Institute of Applied Physics
Russian Academy of Sciences

Mountain pass Ak Baital, 4655m Nothern gate to the Eastern Pamirs

«Even things that are true can be proved»
Oscar Wild

On the advantages of the Eastern Pamirs for sub-mm astronomy

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see details in SPIE – doi: 10.1117/12.2560250

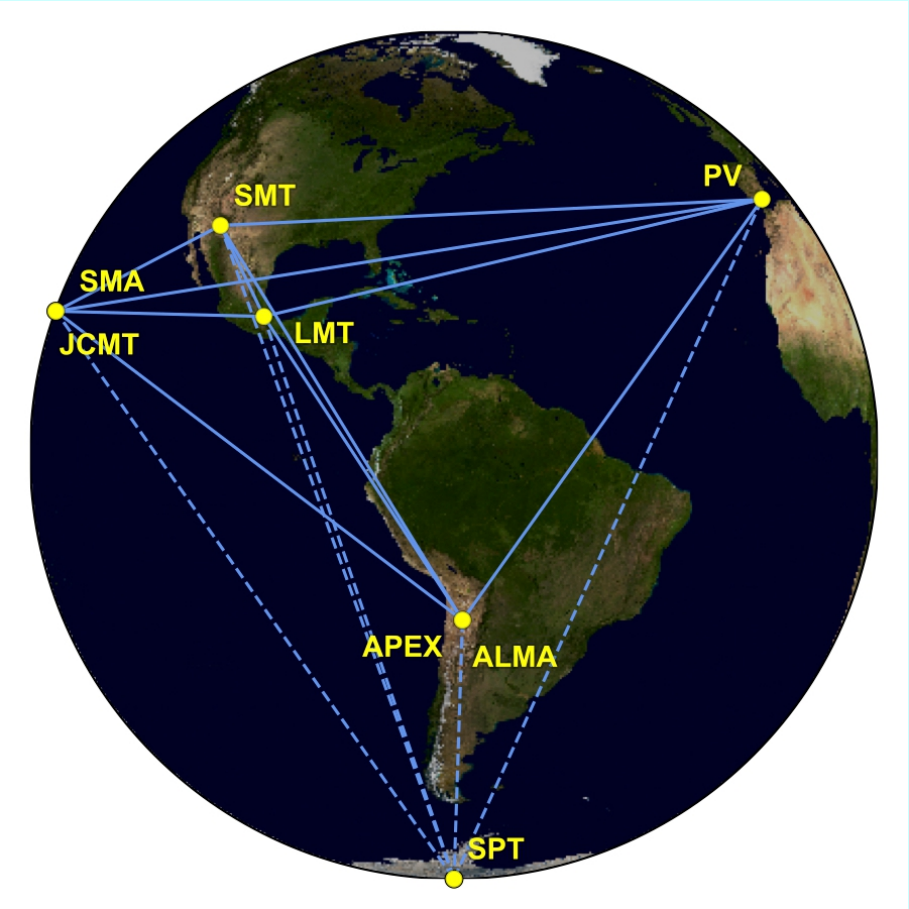
12.04.2021

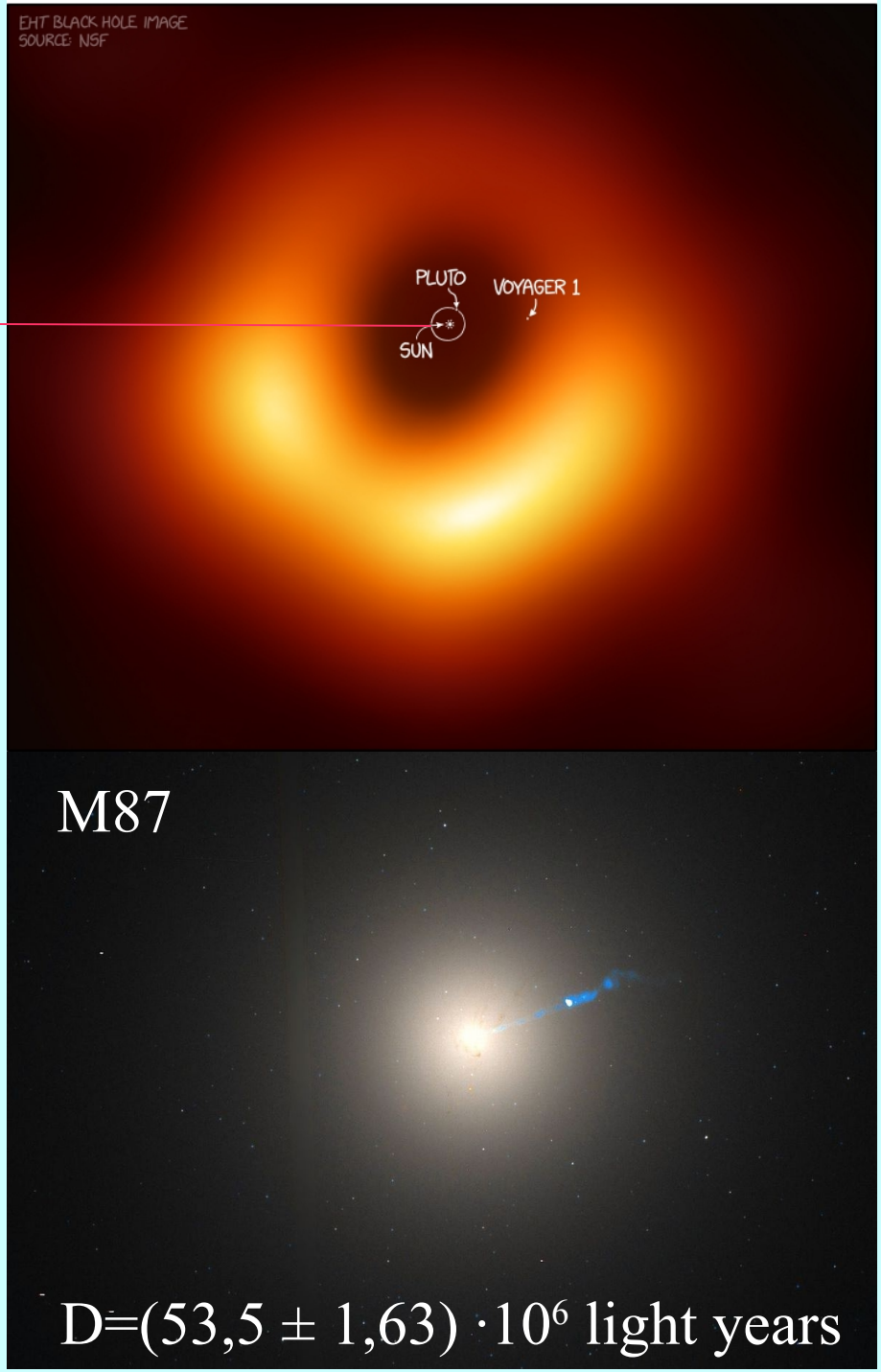
Event Horizon Telescope

(black hole in the galaxy M87)

$M=6.5\cdot10^9\ M_{Sun}$

2019 ApJ 875, L1-L6 April 10



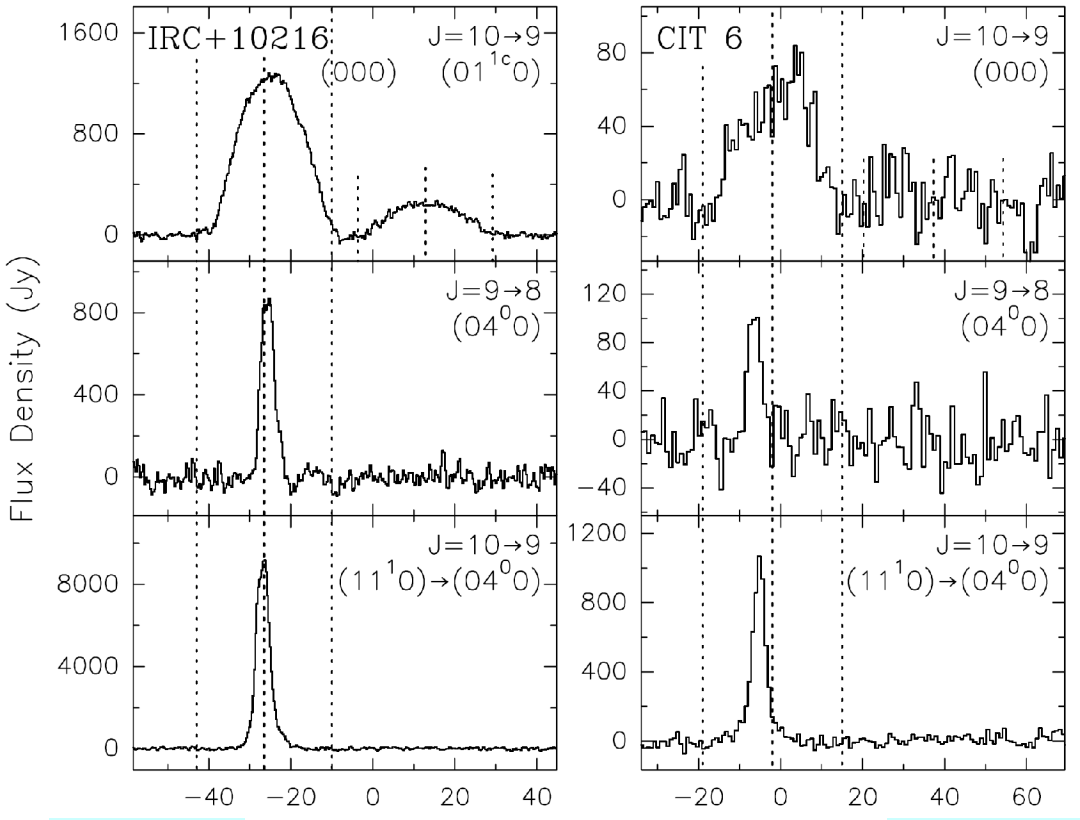


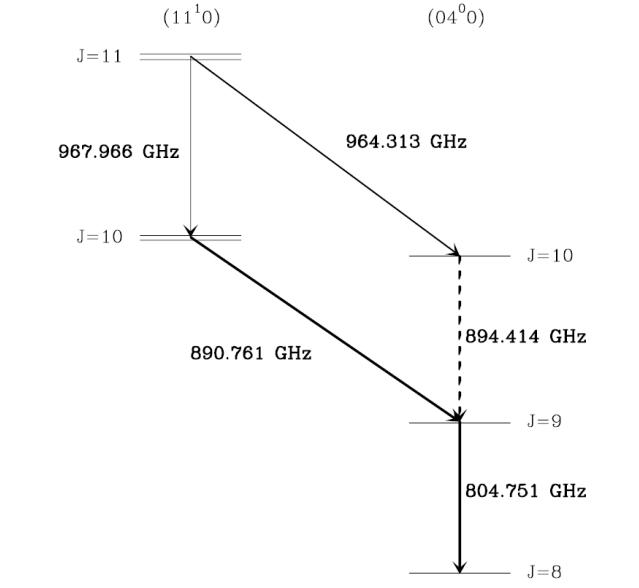
Strong HCN masers near 900 GHz

P.Schilke et. al 2000 ApJ 528, L37

2003 ApJ 583, 446

CSO-10.4m, 4200m





First ground based CO(13-12) at 1.49THz

M.C.Wiedner et al. 2006 A&A 454, L33

APEX-12m, 5104m

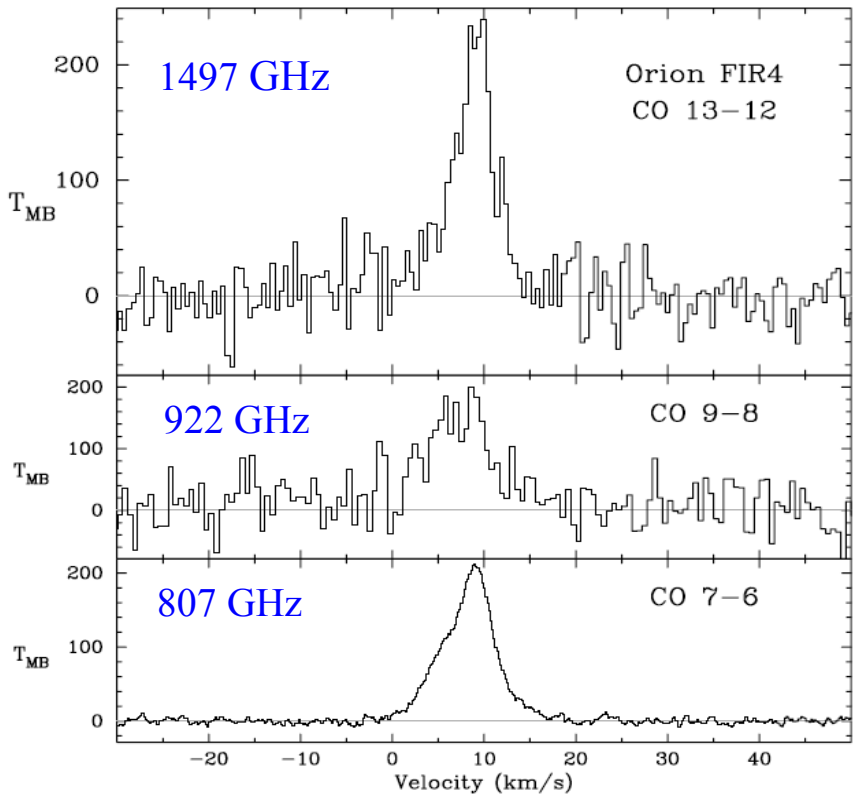


Fig. 2. *Upper panel*: CONDOR detection of CO 13−12 emission from Orion FIR4. The temperature scale is set by using the coupling efficiency of Mars (η_c = 0.09). The channel width is 0.49 km s^{-1} (2.4 MHz); the rms noise level is 22 K. *Middle panel*: CO 9−8 spectrum within 8.5″ beam from Kawamura et al. (2002). *Lower panel*: CO 7−6 spectrum within 13″ beam from Wilson et al. (2001).

First sub-mm experience

CSO-10.4m (Jan.1995)

H=4139 m

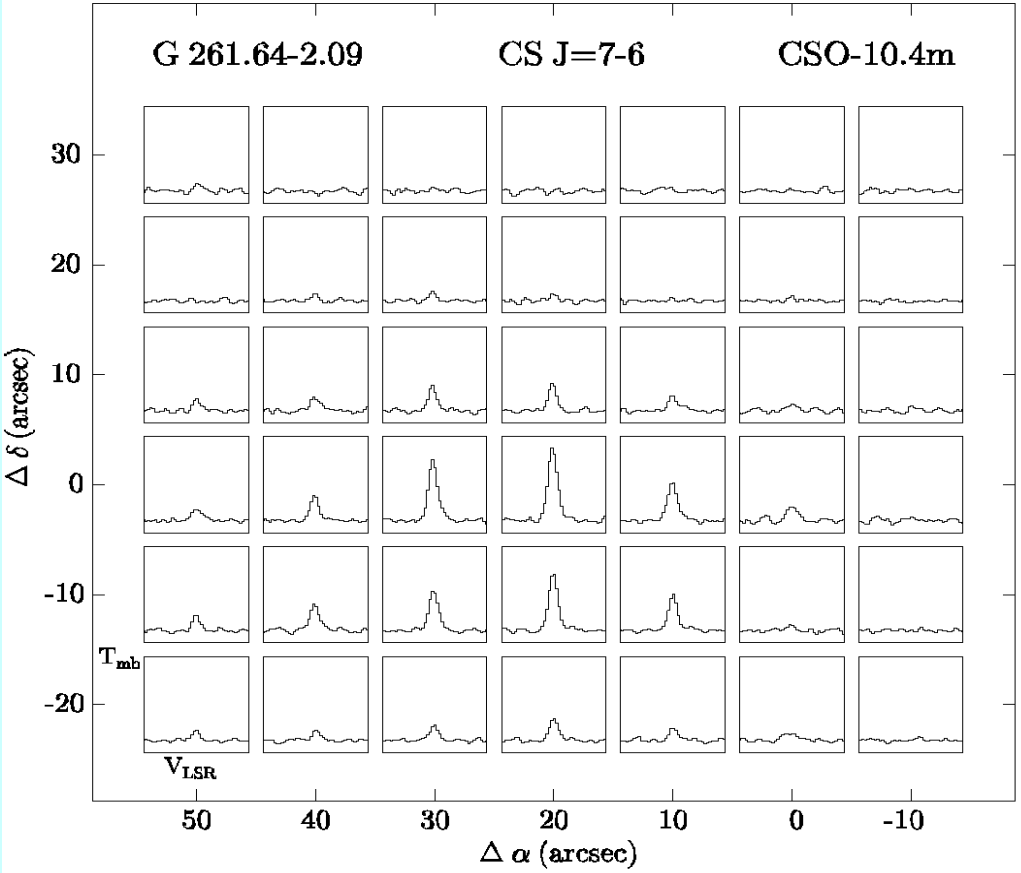
rms=25μm/10μm

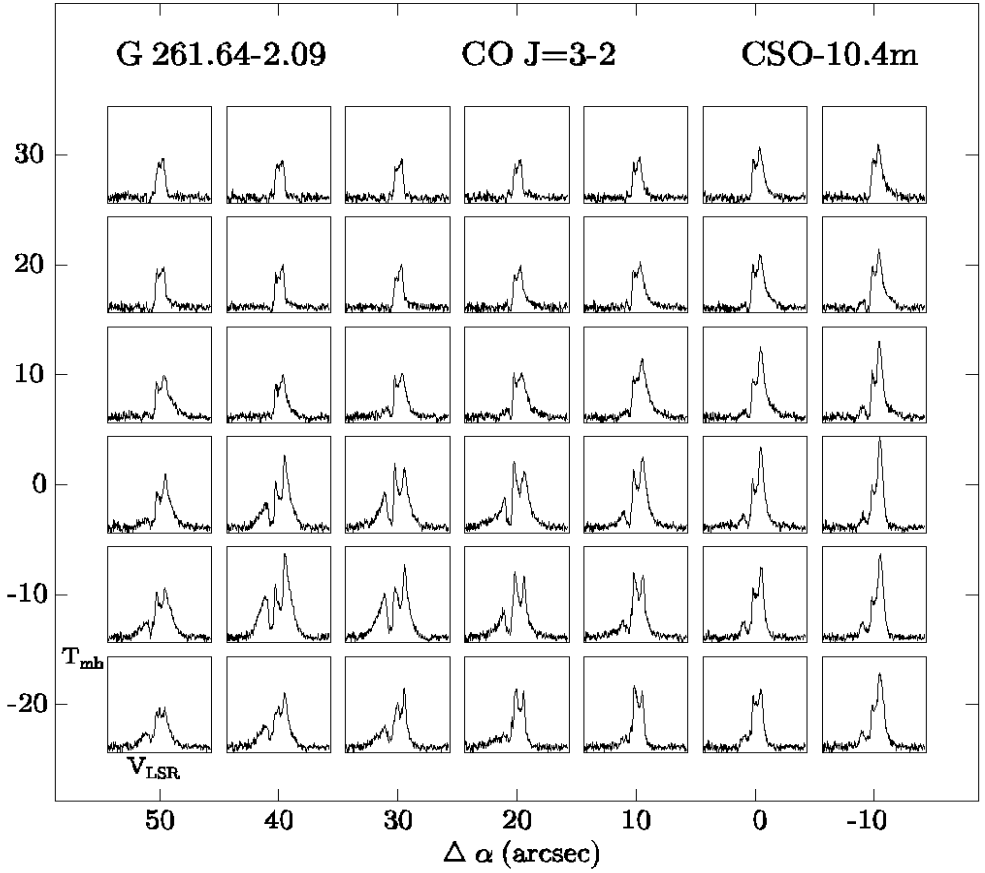
SEST-15m (1994, 1996, 2000)

H=2300 m

rms=70μm

Lapinov et al. 1998 Astron. & Astrophys. 336, 1007



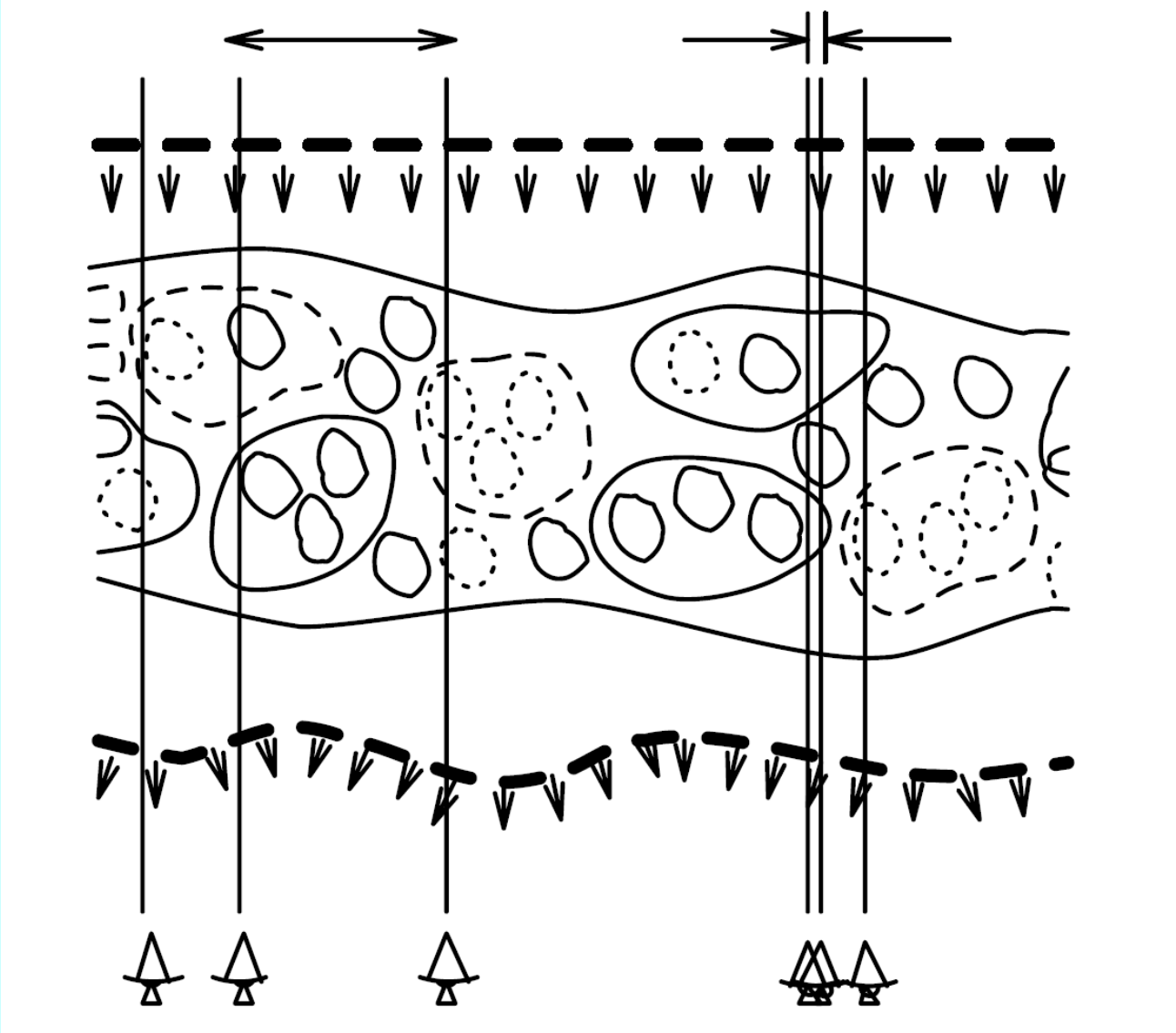


Simultaneous maps of G261.64-2.09 at 0.8mm observed with the same beam

Line	*ν (MHz)*	*μ_0(D)*	*$\tau(=A^{-1})$*	*n^* (cm^{-3})*	*E_{up}(K)*
CS(7-6)	*342882.85484(82)*	*1.958(5)*	*20.0min*	*1.1×10^{7}*	*65.8*
CO(3-2)	*345795.98985(16)*	*0.10980(3)*	*4.7days*	*3.1×10^{4}*	*33.2*

Distortion of the wavefront by atmospheric inhomogeneities

James Battat, 2004, SMA Memo #154

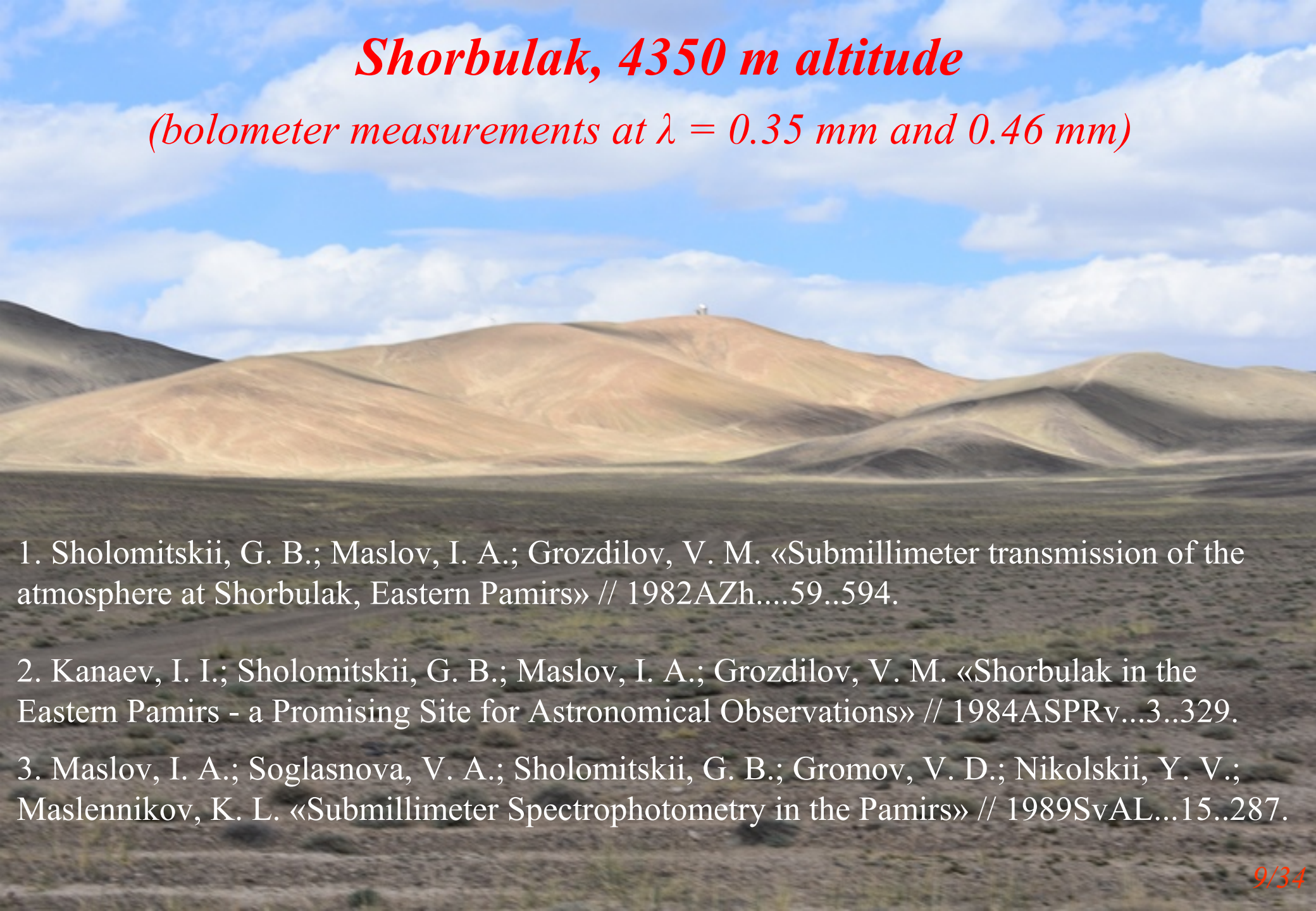


The first mm studies in the Eastern Pamirs (June-Nov. 1962)

(λ = 1.3 mm and 1.8 mm)

Shorbulak, 4350 m altitude

(bolometer measurements at λ = 0.35 mm and 0.46 mm)



1. Sholomitskii, G. B.; Maslov, I. A.; Grozdilov, V. M. «Submillimeter transmission of the atmosphere at Shorbulak, Eastern Pamirs» // 1982AZh....59..594.

2. Kanaev, I. I.; Sholomitskii, G. B.; Maslov, I. A.; Grozdilov, V. M. «Shorbulak in the Eastern Pamirs - a Promising Site for Astronomical Observations» // 1984ASPRv...3..329.

3. Maslov, I. A.; Soglasnova, V. A.; Sholomitskii, G. B.; Gromov, V. D.; Nikolskii, Y. V.; Maslennikov, K. L. «Submillimeter Spectrophotometry in the Pamirs» // 1989SvAL...15..287.

The results of work on Shorbulak (only a small part):

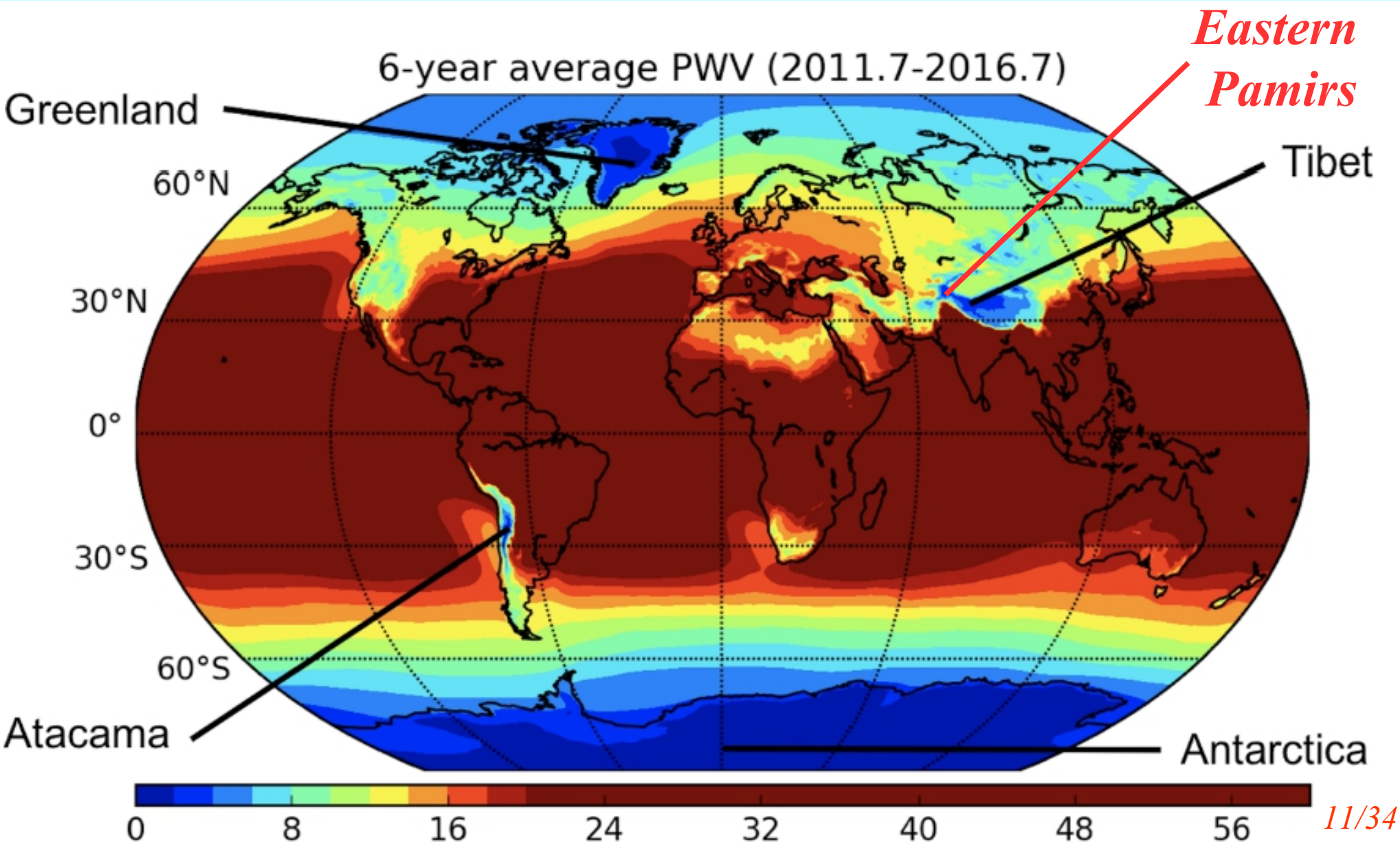
1. The driest climate in the USSR (less than 100 mm of precipitation per year, there is absolutely no grass cover; in most cases - completely snowless winters); total absence of dust; the average annual temperature is -3°C, daily difference is less than 6°C; average wind ~ 6m/s, subsiding at night; over 100 completely clear nights per year!

2. Extinction in optics is much better than on Maydanak, sometimes better than on Mauna Kea, close to Rayleigh scattering!

3. An exceptionally favorable place for sub-mm studies; average winter pwv = 1.2 mm (in Hawaii - 1.9 mm), sometimes pwv = 0.27 mm.

4. Rich observational statistics at λ = 0.35 mm and 0.46 mm, combined with direct pwv measurements by meteo probes.

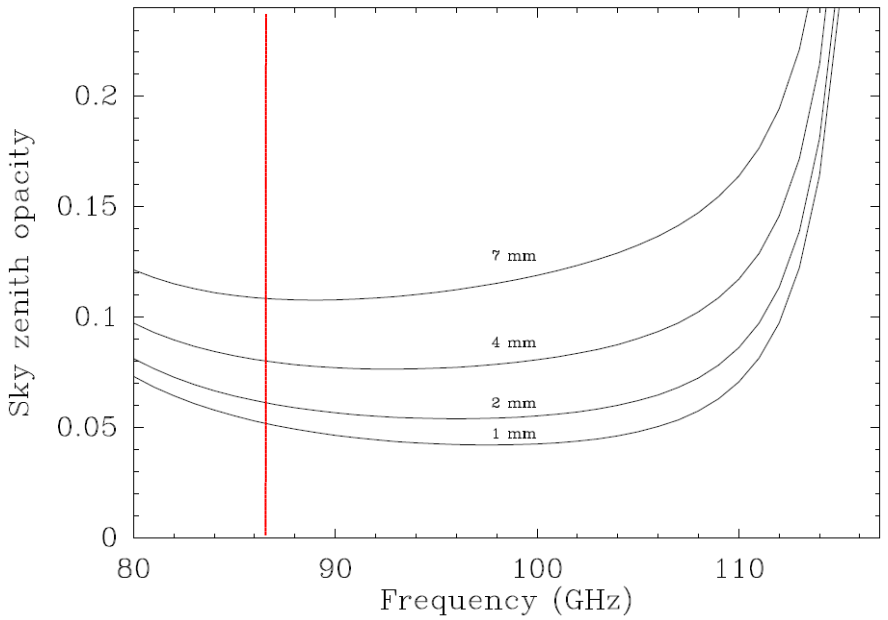
Best astroclimate sites by Hong Li et al., 2017, arXiv171003047L.pdf

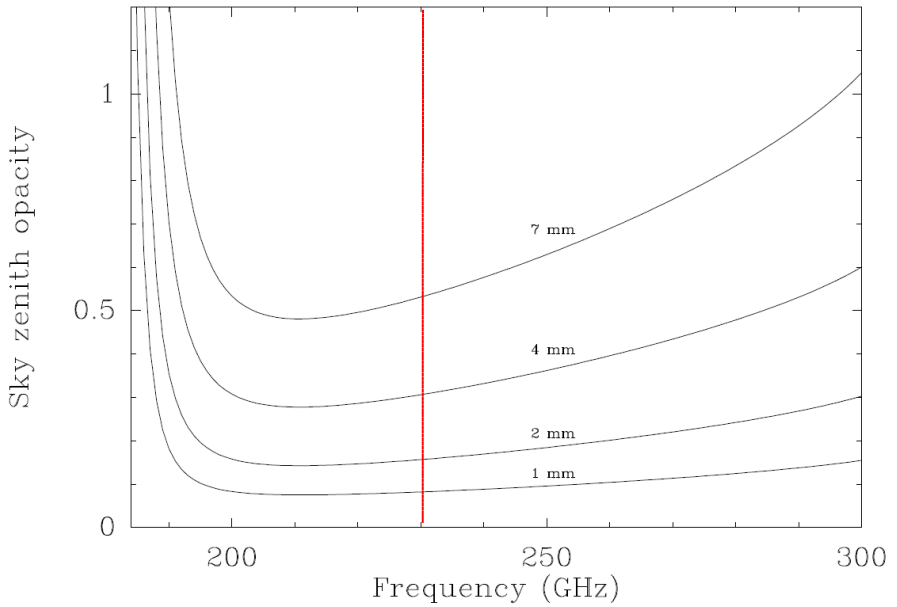


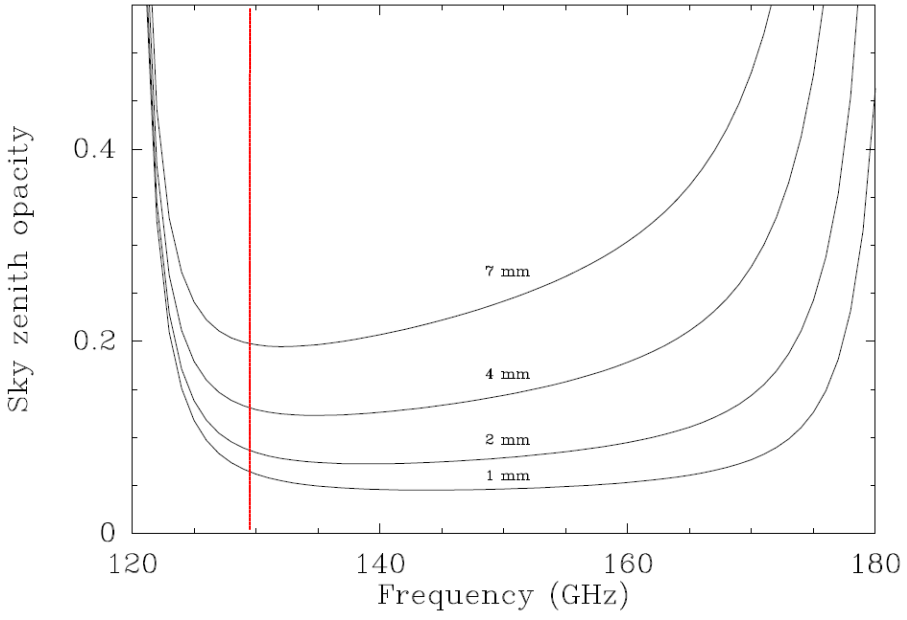

145.926 – 236.484 km in 1 cm
Мургаб
Чечекты
Ак-Архар
Шорбулак
Колуч-Куль
12/34

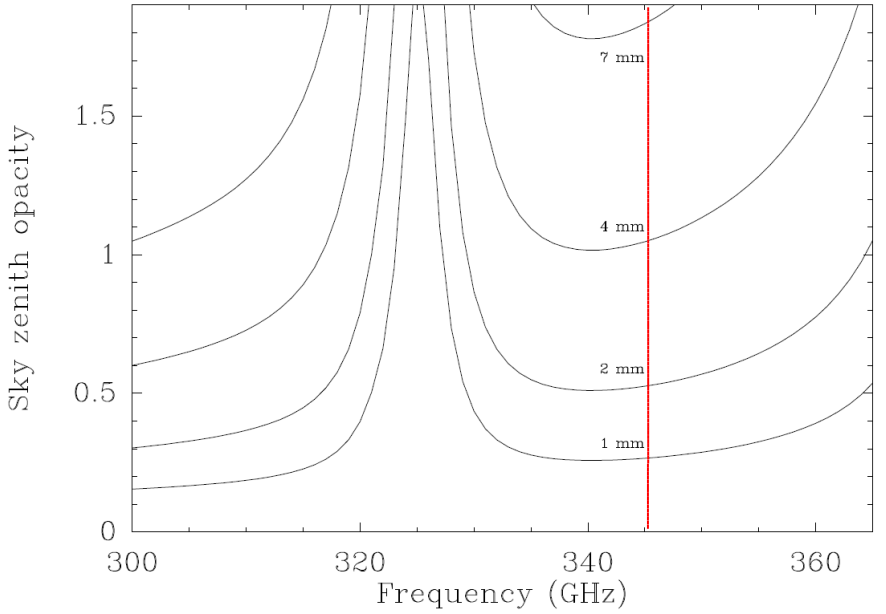

20 km in 1 cm
Чечекты
Мургаб
Ак-Архар
Шорбулак
Колуч-Куль

Atmospheric zenith opacity at various integral values of precipitated water vapor, pwv (IRAM-30m manual, v2.0)



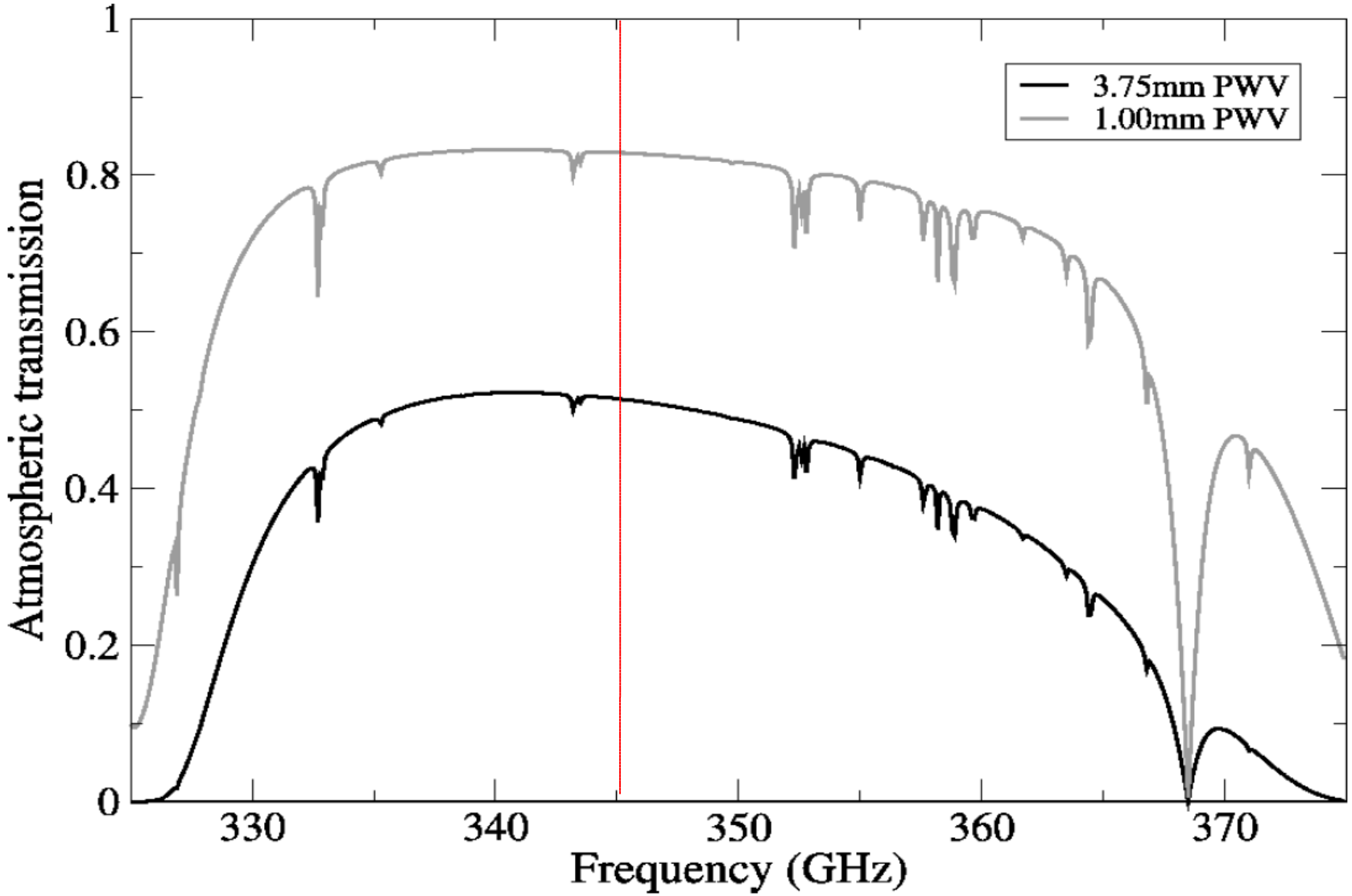




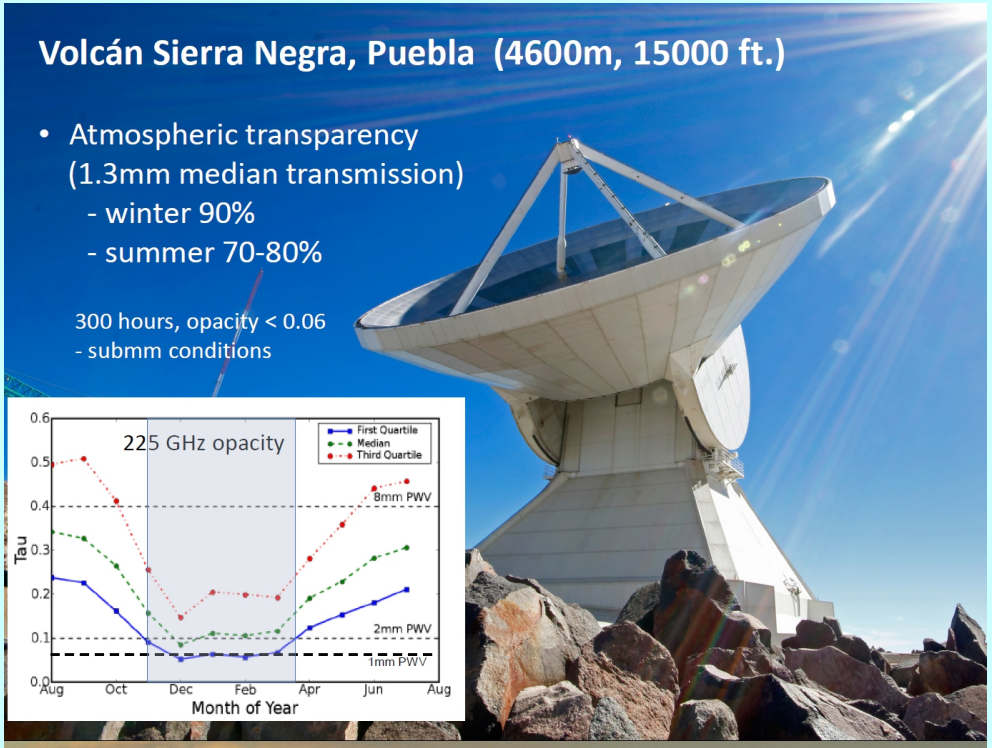


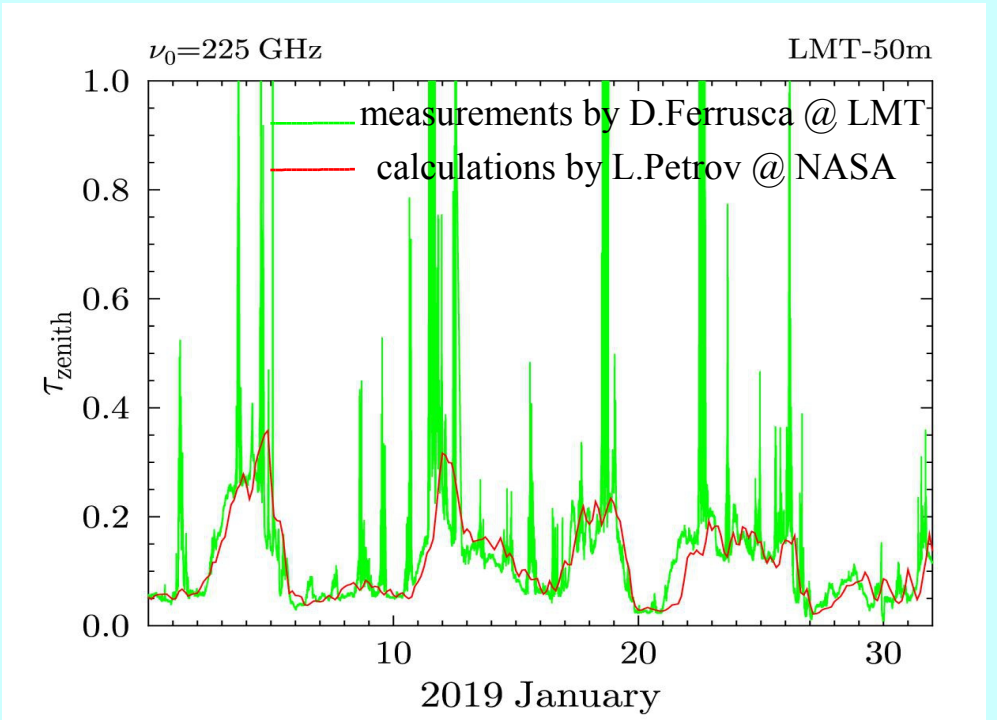
Atmospheric transmission as a function of frequency at 345 GHz

R.Plume et al. 2007 PASP 119, 102



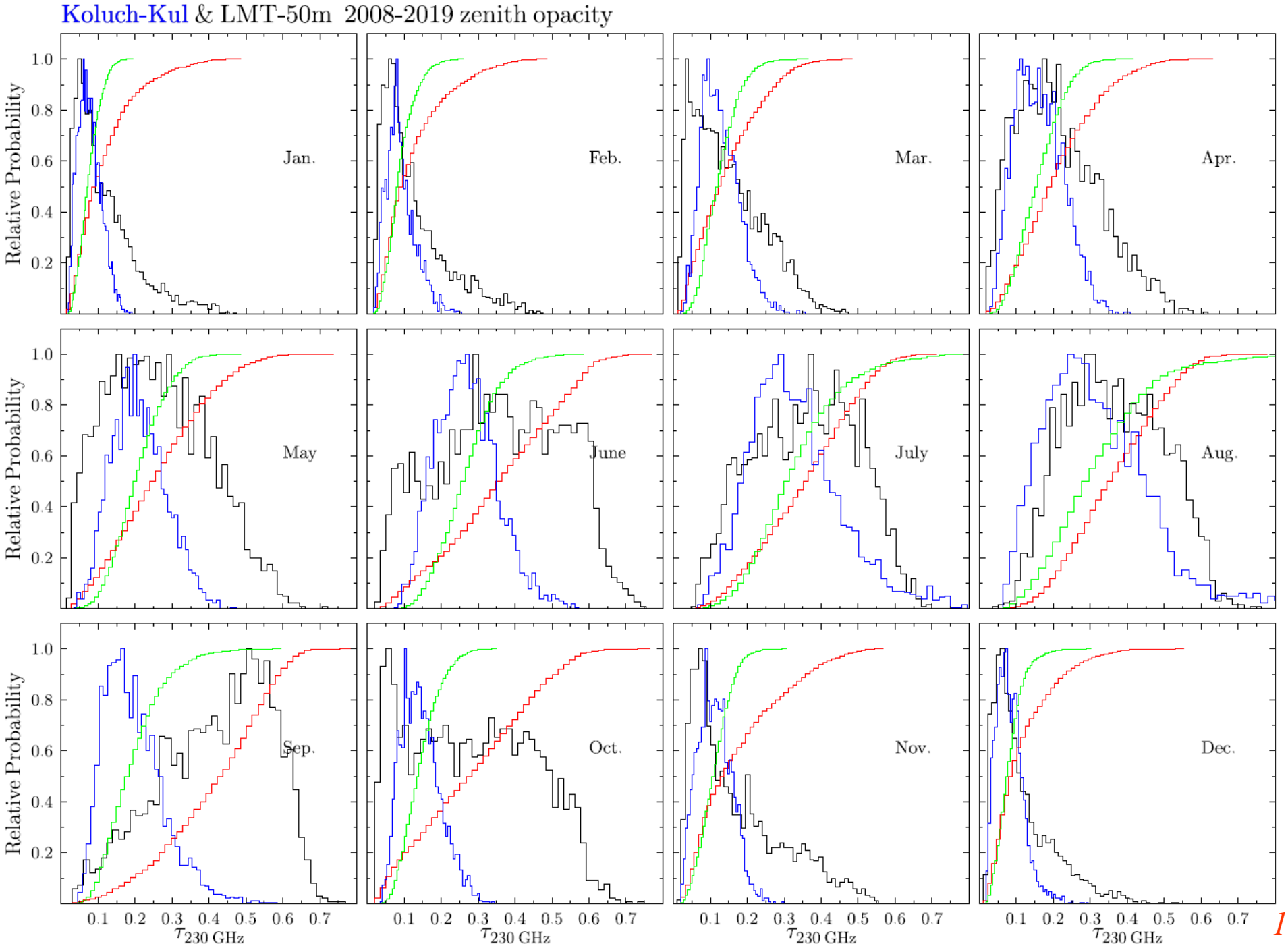
Verification of astroclimate analysis using the LMT-50m

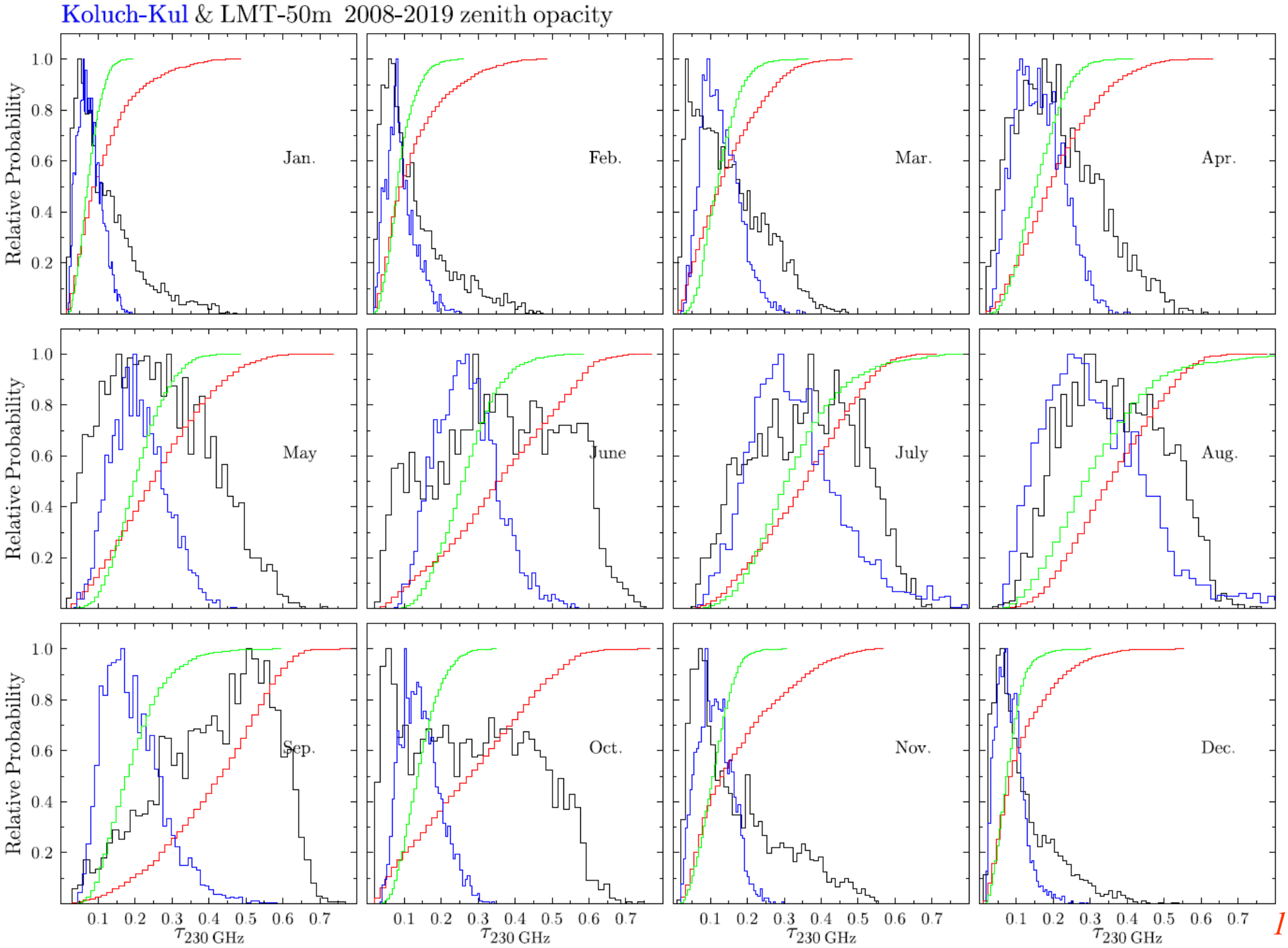


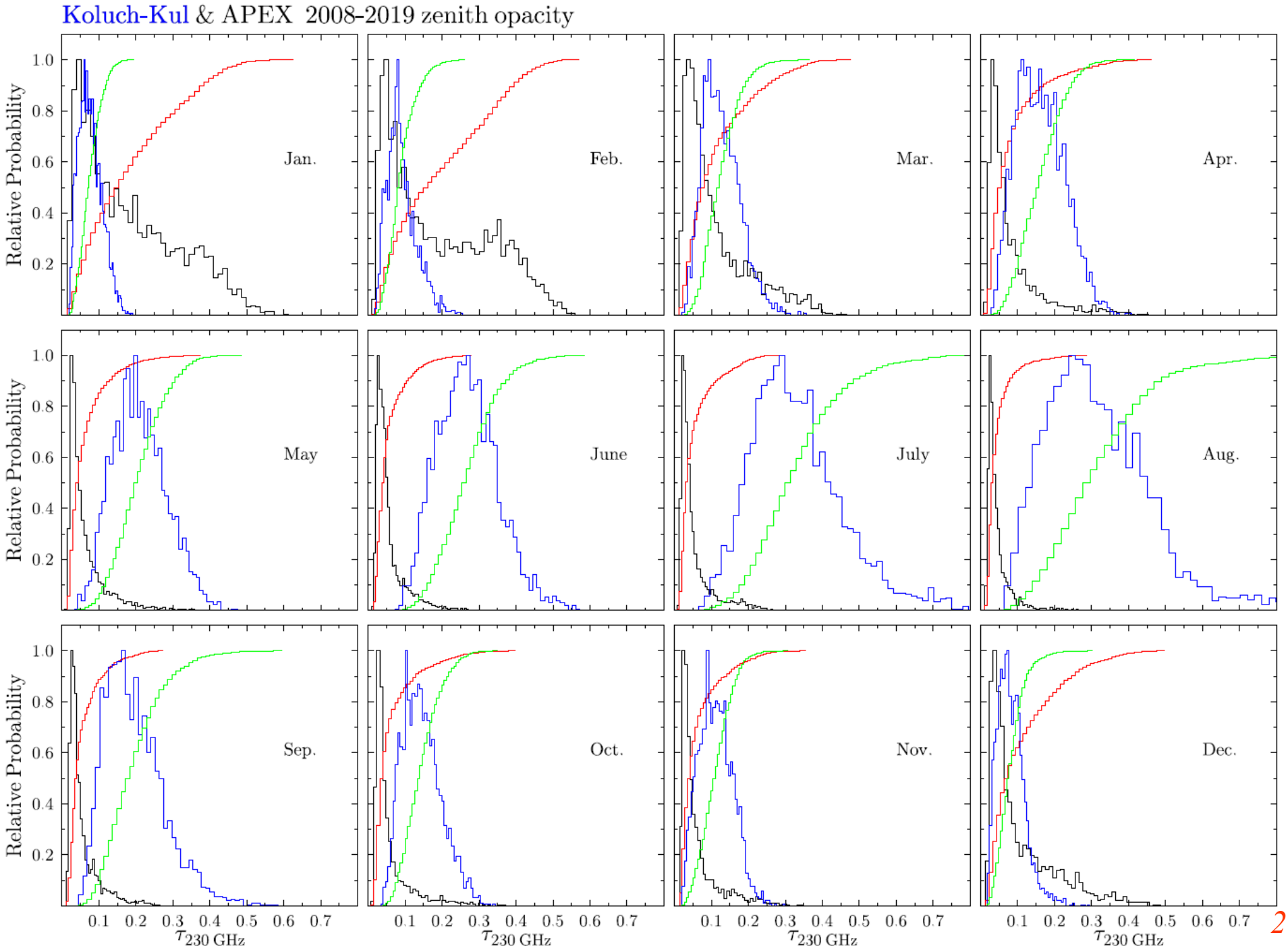


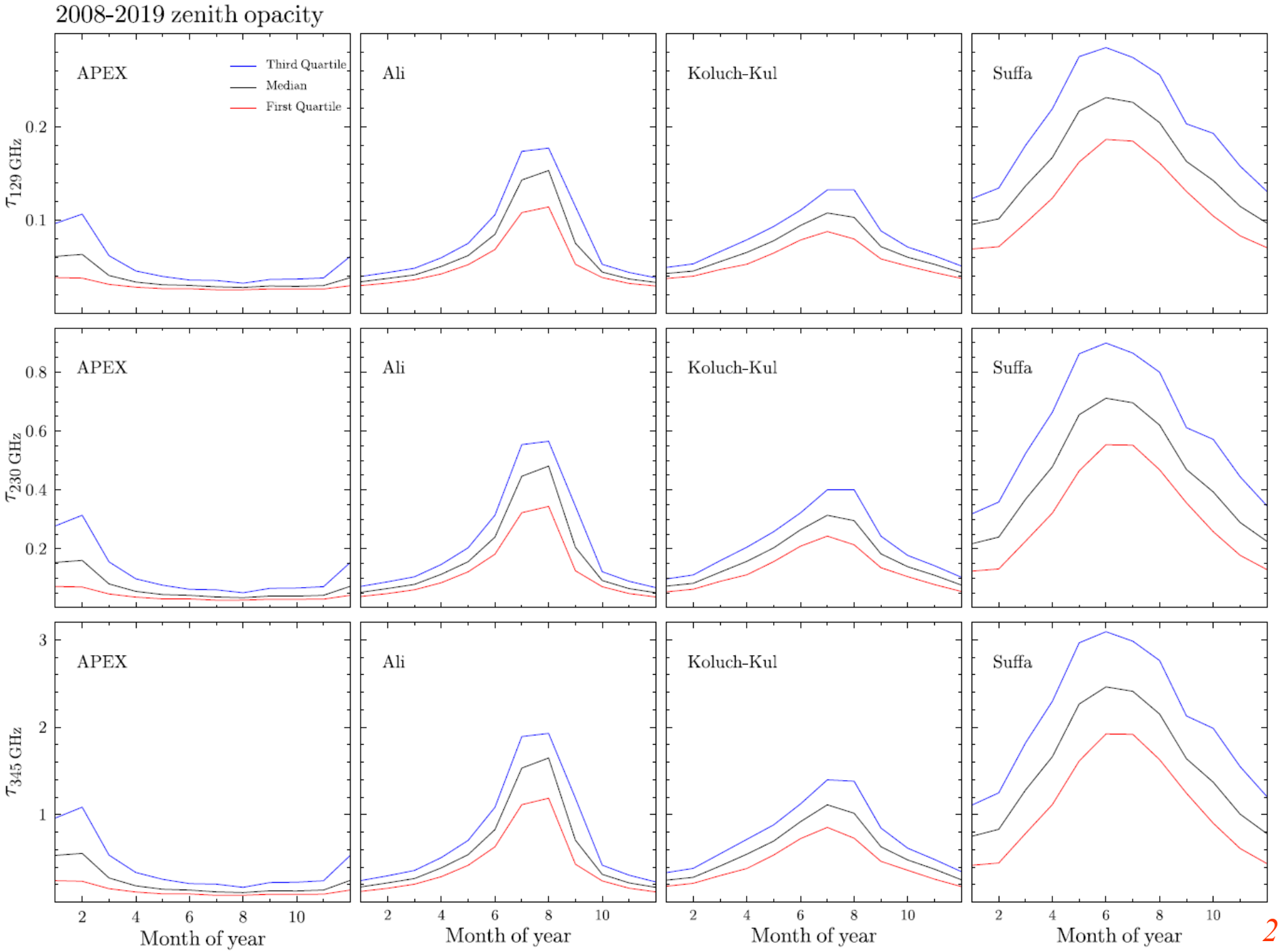
Site parameter statistics for 2008-2019

Station	Altitude	Percent of time with $\tau_{zenith} \leq 0.1$			
	m	86.2 GHz	129 GHz	230 GHz	345 GHz
APEX	5104	100	94.4	73.2	24.7
JCMT-15m	4100	99.7	87.6	50.2	4.7
Ali	5040	99.5	80.8	45.4	3.6
Muztagh-Ata	4520	99.7	80.4	31.1	1.7
Koluch-Kul	4475	99.6	84.2	28.9	1.2
Shorbulak	4290	99.3	78.3	25.0	1.2
Hanle	4490	95.5	74.5	29.3	0.3
LMT-50m	4570	99.8	62.5	24.5	2.5
IRAM-30m	2920	93.5	52.7	13.3	0.5
Terskol	3085	86.6	48.5	12.0	0.3
NOEMA	2560	82.3	38.9	10.1	0.3
Maidanak	2586	83.3	34.4	9.3	0.4
Suffa	2300	66.3	22.6	5.4	0.1
SEST-15m	2300	54.4	29.4	9.3	0.2

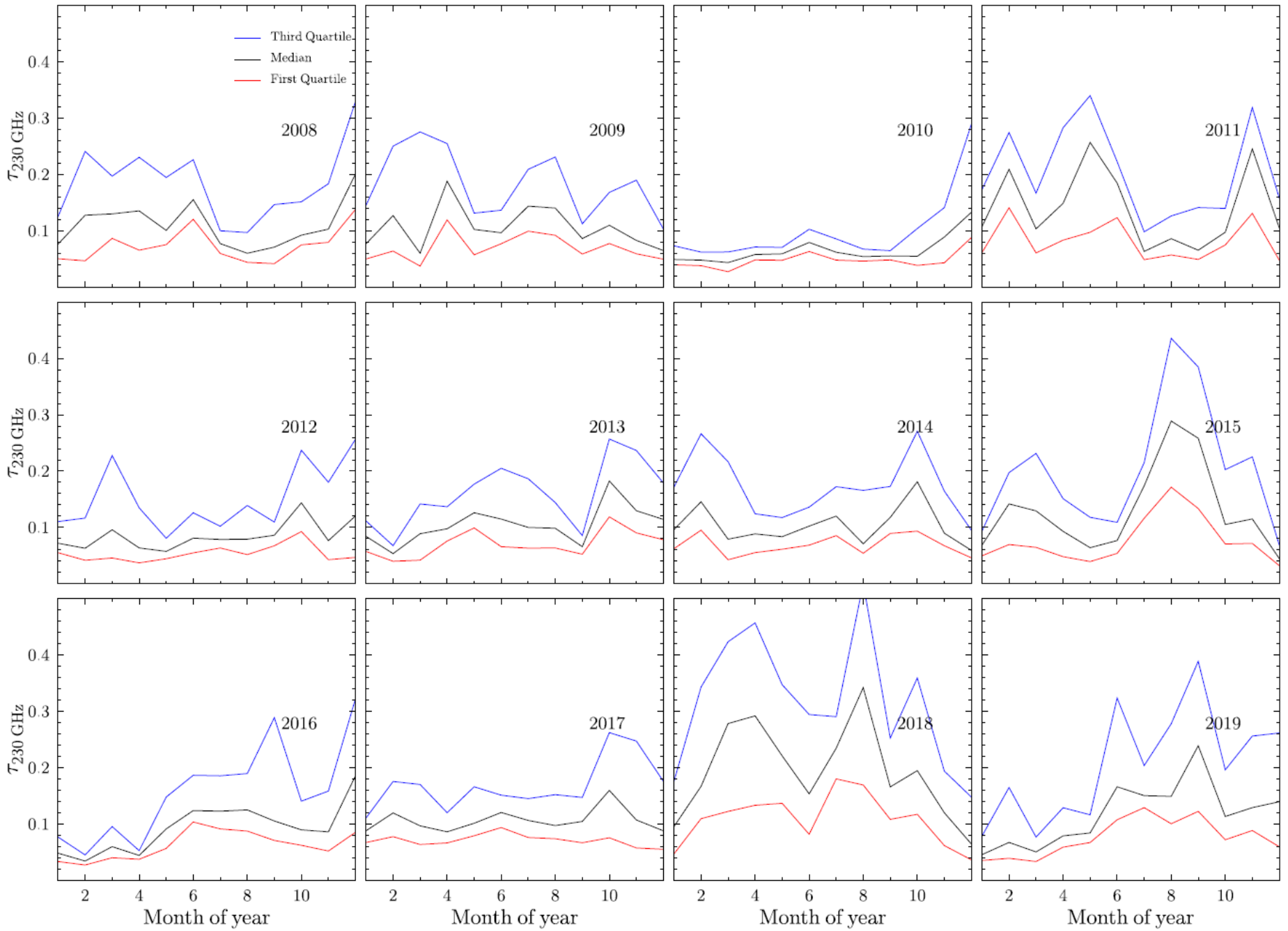

Koluch-Kul & LMT-50m 2008-2019 zenith opacity
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
$\tau_{230\ \mathrm{GHz}}$


Koluch-Kul & LMT-50m 2008-2019 zenith opacity
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
$\tau_{230\ \mathrm{GHz}}$

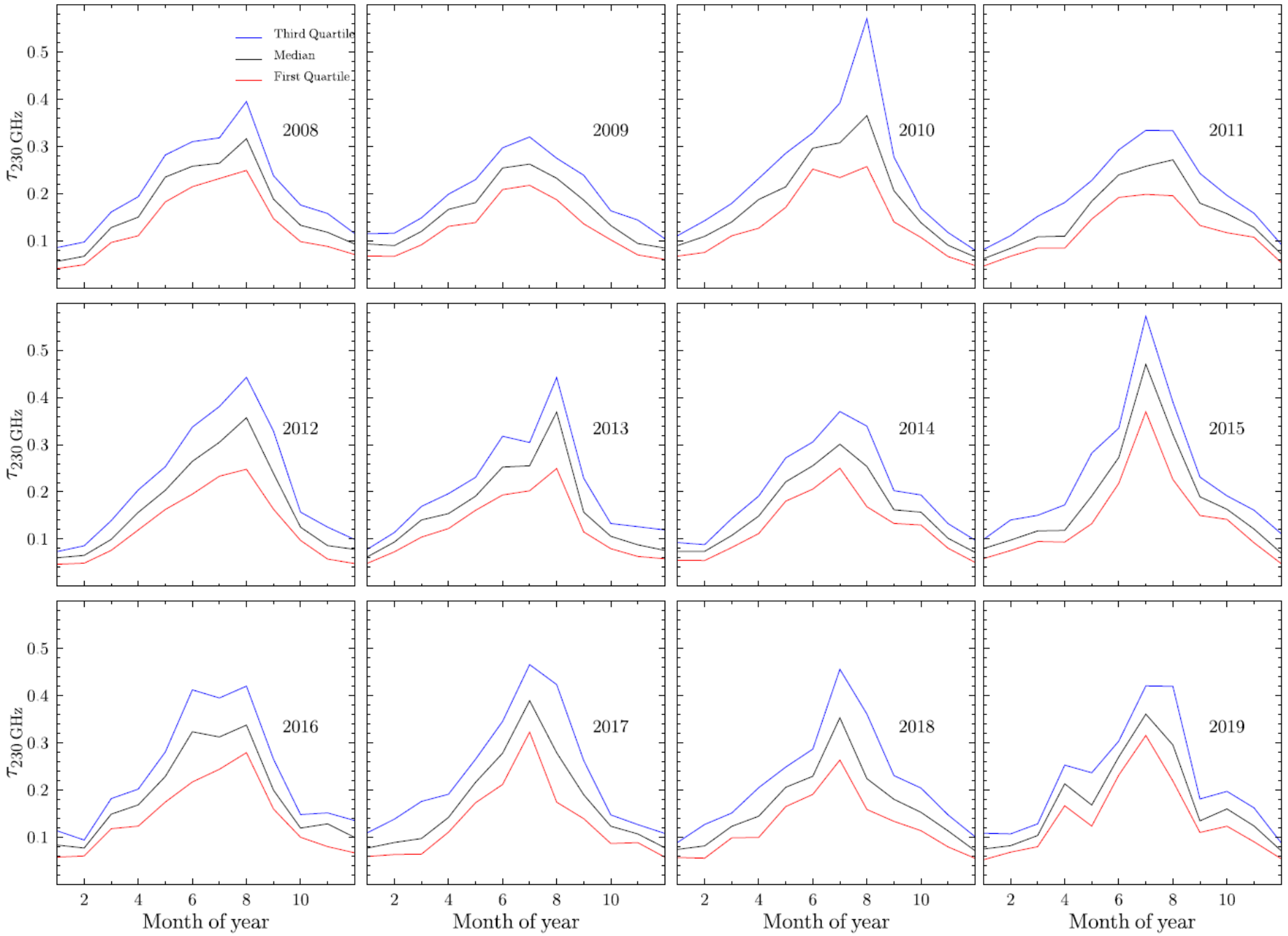

Koluch-Kul & APEX 2008-2019 zenith opacity
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
$\tau_{230\ \mathrm{GHz}}$


2008-2019 zenith opacity
APEX
Ali
Koluch-Kul
Suffa
Third Quartile
Median
First Quartile
$\tau_{129\ \mathrm{GHz}}$
$\tau_{230\ \mathrm{GHz}}$
$\tau_{345\ \mathrm{GHz}}$
Month of year

Example of unstable astroclimate



Example of stable astroclimate



Koluch-Kul Cosmic Ray Station, 4260m – new Pamirs site

Photo by A.S.Borisov @ Lebedev Physical Institute of RAS

First proposed sub-mm sites for Pamirs Large MM Array (PaLMA)

Possible logistics

Proposed telescope

SEST/NOEMA-15m antenna with main current specifications

present surface rms ≤ 27μm, η_A(86.2 GHz)=0.80, η_A(230 GHz)=0.77, η_A(345 GHz)=0.72

Primary	Diameter	15 m
	Focal Ratio	0.325
Secondary	Diameter	1,55 m
	Magnification	15,7
Cassegrain to Prime Focus		7,834 m
FWHM Beam Size at	90 GHz, 150 GHz	54″, 32″
	230 GHz, 350 GHz	21″, 14″
Panels	Surface Quality	20 μm
	Wind (5 m/s) and Gravity (15° – 75° El)	5 μm
	Thermal Deformations	5 μm
Backstructure	Wind (5 m/s) and Gravity (15° – 75° El)	15 μm
	Thermal Deformations	15 μm
Total RMS (Panels and Backstructure)		30 μm
Holography: Amplitude Weighted Surface Quality		35 μm
Pointing rms		1.5 arcsec
Tracking rms		0.2 arcsec
Max antenna speed Azimuth		1°/sec
Max antenna speed Elevation		0.5°/sec
Maximum operation wind speed		14 m/s
Survival wind speed		56 m/s
Operating Temperature Range		-20°C to +20°C

IRAM NOEMA, 2560 m – France

Panoramic view of RT-70 on the Suffa plateau

2324 m altitude (definitely not for 1 mm)

Weather at selected astronomical sites...2019 MNRAS 482, 4941

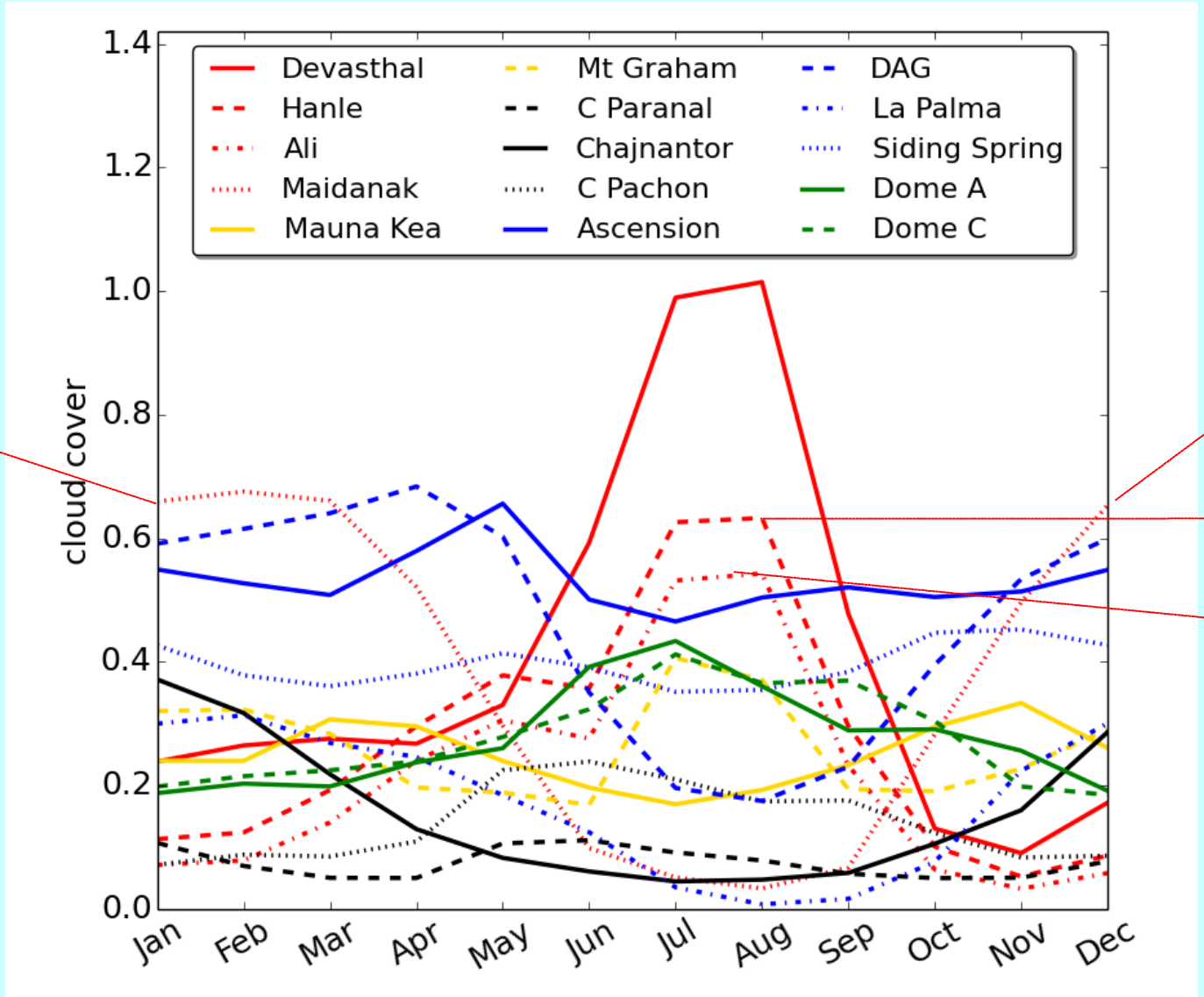
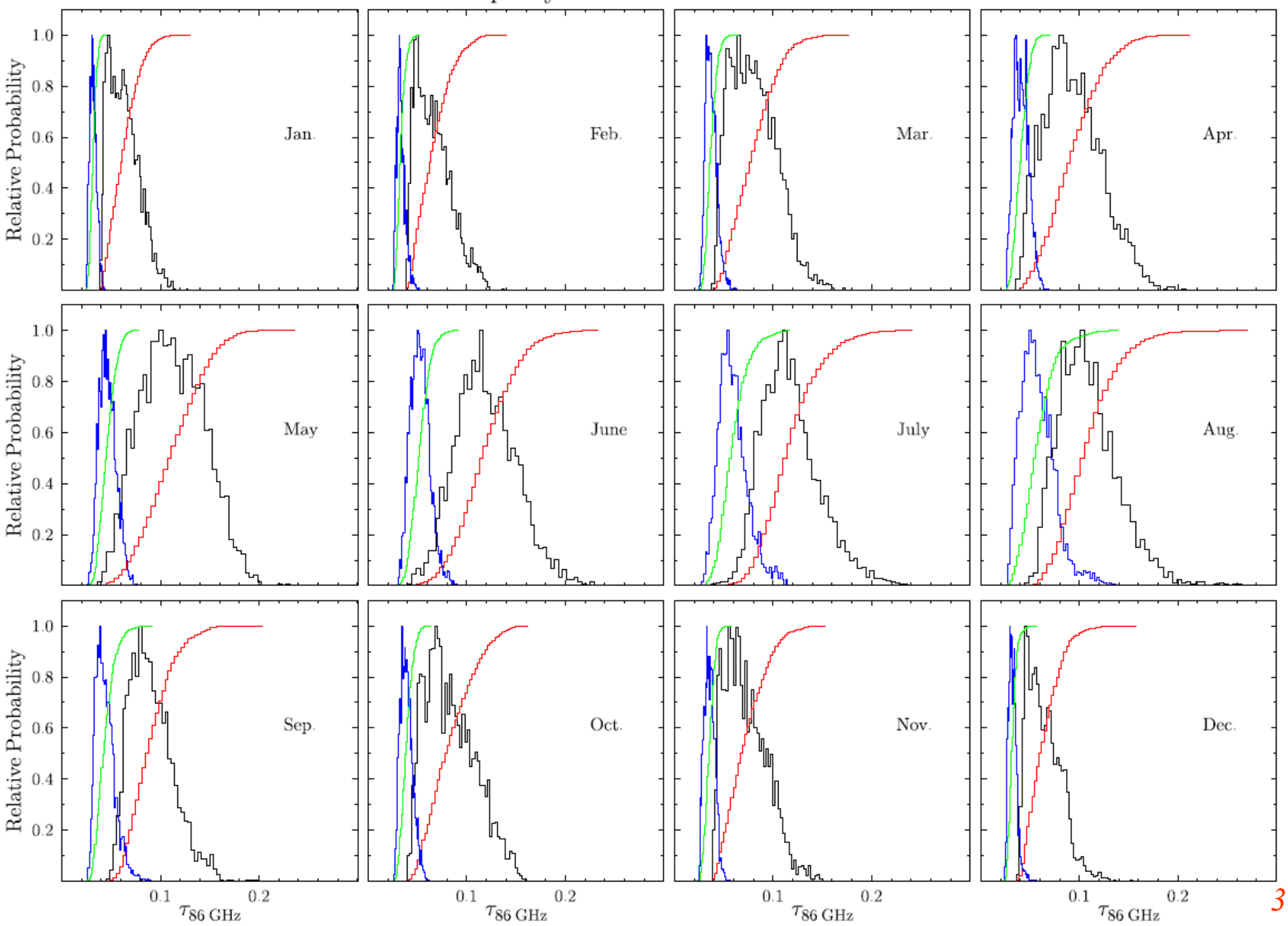
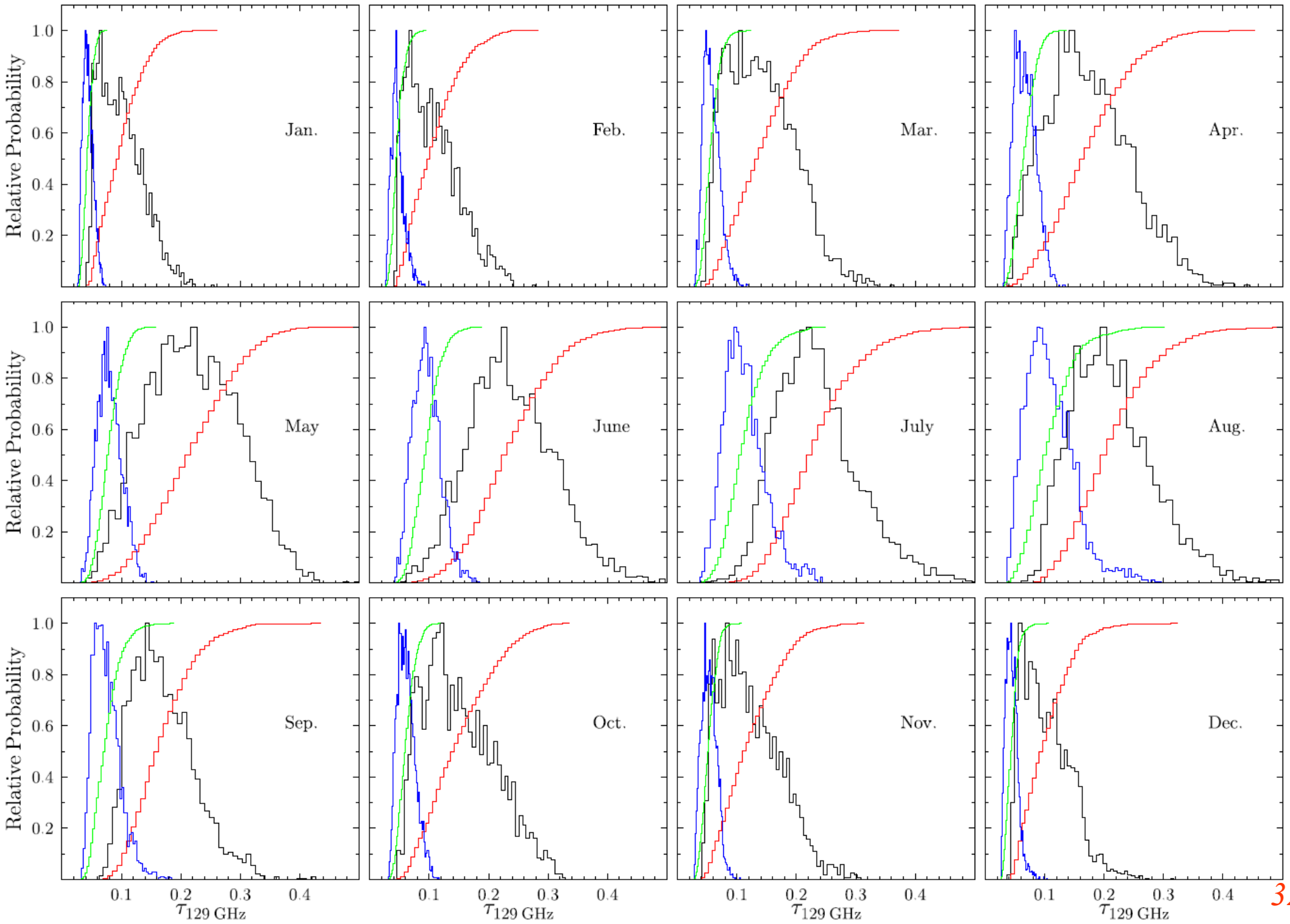
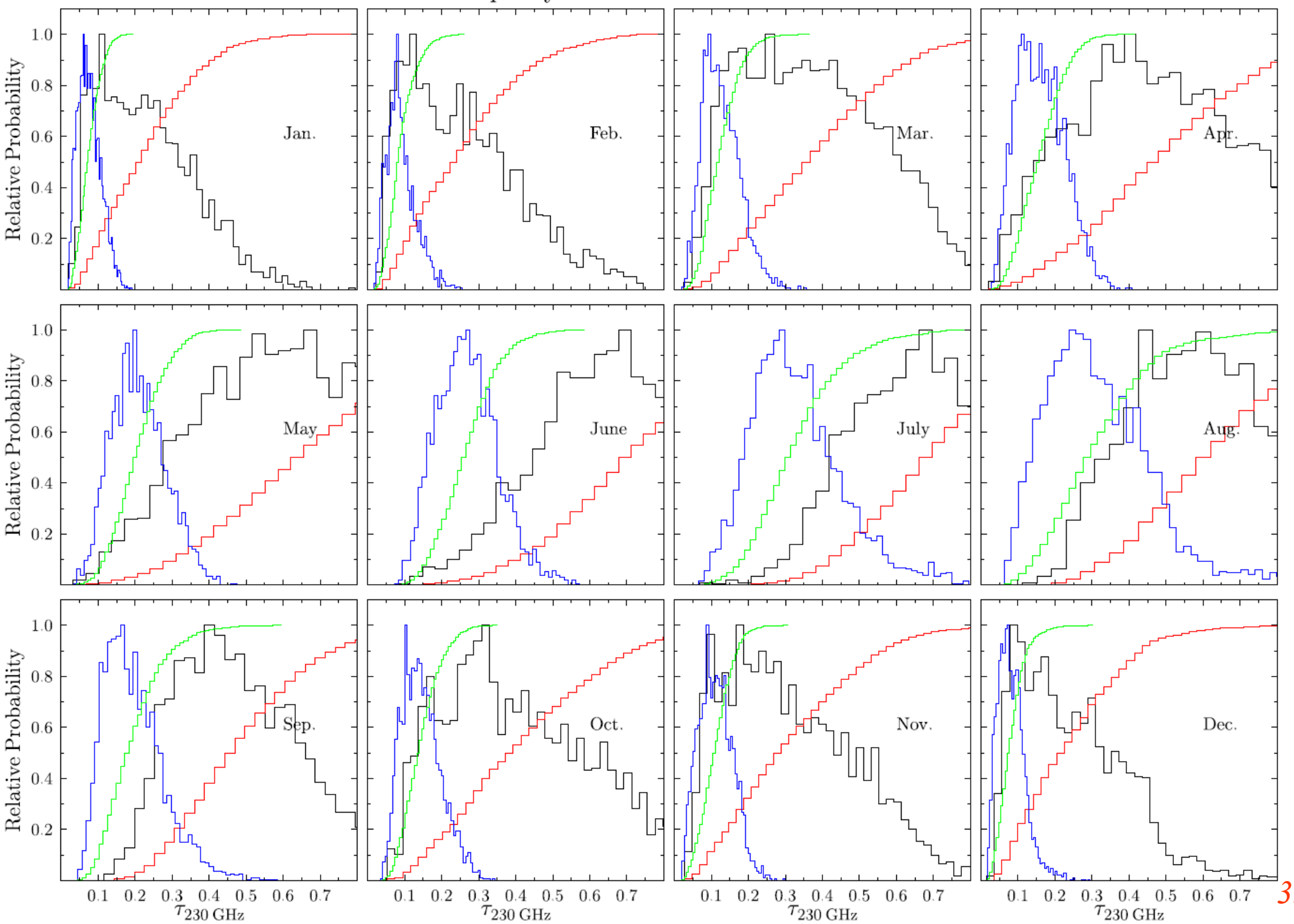


Fig. 4 Monthly averaged fractional cloud cover for Sep.1957 – Aug. 2002


Koluch-Kul & Suffa 2008-2019 zenith opacity
τ ≤ 0.1: 99.6% vs 66.3% at 86.2 GHz
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
τ86 GHz


Koluch-Kul & Suffa 2008-2019 zenith opacity
τ ≤ 0.1: 84.2% vs 22.6% at 129 GHz
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
τ129 GHz


Koluch-Kul & Suffa 2008-2019 zenith opacity
τ ≤ 0.1: 28.9% vs 5.4% at 230 GHz
Relative Probability
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
τ230 GHz

Reference

A.V. Lapinov, S.A. Lapinova, L.Yu. Petrov, D.Ferrusca *On the benefits of the Eastern Pamirs for sub-mm astronomy.* SPIE Proceedings, Vol.11453, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy X; 114532O (2020) https://doi.org/10.1117/12.2560250

Asknowlegments

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Kirill L. Maslennikov, Pulkovo observatory

Gulchehra I. Kokhirova, Institute of Astrophysics of the Tajik Academy of Sciences