The Status of Classical Physics in the Contemporary Scientific Mosaic

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Abstract

This paper argues that the traditional scientonomic portrayal of theories of classical physics (e.g. Newtonian mechanics, thermodynamics) as merely used but no longer accepted is too simplistic. To that end, I consider the current status of the meteorological theory, which is accepted as the best available description of atmospheric phenomenon despite the fact that it is founded on the principles of classical physics, including those of Newtonian mechanics. This apparent paradox is resolved if the distinction between a theory’s ontology and its phenomenological laws is properly appreciated. The phenomenological laws of meteorology are accepted by the scientific community as the best available description of atmospheric phenomena. Yet, this acceptance does not imply that the classical ontology implicit in the current meteorological theory is also accepted. Thus, the modern meteorological theory (as well as many tenets of classical physics) can be said to be accepted as the best available description of the observable atmospheric phenomena even though its classical ontology is no longer accepted.
Introduction

According to the current scientonomic ontology of epistemic stances, there are three stances that one can take towards a theory – acceptance, use, and pursuit. A theory is said to be accepted if it is taken as the best available answer to its respective question (Barseghyan, 2018, p. 31). In scientonomy, a question is defined as a topic of inquiry (Rawleigh, 2018). In contrast, a theory is said to be used if it is taken as an adequate tool for practical application (Barseghyan, 2015, p. 31). Finally, a theory is said to be pursued if it is considered worthy of further development (Barseghyan, 2015, p. 31):

| Theory Acceptance | Theory Use | Theory Pursuit |
|-------------------|------------|----------------|
| A theory is said to be accepted by an epistemic agent if it is taken as the best available answer to its respective question. | A theory is said to be used if it is taken as an adequate tool for practical application. | A theory is said to be pursued if it is considered worthy of further development. |

Some examples of scientific theories that are accepted by our current scientific community include general relativity (GR) and quantum mechanics (QM); general relativity is considered by the physics community as the best available description of very massive and very fast-moving objects, while quantum mechanics is considered as the best available description of the behavior of very small objects. While many of the currently accepted theories are also used in practical applications, it is often the case that a theory used in, say, engineering, is not accepted as the best available description of its domain. For instance, Newtonian mechanics (NM) is still used in a vast array of practical applications, while arguably no longer being accepted as the best available description of physical processes (Barseghyan, 2015, p. 31). Specifically, NM is used for practical applications like bridge-building because the calculations that civil engineers need to make are much simpler in NM than in any other contemporary physical theory (i.e. GR or QM), while at the same time the theory also provides all the accuracy and precision that a bridge builder would require.

This paper argues that the portrayal of NM as merely used but no longer accepted is too simplistic. To appreciate this, I will consider the current status of meteorology. On the one hand, the modern meteorological theory is accepted by the contemporary scientific community as the best available description of atmospheric phenomena. On the other hand, the current meteorological theory itself is founded on classical theories, including NM and classical thermodynamics. There is a seeming paradox here: we have an accepted theory (i.e. meteorology) that is based on theories which are themselves no longer accepted, but merely used (i.e. NM). The case of meteorology is not unique: most theories accepted in the Earth sciences are also based on the theories of classical physics.

I will show that this apparent paradox can be resolved if the distinction between the ontology of a scientific theory and its phenomenological laws is properly appreciated. The phenomenological laws of modern meteorology are accepted by the scientific community as the best available description of atmospheric phenomena. Yet, the acceptance of these phenomenological laws does not imply that the classical ontology implicit in the current meteorological theory, such as the idea of classical particles or the idea of the force of gravity, is also accepted by contemporary science. Thus, the modern meteorological theory can be said to be accepted only as the best available description of the observable atmospheric phenomena; as for the ontology implicit in the theory, it is by no means accepted nowadays. It can be shown that most theories of classical physics are in the same predicament: their classical ontologies are no longer accepted, but most of their phenomenological claims are still accepted as applying to observable phenomena.

The Paradox

It is important to appreciate that the contemporary meteorological theory is not only used to produce weather forecasts but is also accepted as the best available description of the Earth’s atmosphere, as well as the
atmospheres of other planets. According to the initial scientonomic definition of theory acceptance, a theory was said to be accepted if it was taken as the best available description of its object (Barseghyan, 2015, p. 31). Since that definition was formulated, scientonomy has recognized several different types of theories which resulted in redefinitions of the notion of theory acceptance. First, Sebastien’s introduction of normative theories necessitated a redefinition of theory acceptance to ensure that it is applicable not only to descriptive theories but also to normative theories. According to Sebastien’s definition, a theory is said to be accepted if it is taken as the best available description or prescription of its object (Sebastien, 2016, p. 7). When Barseghyan’s modified ontology of scientific change became accepted, it introduced definitions as the third subtype of theory (Barseghyan, 2018).

As a result, the definition of theory acceptance has been changed again to ensure that not only descriptive or normative theories, but theories of all types can be said to be accepted (Barseghyan, 2018, p. 31). That is why the current definition doesn’t make any assumptions about subtypes of theories but is instead formulated in such a way that it applies to theories of all types. Importantly, when applied to a descriptive theory like meteorology, the current definition of theory acceptance amounts to the same thing as the previous two definitions: since a descriptive theory, by definition, attempts to describe a certain object, to accept a descriptive theory is to accept that it is the best available description of that object. Since meteorology’s object is the atmosphere, the question meteorology seeks to answer is “How does the atmosphere work?”. Thus, to accept the meteorological theory is to consider it the best available answer to the question “How does the atmosphere work?”, which is the same as to accept the theory as the best available description of the atmosphere. That is precisely the sense in which today’s scientific community accepts the contemporary meteorological theory.

This is indicated by the fact that contemporary meteorological research goes well-beyond weather predictions and aims at improving our understanding of the workings of atmosphere. Among other things, meteorologists actively pursue a better understanding of atmospheric phenomena, such as how tornados are generated by supercells (Markowski & Richardson, 2009), how tropical storms make the transition into extratropical storms (Jones et al., 2003), and how ocean currents and atmospheric patterns are linked (Seager et al., 2010). The fruits of this research are published in a great number of reputable meteorological journals; publication in any one of these journals is usually an indication of the communal acceptance of the respective theories. In meteorology, the American Meteorological Society (AMS) is the foremost publisher of meteorological journals. Their journals page gives access to The Bulletin of the American Meteorological Society, Journal of Applied Meteorology and Climatology, Journal of Atmospheric Sciences, Journal of Climate, Earth Interactions, Journal of Hydrometeorology, Monthly Weather Review, Weather and Forecasting, and Meteorological Monographs, among others. The AMS is hardly the only publisher of scientific meteorological journals. Others, such as the Canadian Meteorological and Oceanographic Society (CMOS), publish their own journals: in the case of CMOS, it is Atmosphere-Ocean. While these and many other meteorological journals include technical and practical information, they also regularly publish scientific papers that attempt to improve our accepted views of atmospheric phenomena.

One solid indication that the contemporary meteorological theory is accepted is the fact that other recognized scientific communities, such as that of climate scientists, accept meteorology as the best available description of atmospheric phenomena. This can be seen in many climate science texts, such as Climate Change: The Science of Global Warming and Our Energy Future by Edmond Mathez and Jason Smerdon (2018). As can be seen from Chapter 1 of this text, the portion of climate science that deals with atmospheric phenomena is the contemporary meteorological theory. While the entire chapter is a synopsis of meteorological theory, Box 1.1 (Mathez & Jason Smerdon, 2018, pp. 18-19) provides a short introduction to atmospheric thermodynamics. In addition, the text gives a good introduction to the accepted explanation of the Coriolis Effect (Mathez & Jason Smerdon, 2018, pp. 29-30). One additional indicator of the acceptance of the meteorological theory by the contemporary the scientific community is that government weather prediction programs are all derived from contemporary meteorological theory. Governments would not fund these expensive projects if they did not believe that meteorological theory...
was accepted by the scientific community. In short, there is solid evidence that the current meteorological theory is accepted and not merely used.

As with other sciences, what propositions are accepted by the meteorological community can be most readily determined from meteorological textbooks. For instance, the accepted understanding of atmospheric dynamics can be found in Introduction to Dynamic Meteorology by James Holton and Gregory Hakim (2011), a standard textbook on the subject. The accepted concepts of cloud physics can be found in R. R. Rogers and M. K. Yau’s A Short Course in Cloud Physics (1989).

Texts like this are a good indication of what propositions the meteorological community accepts.

Now, the foundations of meteorology consist of classical theories, such as NM and classical thermodynamics. Thus, if we were to follow Barseghyan and classify NM as merely used (Barseghyan, 2015, p. 40), we would arrive at a seeming paradox: how is it possible for an accepted theory to presuppose any unaccepted theories? Isn’t it reasonable to suspect that if the former is accepted by the contemporary physics community, so should also the latter? In this sense, the case of meteorology is not unique: most of the theories accepted in the Earth sciences are similarly based on the theories of classical physics. Thus, the seeming paradox is not restricted to meteorology only, but applies to most theories in the Earth sciences.

How can this paradox be resolved? One obvious way of dismissing the paradox is by claiming that the tenets of meteorology are not accepted but merely used for making weather predictions. Indeed, if this interpretation were correct, there wouldn’t be any paradox: we would be dealing with a used theory (i.e. meteorology) that is based on another used theory (i.e. NM). However, rendering the current meteorological theory as a purely technological activity and its theoretical foundation as merely used meteorological theory is not only used but also clearly accepted. Effectively, the paradox stands: how can an accepted theory be based on something that is not accepted?

### Ontology vs. Phenomenology

To resolve the paradox, it is important to recognize that a typical scientific theory normally attempts to accomplish two things. First, it offers a certain ontology of the processes, entities, and relations that populate the theory’s domain. Second, it also provides a description of observable phenomena of its domain, i.e. a certain phenomenology. Typically, a theory posits a certain ontology, i.e. it tells us “what there is” (Hofweber, 2014), and then attempts to explain how this ontology produces the observable phenomena under study. In contrast, a theory’s phenomenological claims are all about the description of observable states and processes (Smith, 2018). It is also important to note that the ontology and the phenomenological laws are not always tied together. As we shall see, it is quite possible for the same set of scientific laws to have different ontological claims ascribed to them by different epistemic agents.

The distinction between a theory’s ontological and phenomenological claims is not new. It goes at least as far back as van Fraassen’s well-known distinction between accepting a theory as true and accepting it as empirically adequate (van Fraassen, 1980). Van Fraassen contrasted the scientific realist’s notion of acceptance with that of
the constructive empiricist. For a scientific realist, says van Fraassen, “science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true” (van Fraassen, 1980, p. 8). Among other things this implies that scientific realists accept that the theoretical objects postulated by scientific theories are real. In contrast, constructive empiricists, like van Fraassen, accept that “science aims to give us theories which are empirically adequate; and acceptance of a theory involves a belief only that it is empirically adequate” (van Fraassen, 1980, p. 12). Constructive empiricists are agnostic as to the nature of theoretical objects and, therefore, about any ontological claims that scientific theories posit.

It is worth noting that as a descriptive science, scientonomy is entirely agnostic concerning the debates on scientific realism, for it does not aim to make any normative claims about the legitimacy of the stances that scientists take towards theories (Barseghyan, 2015, p. 25). This paper seeks to maintain this agnosticism and make no claim here on this subject. What is important for our purposes is the historical fact that scientific theories often do make ontological claims and scientists often do accept these ontological claims. For instance, GR makes ontological claims about spacetime and many of these claims are currently accepted by physicists as the best available descriptions of spacetime. This simple historical fact is all we are concerned with here.

To understand the difference between ontological and phenomenological claims of scientific theories, let us take a closer look at a few cases from the history of physics. First, according to NM, pieces of matter can interact with each other in one of two ways – action by contact and/or gravitational attraction. Because it is assumed by NM that all material objects occupy some space, i.e. they are extended, it follows that no two material objects can occupy the same point in space at the same time. Therefore, if two material objects approach the same point in space at the same time, they interact by colliding with each other. Additionally, according to NM, two pieces of matter can affect each other at a distance by gravitational attraction. Both the claim that objects can interact by contact and at a distance are the attempts of NM to portray a certain ontology of the physical world. Other ontological claims of the theory include ideas of absolute space and absolute time. In addition to offering a certain ontology, NM also provides a description of the observable behavior of physical phenomena, i.e. a certain phenomenology. Among other things, it describes how the apparent positions of material objects change through time in such processes as free fall, the motion of projectiles, and the motion of planets.

In the nineteenth century, the ontology of classical electromagnetism replaced the concept of action-at-a-distance with the concept of a force field, such as the electric field and the magnetic field. Both of these concepts allowed scientists to explain how electric charges and magnets can attract and repel each other. The acceptance of these concepts led physicists to inquire about the medium in which the waves of electric and magnetic fields propagate. To answer this question, nineteenth century physicists added to the ontology of classical electromagnetism the concept of aether, a ghostly substance that celestial bodies can move through without resistance (Torricelli, 1999, pp. 173-180). As with NM, classical electromagnetism offered a description of the observable behavior of physical phenomena in addition to an ontology. For example, classical electromagnetism was able to describe quantitatively how magnetic and electric forces interact with each other, particularly when one field is moving with respect to the other.

The accepted ontology of physics changed with the acceptance of GR in the early 1920s. GR introduced the concept of curved space-time, which replaced the absolute space and time (Torricelli, 1999, pp. 289-299) that was central to NM (see, for instance, Clarke’s third reply to Leibniz in Ariew (Ed.), 2000, pp. 18-22). Because it was now possible to explain electromagnetic phenomena without the need of aether, aether was removed from the ontology of modern physics. As with NM and classical electromagnetism, GR also offered a description of the observable behavior of physical phenomena in addition to its ontology. For example, the Lorentz transformation describes quantitatively how space-time coordinates in two inertial reference frames are related to each other, i.e. what lengths and what time intervals will be observed in different reference frames.

While it is true that most scientific theories offer both a certain ontology of the processes, entities, and relations of their domain, as well as a certain phenomenology of observable behavior, it would be a mistake to think that this is typically accomplished by means of two different sets of sentences. In many cases, theories offer both their
ontologies and their phenomenologies within the same set of laws. For instance, Newton’s law of gravity can be understood as both giving us a certain phenomenology of how the relative positions of material objects change over time and conveying a certain ontology of the force of gravity acting at a distance between two objects with mass. Similarly, Einstein’s field equations are supposed to tell us both how material objects appear to behave (phenomenology) as well as what the structure of space-time actually is and how it is affected by mass-energy (ontology). In short, the ontological claims of a theory often come together with the theory’s phenomenology merged in one set of equations or laws.

Let us take an example to see how the ontological and phenomenological claims implicit in a scientific equation can be explicated separately and formulated as individual propositions. Consider, for instance, Newton’s law of universal gravitation and Newton’s second law, both of which were accepted until the 1920’s. While they are only two equations, propositionally speaking they are an amalgamation of several propositions, i.e. they express the content of several propositions in a succinct fashion. However, they do not state the entire content of the theory, since the meanings of the variables must be separately specified. For Newton’s law of gravity, some of these propositions can be explicated as follows:

(1) Material objects attract each other at a distance through the force of gravity.
(2) The force of gravity is greater when the masses are greater.
(3) The force of gravity is smaller when the distance is greater.
(4) The observed acceleration between two objects is inversely proportional to the distance between the two objects.
(5) The observed acceleration of an object is proportional to the other object’s mass.

It is easy to see that propositions (1), (2), and (3) are making ontological claims while propositions (4) and (5) are making phenomenological claims. Yet, these distinct propositions were traditionally conveyed by means of two equations:

\[ F = G \frac{m_1 m_2}{r^2} \quad F = ma \]

In the 1920’s, NM was replaced by QM for the microscopic realm and by GR for phenomena that are very massive or involve velocities comparable to the speed of light. Among other things, what this meant was that the ontology of NM was replaced with the ontology of GR. However, importantly, not all of the claims of NM were rejected. Of the five propositions enumerated above, propositions (4) and (5) continue to be accepted to this day as the best descriptions of many macroscopic phenomena, while propositions (1), (2), and (3) are not. This is because propositions (4) and (5) concern only observable variables (acceleration and mass) while the first three propositions contain ontological concepts (i.e. the force of gravity).

While phenomenological claims (4) and (5) do not attempt to give any insight on the structure of reality, i.e. ontology, they nevertheless remain accepted for describing the observable behavior of the phenomena in question. If we consider the Newtonian second law and the law of gravity, their phenomenological claims still remain the best accepted descriptions of macroscopic phenomena, even though the ontological claims originally associated with the laws are no longer accepted. Thus, when we say that NM was replaced by GR and QM, we have to be cautious not to forget that not all the claims of NM were rejected and that its claims about observable macroscopic phenomena are still very much intact.

The history of science knows many similar cases. Consider, for example, Maxwell’s equations of electromagnetism that form the heart of classical electrodynamics (CED). When they were first accepted in the late 19th century, they were accepted both as providing a phenomenological description of certain observable relations, as well making ontological claims about the nature of electromagnetic radiation consisting of waves propagating in luminiferous aether (Torricelli, 1999, pp. 168-180). However, it is safe to say that nowadays the scientific community no longer accepts the ontological claims of CED; these were replaced by the ontology of quantum electrodynamics (QED) in the 1940’s (Torricelli, 1999, pp. 394-397). Yet, the equations of CED are still
accepted as perfectly adequate descriptions of observable electromagnetic phenomena. In fact, the phenomenological claims of CED are still considered superior to those of QED due to the intractable nature of the equations of QED. Here we have another case where the ontology of a theory was rejected while its phenomenological claims are still accepted as the best descriptions of observable phenomena.

It is also possible for a scientific equation to be first accepted only as a description of observable phenomena, with its ontological claims being accepted at a later time. Consider the history of the second law of thermodynamics. Briefly, the second law states that the entropy of a closed system always increases with time. It was originally proposed by Rudolph Clausius in 1865 in order to explain why heat always flows from hot to cold but never the other way around. Initially, Clausius and his colleagues thought of entropy as an observable state variable, but they lacked an understanding of what specific physical features entropy represents (Cropper, 2001, p. 101). Only in 1872 did Ludwig Boltzmann make the conjecture that entropy represents the number of possible microstates that a macrostate of the system can occupy. Since all microstates are equally possible, an unlikely state (such as that of all the warm gas occupying one corner of a container) will have fewer possible microstates than a likely state (a gas of uniform temperature in the container). What enabled this interpretation is the ontology brought to thermodynamics by the kinetic theory of gases. According to this theory, gas is composed of many small molecules that bounce around with significant kinetic energy. With this development in thermodynamics, this ontological claim was added to the second law of thermodynamics (Cropper, 2001, p. 192).

A typical historical case where a set of scientific laws has different ontological claims ascribed to it is that of QM. Many of the physicists who developed quantum mechanics – Bohr, Heisenberg, and the early Einstein – were committed positivists influenced by Ernst Mach and later by logical positivists (Torricelli, 1999, pp. 234-242). To Bohr and Heisenberg (but not to Schrödinger), the equations of QM are applicable only to observables, i.e. they are merely phenomenological and tell us what we would observe in the next measurement if the previous measurement gave such-and-such results. To them, QM says nothing about what happens to a quantum system between two measurements, as they believed that the unobservable aspects of the microscopic world should be irrelevant to science. This anti-metaphysical (anti-ontological) stance is captured in the orthodox Copenhagen interpretation of QM, which tried to restrict quantum physics to making only phenomenological claims. For example, quantum entanglement was initially understood as merely an observable phenomenon when measurements on one entangled particle somehow shape the results of the measurements on the other particle. Similarly, the wave function \( \psi(x) \) was initially accepted as making only phenomenological claims about the probability of finding a subatomic particle at a particular point in space (Cohen-Tannoudji et al., 1977, pp. 253-255). This conception leads to a very counterintuitive interpretation of Young’s double slit experiment (French & Taylor, 1978, pp. 88-93) as well as Schrödinger’s cat paradox (Baggott, 1992, pp. 102-106). To avoid these counterintuitive conclusions, different interpretations of QM have been developed over the years. Many of these interpretations come with distinct ontologies, such as Everett’s many-worlds ontology (Baggott, 1992, pp. 194-201). According to Everett, every time a quantum-sized particle appears to be doing something counterintuitive (such as an electron going through two slits at the same time), the universe actually splits. Thus, for Everett, the laws of QM are making not merely phenomenological claims about the behavior of observable, but also making the ontological claim that the universe is able to split into two. Another ontology is suggested by the Bohmian mechanics (Dürr & Teufel, 2009). According to David Bohm, the source of many quantum effects, like entanglement, is the so-called pilot wave (Cushing, 1994, pp. 42-44). According to this interpretation, the laws of QM include a claim about the existence of a pilot wave. In short, depending on the interpretation of quantum mechanics, the ontological claims ascribed to the equations of QM can be radically different (for a discussion, see Myrvold, 2019 and references therein).

Now that we understand how phenomenological claims of a theory can remain accepted without any specific ontological claims, we can turn to addressing the central question of this essay.
It is my contention that the contemporary scientific community continues to accept many of the phenomenological claims of NM. Although the ontology of NM has been rejected with the acceptance of GR, many phenomenological propositions of NM are still accepted as the best available descriptions of ordinary macroscopic phenomena, i.e., those of the length scales much greater than the size of the atom and moving much slower than the speed of light. For instance, we still accept that Newton’s law of gravitation is as good a description of the apparent behavior of ordinary macroscopic phenomena as any other available theory. Thus, the physics community still accepts the phenomenological claims of the law while rejecting the idea of the force of gravity acting at a distance.

The principles that form the theoretical bedrock of modern meteorology come from two fields – NM and classical thermodynamics. These are taught in university meteorology programs as two required subjects: *dynamic meteorology* and *atmospheric thermodynamics*. One standard textbook used these days is the aforementioned *Introduction to Dynamic Meteorology* by Holton and Hakim. They write (Holton & Hakim, 2011, pp. 3-4):

> Dynamic meteorology applies the conservation laws of classical physics for momentum (Newton’s laws of motion), mass, and energy (First law of thermodynamics) to the atmosphere. … For atmospheric motions of meteorological interest, the forces that are of primary interest are the pressure gradient force, the gravitational force, and friction.

Holton and Hakim then go on to describe these and other forces, such as the Coriolis force. From the treatment of these forces, they derive a series of partial differential equations that describe and predict the motion of air parcels in the atmosphere. The primitive equations that make up the heart of all modern numerical weather prediction (NWP) models all come from dynamic meteorology. A typical text on NWP, *Numerical Prediction and Dynamic Meteorology* by Haltiner and Williams (1980), begins with an overview of dynamic meteorology to show where the theory behind numerical models originates. It shows that modern dynamic meteorology is derived from a small number of phenomenological claims of classical physics, specifically NM. The same can be seen in many other texts on the subject (Coiffier, 2011; Warner, 2011).

The other main foundation of meteorology is classical thermodynamics, which forms the basis of contemporary atmospheric thermodynamics. One prominent text is Iribarne and Godson’s *Atmospheric Thermodynamics* (Iribarne & Godson, 1981). The first chapter of the book is titled “The Thermodynamics of Dry Air”. It reviews the first two laws of thermodynamics plus the ideal gas law. An important cloud physics text is Rogers and Yau’s *A Short Course in Cloud Physics* (1989), which begins with a review of atmospheric thermodynamics. Rogers and Yau start with the same principles as Iribarne and Godson but also introduce the concept of heat capacity in materials (Rogers & Yau, 1989). Similar discussions are a common practice in many other textbooks on atmospheric thermodynamics nowadays (Tsonis, 2007; North & Erukhimova, 2009).

Importantly, both heat capacity and the ideal gas law are currently accepted as phenomenological claims. As was the case with dynamic meteorology, contemporary atmospheric thermodynamics is derived from a small number of phenomenological claims of classical physics. The ontology which was once behind the ideal gas law – the kinetic theory of gases – is no longer accepted. Meteorologists often speak in terms of the ontology of classical physics. A common way that meteorologists think about the atmosphere involves the concept of air parcels. While a particular parcel of air may expand or contract, heat or cool, the existence of air molecules and their conservation is assumed, as is the Euclidean notion of space and time. At the same time, the relativistic notion of mass-energy equivalence is ignored, as is Einsteinian notion of curved space-time. This way of viewing meteorological phenomena is reflected in meteorology textbooks (Tsonis, 2007, pp. 39-41; North & Erukhimova, 2009, pp. 17, 130), but this should not deceive us into thinking that the ontology of classical mechanics is still accepted by contemporary meteorologists. It is not. When pressed, meteorologists will readily acknowledge the existence of curved space-time and quantum phenomena, as well as the fact that the ontology they reference is no
longer accepted. The reason meteorologists speak in terms of classical ontology is largely heuristic. Meteorology makes claims exclusively about atmospheric *phenomena* and doesn’t attempt to say anything about the real features of space-time or the dual wave-particle nature of the subatomic world. In short, the classical notions are taken by meteorologists exclusively as applying to observable phenomena.

Would it not be possible to develop a meteorological theory that not only describes meteorological phenomena but also makes ontological claims consistent with those of GR? Given that the physics community accepts GR as the best available description of physical reality, it would naturally follow that a meteorological theory making the same ontological claims as GR would provide a better description of reality than the current meteorological theories, which do not make any ontological claims but are restrained to describing atmospheric phenomena by means of obsolete notions of classical physics. While in principle it is likely that such a meteorological theory would provide more precise descriptions of atmospheric phenomena, such a theory is currently virtually inconceivable, as it would have to be formulated in the mathematical formalism of GR. Contemporary meteorology is expected to provide equations which are relatively easy to solve. However, it is safe to say that the equations of a hypothetical meteorological theory based on GR would most likely be much more complicated and cumbersome, since solving anything but the simplest problems with GR is extremely difficult. Extrapolating this trend to a complex system like the atmosphere, composed of countless air molecules, leads one naturally to the conclusion that a solution to the state equations would very likely be impossible to develop. Additionally, we have no reason to believe that any added accuracy and precision that would be achieved from such a reformulation would be anything but immeasurably small, likely beneath the bounds of detection. The results obtained by applying the equations of GR deviate significantly from the phenomenological equations of NM only in the case of very massive or very fast-moving objects. Atmospheric phenomena, on the other hand, are neither very massive nor very fast. Thus, the results obtained by applying the equations of NM are as good as those obtained by means of GR. In short, the intellectual effort that would need to be expended on developing a meteorological theory based on GR would be unacceptably immense.

What’s important to the present discussion is that the classically rooted, phenomenological claims of contemporary meteorology are still accepted by the physics community as providing the best description of atmospheric phenomena, and therefore the best available answer to its core question “How does the atmosphere work?” While the classical equations upon which contemporary meteorology is based are still accepted as the best descriptions of ordinary macroscopic phenomena, the ontology of absolute space, the force of gravity, and corpuscles which was once ascribed to these equations is no longer accepted.

**Conclusion**

Contemporary meteorology is a cutting-edge science that conducts research on many atmospheric phenomena. The past twenty years has witnessed an explosion of new research that has been enabled by new technology, specifically numerical weather prediction, the advent of Doppler weather radar networks, and most recently the advent of dual-polarized weather radar networks. Each one of these technologies has allowed meteorologists to examine the atmosphere in ways that we could not before. In addition, with space probes orbiting Mars, Jupiter, and Saturn, we have been able to, for the first time, study the behavior of atmospheres of other planets. All of this is done with a science that is completely rooted in no-longer accepted theories of classical physics.

As I have argued, this seeming paradox is resolved if we appreciate that while classical ontologies are no longer accepted by the physics community, the phenomenological claims of classical theories, such as NM, classical thermodynamics, and classical electrodynamics, are still accepted as the best available descriptions of their respective phenomena. Thus, Barseghyan’s characterization of NM as no longer accepted but merely used is not quite correct. Since many phenomenological claims of classical physics are still accepted by the contemporary physics community, the seeming paradox is resolved: all we have is one set of phenomenological claims (i.e. those of meteorology) being based on another set of phenomenological claims (i.e. those of classical physics). Neither of these sets is taken as making any claims about the actual ontology of physical reality.
These findings raise an interesting observational question: which specific phenomenological claims of classical physics can be said to be still accepted by the contemporary physics community? This important question will require a great deal of additional research.

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Suggested Modification

I suggest the following modification that pertains to observational scientonomy:

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Accept that while the ontologies of classical theories, such as those of Newtonian mechanics, classical thermodynamics, or classical electrodynamics are no longer accepted by the physics community, their phenomenological claims are still accepted as the best available descriptions of their respective observable phenomena, i.e. as the best available answers to their respective questions.

Consequently, reject the idea that these classical theories are no longer accepted but merely used.

Bibliography

Arvey, R. (Ed.) (2000). Leibniz and Clarke: Correspondence. Hackett Publishing Company.
Baggott, J. (1992). The Meaning of Quantum Theory. Oxford University Press.
Barseghyan, H. (2015). The Laws of Scientific Change. Springer.
Barseghyan, H. (2018). Redrafting the Ontology of Scientific Change. Scientonomy 2, pp. 13-38. Retrieved from https://scientojournal.com/index.php/scientonomy/article/view/31032.
Bowler, P. J. & Pickstone, J. V. (Eds.) (2009). The Cambridge History of Science. Volume 6. The Modern Biological and Earth Sciences. Cambridge University Press.
Cohen-Tannoudji, C.; Diu, B.; & Laloe, F. (1977). Quantum Mechanics. Volume 1. John Wiley and Sons.
Coiffier, J. (2011). Fundamentals of Numerical Weather Prediction. Cambridge University Press.
Cropper, W. H. (2001). Great Physicists: The Life and Times of Leading Physicists from Galileo to Hawking. Oxford University Press.
Cushing, J. T. (1994). Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony. University of Chicago Press.
Dürr, D. & Teufel, S. (2009). Bohmian Mechanics: The Physics and Mathematics of Quantum Theory. Springer.
French, A. P. & Taylor, E. F. (1978). Introduction to Quantum Physics. Norton and Company.
Haltiner, G. J. & Williams, R. T. (1980). Numerical Prediction and Dynamic Meteorology. John Wiley and Sons.
Hofheyer, T. (2014). Logic and Ontology. In Zalta, E. N. (Ed.) (2014). The Stanford Encyclopedia of Philosophy (Fall 2014 Edition). Retrieved from https://plato.stanford.edu/archives/fall2014/entries/logic-ontology/.
Holton, J. & Hakim, G. (2011). An Introduction to Dynamic Meteorology. Fifth Edition. Academic Press.
Iribarne, J. V. & Godson, W. L. (1981). Atmospheric Thermodynamics. Second Edition. Springer.
Jones S. C.; Harr, P. A.; Abraham, J.; Bosart, L. F.; Bowyer, P. J.; Evans, J. L.; Hanley, D. E.; Hanstrum, B. N.; Hart, R. E.; Lalaurette, F.; Sinclair, M. R.; Smith, R. K.; & Thorncroft, C. (2003). The Extratropical Transition of Tropical Cyclones: Forecast Challenges, Current Understanding, and Future Directions. Weather and Forecasting 18(6), pp. 1052-1092.
Markowski, P. M. & Richardson, Y. (2009). Tornadogenesis: Our Current Understanding, Forecasting Considerations, and Questions to Guide Future Research. Atmospheric Research 93, pp. 3-10.
Mathez, E. A. & Smerdon, J. E. (2018). Climate Change: The Science of Global Warming and our Energy Future. Second Edition. Columbia University Press.
Maulitz. R. M. (2009). Pathology. In Bowler & Pickstone (Eds.) (2009), pp. 367-381.
Myrvold, W. (2019). Philosophical Issues in Quantum Theory. In Zalta, E. N. (Ed.) (2019). The Stanford Encyclopedia of Philosophy (Fall 2019 Edition). Retrieved from https://plato.stanford.edu/archives/fall2019/entries/qt-issues/.

North, G. R. & Erukhimova, T. L. (2009). Atmospheric Thermodynamics. Elementary Physics and Chemistry. Cambridge University Press.

Rogers, R. R. & Yau, M. K. (1989). A Short Course in Cloud Physics. Third Edition. Butterworth-Heinemann.

Seager, R.; Kushner, Y.; Nakamura, J.; Ting, M.; & Naik, N. (2010): Northern Hemisphere Winter Snow Anomalies: ENSO, NAO, and the winter of 2009/10. Geophysical Research Letters 37, L14703.

Sebastien, Z. (2016). The Status of Normative Propositions in the Theory of Scientific Change. Scientonomy 1, pp. 1-9. Retrieved from https://www.scientojournal.com/index.php/scientonomy/article/view/26947.

Smith, D. W. (2018). Phenomenology. In Zalta, E. N. (Ed.) (2018). The Stanford Encyclopedia of Philosophy (Summer 2018 Edition). Retrieved from https://plato.stanford.edu/archives/sum2018/entries/phenomenology/.

Smolin, L. (2006). The Trouble with Physics. Penguin.

Torretti, R. (1999). The Philosophy of Physics. Cambridge University Press.

Tsonis, A. (2007). An Introduction to Atmospheric Thermodynamics. Second Edition. Cambridge University Press.

van Fraassen, B. (1980). The Scientific Image. Oxford University Press.

Warner, T.T. (2011). Numerical Weather and Climate Prediction. Cambridge University Press.