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Discussion of the observations of the Oceanographer *Discovery* off Somalia during August 1964 to explain absence of fog

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ABSTRACT. Observations of the Oceanographer *Discovery* during 16 to 21 August 1964 presented by Ramage (1968) have been discussed to understand the causes responsible for the absence of fog over the area where the inversion began at the surface inspite of humidity being more than 90 per cent. Topographical features on the two sides of the Gulf of Aden and the south Red Sea and to the west of Somalia coast have to be taken into account as they affect the air flow over the area. Temperaures at the top of the inversion were higher by about 6°C at 10°N than at 7°N because of the differences in the nature of airmasses over the two locations, there being drier air at the former and moist air at the latter location. There is no evidence of massive and persistent subsidence below about 4·0 km in the dry air over the area between 10 to 12°N. Absence of fog was due to strong wind conditions; the latter and high humidity would prevent significant cooling due to radiation.

1. Introduction

Ramage (1968) has presented interesting observations of the Oceanographer *Discovery* off Somalia from about 6·5 to 12·3°N between about 50 and 53°E for 16 to 21 August 1964 in Figs. 2 and 3 of his note. While discussing the causes responsible for the absence of summer time fog over the area of *Discovery* inspite of favourable temperature and humidity conditions he has argued as under:

"A mystery remains — why does fog never form here whereas off California fog frequently occurs under apparently similar conditions? The answer can be found in the character of the summer circulation over the Arabian Sea, as already discussed. As compensation for the great upward motion accompanying the monsoon rains of India, into which the surface south-westerlies feed, convergent easterlies dominate the upper troposphere over the western Arabian Sea north of 7 or 8°N, and in turn cause massive and persistent subsidence. Consequently, warming due to subsidence at the top of the inversion overpowers cooling by both radiation or by upwelled water at the base, a conclusion borne out by the *Discovery* measurements and a possible explanation for the lack of fog. At the inversion top, the temperature at 7°N, south of both the main subsidence and the upwelled water, was 6 deg C below the temperature at 10°N where maximum surface cooling took place".

Desai (1968) has discussed the IIOE sounding data for 30 August 1964 about ten days after the *Discovery* period along the track of the aircraft from 4°N, 56°E—6°N, 55°E—9°N, 53°E—11°N, 52°E—12°N, 50°E, the track from 9°N, 53°E to 12°N, 50°E, being not far from the *Discovery* route. He has shown that where the inversion began from the sea-surface it was due to travel of warm air over the cool sea-surface and where it began at some height above the surface, it was due to airmasses, there being deflected trades airmass in the surface layers and above it either drier unstable airmass or less moist airmass with nearly saturation adiabatic lapse (also *see* Desai 1969). The inversion in that case was not due to subsidence. It is, therefore, proposed to discuss the *Discovery* data given by Ramage in his note to determine the causes of inversion and the absence of fog inspite of humidity at the surface being more than 90 per cent. For facility of discussion, Figs. 2 and 3 of Ramage are reproduced as Figs. 1 and 2 in this paper.

2. Discussion

(*a*) *Topographical features of the area in the neighbourhood of the route of Discovery*

The Gulf of Aden and the south Red Sea have on their one side hills on the coast of southwest Arabia and on the other side the hills to the north of about 9°N and east of 35°E over north Somalia and north Ethiopia. North of the equator to the west of the coast, there are the highlands of Kenya and Ethiopia. These topographical features will affect air motion over the area at least upto their height. As a result, the continental air from northeast Africa will flow over the Gulf of Aden generally from southwest. To the north of the equator upto about 9°N on the western

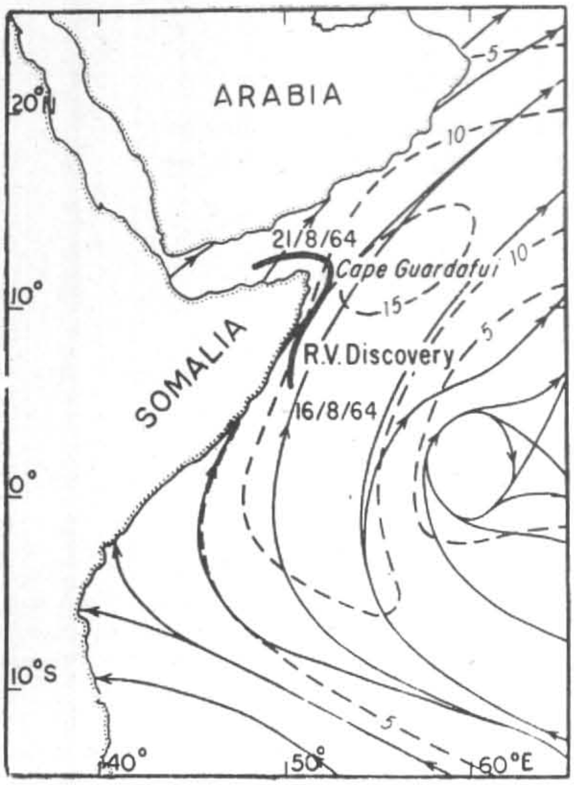

Fig. 1. Kinematic analyses of surface winds for 0600 GMT, 20 August 1964

Streamlines (full lines); isotachs in m/sec (dashed line)

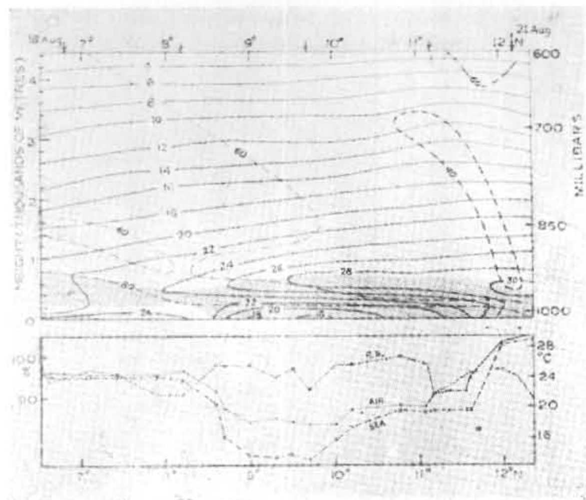

Fig. 2. Analysis of measurements made along about 50°E by R. V. *Discovery* between 16 and 21 August 1964

Upper diagram : Isotherms (full line); relative humidity isopleths (dashed line); inversion layer (stippled). Arrows denote locations of radiosonde ascents

Lower diagram : Air temperature at deck level (full line); relative humidity at deck level (dot-dashed line); sea surface temperature (dashed line)

edge of the monsoon system, there will be southerly to southwesterly winds. Findlater (1966, 1967) has shown that over the flat low-lying area of eastern Kenya which lies astride the equator and on the western edge of the monsoon system, there are to the east of about 38°E nearly southerly winds upto about 3·0 km at least during the months April to October; the winds become southwesterly towards the northern Somalia. Although the wind speeds become 40-100 kt in the levels between 1·2 to 2·5 km, most of such occasions occur during the months June–August; the area of high speed extends from near Mombasa to near Mogadiscio on the coast and upto the highlands to the west.

(b) Discovery data

(*i*) *Surface conditions — Fig. 1 and lower portion of Fig. 2*—No wind data are available to the author for the Somalia coast for the period, but in view of what has been stated in (*a*) above, there would have been southwesterly winds at the surface over there as off the coast, but with speeds presumably less than 10m/sec. This southwesterly air in the coastal region of Somalia will probably have lower relative humidity and higher temperature than the monsoon air off the coast; the southwesterly air while moving over the cold upwelled waters off the Somalia coast will get cooled and its relative humidity increase, and an inversion develop from the sea-surface. This should ordinarily give rise to fog, but as the wind speed near and off the coast increased as seen from Fig. 1, no fog occurred.

If the southwesterly air moving over the upwelled cold water was the monsoon air, an inversion will also develop from the sea surface, but there will be no fog due to strong wind conditions.

The southwesterly air shown over the Gulf of Aden in Fig. 1 was probably not the monsoon air but had its origin in northeast Africa as discussed in (*a*) above; no fog would develop in this continental air as it travels over the colder sea-surface and inversion develops from the surface although the wind speeds were less there (Fig. 1) than off the east coast of Somalia. It is interesting to note from Fig. 2 that the sea and air temperatures were generally about the same — temperature about 21°C near 11°N and 28°C near 12°N; on 30 August 1964, temperature of air at 1000 mb was 31·5° C at 12°N, 50°E and 19·2°C at 11°N, 52°E. The temperatures at 12°N and 11°N on the two occasions were thus comparable if

TABLE 1

Upper winds at Aden and Riyan during 16 to 21 August 1964

Height (ft)	16 Aug		17 Aug		18 Aug		19 Aug		20 Aug		21 Aug	
	Aden	Riyan	Aden	Riyan	Aden	Riyan	Aden	Riyan	Aden	Riyan	Aden	Riyan
2000	—	—	—	—	—	—	SSW/20	—	SW/10	—	—	—
3000	—	—	N/5	ENE/10	—	—	SSW/25	SW/10	SW/10	SSW/10	—	—
5000	W/15	W/20	WNW/15	—	WSW/15	—	SSW/25	SW/25	SW/10	SW/15	W/5	SW/30
7000	—	—	WNW/15	—	—	—	—	—	W/10	SW/15	W/5	—
10000	W/10	NNW/20	—	N/5	—	—	—	W/10	WNW/10	WNW/20	NE/5	NE/5
14000	—	—	NNE/10	—	—	—	—	—	ENE/25	NE/20	—	—
18000	NNE/20	—	E/25	—	NE/20	—	—	ENE/20	—	—	ENE/20	—

it is remembered that surface wind conditions on 20-21 and 30 August might have been somewhat different.

(*ii*) *Upper air conditions — upper portion of Fig. 2* — The weak inversion with base near 200 m from about 6·5 to 8·2°N would appear to be airmass one, there being monsoon air in the surface layer upto 200 m and less moist air (85 to 60 per cent humidity) above upto about 3·0 km, its depth south of 8·2°N increasing, being about 4·5 km at 7°N. The top of the inversion lowered from about 800 m near 6·5°N to about 500 m near 8°N.

The inversion base lowered to the surface between 8·2 and 8·5° N and continued to be so till about 12·3°N. The height of the top of the inversion increased from about 500 m near 8°N to about 800 m near 8·5°N and remained so till about 11·8°N when it began to decrease and became about 500 m near 12·3°N. The inversion was stronger between about 9·5 and 10°N, the area of coldest upwelled water. Temperature at the top of the inversion near 7°N was 22°C and near 12°N it was 30°C.

It would appear from Fig. 2 that where the inversion began from the sea-surface, the air had generally lower humidity than where its base was at 200 m — orientation of 80 per cent humidity isopleth.

The less moist air above the deflected trades south of about 8·5°N was presumably the air from Kenya side, as discussed in (*a*) above. The drier air to the north of about 9°N was probably continental air; upper winds at 06 GMT of Aden and Riyan on the Arabian coast given in Table 1, would support this presumption.

From Fig. 2 it can be stated that there is no evidence of massive and persistent subsidence over the area. One column of drier air (less than 40 per cent humidity) is shown extending from about 3·2 km near 11°N (temp. about 10°C) to about 0·5 km near 12°N (temp. about 30°C). Temperature at the top of the inversion near 12°N is 30°C and Ramage has presumably considered that subsidence was responsible for the high temperature. If it was so, temperature would have been higher than 30°C. Further the column is based on one ascent near 11°N and the other near 12°N and two points of lower humidity, one near 3·2 km near 11°N and the other near 0·5 km near 12°N have apparently been taken to show the column.

Another column of moist air (less than 60 per cent humidity) is shown in Fig. 2 by Ramage; this column is also based on two ascents, one near 7°N and the other near 8°N and the same remarks as made above for drier column hold good. In this case, however, no high temperature at the bottom is seen, a contrast to the conditions in the drier column.

One cannot have objection to localised subsidence both in the dry and moist airmasses, but there was no massive and persistent subsidence to account for temperature of 30°C at the top of the inversion near 12°N.

From the discussion about surface temperatures given earlier, it will be seen that lower air temperature at 11°N than at 12°N was due to travel of continental air over the colder sea-surface; this influence will also extent higher up, but the difference which is about 7°C near the sea-surface would decrease rapidly with height upto the top of the inversion which is clear from temperatures at the top of the inversion near 11°N and 12°N.

The weak inversion near 7°N with base near 200 m and top near 800 m was an airmass one as mentioned above, there being deflected trades in the surface level and less moist air above. The inversion beginning from the surface near and north of 10°N was due to travel of drier warmer continental air over the colder sea-surface. As less moist air near 7°N will have lower temperature lapse than the drier air near 10°N and the temperature at the surface over land of the latter airmass would be much higher than that of the former, it is to be expected that at 10°N and 7°N where the inversion top is near 800 m temperature will be higher by about 6°C at the former than the latter location. Thus airmass ideas explain satisfactorily the differences in temperatues at the top of the inversion at 10 and 7°N. Large-scale subsidence proposed by Ramage would not appear to exist.

The inversion began from the sea-surface over the route of the *Discovery* between about 8·3°N and 12°N, but the airmasses involved to the north and south of about 10°N were different as discussed earlier. As a result of original difference in temperatures at the surface and lapse rates prevalent in the airmasses, it would not appear correct to draw conclusions about temperatures at the top of the inversion as done by Ramage. Further the route of the *Discovery* was roughly northeastwards from near 7°W, 50°E to near Cape Gaurdafui to the east of Somalia coast and thereafter westwards in the Gulf of Aden north of that coast; this would also mean that taking a cross-section from about 6·5 to 12·3°N and between about 50 and 53°E as done by Ramage is not justified.

Ramage has argued that massive persistent subsidence at the top of the inversion overpowers cooling radiation and by upwelled cold water at the base. It may be stated that humidity in the lower 500 m near 10°N was above 80 per cent (Fig. 2) and there were strong wind conditions there; as such, radiation cooling at the base of the inversion there would be negligible inspite of amount of low cloud being less than 10 per cent.

3. Concluding Remarks

The following conclusions will be apparent from the foregoing discussion:

(*a*) Hills and highlands on the two sides of the Gulf of Aden and the south Red Sea and to the west of Somalia coast affected airflow at least upto their height.

(*b*) Where the inversion began at some height *above the sea-surface* south of about 8°N, it was an airmass one, there being deflected trades in the surface layer and less moist air above. North of about 8·5°N where the inversion began *from the sea-surface*, it was due to the travel over colder sea-surface of either moist air (south of about 9°N) or of dry air (north of about 9°N).

(*c*) Fog did not occur off the east coast of Somalia where the inversion began from the sea-surface inspite of the humidity being more than 90 per cent at the surface because of strong wind conditions. Radiation cooling would be negligible as humidity was more than 80 per cent upto about 500 m and there were strong wind conditions.

(*d*) Temperature at the top of the inversion was about 6°C higher at 10°N than at 7°N because of the nature of airmasses present over the area, there being moist air south of aboxt 9°N and drier air to its north. Higher temperature at the top of the inversion at 10°N would not appear to be due to massive persistent subsidence as a result of presence of convergent easterlies of the upper troposphere over the western Arabian Sea as specific humidity changes do not show any evidence of subsidence near 10-12°N at least below about 4·0 km; there was presence of easterlies above that height with speed less than about 30 kt over the area.

Ramage's explanation regarding absence of fog off Somalia would not appear tenable in view of the considerations advanced in this note.

4. Acknowledgement

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