SOME POSSIBLE CONSEQUENCES OF MENVRA IMPACT ON TITAN. K. Zahnle[1], D. Korycansky[2] [1]NASA Ames Research Center (kzahnle@mail.arc.nasa.gov), [2]University California Santa Cruz.

Introduction: Menvra is a ~450 km diameter impact basin on Titan. Conventional crater scaling suggests that the basin was created by a ~50 km diameter comet striking at ~11 km/s. The energy released by the impact would have been on the order of 4e31 ergs, an estimate that is uncertain to at least a factor of 3.

This is a considerable amount of energy. To put 4e31 ergs into perspective, if all of this energy were invested in heating Titan's current atmosphere, the atmosphere would be heated to 400 K. Of course this is not what happens. Only a fraction of the impact energy heats the atmosphere on the time scale of interest (although ultimately all of the impact energy does indeed heat the atmosphere, because the energy is radiated away by the atmosphere). Nevertheless we should expect the atmosphere to be heated considerably, and we should expect also that considerable amounts of energy are invested in melting and evaporating surface volatiles.

A simple energy balance: Most of the energy of the impact is initially invested in the materials close to where the comet struck, and in the materials of the comet itself. These materials are heated, melted, evaporated, and they also acquire significant kinetic energy, such that the bulk of the most strongly heated materials are ejected from the crater. A significant fraction of this energy is quickly shared with the atmosphere, through drag during ejection and then later, globally, when the ejecta re-enter the atmosphere. Because the total mass of Menvra ejecta would have been about a tenth that of the atmosphere as a whole, we suggest that the atmosphere has the right scale to take up much of the energy initially in the impact ejecta.

For specificity, we will consider three cases. As an enthusiastic upper bound on Menvra's effect (Fig 1), we assume that an energy equalt to the nominal impact energy is deposited either in the atmosphere or near enough to the surface that it can take part in events that take place over months to a thousand years, and therefore available to modify the climate. As an intermediate case, we assume that 50% of the nominal impact energy is available for climatic purposes (Fig 2). As a lower bound we assume that only 20% of the impact energy is available. These assumptions implicitly takes into account the uncertainty in the impact energy itself. In all cases the balance of the impact energy is presumed to be either deeply buried and therefore inaccessible on such short time scales, or lost at the time of the impact itself, either by ejection directly into space (far enough from Titan's orbit that it doesn't get quickly swept up by Titan), or by prompt thermal radiation to space at the time the ejecta re-enter.

We then track the time evolution of the climatically available fraction of the impact energy. We consider the following reservoirs: heating the atmosphere; heating a water ice crust by thermal conduction; melting water; evaporating water; and evaporating liquid methane that is presumed to be either in the crust or in open lakes. For simplicity we assume an isothermal N2 (1.4 bars) and CH4 atmosphere at the same temperature as the surface, thermal conductivity and heat capacity of water ice at 273 K, and that the crust contains 5% CH4 that is immediately vented to the atmosphere when the local temperature of the ice becomes high enough for CH4 to evaporate. For the lower bound we also assumed the presence of CH4 lakes or seas covering 3% of the surface to a depth of 50 m. The climatically available energy is initially placed in the atmosphere.

The atmosphere is assumed initially to contain 8% CH4, which evolves upwards at first as CH4 is evaporated from the crust, and then evolves back down according the saturated vapor pressue as the atmosphere and surface cool as the CH4 drizzles out. Latent heats of water and methane condensation and water freezing are accounted for during cooling phase as well as during the initial heating phase. Cooling of the system as a whole is accounted for by assuming that the atmosphere radiates as a black body at the isothermal temperature. Insolation is crudely taken into account by assuming that insolation provides black-body heating at 94 K, so that the cooling histories asymptotically decay to the current surface temperature of 94 K.

The enthusiastic upper bound (Fig 1): In this case 4e31 ergs are initially deposited in an isothermal atmosphere, which briefly raises the surface temperature to 45 C. Quite a lot of water ice melts or evaporates, such that at the peak of the event we expect a global average of 40 m of liquid water, much of which is rainfall. The liquid water event lasts about 1 year. The thermal conduction wave continues to propagate into the crust and release methane, so that methane is steamed out of the crust for about 30 years, and builds up in the atmosphere to a partial pressure greater than 0.4 bars. This excess methane then rains out of the atmosphere over hundreds of years as the planet continues cooling.

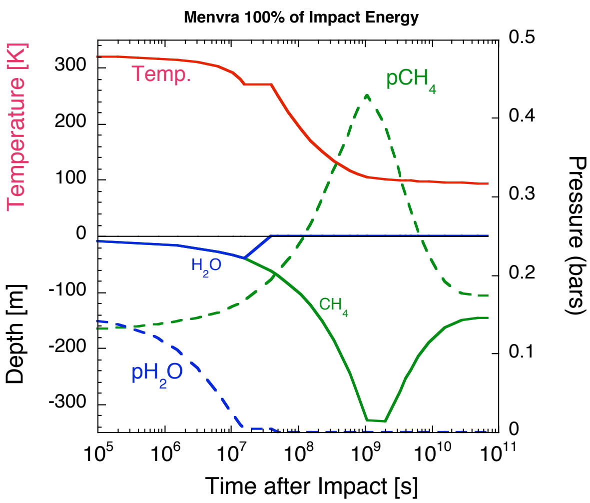

Figure 1. Enthusiastic upper bound, in which an energy equal to the nominal Menvra impact energy is put in the atmosphere. Plotted are the surface temperature (red solid curve), the global average depth of liquid water (blue solid curve), the depth to which thermal conduction has penetrated to a degree that crustal methane can evaporate (solid green curve), the partial pressure of water vapor (blue dashed curve), and the partial pressure of methane vapor (green dashed curve).

The intermediate case (Fig 2): In this case 2e31 ergs are initially deposited in an isothermal atmosphere, which briefly raises the surface temperature to 5 C, just barely passing the melting point of water. Nevertheless there is a considerable melting event, equivalent to a global average of 6 m of liquid water at peak. The liquid water event lasts about two weeks. The water event is therefore very sensitive to the size of the impact. By contrast the effect of the thermal conduction wave on methane is quite similar to the enthusiastic case. Again, methane is steamed out of the crust for about 30 years and builds up to ~0.4 bars, which later drizzles out of the atmosphere over hundreds of years as the planet cools.

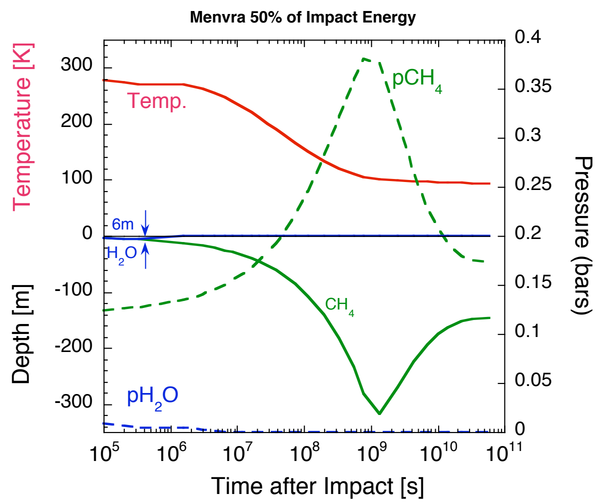

Figure 2. Intermediate case. Notation is the same as in Fig 1.

The lower bounds (Fig 3): In this case 8e30 ergs are initially deposited in an isothermal atmosphere. This is much colder. The peak surface temperature is -100 C, just barely reaching the water-ammonia eutectic. On the other hand, the effect of the thermal conduction wave on methane is again similar to the other cases. Methane is steamed out of the crust for about 20 years and builds up to ~0.3 bars, then drizzles out over hundreds of years.

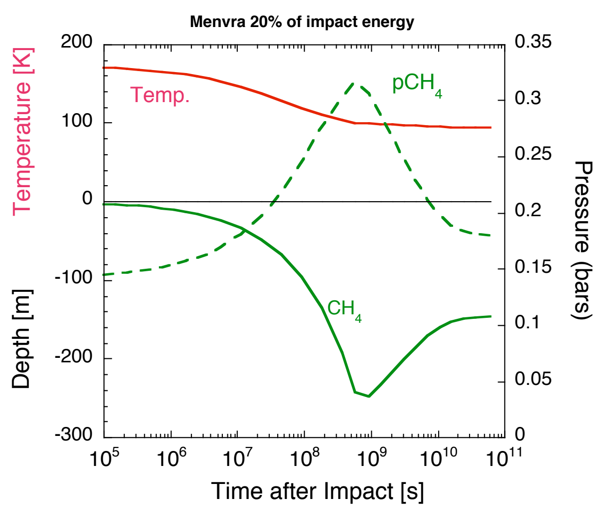

Figure 3. Lower bound. Notation is the same as in Fig 1. This case is much colder, with little global melting of water, but considerable release and rainout of methane.