The Gibbs quantum field

Least action drives the atmosphere's dynamics

- The atmosphere is a dynamic system, and its stability is essential for life.
- The intricate complexity of the atmosphere makes modelling its evolution a daunting task.
- Professor Ivan Kennedy at the University of Sydney, Australia and colleagues introduce a novel theory of heat and energy storage and conversion within the atmosphere.
- This approach offers a potent tool for studying climate evolution and global warming while also fostering innovation in energy production technologies.

The atmosphere is a dynamic and intricate system, which plays a crucial role in sustaining life on Earth while also influencing global warming and climate patterns. Its complexity arises from the interactions among various components including gases, aerosols, and water vapour. The atmosphere's ability to regulate temperature through processes like greenhouse gas absorption is fundamental for maintaining suitable conditions for life. Understanding and addressing these complexities are vital for mitigating the impacts of climate change and safeguarding the delicate balance that sustains life on our planet.

Professor Ivan Kennedy from the University of Sydney, Australia, has taken on this ambitious challenge. Using concepts from climate science, thermodynamics, and quantum mechanics, he has developed a new approach to modelling the dynamics of the atmosphere. His findings provide a staggering new view of the factors that shape the behaviour of the atmosphere, its evolution, and its interaction with our planet and its lifeforms.

The principle of least action

One of the most powerful concepts in physics states that the so-called 'action', a physical quantity integrating the mass of a body, its velocity, and the distance it travels, is always minimised as a system evolves in time. This least-action principle is very important in physics, because it provides an elegant and powerful framework to derive equations of motion, which describe how real-life bodies respond to external forces and follow well-defined trajectories. Irrespective of how complex or large a system of moving bodies is, the least-action principle provides clues on its history and on how it will evolve in the future. Can this powerful law of physics be used to get a grasp of the complex dynamics of the atmosphere?

A hidden quantum field

Kennedy has studied how the principle of least action emerges in dynamical systems in which the total energy is conserved over time. He has analysed in detail a thermodynamic model known as the Carnot heat engine cycle. This is an idealised but physically rigorous representation of how heat between two reservoirs at different temperatures is exchanged with maximum working efficiency. He has shown that, in this class of conservative systems, the least-action principle appears naturally in consequence to the existence of an underlying quantum field, which Kennedy calls the 'Gibbs quantum field'. This field can be thought of as an invisible dynamical network spread throughout space. It is generated by discrete impulses of action, or quanta with wave-particle nature, impulsively determining the trajectories travelled by all material bodies within a system. It also regulates how heat and mechanical work are converted into each other. According to Kennedy, this is one of the keys to understanding a plethora of phenomena that occur every day in the atmosphere.

Cyclones and anticyclones

The Gibbs quantum field contains many times more energy than the total classic kinetic energy calculated from the mass and velocity of winds. This, explains Kennedy, has important implications for understanding the formation and evolution of tropical cyclones and anticyclones. Cyclones are smaller systems of clouds and

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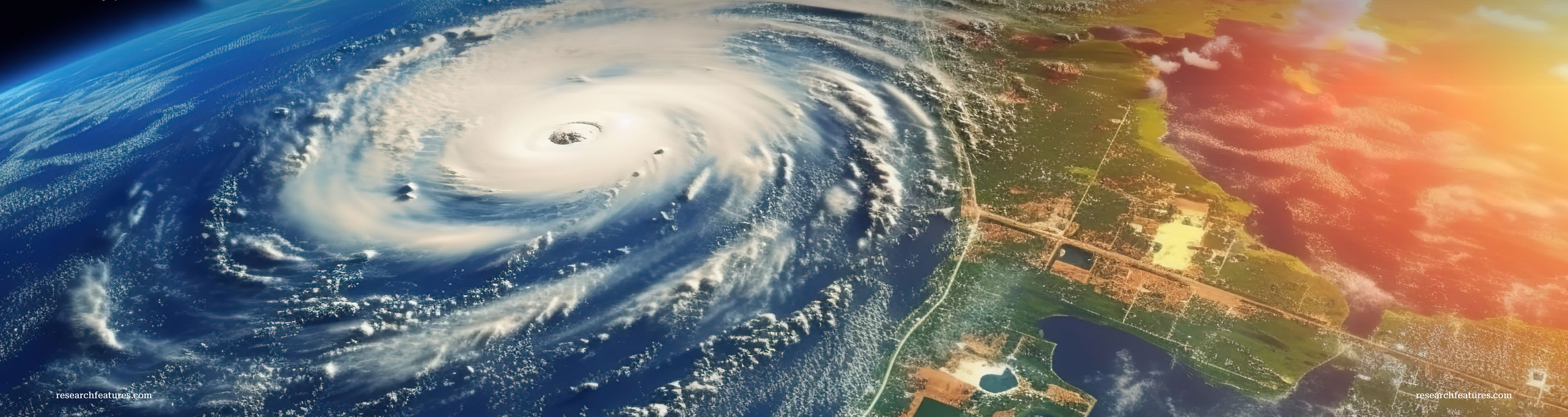
thunderstorms with closing circulation patterns, which typically form over warm ocean waters nearer the equator. They are dynamic and intensifying weather systems, associating gravitationally rising and cooling storms with heavy rainfall. Anticyclones are larger circulation systems, in which descending air warms gravitationally, rotating from high-pressure centres, resulting in fair and more stable weather conditions.

The vortical field

The concept of Gibbs quantum field elegantly explains the energy balance in cyclones and anticyclones. Kennedy postulates the existence of a 'vortical' Gibbs quantum field, which sustains large-scale vortices caused by the inertia of the Earth's rotation to emerge as fundamental features of the air particle dynamics. The action supplied by the quantum field supports the fluid motion of air in winds, which is centrally ascending in cyclones and centrally descending in anticyclones. 'This new hypothesis', explains Kennedy, 'challenges the current continuum mechanics of fluid motion in the atmosphere: it is precisely the quantum vortical field that stores heat in cyclones and anticyclones as rotational energy, without increasing air temperature.' According to Kennedy, cyclones and anticyclones are like Carnot heat engines,



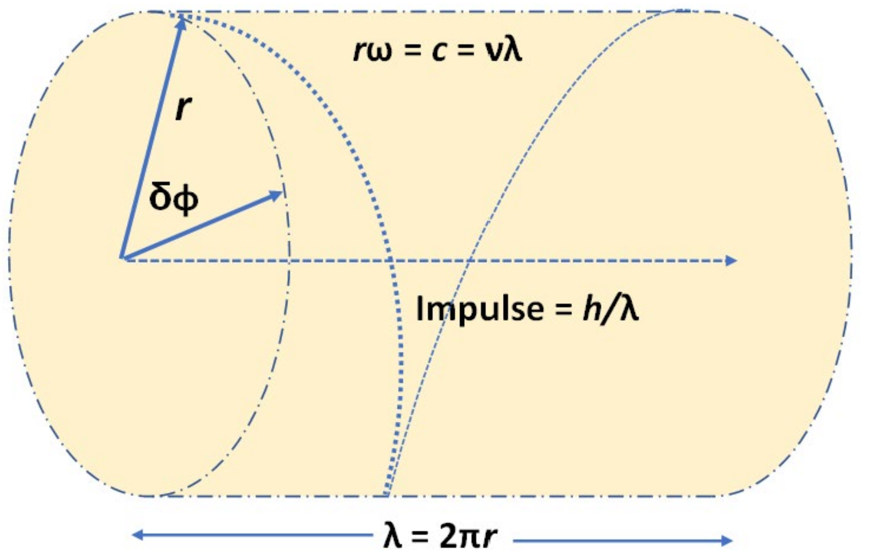


Figure 1. Gibbs field quanta, with wave-particle properties, exerting specific impulses on matter. All quanta of energy $h\nu$ have Planck's quantum of action ($h=m\lambda c$) and equal inertia ($m\lambda$), with variable impulse ($h/\lambda=mc$) giving action ($mvr\delta\varphi$) in matter, inversely weighted with wavelength (λ).

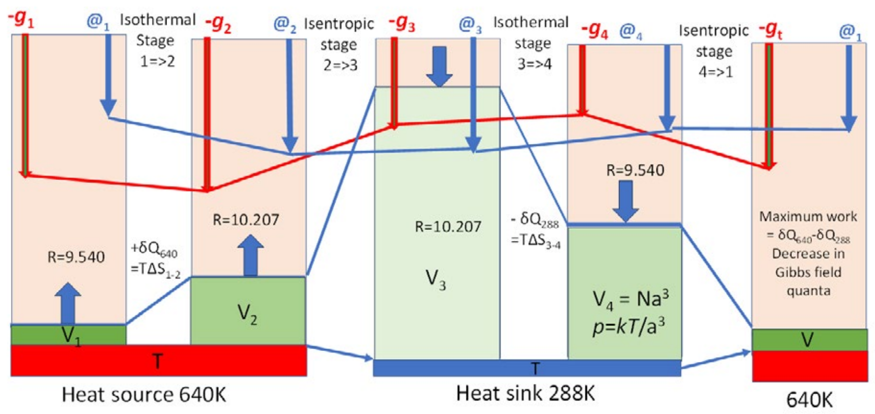
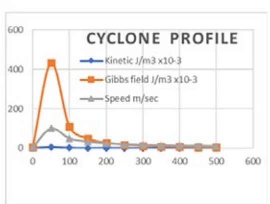
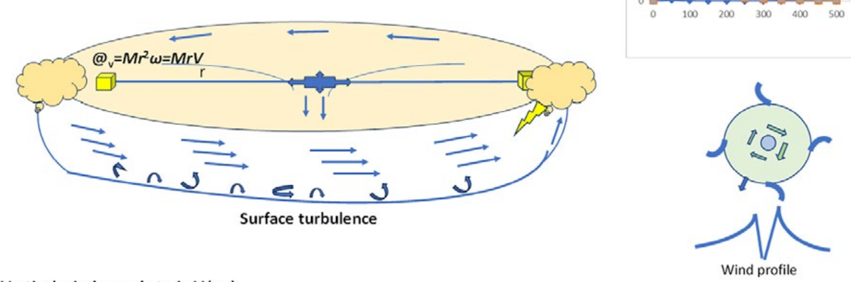


Figure 2. Carnot cycle Gibbs quantum fields. Action ($@_i$=mrv=$n'n$) varies with temperature and volume. Negative Gibbs energy per molecule $-g_i = kT\ln(@/^{t}n) = nth\nu$ per molecule. Ratio of $-g/1.5kT$ for argon is R.

Figure 3. The vortical Gibbs field, by analogy with Gibbs field, by analogy with Gibbs in the Carnot cycle, generates torque and wind speed in anticyclones and cyclones, with turbulent heat release by surface friction replacing downwelling radiation.





Vortical wind speed at r is V ($r\omega$);
Gibbs quantum field for air mass M at r in anticyclone $-G_v = MV^2\ln[(@_v/\hbar)/\sigma] = n_v h\nu$
Gibbs field quanta have energy $h\nu = -Gv/n_v$

'Turbulent wind farm wakes', says Kennedy, 'may have a greater effect on regional environment than previously imagined, drying soil and vegetation in consequence to the turbulent release of thermal heat and potentially increasing fire risk.'

in which heat and work are converted reversibly, but on a much grander scale.

Earth's surface warming

This analogy to heat engines and the concept of vortical field also provide new insight into how heat is transferred from the atmosphere to the Earth's surface. Near the Earth's surface, the air motion undergoes a transition from laminar flow, in which the air moves in smooth parallel layers, to turbulent flow, characterised by a chaotic and irregular motion of the air particles, more common during daytime. Turbulence promotes heat transfer from the air by friction, which means that much more thermal energy can be released when the air is made turbulent.

Kennedy's view challenges common assumptions that the Earth's surface is predominantly heated by the radiation coming directly from the Sun, with even more heat re-radiated in a cycle from greenhouse gases in the atmosphere. According to his view, energy is stored in the vortical motion of cyclones and anticyclones as reversible work that can be released nearer to the surface in the form of heat, if made turbulent. An important consequence of this finding is that all large-scale surface phenomena that promote turbulence, like mass urbanisation and drying by deforestation, can have profound effects on global surface warming.

Vortical power generation

Wind turbines work by converting the kinetic energy of the wind sustained by Gibbs field quanta into mechanical energy, which is then used to generate electricity. They have large blades attached to a hub. The blades are designed to capture the kinetic momentum of the wind as it flows over them, and the angle and shape of the blades must be carefully designed to maximise energy capture as power. Kennedy has studied how the concept of vortical action in cyclones can be used to optimise the efficiency of next-generation turbines.

With several colleagues, Kennedy has proposed a new model for estimating the wind power from torques exerted by deflection of wind momentum from blades, which he has shown to be proportional to a simple function of the angle of wind incidence on the blades. Surprisingly, this model can also be used to explain lift in winged aircraft. His results, however, also highlight some concerns. 'Turbulent wind farm wakes', says Kennedy, 'may have a greater effect on regional environment than previously imagined, drying soil and vegetation in consequence to the turbulent release of thermal heat and potentially increasing fire risk.' This hypothesis, if verified experimentally, can provide important guidelines for future wind energy harvesting strategies.

Personal response

What has led you to use the principle of least action to understand the complexity of the atmosphere?

This principle selects paths of least effort for material action caused by energy through time – an integrated holistic method to understand complex system appeals. We estimate action by simplifying statistical mechanics using Gibbs free energy as potential to do work. Much more heat is needed to melt and vaporise atmospheric gases than their kinetic energy. If this is true for molecules in the laboratory, how much more could be needed to sustain dynamic atmospheres? Wherever the inertia of molecules increases, such as by dilution, we find more heat is absorbed to sustain kinetic from potential energy, a feature of least action appropriate to the scale of the atmosphere.

What is the physical meaning of the Gibbs quantum field and what is its role in the dynamics of the atmosphere?

In re-analysing the Carnot cycle, we calculated the Gibbs energy for gases such as argon and nitrogen. These agreed very well with experimental third law entropy values, for translation of argon and rotation and vibration of nitrogen gas too. From quantum numbers obtained by dividing action by Planck's quantum constant, we estimated mean energy for each Gibbs field quantum. For anticyclones and cyclones, we could use the same approach for vortical motion, regarding torques exerted by quanta and their kinetic energy as surrogates for temperature. We propose that atmospheric Gibbs quantum fields operate cyclically in the same way as for gases in the Carnot cycle.

Can the existence of the Gibbs quantum field be verified experimentally?

Yes, in part for quanta of short wavelength and then by extrapolation for longer. Radiating black body infrared vibrational quanta were predicted accurately by Planck, confirmed many times spectrally since. Specific field quanta are well known for water and carbon dioxide in terms of absorption and emission for vibration and rotation. For water vapour in the atmosphere, there is negligible emission of infrared quanta by comparison with those for rotational and translational quanta. Longer wavelength field quanta are microwaves, even radio-waves. Microwave cooking relies on intense fields of quanta being absorbed by water molecules. We need new sensors for quanta of longer wavelength, most challenging for vortical quanta. The fact we can predict mean values for such quanta allows tests of the hypothesis.

Vortical action is a central concept in your model of heat exchange in cyclones and anticyclones. How does this new concept modify existing theories of atmospheric dynamics?

The proposal for vortical action and Gibbs field quanta to support the kinetic potential for air flows of molecules in anticyclones and cyclones increases the heat capacity of such atmospheres. Compared to the 2.4 MJ of heat per cubic metre needed to bring air from absolute zero to 298 K temperature, vortical energy of 1400 J/cubic metre for wind 10 metres per second is only a small increase. Its kinetic energy would be 61.3 J per cubic metre, 23 times less. This solves the mystery for tropical cyclones that their kinetic energy is negligible compared to their scale of destructive dissipation.

Current theories of atmospheric continuum dynamics based on the Bernoulli equation only count kinetic and pressure-volume potentials. This limits the heat capacity and the range of heat released in the heat-work cycle observed with cyclones but is now extended with the vortical action model. We estimate that heat released in turbulent wakes from wind farms could possibly increase downstream temperature by 2-3°C. This prediction is testable, comparing the air upstream and downstream of a 100 MW windfarm with a 1 km width.

What are the main predictions of your quantum-field based description of the atmospheric dynamics concerning the environment, global warming, and the future of life on Earth?

Many quantitative predictions on these topics are likely in future articles, questioning the IPCC favoured radiative-convective models that lack reversible heat-work cycles. We predict a much greater role for reversible vortical heat storage. If our hypothesis survives experimental testing, meteorologists and climate scientists can have far more confidence in predictions using a more fundamental action theory. None of the current zero carbon policies guarantee environmental success. We invite others to join us in this new frontier for research (by visiting www.ackle.au).

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Collaborators

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Bio

Ivan Kennedy holds a PhD (1965) and DSc in Agriculture from The University of Western Australia. His research students at Sydney University worked on nitrogen fixation, risk management of pesticides, and sustaining ecosystems. His new (almost) independent work is on his speculative 2001 treatise 'Action in Ecosystems: Biothermodynamics for Sustainability' as a quantitative testable hypothesis, recommended by Karl Popper.

Further reading

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- Kennedy, I, Hodzic, M, (2021) Partitioning entropy with action mechanics: Predicting chemical reaction rates and gaseous equilibria of reactions of hydrogen from molecular properties, *Entropy*, 23(8), 1056.

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