Referee Report

Global comment: This paper aims at discussing the influence of ice morphology and disk dynamics on the location of snowlines of main C-, N- and O- bearing species in protoplanetary disks. The authors use static and time-dependent disk models associated with desorption-drift models to depict the fate of ice particles in the disk and to derive the abundance profiles of C, N and O abundances in solids or in the gas phase as a function of the distance to the star. I recommend major revisions before considering the publication of this paper in The Astrophysical Journal. In its present shape, the manuscript poorly addresses the influence of the nature of the ices in the presented results, contrary to the goal announced in the title.

We thank the referee for a thoughtful and detailed report. The major comment was along the lines of clarifying and further explaining the effect of the nature of ices on snowline locations. First off, we clarified both in the abstract and in the main text that we are referring to ice compositions rather than morphology (specifically, we are not discussing the morphology of the water ice substrate), and we removed 'morphology' from the title. Further changes are addressed in the responses below.

Detailed comments:
- Introduction:
1) Titan's atmospheric N2 is not primordial and probably comes from primordial NH3 accreted by the satellite (Atreya et al. 1978; Mandt et al. 2014).

We added this clarification in the text.

2) In the third paragraph, it is stated that N2 was probably the dominant N2 form in the protosolar nebula and that the N/O ratio may be enhanced in the outer disk. These statements are at odds with the mention of the N2 detection in comet 67P/churyumov-Gerasimenko because the abundance of this molecule is very small in the comet.

We removed the reference to comet 67P in the introduction as we discuss the detection of N2 and the low N2/CO ratio in 67P in section 4.

3) Sentence "Because of the high volatility of N2, the N/O ratio in the outer disk should be more enhanced than the C/O ratio..." This argument needs clarification. The equilibrium curves of pure N2 and CO crystalline ices are very close at nebular conditions. There might be just 2-3 K of difference at low pressure (Fray and Schmitt 2009).

We explained that the N/O ratio is expected to be enhanced by many orders of magnitude compared to the stellar value between the CO and N2 snowlines, since oxygen gas is depleted in this region. While CO and N2

have similar condensation temperatures for similar ice compositions, their snowlines can span a wide range of semimajor axes depending on the composition of each species, as we explain in the fourth paragraph of the introduction as well as in section 3. Even when the CO and N2 desorption temperatures only vary by a few K, their snowlines may be separated by 10-20 AU, as we show in Figures 1, 2, 3.

4) There is no indication of the ice state in this section. I also found nothing in the manuscript. I think that it is a major issue because the results presented by the authors strongly depend on the type of material they consider. From the papers they mention, I found that the authors considered icy grains made of amorphous ice. This should be stated in the paper, as well the corresponding conditions enabling the existence of this type of ice in the disk.

We expanded the fourth paragraph of the introduction to address these concerns. We clarified what we mean by pure and water dominated ices, and stated that we consider the pure and amorphous porous water dominated cases. The conditions in which these types of ices can exist in the disk are discussed in the third paragraph of section 4.

- Section 2:
Eq. 2, please detail T_irr

The meaning of T_irr is explained right under equation 2, i.e. T_irr = T from equation 1. We did not write an explicit equation for T_irr as that would just be a repeat of equation 1.

- Section 3.1: This section should include results from different ice morphologies to make more sense. Two extreme cases should be considered: amorphous ice and crystalline ice. The clathrate case could be eventually discussed. All these ices present different condensation/sublimation temperatures and could potentially induce drastic changes of the C/N/O ratios in the disk.

First off, as we noted earlier, we are interested in the effect of the ice composition on snowline locations rather than the effect of the morphology of the water ice substrate in itself. We do not present the results for CO and N2 in an amorphous compact water ice environment as this would move the CO and N2 snowlines outward in the bottom panel of Figure 1, while we are more interested in the extremes (i.e., porous water dominated ices and pure ices). We mentioned the possibility of a crystalline H2O ice substrate in the introduction, but we explained that based on observations amorphous H2O ice is dominant in protostellar cores. In addition, we expect the CO and N2 binding energies to be only slightly larger in the crystalline vs amorphous case (as stated in the introduction), and thus will only result in a modest inward movement of the snowlines, in contrast with

the much larger difference in snowline locations between pure and amorphous water dominated ices.

- Section 3.1: the different snowlines correspond to equilibriums between adsorption/desorption. What are the corresponding temperatures in the disk?

We added the corresponding disk temperatures next to the binding energy values.

- Section 3.2: "In this section we consider pure ices". What does it mean? What is the structure of these ices?

We clarified what we mean by pure ices at the beginning of the section, as well as in the introduction.

- Section 4: please explain what would be the influence of other transport mechanisms such as the "cold finger effect" detailed in Cyr et al. (1999) or Ali-Dib et al. (2014).

Added. We note that the influence of other transport mechanisms on snowline locations and C/O ratios is described in more detailed in Piso et al. (2015).

- Section 5: Last paragraph "Recent measurements... in the gas phase". The N2 (and Ar) depletion measured in 67P may not be a record of the primordial composition. These features may be also due to postformation processes such as radiogenic heating or devolatilization during the orbital history of the comet.

- Section 5: Last paragraph "Theoretical models... more detailed modeling is needed". Recent models suggest that JFCs formed between 5 and >30 AU in the protosolar nebula. It is then difficult to rely any N2 measurement in these bodies to the location of the N2 snowline...

Both of these concerns and uncertainties are addressed in the last paragraph of section 4.