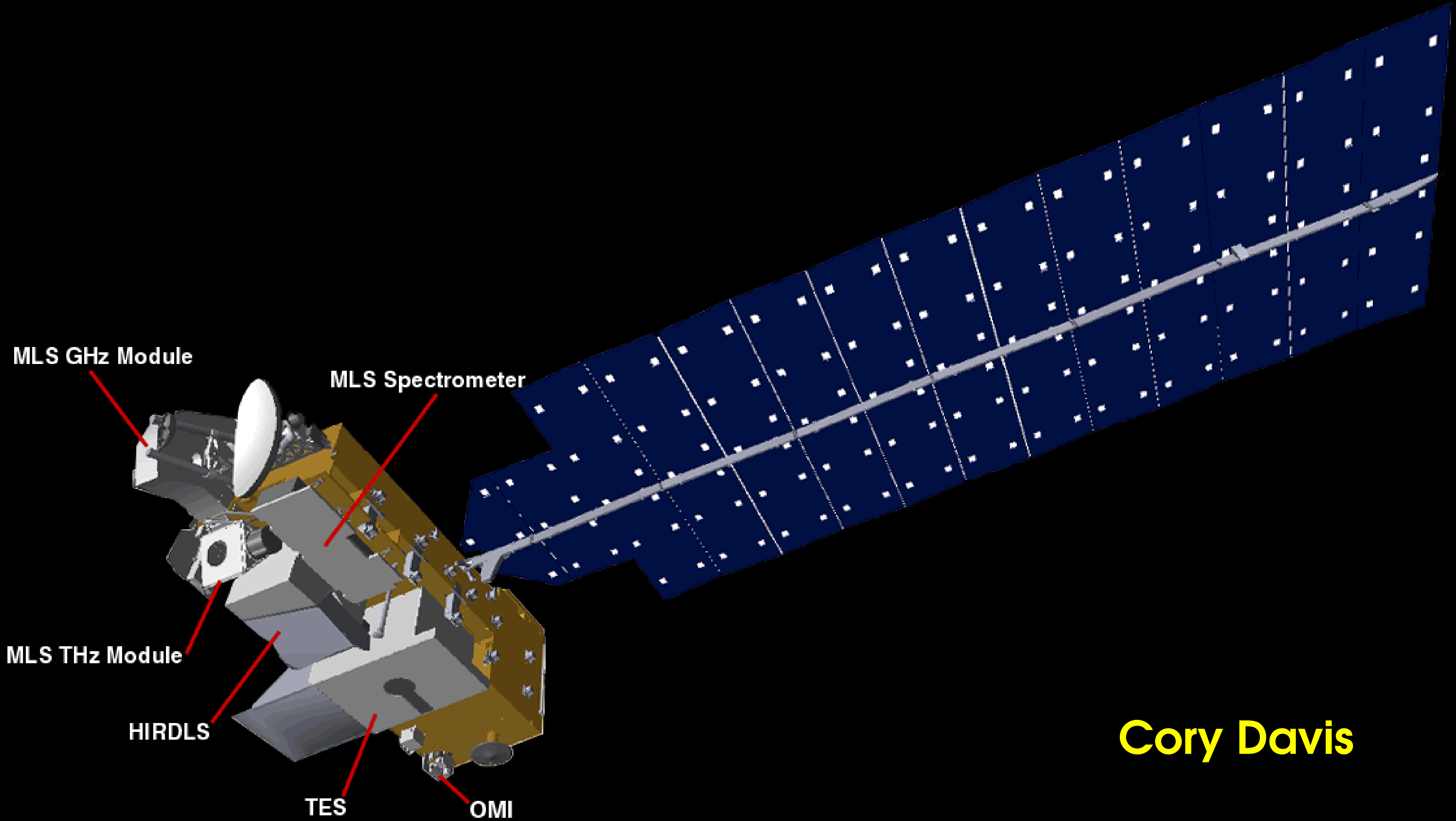
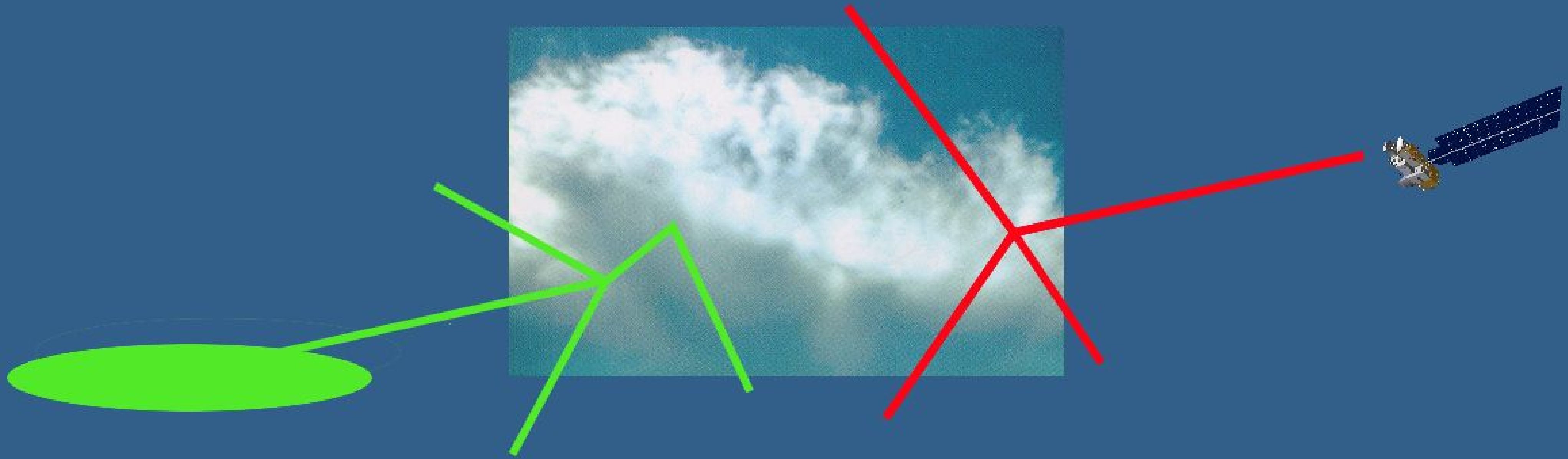
Aura MLS Cloud Observations



Cory Davis

Clouds and MLS



- Scattering by clouds disrupts composition/ temperature measurements.
- Effect of clouds described by $\Delta I_{cir} = I_{cloudy} - I_{clear}$
- in optically thin cases this is proportional to IWP

Polarization

- With scattering comes polarization, defined by the Stokes vector

$$\mathbf{I} = [I, Q, U, V]^T$$

where $I = I_v + I_h, Q = I_v - I_h$

- Simulation studies (with simplified single habit clouds) outline the possibility of significant polarization signal (15 K) for MLS due to preferential horizontal orientation of column and plate crystals.

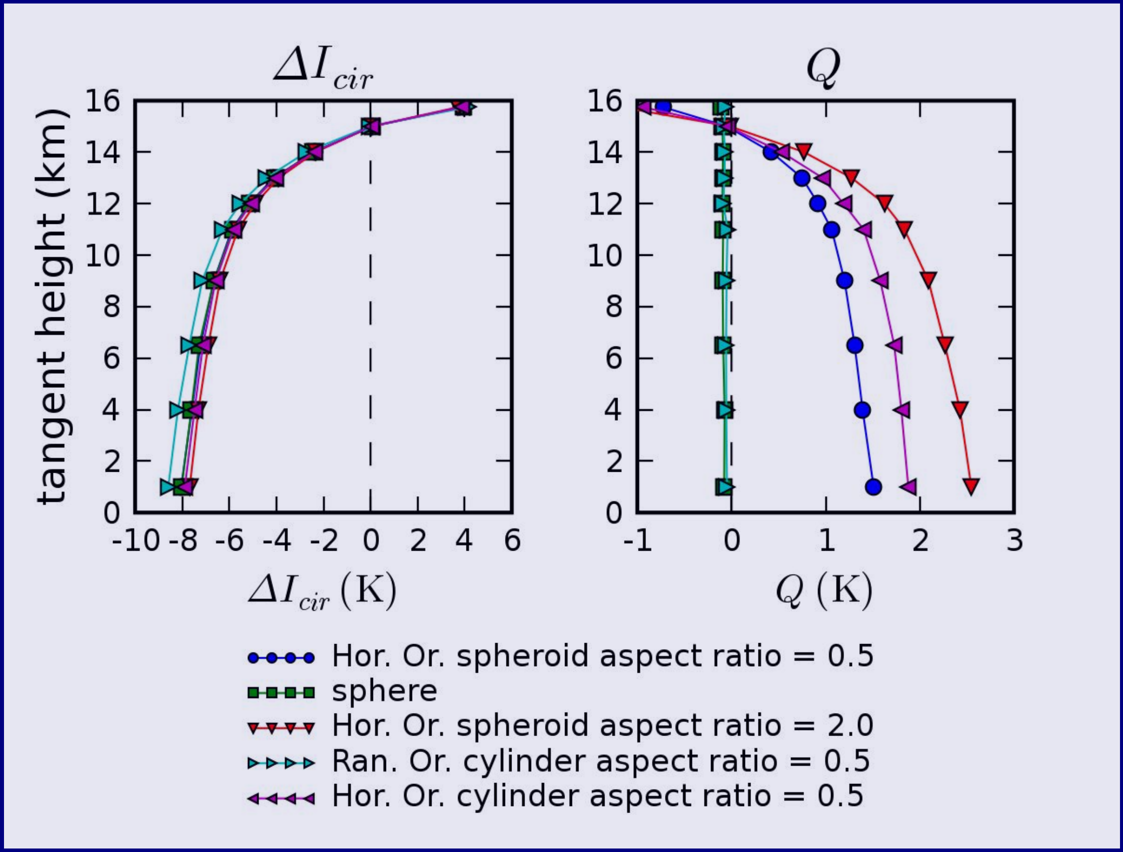
- Column and plate crystals are generally outnumbered by complex aggregate crystals with unclear orientation behaviour -> the extent to which preferential orientation affects optical properties in real cirrus ~~is~~ was unclear

Aura MLS observations

- First dual polarized microwave limb sounding observations of cirrus
- MLS has five radiometers, two of these measure both H and V polarizations. We focus on Radiometer 1, which is centered on an O_2 line at 118 GHz.
- Not ideal for cloud detection
  - O2 absorption => only sensitive to high cloud
  - long wavelength => clouds relatively transparent
  - but still can get ΔI_{cir} as large as -50 K.

What simulations tell us to expect

- Horizontally aligned particles give partial vertical polarisation (+ive *Q*) with magnitude decreasing with tangent height
- *I. Q* for horizontal cylinders or prolate spheroids can be reproduced by oblate spheroids with appropriate aspect ratio
- Randomly oriented particles and spheres give negligible polarisation



Understanding Q

$$\frac{d\mathbf{I}(\mathbf{n})}{ds} = -\mathbf{K}(\mathbf{n})\mathbf{I}(\mathbf{n}) + \mathbf{K_a}(\mathbf{n})I_b(T) + \int_{4\pi} \mathbf{Z}(\mathbf{n},\mathbf{n}')\mathbf{I}(\mathbf{n}')d\mathbf{n}'$$

small τ approximation:

$$Q \approx (J_Q - K_{12}I_0)\, s$$

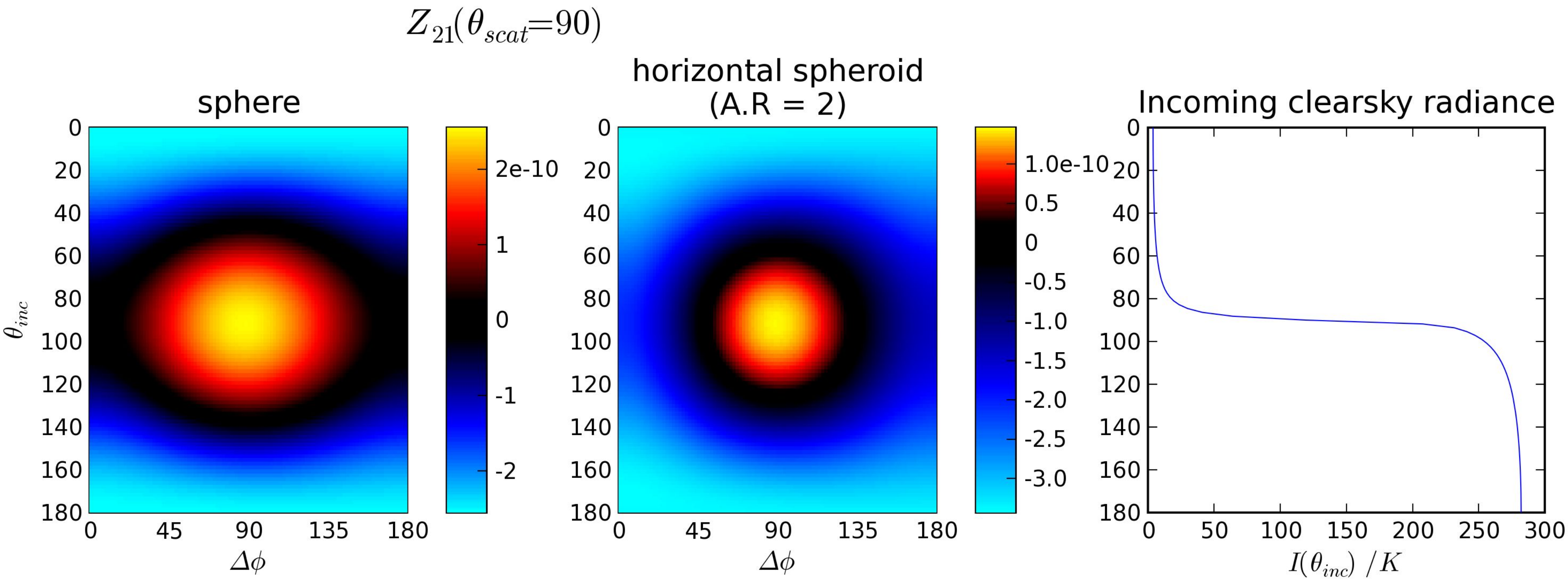
$$J_Q = K_{a2}(\mathbf{n})I_b(T) + \int_{4\pi} Z_{2i}(\mathbf{n},\mathbf{n}')I_i(\mathbf{n}')d\mathbf{n}'$$

for high single scattering albedo:

$$K_{21}(\mathbf{n}) \approx \int_{4\pi} Z_{21}(\mathbf{n},\mathbf{n})d\mathbf{n}'$$

so the phase matrix tells all...

Z_{21}



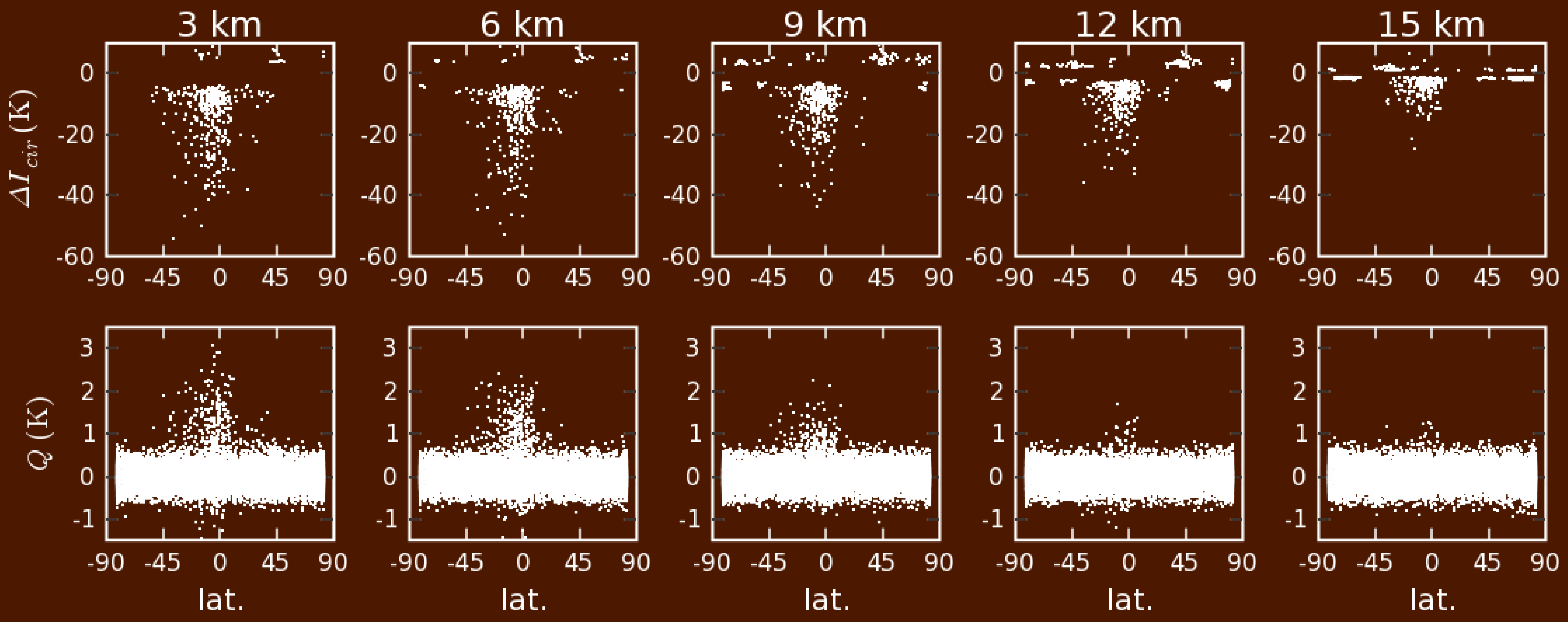
$K_{21} = 0$ $\qquad\qquad$ $K_{21} < 0$

so for low tangent heights

$$K_{21}(\mathbf{n})I_0(\mathbf{n}) \approx I_0(\mathbf{n}) \int_{4\pi} Z_{21}(\mathbf{n}, \mathbf{n}')d\mathbf{n}' > \int_{4\pi} Z_{21}(\mathbf{n}, \mathbf{n}')I(\mathbf{n}')d\mathbf{n}'$$

$$\rightarrow Q > 0$$

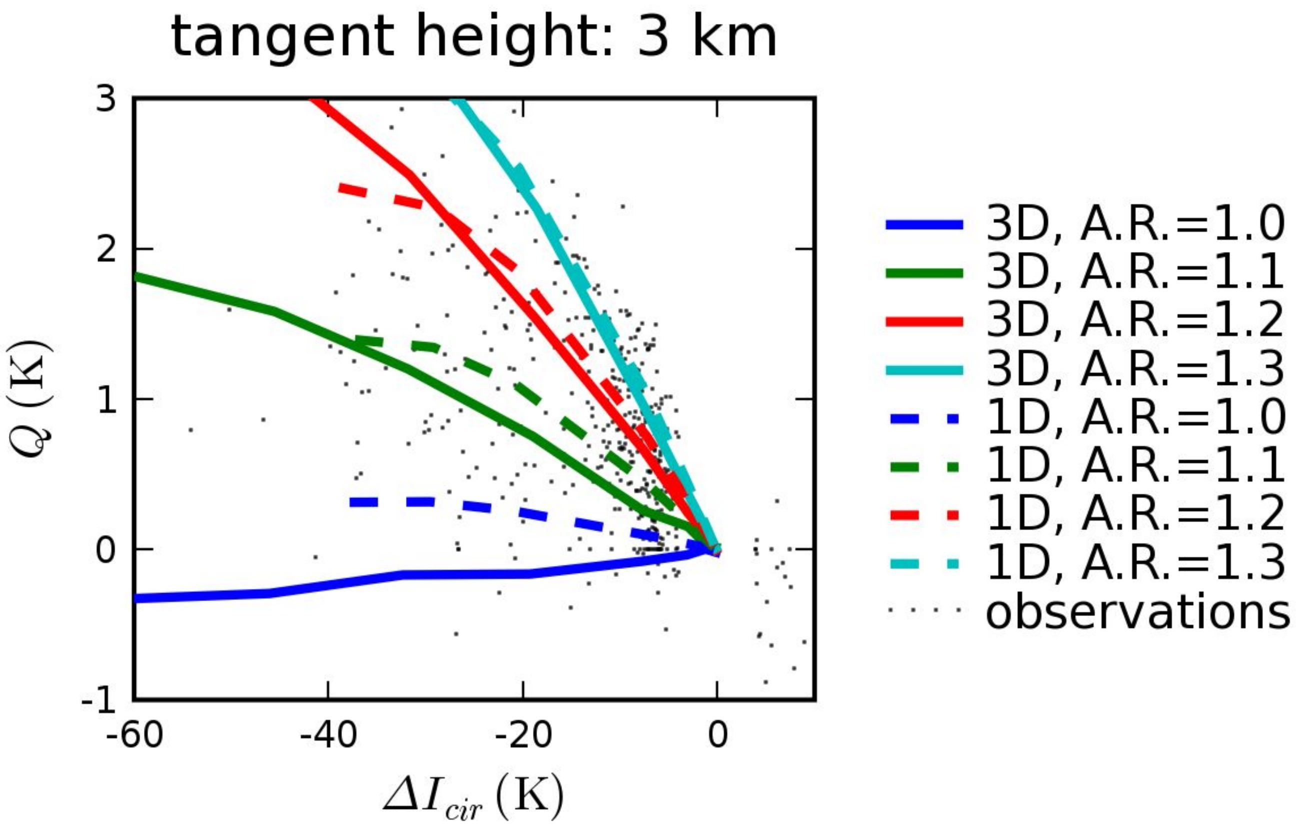
What we actually observe



Interpretation of Observations

- Effect of preferential orientation is mainly determined by the ratio $\frac{K_{12}}{K_{jj}}$
- Effect of changing the orientation distribution can be replicated by taking a single particle shape, horizontally oriented, and modifying the aspect ratio. Easiest to use oblate spheroids.

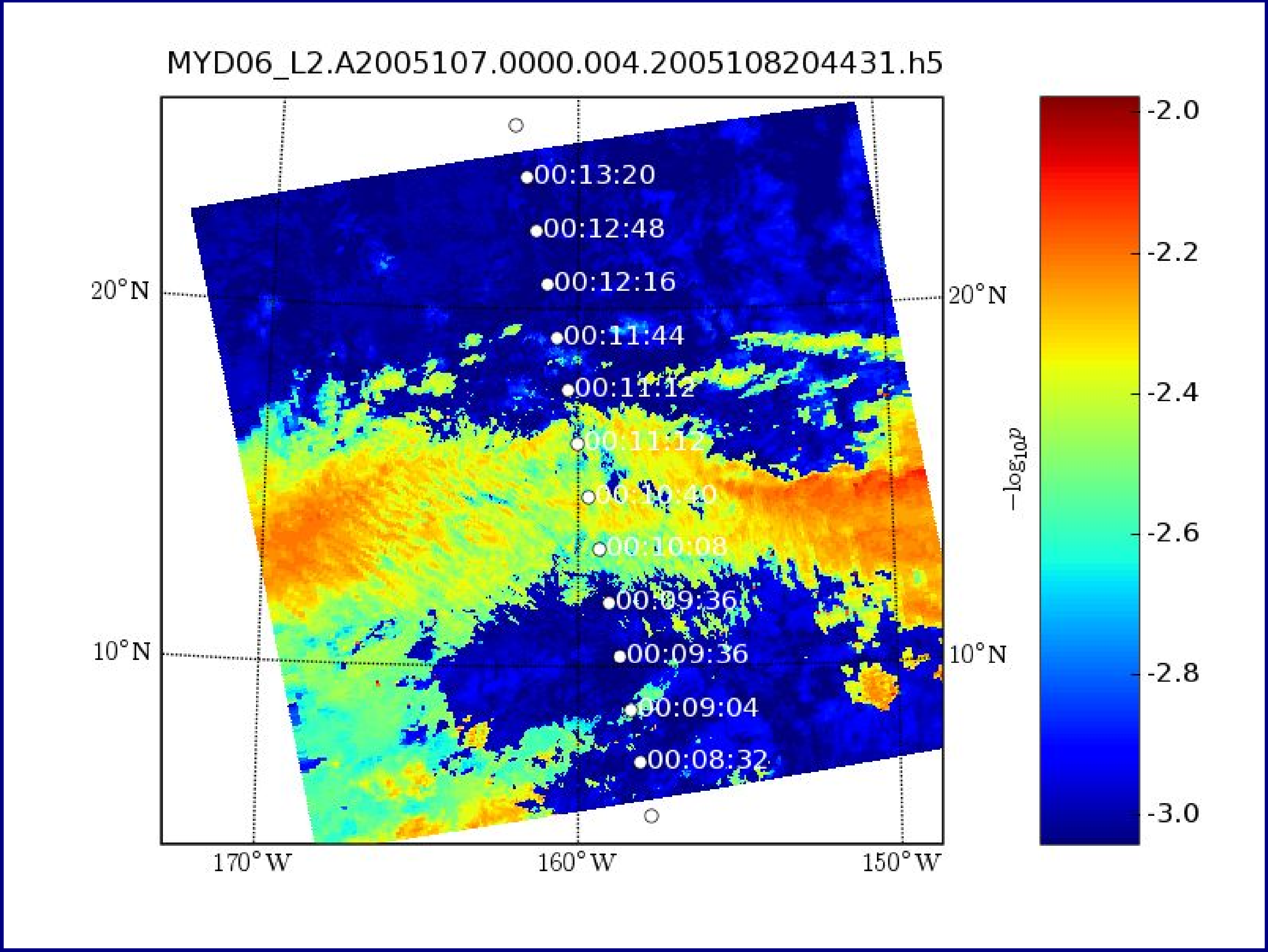
Comparison with RT simulations for 1D and 3D scenarios shows that data is consistent with a range of noticeably, but not particularly, aspherical particle shapes

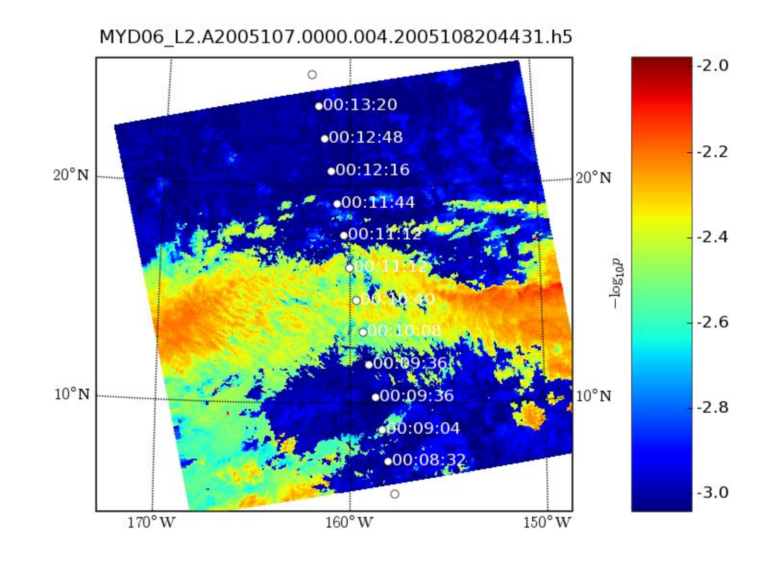


Summary

- First dual polarized microwave limb sounding observations of cirrus
- Tells us something about the degree of preferred ice crystal orientation
  - noticeable but not great – can be reproduced by using only mildly aspherical horizontally aligned particles
  - Operational assumption of random orientation seems justified
  - consequences for radiation balance?

MLS observations and MODIS cloud top heights

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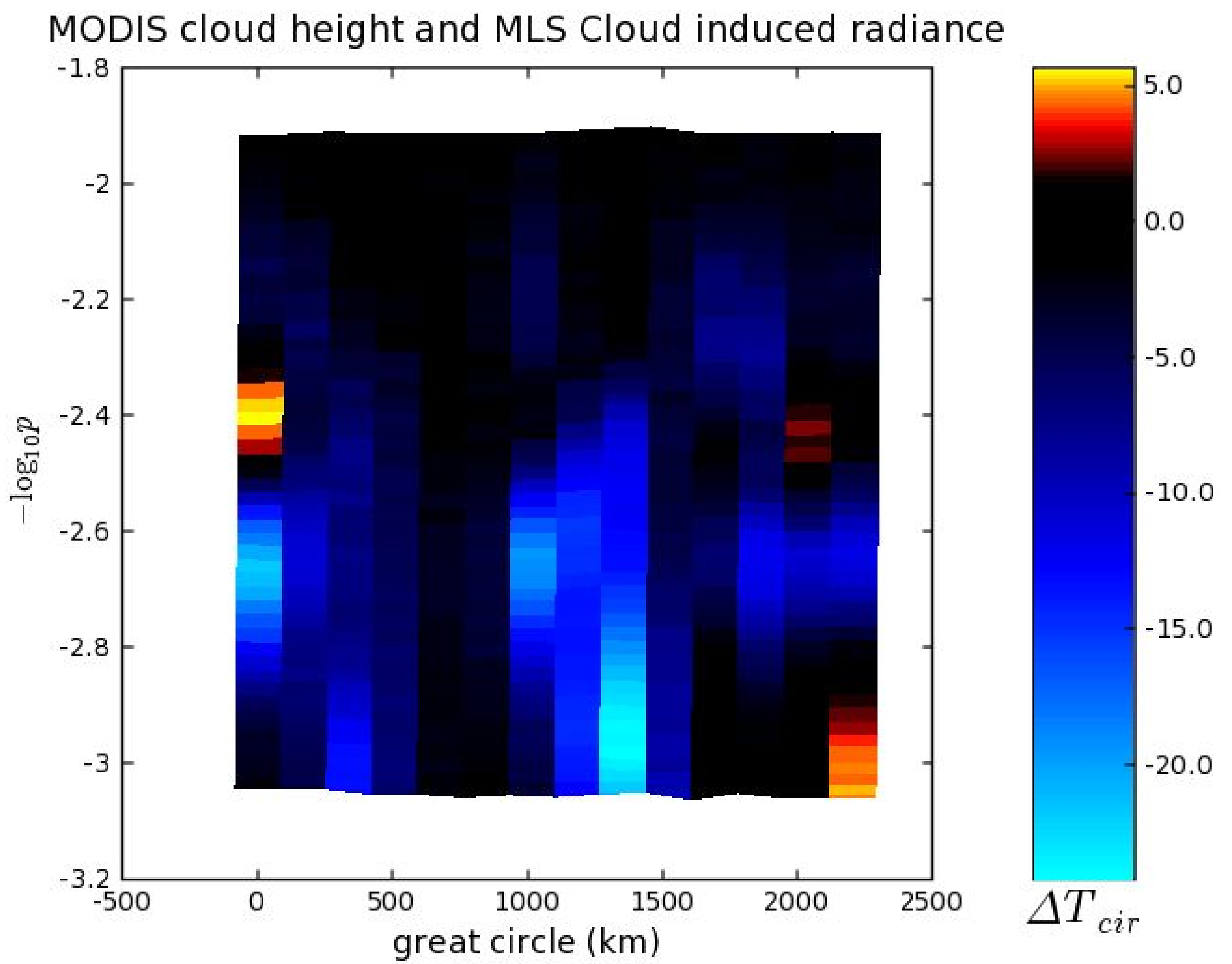
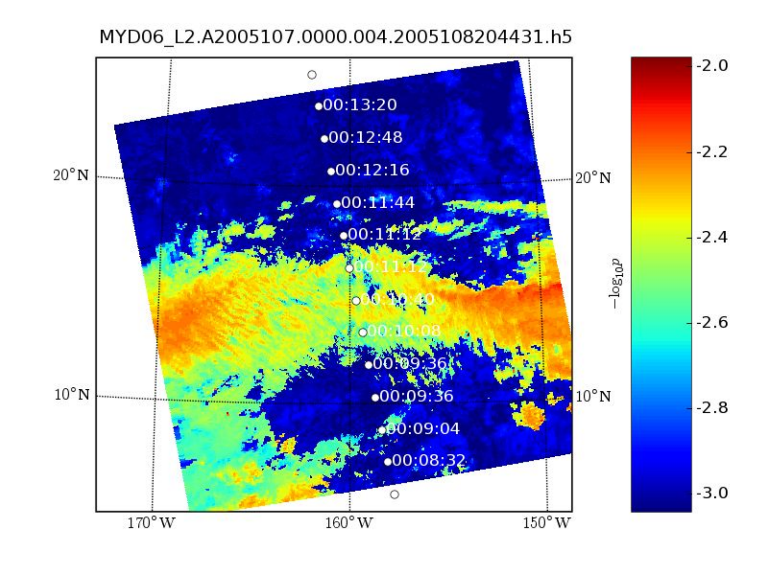
00:13:20
00:12:48
00:12:16
00:11:44
00:11:12
00:11:12
00:10:08
00:09:36
00:09:36
00:09:04
00:08:32
20°N
10°N
170°W
160°W
150°W
-2.0
-2.2
-2.4
-2.6
-2.8
-3.0
$-\log_{10}p$


MODIS cloud height and MLS Cloud induced radiance
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
-3.2
$-\log_{10}p$
-500
0
500
1000
1500
2000
2500
great circle (km)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
ΔT_{cir}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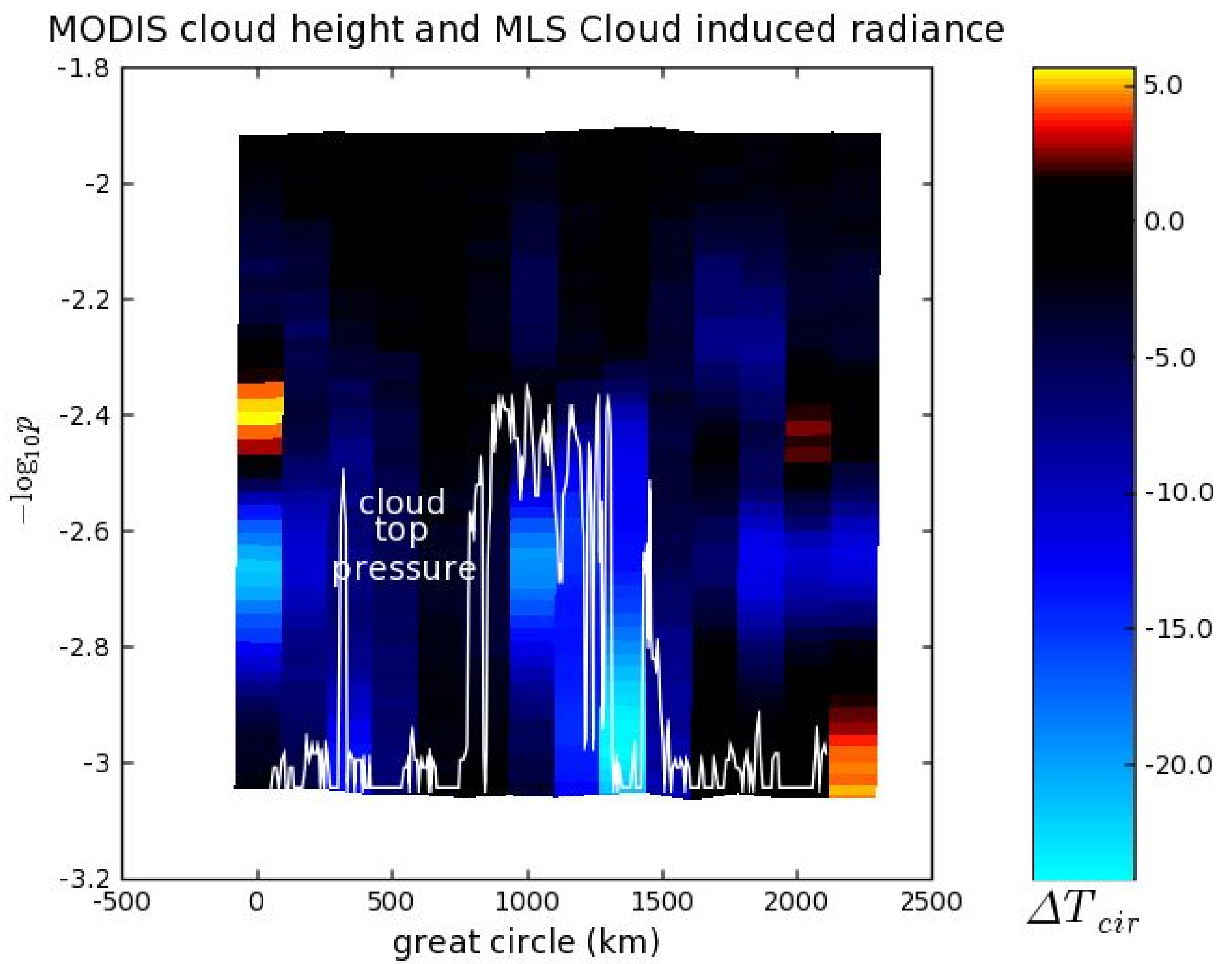
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-1.8
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$-\log_{10}p$
cloud
top
pressure
-500
0
500
1000
1500
2000
2500
great circle (km)
5.0
0.0
-5.0
-10.0
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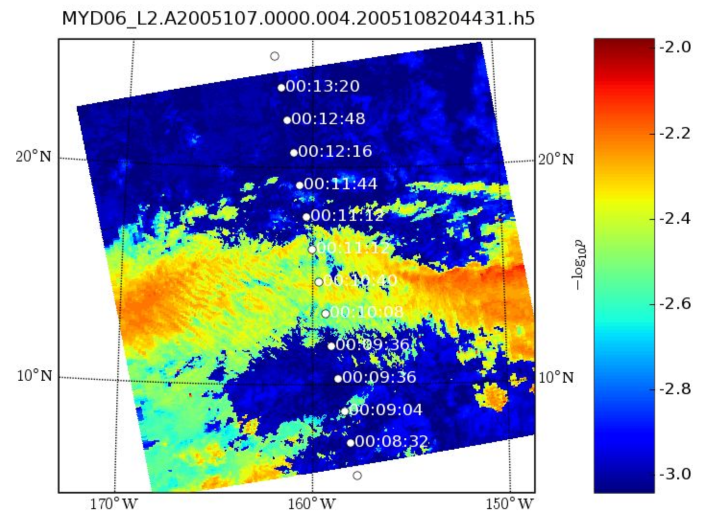
-20.0
ΔT_{cir}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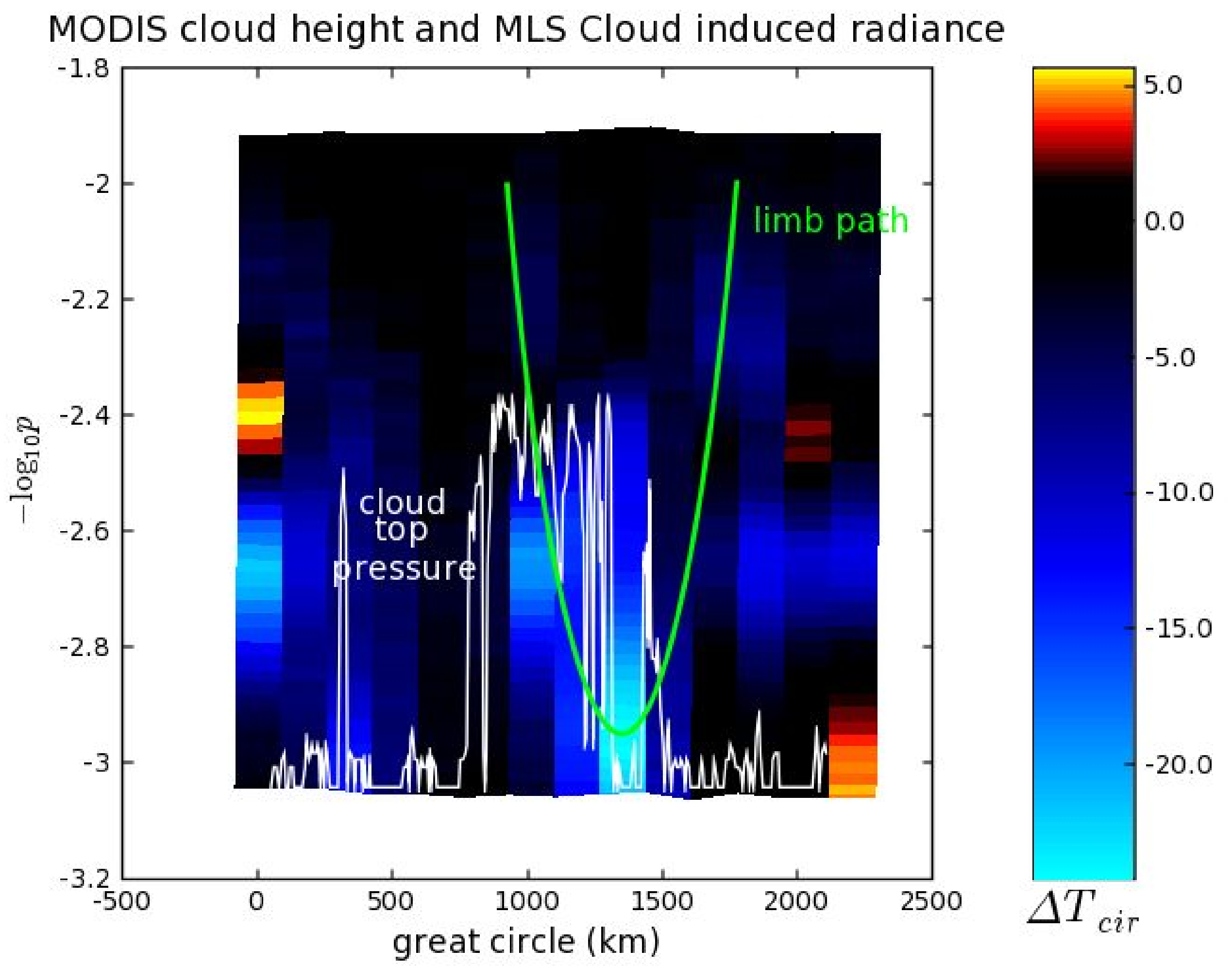
MODIS cloud height and MLS Cloud induced radiance
limb path
cloud top pressure
$-\log_{10}p$
great circle (km)
ΔT_{cir}
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
-3.2
-500
0
500
1000
1500
2000
2500
5.0
0.0
-5.0
-10.0
-15.0
-20.0