NITROGEN, AN EQUIVOCATOR TO CLIMATE C. Goldblatt[1], M. Dewey[1] and B. W. Johnson[1]
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Motivation: In Macbeth [Act II, scene III], a Porter speaks to Macduff on the effects of alcohol:

"...Lechery, sir, it provokes, and unprovokes;
it provokes the desire, but it takes
away the performance: therefore, much drink
may be said to be an equivocator with lechery:
it makes him, and it mars him; it sets
him on, and it takes him off; it persuades him,
and disheartens him; makes him stand to, and
not stand to;..."

The effect of the atmospheric di-nitrogen inventory on planetary climate is equally equivocal. Depending on the conditions, it may either cause a warming effect by pressure broadening of the absorption lines of greenhouse gases or cause a cooling effect by giving increased Rayleigh (molecular) scattering of incoming sunlight.

It is now quite well established that the atmosphere is neither the largest, nor the oldest, of Earth's nitrogen reservoirs and that there has been substantive cycling of N between atmosphere and solid Earth [1, 2]. Likewise, there is no possible justification to assume a 1 bar atmosphere: the varying effects of N_2 inventory need to be be part of our conceptualization of habitable planet climate.

Furthermore, there is rich redox and biosphere sensitive behavior of nitrogen species. Ammonia one of the very best greenhouse gases for a wet planet, absorbing strongly in the 10 micron water vapour window, so was the original proposal to resolve the Faint Young Sun Paradox. However, it is unlikely to be long lived given that is it very soluble and is photochemically unstable. Nitrous oxide is also a potent greenhouse gas, roughly equivalent at equal concentrations to carbon dioxide [3]. It is a biological product, resulting from incomplete denitrification (and hand-waving arguments suggest this should be higher in the past).

New results that we will show: First, have carried out new radiative forcing calculations for varying di-nitrogen inventory, with different greenhouse concentrations. For example, with 400ppmv CO_2, increasing di-nitrogen warms up to around 2 bar N_2, but is a net cooling thereafter. With 40,000ppmv CO_2, increasing di-nitrogen warms up to around 5 bar N_2, but is a net cooling thereafter. These results would largely generalize to other greenhouse gases; the stronger a greenhouse atmosphere, the higher N_2 pressure the transition from warming to cooling will be.

Second, the nitrogen inventory determines where the transition to a runaway greenhouse or snowball Earth should occur. The physics is just the same as above. We have calculations of where these runaway feedbacks (which set the boundary of the habitable zone) will vary with di-nitrogen inventory. No nitrogen, and habitability will be really difficult to find.

Third, we will present a mechanism whereby changes to climate or ocean chemistry can give transient warming via ammonia outgassing from the ocean. Our best understanding of Early Earth ocean chemistry calls for a somewhat substantive dissolved pool of ammonium. Changes to pH and temperature of the surface ocean would alter the equilibrium from ammonium to ammonia, causing ocean to atmosphere transfer. An ammonia mixing ratio of 0.1ppmv will give a radiative forcing of a few Wm^{-2} (depending on background pressure) whereas 1ppmv would give 5 to 15 Wm^{-2} radiative forcing [3]. Thus, whether transient warming from ammonia will be effective depends on the balance between ocean outgassing rate and photochemical destruction.

Fourth, we'd really like to figure out more about N_2O. There is the chance that something on that will sneak in at the last minute. Or in

References: [1] Goldblatt et al. (2009) *Nat. Geosci., 2,* 891-896. [2] Johnson and Goldblatt (2015) *Earth. Sci. Rev., 148,* 150-173. [3] Byrne and Goldblatt (2014) *Clim. Past, 10,* 1779–1801.