

## INSIDE THIS ISSUE

(3 Pages)

Topic	Page No.
-------	----------

## Research Highlight

Edge Biasing and its Impact on the Edge and SOL Turbulence	1
--	---

## HPC Article Series

Running MATLAB Programs on ANTya — Part-4: Using MATLAB Compiler for Compiling Your MATLAB Code	2
---	---

## ANTYA Updates and News

HPC Picture of the Month	2
--------------------------	---

## Tip of the Month

New Portal to Check License Status of Commercially Licensed Applications on ANTya	3
---	---

ANTYA HPC Users' Statistics — MARCH	3
--	---

Other Recent Work on HPC (Available in IPR Library)	3
--	---

## GANANAM (गणनम्)

HIGH PERFORMANCE COMPUTING NEWSLETTER

INSTITUTE FOR PLASMA RESEARCH, INDIA



## Edge Biasing and its Impact on the Edge and SOL Turbulence

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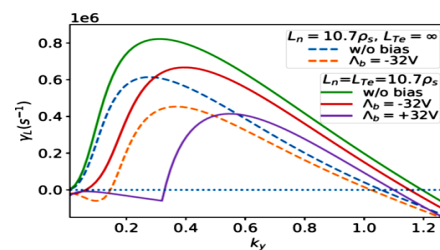


Figure 1: The linear growth rate  $\gamma_L$  vs  $k_y$  on the biasing region is at  $x=1.68$  cm. The uniform temperature  $L_{Te} = \infty$  and finite electron temperature gradient are represented by dashed and solid lines. Horizontal dotted line represents  $\gamma_L=0$ .

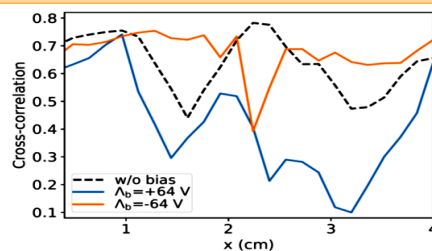


Figure 3: Radial variation of cross-correlation coefficient between fluctuations of  $n$  and  $E_y$  as a function of radial positions at  $L_y/2$  poloidal position.

voltage on them. The linear growth rate  $\gamma_L$  using three different cases ( $\pm 32$  Volts and without (w/o) bias) has been plotted in Fig.1 (represented by solid lines) as a function of  $k_y$  for  $L_n = L_{Te} \sim 10.7\rho_s$  at the position of biasing. Here  $\Lambda_b$  has been expressed in Volts. The two different cases of  $\gamma_L$  for uniform temperature ( $T_e = 1$ ) with the same  $L_n$  and  $L_{Te} = \infty$  also have been shown

in the same figure (represented by dashed lines) to compare the growth rate. It is found that the inclusion of electron temperature gradient increases the growth rate. It can be seen that the growth rate for lower  $k_y$  is lower or even negative compared to w/o biasing for both uniform and non-uniform  $T_e$ . This indicates that the biasing gives stabilization to lower  $k_y$  or large-scale modes. Also, it can be seen that the peak of  $\gamma_L$  in biasing case shifted towards higher  $k_y$  or small scale modes. This indicates that biasing induces turbulence into smaller scales.

A numerical code has been developed to solve the non-linear equations numerically using the BOUT++ framework that uses MPI parallelization. Grid resolution taken here is  $N_x \times N_y = 128 \times 128$  and the code has been run for 200000-time steps using 32 cores of the HPC cluster ANTya which takes almost four hours to complete. We have used flux-driven model

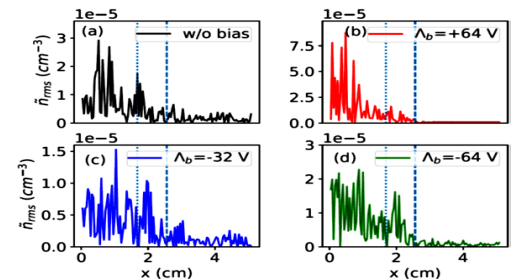


Figure 2: The radial profile of root means square (rms) of density fluctuations for with and w/o bias. Density fluctuations have been obtained as a function of  $x$  using a long time and poloidal average ( $x=0$  represents the beginning of the edge region).

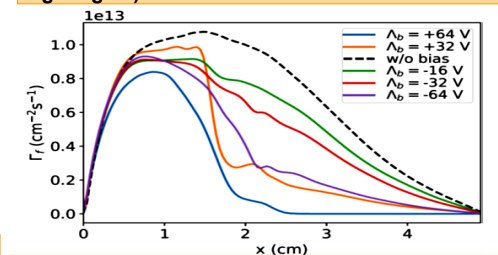


Figure 4: The radial profile of flux ( $\Gamma_r$ ) for different bias voltages. Flux in the presence of biasing for both polarities is lower than the w/o bias.

equations for nonlinear simulations. Results are obtained for both positive and negative biasing and compared in the absence of bias. The numerical simulations using this model show that positive edge biasing is more effective than negative edge biasing in controlling turbulence. Fluctuations of the plasma density data have been analyzed (shown in Fig.2, Vertical dashed line at  $x=2.56$  cm represents the position of LCFS and the vertical dotted line at  $x=1.68$  cm represents the position of the electrode), where it has been found that the fluctuations increase in the presence of positive biasing and decrease slightly in the presence of negative biasing. But radially outward flux decreases in both the cases of biasing (shown in Fig.4). Reduction of flux in case of positive bias is mainly due to the decrease of cross-correlation (shown in Fig.3) between the plasma density and poloidal electric field fluctuations. The reduction of flux in the case of negative biasing is attributed to a decrease in density fluctuations.

## References:

1. N. Bisai, A. Das, S. Deshpande, et.al; Physics of Plasmas, 11(8):4018-4024, August 2004.
2. Ph Ghendrih, Y Sarazin, G Attuel, et.al; Nuclear Fusion, 43(10):1013-1022, sep 2003.
3. Y. Sarazin and Ph. Ghendrih. Physics of Plasmas, 5 (12):4214-4228, December 1998.
4. Harshita Raj, Tanmay Macwan, Kaushalender Singh, et. al; Nuclear Fusion, 60(3):036012, feb 2020.

The boundary region of a tokamak is highly turbulent due to mainly unstable interchange modes [1-3]. The presence of such turbulence is suspected to be the primary cause for the occurrence of anomalous radial transport in this region. Therefore, to control this transport and to improve the confinement time we need to control the interchange instability. For this purpose, various approaches have been taken in the past, such as the use of gas puffs [4], and biasing the plasma with the help of electrodes in the tokamak boundary region. The tokamak boundary region consists of edge and scrape-off layer (SOL) regions. In the edge region, the toroidal magnetic field lines are closed and form nested helical flux surfaces. In the SOL region, the magnetic field lines normally open into the divertor or limiter material plates. The unstable interchange plasma is present in these two regions as the density/pressure gradient is in the opposite direction of

**“Electrode biasing in the edge region reduces radial flux in case of both the biasing (positive/negative) with positive biasing being more effective”**

the force experienced by the rapid toroidal motion of the plasma in the low magnetic field side of the tokamak. The biasing in these regions can be done in several ways e.g., divertor biasing, limiter biasing, emissive probe biasing, and electrode biasing. In this work, biasing of the edge region (edge biasing) has been done by putting an electrode in the edge region. The edge biasing imposes an external electric field shear in the radial direction, which causes higher zonal flows and hence stabilizes plasma turbulence and reduces the anomalous plasma transport in the edge and SOL regions. Our study is based on a two-dimensional (2D) fluid model of the edge and SOL regions that support unstable interchange modes. The model equations are suitably extended to include an electrode biasing term.

A perturbative analysis using a FORTRAN-based code is first carried out to determine the linear growth rates and assess the influence of the bias

## Running MATLAB Programs on ANTya

### Part-4: Using MATLAB Compiler for Compiling Your MATLAB Code

This part-4 of the MATLAB article series demonstrates how the MATLAB compiler can be used to compile your MATLAB codes on ANTya. While running the MATLAB job using the MATLAB compiled executable, there is an added advantage of no MATLAB license restriction.

"A MATLAB code compiled into a standalone executable will never fail due to MATLAB license unavailability"

"Hundreds of concurrent runs are possible with standalone executable without facing license limitations"

"Executable can be run on any machine not have access to MATLAB"

"It can be shared with other users protecting/hiding your source code"

### How to Implement in ANTya?

We will compile both the examples shown in the MATLAB article in issue 16, one of matrix multiplication code and the other of plotting code in MATLAB. We will first compile and make standalone executables for both the codes and then show how these two executables can be run without MATLAB.

**# Example-1: For compiling the program, load the MATLAB module first. This will enable the MATLAB compiler "mcc" in your path.**

```
[user@login1 ~]$ module load MATLAB/2016a
```

**# Step-1: Compile the matrix multiplication MATLAB script/code (.m file). This will generate the "matrix\_multi\_exe" standalone executable. The name can be chosen as per choice. The compilation flags "-mv" also shows actions taken during compilation.**

```
[user@login1 ~]$ mcc -mv -o matrix_multi_exe matrix_multiplication.m
```

Compiler\_logs:

Compiler version: 6.2 (R2016a)

Dependency analysis by REQUIREMENTS.

Parsing file "/scratch/scratch\_run/user/matrix\_multiplication.m"

(Referenced from: "Compiler Command Line").

Deleting 0 temporary MEX authorization files.

Generating file "/scratch/scratch\_run/user/readme.txt".

Generating file "run\_matrix\_multiplication.sh".

**#Step-2: Once the standalone executable is obtained, unload the MATLAB module and load the Compiler runtime module mcr/2016a.**

```
[user@login1 ~]$ module unload MATLAB/2016a
```

```
[user@login1 ~]$ module load mcr/2016a
```

```
[user@login1 ~]$ module list
```

Currently Loaded Modulefiles:

```
1) shared 2) mcr/2016a
```

**# Step-3: Test the standalone executable without any MATLAB module in PATH**

```
[user@login1 ~]$ ./matrix_multi_exe
```

Processing time: 1.4748

**# Example-2: Similarly compile and run the testplot.m code for generating a testplot.png image. Step-1: Compile with MATLAB module loaded.**

```
[user@login1 ~]$ mcc -mv -o testplot_exe testplot.m
```

**# Step-2: Run the standalone executable after unloading MATLAB module and loading mcr/2016a module.**

```
[user@login1 ~]$ ./testplot_exe
testplot.png file is generated
```

## ANTYA UPDATES AND NEWS

### 1. New Packages/Applications Installed

#### ⇒ MATLAB Compiler Runtime Module

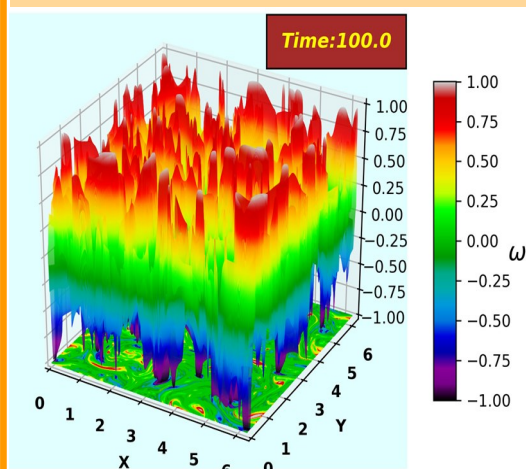
For running the MATLAB code executables without the need of MATLAB software licenses. **mcr/2016a**

#### ⇒ The Open-Source Multiphysics Object-Oriented Simulation Environment (MOOSE) testing module

It uses a conda based environment setup for which the base module mamba has been created. The base module is available. **mamba**

## HPC PICTURE OF THE MONTH

### Long Time Relaxation of 2D Navier-Stokes Turbulence



Pic Credit: **Shishir Biswas**

The figure shows a 3D surface plot along with the 2D plane projection of vorticity evolution. It is generated from In-house developed incompressible hydrodynamic GPU solver GMHD2D.

[Ref: (Under Review) Shishir Biswas and Rajaraman Ganesh, Long time fate of 2-dimensional incompressible High Reynolds number Navier-Stokes turbulence: a quantitative comparison between theory and simulation]

For Visualization an in-house developed Python Script has been used on the Visualization node of ANTya. The time taken for performing this simulation to get the data for a grid size of 2048x2048 is 100.5 Hours in a single GPU P100 card on ANTya GPU node.

## TIP OF THE MONTH

Did you know that Intel Parallel Studio XE Cluster Edition transitioned into Intel oneAPI Toolkits? So from intel-2020 onwards, intel updates will be only in oneAPI modules.

**Intel modules => oneAPI modules**

## New Portal to Check License Status of Commercially Licensed Applications on ANTYA

All the commercially licensed applications available for use on ANTYA have their license status and features details along with the license servers on a new portal. This portal can help you to identify the availability of a particular license and who else is/are using that license.

This single portal shows license usage details of ANSYS, COMSOL, MATLAB, CST, IDL8, STARTCCM+ and Xilinx.

*The portal can be accessed here*

<http://licensewatch.ipr.res.in/lwm/>

## ANTYA HPC USERS' STATISTICS— MARCH

♦ **Total Successful Jobs — 7492**

♦ **Top Users (Cumulative Resources):**

- **CPU Cores** **Amit Singh**
- **GPU Cards** **Suruj Kalita**
- **Walltime** **Someswar Dutta**
- **Jobs** **Someswar Dutta**

## Other Recent Work on HPC (Available in IPR Library)

Microscopic structure of electromagnetic whistler wave damping by kinetic mechanisms in hot magnetized Vlasov plasmas	<b>ANJAN KUMAR PAUL</b>
3D Thermo-fluid MHD analysis of the test mock up with multichannel flow configurations	<b>ANITA PATEL</b>
Influence of diameter and density on the agglomerated nano particle trap efficiency by acoustic field	<b>KANDADA SATYA PRAKASH RAGHUNATH REDDY</b>
Signatures of an energetic charge bunch moving in a plasma	<b>VIKRAM SINGH DHARODI</b>
Utilization of Fission Reactors for Fusion Reactor Material Development	<b>MAYA P. N.</b>
Molecular Dynamics of Active Complex Plasmas	<b>SOUMEN DE KARMAKAR</b>
Ratchet driven transport - A novel paradigm of statistical thermodynamics in 2D Complex Plasmas	<b>ANSHIKA CHUGH</b>
From Rayleigh-Bénard Convection Cells To Shear Flows: A Molecular Dynamics Study Of 2d Yukawa Liquids	<b>PAWANDEEP KAUR</b>
Perturbed plane Couette flow in 3D Yukawa liquids : A Molecular Dynamics study	<b>SURUJ JYOTI KALITA</b>
Strongly coupled rotating dust flow analysis within the Quasi-localized charge approximation (QLCA) framework	<b>PRINCE KUMAR</b>
Investigating the effects of electron bounce-cyclotron resonance on plasma dynamics in capacitive discharges operated in the presence of a weak transverse magnetic field	<b>SARVESHWAR SHARMA</b>
Finite element analyses of Double sided Linear Induction Motor in Electro-Magnetic Launching Application	<b>ANANYA KUNDU</b>
A methodology for quantification of material damage from transmutations in fusion materials using appropriate models and tools	<b>AKASH GARG AGARWAL</b>
Engineering Design Report of Prototype Center Stack	<b>ADITYA KUMAR VERMA</b>

## Acknowledgement

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Please send your request to  
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