A REVIEW OF CLOUD CLASSIFICATIONS IN WARM SEASON WEATHER MODIFICATION OPERATIONS AND RESEARCH

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Abstract. The use and in some cases the origins of unofficial but descriptive cloud classifications in warm season weather modification operations and research during the last twenty-five years (1974-1999) is reviewed. These classifications, while not formally recognized, often offer insight into the nature of the projects during which they originated. In many cases the cloud classifications are indicative of the pressures and frustrations associated with field operations, borne from constant anticipation of ever-changing weather for weeks or months at a time.

1. BACKGROUND

Cloud classification is defined in the *Glossary of Meteorology* (AMS, 1959) as "A scheme of distinguishing and grouping clouds according to their appearance, and, where possible, their process of formation." Traditionally, cloud classifications have been expressed in Latin, in accordance with the cloud's properties, but many cloud types also have recognized common names and variations.

The importance of cloud nomenclature may presently be somewhat diminished. In years past, the non-automated surface aviation weather observations made in the United States provided for the inclusion of remarks by the observer. Such remarks typically would include information about the locations and directions of movement of clouds and storms, lightning, and severe weather, *e.g.* "CB SW MOVG NE", "ACCAS NE-SE", or "FQT LTGICCCCG OVHD ALQDS". Such remarks are no longer used with the international METAR reporting now in use; consequently the need to recognize and identify cloud types may be diminished. Nevertheless, the identification and understanding of cloud types remains an important skill for the serious forecaster.

To the trained weather observer, according the proper name to each cloud observed should be routine (the author, personal opinion). To others, particularly those working within the modernized and increasingly automated National Weather Service, this is perhaps not always the case. For the uninitiated in such matters, it is herein noted that there are ten basic cloud types, grouped into four classes. The high clouds are *cirrus, cirrostratus,* and *cirrocumulus;* the middle clouds, *altocumulus* and *altostratus;* the low clouds *stratus, stratocumulus,* and *nimbostratus;* and the clouds of vertical development are *cumulus* and *cumulonimbus* (see any introductory meteorology text).

In addition to the ten basic types, there are many other cloud sub-species. These names, like the basic groups, are traditionally always given in Latin, though common English names here too also exist. The sub-species names always reveal additional information about the cloud's appearance or origin, or both.

For example, isolated cirrus having a feathery appearance are correctly termed *cirrus uncinus*, or in common English, *mare's tails*. However, the cirrus clouds formed by thunderstorm development, often visible for tens or even hundreds of miles downwind of the parent cloud, are called *cirrus spissatus*. Thus, careful and correct use of these terms can add considerable precision and descriptiveness, without adding a lot of words.

2. CLOUD TYPES IN WEATHER MODIFICATION

Depending on the project and its objectives, numerous local terms for specific cloud types have been coined over the years. A few of these are listed below. Where possible, the project is cited. For obvious reasons, there is a bias towards those projects with which the author has been affiliated. Many cloud names have been employed on more than one project. The reader will note that many of the cloud species do not bear Latin names, but names in English or in "pseudo-Latin". If review of the cloud types below brings others to mind to the reader, the author would like to hear from you.

2.1 Varieties of Cumulus Humilis

Cumulus pancakus

Cumulus pancakus (pre-HIPLEX, 1974) are small *cumulus humilis*, having so little vertical development that if penetrated, the aircraft tail sticks out of the top of the cloud, while the landing gear protrudes from the bottom. Because these clouds are cumuliform, they are the result of convective instability. However, if they had any less vertical development, they wouldn't exist.

Popcorn cumulus

Popcorn cumulus (HIPLEX, *circa* 1979) are so named for their obvious resemblance to their namesake. These clouds are small and white, with some vertical development, just enough that convective elements are visible. As one might expect, liquid water content of these small clouds is extremely limited. If studied carefully for a time, thirst invariably results.

Barleypop cumulus

Barleypop cumulus [North Dakota Cloud Modification Project (NDCMP), pre-1981] are also accorded the moniker "*beer clouds*" by thirsty operational project personnel, who have a day off only when the lack of deep convection is an absolute (almost) certainty. The true *beer cloud* graces the mid-afternoon sky under a July or August ridge, with a 500 mb surface-based lifted index of at least +10°C, when the total combined precipitable water recorded by the three nearest National Weather Service (NWS) upper air soundings is less than 2.5 cm. A genuine *beer cloud* cannot survive to even within an hour of sunset.

Cumulus crocodilius

To the eye, *cumulus crocodilius* (NDCMP, circa 1982) visually resemble *barleypop cumulus* in every respect, at least for the first few hours. However, they form when the boundary layer is more moist and well-mixed, but capped by the passage of a shortwave ridge. Now, most of us focus on the troughs of shortwaves, but the ridges sometimes provide just enough capping to inhibit deep convection– for awhile. With *cumulus crocodilius*, the passage of the ridge brings the onset of the trough, the erosion of the cap, and whoops! The previously fair-weather cumulus aren't anymore. Instead, they grab you by your hindmost parts as they race each other to the tropopause.

2.2 Varieties of Cumulus Congestus

Cumulus poltergeistus

Sometimes, in either research or operational cloud seeding, a flight crew will spot a text-book example *cumulus congestus* turret (*e.g.*, Bomar 1995, p 103). The base will be flat and dark, the tops crisp and white, and the sides vertical. Such clouds are invariably immediately selected for treatment or experimentation, and an intercept heading assumed. However, as one nears the cloud turret, its appearance degrades; the top and sides entrain and evaporate a bit, the base becomes a little ragged, and the top begins to look less like a cauliflower and more like spilled flour. By the time the aircraft gets within a mile or two of the cloud, it is hideous; badly sheared off, no base left, and no sign of any remaining updraft. In disgust and in quest of another candidate cloud, the pilot begins to turn, promptly discovering another great-looking tower back pretty much at the location she/he just left. These clouds are *cumulus poltergeistus* (HIPLEX, 1979).

Cumulus indigestus

Cumulus indigestus (NDCMP, 1990) are *cumulus congestus* that have not formed, but might, and so weigh heavily upon the gastrointestinal tract of the project forecaster. As one might expect, they are most common when synoptic data are incomplete, soundings are missing, or model runs have initialized poorly. Some correlation with forecaster inexperience has also been observed. *Cumulus indigestus,* also known by the generic name *whatifacumulus*, is one of the few virtual cloud types.

Ribeye cumulus

These spectacular *cumulus congestus* look-alikes explode from clear air late in the day, often around sunset, usually when the forecast calls for "no significant weather" that evening. *Ribeye cumulus* (NDCMP, 1982) result from the placement of any thick cuts of USDA Choice beef on a hot grill. The steaks of course then have to be promptly removed, and the grill quickly extinguished prior to the frantic trip to the airport. Sadly, once the steaks are removed from the grill, the forcing function is also removed. Thus, after a wait of 90 min or more at the airport during which the clouds are monitored closely, the *ribeye cumulus* collapse completely, and the original forecast verifies.

If not for concerned project sponsors, *ribeye cumulus* could be blissfully ignored by project personnel. However, they look exactly like regular *cumulus congestus*, and only time will tell if they are–or are not.

Cumulus outsideareaus

These convective clouds have been observed on just about every project– operational or research– conducted since at least as far back as the 1940s. The classification describes, as the name implies, cumulus clouds (usually good-looking ones) outside the operational or research area. *Cumulus outsideareaus* (HIPLEX, 1979) never occur when there are *cumulus insideareaus*. Instead, they develop in clusters just beyond the designated area, often easily within eyesight, taunting project personnel.

On some projects (NDCMP, 1984), *cumulus outsideareaus* have been attributed to the existence of an unidentified force field which may preclude cloud development in the project area, or even deflect approaching storms around its perimeter.

Project personnel can readily identify *cumulus outsideareaus* by any of the following indications:

1. Radar echoes clearly show the subject cloud field to be beyond the target boundaries,
2. The clouds are visible, but so far away the tops look faintly yellowish or pink.
3. Satellite imagery suggests the triggering outflow boundary is just south of the project area, and it is not progged to move north,
4. You are being paid by the number of hours you fly on the project,
5. The project area needs rain desperately, and its been so long since you last flew that you're not certain if your ratings are still current,
6. You spent $1 million to deploy the research facilities, you have to date only two marginal cases, and there are only three days left in the project, or
7. Air traffic controllers tell you, "HIPLEX-2, Dickinson altimeter is two niner eight seven."

Cumulogranitus

Vigorously growing turrets having sharply-defined cauliflower-like tops, and similar-looking sides as well, are termed *cumulogranitus* (NDCMP, 1983). Such clouds may possess positive internal vertical motions (updrafts) in excess of 20 m s^{-1}, and subsidence on the cloud boundaries may be a significant fraction thereof. The result is a shear on the order of 30 m s^{-1}, quite sufficient to gain the attention of air crews who select penetration as their preferred course. The resulting jarring easily moves unsecured objects (and people) about the cabin, which explains the alternative moniker, "hard turret".

Cumulogranitus always develop so fast that even if they are ice-free at the time of unadvised penetration, they won't remain so for long. Aircraft penetrating such clouds normally encounter graupel, copious supercooled liquid water, and sometimes even small hail. A fun ride for those who revel in random, violent motions.

2.3 Varieties of Cumulonimbus

Cumulonimbus Illuminatus

Always nocturnal, *cumulonimbus illuminatus* possess lightning flash rates that exceed 50 min^{-1}. Flashes may be either in-cloud (IC), cloud-to-ground (CG), or cloud-to-cloud (CC). When the CG rate is high, there is concern that the storm may be a significant hail producer. However, when there are few CGs, these unique *cumulonimbi* usually respect the work of Blevins and Marwitz (1968), and seldom produce hail.

Contrary to common thought, the incessant lightning helps out those who might attempt to seed turrets in the vicinity of such clouds, for ample illumination of the subject is available, *gratis*. Nocturnal storms without much lightning pose a much greater challenge for hail suppression air crews.

Cumulonimbus Viriditatis

Observations of green thunderstorms have been reported for decades. Anecdotal evidence has frequently linked the presence of a green tint to storm severity (Fraser, *circa* 1975). However, many severe storms are not green.

The *cumulonimbus viriditatis* is not rare, nor are they all severe as defined by the National Weather Service criteria of hail of 1.9 cm (¾ inch) diameter or larger, winds of 25.7 m s^{-1} (50 kt, 57 mph) or greater, or tornadic storms. However, it seems that a disproportionate number of them are severe, at least in the sense that significant crop damage results. One must remember that even dime-size hail can rip up crops severely, especially if some wind occurs with the hailfall.

Because of the association with severe weather, real or imagined, *cumulonimbus viriditatis* incite alarm in most who observe them. For these persons it is therefore reassuring to see seeding aircraft working such storms; hail suppression project sponsors are especially insistent.

Cumulonimbus Ingestus

This class of cumulonimbus possesses updrafts that exceed the descent rate of many light twin-engine aircraft. Thus, any such aircraft that may wander too near these updrafts can go only one direction: up.

When victimized by *cumulonimbus ingestus* (NDCMP 1982), the pilot must immediately turn to a "bailout heading" that will take the aircraft back into clear air away from the storm, without penetrating the storm core. Typically this is toward the southeast, but it depends upon the direction from which the aircraft approached the storm.

Usually the best way out is the way you came in. After "suck-in" from below cloud base, the ride may get exciting, as the aircraft may occasionally want to turn sideways, objects fly around within the cabin, and lightning may provide sporadic though brilliant illumination. If the correct bailout heading is promptly assumed, the aircraft will eventually exit the malevolent cumulonimbus, several thousand feet above convective cloud base, hopefully in one piece.

Depending upon the project location, *cumulonimbus ingestus* may be known by other names, such as *Hoovernimbus*.

Because *cumulonimbus ingestus* are nearly impossible to visually differentiate from ordinary cumulonimbus, the pilot must always suspect the worst, and be prepared to react accordingly. The author notes that most seeding programs do not intend to treat the most energetic updrafts. Thus, flirtations with *cumulonimbus ingestus* serve only to enhance ice concentrations in the storm anvil; most often after a pilot has become inattentive. At best, this is high-risk behavior.

Cumulonimbus Zenithgenitus

For years the bane of operational hail suppression programs, the *cumulonimbus zenithgenitus* (NDCMP, 1984) forms directly overhead while nobody is watching. These clouds are never observed until they are fully mature. Most (but not all) *cumulonimbus zenithgenitus* develop at night, while project meteorologists are blissfully ensconced in their radars, monitoring more distant storms, unaware of the ominous goings on overhead. Their initial clue that all is not right is often the clatter of the first hailstones upon the roof.

There is little hope of hail suppression projects ever dealing successfully with *cumulonimbus zenithgenitus;* prevention is the only cure.

Cumulonimbus Strahanus

Thunderstorms that develop after dark when "no significant weather" has been confidently forecast have been accorded the name *cumulonimbus Strahanus* (stray-HAN-us), in honor of a North Dakota project forecaster who saw more than his share of such storms. These unforecast thunderstorms are thought to be linked to the passage of stealth vorticity, but because stealth vorticity is so stealthy, nobody knows for sure. *Cumulonimbus Strahanus* are best known for their unique ability to consistently induce crabbiness in field personnel.

Vast Rudeness

A dark, lowering squall line, equipped with well-developed *arcus cloud*, whose appearance is enhanced by lightning, and whose impressive nature is verified by radar, may be accorded the title "*vast rudeness*" (CCOPE, 1981).

The etymology of the first half of this phrase relates to the scale of the system, which extends from the surface to the tropopause and above, and as far as the observer can see in either direction perpendicular to the direction of squall line motion. Though "rudeness" implies to some persons a willful, deliberate mode of conduct, squall lines possess no will, but are capable only of dissipating the energy endowed by the atmospheric thermodynamics and mesoscale dynamics. This energy is considerable, however, and significant damage often results. Thus, "rudeness" seems somehow appropriate. This term first appeared in the *Convective Excitability Scale* (Boe and Politovich 1980), which is tentatively slated for revision in 2000.

3. APPLICABILITY

Though the author reports only cloud types known to be denizens of the High Plains of North America, it is widely suspected (by the author and at least two other persons of guarded reputation) that they actually occur in many other locales.

It is therefore suggested to those of any inclination to do so that other occurrences be reported, that by so doing, more complete climatologies be established.

It is also quite certain that additional cloud types exist which have not been reported herein, but which ought to have been. Likewise, analogous specialized cold season cloud types also should be formally established.

4. CONCLUSIONS

Cloud classification and identification can be both rewarding and fun. Unofficial names often reflect cloud characteristics relevant to project personnel. So much so that many names are carried forward to other projects, and used effectively amongst those familiar with them.

These unique classifications also afford a perspective of weather modification research and operations not otherwise available.

Additional thoughts (and cloud nomenclature) should be available from persons with experiences different from the author's. A more comprehensive cloud nomenclature, perhaps complete with photographic or schematic illustrations, could provide a perspective of meteorological field work heretofore unavailable.

The author encourages the submission of additional cloud types/classifications.

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