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On the Moosinesq Approximation

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ABSTRACT

Did you know moose exist? 'Cause they do, and they're on the loose!

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1. INTRODUCTION

The Boussinesq approximation is a commonly-used approximation in the field of fluid dynamics [liberal citations of authors' work here]. It has [certain advantages] and [certain disadvantages], and is ultimately recognized for its great utility in [fluids jargon here].

However, the Boussinesq approximation must be abandoned in situations where compressibility is an important consideration. This can occur in microbiology (Ravetto et al. 2014), and it has long been known that wildlife ecology is another such situation (e.g. Enright 1963). Such studies have often focused on domains in which animal compressibility is more pronounced (i.e. deep-sea life). However, motivated by a recent report of an unexpected occurrence of acute compression and deformation in a land-animal context (Gudmannsson et al. 2018)—as well as a delightful linguistic coincidence—we present ground-breaking work on fundamental fluid dynamics in the context of the moose (*Alces alces*), a domain which we dub the *moosinesq approximation*. This approximation is suitable for describing the active and dynamic inner lives and environments (both physical and mental; see Gibson 2015) of the moose.

The moose is a large mammal indigenous to North America and Europe, which can have a mass of up to 550 kg and a height of up to 2 m (CPW 2021). ... Our study is not the first time that moose have prompted significant scientific or technological development (see, e.g., Händel et al. 2009).

1.1. *Historical context*

The circumpolar distribution of Alces alces (moose) has led to multiple independent points of cultural connection to and subsequent efforts directed at harnessing the largest cervid with varying levels of success. Rock carvings in the Kalbak-Tash group, Altai Republic, Russia indicate that ab antuquo efforts to ride or cause moose to pull sleds have been documented and subsequently received comment since the Bronze Age and likely earlier (USEEV 2014). In North America, European efforts to colonize Canada have been intermittently aided by the capture of wild individual

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moose more suited to traversing long distances in snow and over boggy ground than domestic alternatives leading to practical applications such as the use of a team of moose to deliver mail by Mr. W.R. Day (of Alberta 2007). The exploitation of this practicality was limited, obviously, by the size and temperament of the moose which after about the age of 3 days is entirely antagonistic towards humans (Sipko et al. 2019). A few spectacular exceptions of moose under harness has kept hope burning for a future with a less fraught relationship. The most noteworthy partnership is widely remembered through the efforts of Albert Vaillancourt of Chelmsford, Ontario who exhibited moose pulling a surrey during the intermissions of horse racing (Chisholm 2019). His pair of racing mooses named Moose and Silver clearly demonstrated the majesty and potential of this species (Landry 1941).

This potential inspires the continuing quest for a fully domestic moose that is somewhat less likely to attack and kill humans. In Russia, moose domestication is the subject of investigations initiated by Prof. P. A. Manteifel who oversaw an effort to create moose nurseries across Russia for the purpose of creating a recognizably domestic animal from about 1934 through the present (Sipko et al. 2019). In an early, perhaps premature demonstration on December 1937, I.V. Stalin watched a military moose drill. He was, “particularly impressed by the moment when moose cavalry flew out of the forest, bristling with machine guns.” He did note that the moose were not yet trained to distinguish the Red Army soldiers from the White Finns (Pererva 2017).

2. NUMERICAL METHODS

We time-evolve the Moosinesq Equations,

$$\boldsymbol{\nabla}\cdot\boldsymbol{u} = 0,, \tag{1}$$

$$\partial_t \boldsymbol{u} + \boldsymbol{u}\cdot\boldsymbol{\nabla}\boldsymbol{u} = -\boldsymbol{\nabla}\varpi - T\boldsymbol{g} + \nu\boldsymbol{\nabla}^2\boldsymbol{u} - \gamma\mathcal{M}\boldsymbol{u},, \tag{2}$$

$$\partial_t T + \boldsymbol{u}\cdot\boldsymbol{\nabla} T = \kappa_T\boldsymbol{\nabla}^2\boldsymbol{u} - \gamma\mathcal{M}T, \tag{3}$$

which are just the Boussinesq Equations (Spiegel & Veronis 1960) with crucial Moose $\mathcal{M}$ terms in the moosementum and temperature equations Eqns. (Eqn. 2- 3). Here, $\boldsymbol{u}$ is the velocity, T is the temperature, ϖ is the reduced pressure, ν is the kinematic viscosity, κ_T is the thermal diffusivity, and γ is a frequency associated with the damping of motions. We solve these equations in polar (r, ϕ) geometry, because we are astrophysicists and this geometry is most applicable to moosive stars. We naturally choose to have gravity point down in a Cartesian sense, $\boldsymbol{g} = -g\hat{z} = -g(\sin\phi\hat{r} + \cos\phi\hat{\phi})$ for increased confusion and lack of clarity.

The Moose is implemented using the volume penalization method described in e.g., Hester et al. (2021). We first take an image of a majestic moose from the internet (Fig. 1, left[1]). We next compute a signed distance function d_s at each pixel to determine how far that pixel is from the edge of the moose. We convert that signed distance function (whose range is [-0.5, 0.5]) into a profile that varies smoothly from 0 to 1 over the moose boundaries, $\mathcal{M} = 0.5(1-\text{erf}(\pi^{1/2}d/\delta))$. We then interpolate from pixel values into polar coordinates (r, ϕ) sampled on the natural grid of our spectral bases (Fig. 1, middle). The resulting moose mask which is fed directly into our equations during timestepping is thus produced and shown in Fig. 1, right.

3. RESULTS

4. CONCLUSIONS & DISCUSSION

The methods developed in this work may suggest a pathway toward unraveling the mysteries of other wildlife-related fluid phenomena, such as the powerful and mysterious otter of Schwab (2021), also known as the Papaloizou-Pringle Patronus. Lessons learned from this and future work on the moosinesq approximation may also be of interest to those working in the yet-underexplored field of *goosinesq* convection.

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[1] Available online at https://www.publicdomainpictures.net/en/view-image.php?image=317077&picture=moose.

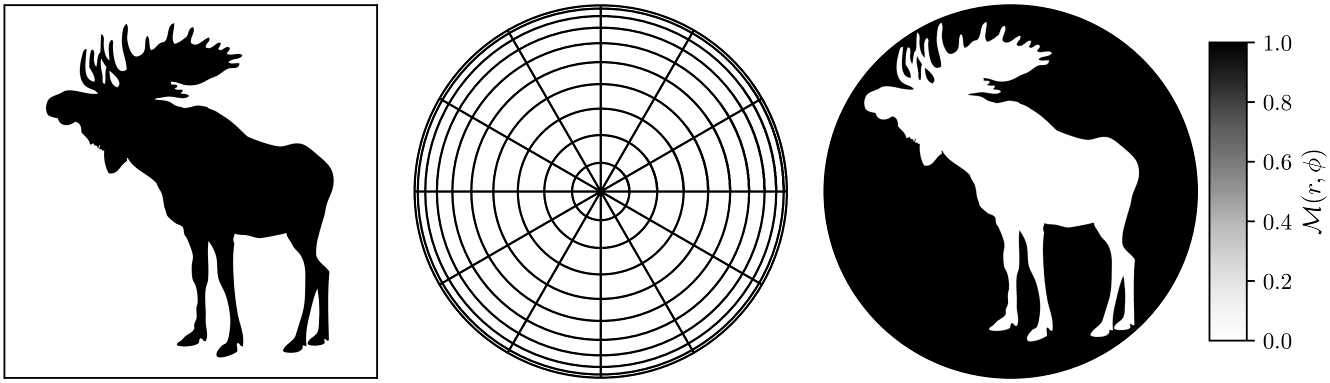

Figure 1. (Left) A public-domain silhouette of a moose. (Middle) A sparse representation of the polar-coordinate grid on which we represent fields in our simulation. (Right) The Moosinesq mask $\mathcal{M}$ felt by our equations; fluid motions are damped where $\mathcal{M} > 0$.

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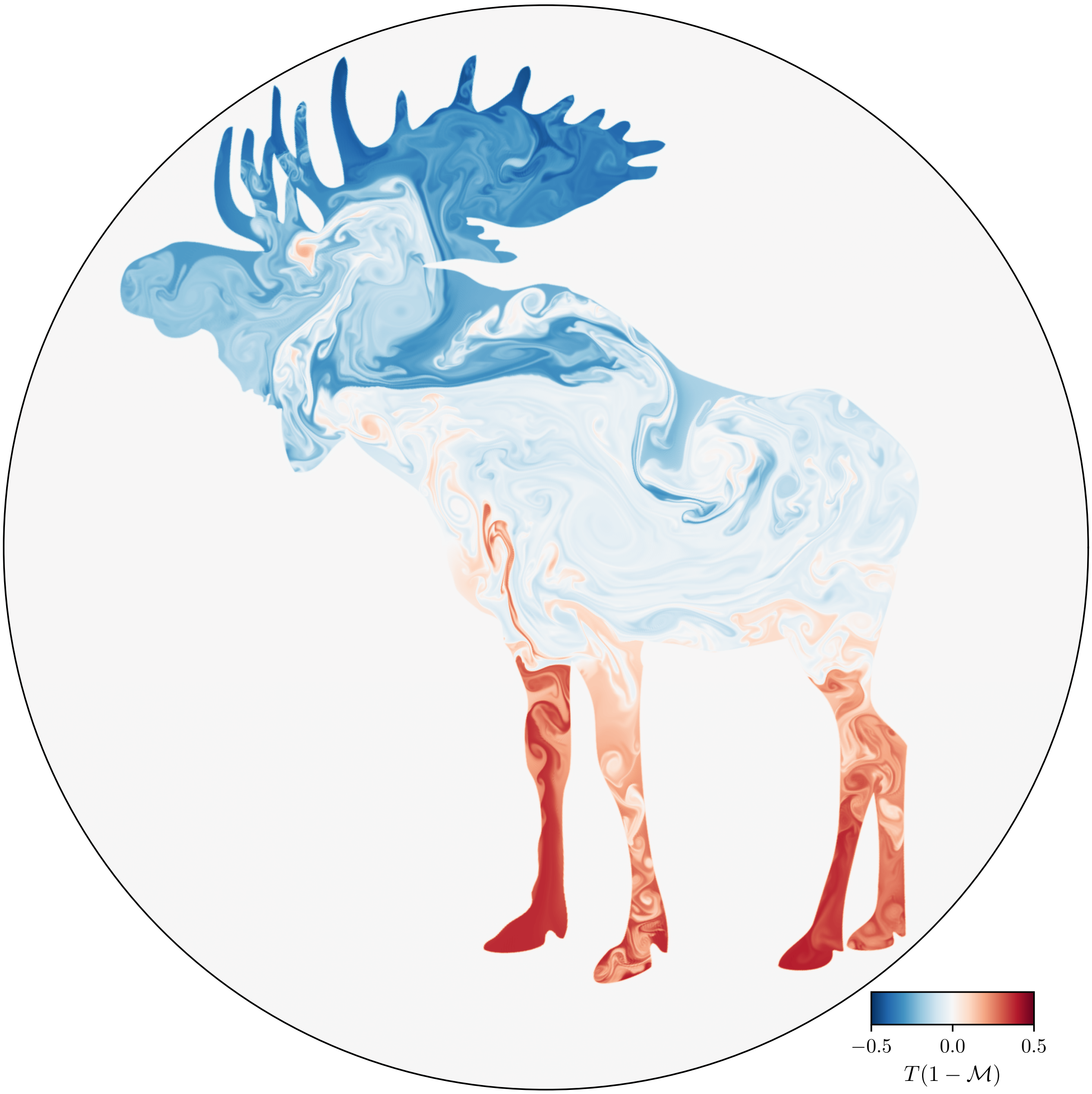

Figure 2. The beautiful, powerful moose.