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A role for spatiotemporal scales in modeling

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A R T I C L E I N F O

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A B S T R A C T

Bogen and Woodward's distinction between data and phenomena raises the need to understand the structure of the data-to-phenomena and theory-to-phenomena inferences. I suggest that one way to study the structure of these inferences is to analyze the role of the assumptions involved in the inferences: What kind of assumptions are they? How do these assumptions contribute to the practice of identifying phenomena? In this paper, using examples from atmospheric dynamics, I develop an account of the practice of identifying the target in the data-to-phenomena and theory-to-phenomena inferences in which assumptions about spatiotemporal scales play a central role in the identification of parameters that describe the target system. I also argue that these assumptions are not only empirical but they are also idealizing and abstracting. I conclude the paper with a reflection on the role of idealizations in modeling.

1. Introduction

Among the many philosophically interesting topics related to modeling, one topic that has not received much attention is how scientists determine their target systems in the world.[1] However, two issues in the modeling literature bear on this topic. One concerns the role of idealization and abstraction in modeling, and the other concerns the relationship between theory, data and phenomena.

Early responses to the issue of idealization and abstraction relied on the notion of 'Galilean Idealization' (Laymon, 1985; McMullin, 1985), according to which an idealization is initially introduced in the model but can be subsequently dispensed with, when more detailed models are constructed.[2] Some philosophers, especially Batterman (2009), have resisted this view of idealization and have argued that idealizations are in many cases indispensable for models to provide knowledge. Weisberg (2013) suggests that there are several non-competing ways in which idealizations are epistemically useful.

In a series of papers, Bogen and Woodward have developed an influential account addressing the issue of the relationship between theory, data and phenomena (Bogen & Woodward, 1988, 1992, 2005; Woodward, 1989, 2000, 2011). Their account involves three important points. First, theory does not explain data (Bogen & Woodward, 1988, p. 305) and there are two conceptually distinct inferential processes in scientific practice, both aimed at characterizing features of the world of scientific interest: one in which explanations of phenomena are derived from theoretical principles, and one in which phenomena are inferred from data (Woodward, 2011, p. 168). Second, inferences from data to phenomena are ampliative and usually involve empirical assumptions. The inferences are ampliative insofar as they 'go beyond the data', and the assumptions are empirical in so far as they can be either true or false (Woodward, 2011, p. 173).[3] Third, pragmatic considerations of the scientist, such as her research interests and resources, can also play a role in these inferences (Woodward, 2011, p. 174).

Bogen and Woodward's account thus raises the need to understand the structure of the data-to-phenomena and theory-to-phenomena inferences (see also Woodward, 2011, p. 170). One way to study the structure of these inferences is to analyze the role of the assumptions involved in the inferences: What kind of assumptions are they? How do these assumptions contribute to the practice of identifying phenomena? In this paper, using examples from atmospheric dynamics, I develop an account of the practice of

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[1] Two exceptions are Alkistis Elliot-Graves' Ph.D. dissertation (2014), which investigates the ontological status of target systems, and Isabelle Peschard's work discussed below. I thank an anonymous reviewer drawing my attention to Peschard's work.

[2] McMullin's definition of idealization includes any simplification of something complicated (1985, p. 248), so it includes what has been more recently called idealization and abstraction (Jones, 2005).

[3] Woodward also suggests that these assumptions can be 'theoretical' when they are about factors that cannot be observed (Woodward, 2011, p. 173).

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identifying the target in the data-to-phenomena and theory-to-phenomena inferences in which assumptions about spatiotemporal scales play a central role in the identification of parameters that describe the target system. I also argue that these assumptions are not only empirical but they are also idealizing and abstracting.

The atmosphere is a particularly helpful case study for illustrating the role of scale related assumptions in the process of identifying target systems. The atmosphere is modeled as a fluid, the energy spectrum of which is 'smooth and continuous between the limits imposed by the mean free path of molecules on the short scale and the circumference of the earth on the large' (Emanuel, 1986, p. 1). Nevertheless, phenomena such as cumulus clouds, hurricanes, and weather fronts are seen to occur and recur on many different but characteristic spatiotemporal scales, somehow discretizing this continuum. The challenge is to individuate these systems at their characteristic scales and separate them from other phenomena at other scales. In order to model the dynamics of the phenomena observed, and explore the way these phenomena transfer energy across their boundaries to other smaller or larger spatiotemporal scales, scientists need to make assumptions about the extent to which these phenomena can be separated from phenomena at other scales.

The challenges involved in finding phenomena are particularly evident in the case of the so-called mesoscale:[4]

> A serious question … is whether there are really inherent scales in the atmosphere that one might reasonably use to define the mesoscale … Do there exist ordered processes in the atmosphere that generate kinetic energy on scales within Ligda's mesoscale domain (does a natural mesoscale exist), or does the "mesoscale" really consist only of a smooth, continuous, and uninteresting spectrum of disordered motions … ? (Emanuel, 1986, p.5)

The problem that the meteorologist has to face is whether one can resolve phenomena within the range of the mesoscale, i.e., whether there are stable patterns that can be characterized as phenomena. Emanuel's quote illustrates that identifying phenomena is not a trivial endeavor, since scientists need to be able to distinguish what, if at all, is a genuine signal of an ordered motion from the noise of disordered motions. There are several challenges associated with identifying a genuine signal: first of all, the observations need to occur at a particular scale. Second, the data needs to be interpreted, for example by choosing the correct tools to eliminate noise. Third, the interpretation needs to be justified—the lack of a theoretical justification can lead scientists and philosophers to discard an interpretation as purely conventional or pragmatic. Major assumptions in these processes are scale related: phenomena are assumed to occur at particular spatiotemporal scales, and the scale separation assumption states that if the scales at which variables recur are sufficiently different from one another, then they describe different phenomena. For example, the scale at which cumulus clouds occur is much smaller than the scales at which large scale phenomena, such as cyclones, occur. It is largely in virtue of this scale separation that they are considered different phenomena.[5]

I proceed as follows. In Section 2 I use Bogen and Woodward's distinction between data, phenomena and theory to describe the process of identifying target systems and I show that target system identification involves two important scale-related assumptions: the scale existence and the scale separation assumptions. I support my account with examples from the atmospheric sciences. I also explain how these assumptions are both idealizing and abstracting. Section 3 further clarifies my account by addressing three objections to my account. These are McAllister's (1997) objection concerning the arbitrariness of certain assumptions in the data-to-phenomena inference, a possible circularity in the data-to-phenomena and theory-to-phenomena inferences, and the importance of what Peschard (2012a, 2012b) calls non-empirical 'relevance judgments' in the identification of phenomena. Section 4 draws some conclusions about the nature of idealization in the context of the current philosophical debate given the discussion in Sections 2 and 3.

2. Idealizations and inferences to phenomena

In Bogen and Woodward's framework, the main difference between data and phenomena is the following. Phenomena repeat themselves under many different conditions: they have 'stable, repeatable characteristics' (1988, p. 317), and can still be recognized as such despite these different conditions. Data, on the other hand, are tainted by the idiosyncrasies of the way the data are collected (1988, p. 317). In other words, data contain both the signal of the phenomenon of interest and the noise coming from possibly irrelevant factors of the world, while phenomena themselves abstract away from these irrelevant factors. Despite the fact that phenomena are abstracted from the irrelevant details generated by the measurement process, Bogen and Woodward claim that phenomena belong 'to the natural order itself and not just to the way we talk about or conceptualize that world' (1988, p. 321).[6]

This characterization of data and phenomena lies at the core of Bogen and Woodward's claim that there are two different inferences to phenomena in scientific practice. First, theory explains phenomena and not individual pieces of data because the data contains both the signal of the phenomenon and various idiosyncrasies from measurement (Woodward, 2011, p. 166). For example, scientists can explain the quantitative value of the melting point of lead by invoking characteristics of electron bonds and the presence of "delocalized electrons" present in lead. This is what Bogen and Woodward call a systematic explanation of a phenomenon from theory (Woodward, 2011, p. 166). Second, a collection of data that measures the melting point of lead will be of statistical nature, the measurement being influenced by other factors the details of which are not typically known by the scientist (Woodward, 2011, p. 167). The theory-to-phenomena and data-to-phenomena inferences can be more or less independent of each other, especially when the

[4] The mesoscale encompasses phenomena that are larger than a cumulus cloud but smaller than hurricanes.

[5] The problem of defining a system at a particular scale and finding a suitable model for it extends to oceanography (Stommel, 1963) and ecology (Levin, 1992). For example, Levin claims that '[scale] is … the fundamental conceptual problem in ecology, if not in all science' (Levin, 1992, p. 1944). Levin understands the term 'scale' as 'identifying relevant patterns at their characteristic scales', and that modeling these patterns (for theoretical or practical purposes) involves 'abstracting and incorporating just enough detail' about the target system (Levin, 1992, p. 1944). The problem of identifying a target system is therefore tied to finding regularities occurring at various spatiotemporal scales and identifying what components describe the system's dynamics.

[6] An anonymous reviewer has raised the worry that what counts as phenomena may be interest-relative. This would imply that there is no principled distinction between phenomena and data as Bogen and Woodward envisage. To address this worry, it may be useful to distinguish between what counts as phenomena and what counts as explananda. According to Bogen and Woodward's view, phenomena are defined as regularities in the world. Of course, scientists may be interested in explaining the absence of regularities, such as the absence of a tide in a particular location. Thus, what counts as explananda may be interest relative, and not all explananda have to be phenomena in Bogen and Woodward's sense. I thank the anonymous reviewer for encouraging me to clarify this point.

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