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Earth System
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Discussions

Interactive comment on "Technology and human purpose: the problem of solids transport on the earth's surface" *by* P. K. Haff

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Page references are to referee's report.

1. pC304 top: "an introductory section is missing that clearly states the mission and organizational structure of the ms."

Response: An introductory section has been added.

2. p304 top: "...displaying equations with inconsistent units is out of question for any academic article ('1000h'). I guess the author has some 'natural units' in mind allowing for the choice displayed in the ms, but for an interdisciplinary audience as the one of ESD, these assumptions should be expressed in a much more transparent way."

Response: I have attempted to use units that will help clarify to the reader the content of the argument. Mostly these are consistent SI units. In a few places I have opted for other units to contextualize the result in terms of processes or events with which the reader is likely familiar. In the example from the ms highlighted above by the referee, the ratio of times, 100/0.1=1000 is indicated, which is the fundamental point, and is unit-free. This happens to work out to 1000 hours when expressed in units for the particular exampe, which I believe for most readers conveys the message about transport times more clearly than using , which the reader will in any case likely translate back into the units normally used when one person tries to explain to another how long his automobile trip took. So I hope to be excused in the particular usage on this point, but agree with the referee as a general principle re the use of SI units.

3. p304: "... is the whole formal scale argument that necessary in the end? It should either be condensed in some way or even left out – or be elaborated on in a formally crisper way, as indicated above?

Response: The appearance of advective-like transport, as in highway or rail transport, is a critical step in the emergence of modern technology, as indicated in the text, representing a decisive point of evolution in earth dynamics away from, or rather in addition to, mostly localized multi-directional diffusion-like transport of animal sized or smaller mass and energy packets by pre-technology humans. Use of basic scale arguments is the principle tool used to distinguish regimes in which disparate processes, such as diffusion and advection, operate. It is not a question of a "formal scale argument", but of taking the first and most natural step in sorting out a complicated problem. I have added a comment in the section on advection to reinforce this point.

4. p304: "Hereby I am either requesting a formal model, or somewhat clearer references to al-ready established models such as motion along the Manhattan metric or Brownian motion."

Response: The present paper attempts to sketch out some of the novel properties of

technological transport, as developed in the various numbered sections, and to indicate reasons why the increase of distance scales from localized to regional and global values required these innovations (innovations such as power-off memory of transported mass). At some stage in the development of these ideas there may be utility for formal models like those based on taxicab geometry. For the exploratory themes of this paper, I believe it is far better to appeal to the basic dichotomy of diffusion(-like) and advection(-like) behavior, a relationship that is necessary and sufficient to illustrate matching of mass and energy supply to a densely populated region with the more straight-line transport of major highways, railways, etc. A freeway cannot as a rule provide direct delivery of food or any other product to a residence. This is the basic organizing structural dichotomy shown by most, and probably all, complex systems that have to deal with the transport and disposition of large fluxes of mass and energy (large compared to the budget of the end member users of these resources) to much smaller scale end-users of these resources. Thus mammals advect oxygen and nutrients in blood carried through the arteries, with the flows becoming increasingly subdivided for delivery by diffusion-like motion of red corpuscles in capillaries as these materials are finally delivered to individual cells. Similarly, in a channel-flow of turbulent fluid, momentum and energy are advected toward the wall by large eddies in the flow, but must be handed off to smaller and smaller eddies whose behavior is treated as an effective (eddy) diffusion process and eventually to molecular diffusion. The Reynolds number is an explicit measure of this dichotomy. Analogs of the Reynolds (or Peclet) number will exist in all such systems, including technological systems. Of course, if eventually one wants to account in more detail for flow patterns and to compute the actual rates of flow and absorption, then a formal model becomes a necessity. In the Introduction section I have added remarks to the text to clarify the use of the term “diffusion” and to indicate that more detailed models may eventually be appropriate.

5. p304: ” Second, the author leaves open to what extent the list that is given indicating in what sense anthropogenically induced transport of solids would differ from natural pro-cesses, is complete – and whether any claim of completeness is made at all..”

Response: No, I do not claim that the list is complete. There is no way to determine or assure completeness. Assuring completeness is not a mathematical or physical possibility because the behaviors are emergent. The processes discussed are some obviously important ones, but there may be others.

6. p304: ” Third, the ms should make minimum attempts to link the arguments given to achieve-ments made in related ïňĄelds: e.g., for the scale argument, one should refer to network modeling approaches as a network seems to be the natural model for the human-induced transport system, rather than the dichotomy of advective vs. diffusive pro-cesses.”

Response: This point was addressed above.

7. p304: ” Please also test to what extent a reference to hybrid processes between ad-vective and diffusive processes might be in order.”

Response: Any simple model advanced to clarify basic behavior of a system always complexifies when looked at more closely. This is true of the advection-diffusion parsingâĂŤfor example Levy flights might play a role in transportâĂŤand of network modelsâĂŤwhere diffusion-like processes may persist even for a fine network scale. But I think the referee makes a point, and I have put in a reference to Levy flights and to cellular automata models.

8. p304: “Also, most branches of macroeco-nomics are dealing with large-scale effects of ‘purposeful planning’. Not mentioning the effects of intertemporal welfare maximization through infrastructure planning and subsequent trade as key ingredients of macroeconomic thinking, makes the ms appear somewhat idiosyncratic.”

Response: YesâĂŤagreed that macroeconomics is concerned with large scale purpose, and that the present ms may be idiosyncratic, the latter condition not necessarily being a demerit, however. Actually, both macro and micro economics deal with purpose, although at different scales. The macro-micro dichotomy in economics in some

ways reflects the advective-diffusive dichotomy of physical metabolizing systems. No doubt for example one could identify the state of the economy in a gross way by a suitable dimensionless number in analogy to the Reynolds number in fluids. One issue for the present paper is that economics, macro or micro, does not effectively account for the fact that economics itself is not a free floating invention of humans, but a product along with humans of earth dynamics. The relation is partly recognized through treatment in economics of externalities such as natural capital for example, but the relationship is backwards, that aspects of the "external" world are not just add-ons to economics, but economics is an add-on to the natural world. The present paper treats a small part of this larger issue, but I agree with the referee that it would be of value to sketch out a little further. I have added some commentary along these lines in the summary section together with references to a couple of recent papers.

9. pp304-305: "In my view, macroeconomics can be interpreted as one – in fact already very elaborate – approach to derive the 'additional dynamical laws' the author is asking for."

Response: Agreed (re # 8 response above), but only up to a point. Again, the problem is that economics does recognize that it is not a discipline independent of earth processes, but is a consequence of those processes. Again, some commentary along these lines added to text.

10. p305: "1. p419,l20: 'long-distance', 'high-volume' are ill-posed terms, as long as the scales of reference have not been introduced. Just give the numbers and explain in what sense they are long/high."

Response: Yes, good suggestion. Scale definitions appeared only later in the paper. Definition of scale descriptors has now been added to Introduction section.

11. p305: "2. p420, §1: When talking about 'diffusion', the audience would expect a nsqrt{n Delta t} scaling of distance. Hence the derivation of 1000h from a scale free (!) Brownian process appears disturbing to the reader. Or does the author work within

a Manhattan-metric picture in combination with a low average velocity, stemming from the need to stop and accelerate very often? Then one should not call this 'diffusion'."

Response: Yes the diffusive signal spreads out like sqrt(t)âĂŤthis is the reason that modern technology cannot run on a purely diffusive transport mechanism. A process can be scale free, but the realization of the process is not scale freeâĂŤfor example here it takes a definite amount of time to diffuse a signal a given distance. The ratio of that time to the advective time (1h) is 1000 in the example given.

12. p305: " And why should 'mass action' (§2) be an interesting property at all? On the one hand the ms tries to look at human processes with concepts stemming from Earth system analysis – but I have not seen 'mass action' in that context yet (but I might have missed it)."

Response: The concept of mass action has appeared in the literature and weights the unit of mass moved by its velocity and distance moved (between changes in direction). It is the simplest metric of mass movement that respects the dynamics (which depends on mass, distance, and time). A discussion of mass action is given in (Haff, 2010).

13. p305: " 'Action' is introduced in physics mainly for periodic processes, being a quantity that is adiabatically stable and is hence the ideal candidate for quantization. In contrast to that, Earth system analysis mainly deals with much more elementary items such as total mass transports / ïňĆuxes etc."

Response: Action first appeared in physics as a classical quantity, only later adapted as a road to quantization. Its classical use is not restricted to periodic motions. Actually it is the quantum that is elementary, not the quantities that characterize earth system dynamics. Mass action has the same dimensions as the familiar action, hence its name, but because it is applied as a metric to mass movement in nonconservative systems, it does not determine the actual trajectory of motion. It is only a useful measure or way of comparing mass transport in diverse systems.

14. p305: “3. p420, l12: ‘km’: units are to be expressed not in n italic, but in nroman – similar effects appear eg for ‘W’.”

Response: Fixed.

15. p305: “4. section 5, §1: I do not understand the ‘two kinds of forces’: in a laminar ïňĆow, I need only 1 parameter for friction, eg the viscosity parameter. At larger scales, of course, turbulence may appear that could introduce further characteristic scales (Eddies in ocean dynamics).”

Response: The forces mentioned are external forces (two modes of friction with the bed), of which there could be any number. Viscosity scales “internal” friction in the flow. Otherwise agree with referee’s comments on laminar vs turbulent flows.

16. p305: “5. Sections 8,9 should be placed in front of the ‘purpose’ section.”

Response: Agreed, done.

17. p305.” 6. The summary should be written in more precise terms along the lines indicated above.”

Response: Summary has been updated in line with above responses.

Interactive comment on Earth Syst. Dynam. Discuss., 3, 417, 2012.