BIG IMPACTS AND TRANSIENT OCEANS ON TITAN. K. J. Zahnle1 D. G. Korycansky2 and C. A. Nixon3,
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Introduction: We have studied the thermal consequences of very big impacts on Titan [1]. Titan’s thick
atmosphere and volatile-rich surface cause it to respond to big impacts in a somewhat Earth-like manner.
Here we construct a simple globally-averaged model that tracks the flow of energy through the environment
in the weeks, years, and millenia after a big comet strikes Titan. The model Titan is endowed with 1.4
bars of N2 and 0.07 bars of CH4, methane lakes, a water ice crust, and enough methane underground to
saturate the regolith to the surface.

We assume that half of the impact energy is immediately available to the atmosphere and surface while the
other half is buried at the site of the crater and is unavailable on time scales of interest. The atmosphere
and surface are treated as isothermal. We make the simplifying assumptions that the crust is everywhere as
methane saturated as it was at the Huygens landing site, that the concentration of methane in the regolith is
the same as it is at the surface, and that the crust is made of water ice. Heat flow into and out of the crust
is approximated by step-functions. If the impact is great enough, ice melts. The meltwater oceans cool to
the atmosphere conductively through an ice lid while at the base melting their way into the interior, driven
down in part through Rayleigh-Taylor instabilities between the dense water and the warm ice. Topography,
CO2, and hydrocarbons other than methane are ignored. Methane and ethane clathrate hydrates are dis-

cussed quantitatively but not fully incorporated into the model.

We find that a nominal Menrva impact would have been big enough to raise the surface temperature by
~80 K. Nominal Menrva would have doubled the methane inventory at the surface. The mobilized meth-
ane would have dripped out of the atmosphere over hundreds of years, filling lake beds, oil pans, whatever.
Uncertainties in the impact energy and the partitioning of the energy into the atmosphere correspond to a fac-
tor two uncertainty in the temperature rise. Menrva was probably not big enough to heat the 1.4 bar N2
atmosphere to the melting point of water, but some global-distributed surface melting cannot be ruled out
at the high end of the uncertainty.

Bigger impacts are more invigorating. If Titan’s surface is mostly made of water ice, the putative Hotei
impact (a possible 800-1200 km diameter basin, [1]) raises the average surface temperature to 350-400 K.
Global meltwaters might range between 50 m to more than a kilometer deep, depending on the size of the
event and how rapidly bedrock ice warms and founders. Water rain must fall, flow, and pool, subject to
choking and crusting over with flotsam, the later including a variety of hydrocarbons, some of them liq-
uid. Global meltwater oceans do not last more than a few decades or centuries at most, but are interesting to
consider given Titan’s organic wealth. When it finally fully freezes the ocean would be on the order of a
kilometer deep.

Hotei scale events, regardless of whether Hotei is itself a real exemplar, must have played a role in the
history of Titan, as it is not plausible to build a world as big as Titan and not have big impacts.

Clathrate hydrates might form under some of the conditions discussed here. Unfavorable kinetics would
seem to restrict formation of the binary methane hydrate to depths greater than ~1 kilometer of ice. None-
theless it appears likely that methane migrating from below could have been caught in clathrates between 1
and 2 km depth, with capacity to store one to two orders of magnitude more methane than is currently in
the atmosphere.

Impacts also create local crater lakes but, in disagreement with previous studies, we conclude that the
lakes are likely to be deeply buried and very short-lived. The problem is that liquid water is denser than
ice. Crater lakes form in shock-heated warm ice of relatively low viscosity. Rayleigh-Taylor instabilities
in the warm ice grow quickly, the lakes founder, and the water mixes with ice. Any liquid water that re-
 mains unfrozen sinks to the bottom of the crater where it either pools kilometers below the surface in contact
with cold bedrock sinks. These concerns are general for any large icy satellite and not particular to Titan.

References: