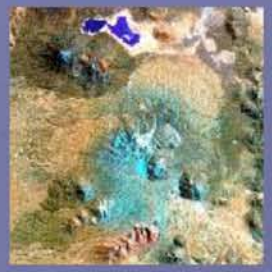
CCAT

A joint project of Cornell University,
the California Institute of Technology
and the Jet Propulsion Laboratory,
the University of Colorado,
the Universities of Waterloo & British Columbia,
the United Kingdom of Great Britain

Austin AAS, 10 Jan 2008

CCAT:



- A 25m class FIR/submm, actively controlled telescope that will operate with high aperture efficiency to λ = 200 μm, an atmospheric limit
- With large format bolometer array cameras (large Field of View ~ 20') and high spectral resolution heterodyne receivers
- At a very high (elevation ~ 5600m), very dry (Precipitable Water Vapor column PWV<1 mm) site with wide sky coverage

CCAT Drivers

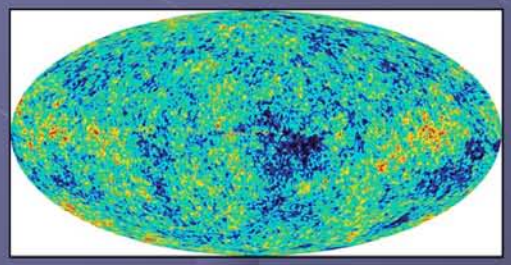
1. Scientific Excellence

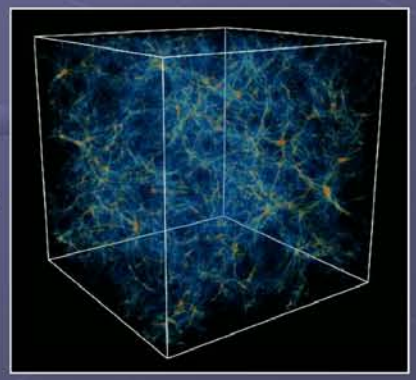
CCAT is a unique project geared towards the investigation of cosmic origins, from planets to galaxies, in the FIR/submm spectral region

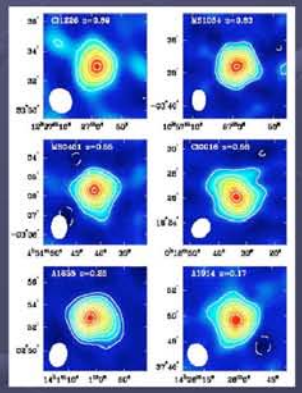
- Early Universe Cosmology
- Galaxy Formation & Evolution
- Disks, Star & Planet Forming Regions
- Cosmic Microwave Background, SZE
- Solar System Astrophysics

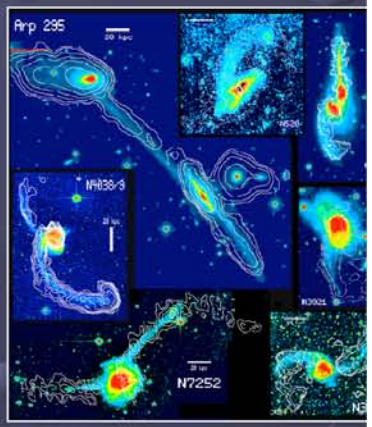
...to this?

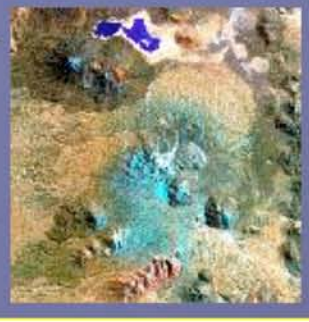
How did we get from this



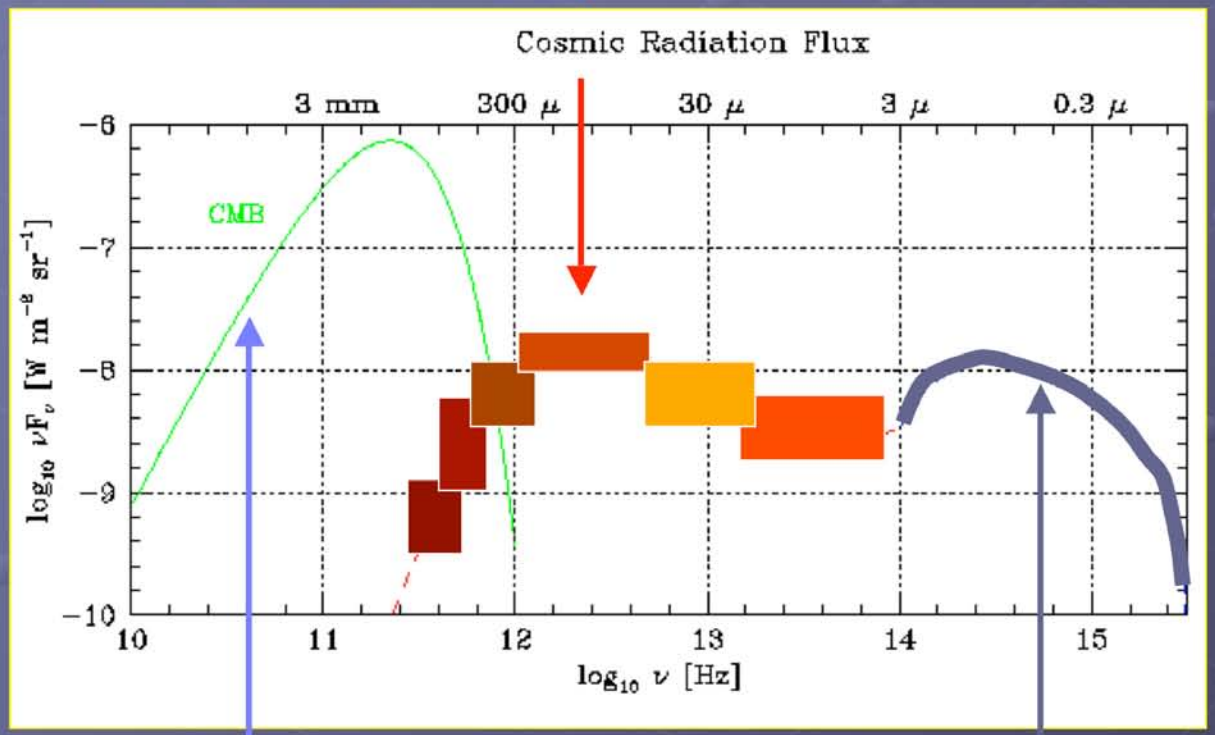








Photospheric light
Reprocessed by dust



Microwave Background

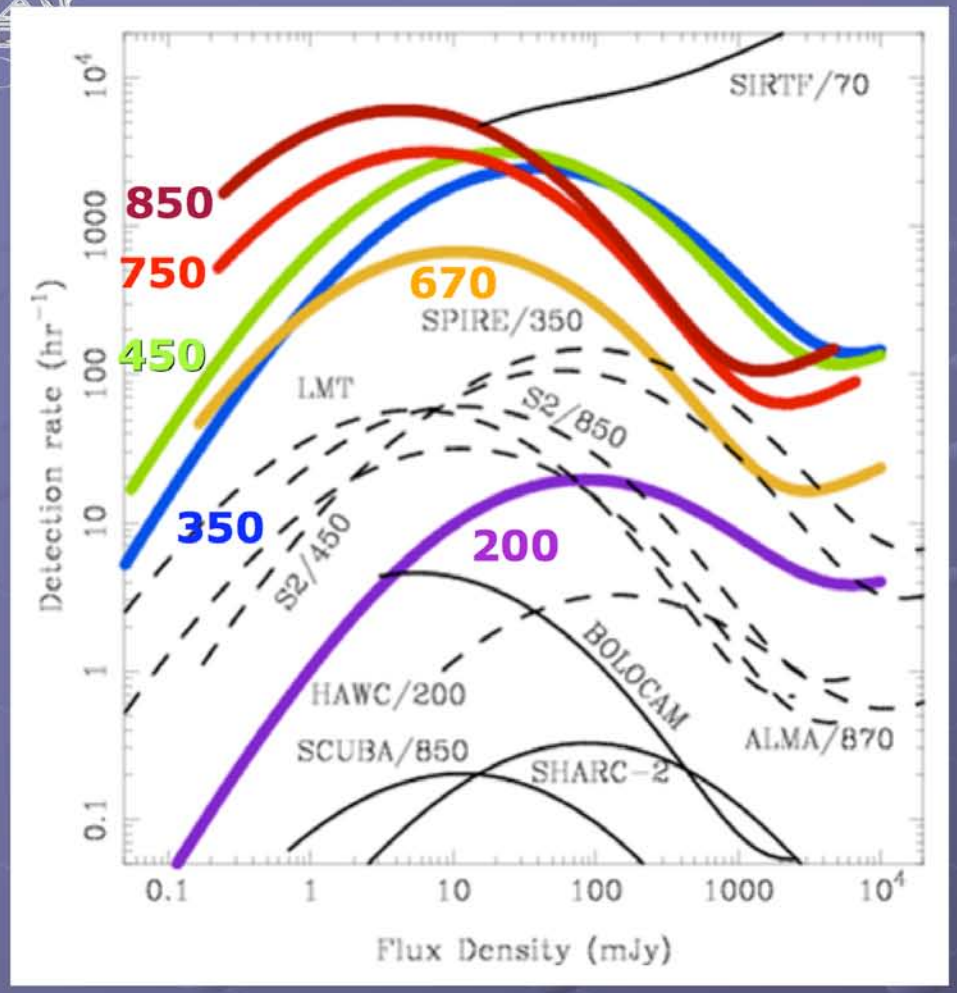
Photospheric light
from stars

Why FIR/submm?

That's the energy regime at which most of the Universe's early light produced after the recombination era reaches us.

And at which radiation produced in star & planet forming regions emerges from the dust cocoons.

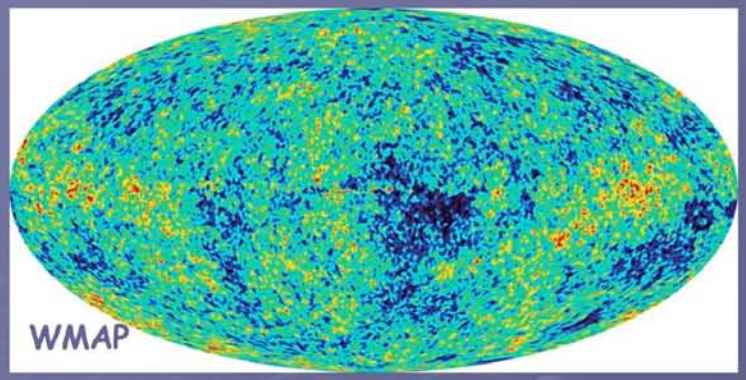
Mapping speed

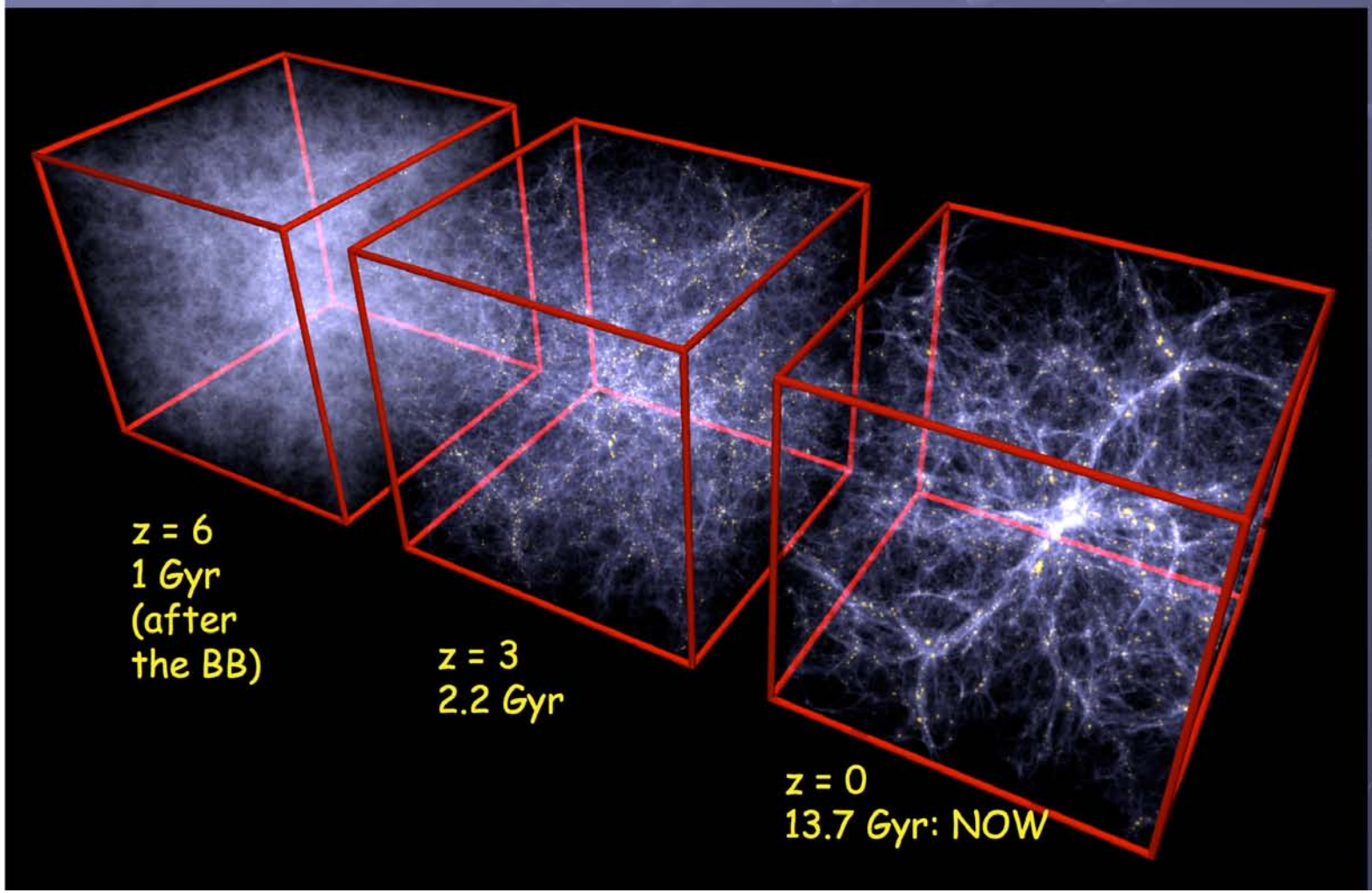


- CCAT is an ultrafast mapper
- Detection rates are
  - About 1000-6000 per hour
  - ~150×SCUBA-2; ~300×ALMA
  - 2000 hour (1 year) survey detects > a ***million*** galaxies
  - 20 year lifetime ~ ***100 million galaxies!***

Assumptions 10,000 pixel Nyquist sampled array, counts match observations & include confusion and photon limits

The large—scale structure of the Universe evolves from initially very small density fluctuations:

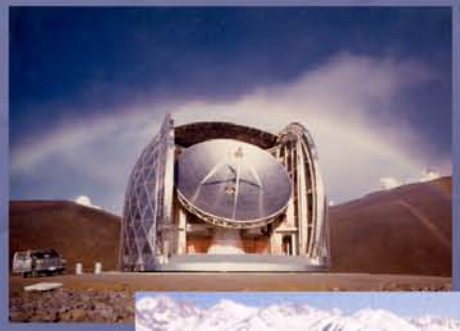


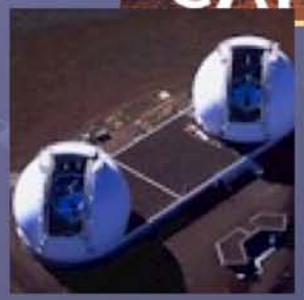


progressively increasing the density contrast ...

2. Internal Synergy

The focus of CCAT emphasizes our institutions' talents in instrument building, the operation of major observatories and the development of forefront technologies.





MER

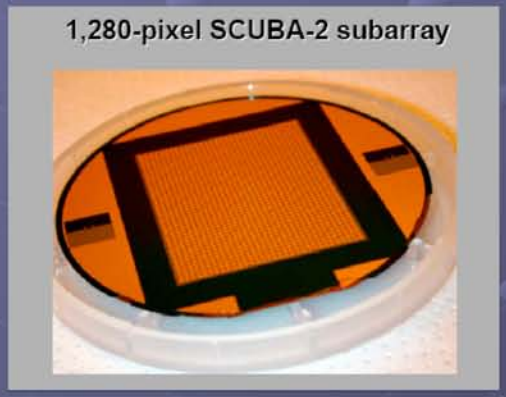
3.Ride the technology wave

in one of the most rapidly developing technological fields in Astronomy: bolometer arrays

Now (384 pix)

→

2007 (1280 pix)



→

2013 (30,000 pix)

late 2010's :

Bolometer array Cameras with $> 10^4$ pix

With actively controlled optics, CCAT will be a testbed for advanced technology solutions, e.g. *Wavefront sensing, Laser metrology and Detector arrays*

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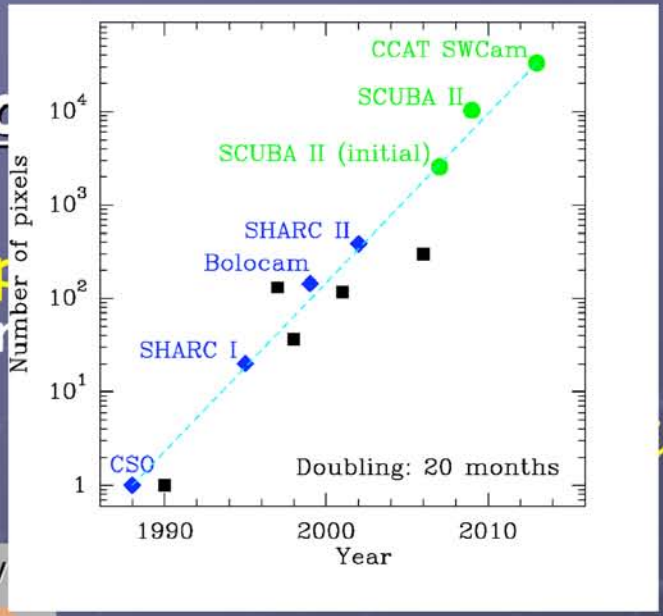
Now (384 pix) *2007 (1280 pix)* *x)*



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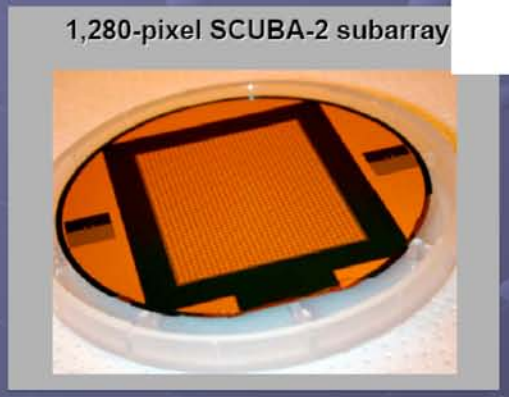


→

Bolometer array Cameras with > 10^4 pix

With actively controlled optics, CCAT will be a testbed for advanced technology solutions, e.g. *Wavefront sensing, Laser metrology and Detector arrays*

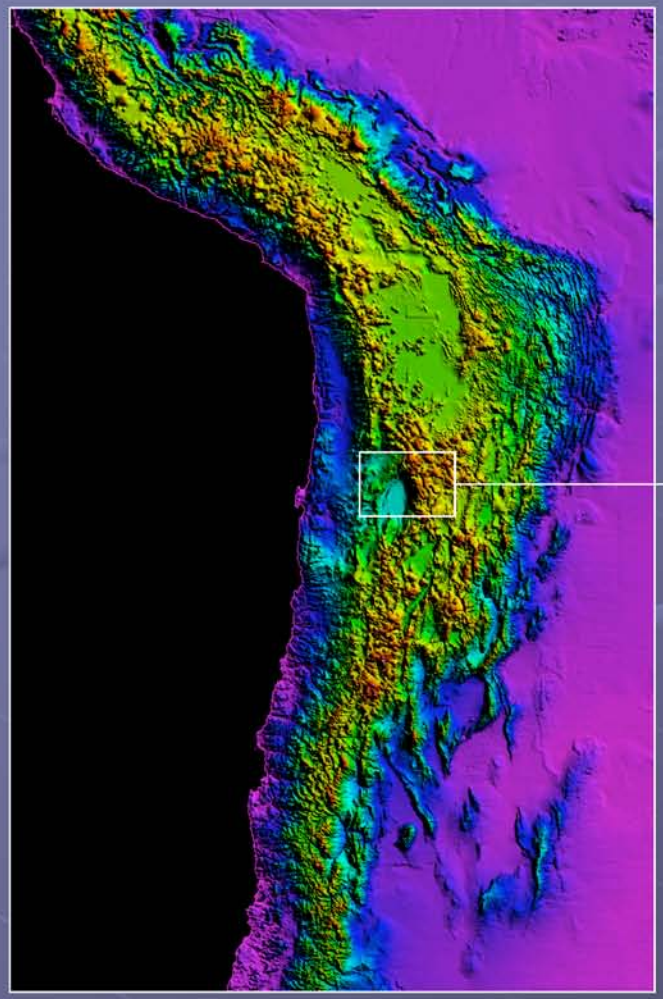
4. A facility of large synergy with ALMA

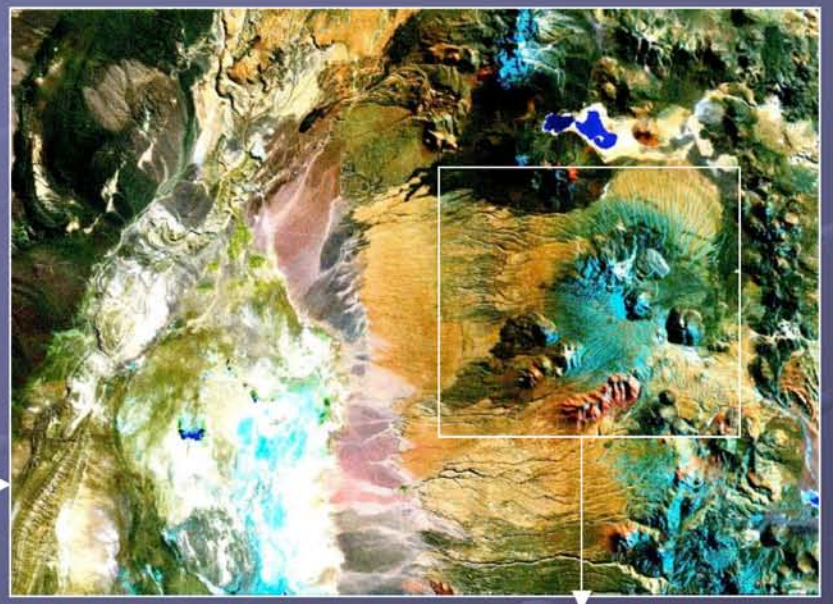
CCAT will match ALMA in point source, continuum sensitivity at 500 μm and will be many orders of magnitude faster as a survey instrument. Although CCAT's beam will be a few arcsec, ALMA will have 100 times the spatial resolution.

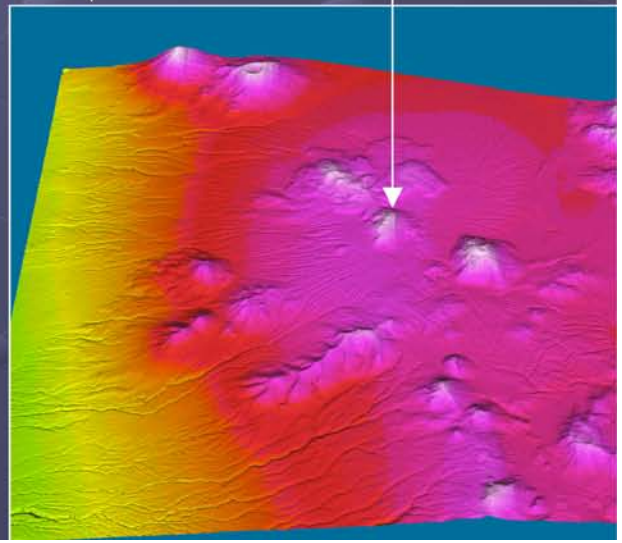
➔ ideal complementarity

Foresee joint, large scale projects coordinated between the two facilities. Institutions with preferred access to CCAT will have a strong leverage arm for access to ALMA.

5. At the driest, high altitude site you can drive a truck to

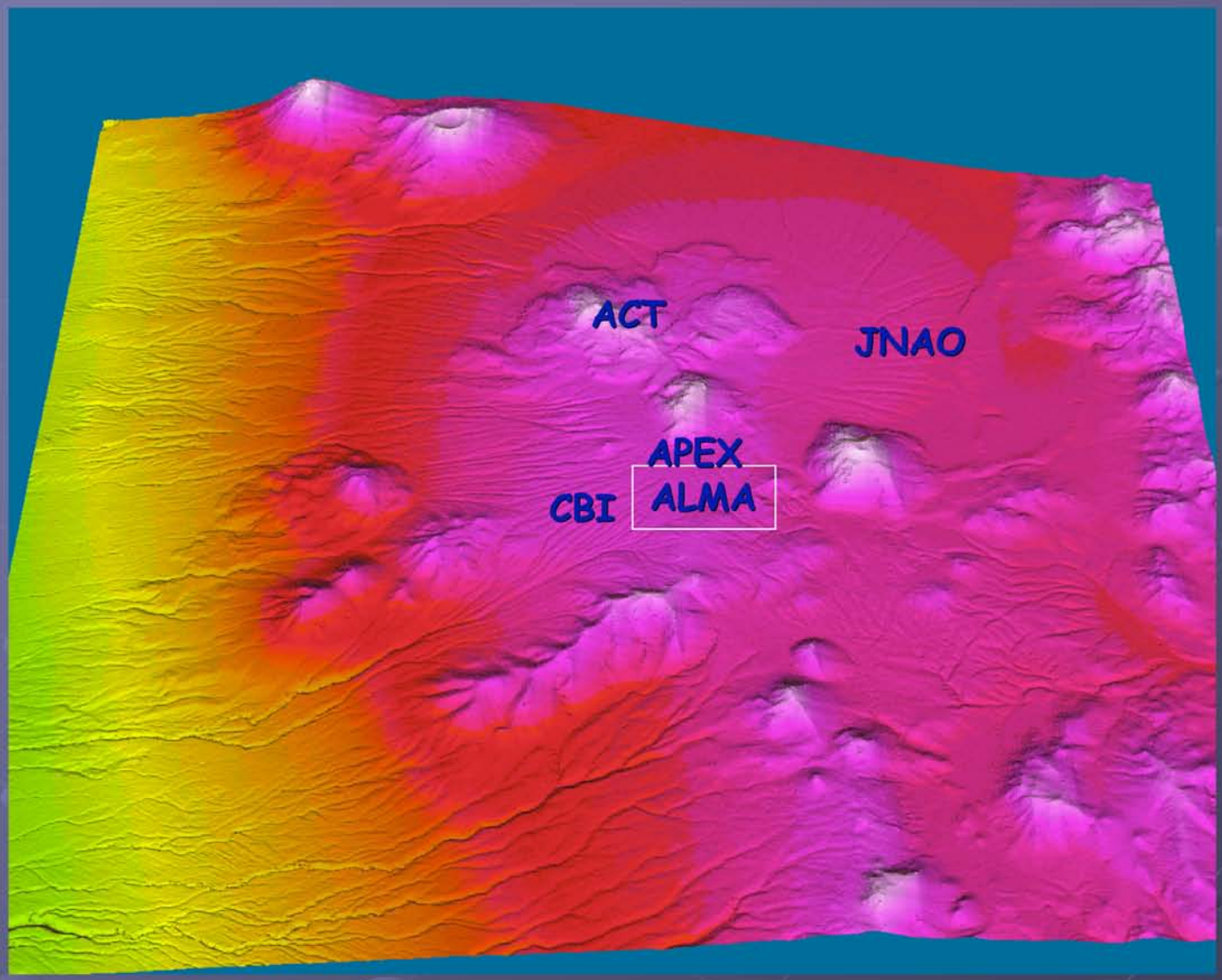


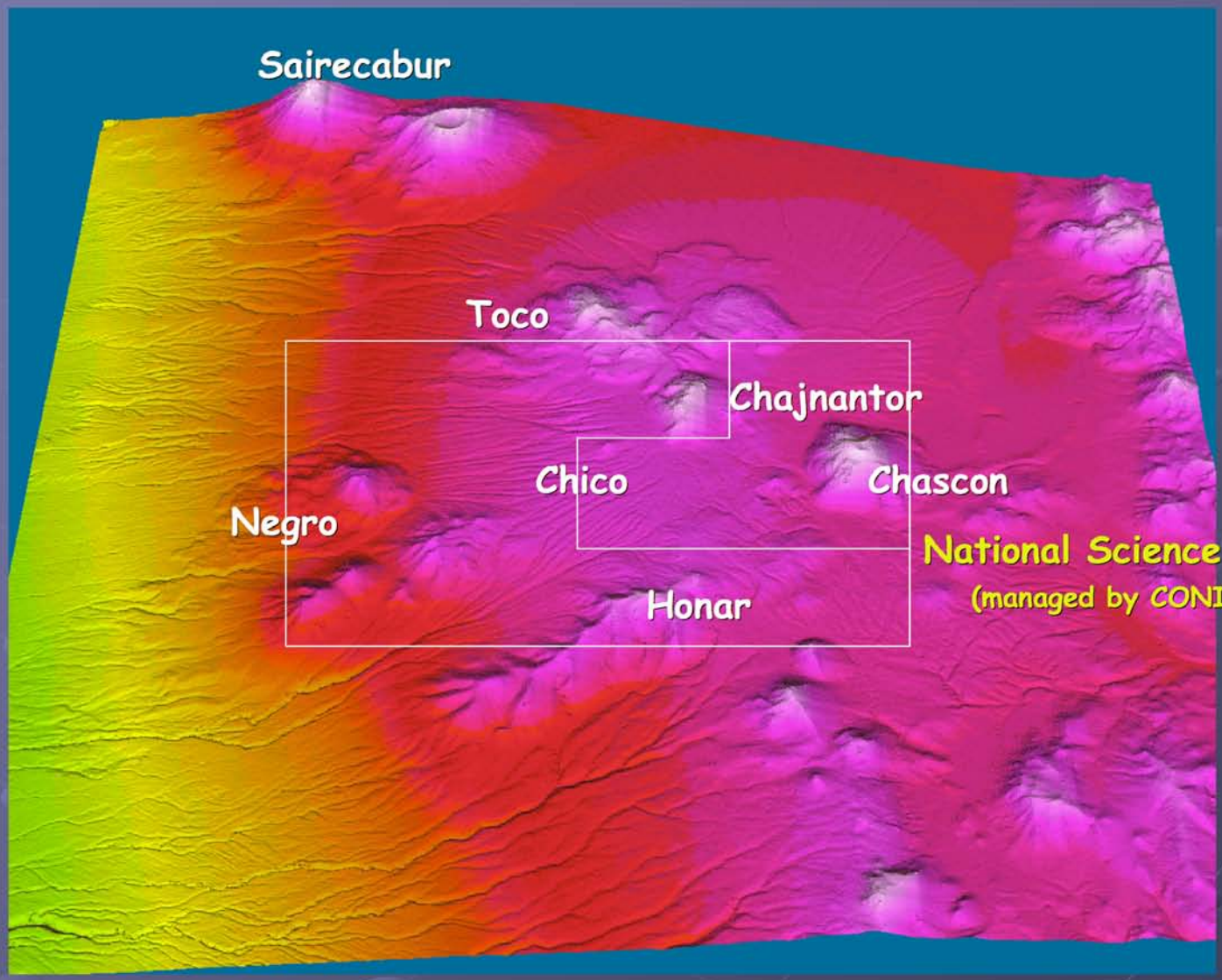


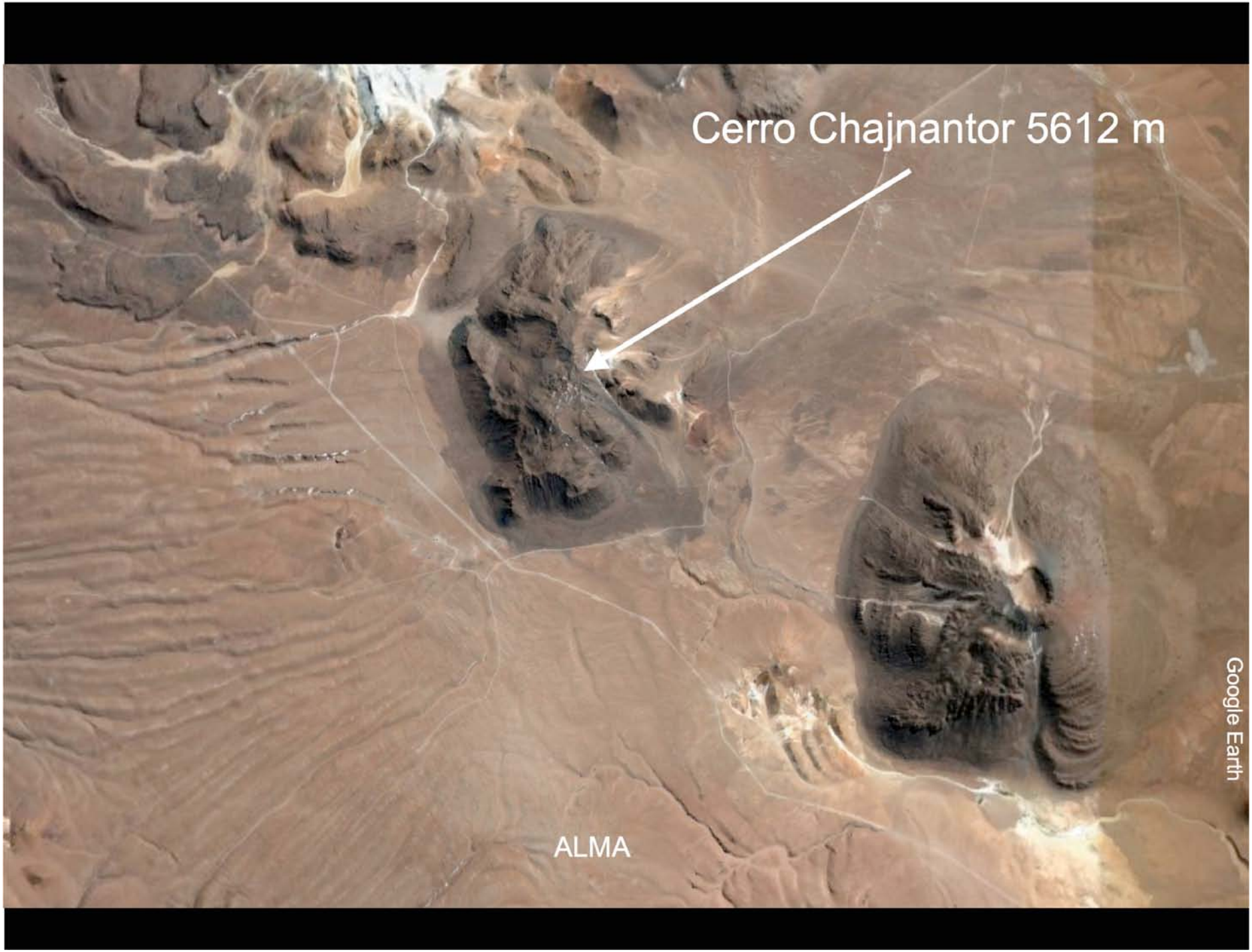


Cerro Chajnantor (18,400 ft)

It's beautiful country, with a rich ecology and historical record

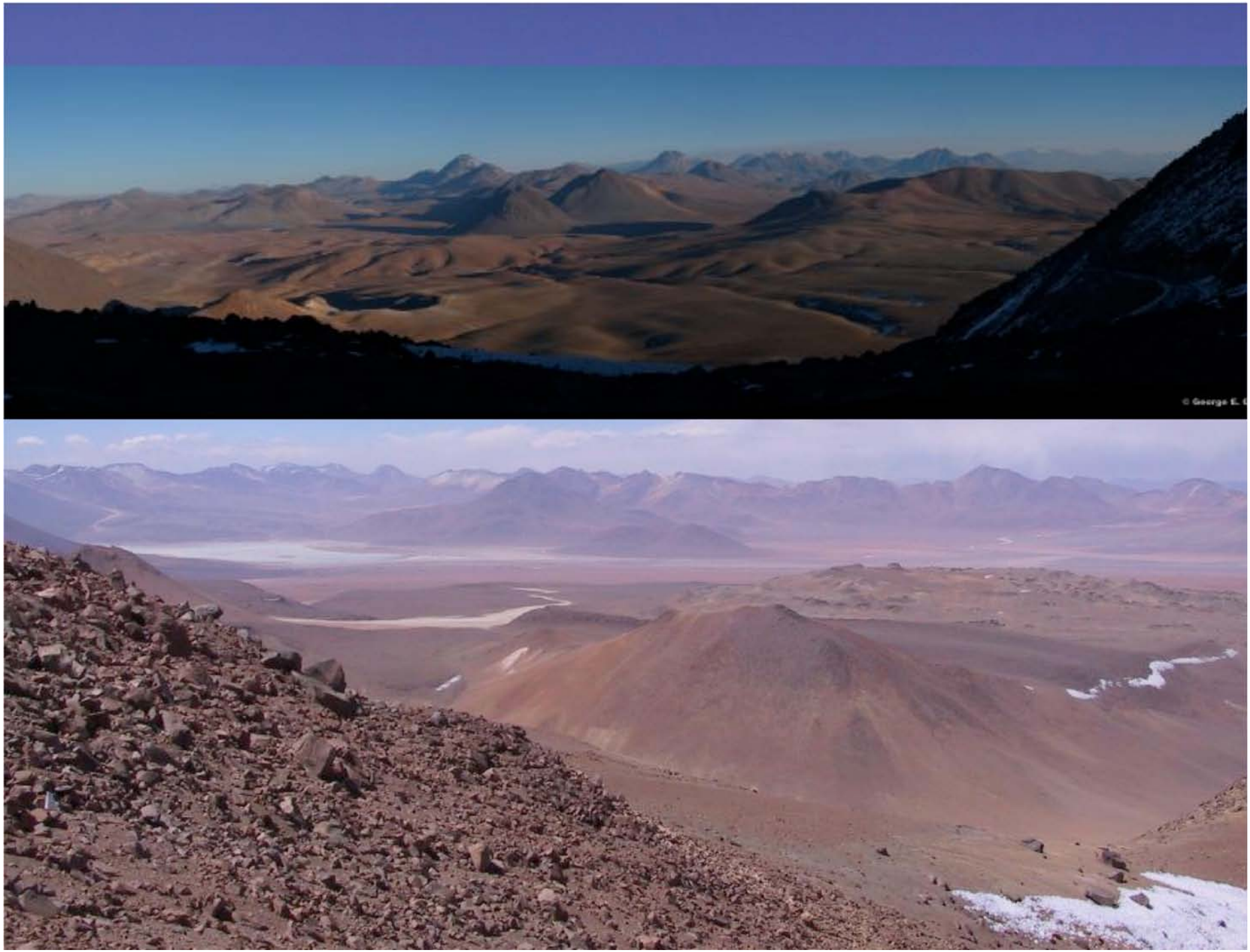

ACT
JNAO
APEX
CBI
ALMA


Sairecabur
Toco
Chajnantor
Chico
Chascon
Negro
National Science Preserve
(managed by CONICYT)
Honar

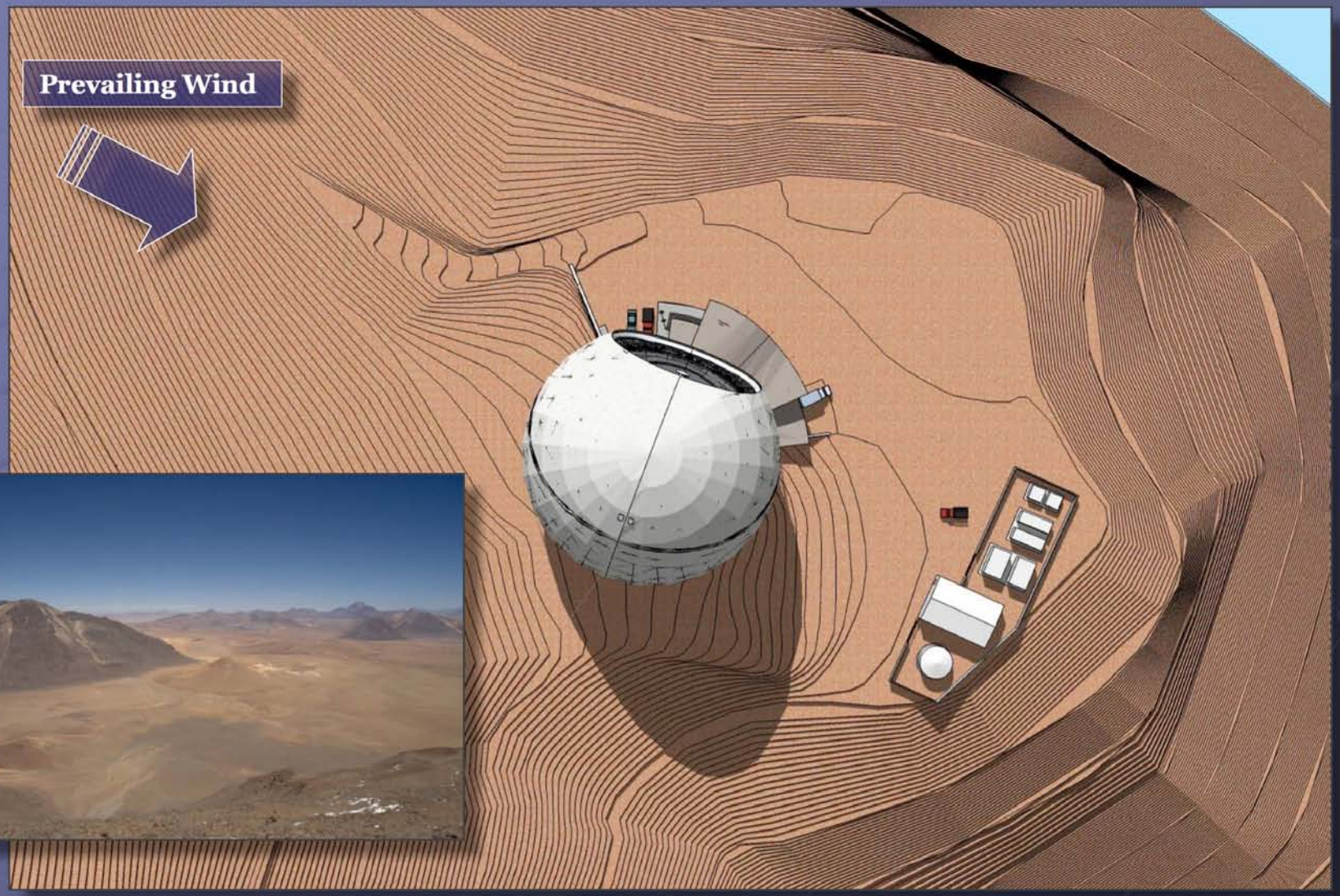

Cerro Chajnantor 5612 m
ALMA
Google Earth

Chajnantor Plateau (5000 m)

Dietrich/Caltech

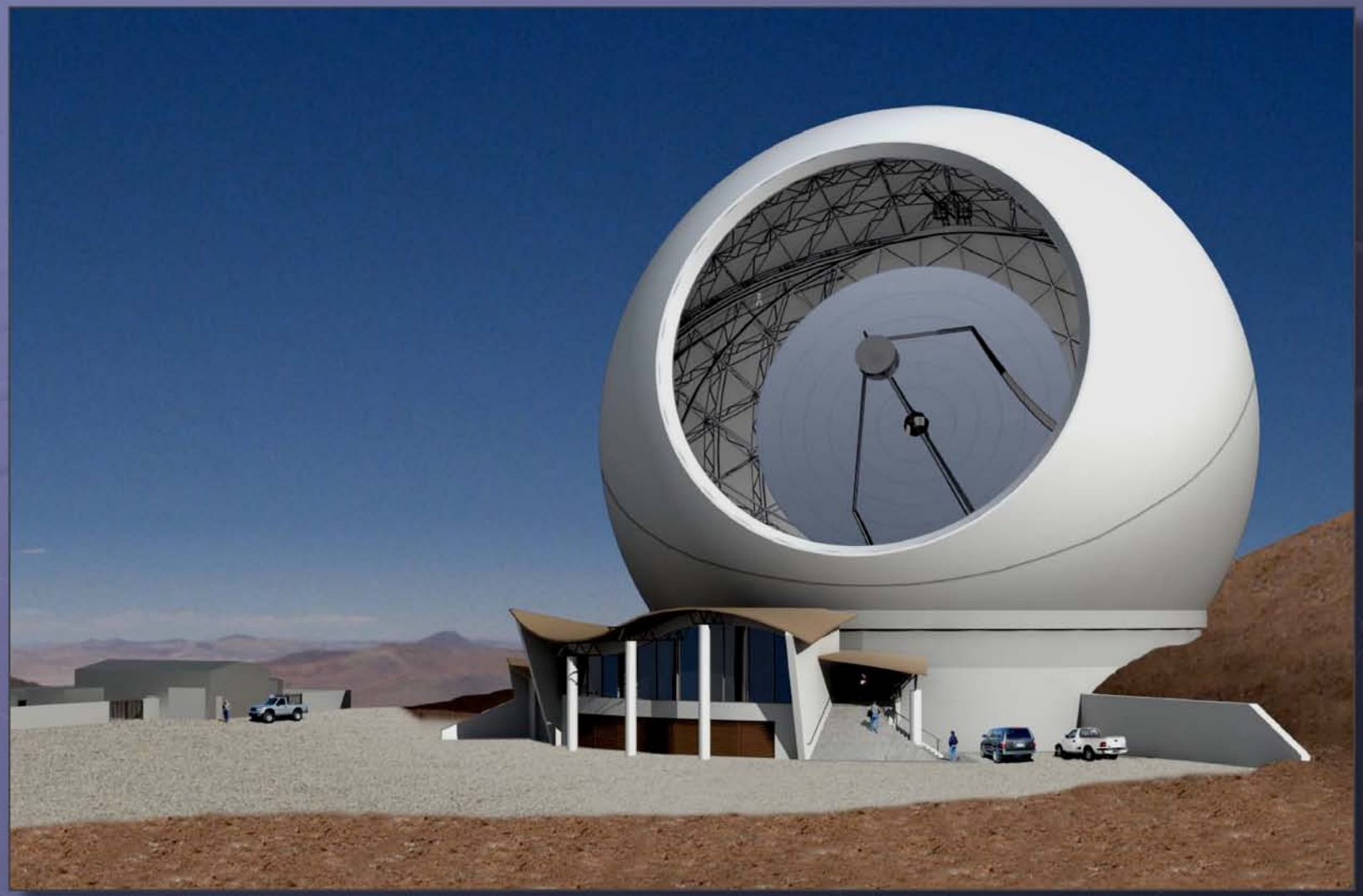


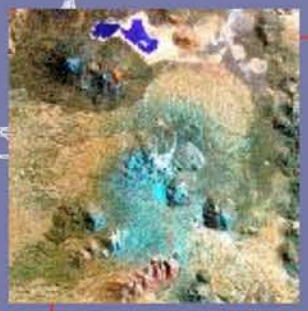
Mountain Facility: Site Plan



Mountain Facility: Exterior

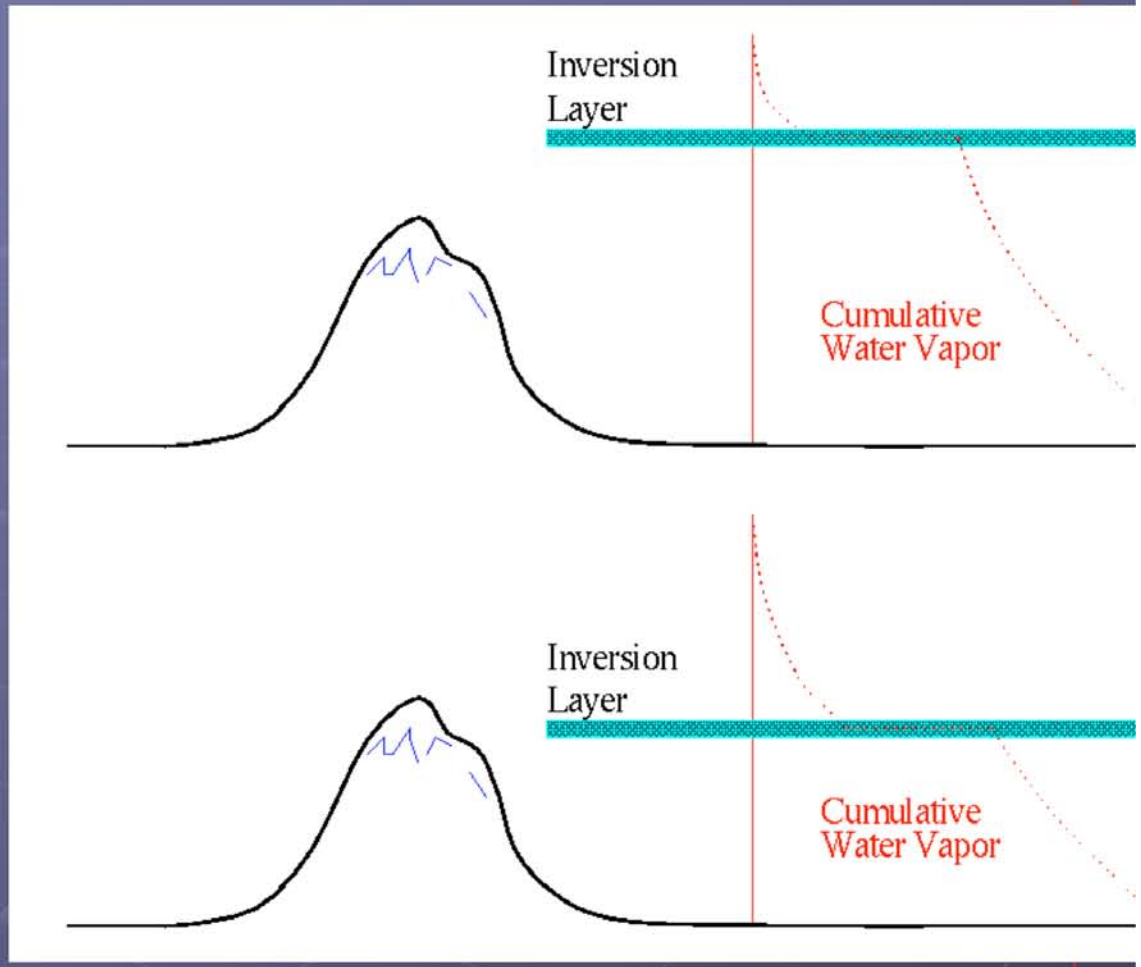
CCAT



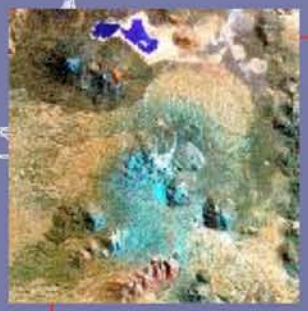


A little gain in PWV
by going to summit

B most PWV below
summit; great gain
by going to summit



T-inversion layers form above extended plateaus. Much of the PWV gets trapped under ther
Is it worth focusing on surrounding summits?
YES! if case B occurs a fair fraction of the time.

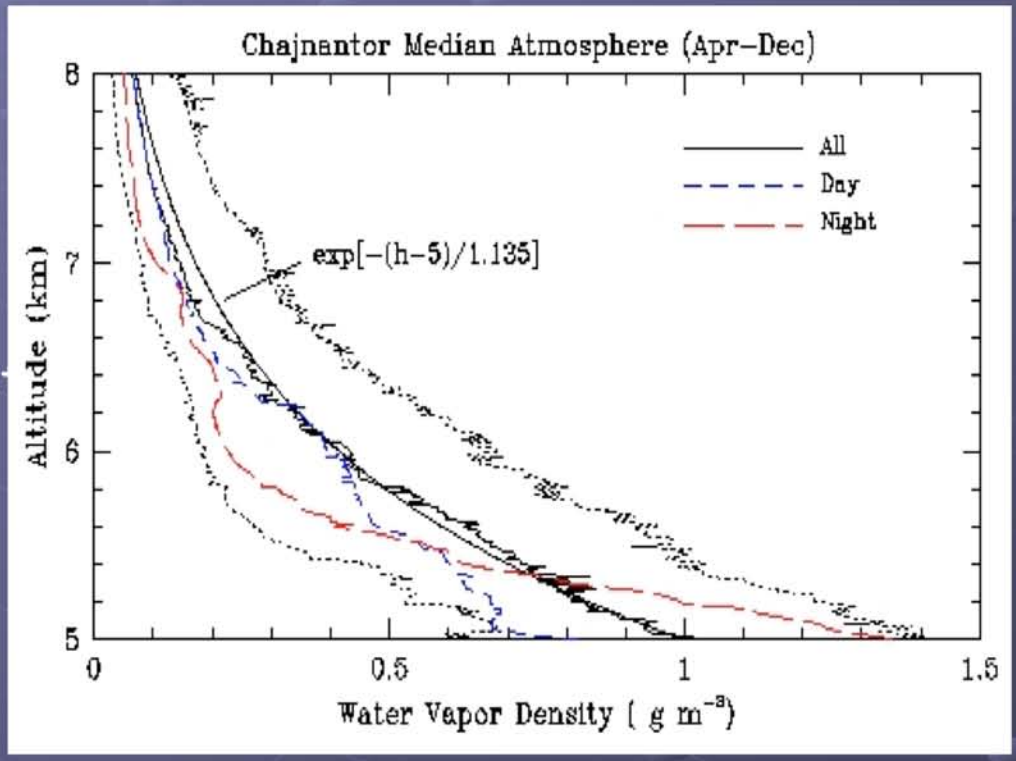


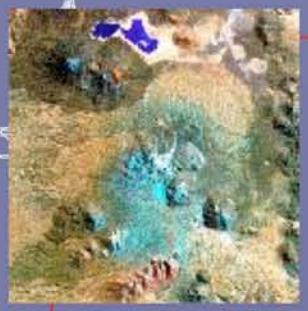
Median WV Distribution over Chajnantor

From radiosondes:

The median WV scale height
Is h=1.135 km

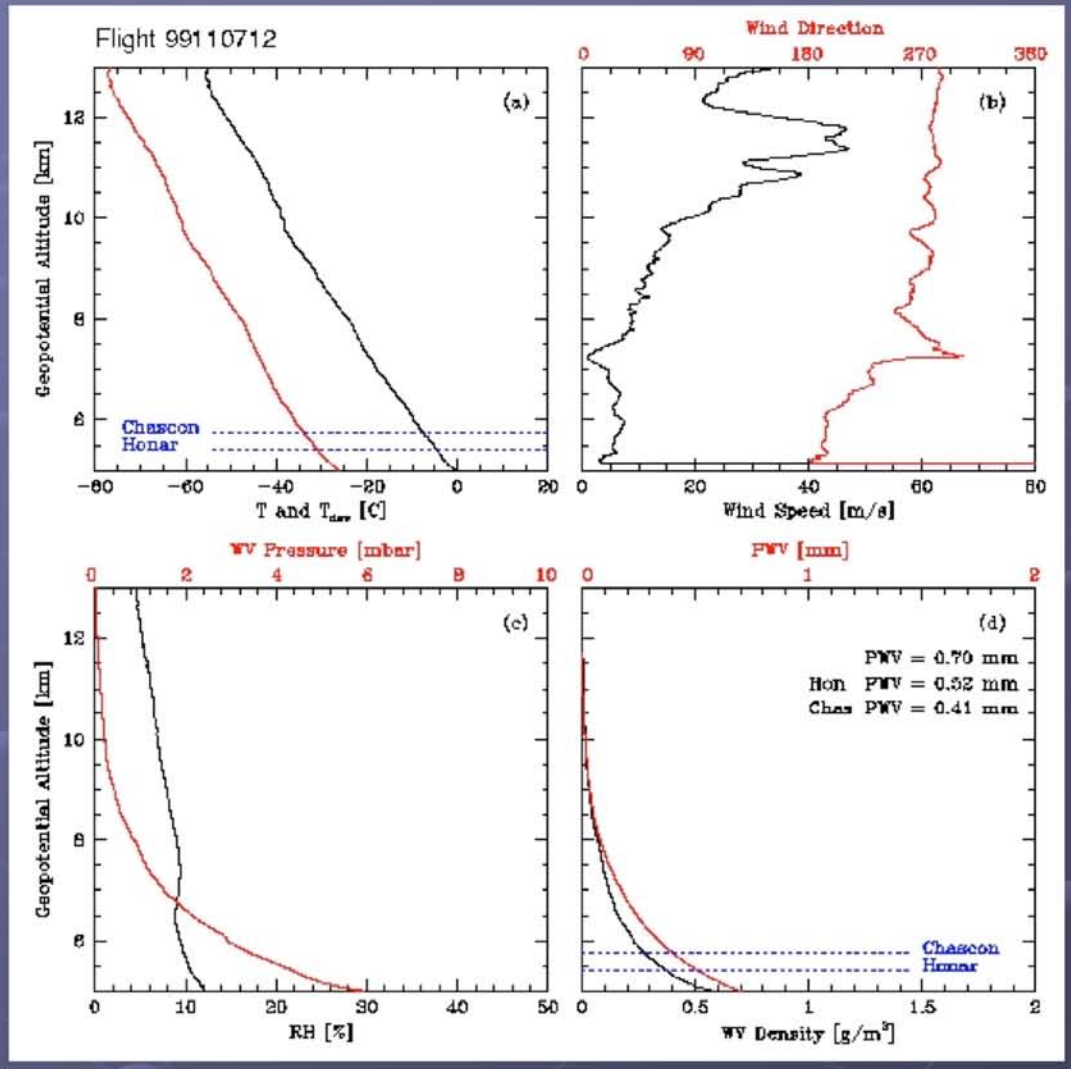
However, it becomes
shallower at night…

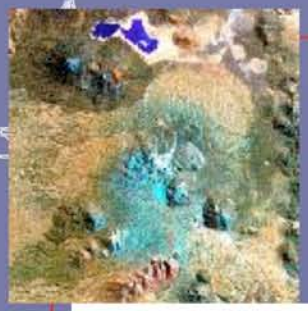


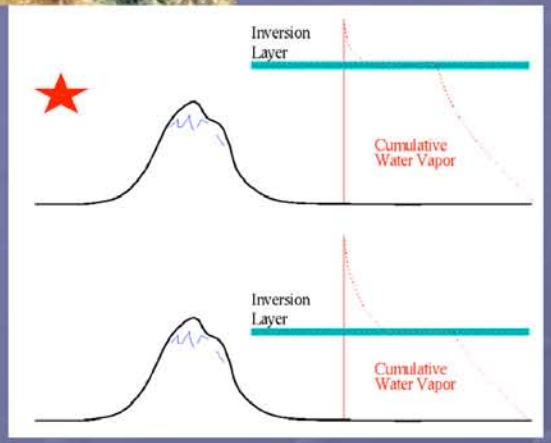


A morning launch:

Dry (PWV=0.70 mm), no inversion layer

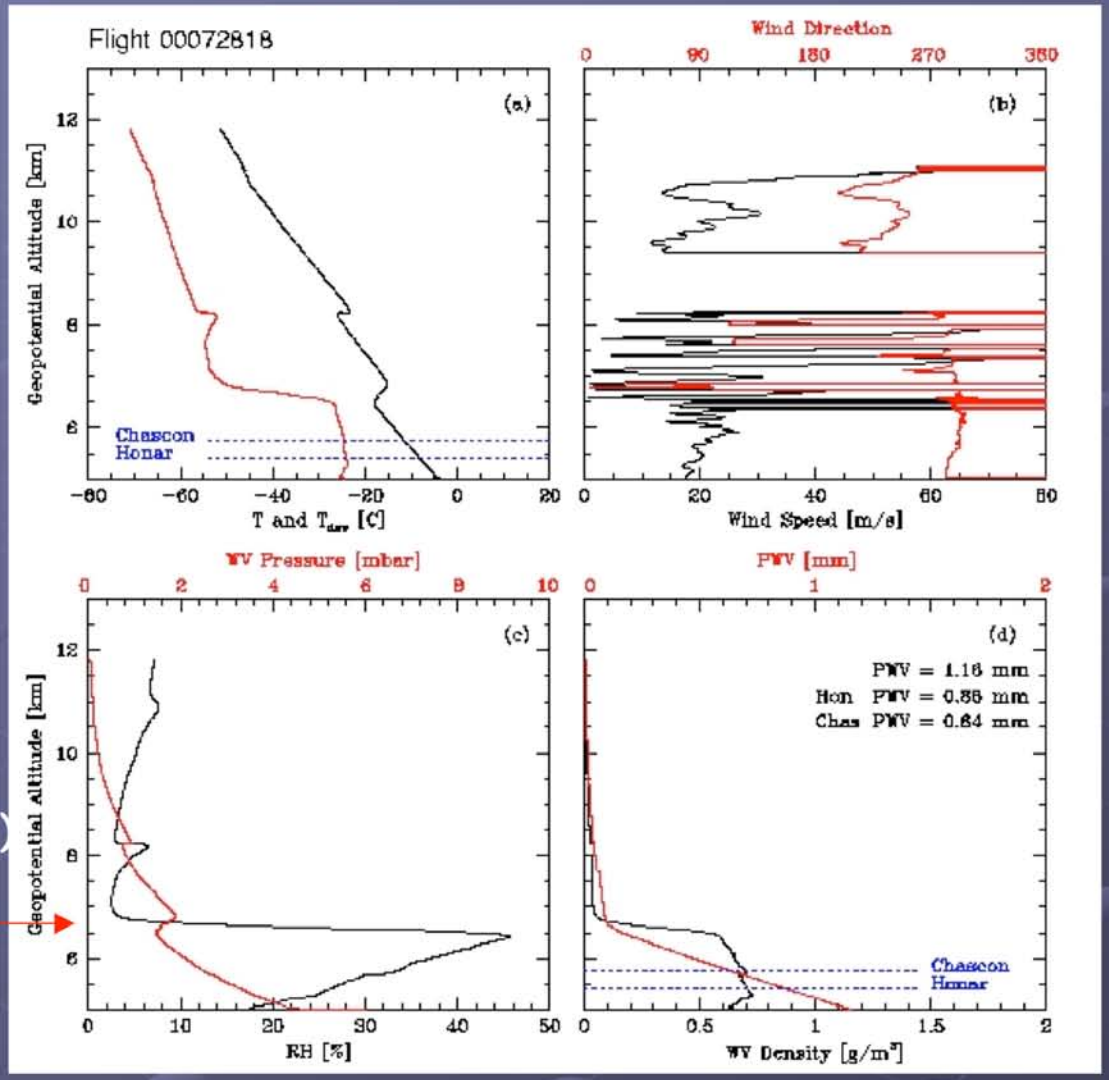


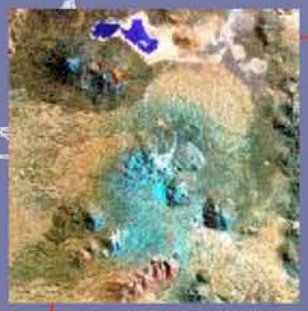


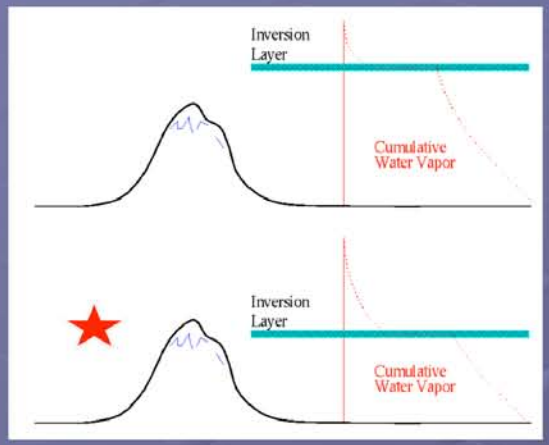


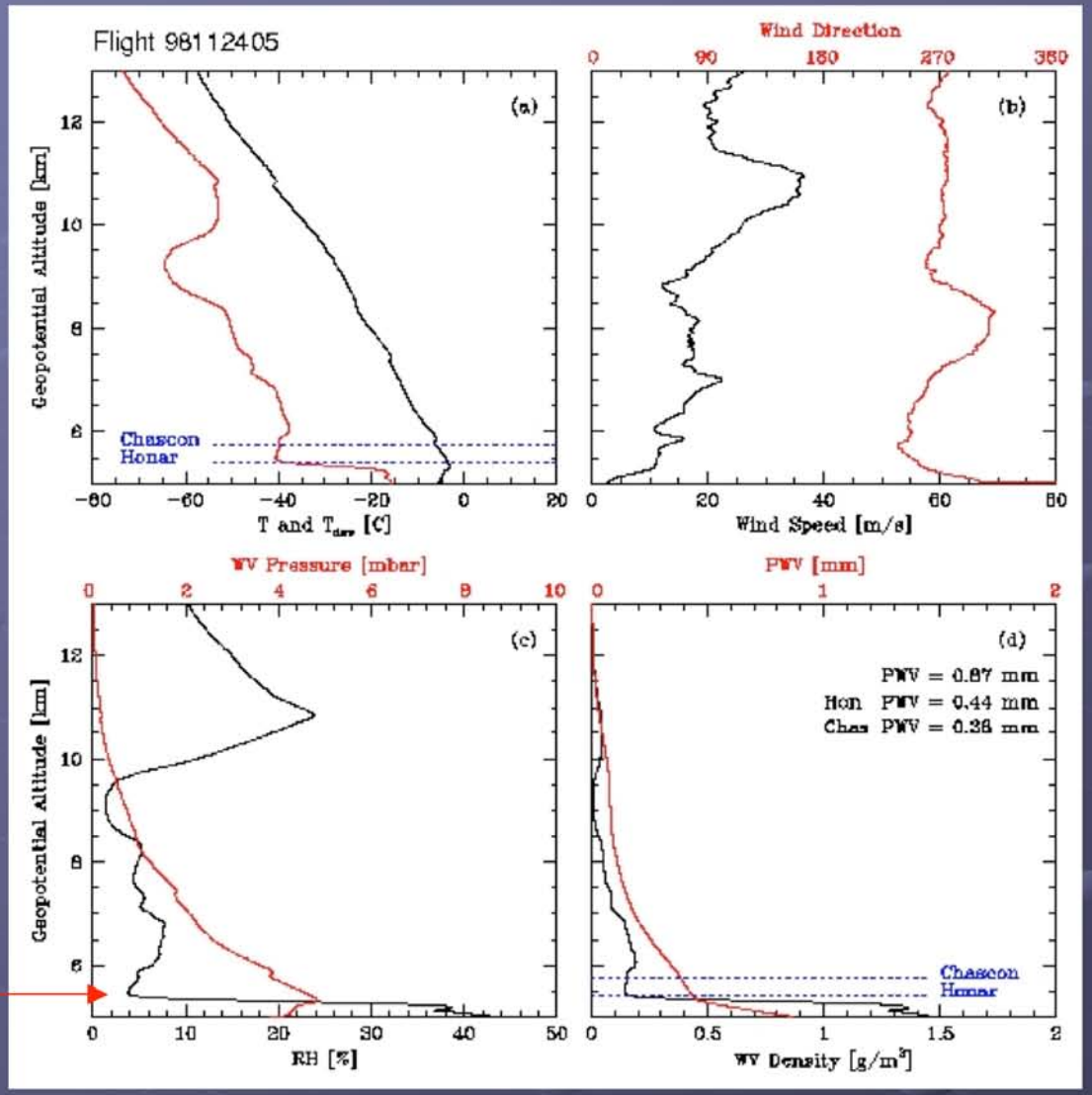
An **afternoon launch**:

Moderately dry (PWV=1.16)
first inversion layer at
6.7 km
It helps little to be on a
summit.





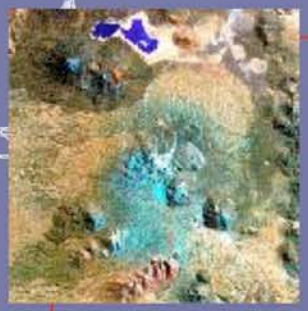




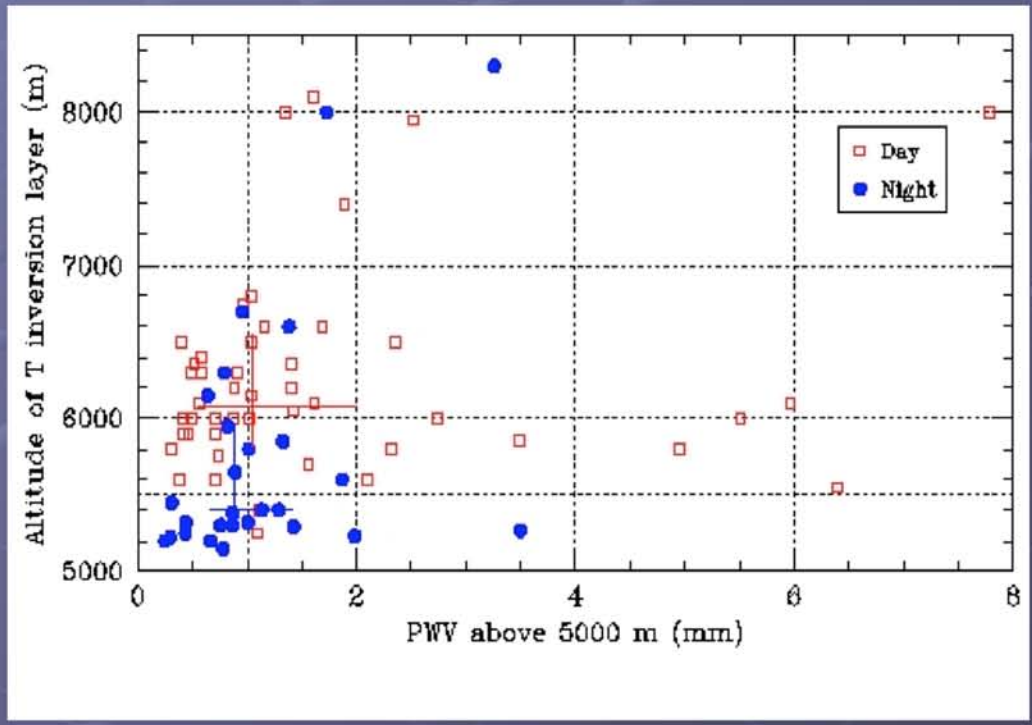
A night launch:

Dry (PWV=0.87 mm), inversion layer at 5.3 km

PWV at summit less than half that at plateau level.



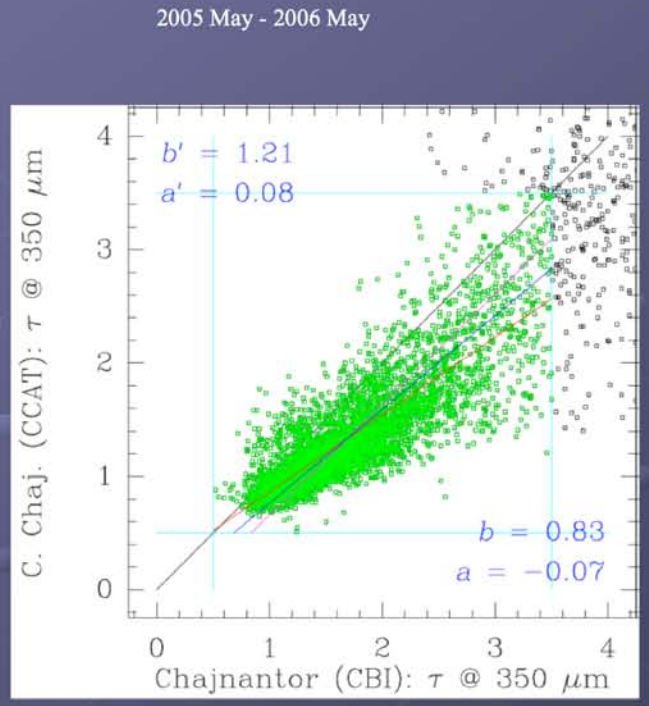
Altitude of T-inversion layer falls at night

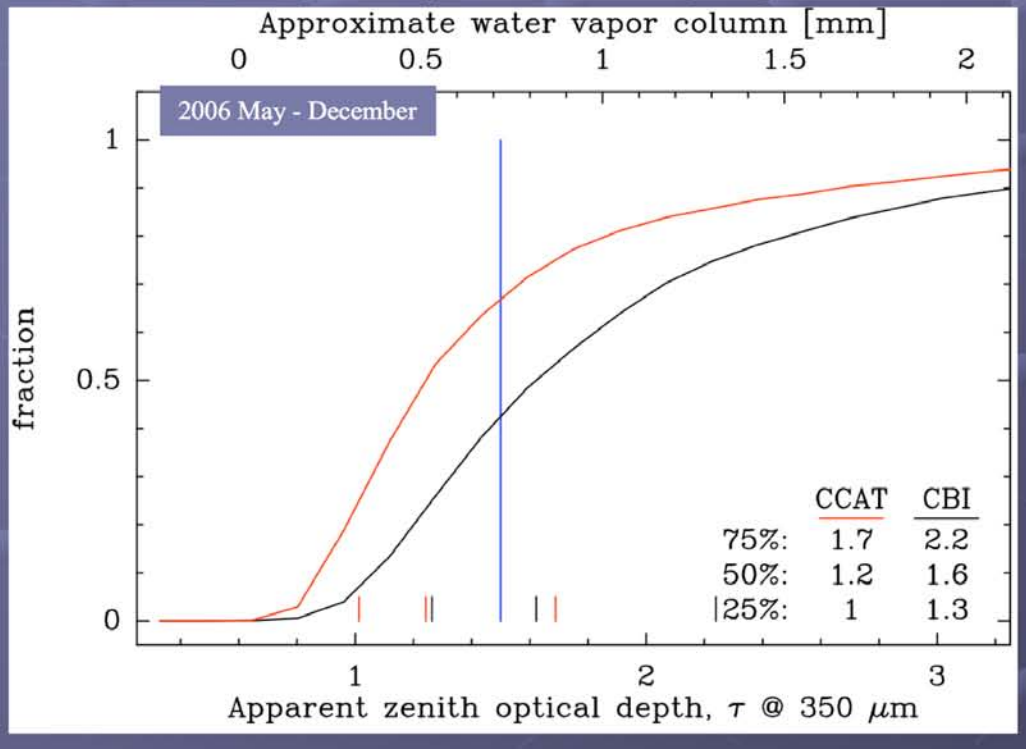


Site at elevation of ~500 m above Plateau will have significantly lower PWV and IR transparency.

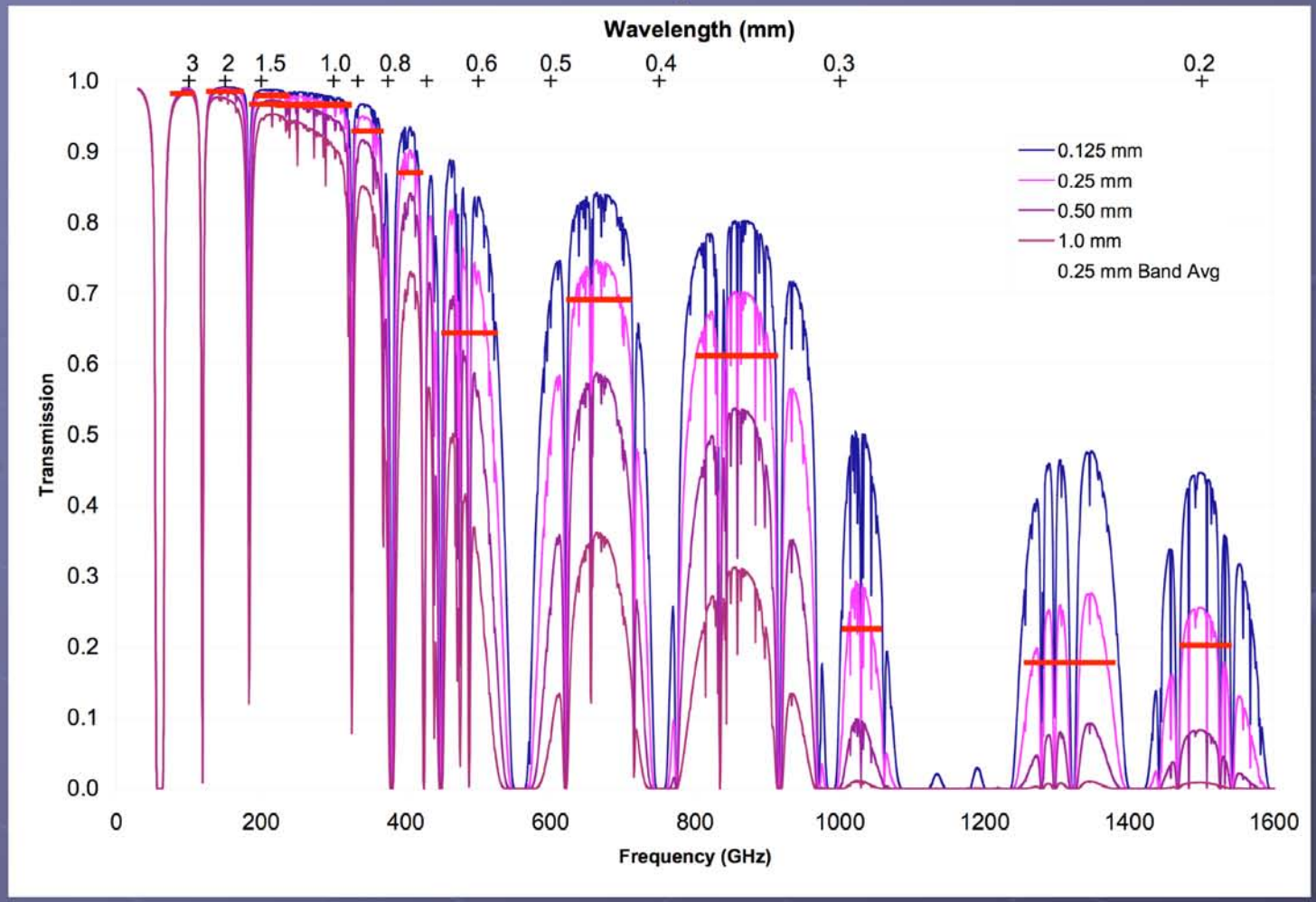
350 μm Transparency

- Two Tippers: CCAT (5600 m) & CBI (5050 m)
- Side-by-Side at CBI: Same Values
- Better Transparency at CCAT
- Less Water Vapor at CCAT
  - $\tau_{off} \approx 0.5$
  - Slope ∝ PVW
  - PWV(CCAT) ≤ 70% PWV(CBI)





Sub-mm Atmospheric Transmission

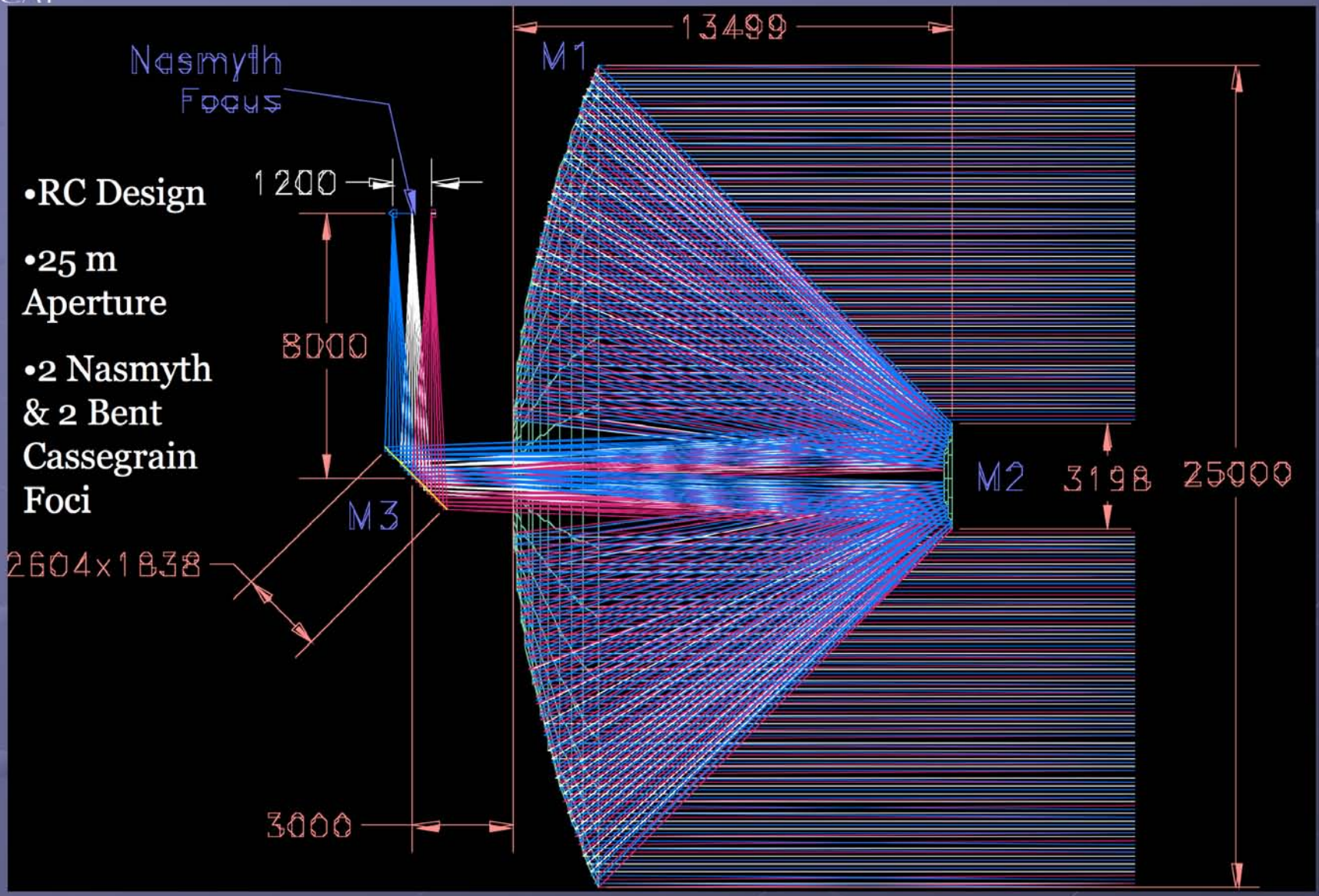


Atmospheric transmission for different amounts of precipitable water vapor. The horizontal red bars represent the adopted bandpasses and the average transmission for 0.25 mm PWV.

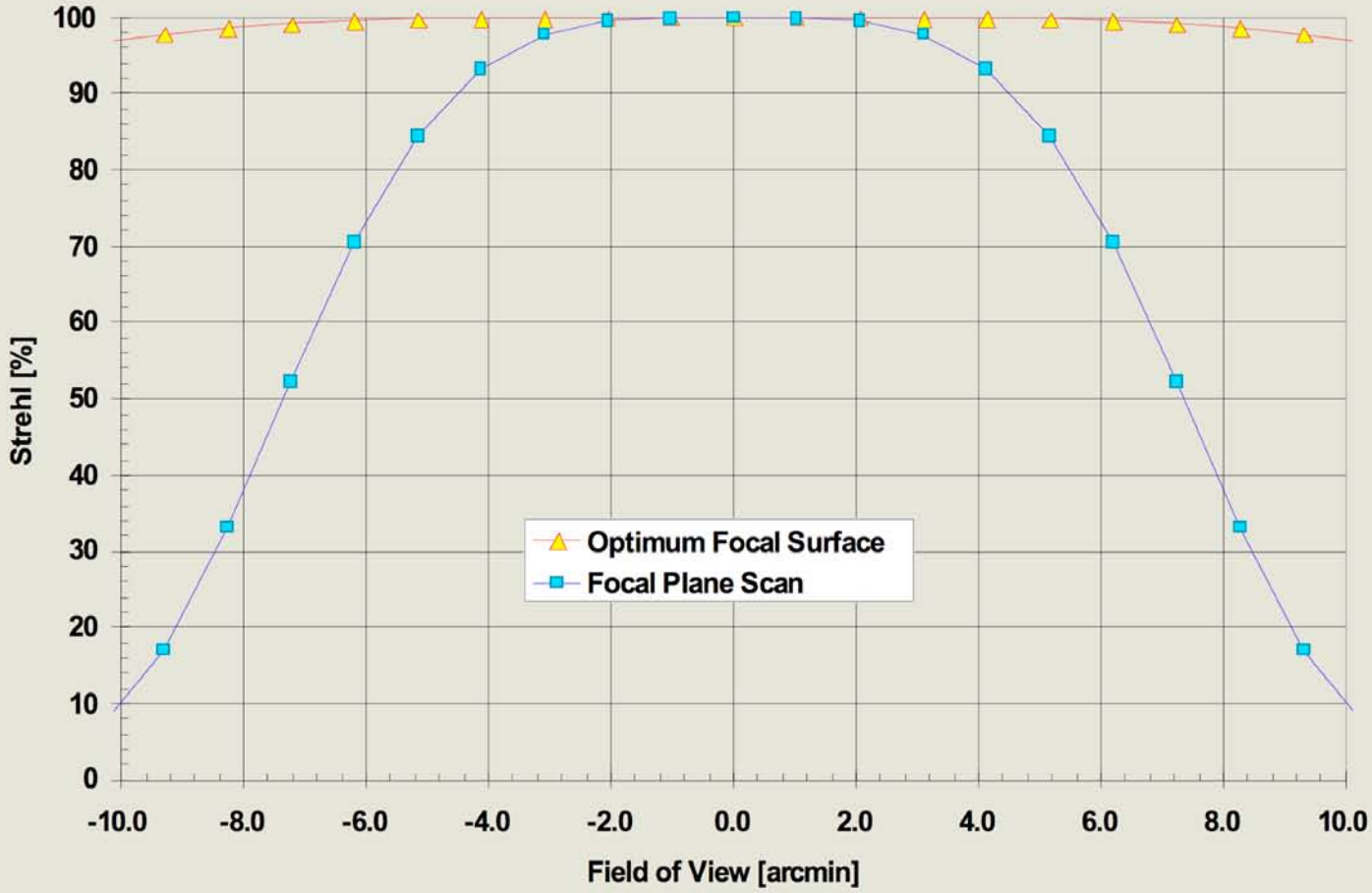
Key Telescope Requirements

- Aperture: 25 m
  - Sensitivity improves as $\propto D^2$ (hence time to a given S/N $\propto D^{-4}$)
- Wavelength range
  - 350 – 1400 μm (200 – 2500 μm goal)
  - High efficiency requires 10 μm rms surface precision
- Field of view: 5' x 5' initially, up to 20' across eventually
  - Unchallenged speed for moderate resolution, wide field surveys
- Chopping and Scanning
  - Bolometer arrays require signal modulation by chopping or scanning
  - For chopping, this must be done at the secondary (~ 1' at ~ 1Hz)
  - Scanning requires moderately large accelerations for efficiency (~ 0.2° sec^{-2})
- Pointing and Guiding
  - Spectrographs require placing to a fraction of slit width
  - And guiding to maintain spectrophotometric accuracy
  - => 0.61" and 0.35" pointing and guiding (1D rms)
- Precipitable Water Vapor
  - Provide significant observing time at 350 and 450 μm

Optical Design…German Cortes
Prescription for Faster M1…Smaller Telescope & M2



Optical Design…German Cortes
Prescription for Faster M1…Smaller Telescope & M2



- Spring 2003 : Partnership initiated
- October 2003: Workshop in Pasadena
- Feb 2004: MOU signed by Caltech, JPL and Cornell
- Late 2004: Project Office established, PM, DPM hired, Study Phase pace accelerates
- July 2005: Study Phase Midterm Review
- Early 2006: Preliminary CDR
- July 2007: Consortium includes Colorado, Canada, UK Site selection completed
- 2006-2008: Detailed Design, Manufacture, Integration
- 2008-2013: Engineering, Construction and First Light

Feb 2006 – Study Review

Review Panel:

- Robert Wilson (Harvard-Smithsonian, Chair)
- Mark Devlin (Penn)
- Fred Lo (NRAO)
- Matt Mountain (STScI)
- Peter Napier (NRAO)
- Jerry Nelson (UCSC)
- Adrian Russell (ALMA, NA)

"CCAT is an important and timely project that will make fundamental contributions to our understanding of the processes of galaxy, star and planetary formation, both on its own and through its connection with ALMA. It should not wait."

CCAT information
www.submm.org