LIGO-G010106-00-Z

LSC Meeting
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E2 Investigation: Tidal Model

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- Tidal Model
- Fits to time derivative of control signals
- Fits to control signals with offsets
- Other possible effects

Tidal Model

The tidal model is based on

- Paul Melchior "The Tides of Planet Earth" (QC 809.E2 M48, 1983).
- F. Raab and M. Fine "The Effect of Earth Tides on LIGO Interferometers" (LIGO T970059-01-D)

as coded by Eric Morganson.

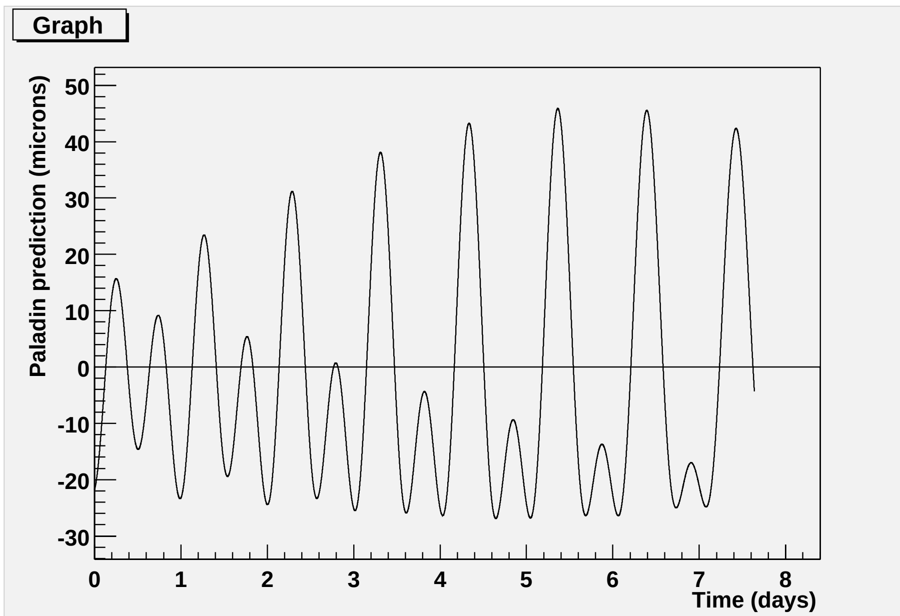
This tidal model has no free parameters. Position of the Sun and Moon are calculated using the FORTRAN NOVAS package. The values of the Love numbers which describe the elastic properties of the Earth, are based on

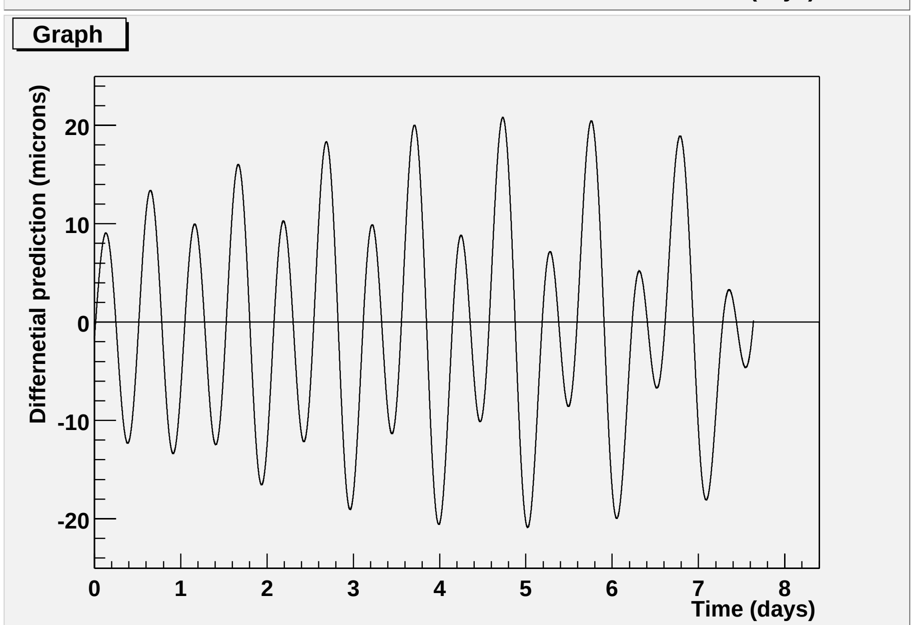
- Mathews, Dehant, Gipson, J. Geophys. Res., v102, 20469-20477, (1997).

Effects which are presently not included in the Tidal model include:

- Ocean loading
- Tilts induced by tidal effects
- Local variations in the Earth's elastic properties

The prediction of the tidal model for the E2 test run are shown below for the common mode and differential signals of the Hanford 2km interferometer.





The expected effects are much larger than the dynamic range of the servos needed to keep the interferometer in lock.

Time Derivative Fits

To avoid problems due to the unknown offsets between the lock segments, fits were performed to the derivative of the control signals.

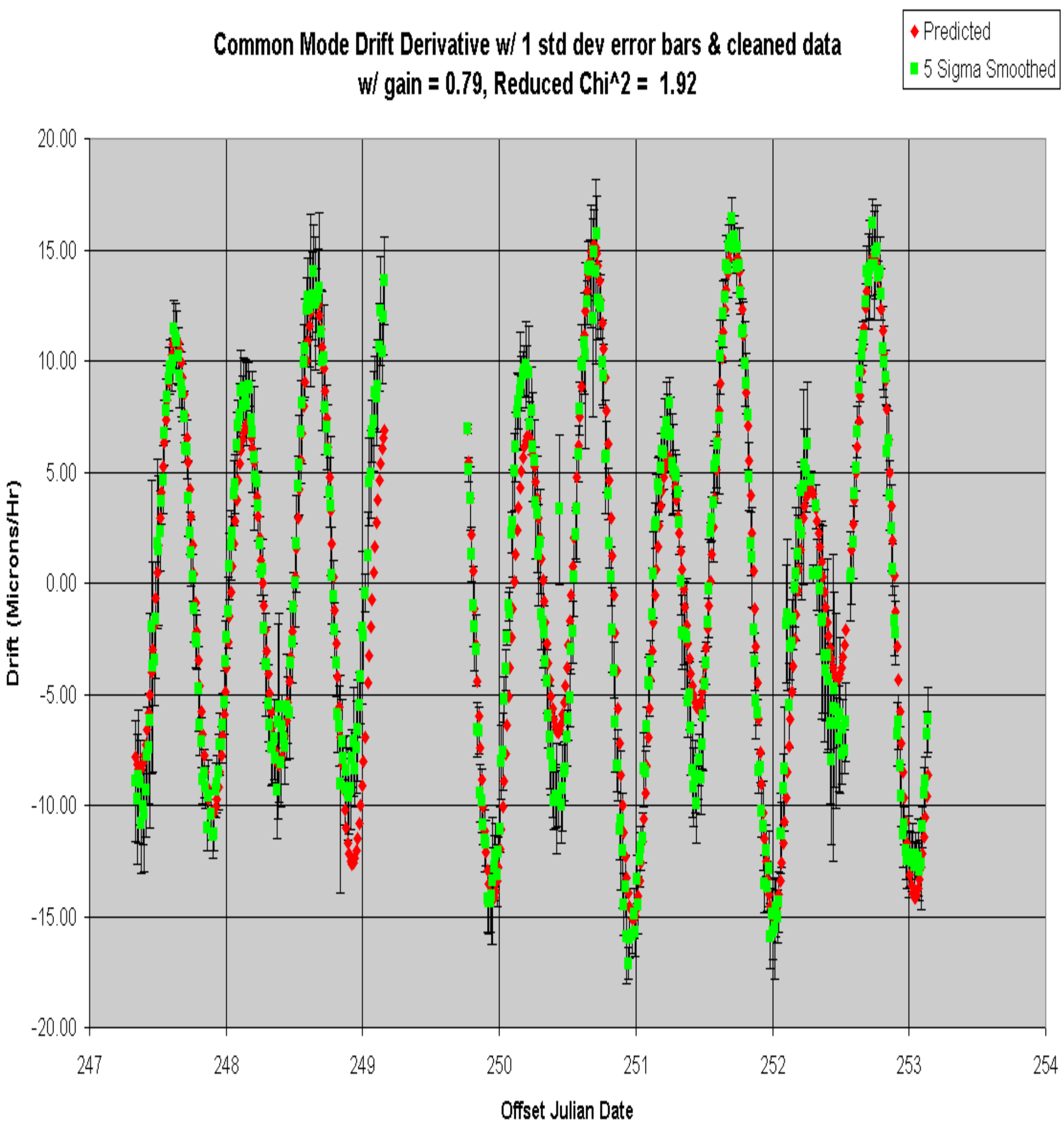
The calibration used for the control signals is

$$
\begin{aligned}
L_{-} &= (6.5 * \text{DARM\_CTRL} + 2.7 * \text{CARM\_CTRL})/1000 \\
L_{+} &= (2.7 * \text{DARM\_CTRL} + 6.5 * \text{CARM\_CTRL})/1000
\end{aligned}
$$

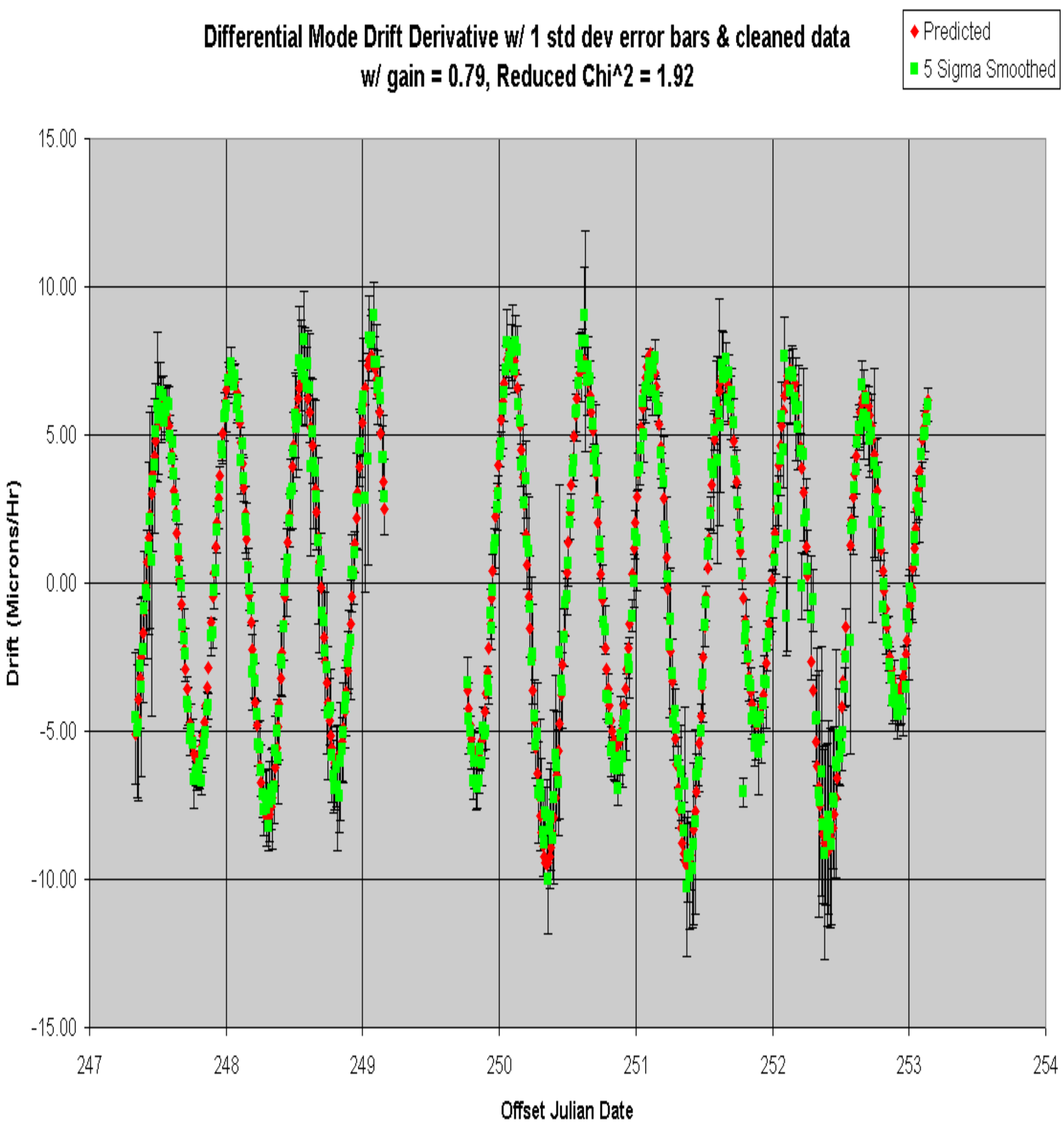
where L_{-} and L_{+} are the common mode and differential mode expansion of the arms in microns.

To avoid problems with normalization of individual lock segments, the derivatives are plotted in units of microns/hour. For these fits L_{-} and L_{+} are also multiplied by -1.

Comparison of common mode signal (with fitted gain factor for calibration) and data:

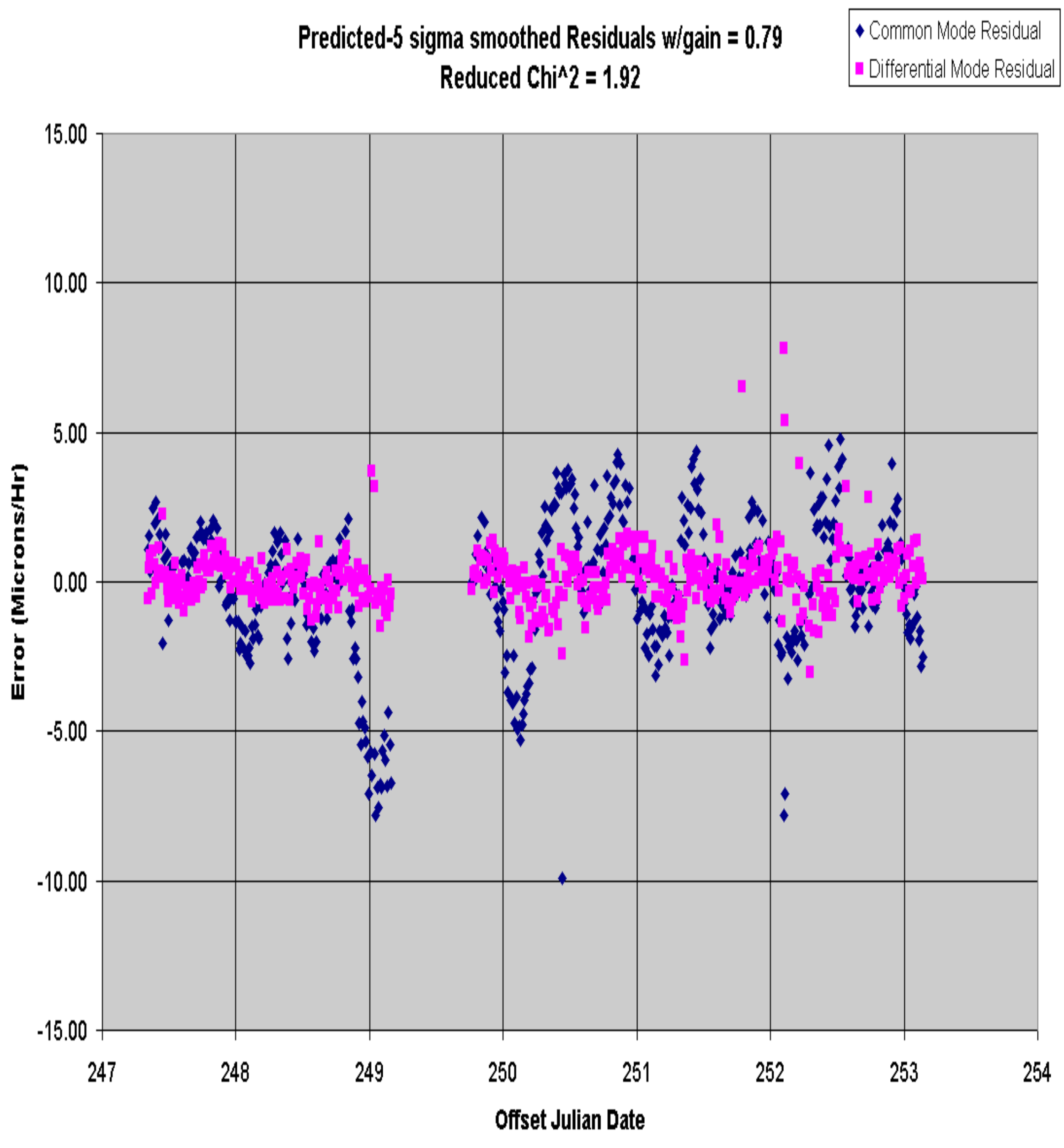


Comparison of differential mode signal (with fitted gain factor for calibration) and data:



Bottom line, residuals are within a few microns/hour.

E2 Tidal Residuals w/ gain 0.79



Brute force method:
use fitted offsets for each lock period

- Various attempts to stitch together the lock periods of the interferometer found that the results are sensitive to details in the stitching procedure.

- Another approach is to fit for a free offset for each lock period.

  This approach seems to be robust, but is limited to about 100 lock periods. To avoid this problem a hierarchical fit was performed. First each 24-hour period was fit with a free offset for each day and a scale factor for the model. Then all of the days are fit with the individual lock periods fixed and free offsets for each day, as well as a single free scale factor for the model.

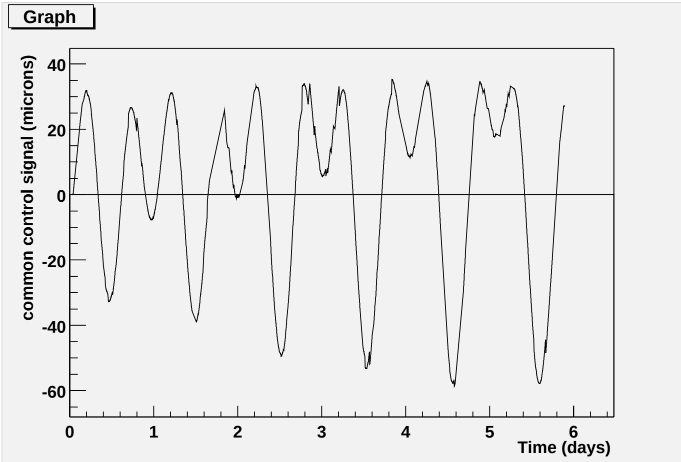
  ⇒ The scale factors are quite robust against changes in this fitting method, minimum lock length, inclusion of other effects, ...

- Separate fits were down for the common mode and differential mode signals.

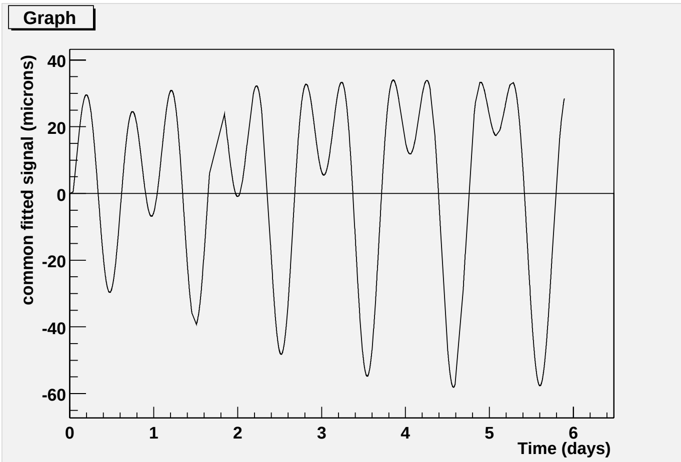
- Error on minute trend measurements was arbitrarily assumed to be 1 micron.

Common Mode Results

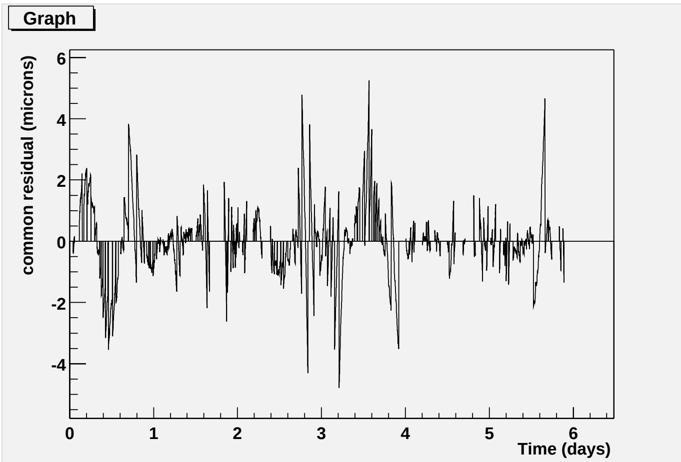
Calibrated data with fitted offsets:



Fitted function



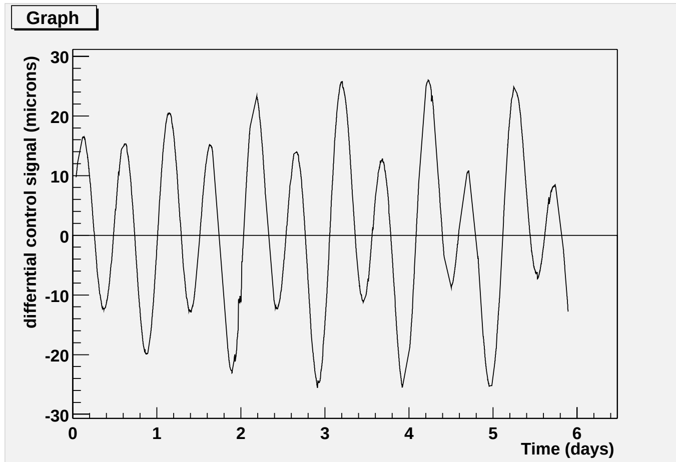
Residuals



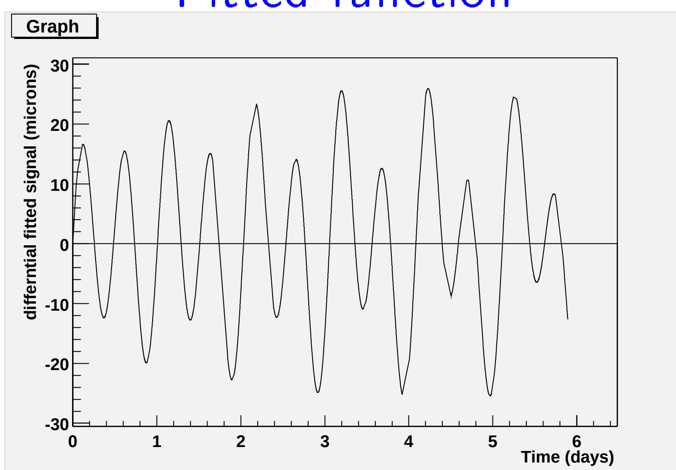
Model scale factor = 1.26 (equivalent to gain scale of 0.79)
Reduced $\chi^2 \sim 1.0$.

Differential Mode Results

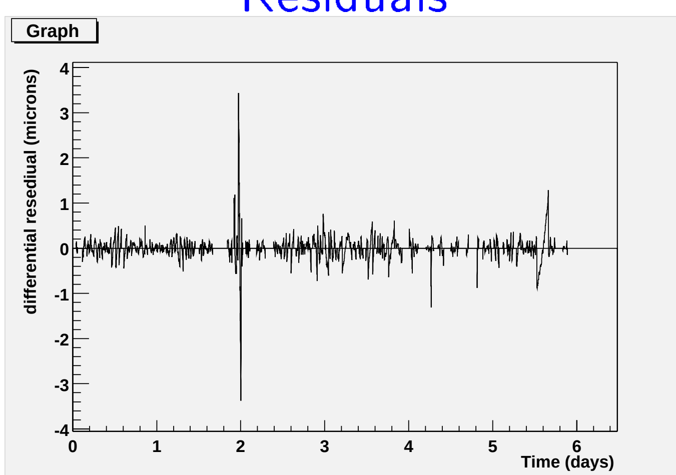
Calibrated data with fitted offsets



Fitted function

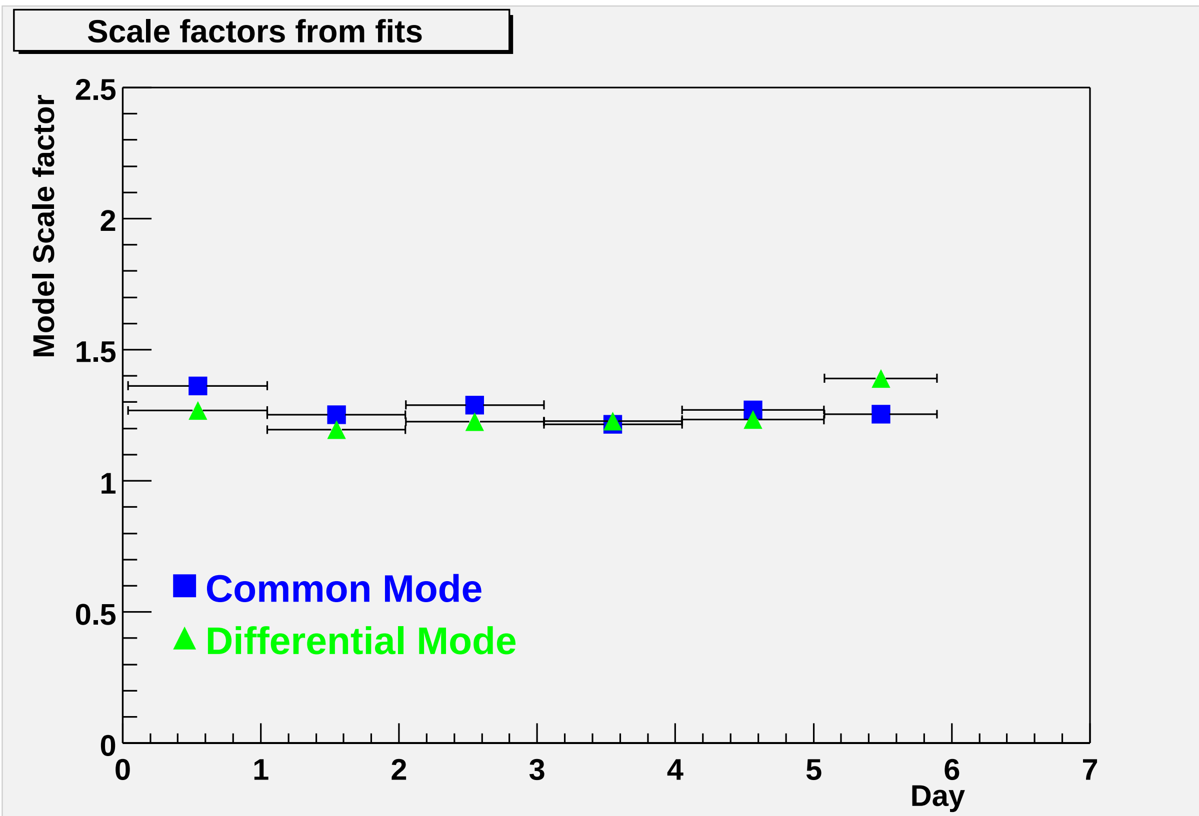


Residuals



Model scale factor $= 1.24$ (equivalent to gain scale of 0.81)
Reduced $\chi^2 \sim 0.05$.

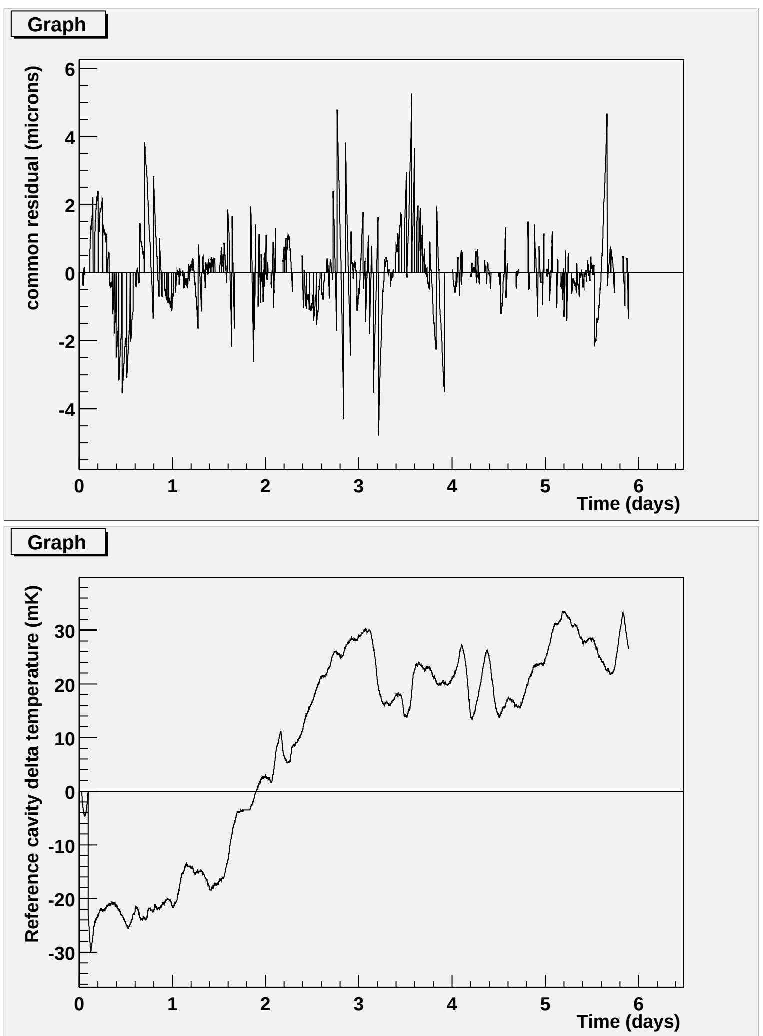
Scale factors from day-by-day fits are relatively stable:



Correlation of control signals with other factors

The most important signal for the stability of common mode signal is the temperature of the reference cavity. This temperature is measured on the outside of vacuum, so a time delay is expected between the change in the measured temperature and that of the cavity itself.

There is no obvious correlation between the residuals of the common mode tide fit and a two hour running average of cavity temperature:



Correlation with reference cavity temperature (continued)

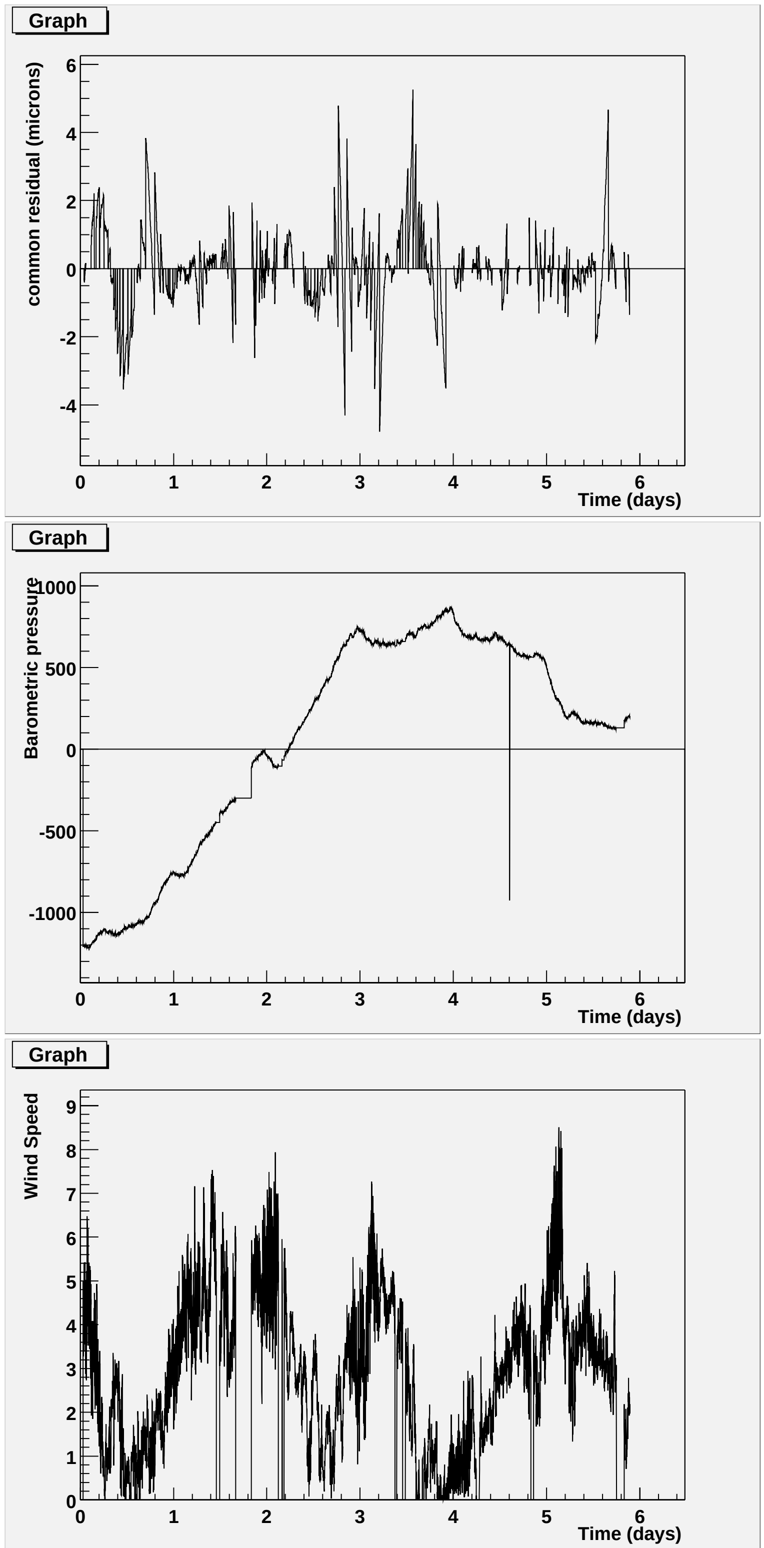
- Most of the changes in the reference cavity temperature are slow enough that the "fitted offsets" for each lock period can easily compensate for changes due to the temperature.

- Since the reference cavity is made of quartz with temperature coefficient of 5×10^{-7}/K, the expected effect for the 2K interferometer is roughly 1.0micron/mK.

- The fit can easily accommodate the expected effect, but there is no significant improvement in χ^2, even with a fitted time lag between the temperature measurement and the temperature of the quartz cavity.

- Temperature of the reference cavity can be used in a feed-forward to compensate for common mode tidal effects.

First look for correlations between wind speed and barometric pressure does not show large effects:



(n.b. Holes in weather data under investigation.)

Conclusion

- Residuals from tidal model at Hanford are less than a few microns.

- No large unexplained effects were seen in the behavior of the interferometer.
  $\Rightarrow$ Cannot rule out significant drifts which are longer than the typically lock time of $\leq$ 1 hour.

- Feed-forward system to allow for longer locks is presently under development.