ALMA

The Atacama Large Millimeter Array

ALMA at Chajnantor
(Courtesy NAOJ)

ESO PR Photo 14/01 (6 April 2001)

ALMA site

5 km altitude at the foot of the high Andes

ALMA telescopes (EU)

ALMA telescopes (US)

ALMA specifications

- 64 antennas, at 5km height
- 12m diameter, ±20 μm, 0.6” in 9m/s wind
- arrays of 150m to 12km
- 10 bands in 31-950 GHz + 183 GHz WVR. Initially:
    - 86-119 GHz
    - 211-275 GHz
    - 275-370 GHz
    - 602-720 GHz
- 8 GHz $\Delta\nu$, dual polarisation, 4096 channels/IF

  (Note: varying numbers mentioned throughout project)

- 650 M€

ALMA specifications

- all bands online
- any 1 + 0.5 bands accessible
- filled (150m) to ring (12km) and log-spiral or ring
- data rate: 2M visibilities/s average (12M vis/s peak)

  (= 6Mb/s average; 60Mb/s must be sustainable)
- all data archived (raw + images)
- AC (Compact or Complementary)A (optional JP)
  - 6-10 antennas of 6-8m diameter in ring or hexagon for short spacings

ALMA specifications

- ESO (with 5% E) and US (with 5% CA)
- ESO/US each half of capital cost
- No exchange of funds
- Project split in Project Teams, with leader in both parties: one of them the overall PT leader
- JP will probably join (they hope in 2004): politically difficult. They will contribute
  - 4 12m telescopes
  - 7m telescopes for ACA (with infrastructure)
  - next generation correlator

Sensitivity goals

GHz	$\Delta S(\mu Jy)$	$\Delta S(mJy)@1km/s$
35	20	5.1
90*	27	4.4
140	39	5.1
230*	71	7.2
345*	120	10.0
650*	849	51.0
850	1260	66.0

At 50 deg elevation and best 25% weather for λ<1mm;
best 75% for λ>1mm

Other arrays

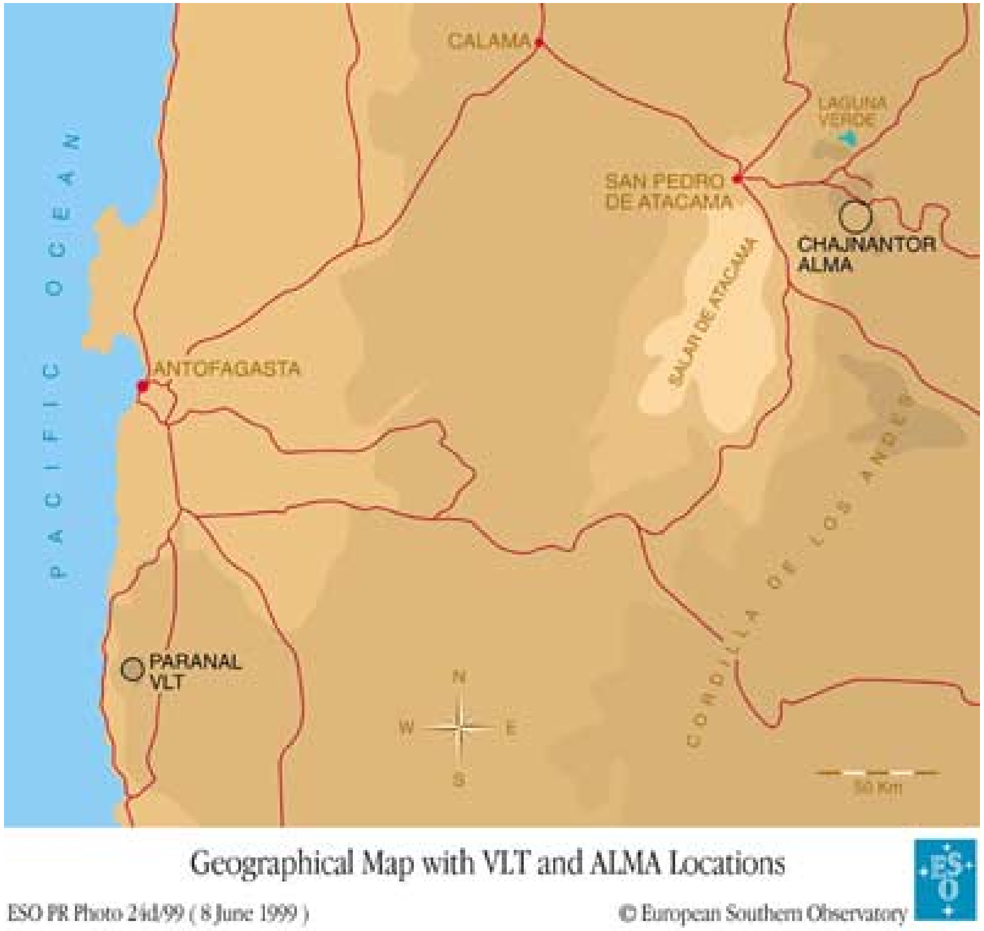
Comparison with other mm arrays

Array	Total Area (m^2)	Mosaic Speed (nD)	SSB Tsys @ 90 GHz	η_a	Freq. range (GHz)	Pol	BW (GHz)	Max. Bsln (km)	Line sens. (mJy)	Cont. sens. (mJy)
BIMA (10*6.1m)	290	61	150	0.7	70-115, 210-270	1	0.8	1.5	23	1.4
OVRO (6*10.4m)	510	62	250	0.7	86-116, 210-270	1	1.0	0.2-0.4	23	1.3
NMA (6*10m)	470	60	400	0.65	85-116, 126-152, 213-237	1	1.0	0.4	43	2.4
IRAM PdB (5[6]*15m)	880 [1060]	75 [90]	150	0.7	80-115, 210-250	1	0.5	0.4	8.2 [6.7]	0.63 [0.5]
ATCA (5*22m)	1900	110	250	0.4	85-110	2	0.2	3.0	7.9	1.0

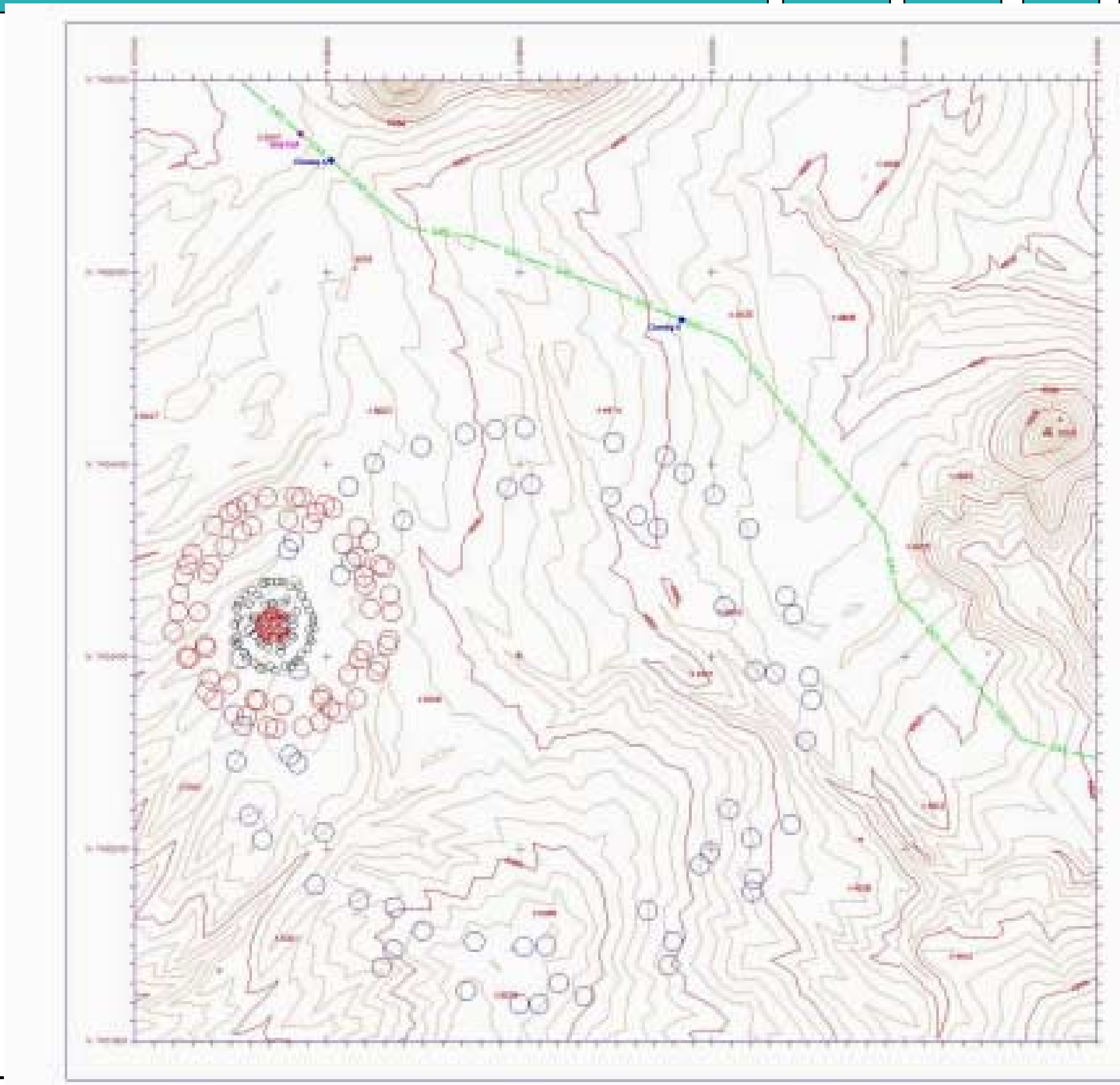
Sensitivity estimates are for 1 hr integration at 90 GHz, all pols. combined.
Line sensitivity is for a 10 km/s channel.
Actual sensitivity will depend on atmospheric phase.

(Courtesy Tony Wong)

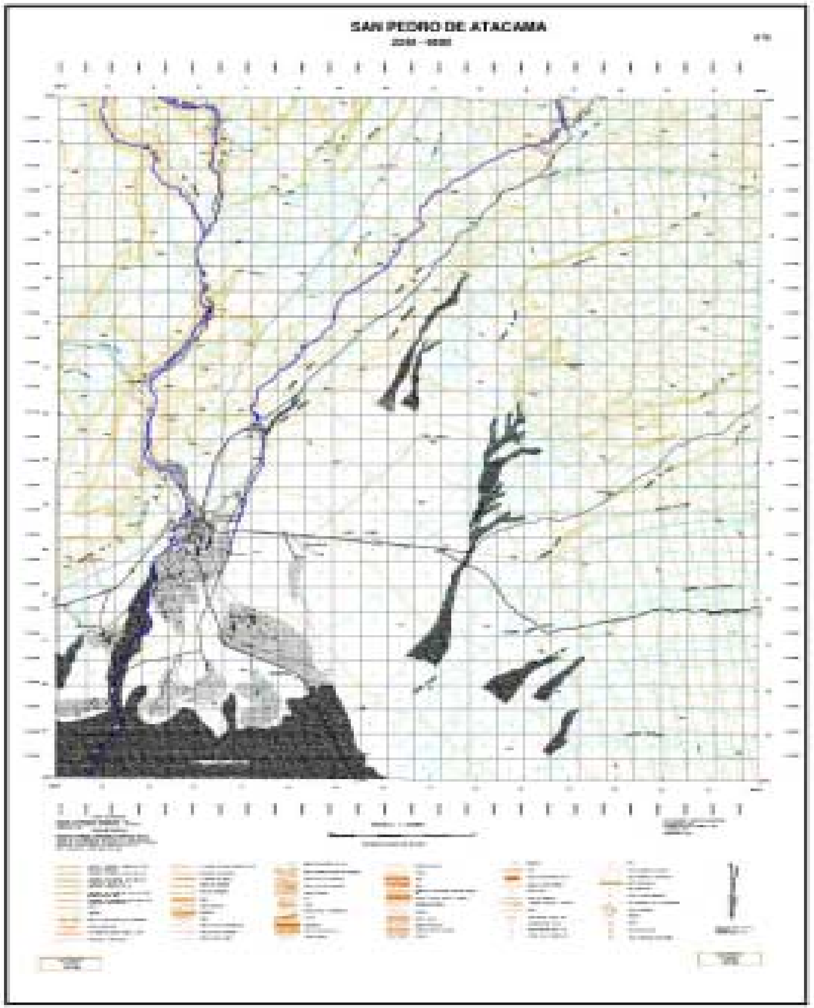
ALMA map


CALAMA
LAGUNA VERDE
SAN PEDRO DE ATACAMA
CHAJNANTOR ALMA
SALAR DE ATACAMA
PACIFIC OCEAN
ANTOFAGASTA
CORDILLA DE LOS ANDES
PARANAL VLT
N
W
E
S
50 Km
Geographical Map with VLT and ALMA Locations
ESO PR Photo 24d/99 (8 June 1999)
© European Southern Observatory
ESO

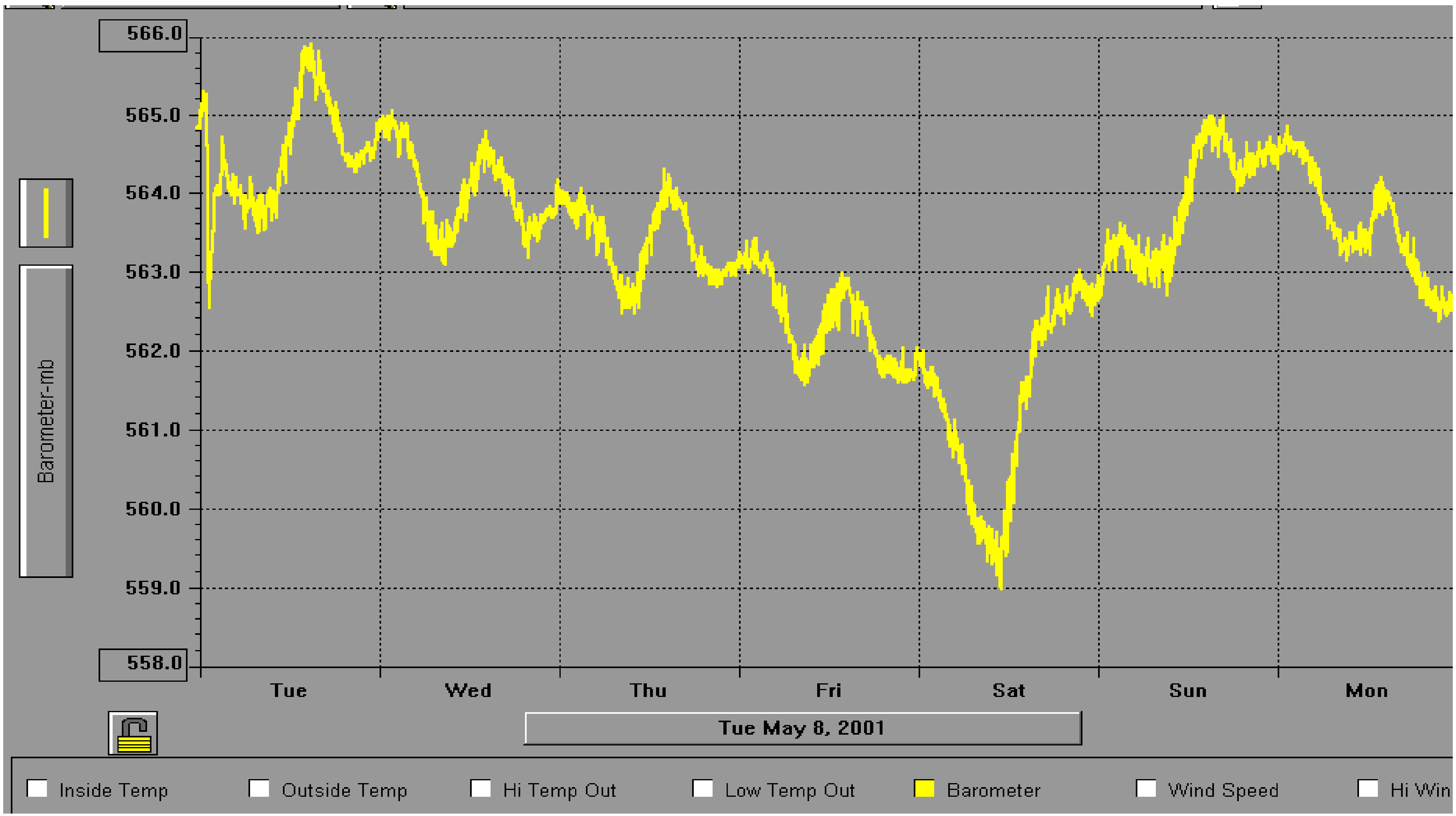
ALMA local area



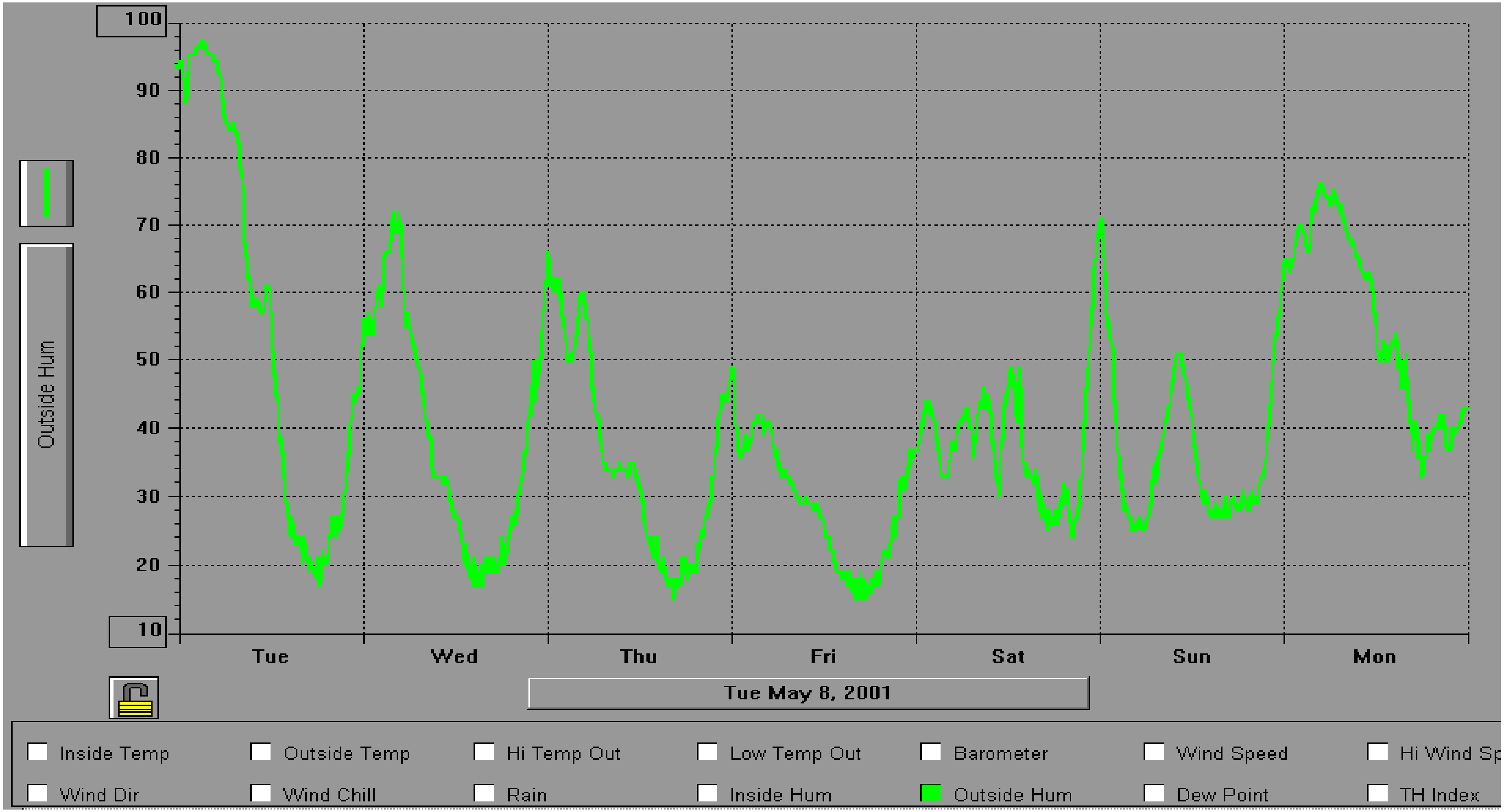
ALMA topo



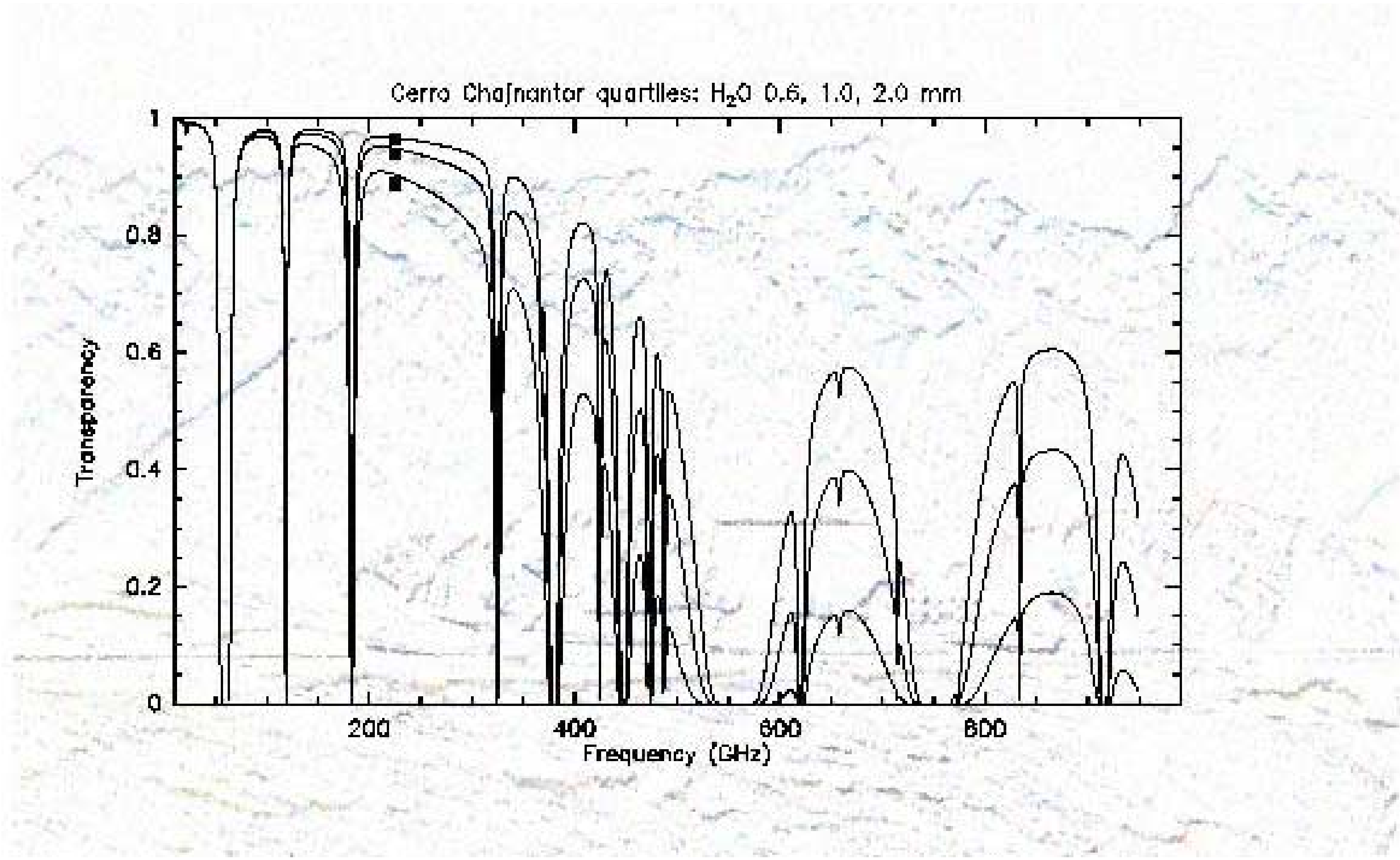
ALMA barometer



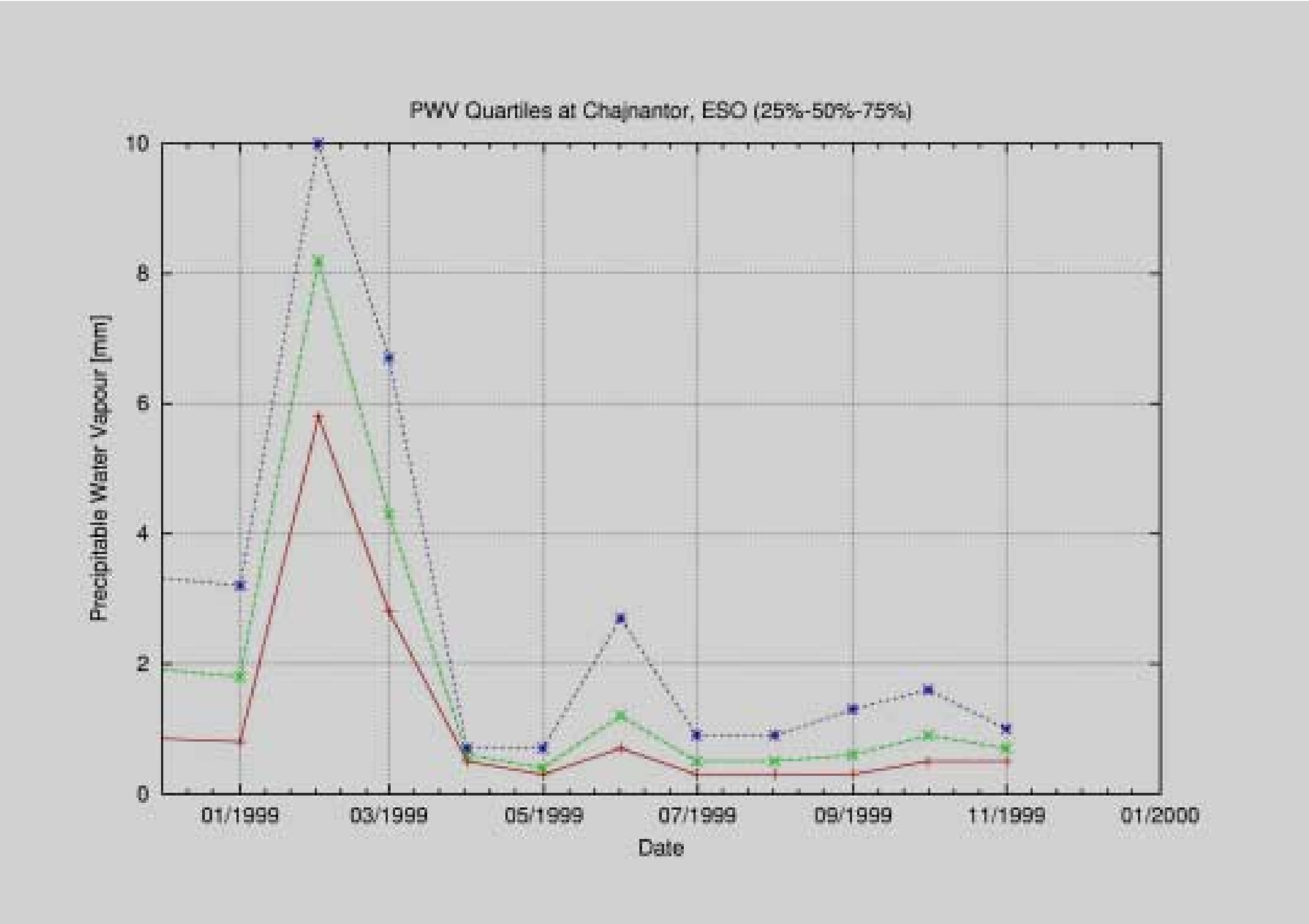
ALMA humidity



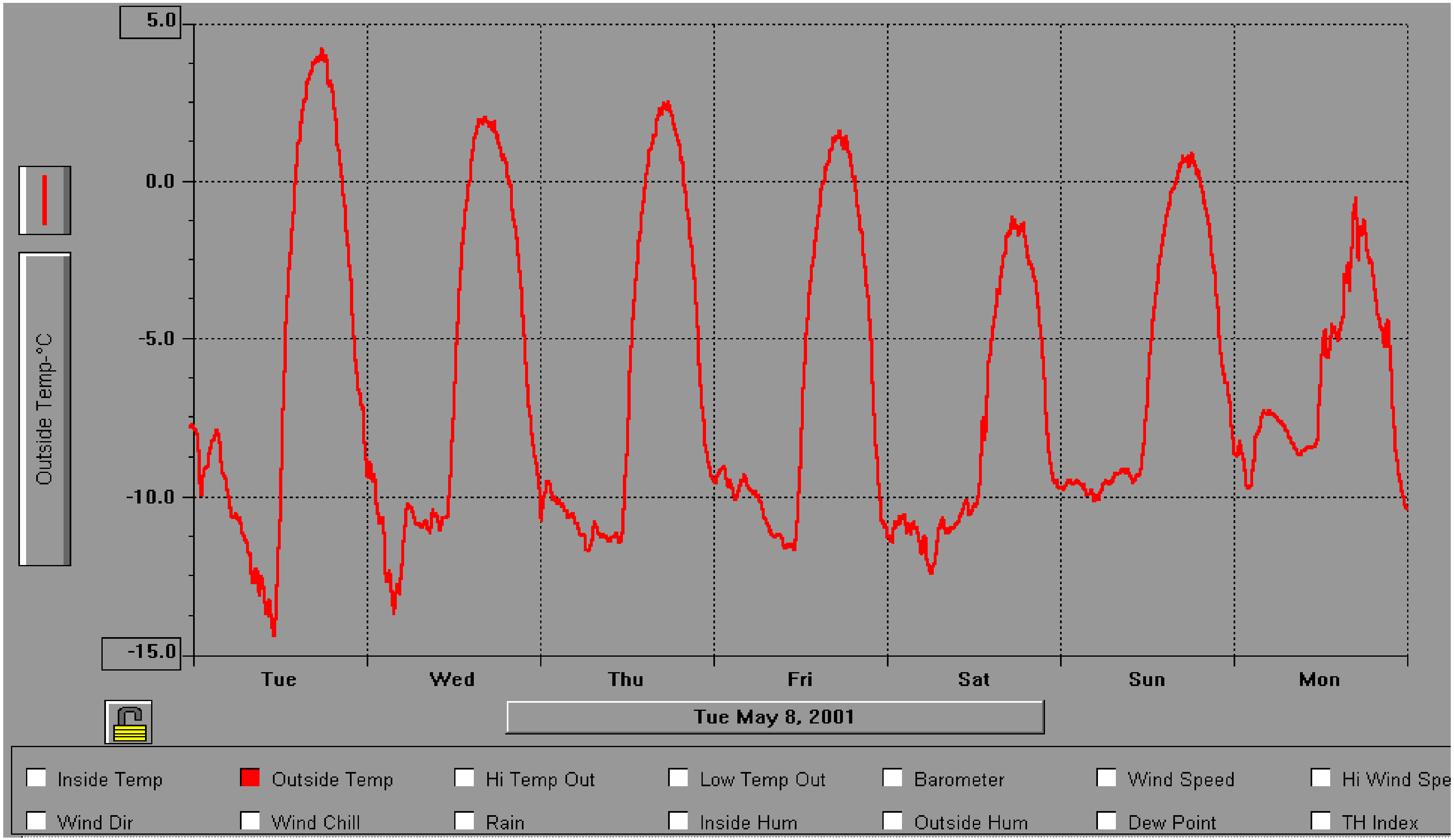
Atmospheric transparency



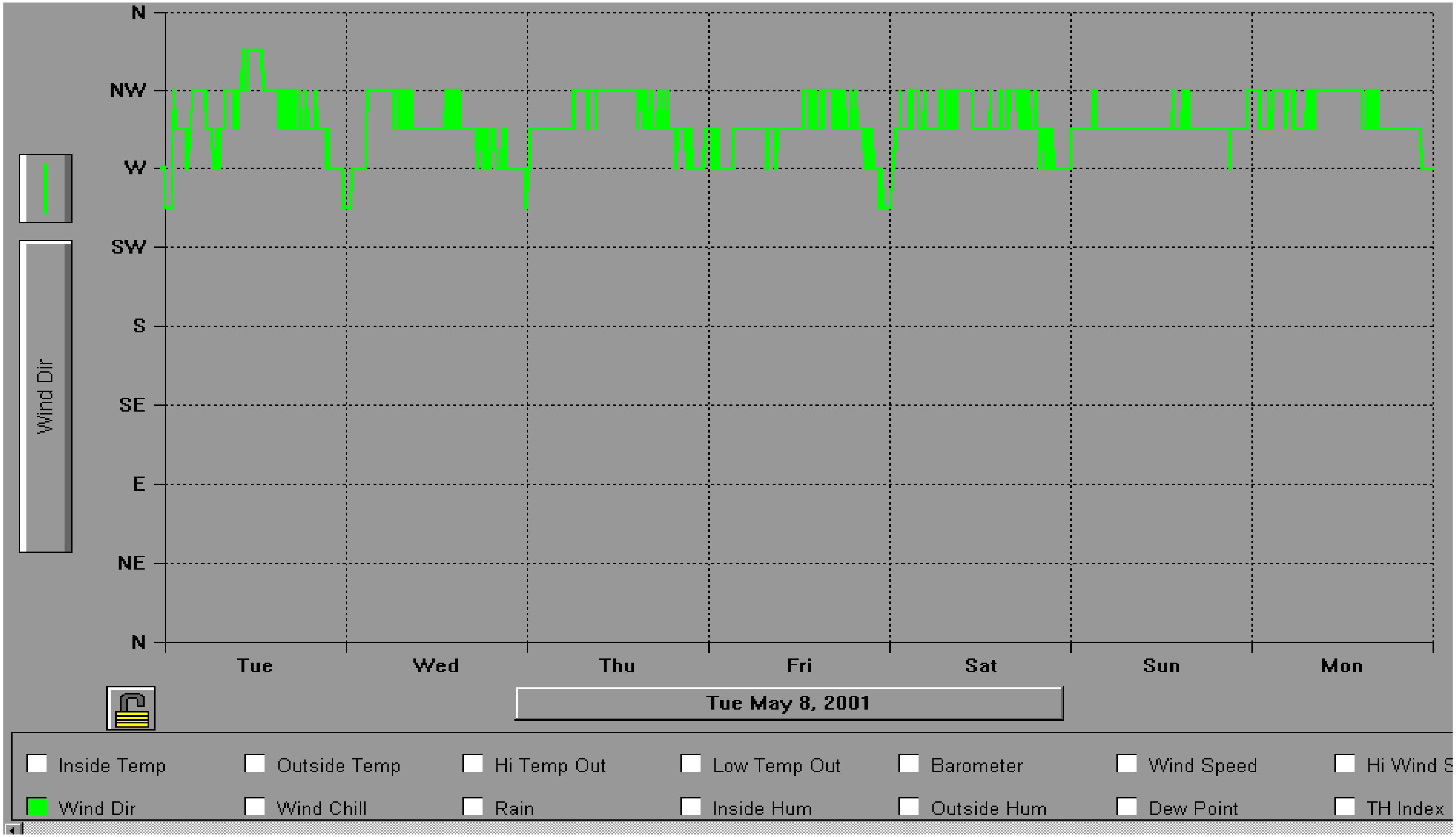
ALMA water vapour



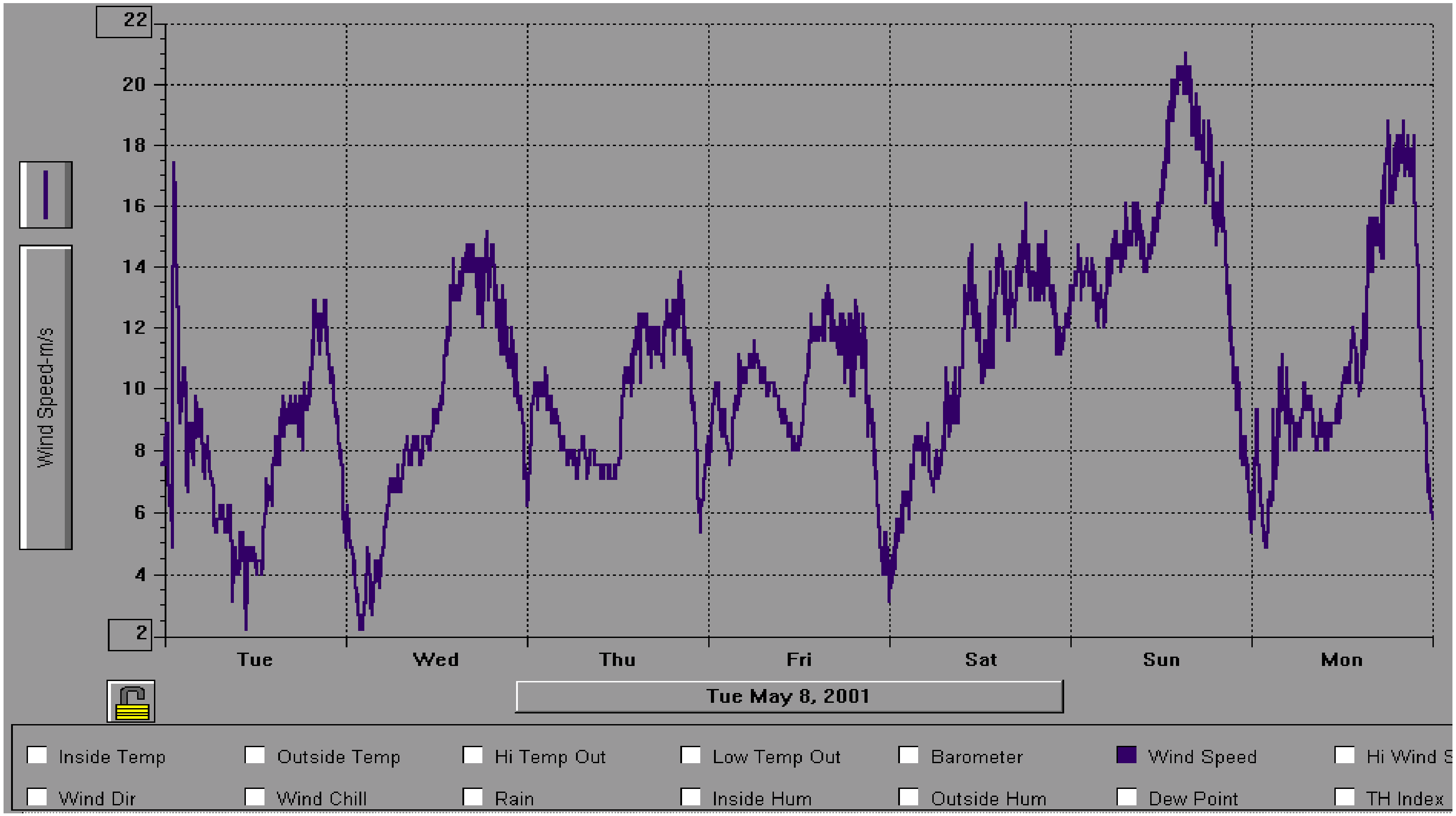
ALMA temperature



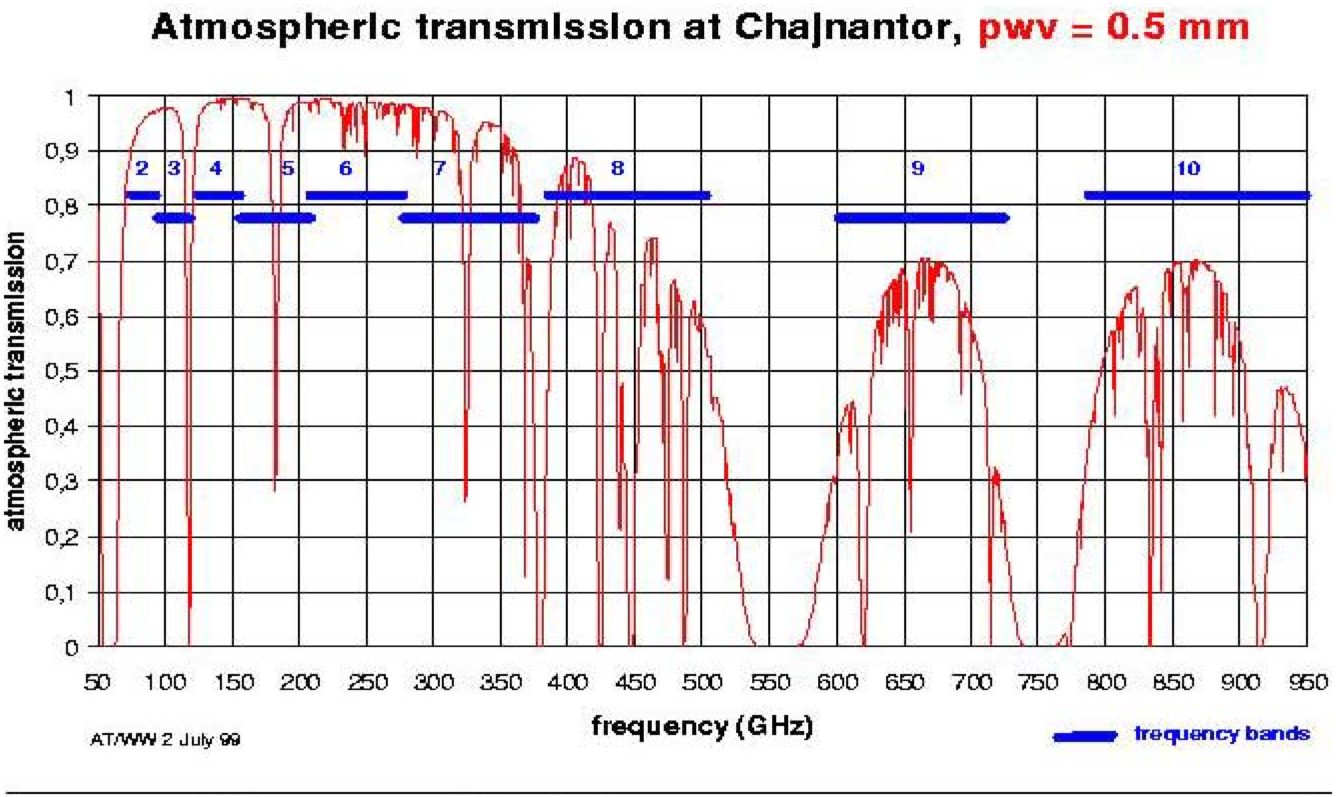
ALMA wind direction



ALMA wind speed

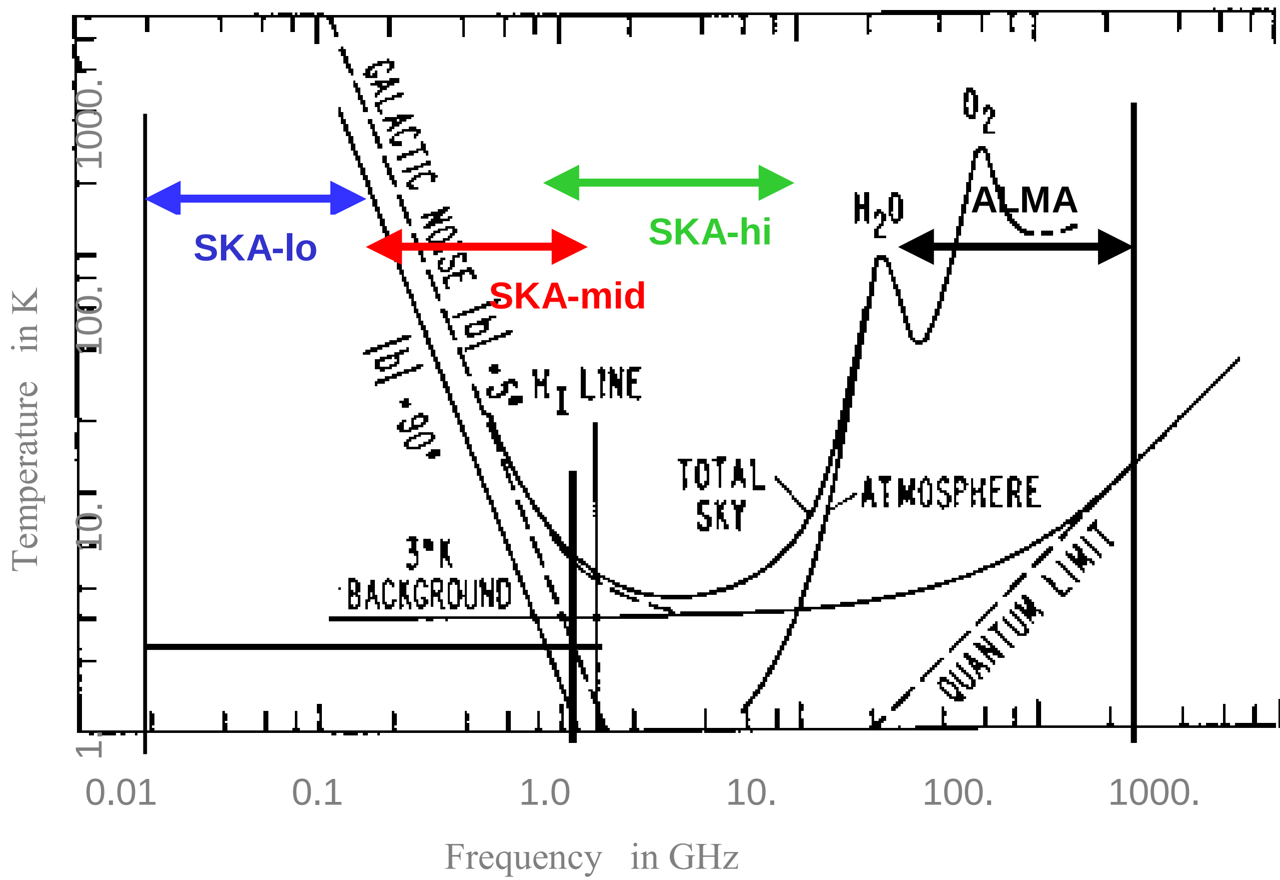


ALMA bands



(courtesy Wolfgang Wild)

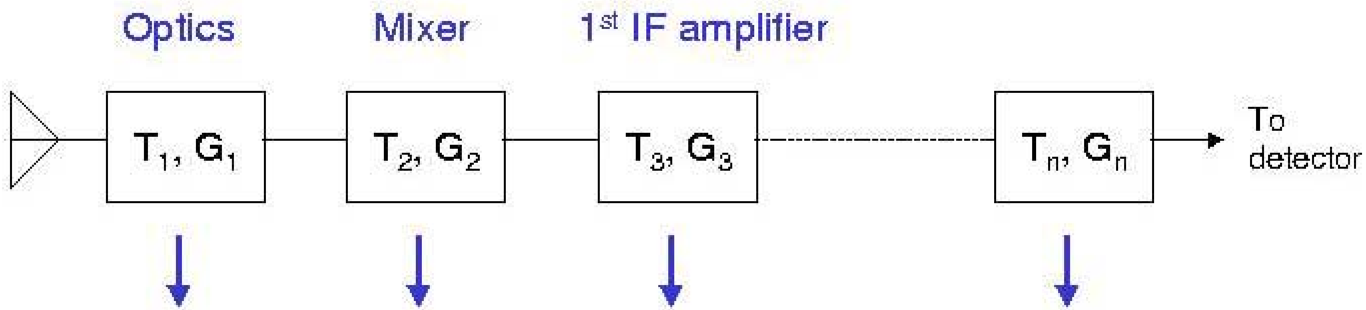
Noise regimes



System noise source

Noise Contributions from Receiver Components

Receiver as a series of linear two-ports:



$$T_{rx} = T_1 + T_2 / G_1 + T_3 / (G_1 G_2) + \ldots + T_n / (G_1 G_2 \ldots G_n)$$

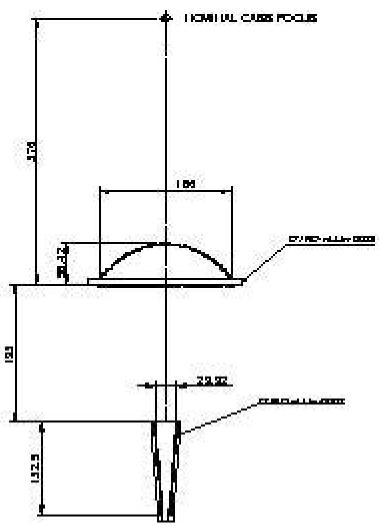
⇒ Receiver noise temperature determined by first few elements

⇒ Cooled optics for high frequencies

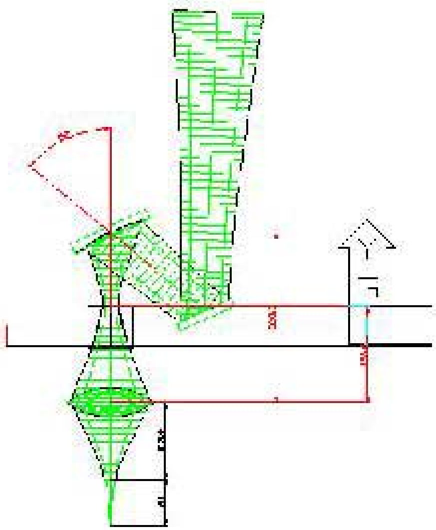
(courtesy Wolfgang Wild)

Receiver optics

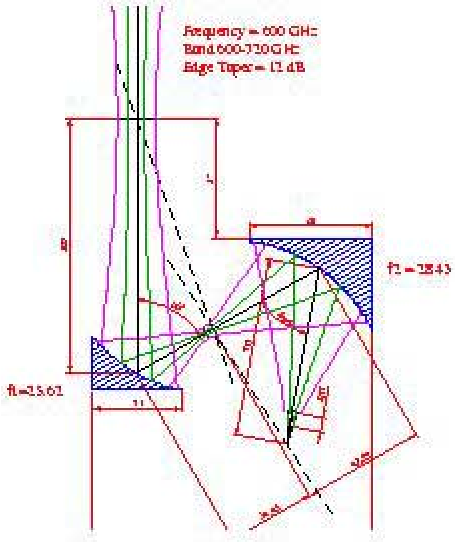
ALMA Receiver Optics



Bands 1 and 2
(only warm optics)



Bands 3 and 4
(warm and cold)



Bands 5 to 10
(only cold optics)

(courtesy Wolfgang Wild)

ALMA schedule

Proposed original schedule:

- 2 prototype (US and EU) antennas in August 2002
  - US started test April 2003; EU October 2003
- January 2002: Construction (Phase 2) start

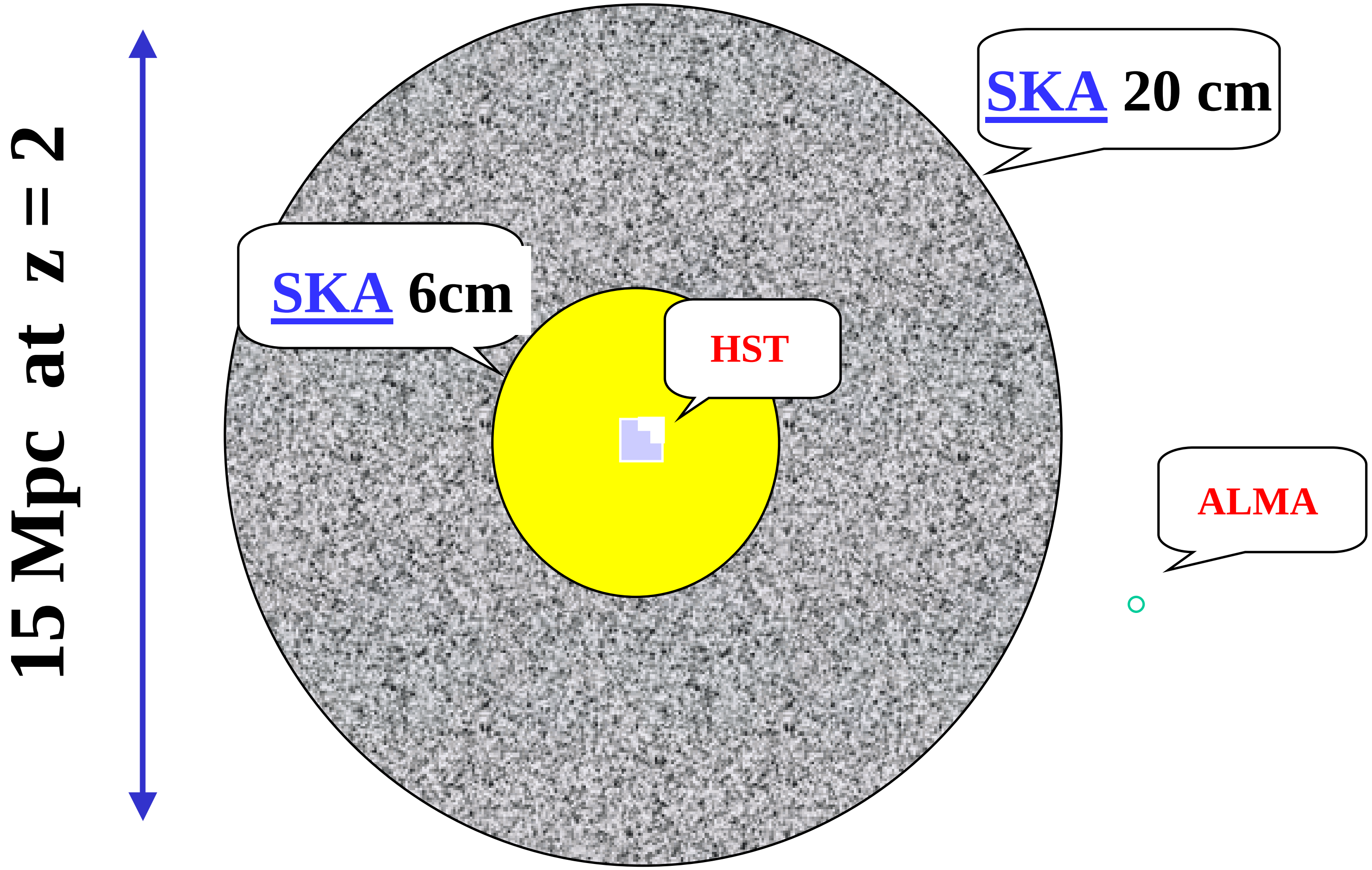
- April 2003 decision on antennas (+ 1 year?)
- 2006 interim operations
- 2011 full science operations

ALMA status

Decisions:

- ESO (+E) July 2, 2002
- USA (+CA) July 13, 2003
- JP Contract signed in April 2001 – withdrawn June 2002
- First talks about work division for 3 partners held in Paris
- For computing 3rd partner adds 12% to cost
- JP still hopes to add extra bands; next correlator; ACA; 12m prototype: in 2004
- 15 February 2003 Phase 2 contract signed US/EU for about 650 M€

Field-of-view



Primary beam from 180” (30GHz) – 6” (900GHz)

ALMA mosaicing

Many objects to be observed by ALMA, such as nearby galaxies and molecular clouds in our own galaxy, will be diffuse and much larger than ALMA's primary beam.
Mosaicing will have to be done. However, mosaicing places stronger constraints on the antennas than single pointing interferometry.
Why not build a 70~m single dish to observe these big sources?
Mosaicing is faster than single dish observations, mainly because of the multiple synthesised beams which can be formed within each primary beam.

Mosaicing limits

Pointing: Because the emission spans beyond a single primary beam in mosaicing, small antenna pointing errors can have a large effect on the observed flux of a feature which lies near the half power point of the beam. Pointing accuracy of about $1/25^{th}$ of the beamwidth will permit mosaics of about 1000:1 dynamic range (linear with ν).

Surface Accuracy: Surface errors will scatter radiation into the primary beam sidelobes, and unmodeled primary beam sidelobe structure will limit the quality of mosaic images. While surface accuracy of 1/16th of a wavelength only degrades the dish efficiency by a factor of 2 from Ruze losses, 1000:1 dynamic range mosaics will require surface accuracies of about 1/40th of a wavelength (quadratic with ν).

Mosaicing limits

Getting Very Short Spacings: The homogeneous array concept requires that the antennas be fairly close together (ie, 1.3 times the dish diameter for zenith observations) to be able to measure spatial frequencies in the range of the dish diameter. However, the antennas can actually smack into each other if the separation is less than about 1.5 dish diameters (depending upon the design). To improve the short spacing capabilities (i.e. the large scale structure) the ACA has been proposed with about 10 antennas of about 7m diameter.

Phase stability

Inhomogeneously distributed water vapour results in different electrical path lengths above the different antennas, or phase errors. The phase errors scatter flux, limiting the dynamic range, and also cause decorrelation, which artificially decreases the source amplitude.

The initial calibration is planned with a 183GHz spectral line WVR (*cf* the ATCA 22GHz WVR).

Calibration possibilities

The complete ALMA array, with 64 telescopes has about 2000 baselines, many more than any other existing telescope. This enables the use of algorithms different from used in today’s mm instruments. E.g.:

- use of redundant and quasi-redundant baselines
- use of parameterised models for the phase errors across telescope aperture
- use of pointing correction model parameters

ALMA

With JWST, ALMA and SKA in the second decade of this century the electro-magnetic spectrum from 1μm till 10m will be available to the next generation of astronomers with a resolution of about 0.02”, and sensitivities of about two orders of magnitude higher than today’s..