CLIMATE AT THE TIMAU NATIONAL OBSERVATORY, INDONESIA

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Seimei Users Meeting (2024/09/09)

OUTLINE

- History: Modern Astronomy in Indonesia
- The need of new observatory
- Site Selection & Characterization
- Timau National Observatory
- Future direction

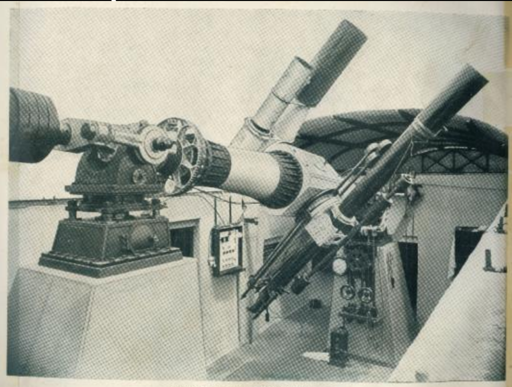
Mutis – Timau, 28 Sept 2008

Timau, 17 July 2012

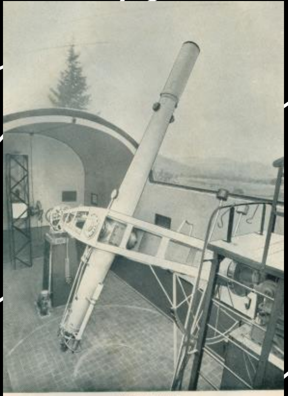
Timau, 7 May 2013

BOSSCHA OBSERVATORY: 1923

THE THIRD OBSERVATORY IN SOUTHERN HEMISPHERE

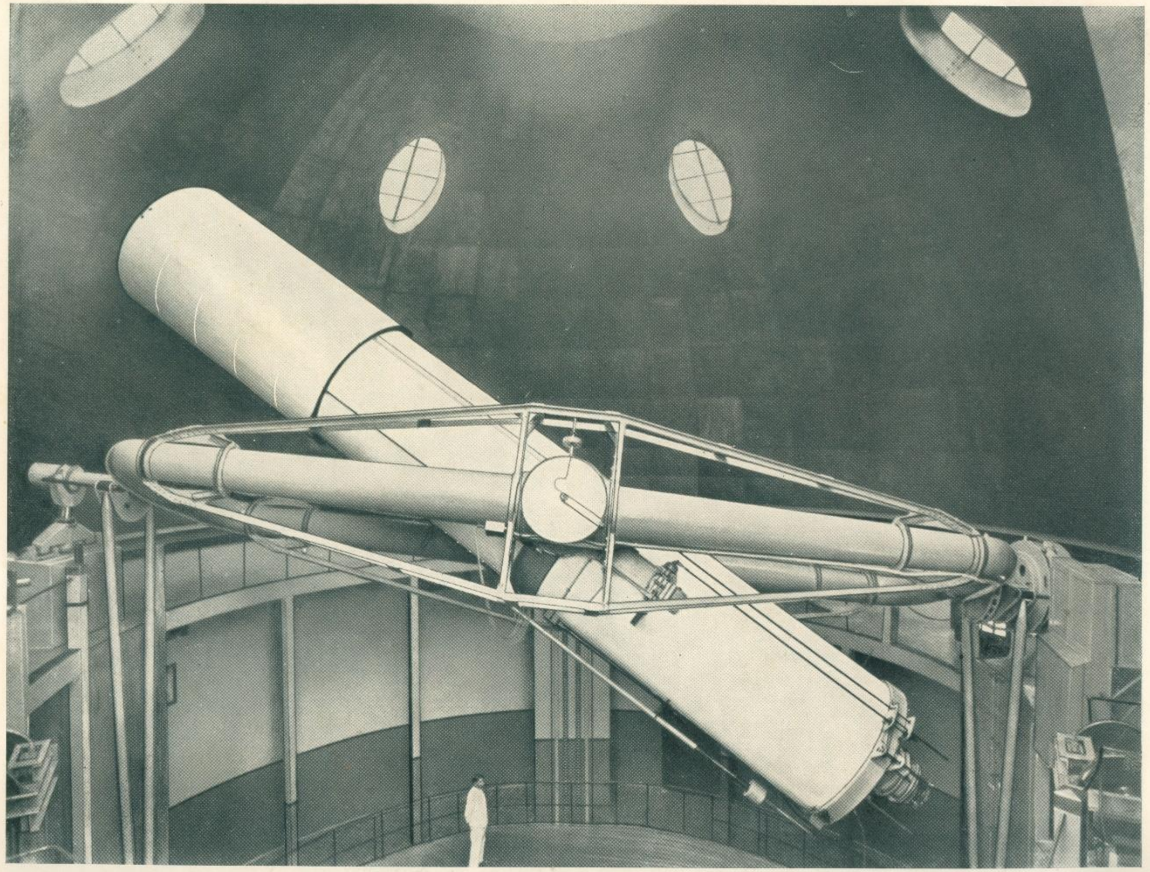


BAMBERG ASTROPHOTOGRAPHIC REFRACTOR
with a Merz 19 cm. visual telescope, two cameras resp. with a Zeiss 15 cm. UV-triplet and a Zeiss 12 cm. Astro-tessar.



BAMBERG REFRACTOR.
With a Schmidt 37 cm. visual objective.

PLATE V



ZEISS 60 cm. DOUBLE REFRACTOR.

Bosscha Observatory: still running well, but highly light polluted since 2000s

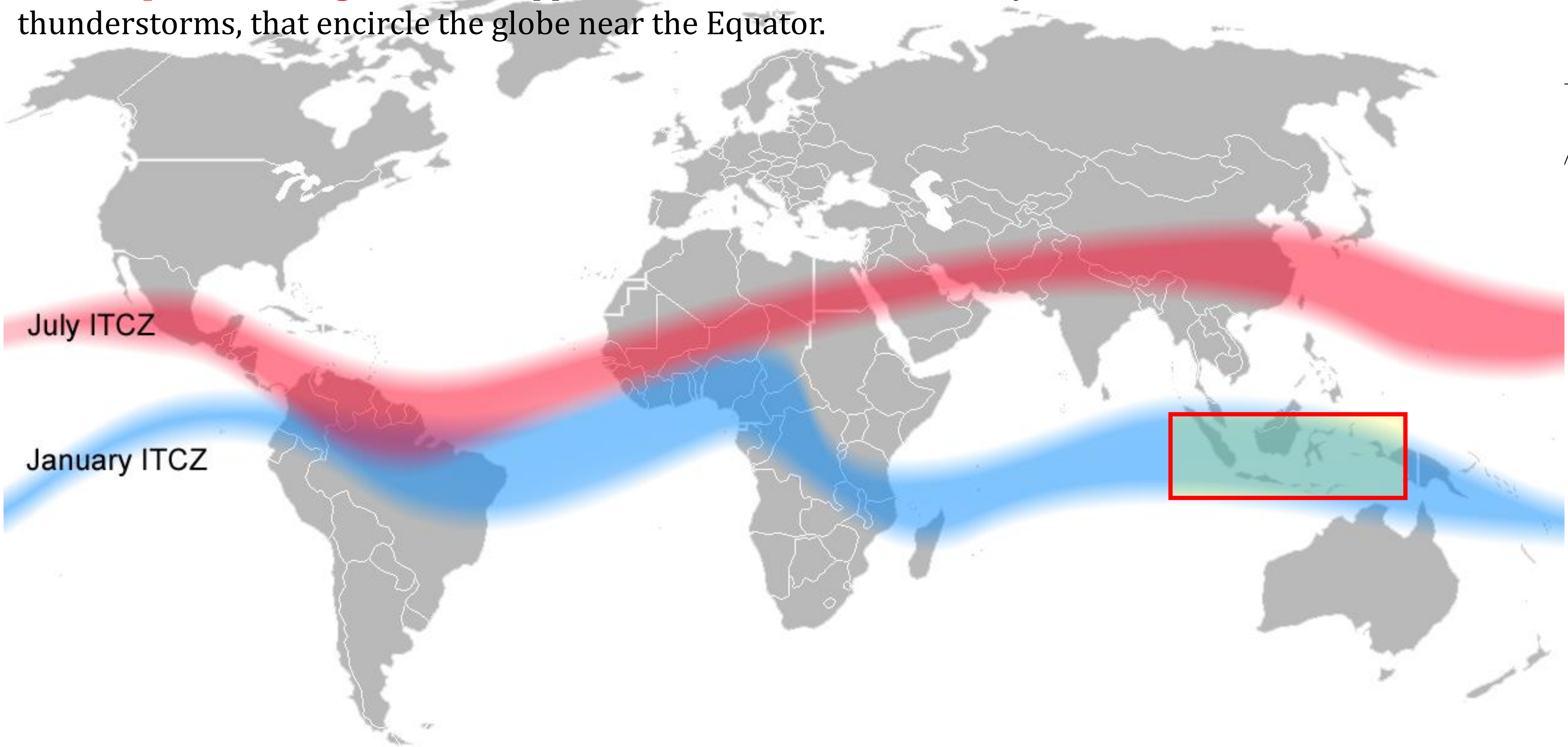
Bandung as seen from Bosscha Observatory (photo by Alfan Nasruloh) (https://alfannas.wordpress.com/my-photo-works/#jp-carousel-238)

THE NEED OF NEW OBSERVATORY

CHALLENGES FOR SITE SELECTION IN INDONESIA

- As a country with a very large area, Indonesia occupies an area that is entirely tropical: “Maritime Continent” (Ramage, 1968), complex topography
- In fact, many areas with high mountain zones, mostly active, are not entirely suitable to host an astronomical observatory
- Lack of infrastructures in remote areas, difficult to access
- Lack of meteorological ground data

Intertropical Convergence Zone appears as a band of clouds, usually thunderstorms, that encircle the globe near the Equator.



Is there "Atacama-like" site in Indonesia? A question raised in 2006...

BACKGROUND

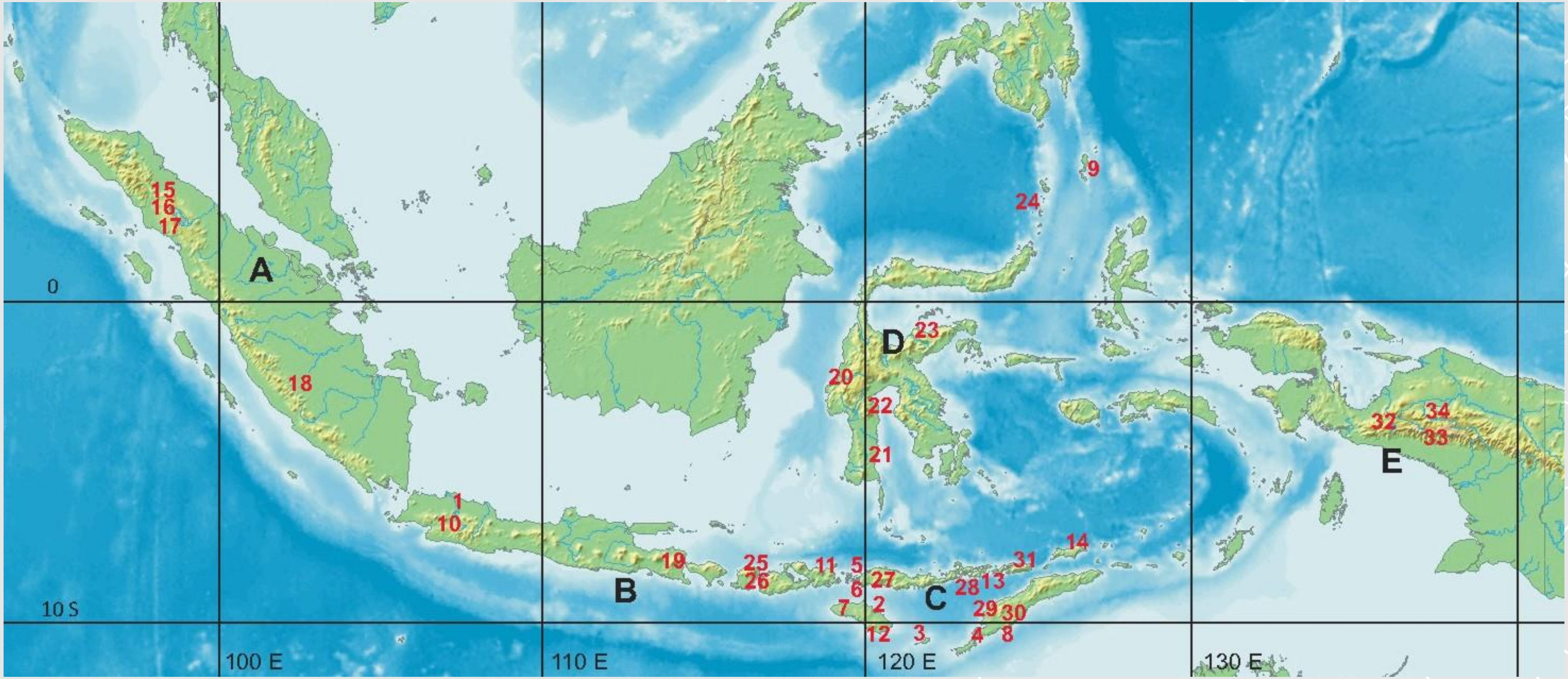
- Ground data were scarce, time consuming, budget consuming. If you need to survey 100 locations, you need at least 100 AWS. It is practically impossible.
- BMKG cannot provide data in most remote areas. Needs special permission. We have to pay too to get them!
- But, there are terabytes of data from worldwide meteorological satellites. They provide various atmospheric parameters. Spanning for decades and free! They are homogeneous...
- So, why don't we use satellite data?
- Therefore using satellite data is much more suitable to guide an initial process in our site selection.

PREVIOUS PRELIMINARY STUDIES

- Investigations on: *global atmospheric parameters (T, RH, precipitation, OLR, winds), cloud fraction, aerosol distribution, precipitable water vapour, "seeing" measurement*, ...
- Reassessment of Lembang site and tropical atmosphere: transmittance and radiance in multiwavelength (Hidayat et al. 2010)
- Hidayat et al. (2007, 2008, 2009), Lestari (2009), Hidayat et al. (2010a, 2010b), Dermawan et al. (2010), Mahasena et al. (2010), Lidinillah (2011), Farid (2011), Hidayat (2011), Ridwan (2012).
- All suggest to do *in situ measurement*, seeing condition and area survey in Kupang, Timor Barat, NTT

Study of Astroclimatology (started in 2006)

Site selection and evaluation: more than 30 regions in Indonesia were studied



USE OF METEOROLOGICAL SATELLITE DATA

GAME (GEWEX Asian Monsoon Experiment) Data from: **GMS 5, GOES 9, MTSAT-1R** (GEWEX = Global Energy and Water Experiment)

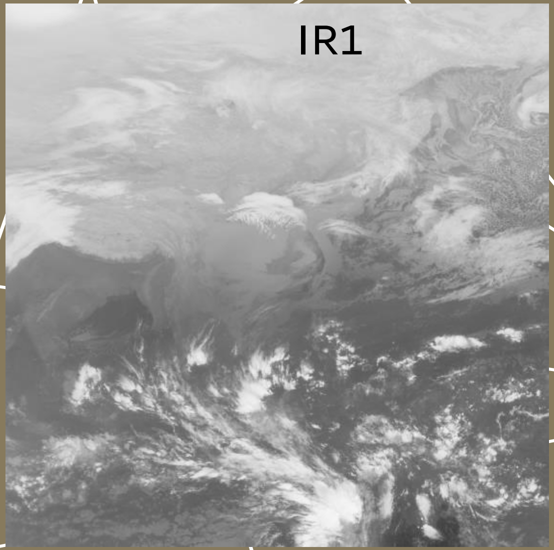
Coverage: N70 – S20, E70 – E160, so the whole Indonesia is covered.

Observations since mid-1995 to present

Spatial resolution: 1/20° in *pgm* format (portable gray map, image), recorded in 1800 × 1800 pixels; equivalent to 5 km.

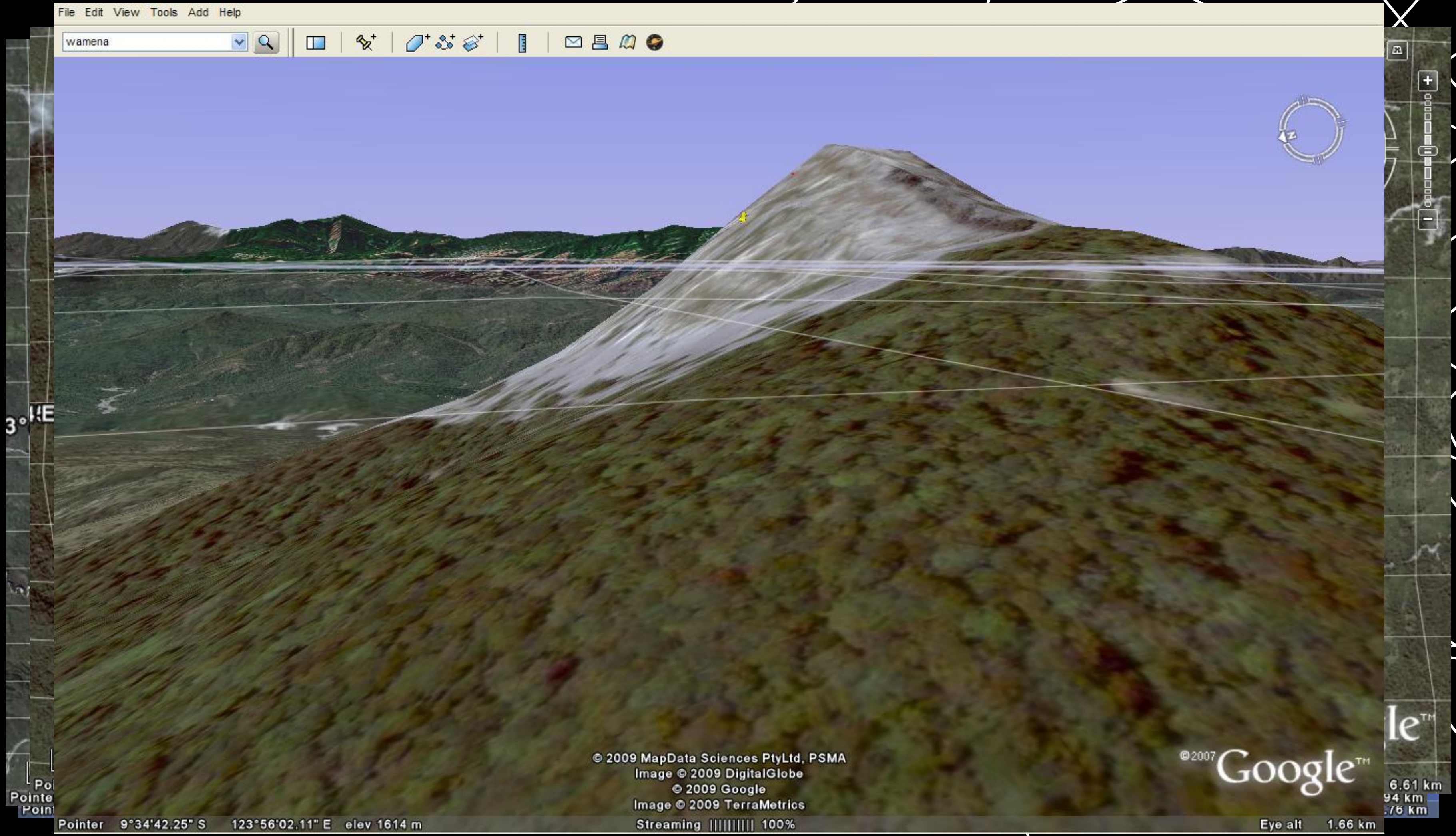
CHANNEL DATA OF METEOROLOGICAL SATELLITE

Channel	Wavelength (μm)
IR1	10,3 – 11,3
IR2	11,5 – 12,5
IR3 (water vapor)	6,5 – 7,0
IR4 (NIR)	3,5 – 4,0
VIS (albedo)	0,55 – 0,90



TIMAU WAS "TERRA INCOGNITA"

Timau Expedition I, II, III
(28 Sept. 2008, 17 Aug, and 17 Sept. 2009)



Site Survey (2006 – 2012)

Kalimantan Barat, Sulawesi Tengah, Jawa Timur, Timor, ...





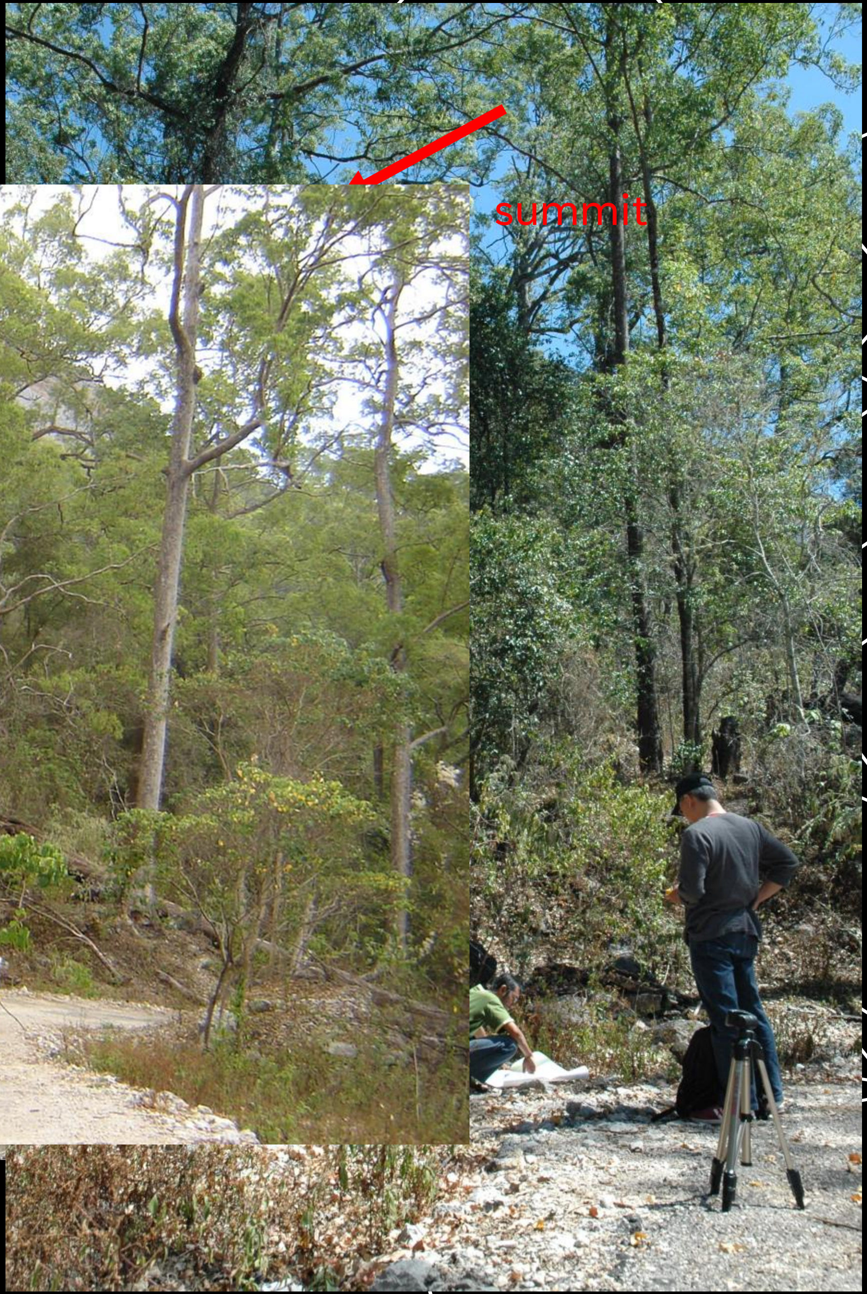

Fatumetan (Lelogama), 123° 59' 17.1'' E, 9° 40' 35.9'' S, 1028 m

FINALLY TO TIMAU

17 Agustus 2009

17 Sept 2009

TIMAU EXPEDITION II



We are closer...

“Batu Reok” (Timau), 123° 56' 29.9'' E, 9° 35' 8.0'' S, 1428 m

TIMAU EXPEDITION III (17 SEPT. 2009)

View from Timau

CLOUD COVER (CLEAR SKY FRACTION)

- Clear sky fraction (Hidayat *et al.* 2012) using meteorological satellite data spanning for 15 years (1996-2010).
- Analysing 32 locations in Indonesia (Sumatra, Java, Sulawesi, NTB, NTT, and Papua): reference sites, low altitude sites, and mountain sites
- Using data from *Geostationary Meteorological Satellite* 5 (GMS 5), *Geostationary Operational Environmental Satellite* 9 (GOES 9), dan *Multi-functional Transport Satellite*-1R (MTSAT-1R), providing 5 km spatial resolution (HIMAWARI series)
- Cloud detection: Adopting thresholding method (Soden & Bretherton 1996, Erasmus & Sarazin 2002)
- Using channel IR3 (6.7 µm) and IR1 (10.7 µm)

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **427**, 1903–1917 (2012)   doi:10.1111/j.1365-2966.2012.22000.x

Clear sky fraction above Indonesia: an analysis for astronomical site selection

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ABSTRACT

We report a study of cloud cover over Indonesia based on meteorological satellite data spanning 15 years (from 1996 to 2010) to aid in the selection of a new astronomical site capable of hosting a multi-wavelength astronomical observatory. High-spatial-resolution meteorological satellite data acquired from *Geostationary Meteorological Satellite 5* (*GMS 5*), *Geostationary Operational Environmental Satellite 9* (*GOES 9*) and *Multi-functional Transport Satellite-1R* (*MTSAT-1R*) are used to derive yearly average clear fractions over various regions of Indonesia. This parameter is determined from temperature measurements in the IR3 channel (water vapour, 6.7 µm) for high-altitude clouds (cirrus), and from the IR1 channel (10.7 µm) for lower-altitude clouds. An algorithm is developed to detect the corresponding clouds. The results of this study were used to select the best possible sites in Indonesia, which will be analysed further by performing in situ measurements in the future. The results suggest that regions of East Nusa Tenggara, located in southeastern Indonesia, are the most promising candidates for such an astronomical site. The yearly clear sky fraction of this region may reach better than 70 per cent, with an uncertainty of 10 per cent.

Key words: atmospheric effects – methods: statistical – site testing.

et al. 2006, 2007, 2008), and also in Calar Alto (Sánchez et al. 2007)

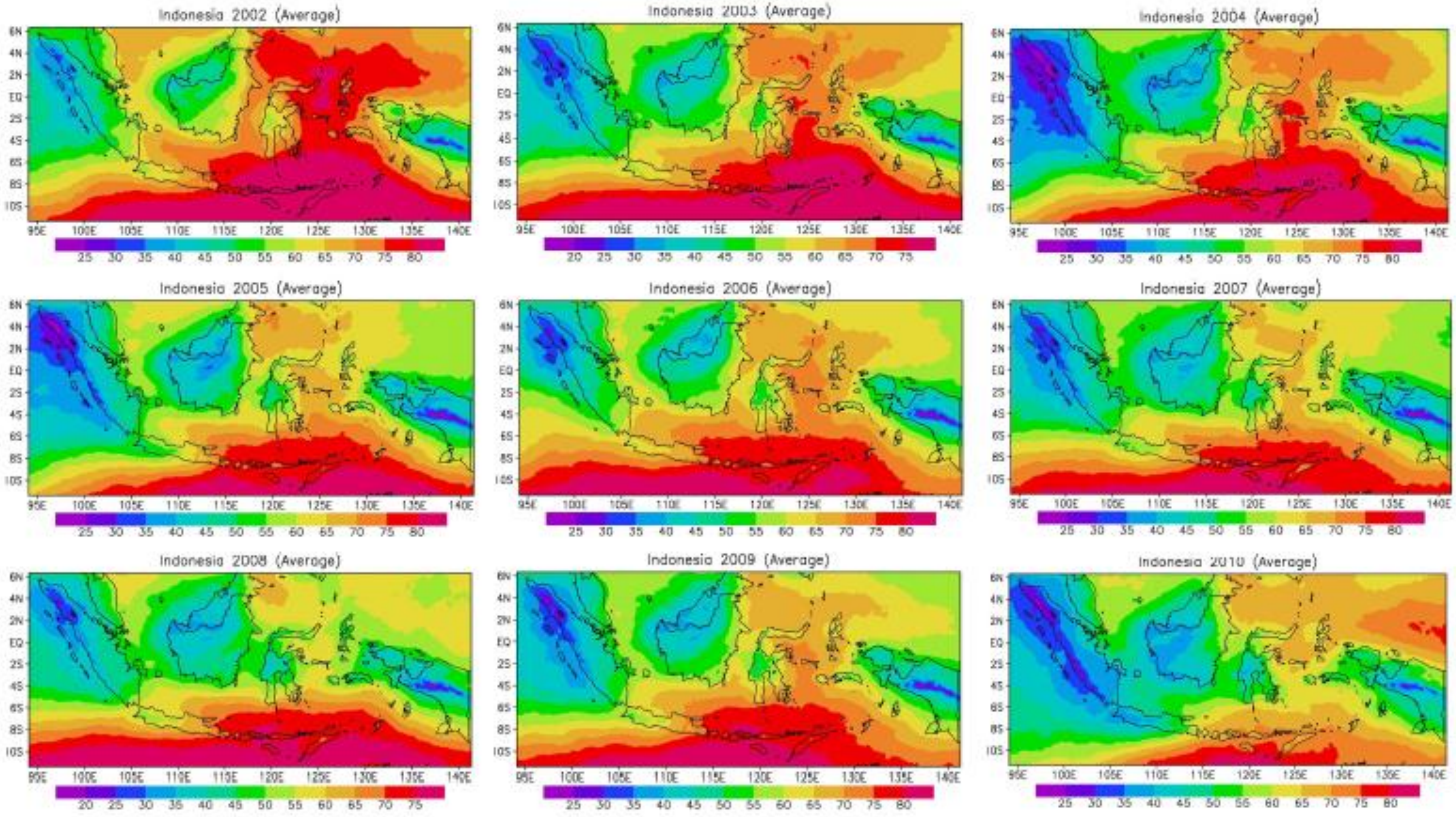


Figure 5. Yearly average clear sky fraction in Indonesia from 1996 to 2010. Note that the scale in the legend is not the same for each figure. We see that south-eastern part is consistently clear.

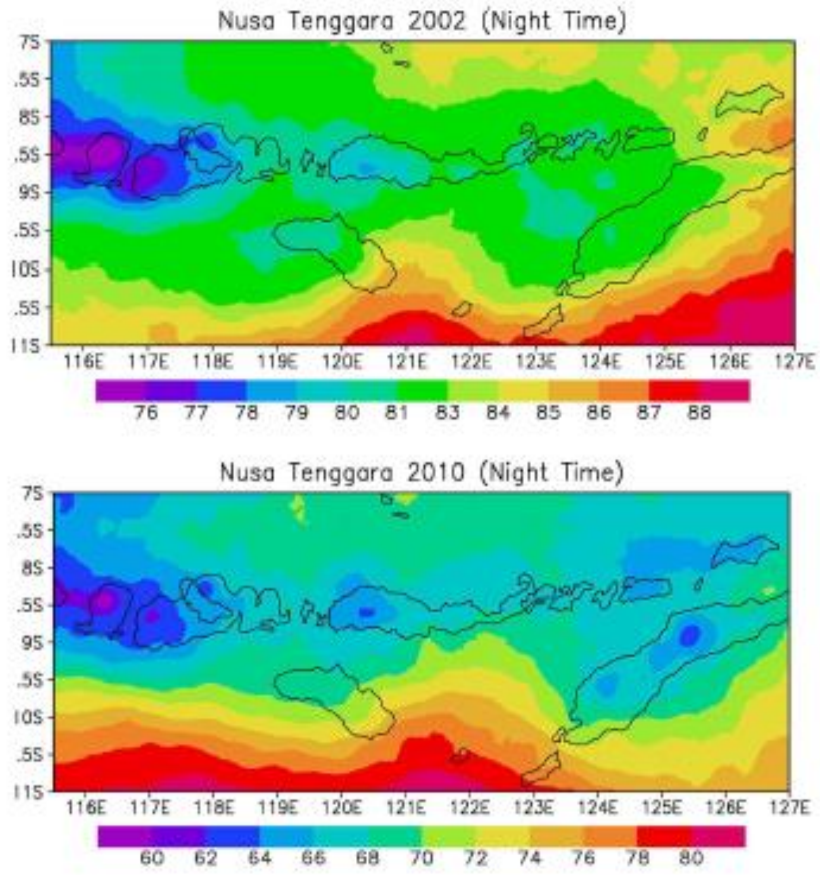
(Hidayat et al. 2012)

(HIDAYAT ET AL. 2012)

Table 4. Mean of 15 years of the night fraction in percentage

Sites	Cl.	Tr.	Op.	Usable	σ*
(4) Sawu**	65.0	4.1	30.9	69.1	5.9
(3) Kupang**	61.6	4.6	33.7	66.3	6.0
(29) Timau	58.6	4.6	36.7	63.3	6.3
(12) S. Waingapu	58.2	4.5	37.3	62.7	7.8
(31) Alor	57.1	5.6	37.4	62.6	6.3
(30) Mutis	57.1	4.7	38.2	61.8	6.5
(26) Rinjani 2	56.2	5.5	38.3	61.7	6.1
(27) Ruteng	56.3	5.1	38.5	61.5	6.9
(25) Rinjani 1	55.1	5.6	39.3	60.7	6.0
(11) E. Sumbawa	55.2	5.2	39.5	60.5	8.2
(14) Wetar	54.3	5.6	40.1	59.9	7.3
(13) Sirung	54.4	5.1	40.6	59.4	7.3
(28) Lembata	54.3	4.9	40.8	59.2	7.5
(19) West Ijen	49.8	5.9	44.3	55.7	6.3
(24) Sangihe-Siau	44.8	8.0	47.1	52.9	8.7
(23) Binohoe	39.4	8.0	52.6	47.4	8.5
(10) Lembang**	33.8	5.5	60.7	39.3	8.2
(22) Rantemario	25.1	6.1	68.8	31.2	8.8
(18) Kerinci	24.1	6.5	69.4	30.6	3.8
(20) Tibo	22.5	6.2	71.3	28.7	7.8
(21) Lombosang	38.3	6.0	71.3	28.7	8.6
(15) Sinabung	13.0	4.7	82.3	17.7	4.4
(16) Sibayak	12.3	4.5	83.2	16.8	4.0
(17) Silimapuluh	12.2	4.5	83.2	16.8	3.9
(32) Erekebo	9.3	5.2	85.5	14.5	5.3
(34) P. Jaya 2	8.9	5.4	85.6	14.4	3.5
(33) P. Jaya 1	2.9	4.0	93.0	7.0	3.0

Notes: *Standard deviation of usable night; **Reference site; Cl. = clear, Tr. = Transitional, Op. = opaque; the number in the bracket corresponds to the site number (see Table 3).



Figur... for con... wester... 02 (the best) and 2010 (the worst) both in day time and night time for each figure. Notice again that the eastern part is clearer than the

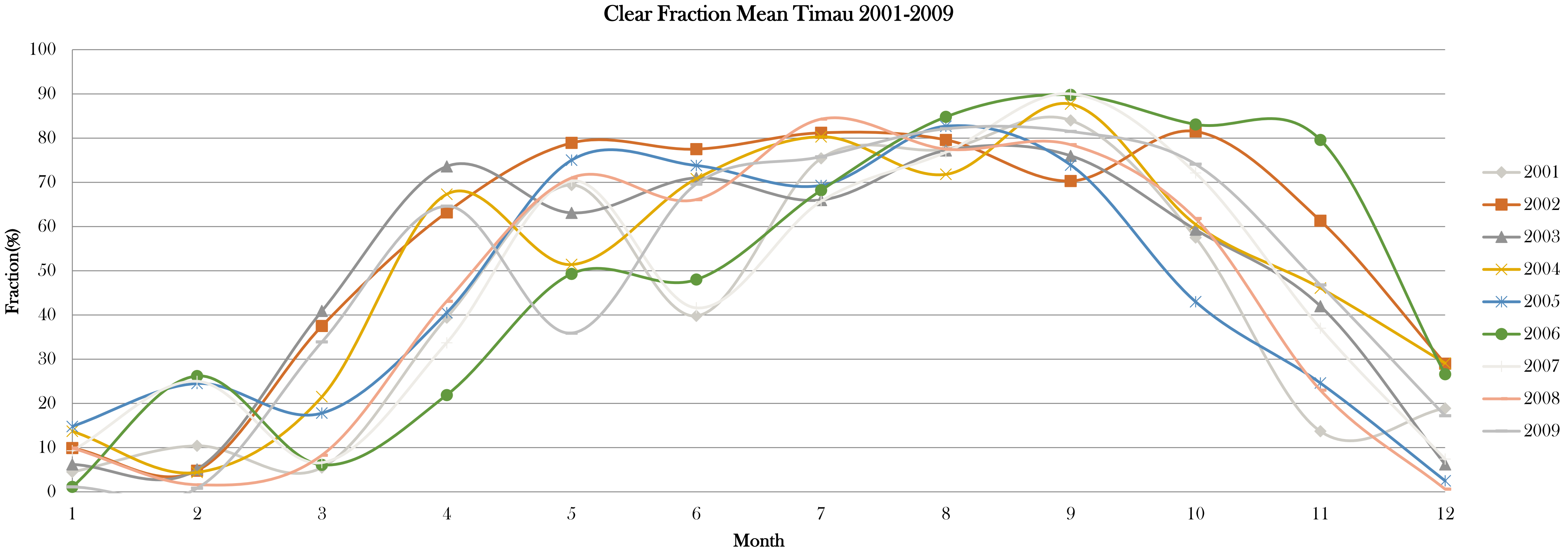
Main results: **Nusa Tenggara Timur** provides the best clear fraction: ~70% with uncertainty of 10% comparable to the best sites in west coast of America and some Chilean sites in terms of cloud cover.

USE OF NASA-EOS (AQUA & TERRA)

- Verification of Hidayat et al. (2012) using **independent measurement**: we choose data from *Moderate Resolution Imaging Spectroradiometer* (MODIS) onboard NASA-EOS Terra Satellite (since 2000); prior to *in situ* measurement
- Altitude: 705 km, *polar sun-synchronous orbiting satellite*
- Period: 99 min (16 orbits/day)
- Different retrieval algorithm (King et al. 1997, 2003; Mote & Frey 2006, Wind et al. 2010)

CLEAR FRACTION IN TIMAU

Very clear.
Clear Fraction between **May -October ~70-80%**



MORE RECENT STUDIES

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 511, 5363–5371 (2022) https://doi.org/10.1093/mnras/stac408

New analysis of the fraction of observable nights at astronomical sites based on *FengYun*-2 satellite data

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ABSTRACT
The fraction of observable nights is an essential parameter for selecting astronomical sites. In recent years, meteorological satellite data have played an essential role in recognizing and providing statistics of observable nights. We present a method to estimate the fraction of observable nights based on the *FengYun*-2 series of geostationary meteorological satellites and weather records of multiple astronomical sites. We have calculated the fraction of observable nights at 27 sites in Indonesia and two astronomical sites in China to validate the method. The results derived from our method show good agreement with previous works. Furthermore, we have derived the yearly distribution of the fraction of observable nights above China, which indicates that the area near 40°N has more observable nights than other areas in China.

Key words: site testing – methods: statistical – methods: data analysis.

1 INTRODUCTION

When researchers perform search campaigns (e.g. Erasmus & Sarazin 2001; Sarazin, Graham & Kurlandczyk 2006; Ma et al. 2020) observation logs are essential and can robustly characterize observing conditions. Such logs are usually detailed and accurate because observers record the observing conditions for every night that astronomical observations are carried out. However, observation logs

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 518, 4073–4083 (2023) https://doi.org/10.1093/mnras/stac3349

Characterization of Timau National Observatory using limited *in situ* measurements

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ABSTRACT
A new astronomical observatory in south-eastern Indonesia is currently under construction. This Timau National Observatory will host a 3.8-m telescope for optical and near-infrared observations. To support the operation and planning, the characterization of the site needs to be appropriately performed. However, limited resources and access to the site hindered the deployment of instruments for comprehensive site testing. Fortunately, *in situ* sky brightness data from the Sky Quality Meter (SQM) have been available for almost 2 yr. Based on the data acquired in 470 nights, we obtain a background sky brightness of $\mu_0 = 21.86 \pm 0.38$ mag arcsec^{-2}. Additionally, we evaluate the moonlit sky brightness to estimate the atmospheric extinction coefficient (k) and level of scattering on site. We find an elevated value of $k = 0.48 \pm 0.04$, associated with a high atmospheric aerosol content. It is considered regular for an equatorial area situated at a low altitude (∼1300 masl). By analysing the fluctuation of the sky brightness and infrared images from *Himawari-8* satellite, we estimate the available observing time (AOT) of at least 5.3 h/night and the yearly average percentage of usable nights of 66 per cent. The monthly average AOT from SQM and satellite data

Priyatikanto et al. (2023): By analysing the fluctuation of the sky brightness and infrared images from *Himawari-8* satellite, we estimate the available observing time (AOT) of at least 5.3 h/night and the yearly average percentage of usable nights of **66 per cent**.

Lembang 40% = 146 days, ~4,9 month
Timau 63% = 230 days, ~7,7 month

Table 4. Mean of 15 years of the night fraction as a percentage.

Site	Cl.	Tr.	Op.	Usable	σ*
(4) Sawu**	65.0	4.1	30.9	69.1	5.9
(3) Kupang**	61.6	4.6	33.7	66.3	6.0
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Notes: *Standard deviation of usable night; **reference site; Cl., clear; Tr., transitional; Op., opaque; the number in brackets corresponds to the site number (see Table 3).

Hidayat et al. (2012)

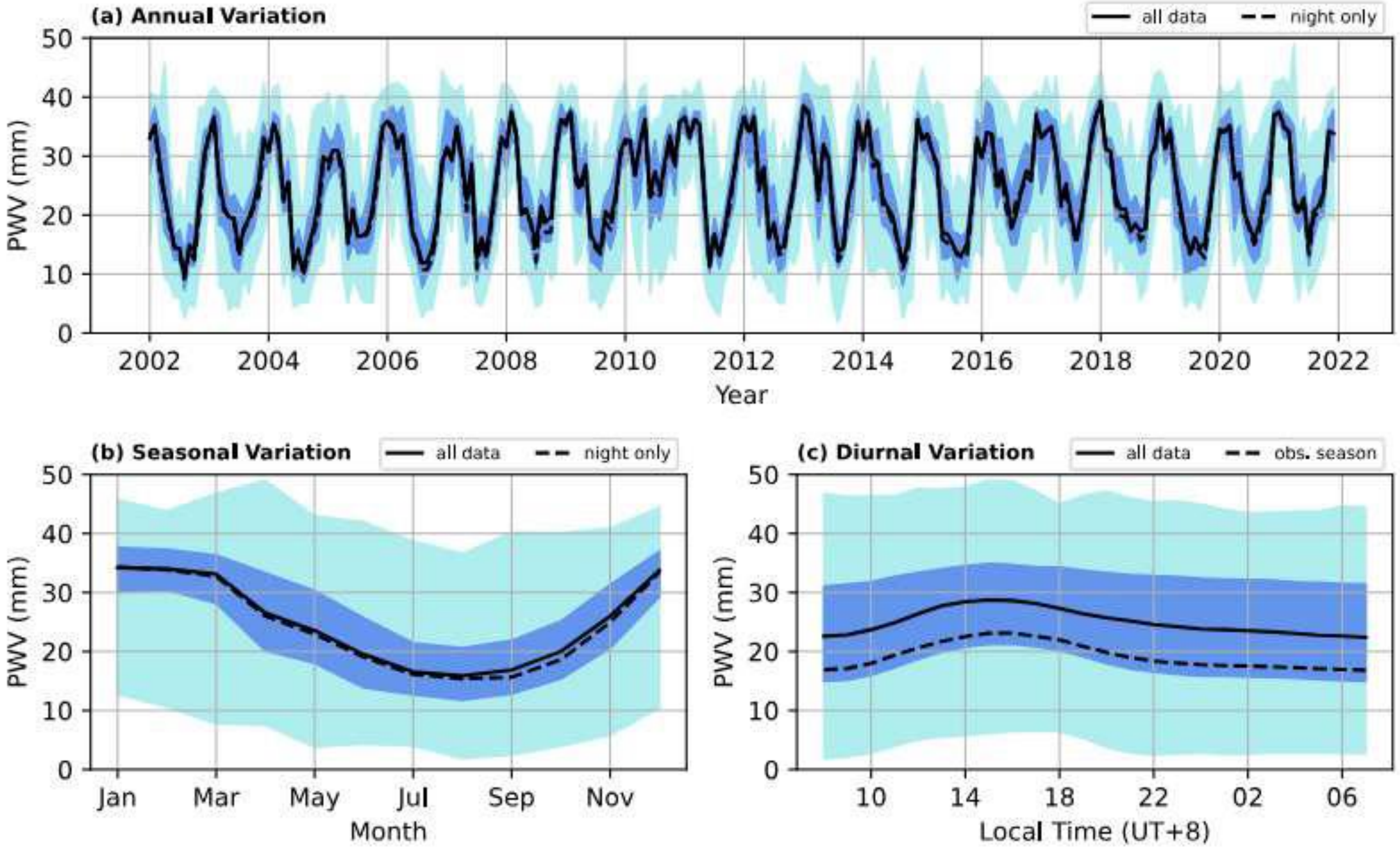
Table 4. Yearly FON from 2008–2010 for 27 sites in Indonesia.

Site	Hidayat et al. (2012)			This work			Hidayat et al. (2012) – this work			
	2008 (%)	2009 (%)	2010 (%)	2008 (%)	2009 (%)	2010 (%)	2008 (%)	2009 (%)	2010 (%)	Average (%)
Alor	65.10	65.30	57.60	52.02	65.23	48.73	13.08	0.07	8.87	7.34
Binohoe	42.80	51.00	50.50	17.73	46.89	20.40	25.07	4.11	30.10	19.76
E Sumbawa	67.00	66.80	59.00	57.70	72.48	49.90	9.30	– 5.68	9.10	4.24
Erekebo	9.60	14.00	16.90	6.37	19.23	9.45	3.23	– 5.23	7.45	1.82
Kerinci	32.30	32.80	32.00	22.11	35.11	8.35	10.19	– 2.31	23.65	10.51
Kupang	67.90	69.80	64.50	58.80	70.43	55.85	9.10	– 0.63	8.65	5.71
Lembang	44.10	45.70	24.70	44.90	53.18	23.00	– 0.80	– 7.48	1.70	– 2.19
Lembata	63.90	64.50	59.50	54.00	67.97	48.60	9.90	– 3.47	10.90	5.78
Lombosang	43.70	51.70	36.10	34.50	52.09	18.07	9.20	– 0.39	18.03	8.95
Mutis	63.80	65.70	58.90	56.54	70.36	54.35	7.26	– 4.66	4.55	2.38
P Jaya 1	4.60	6.60	9.70	7.12	22.66	10.54	– 2.52	– 16.06	– 0.84	– 6.47
P Jaya 2	11.00	13.90	19.70	6.09	19.99	13.35	4.91	– 6.09	6.35	1.72
Rantemario	25.10	35.40	20.00	21.70	42.71	11.36	3.40	– 7.31	8.64	1.58
Rinjani 1	63.20	65.10	56.60	57.43	68.38	49.28	5.77	– 3.28	7.32	3.27
Rinjani 2	64.10	65.90	57.20	56.88	69.40	49.90	7.22	– 3.50	7.30	3.67
Ruteng	65.20	64.40	58.10	59.41	70.77	50.72	5.79	– 6.37	7.38	2.27
S Waingapu	68.20	69.50	66.90	58.80	72.01	50.10	9.40	– 2.51	16.80	7.90
Sangihe-Siau	46.70	53.70	55.50	24.57	46.00	46.54	22.13	7.70	8.96	12.93
Sawu	72.20	71.40	71.80	61.67	71.39	59.89	10.53	0.01	11.91	7.48
Sibayak	15.00	15.30	15.70	10.47	19.64	7.80	4.53	– 4.34	7.90	2.70
Silimapuluh	15.50	16.50	16.20	11.50	20.81	5.54	4.00	– 4.31	10.66	3.45
Sinabung	16.20	15.20	16.70	10.13	19.85	7.73	6.07	– 4.65	8.97	3.46
Sirung	63.10	65.40	59.70	53.32	67.08	48.73	9.78	– 1.68	10.97	6.36
Tibo	23.10	32.30	20.30	20.05	41.75	10.54	3.05	– 9.45	9.76	1.12
Timau	65.20	66.30	59.80	56.40	70.09	55.03	8.80	– 3.79	4.77	3.26
West Ijen	58.70	60.60	48.70	53.59	64.89	43.12	5.11	– 4.29	5.58	2.13
Wetar	64.30	63.20	56.90	50.99	62.97	48.19	13.31	0.23	8.71	7.42

Wang et al. (2022)

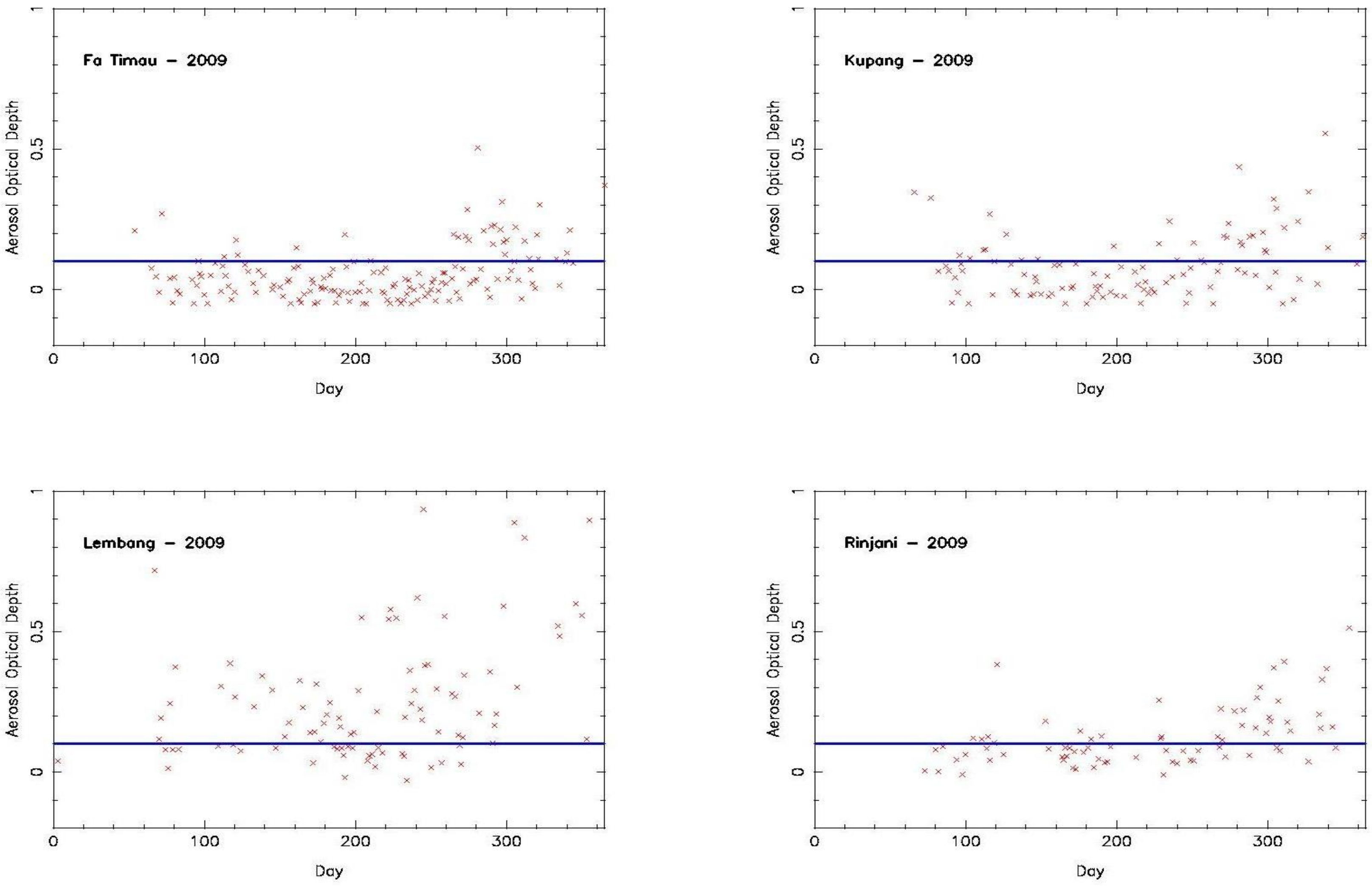
PWV

- Priyatikanto et al. (2024): At Timau, PWV fluctuates between 3 to 45 mm.
- Relative humidity of around 69%



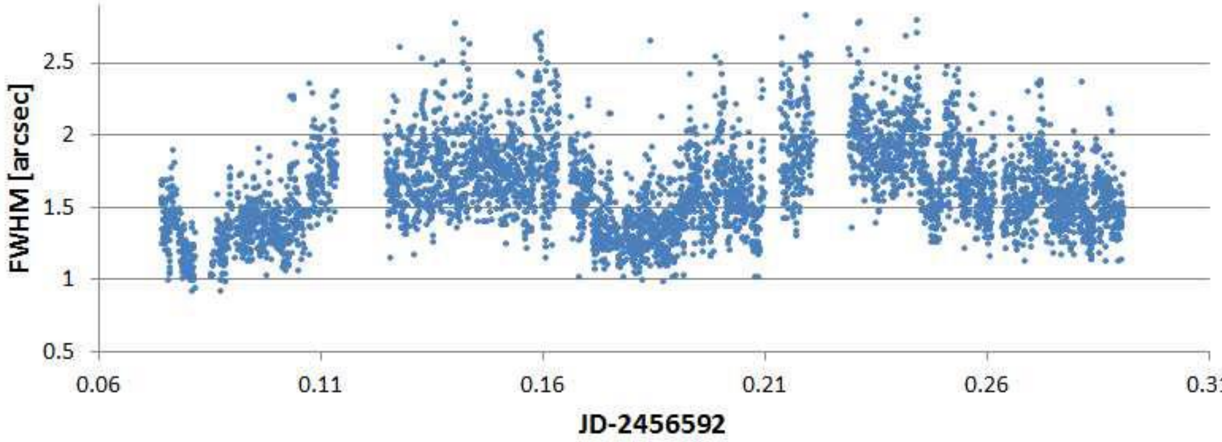
AEROSOL CONTENT (AOD)

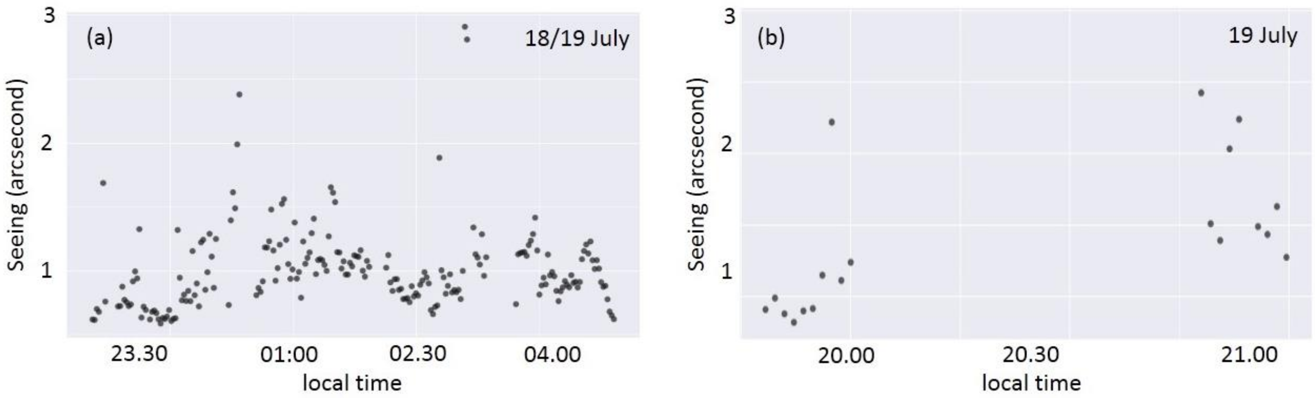
No	Site	Dusty days (%)
1	Timau	10.95
2	Kupang	9.03
3	Lembang	21.71
4	Rinjani	10.76

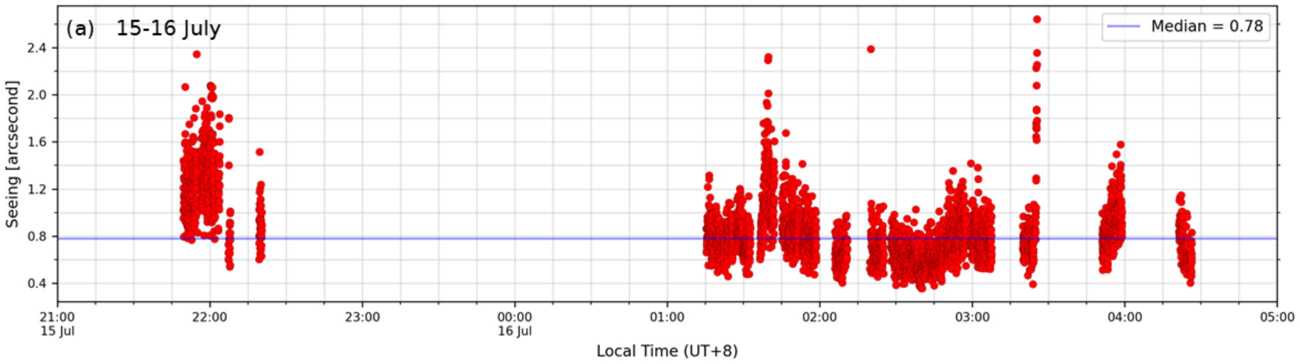


SEEING

- Dermawan et al. (2010): seeing conditions at Kupang are ~50% better than that of Lembang.
- Mahasena et al. (2013): 0.55 – 1.65 arcsecond
- Akbar et al. (2018): median of 0.93 arcsecond and sky brightness around 22.18 magnitude per arcsecond square after midnight.
- Saputra et al. (2022): 0.92 arcseconds and most sky brightness values are around 22.02 magnitude per square arcsecond

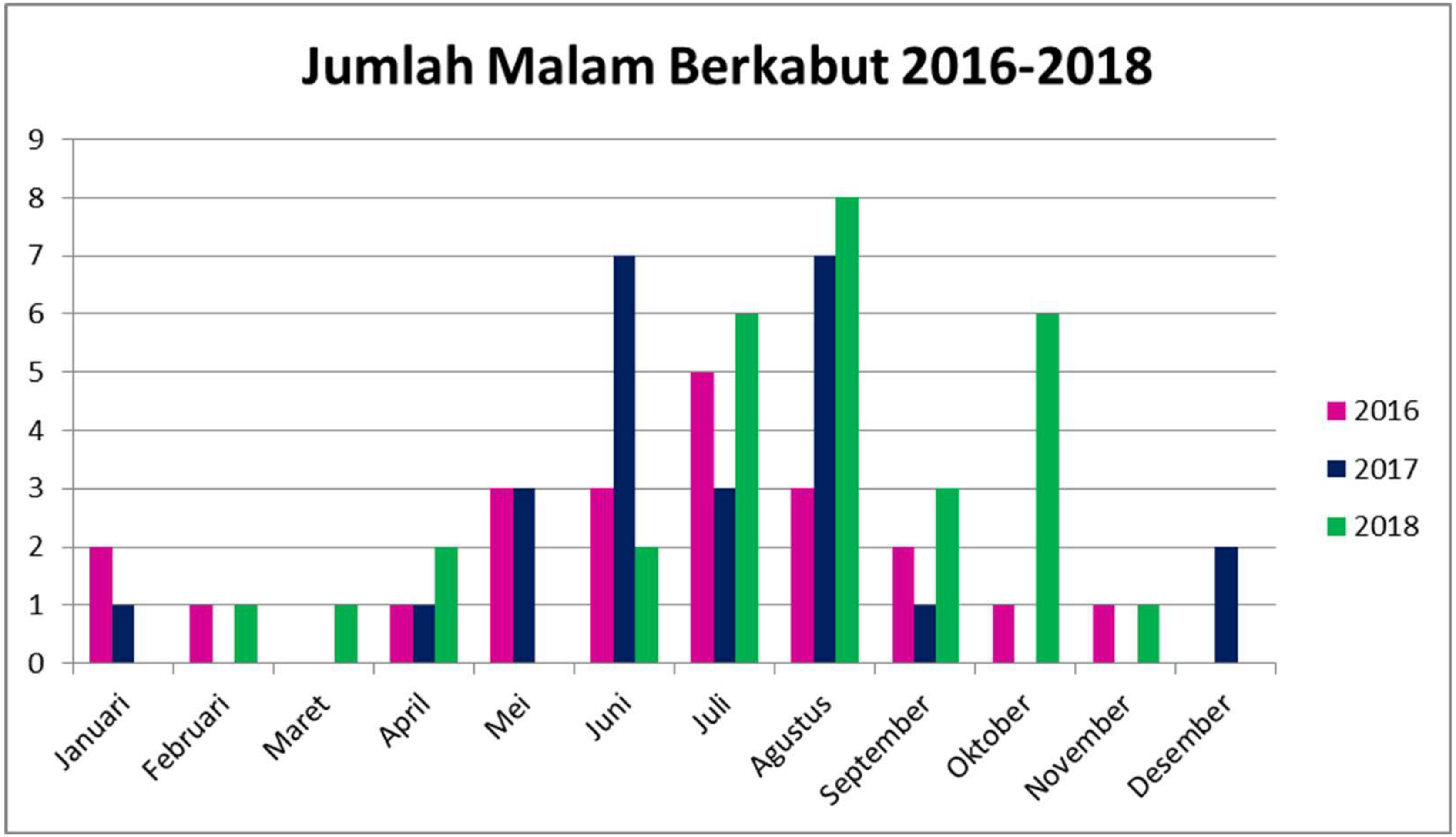


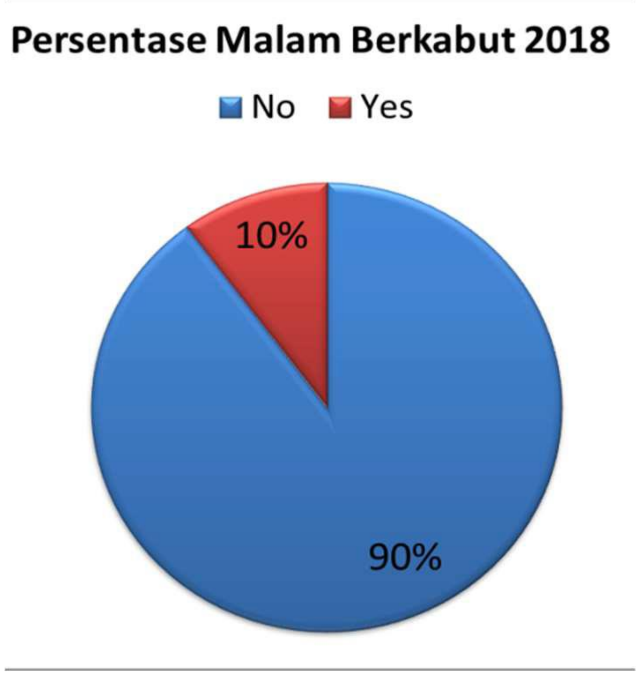




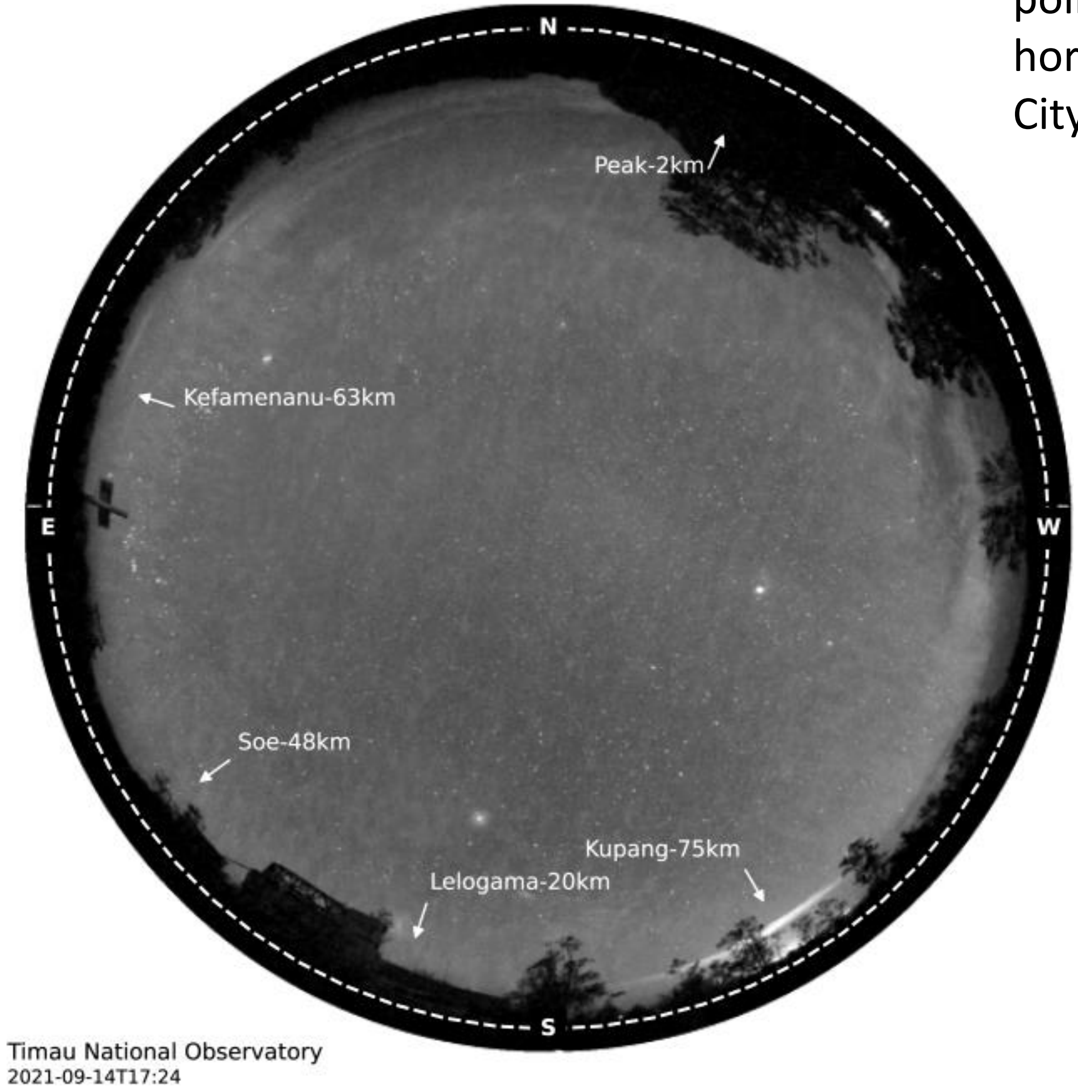
NIGHT TIME FOG DETECTION BASED ON MODIS DATA

Using Chaurasia et al. (2011) Algorithm

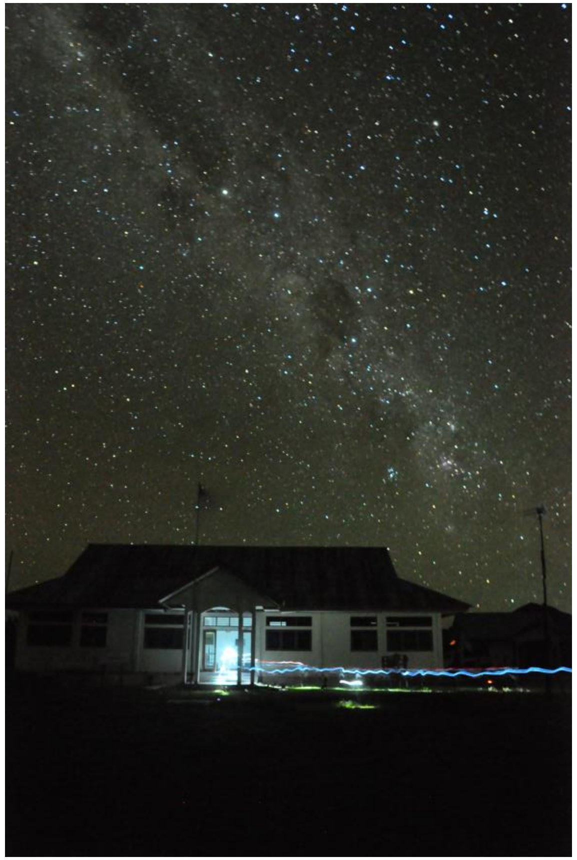




LIGHT POLLUTION

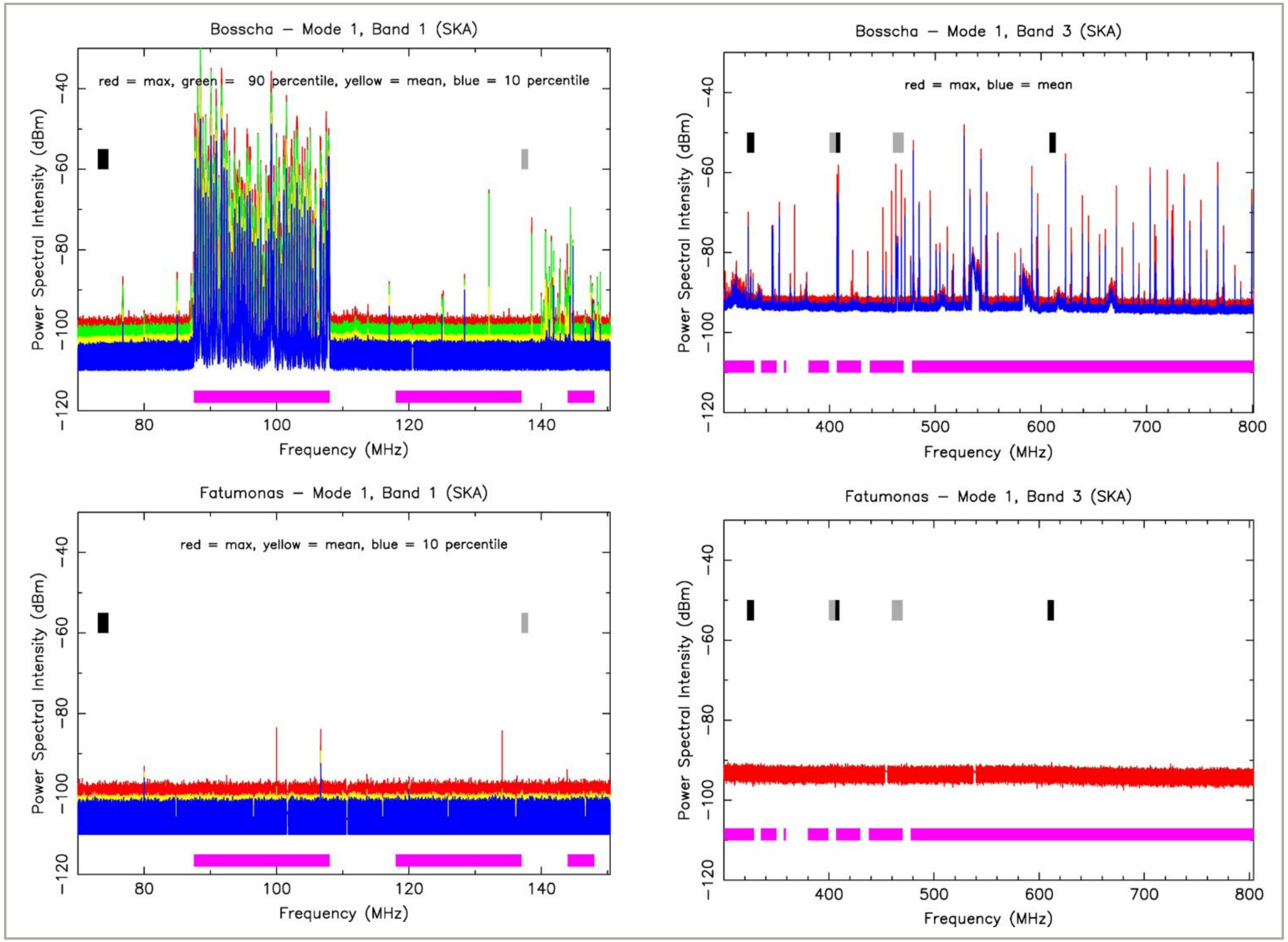


Priyatikanto et al. (2023): All-sky image acquired at Timau on 2021 September 14 shows a starry dark sky with little light pollution at the south–south-west horizon, which is coming from Kupang City.



Radio Frequency Environment (RFI) in Timau (Hidayat et al. 2014)

The Fatumonas site in West Timor, near the observatory location, is exceptional!



CONCLUSION

- Timau is very suitable for optical measurements
- Infrared is also possible...
- Still more ground measurements are needed
- Need to be protected from now!
- The radio sky also needs to be protected.
- Let us work together...

THANK YOU

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