SIO 217A Team Project: Group 6 Marine Stratocumulus Cloud over South Indian Ocean

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Project Object

- Stratocumulus cloud, Male, Maldives
- Cloud droplet size distribution, Sounding data ,Cloud images
- Possible precipitation vs. Actual precipitation

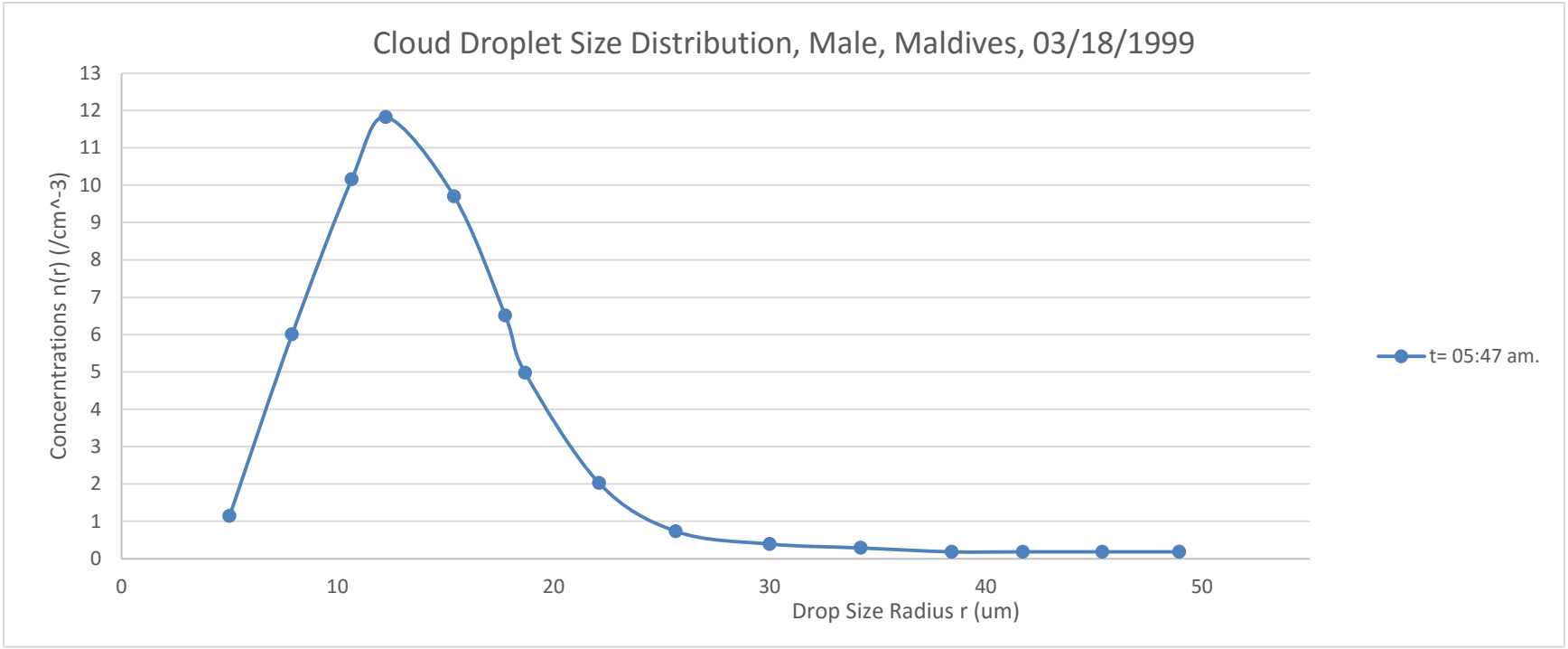
Stratocumulus Cloud

- Altitude: Low cloud, Under 2000m
- On satellite image: greyish and patchy
- On cloud image: white or grey, can block the sunlight
- Precipitation type: Drizzle

Data Source

- INDOEX project
  - PMS FSSP-100 on C130 aircraft, Flight altitude 2000m
  - POES satellite
  - NOAA R/V Ron Brown
  - Kaashidhoo Climate Observatory

Cloud droplet size distribution

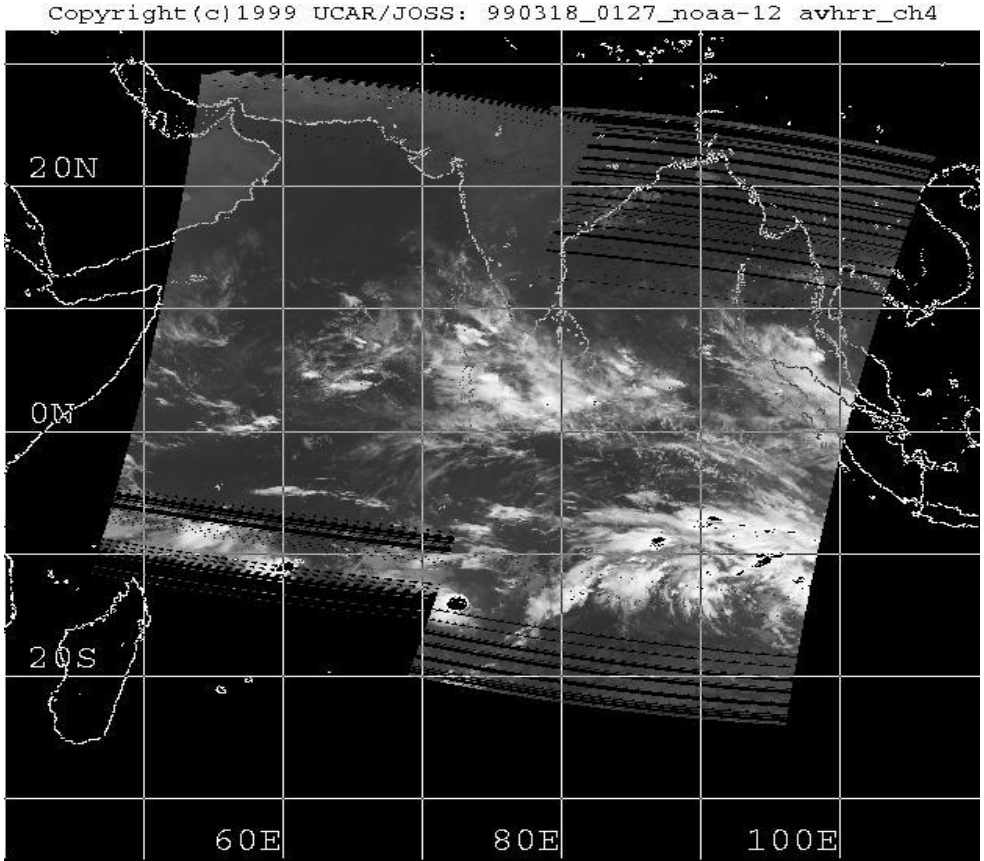


Cloud Droplet Size Data

r	n(r)	n(r)*r	n(r)*r^2	n(r)*r^3
5	1.135338	5.676692	28.38346	141.9173
7.894737	6.000396	47.37155	373.9859	2952.52
10.65789	10.15448	108.2254	1153.455	12293.4
12.23684	11.81772	144.6116	1769.589	21654.18
15.39474	9.696824	149.2801	2298.127	35379.06
17.76316	6.507469	115.5932	2053.3	36473.1
18.68421	4.971112	92.8813	1735.414	32424.84
22.10526	2.022161	44.70039	988.114	21842.52
25.65789	0.731549	18.77001	481.599	12356.82
30	0.390977	11.72932	351.8797	10556.39
34.21053	0.286803	9.811666	335.6622	11483.18
38.42105	0.182628	7.016745	269.5907	10357.96
41.71053	0.182628	7.617494	317.7297	13252.67
45.39474	0.182628	8.290333	376.3375	17083.74
48.94737	0.182628	8.939141	437.5475	21416.8

Data Resource:Mcfarquhar, Greg M., and Andrew J. Heymsfield. *Parameterizations of INDOEX Microphysical Measurements and Calculations of Cloud Susceptibility: Applications for Climate Studies*

Satellite Image &Cloud Image



Sounding Measurement

- Date: Mar. 4^{th}, 1999
- Altitude: 2000m (800hpa)
- Air Temperature (T) = 21.2℃
- Potential Temperature (θ) = 313.1k
- Liquid Water Content (LWC) = 0.18 $g \cdot m^{-3}$

Sounding Measurement

43369 Minicoy Observations at 12Z 04 Mar 1999

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1006.0	2	31.8	24.8	67	20.06	0	4	304.4	364.7	308.1
1000.0	57	31.6	23.6	63	18.74	0	5	304.8	361.1	308.2
925.0	755	27.6	17.6	54	13.88	55	12	307.5	349.7	310.1
861.0	1385	23.9	3.7	27	5.83	90	20	310.0	328.4	311.1
850.0	1498	23.2	1.2	23	4.93	85	20	310.4	326.1	311.4
806.0	1959	21.2	-5.8	16	3.09	77	19	313.1	323.2	313.6
700.0	3157	12.8				55	15	316.6		316.6
693.0	3241	12.2				52	14	316.9		316.9
677.0	3434	11.3				45	13	318.0		318.0
600.0	4430	6.6				315	6	323.7		323.7
576.0	4760	4.9				285	4	325.5		325.5
555.0	5060	3.3				65	4	327.1		327.1
514.0	5680	0.0				80	16	330.4		330.4
502.0	5868	-0.9				84	19	331.5		331.5
500.0	5900	-1.1				85	20	331.6		331.6
433.0	7023	-8.4				80	31	336.3		336.3
404.0	7564	-11.9				84	30	338.5		338.5
400.0	7640	-12.5				85	30	338.6		338.6
300.0	9770	-28.7				45	15	344.8		344.8
298.0	9817	-29.1				45	15	345.0		345.0
257.0	10856	-36.9				90	6	348.4		348.4
250.0	11050	-38.3				100	8	349.0		349.0
211.0	12190	-47.3				150	28	352.3		352.3
200.0	12550	-50.1				150	29	353.3		353.3
162.0	13883	-60.1				145	7	358.4		358.4
150.0	14370	-63.7				110	12	360.1		360.1
144.0	14619	-65.9				96	12	360.6		360.6
117.0	15838	-73.6				25	9	368.3		368.3
100.0	16760	-79.5				35	12	373.9		373.9
95.9	16997	-80.9				36	12	375.6		375.6
85.4	17647	-82.3				40	13	385.5		385.5
71.0	18699	-75.6				30	23	420.6		420.6
70.0	18780	-75.1						423.4		423.4
69.0	18864	-74.7						426.0		426.0

Term Calculation

- Liquid Water Path

$$W_l = \int_{z_b}^{z_t} \rho_a w_l dz = 2175.40\ kg\ m^{-2}$$

- Average droplet radius

$$\bar{r} = \frac{\int_0^\infty n(r) r dr}{\int_0^\infty n(r) dr} = \frac{\sum n_i r_i}{N} = 14.34\ \mu m$$

Term Calculation

- Total number concentration of particles

$$N = \int_0^\infty n(r)dr = \sum_i n_i(r) = 54.45 \ cm^{-3}$$

- Liquid Water Mixing Ratio

$$w_l = \frac{\rho_l}{\rho_a}\int_0^\infty \frac{4}{3}\pi n(r)r^3 dr = \frac{\rho_l}{\rho_a}\frac{4}{3}\pi\sum n_i r_i^3$$

$$= 0.888 \ g/kg$$

Term Calculation

- Effective radius

$$r_e = \frac{\int_0^\infty n(r) r^3 dr}{\int_0^\infty n(r) r^2 \, dr} = \frac{\sum n_i r_i^3}{\sum n_i r_i^2} = 20.02 \; \mu m$$

- Extinction coefficient

$$\sigma_{ext} = \int_0^\infty n(r) \, \pi r^2 Q_{ext}(x) dr = \pi Q_{ext}(x) \sum n_i r_i^2 = 0.0815 \; m^{-1}$$

- Optical depth

$$\tau_{ext} = \int \sigma_{ext} dz = \frac{3 w_l}{2 \rho_l r_e} = 162.99$$

Precipitation Evaluation

- Drop Size
  - The cloud type: stratocumulus cloud at 2km.
  - Cloud drop sizes range: 5 ~ 50μm.
  - Mean cloud droplets: 14μm
  - Small spherical drops.

Precipitation Evaluation

- Temperature
  - Air Temperature is 21.2°C.
  - The cloud process: warm process

Precipitation Evaluation

- Updraft velocity

small spherical drop ($r < 30\mu m$), $k_1 = 1.19 \times 10^6 cm^{-1}s^{-1}$;

$$u_T = k_1 r^2$$

larger spherical drop ($40\mu m < r < 0.6mm$), $k_2 = 8 \times 10^3 s^{-1}$;

$$u_T = k_2 r$$

mean terminal velocity of droplets in the stratocumulus cloud is $2.4 \times 10^{-4} m/s$. much smaller than the updraft velocity for drizzle (0.1-1m/s) and the updraft velocity of rain (1-10m/s).

- The drops are unlikely to fall out of the cloud.

Precipitation Evaluation

- Condensed water
  - Low LWC: $0.18 g/m^3$.
  - It is not high enough to allow the continues grow of the cloud droplets

Conclusion & Comparison

Calculated precipitation

- Stratocumulus cloud over Maldives on Mar.4th 1999 was not able to form precipitation
- Cloud droplet size: too small
- No necessary condition exists for cloud droplets to fall.

Recorded actual precipitation

	DOY1999	WndSpd	WndDir	Pressure	AirTmp	RelHum	Rain
decimal	decimal	m/s	degrees	hPa	degC	%	mm/hour
36224.02	64.02083	4	46.8	1005.2	28	81.3	0
36224.06	64.0625	3.3	39.6	1005.8	28	81.8	0
36224.1	64.10417	3.1	28.1	1006.3	28	80.9	0
36224.15	64.14583	3.3	27.9	1006.9	28.2	80.1	0
36224.19	64.1875	4.5	34.3	1007.2	28.3	80.8	0
36224.23	64.22917	4.7	29.7	1007.1	28.4	80.5	0
36224.27	64.27083	4	38.2	1006.4	28.5	79.5	0
36224.31	64.3125	3.3	38.6	1005.5	28.7	77.9	0
36224.35	64.35417	3.7	26.8	1004.7	28.7	78.3	0
36224.4	64.39583	3.5	22.9	1003.9	28.8	77.3	0
36224.44	64.4375	3.2	28	1003.5	28.8	76.8	0
36224.48	64.47917	3.7	28.8	1003.5	28.9	76.7	0
36224.52	64.52083	3.8	31.2	1003.7	28.8	77.7	0
36224.56	64.5625	3	29.5	1004.4	28.7	78.6	0
36224.6	64.60417	3	36	1005	28.6	78.9	0
36224.65	64.64583	3.2	42.3	1005.7	28.5	78.7	0
36224.69	64.6875	3.2	37.4	1006	28.4	80	0
36224.73	64.72917	2.9	35.5	1006.1	28.4	79.2	0
36224.77	64.77083	2.5	27.7	1005.7	28.2	79.8	0
36224.81	64.8125	2.8	26.7	1004.7	28	80.8	0
36224.85	64.85417	2.7	17.7	1004	27.9	80.4	0
36224.9	64.89583	1.9	32.3	1003.5	27.7	80.4	0
36224.94	64.9375	2.4	37.1	1003.2	27.7	79.7	0
36224.98	64.97917	1.5	74.9	1003.3	27.4	79.8	0

References

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Data provided by NCAR/EOL under sponsorship of the National Science Foundation. http://data.eol.ucar.edu/