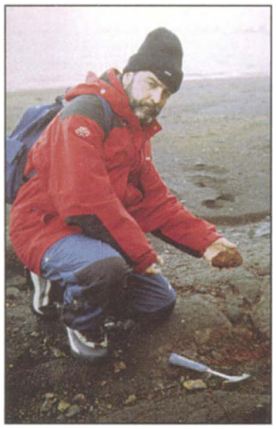
METEOROLOGY

Great Balls of Ice!

Scientists are still struggling to explain a spate of large ice chunks that rained on Spain a couple of years ago

MADRID—After a football-sized chunk of ice plummeted from the sky on a sunny day in January 2000, smashing through the windshield of a parked car in Tocina, Jesús Martínez-Frías raced to the Andalusian village to retrieve the 2-kilogram object. Over the course of a week, the planetary geologist with the Madrid-based Center for Astrobiology gathered up several more projectiles. Then the phenomenon ended as suddenly as it had begun. But the mystery of where the ice balls came from lingered, and Spain's Higher Council of Scientific Research asked Martínez-Frías to lead a team to solve it.



From thin air? Jesús Martínez-Frías is leading a probe into the mysterious ice balls, including this one that fell in Spain earlier this year.

Two and a half years later, the Spanish researchers have proposed a novel mechanism for generating "hail" on a clear day. It's an "important advance in that it thoroughly documents and provides an explanation for a spectacular phenomenon," says geologist Roger Buick of the University of Washington, Seattle, who has studied an ice ball that fell from a clear sky in Australia last year. Other experts are far from convinced, in part because it would take so much time to accrete such large masses that the whole notion seems implausible. "I don't like to claim that anything is absolutely impossible, but this comes awfully close," says Charles Knight, an expert on hail at the University Corporation for Atmospheric Research in Boulder, Colorado.

Like crop circles, ice balls could be the product of an ingenious hoax. However, the "amazing similarity in the details" of about 50 reported ice balls from all over the world over the past decade suggests that researchers have not been hoodwinked, insists David Travis, a climatologist at the University of Wisconsin, Whitewater. A few phony ice balls did turn up in Spain after the initial smattering, but the Spanish team says it was able to distinguish them from the ice balls that fell in January 2000 by their chemical and isotopic composition. The researchers focused on five of the original projectiles.

Martínez-Frías and his colleagues quickly dismissed other likely explanations. The ice balls could not have fallen from jets as frozen waste flushed from toilets because they lacked traces of urine or feces or the blue disinfectant used in airplane toilets. Nor were they likely to have been dislodged from a fuselage, the team maintains, as air traffic control records indicated that no planes overflew the region on the dates when two of the ice balls fell. They could not be of extraterrestrial origin—cometary debris, for instance—as they were made of rainwater.

That left researchers with the seeming conundrum of how to create massive chunks of ice in the absence of precipitation. Sawing into the ice balls provided clues. They were chock-full of air bubbles, had some onion-like layering, and contained gases such as ammonia and particulates such as silica, both of which get trapped in hailstones. The isotopic distribution of oxygen-18 and deuterium, as described in the June issue of the *Journal of Chromatography A*, also tracked that of hail.

To Martínez-Frías, the ice balls had hail written all over them. Hailstones form when ice crystals in a storm cloud collide with cloud water droplets at below-freezing temperatures. He and his colleagues suggest that a similar mechanism—ice crystals swept through cold, humid air pockets—could account for ice-ball formation. To support this notion, they cite a meteorological anomaly. Beginning on 7 January 2000—3 days before the first reported fall—NASA satellite imagery revealed that ozone levels were unusually low over southeastern Spain. In a well-known phenomenon, depressed ozone levels permit more solar radiation to reach the troposphere, triggering a concomitant cooling in the lower stratosphere. Around the time of the ice-ball falls, these temperature differences in the atmospheric layers created strong wind shears, Martínez-Frías says.

A second atypical phenomenon might also have been at play. A team led by meteorologist Millán Millán, head of the Mediterranean Center for Environmental Studies in Valencia, has found that the lower stratosphere was unusually moist at the time the ice balls fell. Millán estimates that a "condensation aggregate"—a growing ice ball—would free-fall about 19 kilometers through a nearly saturated atmosphere. The roughly 10 minutes of free-fall would be enough time for kilogram-sized ice balls to form, Millán argues: "We appear to be looking at nuclei that have descended through a very moist atmosphere, growing as they fell." The source of the nuclei, Martínez-Frías and Travis suggest, could have been lingering jet contrails. Remnants of contrails can last for days as wispy cirrus clouds that are sometimes invisible to the naked eye. Many fewer nuclei would be available in these conditions than in a hail-forming thunderstorm, thus explaining why there were so few "megacryometeors," as Martínez-Frías calls the ice balls.

Several experts contacted by *Science* reject the notion that hailstonelike processes can happen on clear days. "Solid ice cannot form in the absence of thick, highly visible clouds," says Knight. He speculates that the conditions above Spain could have generated unusual precipitation—but not an ice ball. With "incredibly clean air and an incredibly long [free-fall] time," he says, "the result would be an incredibly large snow crystal." One atmospheric physicist suggests that an ice ball might form when rainwater pools in a cavity of a plane, then freezes and breaks off during flight. Commercial databases might not have logged military or private planes in the area when the ice balls fell, Knight says, adding, "the meteorological explanations just don't make sense to me."

Martínez-Frías and his colleagues acknowledge that their mechanism is highly speculative. He is building an ice-ball library and forging links, through his Web site (tierra.rediris.es/megacryometeors), with scientists in other countries in pursuit of the mysterious objects. But it might take years to write the last chapter of this meteorological detective story—unless a fiendishly clever perpetrator confesses to an elaborate hoax.

–**XAVIER BOSCH**

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