SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 94, NUMBER 9

Thomas Lincoln Casey Fund

REVIEW OF THE GENUS CHLAENOBIA BLANCHARD (COLEOPTERA : SCARABAEIDAE)

BY
EDWARD A. CHAPIN
Curator, Division of Insects, U. S. National Museum

(Publication 3338)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 23, 1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Thomas Lincoln Casey Fund

REVIEW OF THE GENUS CHLAENOBIA BLANCHARD (COLEOPTERA: SCARABAEIDAE)[1]

By EDWARD A. CHAPIN

Curator, Division of Insects, U. S. National Museum

The tribe Rhizotrogini of the scarabaeid subfamily Melolonthinae is represented in the New World by about 450 known species, distributed among what are usually considered as five genera. Somewhat more than three-fourths of these species are assigned to *Phyllophaga* Harris (*Lachnosterna* Hope). One species is the sole member of the genus *Chirodines* Bates. *Listrochelus* Blanchard and *Phytalus* Erichson together number about 100 species. *Chlaenobia* Blanchard, as defined in the present paper, contains 15 named forms, of which 2 are given but subspecific rank.

In describing *Chlaenobia,* Blanchard allied it to certain genera which are grouped about *Macrodactylus* Latreille. Lacordaire followed Blanchard's suggestion in this matter. Bates, the first to have an adequate series of specimens for study, recognized the genus as Rhizotrogine and not Macrodactyline and so treated it in the Biologia Centrali-Americana. Dalla Torre returned to the views of Blanchard and Lacordaire in the Junk Catalog, but there is ample evidence to show that this work is not at all critical. The present treatment of the genus follows Bates.

Arrow, in 1920, suggested that the American genus *Phytalus* Erichson and the Asiatic genera *Brahmina* Blanchard and *Holotrichia* Hope should be abandoned and their species placed in *Lachnosterna* Hope (*Phyllophaga* Harris). If this is necessary, it is also necessary to add those species now contained in *Chlaenobia,* for that genus is certainly intimately connected with *Phytalus. Chirodines* is also very close to *Phytalus,* and when its female is known, it may seem best to add this genus to *Phyllophaga* also. On the other hand, a study of the Rhizotrogini may show that an entirely new grouping of the

[1] This is the second contribution to be published by the Smithsonian Institution under the Thomas Lincoln Casey Fund.

species along lines other than those at present used will result in more clean-cut genera. There is a greater diversity of structure displayed among the species of *Phyllophaga* than between those of *Phytalus* and *Chlaenobia*.

Pending a reinvestigation of the whole complex, the five genera of Rhizotrogini known to occur in the New World may be separated as follows:

1. Claws of front and middle legs simple, those of hind legs cleft *Chirodines* Bates.
   All tarsal claws toothed, cleft, pectinate or serrate........................2.
2. Tarsal claws cleft..3.
   Tarsal claws toothed, pectinate or serrate..............................4.
3. Prothorax somewhat narrowed at base; female pygidium usually profoundly modified; tarsi usually with dense pubescence on plantar surfaces *Chlaenobia* Blanchard.
   Prothorax wider across basal angles than across anterior angles; female pygidium not modified; tarsi without dense pubescence on plantar surfaces *Phytalus* Erichson.
4. Tarsal claws strongly bipectinate or feebly serrate, sometimes with a more or less well developed subapical tooth on one or both of the claws of a foot ....*Listrochelus* Blanchard.
   Tarsal claws neither pectinate nor serrate, with a more or less strongly developed tooth which may be subbasal, median, or subapical in position *Phyllophaga* Harris.

CHLAENOBIA Blanchard

Blanchard, 1850, Cat. Coll. Ent. Paris, Coleopt., vol. 1, p. 116; Lacordaire, 1856, Gen. Coleopt., vol. 3, p. 265; Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 166; Arrow, 1933, Ann. Mag. Nat. Hist., Ser. 10, vol. 11, p. 146.

Type species.—*Chlaenobia ciliatipes* Blanchard 1850 (monobasic; also by subsequent designation of Arrow 1933).

KEY TO THE SPECIES OF CHLAENOBIA BLANCHARD 1850

MALES

1. Antenna nine-segmented ....2.
   Antenna ten-segmented ....3.
2. Spurs of posterior tibia short, straight, and tapering.........*aegrota* Bates.
   Spurs of posterior tibia somewhat spatulate and twisted, the spur more remote from the insertion of tarsus strongly hooked at apex...*arrowi* n. sp.
3. Metasternum sparsely set with bristles, the portion adjacent to the median line glabrous or nearly so......................................4.
   Metasternum moderately hairy to very densely pilose, with never more than a small spot on median line glabrous; plantar surface of second segment of anterior tarsus pilose; pronotum unicolorous.........................5.

4. Plantar surface of second segment of anterior tarsus bare, its margins fimbriate with long hairs; pronotum bicolored (not always distinctly so in greasy specimens), disk castaneous and flanks testaceous; body form unusually broad for genus.................................*panamana* n. sp.
   Plantar surface of second segment pilose; pronotum unicolorous; body form normally slender ....*vexata* Horn.
5. Clypeus deeply concave, the anterior third or more strongly reflexed; second segment of anterior tarsus about twice as long as broad.....*latipes* Bates.
   Clypeus shallowly concave, only the marginal fifth reflexed; second segment of anterior tarsus at least three times as long as wide..................6.
6. Hind tibia gradually but distinctly widened from base to apex; lower half of inner face finely engraved and bounded beneath by a knife-edge margin ....7.
   Hind tibia not evenly expanded from base to apex; lower half of inner face without fine engraving, not bounded beneath by a knife-edge margin....8.
7. Outer apical angle of middle tibia produced outward; inner acute margin of hind tibia starting near base.......................*colimana* Arrow.
   Outer apical angle of middle tibia not outwardly produced; inner margin of hind tibia acute in apical half only.....................*dissimilis* n. sp.
8. Spurs of hind tibia dissimilar in shape, the inner broader than the outer and twisted ....*aequata* Bates.
   Spurs of hind tibia slender, straight, and similar.........................9.
9. Pronotum less densely punctured on disk than on flanks; fifth visible abdominal sternite without median patch of asperities..........*scabripyga* Bates.
   Pronotum less densely punctured on flanks than on disk; fifth visible sternite with median patch of asperities from which long hairs arise
   tumulosa Bates.

Note: The males of the following species are unknown to the writer: *ciliatipes* Blanchard, *rodriguezi* Bates, *personata* n. sp.

FEMALES

1. Antenna nine-segmented ....2.
   Antenna ten-segmented ....5.
2. Pygidium with a deep, subconical excavation on apical half which is connected with the basal margin by a broad and rather deep groove
   arrowi n. sp.
   Pygidium without a deep, subconical excavation near apex..............3.
3. Pygidium with a median longitudinal groove; third and fourth segments of antenna equal.....................................*ciliatipes* Bl.
   Pygidium without a median longitudinal groove; fourth segment longer than third ....4.
4. Clypeus deeply concave, the anterior third strongly reflexed; lateral marginal bead of pronotum wider near anterior and posterior angles than at middle; apical portion of pygidium with shallow, vaguely defined depression ....*rodriguezi* Bates.
   Clypeus not deeply concave, anterior fifth reflexed; lateral marginal bead of pronotum uniformly narrow throughout length; apical portion of pygidium with deep, well-defined depression..................*aegrota* Bates.

5. Apical margin of sixth visible abdominal sternite more or less produced at middle, the projection usually seated in a broad and very shallow emargination ....6.
   Apical margin of sixth sternite broadly, deeply and evenly emarginate, not at all produced on median line..................................11.
6. Pygidium bicallose, the callosities separated more or less completely by a median longitudinal groove..................................7.
   Pygidium not bicallose..8.
7. Callosities of pygidium well separated, the median longitudinal groove passing between them and very nearly attaining the basal margin *latipes* Bates.
   Callosities approximate, coalescing above, the median longitudinal groove short, not passing completely between them...............*dissimilis* n. sp.
8. Pygidium with a single median callosity near base, the remaining portion shallowly concave, floor of the concavity with a pronounced median groove *colimana* Arrow.
   Pygidium broadly, shallowly, and transversely excavate in apical half, the floor of the excavation not grooved..................................9.
9. Pygidium subacutely angulate at apex, with a single low median callosity on the upper margin of the subapical excavation; pronotum unicolorous *vexata* Horn.
   Pygidium broadly rounded at apex, without a callosity on the basal portion above the excavation; pronotum bicolored as in the male sex.........10.
10. Pronotum strongly narrowed basally, as wide across anterior angles as across base; pygidium moderately coarsely and very sparsely punctured *panamana* n. sp.
   Pronotum not strongly narrowed basally, width across anterior angles much less than across base; pygidium coarsely and rather densely punctured *personata* n. sp.
11. Pygidium subapically with a large hemispherical cavity which is bounded laterobasally by two low and poorly defined callosities and apically by a sharp protruding margin..............................*tumulosa* Bates.
   Pygidium virtually simple, without modification other than a shallow and inconspicuous median impression near apex..............*aequata* Bates.

Note: The female of *ciliatipes* Blanchard is known to the writer only by description. The female of *scabripyga* Bates is unknown to him.

DESCRIPTION OF SPECIES

CHLAENOBIA CILIATIPES Blanchard

Chlaenobia ciliatipes Blanchard, 1850, Cat. Coll. Ent. Paris Coleopt., vol. 1, p. 116; Lacordaire, 1856, Gen. Coleopt., vol. 3, p. 266.

Head black, punctate, clypeus rufotestaceous, margin reflexed and feebly emarginate. Body entirely testaceous, upper parts glabrous and somewhat shining, underparts sericeous. Antenna nine-segmented, with the third and fourth segments elongate and equal. Pronotum transverse, widest anteriorly, sides obtusely angulate, uniformly and densely punctured. Elytra with discal costae hardly perceptible. Propygidium very large and only partly covered by elytra, pygidium moderately convex, with a median longitudinal groove (female?). Anterior tibia obtusely bidentate.

Length.—13 to 14 mm.

Type locality.—Not stated in original description; by Lacordaire as Brazil.

Type.—In the Paris Museum.

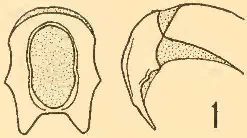
This species is known to me only from the descriptions of Blanchard and Lacordaire. The above diagnosis is made up from the statements of these authors. Following Lacordaire's suggestion that the specimens available to him are females, the species has been inserted in that part of my key.

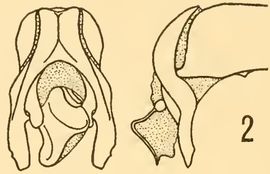
CHLAENOBIA AEGROTA Bates

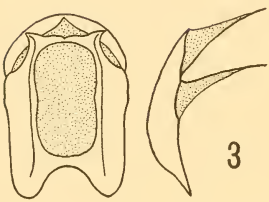
Chlaenobia aegrota Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167, pl. 10, fig. 1.

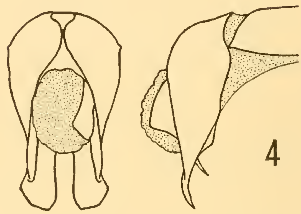
Head moderately coarsely and most densely punctured on upper portion of frons, vertex and lower portion of frons sparsely punctured, frons slightly concave, clypeofrontal suture moderately impressed and bisinuate, clypeus more coarsely and sparsely punctured, deeply concave, the outer third strongly reflexed, margin feebly sinuate at middle. Antenna nine-segmented. Pronotum transverse, side margins obtusely angulate just before the middle, lateral margin feebly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles narrowly rounded; punctures coarse, very sparsely placed on disk, more densely on flanks. Scutellum equilateral, side margins curved, with a few punctures along sides. Elytra with sutural margins broadly tumid, each with two faintly indicated costae, the one nearer the suture a little better defined; punctures a little less coarse but more densely placed than on pronotum, epipleura narrow, disappearing before the extreme apex. Metasternum moderately coarsely and most densely punctured, rather densely clothed on median portion with moderately long erect hairs.

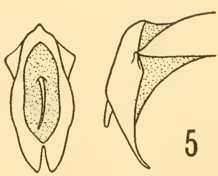
Male.—Antennal club one-fifth longer than second to sixth segments combined. Fifth sternite without special hair tuft, sixth sternite with a shallow median longitudinal groove, its free margin transverse, very feebly produced at middle. Pygidium strongly convex, coarsely, sparsely and irregularly punctured, sparsely set with erect hairs, transversely grooved just before apex, floor of this groove impunctate, apical margin strongly reflexed. Anterior tibia bidentate with a trace

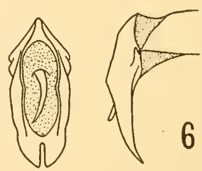

1

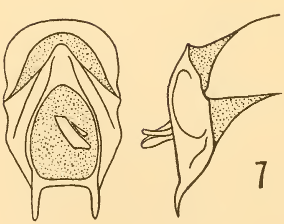

2

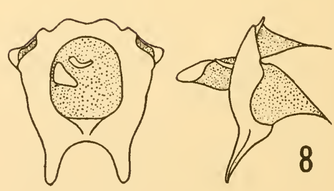

3

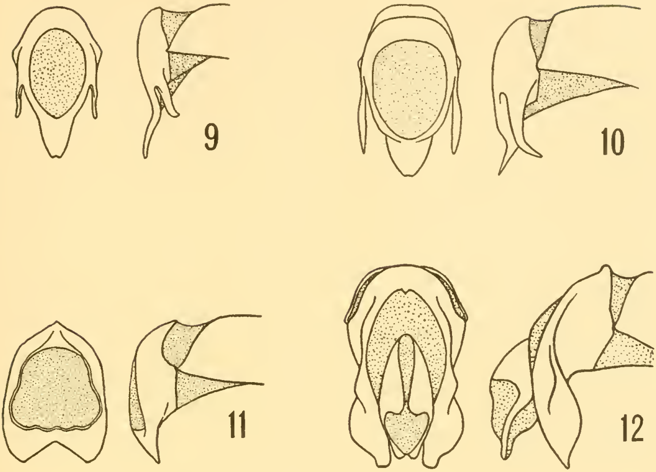

4


5


6


7


8



Figs. 1-12.—En face and lateral views of aedeagus.

1. *Chlaenobia aegrota* Bates. Mexico? British Museum.
2. *Chlaenobia arrowi,* n. sp. Venodio, Sinaloa, Mexico. Paratype.
3. *Chlaenobia latipes* Bates. Cordoba, Vera Cruz, Mexico.
4. *Chlaenobia panamana,* n. sp. Cano Saddle, Gatun Lake, Canal Zone. Type.
5. *Chlaenobia vexata* (Horn). Brownsville, Texas.
6. *Chlaenobia unituberculata* Bates. North Yucatan, Gaumer. British Museum.
7. *Chlaenobia colimana* Arr. Colima Volcano, Mexico.
8. *Chlaenobia dissimilis,* n. sp. Venodio, Sinaloa, Mexico. Type.
9. *Chlaenobia aequata* Bates. Costa Rica. British Museum.
10. *Chlaenobia chiapensis,* n. subsp. Chiapas, Mexico. Type.
11. *Chlaenobia scabripyga* Bates. Juquila, Mexico. British Museum.
12. *Chlaenobia tumulosa* Bates. Palin, Guatemala.

of a third tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 1.

Female.—Antennal club as long as second to sixth segments combined. Sternites not modified, free margin of sixth rather strongly produced. Pygidium somewhat as in male but with all characteristics greatly accentuated, the punctures coarser and more densely placed, the transverse groove enlarged and deepened and with apical margin produced into a liplike structure. Anterior tibia tridentate with upper tooth small.

Length.—14 mm.

Type locality.—Jalapa, Mexico (as here restricted).

Type.—In the British Museum.

Material examined.—Three males and one female from Jalapa, Mexico, Hoege, probably paratypes; one male and four females from Cordoba, V. C., Mexico, F. Knab; one male from Mexico, D. F., J. R. Inda. Three of the Jalapa specimens were loaned for study by the British Museum, the fourth was received some years ago as a gift from the same source.

CHLAENOBIA RODRIGUEZI Bates

Chlaenobia rodriguezi Bates, 1889, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, supplement, p. 399.

Head very coarsely and closely punctured except just above the impressed bisinuate clypeofrontal suture, outer or marginal third of clypeus gradually reflexed, the central portion tumid, the anterior margin broadly and shallowly notched at middle. Antennae nine-segmented. Pronotum transversely oblong, side margins obtusely angulate before the middle, lateral margin strongly bisinuate as viewed from side, viewed from above the anterior and posterior angles are obtuse and rounded; punctures coarse, sparsely and irregularly distributed. Scutellum equilateral, lateral margins curved, surface with a few punctures near margins. Elytra with sutural margins tumid to apices, where the extreme margins are sharply carinate, discal costae not evident, punctures coarse and more densely placed than on pronotum, epipleura very narrow and failing to reach sutural angle. Metasternum coarsely and rather densely punctured at sides, with a few scattered punctures in median portion.

Male.—Unknown to the writer.

Female.—Antennal club as long as second to sixth segments combined. Sternites not modified, finely punctured and sparsely set with short hairs. Pygidium broadly triangular, convex basally from side to side, apical portion flattened and set off from basal portion by two very faintly indicated callosities. Anterior tibia tridentate with basal tooth poorly developed. Anterior tarsus with slender, parallel-sided segments.

Length.—14 mm.

Type locality.—Capetillo, Guatemala.

Type.—In the British Museum.

Material examined.—A female from the type locality, collected by Rodriguez and apparently a paratype, loaned for study by the British Museum.

CHLAENOBIA ARROWI, n. sp.

Head coarsely and moderately densely punctured on frons, vertex virtually impunctate, clypeofrontal suture sharply impressed and bisinuate, clypeus concave, the marginal fifth sharply reflexed, coarsely and very sparsely punctured, margin feebly sinuate at middle. Antenna nine-segmented. Pronotum transverse, side margins obtusely angulate just before the middle, lateral margin straight near posterior angle as viewed from side, viewed from above anterior and posterior angles obtuse, bluntly rounded, equal; punctures more coarse than those of head, sparsely and irregularly placed. Scutellum with base longer than a side, sides evenly curved, with a few scattered punctures. Elytra with sutural margin broadly tumid and each with a single, faintly indicated discal costa, punctures less coarse but more densely placed than on pronotum, epipleura very narrow, terminating just before extreme apex. Metasternum finely and densely punctured on median area, coarsely and more sparsely punctured laterally, clothed with rather short erect hairs. Sternites, especially first and second, with short, fine bristlelike setae on median portion.

Male.—Antennal club one-fourth longer than second to sixth segments combined, fourth segment much longer than third. Sixth sternite with a median longitudinal depression, its free margin transverse. Pygidium strongly and evenly convex, sparsely and moderately coarsely punctured and sparsely hairy, the extreme apical margin sharply reflexed and produced at middle. Anterior tibia bidentate. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 2.

Female.—Antennal club as long as second to sixth segments combined. Sixth sternite without depression, its free margin moderately strongly produced at middle. Pygidium very sparsely punctured, with a deep, nearly hemispherical depression at middle, which is connected with the basal margin by a deep groove, half as wide as the pit itself. Apical margin strongly produced in an acute, reflexed lip. Anterior tibia tridentate.

Length.—13 to 14.5 mm.

Type locality.—Venodio, Sinaloa, Mexico.

Type.—U.S.N.M. no. 51041.

Material examined.—Type (male) and 35 paratypes of both sexes collected at the type locality June 10-15, 1918, Kusche, donated to the National Museum by B. P. Clark; one male paratype from Sinaloa, Mexico, without further data.

In the 37 specimens before me, 3 show a partial division of the fourth antennal segment into two segments on one or both sides of the insect. In no case is the division complete on both sides of the same specimen and in the other specimens both antennae are without doubt nine-segmented.

CHLAENOBIA LATIPES Bates

Chlaenobia latipes Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167.
Chlaenobia bicallosa Bates, 1888, loc. cit., p. 168.

Head rather densely and moderately coarsely punctured on frons, region adjacent to the feebly impressed but strongly bisinuate clypeofrontal suture more sparsely punctured. Frons slightly convex. Antenna ten-segmented. Pronotum transverse, side margins obtusely angulate well before the middle, lateral margin sinuate just before posterior angle as viewed from side, viewed from above anterior angles narrowly rounded, posterior angles acute and slightly produced; punctures a little coarser than those of head, rather sparsely and irregularly distributed. Scutellum equilateral, sides curved, with a few scattered punctures. Elytra with sutural margins strongly tumid, discal costae feebly indicated; punctures finer and more densely placed than on pronotum, epipleura very narrow, obsolete toward apex. Metasternum moderately coarsely and densely punctured, vestiture moderately long and suberect.

Male.—Clypeus deeply concave, rather coarsely and densely punctured, subtrapezoidal, anterior margin feebly emarginate. Antennal club half again as long as second to seventh segments combined. Sixth sternite broadly and shallowly impressed, its free margin broadly rounded and slightly produced. Pygidium transverse, slightly convex, median area slightly impressed, apex transverse, slightly lipped. Anterior tibia slender, bidentate, second segment of anterior tarsus broadly oval, less than twice as long as wide. Aedeagus, figure 3.

Female.—Clypeus feebly concave, coarsely, densely and somewhat confluently punctured, biarcuate with median indentation shallow.

Antennal club a little shorter than second to seventh segments combined. Sixth sternite with its free margin rather strongly produced in a broad lobe. Pygidium transverse, median line sharply impressed, with a conical boss on either side of median line at middle of length, apical third shallowly excavate, apical margin subtransverse and sharply reflexed. Anterior tibia tridentate.

Length.—13.5 to 15 mm.

Type locality.—Teapa, Mexico (*latipes*); Tomatlan and Tuxtla, Mexico (*bicallosa*).

Types.—In the British Museum.

Material examined.—Two males from Cordoba, determined as this species by Arrow but previously determined by Bates as *aegrota;* one female, apparently a paratype of *bicallosa,* from Tomatlan; seven males and nine females from Cordoba, V. C., Mex., May 12–June 9, Fred. Knab; one male and one female from Chiapas, Mexico, in collection of L. W. Saylor.

Two males and a female were taken by Knab on May 12 and again on May 16. It seems unlikely that these sexes are not of the same species. The males compare favorably with the two specimens determined by Arrow, and one of the females has been compared by Arrow with the type of *bicallosa.* The original description of the female of *latipes* is not materially different from that of *bicallosa.*

CHLAENOBIA PANAMANA, n. sp.

Head densely and moderately coarsely punctured on frons, vertex and region adjacent to clypeofrontal suture, which is deeply impressed and strongly biarcuate, very sparsely punctured. Frons evenly and slightly convex. Clypeus shallowly concave, its outer portion not sharply reflexed, margin distinctly indented at middle. Antenna ten-segmented. Pronotum transverse, side margin obtusely angulate just before the middle, lateral margin strongly sinuate just before the posterior angle as viewed from the side, viewed from above anterior angle subacute, posterior angle acute and slightly produced; punctures coarse, densely placed on disk, more sparsely so on flanks. Scutellum equilateral, rather sparsely punctured. Elytra with sutural margins narrowly tumid, each with two feebly indicated discal costae, of which the first (from suture) is more developed than the second; punctures as coarse and a little more densely placed than on disk of pronotum, epipleura very narrow, not well defined beyond middle of the length. Metasternum moderately coarsely and very sparsely punctured, the median area puncture-free; vestiture moderately long but sparse.

Male.—Antennal club about one-fifth longer than second to seventh segments combined. Abdominal sternites not noticeably modified, sixth with the free margin slightly produced at middle. Pygidium moderately strongly convex in basal half, which is rather coarsely but not densely punctured, apical half less convex, shining, nearly puncture-free, the extreme apex not strongly reflexed. Anterior tibia long and slender, bidentate with a feeble indication of a third tooth, second segment of anterior tarsus narrow, about four times as long as wide. Aedeagus, figure 4.

Female.—Antennal club as long as second to seventh segments combined. Abdominal sternites convex, not modified, the sixth with its free margin produced at middle in a small triangular process. Pygidium with a moderately deep, transversely oval depression covering almost the entire apical three-fifths, the apical margin slightly produced, basal portion sparsely and moderately coarsely punctured. Anterior tibia short and broad, distinctly tridentate.

Length.—13.5 to 15 mm.

Type locality.—Cano Saddle, Gatun Lake, Canal Zone.

Type.—U.S.N.M. no. 51042.

Material examined.—Type (male) and three paratypes (males and females) from the above locality, collected May 8-12, 1923, R. C. Shannon; one paratype (female) from Barro Colorado Island, Panama, June 25, 1933, J. D. Hood.

This broad species, when fresh and without grease, has a very distinctive appearance due to the bicolored pronotum. In greasy specimens the disk of the pronotum appears nearly black, while the flanks and elytra are moderately dark brown.

CHLAENOBIA PERSONATA, n. sp.

Head coarsely and densely punctured except on vertex, clypeofrontal suture deeply impressed, bisinuate, frons with a short median impressed groove extending backward a short distance from the clypeofrontal suture, outer third of clypeus gradually reflexed, anterior margin broadly and shallowly emarginate at middle. Antenna ten-segmented. Pronotum transverse, side margin obtusely angulate just before the middle, lateral margin feebly sinuate near posterior angle as viewed from side, viewed from above the anterior angles are obtuse and rounded, the posterior angles subacute, surface moderately coarsely and rather irregularly punctured. Scutellum equilateral, side margin curved, surface sparsely and rather coarsely punctured. Elytra with sutural margins tumid to apices, discal costae not evident, punctation similar to that of pronotum, epipleurae very narrow but complete. Metasternum coarsely punctured, very densely at sides and less densely at middle.

Male.—Unknown to the writer.

Female.—Antennal club as long as the second to seventh segments combined. Sternites moderately coarsely and densely punctured, sparsely hairy. Sixth sternite very coarsely punctured. Pygidium broad, not angulate, convex basally from side to side; apical portion with a shallow excavation, the floor of which is virtually devoid of punctures, rest of surface coarsely and rather densely punctured. Anterior tibia tridentate, basal tooth well defined. Anterior tarsus with slender, parallel-sided segments.

Length.—15.5 mm.

Type locality.—Mexico.

Type.—In the British Museum.

Material examined.—A single specimen, number 21975, from the Frye Collection. The specimen bears the pin label " Liogenys personata Reiche—Mexico ".

CHLAENOBIA VEXATA (Horn)

Phytalus vexatus Horn, 1885, Trans. Amer. Ent. Soc., vol. 12, p. 120.
Phytalus cavifrons Linell, 1896, Proc. U. S. Nat. Mus., vol. 18, p. 729.

Head moderately coarsely and densely punctured on frons. Clypeofrontal suture deeply impressed, biarcuate. Clypeus coarsely but less distinctly punctured than frons, very slightly elevated at middle, the outer third abruptly reflexed, anterior margin feebly indented. Antenna ten-segmented. Pronotum transverse, broadest across middle, side margins very broadly angulate, lateral marginal carina slightly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles subacute; punctures slightly less coarse and much less densely placed than those on frons, irregularly distributed. Elytra with sutural margins tumid, discal costae faintly indicated; punctures slightly finer but about as densely placed as those on pronotum; epipleura narrow. Metasternum polished and sparsely punctured at middle, coarsely and more densely punctured at sides, vestiture short and sparse.

Male.—Antennal club a little longer than second to seventh segments combined. Second to fifth sternites polished at middle with a very few scattered punctures. Sixth sternite feebly depressed at middle. Pygidium convex, moderately coarsely and very sparsely punctured, apex rounded and lipped. Anterior tibia with three teeth, the upper not strongly developed. Second segment of anterior tarsus elongate with parallel sides, about four times as long as wide. Aedeagus, figure 5.

Female.—Antennal club a little shorter than second to seventh segments combined. First to fifth sternites unmodified, sixth sternite convex, with a broad shallow emargination behind. Pygidium strongly convex in basal half, shallowly and transversely excavated apically, with a single, low, median callosity. Anterior tibia strongly tridentate. Second segment of anterior tarsus elongate, parallel-sided, about three times as long as wide.

Length.—11 to 13.8 mm.

Type locality.—Texas.

Types.—In the Academy of Natural Sciences, Philadelphia (*vexatus* Horn); in the United States National Museum, no. 574 (*cavifrons* Linell).

Material examined.—One female from Texas in the Philadelphia Academy (type of *vexatus* Horn); two males and one female from Brownsville, Tex., May 24–June 11, C. H. T. Townsend (type and paratypes of *cavifrons* Linell); five males and one female from same locality, May 15–Aug. 17, C. Schaeffer (Brooklyn Museum Collection, U.S.Nat.Mus.); one male from Texas, Fry Collection 1905-100 (British Museum).

This species is unusual in the genus in having a moderately well defined third tooth on the anterior tibia of the male.

CHLAENOBIA VEXATA subsp. UNITUBERCULATA Bates

Chlaenobia unituberculata Bates, 1889, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, supplement, p. 399.

Very similar to the typical form of the species. The punctation of the head and pronotum is a little coarser in *unituberculata* than in *cavifrons*. The aedeagus offers the only sure means of identification. In the present subspecies (fig. 6) the apical portion of the organ narrows sharply from a point at about the level of the terminus of the median fissure.

Type locality.—Temax, N. Yucatan (Gaumer).

Type.—In the British Museum.

Material examined.—A pair, probably paratypes, from the type locality, loaned for study by the British Museum and a pair from Rin Antonio, Oaxaca, Mexico, F. Knab, collector.

CHLAENOBIA COLIMANA Arrow

Chlaenobia colimana Arrow, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. 11, p. 145.

Head rather sparsely and moderately densely punctured on frons, median line, vertex and along the lightly impressed and feebly sinuate clypeofrontal suture almost free of punctures. Frons almost plane. Clypeus not concave, its outer margin slightly reflexed and very feebly indented at middle. Antenna ten-segmented. Pronotum transverse, side margins very obtusely angulate before the middle, lateral margin strongly sinuate just before the posterior angle as viewed from side, viewed from above anterior and posterior angles acute; punctures coarse and rather sparse on disk, finer and sparser on flanks. Scutellum equilateral, with a few coarse punctures along side. Elytra with sutural margin broadly tumid at middle of length, narrowed basally and apically, discal costae almost completely effaced; punctures a little finer and as densely placed as those on pronotal disk, epipleura very narrow, disappearing just before the extreme apex. Metasternum very finely and densely punctured on median portion, more coarsely and sparsely at sides, vestiture short and erect, absent from a minute spot at center.

Male.—Antennal club half again as long as second to seventh segments combined. Abdominal sternites short and crowded along median line, sixth sternite as long, along median line, as fourth and fifth combined, its median portion flattened and with a poorly defined longitudinal groove. Pygidium strongly convex, apical half sparsely hairy, apical margins transverse and slightly lipped. Anterior tibia slender, bidentate with a trace of a third tooth, second segment of anterior tarsus elongate oval, about three times as long as wide. Aedeagus, figure 7.

Female.—Antennal club very slightly longer than second to seventh segments combined. Abdominal sternites somewhat flattened along median line but not concave, sixth sternite long, with its free margin bisinuate. Pygidium with a single well-developed median tubercle on basal half, apical two-thirds cut away and with a deep, narrow median groove extending from below the tubercle toward apex. Apical margin with two small processes which fit into the sinuations at apex of sixth sternite; concave portion sparsely hairy. Anterior tibia slender, tridentate.

Length.—13.5 to 16.5 mm.

Type locality.—Colima, Mexico.

Type.—In the British Museum.

Material examined.—Six males and three females from Colima Volcano, Jalisco, L. Conradt. Specimens from this lot have been compared with the type by Arrow.

CHLAENOBIA DISSIMILIS, n. sp.

Head moderately coarsely and densely punctured near eyes, rest of frons, vertex and clypeus sparsely punctured. Clypeofrontal suture feebly impressed and biarcuate. Clypeus flat with outer fourth gradually reflexed, its anterior margin feebly and broadly indented. Antenna ten-segmented. Pronotum transverse, side margins obtusely angulate well before the middle, lateral marginal carina weakly sinuate just before the posterior angle as viewed from the side, viewed from above anterior and posterior angles acute, not produced; punctures a little more coarse than those of head, sparsely placed on disk, very sparsely on flanks. Elytra with sutural margins strongly tumid, discal costae obsolete; punctures almost as coarse as those on pronotum and a little more densely placed; epipleura very narrow, obsolete toward apex. Metasternum coarsely and densely punctured at sides, very finely and very densely at middle except for the small median area, which is puncture-free; vestiture sparse at sides, very dense at middle.

Male.—Antennal club about one-third longer than second to seventh segments combined. Abdominal sternites each with a median patch of short, fine and dense hairs, sixth with a shallow median longitudinal impression, its free margin transverse, not noticeably produced. Pygidium strongly convex, rather sparsely punctured, apex subtransverse and slightly lipped. Anterior tibia moderately stout, bidentate. Second segment of anterior tarsus oval, about two and one-half times as long as wide. Aedeagus, figure 8.

Female.—Antennal club a little shorter than second to seventh segments combined. First and fifth abdominal sternites convex, not modified, sixth sternite with a broad and rather deep pit on either side of the median line, its free margin strongly tumid and sinuous. Pygidium with a pair of strong, conical bosses on basal half which are confluent basally, apical half excavate, apex transverse. Punctures sparse on basal half, almost wanting on apical half. Anterior tibia short, distinctly tridentate.

Length.—14.5 to 16 mm.

Type locality.—Venodio, Sinaloa, Mexico.

Type.—U.S.N.M. no. 51043.

Material examined.—Type (male) and three paratypes (males and females) from above locality, collected from June 10–July 30, Kusche.

The extremities of this species are unusually pilose in the male, the posterior femora at base and posterior tibia at apex bear dense brushes of long hair on their inner margins. All tarsi are also exceedingly pilose.

CHLAENOBIA AEQUATA Bates

Chlaenobia aequata Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 168.

Head coarsely punctured, densely so on vertex and upper portion of frons, moderately densely so on clypeus and very sparsely so on lower part of frons in the region of the clypeofrontal suture which is strongly impressed and bisinuate; clypeus with marginal fourth reflexed, the central portion nearly flat, the margin slightly notched at middle. Antenna ten-segmented. Pronotum transverse, side margins strongly angulate at middle, lateral margin strongly sinuate near posterior angle as viewed from side, viewed from above, the anterior angles are obtuse and rounded, basal angles prominent and subacute; punctures coarse, more sparsely placed on disk than on flanks where their density is similar to those on clypeus. Scutellum equilateral, the side margin curved, surface sparsely and rather finely punctured near margins. Elytra with sutural margins broadly tumid except at apex where the extreme margins are sharply carinate, discal costae not evident, punctures less coarse but as densely placed as on flanks of pronotum, epipleura very narrow. Metasternum moderately coarsely and very densely punctured at sides, a little more sparsely so in median portion.

Male.—Antennal club almost as long as all the remaining segments combined. Fifth sternite with a sparse patch of hair at middle, arising from a patch of asperities, sixth sternite tumid with a central depression surrounded by a few very coarse punctures or pits, free margin with a broad and not very prominent process. Pygidium uniformly and strongly convex, coarsely and sparsely punctured, a little more densely so toward base; apical margin sharply and narrowly reflexed. Anterior tibia bidentate with a faint indication of a third tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 9.

Female.—Antennal club as long as second to seventh segments combined. Sternites not noticeably modified. Pygidium elongate triangular, basal half evenly convex from side to side, apically flattened with indications of two broad callosities just above the flattened portion. Anterior tibia tridentate.

Length.—12 mm.

Type locality.—Chontales, Nicaragua and Costa Rica.

Type.—In the British Museum.

Material examined.—A pair (of which the female is probably a paratype) from Costa Rica, loaned for study by the British Museum; one female from Tuis, C. R., 2,400 feet, C. H. Lankester.

CHLAENOBIA AEQUATA subsp. CHIAPENSIS, n. subsp.

Similar in most respects to the typical subspecies but differing in the slightly coarser punctures of the head and pronotum and in the conformation of the aedeagus. The lateral appendages of the aedeagus in the typical subspecies are short and extend about half-way from their insertion to the apex of the conjoined lateral lobes. In the subspecies *chiapensis* (fig. 10) these appendages are considerably longer, almost reaching the level of the apex of the lobes.

Type locality.—Chiapas, Mexico.

Type.—U.S.N.M. no. 51044.

Material examined.—Type (male), three paratypes (males) and two paratypes (females) from the Pacific slope of the Cordilleras, altitude 800 to 1000 meters, state of Chiapas, L. Hotzen, 1919.

CHLAENOBIA SCABRIPYGA Bates

Chlaenobia scabripyga Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167.

Head coarsely punctured, moderately densely so on clypeus and frons, sparsely so on median portion of vertex, clypeofrontal suture deeply impressed and strongly biarcuate, with the median cusp prolonged a short distance onto the frons as a median impressed line, clypeus with margin more or less following the curvature of the clypeofrontal suture, feebly reflexed, central portion nearly flat. Antenna ten-segmented. Pronotum transversely oblong, sides obtusely angulate at middle, lateral margin nearly straight throughout its length as viewed from side, viewed from above both anterior and posterior angles are obtuse and rounded; punctures similar in size to those on frons, moderately densely placed except along the lateral margins and on median portion of disk, where they are slightly less dense. Scutellum equilateral with side margins curved, surface moderately coarsely and densely punctured. Elytra with sutural margins broadly and strongly tumid, discal costae not well defined, punctures about as coarse and as densely placed as on disk of pronotum, epipleura very narrow. Metasternum moderately coarsely and rather evenly punctured, median portion set with rather long erect hairs.

Male.—Second to fourth sternites each with a dense median patch of short erect hairs, fifth sternite with surface generally uneven but without asperities or hair patch at middle. Sixth sternite with median area slightly depressed, its posterior margin not noticeably sinuate. Pygidium strongly convex in its upper (basal) half, which is coarsely and densely punctured, the lower half is more flattened, coarsely wrinkled and convoluted, apical margin sharply and narrowly reflexed. Anterior tibia feebly tridentate, the upper tooth at some distance from the middle tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 11.

Female.—Unknown to the writer.

Length.—12 mm.

Type locality.—Juquila, Mexico.

Type.—In the British Museum.

Material examined.—A male, probably a paratype, from the type locality, loaned for study by the British Museum. Unfortunately, both of the antennal clubs are missing.

CHLAENOBIA TUMULOSA Bates

Chlaenobia tumulosa Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 168.

Head rather densely and moderately coarsely punctured except for a small area on vertex which is free of punctures. Clypeofrontal suture moderately sharply impressed and not strongly sinuate. Clypeus evenly, densely, and moderately coarsely punctured, slightly convex at middle, and with outer third gradually reflexed, anterior margin moderately strongly indented at middle. Antenna ten-segmented. Pronotum transverse, broadest across middle, side margins broadly rounded, lateral marginal carina rather strongly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles subacute, the latter slightly produced; punctures as coarse but less dense than those on frons, irregularly distributed. Elytra with sutural margins tumid, discal costae faintly indicated; punctures about as dense and coarse as those on pronotum; epipleura very narrow. Metasternum very finely and densely punctured at middle, more coarsely and sparsely at sides, vestiture fine and dense at middle.

Male.—Antennal club one-fifth longer than second to seventh segments combined. Second to fourth abdominal sternites each with a median patch of fine, short hair. Fifth sternite with a transverse patch of asperities along the posterior margin from which arise moderately long, fine hair. Sixth sternite with a median longitudinal groove. Pygidium convex, coarsely and rather densely punctured on basal half, very sparsely punctured on apical half, apex subtransverse and slightly lipped. Anterior tibia slender, bidentate, second segment of anterior tarsus elongate oval, about three times as long as wide. Aedeagus, figure 12.

Female.—Antennal club a little shorter than second to seventh segments combined. First to fifth sternites unmodified, sixth sternite with a broad semicircular emargination on free margin. Pygidium conical with apex replaced by a deep hemispherical cavity bounded at sides by blunt crests, below by an acute and somewhat produced margin. Anterior tibia stout, tridentate.

Length.—14 to 15 mm.

Type localities.—British Honduras, R. Sarstoon; Guatemala, near city, Duenas, Capitillo.

Type.—In the British Museum.

Material examined.—Two specimens, male and female, from Guatemala (Sallé), apparently paratypes, loaned for study by the British Museum; three males and four females from Palin, Guatemala, May 1924, W. M. Mann; three males and one female from Tegucigalpa, Honduras, May–June, 1917, F. J. Dyer; one male from Finca Gibraltar, Mexico, September 1910, in collection of L. W. Saylor.

In the Honduras specimens noted above, the aedeagus differs from the Guatemala type in that the triangular tooth at the middle of the outer margin of each lateral lobe is somewhat accentuated. A separate name for each race does not seem necessary.

I also refer to this species a single female from Cacos, Trece Aguas, Alta Vera Paz, Guatemala. The specimen is evidently abnormal, as the head is very asymmetrical, the clypeus projecting forward nearly twice as far on the right side of the head as on the left. The pygidial characters are like those of the other female specimens but are less accentuated.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 94, NUMBER 10

Roebling Fund

SOLAR RADIATION AND WEATHER STUDIES

(With Three Plates)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(Publication 3339)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 15, 1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

CONTENTS

ILLUSTRATIONS

PLATES

TEXT FIGURES

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 94, NUMBER 12

MOUNT ST. KATHERINE, AN EXCELLENT SOLAR-RADIATION STATION

(With Two Plates)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(Publication 3342)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 5, 1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

MOUNT ST. KATHERINE, AN EXCELLENT SOLAR-RADIATION STATION

By C. G. ABBOT
Secretary, Smithsonian Institution

(With Two Plates)

For many years the Smithsonian Astrophysical Observatory has been engaged in measuring solar radiation on mountain peaks in desert lands, and computing therefrom the solar constant of radiation. By that we mean the intensity of the sun's radiation as it would be found by an observer with a perfect instrument, constantly stationed in free space, outside the earth's atmosphere, at the earth's mean distance from the sun. Our object in this work is to determine to what degree the sun's output of radiation is variable, and what effects its variations produce on weather.

In his "Report of the Mount Whitney Expedition", Langley speaks strongly of the difficulty of measuring solar radiation *anywhere* as *"formidable"*, and that of correcting such measurements for *atmospheric losses* as *"perhaps insuperable"*. But over 50 years have passed since Langley made this statement, and new apparatus and new methods have been devised.

About one million dollars has been spent in making solar measurements at the most favorable stations to be found on the earth. The most earnest efforts have been made to conquer the difficulties so forcibly stated by Langley. Many discussions of the sources of error and the degree of their elimination have been published. Tests and tested inferences which indicate very high present accuracy have been disclosed. We have not, indeed, claimed to determine the exact intensity of that ultraviolet part of the solar radiation which never reaches the earth because it is cut off completely in the upper atmosphere by ozone. This is, however, but a very small fraction of the solar constant. This region of the solar spectrum is probably the most variable. Because its rays are lost at high altitudes, its variations do not perceptibly affect the variation of the sun as an agency to be taken account of in weather.

Meteorologists have, I feel, somewhat neglected our proofs of the accuracy of our work, and have been, I think, somewhat misled by certain criticisms which have appeared in the literature.

Hence it is with unusual satisfaction that I am able to report the close agreement between the results obtained at Mount St. Katherine, our new station in Egypt, and those obtained on the same days at Montezuma in Chile. For since these totally independent stations are in opposite hemispheres, winter at the one coincides with summer at the other. If the contrasting atmospheric and geometric conditions of winter and summer do not bring about appreciable discordance, we may, it would seem, now admit that Langley's two obstacles are sensibly overcome, and the work which has gone on at Montezuma for some years may be accepted with still greater confidence than heretofore.

In the year 1931 I published, under the title " Weather Dominated by Solar Changes ", evidence that the short-interval changes in the intensity of the sun's radiation are of considerable influence in governing the ordinary fluctuations of weather. The solar-radiation values used in that paper were exclusively from the Smithsonian station at Montezuma, Chile. The results seemed to indicate that solar fluctuations of less than 0.5 percent are associated with notable weather changes. But it was impossible from the observations at one station, subject to accidental errors of the instruments and observers and to the difficulty of evaluating the losses in our atmosphere, to be sure of distinguishing solar changes of less than 0.5 percent from errors of observation, except when numerous apparently favorable cases were averaged.

Our station at Table Mountain, Calif., did not then and does not now yield results as accurate as those of Montezuma. The difficulty at Table Mountain lies not in the inadequacy of the apparatus or the observers, but in some obscure invisible changes of atmospheric conditions, whose effects we have hitherto been unable to eliminate completely. New efforts to improve Table Mountain results are now on foot.

With the generous support of the National Geographic Society, an attempt was made about 10 years ago to find and equip a supporting station in the Eastern Hemisphere equal to Montezuma. After a journey to Algeria, Egypt, Baluchistan, and South Africa, I fixed on Mount Brukkaros in South-West Africa as most suitable. Five years of observing there demonstrated that owing to high winds, which carry dust over the mountain, this station was inferior both to Montezuma and to Table Mountain.

Thereupon, with generous support from Mr. John A. Roebling, Mr. and Mrs. A. F. Moore made a second journey of exploration occupying about 20 months. They were equipped with portable in-

Solar Observing Station on Mount St. Katherine. Sinai Peninsula

View Showing the West and North Sides of the Observatory and the Dwelling, Mount St. Katherine struments, almost, indeed, adequate to observe the solar constant of radiation, and they spent weeks and even months in observing at some of the more promising stations. In this way they visited the Cape Verde Islands, many peaks in South-West Africa, and finally Mount St. Katherine, about 10 miles from Mount Sinai in Egypt, having an altitude of about 8,500 feet. No station visited proved as promising as the last mentioned. Mr. and Mrs. Moore observed there on about 100 days during the months of March, April, May, June, and July, 1932. As a result I was convinced that Mount St. Katherine had a fair chance of proving to be nearly as satisfactory as Montezuma in Chile for solar-constant observations.

With further support from Mr. Roebling, and with the generous gift from the National Geographic Society of the apparatus which had formerly been installed at Mount Brukkaros, Mount St. Katherine was occupied in the summer of 1933, and regular observations of the solar constant of radiation were begun there in December 1933.

It is a pleasure to acknowledge the great aid received and the cordial relations which have prevailed at all times with His Eminence Porphyrios III, Archbishop of Mount Sinai, and with the monks of St. Katherine's Monastery, under his direction, on Mount Sinai. During Mr. and Mrs. Moore's reconnaissance, the monks placed an existing structure on Mount St. Katherine at the disposal of these observers and brought them supplies. When a permanent occupation was undertaken, the authorities of the Monastery built the observatory and living quarters of stone on Gebel Zebir, a spur of Mount St. Katherine, built trails, and developed water. They still continue to transport supplies to the station from the Red Sea, and are helpful in uncounted ways.

The station was built, equipped, and occupied under the supervision of Harlan H. Zodtner, our field director, assisted by Frederick A. Greeley. Mrs. Zodtner and their two children accompany Mr. Zodtner, and she makes a home for the expedition.

Plates 1 and 2 show the inhospitable mountain site, and the buildings erected by the authorities of the Monastery for the instruments and observers.

Records of the observations made from December 1933 to April 1935 have now been reduced under the direction of my colleague, L. B. Aldrich. A short method similar to those in use at our stations Montezuma and Table Mountain was developed by him for St. Katherine. Also some improvement based on additional observations has recently been made by him in the reduction tables for Montezuma, and more correct new values, differing by a few thousandths of a calorie from those first computed, have been substituted for the broadcasted Montezuma observations of the solar constant of radiation for the past few years.

Our first care was to reduce the St. Katherine results to the same average scale as Montezuma. The scale depends on the adopted constants of the pyrheliometers, and no favorable weather for determining these was available in Washington before the departure of the Egyptian expedition. The scale correction was obtained by computing the average difference for 180 individual days of good quality at both stations. The resulting mean difference, 0.034 calorie, was subtracted from all St. Katherine daily values.

Next the average mean difference of the daily results of good quality common to the two stations was computed for each month without regard for sign, as shown in table 1, together with the number of days represented in each mean. The values given are in thousandths of a calorie.

TABLE 1.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine*

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean Value	..	..	..	..	..	..	..	..	..	..	..	7
	Number days	..	..	..	..	..	..	..	..	..	..	..	4
1934	Mean Value	4	8	7	14	12	9	5	7	7	11	7	8
	Number days	4	7	10	13	5	11	19	19	26	14	11	8
1935	Mean Value	13	12	8	12	..	..	..	..	..	..	..	..
	Number days	9	4	7	11	..	..	..	..	..	..	..	..

General mean, 182 days, 0.0086 calorie.

Thus the general mean of all the daily differences, numbering 182 in all and covering a period of 17 months, is approximately 0.45 percent of the solar constant, taken as 1.940 calories. Omitting 6 aberrant values, it is 0.0079 calorie, or approximately 0.40 percent. Dividing by $\sqrt{2}$, we find the average daily accidental error of a single station is 0.30 percent.

It was particularly important to determine whether the daily differences, Montezuma minus St. Katherine, show a yearly period. Accordingly mean values of them were computed monthly having regard to sign. The results are given in table 2. They are expressed in thousandths of a calorie.

TABLE 2.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine Taken with Regard to Sign*

Year	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean	..	..	..	..	..	..	..	..	..	..	..	+1
1934	Mean	+3	−4	0	+14	+12	−4	+1	+2	−3	−9	+4	+2
1935	Mean	+13	−1	−6	−6	..	..	..	..	..	..	..	..

calorie from those first computed, have been substituted for the broadcasted Montezuma observations of the solar constant of radiation for the past few years.

Our first care was to reduce the St. Katherine results to the same average scale as Montezuma. The scale depends on the adopted constants of the pyrheliometers, and no favorable weather for determining these was available in Washington before the departure of the Egyptian expedition. The scale correction was obtained by computing the average difference for 180 individual days of good quality at both stations. The resulting mean difference, 0.034 calorie, was subtracted from all St. Katherine daily values.

Next the average mean difference of the daily results of good quality common to the two stations was computed for each month without regard for sign, as shown in table 1, together with the number of days represented in each mean. The values given are in thousandths of a calorie.

Table 1.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine*

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean Value	..	..	..	..	..	..	..	..	..	..	..	7
	Number days	..	..	..	..	..	..	..	..	..	..	..	4
1934	Mean Value	4	8	7	14	12	9	5	7	7	11	7	8
	Number days	4	7	10	13	5	11	19	19	26	14	11	8
1935	Mean Value	13	12	8	12	..	..	..	..	..	..	..	..
	Number days	9	4	7	11	..	..	..	..	..	..	..	..

General mean, 182 days, 0.0086 calorie.

Thus the general mean of all the daily differences, numbering 182 in all and covering a period of 17 months, is approximately 0.45 percent of the solar constant, taken as 1.940 calories. Omitting 6 aberrant values, it is 0.0079 calorie, or approximately 0.40 percent. Dividing by $\sqrt{2}$, we find the average daily accidental error of a single station is 0.30 percent.

It was particularly important to determine whether the daily differences, Montezuma minus St. Katherine, show a yearly period. Accordingly mean values of them were computed monthly having regard to sign. The results are given in table 2. They are expressed in thousandths of a calorie.

Table 2.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine Taken with Regard to Sign*

Year	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean	..	..	..	..	..	..	..	..	..	..	..	+1
1934	Mean	+3	−4	0	+14	+12	−4	+1	+2	−3	−9	+4	+2
1935	Mean	+13	−1	−6	−6	..	..	..	..	..	..	..	..

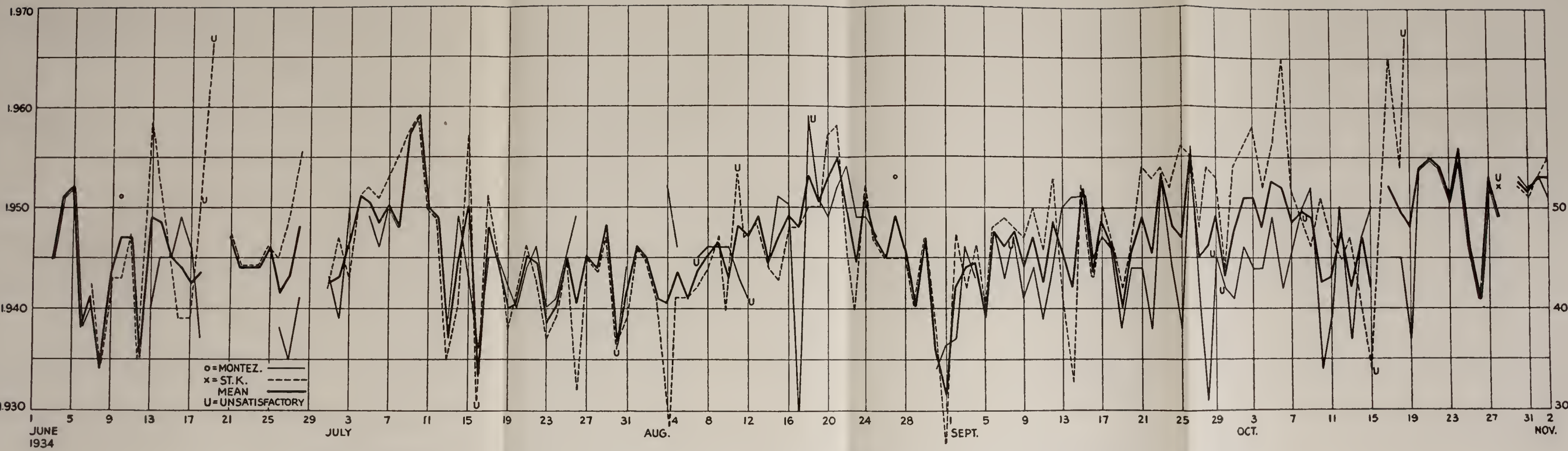


FIG. 1.—Comparison of solar-constant values from two stations 7,000 miles apart on opposite sides of the Equator. One percent equals four vertical divisions.

Except for the large positive values found sporadically in January 1935, and April and May 1934, there seems to be no evidence of appreciable yearly periodicity. For the differences are no larger than would be expected as the result of unbalanced experimental errors. During the months just excepted somewhat unsatisfactory conditions prevailed at one or both stations. This general conclusion is highly satisfactory. It means that on good days the differences of exposure of instruments caused by unequal altitudes of the sun and the differences of procedure and magnitudes in allowing for atmospheric losses at two independent stations in opposite hemispheres, separated by nearly a third the circumference of the earth, produce no differential periodicity in excess of two or three tenths of 1 percent of the solar constant of radiation. Accordingly the yearly range of systematic error for one station, being half as great as the combined ranges of two stations, is surely negligible. Summer with its increased heat, haziness, and humidity, opposed by winter with its greater cold, clearness, and dryness, and besides these the observation of the sun at different angles above the horizon at the constrasted stations, have altogether failed to produce differences in the results which indicate that systematic errors are certainly appreciable.

Finally, the individual daily values at the two stations during the five best months, June to October, 1934, have been tabulated in table 3, and plotted in figure 1. In computing the mean values and deviations in the table, I have included a few fairly good values marked " unsatisfactory " which were excluded in tables 1 and 2.

A heavy line in the figure gives the best value of the march of the solar constant of radiation.[1] The independent results of the two stations are indicated by a lighter line for Montezuma and a dotted line for St. Katherine. The close accord shown by these two remote and contrasting stations cannot but encourage the belief that the observations of the variability of the sun hitherto reported from Montezuma are very close to the truth.

Every day but six within this interval of 152 days from June to October 1934 is covered by good observations at one station or both. The two stations obviously support each other in displaying in common many variations of the intensity of solar radiation. The most conspicuous variation of long period shown has a periodicity of a little more than 40 days, perhaps even 45 days, and has an amplitude of about $\frac{3}{4}$ of 1 percent. This effect is doubtless to be associated with that solar periodicity of about 45 days to which I once drew attention

[1] The table and diagram were prepared independently and may differ slightly.

TABLE 3.—*Comparative Solar-Constant Results at Montezuma and St. Katherine*

The values given are thousandths of a calorie, and in columns 2, 4, 6 are to be understood as added to 1.900 calories

1934	Montezuma S. C.	Montezuma Gr.	St. Katherine S. C.	St. Katherine Gr.	S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
June 1	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..
3	45	S—	..	..	45	M	..
4	51	S—	106	U	51	M	..
5	52	U	..	..	52	M	..
6	38	S—	102	U?	38	M	..
7	40	S	42	S—	41	B	— 2
8	..	..	34	S—	34	K	..
9	..	..	43	S—	43	K	..
10	51	S—	43	S—	47	B	+ 8
11	..	..	47	S—	47	K	..
12	..	..	35	S—	35	K	..
13	40	S—	58	S—	49	B	—18
14	45	S—	52	S—	48	B	— 7
15	45	S	..	..	45	M	..
16	49	S—	39	S	44	B	+10
17	46	S	39	S—	42	B	+ 7
18	37	S—	50	U	43	B	—13
19	..	..	66	U	..	..	..
20	..	..	91	U	..	..	..
21	39	S—	47	S	43	B	— 8
22	..	..	44	S—	44	K	..
23	45	S—	44	S	44	B	+ 1
24	..	..	44	S—	44	K	..
25	..	..	46	S—	46	K	..
26	38	S—	45	S—	42	B	— 7
27	35	S	49	S	42	B	—14
28	41	S—	55	S—	48	B	—14
29	..	..	..	..	..	..	..
30	..	..	..	..	..	..	..
July 1	43	S—	42	S—	42	B	+ 1
2	39	S—	47	S—	43	B	— 8
3	50	S—	43	S—	46	B	+ 7
4	..	..	51	S—	51	K	..
5	49	S	52	S—	50	B	— 3
6	46	S—	51	S—	48	B	— 5
7	50	S	..	..	50	M	..
8	48	S—	..	..	48	M	..
9	..	..	57	S—	57	K	..
10	..	..	59	S	59	K	..
11	..	..	50	S	50	K	..
12	..	..	49	S—	49	K	..
13	39	S	35	S—	37	B	+ 4
14	49	S	40	S—	44	B	+ 9
15	43	S	57	S—	50	B	—14
16	36	S—	31	U	34	B	+ 5
17	45	S	51	S—	48	B	— 6
18	45	S	45	S—	45	B	0
19	42	S	38	S	40	B	+ 4
20	38	S—	41	S	40	B	— 3
21	44	S	46	S	45	B	— 2
22	46	S—	43	S	44	B	+ 3
23	40	S	37	S—	38	B	+ 3
24	41	S—	39	S	40	B	+ 2
25	45	S	45	S	45	B	0
26	49	S	32	S—	40	B	+17
27	..	..	45	S—	45	K	..
28	..	..	44	S—	44	K	..
29	..	..	48	S—	48	K	..
30	36	U	47	S—	42	B	—11
31	44	S	39	S—	42	B	+ 5

[a] M = Montezuma. K = St. Katherine. B = Both.

TABLE 3.—*Continued*

1934		Montezuma S. C.	Montezuma Gr.	St. Katherine S. C.	St. Katherine Gr.	S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
Aug.	1	..	..	46	S—	46	K	..
	2	..	..	45	S—	45	K	..
	3	..	..	41	S—	41	K	..
	4	52	S—	28	S—	40	B	+24
	5	46	S	41	S—	44	B	+ 5
	6	..	..	41	S—	41	K	..
	7	45	U	42	S—	43	B	+ 3
	8	46	S	44	S—	45	B	+ 2
	9	46	S—	47	S—	46	B	— 1
	10	46	S—	40	S—	43	B	+ 6
	11	43	S—	53	U	48	B	—10
	12	41	U	47	U	44	B	— 6
	13	..	..	49	S—	49	K	..
	14	45	S—	44	S—	44	B	+ 1
	15	51	S—	43	S—	47	B	+ 8
	16	50	S—	48	S—	49	B	+ 2
	17	30	S—	48	S	39	B	—18
	18	59	U	50	S	54	B	+ 9
	19	51	S	50	S	50	B	+ 1
	20	49	S—	57	S—	53	B	— 8
	21	52	S	38	S	45	B	+14
	22	54	S	45	S	50	B	+ 9
	23	49	S	40	S	44	B	+ 9
	24	49	S	52	S	50	B	— 3
	25	47	S—	47	S	47	B	0
	26	..	..	45	S	45	K	..
	27	53	S—	45	S—	49	B	+ 8
	28	..	..	46	S—	46	K	..
	29	..	..	40	S	40	K	..
	30	..	..	47	S	47	K	..
	31	34	S—	37	S	36	B	— 3
Sept.	1	36	S	26	S	31	B	+10
	2	37	S—	47	S—	42	B	—10
	3	46	S—	42	S—	44	B	+ 4
	4	43	S—	46	S	44	B	— 3
	5	..	..	39	S—	39	K	..
	6	47	S—	48	S—	48	B	— 1
	7	43	S	49	S—	46	B	— 6
	8	47	U	48	S—	48	B	— 1
	9	41	S	47	S—	44	B	— 6
	10	44	S—	50	S	47	B	— 6
	11	39	S—	46	S	42	B	— 7
	12	44	S—	53	S	48	B	— 9
	13	50	S—	41	S—	46	B	+ 9
	14	51	S	33	S—	42	B	+18
	15	51	S	52	S—	52	B	— 1
	16	44	S	43	S—	44	B	+ 1
	17	47	S—	50	S	48	B	— 3
	18	46	S	46	S	46	B	0
	19	38	S	42	S	40	B	— 4
	20	44	S—	47	S—	46	B	— 3
	21	44	S—	54	S—	49	B	—10
	22	38	S—	53	S—	46	B	—15
	23	53	S—	54	S—	54	B	— 1
	24	44	S—	52	S—	48	B	— 8
	25	38	S	56	S—	47	B	—18
	26	56	S	55	S—	56	B	+ 1
	27	42	S	48	S	45	B	— 6
	28	31	S—	52	S	42	B	—21
	29	45	U	53	S—	49	B	— 8
	30	42	U	46	S—	44	B	— 4

[a] M = Montezuma. K = St. Katherine. B = Both.

TABLE 3.—*Continued*

1934		Montezuma S. C.	Montezuma Gr.	St. Katherine S. C.	St. Katherine Gr.	S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
Oct.	1	41	S—	54	S—	48	B	—13
	2	46	S—	56	S	51	B	—10
	3	44	S	58	S	51	B	—14
	4	44	S—	52	S	48	B	— 8
	5	49	S—	56	S	52	B	— 7
	6	42	S—	65	S—	54	B	—23
	7	45	S—	52	S—	48	B	— 7
	8	50	U	49	S	49	B	+ 1
	9	52	S—	46	S—	49	B	+ 6
	10	34	S—	51	S—	42	B	—17
	11	39	S	47	S—	43	B	— 8
	12	50	S—	45	S—	48	B	+ 5
	13	37	S—	47	S—	42	B	—10
	14	47	S	19	U	47	M	..
	15	50	S	34	U	42	B	+16
	16	..	..	43	S—	43	K	..
	17	45	S—	65	S—	50	B[b]	—20
	18	45	S—	54	S—	50	B	— 9
	19	37	S—	67	U	37	M	..
	20	54	S—	82	U?	54	M	..
	21	55	S	92	U?	55	M	..
	22	54	S	..	..	54	M	..
	23	51	S	..	..	51	M	..
	24	56	S	..	..	56	M	..
	25	46	S	103	U?	46	M	..
	26	41	S	..	..	41	M	..
	27	53	S	..	..	53	M	..
	28	49	S—	52	U	50	B	— 3
	29	..	..	..	..	..	..	..
	30	53	U	52	S—	52	B	+ 1
	31	52	U	51	S—	51	B	+ 1
Nov.	1	53	S—	53	S	53	B	0
	2	51	S—	55	S—	53	B	— 4
	3	58	S—	56	S—	57	B	+ 2
	4	..	..	67	U?	..	..	..
	5	58	S	..	..	58	M	..
	6	57	S—	47	S—	52	B	+10
	7	42	S—	94	U	42	M	..
	8	50	S	..	..	50	M	..
	9	..	..	51	S—	51	K	..
	10	63	S—	45	S—	54	B	+18
	11	45	U	52	S—	49	B	— 7
	12	..	..	58	U	..	..	..
	13	..	..	..	..	..	..	..
	14	50	S	..	..	50	M	..
	15	59	S—	46	S	52	B	+13
	16	..	..	50	S	50	K	..
	17	..	..	58	S—	58	K	..
	18	..	..	58	S—	58	K	..
	19	53	S	52	S—	52	B	+ 1
	20	53	S—	44	S—	48	B	+ 9
	21	44	S	..	..	44	M	..
	22	44	S—	..	..	44	M	..
	23	55	S—	..	..	55	M	..
	24	..	..	48	S—	48	K	..
	25	52	S—	..	..	52	M	..
	26	50	S	43	S—	46	B	+ 7
	27	53	S—	54	S—	54	B	— 1
	28	47	S	57	S	52	B	—10
	29	43	U	66	S—	55	B	—23
	30	..	..	54	S—	54	K	..

[a] M = Montezuma. K = St. Katherine. B = Both.
[b] Montezuma given greater weight in the mean.

as having occurred in the year 1924.[2] Many short interval fluctuations are also supported by both stations.

There is little to choose between the two stations as to the smoothness (*i. e.,* freedom from wild values) of their curves during this interval of 5 months. St. Katherine yields a few more days than Montezuma. As the average daily discrepancy between the stations during these 5 months is only 0.007 calorie, we infer that the average accidental error of a single station then was but 0.005 calorie, or $\frac{1}{4}$ of 1 percent.

A careful record of conditions at St. Katherine has been kept under Mr. Zodtner's direction. It is set forth in table 4.

On the whole it appears that Mount St. Katherine, except for a greater average wind velocity during the usual hours of observing, and greater haziness during the spring months, is equally as favorable a station for solar-constant observations as Montezuma. Moreover, the two drawbacks just mentioned do not seem to have lowered the quality of the daily St. Katherine observations below those of Montezuma. Thus far her numbers of days of good observing quality per year have slightly exceeded those of Montezuma, so that St. Katherine may be ranked quite as high on the whole as Montezuma.

In my paper " Weather Dominated by Solar Changes ", cited above, I indicated the dependence of weather on solar fluctuations of short interval. The results seemed to point to a possibility that at least at some stations and during some months of the year forecasts of weather for 10 days in advance might profitably be based on solar-radiation observations if these could be of sufficient accuracy and continuity. At that time it seemed doubtful if stations could be found whose combined results would yield on nearly every day in the year solar-constant values accurate to $\frac{1}{4}$ of 1 percent as regards accidental error, which seemed to be the minimum requirement for the purpose suggested. But not only do our two best stations now nearly reach that desired accuracy, but the impending substitution of Ångström type pyrheliometers at both stations as secondary instruments will probably increase this accuracy.

For nearly 20 years H. H. Clayton has worked assiduously on the problem of the correlation of solar variation with weather. In a recent paper[3] crammed with statistical results, he states: " In short, these extensive data, covering all parts of the world, prove that solar

---

[2] See Smithsonian Misc. Coll., vol. 85, no. 1, fig. 3, 1931.

[3] Clayton, H. H., World weather and solar activity. Smithsonian Misc. Coll., vol. 89, no. 15, p. 24, 1934.

TABLE 4.—*Observing Conditions at St. Katherine*

Month and year	Number of days: Clear	Part Cloudy	Cloudy	Observations possible: Long method	Short method	Sky quality, Haze near sun: None	Light	to	moderate	to	thick	Wind in m. p. h.: Max. 24 h.	Min. 24 h.	Average for month
1933														
Oct.	17	14	0	23	31	4	6	6	12	3	0	30.7	3.6	13.3
Nov.	9	14	7	14	23	0	8	5	9	1	0	27.9	3.0	8.0
Dec.	7	5	19	8	12	8	2	0	1	1	0	46.4	5.1	16.2
1934														
Jan.	7	11	13	8	17	7	5	3	1	2	0	29.0	3.5	13.7[+]
Feb.	15	6	7	16	21	6	7	2	2	2	2	41.4	1.9	14.3
Mar.	13	11	7	13	23	9	2	2	3	4	3	30.0	0.5	8.0[+]
Apr.	15	11	4	20	26	4	5	3	7	3	4	32.2	1.8	9.8
May	5	12	14	9	17	0	4	4	3	0	6	25.0	0.8	8.1
June	13	12	5	19	25	2	6	2	4	1	10	13.5	0.7	5.3
July	16	13	2	27	29	8	5	5	8	2	0	11.0	0.2	3.6
Aug.	21	10	0	26	31	10	7	4	7	2	1	10.4	0.9	4.1
Sept.	23	7	0	30	30	8	10	3	7	0	2	18.6	1.2	5.5
Oct.	9	17	5	14	25	3	10	0	6	1	5	28.8	2.3	9.2[+]
Nov.	3	19	8	10	22	11	8	1	2	0	0	18.4	0.9	8.2
Dec.	8	16	7	14	24	21	3	0	0	0	0	35.1	2.8	12.0
1935														
Jan.	5	16	10	11	18	13	2	2	0	1	0	...	..	19.0[+++]
Feb.	10	12	6	12	20	14	1	0	0	2	3	...	..	16.5[++]
Mar.	10	16	5	12	25	8	1	2	1	3	10	...	..	12.5[++]
Apr.	14	12	4	21	26	9	4	1	3	0	9	...	..	11.6
May	8	15	8	18	23	1	1	4	5	3	9	...	..	8.5
June	14	16	0	23	30	4	6	2	7	1	10	...	..	6.8
July	19	11	1	22	30	2	15	6	4	0	3	...	..	8.2

[+] [++] [+++] One, two, and three days, respectively, lost owing to very high winds.

variation is an important weather factor, even the dominating one, as also appears from figures 13 and 14 and 23-26."

Our experience in selecting and operating solar-radiation stations has now placed us in a position where we might with relatively moderate additional financial support set up several additional solar-radiation stations competent to produce first-rate results. We could then furnish almost every day in the year solar-constant values with accidental errors not exceeding ¼ of 1 percent. The conclusions of Clayton and ourselves relative to the dependence of weather on solar variation seem to have reached such a stage of probability as to warrant this additional expense in the interest of producing a new tool of possible value for meteorology.