天体計測学特論 I
Observational Astronomy I

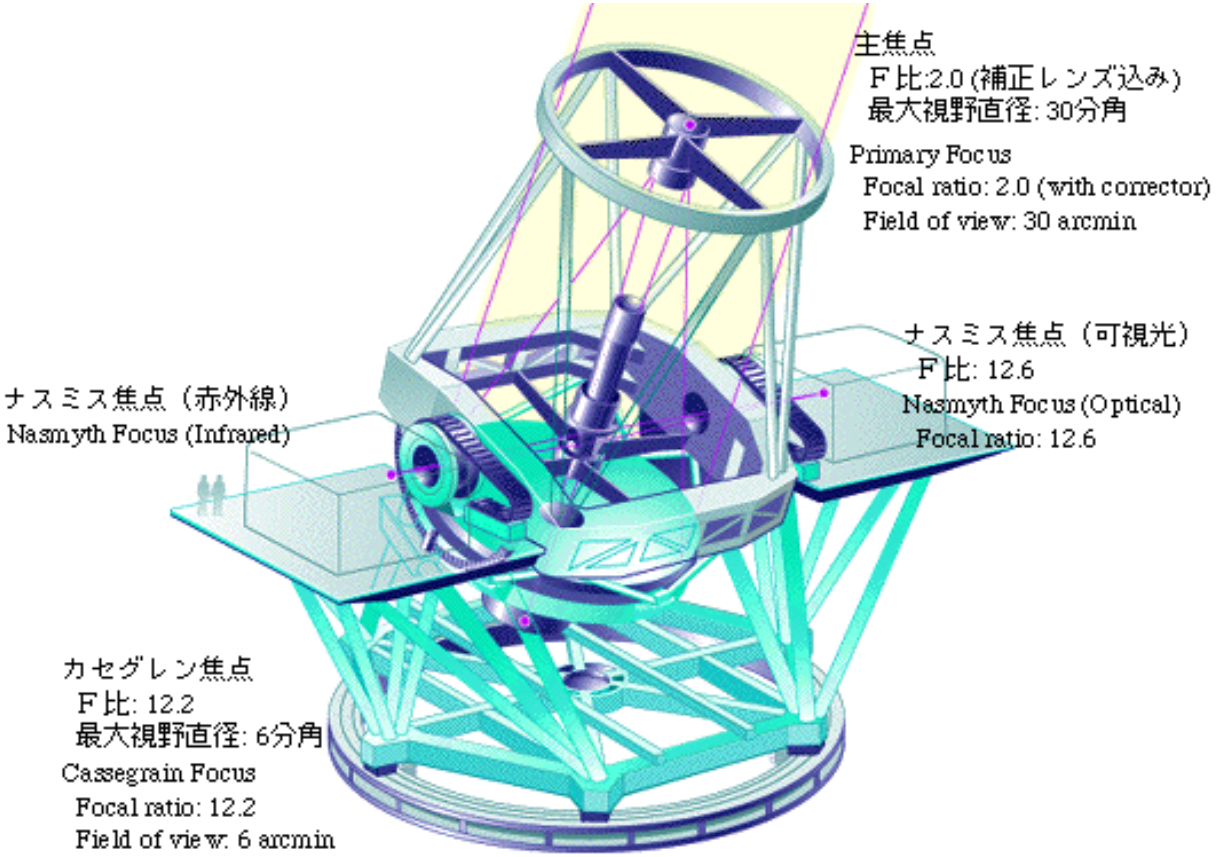
Lecture 01:
Introduction to ground-based visible/near-infrared astronomical observation

Report

- Pick-up one scientific topic you are interested in, then design an “instrument” to address the problem.
- Describe required wavelength coverage, spatial resolution, spectral resolution, required SN, etc.
  - You may need d=100m telescope.
  - You may need t=100hours of integration.
  - You may need multiplicity of >10,000 objects.
  - You need to go to space !
- Consider optical and/or IR wavelength observations.

- Goal:
  - AA : A and instrument design well considered
  - A : B and instrument specification well considered
  - B : scientific program well designed
  - C : scientific program acceptable

Subaru telescope and its foci



遠藤孝悦・画　日経サイエンス 1996年2月号より
Illustration by Takaetsu Endo, taken from Nikkei Science 1996

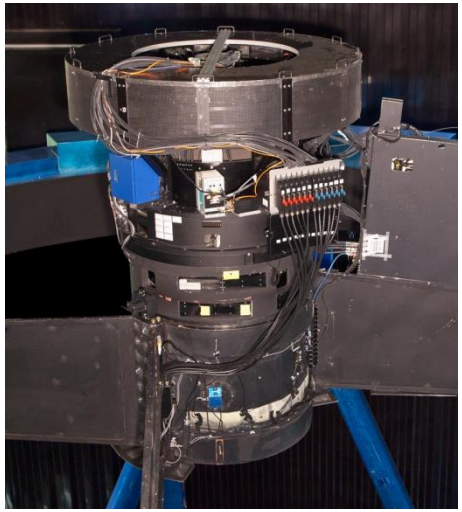
From www.naoj.org

Subaru: Prime focus instruments

- Hyper Suprime-Cam : Wide-field visible imager

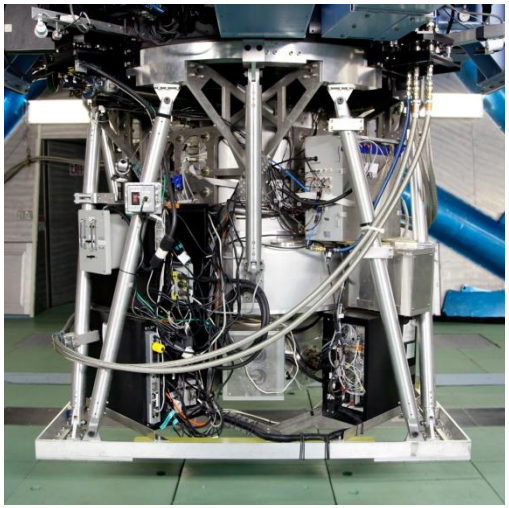
Not available

- Suprime-Cam : Wide-field visible imager
- FMOS : Near-infrared multi-fiber spectrograph

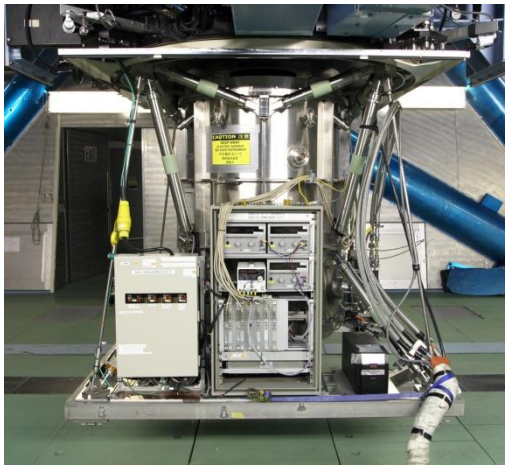


Subaru: Cassegrain focus instruments

- FOCAS : Visible multi-slit spectrograph
- MOIRCS : near-infrared multi-slit spectrograph



- COMICS: mid-infrared imaging/spectrograph

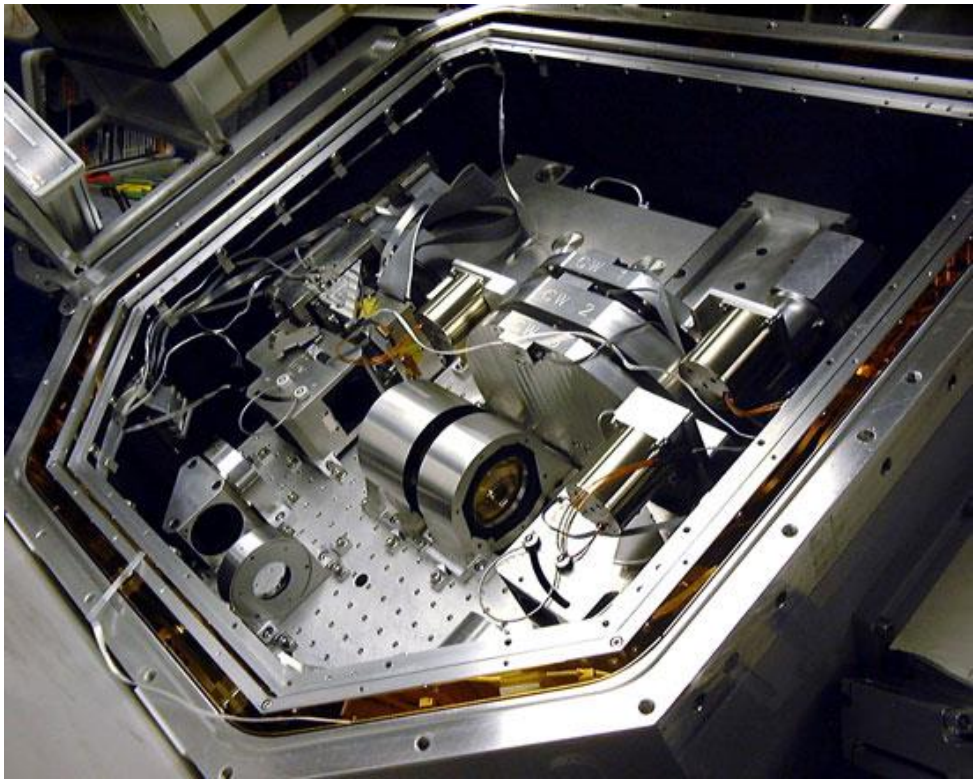


Subaru: Opt.-Nasmyth focus instruments

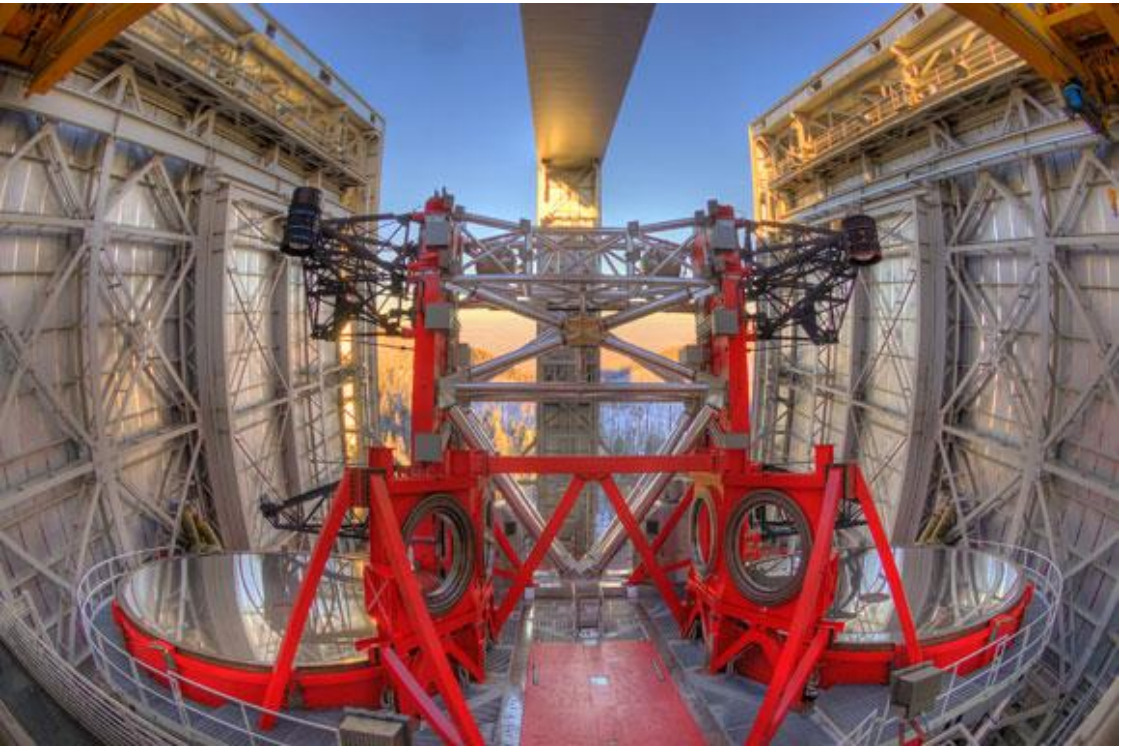
- HDS : high-dispersion visible spectograph

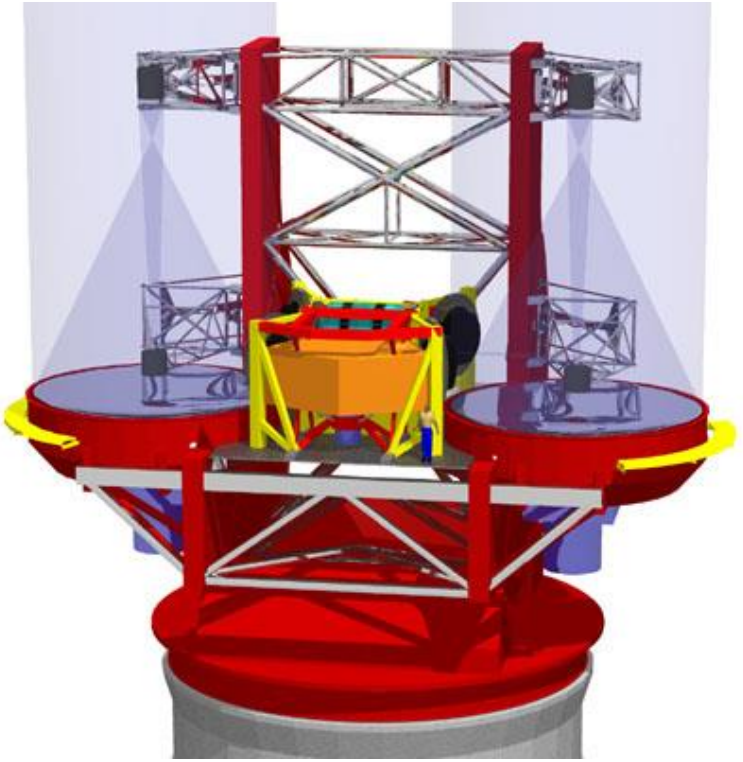
Subaru: infra-red-Nasmyth focus instruments

- IRCS : near/mid-infrared camera and spectrograph



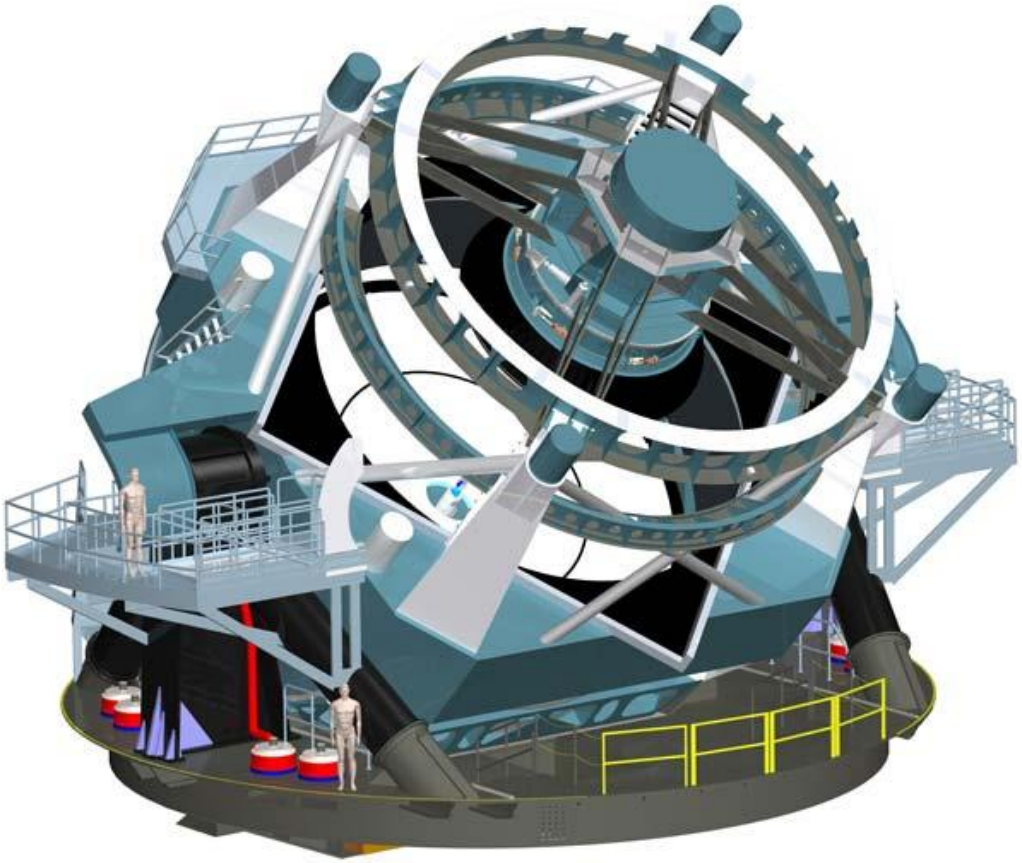
Large Binocular telescope telescope optical design

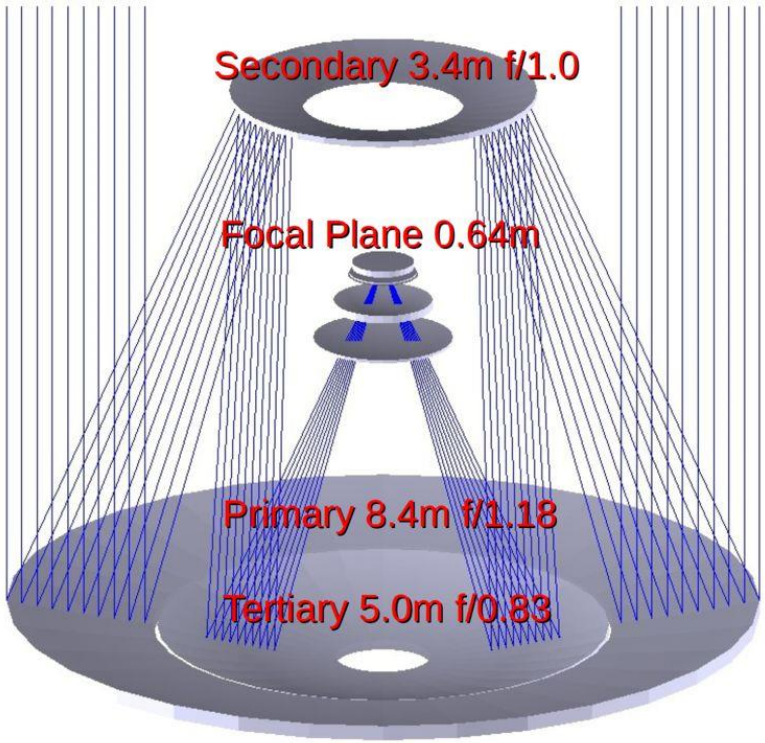




From www.astro.uni-koeln.de

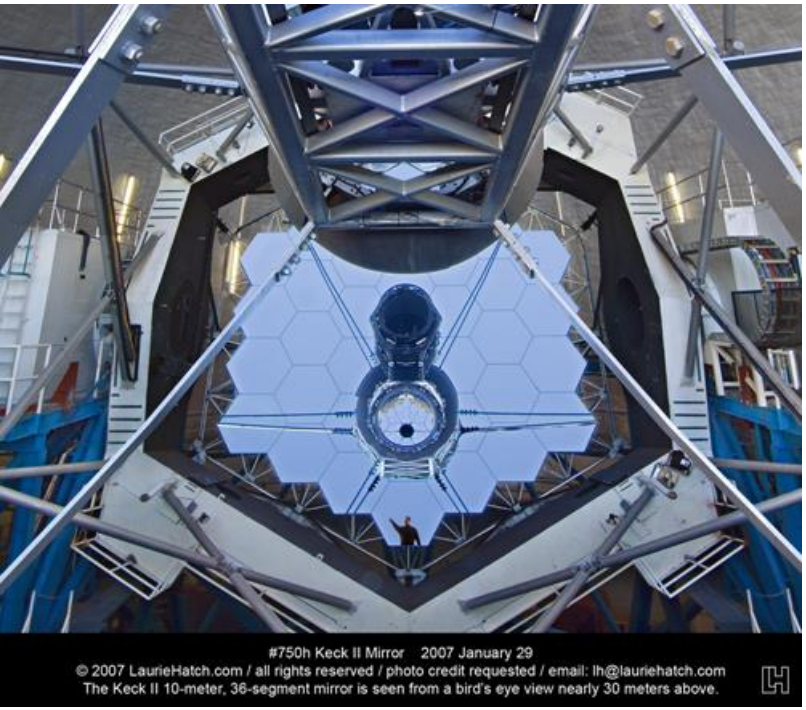
Large Synoptic Survey Telescope
telescope optical design





From ast.noao.edu

Larger telescopes with segmented mirrors



Keck telescope

Thirty Meter Telescope

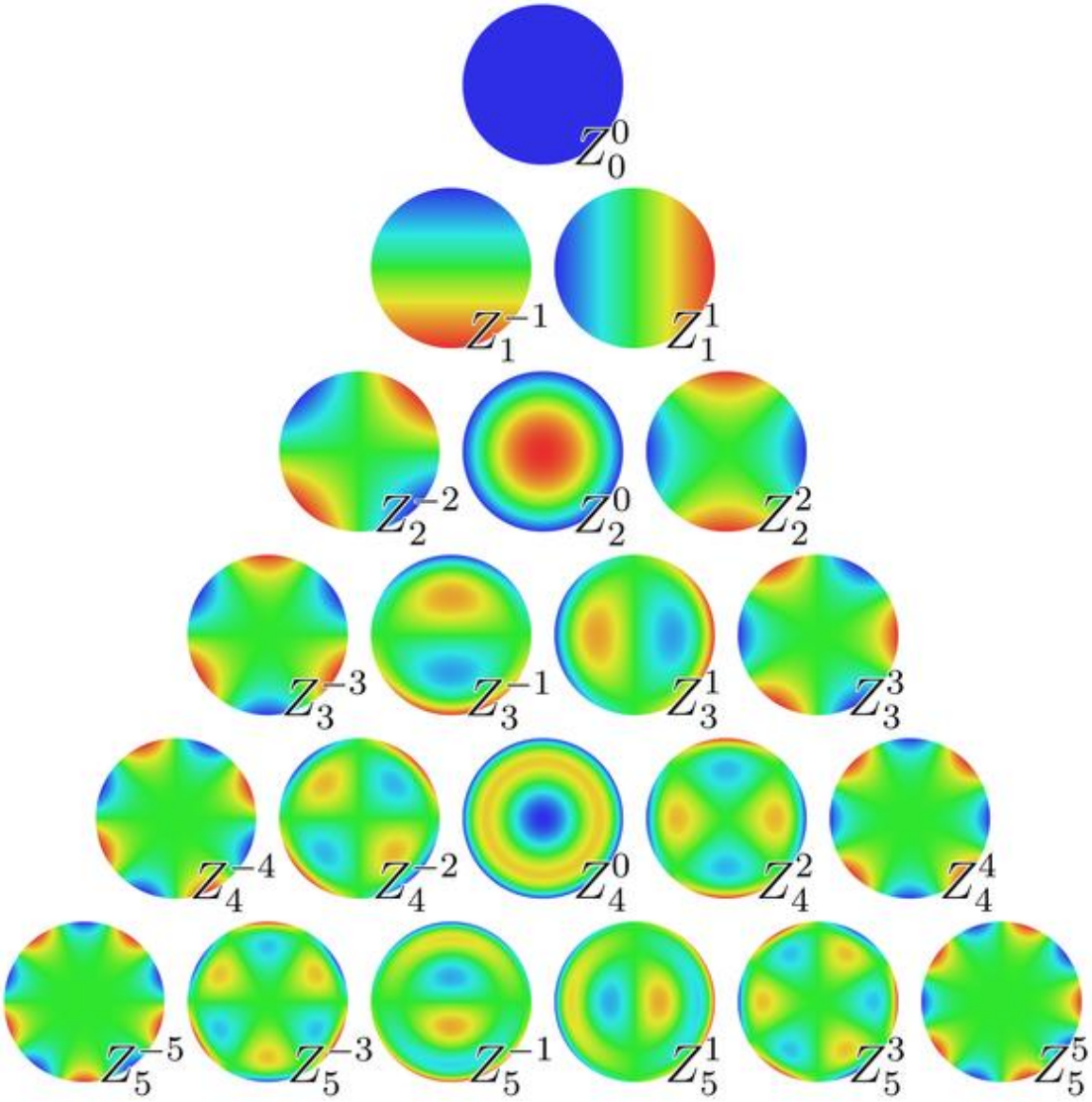
Optical systems for (visible/near-infrared) observations

- Telescope / camera / spectrograph
- Imaging / spectroscopy / polarimetry
- Geometric optics (light rays, no diffraction)
- Aberrations in the optical systems

Basic properties of electromagnetic wave / Introduction to Fourier optics

- Discussion on electromagnetic wave propagation and diffraction theory
- Understand the optical aberration with shape of wavefronts based on Fourier optics

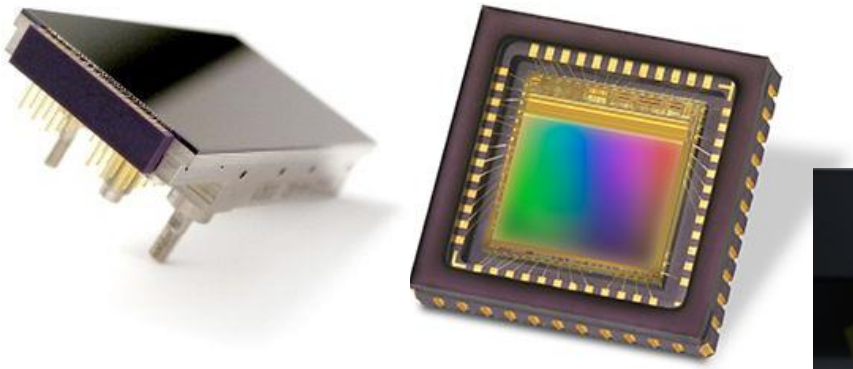
Optical systems and aberrations

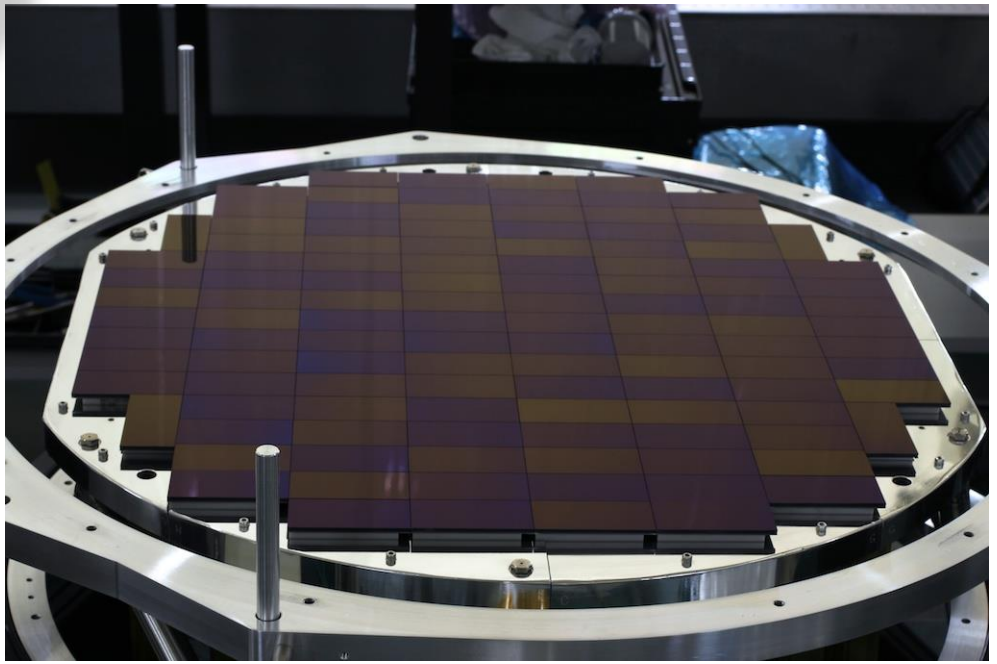


From en.wikipedia.org

Detectors in visible wavelength

- CCD vs. CMOS sensors : Silicon



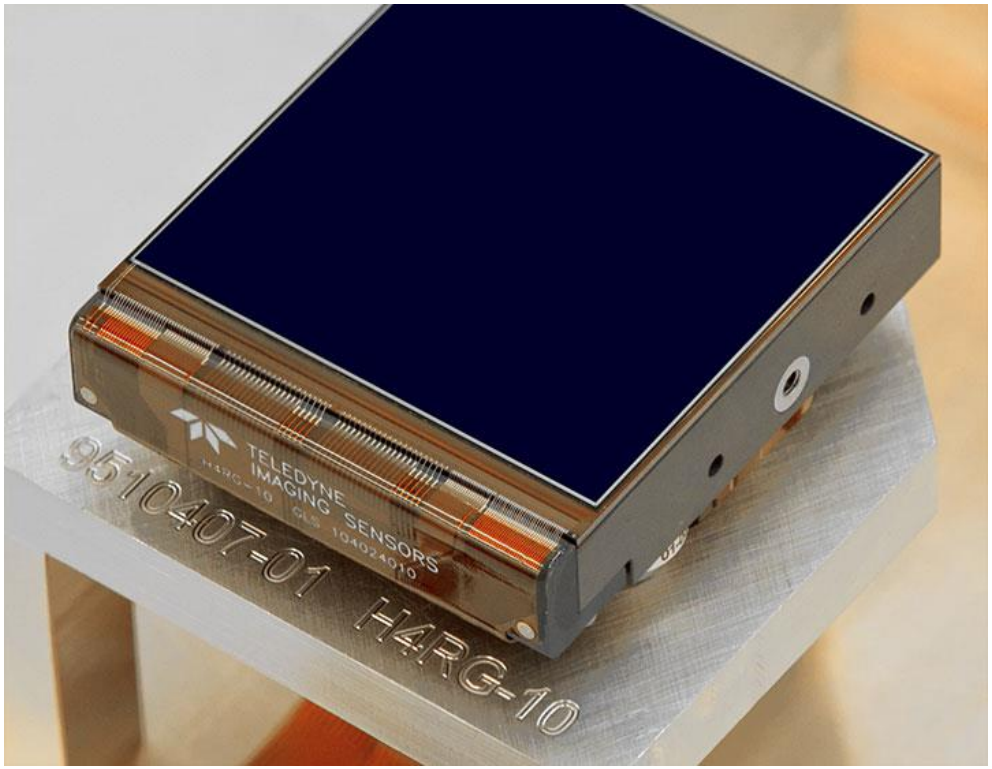


From www.naoj.org

- Noise properties

Detectors in near-infrared wavelength

- HgCdTe array (Hawaii 4RG)



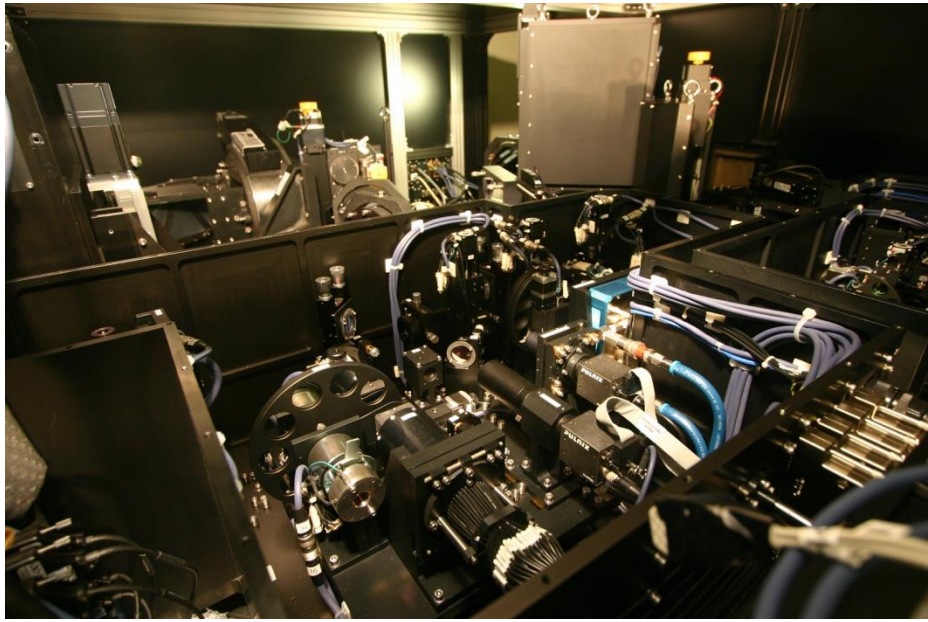
- Noise properties

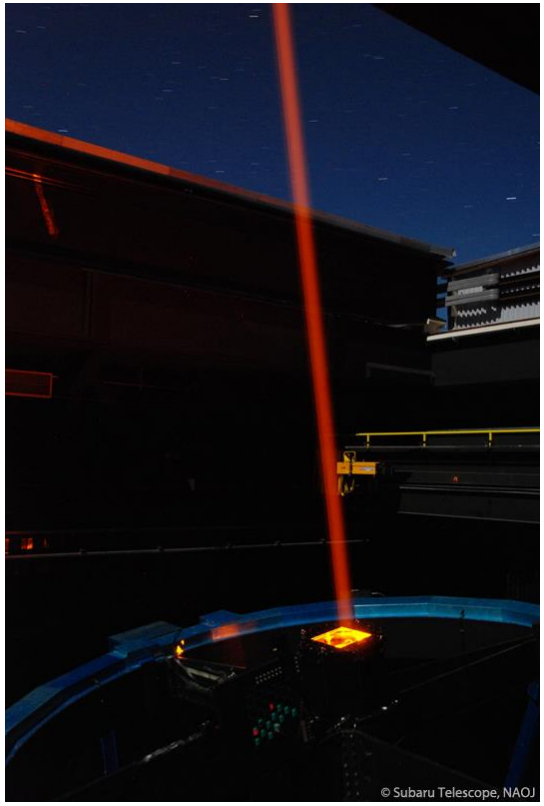
Designing systems for imaging/spectroscopic observations

- Components / optical elements
- Optical design
- Noise statistics
- Limits of the imaging / spectroscopic observations

Advanced technology for optical/IR observations

- Wavefront sensing
- Wavefront correction



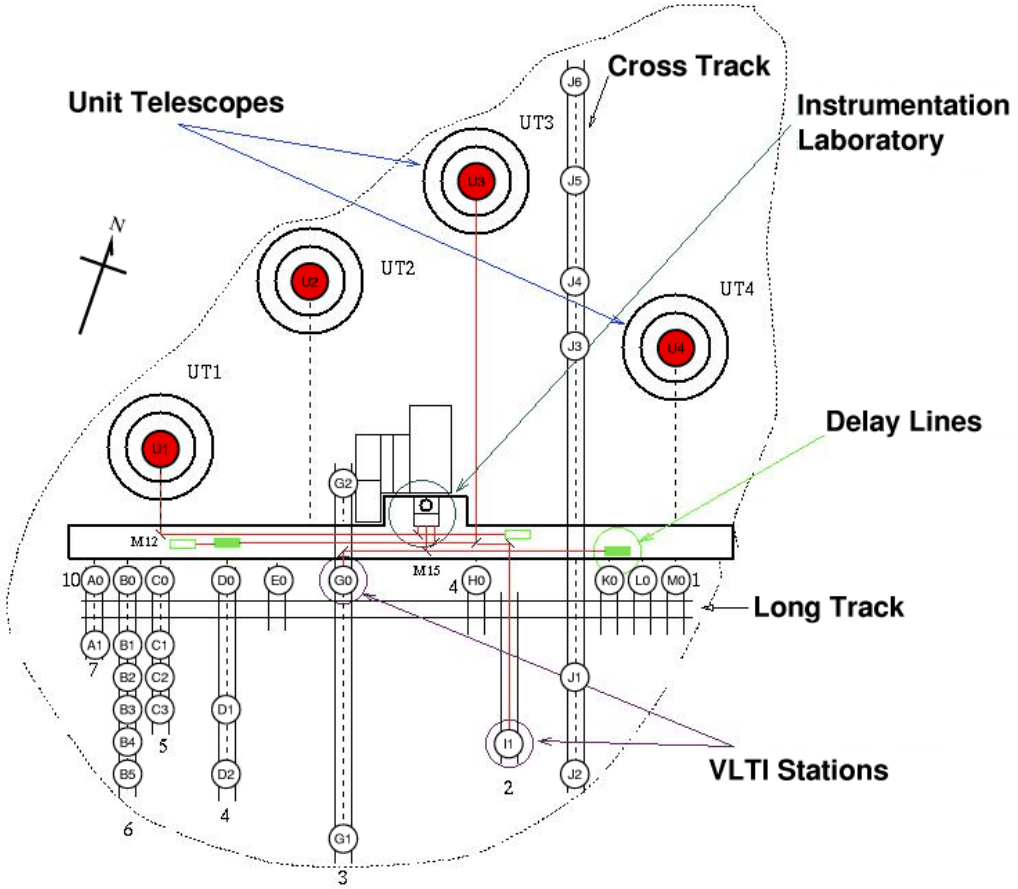


Advanced technology for optical/IR observations

The Very Large Telescope (VLT) interferometer

The VLT Array on the Paranal Mountain

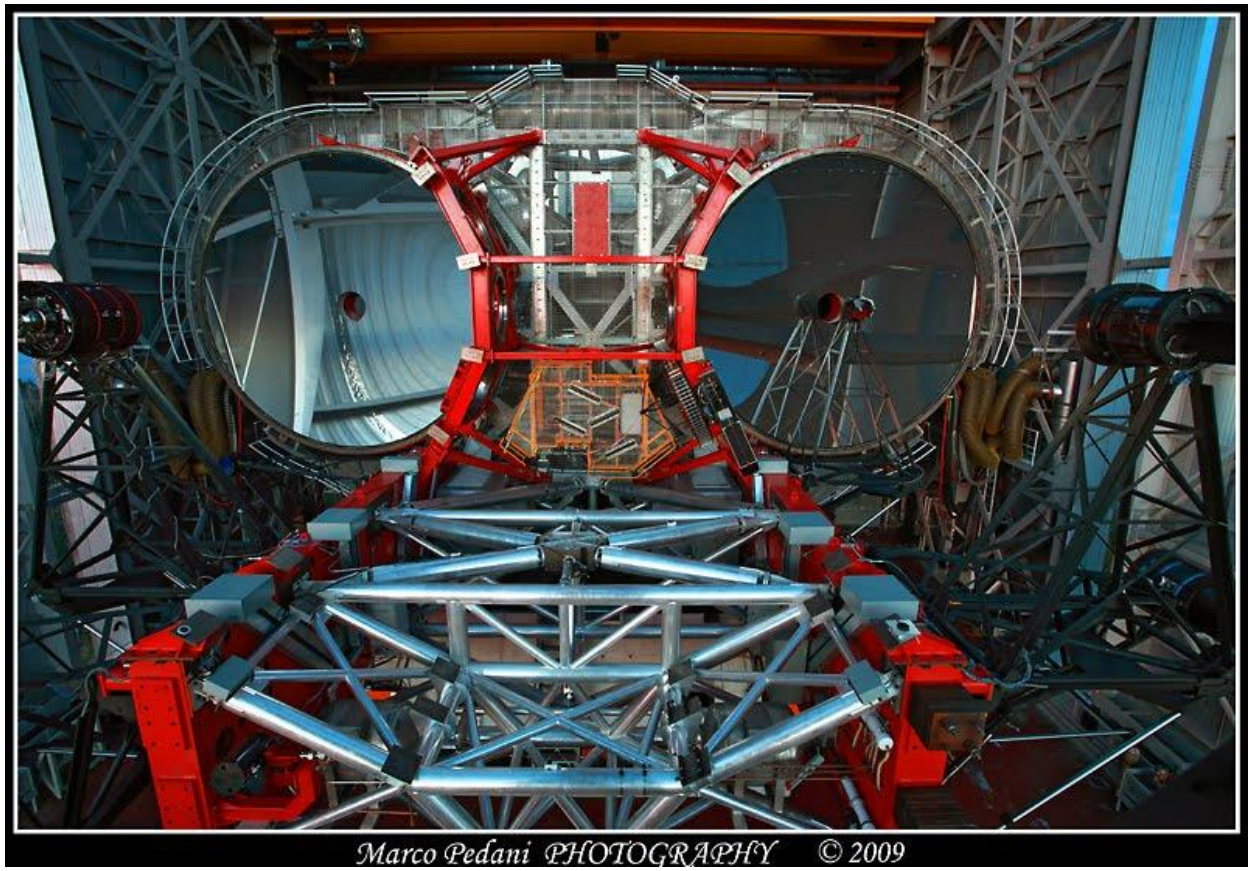
ESO PR Photo 14a/00 (24 May 2000) ©European Southern Observatory

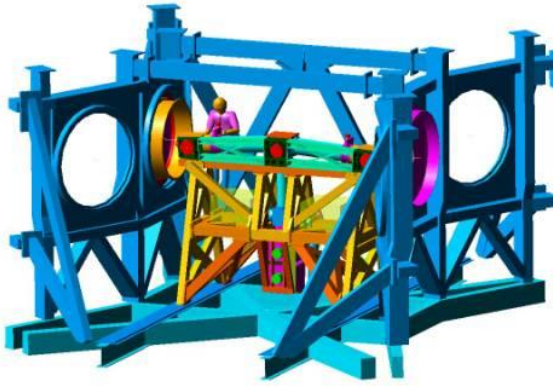


ESO website

Interferometer

The Large Binocular Telescope



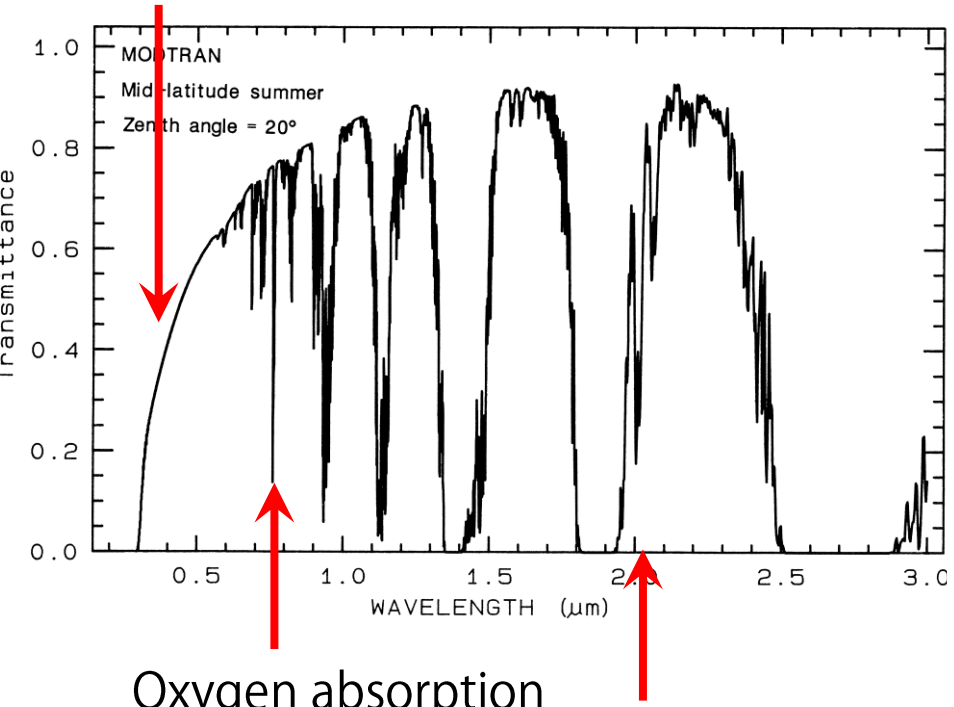


LBT website

Atmospheric Transmission in visible/near-infrared

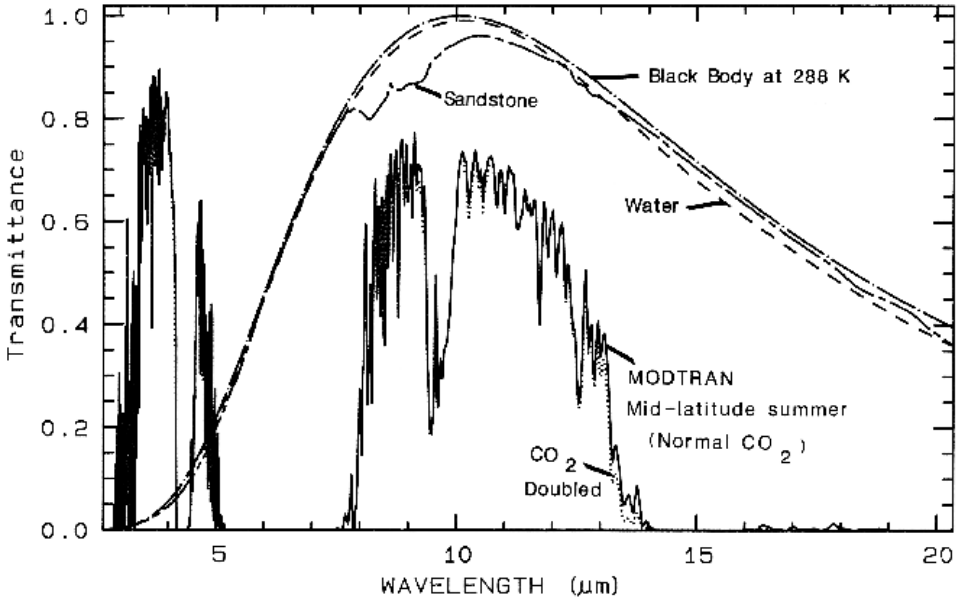
- Absorption by water +

Scattering + Ozone absorption



Oxygen absorption

Absorption by CO2



From speclab.cr.usgs.gov

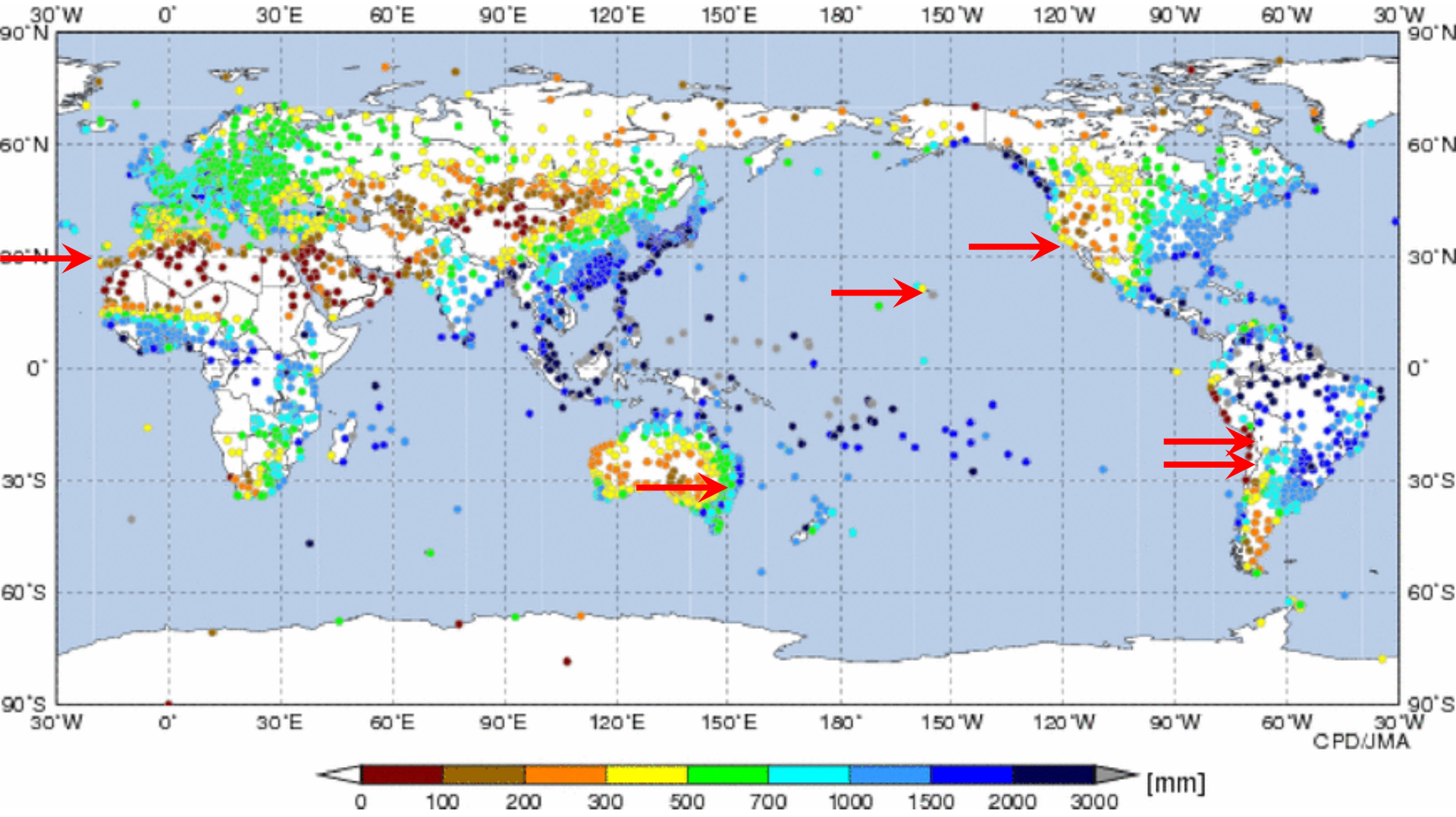
Telescopes on Maunakea

Subaru telescope and other telescopes on Maunakea (from www.naoj.org)

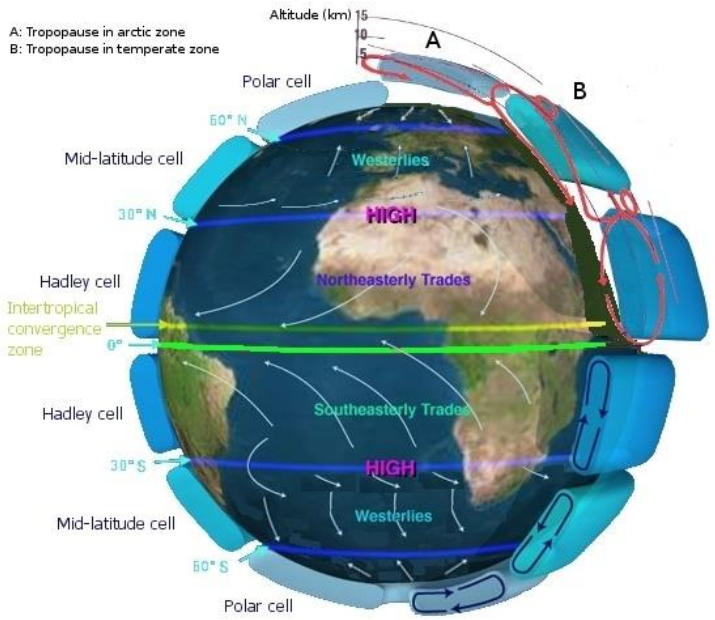
Telescopes on Paranal

Very Large Telescope on Paranal (from www.eso.org)

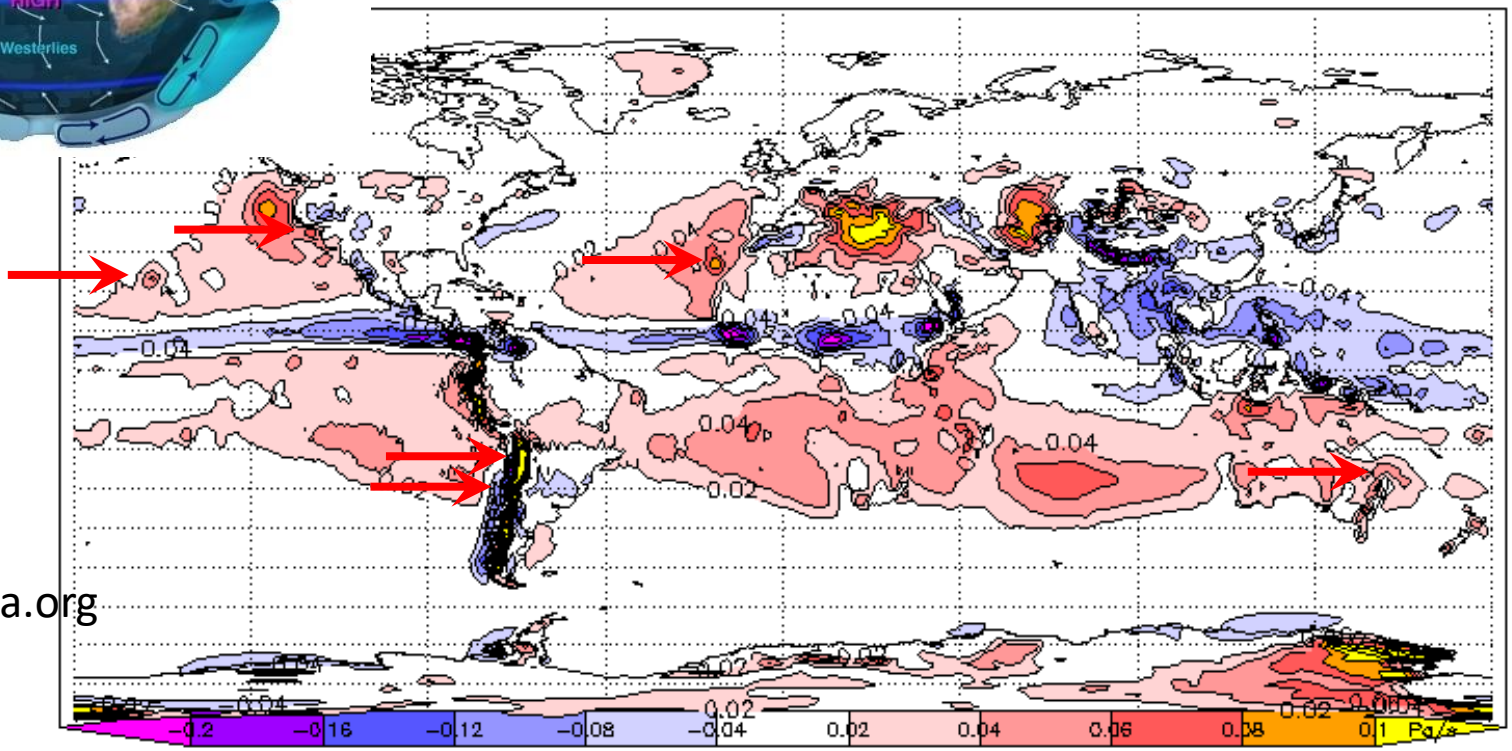
Precipitation per year
(from Japan Meteorological Agency)



Earth global circulation and good astronomical site



Vertical wind velocity at 500hPa



From en.wikipedia.org

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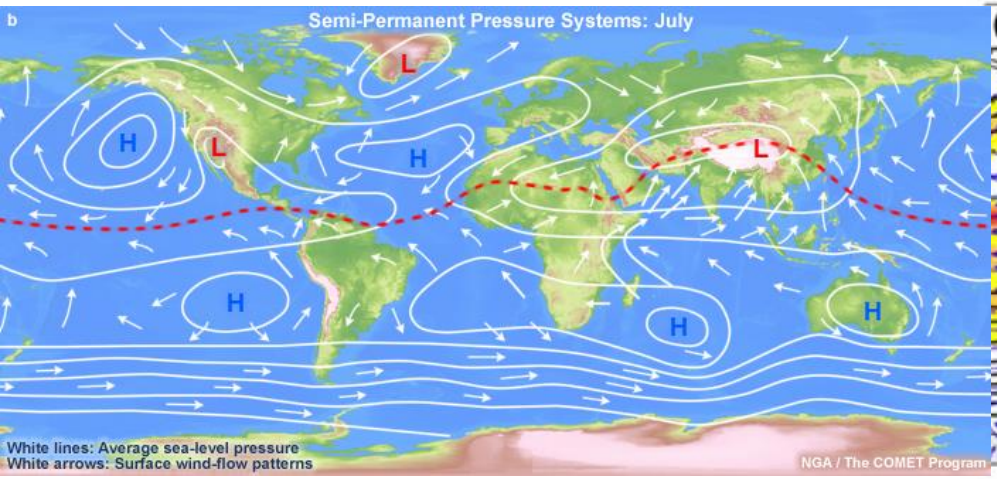
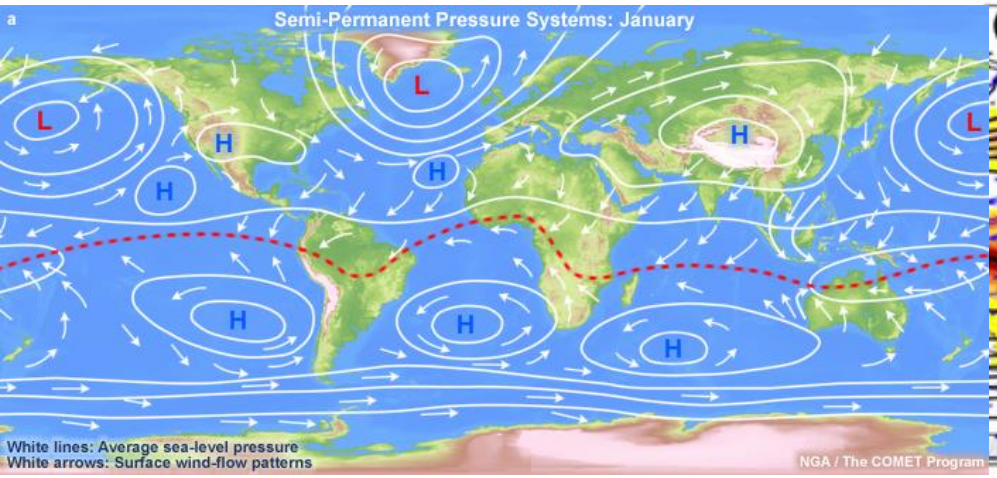
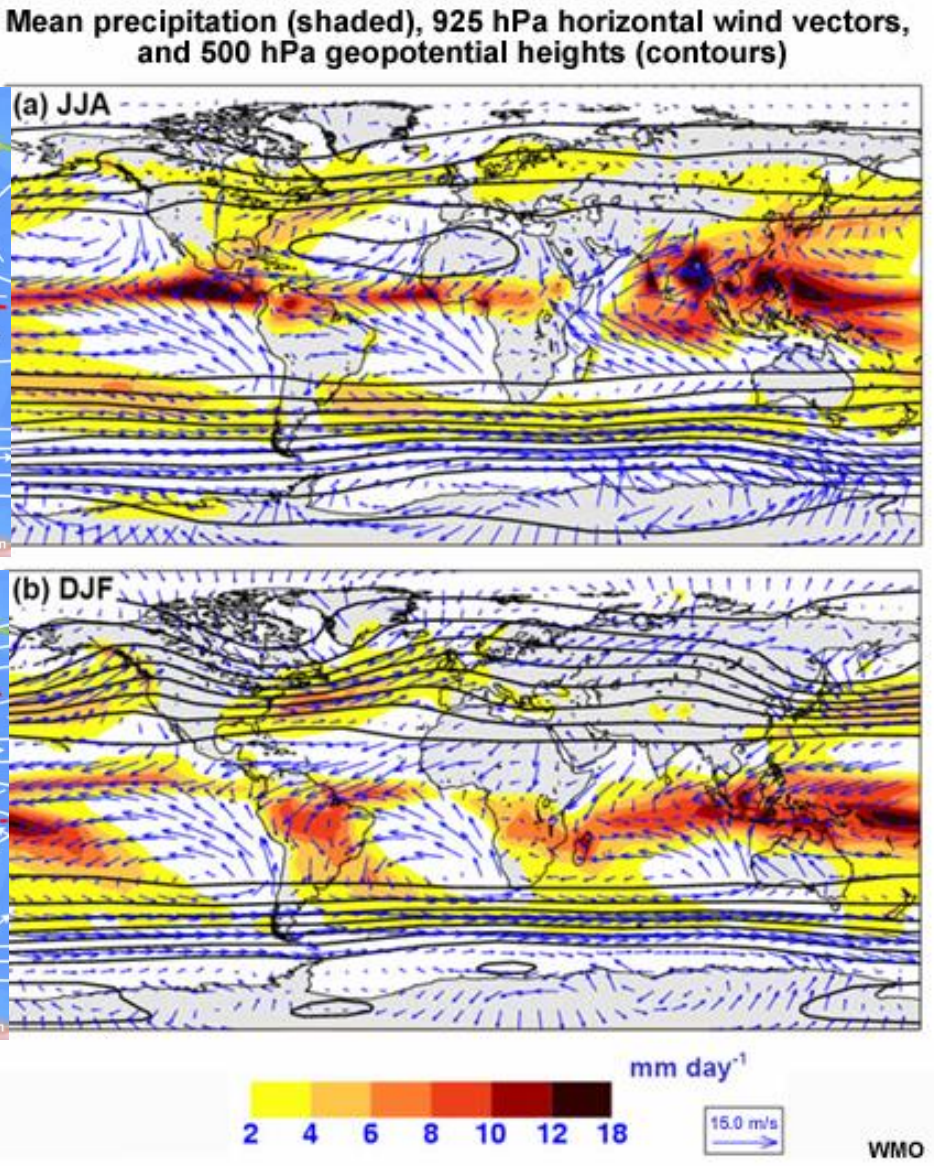
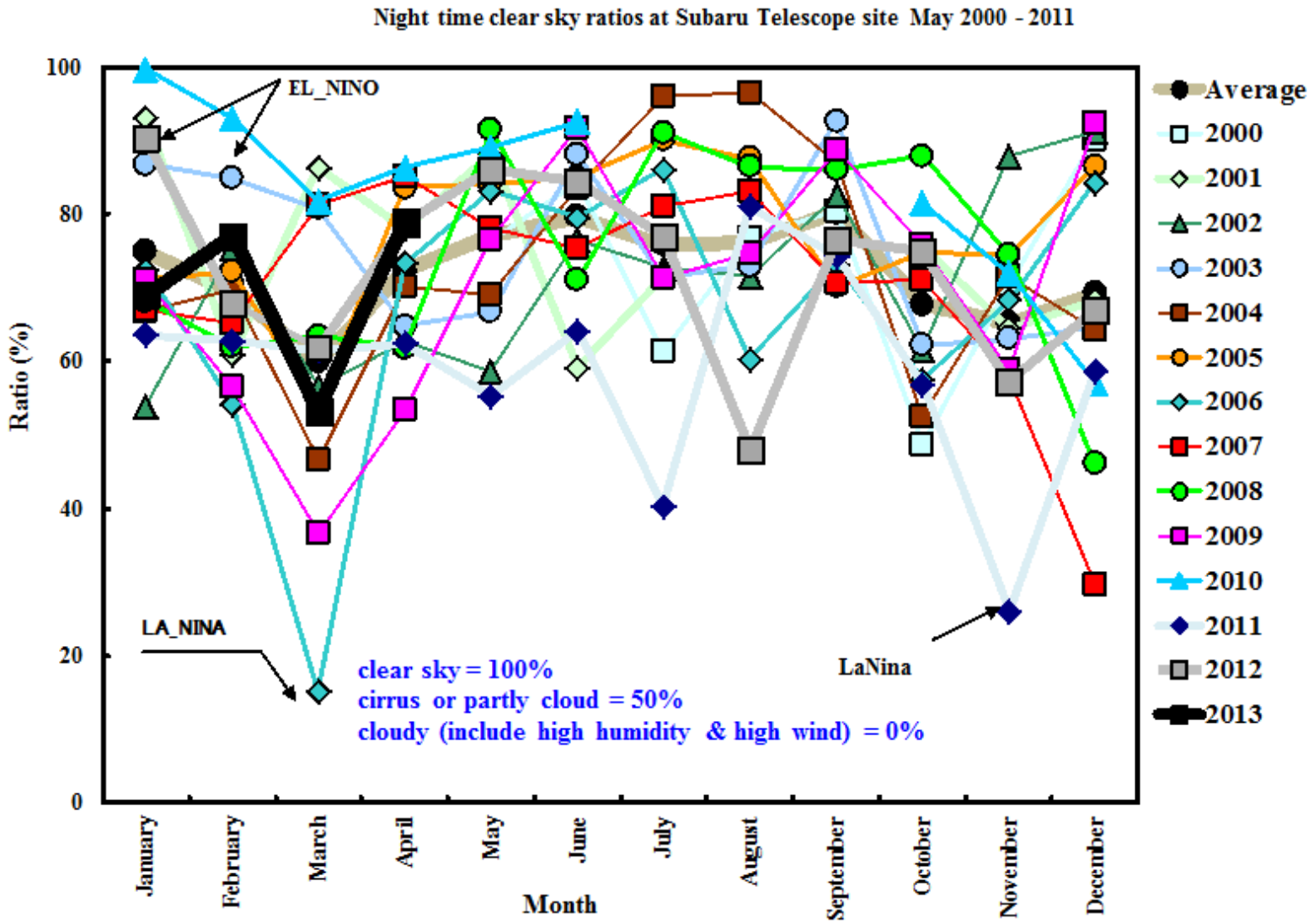






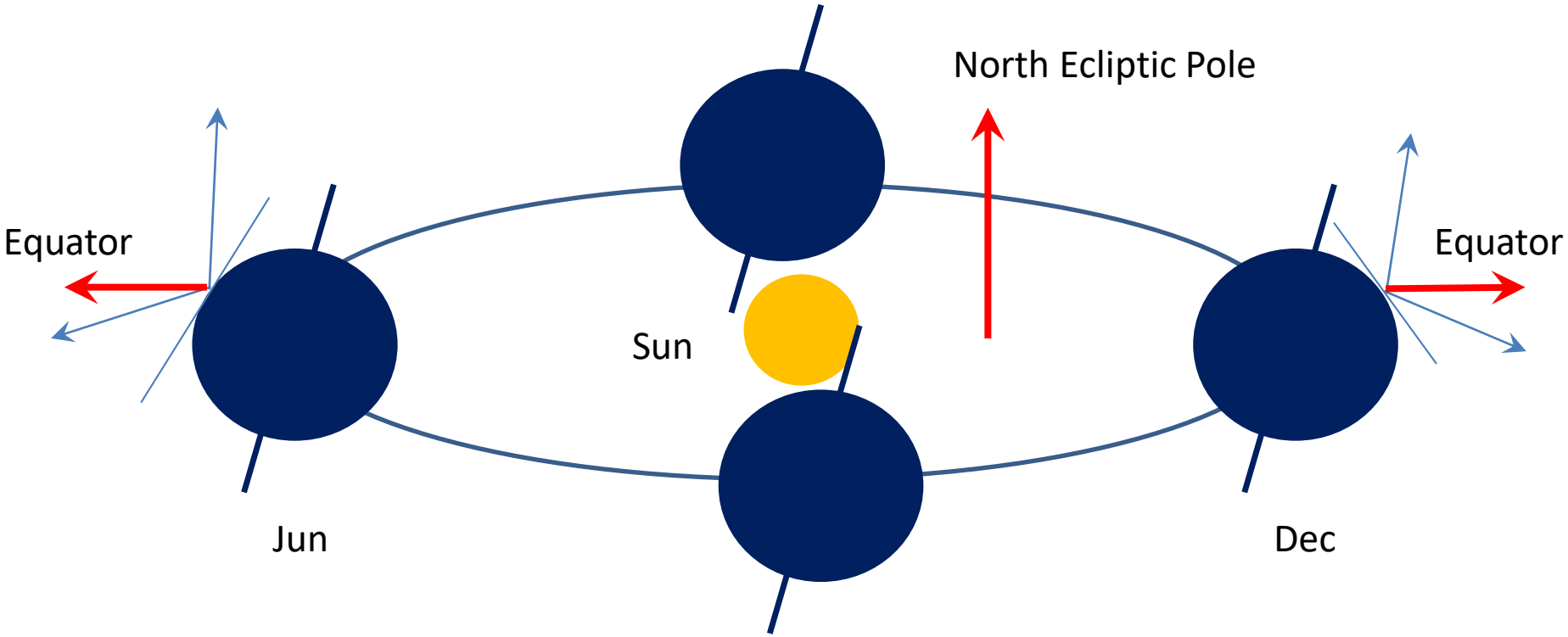
From www.goes-r.gov

Maunakea site statistics : clear sky ratio



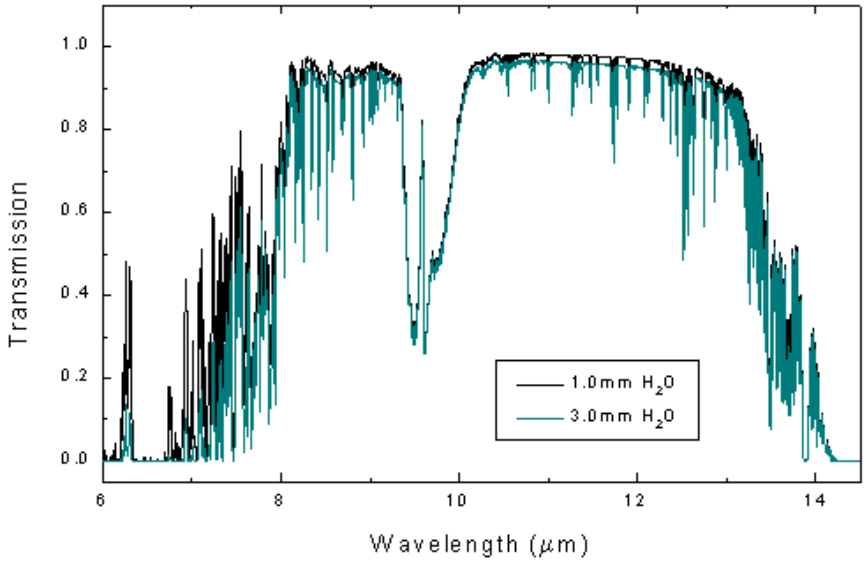
From www.naoj.org

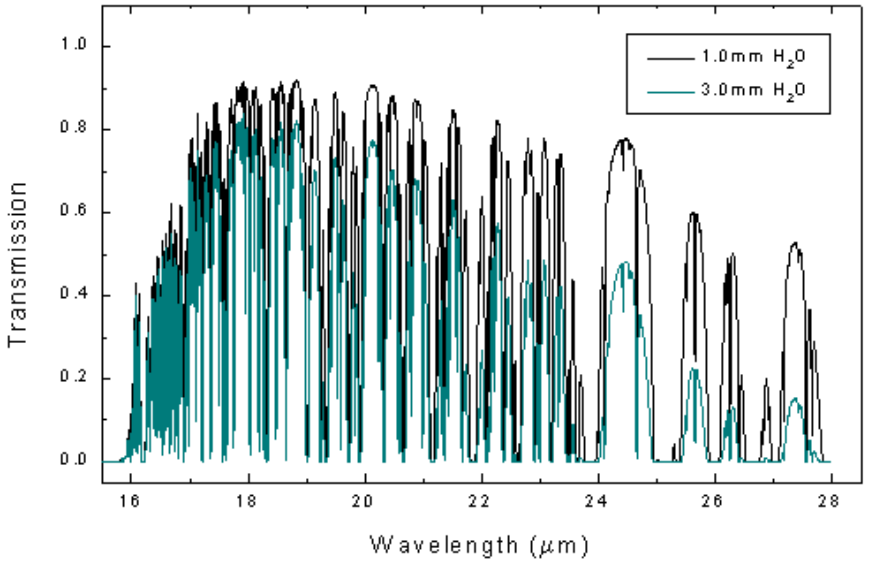
Visibility



Atmospheric Transmission

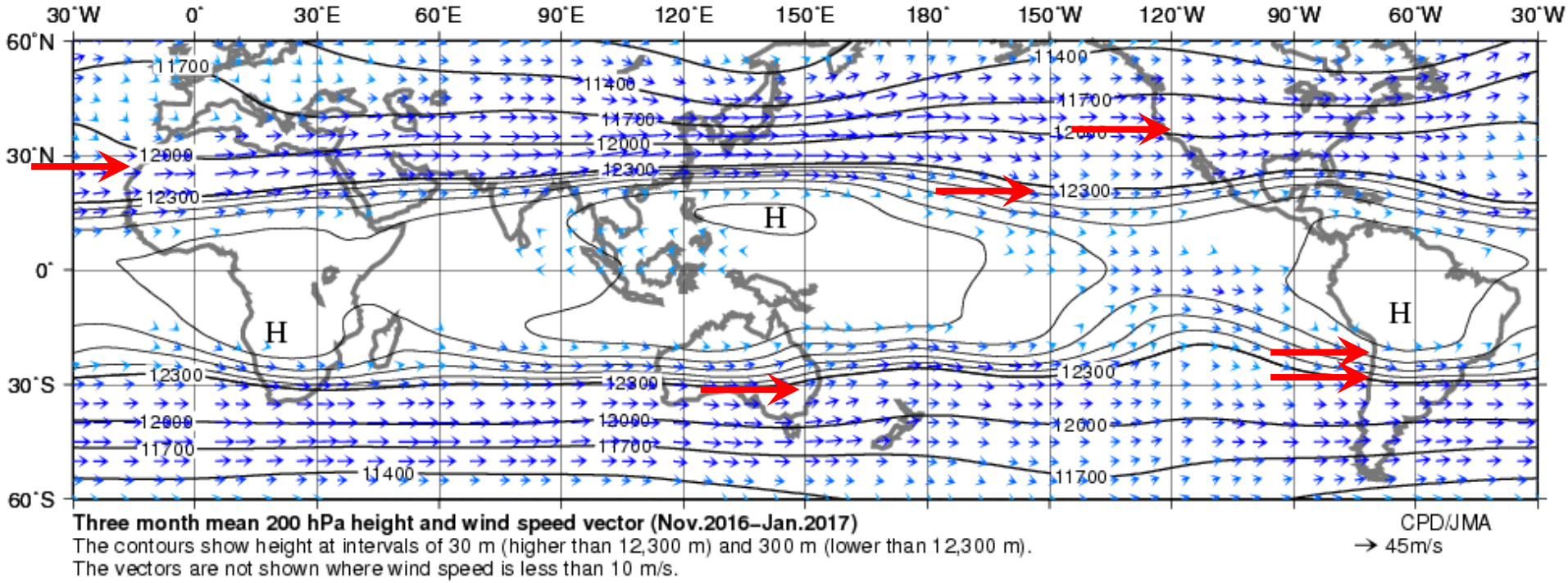
- If we go “dry” site = (low water vapor)
- Go higher (Maunakea, Atacama), or more freezing (Antarctica)



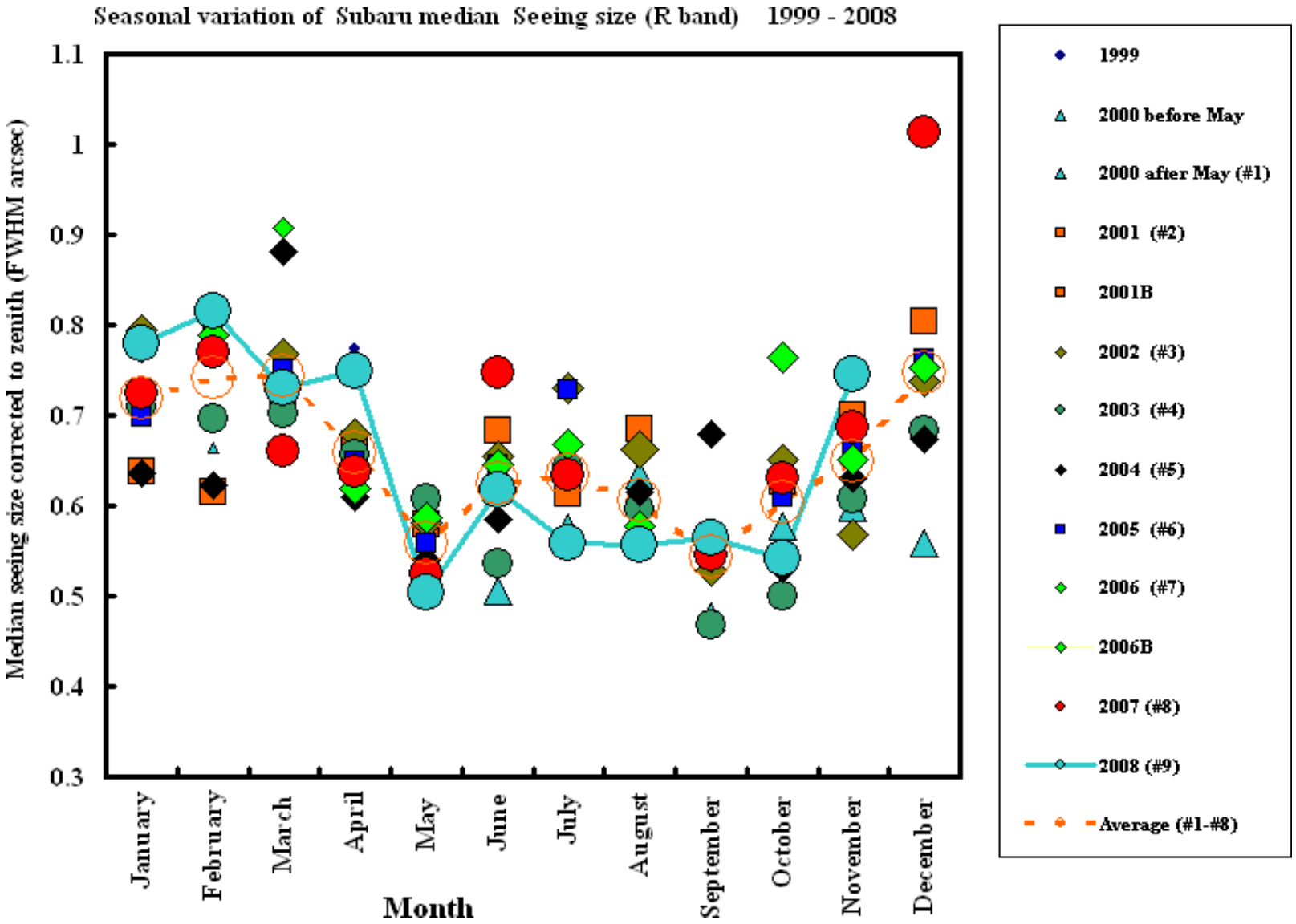


From www.gemini.edu

Wind velocity at 200hPa (h=13,000m) : jet stream (from Japan Meteorological Agency)



Maunakea site statistics : seeing



From www.naoj.org

Vertical structure of the atmosphere

Exosphere

Thermosphere

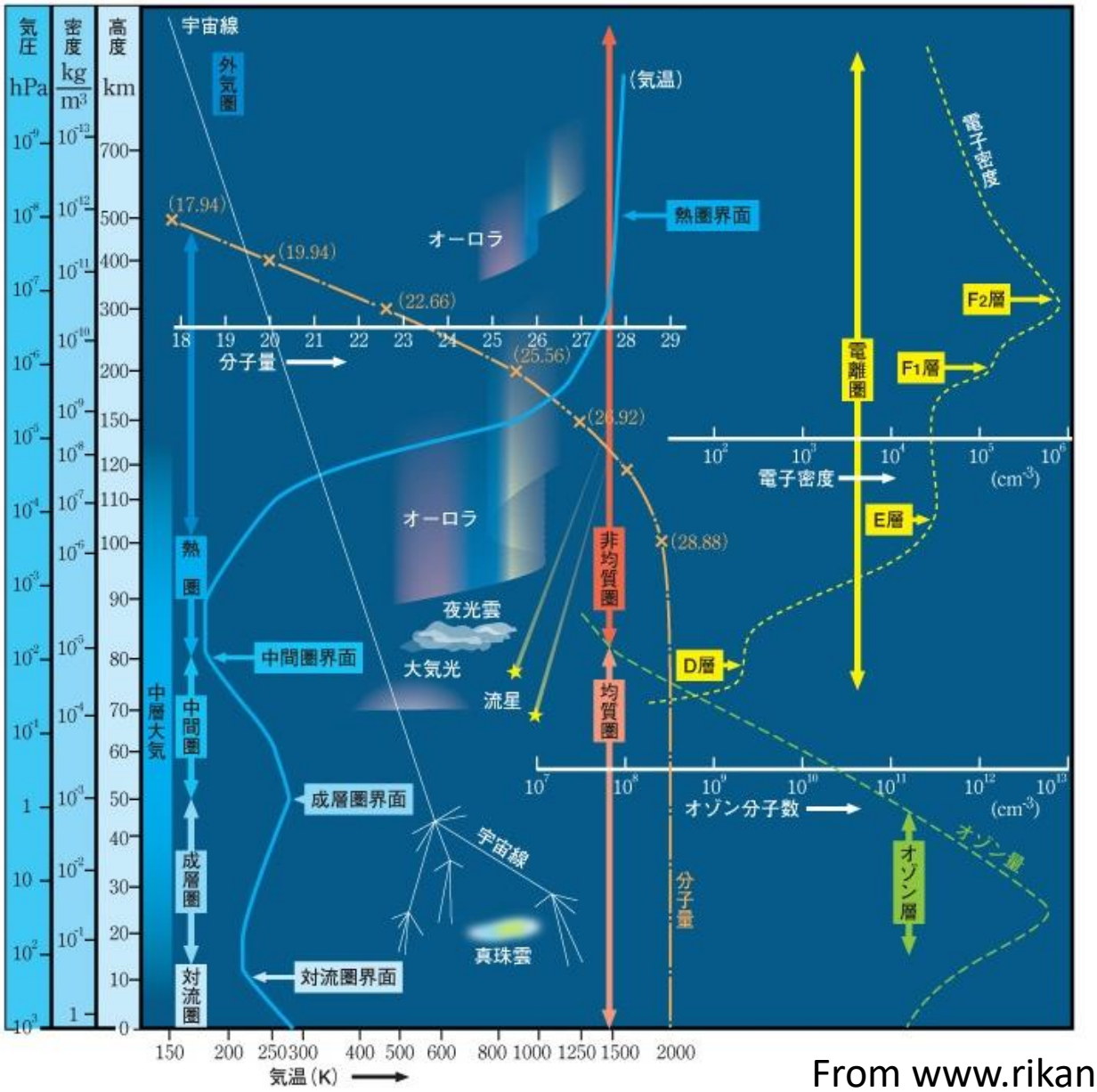
Mesosphere

Stratopause

Stratosphere

Tropopause

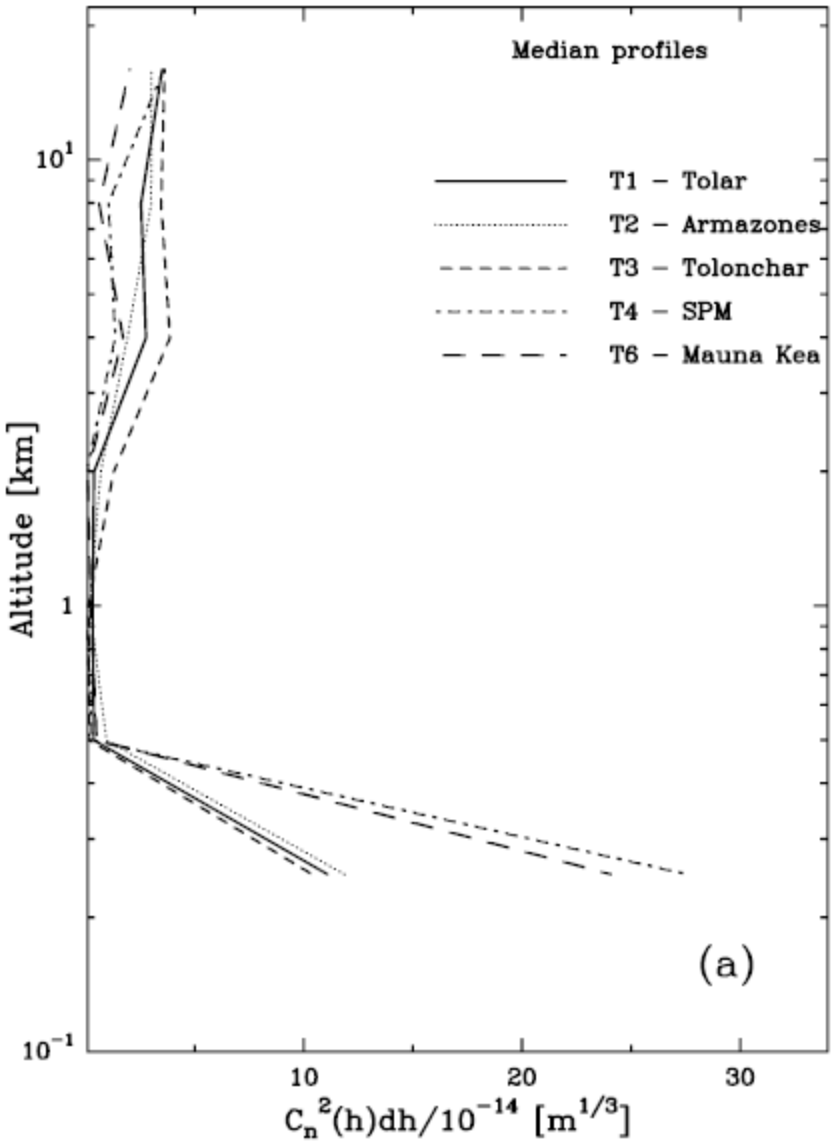
Troposphere



From www.rikanenpyo.jp

Site statistics : turbulence profile

250hPa



Els et al. 2009, PASP, 121, 527

Site statistics : turbulence profile

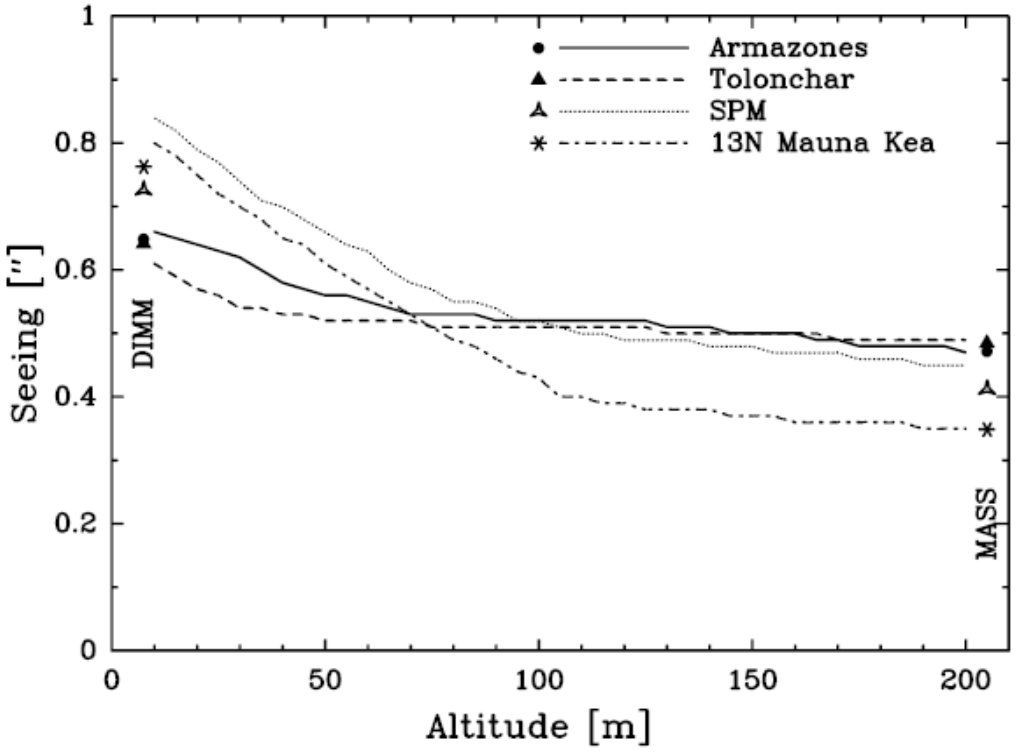


FIG. 3.—High-resolution turbulence profiles measured by the SODAR. The markers indicate the MASS and DIMM seeing measured simultaneously with the SODAR above the respective sites. The lines show how the seeing measured by the SODARs accumulates onto the MASS seeing, thus providing the seeing an observer would see at the corresponding altitude. Note that these data are nonrepresentative for the sites.

Els et al. 2009, PASP, 121, 527