Evaluating the Performance of the WRF Model in Representing the Antarctic Boundary Layer

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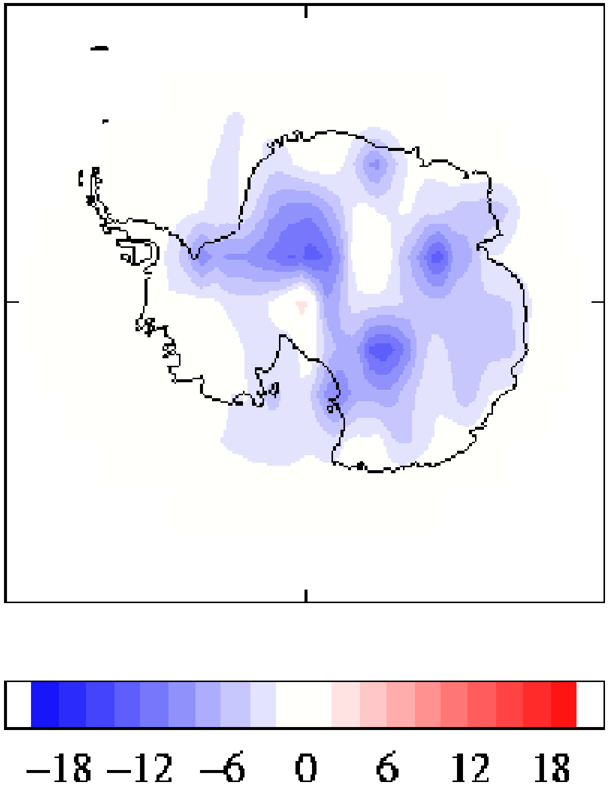
Acknowledgements: Jimy Dudhia, Kevin Manning, Julie Phillipson, and

Introduction

- Most strongly stratified BLs observed on Earth
  - Existence of persistent stable BLs
  - Existence of turbulent burstings
- BL parameterizations are traditionally tuned for mid-latitude regions
- Implications for global warming research



Difference between two BL schemes for 1.5 m temperature, JJA season, 5 year mean

Source: King et al. (2001)

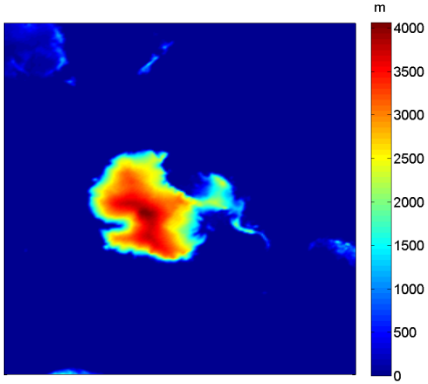
Project Description

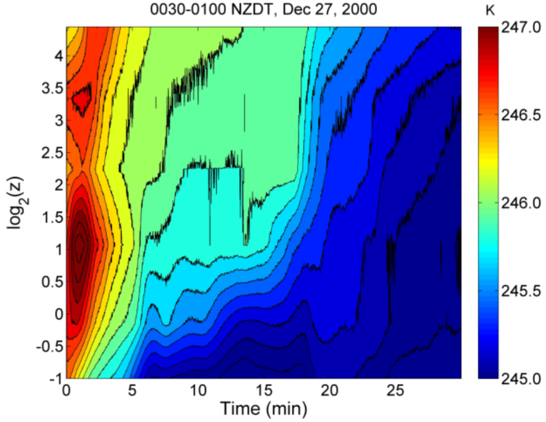
Phase 1:

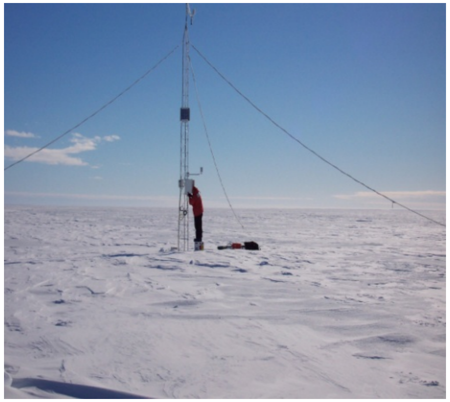
Investigate the capabilities of the new-generation WRF-PBL schemes in simulating Antarctic BLs.

Phase 2:

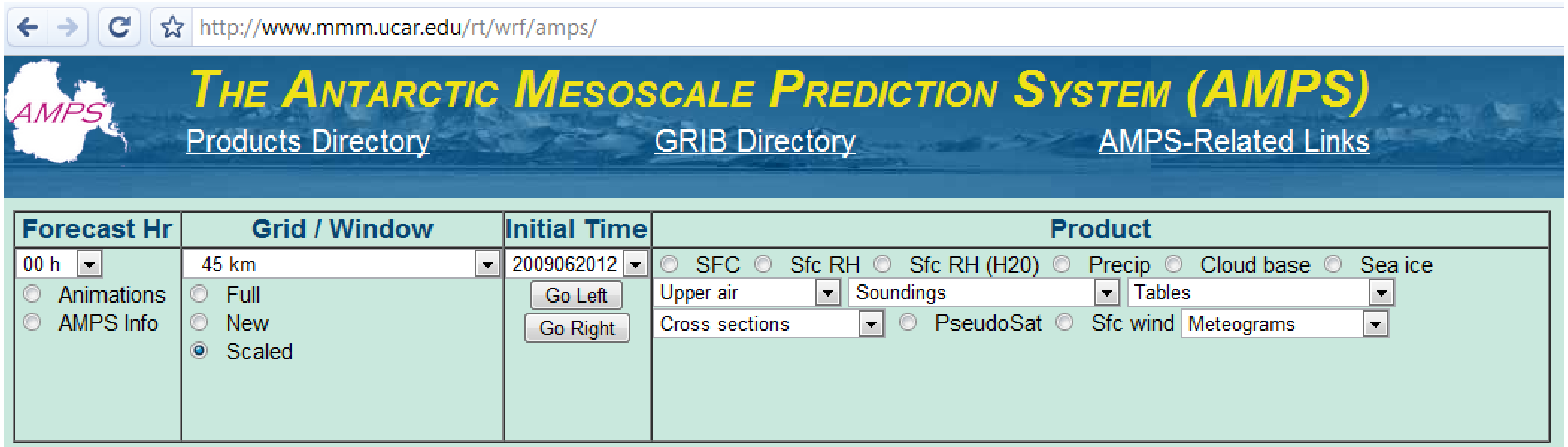
Develop improved and physically-based BL parameterizations based on large-eddy simulation-generated databases in conjunction with field observations.







The Antarctic Mesoscale Prediction System (AMPS)



Long-wave Radiation: RRTM radiation scheme (ra_lw_physics=1; radt=10)
Short-wave Radiation: Goddard radiation scheme (ra_sw_physics=2; radt=10)
Boundary Layer: Mellor-Yamada-Janjic (Eta) TKE scheme (bl_pbl_physics=2; bldt=0)
Surface Laye
Land Surfac
Microphysic

Polar-WRF

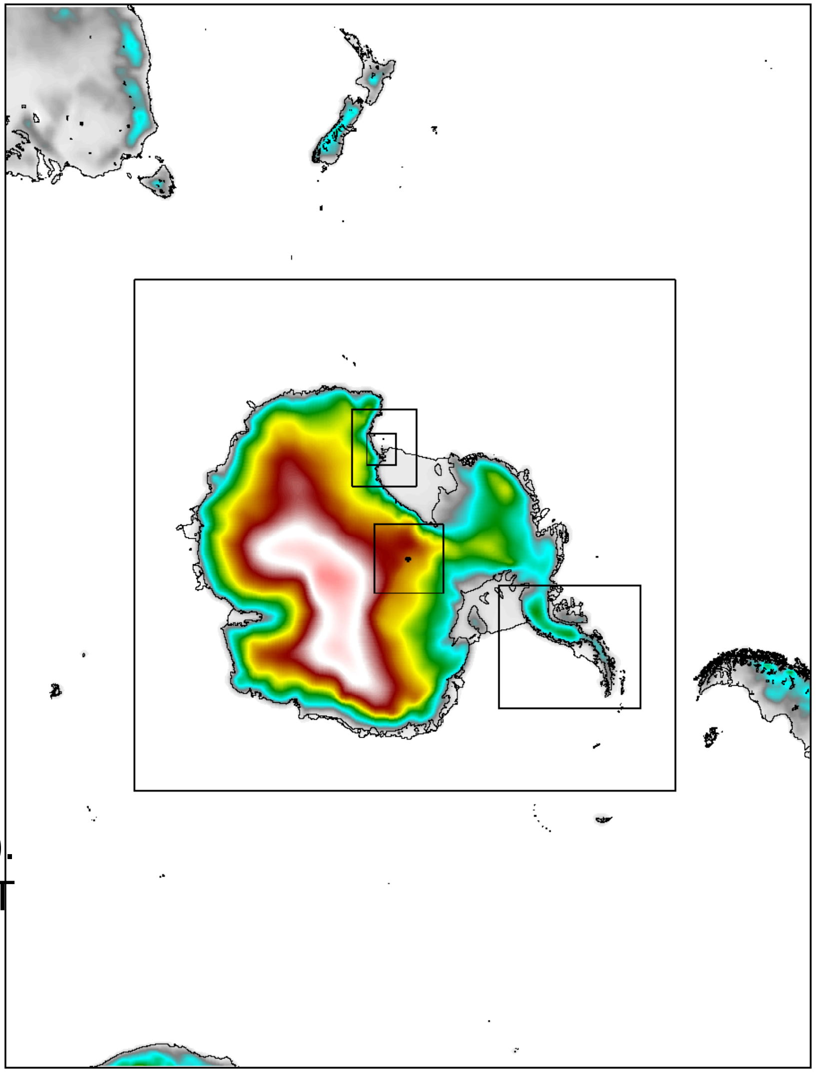
Cumulus Parameterization: Kain-Fritsch (new Eta) parameterization (cu_physics=1; cudt=5) on 45- and 15-km grids; No cumulus parameterizations (cu_physics=0) on 5- and 1.667-km grids

AMPS (Cont.)

Polar WRF:

• Optimal turbulence (PBL) parameterization
• Implementation of a fractional sea ice description in the Noah LSM
• Improved treatment of heat transfer for ice sheets and revised surface energy balance calculation in the Noah LSM
• …
• …

http://polarmet.mps.ohio-state.edu/PolarMet/pwrf.html



In this work, we used the regular WRF (v3.1). We did not use real-time sea ice fields and SST data.

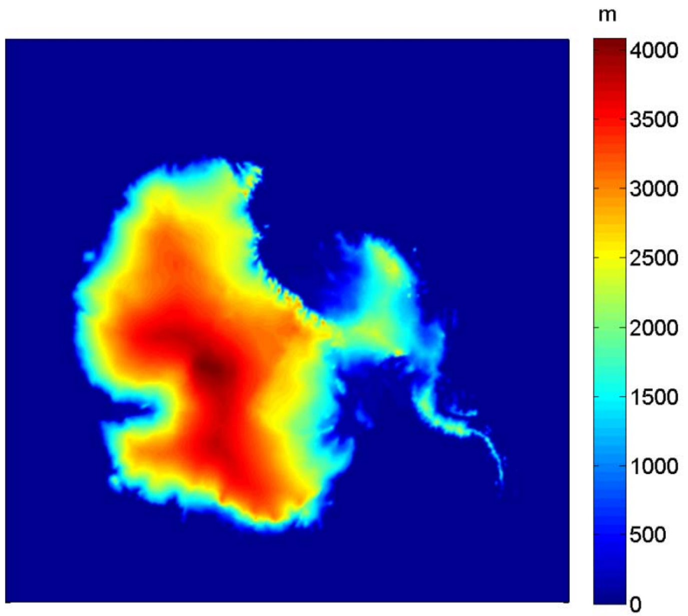
http://www.mmm.ucar.edu/rt/wrf/amps/information/configuration/maps.html

WRF Configuration

Initialization and Boundary Conditions: NCEP Final Analysis (FNL from GFS), 1 degree resolution, every 6 hours

Long-wave Radiation: RRTM
Short-wave Radiation: Goddard
Land Surface: Unified Noah LSM
Microphysics: WSM 5-class
Cumulus Parameterization: Kain-Fritsch

Boundary Layer: YSU, MYJ, QNSE, and MYNN2
Surface Layer: YSU, MYJ, QNSE, and MYNN2



d02 (RAMP2 dataset), 417x441
Courtesy: Dr. Kevin Manning

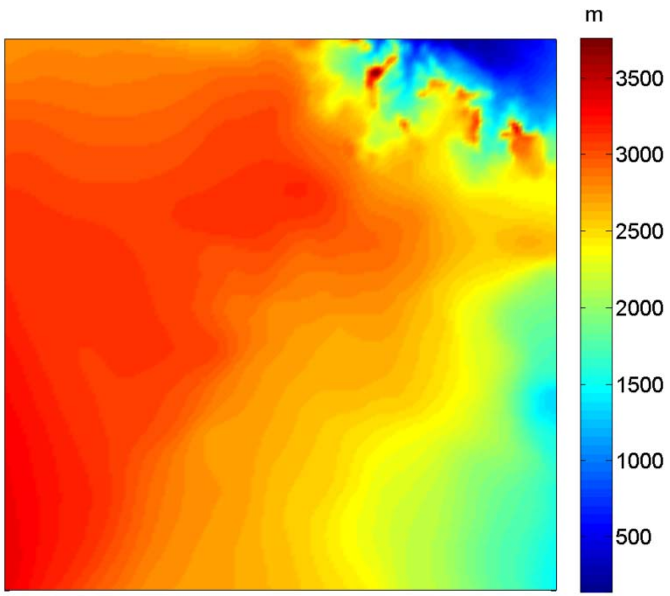
Time Period: 15 Nov – 31 Dec, 2000
Integration (run_hours): 36 hours (0 UTC, day n to 12 UTC, day n+1)
Analysis Period: 24 hours from each run (12 UTC, day n to 12 UTC, day n+1)
Output Frequency: 10 min (d03)

 # Runs: 184
Total Simulation Time: ~2 CPU-Years (dual-slot quad-core nodes with Intel 5450 processors - 3.0 GHz cores, connected with DDR Infiniband)

Site Selection: South Pole Region of the Antarctic Plateau

Excellent Site for Boundary Layer Research

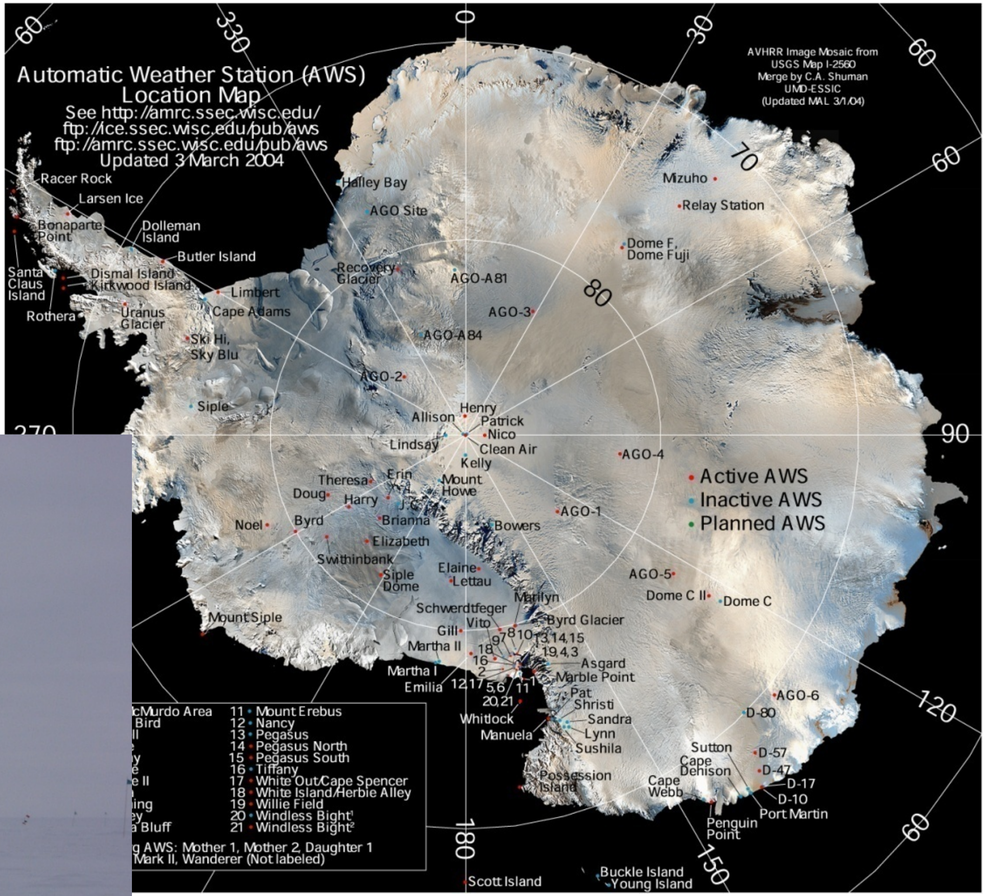
- Absence of strong topographical forcings (slope ~0.001 m/m)
- Devoid of several complicated processes (e.g., hydraulic jump, barrier winds)
- Predominant plateau 'high' provides cold dry conditions throughout the year
  - Mostly clear skies
  - Infrequent formation of precipitation
  - Availability of observational data



d03 (RAMP2 dataset), 168x168
Courtesy: Dr. Kevin Manning

Observational Data

- Automatic Weather Station (AWS)
  - Clean Air Station
  - 3 m wind speed, wind direction, temperature, etc.
  - Available in 10 min interval



Source: AMRC

Source: AMRC

Observational Data (Cont.)

- GMD Radiation Group (G-RAD)
  - SW_DN, SW_UP, LW_DN, LW_UP
  - Available in 1 min interval

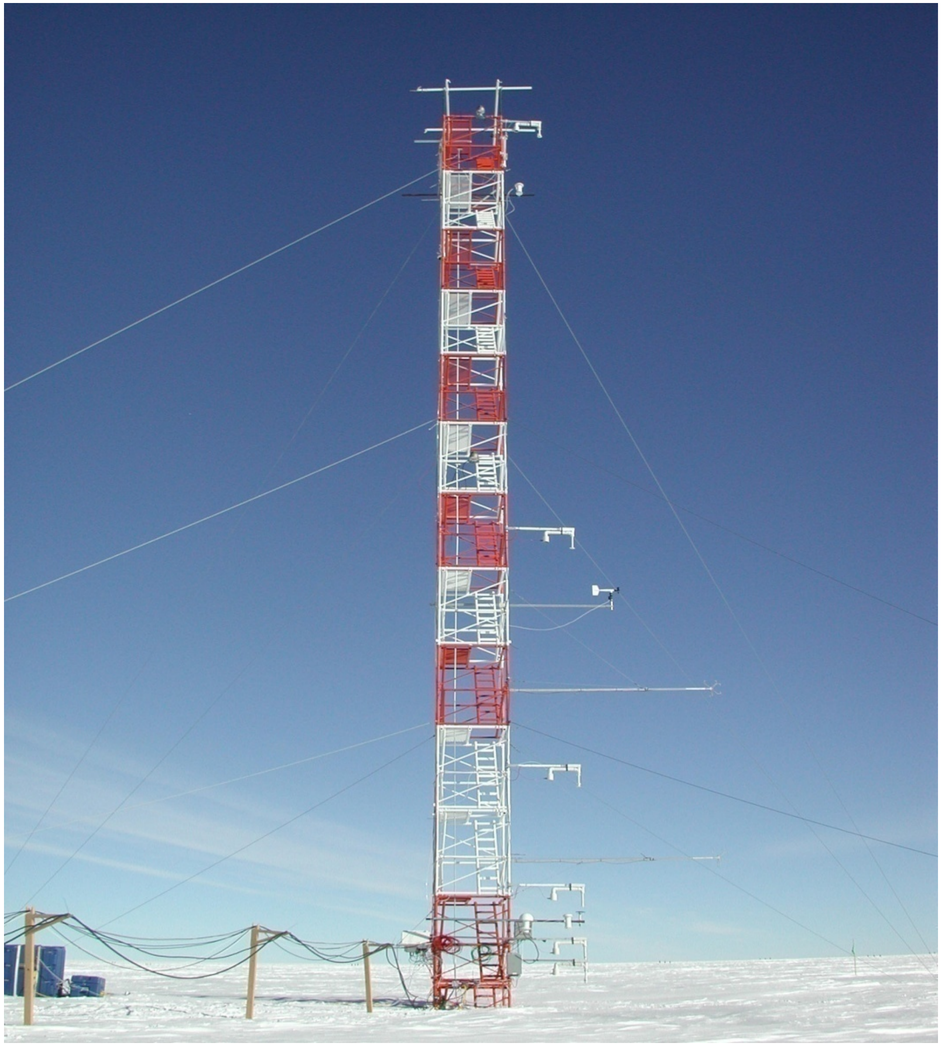
- Radiosonde data from the South Pole Station (0 UTC and 12 UTC)

Source: NOAA-ESRL

Observational Data (Cont.)

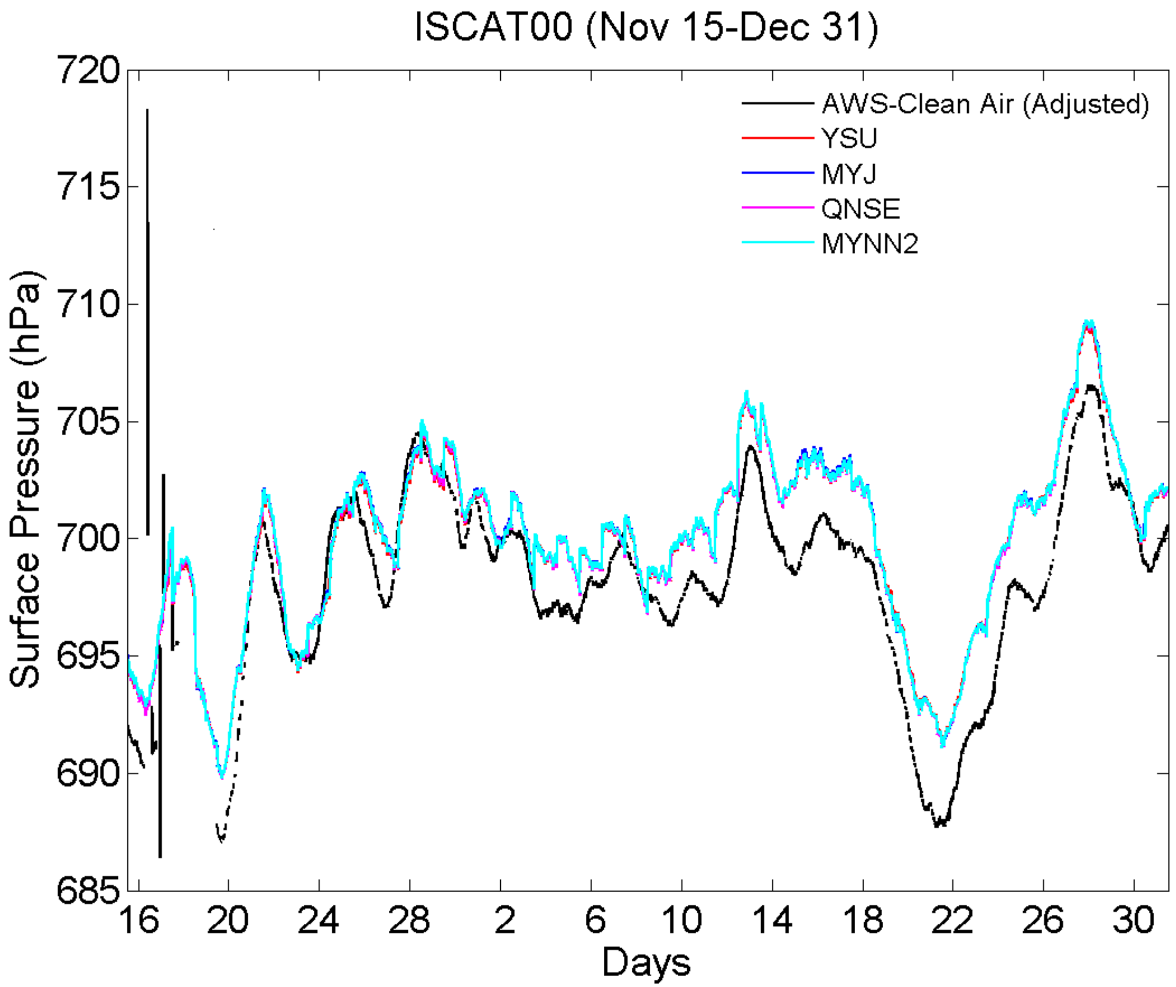
- ISCAT-2000
  - 15 November – 31 December, 2000
  - 22 m scaffolding tower
  - Sonic anemometers at 3.1 m and 7 m (20 Hz)
  - Temperature and humidity sensors at 0.5, 0.9, 2.1, 4.7, 10.1, and 21.8 m

- Quality control
  - De-spiking
  - Wavelet-based detrending (following Basu et al. 2006, *BLM*)



Source: NCAR

Surface Pressure



Average Surface Pressure

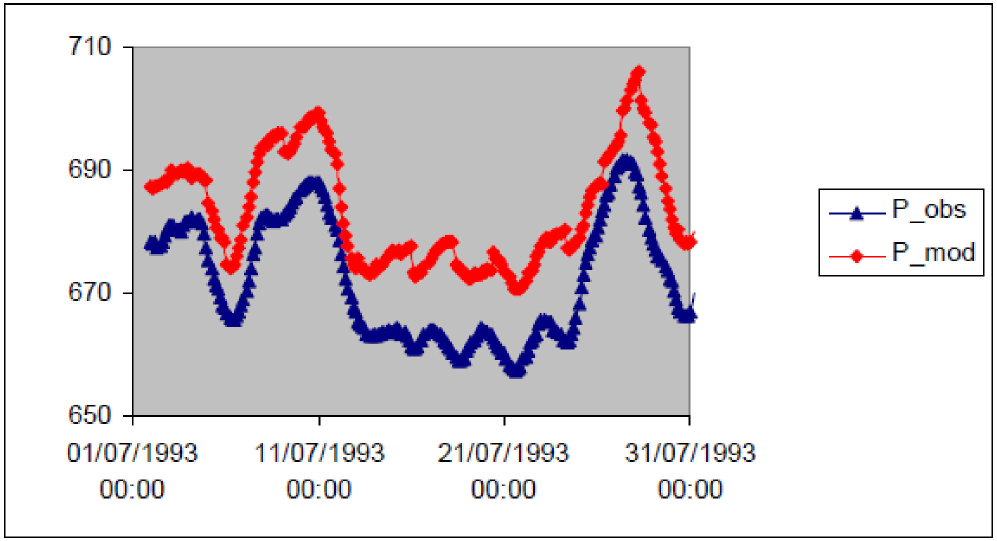
Clean Air: 697.93 hPa
WRF: 699.75 - 699.83 hPa

- Synoptic patterns are reasonably well captured

Surface Pressure (Cont.)

Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio

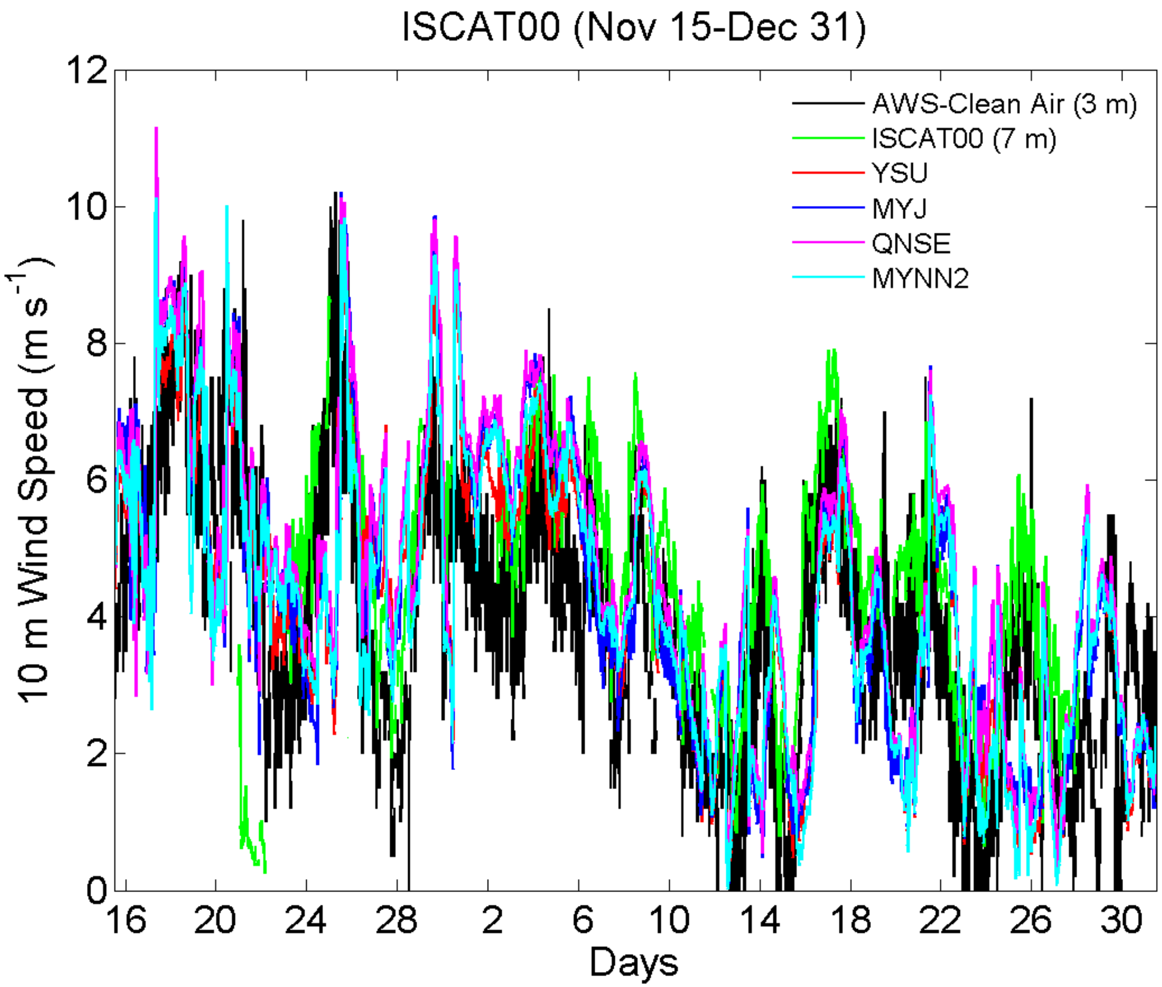
South Pole



Surface pressure (hPa)	
Correlation	0.97
Bias	11.22
RMSE	11.22

Source: Bromwich et al. (2008)

Surface Wind



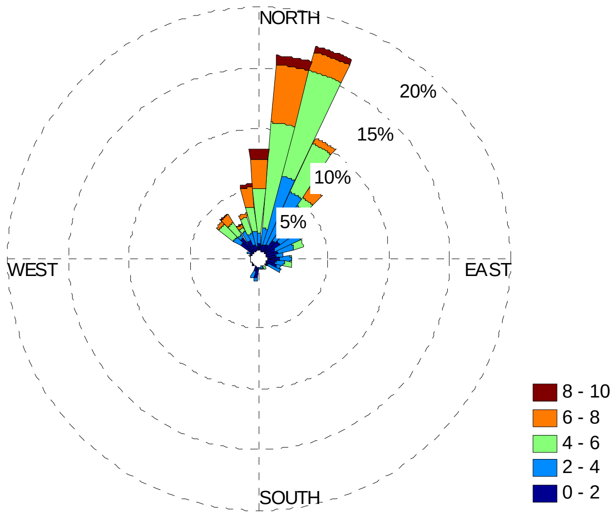
Average 10 m Wind

ISCAT00 Extrap: 4.53 m s^{-1}
WRF: 4.11-4.54 m s^{-1}

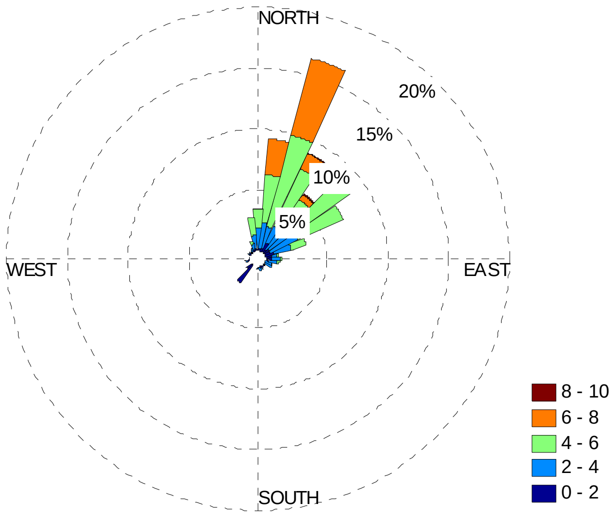
- Surface wind speed patterns are reasonably well captured

Surface Wind (Cont.)

YSU (10 m)

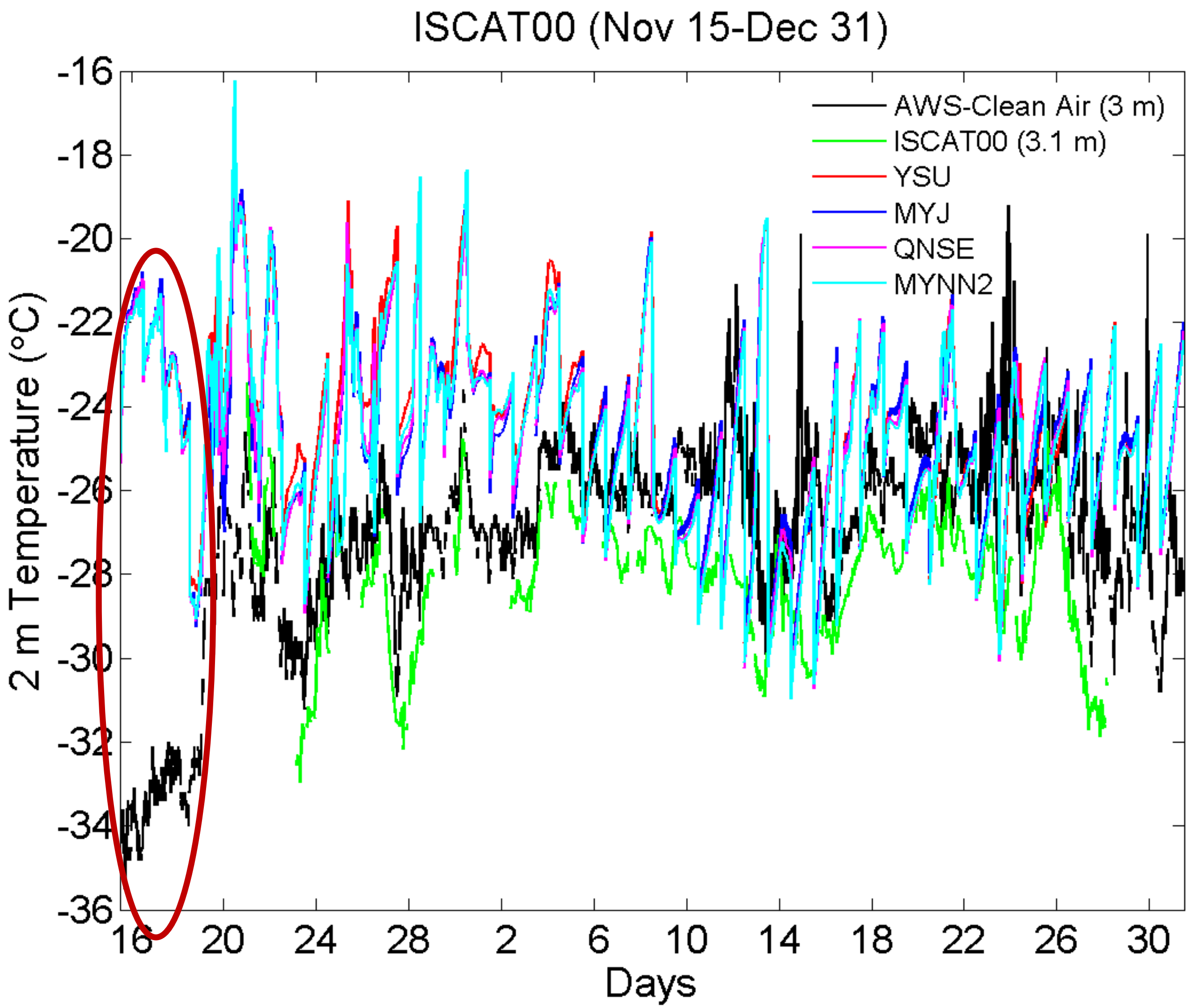


ISCAT00 (7 m)

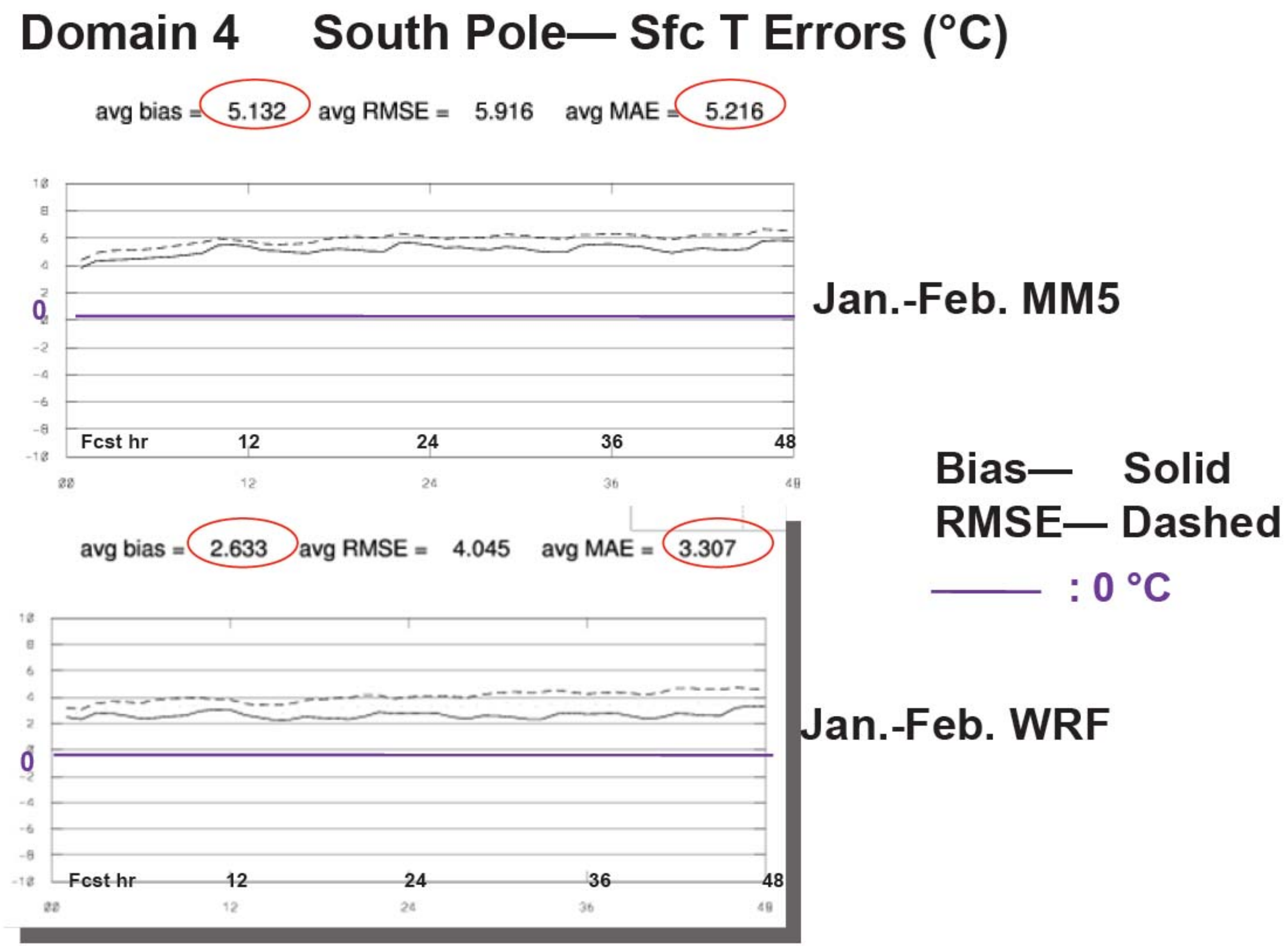


- 0º-120º section is known as the Clean Air sector
- Upwind of the main SP dome and all power generating facilities
- Flow coming off of the Antarctic Plateau (downslope flow, colder, drier)

Surface Temperature

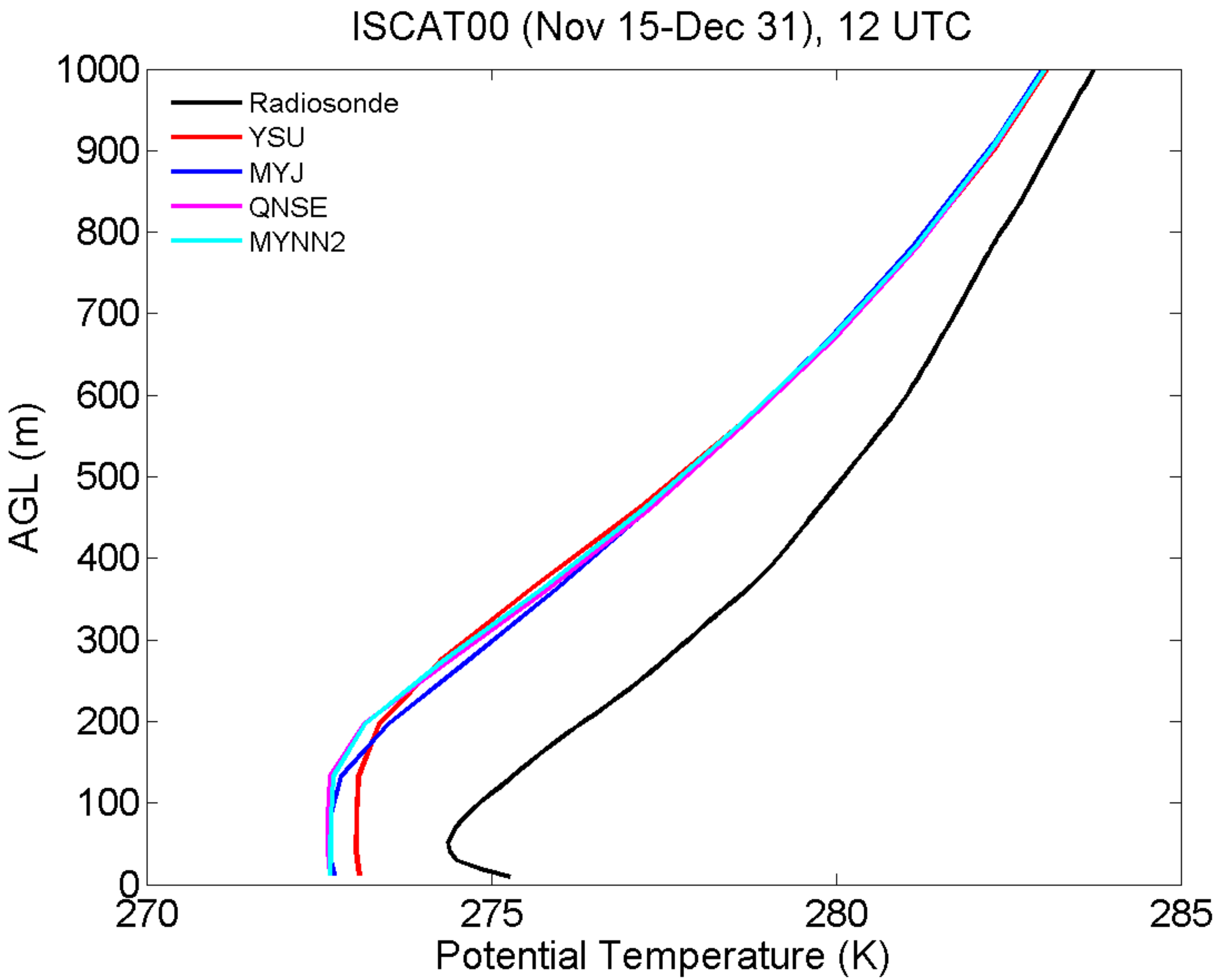


Surface Temperature (Cont.)

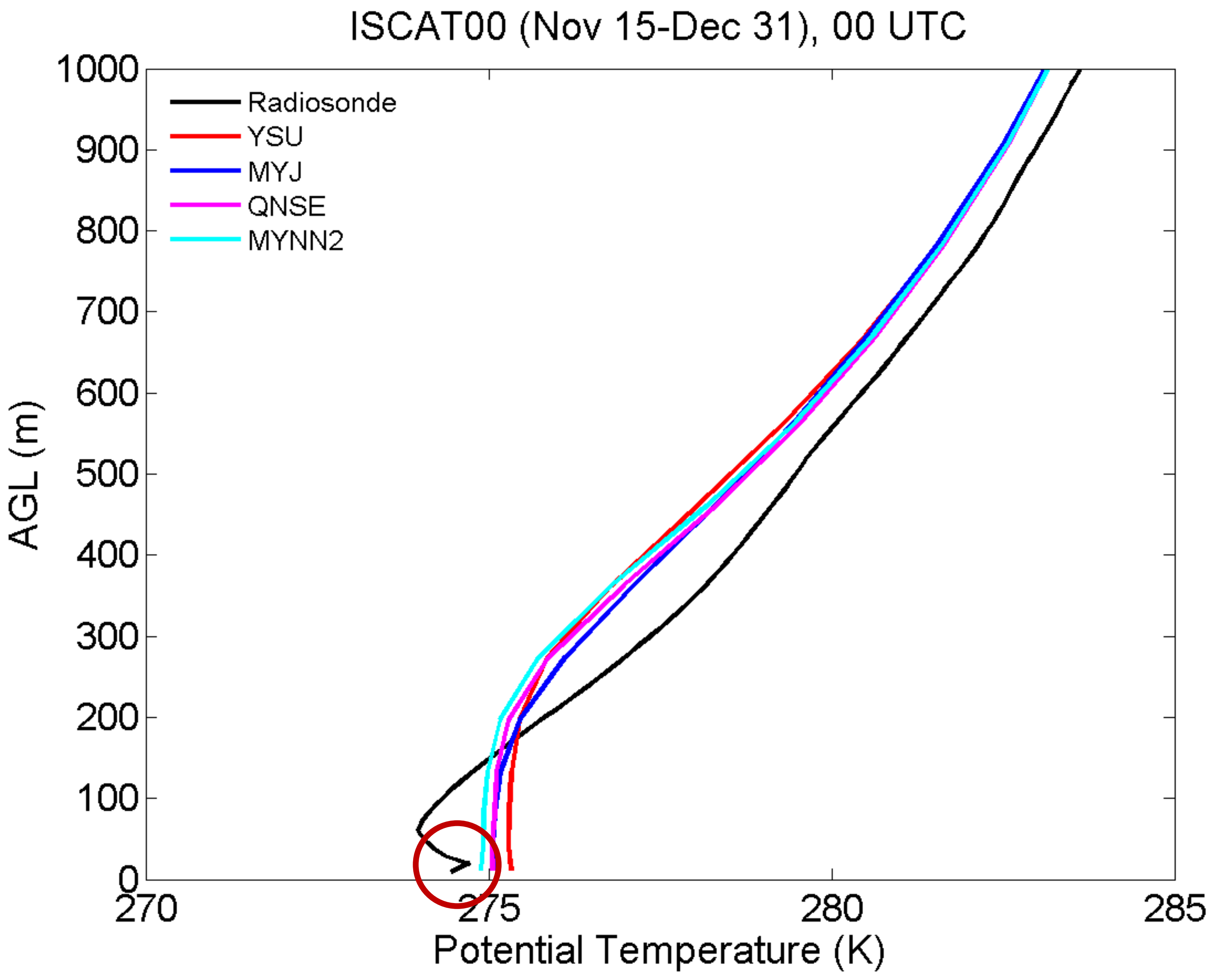


Source: Powers and Manning (2008)

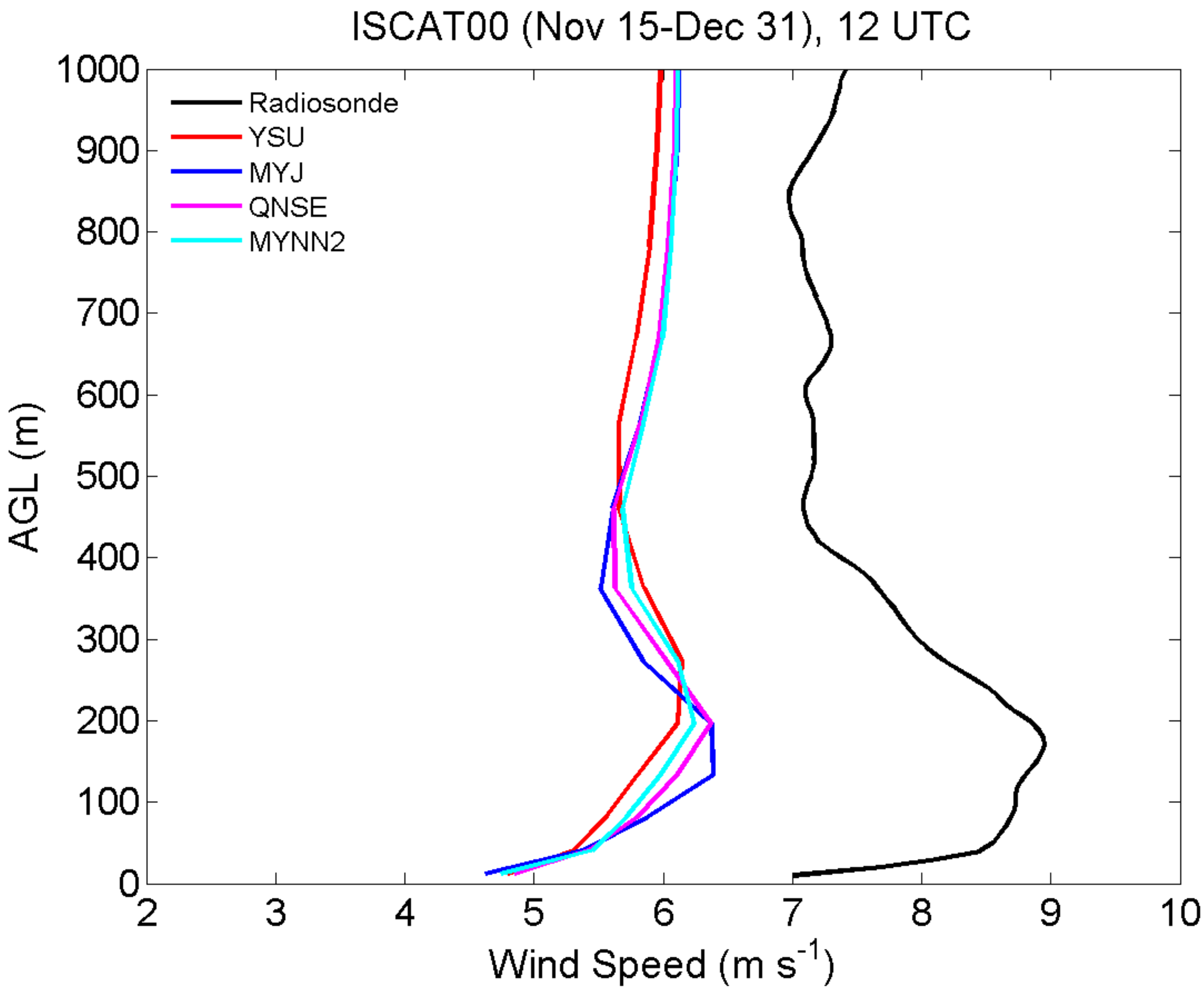
Potential Temperature



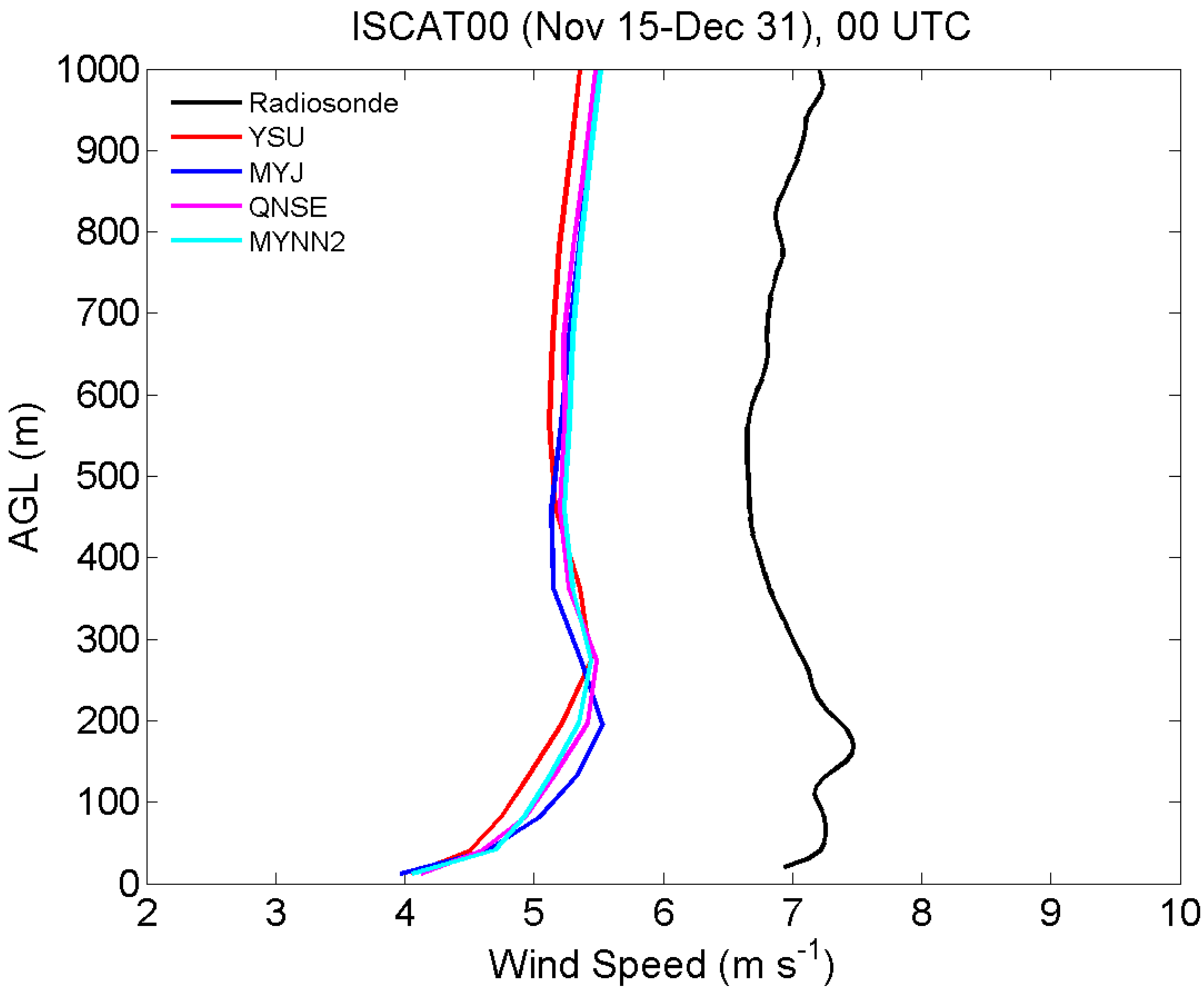
Potential Temperature (Cont.)



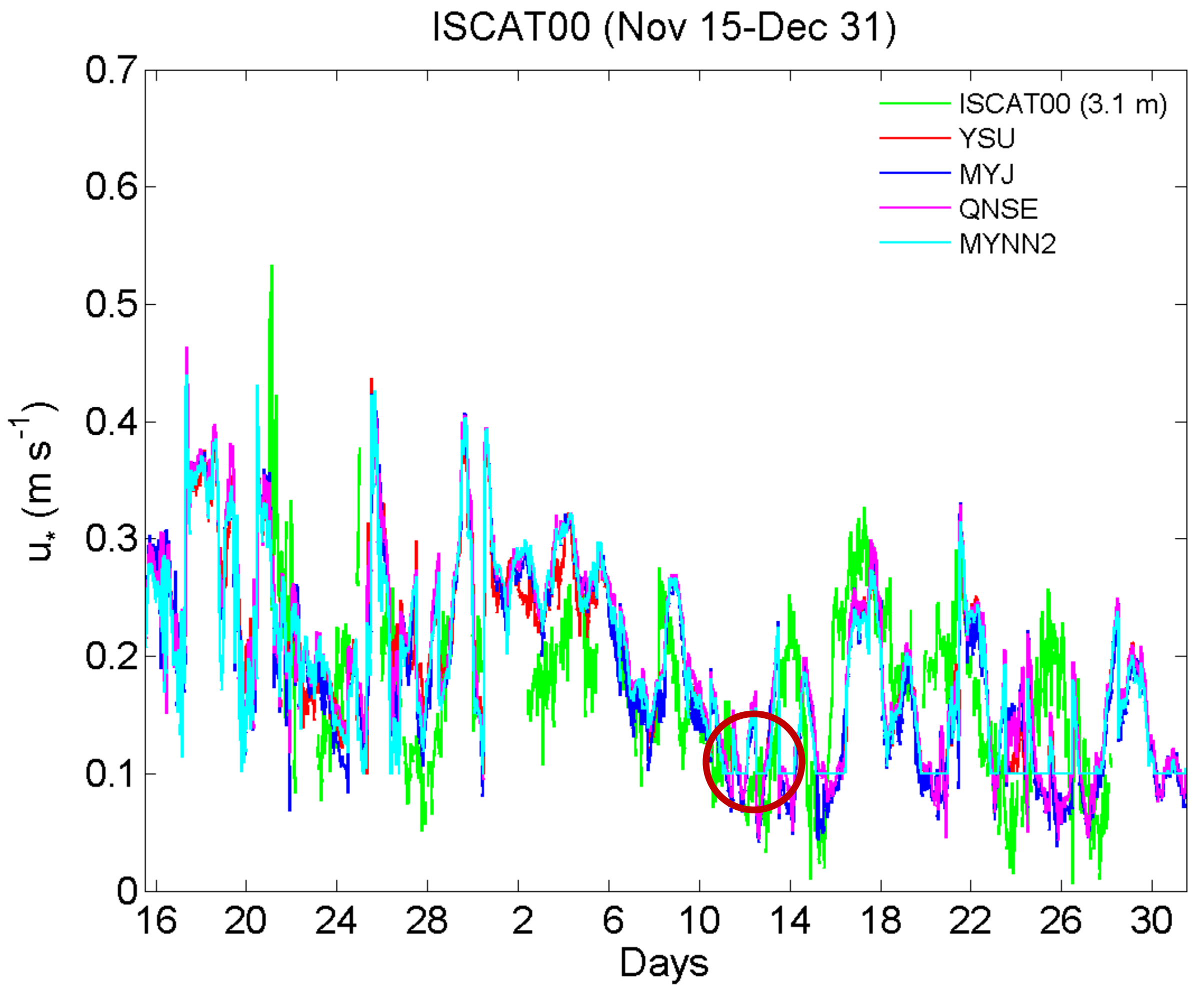
Wind Speed Profile



Wind Speed Profile (Cont.)



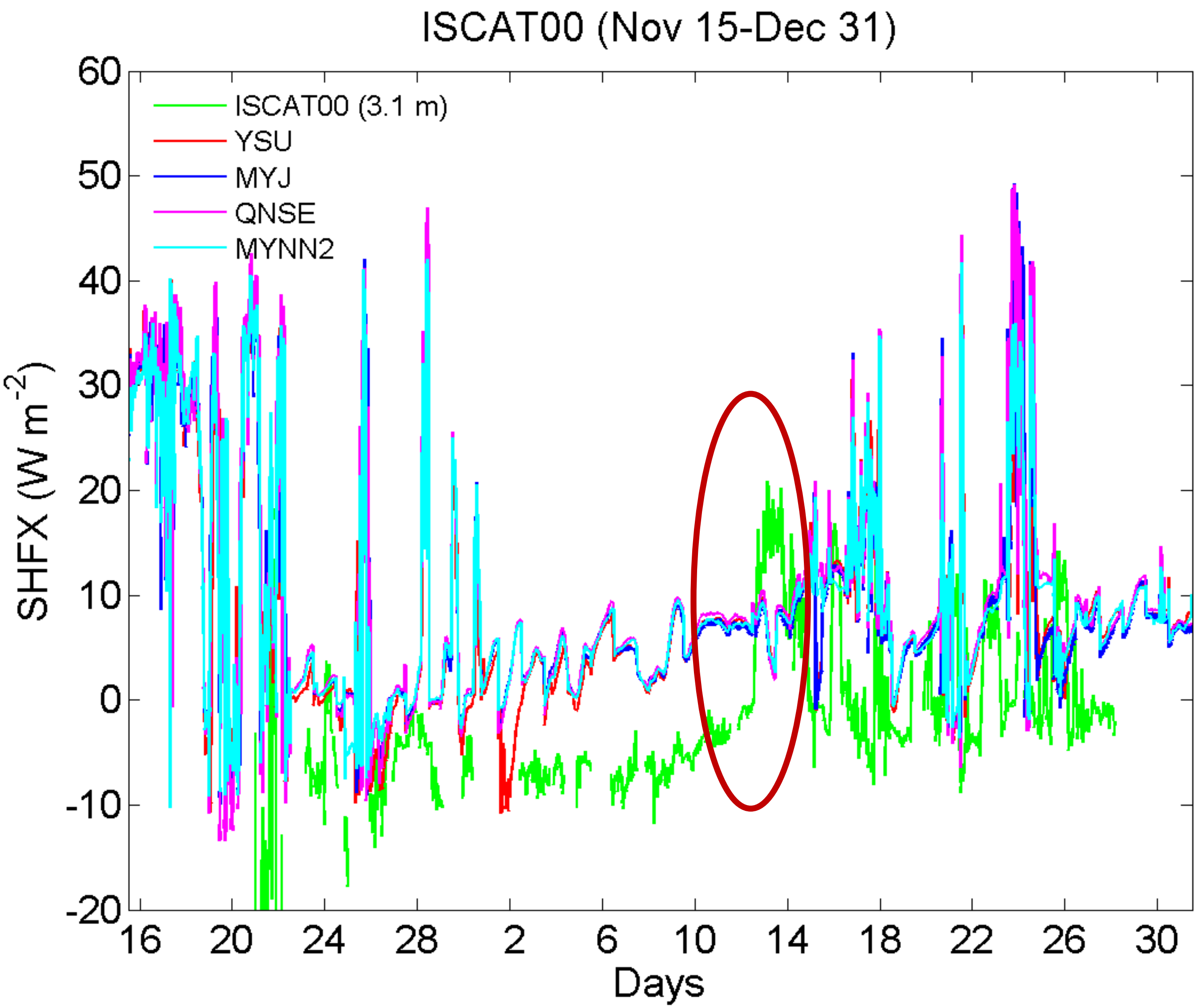
Friction Velocity



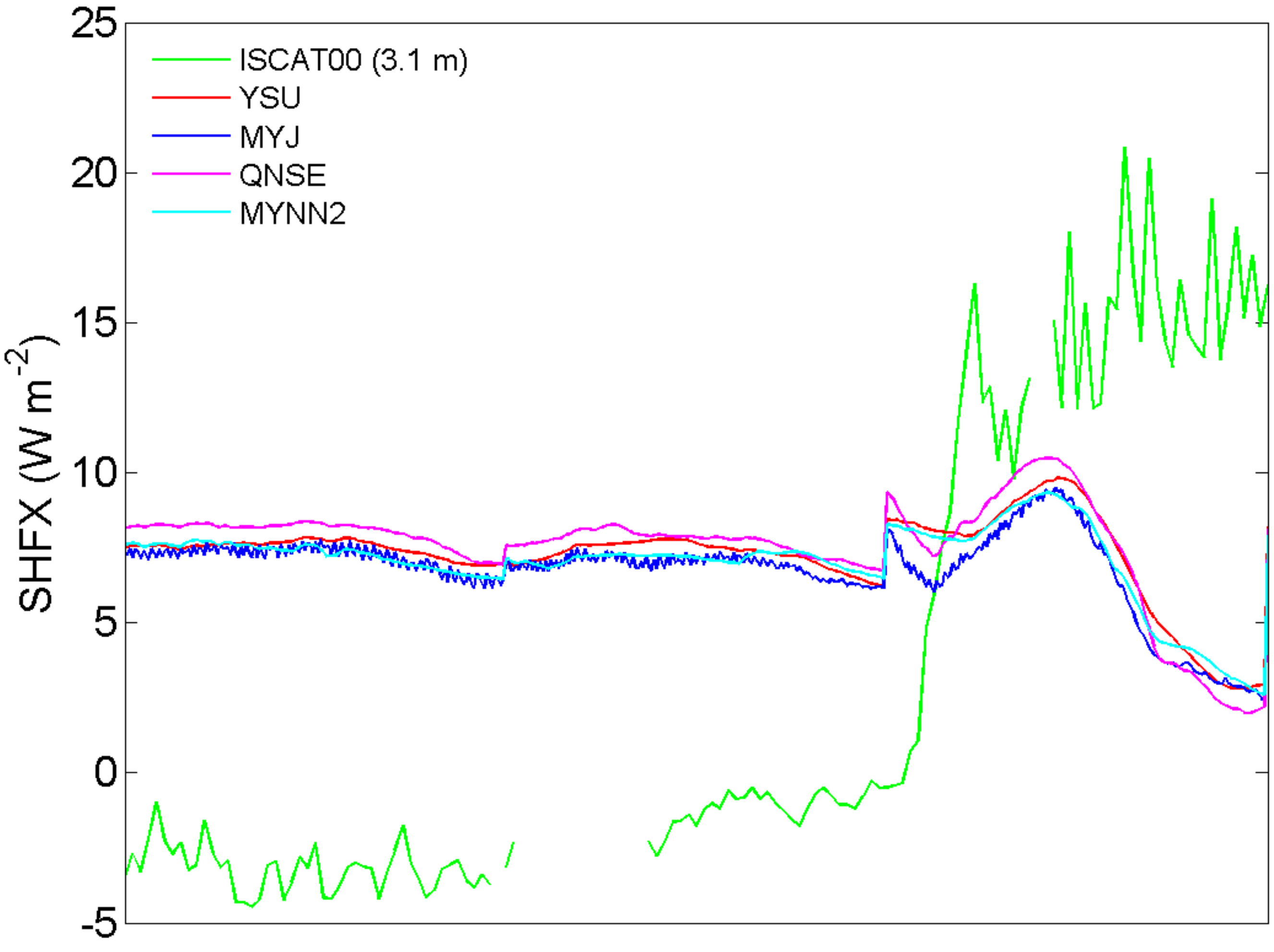
Average u_*

ISCAT00 (3.1 m): 0.16 m s^{-1}
ISCAT00 (7 m): 0.16 m s^{-1}
WRF: 0.19-0.20 m s^{-1}

Sensible Heat Flux



Sensible Heat Flux (Cont.)



- Numerical instability in the case of MYJ?
- See also Pagowski (2007)

Near Neutral or Very Stable?

VERSITA

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An inconvenient "truth" about using sensible heat flux as a surface boundary condition in models under stably stratified regimes

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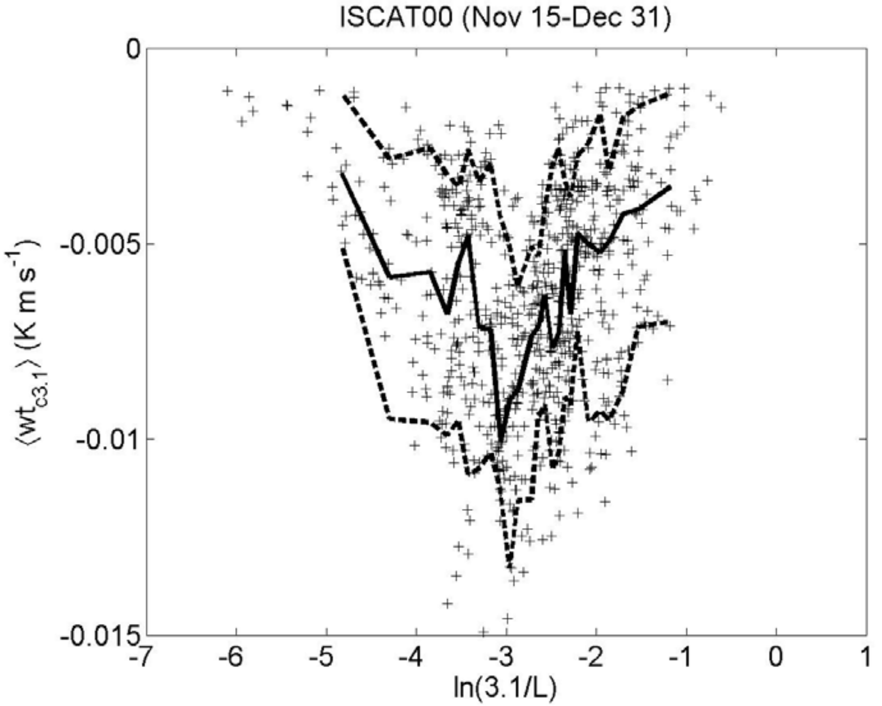
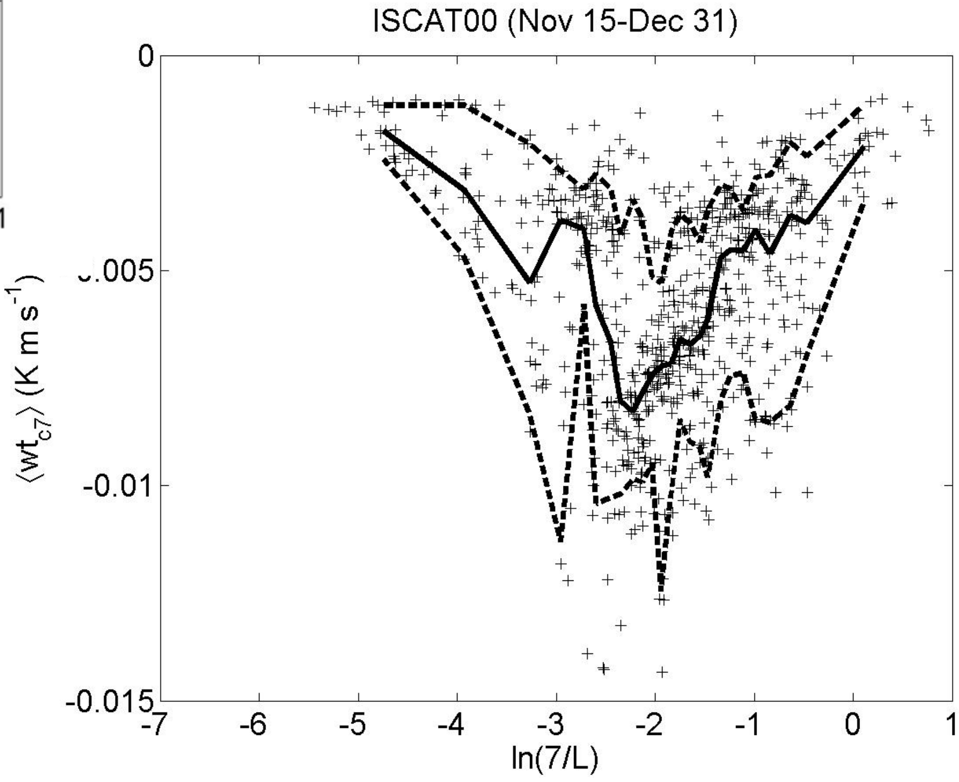
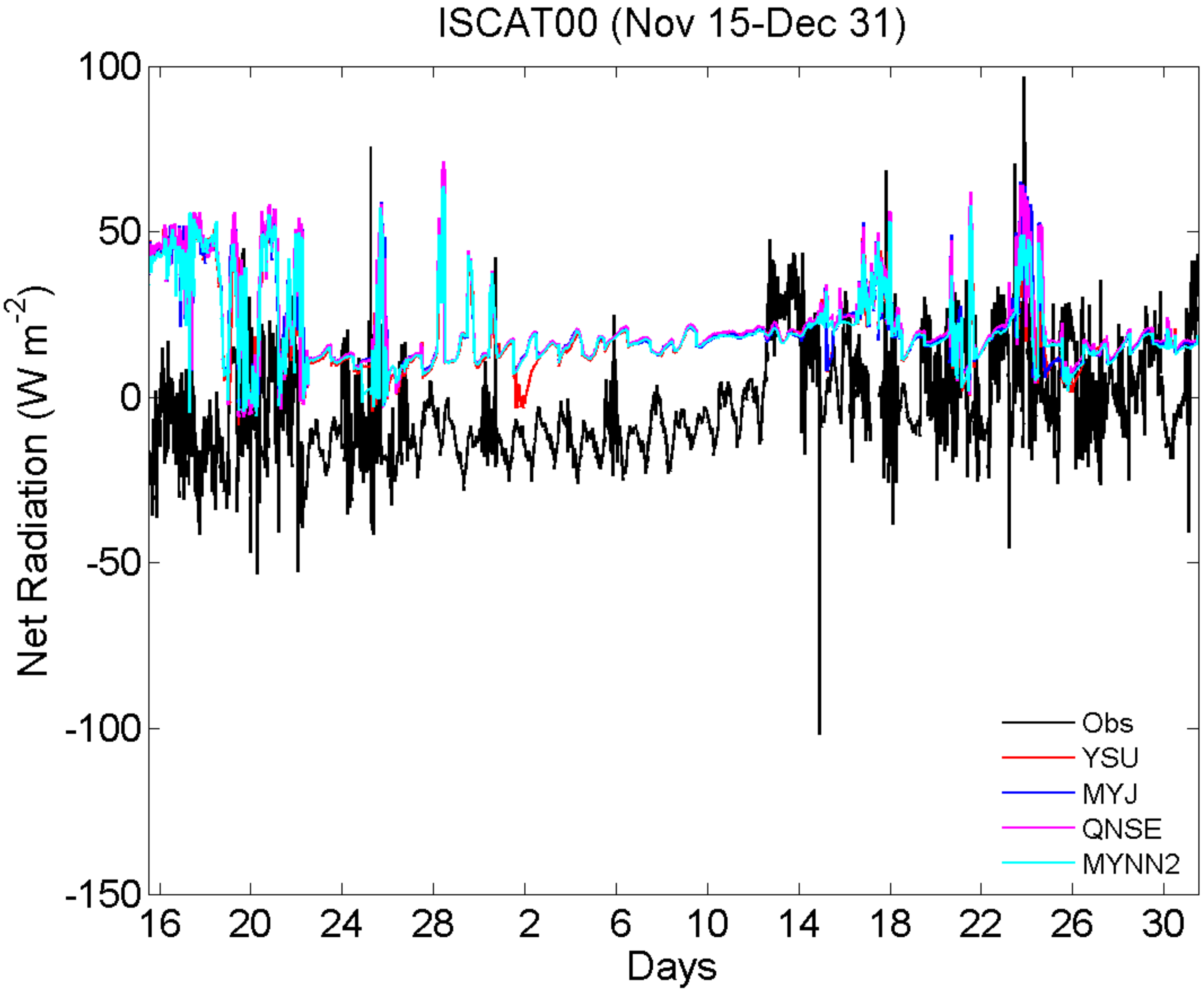
Arnold F. MOENE[2], and Gert-Jan STEENEVELD[2]

Near Neutral or Very Stable? (Cont.)

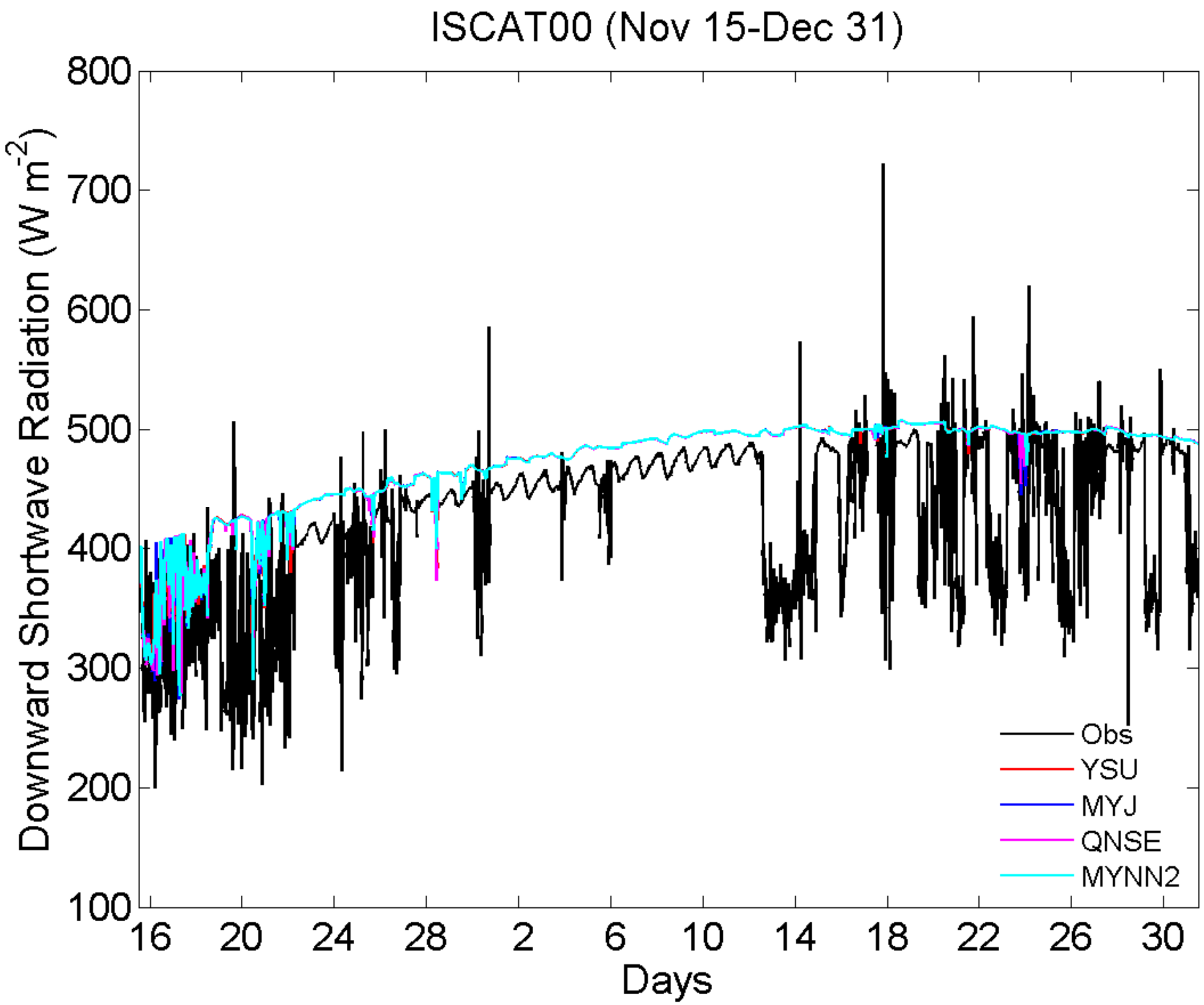




Net Radiation

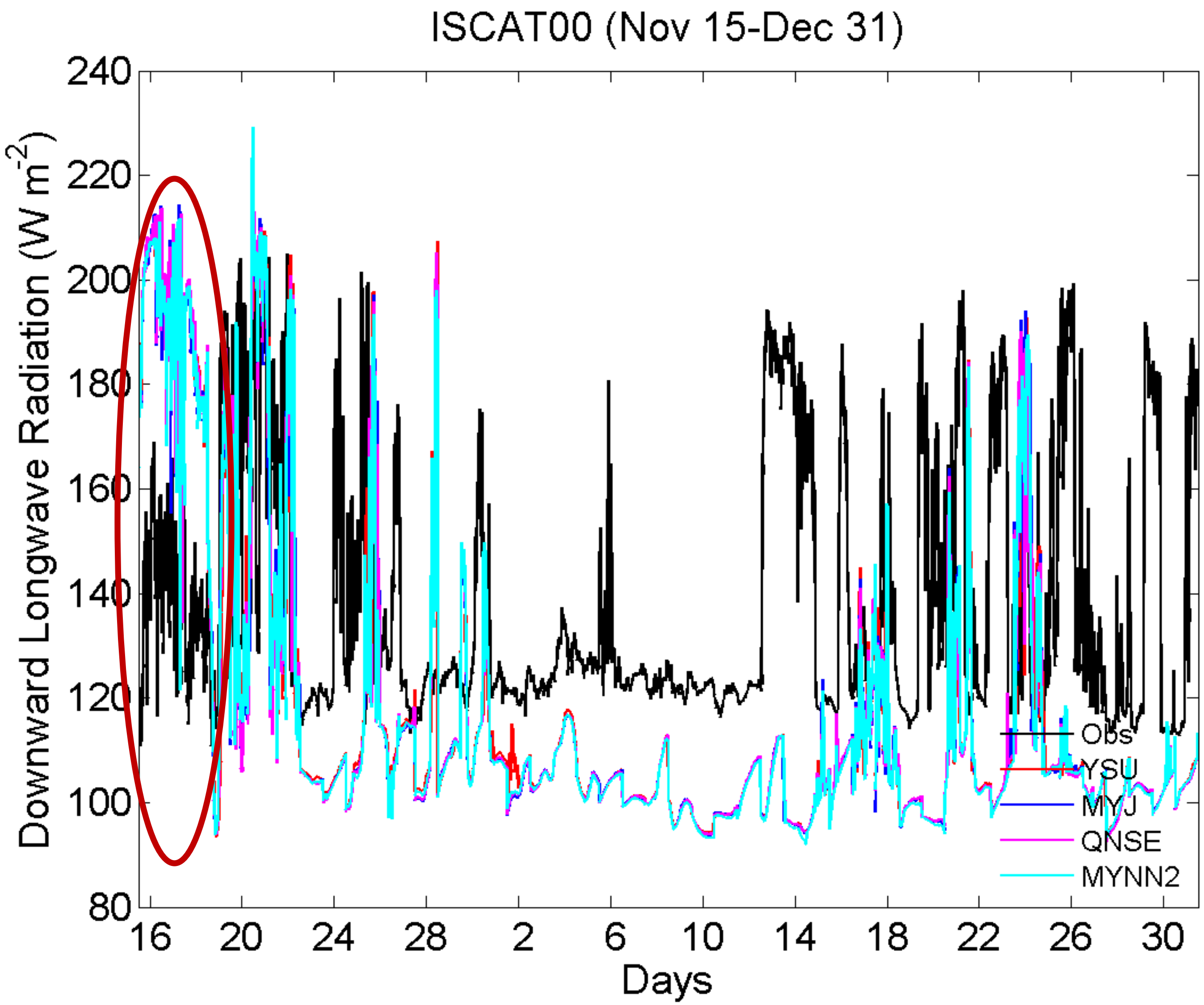


Downward SW Radiation

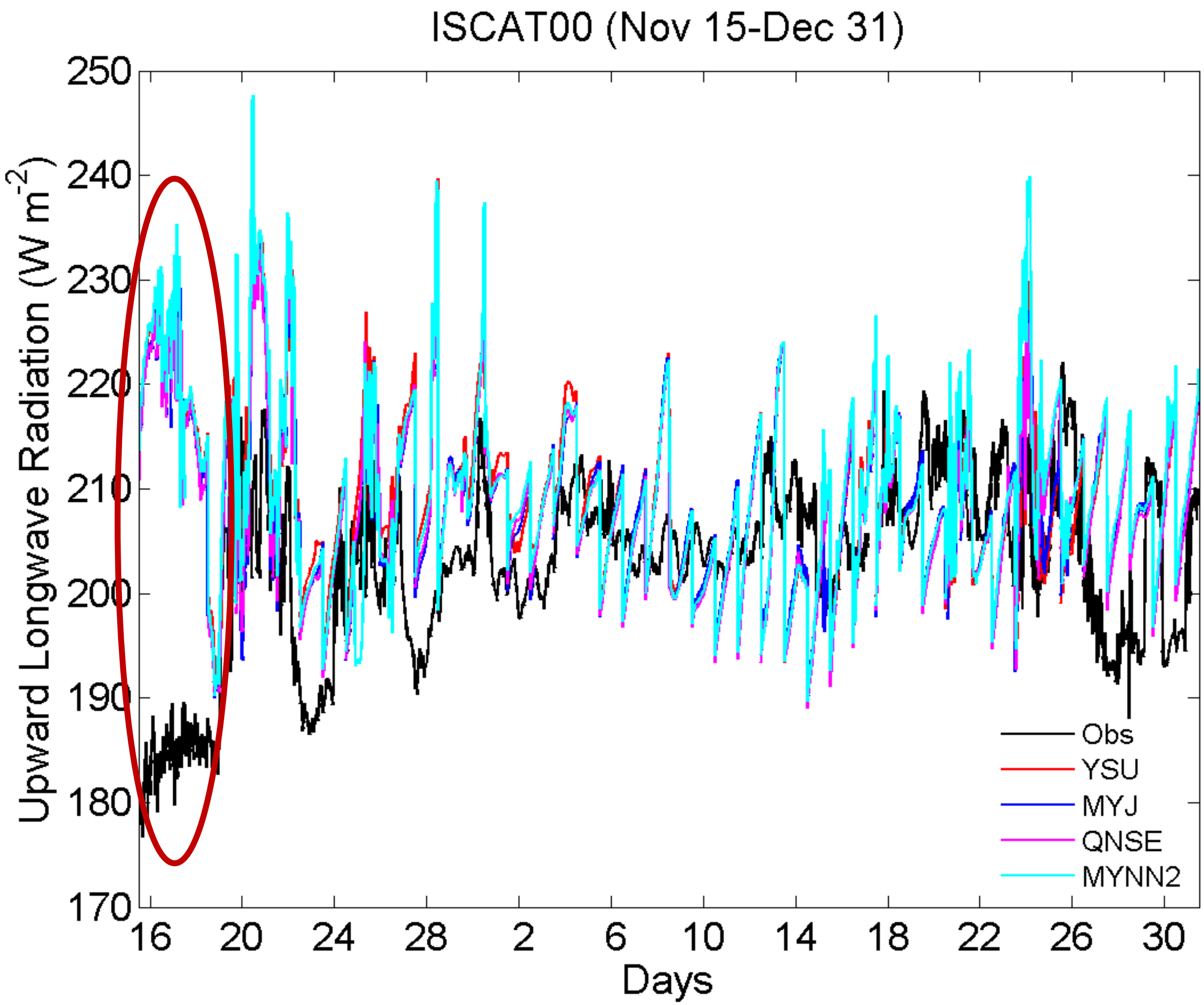


- WRF simulations: absence of diurnal cycles

Downward LW Radiation



Upward LW Radiation



To be continued…

Courtesy: www.globalgreen.org