1. What physical hypotheses about earthquake predictability have motivated your research?

   Seismo-electromagnetic signals generated during the earthquake preparation period, Lithosphere-atmosphere-ionosphere, Reliable precursors should help earthquake forecasts.

2. What evidence can be used to support or reject these hypotheses?

   Statistical results and event studies on seismo-electromagnetic signals, especially pre-earthquake ionospheric electron density/temperature, such as GPS total electron content (TEC), Ne, Te, anomalies can be used to support or reject the hypotheses.

3. What data are used? What is the spatial and temporal extent of the data? How often are there gaps in the data? What uncertainties exist in the data? Are there authoritative data sources and are they openly available?

   The TEC and/or electron density are used. The spatial extent vary from 50/100km to worldwide, and for the temporal, early 90s-pesent. The data temporal and spatial resolutions are 30-min~2hr and <250/500km. Uncertainties result from the ambient or sensor-generated. For the worldwide, such as GIM (global ionospheric map) TEC, is openly available, while the regional data are from local networks.

4. How is "noise" (ambient or sensor-generated) treated in the data collection and analysis process?

   The GPE TEC noises could be from the ionosphere, the troposphere, as well as the ground-based receiver and satellite bias. They are treated by the international GNSS services (IGS).

5. Have earthquake-forecasting models that incorporate these hypotheses been formulated? Is the model under development or ready for retrospective or prospective testing? Are these models automated such that they could be submitted for independent evaluation? Are there parameters (e.g. time, space, and magnitude windows, thresholds when forecasts are made) that still need to be determined?

The model is under development and almost ready for retrospective or prospective testing. The model is automated and could be submitted for independent evaluation. Time and space windows and their thresholds are determined.

6. Is there corroborating evidence within a forecast (e.g. Is this forecast made based on 1 indicator or multiple indicators)?

   The forecast is made based on both temporal and spatial indicators.

7. Under which circumstances have the forecasting models been tested Retrospectively? Prospectively?

   For the moment, mainly retrospective forecasts have been tested.

8. What are the statistical results of formal testing (e.g., false-alarm and failure-to-predict error rates, skill scores, or relative information/probability gain)?

   The probability gain of the foF2 reduction anomaly reaches its maximum at 3.75 for alerting the M ≥ 6.0 earthquakes in 1 day. A 3-day alarming for M≥6.0 earthquakes based on the foF2 reduction anomaly has the largest R score at 0.43[Chen et al., TAO 2004]. A statistical result shows that in Taiwan about 78% M>=5.0 earthquakes are preceded by reduction anomalies of the ionospheric electron density day 1-5 before the earthquakes, and about 52% the reduction anomalies are followed by the earthquakes with 5 days [Liu et al., JGR 2006]. A spatial analysis has been developed to statistically search forthcoming earthquakes [Liu et al., GRL 2001, JGR 2009, JGR 2010, JGR 2010; Le et al., 2011].

9. Is currently significant information from this research ready for “operational” earthquake forecasting? What is the scale of the forecast elements (e.g. Time, Location, Magnitude, depth, probability) and what weight is placed on each.

   It is almost ready for “operational” earthquake forecasting. Time (1-6 days before) and location (+/- 200km).

10. What are next steps for moving towards the use of this information in earthquake forecasting?

    Forecast Magnitude

11. What are the next steps for improving our understanding of the physical hypotheses?

    Develop a lithosphere-atmosphere-ionosphere coupling model for improving our understanding of the physical hypotheses.