

thermally excited transport systems which extend over the whole globe and deep down to the bottom of the oceans and which work in the same sense as the wind-driven circulations in the northern Hemisphere but, on a broad basis, oppose them in the southern Hemisphere.

The Cromwell Current.—One of the very recent important discoveries which has baffled Physical Oceanographers and stimulated considerable amount of thinking among dynamical oceanographers and meteorologists is the Cromwell Current known by the name of its discoverer. This sub-surface undercurrent flows eastward in the equatorial Pacific extending symmetrically on either side of the equator (Knauss¹¹). It is considered as a major current and is characterised by low temperatures and high oxygen values (see Fig. 4). There is evidence (Gerhard Neumann¹²) that the equatorial Atlantic has also such a current. Neumann¹² concludes that one may expect to find this undercurrent in the Atlantic strongest west of 20° W. longitude and weaker towards the east.

No completely satisfactory explanation for the Cromwell Current has yet been given. Knauss¹¹ believes that upwelling "will be a necessary part of any explanation of the current". Robert S. Arthur,¹³ Henry Stommel,¹⁴ Jules G. Charney,¹⁵ Allan R. Robinson¹⁶ and G. Veronis¹⁷ have formulated various types of theoretical models to account for the existence of this remarkable sub-surface current. All these models associate this current with the surface

wind stress. Special mention should be made here of the contribution by Jules G. Charney. He has shown that for the range of parameters applicable to the Cromwell Current, the inertial forces are as important as the frictional forces. He calculates the motion for several values of the coefficient of eddy viscosity. His calculation gives an undercurrent whose intensity increases with decreasing values of the coefficient of eddy viscosity. For sufficiently small values of eddy viscosity, the undercurrent resembles the Cromwell Current in intensity, in width and in horizontal and vertical velocity variations with depth.

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SOME ASPECTS OF THE SEASONAL AND DIURNAL CHANGES OF CIRCULATION OVER INDIA AND NEIGHBOURHOOD*

R. ANANTHAKRISHNAN

1. SEASONAL VARIATIONS

THE ultimate source of energy for all weather processes is the Sun. The working substance for the atmospheric heat engine is water vapour which is transported to the atmosphere from the oceanic surface as a result of sea-air interaction. Along with it the water vapour also transports heat energy in the form of latent heat from the great oceanic reservoir to the atmosphere.

Consequent on the apparent annual movement of the Sun between the Tropic of Cancer and the Tropic of Capricorn, the solar insolation intercepted by the latitudinal belts of the two hemispheres undergoes corresponding variations. While this is the primary cause for the seasons, the seasonal changes of weather are profoundly dependent on the distribution of land and sea masses over the earth's surface because of the differences in the physical properties of soil and water in respect of their response to incident solar radiation. This differential response sets up temperature contrasts between land and sea which in turn give

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rise to pressure variations and associated air movements on which weather processes depend. The temperature and pressure patterns control the weather patterns and in turn are controlled by them. The quasi-stationary patterns of temperature, pressure and wind distribution that result from this complex chain of action and reaction are known as the seasonal patterns.

The seasonal patterns are most strikingly manifested over India and neighbourhood by the south-west or summer monsoon and the north-east or winter monsoon. The southwest monsoon has its sway over India and south-east Asia during the months June to September which is the principal rainy season for this area. During this season, the hot arid tracts of West Pakistan, Afghanistan and adjoining areas become the centre of a low pressure cell while two high pressure cells lie over the north Pacific Ocean and the south Indian Ocean respectively. The low level circulation over India and neighbourhood which is controlled by these three major pressure systems results in an inflow of air from sea to land. The low pressure area over land which is essentially of thermal origin extends up to a height of 5 or 6 Km. only. Above that level the Afghan-Tibetan plateau region becomes the seat of a high pressure cell so that there is a complete reversal of wind circulation over India and neighbourhood, the westerlies of the lower levels giving place to easterlies. Over the Indian peninsula, the easterlies increase in strength with height and attain their maximum speed near the level of the tropopause at a height of 15 to 16 Km.

Beginning from September, the south-west monsoon circulation weakens on account of decreasing insolation intercepted by the northern hemisphere. In the winter months the land-sea contrasts of temperature and pressure are reversed. Central Asia with sub-freezing temperatures is now the seat of a strong anticyclone while a low pressure cell lies over the Aleutian arc in the north Pacific and two other low pressure regions over north Australia and south-east Africa in the southern hemisphere. The low level circulation over India and adjacent areas is now directed from the land towards the sea. Winter is, therefore, the season of fine weather and bright sunshine over the greater part of India. The upper air circulation over India and neighbourhood in this season is one of solid westerlies north of latitude 15° N. The westerlies strengthen with height and attain their peak speed nearabout 12 Km. over north India.

2. DIURNAL VARIATIONS

Superposed on the large-scale seasonal patterns, there is a diurnal variation which is present throughout the year. The land and sea breezes experienced at coastal places like Madras and Bombay are the direct manifestations of this diurnal effect. Meteorological phenomena such as this resulting from diurnal contrasts of temperature between land and sea are a characteristic feature of the tropics. The geographical configuration of the Indian sub-continent renders this country an excellent laboratory for the study of these phenomena.

Beginning from about 1950 surface meteorological observations are being taken at the four synoptic hours of 00, 06, 12 and 18 hours GMT at some 75 observatories in India. Upper wind measurements at these four hours are also being made from many of these stations. The data which have now been collected for a period of over ten years have been utilised for the study of the diurnal variations of circulation over the country. Although the importance of the diurnal variations has been recognised by Indian meteorologists, the observational material required for a quantitative study from the synoptic and climatological angles were not available until recently. The study which the present writer and his collaborators has undertaken is still incomplete. Some of the preliminary results of the study were briefly presented at the Annual Session of the Academy. Charts showing the mean monthly isobars and winds for four representative months January, April, July and October for the four synoptic hours were exhibited. In all the months, a thermally induced low pressure area is set up over the land in the afternoons giving rise to inflow of maritime air into the country at the lower levels. In January this heat low lies over the south peninsula. In April it lies over the central parts of the country and moves further northward in May and June. With the weakening of the summer monsoon by September, the thermal low moves southward following the sun. Broadly speaking, the thermally induced circulation which builds up from morning towards evening tends to weaken the seasonal circulation in the winter months and to strengthen it in the monsoon months. As the pressure gradients of the winter season weaken by March, the diurnal circulation becomes more and more vigorous with increasing indraft of maritime air into the country, development of latent instability and increasing frequency of convective pheno-

mena such as thunderstorms and dust-storms particularly in the afternoons and evenings. The post-monsoon transitional months of October and November are also characterised by convective activity in the south of the peninsula.

The programme of work that has been undertaken comprises a detailed study of the diurnal variations of the fields of pressure, temperature and wind distribution over India and the associated effects on weather over the country.

NEW SWEET MAIZE HYBRIDS FOR THE NORTHERN PLAINS

BHAG SINGH, N. L. DHAWAN, E. W. SPRAGUE, R. L. PALIWAL AND S. M. VAIDYA

Division of Botany, Indian Agricultural Research Institute, New Delhi

THE roasted or boiled green ears of maize are a popular snack in this country, particularly in and around the cities. For want of suitable sweet grained types, the green ears of flint grained varieties, normally cultivated in the country, are used for this purpose. If productive sweet grained varieties and/or hybrids can be developed, a significant contribution would be made to meet the demands of kitchen gardens and farmers located around the cities.

At present sweet maize is mainly cultivated in the Kashmir Valley, where mild temperatures during the growing season, are conducive to its culture. Tests conducted over several years, at the Indian Agricultural Research Institute, with sweet maize varieties from Kashmir and U.S.A., showed that these varieties are unadapted and hence unproductive in the plains and peninsular India. A project for developing such varieties, which could be profitably cultivated in these areas, was therefore initiated.

One recessive gene *su* is normally present in the commercial sweet maize, and is responsible for the development of sweetness in sweet maize kernels.¹ This gene prevents the conversion of a part of the sugar into starch. Though there are modifying factors,^{2,3} the simple mode of inheritance of the major sugary gene *su* allows for its successful transference to a highly adapted and productive flint or dent variety. The normal procedure is to make a cross between a sweet maize and a flint or dent variety possessing desirable agronomic characters, and then carrying out the conventional back-crossing programme. In this manner, the *su* gene can be transferred into different genetic backgrounds. The resulting sweet grained segregates can then be used as follows: (1) if they are true breeding and productive, then the outstanding among them can be released as an open pollinated sweet maize variety; (2) inbred lines can be developed from them for the production of top performing double cross hybrids; and (3) suitable hybrids can be developed by crossing two such segre-

gates which are genetically different but for the *su* gene.

Work along these lines was initiated at the IARI, in 1959. Two sweet maize varieties, Stowell's Evergreen and Golden Bantam, from the U.S.A., were each crossed to the adapted flint variety, Amarillo-de-Cuba (AdeC) from the Caribbean region, and the advanced generation of the semi-flint varietal cross KII \times AdeC. The F_1 hybrids were selfed in 1960, and from these, four genetically different crosses, sweet-grained segregates were obtained. Next the procedure outlined under item 3 above was followed to develop two sweet maize hybrids. These two hybrids were tested in a replicated randomized trial in 1962, against the four parents, three other best sweet maize varieties available and KT 41, a popular flint variety. The yields obtained with regard to green ears and dry grain are presented below along with days to silk.

Name		Yield in Kilograms/Hectare		Days to Silk
		Green ears at milk stage	Grain yield at 15% moisture	
Hybrid No. 1	..	8133	3715	48
" 2	..	5382	2561	46
Amarillo-de-Cuba (flint parent)		6219	3090	55
KII \times Amarillo-de-Cuba (semi-flint parent)		7702	2921	53
Stowell's Evergreen (sweet parent)		5860	1669	48
Golden Bantam (sweet parent)		2643	1278	42
Golden 60 days	..	3719	1868	43
Extra Early Golden Bantam		2362	1458	40
Hawaiian Sugar	..	5130	2544	50
KT 41	..	6051	2403	47
C. D. at 5% level	..	1520	658	..

Hybrid No. 1 significantly outyielded the two sweet maize parents and also the flint variety, Amarillo-de-Cuba at the green ear stage, while there was no significant difference when com-