Global and Planetary WRF

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planetWRF

Overview

- **Introduction**

  Who are we and what are our aims?

- **PlanetWRF**

  How we globalized WRF and made it planetary

- **Results**

  Selected **MarsWRF** and **TitanWRF** results

- **Get planetWRF**

  How to download planetWRF at www.planetwrf.com

planetWRF

Who are we and what are our aims?

We are a group of planetary scientists who wanted a *single model* to look at:

- a range of atmospheric phenomena
- from the global down to the microscale
- on Earth, Mars, Venus, Titan and ?

PlanetWRF development was originally based at Caltech, Cornell and Kobe University, with a lot of help from the NCAR team.

Soon to be based at **Ashima Research** and **Cornell** - *and still very grateful for the NCAR team's help!*

planetWRF

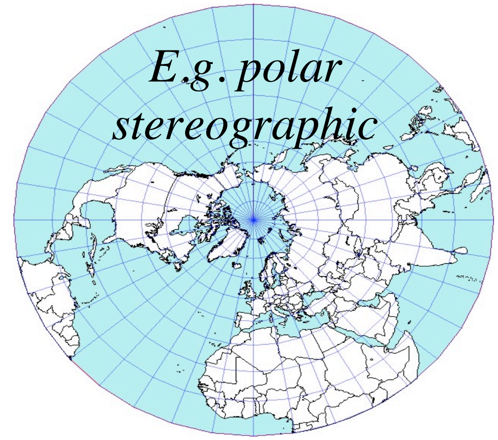
NB: Global WRF is part of the WRFv3.1 public release

planetWRF is publicly available at

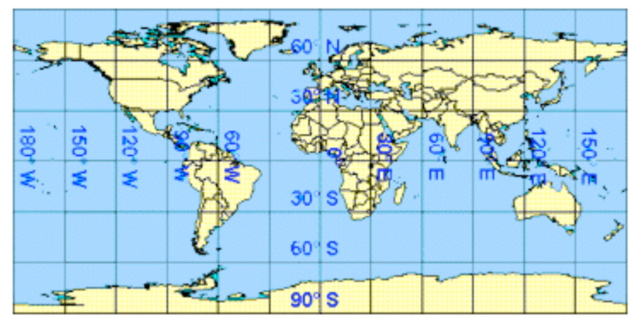
www.planetwrf.com

Globalizing WRF 1. Map scale factors

WRF used *conformal* rectangular grids
=> map-to-real-world scaling factor *m* was the same in x and y directions ($m_x = m_y = m$)



But we needed a *non-conformal* (lat-lon) grid to reach from pole to pole and make the mother domain global

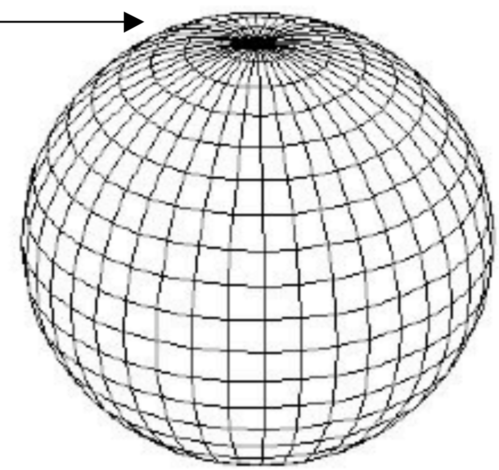


=> $m_x = dx/dX = 1/\cos(\text{latitude})$, $m_y = dy/dY = 1$ => $m_x \neq m_y$

=> Needed to identify which map scale factor was required in all equations where *m* appeared, and reintroduce map scale factors where they previously cancelled (so had been omitted)

Globalizing WRF 2. Polar filters

In a lat-lon grid the spacing Δx between E-W grid-points becomes small near the poles



But CFL (Courant Friedrichs Lewy) criterion requires $\Delta t \lesssim \Delta x / U$ for stability

To avoid using small Δt everywhere because of small Δx near poles, we increase largest *effective* Δx by filtering out shorter wavelengths

In global WRF the Fourier filter turns on at 45° and allows fewer wavenumbers as latitude increases [`module_polar_fft.F`]

You can change the filtering latitude via namelist variable `fft_filter_lat` **- or set it to 90 to turn off polar filtering entirely**

Advantages of global WRF

- Extends WRF's existing 1- and 2-way coupling between domains: ***except now mother domain can be whole planet!***
- No change in basic dynamics / physics at different scales
- No more complex coupling between two *different* global and mesoscale models
- 2-way => study multi-scale feedbacks in a global model

Global WRF is already in the WRFv3.1 public release

Ideal case for Earth uses Held-Suarez forcing (BAMS 1994):

`compile em_heldsuarez`

Planetary changes

- **Clocks and calendars**: in namelist we use planetary seconds, hours etc. (24 planetary hours = solar day, etc.) then convert to SI inside WRF

- **Planetary constants**: `share/module_model_constants.F` holds most [*e.g*. gravity, rotation rate] and others are set during initialization

- **Solar fluxes for sw radtran**: orbital parameters, time of day and location are used in non-planet-specific code to find incident solar flux

- **Adapted physics**: we use adapted versions of the MRF PBL and SFCLAY surface schemes (with *e.g*. hardwired minimums removed)

- **New physics**: we use a similar sub-surface scheme for each planet and a radiative transfer scheme tailored to each atmosphere. Mars has a CO_2 condensation/sublimation cycle; Titan has simple methane ‘hydrology’

- **For more details see Richardson *et al*. 2007**

Selected current and planned future uses of planetWRF

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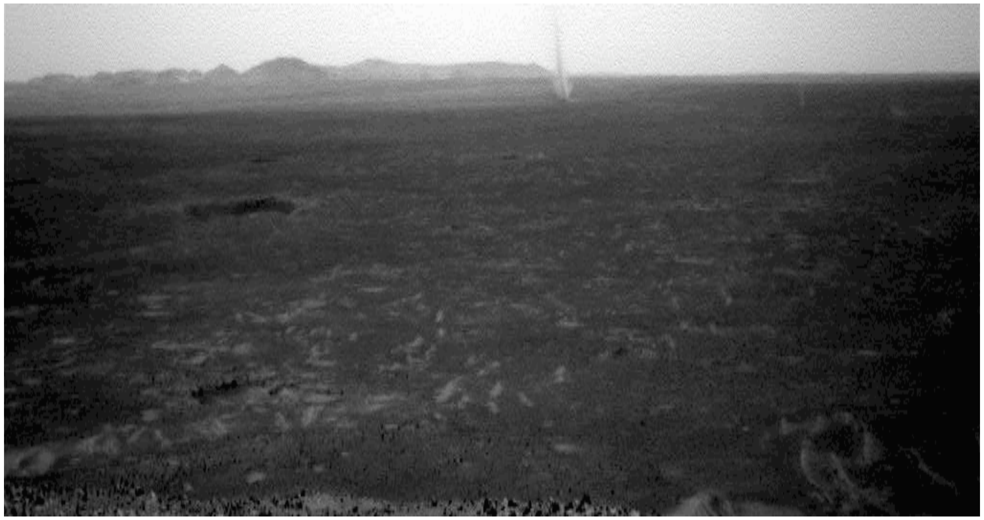
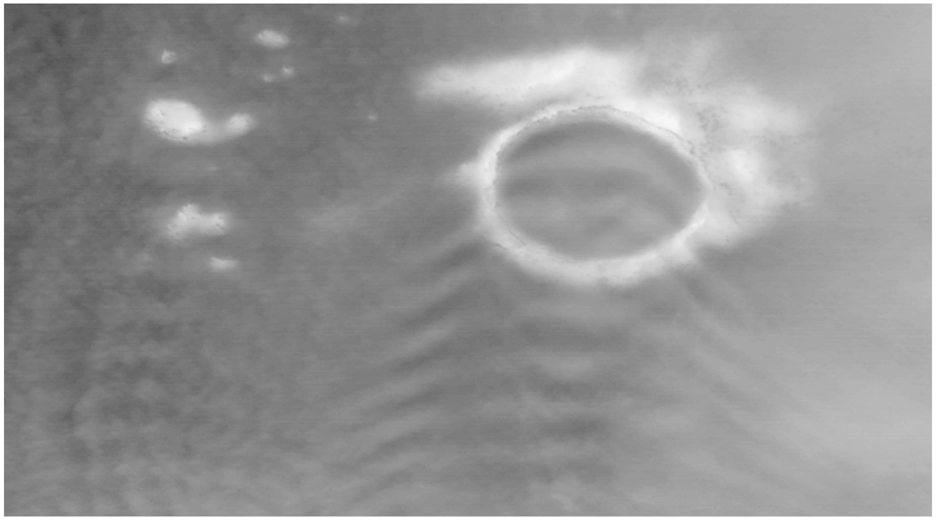
MarsWRF

Topics of interest: on Mars

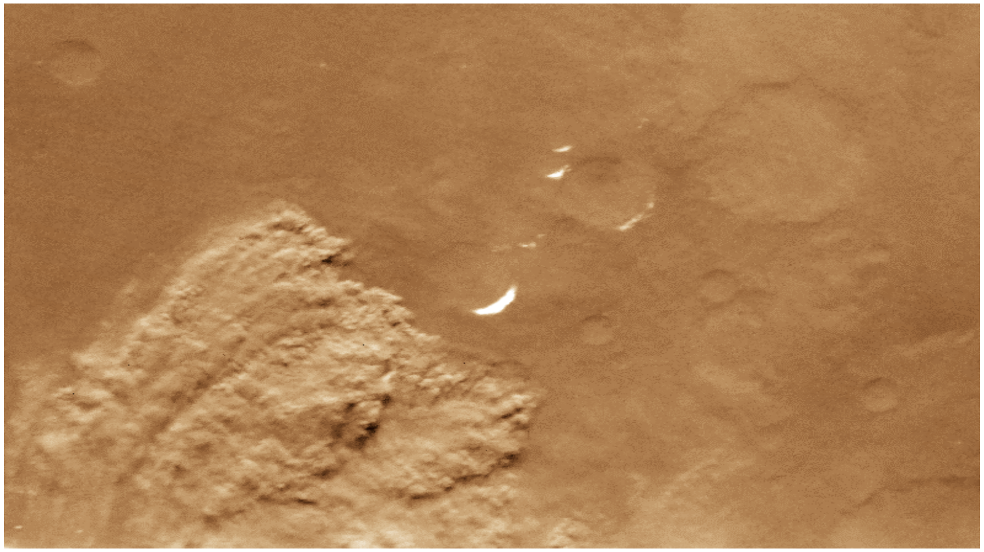
Dust devils



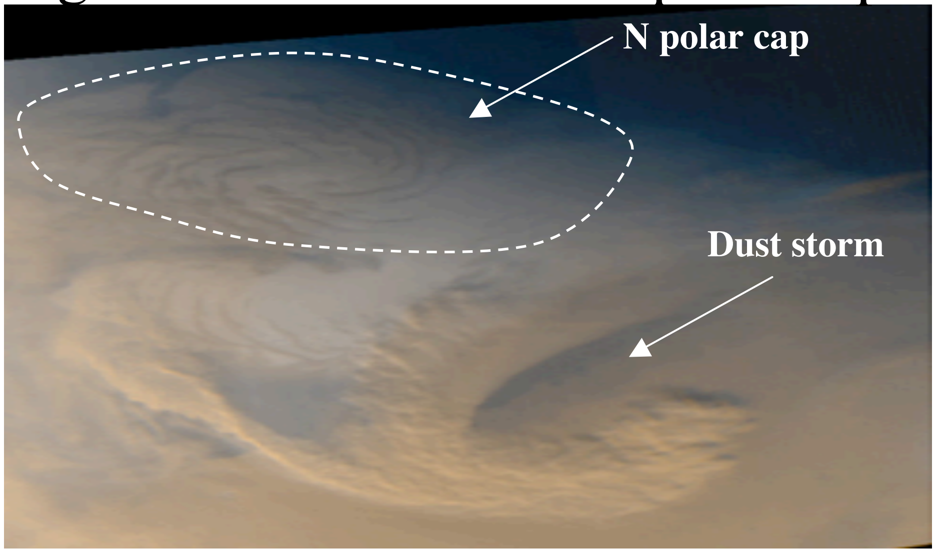
Orographic clouds



Local dust storms



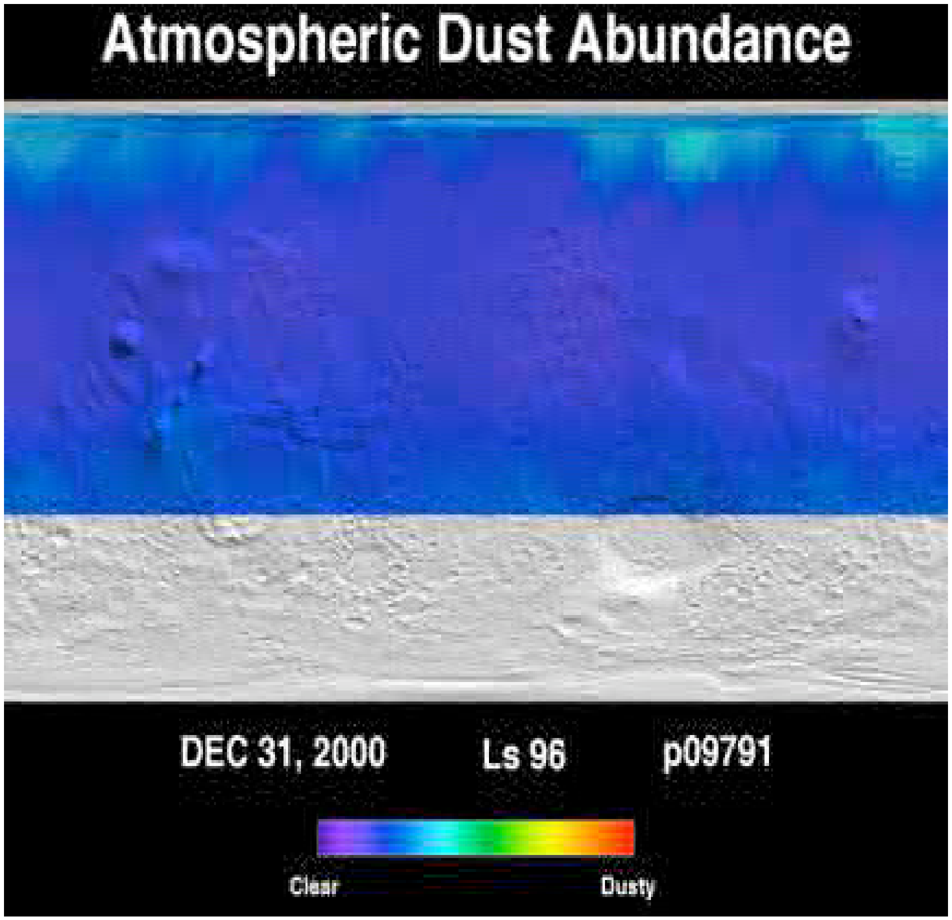
Regional dust storms and polar caps

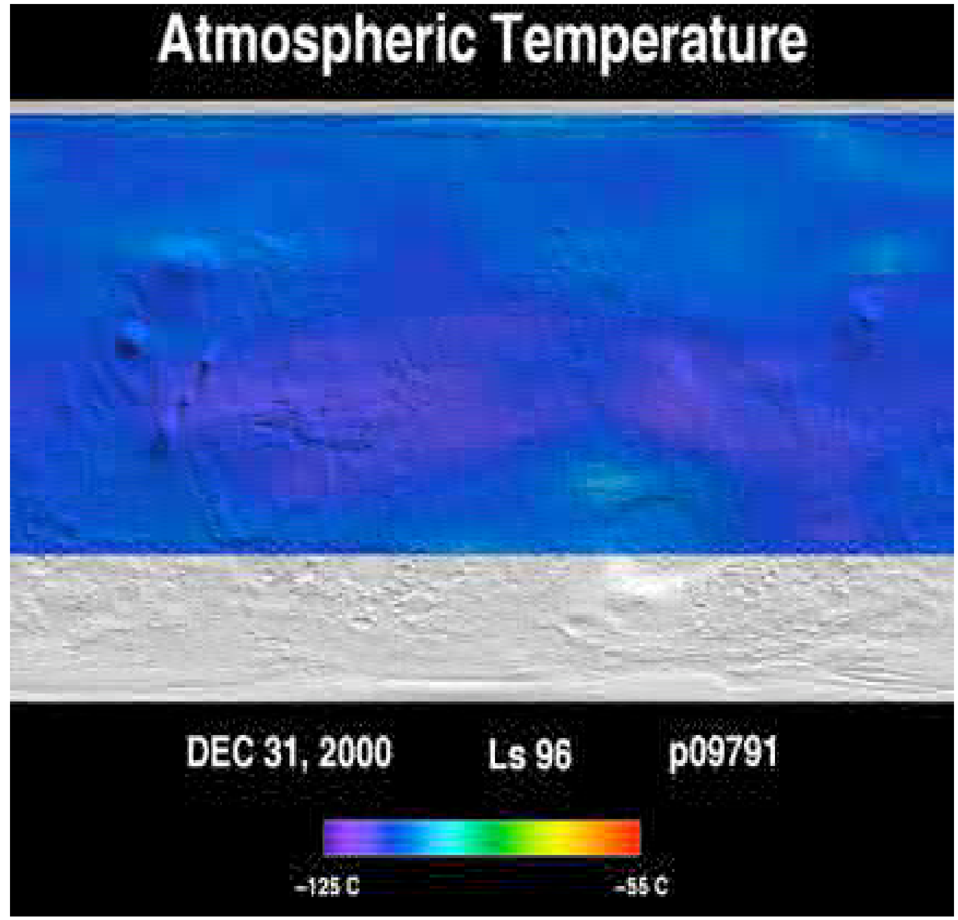


MarsWRF

Topics of interest: on Mars

Global / planet-encircling dust storms

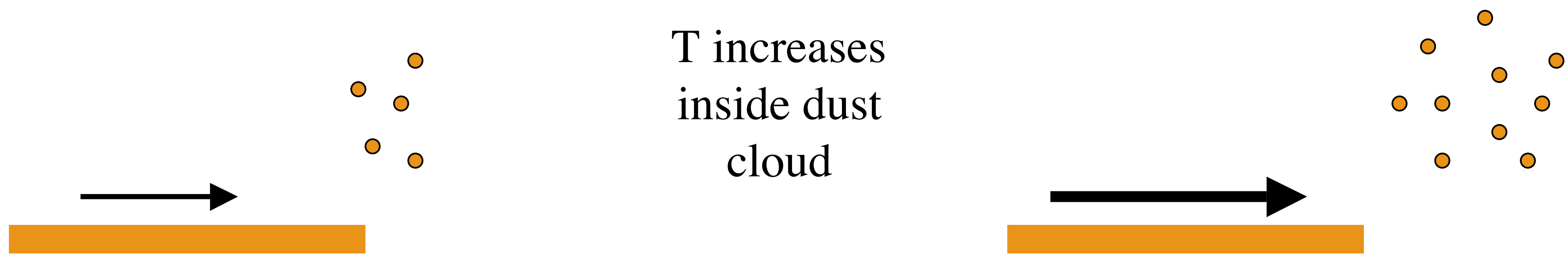




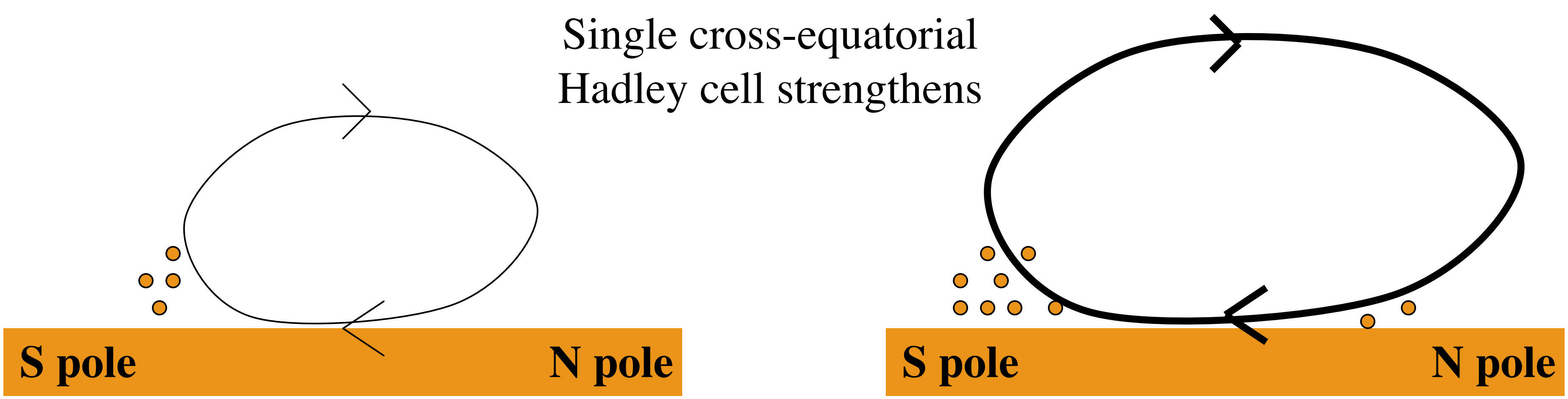
Multi-scale feedbacks are *vital* to modeling their onset and growth

Modeling Martian dust storms

Local positive feedback:



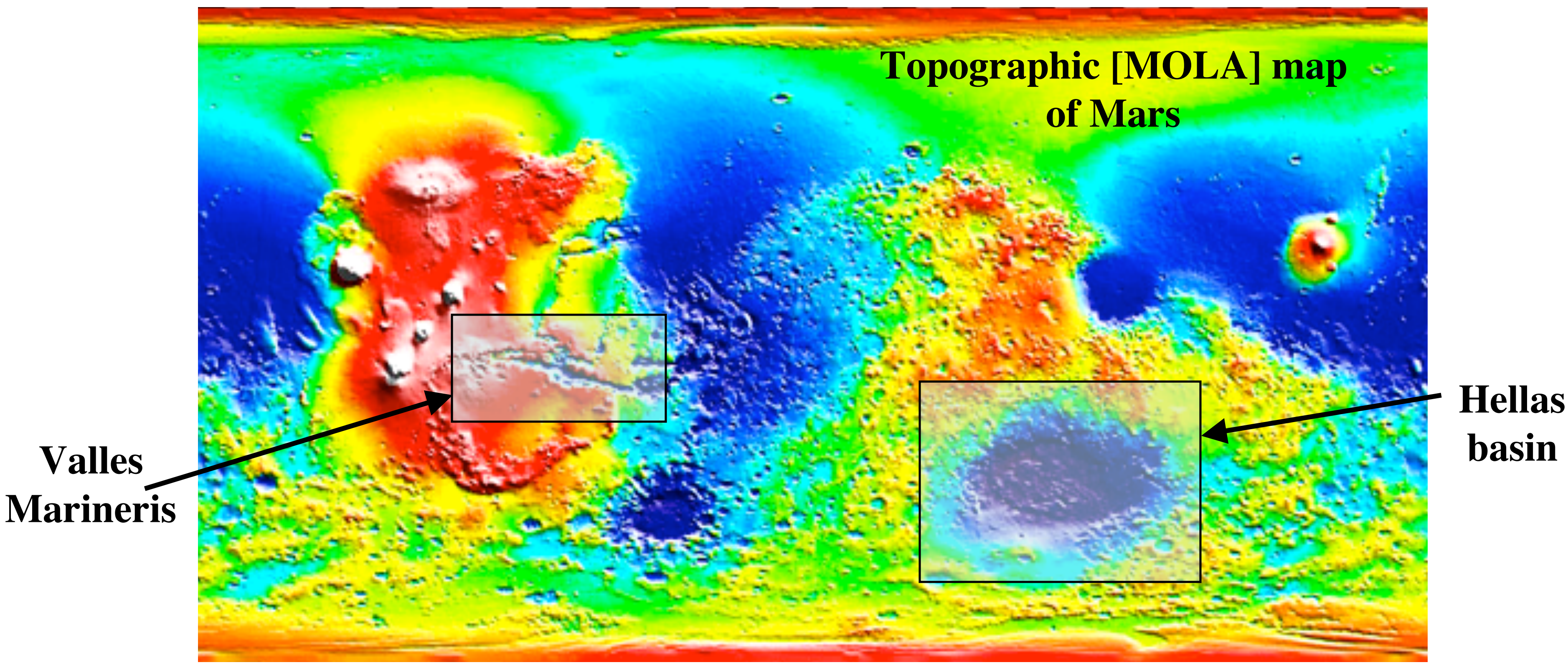
Global positive feedback:



Modeling Martian dust storms

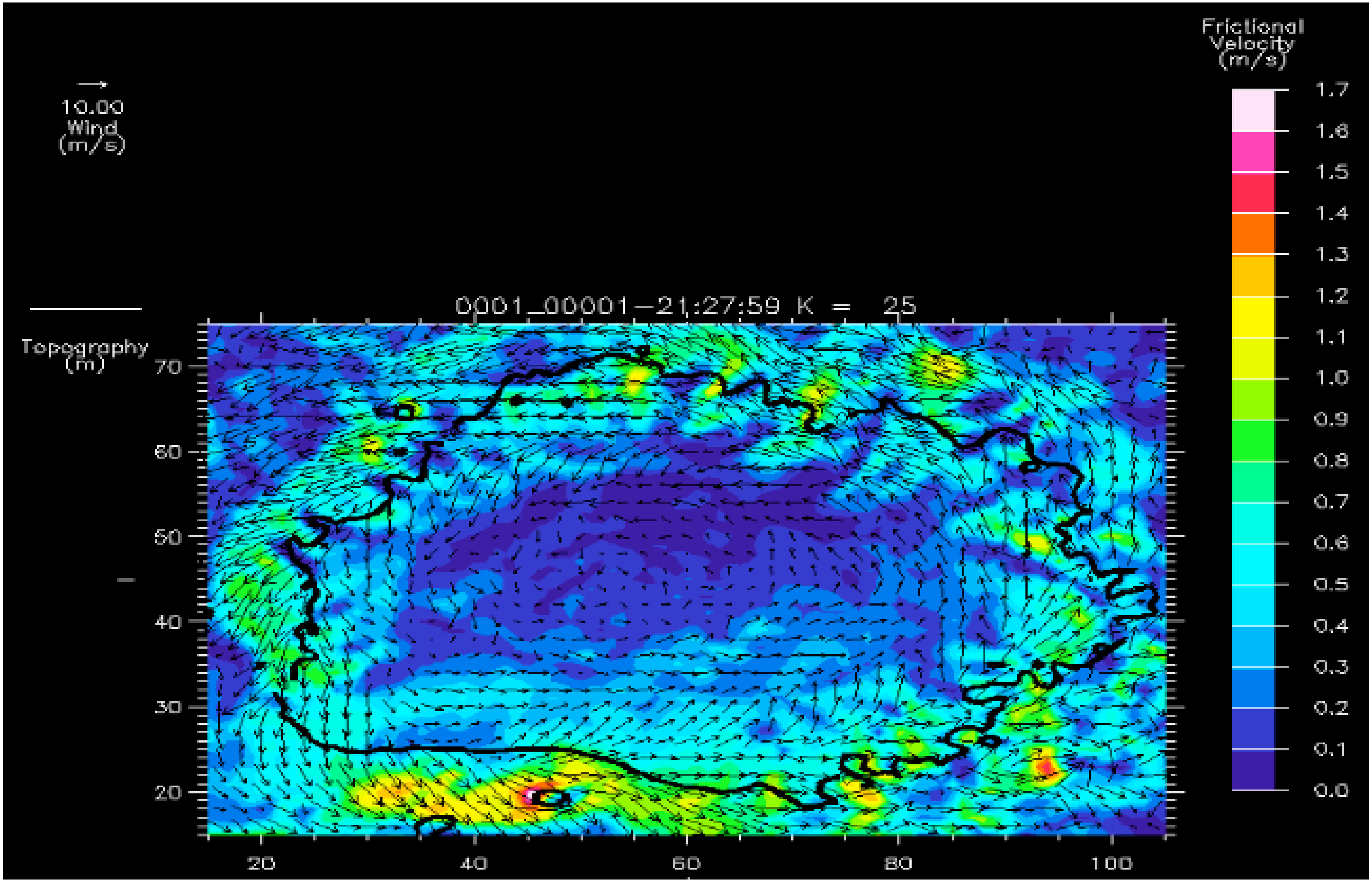
Need to capture *multi-scale feedbacks* - three approaches:

1. Limited-area simulations to study dust lifting and *local* feedbacks
2. *Global high resolution* dust simulations
3. Global standard resolution dust simulations with *nesting* - *e.g.*:



MarsWRF

1. Limited-area simulation of the Hellas basin



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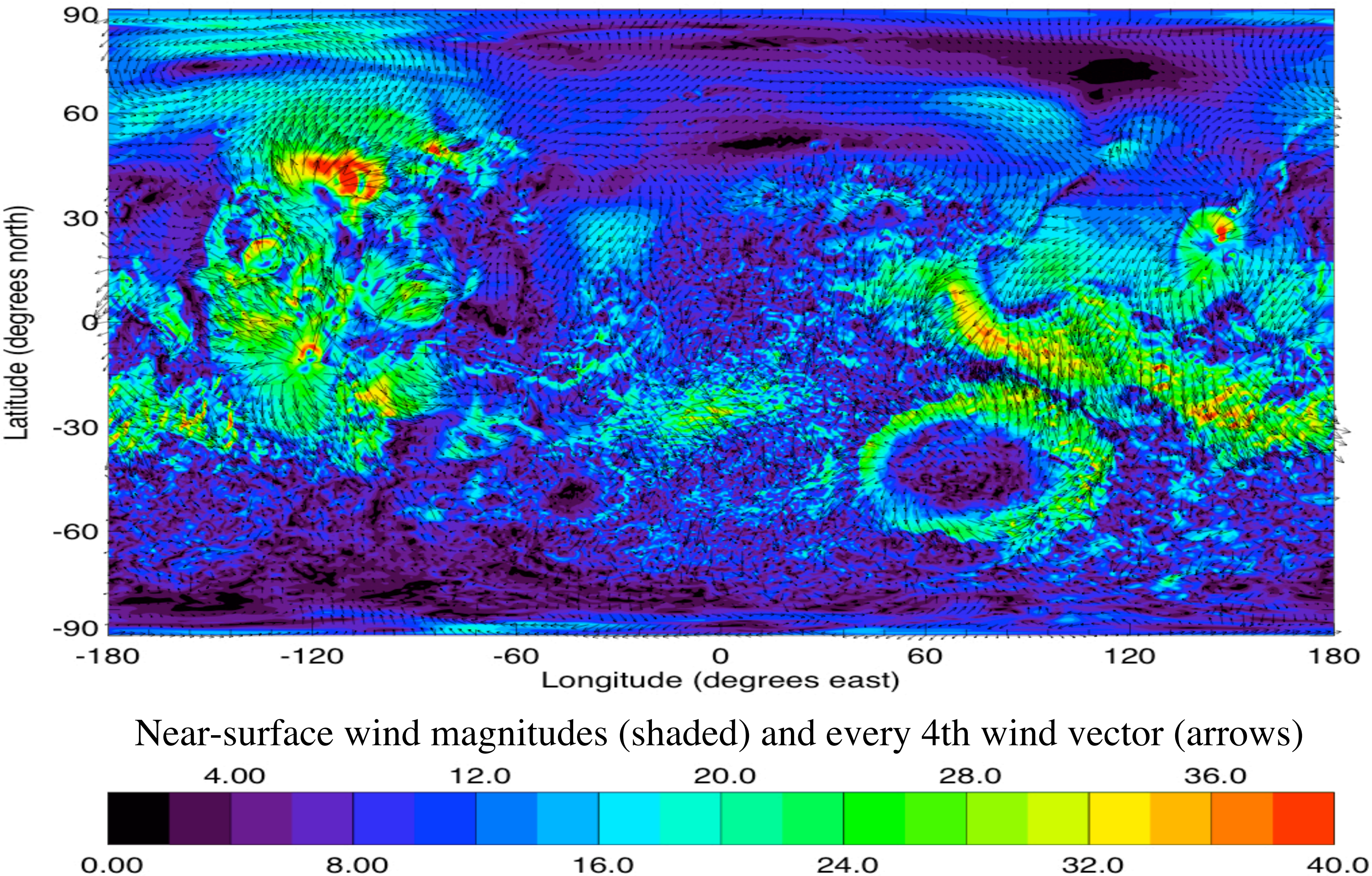
MarsWRF

2. MarsWRF run at 0.5° global resolution



Near-surface wind magnitudes (shaded) and every 4th wind vector (arrows)

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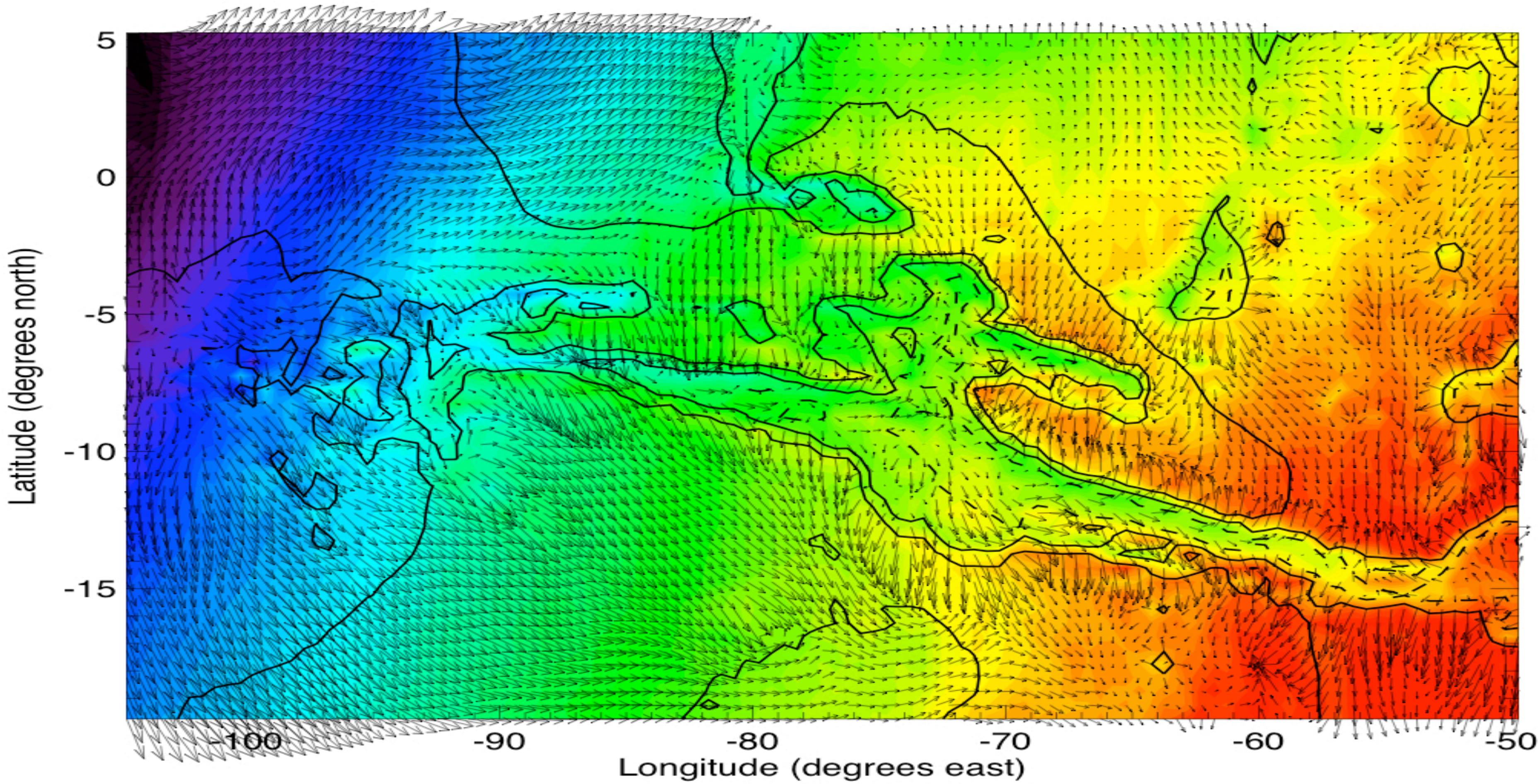
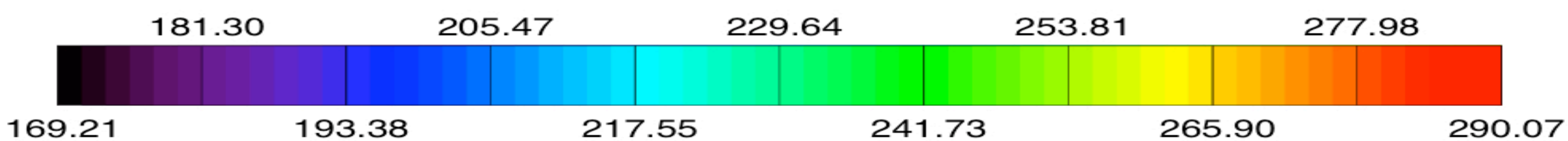
MarsWRF

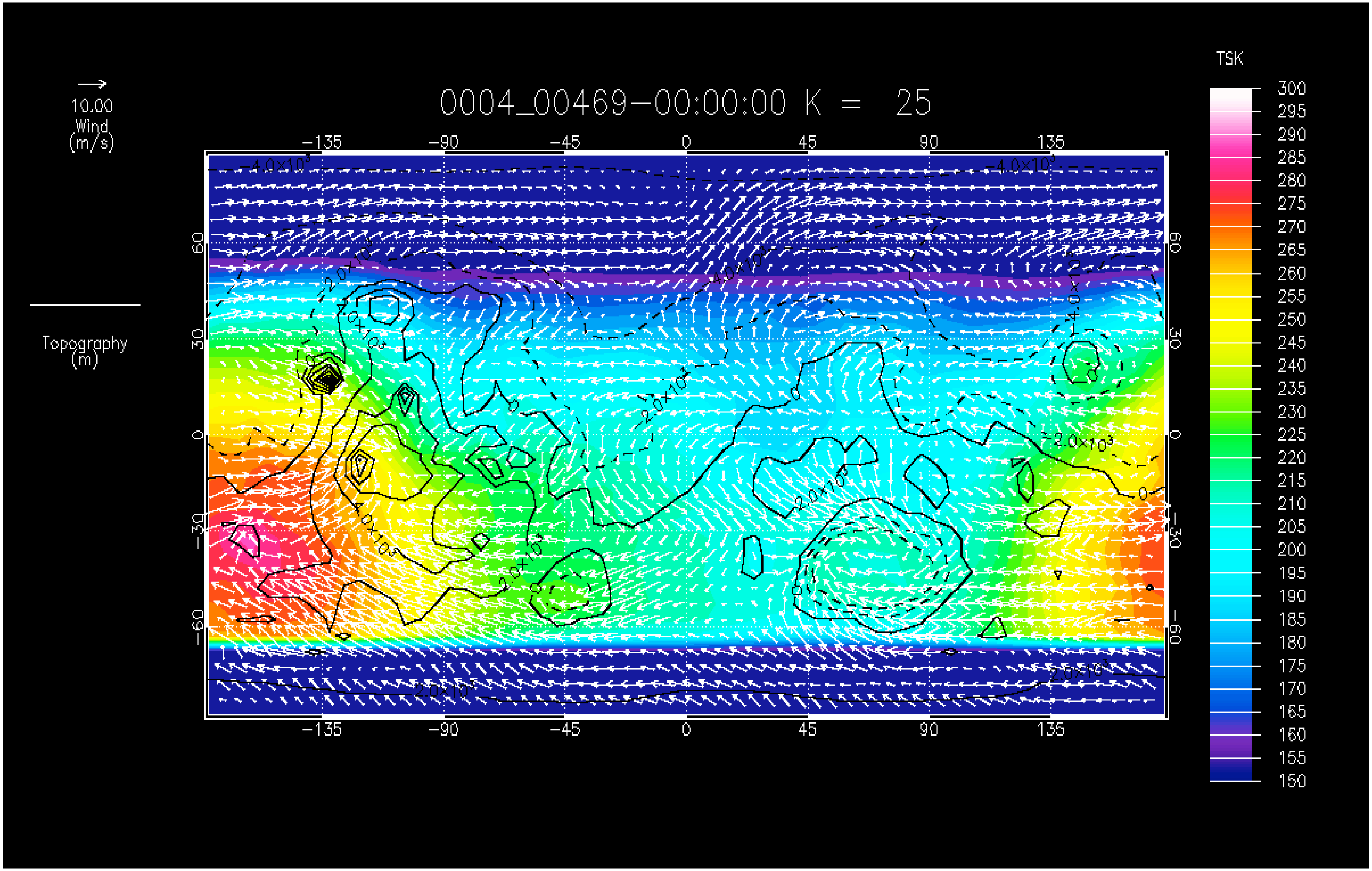
3. Nesting to study slope flows in Valles Marineris



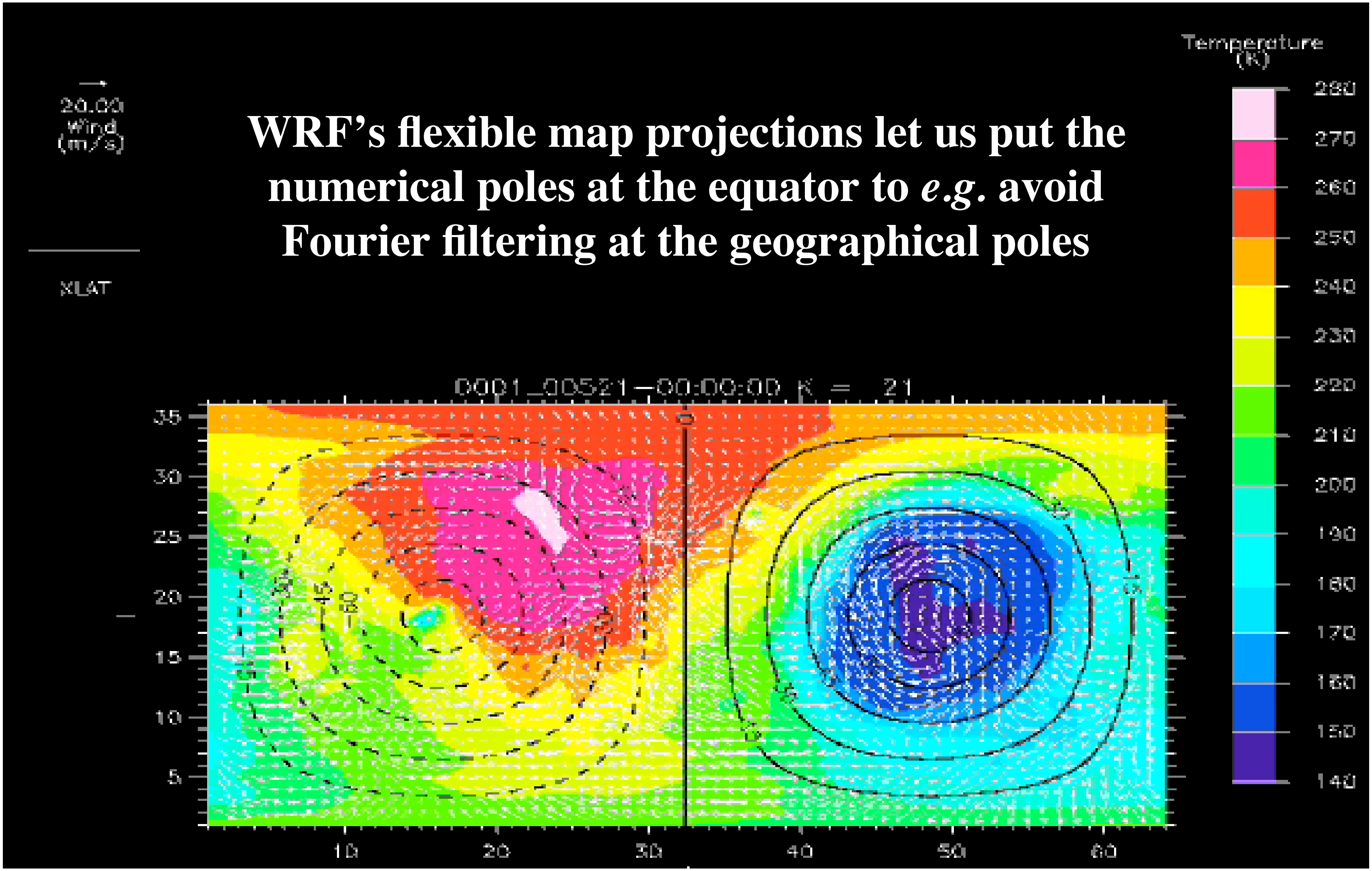
Surface temperatures (shaded) and near-surface wind vectors (arrows)



We run MarsWRF on a standard lat-lon grid…



…or as a 'rotated pole' simulation



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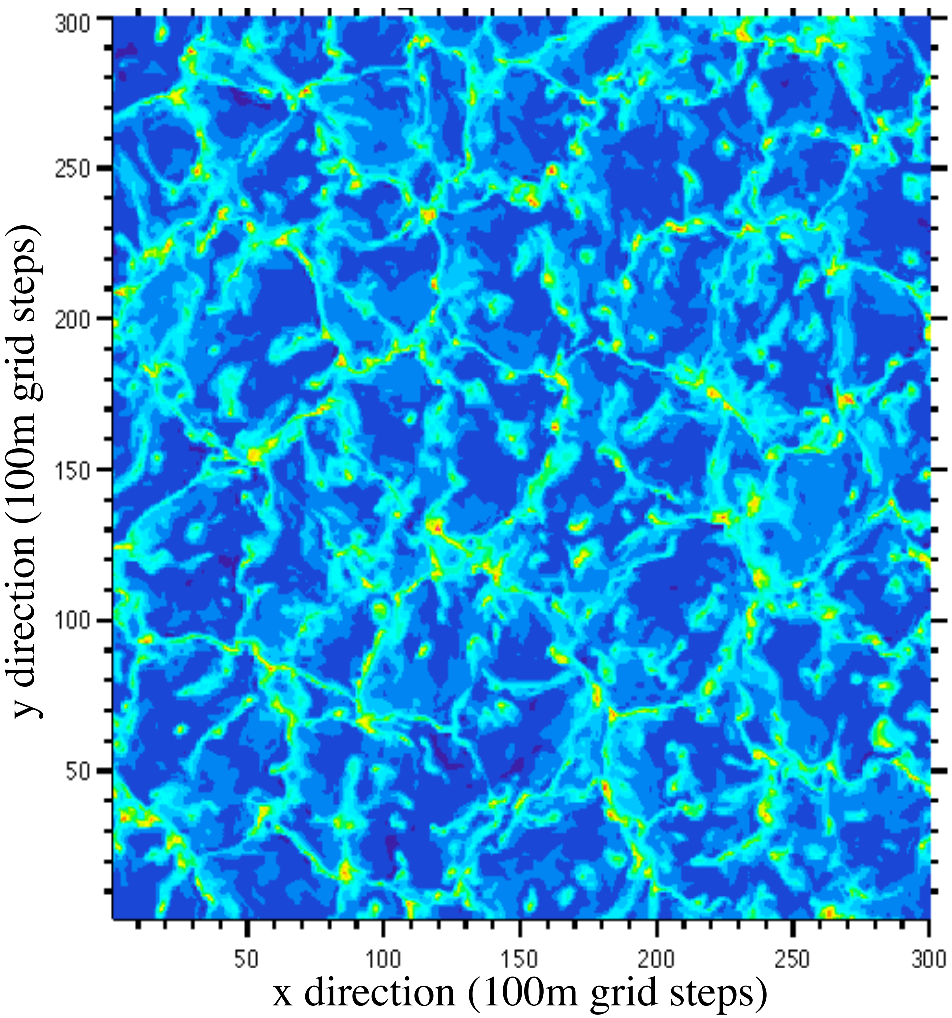
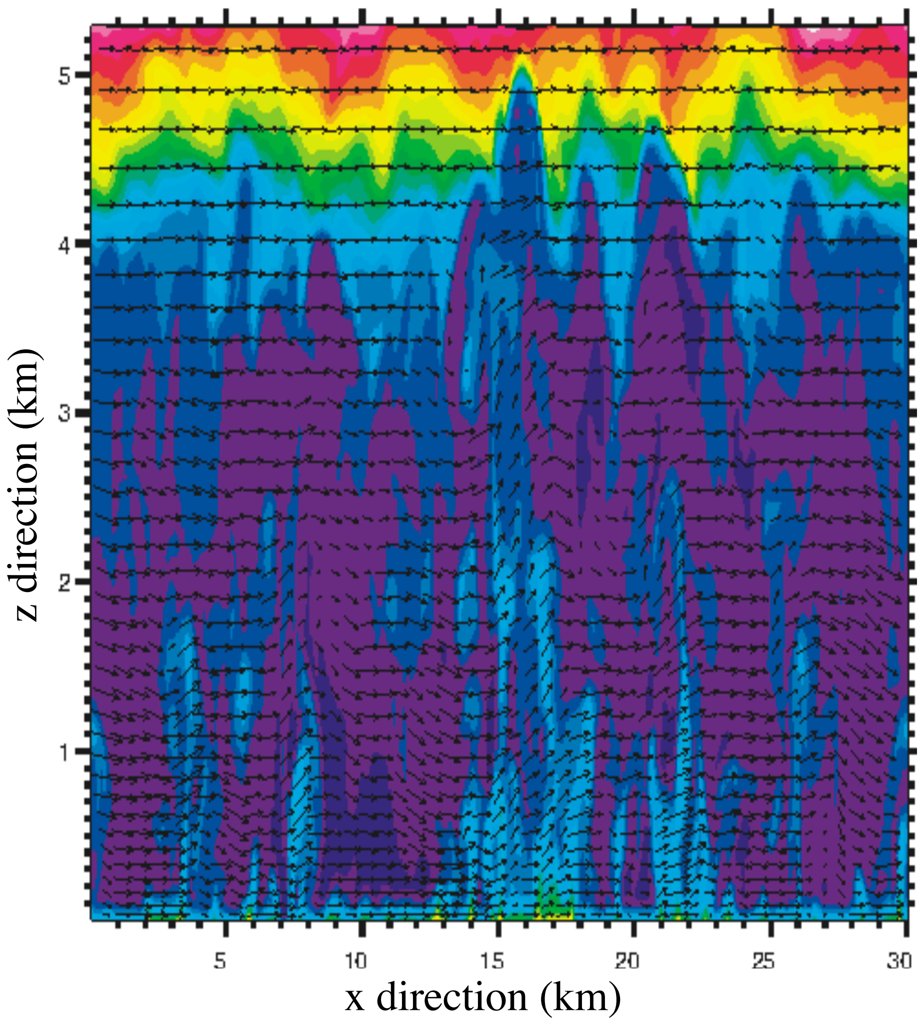
Large eddy simulation of convection on Mars

Vertical velocity (looking down)



Potential temperature (from the side)



Horizontal grid spacing is 100m [total domain size 30kmx30km]

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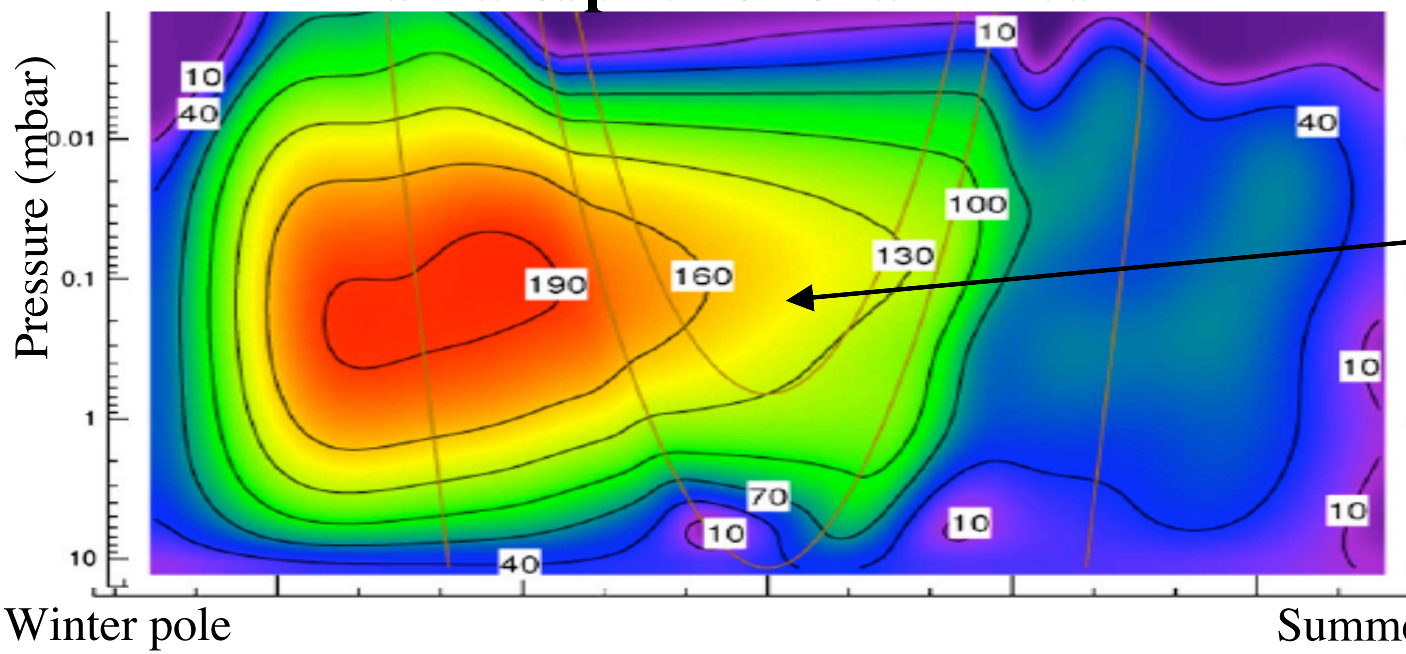
TitanWRF

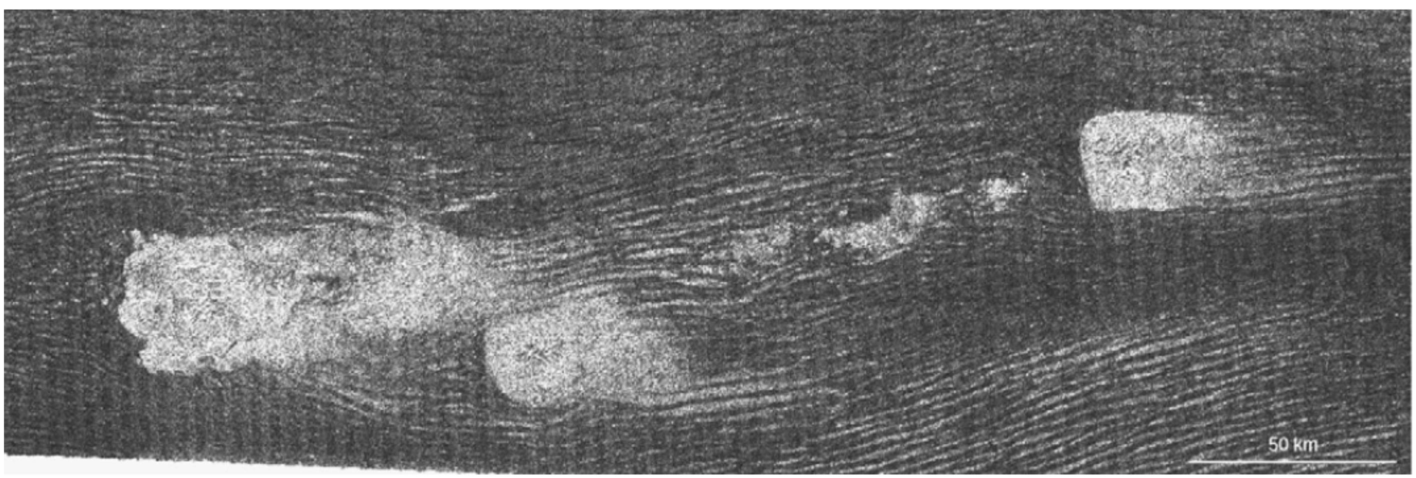
Topics of interest: on Titan

Stratospheric zonal winds



Massive equatorial superrotation

Surface dunes



Providing information about surface winds

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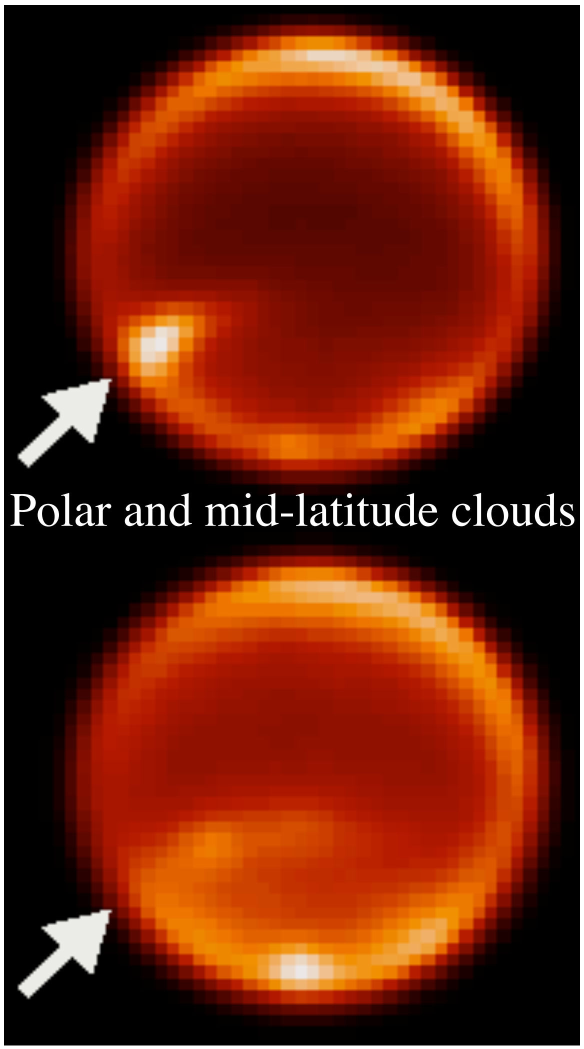
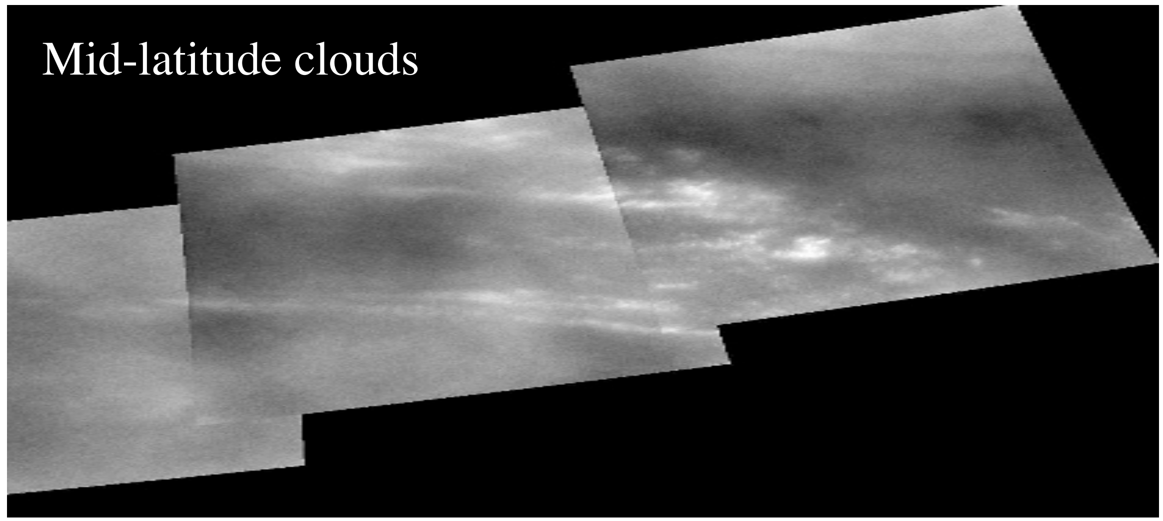
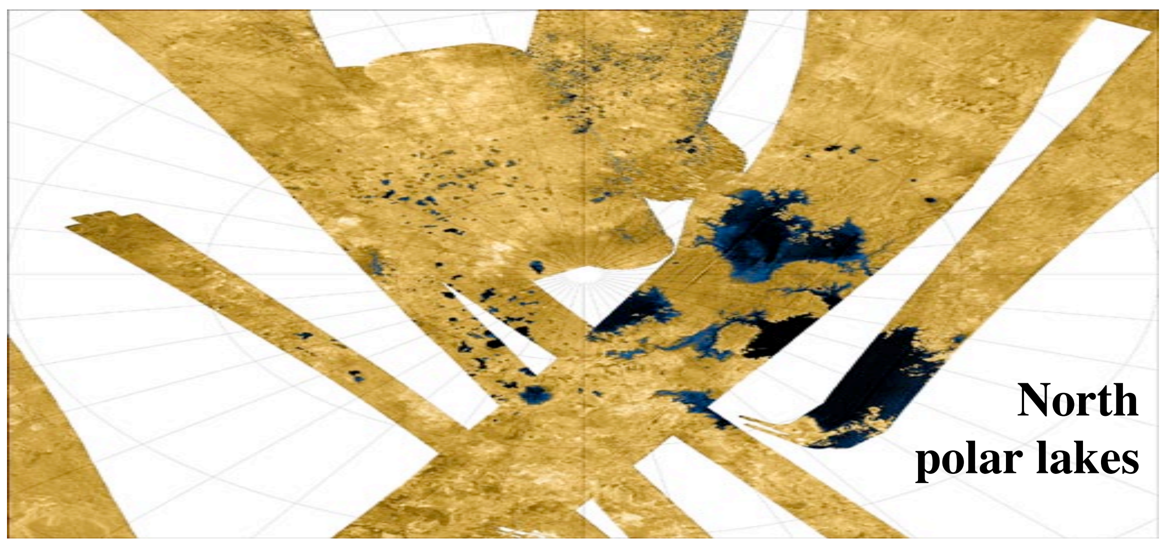
Topics of interest: on Titan

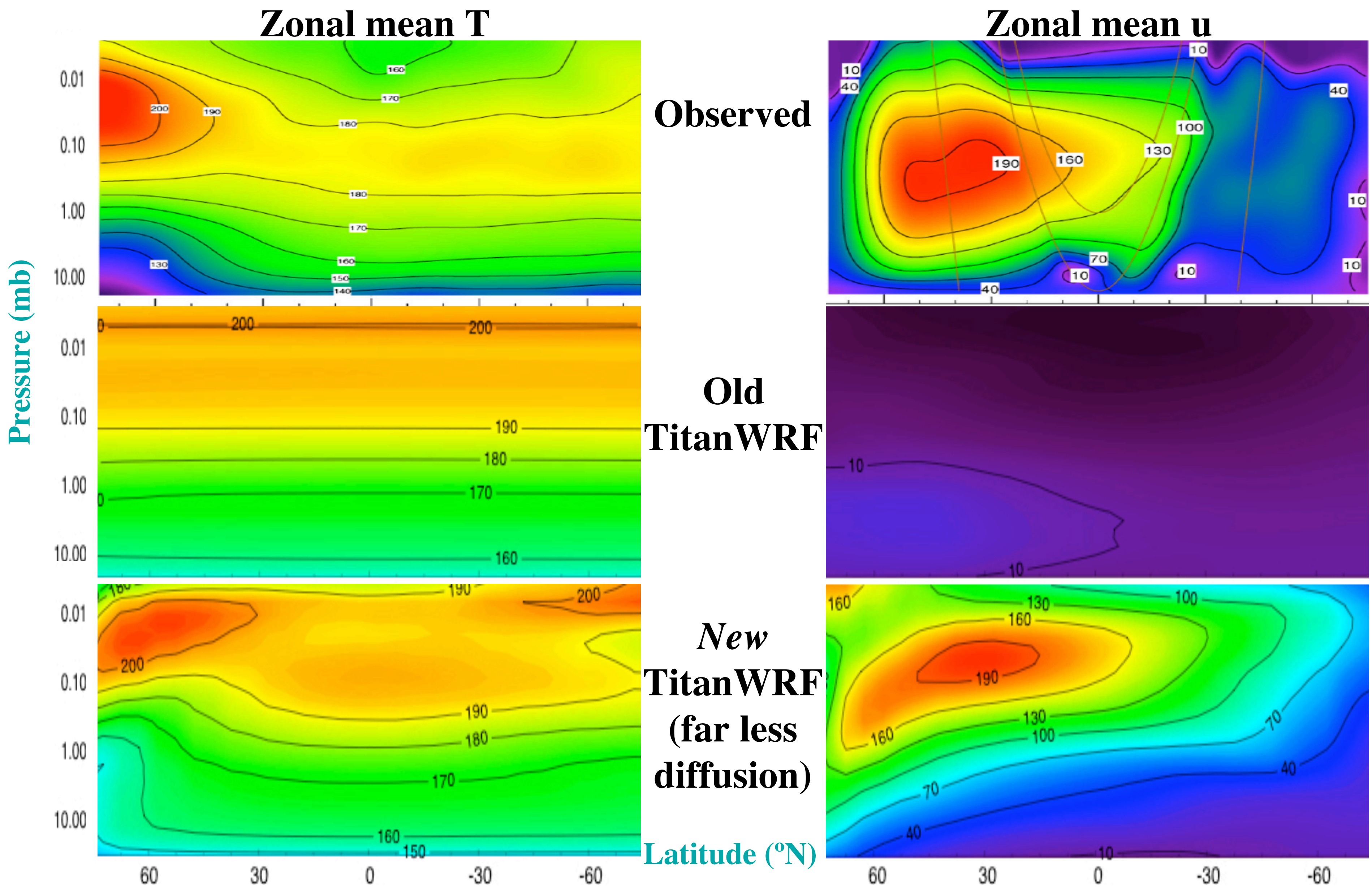
Tropospheric methane clouds and polar lakes





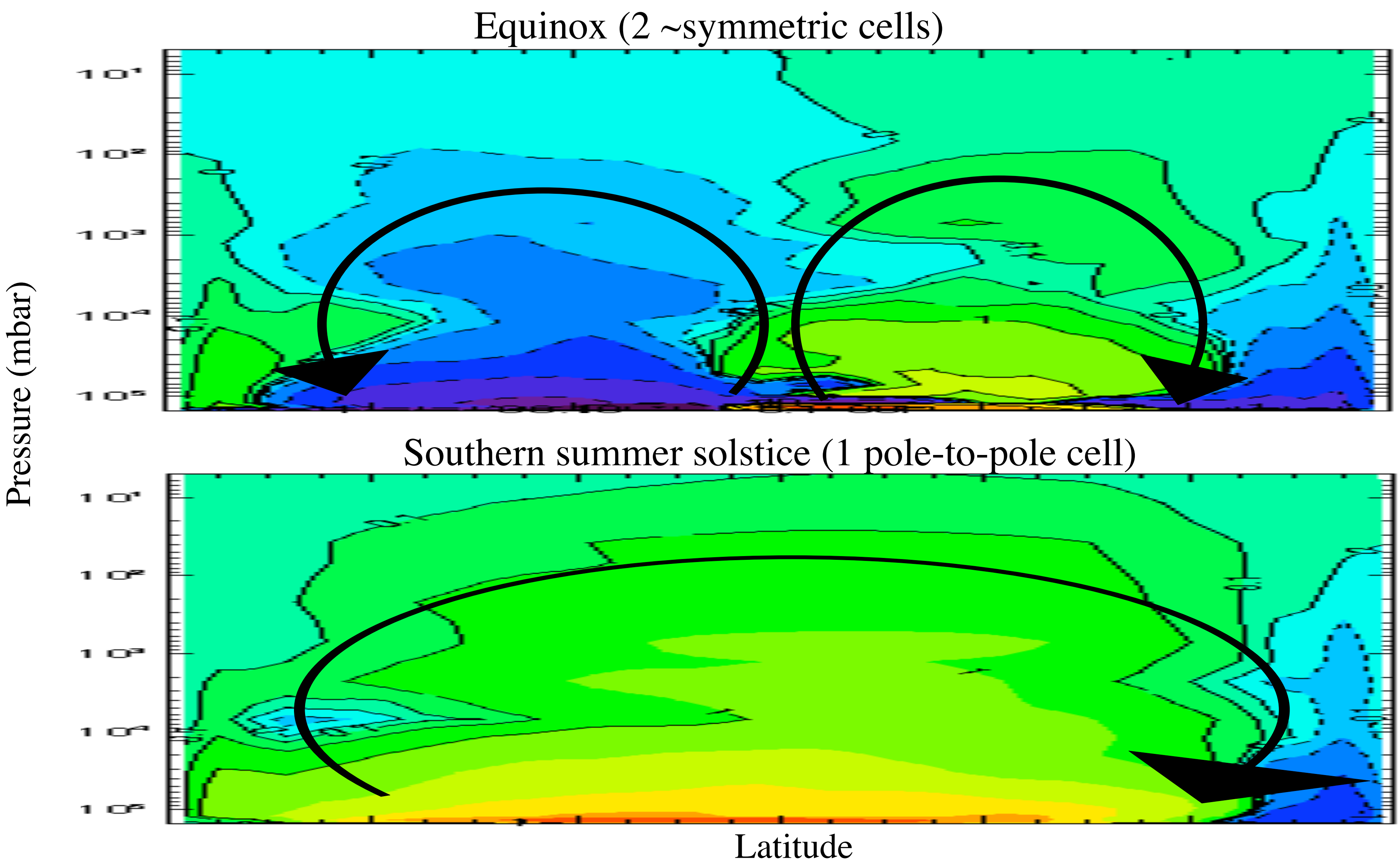


Reducing horizontal diffusion in TitanWRF

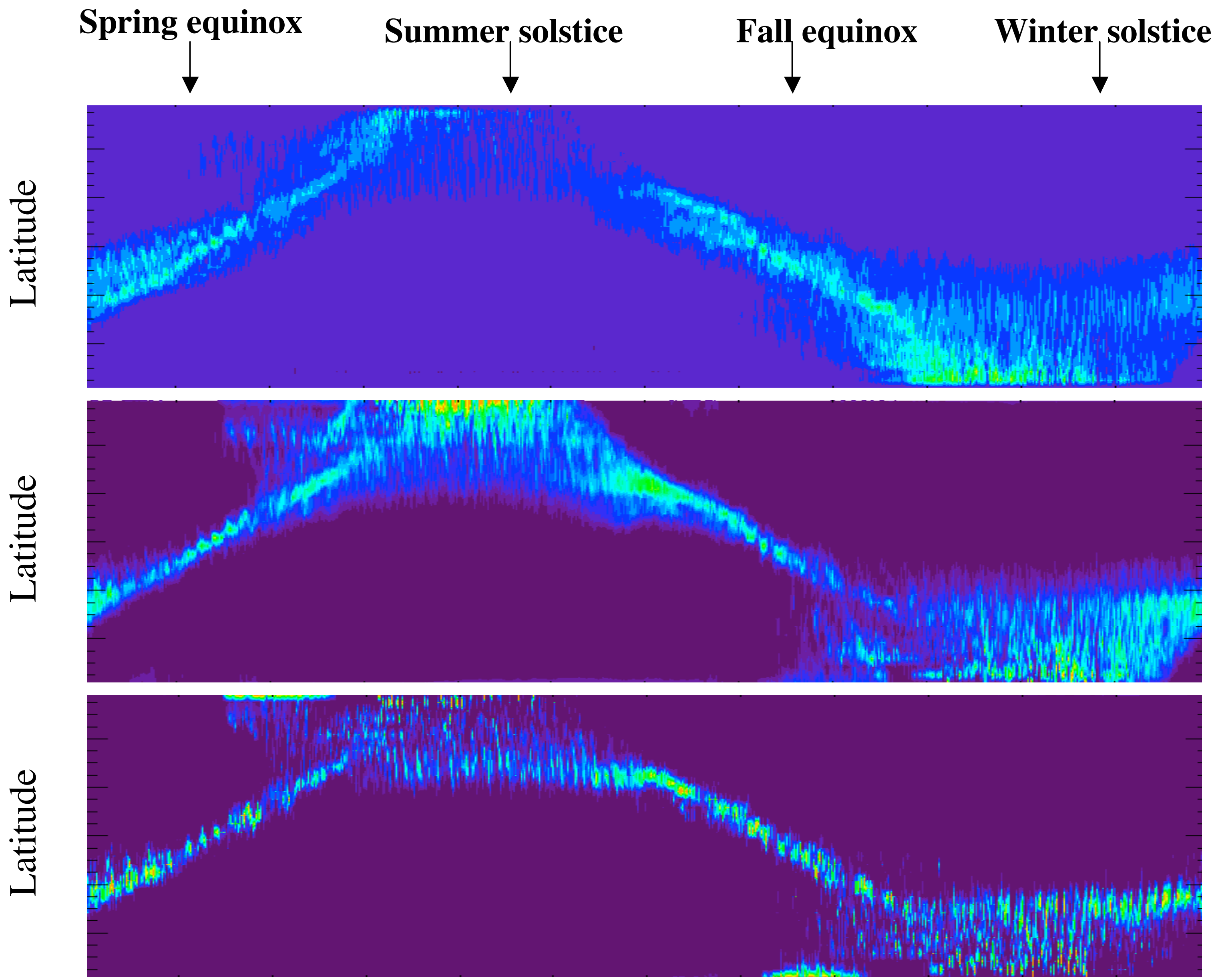


TitanWRF

TitanWRF's troposphere



TitanWRF's methane cycle



Maximum vertical velocity in troposphere

=> Methane cloud condensation

=> Surface precipitation

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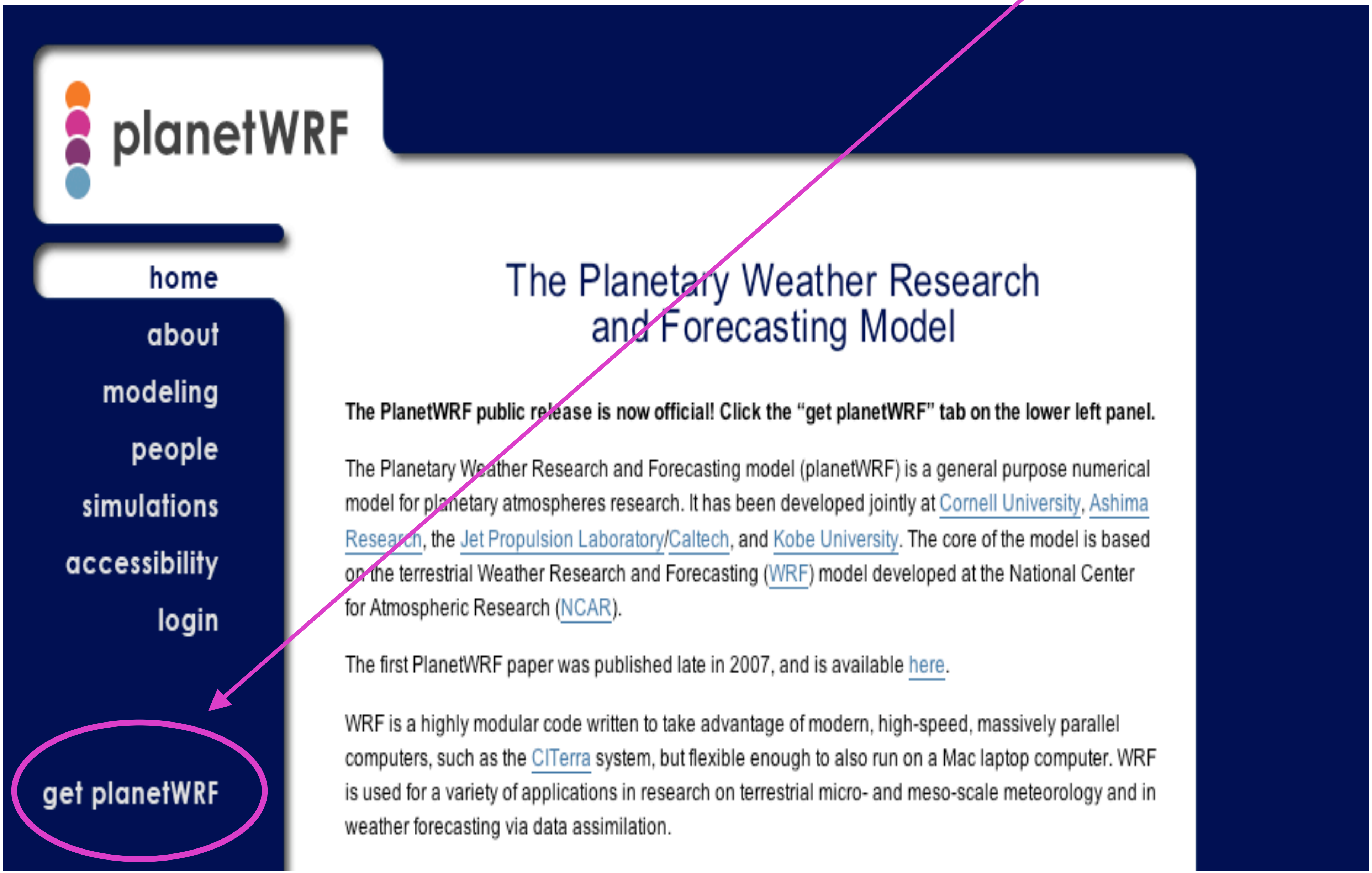
Get planetWRF

Download planetWRF at www.planetwrf.com



Download planetWRF at www.planetwrf.com

- Click on 'Get planetWRF' and follow the instructions:

  Step 1: download and untar **WRFv3.0.1.1** from NCAR (*planetWRF for WRFv3.1 is coming soon*)

  Step 2: download the **planetWRF** 'patch kit' from planetwrf.com (adds and modifies files to basic WRF)

  Then follow further instructions on how to configure, compile, run and verify a standard MarsWRF run

Further work

- Biggest 'to do' item is a positive definite and monotonic advection scheme (the polar filter causes problems)

For more information about planetWRF

- Talk to me or contact us at planetwrf@gmail.com

- See also planetWRF paper [Richardson *et al*. JGR 2007]

If dx = gap between grid points in map coordinates,
and dX = actual distance (in meters),
then **$dX = (1/m_x)\, dx$** and likewise **$dY = (1/m_y)\, dy$**

Original WRF

Conformal grid
=> for all map projections available (mercator, polar stereographic, etc.),
$m_x = m_y$ at all points

=> Only one map scale factor (m) used, and omitted altogether when m_x and m_y cancelled

Global WRF

Lat-lon grid => $x = a\lambda$, $y = a\phi$,
=> $dx = a\, d\lambda$, $dy = a\, d\phi$,
whereas $dX = a \cos\phi\, d\lambda$, $dY = a\, d\phi$
=> $m_x = dx/dX = \sec\phi$, $m_y = dy/dY = 1$
=> $m_x \neq m_y$

=> Needed to identify which map scale factor was required in all equations where 'm' appeared, and reintroduce map scale factors where they previously cancelled (so were omitted)

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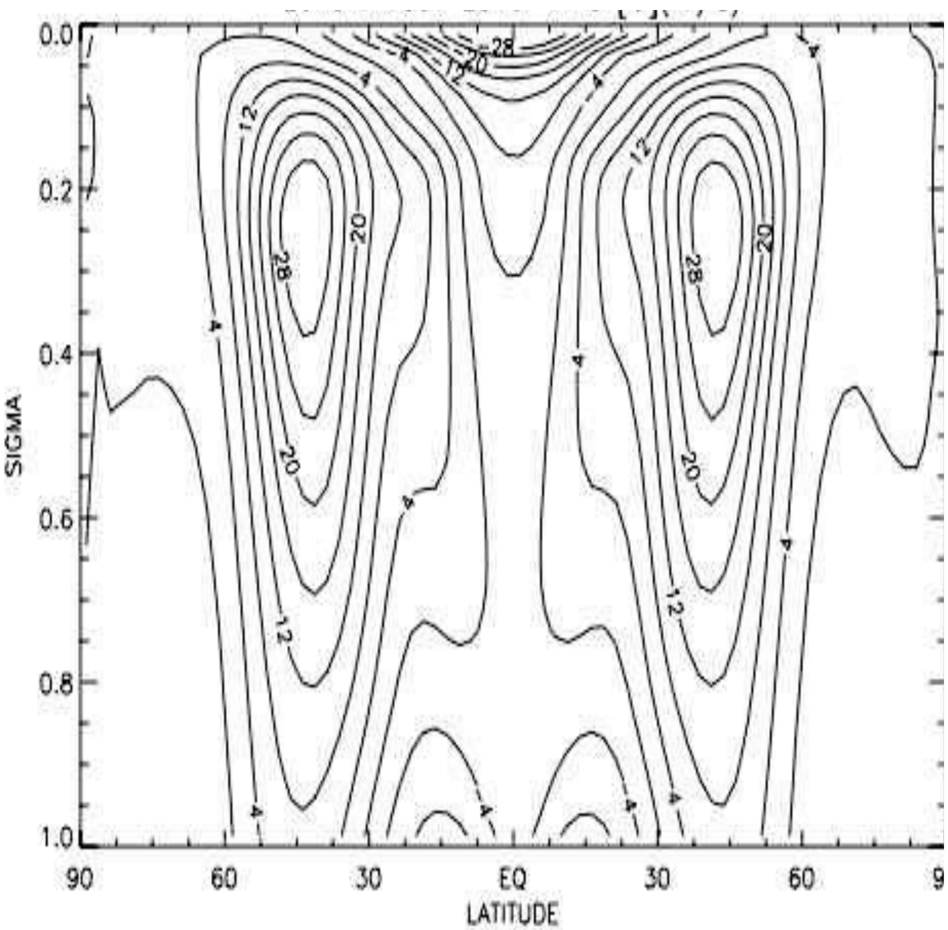
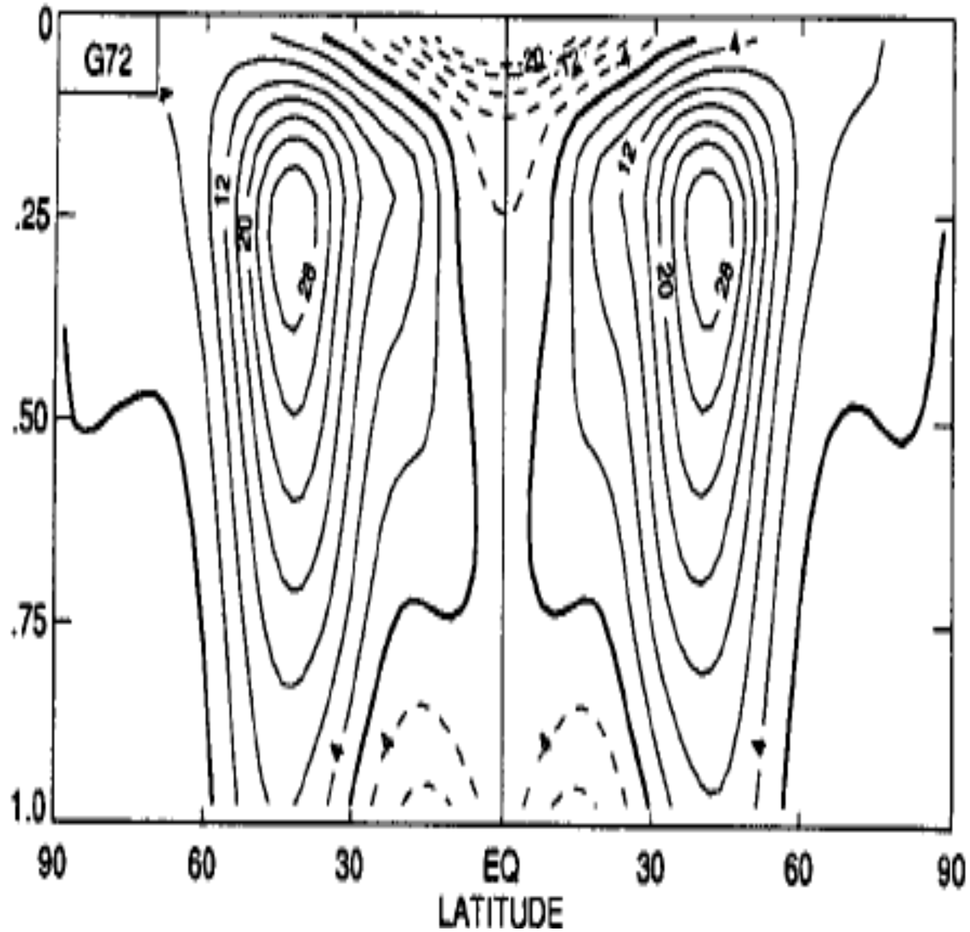
Testing global WRF

(As before but for zonal mean u)

Global WRF



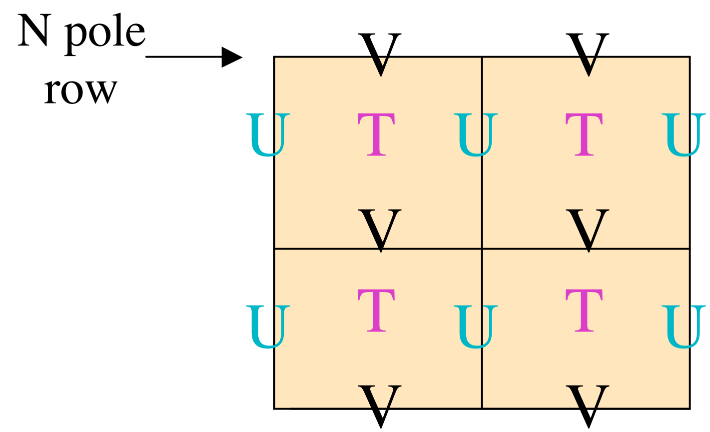
Expected result



For more tests see Richardson *et al*. JGR 2007

Globalizing WRF 3. Other changes

• **Polar boundary condition**: the initial solution was stable (v = 0 at the poles with no fluxes to or from the poles) but has been improved by the NCAR team

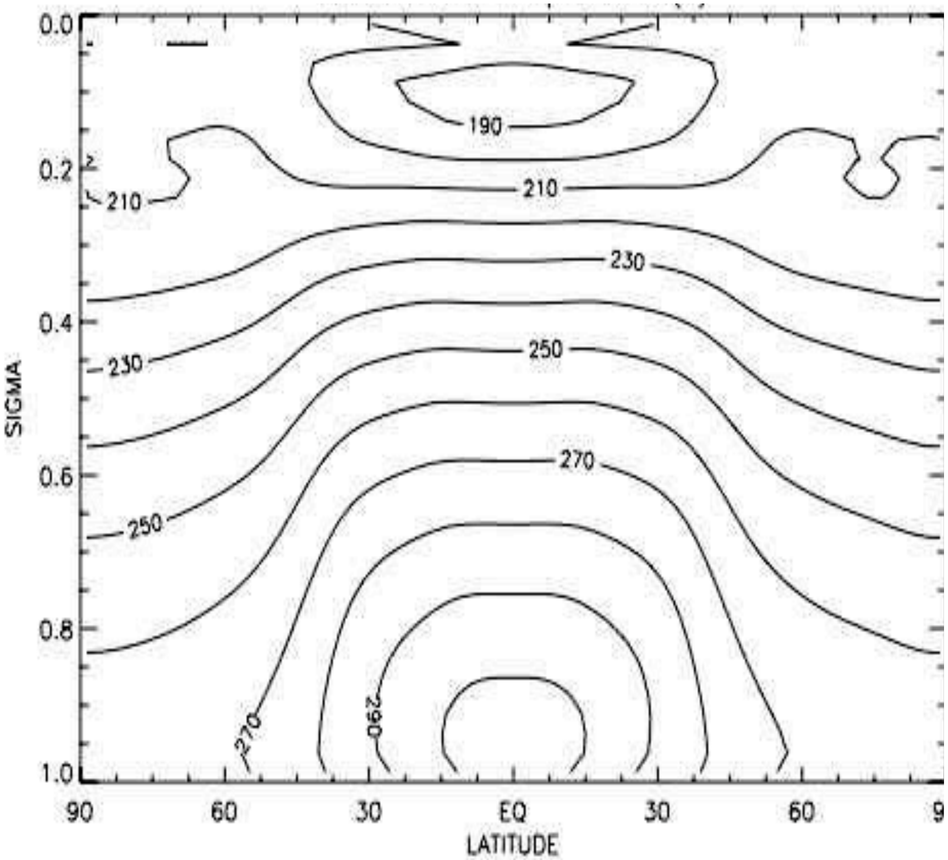


• **Sponge layer**: planetWRF is run as a standalone model with a high model top (over ~10 scale heights) for most applications, so damping of spurious waves in the top 3 or 4 layers was added to prevent reflection [`module_planetary_damping.F`]

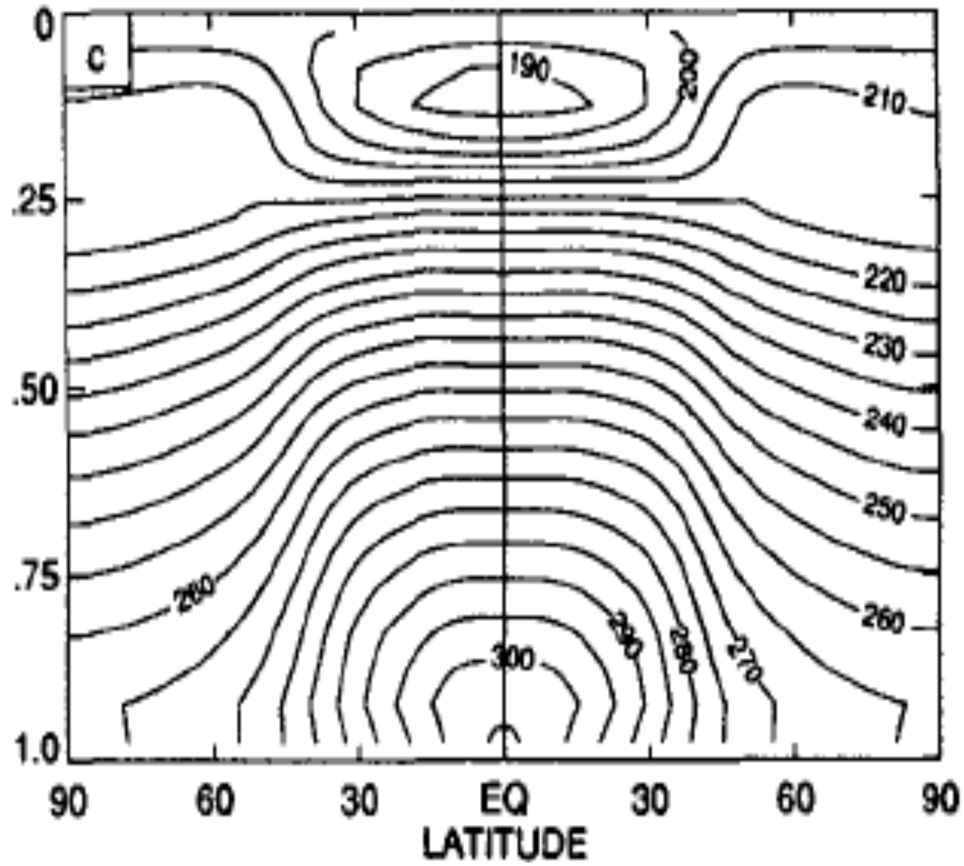
Testing global WRF

Time and zonal mean T using Held and Suarez forcing (BAMS, 1994)

Global WRF



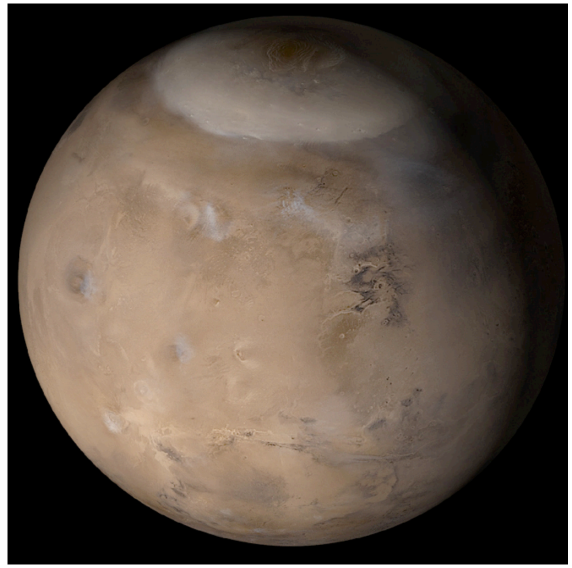
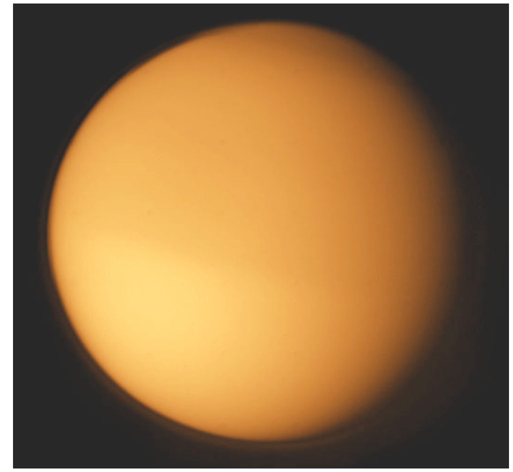
Expected result



For more tests see Richardson *et al*. JGR 2007

Compile as an ideal WRF case using: compile em_heldsuarez

Objects of interest

Earth	Mars	Titan
		
N_2 atmosphere P_s ~10^5 Pa, T_s ~288 K	**CO_2** atmosphere P_s **~10^3** Pa, T_s **~150-300** K	N_2 atmosphere P_s ~10^5 Pa, T_s **~90** K
	Very eccentric orbit	Rotates **16x** slower Year lasts **30x** longer
Water cycle Oceans & land surfaces	**Major topography** **Dust storms**	**Thick haze layers** **Methane** 'hydrology'