separable compounds, $LiNO_3$ and HI. The two subsequent reactions make it possible to recover the products, elemental hydrogen and oxygen, and at the same time to recover the original reactants. The reaction requiring the highest temperature for its completion is the thermal dissociation of the alkali nitrate. Published data (*4*) place the decomposition temperature of $LiNO_3$ at about 750°K (at a dissociation pressure of 1 atm). For $NaNO_3$ and $CsNO_3$ the corresponding temperatures are from 50° to 150° higher. Withdrawal of the oxygen does not drive the reaction to completion because the oxygen pressure is a function of the activity of the nitrate in the molten mixture. Complete or nearly complete conversion, however, is really not essential except possibly for reaction 1. The use of nitrates other than the alkali metal nitrates does not appear to offer any advantages as most of the others seem to prefer to decompose by releasing nitrogen oxides and forming the metal oxide.

As to reaction 2, even with modern techniques (*5*) there has been no improvement over the classical kinetic and equilibrium studies of the hydrogen-iodine system by Bodenstein (*6*). It is well established that HI is 18 percent dissociated at 575°K, 25 percent at 800°K, and 29 percent at 1000°K, so that little is gained with temperatures above 700°K. The HI can easily be removed from the reaction mixture by distillation. After this stage it may be desirable to remove the water vapor with a regenerative dryer so as to conserve heat in the next step. The HI would then be decomposed in the presence of a porous membrane to take advantage of the different rates of diffusion to separate H_2 from HI and I_2. Alternatively, the separation may be achieved by quenching the equilibrium mixture. The point being made here is that the separation of H_2 from I_2 and HI should present no great problem.

Reaction 1 is, of course, the key to the cycle. An inspection of the standard electrode potential of iodine (+ 0.54 volt) and the oxidation-reduction potential of the nitrite-nitrate couple (0 volt) shows that in the standard state nitrite ion can be oxidized to nitrate by iodine. The kinetics of reaction 1 has been the subject of a number of investigations aimed at an understanding of the mechanism in the light and in the dark, since the reaction is photosensitive (*7*).

There appears to be no question that reactions 1, 2, and 3 will go as written. The crucial question is, Will they go under conditions that will make a practical cycle? This question can only be answered by the appropriate experiments.

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Heat Flux and Precipitation Estimates from Oceanographic Observations

Abstract. *Surface meteorological observations and salinity and temperature profiles were made in the intertropical convergence zone during July 1972. Over an 18-hour period, estimates of the heat budget in the top layer of the ocean and estimates of the total heat flux made by using aerodynamic parameterization equations balance within 10 percent. The salinity budget provides a precipitation estimate. Due to the stable stratification established by the salinity dilution in the wave-mixed layer by rain, the total heat flux to the atmosphere is being extracted from this shallow layer. As a result, large sea surface temperature drops occur regionally and may be capable of inhibiting atmospheric convection.*

During the second phase of the Soviet national tropical experiment in July 1972, two of us (Ostapoff and Tarbeyev) had the opportunity to conduct an oceanographic experiment on board the R.V. *Professor Zubov*. The objective of the study was to estimate total heat fluxes from oceanographic measurements on short time scales (less than 1 day) and under the disturbed conditions of the intertropical convergence zone (ITCZ). The *Professor Zubov* was positioned at 5°N, 21°W during the experimental period. The most significant result of this study is the short-term response of the top layer of the ocean to meteorological events such as precipitation from convective systems embedded in the ITCZ.

The meteorological conditions were not completely favorable inasmuch as the ship was at the southern edge of the ITCZ most of the time. Precipitation occurred only on 19 July, and this day was chosen for the analysis reported here as a case study.

The structure of the atmosphere was not typical of deep-reaching convection, as evidenced by the types of clouds, mostly altocumulus and stratocumulus. During 19 July cloud tops were observed by radar not to exceed 5 km, and the rain was rather steady. A rain bucket mounted on the flying bridge on the starboard side of the ship in lee of the wind collected a total of 17.5 mm of rain between 0923 and 2240 Greenwich mean time.

Surface meteorological observations were made routinely, as well as 2-hourly salinity-temperature-depth (STD) profiles down to 200 m. Here we present the data and compare the estimated budgets for heat and salt in the top layer of the ocean with estimates of the total heat flux made by using aerodynamic parameterization equations (*1, 2*).

The surface meteorological data obtained aboard the *Professor Zubov* were used to calculate the sensible and latent heat fluxes. The bulk aerodynamic equations were used for the flux calculations. Because relatively large instabilities in the atmospheric boundary layer exist during such events, coefficients were used which depend on the stratification (*1–3*).

The wind speeds were observed at 28 m (on top of the mast) by means of anemometers, and all other meteorological parameters were observed at a height of 10 m. Therefore, it was necessary to calculate the wind speed for 10 m, taking into account the stability of the boundary layer (*3*). Figure 1 shows a diagram of the average radiation, heat, and mass fluxes during the period of interest.

As seen from Fig. 1, the total heat flux for the period amounted to about 246 langleys (ly) per day (*4*). The mean Bowen ratio for the period was $Q_S/Q_L = 0.196$, where Q_S is the sensible heat flux and Q_L the latent heat flux; the ratio varied from 0.048 to 0.247. A climatological Bowen ratio of this magnitude would be characteristic of higher latitude regions. In the tropics and subtropics, under undisturbed meteorological conditions, a Bowen ratio of 0.05 to 0.10 is more common. However, under the disturbed conditions that prevailed during the observational period, the calculated values of the Bowen ratio are comparable to the results reported by Garstang [table 2 in (*5*)] and Garstang *et al.* (*6*). The latent heat flux decreases drastically under conditions of broad light rain due to decreased wind speeds and high humidities. The air temperature drops markedly due to the cold downdrafts associated with the heavy precipitation of the convective clouds (*6*). Since the wind speed decreases only moderately, the sensible heat flux usually increases. Therefore, the Bowen ratio under disturbed conditions in the tropics typically becomes several times larger than its climatological value.

Although no net radiation was observed on that day, the total incoming solar radiation was measured to be 108 ly/day. The net long-wave radiation was calculated according to the following equation as given by Sverdrup *et al.* (*7*)

$$Q_B = Q_1[0.56 - 0.08(e)^{\frac{1}{2}}](1 - 0.083C)$$

where Q_1 (langleys per day) represents blackbody radiation for the sea surface temperature, e (millibars) water vapor pressure, and C cloudiness on a scale of 1 to 10 (in this case 10). We estimate Q_B to be about 13 ly/day and the reflected short-wave radiation to be approximately 5 percent of the incoming solar radiation, or 5 ly/day. During the period of interest the change in heat storage in the ocean occurs only in the top 11 m, as discussed below, but the solar radiation is absorbed over a much deeper layer. If the incoming solar radiation spectrum was that for a cloud-free day, the radiation passing through the layer of interest would be 22 ly/day

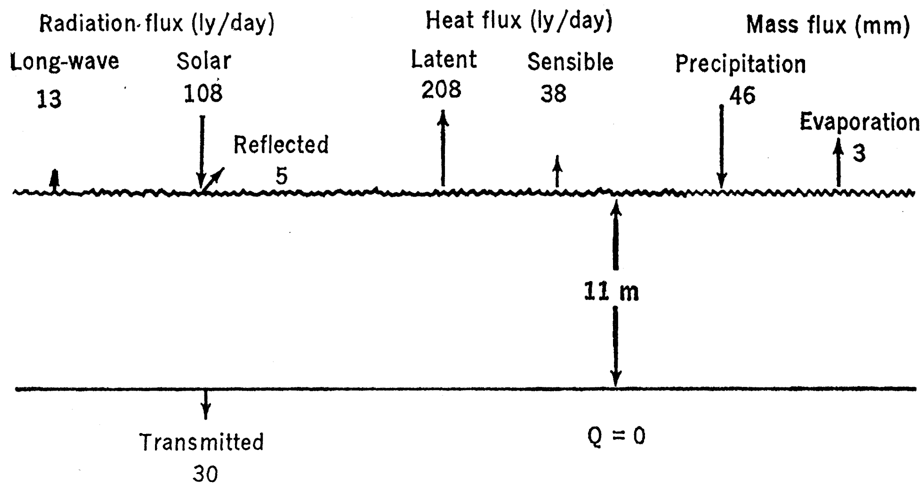

Fig. 1. Schematic diagram of the heat and mass budgets in the upper layer of the ocean on 19 July 1972 during overcast rainy conditions.

(*8*). However, the clouds substantially decreased the contribution of near-infrared radiation to the total incoming radiation (*9*). Since the uppermost portion of the ocean absorbs the near-infrared components first, and Jerlov's absorption coefficients (*8*) apply to a "normal" spectral distribution, we estimate the radiation passing through the 11-m layer to be 30 ly/day. Accordingly, the net radiation absorbed in the layer of interest is about 60 ly/day (see Fig. 1).

The oceanographic soundings at 0830 on 19 July and at 0230 on 20 July are presented in Fig. 2. Within 18 hours the salinity dropped by 0.14 per mil over a layer of about 11 m. This can be attributed to the amount of rain that fell during the period. As mentioned above, 17.5 mm of rain was measured on the ship, while approximately 43 mm is needed to dilute the salinity of 11 m of water from 35.64 to 35.50 per mil. The salinities given here are uncorrected STD values. These differ systematically by about 0.2 per mil when compared with values obtained by titration methods on board the *Professor Zubov*. However, this difference is immaterial for the purpose of our discussion, since we deal only with differences. The precision of the salinity measurement was ± 0.01 per mil. The depth could be determined to ± 0.5 m. Therefore, for a mean salinity of 35.5 per mil over a depth of 1 m, the measurement error is about ± 3 mm.

Evidently a large discrepancy exists between the rain gauge observations and the values derived from the salinity budget. This could mean that the method of collecting rain on ships is not very accurate, or that more rain fell in the vicinity and the diluted water was advected, or both. Since the precipitation area was rather large (10 to 20 km) and the surface currents rather low (5 to 10 cm/sec), horizontal advection of heat or salt can be neglected on this scale. In other words, we believe that the sampling was representative over an area commensurate with the time and space scales involved.

With the lowering of salinity in the layer stirred by the wind waves, stable

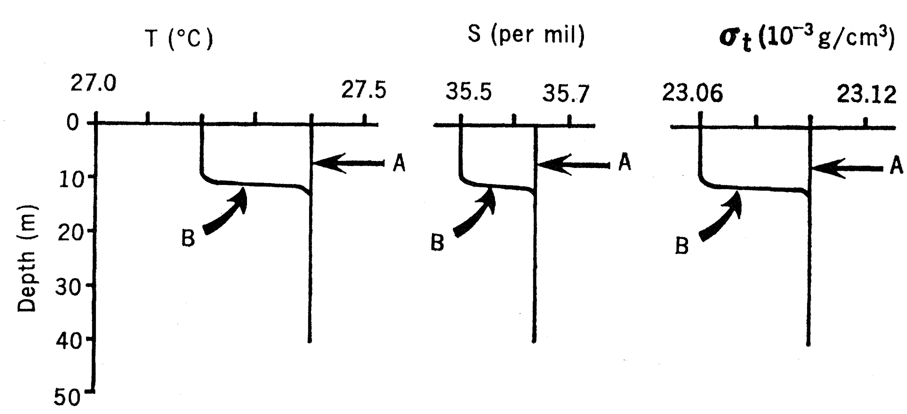

Fig. 2. Temperature (*T*), salinity (*S*), and density (σ_t) profiles before and after precipitation: (*A*) profiles at 0830, 19 July 1972; (*B*) profiles at 0230, 20 July 1972.

density stratification (see Fig. 2) is set up, limiting vertical convection to that layer. Continuing heat losses to the atmosphere are now derived from a much shallower layer (about 10 m) than the usual mixed layer (about 60 m), and the temperature profiles show dramatically the effects of net heat flux to the atmosphere. This cooling process will continue until the entire mixed layer assumes neutral stratification.

From the 18-hour temperature drop in the surface layer of the ocean, the total heat loss can be calculated as 210 ly/day. We can summarize the heat and precipitation budgets as follows.

Ocean:	
Heat storage change	− 210 ly/day
Atmosphere:	
Total heat flux	246 ly/day
Net radiation	− 60 ly/day
Total:	− 24 ly/day
Ocean:	
Evaporation	+ 3 mm
Net dilution	+ 43 mm
Precipitation	+ 46 mm
Atmosphere:	
Precipitation (observed)	17.5 mm

This shows that the heat budget, neglecting advection, can be balanced within about 10 percent. This is definitely within the uncertainty of our STD measurements, while the heat flux calculations made by using the refined bulk equations may be no better than ± 20 percent. Also, the precipitation calculated from the dilution of the top layer is slightly more than 2½ times as high as that observed with the rain gauge. This shows the difficulty of obtaining representative precipitation data aboard ship. It is well known that shipboard rain gauge measurements are inadequate. We suggest that the method outlined above may provide a more reliable precipitation estimate in some situations.

The method presented here for obtaining oceanic heat flux measurements and precipitation estimates independently of meteorological techniques seems to us specifically applicable to tropical regions and experiments such as the global atmospheric research program (GARP) Atlantic tropical experiment (GATE). A method of providing reliable estimates of heat, mass, and momentum transport across the air-sea interface during a meteorological event is essential. The observations show that on the time scale of a few hours, significant cooling and freshening occurs only over the wave-mixed layer. This allows the temperature of the ocean surface to become much lower than in the case where the heat loss is derived from the entire mixed layer. Since the stratification is stable, the ocean surface remains cool, inhibiting further atmospheric convective development. This air-sea feedback mechanism, which tends to limit the development of atmospheric convective systems, is important to the energetics of the tropical atmosphere. Therefore, this mechanism must be considered if a reliable prediction of long-term atmospheric behavior is to be made.

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Electrical Breakdown Caused by Dust Motion in Low-Pressure Atmospheres: Considerations for Mars

Abstract. *Electrification of agitated dust can cause visible breakdown in a carbon dioxide atmosphere at low pressure in a laboratory experiment. Dust storms on earth become electrified, with accompanying breakdown phenomena. Martian dust storms may reduce the atmospheric conductivity by capturing fast ions on particles, and, by electrifying, may cause discharges in the relatively low pressure atmosphere.*

Agitated dust is well known to become highly electrified due to surface processes which are poorly understood and are generally referred to as triboelectric. This occurs on all scales, from the microscale as in electrostatic office copying to the scale of dust storms. In laboratory experiments blown dusts have been found to electrify to breakdown voltages with charges estimated up to 10^4 *e* per particle (*1*). Dust devils and storms are known to be accompanied on occasion by point discharge from the earth, with typical values for the local electric field of the order of 1000 volt/m and space charge concentrations up to 10^6 *e* cm^{-3} (*2*). On larger scales, lightning has been observed and photographed in dust clouds, for example, in the phreatic eruption of the volcano Surtsey off Iceland in 1964 (*3*).

The potential difference required for breakdown in gases decreases with the gas pressure to a minimum at very low pressures. Typical Paschen curves indicate that potential gradients of only a few hundred volts per centimeter are required for spark breakdown in gases at pressures of the order of 10 mbar [for example, see (*4*)]. In an atmosphere at a lower pressure than the earth's, for example on Mars, the movement of dust might give rise more readily to electrical breakdown, possibly to phenomena that might be classed as glow discharges rather than sparks.

There are descriptions in the early literature of experiments in which electrical discharges were readily obtained in evacuated vessels by a variety of mechanisms; these involved frictional electrification either of materials within the vessel or of the walls (*5*). None of these, however, employed the movement of dust as a source of electrification. We performed an experiment to investigate whether dust becomes electrified when agitated in an atmosphere at an appreciably lower pressure than at the earth's surface, and whether any breakdown could be observed as a consequence. A 1-liter glass flask containing about 50 g of dried, well-dispersed sand in an atmosphere of CO_2 was evacuated to 10 mm-Hg. Two electrodes were sealed through the walls