Modeling and Evaluation of Antarctic Boundary Layer

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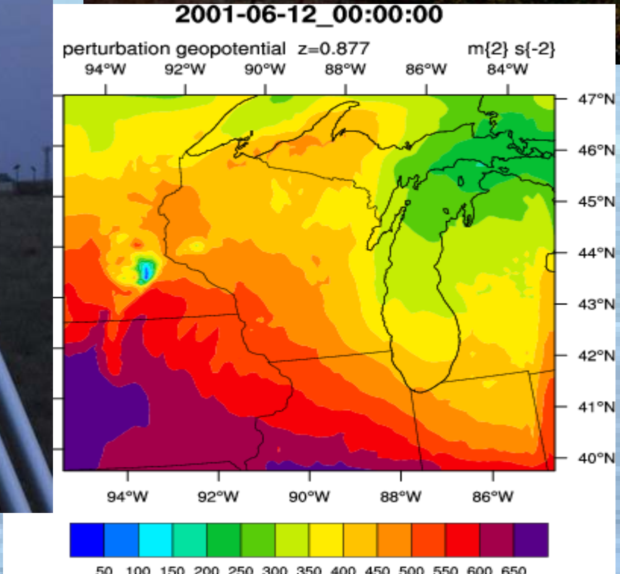
My Research Interests

- **Atmospheric Boundary Layer (Stable)**
- **Modeling (WRF, LES)**
- **Experimental Aspects (Scintillometry)**



Planetary Boundary Layer (PBL)

- The planetary boundary layer (PBL) is the region of the atmosphere near the surface where the influence of the surface is felt through turbulent exchange of momentum, heat and moisture.

- The large-scale budgets of momentum heat and moisture are considerably affected by the surface fluxes on time scales of a few days

- Model variables in the boundary layer are important model products

- The boundary layer interacts with other processes e.g. clouds and convection.

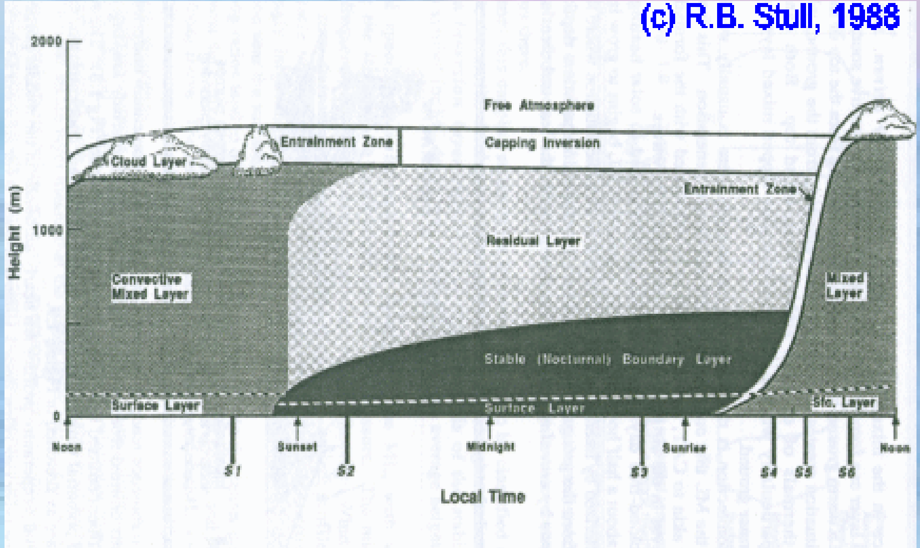
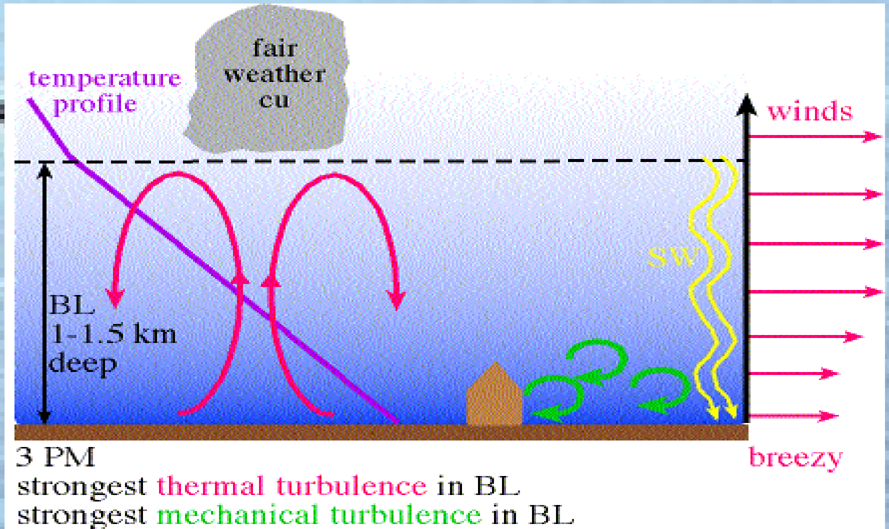


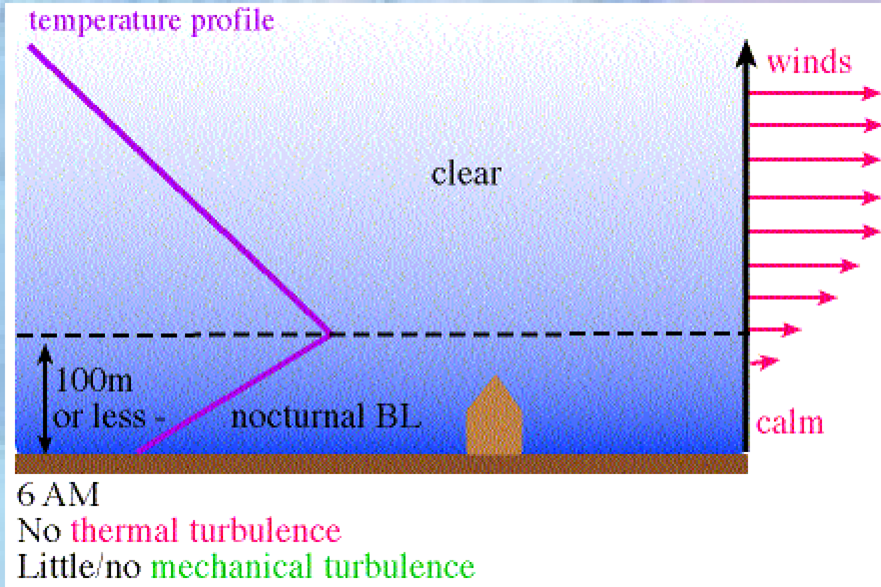
Fig. 1.7 The boundary layer in high pressure regions over land consists of three major parts: a very turbulent mixed layer; a less-turbulent residual layer containing former mixed-layer air; and a nocturnal stable boundary layer of sporadic turbulence. The mixed layer can be subdivided into a cloud layer and a subcloud layer. Time markers indicated by S1-S6 will be used in Fig. 1.12.



stable boundary layer (SBL)

Surface temperature forecasting at night.

- Fog forecasting.
- Polar climate.
- Land Climate.
- Dispersion studies.
- Wind energy applications.



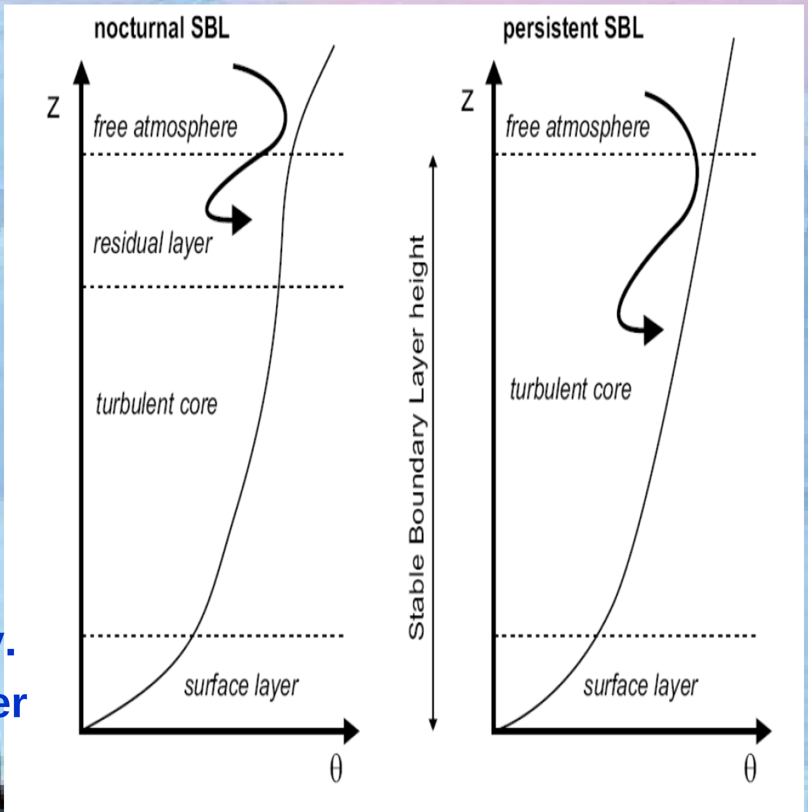
apollo.lsc.vsc.edu/

Stable Boundary Layer Characteristics

- Land Surface is cooler than air (Inversion).
- Turbulence generation by mechanical shear and turbulence suppression by negative buoyancy force.
- Stratification of boundary layer flows.
- Shallow boundary layer.
- Prevalence of smaller eddies.

The NBL vs Persistant SBL

- Formed by radiative cooling during
  night time.
- Pronounced diurnal cycle.
- Residual layer.
- Never reach a state of equilibrium.
- Local feature like vegetation, surface
- roughness may influence turbulence
  generation.



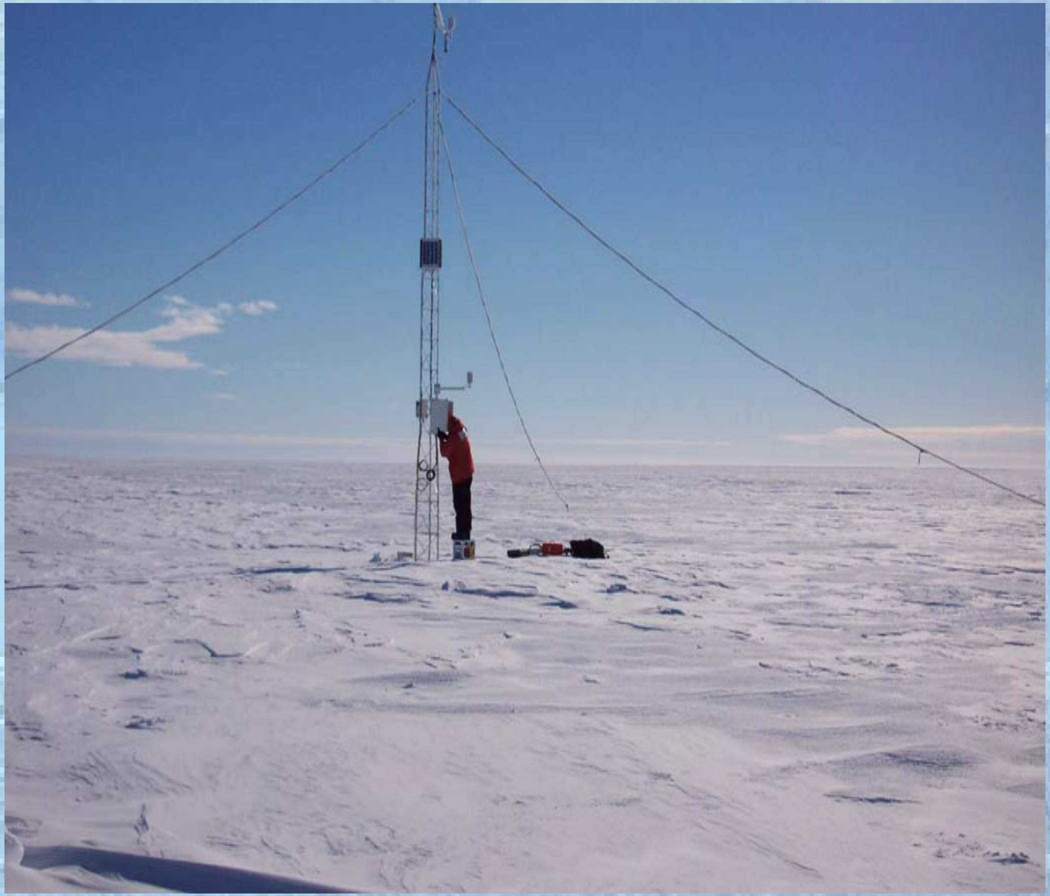
- Stable stratification dominant through out the day.
- Due to high surface albedo prevalent even summer time.
- SBL directly coupled with overlying atmosphere.
- Additional influences like Katabatic winds,IGW

Source: H. Sodemann

Why Antarctic Plateau ?

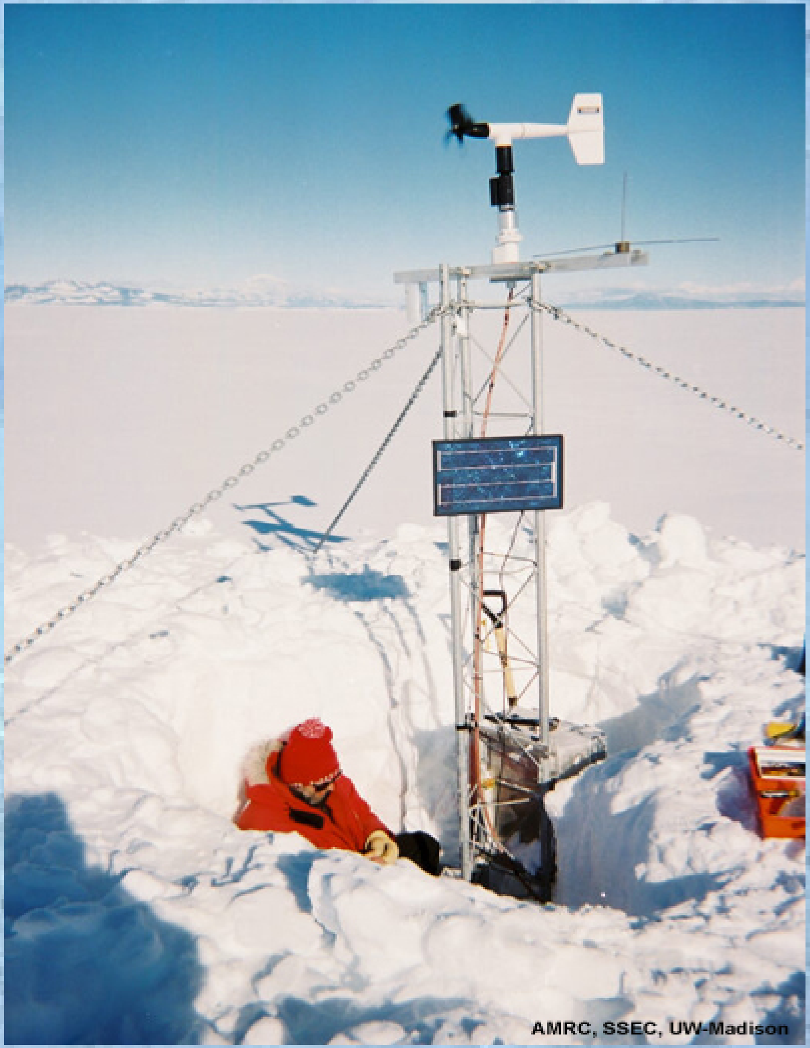
- **Underlying surface is flat or gently sloping.**
- **Stratification of the near-surface layer is generally moderate.**
- **Diurnal cycle is absent or weak.**
- **Responding only to slower synoptic changes.**
- **Whole lower atmosphere is stably stratified as a result of radiative cooling.**

- **Most strongly stratified BL observed on earth.**



Why Antarctic BL is difficult to Model

- Smaller Eddies
- Intermittency
- All the field experiments were conducted on mid latitudes
- Additional Effects

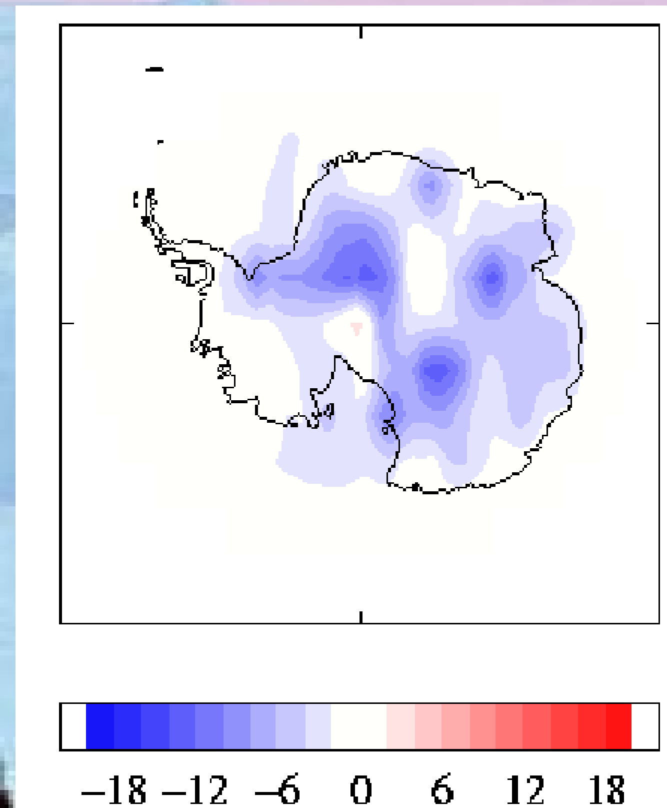


Model Sensitivity to SBL Parameterizations

SL	Ri_B*	Median ND_{SH}	IOA	Correl
BT	All	0.04	0.58	0.37
CCM2	All	0.00	0.60	0.39
CCM3	All	−0.05	0.63	0.40
L79	All	0.12	0.54	0.34
MRF	All	0.07	0.59	0.39
PW87	All	0.15	0.54	0.34
UKMO	All	0.12	0.54	0.34
BT	≤0.02	0.03	0.60	0.41
CCM2	≤0.02	0.01	0.61	0.42
CCM3	≤0.02	−0.02	0.63	0.42
L79	≤0.02	0.06	0.58	0.40
MRF	≤0.02	0.04	0.59	0.41
PW87	≤0.02	0.05	0.58	0.40
UKMO	≤0.02	0.06	0.58	0.40
BT	>0.10	−0.73	0.22	−0.10
CCM2	>0.10	−0.80	0.12	−0.10
CCM3	>0.10	−0.42	0.58	0.09
L79	>0.10	−0.63	0.50	−0.11
MRF	>0.10	−0.18	0.79	0.35
PW87	>0.10	0.17	0.82	0.24
UKMO	>0.10	−0.52	0.44	−0.10

* Calculated statistics for cases with observed SH ≤ −10 W m^{-2}

Source: Cassano et al. (2001)



Difference between new and current BL scheme for 1.5 m temperature, JJA season, 5 year mean

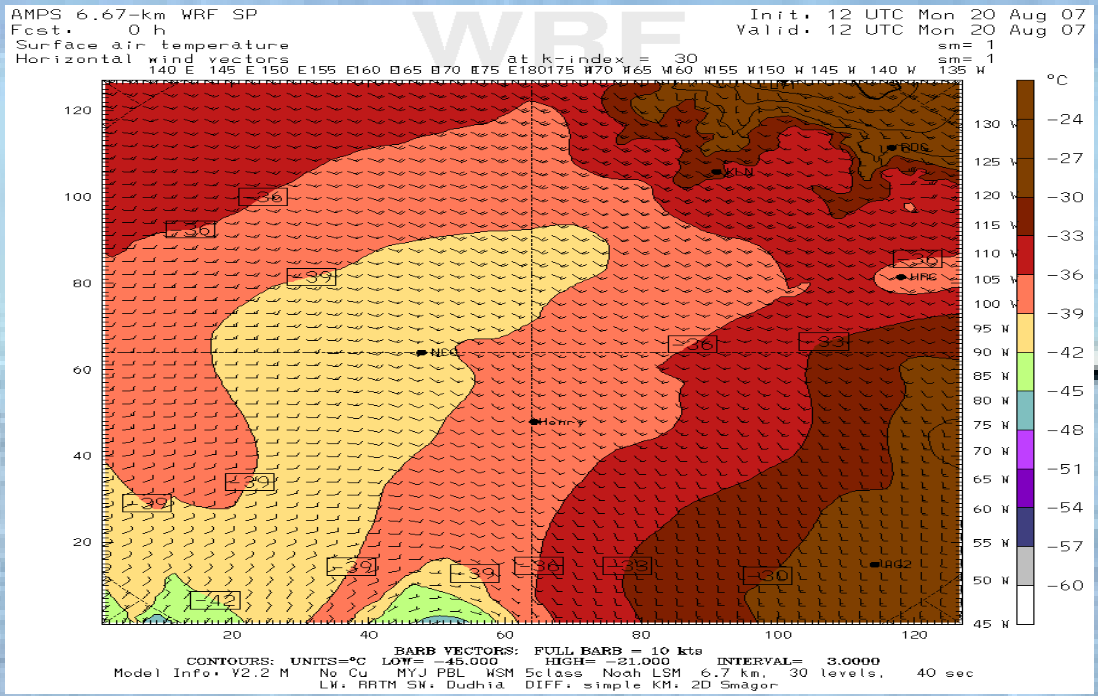
Source: King et al. (2001)

ARW Model

- **Advanced Research WRF is a large subset of WRF.**
- **Eulerian Mass coordinate.**
- **Idealized simulations at many scales.**
- **Atmospheric Physics/parameterization research**
- **Data assimilation research**
- **Real-time NWP and forecast system research.**
- **Couple-model application.**
-

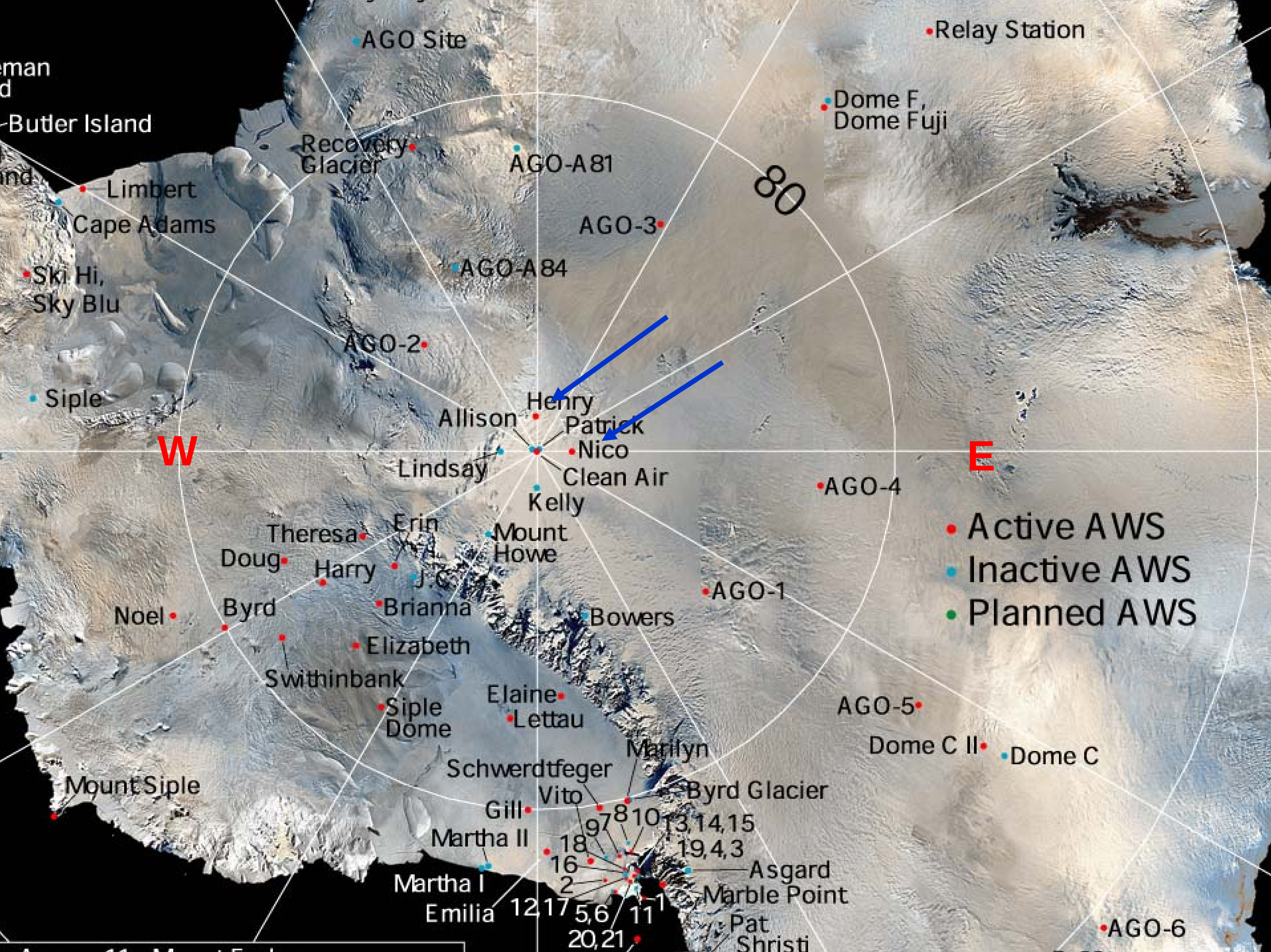
AMPS: The Antarctic Mesoscale Prediction System

- Nested NWP system dedicated to supporting the operations of the U.S. Antarctic Program and International programs.
- Employs “Polar WRF”, a limited-area atmospheric model adapted for high-latitude applications by Ohio State University’s Polar Meteorology Group.

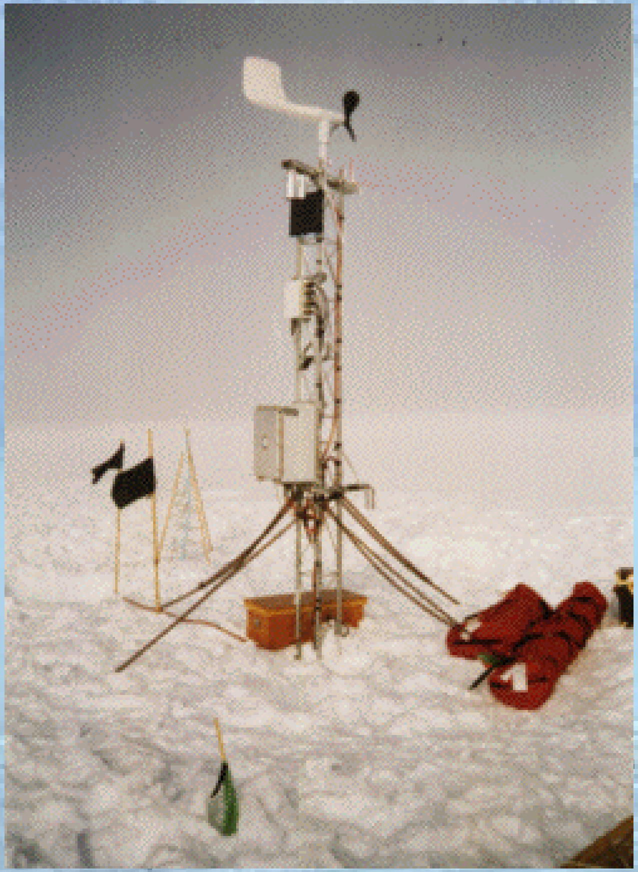


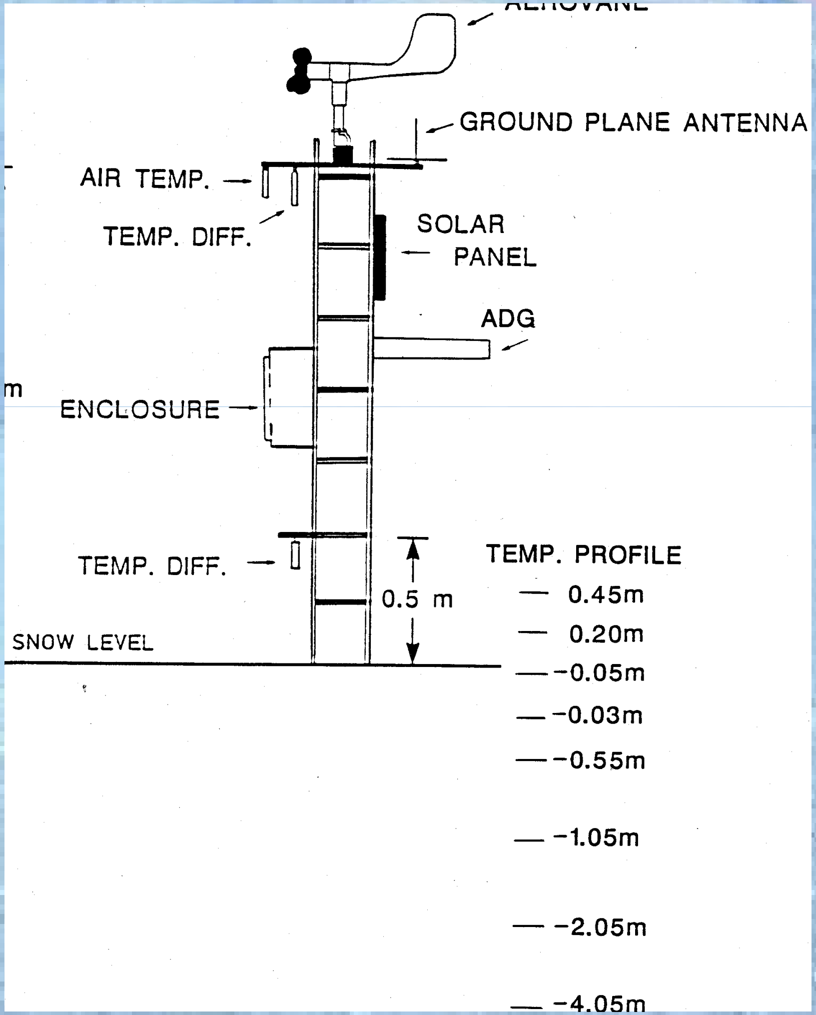
WRF Configuration

Resolution	6.67 Km
# Grids	126X126X30
PBL	MYJ
Longwave	RRTM
Shortwave	Dhudhia
LSM	NOAH
Microphysics	WSM
Time step	40 seconds


AGO Site
Relay Station
Butler Island
Recovery Glacier
AGO-A81
Dome F, Dome Fuji
Limbert
Cape Adams
80
AGO-3
AGO-A84
Ski Hi, Sky Blu
AGO-2
Siple
Henry
Allison
Patrick
Nico
W
E
Lindsay
Clean Air
AGO-4
Kelly
Active AWS
Inactive AWS
Planned AWS
Theresa
Erin
Mount Howe
Doug
Harry
J.C.
AGO-1
Brianna
Noel
Byrd
Bowers
Elizabeth
Swithinbank
Elaine
Siple Dome
Lettau
AGO-5
Dome C II
Dome C
Marilyn
Schwerdtfeger
Mount Siple
Vito
Byrd Glacier
Gill
9
7
8
10
13,14,15
Martha II
18
19,4,3
16
Asgard
2
Martha I
Marble Point
Emilia
12,17
5,6
11
1
Pat
20,21
AGO-6

Automatic Weather Stations – Snow profile version

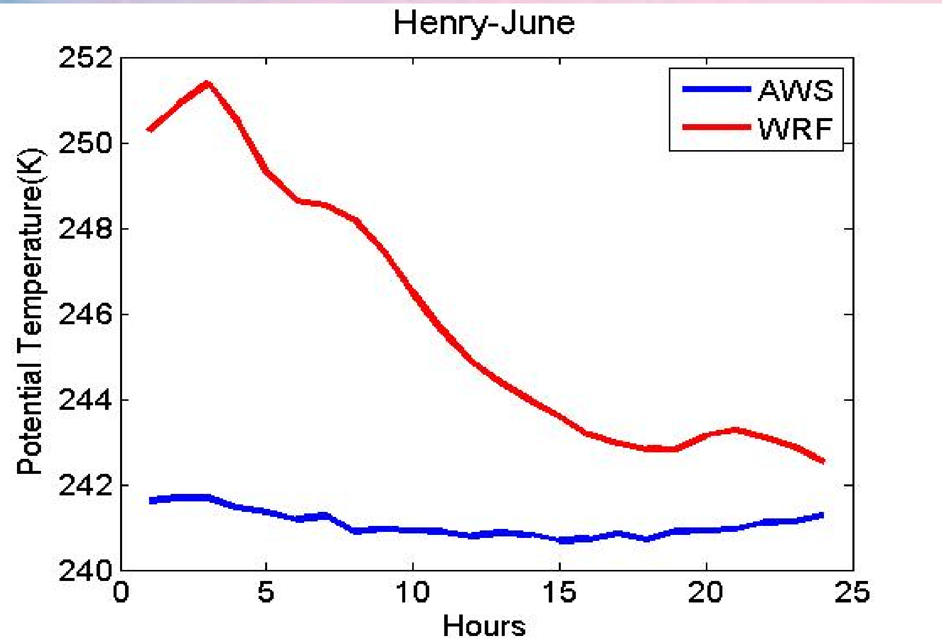


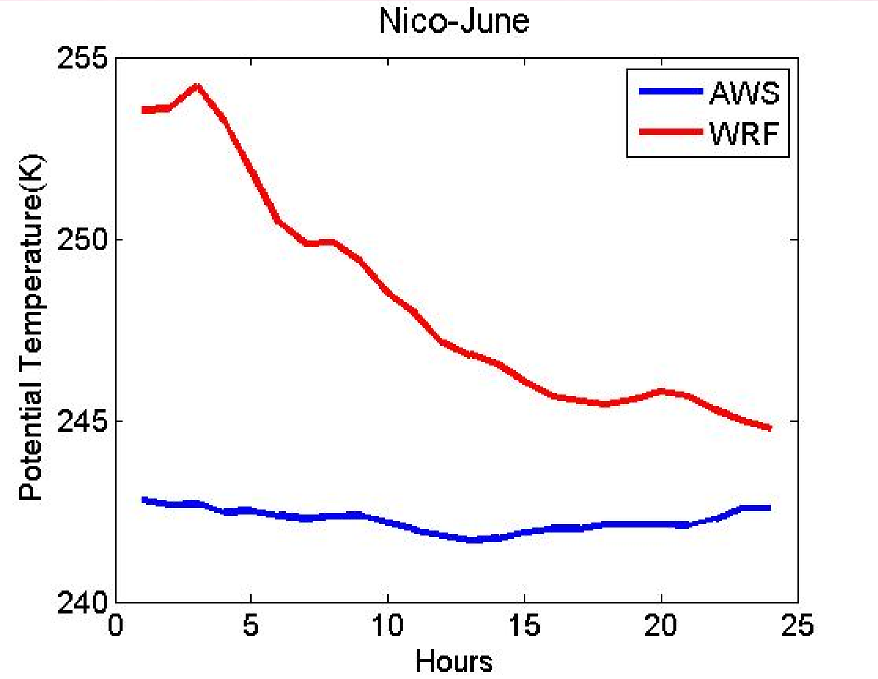


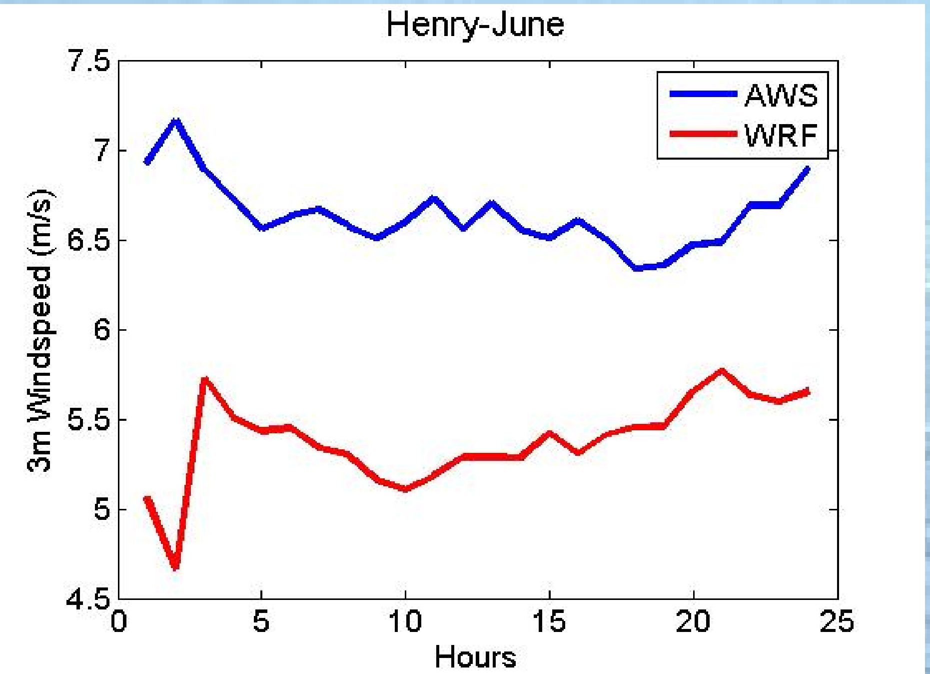
Methodology

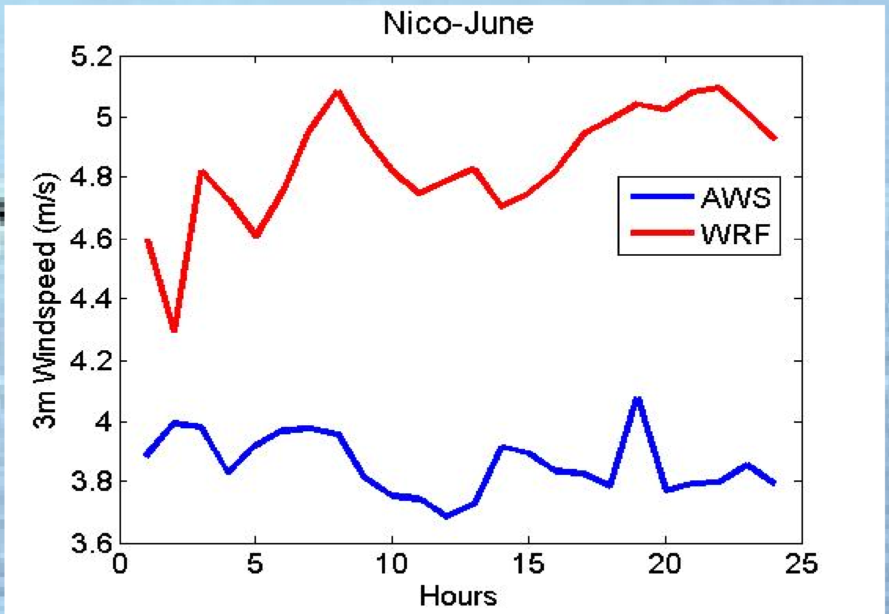
- Extracted the WRF data over the two locations in south-pole ‘Henry & Nico’ AWS sites
- The Observation from AWS and WRF are compared for June 2006
- WRF output is extrapolated to AWS height levels using Monin Obukhov similarity theory formulation
- Possible statistical parameters are computed from the observed & modeled data sets

Monthly Mean

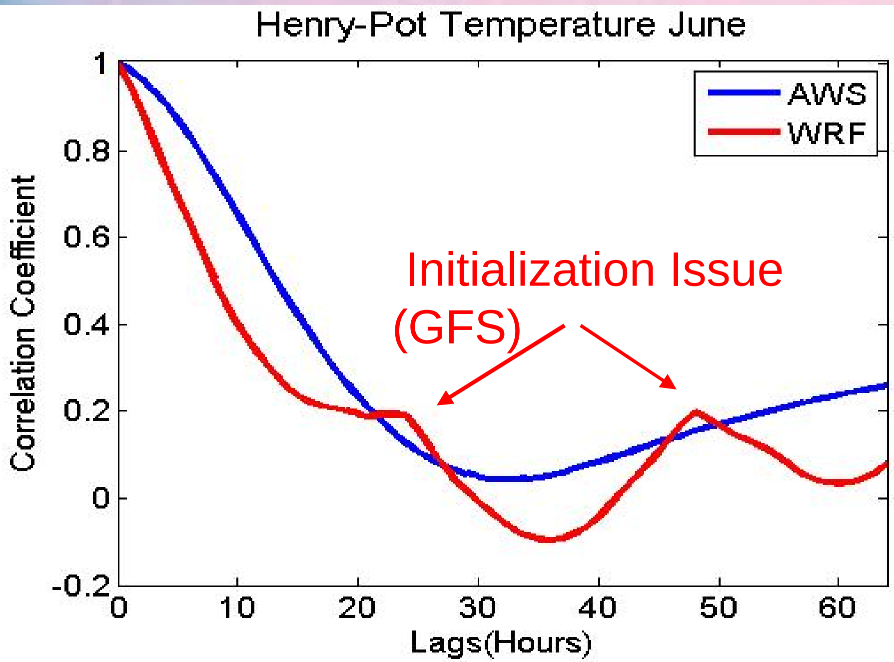


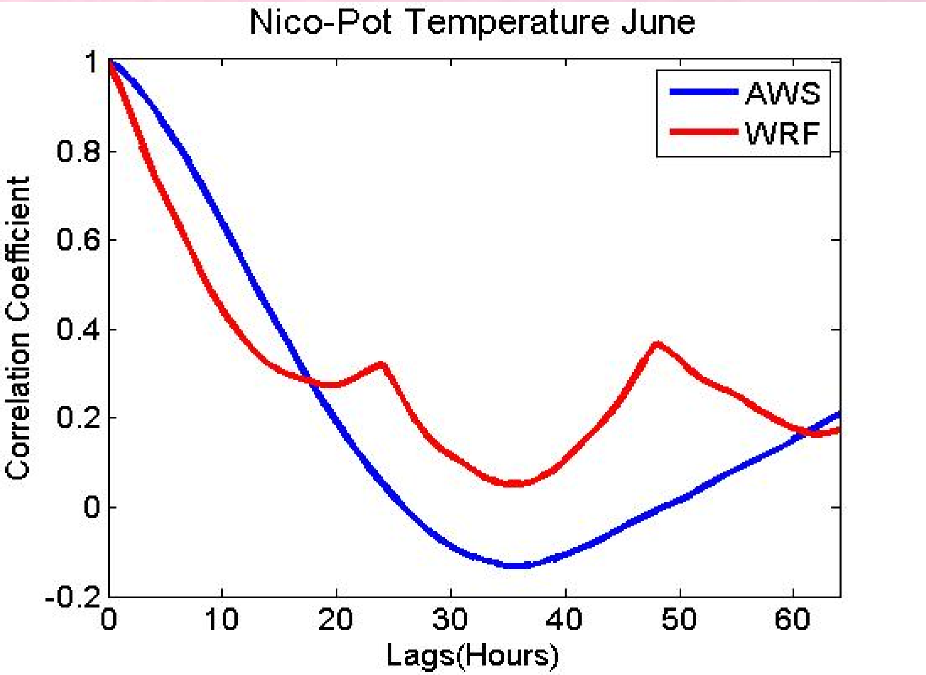


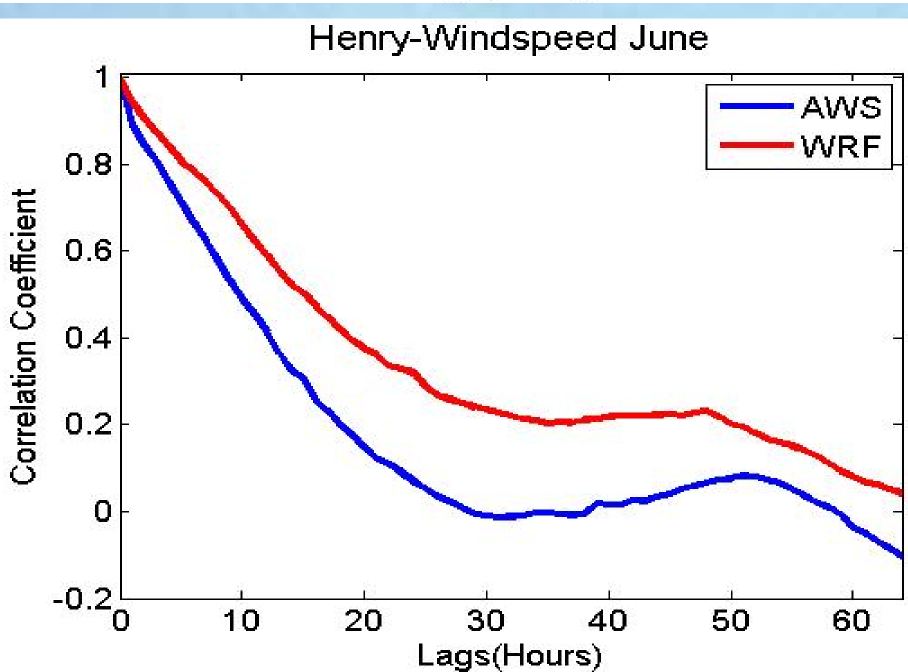


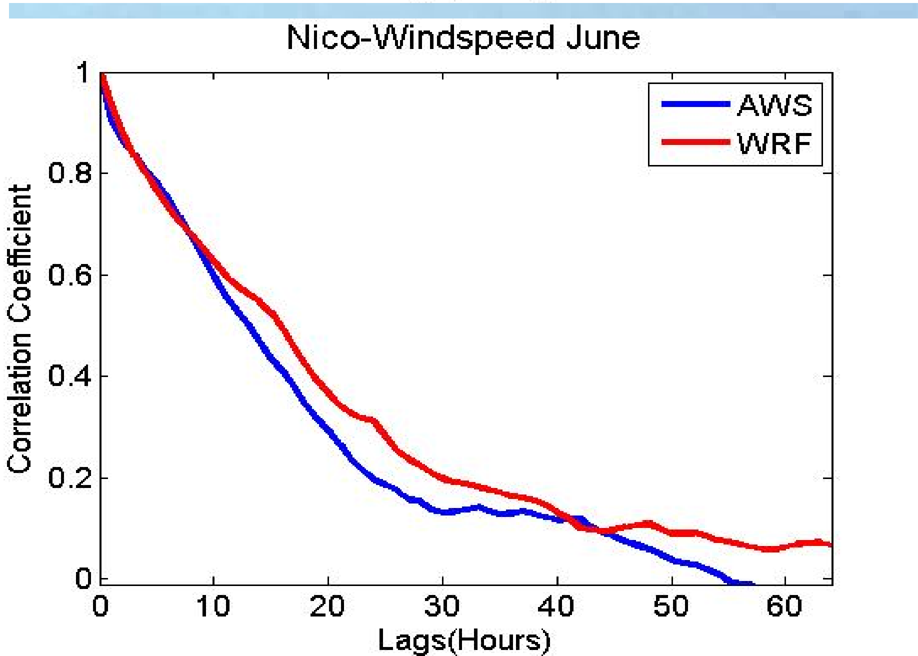


Auto-correlation

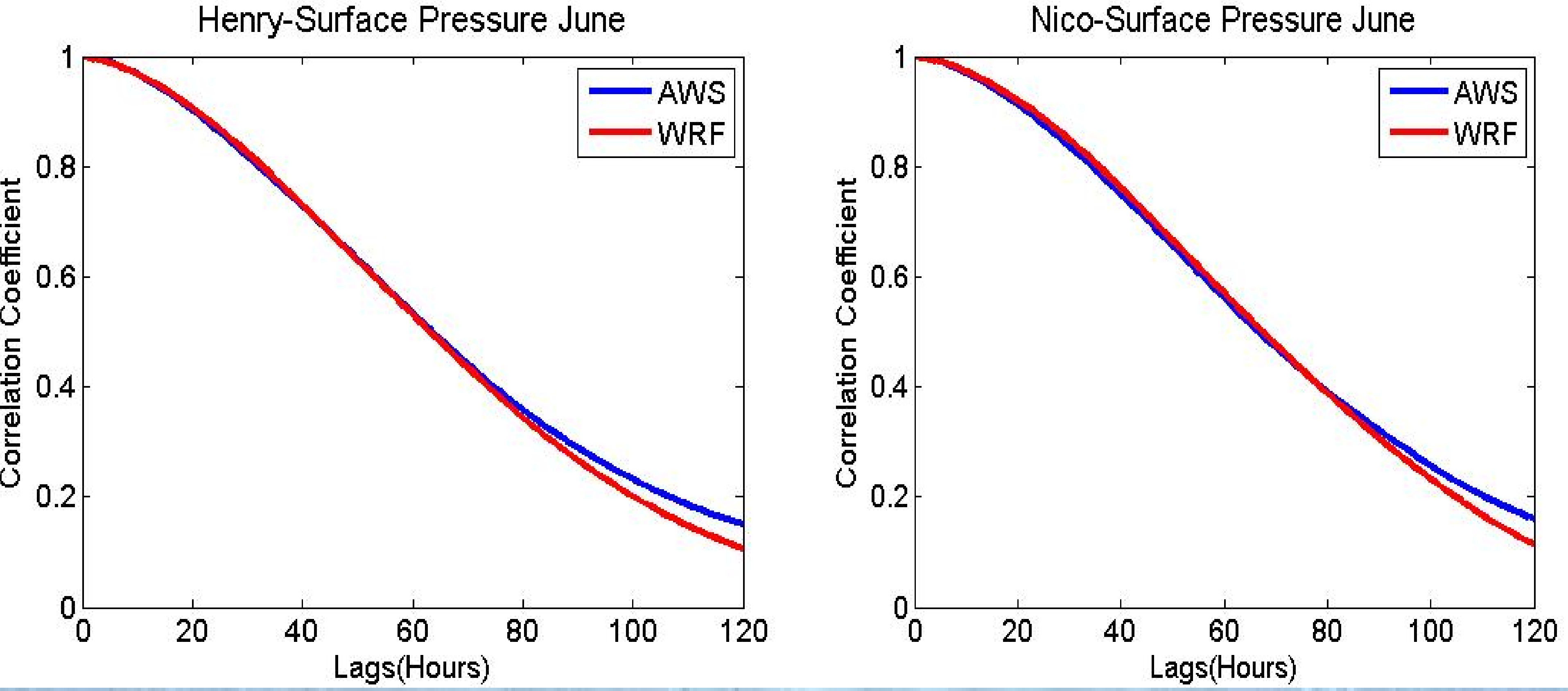








Auto-Correlation



WRF vs AWS

CORRELATION	HENRY	NICO
Pressure	0.99	0.99
Pot Temp	0.74	0.71
Wind speed	0.4748	0.63

RMSE	HENRY	NICO
Pressure	5.14	5.039
Pot Temp	7.02	8.33
Wind speed	2.18	1.83

BIAS	HENRY	NICO
Pressure	4.85	-5.0
Pot Temp	4.80	5.90
Wind speed	-1.30	0.99

RESULTS

- WRF shows a strong positive bias for 3m temperature at beginning of each forecast
- T_3 and Psfc shows a strong correlation with corresponding observation
- Psfc has a constant bias during the entire period of forecast
- There is no prominent diurnal cycle evident
- WRF show a poor skill in predicting 3 m wind speed

Future Work

- Validation of AMPS forecasts for one full year
- Model sensitivity studies to different parameterization schemes
- Improved and physically-based flux parameterizations for mesoscale models based on LES-generated databases in conjunction with field observations
- Incorporation of BL parameterizations in the WRF model and systematic verification of the model forecasts against observations