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CHARLES S. PEIRCE ON CREATIVE METAPHOR: A CASE STUDY ON THE CONVEYOR BELT METAPHOR IN OCEANOGRAPHY *

ABSTRACT. Within Charles Sanders Peirce's semiotical theory, two different kinds of creative metaphorical reasoning in science can be identified. One of these, the building of remainder metaphors, is especially important for creating new scientific models. We show that the conveyor belt metaphor provides an excellent example for Peirce's theory. The conveyor belt metaphor has recently been invented in order to describe the oceanic transport system. The paradigm of the oceanic conveyor belt strongly influenced the geoscience community and the climate change discussion. After identifying structures of metaphorical reasoning in science (section 2), these structures are examined in section 3 for the conveyor belt metaphor in the field of oceanography. Finally, concluding remarks are given in section 4.

KEY WORDS: metaphor, creativity, heuristics, C. S. Peirce, oceanography

1. METAPHORS IN SCIENCE

Charles S. Peirce's triadic relation of signs provides a theory of metaphor with a systematic background. The most important of his statements about metaphor can be found in a covering note to the Lowell-Lectures from 1903.

Hypoicons may be roughly divided according to the mode of Firstness of which they partake. Those which partake of simple qualities, or First Firstnesses, are *images*; those which represent the relations, mainly dyadic, or so regarded, of the parts of one thing by analogous relations in their own parts, are *diagrams*; those which represent the representative character of a representamen by representing a parallelism in something else, are *metaphors*.[1]

* A more detailed description of creative metaphors in science and of the case study on the conveyor belt metaphor can be found in Brüning (1999), chapter 4–6.

[1] Peirce (1974), Collected Papers 2.277, MS 478 (MS: unpublished manuscript of C. S. Peirce on microfiche, followed by a number).

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By dividing a specific class of signs, the hypoicons,[2] according to his three basic categories, he gets: *image* for the Firstness, *diagram* for the Secondness and *metaphor* for the Thirdness. Peirce gives as an example of an image predicate the proposition "Cain murders Abel". For a diagram predicate he gives "A is like B" as a one-figure example and "A–B–. . . is like H–I–. . . " as a many-figure example. But Peirce does not clearly describe what a metaphor predicate could be. A metaphor should contain two qualities mediated by a third that is added by an interpretant. Following Christian Strub's interpretation of Peirce's text,[3] metaphor describes the two qualities as a parallelism predicate that contains two parts: The diagrammed subject and its diagram (analogous to the terminology of Black (1954) as the principal subject and its subsidiary). For instance, in the metaphor "The man is a wolf" wolf forms the diagram of the diagrammed man.

A metaphor is in most cases literally an absurd proposition. This means that it is a kind of irregularity that can be described in two ways. (I) The metaphor seems to break the rules, but in the end is only an encoding of the rules. In this case, metaphor is a shorter way to express something that can also be expressed literally. (II) The metaphor follows new rules that violate the old rules. Such a description emphasizes the irreplaceability of metaphor with literal descriptions. Black calls this class emphatical metaphors. In this case, we have something analogous but not identical to everyday speech.

For both of these descriptions, two strategies exist to interpret a metaphor as something sensible: (A) At the level of a term; or (B) at the level of a sentence.

The result is four classes of metaphor: (AI) The metaphorical term expresses another term that has a standard meaning; or (AII) The metaphorical term does not have the standard meaning but another meaning instead. The other two classes (BI) and (BII) describe metaphor at the level of a sentence, whereby a new parameter for the sentence is used to resolve the absurdity. The

[2] An icon exhibits a similarity or analogy to the subject of discourse. A portrait is an example for that kind of sign. Peirce speaks of *hypoicons* to make clear that a pure icon does not exist.

[3] Strub (1994).

connection between terms rather than the terms themselves is interpreted in a new way. The sentence is only absurd because of a normal interpretation of this connection. We then have: (BI) The absurd sentence is transformed with words such as ‘is like’ or ‘is as’ into a normal sentence. Here, metaphor is an elliptical comparison. (BII) A special metaphorical copula is introduced that contains the metaphorical aspect of the predicate. Miller (1995, p. 201) uses this strategy when he standardizes metaphor with the construction: “The term metaphor will be used as follows: x behaves as if it were a y.”

Only emphatical metaphors appear as creative metaphors in science. They cannot be replaced by literal language. Following Peirce, we prefer the ‘term strategy’ rather than the ‘sentence strategy’ for our description of metaphor in science. Thus, we have a parallelism predicate instead of a parallelism copula. Let’s take an example from science: the metaphor “The atom is a solar system.” Following the term strategy this metaphor can be interpreted as a parallelism predicate:

The atom is (an atom ∥ a solar system).[4]

The parallelism predicate contains no simple duplication of the subject because in the first position ‘atom’ works as an index, and in the parallelism predicate it describes a quality. The metaphor focuses attention not only on the similarities between the qualities of ‘atom’ and ‘solar system’, but especially on the differences. Pointing out the differences is the very core of the irreplaceability of metaphor.

There are two kinds of emphatical metaphor in science: the stock metaphor and the remainder metaphor. Stock metaphors are emphatical because they can never be replaced. In this case, metaphor is the only way to describe terms that can never be exemplified. Remainder metaphors are introduced in order to be replaced later on. They are emphatical in that in the present they cannot be replaced. Following Strub’s interpretation of Peirce’s metaphor theory, there are two possibilities in which remainder metaphors can prestructure and prepare the building of a model in science:[5]

4 ∥ : = parallel to.

5 Strub (1991, pp. 430–435).

(i) Deepening metaphor: the diagram of the parallelism predicate is less complicated than its subject. Its simpler composition helps to structure the subject by emphasizing special features of the complicated structure.
(ii) Extension metaphor: in this case the diagram is richer than its subject. It focuses on poor or unclear elements or parts of the diagrammed subject.

How can remainder metaphors work in building scientific models? A metaphor can complicate an old model M_1 in science by pointing to dissimilarities. By doing this it prepares a new model M_2. One can divide this development into three steps. First, on the basis of the old model an *emphatical metaphor* is made. With the second step of *conventionalizing the metaphor* a new model is established. This model metaphor further develops and in a third step is then *lexically proscribed*. Now the predictive quality of the metaphor has completely disappeared. All qualities of the model can be described literally without using the metaphor. The metaphor remains only as a more concise way to express literal qualities, and as a reminder of the developmental process used to achieve the new model.

2. THE CONVEYOR BELT METAPHOR

In the following section, the different aspects of metaphor that have been mentioned so far will be discussed in more detail. We shall present the results of an historical case study from contemporary geoscience in that an emphatical remainder metaphor plays an important role. This metaphor is called the *conveyer belt metaphor*. It was created by Wallace S. Broecker,[6] as part of a model describing deep sea circulation in large scale oceanography. Arnold L. Gordon used a similar model in work that was not published.[7]

[6] Broecker and Peng, 1982.

[7] Gordon (1986) used the metaphor ‘circulation cell’ instead. Broecker (1997, p. 5, internet edition) comment on the question of who is recognized as the inventor of the ‘conveyor belt’: “People now refer to it as Broecker’s conveyor belt, but I have a colleague, Arnold Gordon, who thinks it’s his conveyor belt rather than mine. It doesn’t really matter, though; we both agree that it’s an extremely important feature of Earth’s climate system.”

Before discussing three different historical steps of development of the conveyor belt model, we give a short historical introduction on deep sea circulation models.

2.1. *History of deep sea circulation models*

In 1749, Henry Ellis, captain of a British slave trader, made the first documented temperature measurements of deep ocean water in the open sea. Though his measurements were quite inexact, they made clear that the Atlantic has only a small top layer of warm surface water and the rest of the water is colder. In 1797, the Count of Rumford was the first who explained Ellis' findings and additional data. Starting with laboratory experiments, he developed an ocean circulation model that was published under the title, "The Propagation of Heat in Fluids" and was translated in several languages:

> But if the water of the ocean, which, on being deprived of a great part of its Heat by cold winds, descends to the bottom of the sea, cannot be warmed where it descends, as its specific gravity is greater than that of water at the same depth in warmer latitudes, it will immediately begin to spread on the bottom of the sea, and to flow towards the equator, and this must necessarily produce a current at the surface in an opposite direction.[8]

In 1814, Alexander v. Humboldt published a similar model in which he assumed that the ocean bottom water originated from polar regions. This model was refined by the physicist Emil von Lenz.[9] He described the first model of longitudinal circulation as consisting of two big vortexes symmetrical to the equator (cf. Figure 1).

This structure explains why subtropical surface water is warmer than tropical surface water in spite of the fact that the latter region receives more solar radiation.

Detailed measurements of the Atlantic's current structure were made by an expedition of the research vessel 'Meteor' from 1925–1927. On the basis of these data, Georg Wüst (1935) characterized water masses necessary to describe the Atlantic's currents and tracer distribution.

Wallace S. Broecker proposed a circulation model based on findings of the Meteor and other worldwide expeditions. In his

[8] Rumford (1800), quoted according to Warren (1981, p. 8).

[9] Von Lenz (1847a, b).

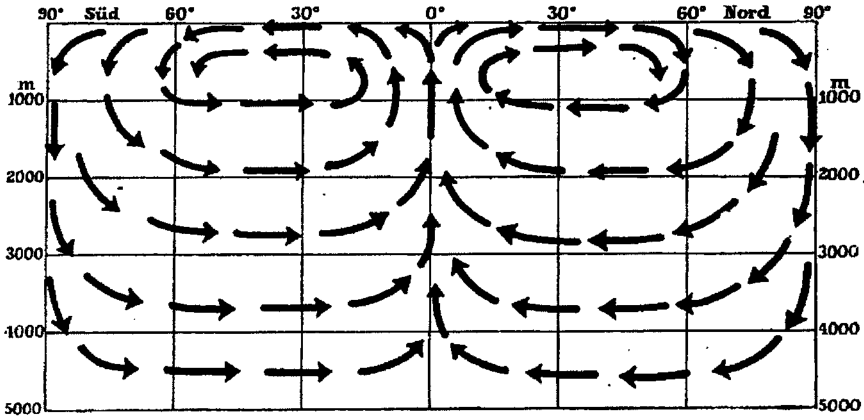

Figure 1. Atlantic circulation model according to (von Lenz, 1847a, b), figure after (Merz and Wüst, 1922)

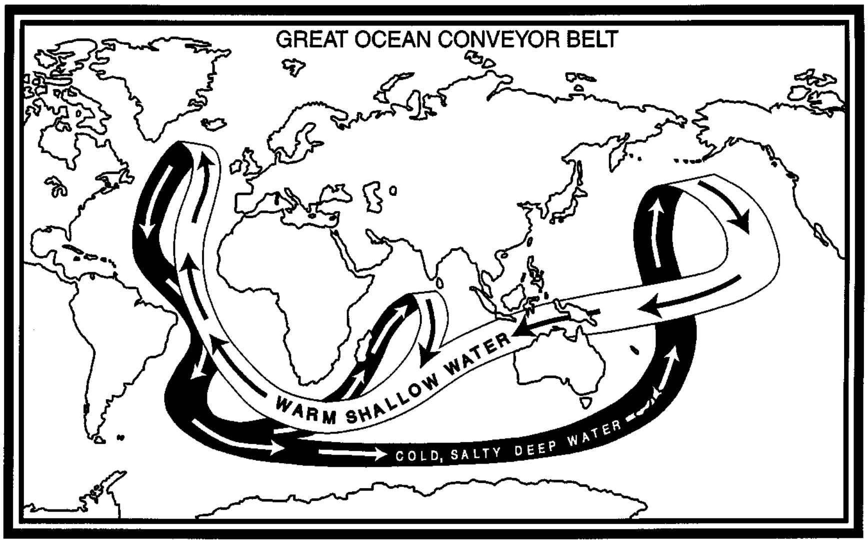

Figure 2. Broecker's great ocean conveyor logo. Warm and salty water entering the north Atlantic region is cooled. The dense water formed at the surface is convected to the deep ocean and is part of the southward return flow.

model, large scale oceanic circulation is represented by the transport system of a conveyor belt. In Broecker's model, (cf. Figure 2) the conveyor is driven by deepwater formation in the northern North Atlantic, making it the engine of conveyor belt circulation. Broecker's concept provides a successful approach for global ocean circulation.

2.2. *Three historical steps of the conveyor belt metaphor*

Now the following three historical steps of Broecker's conveyor belt metaphor are discussed:

I) conventionalized model metaphor$_1$
II) model metaphor$_1$ restored to life as emphatical remainder metaphor$_2$
III) communication of the conventionalized model metaphor$_3$

2.2.1. *Step I) conventionalized model metaphor$_1$*

In 1982, the conveyor belt appeared for the first time in a publication by Broecker and Peng. As conventionalized model metaphor$_1$, the conveyor belt is part of an allegory that was made to explain the distribution of nutrients in the sea.

> The exhibits in a fun house are located on two levels. The upper floor has a large conveyor belt that moves from right to left; the lower floor, a belt that moves from left to right. Those who enter are free to observe the horrors in any order they wish. There are innumerable escalators from the lower to the upper level. However, there is only one escalator from the upper to the lower level, located at the end of the upper belt. Those who venture to the upper level are harassed by monsters lurking in dark alcoves. These monsters grab the unsuspecting visitors and, after a suitable frightening, drop them through holes to the lower level. The average fun-seeker has to ride to the upper level many times to view all its mysteries before leaving the fun house.[10]

This text can be classified as an allegory in a pedagogical context because later on it is explicitly explained that "the fun-seeker is the limiting nutrient and the monster is the plant. The belts and escalators represent the organized flow of water, and the wandering of the people is the turbulent mixing superimposed on this organized flow."[11] The text contains a whole field of different metaphors, but only the conveyor belt metaphor has further importance later on.

Following Peirce, the metaphor "the ocean is a conveyor belt" can be interpreted as a parallelism predicate that contains two incompatible meanings:

The ocean is (an ocean ‖ a conveyor belt).

[10] Broecker and Peng, 1982, p. 35.
[11] Ibid.

For the interpretation of this metaphor, first the qualities of both predicates (Max Black speaks of ‘associated commonplaces’) are developed separately. The meaningful structures are set in relation to each other. The conveyor belt structure is the diagram of the ocean current structure. For the interpretation of the metaphor the differences rather than the similarities between the structure of the diagram and the diagrammed subject are important. One difference is, for example, the current’s quality “to consist of water” and the conveyor’s quality “that it is used to manufacture technical mass products”. Together with similarities like “has a closed circulation” or “is used as a transport system”, differences are always activated. They warn of unjustified similarities. Furthermore, ‘conveyor belt’ works as a deepening metaphor. It has a simpler structure than ‘current’ and makes the complicated pattern of ocean currents more understandable. Therefore, it is important for the use of the metaphor in the pedagogical context of the allegory as found in (Broecker and Peng, 1982). However, two years later it became important as a research guiding tool. That leads us to:

2.2.2. *Step II) model metaphor$_1$ restored to life as emphatical remainder metaphor$_2$*

In 1984, Broecker succeeded in including North Atlantic deep water production in the global climate context. In doing this, he inspired a new field of research. The starting point came from the results of experiments in Greenland that he could connect to his work on ocean currents. Broecker explained the circumstances under which he realized the importance of deep water production: “In 1984 after listening to a lecture by Hans Oeschger in Bern, Switzerland, he pointed out that Greenland’s core records suggested millennial duration oscillations between two states of climate.”[12]

Oeschger had measured the CO_2 content of air, a signal preserved in the Greenland glaciers that indicated CO_2 fluctuations throughout the paleo record. With the differences in ice levels, it was possible to identify oscillations between two global climatic states. However, an explanation for these two different states was not clear. “A few days

[12] Broecker (1997, personal communication), also cf. Broecker (1997, p. 5., Internet Edition).

later it popped into my head that these two states could be North Atlantic Deep Water production 'on' and 'off'."[13]

For Broecker's findings, it was necessary to a) identify the relevance of North Atlantic deep water production and b) realize the possibility of two different ocean current states and their association with two different climatic states.

a) To establish the relevance of North Atlantic deep water production Broecker emphasized the importance of the conveyor belt. In the industrial world, the introduction of the conveyor belt in factories greatly increased productivity and had a major impact on economic development. In a similar way, Broecker realized the importance of the conveyor belt in deep water production. "Its flow is equal to that of 100 Amazon Rivers and is similar in magnitude to all the planet's rainfall. This came out of a knowledge of the strength of this conveyor flow based on C^{14} measurements I made as part of my thesis research."[14]

For getting his second idea, two different research interests were necessary to combine as Broecker (1997) described:

I had known about this because my career has had a dual aspect. One part of it involved a study of the ocean's deep circulation by means of radiocarbon and other tracers. The focus was to try to understand how rapidly fossil-fuel CO_2 would be absorbed into the ocean. The other aspect involved studies of paleoclimate. I was captivated by the observation that each of the major 100,000-yr-duration glacial cycles that have hounded us during the past million years came to a catastrophic close. So in 1984, I realized that I could merge these two studies and ask the question, 'What would happen if this major current were to be shut off or turned down?'[15]

b) The possibility of two different ocean current states had to be realized and identified with the different climatic states obtained from the ice core records. All climate models with which Broecker was acquainted at that time were only concerned with present day ocean circulation.[16] Nevertheless, Broecker had the idea that a different mode without deepwater production was possible. The 'on' and 'off' states of deepwater production were

13 Broecker (1997, p. 5, Internet Edition).
14 Ibid.
15 Broecker (1997, p. 6, Internet Edition).
16 Broecker (1998, personal communication).

activated by the conveyor belt's 'on' and 'off' operation modes. While working out his concept, Broecker recognized the possibility of a third mode of operation corresponding to the direction of deep water flow during the Ice Age which was probably different from that of today. And indeed, numerical modeling studies (Bryan, 1986; Manabe and Stouffer, 1988) confirm this idea of multiple equilibria in oceanic circulation.

The finding of the connection between states of deep water production and global climate is an example for the creative potential of metaphor by pointing to differences rather than similarities.

Let us now turn to the restoration of model metaphor$_1$ as emphatical remainder metaphor$_2$. After 1982, the conventionalized model metaphor$_1$ was no longer emphatical. That is, the differences between an ocean current and a conveyor belt would no longer be well shown with this metaphor. Consequently, the conveyer belt's quality of having different states became irrelevant under the model's standard interpretation. Thus, model metaphor$_1$ no longer focused on that difference.

In 1984, the metaphor reappeared as emphatical remainder metaphor$_2$ and the quality of having different states was vitalized. This became a key to the interpretation of climate records from glacial times.

This example makes clear that besides the normal development of a metaphor from an emphatical to a lexical metaphor via a conventionalized model metaphor, a reverse step is also possible.

While refining his concept, Broecker realized that others would consider the possibility that different modes of circulation existed and could have an impact on global climate. As early as 1906, T.C. Chamberlin published these ideas in an article with the title "On a Possible Reversal of Deep-Sea Circulation and its Influence on Geologic Climates". He was the first to systematically connect oscillating climate states with different modes of currents.

The climatic student seems therefore compelled to face oscillations within the known geologic periods, ranging from sub-tropical congeniality within the polar circles, on the one hand, to glacial conditions in low latitudes, on the other, and these *in alternating succession*; while neither of these oscillations was permitted to swing across the narrow limital lines of organic endurance. There is little doubt that the ocean, the daughter of the atmosphere, is one of the most potential agencies in controlling these oscillations. It is one of its possible functions in such regulation that invites our present attention.[17]

Chamberlin's central idea was the possibility of a reverse current operation mode. He realized that the agencies that influenced the deep-sea movements in opposite phases were nearly balanced.

From this sprang the suggestion that, if their relative values were changed to the extent implied by geological evidence, there might be a reversal of the direction of the deep-sea circulation, and that this might throw light on some of the strange climatic phenomena of the past and give us a new means of forecasting climatic states in the future.[18]

Independently from Chamberlin, Stommel (1961) developed a model from a theoretical point of view that indicated that the ocean must have different modes of operation, but he did not connect this idea with climate records. This connection was realized by Rooth (1982) in a similar model, without knowing the ideas of Chamberlin and Stommel.

The fact that none of these authors used the conveyor belt metaphor (Stommel's model does not rest on any metaphor at all) indicates that neither a special metaphor nor metaphorical reasoning in general was necessary to discover the connections.

However, it is interesting that Chamberlin also used a metaphor for describing the importance of the ocean current: "the ocean, the daughter of the atmosphere". An investigation of this metaphor cannot be done in this paper, but such an approach is valuable, because in the first decades of this century oceanography was strongly influenced by the field of meteorology.

2.2.3. *Step III) communication of the conventionalized model metaphor$_3$*

It is striking that after 1982 the conveyor belt metaphor was not mentioned again in the literature until 1987. Although the conveyor belt metaphor played an outstanding role in Broecker's findings, the metaphor is not mentioned in any of his publications from 1984 and 1985. A reason for that could be the emphatical structure of the metaphor. This irreplaceability goes hand in hand with the creative potential of the metaphor, but also with its typical

17 Chamberlin (1906, p. 366).

18 Ibid., pp. 367–368.

resistance and scandalous nature. As long as the metaphor is emphatic, its absurdity is still recognized and the objection is always included: "The ocean current is obviously not a conveyor belt!" With the progress of conventionalizing, model metaphor$_3$ is less and less scandalous. Consequently, the conveyor belt metaphor appears again in Broecker's publications after 1987. With lexical proscription the metaphor completely loses its resistance. An example for such a metaphor is the electron cloud in physics. The conveyor belt metaphor has not yet reached this stage, and speaking of a final stage would not be appropriate as every lexicalized metaphor can be revitalized at any time.

Broecker's publication in 1987 gives a detailed description of his developed model$_2$. This time the conveyor belt metaphor has the function of presenting his model to a wider circle of readers outside the geoscience community. Included is a large logo of the conveyor's structure covering two pages (cf. Figure 2). In this form, Broecker's model became much better known, and was partly used as the logo of the organization "Global Change Research Initiative".

Readers without a background knowledge of oceanography may have problems understanding Broecker's metaphor. Laypeople may transfer qualities of the conveyor belt to this model that experts know to be inappropriate. Broecker (1991, p. 79) mentions about his logo, "that it implies that if one were to inject a tracer substance into one of the conveyor's segments it would travel around the loop as a neat package eventually returning to its starting point." Because of complicated mixing processes this does not happen.

Following Peirce, building a metaphor is a process of communication. Important is the knowledge shared by author and interpreter. Besides simple misunderstanding that can disturb the communication, something like a creative misunderstanding can also happen. An example for that is again Broecker's 1987 text. Broecker (1991, p. 88) writes about his communication with the editor of this publication:

> the editor put a sales 'stimulator' on the cover that stated 'Europe beware: the big chill may be coming.' At the time I was much annoyed because no mention of the conveyor's future was made in the article. To make matters worse, even after reading the article itself, many people were left with the impression that I was warning of an imminent conveyor shutdown. The fact is that I thought, at that time, that the coming greenhouse warming would, if anything, strengthen the

conveyor by increasing the rate of vapor loss from the Atlantic basin. I had not given serious thought to the question as to whether any changes associated with human's (sic) activities might threaten the conveyor.

The editor and some readers connect Broecker's model with the future of global climate. In this case, the model metaphor contains more than the author had intended originally. The final interpretation appears to be creative and invites Broecker to check its relevance. Broecker changed his mind and ten years later wrote that the transfer the editor had done the first time was a natural extension of the model: "The question *naturally* arises as to whether this finding about past climates has any implications for the future. I think it does."[19]

The connection with the future became apparent with fruitful consequences. It was followed by an intensive scientific discussion about the stability of today's and future deepwater production.[20]

3. CONCLUDING REMARKS

We have explored the very different ways in which metaphor can work within science. We think that it is necessary to differentiate between distinct kinds of metaphor to analyze their role in model and theory development. In Peirce's model of emphatical metaphor, the *differences* between subject and diagram of the metaphor are at least as important as the similarities. For the conveyor belt metaphor in the field of oceanography, we show that the emphatical remainder metaphor provides a fundamental tool to develop scientific models. The creative potential of the remainder metaphor is especially helpful in the first stage of theory when other heuristic tools are not available. Therefore, we think that the application of remainder metaphors to other case studies in science would be a useful asset in furthering investigations.

[19] Broecker (1997, p. 8, Internet Edition), italics added by the authors.
[20] see, e.g. Rahmstorf (1999).

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