# Watch out for the 'morning glory'

'We stood waiting before sunrise... no-one was talking very much; the magpies were singing. And then I saw something change on the horizon: an isolated cigar-shaped cloud with the ends reaching almost to infinity.

'This dark-grey thing came rapidly towards us with the red sun behind it. It was a bit nightmarish, like a big quiet cushion. The leading edge was undulating a little — unbelievable.'

So one meteorologist, Dr Klaus Fraedrich, describes his first encounter with a 'morning glory', a spectacular roll cloud that frequently visits the Gulf country around Burketown, Qld, in the early morning hours. It almost invariably flies in from the east, and springtime gives you the best chance of a sighting.

A morning glory may appear as a single huge cylindrical cloud, or come in evenly spaced sets, with up to ten carpet rolls sweeping low overhead at 10-minute intervals. It may travel at up to 60 km per hour and traverse hundreds of kilometres before the heat of the day catches up with it.

In their advance, the clouds often appear to be rotating backwards, as air ascends and condenses in front and descends and dissolves again at the rear. Cross winds can sometimes create a corkscrew motion.

The local Aborigines call it 'kangoli', and regard its strange form as an omen of abundant bird life.

Recently, scientists have come closer to penetrating the atmospheric dynamics that underlie this mysterious phenomenon. They now describe the morning glory as 'an internal undular bore' and see it as a sort of shock wave, carrying energy away from a head-on collision between two large air masses — a sea breeze generated on the east of Cape York Peninsula and a similar one on the west.

Over the last decade, a number of expeditions have set out for Burketown, laden with the tools of the meteorologist's art. On one fruitful quest, an aircraft flew instruments right through a kangoli.

The first large field trip to morning glory country took place in the spring of 1979, and it included Dr Reg Clarke of the University of Melbourne's Meteorology Department, Dr Roger Smith of Monash University's Department of Mathematics, and Mr Derek Reid of the CSIRO Division of Atmospheric Research.

Dr Clarke and Mr Reid have, after several northern safaris, retired, but Dr Smith, still fascinated after seven field trips to the Gulf, continues to make instrumented forays to refine scientific understanding of what's going on. Dr Bill Physick of the Division of Atmospheric Research is another who has responded to the lure, and he accompanied Dr Smith on a 1982 expedition.

From their probings, scientists have been able to trace the beginnings of a morning glory to happenings at Cairns, 650 km east of Burketown, the previous evening. A morning glory, their instruments tell them, owes its origin to the daily 'breathing' of the continent — the alternating sea and land breezes.

Every day, the land heats up until the temperature contrast between land and sea creates a surge of cool sea air — a strong in-breathing — that sweeps inland to relieve the heat. During the night, the opposite happens, but less energetically, and the continent gently breathes out — the early morning land breeze.

Queensland has very clear skies in October; consequently the evening sea breezes are particularly vigorous then. Currents of relatively heavy cool air rush in from both sides of Cape York, lifting the warmer air ahead of them. These masses of air spill inland, each running like the foaming head of a breaking ocean wave. Meteorologists call such outpourings — whether sea breeze, cold front, or other cascade of cold air — 'gravity currents'. About midnight, two powerful gravity currents collide over Cape York. An enormous turbulent mountain of cool air results and, collapsing back, it releases energy.

The morning glory is a repercussion, on the western side, of that event. Apparently, steady winds from the Coral Sea prevent a similar occurrence on the east.

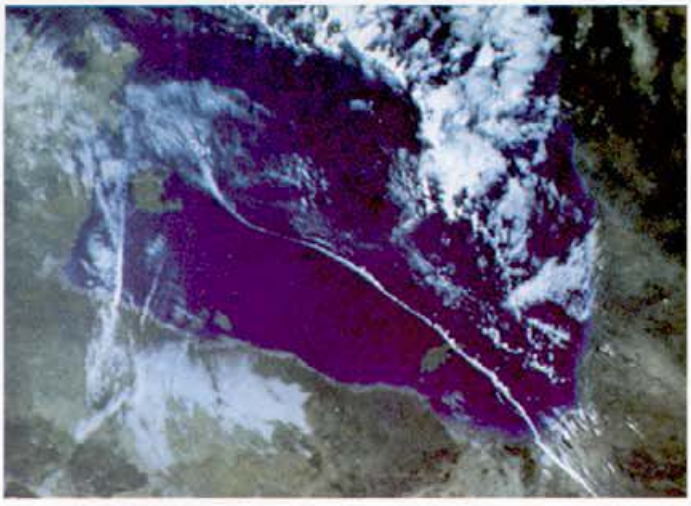
However, field measurements make it clear that the morning glory is not just a backwash from that monumental collision. If it were, and it ran forwards like all good gravity currents do, its speed would register as the same as that of the associated wind.

But the morning glory moves forward considerably faster than any detectable wind. The disturbance travels as a wave through the atmosphere and, like a ripple on a pond, it fails to carry the agitated fluid along with it. Nevertheless, it is true that gravity currents do emanate from the collision, and frequently show up as a 'cloud line' some distance behind the morning glory.

To explain such a wave we have to look to the theory of fluid mechanics. Hydrodynamics tells us that a sudden shift in the level of a stream produces a disturbance — a 'hydraulic jump' or 'bore' — that propagates upstream. Under certain conditions, the disturbance can be undular, or wave-like.

**A morning glory approaching Burketown.**

**Looking like a morning glory, this strange set of clouds rolls in towards Melbourne.**



**The long thin line of a morning glory over the Gulf of Carpentaria, as seen by the NOAA–6 meteorological satellite. The image was received and processed 'on the fly' at the CSIRO Division of Atmospheric Research using its CSIDA facility.**

**The same morning glory seen at 9 a.m. from a plane.**

In 1981, Dr Clarke, Dr Smith, and Mr Reid proposed that the morning glory was an atmospheric undular bore, and all the observations since have confirmed this supposition.

The complication for theory is that the morning glory doesn't travel at the surface of a single layer of fluid, but rather at the interface between two atmospheric layers. It propagates westwards on top of a stable boundary layer (perhaps 1000 m deep) formed by the earlier eastward passage of the west-coast sea breeze. This situation is difficult to treat theoretically, and no detailed mathematical description of it has yet been advanced.

However, Dr Smith and Dr Julie Noonan have performed a reasonably good simulation of a morning glory on a computer using some theoretical approximations, and Dr Peter Baines of the Division of Atmospheric Research has carried out water-tank experiments that reproduce the essential aspects of the phenomenon quite vividly.

He poured water into a 9-m-long tank, topped it with

**Waves of advancing clouds — a 'morning glory' from the air.**

**How a morning glory forms**


during the day the land heats up, and the temperature contrast with the ocean creates sea breezes (advancing currents of cold air)

easterly trade wind from the Coral Sea assists the east-coast sea breeze

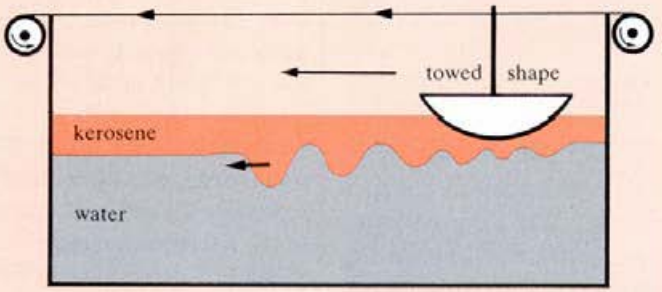

about midnight the currents collide over Cape York, producing a turbulent mountain of cold air


the mountain collapses, and 'gravity currents' of cold air spill out on top of the boundary layer formed by the preceding sea breezes

a shock wave — an undular bore — forms ahead of the spreading spill

air rising and falling in this disturbance creates the roll clouds

**'Morning glory' in a water tank**




**Dr Baines towed a wooden shape through a tank of kerosene floating on water, and watched what happened at the interface. At certain towing speeds, a travelling wave train appeared ahead of the shape.**

a layer of kerosene, and pulled a rounded block of wood across the surface of the kerosene.

In some situations, the block's motion created a series of waves at the water–kerosene boundary some distance ahead. Translating the experiment to the Gulf situation, the block represents a gravity current spilling out from the mountain of cold air, which excites a wave train — a morning glory — that moves out ahead of the current.

This picture squares nicely with most of the recorded meteorological circumstances surrounding morning glories. An apparent anomaly is that the number of observed morning glories (perhaps a dozen at Burketown for the month of October) is much less than the number of sea breezes (nearly every day).

But the discrepancy diminishes if we recognise the existence of 'invisible' morning glories. That is, a morning glory only shows itself if the moisture at the top of the boundary layer is conducive to cloud formation. And the amplitude of the travelling wave has to be enough to lift the moist air through several hundred metres to produce condensation.

If these special conditions don't hold, the morning glory remains invisible. This has an important implication for aviation, for it means that a low-flying aircraft may suddenly find itself in a dangerous 'clear-air disturbance', where an updraught of perhaps 5 m per second blows adjacent to a downdraught of the same strength.

Another implication is that morning-glory-like phenomena may be much more prevalent than was previously thought. The Gulf may regularly produce just the right combination of ingredients, but it doesn't have a monopoly on sea breezes or similar gravity currents.

Indeed, now that meteorologists are alert to the possibilities, quite a number of morning glory lookalikes have been observed at various places around Australia, and overseas.

The picture shows a remarkable set of roll clouds approaching the laboratories of the Division of Atmospheric Research at Aspendale, a bayside suburb of Melbourne, on January 6, 1984. Dr Physick analysed the concurrent meteorological data and concluded that it was a wave train triggered by a nearby pre-frontal trough.

Scientists have even seen what looks like a morning glory in the atmosphere of Mars.

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