

Contents

1. Introduction	1
2. The Natural Phenomena Simulated in Rotating Shallow Water Experiments	5
2.1 Length, Rotation Velocity, and Lifetime of the Structures	5
2.2 Large-Scale, Long-Lived Rossby Vortices in the Atmospheres of Giant Planets.	
The Cyclone-Anticyclone Asymmetry	13
2.3 Rossby Vortices in the Oceans	19
2.3.1 Open Sea Vortices	20
2.3.2 Rings of the Gulf Stream and the Kuroshio Current	21
2.3.3 Internal Thermoclinic Vortices (Lenses)	24
2.4 Spiral Structures in Galaxies	26
3. Common Features of the Simulated Natural Phenomena	31
3.1 Quasi-Two-Dimensionality	31
3.2 Structure Generation by Flows with Horizontal Velocity Shear	32
3.3 Horizontal Dimensions Exceeding the Characteristic Rossby Radius	33
4. Physical Prerequisites of the Laboratory Simulation of Large-Scale Rossby Vortices and Galactic Spiral Structures	35
4.1 The Analogy Between Two-Dimensional Gas Dynamics and the Dynamics of Shallow Water	35
4.1.1 Theory	35
4.1.2 Experiment	37
4.2 Principal Similarity Parameters in Nature and Experiment ..	38
5. Physical Basis for the Experimental Investigation of Rossby Solitons and Laboratory Simulation of Drift Vortices and Solitons in Magnetized Plasma	43
5.1 Two-Dimensional Motion of Charged Particles in Magnetized Plasma and Particles in Rotating Shallow Water	43

5.2	General Nonlinear Equation for Drift Motion	44
5.3	Linear Rossby Waves and Plasma Drift Waves	48
5.4	Linear Packet of Rossby Waves and the Time of its Dispersion Decay. Definition of a Soliton	52
5.5	Nonlinear Rossby Waves: Vortices and Solitons	55
5.6	Viscous Damping of Rossby Vortices	65
6.	Experimental Configurations	67
6.1	Geometry and Rotation Regime of the Vessels for the Observation of Rossby Solitons	67
6.2	Techniques for Local Generation of Rossby Vortices	73
6.3	Devices for Generating Rossby Vortices by Counterflows ..	74
6.4	Devices for the Simulation of Galactic Spiral Structures ..	76
6.5	Diagnostic Techniques	79
7.	Laboratory Simulation of Rossby Vortices and Solitons in Planetary Atmospheres and Oceans	81
7.1	Generation of Rossby Vortex Chains by Zonal Counterflows in Rotating Shallow Water. The Cyclone-Anticyclone Asymmetry	81
7.2	Self-Organizing Solitary Anticyclonic Rossby Vortex in Zonal Flows as a Model of Jovian Great Red Spot	88
7.3	Regularity in the Generation of Chains with Different Numbers of Vortices and the Problems of Uniqueness and Stationarity of the JGRS ..	93
7.4	Two- and Three-Dimensional Models of the JGRS	97
7.5	Alternative JGRS Laboratory Models	99
7.6	Stationary Rossby Vortices in Flows and the Blocking Phenomenon	103
8.	Laboratory Simulation of Galactic Spiral Structures	107
8.1	Generation of Spiral Structures in Differentially Rotating Shallow Water	107
8.2	Spiral-Vortex Structures	110
8.3	The Common Mechanism Generating Solitary Rossby Vortices in Planetary Atmospheres and Spirals in Galaxies ..	115
8.4	Asymmetrical and Outbranching Spirals	117
8.5	The Influence of Viscosity and Friction	119
8.6	Laboratory Simulation and Astronomical Observations. Predictions for Astronomers	123
9.	Rossby Vortices and Solitons in Free Motion	129
9.1	A Short History of the Experiments	129
9.2	Rossby Solitons in the Laboratory and Their Properties ...	131

9.3	Collisions of Rossby Vortices	139
9.4	Cyclone-Anticyclone Asymmetry	139
9.5	Quasi-Two-Dimensionality of Rossby Vortices. The Non-Principal Role of Viscosity	147
9.6	Vortex-Wave Dualism	149
9.7	Comparison between Experiment and Theory	150
10.	Solitonic Model of Natural Vortices	155
10.1	Solitonic Model of the JGRS and Other Large-Scale, Long-Lived Vortices in Planetary Atmospheres	155
10.2	An Alternative Model of the JGRS: Numerical Calculation	159
10.3	Solitonic Vortices in the Oceans	161
11.	Dipolar Rossby Vortices	165
11.1	Preliminary Experiments	165
11.2	Dipolar Vortex Decay for Moderate Liquid Depths	166
11.3	Solitonic Properties of Dipolar Vortices for Large Liquid Depths	167
12.	Shallow-Water Simulation of Drift Vortices and Solitons in Magnetized Plasma	177
12.1	Prediction of Drift Soliton Properties Based on Shallow-Water Simulation. Drawbacks of the “Purely Wave” Concept	177
12.2	Vortical Mechanism for the Enhanced Diffusion of Plasma Across a Strong Magnetic Field	180
13.	Conclusion	185
S.	Supplements	189
References	207
Subject Index	221