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Global regularity for the tropical climate model with fractional diffusion on barotropic mode

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Abstract

In this paper, we study the global regularity for the tropical climate model with fractional diffusion on barotropic mode with $\alpha \geq \frac{5}{2}$.

Mathematics Subject Classification (2010): 35B65; 76W05; 35Q35

Keywords: Global regularity; tropical climate model; fractional diffusion

1 Introduction

In this paper, we consider the following tropical climate model with fractional diffusion on barotropic mode

$$u_t + (u \cdot \nabla)u + \nabla p + \Lambda^{2\alpha} u + \mathrm{div}(v \otimes v) = 0, \tag{1.1}$$
$$v_t + (u \cdot \nabla)v + \nabla \theta + (v \cdot \nabla)u = 0, \tag{1.2}$$
$$\theta_t + (u \cdot \nabla)\theta + \mathrm{div} v = 0, \tag{1.3}$$
$$\mathrm{div}\, u = 0, \tag{1.4}$$
$$(u, v, \theta)(x, 0) = (u_0, v_0, \theta_0), \tag{1.5}$$

where $x \in \mathbb{R}^3$ and $t > 0$. $u = u(x,t)$, $v = v(x,t)$ and $\theta = \theta(x,t)$ denote the barotropic mode, the first baroclinic mode of the velocity and temperature, respectively. A fractional power of the Laplace transform, $(-\Delta)^\alpha$ is defined through the Fourier transform

$$\widehat{(-\Delta)^\alpha f}(\xi) = |\xi|^{2\alpha} \hat{f}(\xi).$$

In particular, $\Lambda = (-\Delta)^{\frac{1}{2}}$ is defined in terms of Fourier transform by $\widehat{\Lambda f}(\xi) = |\xi| \hat{f}(\xi)$.

In [1], Frierson, Majda and Pauluis derived the original version of system (1.1)-(1.5) without $\Lambda^{2\alpha} u$ by using a Galerkin truncation to the hydrostatic Boussinesq equations. For the 2D case, when $\alpha = 1$ and adding $-\Delta v$ in (1.2), Li and Titi [2] established the global well-posedness of strong solutions. They introduced a new pseudo baroclinic velocity

$$\omega = v - \nabla(-\Delta)^{-1}\theta$$