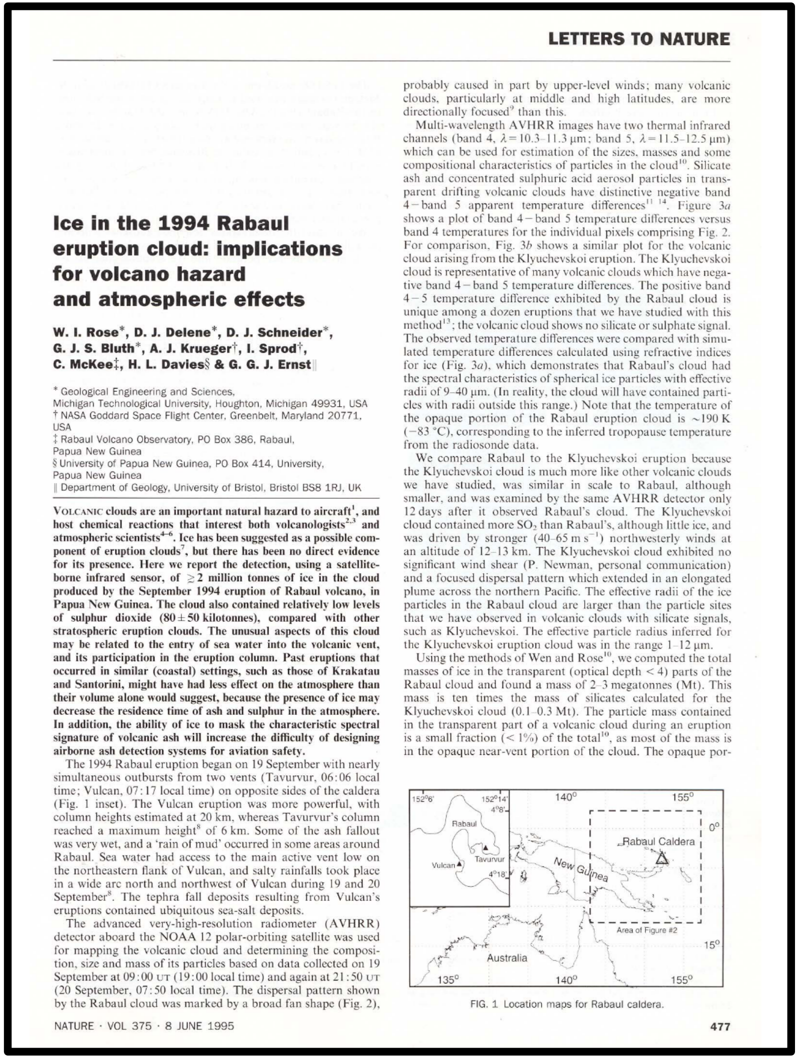
Responsible Research (David Delene, Atmospheric Sciences)

1995



Ice in the 1994 Rabaul eruption cloud: implications for volcano hazard and atmospheric effects

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VOLCANIC clouds are an important natural hazard to aircraft[1], and host chemical reactions that interest both volcanologists[2,3] and atmospheric scientists[4–6]. Ice has been suggested as a possible component of eruption clouds[7], but there has been no direct evidence for its presence. Here we report the detection, using a satellite-borne infrared sensor, of ≳2 million tonnes of ice in the cloud produced by the September 1994 eruption of Rabaul volcano, in Papua New Guinea. The cloud also contained relatively low levels of sulphur dioxide (80 ± 50 kilotonnes), compared with other stratospheric eruption clouds. The unusual aspects of this cloud may be related to the entry of sea water into the volcanic vent, and its participation in the eruption column. Past eruptions that occurred in similar (coastal) settings, such as those of Krakatau and Santorini, might have had less effect on the atmosphere than their volume alone would suggest, because the presence of ice may decrease the residence time of ash and sulphur in the atmosphere. In addition, the ability of ice to mask the characteristic spectral signature of volcanic ash will increase the difficulty of designing airborne ash detection systems for aviation safety.

The 1994 Rabaul eruption began on 19 September with nearly simultaneous outbursts from two vents (Tavurvur, 06:06 local time; Vulcan, 07:17 local time) on opposite sides of the caldera (Fig. 1 inset). The Vulcan eruption was more powerful, with column heights estimated at 20 km, whereas Tavurvur's column reached a maximum height[8] of 6 km. Some of the ash fallout was very wet, and a 'rain of mud' occurred in some areas around Rabaul. Sea water had access to the main active vent low on the northeastern flank of Vulcan, and salty rainfalls took place in a wide arc north and northwest of Vulcan during 19 and 20 September[8]. The tephra fall deposits resulting from Vulcan's eruptions contained ubiquitous sea-salt deposits.

The advanced very-high-resolution radiometer (AVHRR) detector aboard the NOAA 12 polar-orbiting satellite was used for mapping the volcanic cloud and determining the composition, size and mass of its particles based on data collected on 19 September at 09:00 UT (19:00 local time) and again at 21:50 UT (20 September, 07:50 local time). The dispersal pattern shown by the Rabaul cloud was marked by a broad fan shape (Fig. 2), probably caused in part by upper-level winds; many volcanic clouds, particularly at middle and high latitudes, are more directionally focused[9] than this.

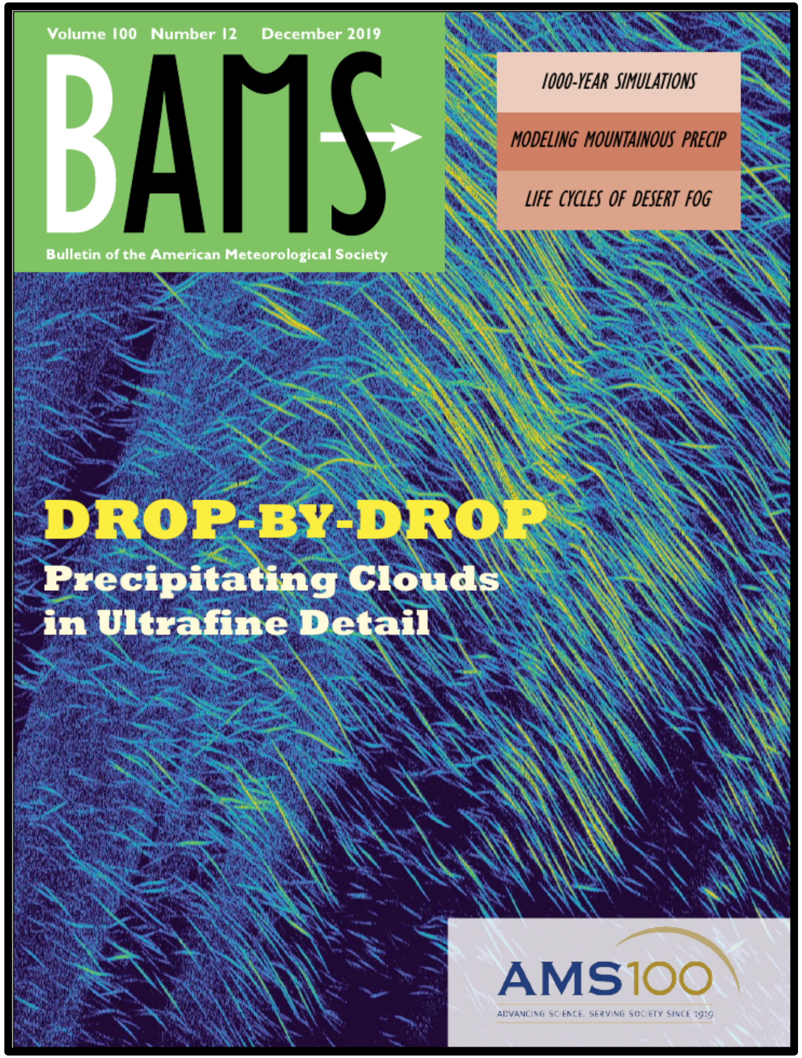
Multi-wavelength AVHRR images have two thermal infrared channels (band 4, $\lambda = 10.3$–$11.3\ \mu m$; band 5, $\lambda = 11.5$–$12.5\ \mu m$) which can be used for estimation of the sizes, masses and some compositional characteristics of particles in the cloud[10]. Silicate ash and concentrated sulphuric acid aerosol particles in transparent drifting volcanic clouds have distinctive negative band 4 − band 5 apparent temperature differences[11–14]. Figure 3*a* shows a plot of band 4 − band 5 temperature differences versus band 4 temperatures for the individual pixels comprising Fig. 2. For comparison, Fig. 3*b* shows a similar plot for the volcanic cloud arising from the Klyuchevskoi eruption. The Klyuchevskoi cloud is representative of many volcanic clouds which have negative band 4 − band 5 temperature differences. The positive band 4 − 5 temperature difference exhibited by the Rabaul cloud is unique among a dozen eruptions that we have studied with this method[13]; the volcanic cloud shows no silicate or sulphate signal. The observed temperature differences were compared with simulated temperature differences calculated using refractive indices for ice (Fig. 3*a*), which demonstrates that Rabaul's cloud had the spectral characteristics of spherical ice particles with effective radii of 9–40 μm. (In reality, the cloud will have contained particles with radii outside this range.) Note that the temperature of the opaque portion of the Rabaul eruption cloud is ~190 K (−83 °C), corresponding to the inferred tropopause temperature from the radiosonde data.

We compare Rabaul to the Klyuchevskoi eruption because the Klyuchevskoi cloud is much more like other volcanic clouds we have studied, was similar in scale to Rabaul, although smaller, and was examined by the same AVHRR detector only 12 days after it observed Rabaul's cloud. The Klyuchevskoi cloud contained more SO_2 than Rabaul's, although little ice, and was driven by stronger (40–65 m s^{-1}) northwesterly winds at an altitude of 12–13 km. The Klyuchevskoi cloud exhibited no significant wind shear (P. Newman, personal communication) and a focused dispersal pattern which extended in an elongated plume across the northern Pacific. The effective radii of the ice particles in the Rabaul cloud are larger than the particle sites that we have observed in volcanic clouds with silicate signals, such as Klyuchevskoi. The effective particle radius inferred for the Klyuchevskoi eruption cloud was in the range 1–12 μm.

Using the methods of Wen and Rose[10], we computed the total masses of ice in the transparent (optical depth < 4) parts of the Rabaul cloud and found a mass of 2–3 megatonnes (Mt). This mass is ten times the mass of silicates calculated for the Klyuchevskoi cloud (0.1–0.3 Mt). The particle mass contained in the transparent part of a volcanic cloud during an eruption is a small fraction (< 1%) of the total[10], as most of the mass is in the opaque near-vent portion of the cloud. The opaque por-

FIG. 1 Location maps for Rabaul caldera.

2019



Responsible Conduct of Research

What domain of conducting research do you have ethical concerns/questions?

- **Mentoring and Trainee Responsibility**
- **Collaboration Science**
- **Publication and Responsible Authorship**
- **Peer Review**
- **Data Management and Ownership**
- **Research Misconduct**
- **Communication and Difficult Conversations**

Responsible Conduct of Research

Publishing, Time Commitments, and Harassment

Wagner, Shawn and David J. Delene, Technique for comparison of backscatter coefficients derived from in-situ cloud probe measurements with concurrent airborne Lidar, Atmospheric Measurement Techniques, https://doi.org/10.5194/amt-2022-87, in press, 2022.

(Data Collection, Software Repository, Software Archive - doi:10.5281/zenodo.3740798) [Journal of Applied Meteorology and Climatology, **Preparation - 12/16/2018**, Submitted - 10/27/2020 (JAMC-D-20-0250, odt, pdf), Major Revisions Review Received - 02/10/2021, Major Revision Submitted - 06/10/2021, **Withdrew - 12/2021**, Submitted to Atmospheric Measurement Techniques, Technical Revision Request Received - 04/22/2022, Submission Validated - 05/11/2022, Preprint Posting Accepted - 05/16/2022, Preprint Available - 05/18/2022, Major Revision Submitted - 09/02/2022, Minor Revision Submitted - 09/20/2022, **Accepted – 10/04/2022,** Published -]

http://aerosol.atmos.und.edu/publications.html

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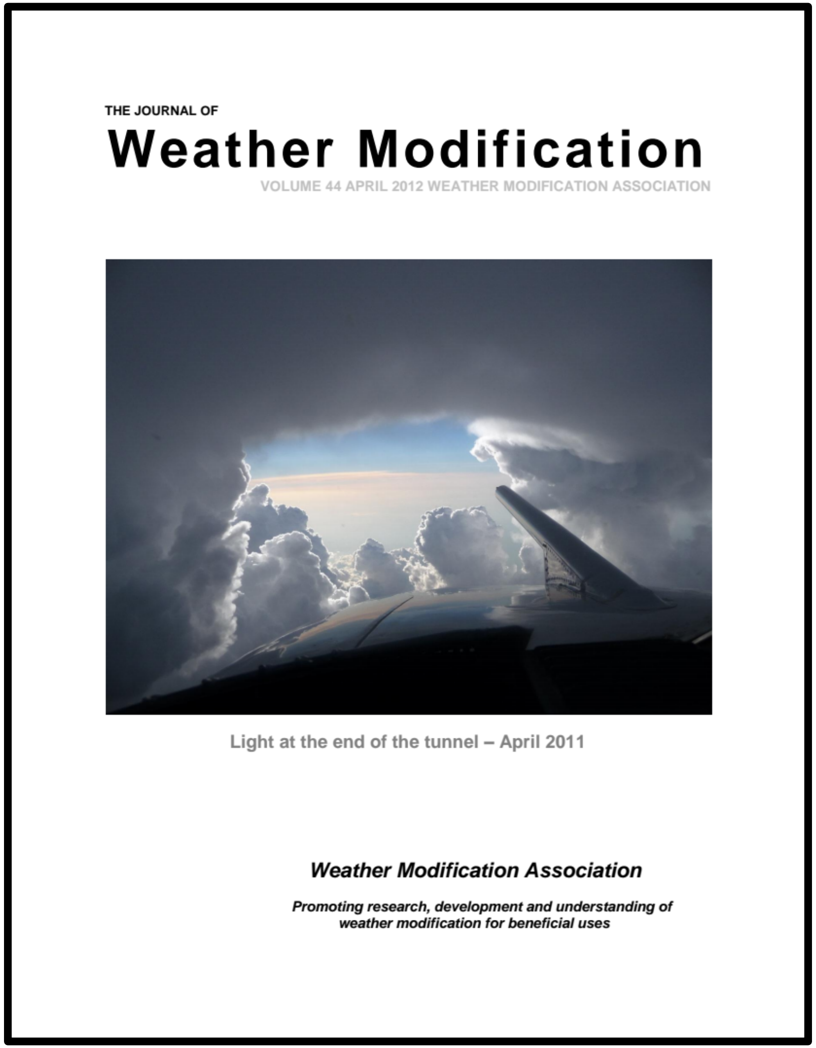
- **Authors:**
  - **Satisfied with the work!**
  - **Concise and Judgment Free.**
  - **All authors have reviewed the work.**

Scientific Publication System: Expectations and Trust

- **Reviewers (Volunteer, Anonymous):**
  - **Reviewers are consider gatekeepers.**
  - **Should reviewers only allow correct and significant papers?**
  - **Work should be reproducible.**
  - **Decision on publishing the paper is made by the editor, with advise provided by reviewers.**
  - **Do reviewers have to be anonymous?**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Time Commitments: Expectations and Trust

- **Sponsors and Institutions:**
  - **Honor Time Commitments**

    (Percentage of time charge to grant.)
    - **Don’t charge two funding sources for the same time.**
  - **Manage Roles in Relationships**
    - **Mentor students into independent researchers.**

      Employ of students in companies?
    - **Additional Income Interests**

      Working on consulting projects?

Time Commitments: Expectations and Trust

- Individual Commitments:
  - Know and honor time commitments.
  - Really work the hours you report.
  - Don’t charge two funding sources for the same time.
    - Does good time manage help?

Harassment: Expectations and Trust

- It not the intent, but the perception that is important.
  - What issues could this cause?

References / Questions

"The Scientific Paper Is Obsolete" by James Somer
"What makes influential science? Telling a good story" by Ryan Kelly
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Office of Research Integrity – Conflicts of Commitment

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