2D Simulations of Edge Turbulence and Blob Transport & Comparison with GPI Data

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Presented at the 2008 NSTX Results & Theory Review

Introduction

- The Lodestar SOLT code is a 2D turbulence code that fully evolves the n, T_e and Φ profiles (strong turbulence, blobs, etc.) For the work reported here, a simulated gas-puff-imaging diagnostic was added to the SOLT code.

- This allows detailed comparisons between the 2D simulations and the GPI data to see whether a 2D simulation can reproduce some aspects of the experimental edge turbulence data

- Results are reported here for a computational study of L-mode shot #112825 (He gas puffing).

Optimization

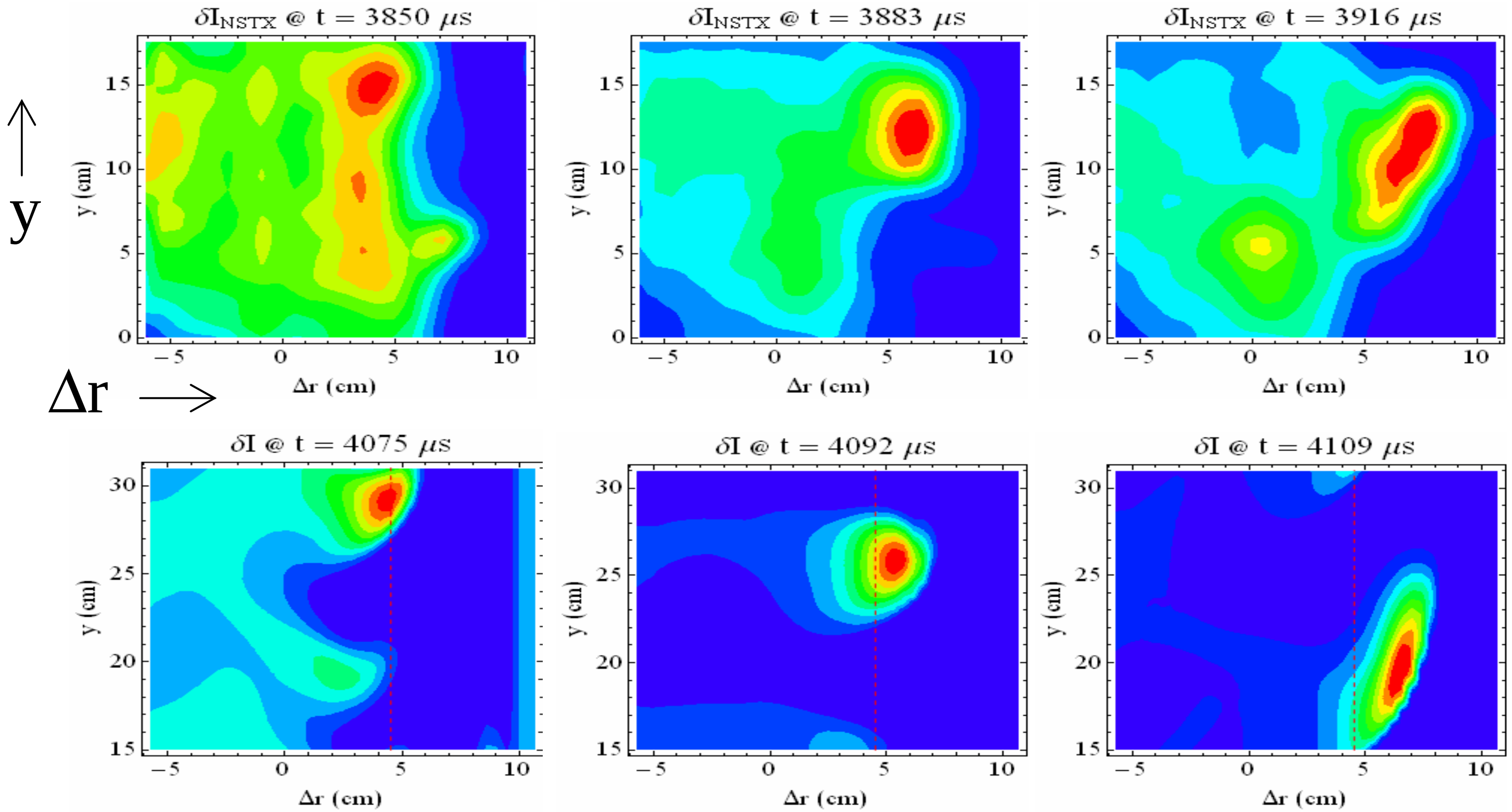
Simulation profiles n(x), $T_e(x)$ are constrained by Thomson scattering data, and machine parameters (R, B) are used as input. Some code parameters (e.g. dissipation) are free to vary and were optimized to give best agreement with the data. The following **figures of merit** were used:

1. Turbulence is intermittent, blobs emitted in bursts
2. Radial profile of GPI radiation intensity I(x) agrees
3. Radial profile of skewness S(x) for n, T and I in radial region where fluctuations are large ($x > x_{LCS}$)
4. PDFs of blob size a_b and velocity v_x

turbulence ⇒ 1 - 3 , blob tracking ⇒ 4

1. SOLT simulation shows intermittency and "intensity blobs" similar to NSTX movies

NSTX GPI Data - plot of $\delta I(\Delta r,y,t) / \langle I \rangle_{y,t} = (I - \langle I \rangle_{y,t}) / \langle I \rangle_{y,t}$



SOLT simulated GPI signal -- similar behavior

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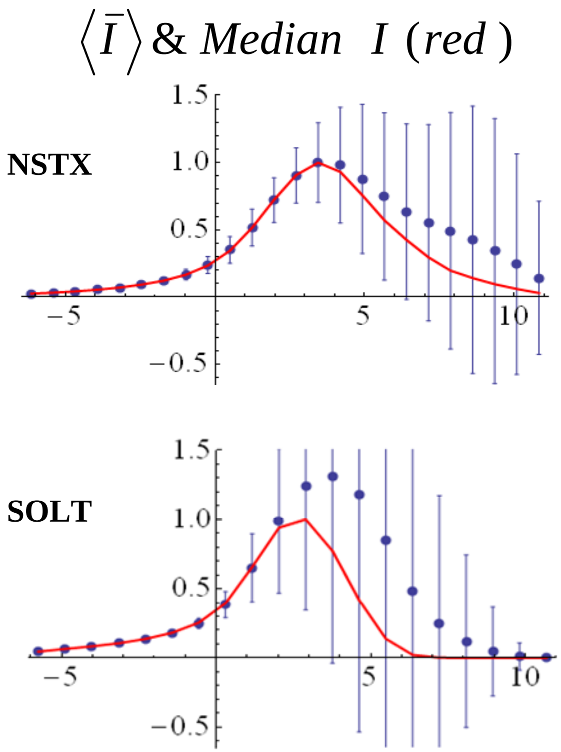
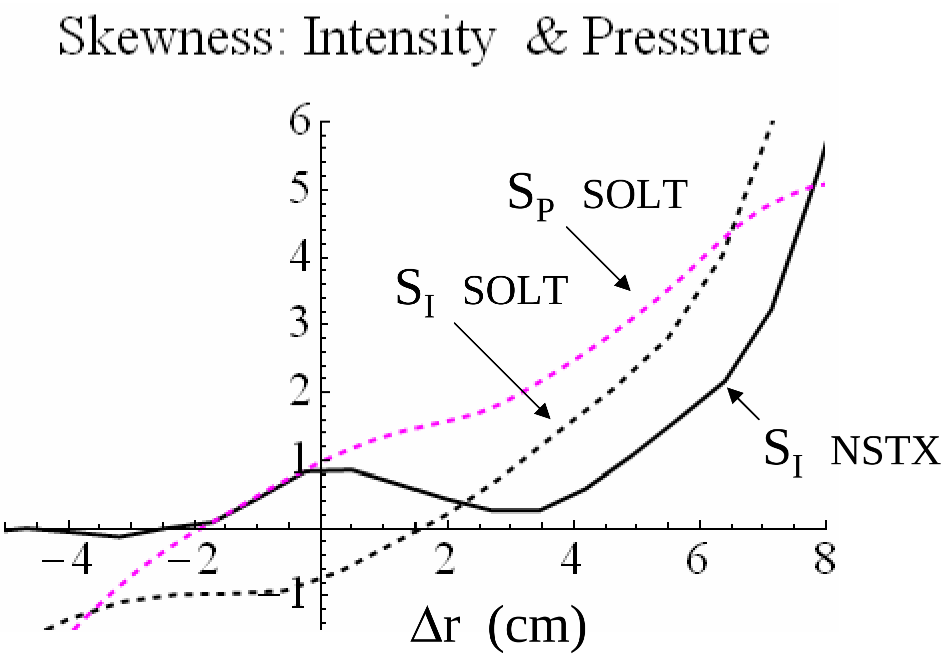
2. Radial Profile of GPI Intensity



- Simulated and measured data are treated in the same way (smoothed); maximum I normalized to unity
- Profiles are sensitive to location and strength of **sheath conductivity α_{sh}**
- in simulation, field lines terminate in sheaths for $\Delta r > 4.5$ cm
- Peak of intensity agrees with data but I(x) is too small in sheath region $\Rightarrow$ **α_{sh} is too large in this run**

(further optimization is possible)

3. Skewness profile $S_I(x)$



$$S_I(\Delta r) = \frac{\left\langle \left(I(\Delta r, y, t) - \langle I \rangle_{y,t} \right)^3 \right\rangle_{y,t}}{\left\langle \left(I(\Delta r, y, t) - \langle I \rangle_{y,t} \right)^2 \right\rangle^{3/2}}$$

- **I ∝ radiation function, non-monotonic in $T_e \Rightarrow S_I < 0$ when $T_e > T_{crit}$**
- **T_e in simulation too large outside LCS ($\Delta r > 0$) due to turbulent heat transport.**
- ***Source and dissipation parameters are constrained by requirement that $S_I > 0$ near LCS***

Reasonable agreement is obtained in region where fluctuations are large

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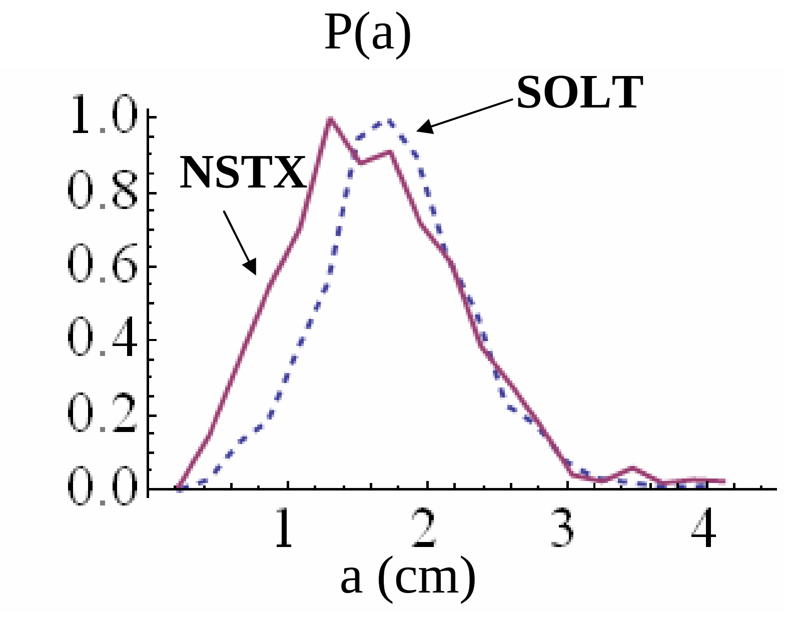
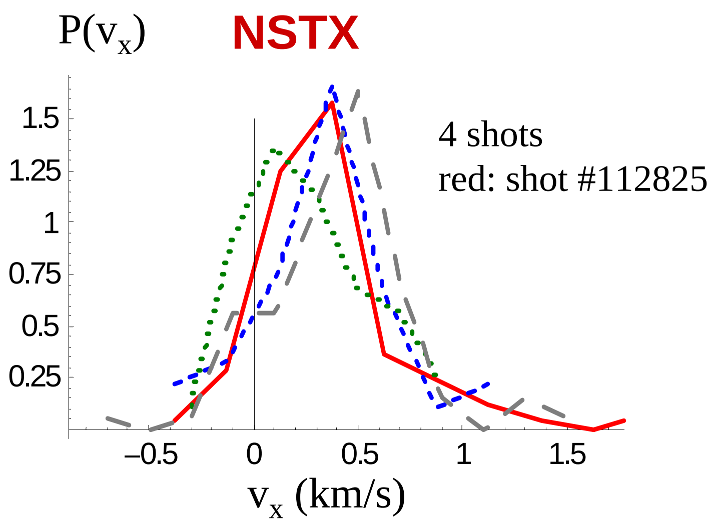
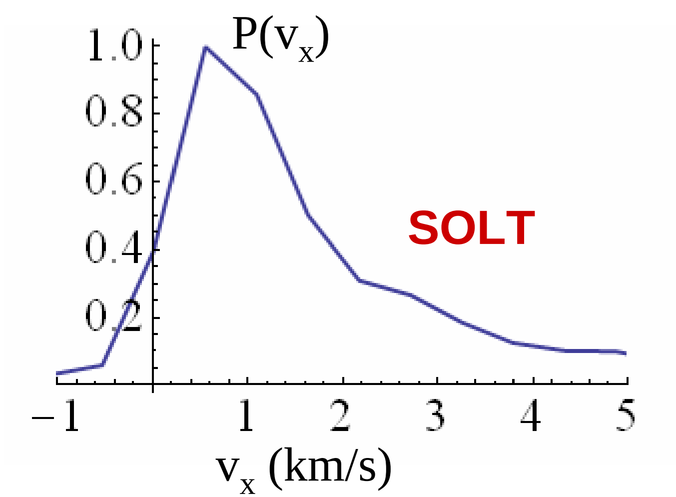
4. Blob statistics: PDFs of blob size



- good agreement between simulation and experiment for peak blob size and width of PDF.
- analysis covers a spatial range $0 < \Delta r < 10$ cm and a time slice of 1200 μs
- both NSTX and SOLT data were processed in the same way
- detailed shape of PDF and location of peak is sensitive to the method of processing (e.g. amount of smoothing)

4. Blob statistics: PDFs of blob velocity





- v_x (data) is the **kinematic velocity** of the intensity blob;
- v_x (SOLT) is the **E × B velocity**
- v_x (SOLT) peak agrees but **the distribution is wider**
- possible explanation: turbulence too strong in simulation (too far from marginal stability)
- future work: kinematic v_x (data & SOLT) will also be calculated using Tobin Munsat's optical algorithm

Summary

- A detailed study of one NSTX shot gives reasonable agreement between simulated GPI emission in the SOLT 2D turbulence code and the GPI measurements.
- We are learning how the experimental profiles constrain the simulation parameters in the optimization.
- The simulated turbulence is sensitive to parameters that control how close the system is to marginal stability, e.g. through sheared flows and dissipation. The simulated GPI signal is sensitive to $T_e(x)$ and $n_0(x)$.
- It is essential to analyze the simulation and diagnostic data using exactly the same numerical algorithms!
- The analysis of one shot is very time consuming. Can it be streamlined and parts of it automated?
- Future plans: extend this analysis to other shots with different B and ∇p (new work by Lundberg and Stotler allow use of D gas puffing shots)