CEMAC DCMEX subtask

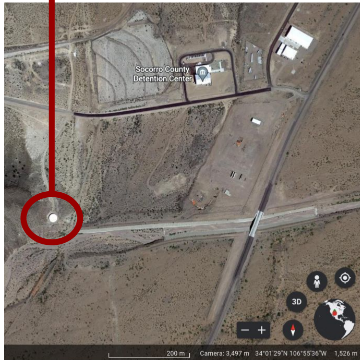
Evaluate manual estimation of cloud height from camera image

Well known points of comparison in images

We focus on getting these accurately before further work with clouds

Magdalena Ridge Observatory 2m telescope
Graydon NMT: “The white speck is the MRO 2m telescope. It is the domed (and first) building you see when looking south along the ridge from the Kiva on South Baldy. It is also the only ridge building you can actually see from the airport.”

Circular building
visible on google Earth



Calculation of cloud base height from lifting condensation level

Magdalena observatory surface weather observations are available on JASMIN in:
/gws/nopw/j04/dcmex/data/magdaObserv_weather

Example input:

```
import metpy.calc as mpcalc
from metpy.units import units
mpcalc.lcl(p*units.hPa, T*units.degC, Td*units.degC)
```

→ Estimated LCL pressure (p_{LCL}) and temperature (T_{LCL})

Dry adiabatic lapse rate (-9.8degC / 1km) assumed from surface to LCL so:
Height relative to observatory, $\Delta h_{ob} = (T_{LCL} - T)/-9.8$
Height of observatory and socorro airport ASL are $h_{ob} = 3230m$, $h_{soc} = 1460m$
Height relative ASL $\Delta h_{ASL} = \Delta h_{ob} + h_{ob}$ and relative to Socorro airport $\Delta h_{soc} = \Delta h_{ASL} - h_{soc}$

Δh_{soc} should be equivalent to height estimated from camera image, give or take height of camera

	p, T, Td	p_{LCL}, T_{LCL}	Δh_{ob}	Δh_{ASL}	Δh_{soc}
25/Jul 17:04	697.3, 13.2, 10.2	666.5, 9.5	378m	3608m	2148m
31/Jul 17:33	699.9, 14.3, 8.4	640.4, 7.1	602m	3832m	2372m

Comparison to image estimates

See shadow on mountain in 31/jul 173301 image

Probably too large given observatory is 27km and cloud look closer

Date	**D**	**CB1**	**CB2**	**CB3**	**LCL estimate**
2022-07-25-1704	28	5.94	5.61	5.63	2.15
2022-07-25-1704	36	7.22	6.8	6.83	
2022-07-31-1733	27	5.58	5.59	6.07	2.37
2022-07-31-1733	31	6.19	6.21	6.75	

These are further off than I would have expected.

25/Jul made a 1min cloud run at 17:14:48. Lower passes occurred but this is a robust value as successive runs followed at higher heights.
Pressure alt should be relative to ASL:

GIN altitude	4473.228	eqv to Δh_{soc} = 3.01km
Pressure alt	4203.802	eqv to **Δh_{soc} = 2.74km**
Pressure	600.2064	

31/Jul made a 30sec cloud run at 17:40:23.
Pressure alt should be relative to ASL:

GIN altitude	4468.5117	eqv to Δh_{soc} = 3.01km
Pressure alt	4166.7876	**eqv to Δh_{soc} = 2.71km**
Pressure	603.1218	

LCL est. are lower edge of cloud so would expect to be below cloud passes. Aircraft also has limit on height above terrain which looks like might be occurring here.

Understanding errors in image-based estimate

$\Delta h_{soc} = (D * OHS) / F$ where D is distance to cloud, OHS is height of cloud on sensor, F is focal length

REF: http://phylabs1.physics.sunysb.edu/~physlab/ReferenceDocs/ErrorAnalysis.pdf

$\sigma_{rel}(A \times B) = \sqrt{((\sigma_{rel}A)^2 + (\sigma_{rel}B)^2)}$ [1]
$\sigma_{rel}(cA) = \sigma_{rel}(A)$ where c is a constant [2]

If we can assume OHS/F is constant then $\sigma_{rel}(\Delta h_{soc}) = \sigma_{rel}(D)$

Is relative error on OHS small? Depends on how accurate do we estimate pixels (±2 pixel?)?
That would give 2/4160 ~ 0.0005. This would be negligible compared to distance rel err probaby but should ***confirm with Helen***

LCL-estimated height varies by ~200m between 25th and 31st. To distinguish these then we want $\sigma_{abs}(\Delta h_{soc})$<100m or a rel err of <<100/2000=0.05
Rel err in D of 0.05 is approx equivalent to 0.05*30km = 1.5km.

Conclusions:

- We want to **estimate D to within about 1km** to resolve some variation in cloud base height. That seems like a realistic goal.
- Cloud tops are about 5x higher than base so equivalent absolute error will be more like 500m, which will just about resolve some of coarsest differences given most days GOES cloud top within 12.2-13.5km