I congratulate Heymsfield and colleagues for the detailed study of aircraft-induced hole-punch and canal clouds (Heymsfield et al. 2010). They hypothesized that latent heat produces an updraft–downdraft mechanism that partially explains the growth and circular nature of the hole-punch clouds. The mechanism was confirmed theoretically in their Science article (Heymsfield et al. 2011) and the mechanism was highlighted in the Physics Today “Back Scatter” page (Heymsfield 2011).

For the sake of completeness and historical accuracy, I would like to point out a few errors and omissions in the BAMS article. The authors wrote of a photograph of a hole in a cloud published in the August 1968 Weatherwise that generated considerable interest in the U.S. meteorological community and set off a round of speculation as to its cause. They wrote that proposed explanations were published in the February 1969 Weatherwise and following issues. There, indeed, were explanations in the February 1969 issue but no explanations in the following issues. The explanations were confined to three consecutive issues—October and December 1968 and February 1969.

In December 1968, I proposed the same mechanism elucidated by Heymsfield et al. (2010) when I wrote in the December 1968 issue of Weatherwise, “Another mechanism, however, could explain the circular hole. A point-source nucleation with a rapid release of latent heat produced an updraft in the thin, stable cirrocumulus layer. To compensate for the updraft the surrounding air subsided. This subsidence could cause a circulation. The ice crystal zone propagated radially outward somewhat, but the sharply defined edge was probably caused by subsidence” (Hindman 1968, p. 241). The authors either overlooked or were unaware of this explanation.

Additionally, they overlooked a thorough paper by Johnson and Holle (1969). The Johnson–Holle article carefully developed a three-step process forming the “hole-punch” clouds, the third step being my updraft–downdraft mechanism. Heymsfield et al. (2010) could have easily overlooked this reference because the BAMS online archive starts at volume 51.

Finally, I submit that the authors’ statement in their Science article, “It is plausible that a small-scale and persistent updraft could develop in the ice region with compensating downdrafts on the outside edges, causing the water cloud to erode by evaporation (A. J. Heymsfield et al., BAMS, 91, 753, 2010)” (Heymsfield et al. 2011, p. 80) should have been referenced “Hindman (1968), Johnson and Holle (1969), and Heymsfield et al. (2010).”

REFERENCES


DOI:10.1175/BAMS-D-12-00088.1
Reply to “Comments on ‘Aircraft-Induced Hole-Punch and Canal Clouds: Inadvertent Cloud Seeding’”

—ANDREW HEYMSFIELD
NCAR/MMM
Boulder, Colorado

Professor Hindman notes that

In December 1968, I proposed the same mechanism elucidated by Heymsfield et al. (2010) when I wrote in the December 1968 issue of Weatherwise, “Another mechanism, however, could explain the circular hole. A point-source nucleation with a rapid release of latent heat produced an updraft in the thin, stable cirro-cumulus layer. To compensate for the updraft the surrounding air subsided. This subsidence could cause a circulation. The ice crystal zone propagated radially outward somewhat, but the sharply defined edge was probably caused by subsidence” (Hindman 1968, p. 241). The authors either overlooked or were unaware of this explanation.

We thank Prof. Hindman for his pointing out the mechanism he proposed and ones elucidated by Johnson and Holle (1969). Doctor Holle pointed out his valuable contribution directly to us. We were unaware of either of these valuable contributions. We also thank Prof. Hindman for his corrections and additions. Important additions to the references he suggests are Pedgley (2008) and Westbrook and Davies (2010). We initially referenced those two articles in our Science article but had to remove them because of space limitations. We want to correct the credit given for the picture of the Antarctic hole-punch cloud that appeared in our Science article. Eric Brown took that picture.

We do want to respond to a few points raised in Prof. Hindman’s comments about our articles. The first observation of a hole-punch cloud reported in the formal meteorological literature was in an article by Simon (1966) that we reported in our BAMS article. Simon identified the cause as by aircraft, identified the hole in an altocumulus cloud, and estimated the air temperature to be −7.5°C from a sounding six hours earlier. He noted that the hole appeared about 20 min after the aircraft flew through the cloud and that ice streamed from it. This important set of observations was overlooked in discussions of the Weatherwise hole-in-cloud observation.

We also wish to clarify what types of clouds were present in the Weatherwise observation as it relates to the formation of holes in clouds via “point sources.” Cirrus forms primarily in the upper troposphere, above ~8 km (25,000 ft), when temperatures are mostly below −35°C, and are composed almost entirely of ice crystals. A cirrocumulus cloud is a cirrus with small cloud elements in the form of separate or merged grains, ripples, etc. These clouds do not contain cloud droplets—an important component in the production of hole-punch clouds, as we show in our Science article (Heymsfield et al. 2011) and summarize below. From modeling calculations, we have examined how much temperature rise would occur from a point source in a cloud field at water saturation at −40°C (an upper limit for a cirrus cloud) and −15°C (in an altocumulus cloud) that drives the ambient vapor density to ice saturation. At −40°C, there would be at most a local heating of 0.32°C, whereas at −15°C this would be 0.82°C. Altocumulus clouds are conducive to heat generation; cirrus are not because their lapse rate is already affected by ice latent heating. The only explanation of how the “cirrocumulus” in the Weatherwise article could have been affected by the passage of a “point source” is via condensation or aerodynamic contrails. Contrails were known at the time to occur in the upper troposphere only at temperatures below about −40°C (Appleman 1953). It is not understood by us how this would have led to a clearing effect in otherwise ice clouds because the ice crystals would have generally maintained a small size with generally low terminal velocities, not the larger ice particles that sedimented in the Weatherwise (1968) “hole-in-cloud observation” and the Simon (1966) photograph.

We also want to point out how the mechanism we propose differs from the description provided in the Hindman letter to Weatherwise (Hindman 1968). Regarding the production of updrafts via latent heat release and compensating downdrafts around the edges, this process had been discussed in connection with the dynamical cloud seeding concept developed in the 1950s (Braham et al. 1957). Via the mechanism we propose (Heymsfield et al. 2010, 2011), ice crystals
are generated behind the tips of engine propellers or in overwing aerodynamic contrails as air is cooled essentially adiabatically and the preexisting and/or resulting condensate in the form of droplets cool to a temperature where they homogeneously freeze. We emphasize that high concentrations can occur in these thin veils of ice but that potentially lower concentrations of heterogeneously nucleated ice can occur at these and warmer temperatures. This narrow ice ribbon initially spreads laterally primarily by turbulence and thereafter is quite slow (see Heymsfield et al. 2010). Downward spreading initially is several hundred meters in the wake vortex. At the interface of the ice and preexisting cloud droplets (assuming for this discussion that a supercooled altocumulus cloud exists), the Bergeron–Findeisen (B–F) process kicks in and erodes the cloud droplet population at the ice–droplet interface. According to the B–F process, if ice is introduced into a liquid water cloud at subfreezing temperatures, the liquid droplets will be out of vapor pressure equilibrium relative to the ice and the liquid will evaporate, with vapor depositing onto the ice crystals and causing them to grow larger. As shown in the Heymsfield et al. (2011) paper, this necessary process, together with the resulting dynamical effects—updrafts in the ice regions induced by the latent heat released largely by conversion of droplets to vapor to deposition on ice—can produce a visual hole or canal. The ice crystals deplete the vapor supplied by the updraft and prevent the hole or canal from filling in with cloud and the ice crystals are suspended in the updraft until they are large enough to fall through and below the increasing vertical velocities. The B–F process is a component that is necessary to widen the hole and produce a long-lived updraft–downdraft couplet.

**REFERENCES**


Weather on the Air: A History of Broadcast Meteorology
ROBERT HENSON

From low humor to high drama, Weather on the Air documents the evolution of weathercasts—the people, technology, science, and show business that combine to deliver the weather to the public each day. An invaluable tool for students of broadcast meteorology, this book will entertain anyone fascinated by the public face of weather. Includes over 100 photographs!

LIST $35 MEMBER $25

Adaptive Governance and Climate Change
RONALD D. BRUNNER AND AMANDA H. LYNCH
LIST $35 MEMBER $22

The Forgiving Air: Understanding Environmental Change, 2nd ed.
RICHARD C. J. SOMERVILLE
LIST $22 MEMBER $16

The Callendar Effect: The Life and Work of Guy Stewart Callendar (1898–1964)
JAMES RODGER FLEMING
LIST $34.95 MEMBER $24.95

Mesoscale Meteorology and Weather Analysis and Forecasting
EDITED BY PETER S. RAY
LIST $76.25 MEMBER $66.25 STUDENT MEM. $56.25

Northeast Snowstorms
PAUL J. KOCIN AND LOUIS W. UCCELLINI
LIST $100 MEMBER $80 STUDENT MEM. $60

The Life Cycles of Extratropical Cyclones
EDITED BY MELVYN A. SHAPIRO AND SIGBJÖRN GRÖNÁS
LIST $75 MEMBER $55

Synoptic–Dynamic Meteorology and Weather Analysis and Forecasting: A Tribute to Fred Sanders
EDITED BY LANCE F. BOSART AND HOWARD B. BLUESTEIN
LIST $120 MEMBER $80 STUDENT MEM. $60

MIDLATITUDE WEATHER SYSTEMS

Booksellers and wholesale distributors, to place an order please contact The University of Chicago Press: 1-800-621-2736 (US & Canada) 773-702-7000 (all others) custserv@press.uchicago.edu
BESTSELLERS

The AMS Weather Book: The Ultimate Guide to America’s Weather
JACK WILLIAMS WITH FOREWORDS BY RICK ANTHEIS, PRESIDENT OF NCAR, AND STEPHANIE ABRAMS OF THE WEATHER CHANNEL

Former USA Today Weather Page editor Jack Williams has written the most comprehensive, up-to-date guide to the weather and atmosphere, covering everything from daily weather patterns to air pollution and global warming.


LIST $35   MEMBER $25

This CD companion to The AMS Weather Book provides more than one hundred detailed graphic illustrations.


LIST $50   MEMBER $30

DIGITAL EDITION NOW AVAILABLE

Midlatitude Synoptic Meteorology: Dynamics, Analysis, and Forecasting
GARY LACKMANN

This textbook links theoretical concepts to modern technology, facilitating meaningful application of concepts, theories, and techniques using real data. It serves those planning careers in meteorological research and weather prediction and provides a template for the application of modern technology in the classroom. Extratropical cyclones and fronts, topographically trapped flows, weather forecasting, and numerical weather prediction are all covered in depth.


LIST $100   MEMBER $75   STUDENT MEMBER $65

Eloquent Science: A Practical Guide to Becoming a Better Writer, Speaker, and Atmospheric Scientist
DAVID M. SCHULTZ

The ultimate communications manual for undergraduate and graduate students as well as researchers in the atmospheric sciences and their intersecting disciplines. Every student, teacher, and science department should have a copy.


LIST $45   MEMBER $30

AMS BOOKS

RESEARCH  APPLICATIONS  HISTORY

2013 HIGHLIGHTS

COMPLETE CATALOG AND DIGITAL EDITIONS ONLINE

WWW.AMETSOC.ORG/AMSBOOKSTORE

NEW!

Deadly Season: Analyzing the 2011 Tornado Outbreaks
KEVIN M. SIMMONS AND DANIEL SUTTER

In 2011, the U.S. was hit by the deadliest tornado season in decades. Simmons and Sutter examine the factors that contributed to the outcomes of these tornadoes, identifying both patterns and anomalies. Their conclusions, and assessment of early recovery efforts, are aimed at helping community leaders and policymakers keep vulnerable populations safer in the future.


LIST $25   MEMBER $20

Economic and Societal Impacts of Tornadoes
KEVIN M. SIMMONS AND DANIEL SUTTER

Two economists’ unique database has enabled a fascinating and game-changing study of tornado impacts and how factors such as storm timing and warning lead time affect impacts; whether Doppler radar and shelters are worth the investment; and more. For meteorologists, social scientists, and emergency managers.


LIST $10   MEMBER $22
Learn the latest in atmospheric and related oceanic and hydrologic sciences and the latest in research and scientific applications. Meet and network with oceanographers, meteorologists, hydrologists, geographers, and more. Join AAG in Tampa April 8-12, 2014.

MEETING HIGHLIGHTS

• **The Latest Research** - Presentations and posters by leading scholars and researchers

• **Exhibit Hall** - Booths and exhibits showcasing recent publications and new geographic technologies

• **Career and Networking Opportunities** - An international networking reception, a Jobs and Careers Center highlighting the latest employment opportunities for geographers, and career development sessions

• **Special Events** - Keynote presentations from distinguished speakers from inside and outside of geography, World Geography Bowl, and Awards luncheon

• **Workshops** - Training sessions and workshops to help further your professional or academic career

• **Field Trips** - Attendees also will have several options to explore the rich cultural and physical geography of Florida through informative field trips and excursions

Join us in Florida