Forecast Summary Questions

1. Describe a typical forecast:
   a. What area do they cover?
   b. What is the magnitude range?
   c. How long is the time period?
   d. Do you include a probability of an event during the forecast?
   e. Do you include a confidence level in the forecast?

2. Describe the process for making a forecast:
   a. Is it automatic or manual?
   b. What data are used?

3. Do you have a preference for which earthquake data should be used to test your forecasts?

4. Do you have a preferred testing method?

5. What physical hypotheses about earthquake predictability have motivated your research?
CSEP Forecasts on Six Oceanic Transform Fault Segments

Margaret Boettcher, UNH
Jeff McGuire, WHOI
Jeanne Hardebeck, USGS

Ryan et al., 2009
Are the largest earthquakes on oceanic transform faults governed by a renewal process?

Some global characteristics:
✧ The largest earthquakes are small ($6 \leq M_W \leq 7.1$) despite large fault areas
✧ Recurrence intervals between large earthquakes with centroids less than 10 km apart are short (5-20 years for fast to moderate rate transform faults; McGuire, 2008; Boettcher and McGuire, 2009)
Oceanic Transform Fault CSEP Forecasts

1. Designed to quantify the natural variability in oceanic transform fault seismic cycles, presumably due to:
   ♦ Heterogeneity of material properties along the fault
   ♦ Time dependence of stressing-rate and fault strength

2. For each segment we are testing
   ♦ the magnitude range of the “largest earthquakes”
   ♦ the range of inter-event times

3. Specifically we are predicting
   ♦ No earthquakes larger than the mean $M_w + 0.3$ will occur
   ♦ The rate of the mean $M_w \pm 0.3$ will be governed by the time-dependent Brownian Passage Time distribution
   ♦ The CMT location of the largest earthquakes will be within 15 km along strike and 10 km perpendicular to the fault relative to the location of the previous earthquake
Gofar Transform Fault, EPR

- Seismic cycles are ~5 years
- Largest events are ~$M_W$ 6.0
- McGuire et al. (2012) captured the end of a seismic cycle including the >20,000 foreshocks, $M_W$ 6.0 mainshock, and aftershock sequence
Poor Location Accuracy on Oceanic Transform Faults

✧ To determine if earthquakes have overlapping centroids, we use a surface wave relative relocation technique (McGuire, 2008)

✧ For example- 2003 & 2008 centroids are 3.7± 3.7 km apart

✧ A spatial box with uniform probability

✧ The boxes are currently not sufficiently large… so we will update this for the next CSEP version
Blanco Transform Fault, Juan de Fuca Ridge

✧ Seismic Cycles are ~13.5 years
✧ Largest Earthquakes are ~$M_W 6.3$
Clipperton Transform Fault, EPR

- Seismic Cycles are ~20 years
- Largest Earthquakes are ~$M_W 6.6$
Brownian Passage Time PDFs

✧ Brownian-Passage Time (BPT) model (e.g. Matthews et al., 2002)

\[
f(t; \mu, \alpha) = \left( \frac{\mu}{2\pi \alpha^2 t^3} \right)^{1/2} \exp \left\{ -\frac{(t - \mu)^2}{2\mu \alpha^2 t} \right\}
\]

✧ Small sampling has bias towards the mode (e.g. Parsons, 2008)

✧ Assume the mean of observed repeat times is the mode of the BPT and calculate the mean from the mode following Matthews et al., 2002:

\[
\text{mode} = \mu \left[ \left( 1 + \frac{9\alpha^4}{4} \right)^{1/2} - \frac{3\alpha^2}{2} \right]
\]

Parsons, 2008
Gofar Transform Fault CSEP Forecasts

(1) Gofar2: Last Event was 2011/09/20
   Mean of Repeat Dates: 2016/7/14
   No Event Yet

(2) Gofar3W: Last Event was 2008/09/18
   Mean of Repeat Dates: 2014/2/8
   Occurred on: 2012/9/6

(3) Gofar3E: Last Event was 2007/08/04
   Mean of Repeat Dates: 2012/10/8
   No Event Yet…
Gofar Transform Fault CSEP Forecasts

The probability densities on 2012/9/6 in the G3W box is:
CV 0.2 = 0.00030297
CV 0.1 = 0.00001766
CV 0.05=0.00000000
CSEP Forecasts on Clipperton and Blanco

(4) Clipperton: Last Event was 1995/12/01
Mean of Repeat Dates: 2015/10/2
No Event Yet

(5) BlancoRidgeW: Last Event was 2008/01/10
Mean of Repeat Dates: 2021/2/11
No Event Yet

(6) BlancoRidgeE: Last Event was 2000/01/20
Mean of Repeat Dates: 2014/11/28
Occurred on: 2012/4/11, but outside of the spatial window
What have we learned so far?

1. Seismic cycles on oceanic transform faults have coefficients of variation greater than 0.05.

2. So far no larger events have occurred than our forecasted maximum magnitudes (i.e. the mean of the previous cycles ± 0.3 units of magnitude)
   - Gofar 2: $5.4 \leq M_w \leq 6.0$
   - Gofar 3W: $5.7 \leq M_w \leq 6.3$
   - Gofar 3E: $5.6 \leq M_w \leq 6.3$
   - Clipperton: $6.3 \leq M_w \leq 6.9$
   - Blanco Ridge W: $6.0 \leq M_w \leq 6.6$
   - Blanco Ridge E: $6.0 \leq M_w \leq 6.6$

3. Our spatial boxes under estimate the error in the CMT catalog

4. It would be great to incorporate waveforms so that our surface wave relocation codes could be used to determine whether events actually have overlapping centroids, rather than require a large spatial window