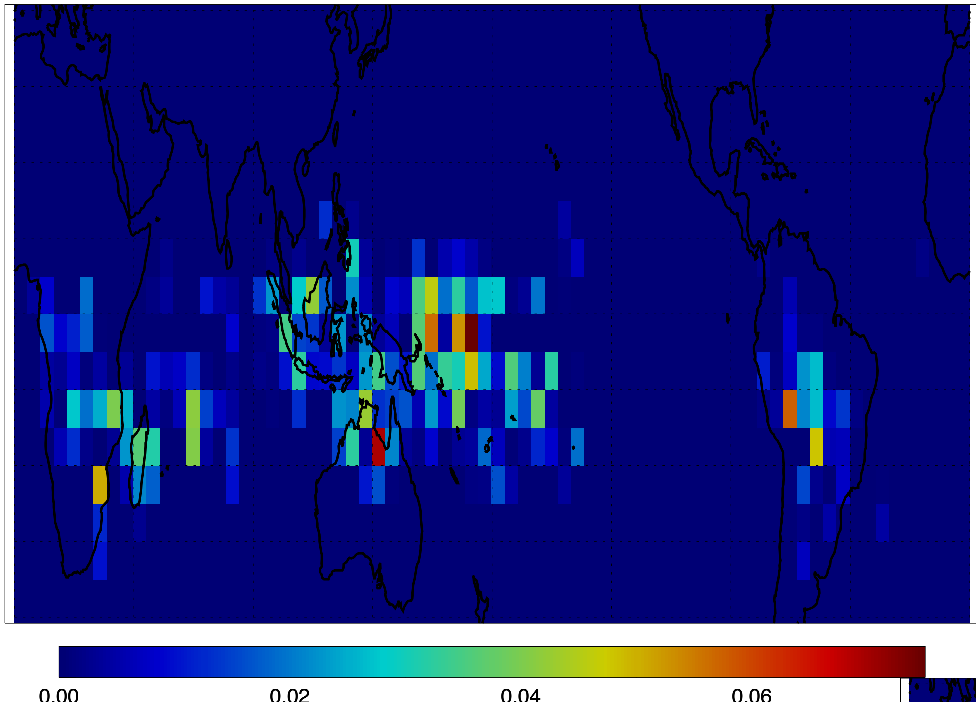
- Developed a scheme to represent convective cloud top potential temperatures globally on a 3-hourly basis.
- Good agreement with cloudsat-calipso based convection.
- Issue of cloud top altitudes versus cloud top thetas.
- Product has demonstrated usefulness in simulating clouds, water, and CO in global trajectory models.
- Useful for analysis of aircraft data.
- ATTREX-3 strongly convective case shows significant diversity of convective sources even in the vicinity of a tropical cyclone



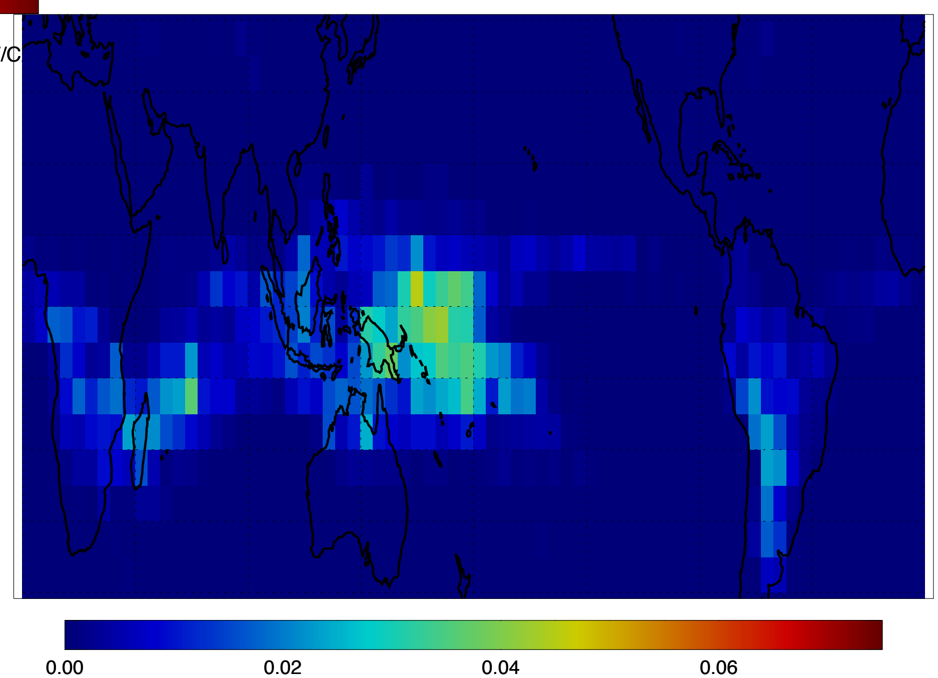
Local Analysis T Profile
Isentrope of Cold Point T (dashed)
Isentrope of convective plume
Brightness T of convective cloud
Cloud T profile for .70 plume fraction
Cloud T profile for .55 plume fraction
Square Symbols -- average T deviation in our model
Diamonds -- Deviations from Johnson and Kriete, 1982
Pressure, Alt, km
Temperature,K
18
17
16
15
14
180
185
190
195
200
205
210



Cloudsat/Calipso vs TRMM/GOES, nighttime only
Correlation: 0.680972
CLOUDSAT/CALIPSO Deep Convective Altitude (km)
IR-based cloud top altitude (km)
10
12
14
16
18
20



Nighttime Deep Convective Cloud Top Fraction above 15.5 km (Pressure Altitude) -- CLOUDSAT/C



Nighttime Deep Convective Cloud Top Fraction above 15.5 km (Pressure Altitude) -- TRMM/GOES