High resolution LES experiment on Marian PBL

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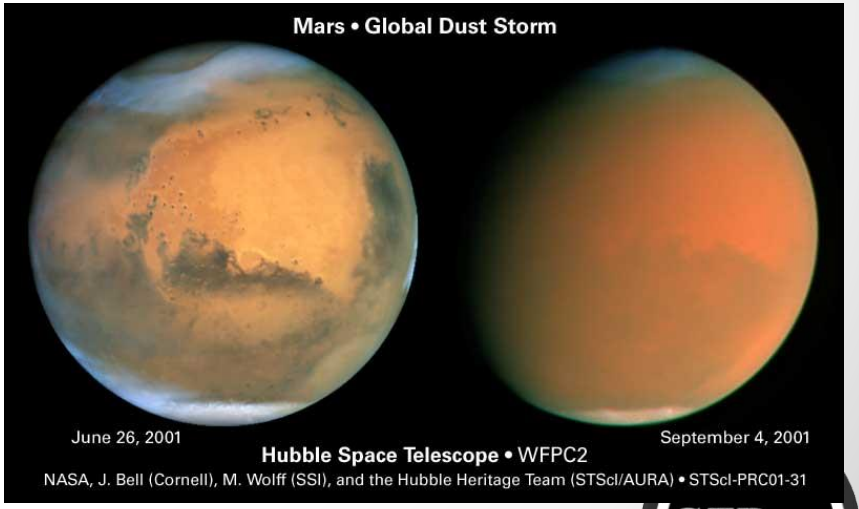
Introduction

- Martian planetary boundary layer
  - Well mixed atmospheric layer near the surface (result of heating by solar radiation)
    - Strong convection and turbulence
  - Exchange heat and materials between the ground and atmosphere
  - Lift dust (dust storm)

http://marsrovers.jpl.nasa.gov/gallery/press/spirit/20050527a.html



http://science1.nasa.gov/science-news/science-at-nasa/2001/ast11oct_2/

Introduction (Cont.)

- Purpose of this study
  - To understand
    - Turbulent statistics
    - Character of dust devil

Smaller scale variability at lower layer

High resolution simulation is necessary

Model

- SCALE-LES
  - An LES model developed by RIKEN AICS
  - Fully compressive equations
  - Open software (http://scale.aics.riken.jp/)

- Schemes used in this study
  - Dynamics: full explicit (HE-VE), 3-step RK
  - SGS turbulence: Smagorinsky type
  - Surface flux: Louis type

Experimental configurations

- Experimental configurations
  - Domain: 19.2km x 19.2km x 21km
  - Lateral boundaries: double periodic
  - Bottom boundary: flat (no topography), uniform roughness
  - Moist processes: dry condition
  - Radiation, surface temperature: external radiative heating rate and surface temperature obtained by a vertical 1D model experiment (Odaka et al. 2001)
- Experimental parameter
  - Spatial resolution
    - Δxyz: 100, 50, 25, 10, 5 m (isotropic grid)
- Initial condition
  - Vertical temperature profile (Odaka et al. 2001) + small random perturbations, steady state
  - For the 5m run, state at 14:00LT of the 10m run is used as the initial condition
- Temporal integration
  - 1 day integration from 00:00 LT (1 hour integration for the 5m run)
    - Analyses are done using 14:30LT data

Vertical velocity distribution

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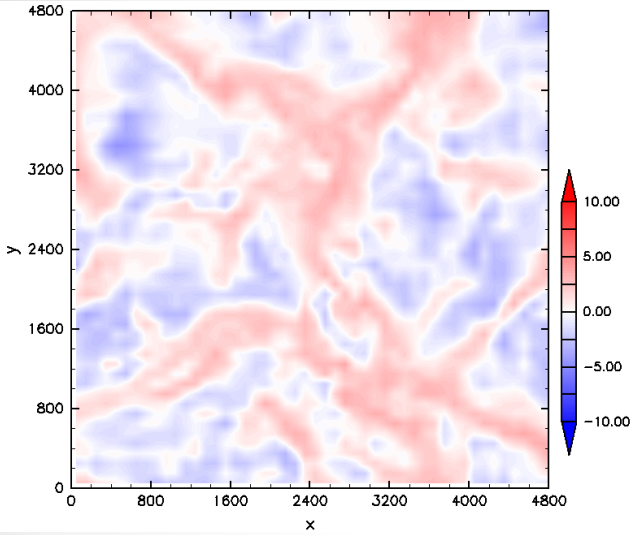
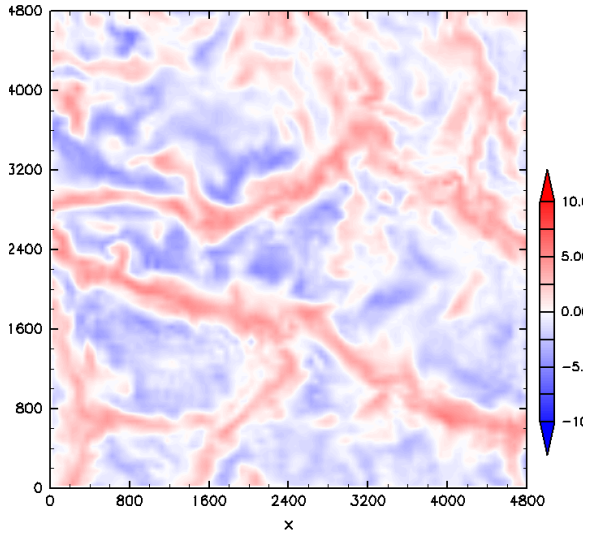
Dependency on resolution (z=200m)

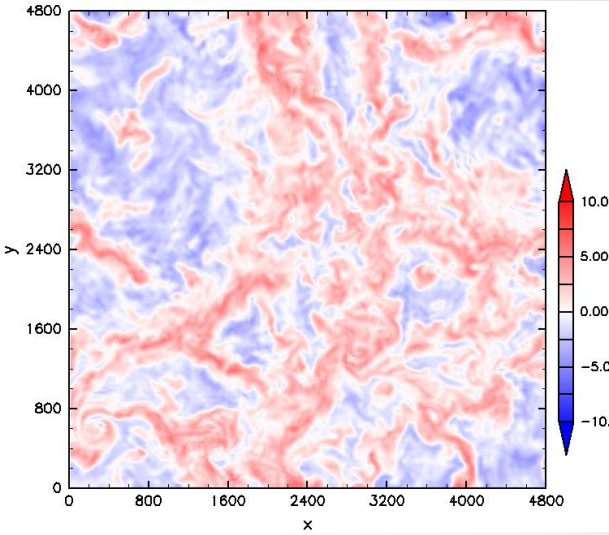
100m run



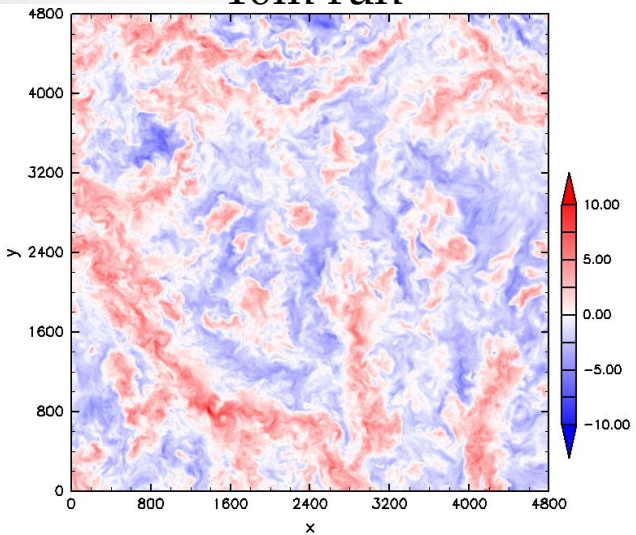
50m run



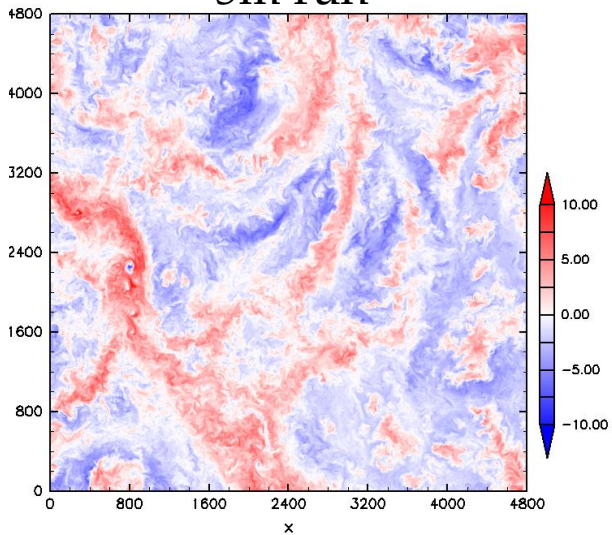
25m run



10m run

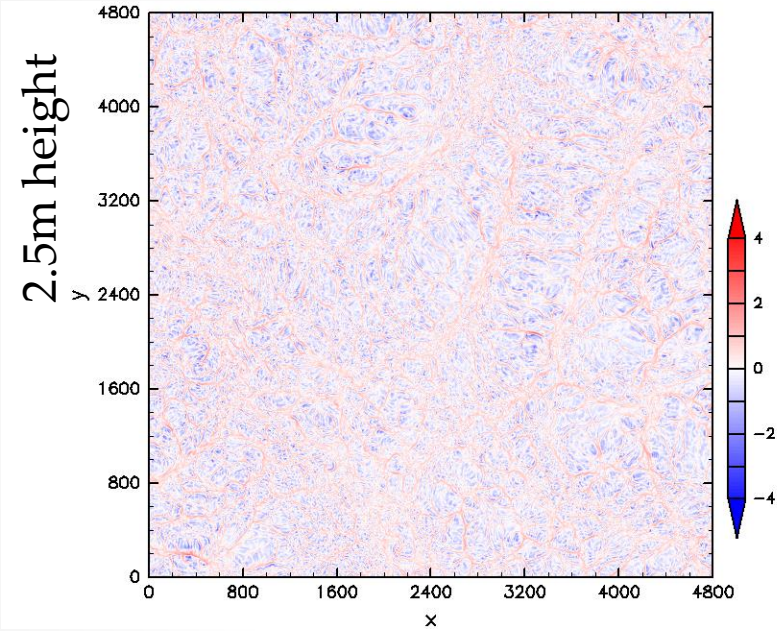


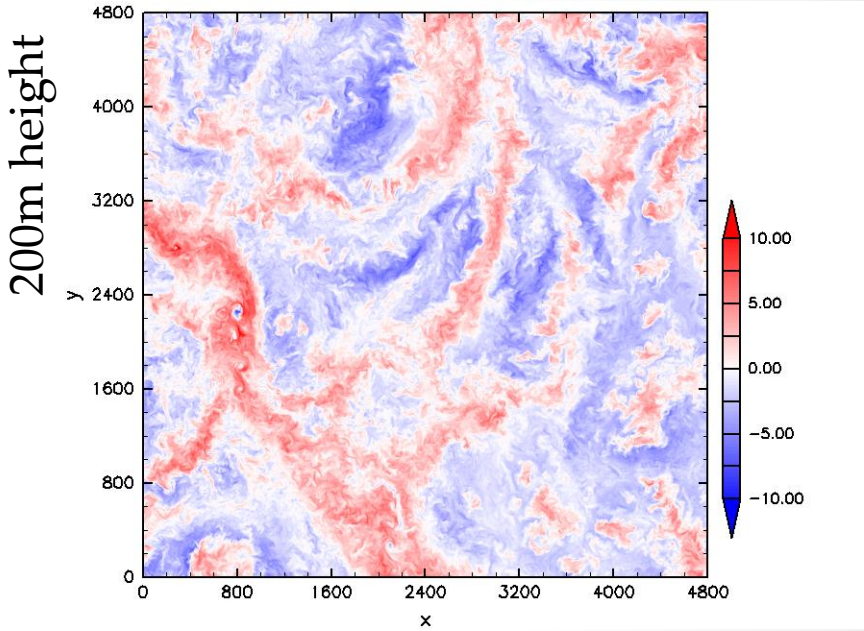
5m run



1/16 domain
14:30LT

Dependency on height (5m run)





red: upflow, blue: downflow

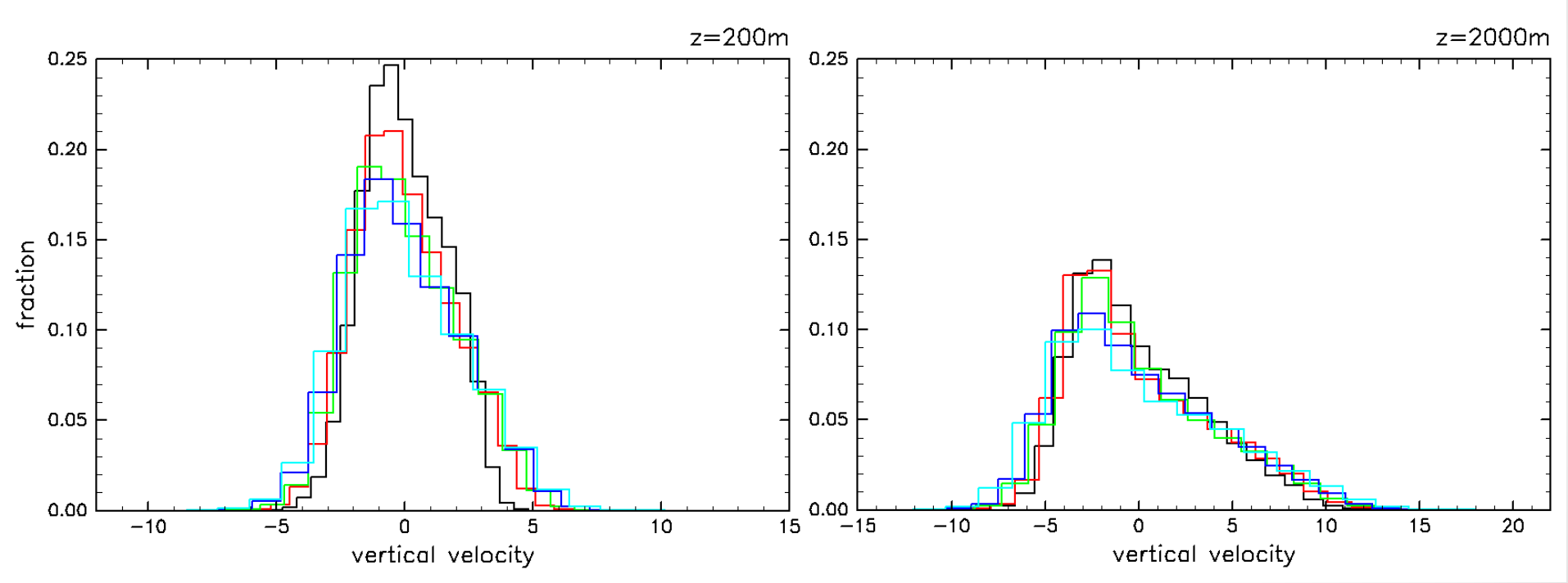
1/16 domain
14:30LT

- Narrow and strong upward flow
- Finer structure at lower level

Frequency distribution

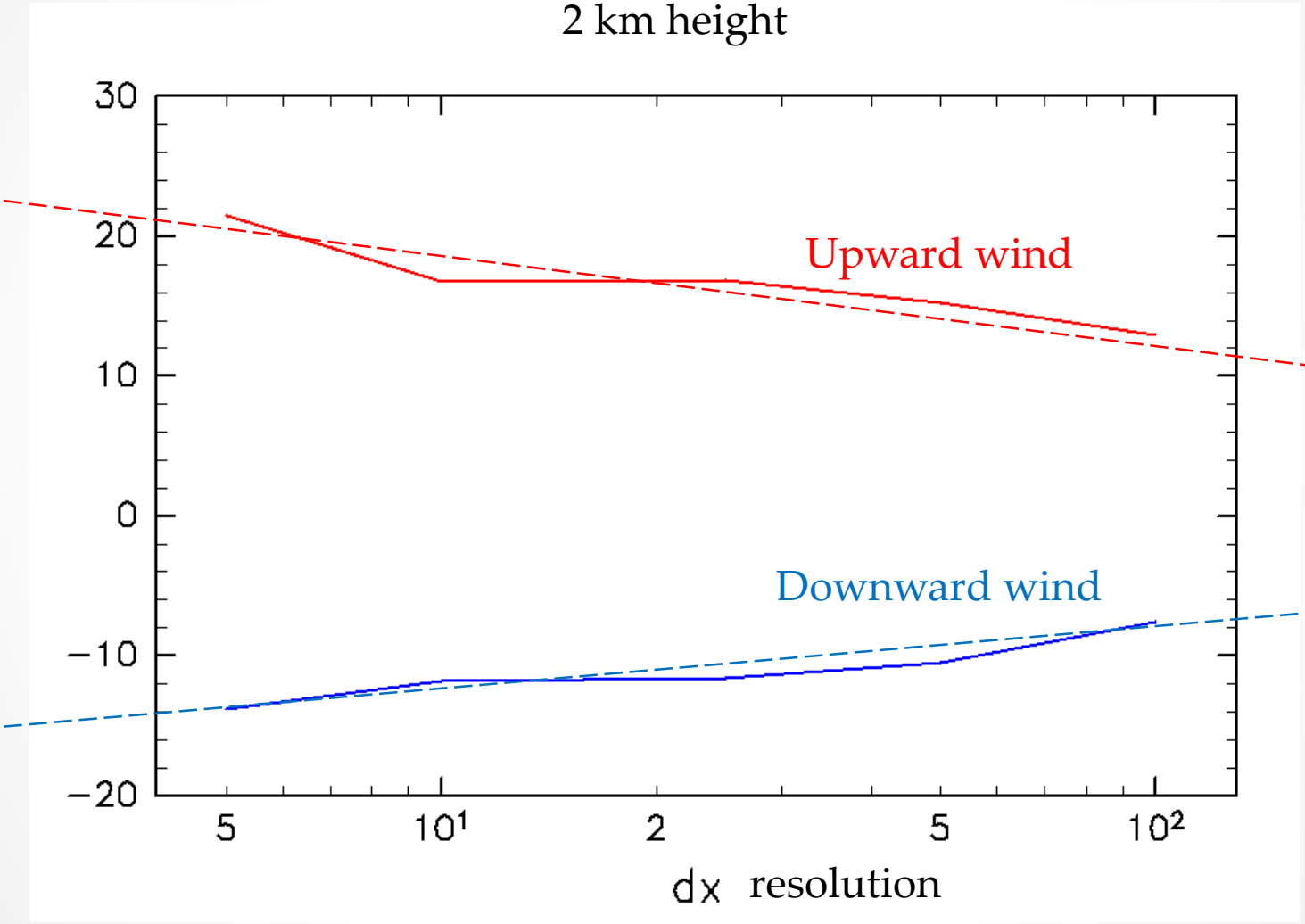
200 m height

2 km height



5m run 10m run 25m run 50m run 100m run

Maximum instantaneous vertical wind



Turbulent statistics

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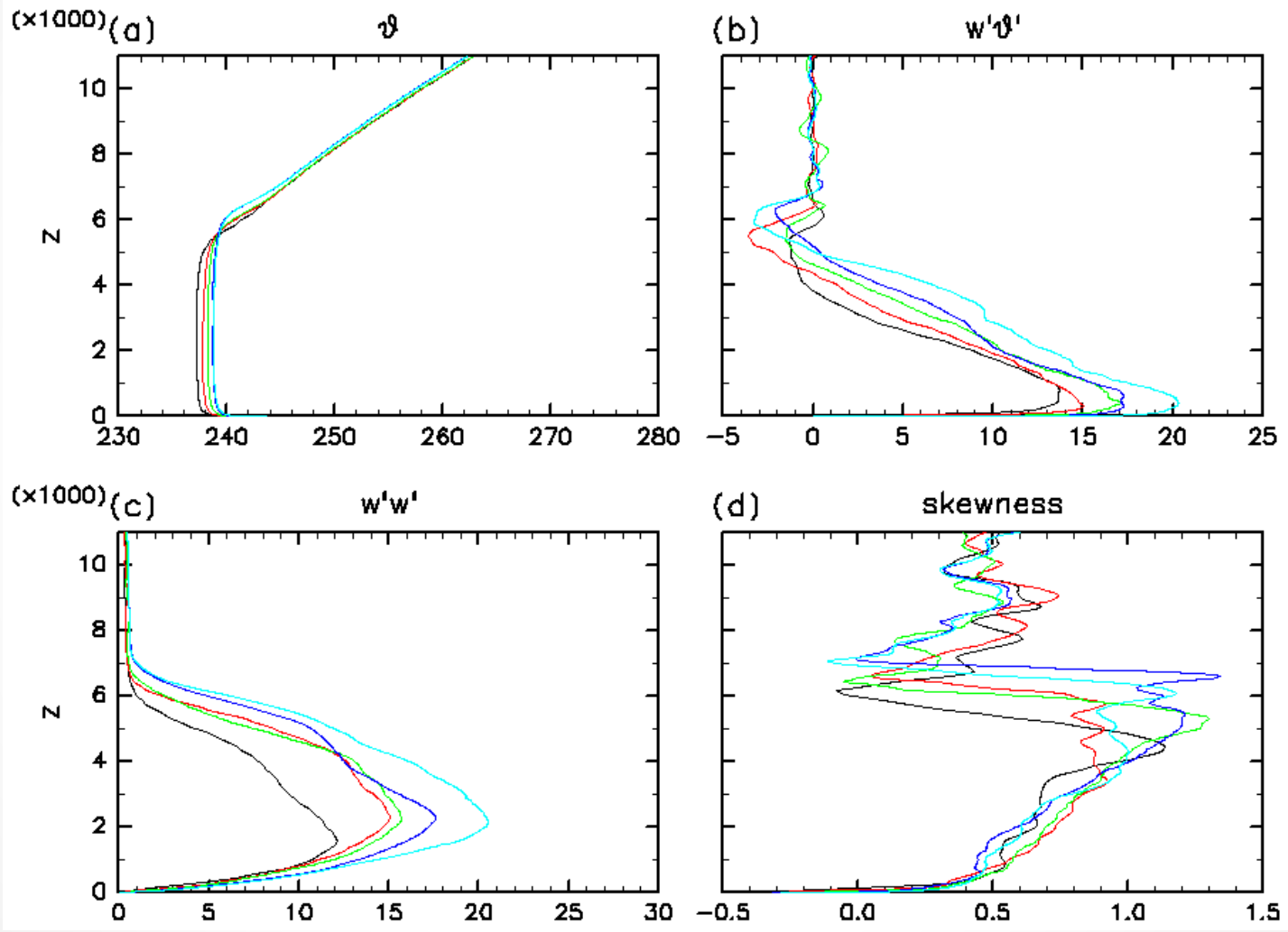
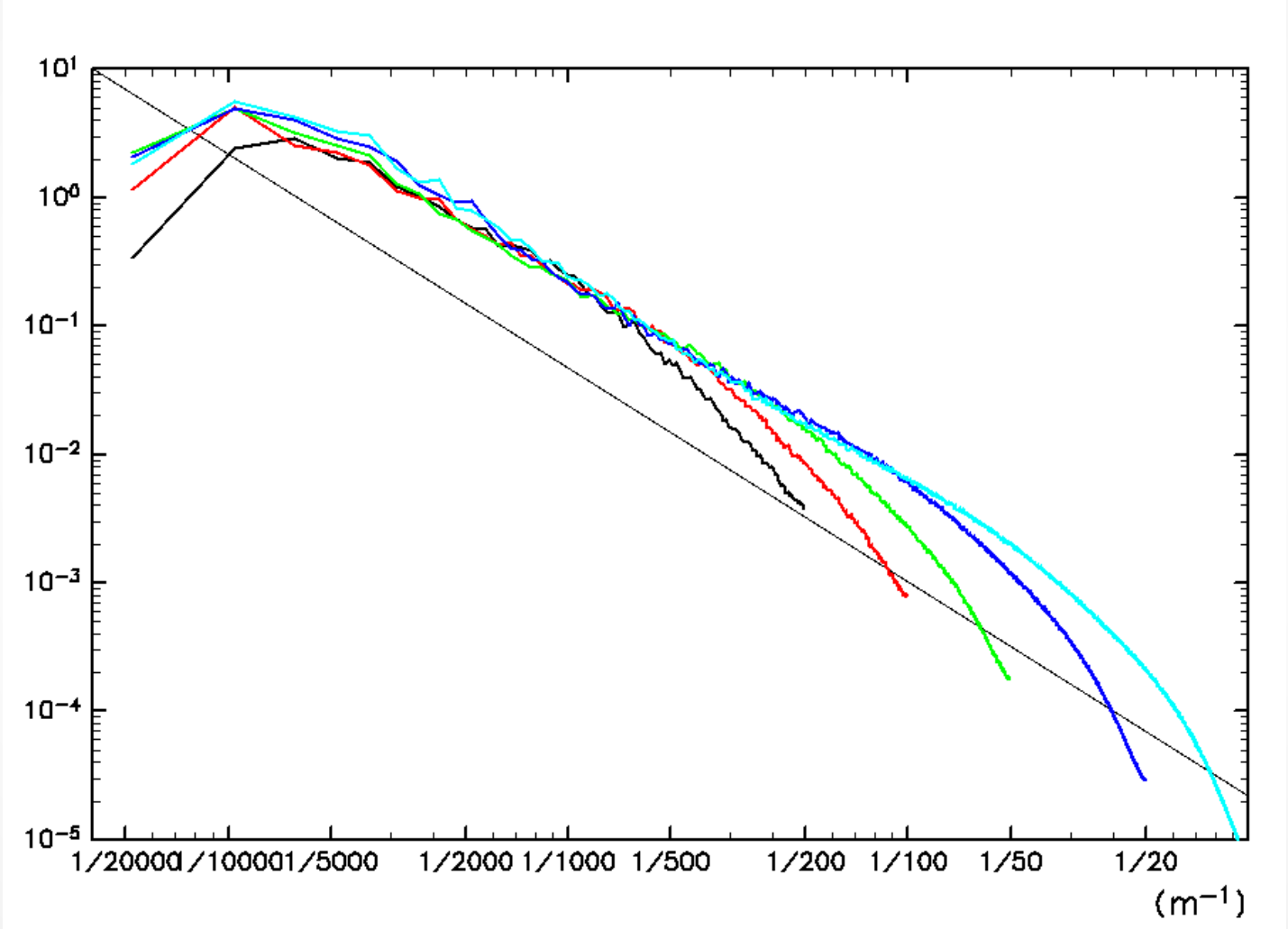
Vertical profiles



Δxyz=100m,50m,25m,10m,5m

Energy spectrum



z=2km, Δxyz=100m,50m,25m,10m,5m


SCALE
Scalable Computing for Advanced Library and Environment

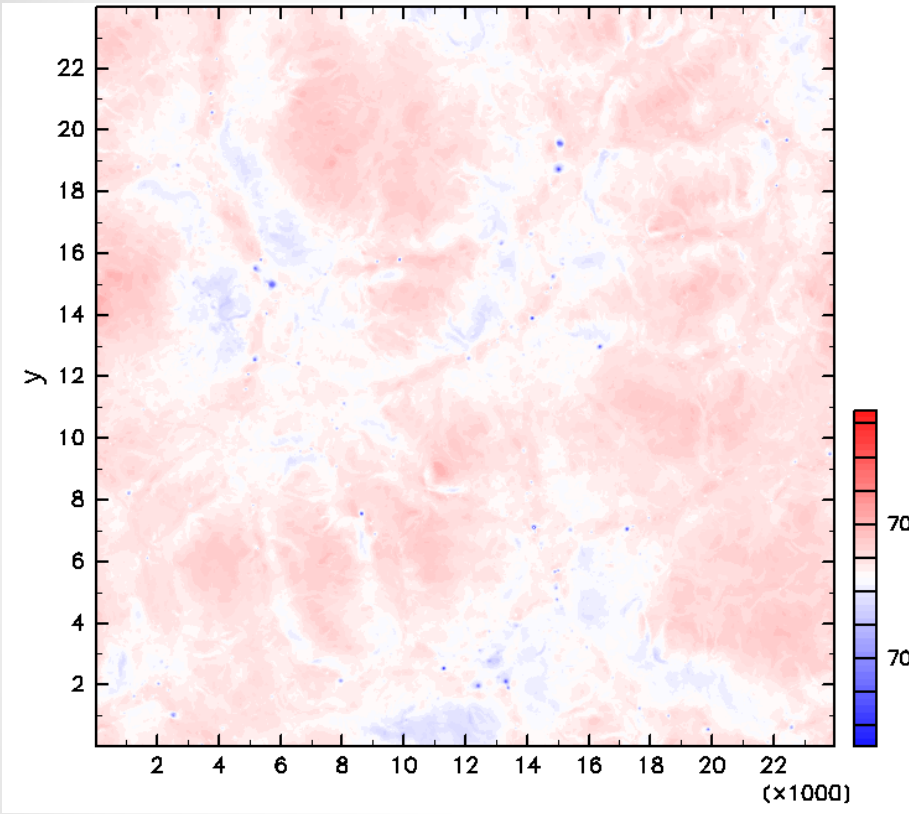
vortex

• • •

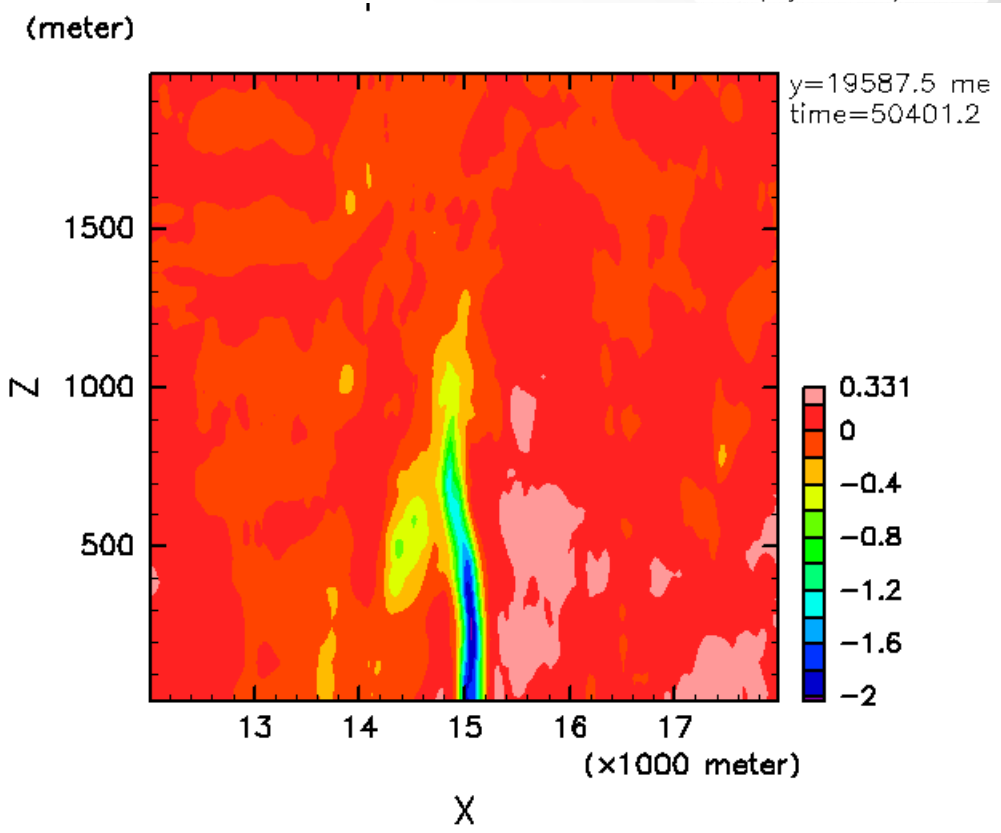

CLIMATE
Computational Climate Science Research Team / AICS/ RIKEN


GFD
電脳倶楽部

Pressure distribution



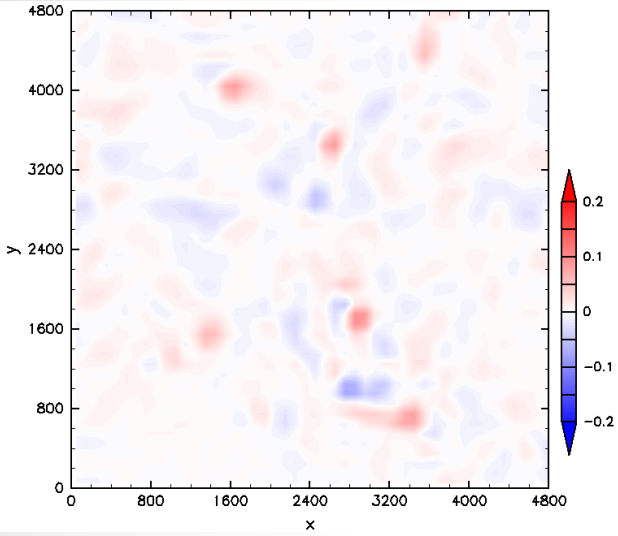
tau=0.2, Δxyz=25m, z=12.5m, t=14:00



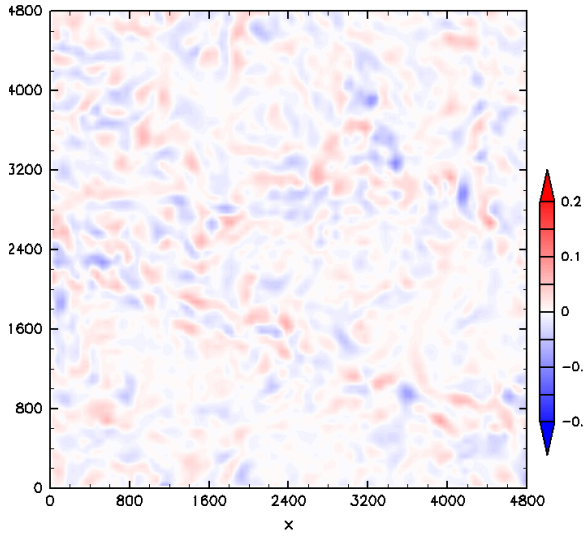
tau=0.2, Δxyz=25m, y=20km, t=14:00

Vertical vorticity (z=200m)

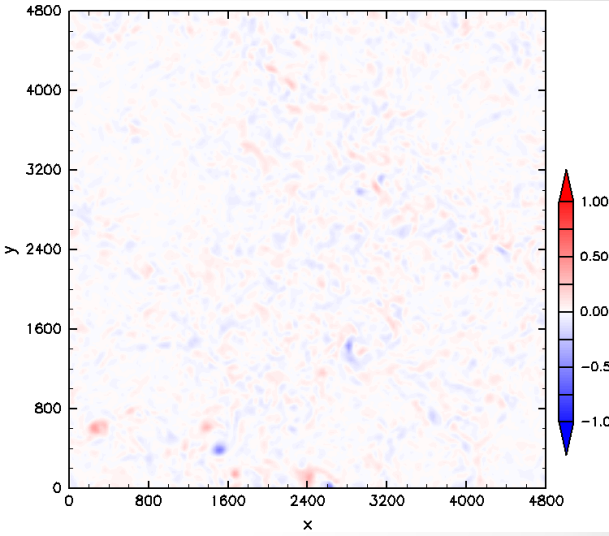
100m run



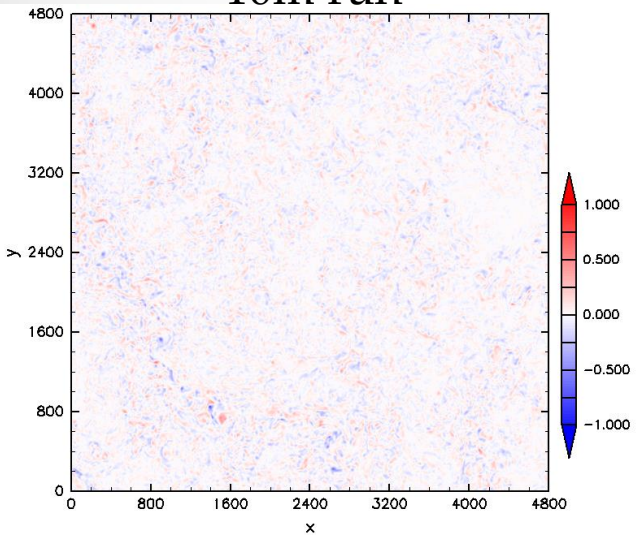
50m run



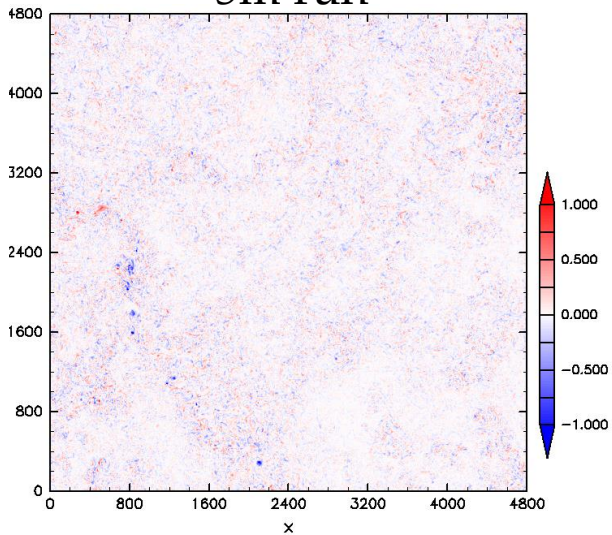
25m run



10m run



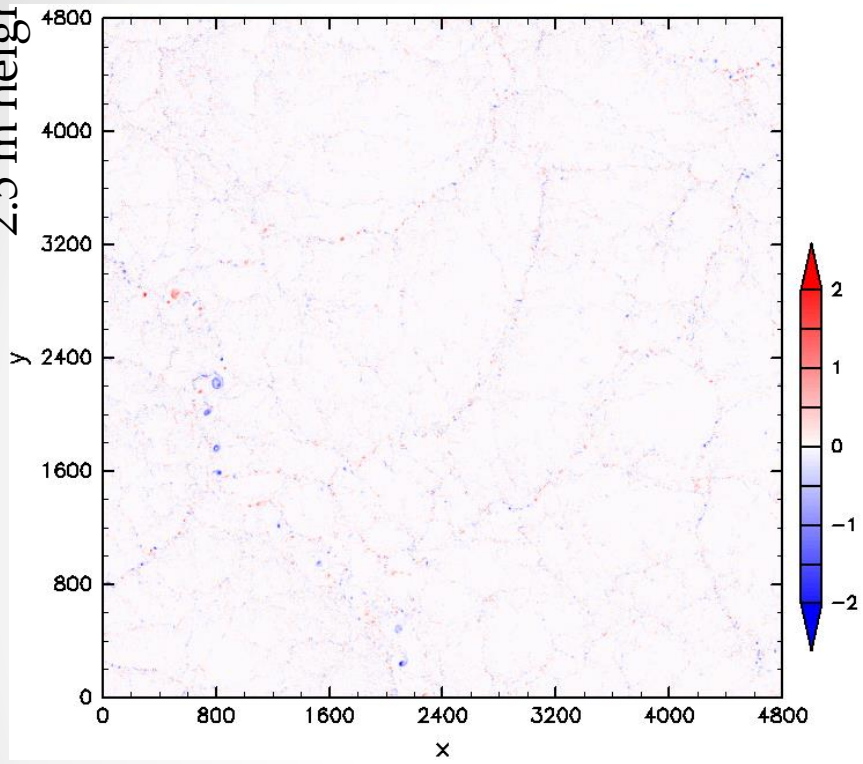
5m run



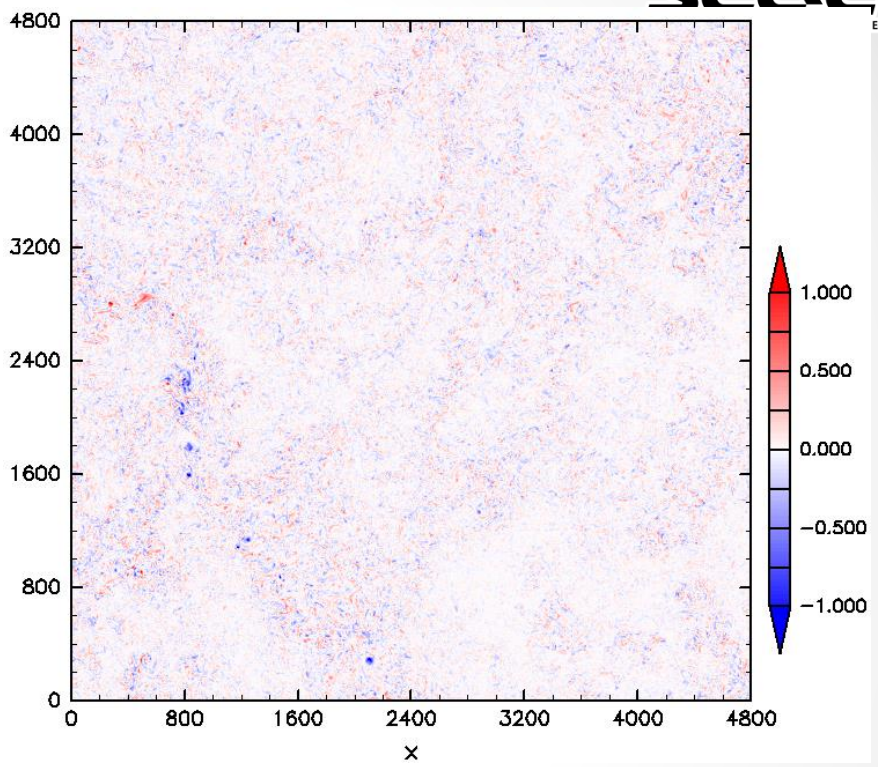
1/16 domain
color scale is different

Vertical vorticity (5m run)

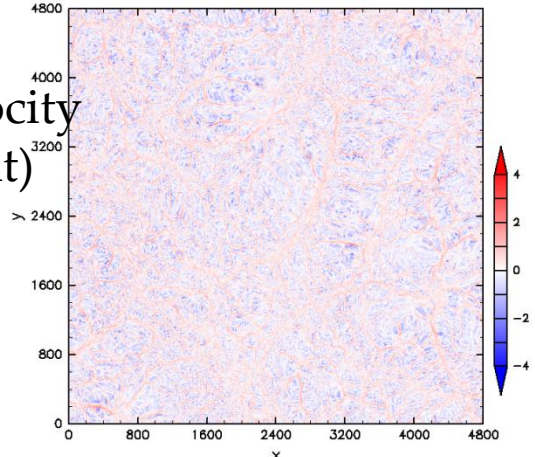
2.5 m height



200 m hight



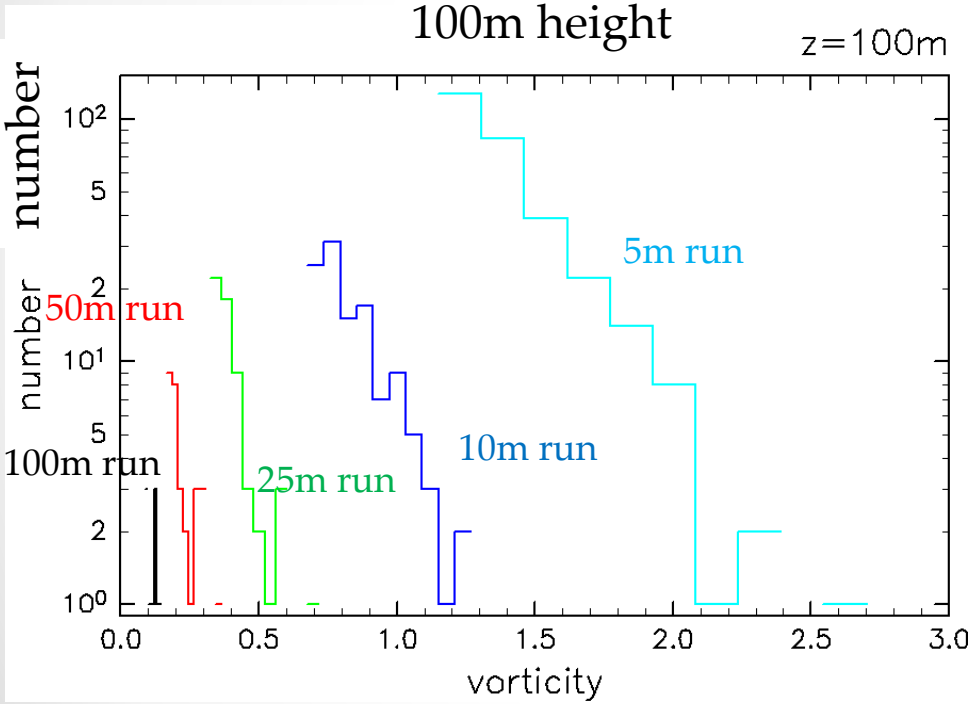
Vertical velocity (2.5 m height)



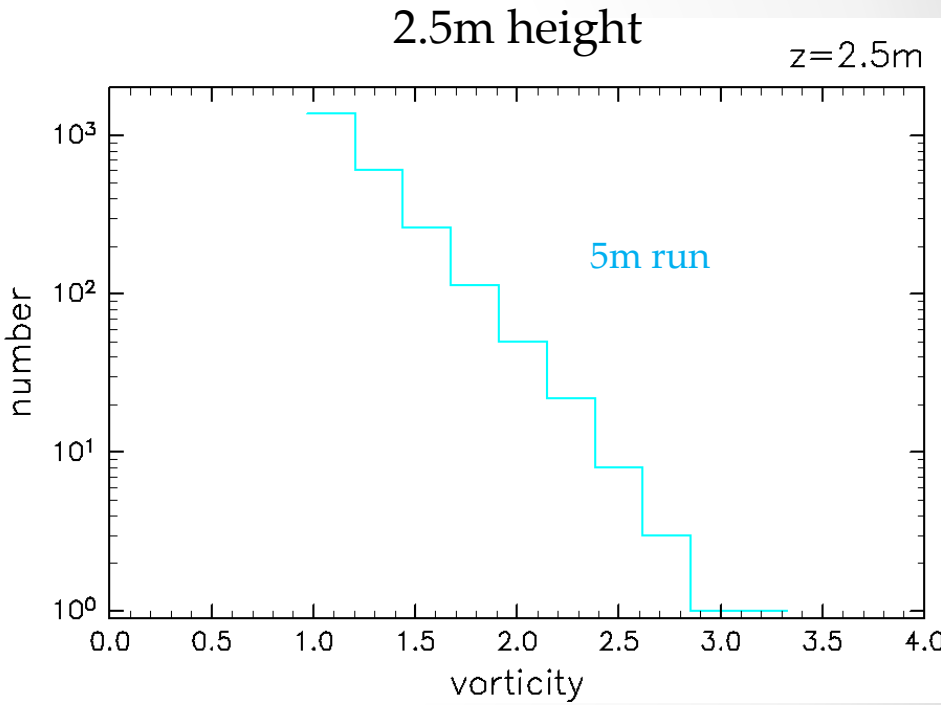
- Represent localized strong vortices
  - Hundreds m height
  - Larger vorticity at lower level
  - Located at upflow region

Frequency distribution

Number frequency distribution of isolated vortices



Maximum vorticity

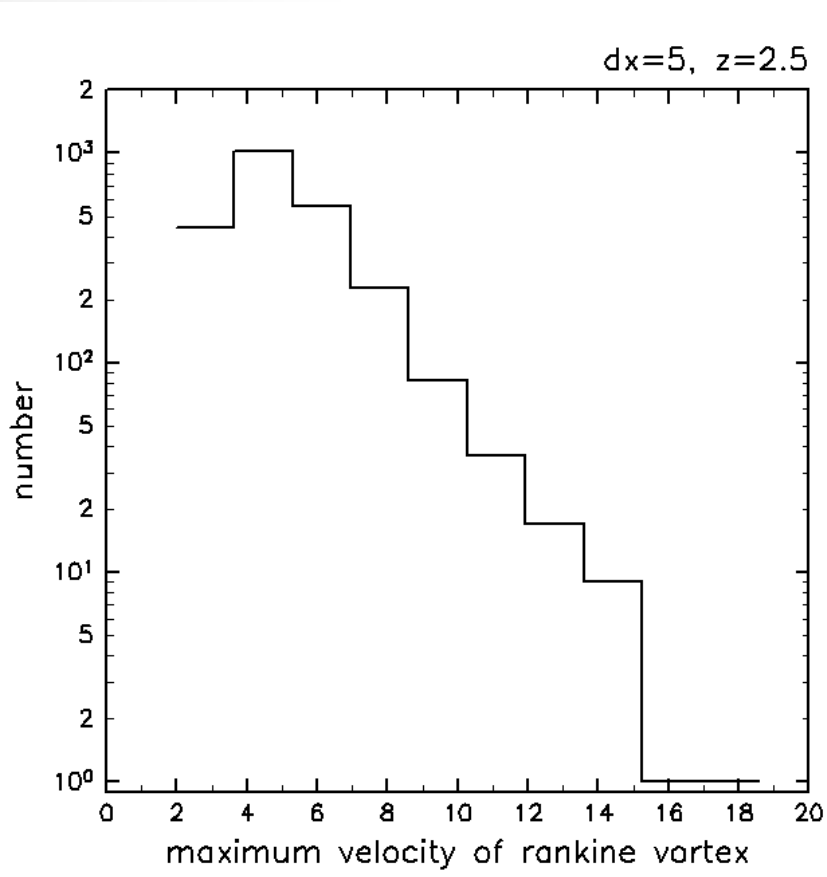


Maximum vorticity

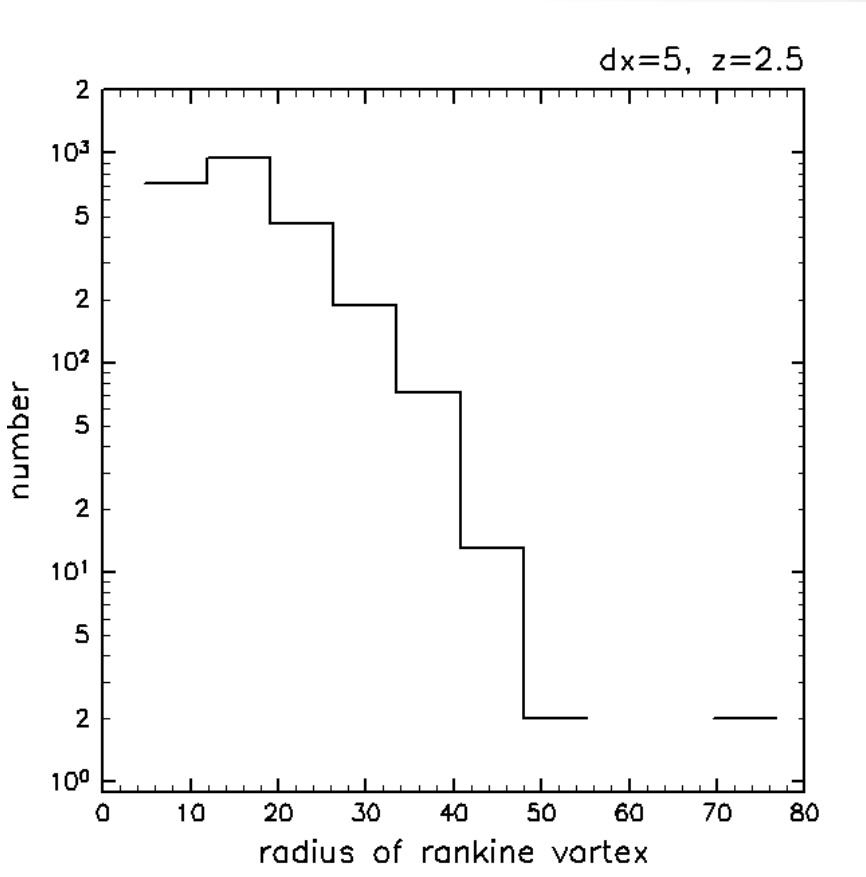
A logarithmic law can be seen

Assuming the Rankine's vortex
(5mrun, 2.5m height)

Maximum wind speed



Radius



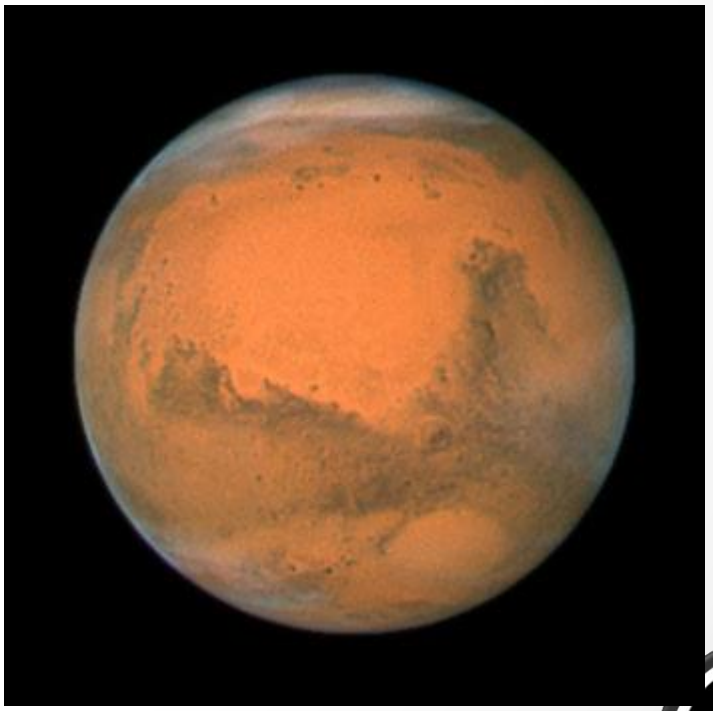
Summary

- 20km domain PBL experiment with several resolutions
  - Fine structure at lower level is represented with such high resolution simulation
  - Strong vortices are reasonably represented
    - A logarithmic law of intensity, maximum speed, and radius of vortices are found

- 以下予備の図

Introduction 1

- 火星とは
  - 軌道長半径: 約 1.5AU
  - 公転周期　: 約 1.88地球年
  - 自転周期　: 約 1.026地球日
  - 赤道半径　: 約 3396km
  - 大気組成　: 二酸化炭素 約95%
  - 地表大気圧: 約 7hPa
  - 地表温度　: 130-300K



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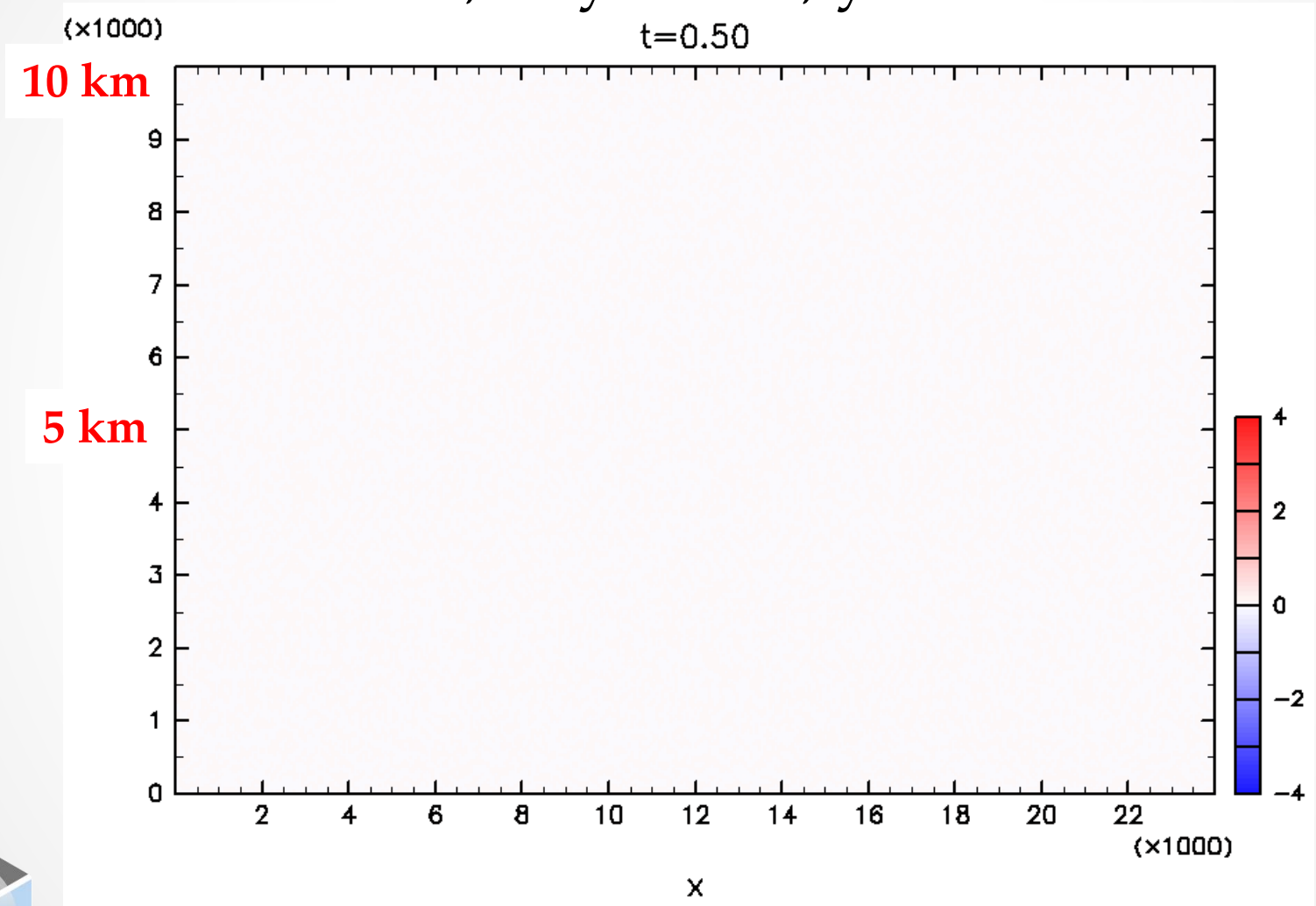
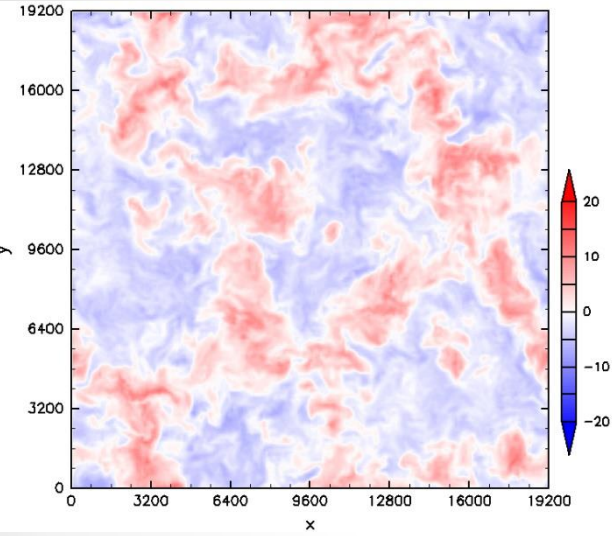
Potential temperature

tau=0.2, Δxyz=25m, y=0

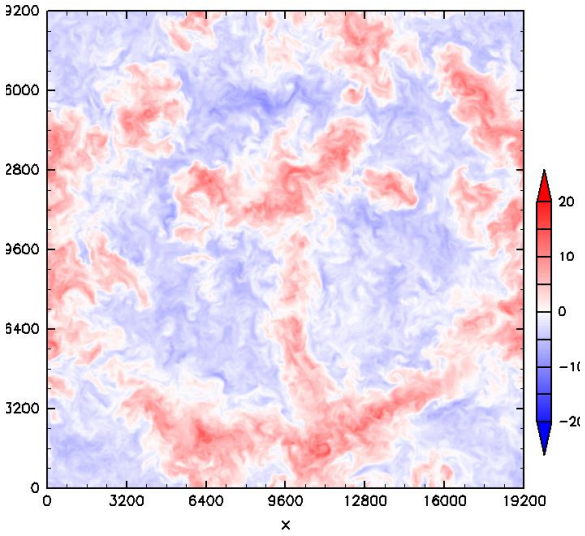


Dependency on resolution (z=2km)

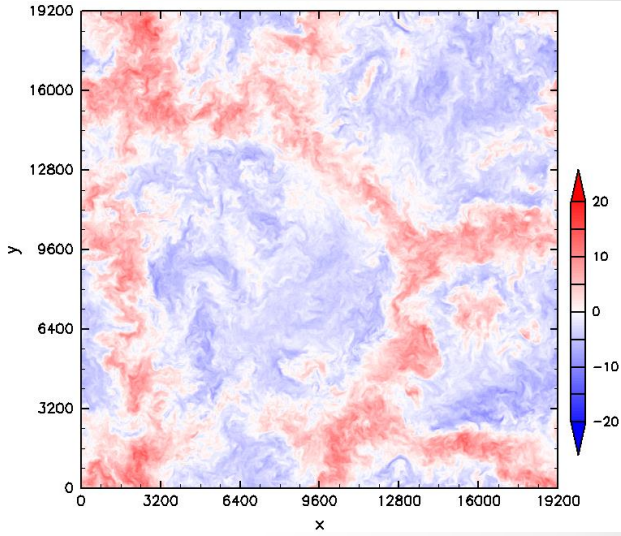
100m run



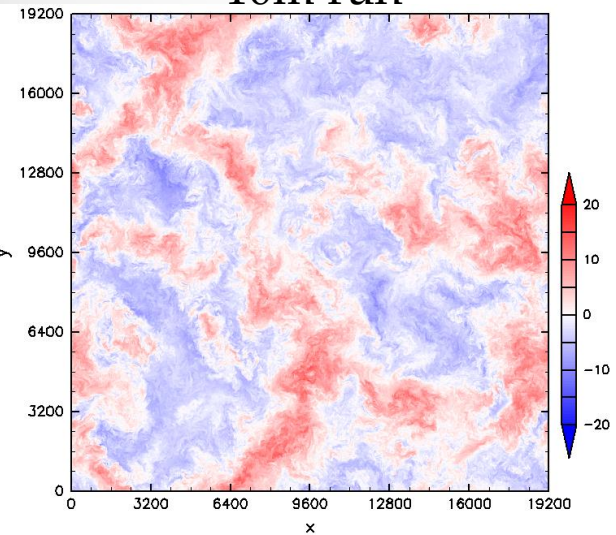
50m run



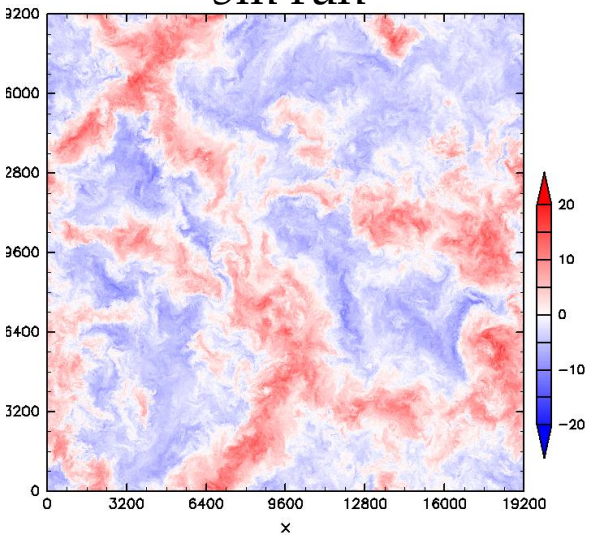
25m run



10m run



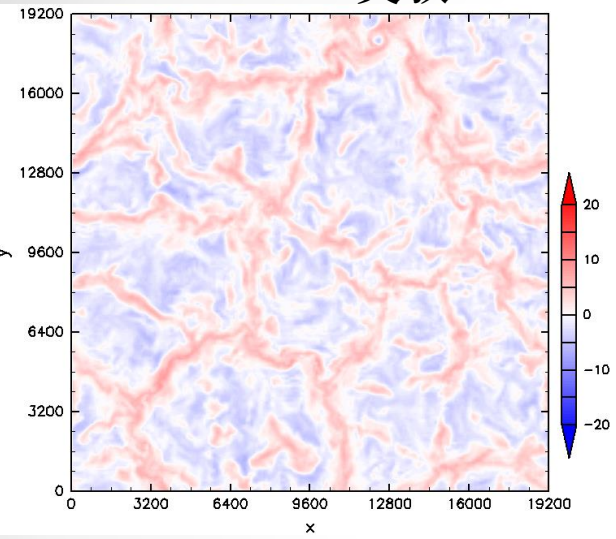
5m run



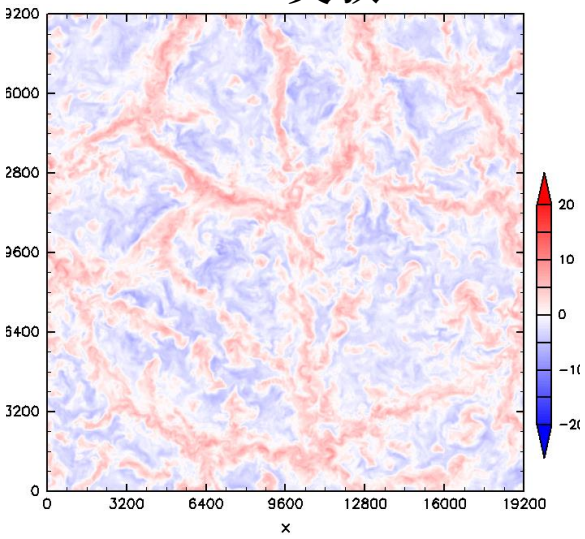
14:30LT

鉛直速度 高度500m 解像度依存性

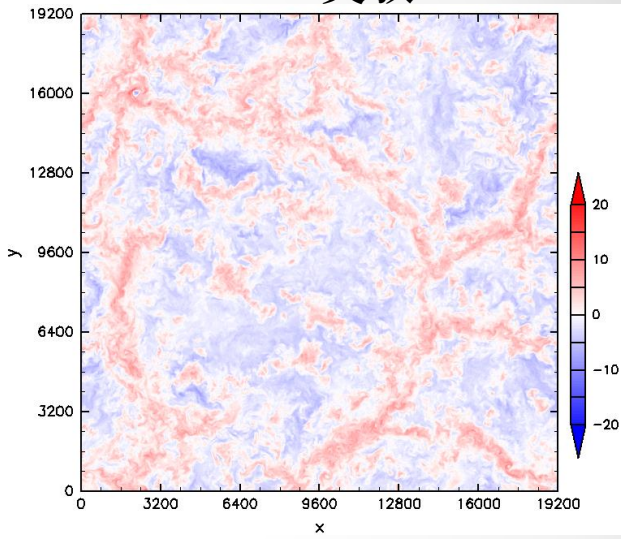
100m実験



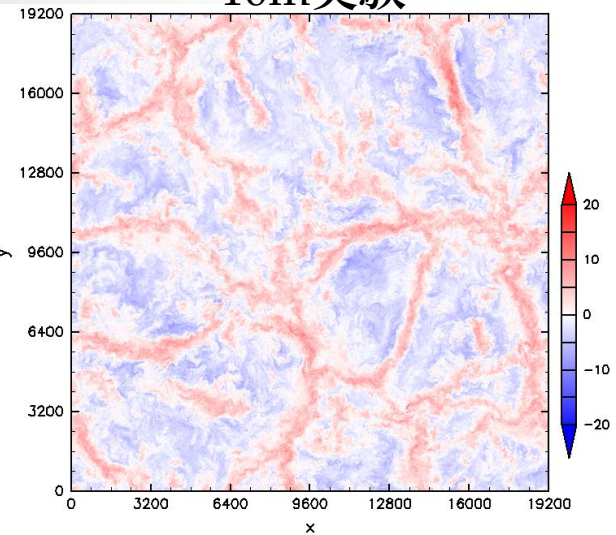
50m実験



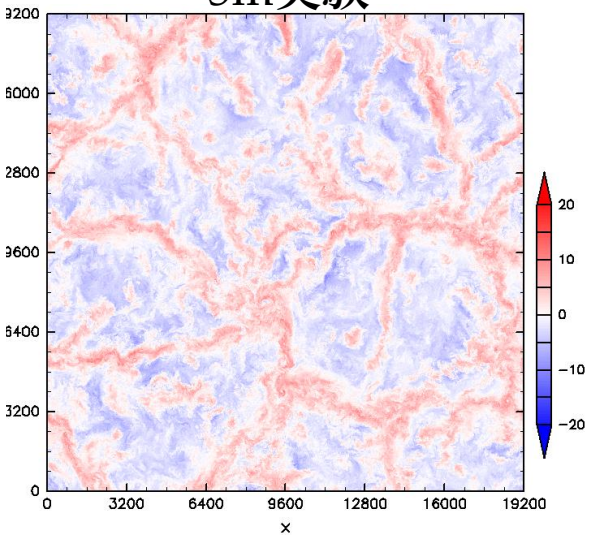
25m実験



10m実験

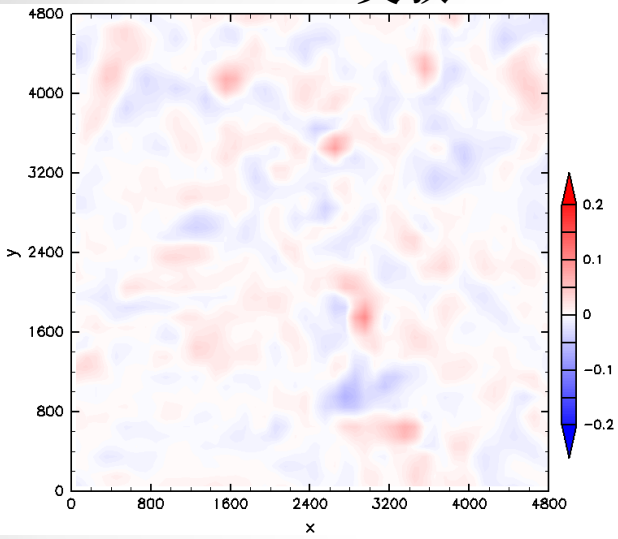


5m実験

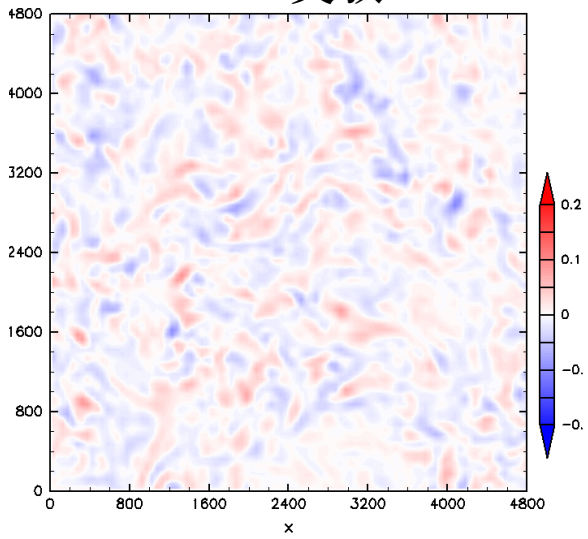


渦度 500m 解像度依存性

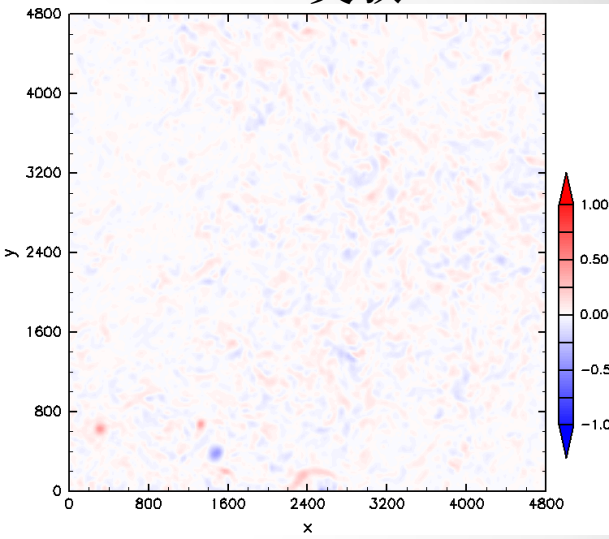
100m実験



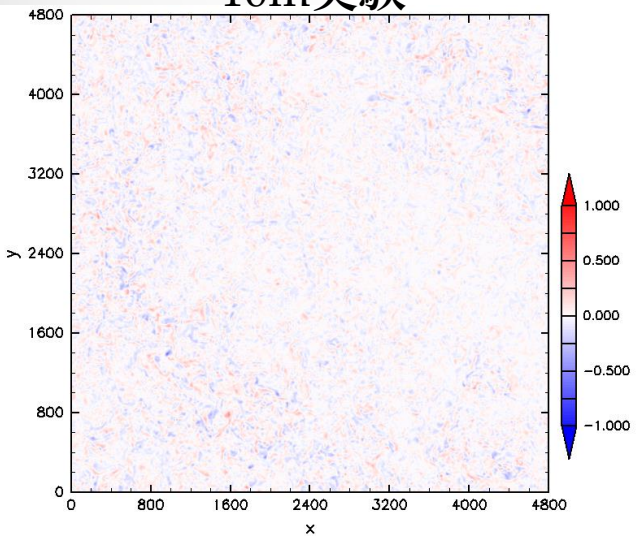
50m実験



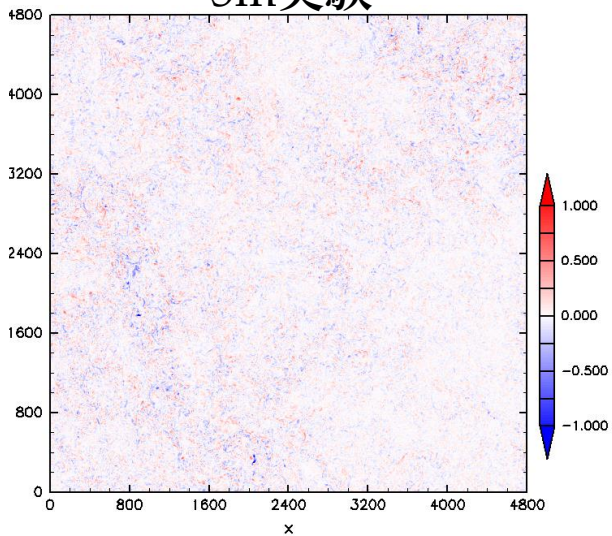
25m実験



10m実験



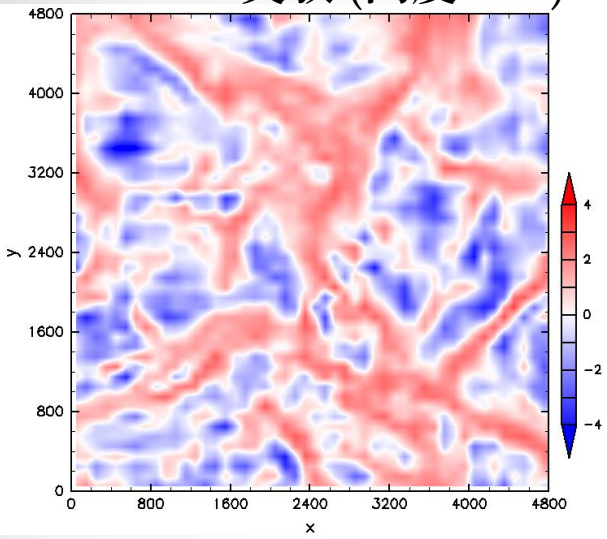
5m実験



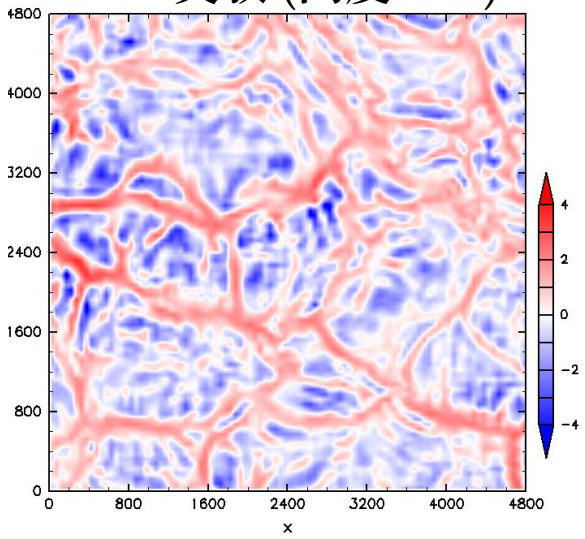
1/16領域
色階調が異なっていることに注意

鉛直速度 最下層 解像度依存性

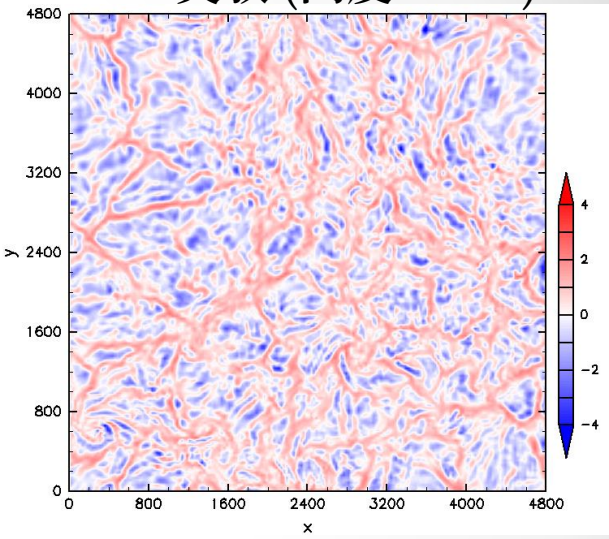
100m実験 (高度50m)



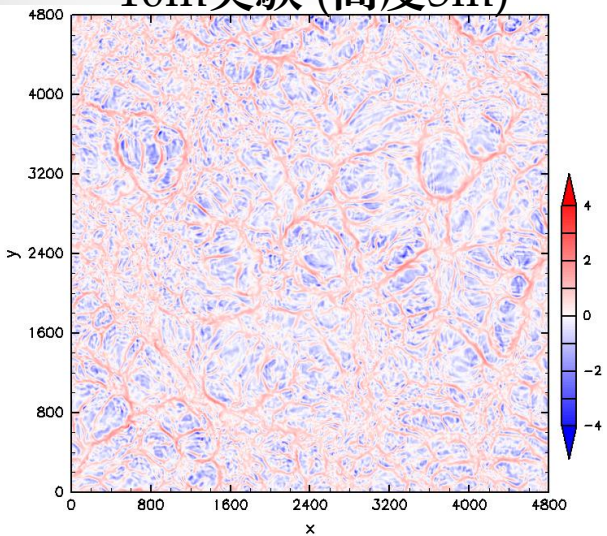
50m実験 (高度25m)



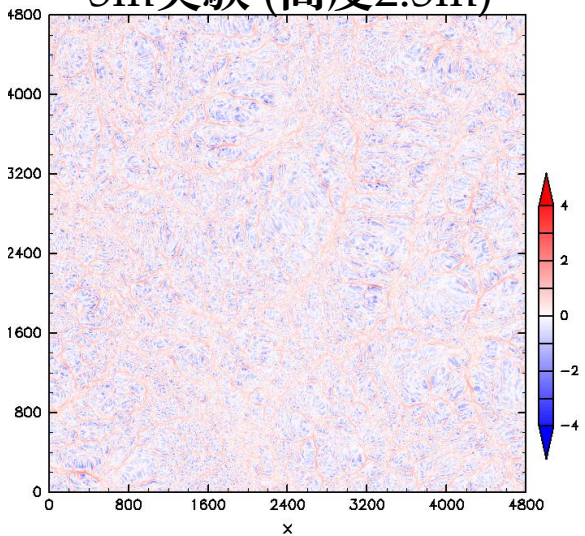
25m実験 (高度12.5m)



10m実験 (高度5m)



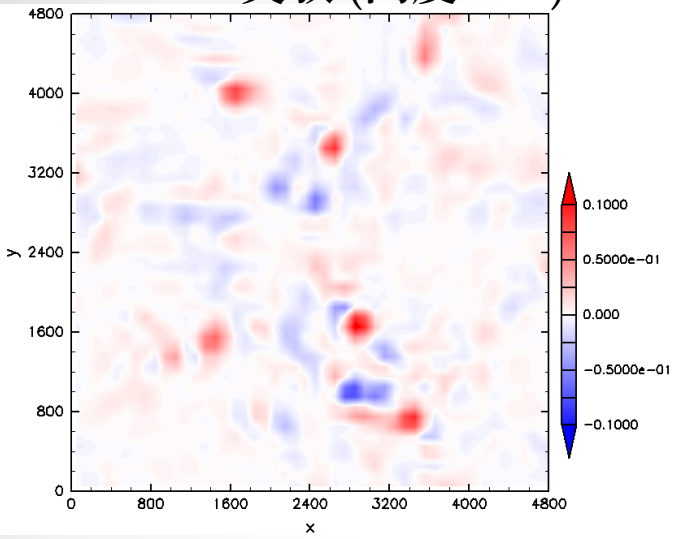
5m実験 (高度2.5m)



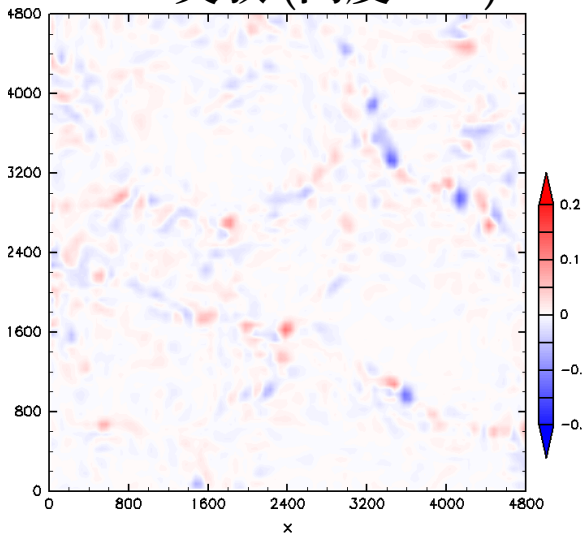
1/16領域
14:30LT
（初期値から14.5h後）

渦度 解像度依存性 (最下層)

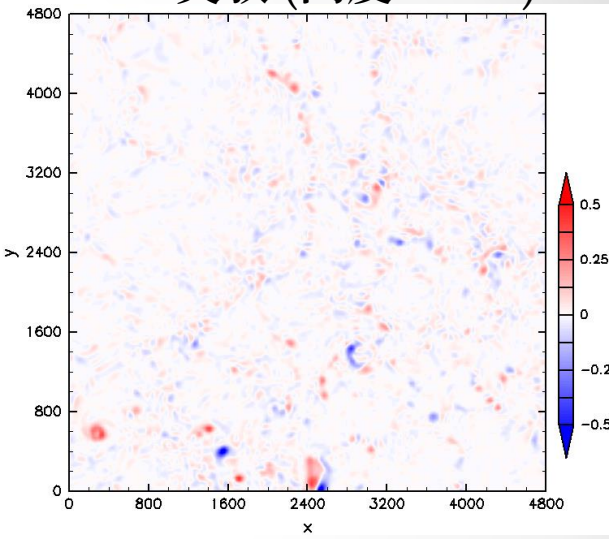
100m実験 (高度50m)



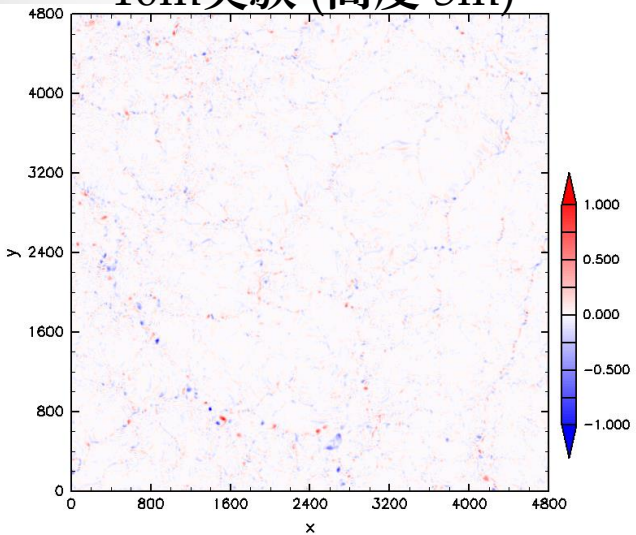
50m実験 (高度25m)



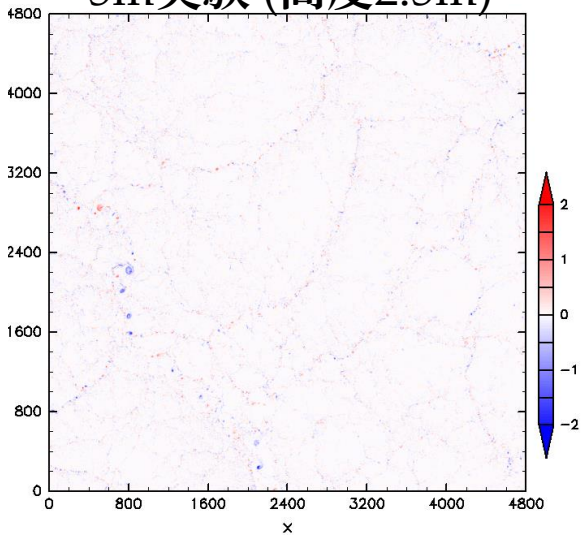
25m実験 (高度12.5m)



10m実験 (高度 5m)



5m実験 (高度2.5m)



1/16領域
色階調が異なっていることに注意

計算概要

- 火星大気の境界層の高解像度ラージエディーシミュレーション(LES)
  - 使用モデル: 理研AICSソフトウェア “SCALE-LES”
    - 構造格子 有限体積法
    - 完全陽解法 3段RK(大域通信の必要無し)
  - 最大問題規模: 約500億格子
- 計算諸情報
  - 使用計算機: 京
  - 演算実効効率: 7.9% (5m解像度計算時)

	100m実験	50m実験	25m実験	10m実験	5m実験
積分時間	24時間 x 3	24時間 x 3	24時間 x 3	19時間	1時間
Δ t	0.12 s	0.06 s	0.03 s	0.012 s	0.006 s
時間ステップ数	720K x 3	1.4M x 3	2.9M x 3	5.7 M	600K
格子数	6.8M	52M	410M	6.3G	49G
使用コア数	96	1,152	18,432	115,200	57,600
Elapse time	100 h	100 h	100 h	200 h	200 h