Statistical Analysis of Deflation in Covariance and Resultant Pc Values for **AQUA**, **AURA** and **TERRA**

Syed Hasan

EOS Lead Collision Avoidance Engineer

INTRODUCTION

- Since mid-2015, the EOS team as well as many other Low Earth Orbit (LEO) satellite support teams have noticed a significant reduction in Probability of Collision (Pc) of their close approach events, but nobody has yet figured out why this has occurred

- Bill Guit (NASA Aqua Mission Director) requested that I mine through raw Earth Observing Satellite (EOS) Aqua, Aura and Terra Conjunction Data Messages (CDMs) to assist in examining this phenomenon

- This investigation has led to what we believe may have caused this reduced shift in Pc

BACKGROUND

- A change in covariance leading to a reduction in Pc can be one of two things:

  1. An inflation of the covariance leading to larger error ellipsoid and thus higher uncertainty (larger n in a m/n ratio will lead to reduced probability value)

  2. A deflation of the covariance leading to smaller error ellipsoid and thus lower conjunction plane intersection area (smaller m in a m/n ratio will lead to reduced probability value)

  m – conjunction plane intersection between primary and secondary objects

  n – covariance error ellipsoid

CDM ANALYSIS APPROACH

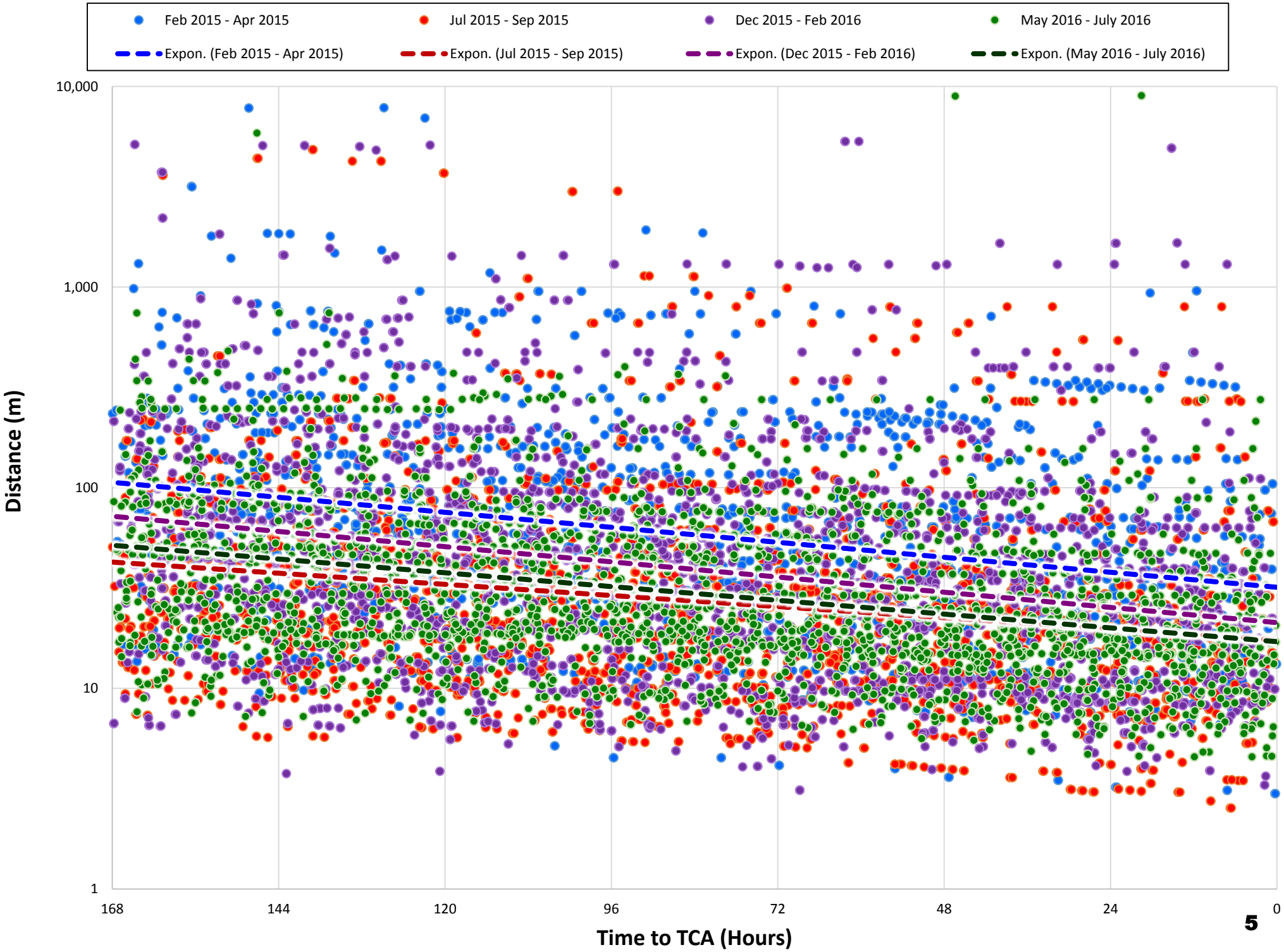
- To determine which of the two (inflation or deflation) impacts we are seeing on the secondary object covariance, the EOS CDM database was mined for CDMs stored by SpaceNav since February of 2015. Four date ranges were selected for data retrieval and comparison:

  1. February 2015 through April 2015
  2. July 2015 through September 2015
  3. December 2015 through February 2016
  4. May 2016 through July 2016

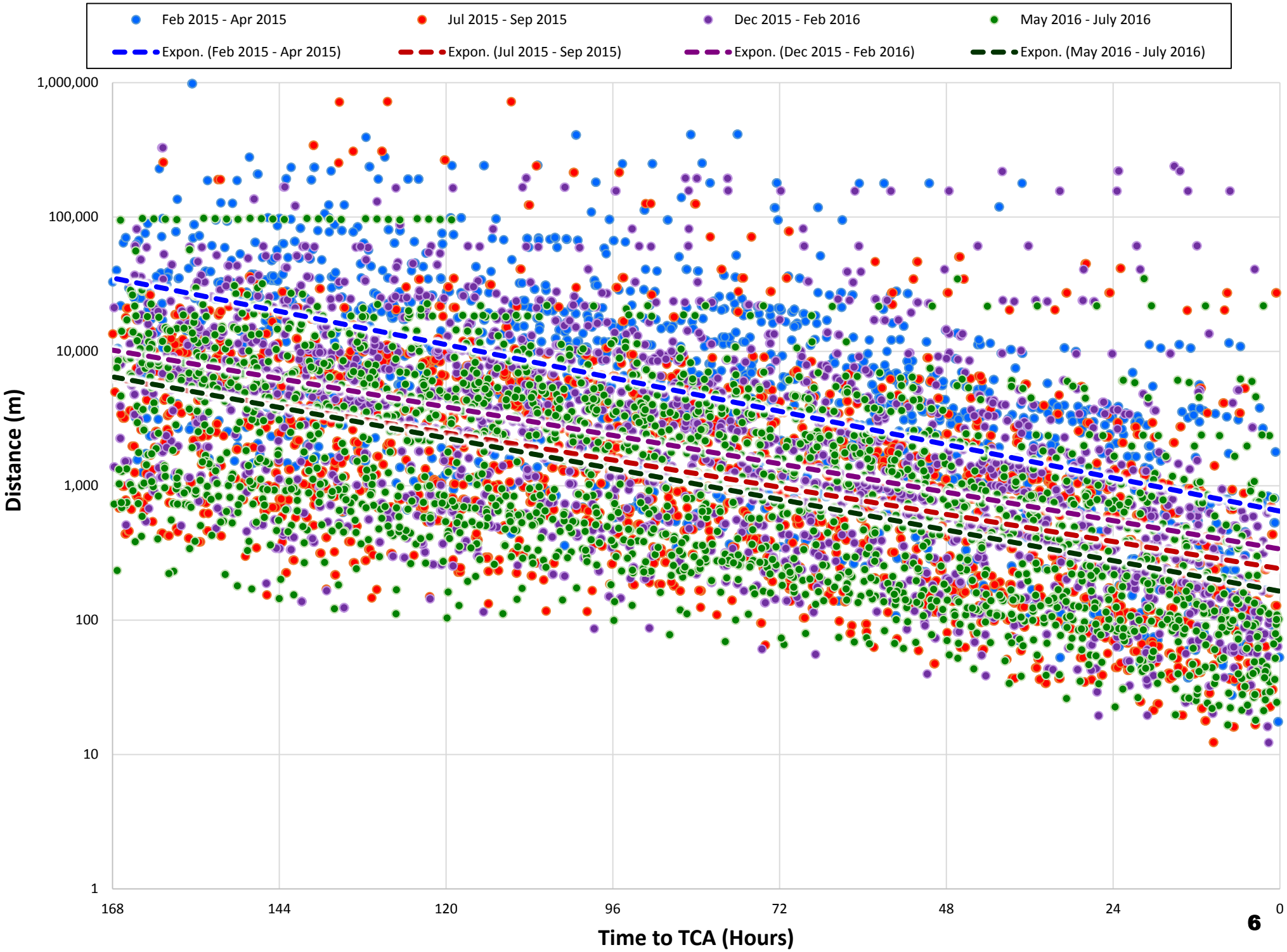
- Comparisons of the radial, in-track, and cross-track variance values were plotted for each of the ranges, as well as their exponential trend lines, to indicate an overall increase or decrease in the variance values

- The plots are provided in the next few slides, on a logarithmic scale

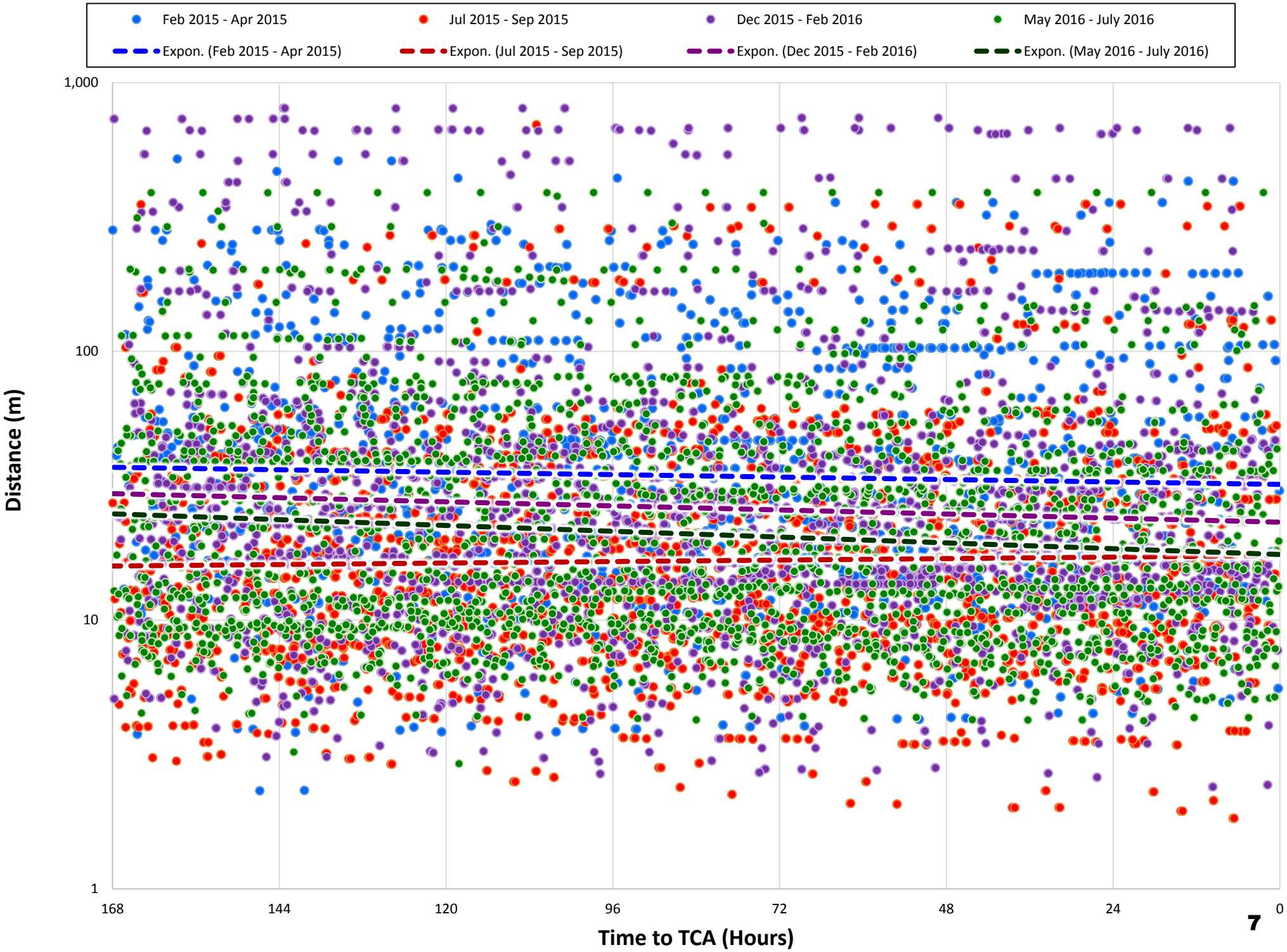
AQUA Radial Covariance of Secondary Objects



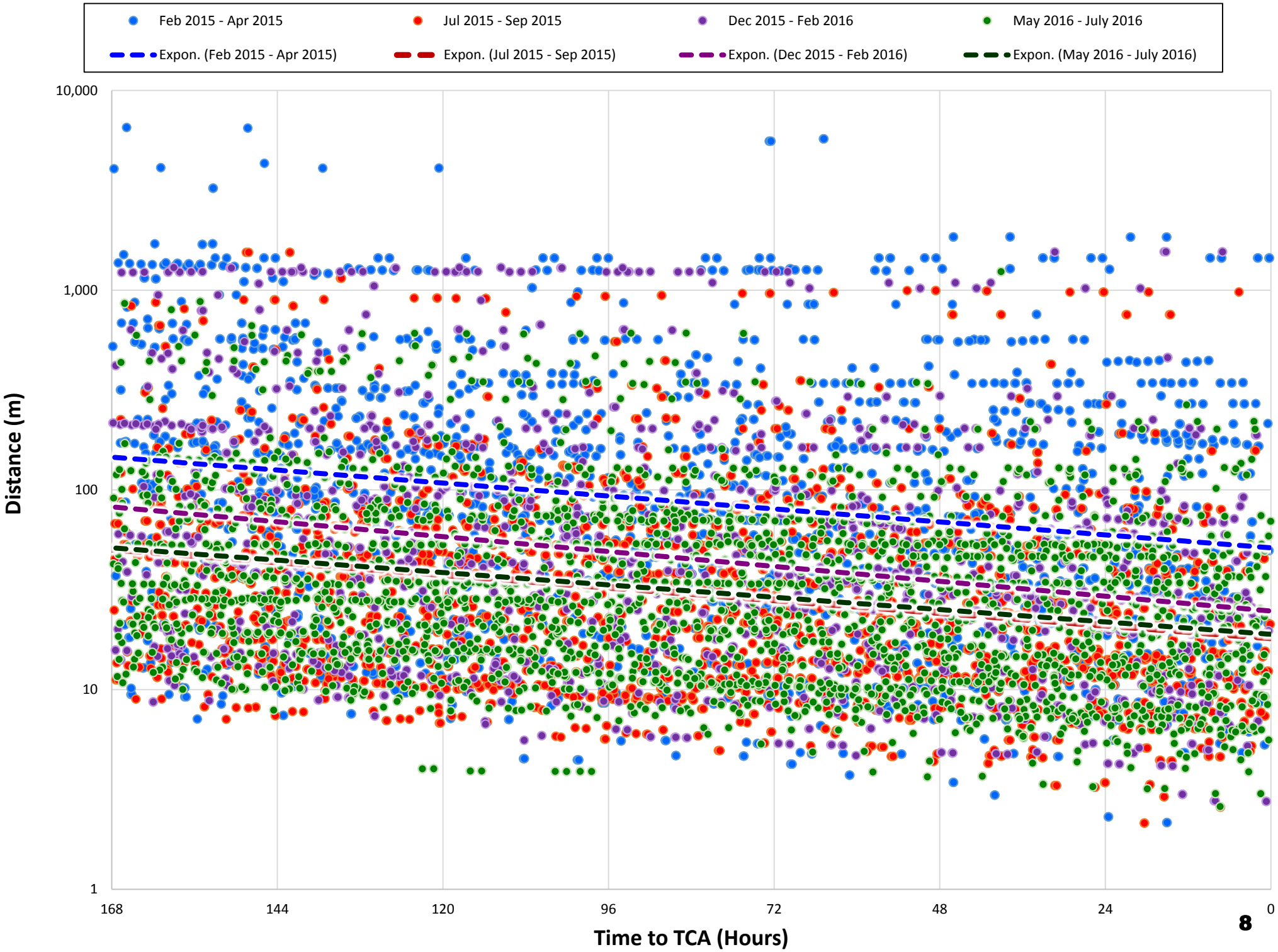
AQUA In-track Covariance of Secondary Objects



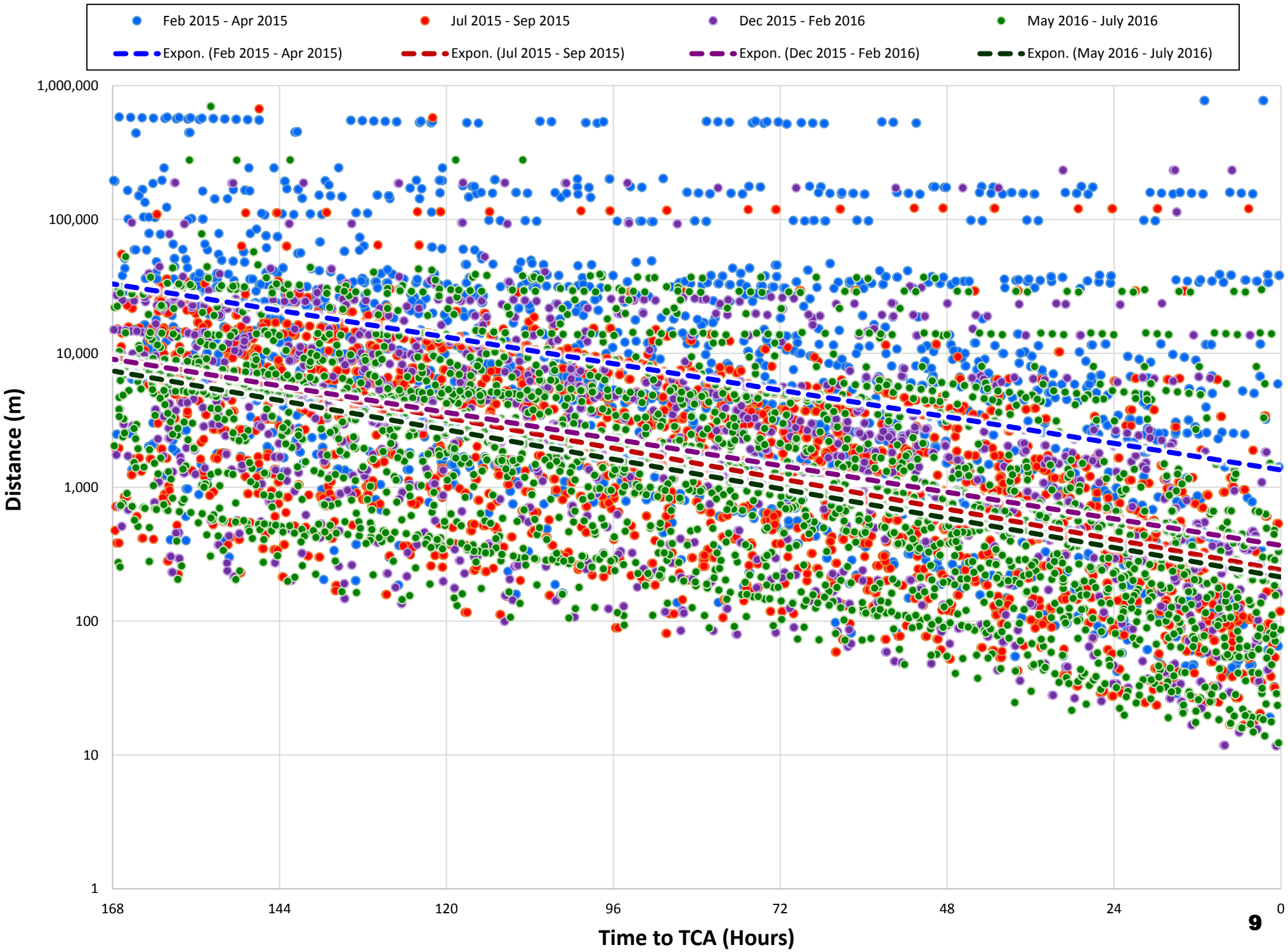
AQUA Cross-track Covariance of Secondary Objects



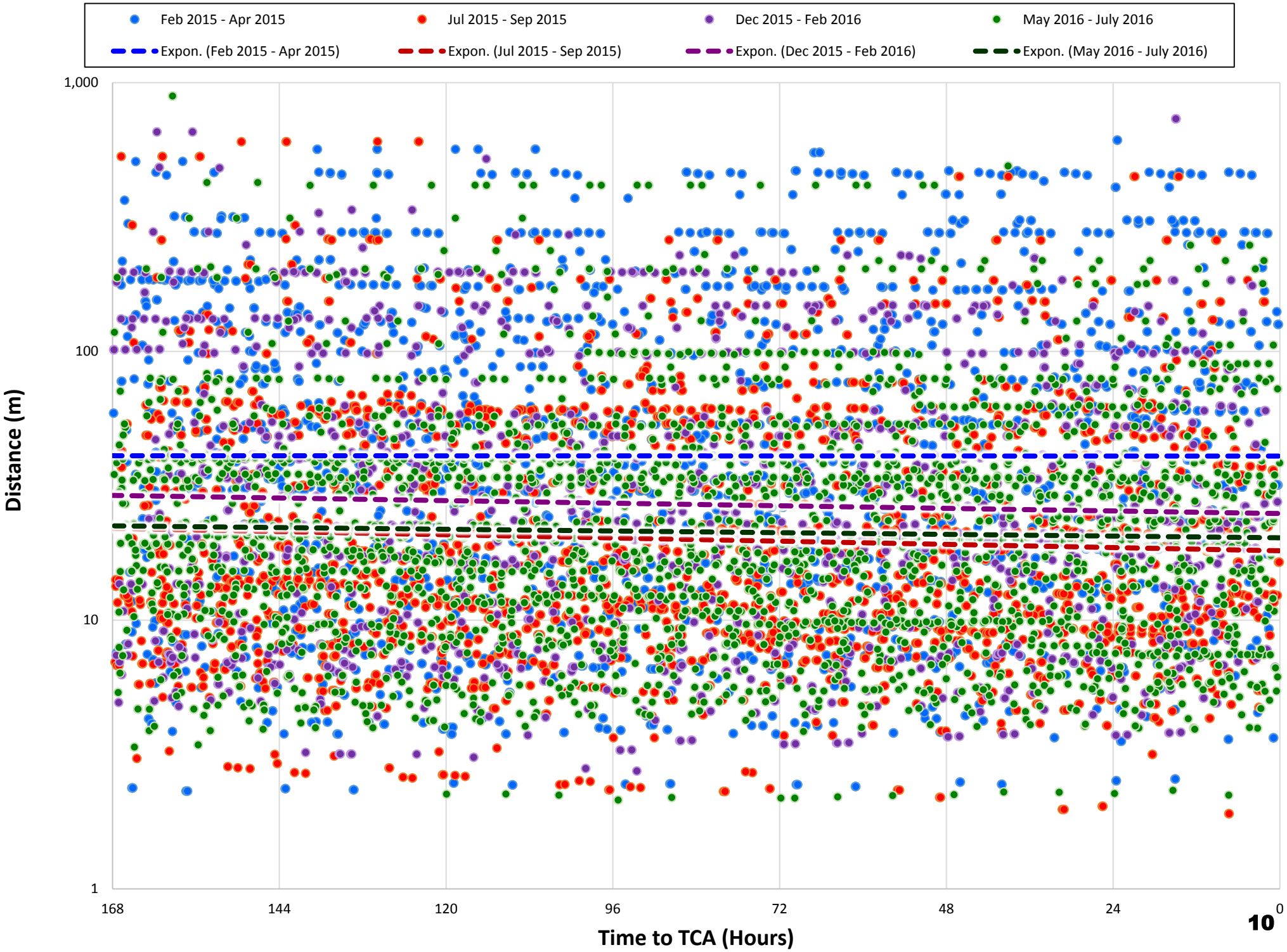
AURA Radial Covariance of Secondary Objects



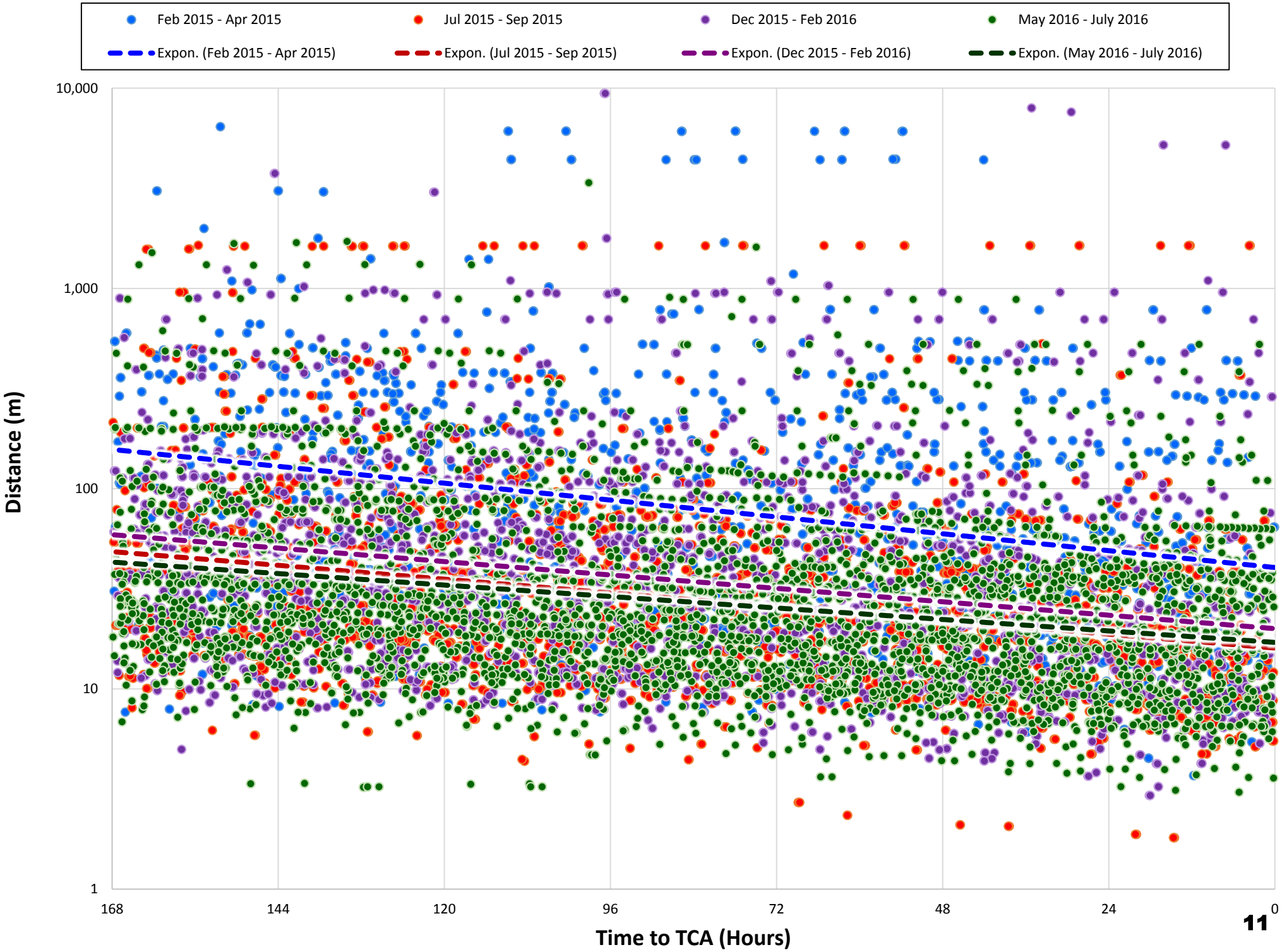
AURA In-Track Covariance of Secondary Objects



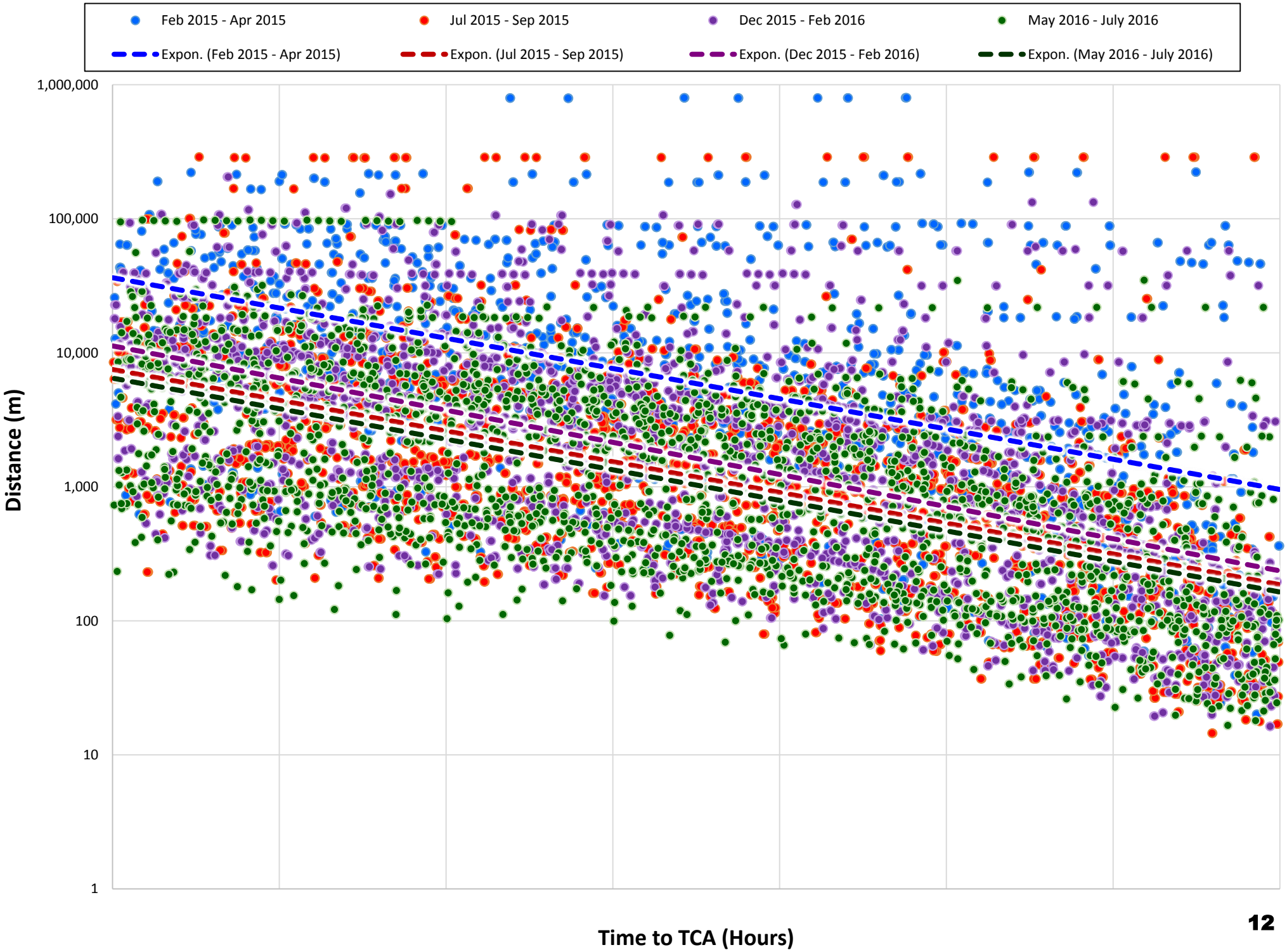
AURA Cross-Track Covariance of Secondary Objects



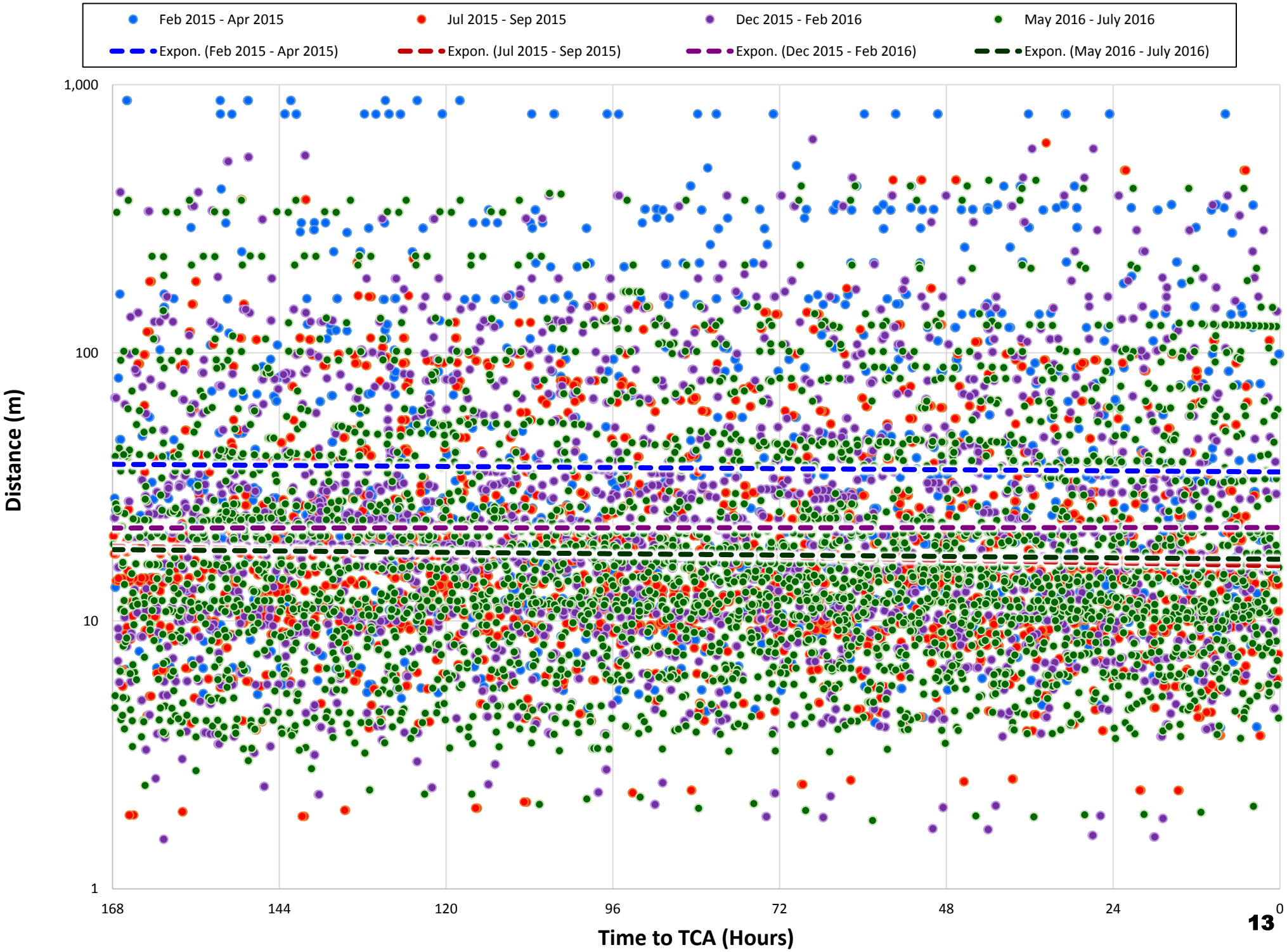
TERRA Radial Covariance of Secondary Objects



TERRA In-Track Covariance of Secondary Objects



TERRA Cross-Track Covariance of Secondary Objects



CDM ANALYSIS RESULTS

- For all three variance components of secondary objects that came within the screening volume for all three satellites, we observe a discernable deflation in covariance after May 2015

- This indicates a reduction of the conjunction plane intersection of the primary and secondary objects, due to a smaller covariance error ellipsoid, leading to a lower Pc

Pc ANALYSIS APPROACH

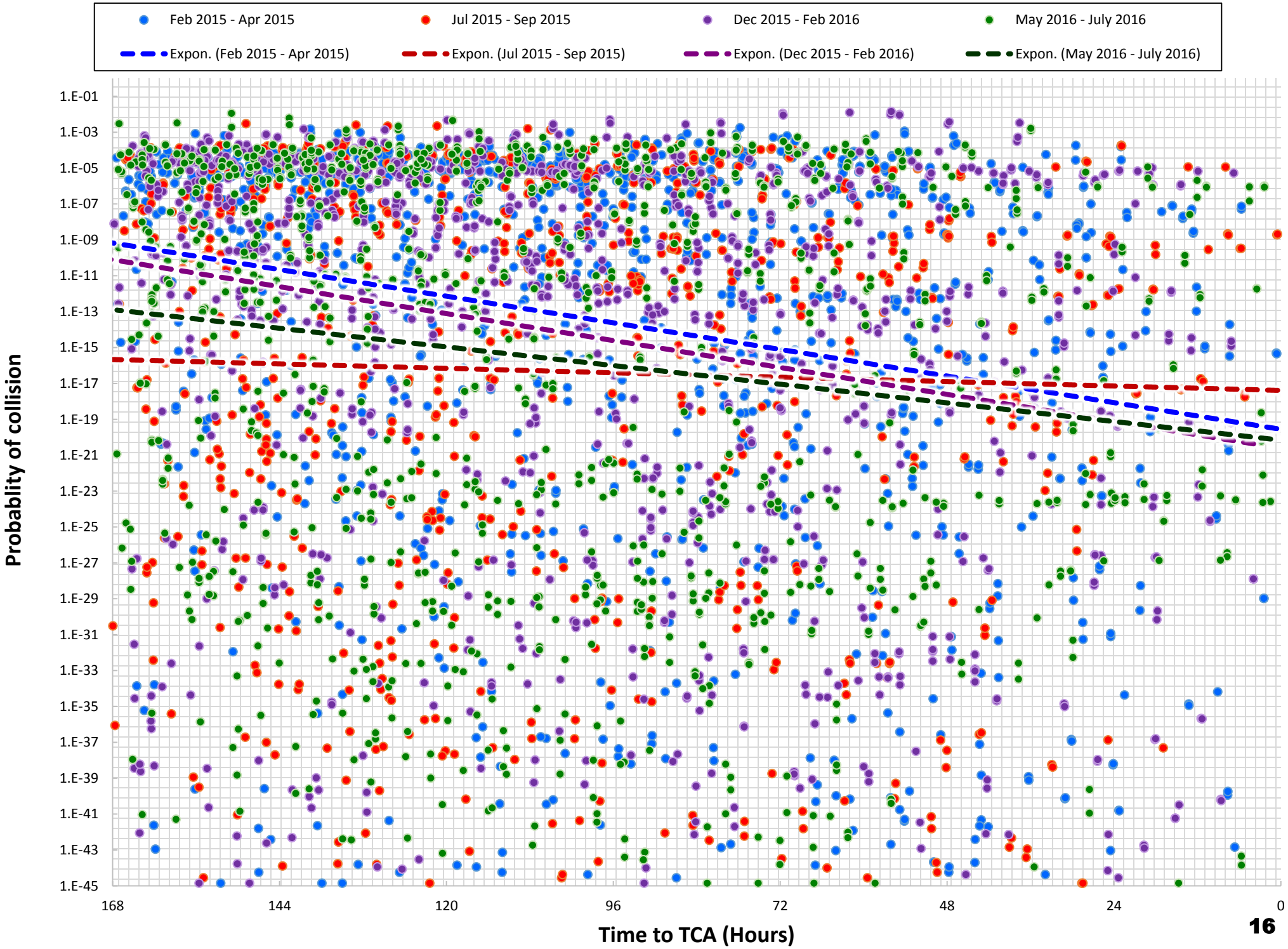
- To verify a reduction in the Pc, the EOS Derived Parameters database was mined for Pc values calculated by the SpaceNav Collision Risk Management System (CRMS) for CDMs and stored since February of 2015. The same date ranges were selected for data retrieval and comparison:

  1. February 2015 through April 2015
  2. July 2015 through September 2015
  3. December 2015 through February 2016
  4. May 2016 through July 2016

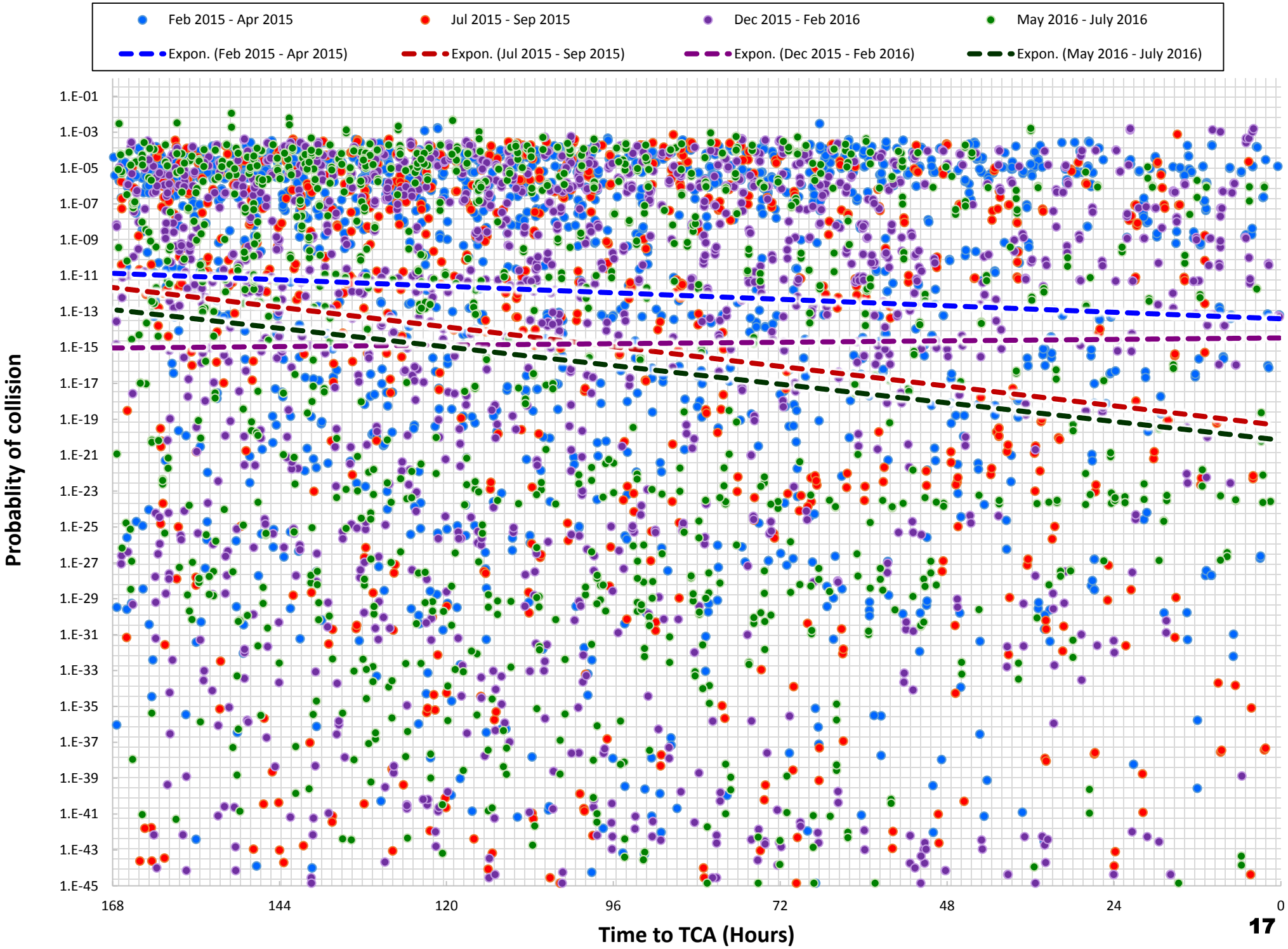
- Comparisons of the non-zero Pc values were plotted for each of the ranges, as well as their exponential trend lines, to indicate an overall increase or decrease in the Pc

- The plots are provided in the next few slides, on a logarithmic scale

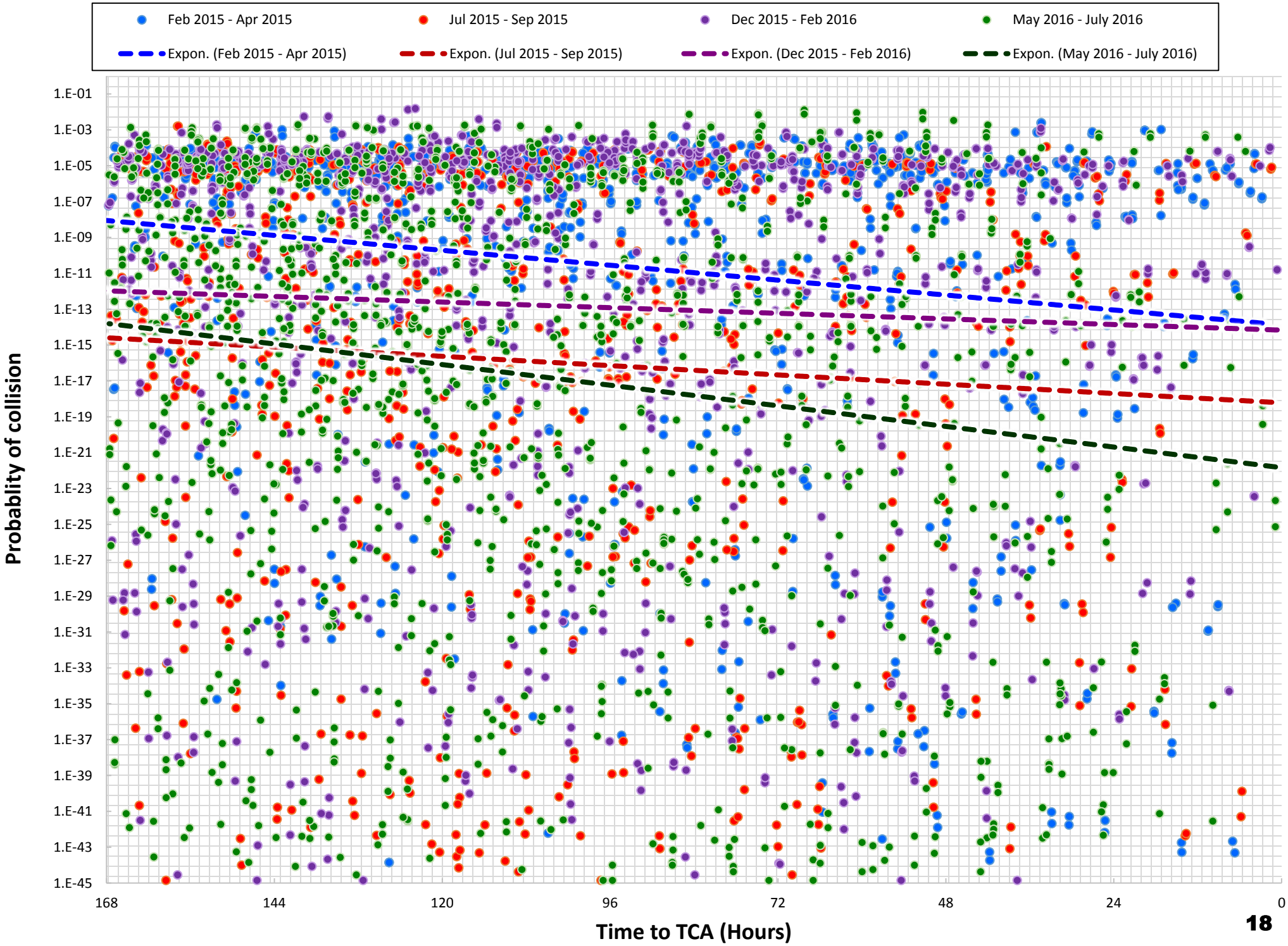
AQUA Pc with Secondary Objects



AURA Pc with Secondary Objects



TERRA Pc with Secondary Objects



Pc ANALYSIS RESULTS

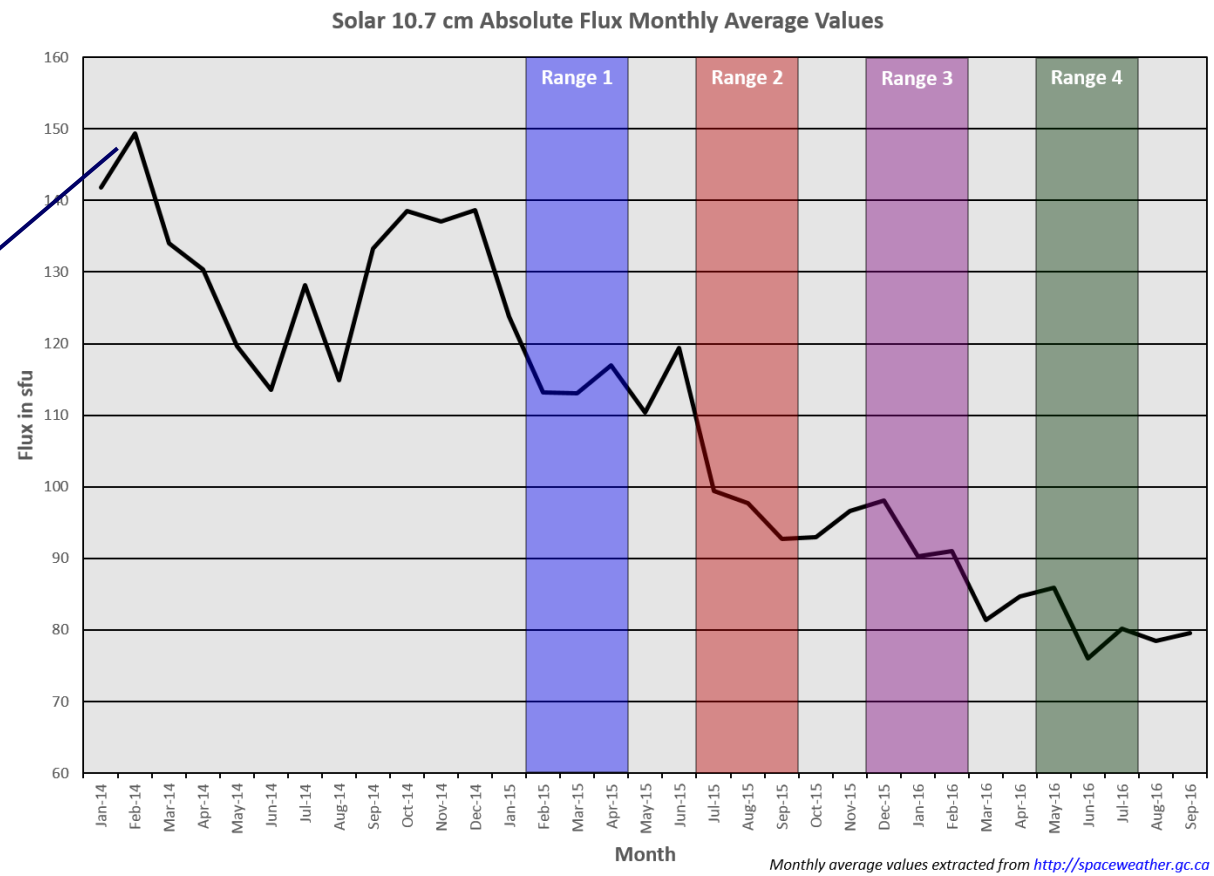
- After analyzing the data in these plots we detect a very noticeable drop in the Pc values for all three satellites after April 2015, similar to what is observed in analyzing the raw CDM covariance values

- Based on these results, we conclude that the overall Pc reduction observed by the EOS team is <u>most likely</u> a factor of a deflation in the covariance values used for secondary objects

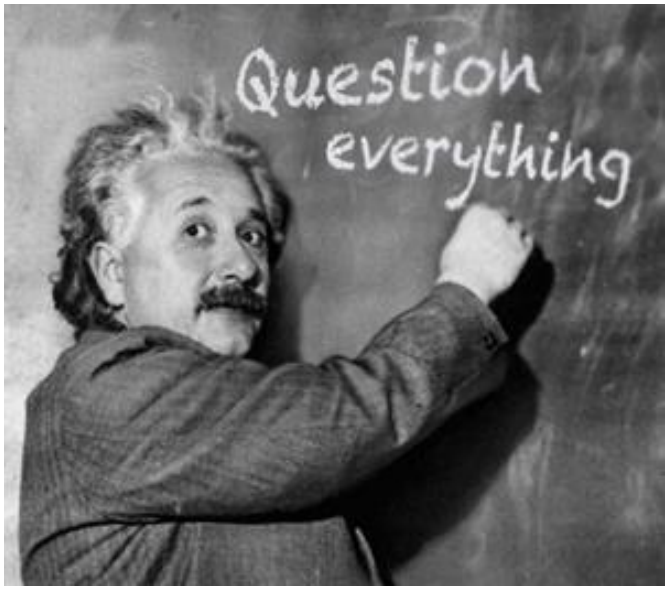
WHY HAS COVARIANCE DEFLATED?

- What this study does not tell us is: Why are we seeing such a significant reduction in the covariance error ellipsoids?
- Has there been some atmospheric modeling update at the Joint Space Operations Center (JSpOC) after April 2015 that has led to deflated covariance calculations?
- Has the decrease and stability in solar flux been a factor in density predictions leading to reduced covariance values?

Solar maximum occurred in early 2014. We are expecting a decline in solar flux until the next solar minimum predicted to occur in 2019.



Monthly average values extracted from http://spaceweather.gc.ca

QUESTIONS MOVING FORWARD

- Will we see an increase in covariance values in the future?
- If so, then when, and by how much?
- How will this impact our support when the space fence is used about 2 years from now and we have a large increase in the number of screened objects?