651-2124-00:

Atmospheric General Circulation Dynamics (HW 5, due May 30):

Norman Phillips' 1956 paper "The general circulation of the atmosphere: a numerical experiment" marks the beginning of numerical weather prediction, numerical general circulation and climate studies, and, arguably, the beginning of computational science more broadly. (The paper is available at the course website.) Please read the paper (you can skim technical details) and reflect upon the following questions:

1. Section 2 of the paper begins "by listing some of the most striking features of the atmosphere, calling for explanation." Reflect to what degree Phillips' own paper, as well as the almost 60 years of atmospheric science research since then, have provided "explanations" of these features. (We have not covered all of the features in class yet; you can use search engines or ask your instructors for the state of today's science regarding these features.)

2. In which respects is Phillips' general circulation model (GCM) similar to today's GCMs, i.e., which fundamental physical processes does it take into account? What are some of the principal differences to GCMs today, i.e., which fundamental processes are included in today's GCMs that were neglected or simplified in Phillips'? (Please focus only on physical aspects of models and only on the atmosphere, i.e., disregard biological and chemical processes, oceans, etc.)

3. What energy transformations are taken into account in Phillips' model, and how does energy flow through the model? (A qualitative description suffices. Equations are optional.)

4. Phillips reports a strengthening of meridional temperature gradients and the formation of a sharp jet in midlatitudes. How does that arise?

5. Phillips' GCM did not reach a statistically steady state. Why not?

6. Phillips' paper concludes with stating

   > Progress in the past in developing an adequate theory of the general circulation has had as its main obstacle the difficulty of solving the non-linear hydrodynamical equations. Highspeed

> computing machines have to some extent eliminated this problem, and further progress in understanding the large-scale behaviour of the atmosphere should come to depend more and more on a fuller understanding of the physical processes mentioned above.

In light of the past decades, has Phillips' vision come to fruition, that the obstacles posed by the non-linear equations of fluid dynamics have largely been eliminated in our quest toward a theory of the general circulation and climate?

7. The two-layer model is a simple conceptual model of how baroclinic instability arises. It has the feature that baroclinic instability only arises for sufficiently long waves. Why, in physical terms, does this shortwave cutoff for baroclinic instability arise, and how long do waves have to be so they can be baroclinically unstable?