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The ocean and its atmosphere as seen from gemini spacecraft

by

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Abstract

During the manned flights of the Gemini spacecraft conducted by the National Aeronautics und Space Administration, photographs of the earth's surface were obtained with a hand-held, Hasselblad 500 C camera. About one-third of the color photographs are suitable for interpreting features of the ocean surface and the marine atmosphere.

The interpretation of these photographs has provided information on sea-surface features that were previously unknown, or that were known, but for which data were lacking. The surface texture (roughness) of the sea over aeras as great as 10.000 square kilometers has been photographed and is now known to define current boundaries, divergences, convergences, upwelling, and other dynamic features in the ocean.

Zusammenfassung

Alle von Gemini-Astronauten aufgenommenen Photos sind vom Autor geprüft und etwa 100 für eine detaillierte Deutung ausgesucht worden. Als Ergebnis glaubt der Autor, daß Ozeanographie vom Weltraum aus der einzige, bedeutsamste Fortschritt seit der Expedition der HMS Challenger ist. Die Möglichkeit, die Erde vom Weltraum aus zu sehen, kann vielleicht die weitreichendste Anwendung in der Geschichte der Geo-Wissenschaften werden. Solche Fortschritte werden allerdings nur dann vorhanden sein, wenn es einwandfreie, zweckmäßige Forschungsprogramme gibt. Es müssen gut koordinierte Weltraumunternehmungen mit weitverbreiteten — sowohl allgemeinen als auch speziellen ozeanographischen — Untersuchungen verbunden werden. Der Wissenschaftler muß genau wissen, worum es sich handelt, wenn er Daten aus dem Weltraum betrachtet. Ein zweckmäßig angelegtes Forschungsprogramm erfordert Zeit, es zu planen und Zeit, es in Einsatz zu bringen. Solcher Untersuchung geht für Jahre eine wirklich gleichzeitige, synoptische Bestandsaufnahme des Meeres und seiner Atmosphäre voraus. Je schneller diese Forschungen beginnen und je besser sie koordiniert werden, desto schneller werden die Vorteile realisiert. Die Möglichkeit, einen weitreichenden, synoptischen, schnellen Überblick über viele Begebenheiten des Systems Ozean — Atmosphäre zu bekommen, ist ungeheuer bedeutend. Durch einige Photos des Ozeans und seiner Küstenregionen, aufgenommen aus dem Weltraum, wird der erstaunlich brauchbare Informationsgehalt solcher Bilder demonstriert. Die Arten und Größen der ozeanischen und atmosphärischen Gebilde, die vom Weltraum aus gesehen werden können, werden angegeben. Es ist klar, daß mit verfeinerten Systemen, die das Infrarot-, Mikrowellen- und Ultraviolett-Spektrum als Erweiterung der sichtbaren Lichtwellen einschließen, sich unser Wissen über das Verhalten der Ozeane und der Atmosphäre beträchtlich erweitern wird.

The common view, the natural view, that most men have of the sea is its surface. The view is intriguing, for the surface is never still, nor will it ever be exactly the same again. It has a texture that can be described, measured, and examined. Yet, the details of the origin of the moving, glittering, surging texture are not precisely known.

Now there is another view that was not available until man ventured into space — the synoptic, instantaneous view from a distance of hundreds of kilometers. This view presents to man a new order of magnitude that challenges his rationale. Now, rather than the wave, the current, the fish, or the beach, he must deal with features heretofore presented only on charts — features which he has never before seen from his view on the surface; features which are the result of the integration of all those surface conditions with which he is familiar.

The ocean and atmosphere are dynamic. Air and water are in constant motion and interaction. Processes and movements vary in size from molecular to global. The interaction of these processes is so complex that totally practical rationalizations will not result from classical investigations. Yet, practical applications must be developed, for the ocean and atmosphere are part of man's environment. The cost for not adequately understanding the processes of these environments is enormous — not only in money, but also in the lives lost through inadequate prediction and protection.

It seems reasonable, then, that man's hope of satisfactorily understanding the air-sea processes, and of reaping the practical benefits therefrom, lies in the broad view of the oceans and the overlying atmosphere that is now possible from spacecraft.

I have examined all of the 575 photographs taken by Gemini astronauts — all taken with a hand-held, Hasselblad 500 C, 70-mm. camera. Even though such a photographic system is unsophisticated, the resulting information has been amazingly usable. The types and magnitude of oceanic and atmospheric features that can be viewed from space are readily evaluated.

I have chosen about 100 of the Gemini photographs for detailed interpretation. As a result, I believe that oceanography-from-space can be the single, most significant advancement in oceanography since the cruise of HMS CHALLENGER and that the capability of viewing the earth from space may have the most far-reaching application of any technique developed in the history of earth science.

Such advances will, however, come only if there are sound, functional, research programs. Well-coordinated space efforts must be combined with wide-spread oceanographic surveys — both general and special-purpose. The scientist must know precisely what it is he is seeing in the data gathered from space.

A properly oriented research program will require time to plan and put into operation. Such research precedes by years, realtime, operational, synoptic coverage of the sea and its atmosphere. The sooner the research begins and the better it is coordinated, the sooner the benefits will be realized.

Although a number of unmanned satellites are now orbiting the earth and returning data of great value to meteorologists, the oceanographer will, of necessity, require more detail. Ocean-from-space research can come only from high-resolution data acquired by a range of remote sensors under human direction. Discretion, ingenuity, and rationalization are imperative in this fundamental research effort.

Many of the features that have nurtured the thoughts expressed here can be seen in the photographs taken of the ocean from space.

Fig. 1
Upwelling and Taiwan National Aeronautics und Space Administration/Manned Spacecraft Center Color No. S 66 — 458 68 taken on July 20, 1966, during the Gemini flight X by astronauts Cdr. JOHN W. YOUNG and Major MICHAEL COLLINS with an 80-mm., Xenotar lens.

Upwelling and Taiwan (figure 1)

The major current system in the western Pacific Ocean flows from south to north past the island of Taiwan. Around the island, and especially in the Formosa Straits, the currents are complicated by the tides, which ebb to the south along the southern shores of Taiwan.

On July 19, the day before this photograph was taken, tropical storm "Nina" was about 167 kilometers east of Taiwan. The storm was not well developed and winds of Beaufort Force 3 were the highest recorded. By 1200 GCT, July 20, the storm had dissipated and winds of Force 2 blew around Taiwan from an easterly direction.

In the photograph, the light blue of the sea is the result of a diffuse sun's reflection from an evenly roughened sea surface. Winds from the east und northeast increased the roughness of the northerly flowing waters. The reflective, specular pattern from the sea surface thus depicts the features of water motion around the southern end of Taiwan.

The major current is parted by the island, much as a ship parts the water. As the "bow" wave spreads from the island, upwelling must take place near the shore. Part of the dark blue water is upwelled.

The fishing ports along the west coast of Taiwan are concentrated north of the lagoonal complex on the southwest coast.

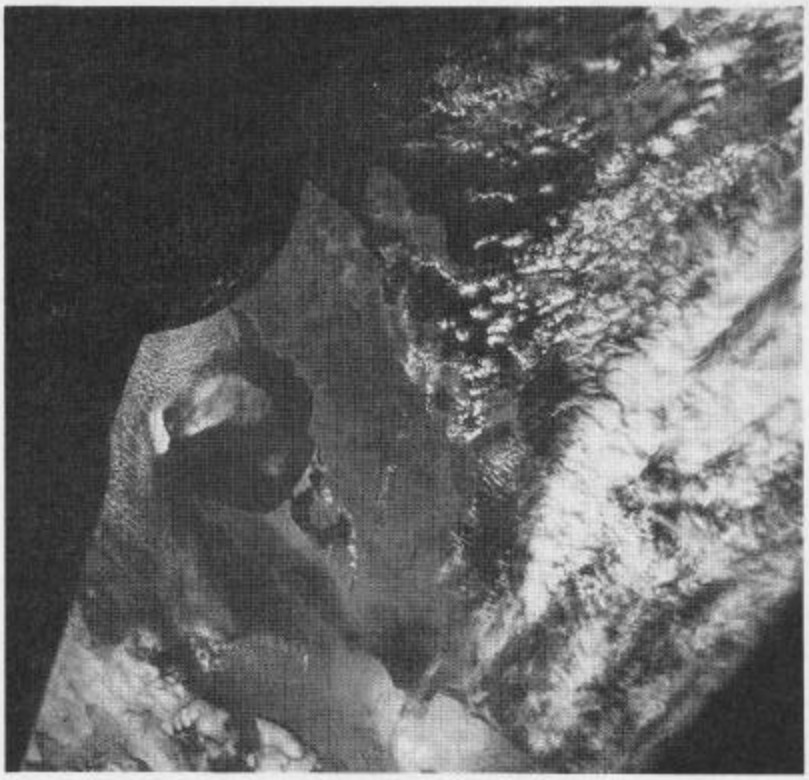

Fig. 2
The Ebbing Tide and Bahia Ballenas National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S 66 — 63 047 taken on November 14, 1966, during the Gemini fligth XII by astronauts Capt. JAMES A. LOVELL, Jr. and Major EDWIN E. ALDRIN, Jr. with a 38-mm. Biogon, wide-angle lens.

The Ebbing Tide and Bahia Ballenas (figure 2)

This unusual photograph, taken over the Gulf of California, shows a great variety of clouds within the field of view, and a number of water motions in the sun's glitter pattern.

On this day, two basic types of BÉNARD cells were apparent west of the Peninsula of Baja California. Derectly north of Sebastian Vizcaino Bay were broken clouds of closed cells. To the west, the BÉNARD cells were elongated, clearly defining the offshore shear in the coastal wind field. Still farther west, great blankets of stratocumuli with wave-like sutures, spread over the sea. The sharp, black, shadows from the clouds form distinct outlines in the reflective pattern from the sun. The wide band of clouds, extending roughly east-west across Baja California and the adjacent of California, are said by personnel of the Environmental Science Services Administration to lie in the jet stream.

Atmospheric BÉNARD cells are convective systems that form over water surfaces that are warmer than the overlying air. A great number of interacting conditions in the water and in the air determine the magnitude and persistence of the cells. BÉNARD cells always have a polygonal outline, however, and if conditions are optimum, a perfect hexagon of clouds is developed.

Sun glitter from the water (left center) provides a unique tool to study water circulation in this region. The bright, golden, wormlike images within the sun's reflection were slicks on the sea surface. A sea surface more evenly roughened by wind waves produced the diffuse reflection. To the west of Punta Abreojos, just north of Bahia Ballenas, the slicks lie in S-shapes, depicting the interference in the main stream of the current as it moved south past the Punta. The eddy moving counterclockwise into the embayment south of Punta Abreojos is a typical reaction of a current flowing past a headland.

Opposite the mouth of Bahia Ballenas, an offshore slick marks the boundary of the water that was ebbing from the Bahia and spreading south along the coast. At the time the photograph was taken, the water was at mid-ebb from a 2.5-meter spring tide. A similar volume of water was surely flowing from Scammon Lagoon into Vizcaino Bay, but the flow was not visible in this view.

BÉNARD Cells and Baja California (figure 3)

The ocean waters of the coasts of California and Baja California are cool in response to the major north to south circulation in the eastern Pacific Ocean. Stratus and stratocumulus clouds form over the cool waters and are nearly constant features of the overlying marine atmosphere. The normal atmospheric circulation over this portion of the Pacific Ocean is also north to south, with variations in response to seasonal modifications in the Hawaiian High Pressure System and to local conditions usual to any coast.

A typical low layer of stratocumulus clouds is seen to be moving at 10—20 kilometers per hour past Guadalupe Island. The Island peaks reach to 1.500 meters and therefore project through, and interfere with, the cloud layer. A "shock", or "bow" wave spreads from the north end of the island, similar to waves formed by a ship

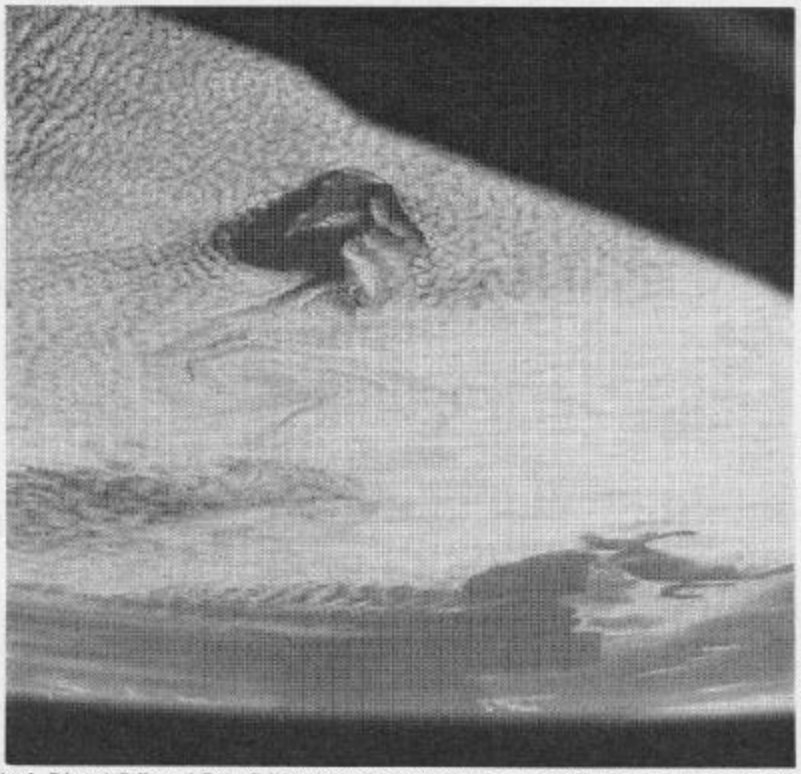

Fig. 3 Bénard Cells and Baja California National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S 65 — 45697 taken on August 21, 1965, during the Gemini flight V by astronauts Lt. Col. L. G. COOPER and Cdr. CHARLES CONRAD, Jr. with an 80-mm., Zeiss lens.

Fig. 4 A Sea Breeze and India National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S 66 — 54677 taken on September 14, 1966, during the Gemini flight XI by astronauts Cdr. CHARLES CONRAD, Jr. and R. F. GORDON, Jr. with a 38-mm., Biogon, wide-angle lens.

moving through the water. Downstream, south of the island, von KÁRMÁN vortices rotating to the right and to the left are formed as a turbulent "island wake". These cloud features, waves, and eddies were photographed during four Gemini missions and must, therefore, be considered climativ features of the Guadalupe marine atmosphere.

Similar waves and eddies appear in the water around islands (see figure 1). It is clearly necessary to investigate the details of these fluid motions to allow proper analyses of atmospheric and oceanic flows.

The clouds west and northwest of Guadalupe Island (or toward the spacecraft), were formed into convective, polygonal BÉNARD cells. Several areas of "open" cells were distributed among the more common "closed" cells of the stratocumulus layer. Most cells west of the island were regular in shape and some were typically hexagonal.

North of Guadalupe Island, the cells were deformed, showing extensions to the south. Between the island and the west coast of Baja California, the severe elongation of the BÉNARD cells indicates a well-developed atmospheric shear passing north and south by Guadalupe Island. The concurrence of "open" and "closed" BÉNARD cells offers interesting speculation, especially considering the nearly constant temperature inversion over these cool waters.

A Sea Breeze and India (figure 4)

The cloudless skies along the entire coast of India are probably the result of subsiding air, as would occur during the daytime sea breeze. The weather map of 1200 GCT, 5 hours after the photograph was taken, depicted the winds blowing toward the shore along all coasts. The air over central India was calm and a slight low pressure system was over the northern part of the subcontinent. Temperatures of coastal air were about 27.5° C. and temperatures of inland areas were 4°—5° C. warmer. Conditions were typical of a sea breeze day.

The ability to "see" such a system in toto is tremendously significant. Not only can the seaward extent of the sea breeze be precisely measured for the first time, but sea-surface wind drift, areas of potential upwelling, and convergences can be plotted synoptically for an entire coast. Were such a view available daily, the value to fisheries, shipping, and meteorology would be incalculable.

Seaward of the sea breeze zone, the polygonal BÉNARD cells of cumulus clouds indicate even distribution of water temperatures and the lack of surface winds.

It should be emphasized that these photographs were taken with a relatively simple hand-held camera. It is clear that with more sophisticated photographic system that include the infrared, microwave, and ultra-violet spectra in addition to the visible wave lengths, our knowledge of ocean-atmosphere responses will expand remarkably.