

# Why understanding Venus' atmosphere is important

Venus' atmosphere extreme environment

- surface atmospheric pressure 92 bars
- surface temperatures around 740 K
- strong zonal winds with equatorial velocities  $\sim 100$  m/s at cloud tops

We currently do not understand why Venus' atmosphere circulates the way it does and how the atmosphere it reached its extreme state, and amongst other things we need to determine :

- why the atmosphere is in its extreme state of rapid superrotation
- possible relevance to the future climate of our own atmosphere

## Observational limitations

Key atmospheric characteristics are not well known or known at all, including:

- global vertical profiles of winds
- solar thermal tidal amplitudes and phases
- horizontal structure of the nighttime circulation on multiple levels
- transport of heat and trace species
- exchange of angular momentum between the atmosphere and the solid planet over time
- long term variations in atmospheric quantities and wind structure

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## **Observational limitations**

The above quantities are not well measured or measured at all because of some major measurement challenges, e.g.

- we do not have observational tools that can provide us with horizontally-distributed measurements at the same vertical level on both the day and night side of Venus.
- difficulties in resolving cloud level winds accurately with the available instrumentation and viewing geometries and possible obscuration by haze layers.

### **Future missions**

- may be limited in scope e.g. may only have one balloon or one probe available
- to make measurements

## **Why models are important for Venus**

General circulation models (GCMs) of the Venus atmosphere are essential for a good understanding of the processes occurring in Venus' atmosphere, e.g.

- the nature and the role of the thermal tides
- vertical and meridional transport of angular momentum by the eddy and mean circulations and by waves
- horizontal transport of heat and trace species
- processes that maintain the superrotation

### **A realistic Venus GCM is needed**

- not only to interpret data from past and present missions, but also to plan future missions, especially ones with in situ probes, balloons, and landers.

## UCLA Venus Atmosphere Model

Based on NCAR Community Atmosphere Model (CAM) Earth-based climate model

By far highest resolution Venus atmosphere model currently in use:

**Resolution:**  $1^{\circ}$  latitude by  $1^{\circ}$  longitude

50 vertical levels, upper boundary around 95 km altitude

correspondingly short 150 s time steps

Other GCMs typically have only 5 x 5 degree resolutions. Processing power multiplies up as every dimension increased (x 25 to 100 times).

Increased resolution - allows us to more accurately take account of small-scale dynamical processes important on Venus e.g. small scale eddies, thought to be important in transport of momentum and possibly in superrotation.

We use state-of-the-art supercomputers at Lawrence Livermore National Laboratory, currently 2304-processor machine, more powerful 13,824-processor in the future.

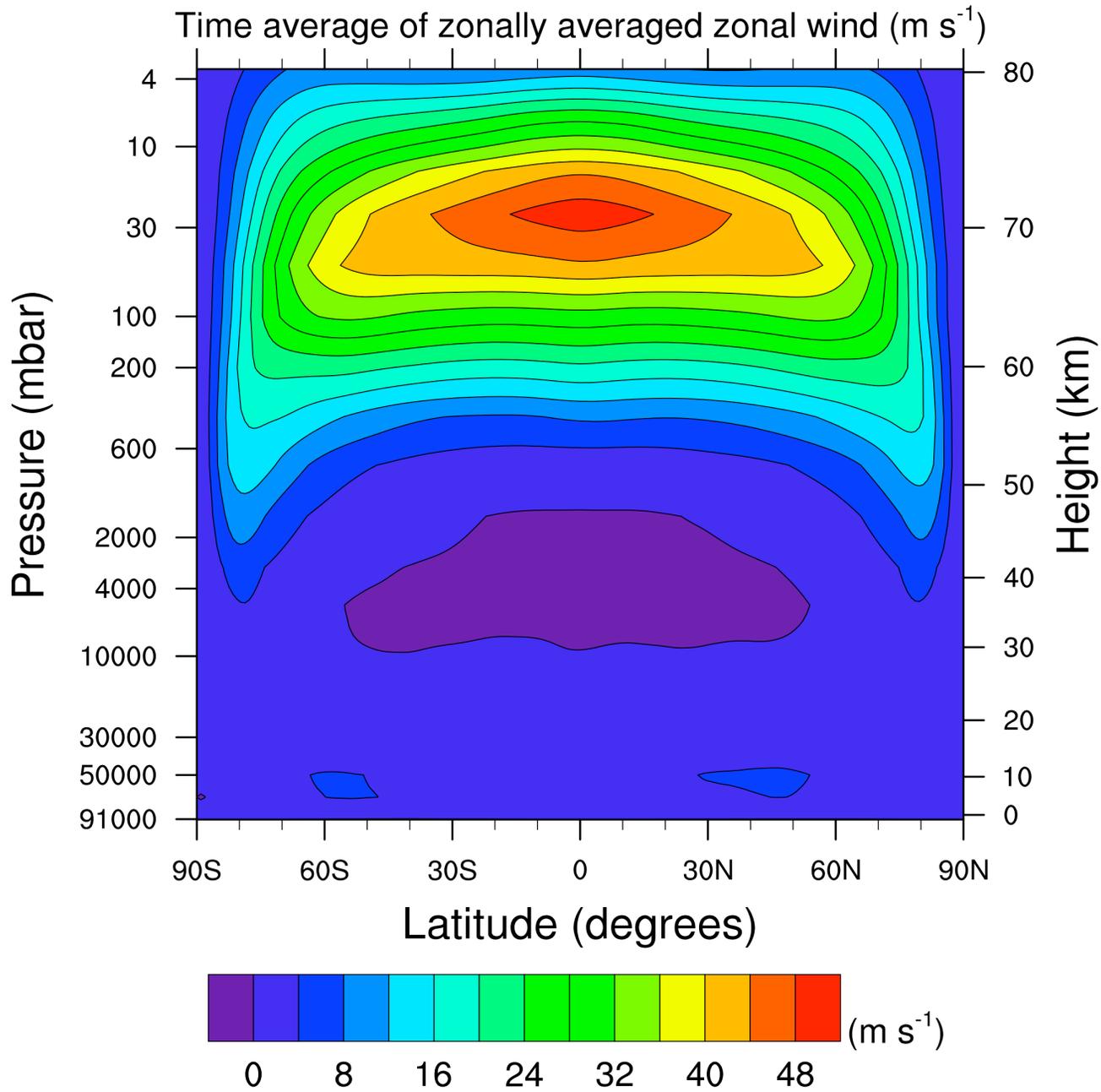
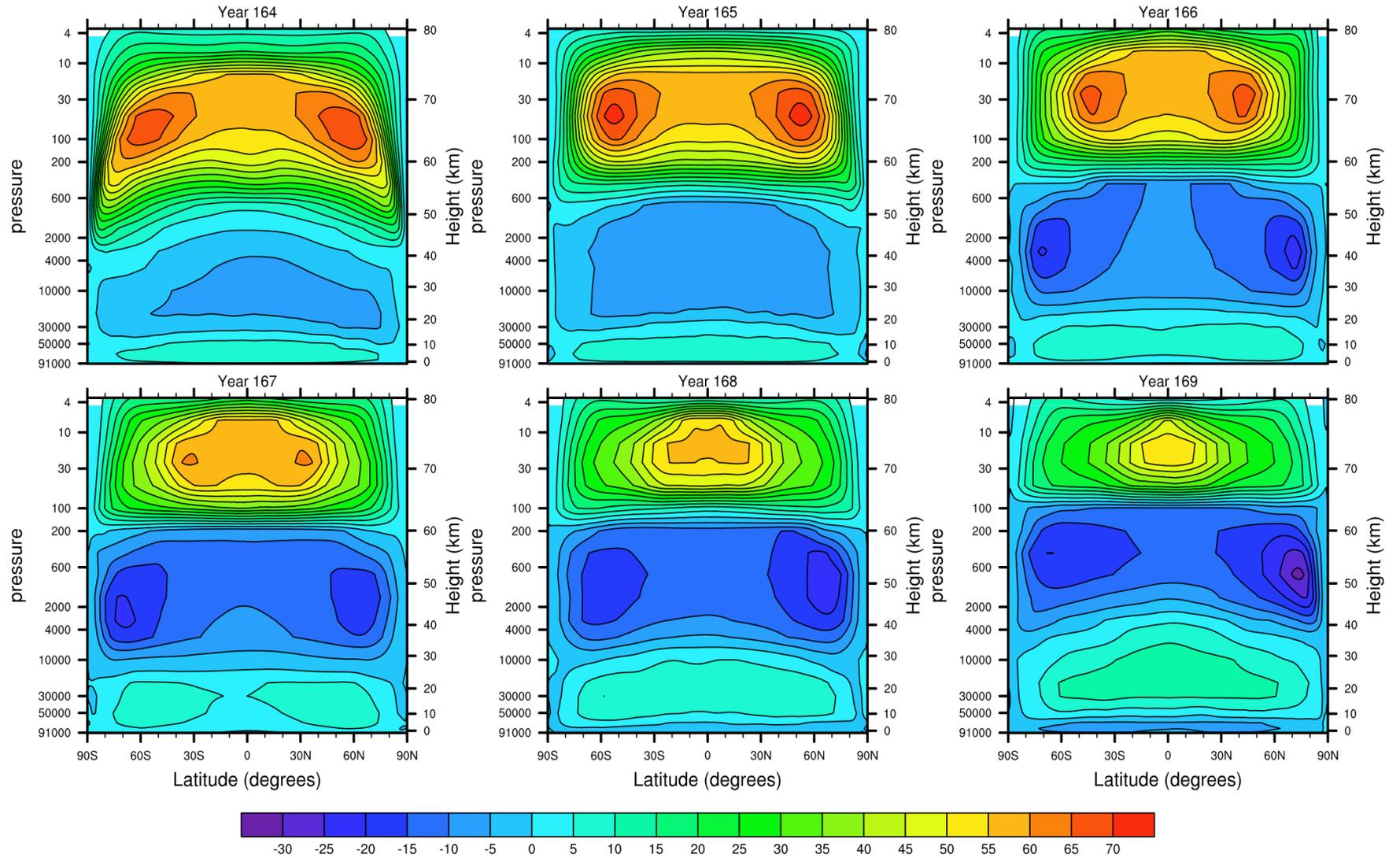
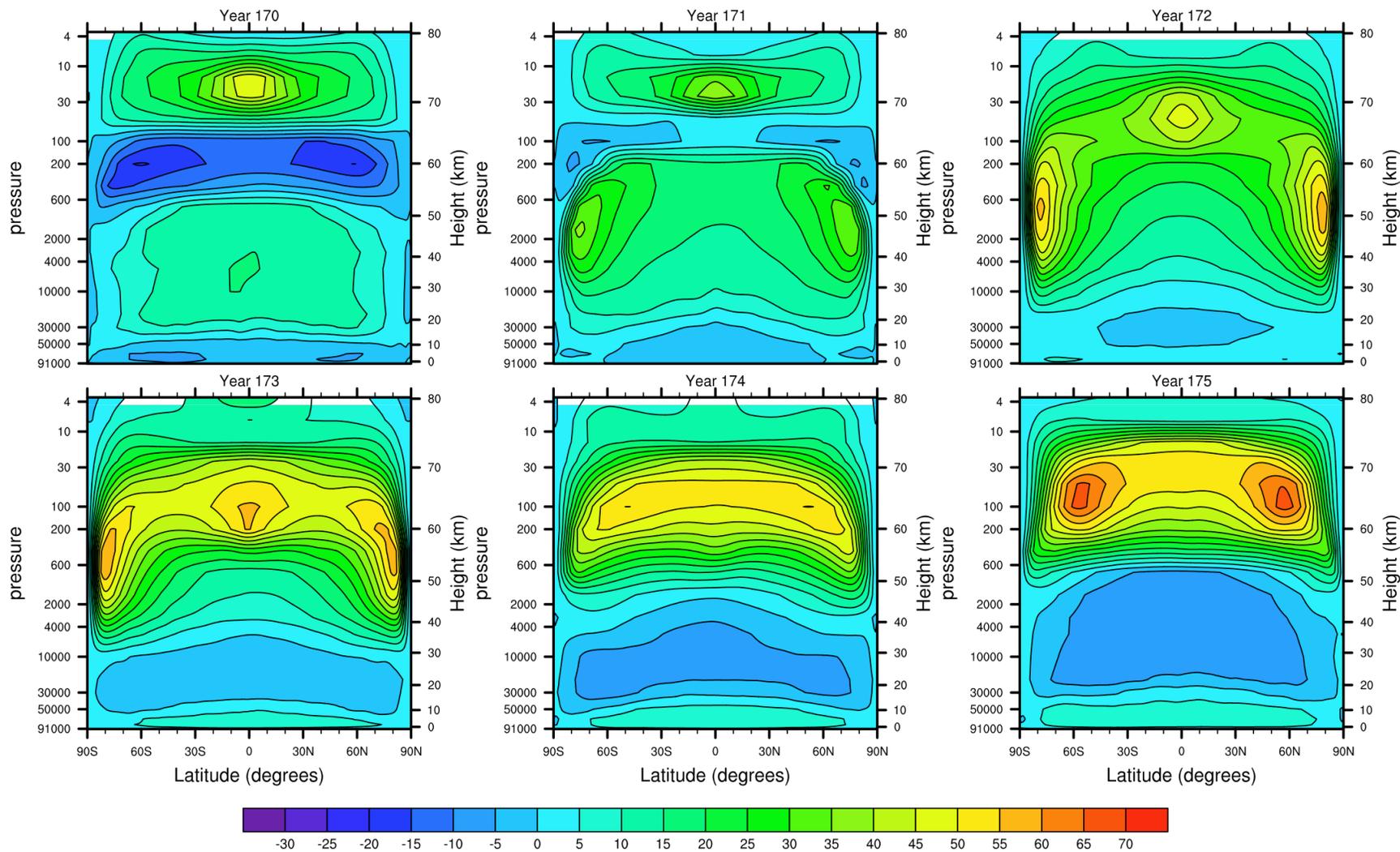


Fig 2b. Parish et al.

# Zonally Averaged Zonal wind



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## **Modeling efforts**

Venus modeling efforts around the world - France, Japan, UK, and US. Results differ in many ways e.g. nature of long term variations, sensitivity to changes in e.g. topography. We see features in high resolution UCLA model that are not seen in models using lower resolutions.

Important to reach understanding and consensus in the results from simulations of Venus' atmosphere by different investigators to arrive at a consistent picture and comprehension of the dynamical and thermal features of Venus' atmosphere.

The Coupled Model Intercomparison Project (CMIP), has served the Earth climate science community for the past decade, and has revolutionized the application of GCMs to Earth climate studies (Meehl et al., 1989).

A similar Venus Intercomparison Project recently started among several independent groups, under the auspices of ISSI (International Space Science Institute) in Bern, Switzerland.

## Summary

Processes responsible for unique characteristics of Venus' atmosphere still not understood.

In order to do so we need good models, not observations alone !.



## Results of Model Simulations

Run from an initial isothermal state, temperature 400 K, and winds at rest

Simulations were run for around 200 Earth years (625 Venus solar days)

Figures show changes in the zonally averaged zonal wind over the time interval (Earth) years 164 to 175. This cycle repeats.