The webinar will start at 10am US Pacific time

TMT Site(s) Update

Webinars
June 29 & July 08, 2020

TMT International Observatory

Welcome to the TMT webinars!

- Some logistical information
  - Latest update on Site Characterization documents can be found on our website: https://www.tmt.org/page/site
  - **Greg is the meeting moderator (Thx!)**, and will collect your questions:
    - During the presentation, please ask questions using the ”Chat” feature in Zoom (either “anonymously” directly to Greg, or to “everyone”, as you wish)
      - Greg will ask the questions collected when the presentation is over
    - You will also be able to ask questions directly after the presentation by using the “Raise Hand” Zoom function
  - The **presentation will be recorded**, and later posted on the TMT website, together with the slides of the presentation
  - If you’d like to repeat such webinars in the future, and you have **ideas for webinar topics of discussion**, please let us know!

Webinars plan

- Part 1: Overall situation with site access
- Part 2: Astro2020 process and NSF prospects
- Part 3: Brief intro about ORM as alternate site
- Part 4: Comparative study: MK13N and ORM
- Part 5: Q&A

Part 1:
Overall situation with site access

Timeline of construction permit process

- **Maunakea:**
  - **2009:** Maunakea selected
  - **2009-2014:** Many meetings and discussions with Hawaii community leaders, including Native Hawaiian groups, to discuss concerns, find compromises and remove obstacles
    - **2010:** Environmental Impact Study (EIS) is approved after two-year review process
    - **2014:** BLNR issues Construction District Use Permit (CDUP) after 1-year contested case
  - **2015:** Opposition prevents start of construction
  - **2016-2017:** 2nd contested case (1.5y)
  - **Sep. 2017:** BLNR re-approves the CDUP
  - **Oct. 2018:** Hawaii Supreme Court affirm BLNR's approval of CDUP
  - **July 2019:** Attempt to re-start construction was blocked again by TMT opponents
  - **Now:** Several parallel mediation processes are on-going, their outcome is uncertain

- **La Palma:**
  - **2016:** La Palma becomes TMT's alternate site
  - **2017:** Hosting Agreement signed between TIO and IAC
  - **2017:** Collaboration agreement signed between TIO, IAC, La Palma government & local municipality
  - **Nov. 2018:** Authorities validated our Environmental Impact Study.
  - **Summer 2019:** Ecologists (Ben Magec – BM) contest chronogram of admin process *wrt* land concession (one admin step to be redone)
  - **November 2019:** Land concession granted and all construction licenses obtained
  - **January 2020:** New appeal by BM against land concession. The legal process could take another ~9months
    - **June 2020:** BM just lost a separate appeal against CTA-North construction at ORM

What do recent polls say about going forward with TMT construction?

- **Hawaii** (Jan.-Feb. 2020):
  - **Pro: 62%** of Hawaii residents (all islands) support TMT construction on Maunakea.
  - **Con: 32%**. **Issues are multiple and complex**: Hawaiian sovereignty, right of land, cultural/religious practices, indigenous/minorities rights, management of Maunakea, environmental concerns *(March 2013 Hawaii poll: 83% of persons polled agreed that "The protest on Maunakea is really about issues larger than TMT, such as sovereignty, Hawaiian homelands, overthrow of the Hawaiian kingdom, and land management")*
    - Percentage of **Native Hawaiian opposing the project is ~50-60%** (from recent polls)
- **La Palma** (Nov. 2019):
  - **Pro: 94%** of Canary Islands residents (all islands) support TMT construction on La Palma.
  - **Con: 4.5%**. **Issues are solely about environmental concerns**

TMT
Thirty Meter Telescope

Timeline to start of construction

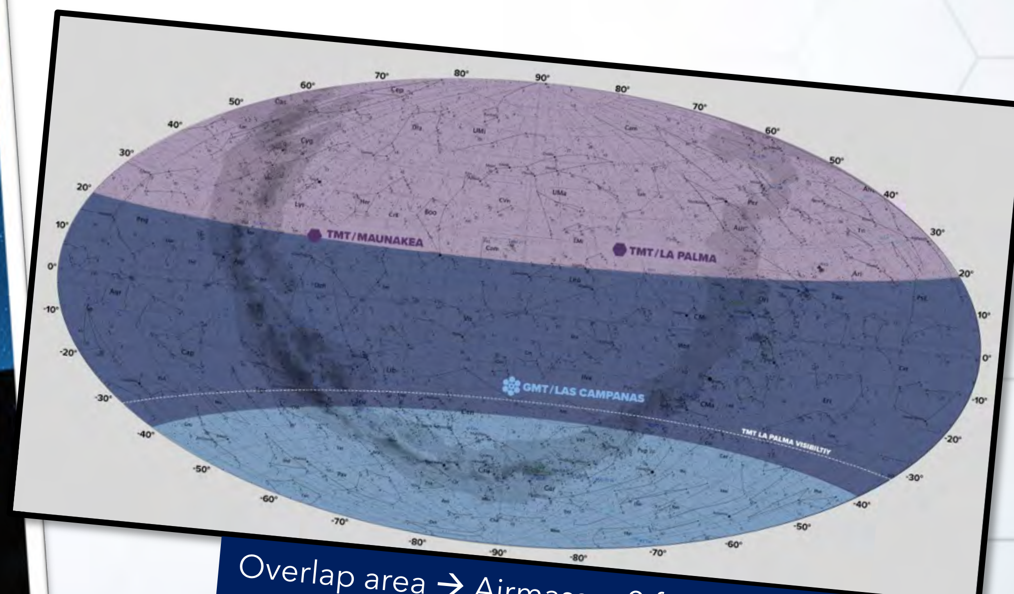
- When can we start construction?
  - Covid-19 pandemic should be under control to eliminate risk to workers (or anyone actively supporting/opposing the project through social gathering)
  - Risks:
    - Hawaii: Risk of facing major protests again
    - La Palma: Should ideally have pending legal obstacles fully removed prior to start construction
  - **Timeline to start construction remains uncertain**
- Construction, when started, will take about ~7 years
  - Three additional years for technical and science commissioning
  - First-light about 10 years after construction kick-off

Part 2:
Astro2020 process and NSF prospects

TMT Thirty Meter Telescope

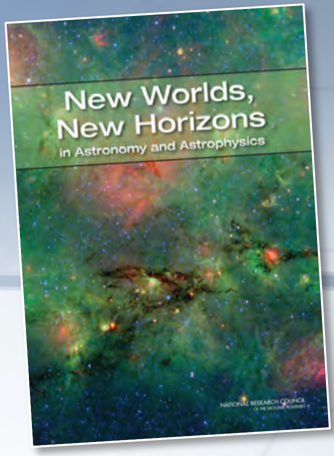
US-ELT Program (USELTP)

2 telescopes, 2 hemispheres, 1 system
All-sky coverage
Broad instrument suite
US-led Key Science Programs



Overlap area → Airmass < 2 for 2 hours or more

Astro2020 & US-ELT Program



- **Planning for US-ELTP proposal submission to the National Science Foundation (NSF) …**
  - Feb. 2020: Presentations made to Astro2020 panel on *"Optical and Infrared Observations from the Ground"*
  - US-ELTP construction proposal reviews will be carried out in full after NAS/Astro2020 recommendations (~mid-2021?)
  - US-ELTP needs to be ranked on top by Decadal Survey to trigger NSF funding process. Funding could start as early as 2023.
    - US congress will need to approve NSF US-ELTP funding

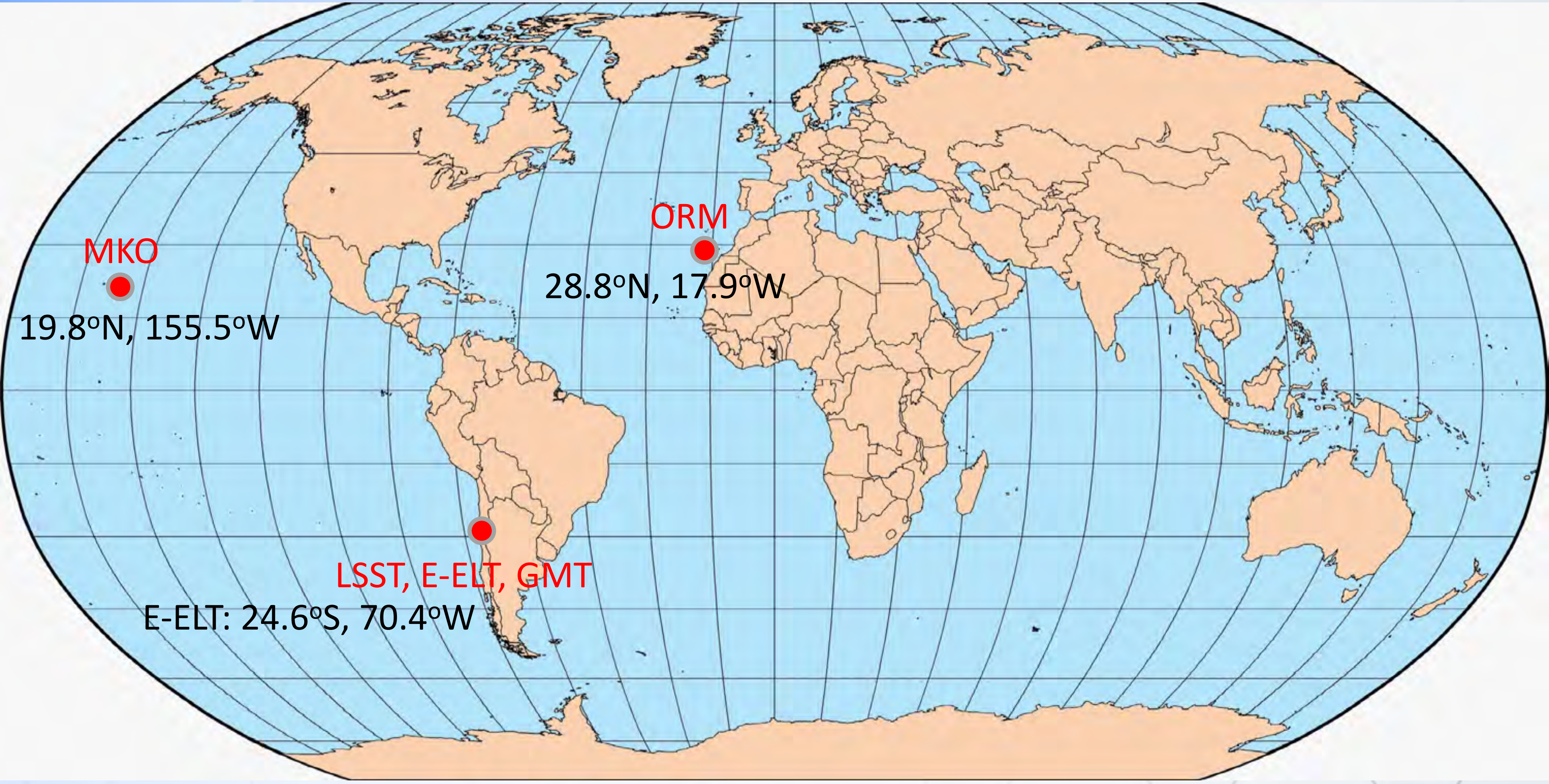
- … and, if NSF funding is approved:
  - TMT funding will be secured until end of construction
  - AURA will become a major partner of TIO
  - US scientists will have access to both GMT (South) and TMT (North)
  - NSF's NOIRLAB (formerly NOAO) will work with TMT and GMT to provide common interface for USELTP partners

Part 3:
Brief intro about ORM as alternate site

La Palma, Canary Islands

Roque de Los Muchachos Observatory

ORM's lat/lon wrt MKO and Chile



Observatorio del Roque de los Muchachos (ORM)

- ORM is managed by IAC and was inaugurated in 1985. It is the most developed astronomical observatory in the Northern hemisphere after Maunakea Observatory (MKO)
- ORM has international representation from 26 countries, including from TMT partners, e.g. USA, Japan, India and China
- ORM hosts the GTC (10.4m), CTA-North (five 23m + fourteen 12m), WHT (4.2m) and about a dozen other smaller telescopes/experiments
- Since 2016, TMT is a CCI associate member:
  - CCI is ORM (and Teide)'s **International Scientific Committee,** meeting twice a year with ORM/Teide management teams
  - Also part of **Operations sub-committee (SUCOSIP)**: Working-group on Laser Traffic Control System for ORM (upgrade in the era of CTA, GTC, TMT, …)
  - TMT has attended 2019 meeting focused on next decade instrumentation/facility roadmap for ORM and Teide

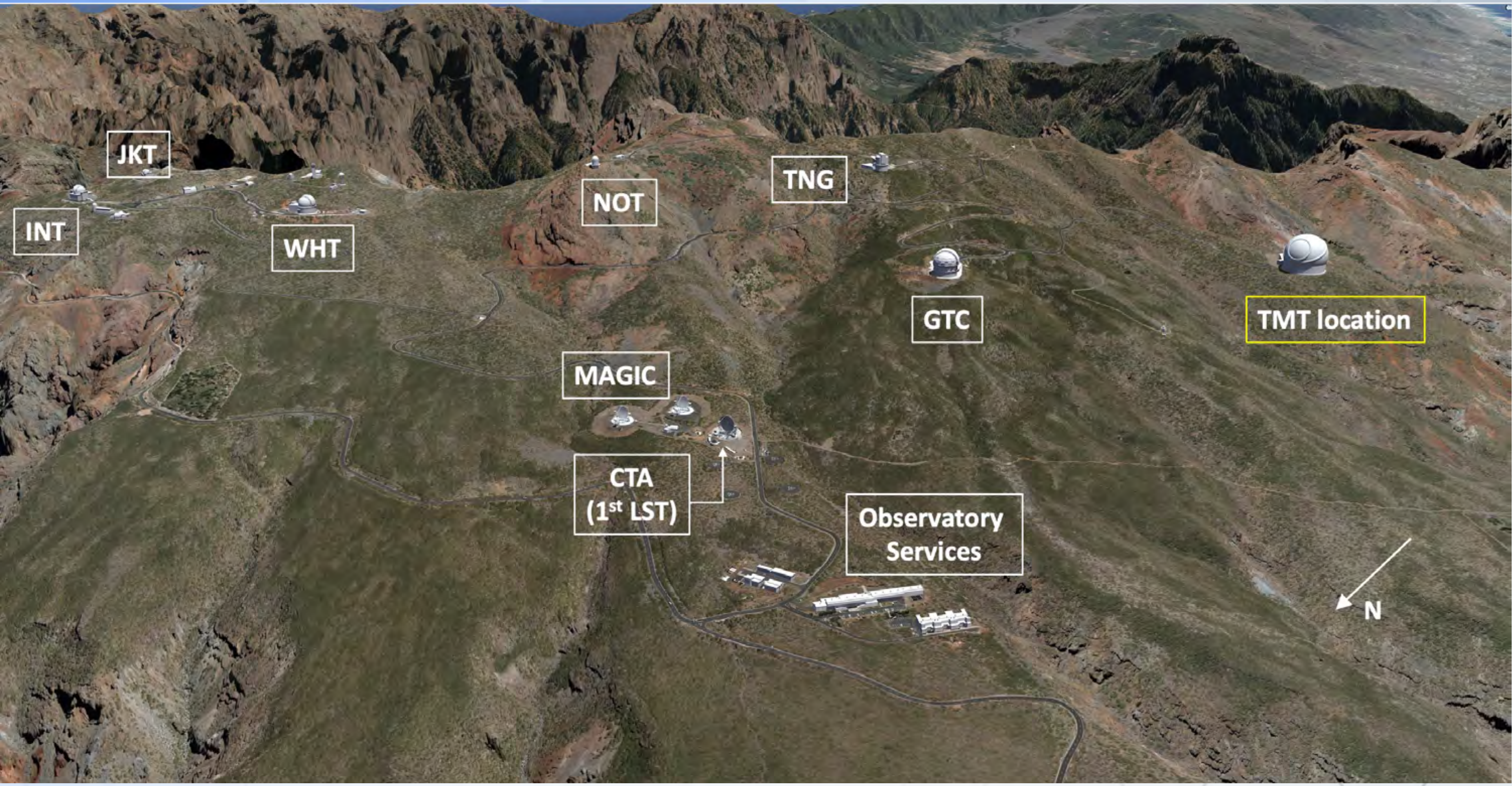
"LEY DEL CIELO" (1988)

IAC community was a pioneer in protecting night-sky against contamination from:

- **Light**
- **Radio-electric waves**
- **Aerial routes (ORM is a no flight-zone)**

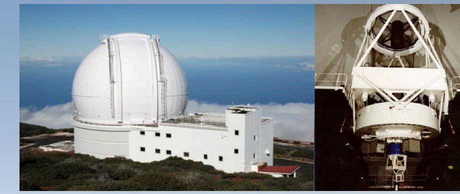
Average night-sky background is *stable over years* (V~21.7mag.arcsec^{-2})

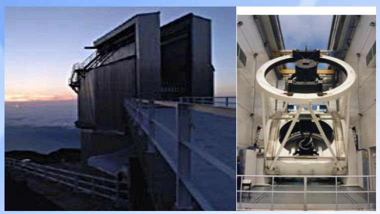
Roque de los Muchachos Observatory: TMT Alternate Site



ORM: Family portrait

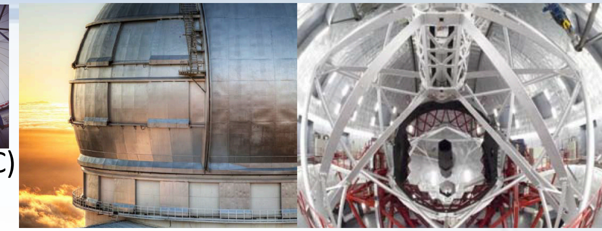

CTA-N (1st LST, 23m)


WHT (4.2m, UK, NL, IAC)


TNG (3.6m, IT)


INT (2.5m, UK, NL, IAC)

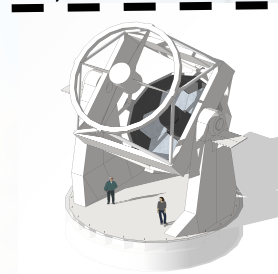

JKT (1m, UK, NL, IAC)


GTC (10.4m, ES, MX, USA)

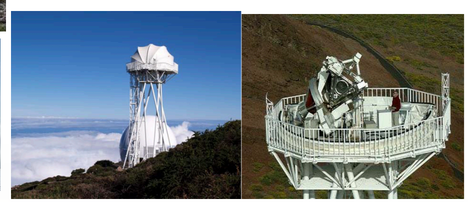

MAGIC (2x17m)

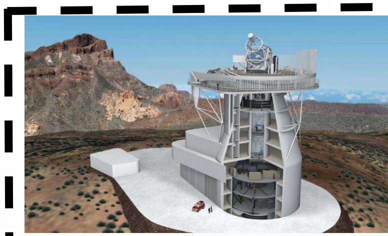

SST (1m, Swedish Solar T.)

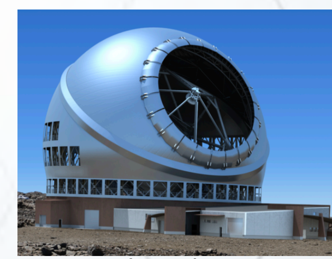

NOT (2.6m, DK, FI, NO, SE, IS)


4m-LT2


Liverpool Telescope (2m, UK)


DOT (0.5m, Solar, NL)


4m-EST (or on Teide)


?? TMT (30m)??


GOTO


Mercator Telescope (1.2m, B, CH)


MASCARA-N (NL)


Super-Wasp, UK

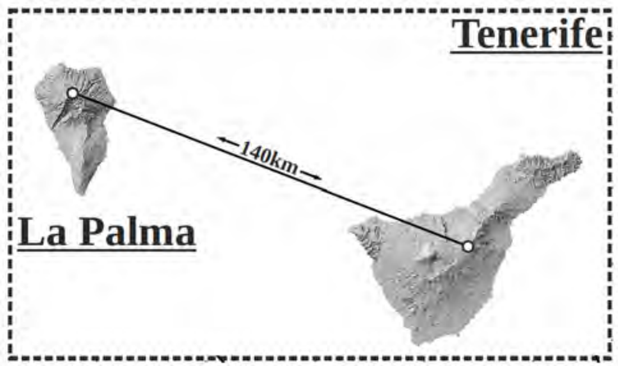

CTA-N (19 telescopes total: 15x12m + 4x23m)

So, why was ORM chosen for TMT alternate site? (1/2)

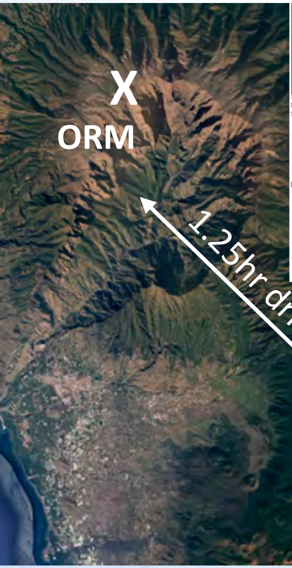
- Science & site quality:
  - Site selection used same analysis method as 2008 downselect
    - 2nd best Northern-Hemisphere site after Maunakea
    - ORM can support all of TMT core science

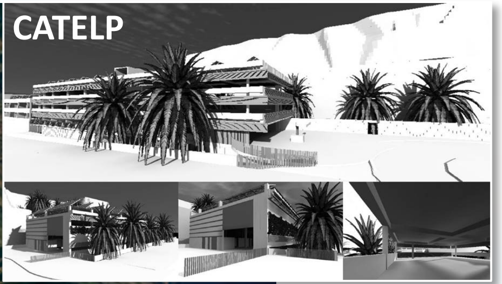
Site Characteristics (median values, unless stated)	MK13N (USA)	ORM (Spain)	Armazones (Chile)
Altitude of site (m)	4050	2250	3060
Fraction of yearly usable time (%)	72	72	86
Seeing at 60m above ground (arcsecond)	0.50	0.58	0.50
Isoplanatic angle (arcsecond)	2.55	2.31	2.05
Atmospheric coherence time (ms)	7.3	6.0	5.0
Calculated Adaptive Optics Strehl merit function	1.0	0.93	0.92
Precipitable water vapor (% time < 2mm)	54	20	50
Mean nighttime temperature (°C)	2.3	7.6	7.5
Atmospheric Extinction (V_{mag}/airmass)	0.11	0.13	0.13

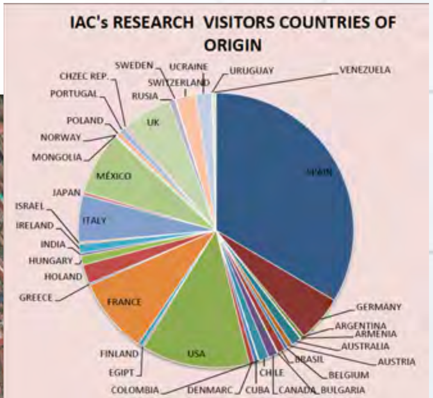
So, why was ORM chosen for TMT alternate site? (2/2)



- Project & operations factors:
  - Existing infrastructures supporting science and operational synergies
    - TMT **technical operations in La Palma**, at CATELP (future observatory operations center)
      - Immediate access to La Palma airport, synergies with ORM facilities (GTC, CTA, WHT, etc)
      - Hosting capacity > 400 persons. 12,500 m^2 facility (+ parking)
    - TMT **science operations in Tenerife,** on IAC campus (former GTC building)
      - Immediate access to Tenerife-North airport, science synergy with IAC/ULL faculty/students
      - Immediate access to new IACTec facility (instrument development/integration)
    - Both science & technical headquarters are 1.5h door-to-door





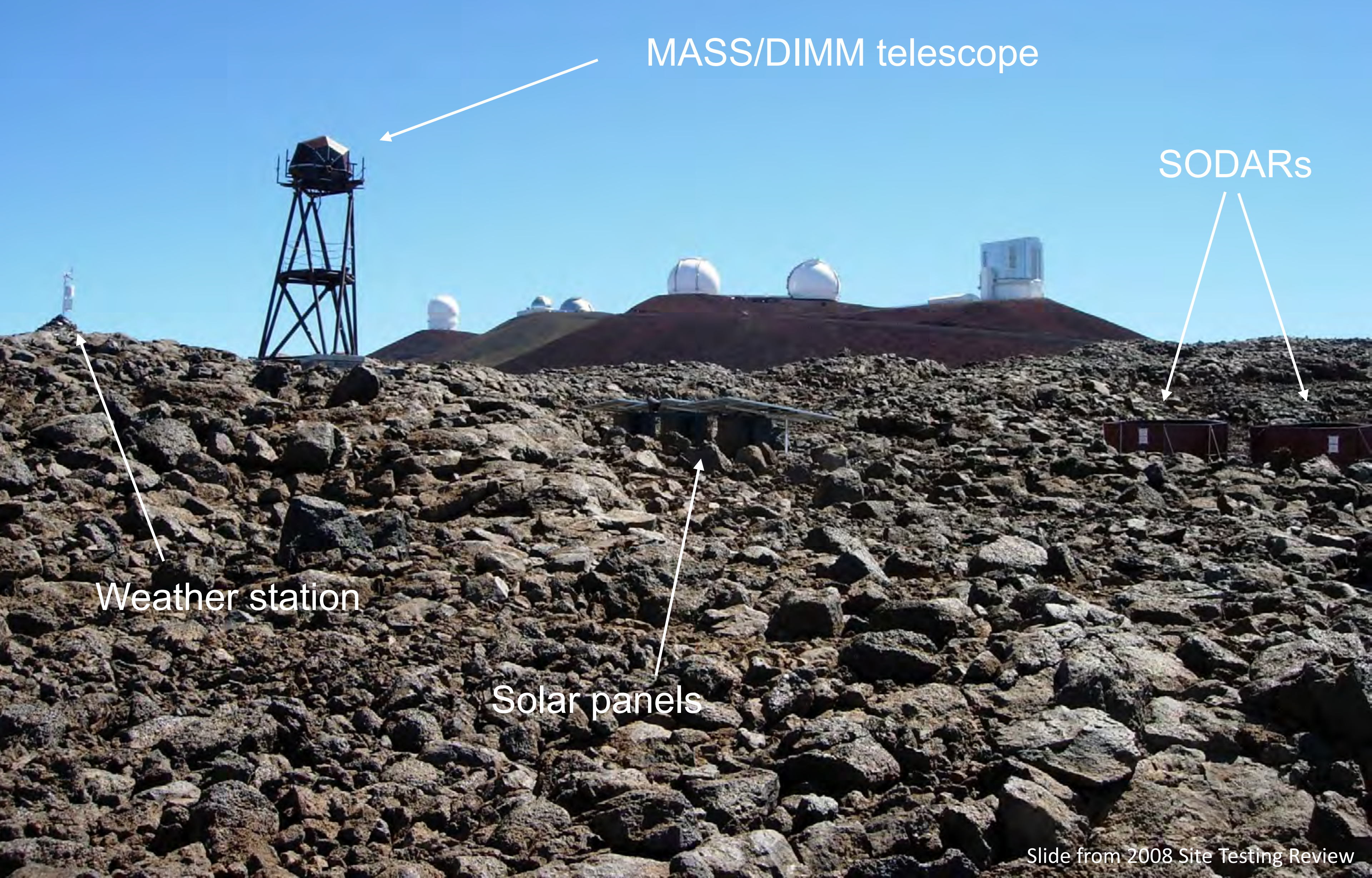


Part 4:
Comparative study: MK13N and ORM

Overview

- Sources of data for Maunakea 13N and ORM
- Summary of main site characteristics
- Details of site characteristics
  - Turbulence and adaptive optics (AO) performance
  - Precipitable water vapor (PWV)
  - Mid-IR performance
  - Atmospheric extinction and dust
- Summary of main site characteristics

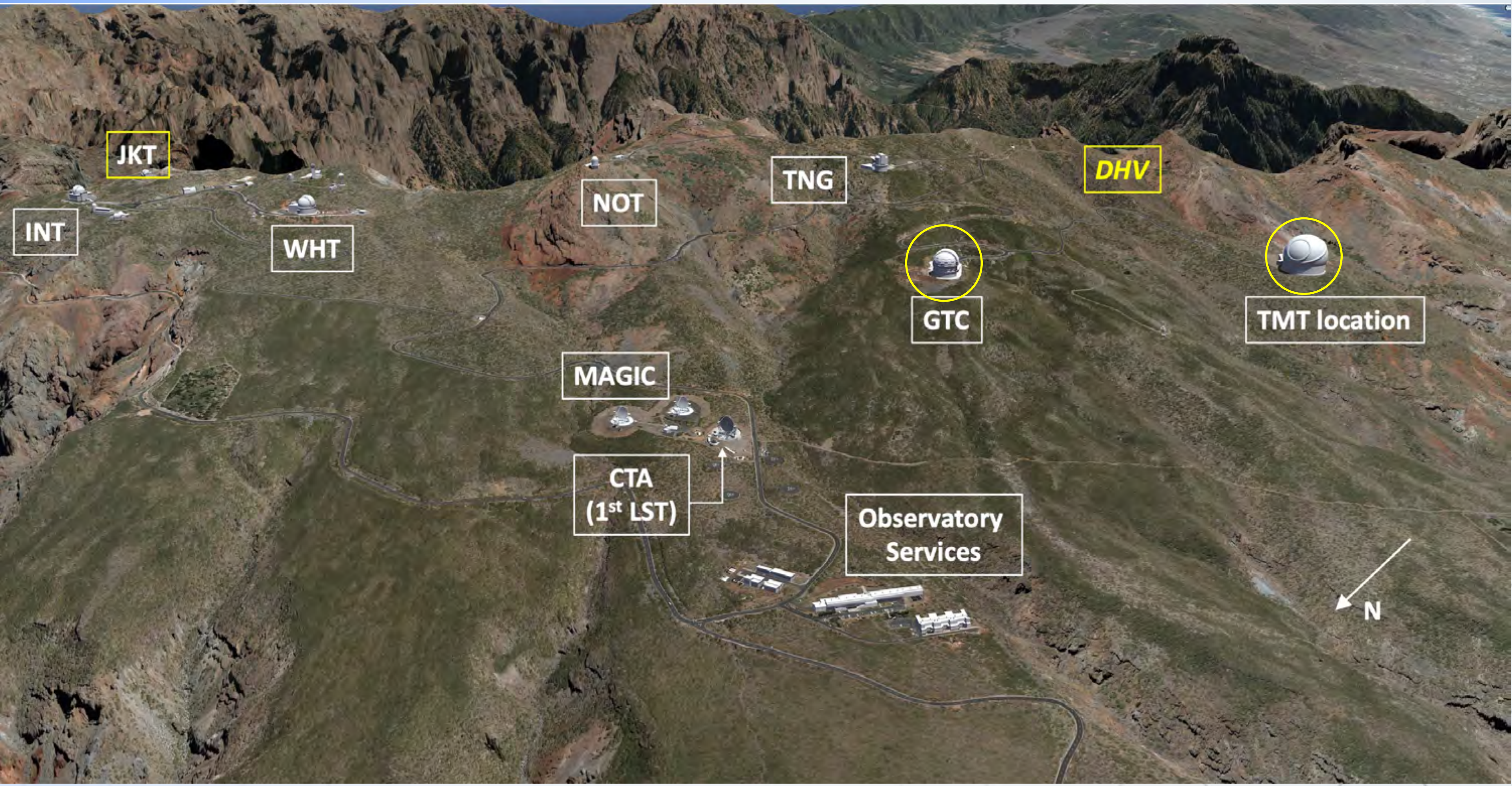
TMT Site Testing
Setup at Maunakea 13N (2005 – 2008)

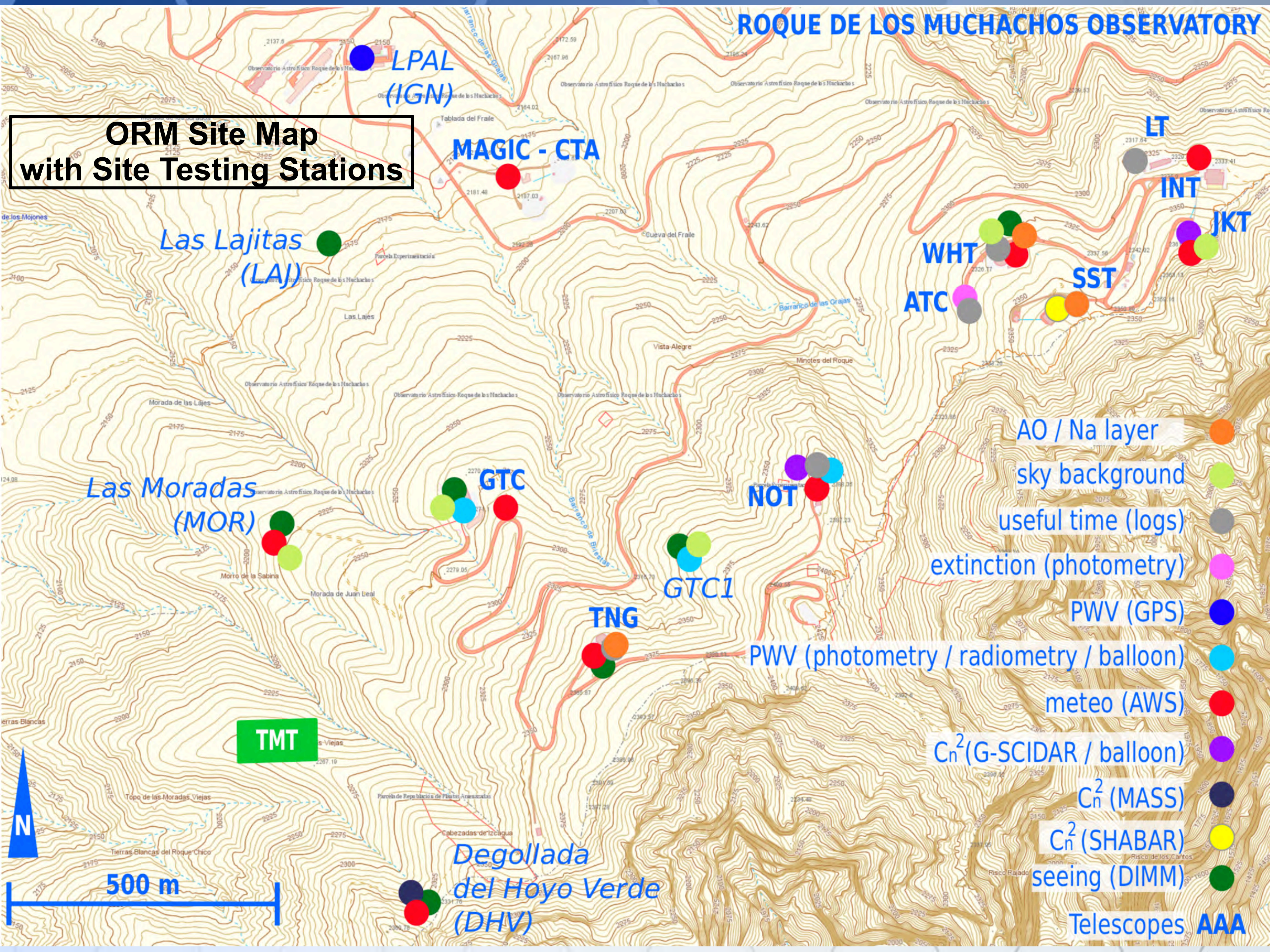


Slide from 2008 Site Testing Review

The Instruments

Roque de los Muchachos Observatory





ROQUE DE LOS MUCHACHOS OBSERVATORY
ORM Site Map
with Site Testing Stations
LPAL
(IGN)
MAGIC - CTA
Las Lajitas
(LAJ)
LT
INT
JKT
WHT
SST
ATC
GTC
NOT
Las Moradas
(MOR)
GTC1
TNG
TMT
Degollada
del Hoyo Verde
(DHV)
N
500 m
AO / Na layer
sky background
useful time (logs)
extinction (photometry)
PWV (GPS)
PWV (photometry / radiometry / balloon)
meteo (AWS)
C_n^2(G-SCIDAR / balloon)
C_n^2 (MASS)
C_n^2 (SHABAR)
seeing (DIMM)
Telescopes AAA

TMT
Thirty Meter Telescope

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Note: NAOJ did an independent analysis of ORM site data earlier this year and confirmed results shown in this presentation

ORM Atmospheric Turbulence Profiles

- We need turbulence *profiles* for our analysis
  - For AO performance analysis
  - For estimation of seeing experienced at 60 m above the ground
    - 60 m is height of TMT enclosure
    - Computational fluid dynamics simulations show that turbulence below that height is dominated by enclosure and telescope
    - (Small) fraction of turbulence below 60 m entering the dome affects performance, but is not distinguishing factor between MK13N and ORM as ground layer strength is the same
- MK13N: TMT MASS/DIMM data
- ORM: two large data sets
  - gSCIDAR turbulence profiles: JKT site
  - E-ELT site testing MASS/DIMM data: DHV site
  - We have carefully investigated the properties of both data sets (as well as other total-seeing-only sets) with (a lot of) help from IAC Sky Quality Team and confirmation by NAOJ

ORM Atmospheric Turbulence Profiles

- gSCIDAR turbulence profiles (JKT site):
  - We use gSCIDAR data because of their long-term coverage: 2004 – 2009

Percentile	Total Seeing	Total Ground-Layer	**Seeing 60m & up**	Ground-Layer 60m & up	Free Atmosphere
25%	0.64	0.44	**0.45**	0.22	0.32
50%	**0.82**	**0.64**	**0.58**	**0.33**	**0.4**
75%	1.13	0.94	**0.75**	0.48	0.52
95%	1.62	1.39	**1.09**	0.71	0.82

- E-ELT MASS/DIMM profiles: lower overall and free-atmosphere seeing
  - At DHV, closer to TMT site; cover much shorter period
  - 0.7 – 0.8” total seeing; 0.31” free atmosphere (MASS) seeing
- Many other integrated (no profiles) seeing measurements exist
  - GTC site DIMM (1995 – 1999; before GTC construction): 0.65” total seeing
  - Other integrated seeing measurements: 0.64 – 0.84” total seeing

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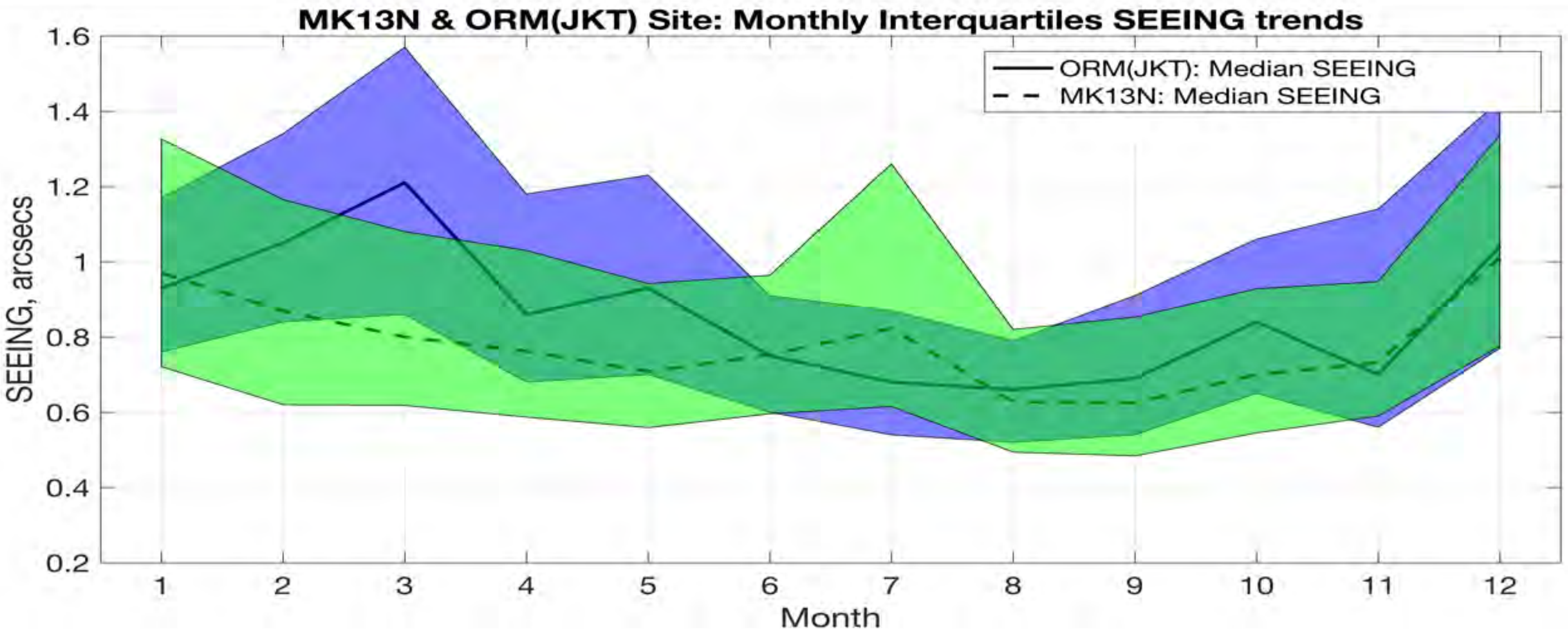
MK13N & ORM SEEING STATISTICS & MONTHLY TRENDS



60-m seeing [arcsec]:

Site	Altitude	25%	50%	75%	95%
MK13N	4,050m	0.37	0.50	0.70	1.13
ORM	2,250m	0.45	0.58	0.75	1.09

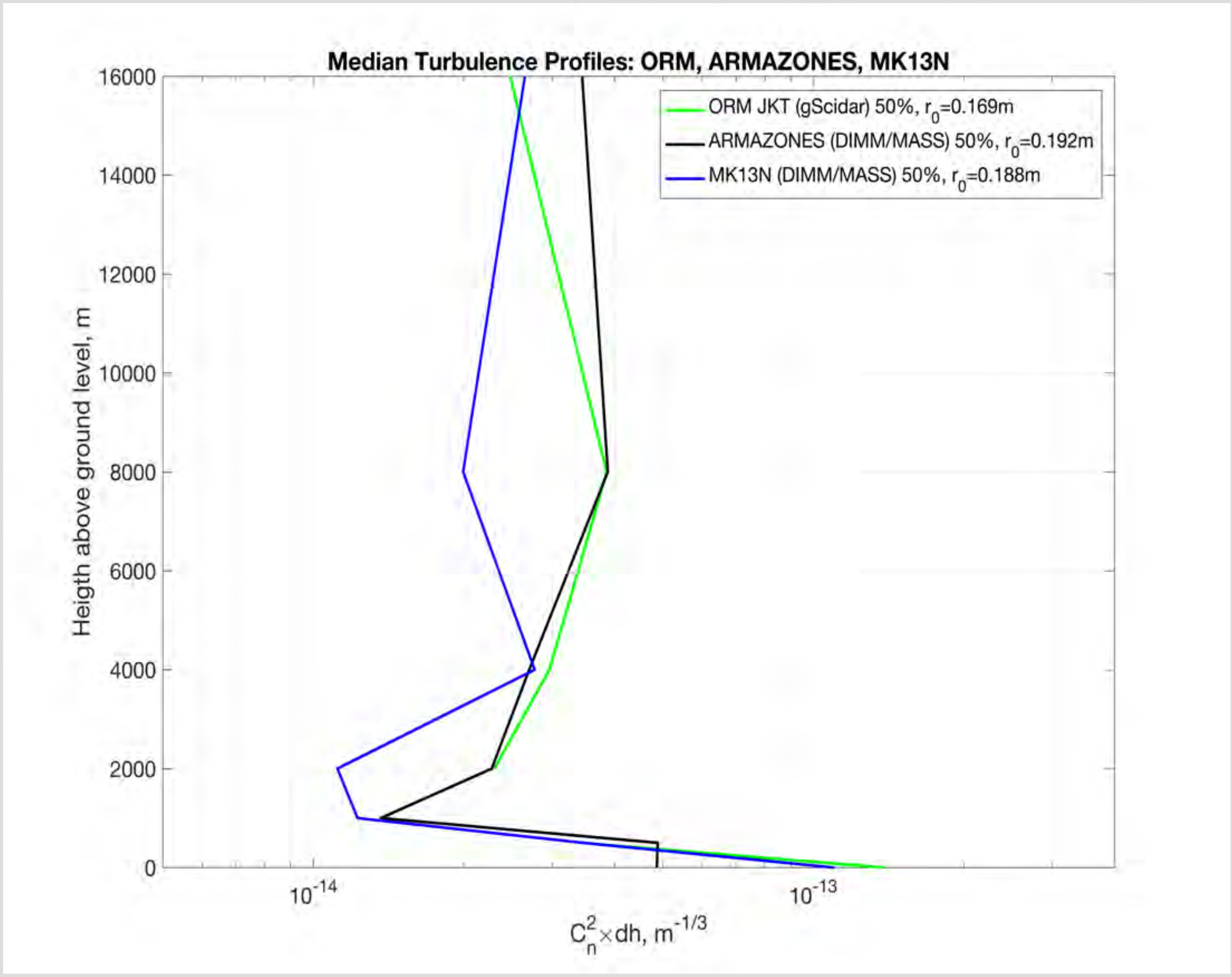
MASS seeing (500 m and up)

0.34 MK
0.40 ORM: JKT gSCIDAR
0.31 ORM: DHV M/D

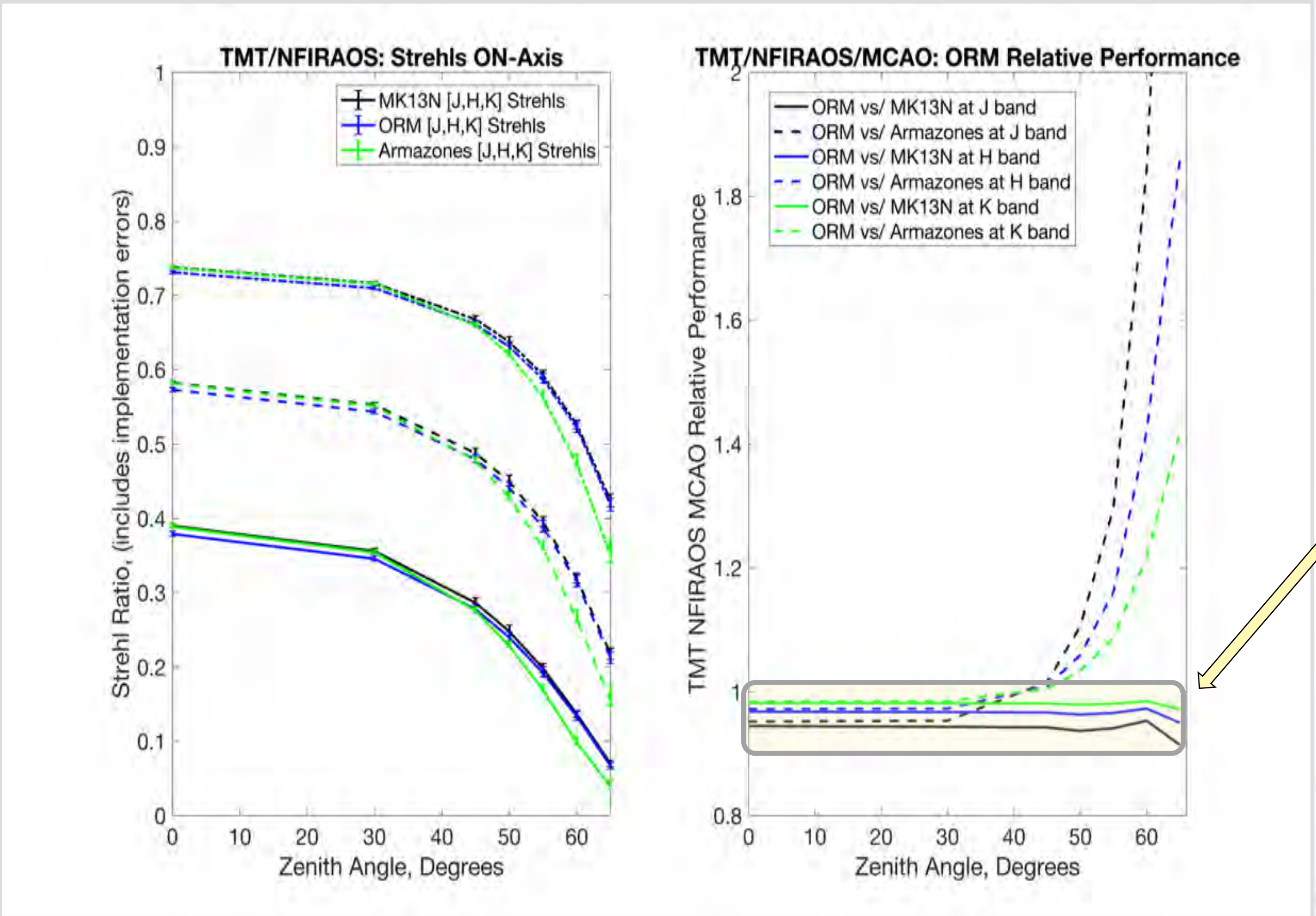
GL fraction @ MK13N ~ 50%
GL fraction @ ORM ~ 65%

GL: ground layer

Atmospheric Turbulence Vertical Profiles



NFIRAOS MCAO Performance
Strehl Ratios & Relative Exposure Times



This is the relative difference between the sites due to AO performance only

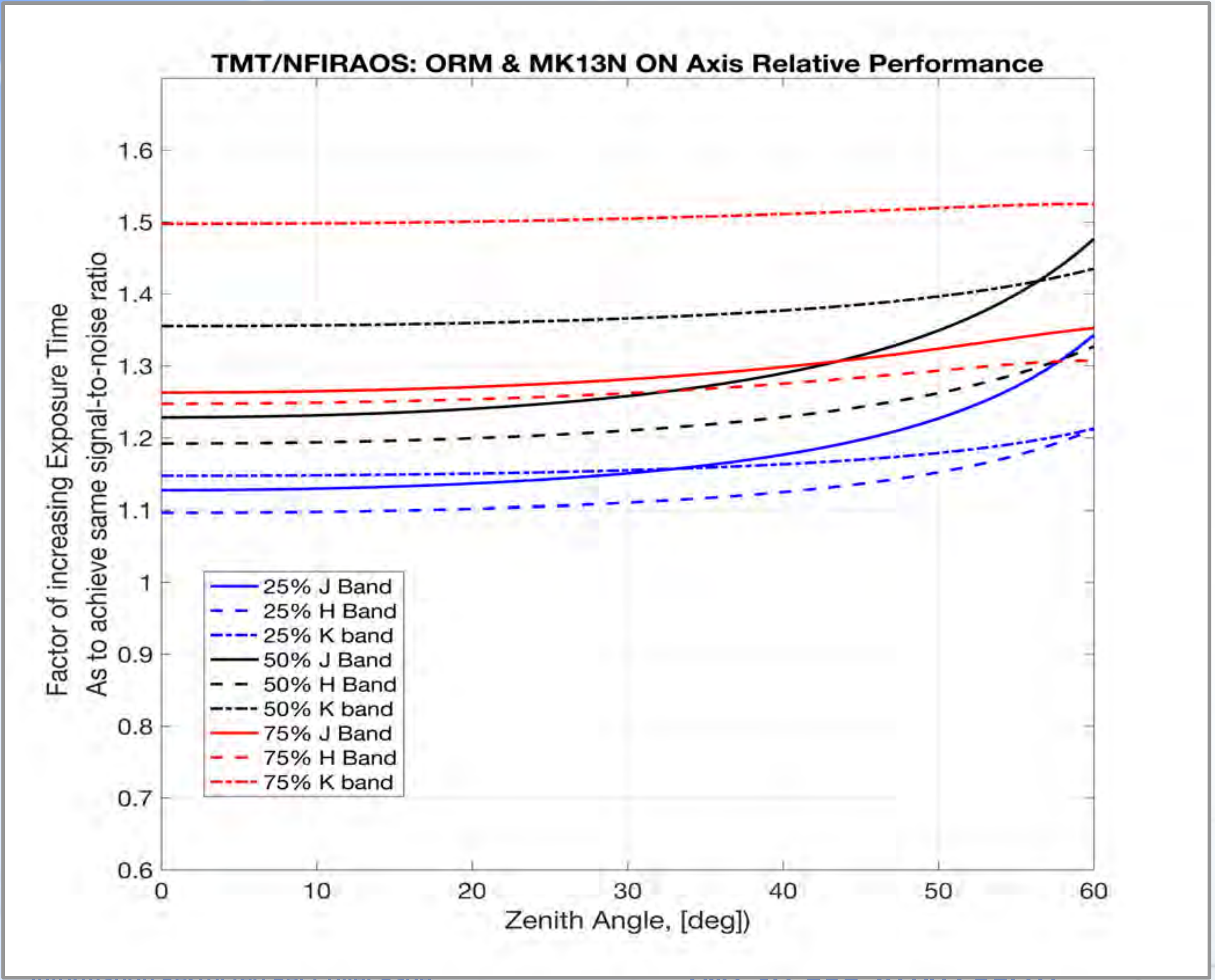
$(S_{ORM}/S_{MK})^2 > 90\%$

(for most part > 95%)

When we use DHV MASS/DIMM profiles, ratio is very close to 1

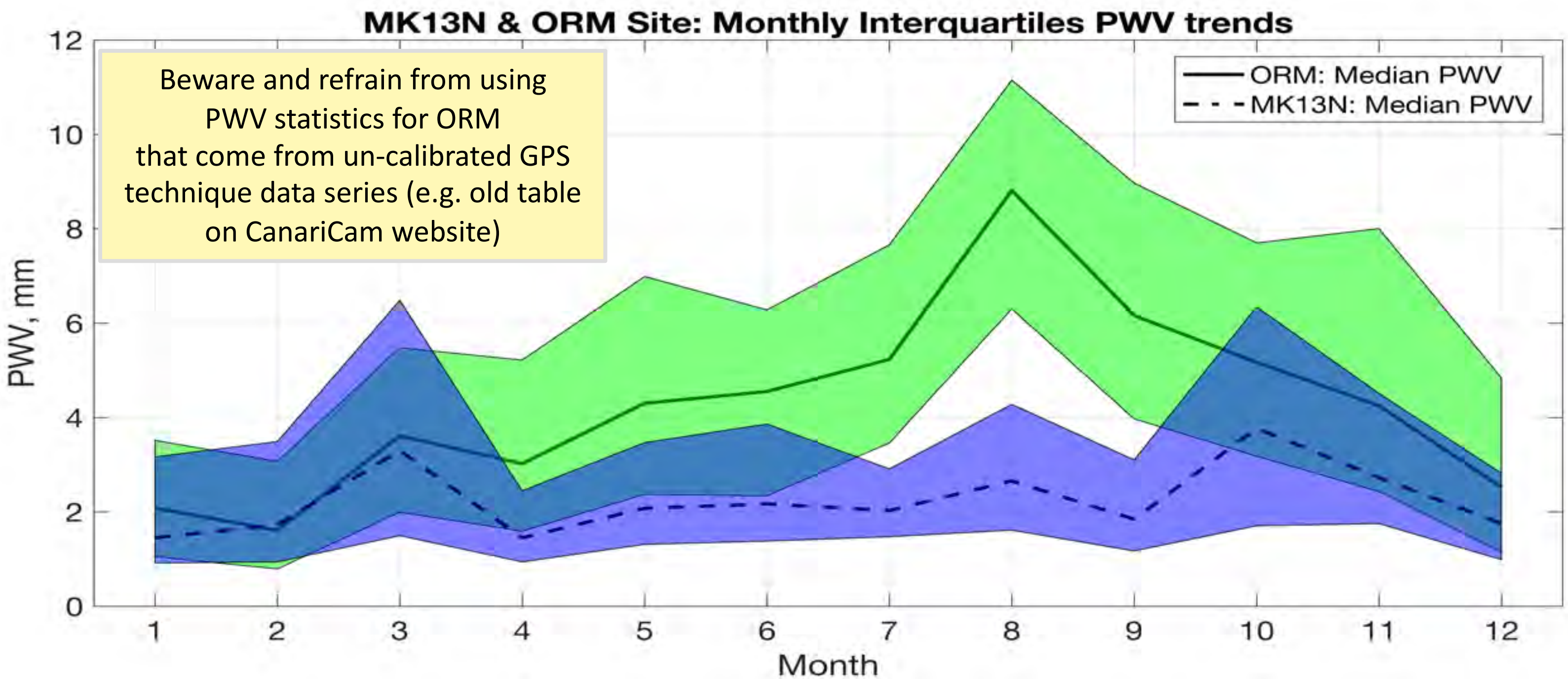
NFIRAOS: TMT's first light MCAO system
MCAO: Multi Conjugate Adaptive Optics

Near Infrared Relative Exposure Times
All Effects



This includes the effects of AO performance (Strehl), atmospheric extinction and atmospheric background

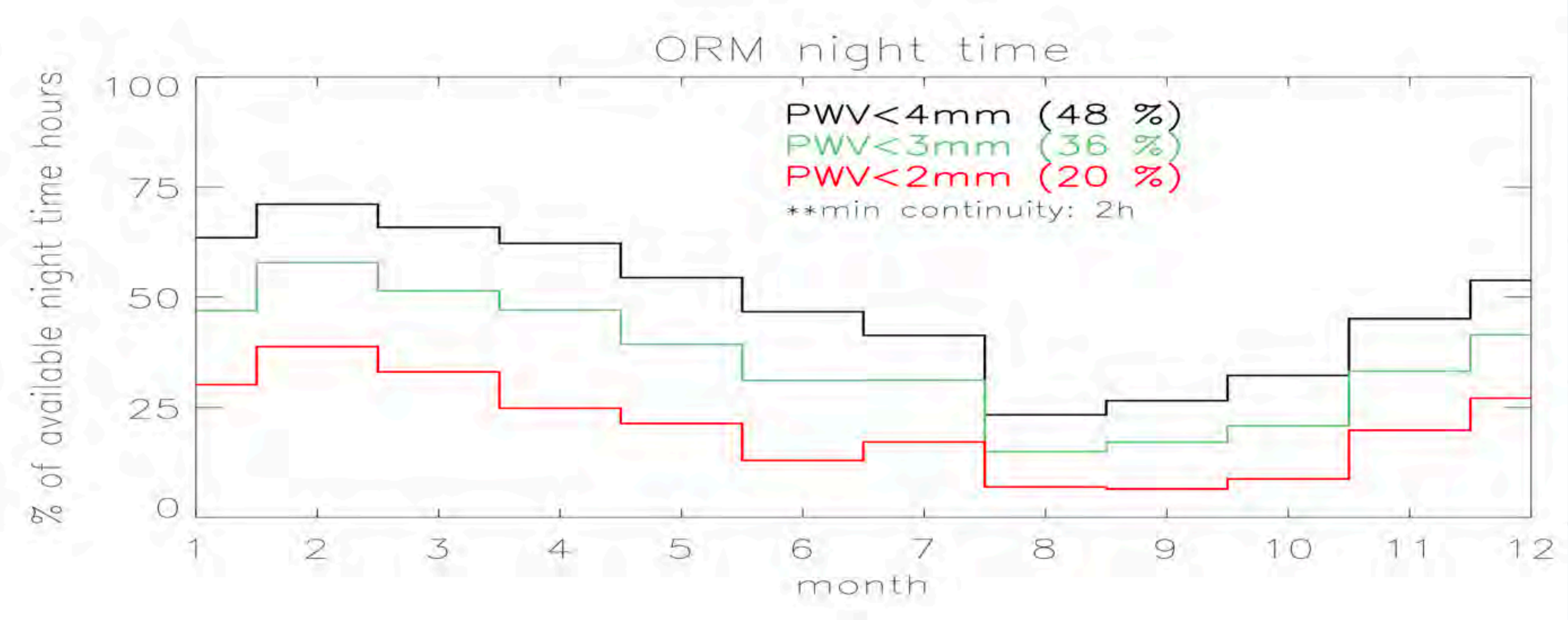
MK13N & ORM
Precipitable Water Vapor (PWV)



Site	Altitude	5%	10%	20%	25%	50%	75%	95%
MK13N	4,050m	0.59	0.78	1.03	1.15	1.91	3.54	8.15
ORM	2,250m	1.02	1.42	**2.00**	2.20	4.24	7.03	12.2

ORM statistics come from 2 years (2012 – 2013) of nighttime radiosonde soundings from Güimar Station. Statistics from 2 years (2012 – 2013) of calibrated GPS-slant—technique PWV data, agree within 10%.

MK13N & ORM
PWV: Fraction of PWV ≤ 2mm



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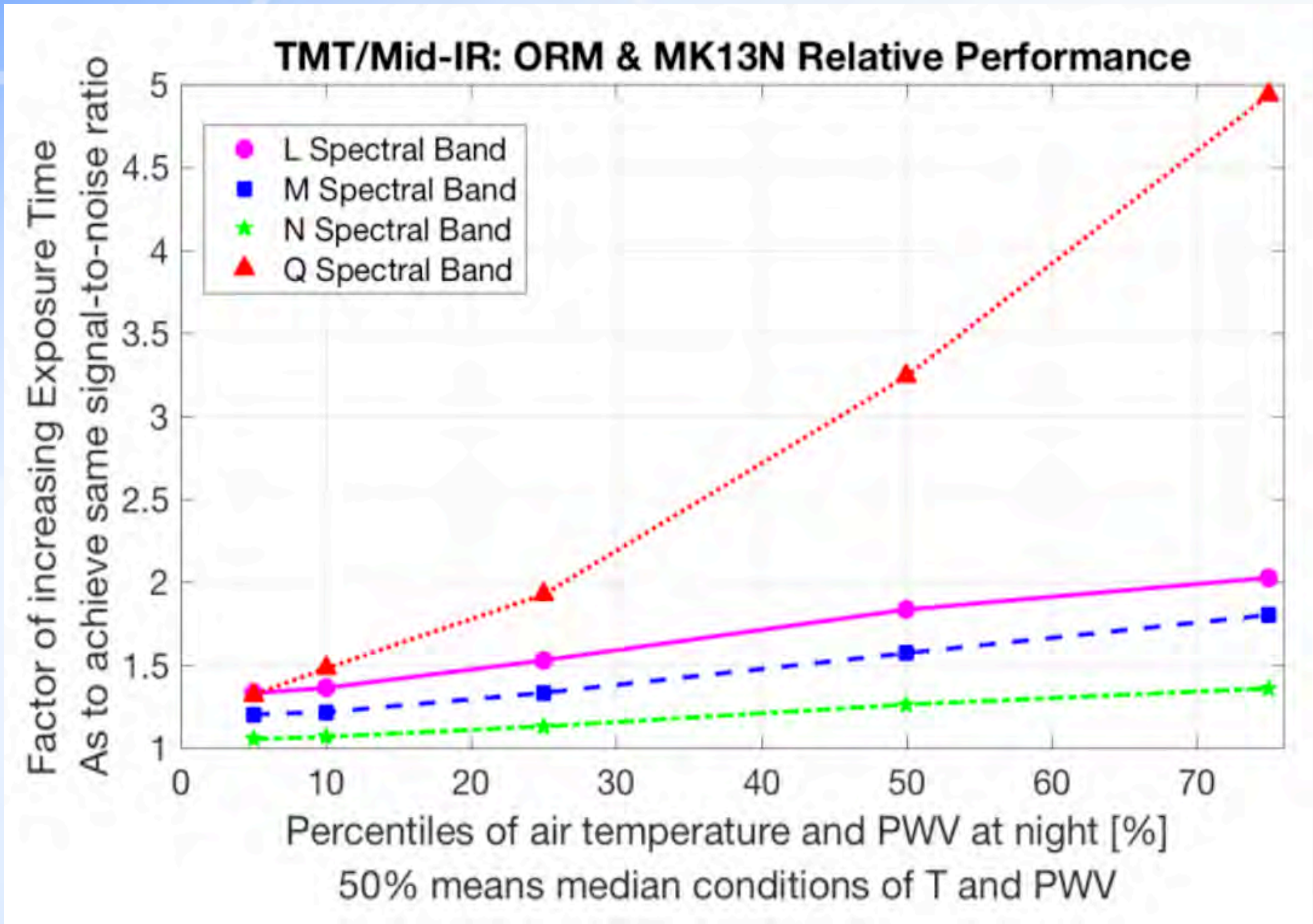
Very dry conditions with PWV < 2 mm exist at all times of year. Adaptive scheduling can make use of these. 10% of observations expected to be at Mid IR wavelengths.

Mid Infrared: Relative Exposure Times



This includes the effects of AO performance (Strehl), atmospheric extinction and background, and telescope background

Flexible queue scheduling of observations allows best use of dry conditions

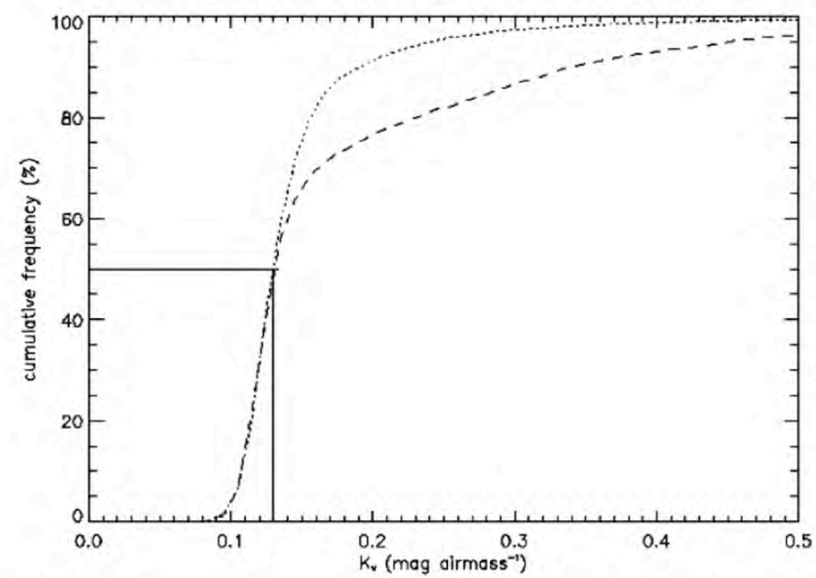
Dust and Atmospheric Extinction

- Dust events ("calima") typically occur for a few days in the summer
- Events with high optical extinction or high dust concentration at ground level are taken into account in the fraction of available nights
  - Just as tropical cyclones and thick cirrus are taken into account for Maunakea
  - Usable time is 72% at both sites
- Extinction measurements (K_V) by the ATC telescope cover 3 decades: 1984 to 2013

MK K_V extinction 0.11-0.12 (median)

	summer	non-summer	all data
Median	0.131	0.129	0.130
Std. dev	0.119	0.061	0.092

Table 11: Summary of K_V statistics in mag airmass^{-1} from a 20 yrs database of atmospheric extinction coefficient at the ORM (García-Gil et al., 2010)



(b) Seasonal statistics. Summer (dashed) are June to September and *non-summer* (dotted) is the rest of the year.

Summary of Main Site Characteristics

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THANK YOU!!!

Time for Questions!

Acknowledgments

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