# Nonlinear interactions of Rossby waves and large-scale zonal flow formation in two-dimensional turbulence on a rotating sphere.

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## Abstract

Two-dimensional barotropic model on a rotating sphere is one of the simplest mathematical models describing the dynamics of planetary atmospheres. The two-dimensional turbulence shows the spontaneous formation of large-scale zonal flows similar to those seen on giant gas planets such as Jupiter. However, this mechanism has not been fully clarified yet. The aim of this study is to understand the formation mechanism of zonal flows by investigating in detail the non-linear interactions of Rossby wave solutions, which is characteristic of this system.

## Reasons and benefits of using JAXA Supercomputer System

Since the research group with which we might collaborate had an account on the JAXA supercomputing system, we considered it desirable to use this system for sharing data in case of collaboration. Also, as the research was a continuation of the previous year's research and most of the data required was located on the JAXA supercomputing system, we wished to continue using the system.

## Achievements of the Year

The effect of three-wave nonlinear interactions of Rossby waves on large-scale zonal flow formation in two-dimensional turbulence on a rotating sphere was investigated. We considered near-resonant, far-resonant, local, and non-local three-wave nonlinear interactions of Rossby waves, and calculated energy transfer to large-scale zonal flow components by each type of interaction, to clarify the nonlinear interactions involved in the formation of large-scale zonal flows. It was found that energy is directly transfered to large-scale zonal flows by near-resonant interactions and non-local interactions. Since the near-resonance and non-localness are completely different concepts, we further investigated the relation between near-resonant and non-local interactions. Then it was suggested that the sets of near-reosnant interactions and non-local interactions almost completely coincide in the considered system, so that the dyrect factor of the formation of large-scale zonal flow is the non-local energy

transfer by near-resonant interactions fo Rossby waves.

## Publications

- Peer-reviewed papers

Yusuke Hagimori, Kiori Obuse, and Michio Yamada, "Effect of non-local near-resonant interactions of Rossby waves on formation of large-scale zonal flows in unforced two-dimensional turbulence on rotating sphere", Physics of Fluids, accepted.

- Invited Presentations

1) Kiori Obuse, Yusuke Hagimori, and Michio Yamada, "Formation of large-scale zonal flows in two-dimensional turbulence on a rotating sphere', Layering - A structure formation mechanism in oceans, atmospheres, active fluids and plasmas, Isaac Newton Institute Cambridge University, 15th-19th January 2024

2) Kiori Obuse, Yusuke Hagimori, and Michio Yamada, "Formation of zonal flows and Rossby wave nonlinear interactions in two-dimensional turbulence on a rotating sphere", AAPPS-DPP2023, Port Messe Nagoya, 13th-17th November 2023

3) Kiori Obuse, Yusuke Hagimori, and Michio Yamada, "Large-scale zonal-flow formation in two-dimensional turbulence on a rotating sphere", Fusion Plasma Seminar, Seoul National University, 17th October 2023

4) Kiori Obuse, Hagimori Yusuke, and Michio Yamada, "Zonal-flow formation and three-wave nonlinear interactions in two-dimensional turbulence on a rotating sphere", 28th NEXT workshop, Kyoto University, 2nd-3rd Auguust, 2023

5)Kiori Obuse, Yusuke Hagimori, and Michio Yamada, “Rossby wave nonlinear interactions and large-scale zonal flow formation in two-dimensional turbulence on a rotating sphere”, The Grad Conjecture in Fluid Mechanics and Magnetohydrodynamics: Theory and Applications, I-site Namba, 26th-28th March 2024

## Usage of JSS

### Computational Information

| | |
|---|---|
| Process Parallelization Methods | N/A |
| Thread Parallelization Methods | N/A |
| Number of Processes | 1 |
| Elapsed Time per Case | 24 Hour(s) |

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.00

Details

| Computational Resources | | |
|---|---|---|
| System Name | CPU Resources Used (core x hours) | Fraction of Usage[*2](%) |
| TOKI-SORA | 93,409.07 | 0.00 |
| TOKI-ST | 6.24 | 0.00 |
| TOKI-GP | 43.58 | 0.00 |
| TOKI-XM | 0.00 | 0.00 |
| TOKI-LM | 0.00 | 0.00 |
| TOKI-TST | 0.00 | 0.00 |
| TOKI-TGP | 0.00 | 0.00 |
| TOKI-TLM | 0.00 | 0.00 |

| File System Resources | | |
|---|---|---|
| File System Name | Storage Assigned (GiB) | Fraction of Usage[*2] (%) |
| /home | 140.00 | 0.12 |
| /data and /data2 | 10,240.00 | 0.06 |
| /ssd | 0.00 | 0.00 |

| Archiver Resources | | |
|---|---|---|
| Archiver Name | Storage Used (TiB) | Fraction of Usage[*2] (%) |
| J-SPACE | 0.00 | 0.00 |

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

| ISV Software Licenses Resources | | |
|---|---|---|
| | ISV Software Licenses Used (Hours) | Fraction of Usage[*2] (%) |
| ISV Software Licenses (Total) | 0.00 | 0.00 |

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.