WRF model evaluation over Hindu-Kush Himalaya region

ICIMOD

17th WRF Users Workshop
Boulder, Colorado
June 27-July1

Bhupesh Adhikary

International Centre for Integrated Mountain Development

Kathmandu, Nepal

Shreta Ghimire[1], Siva Praveen Puppala[1], Arnico K. Panday[1], Paolo Cristofanelli[2], Paolo Bonasoni[2]

[1]International Center for Integrated Mountain Development, Kathmandu, Nepal
[2]Institute for Atmospheric Sciences and Climate, National Research Council of Italy

FOR MOUNTAINS AND PEOPLE

ICIMOD

International Centre for Integrated Mountain Development

Mission:

To enable sustainable and resilient mountain development for improved and equitable livelihoods through knowledge and regional cooperation

Inter-governmental organization

8 member countries:

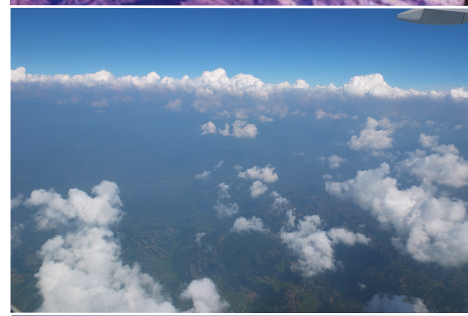
Afghanistan
Bangladesh
Bhutan
China
India
Myanmar
Nepal
Pakistan

Air pollution in our region has far-reaching consequences:

ICIMOD

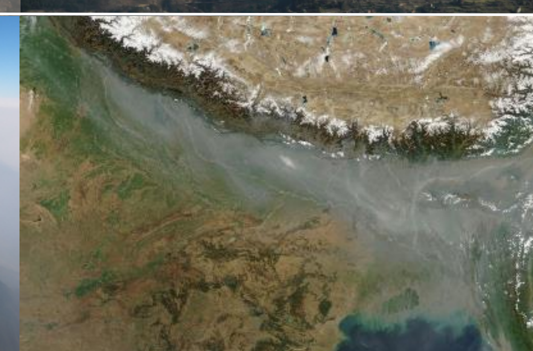
1. **Melting of the cryosphere (partly by black carbon)**

2. **Changing monsoon patterns => agriculture impacts**



3. **Increasing urban air pollution => health impacts**

4. **Regional haze over the Indo-Gangetic Plains**



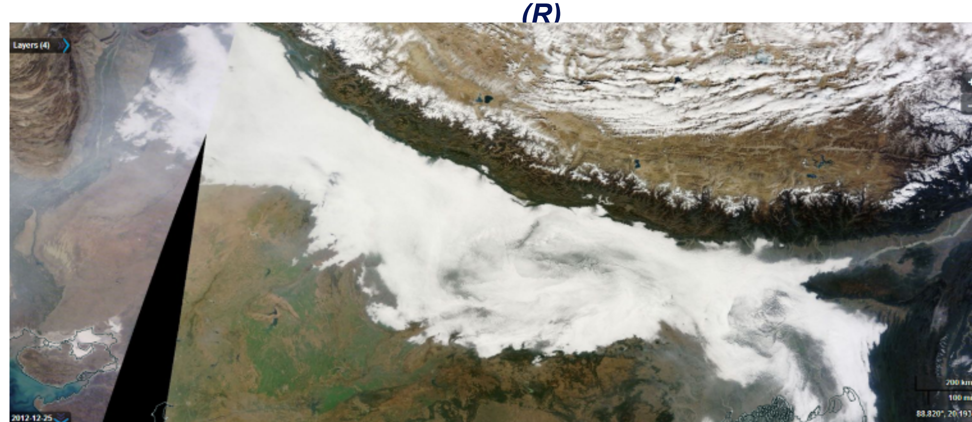
Photos © Arnico Panday, ICIMOD

ICIMOD

5. Reduced visibility has economic impact on tourism

View from Hattiban Resort, Nepal, on 28 February 2013 (L) and 2 March 2013 (R)

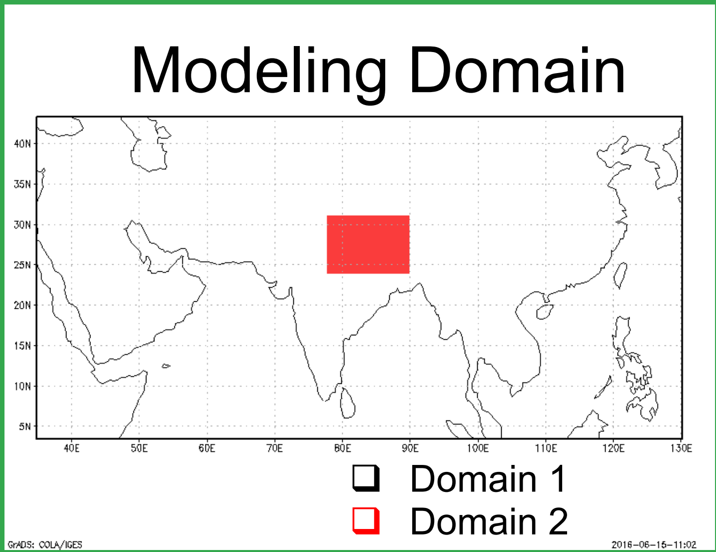
6. Increased persistent winter fog affects lives of several hundred million including most of Nepal’s Tarai residents.



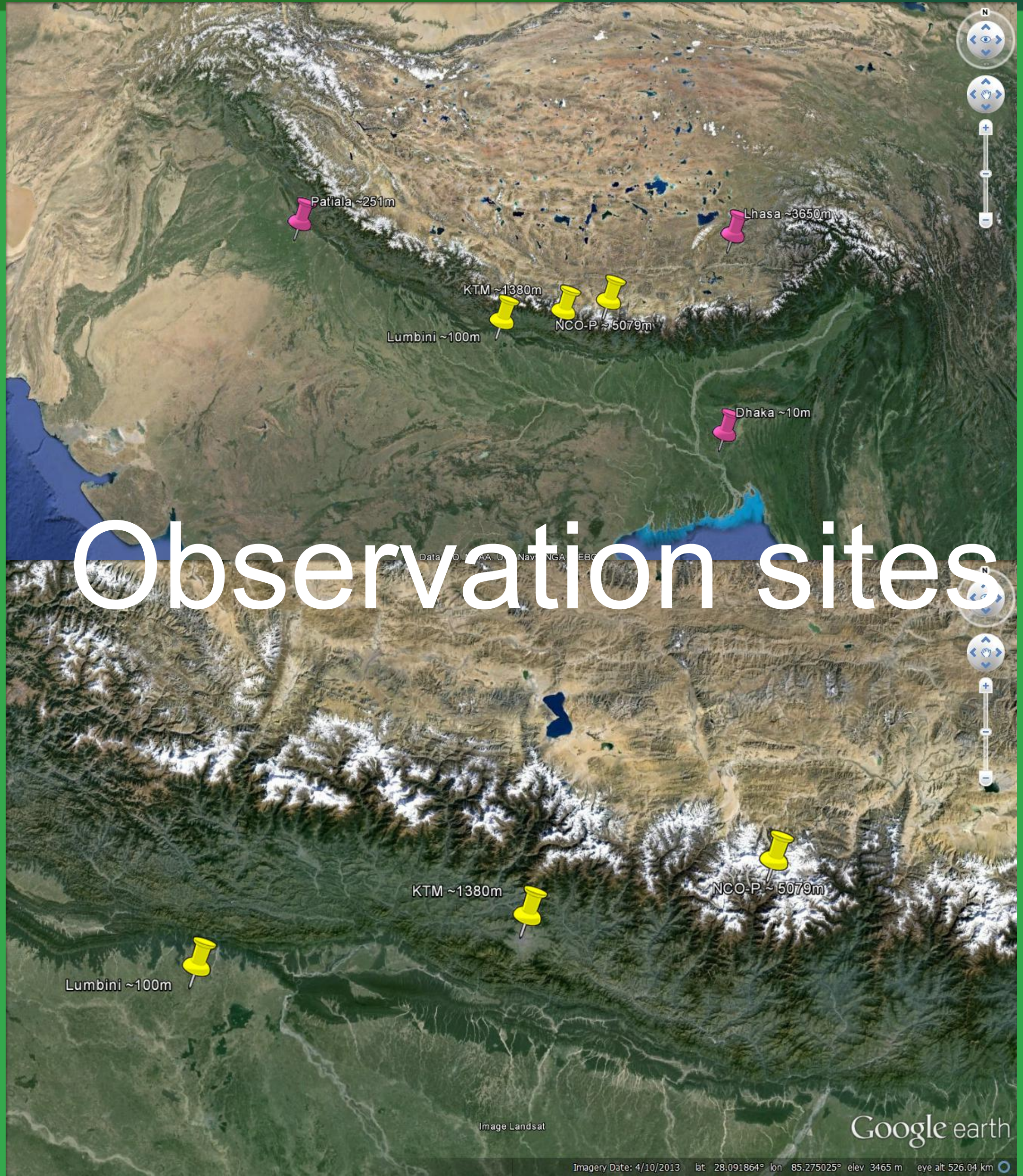
WRF modeling framework

ICIMOD

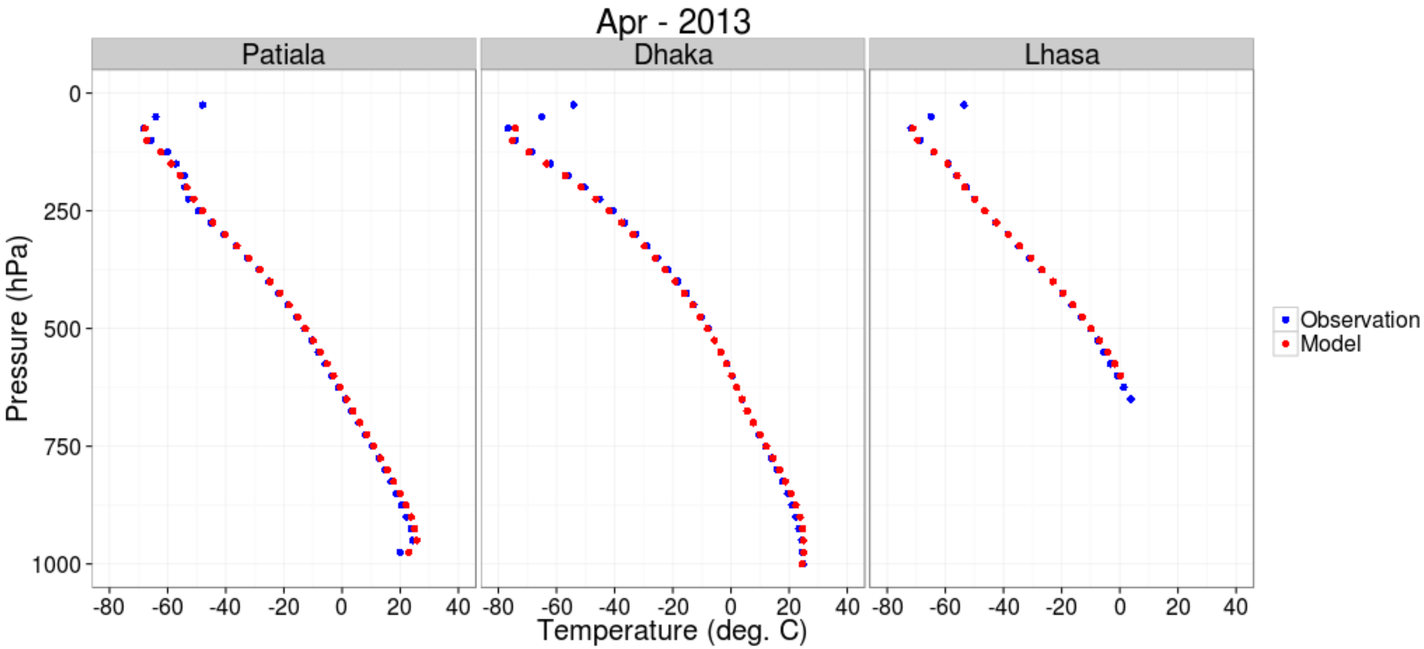
Model Input:	**FNL data**
WRF model version	3.5.1
Horizontal grid spacing	25 and 5 km
Model top pressure (hPa)	50
Vertical levels	40
Microphysics	WSM 3-class simple ice scheme
Cumulus	Kain-Fritsch scheme
Planetary boundary layer	YSU scheme
Surface layer	MM5 Monin-Obukhov
Land surface	Unified Noah land-surface

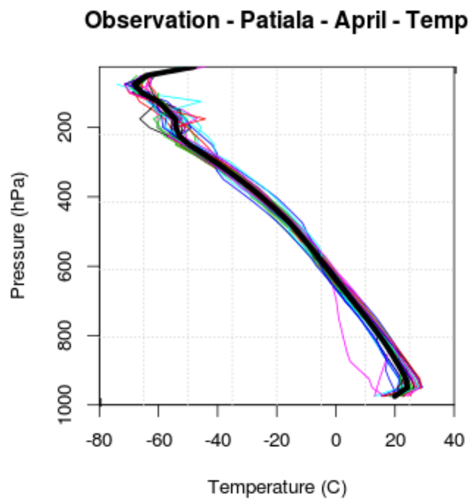


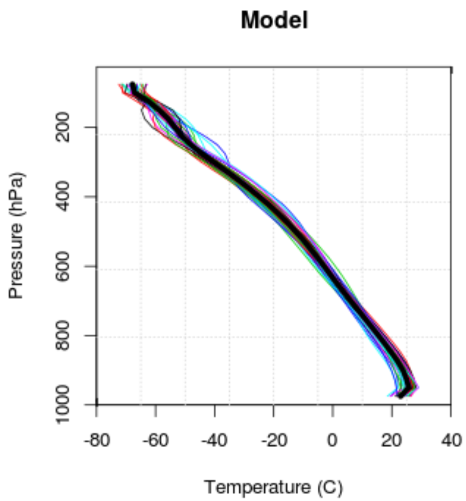
Observation sites



Upper Air Analysis: Temperature
@25x25 km @ 0Z







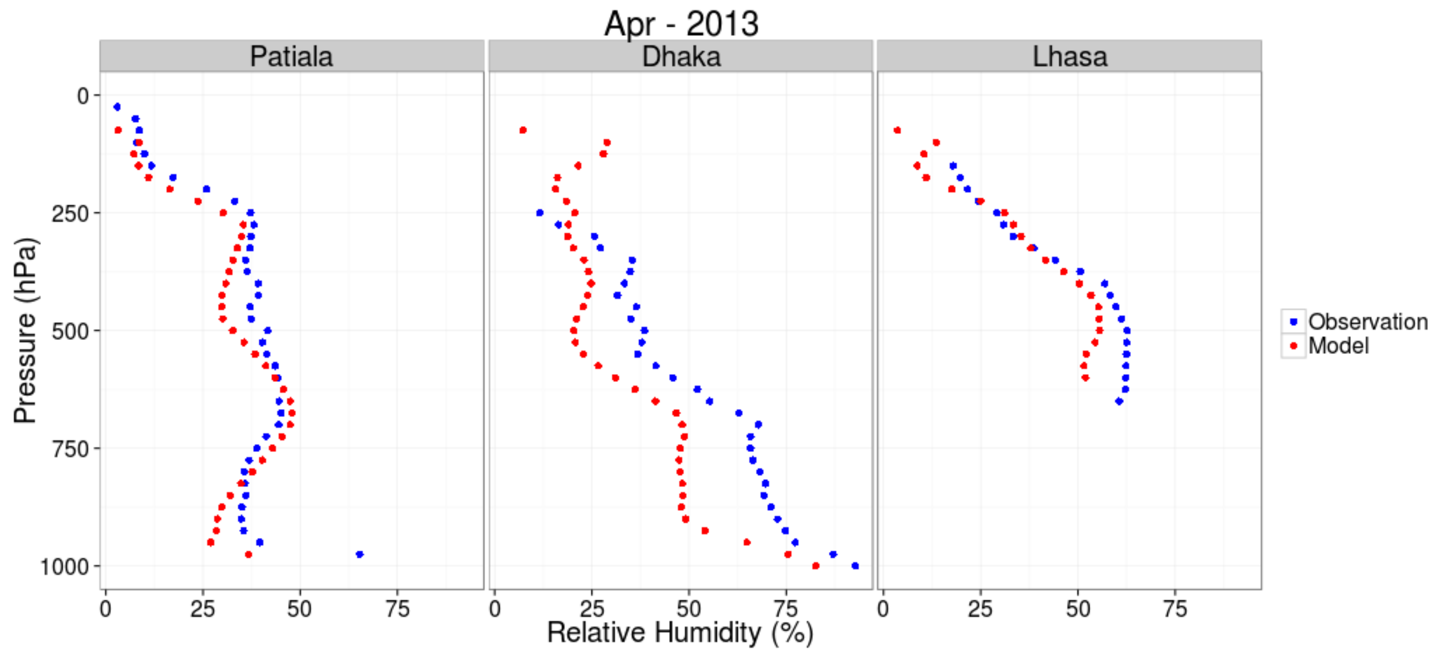
Statistics

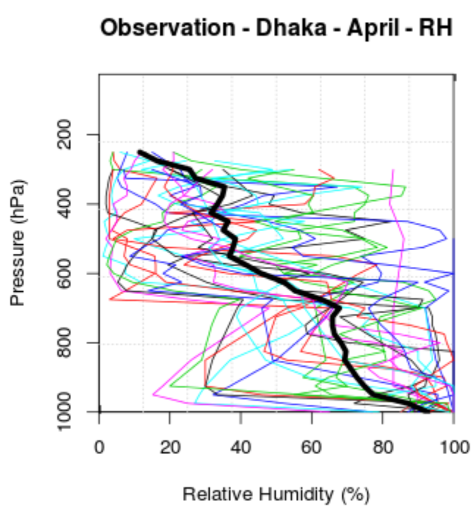
Station	Patiala	Dhaka	Lhasa
T Bias	0.521	-0.109	0.308
T RMSE	1.092	0.912	0.603
T Correlation Coefficient	1.000	1.000	1.000

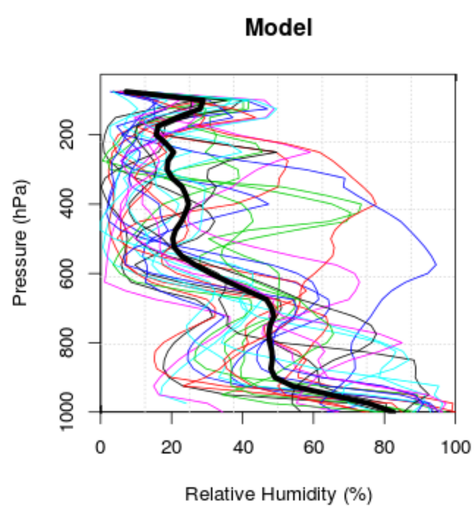
Upper Air Analysis: RH

@25x25 km @ 0Z

ICIMOD





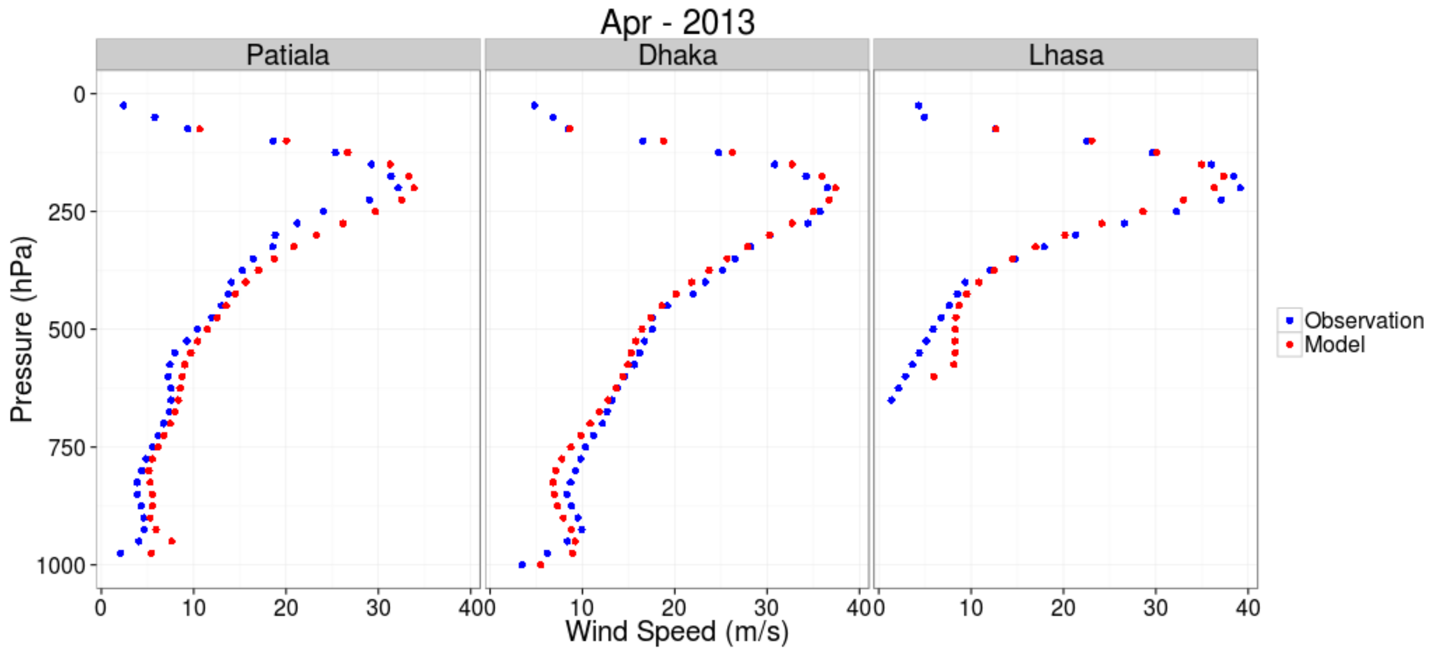


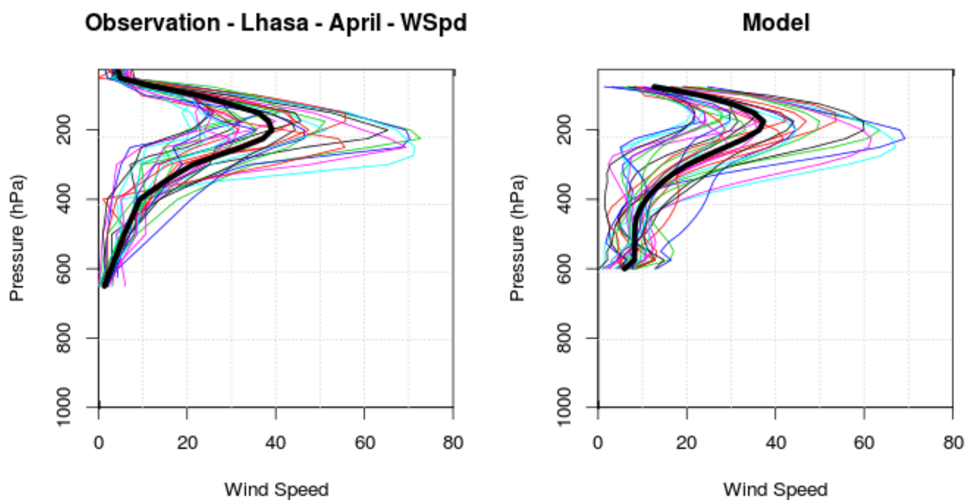
Statistics

Station	Patiala	Dhaka	Lhasa
RH Bias	-4.165	-13.948	-4.776
RH RMSE	7.243	15.576	6.421
RH Correlation Coefficient	0.867	0.953	0.969

Upper Air Analysis: Wind Speed @25x25 km @ 0Z

ICIMOD

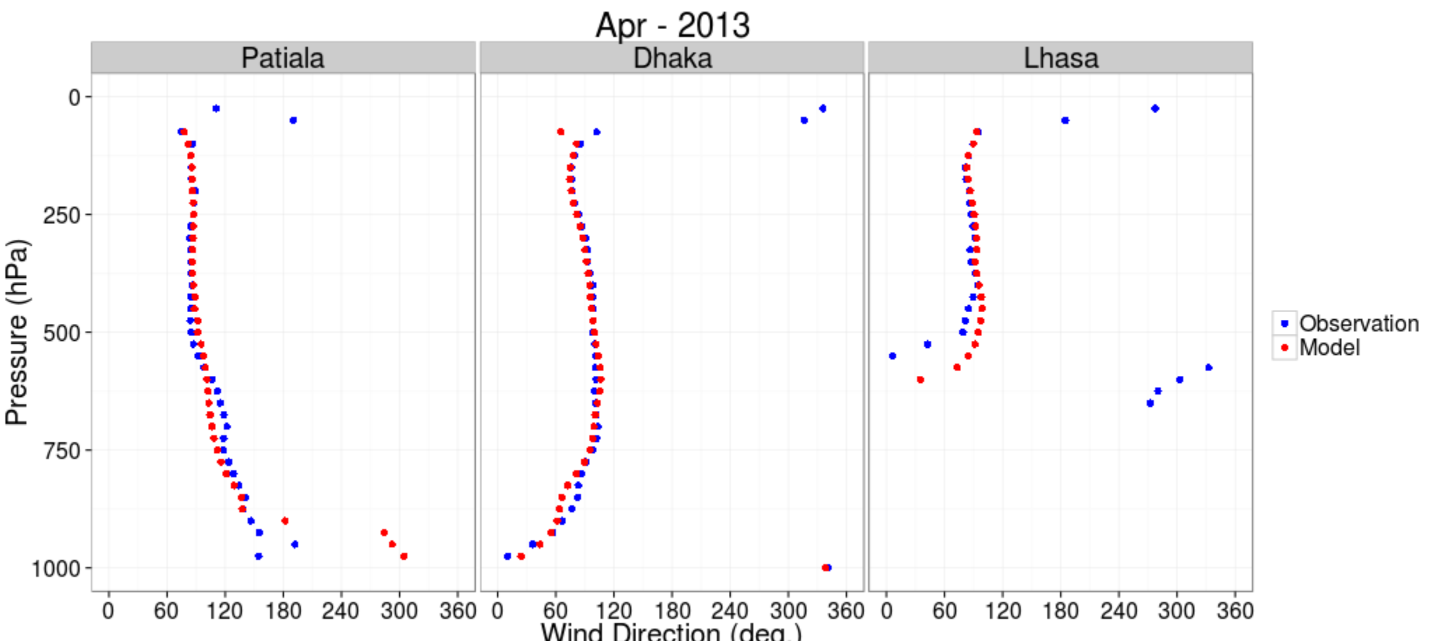


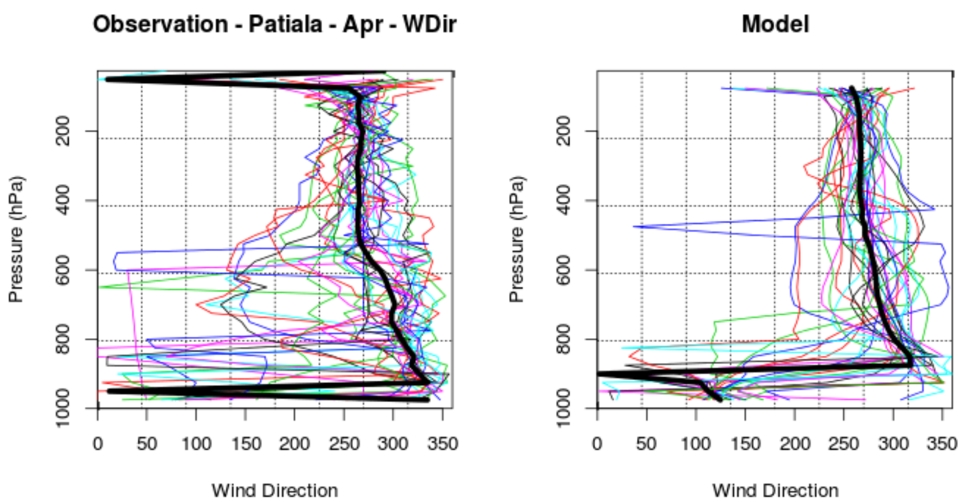


Statistics

Station	Patiala	Dhaka	Lhasa
WS Bias	1.725	-0.432	0.276
WS RMSE	2.129	1.359	2.300
WS Correlation Coefficient	0.992	0.992	0.994

Upper Air Analysis: Wind Direction @25x25 km @ 0Z

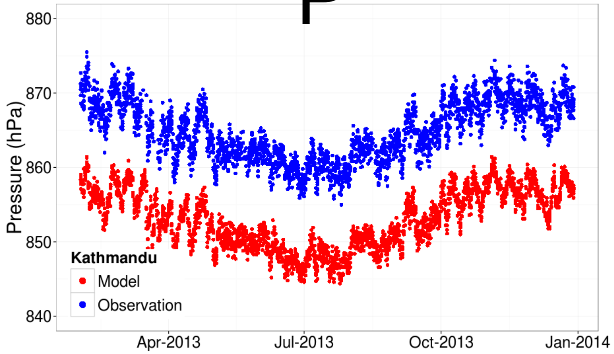




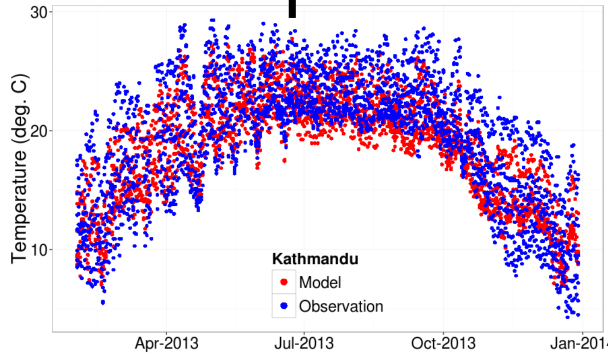
Seasonal Cycle – Kathmandu ~ 1380 m Mountain Valley (25x25 km)

ICIMOD

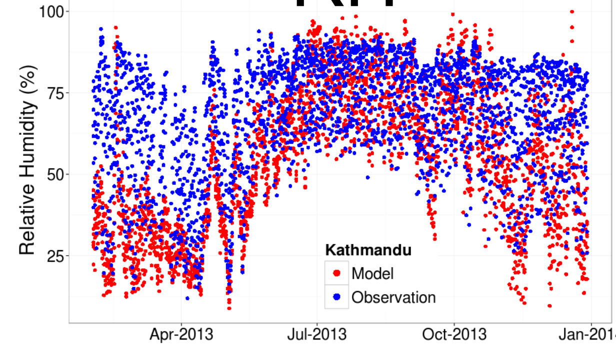
P



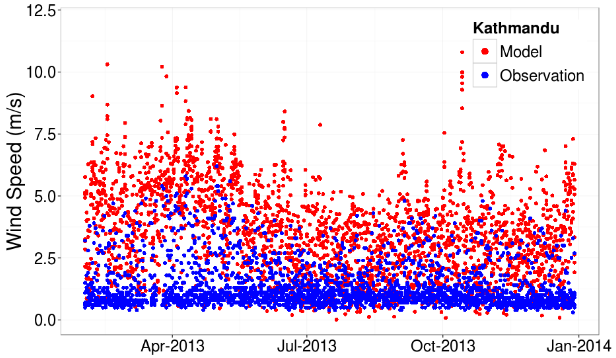
T



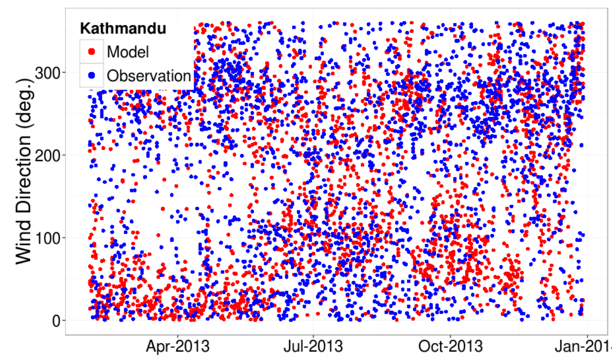
RH



Wspd

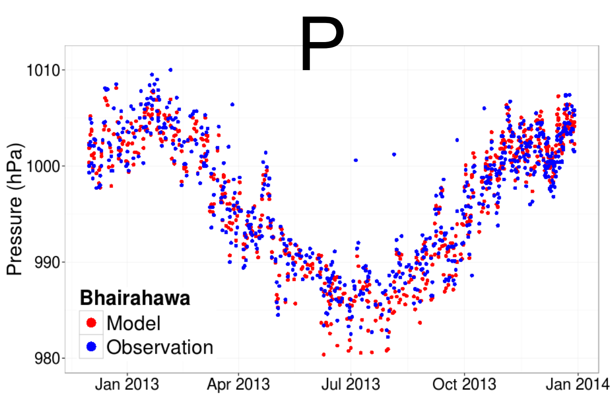


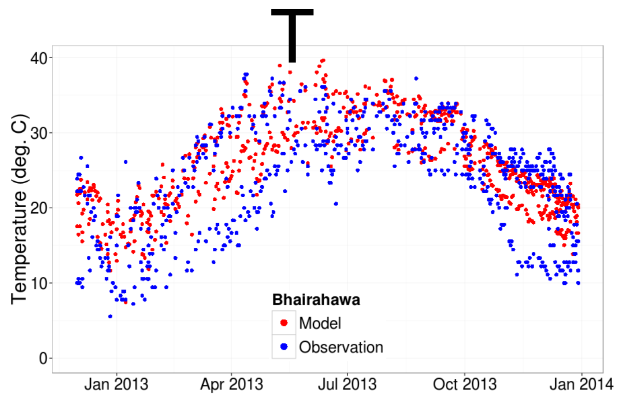
WDir

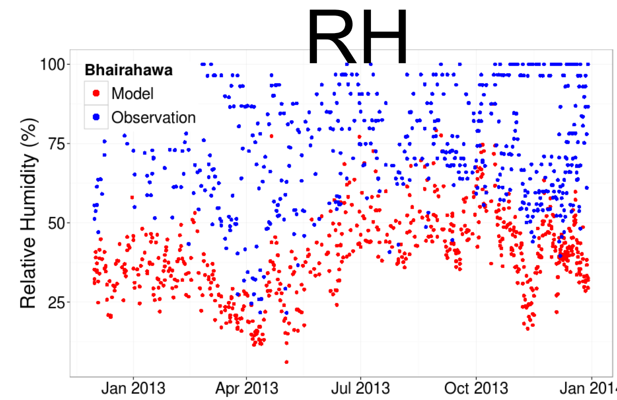


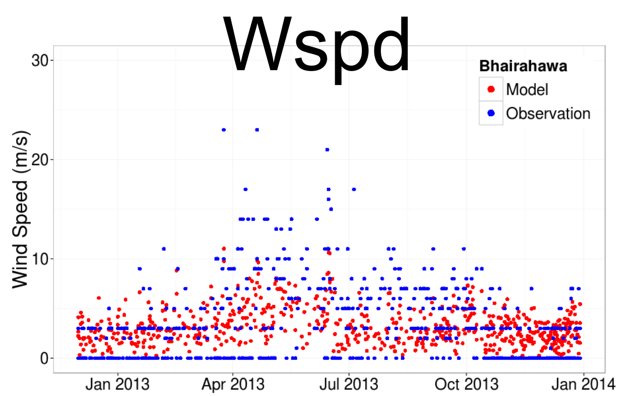
Kathmandu	RMSE	Bias	Correlation Coefficient
Pressure	12.007	-11.933	0.943
Temperature	4.002	-0.876	0.692
RH	26.512	-13.142	0.324
Wspeed	2.917	2.161	0.073

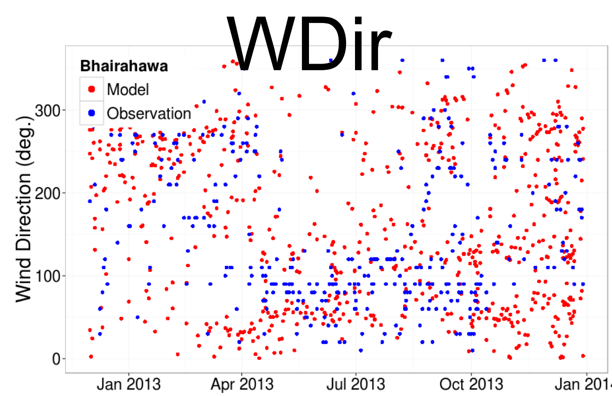
Seasonal Cycle – Lumbini (25x25 km) Foothills - Indo Gangetic Plains (~100 m)









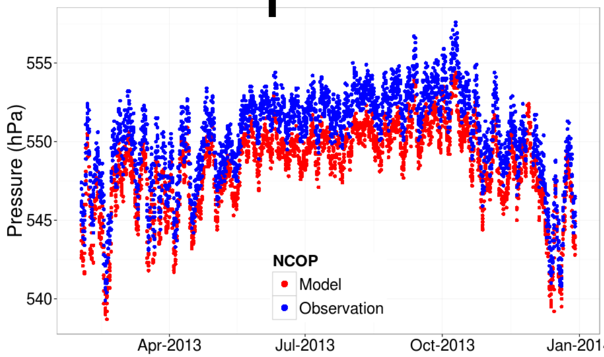


Bhairawhawa	RMSE	Bias	Correlation Coefficient
Pressure	3.305	-0.08	0.888
Temperature	4.102	2.069	0.877
RH	39.897	-35.392	0.315
Wspeed	6.62	-0.34	0.221

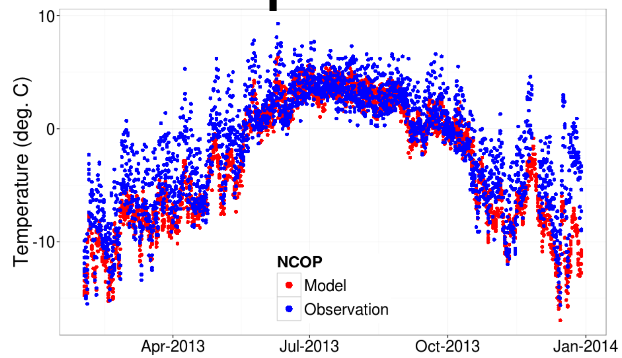
Obs Data: NCDC (~ day time)

Seasonal Cycle – NCOP (25x25 km) (~Everest base camp, 5079m)

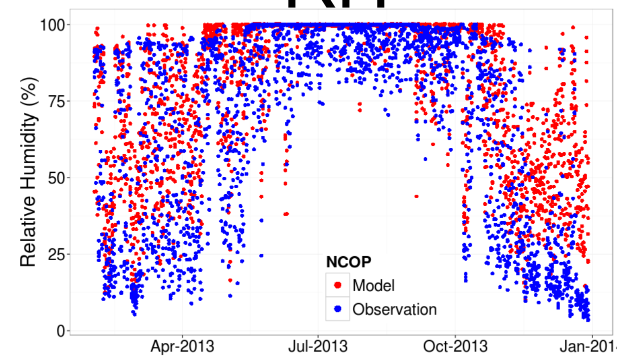
P



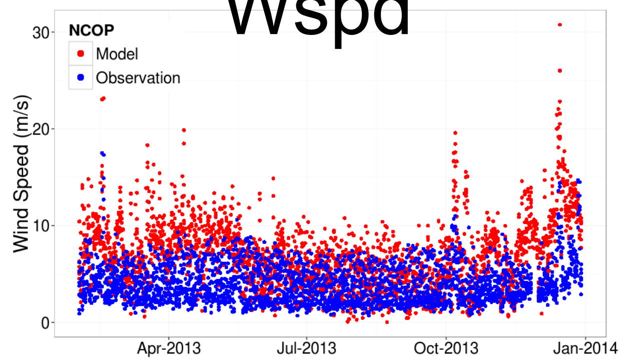
T



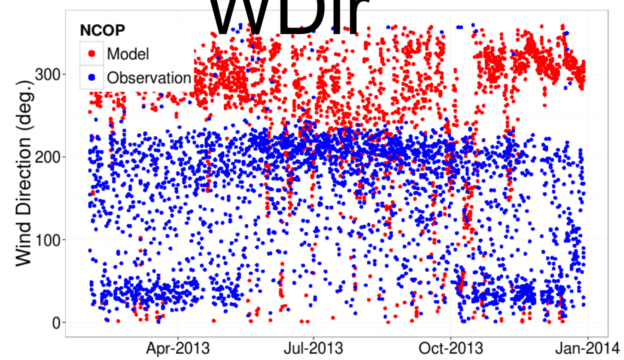
RH



Wspd



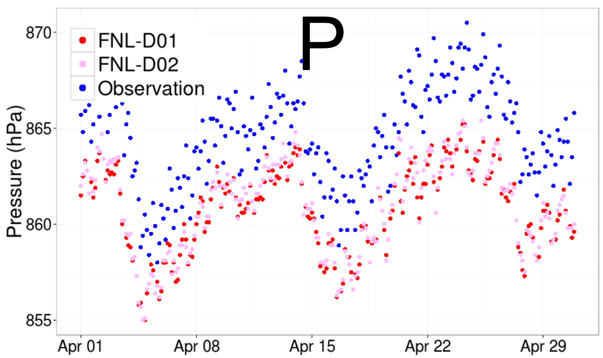
WDir

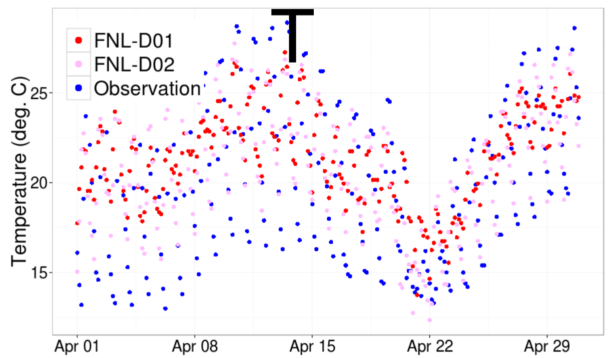


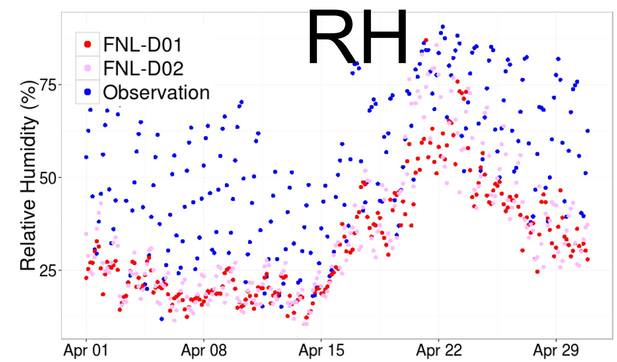
NCO-P	RMSE	Bias	Correlation Coefficient
Pressure	2.226	-2.065	0.958
Temperature	2.877	-1.612	0.899
RH	25.759	10.972	0.691
Wspeed	4.539	2.946	0.291

Model Resolution – Kathmandu Valley 25x25 km D01 and @ 5kmx5km D02

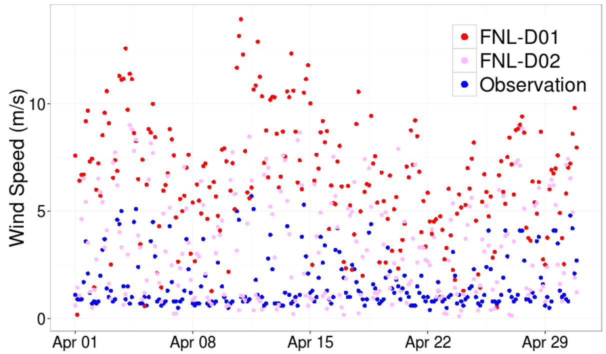
ICIMOD

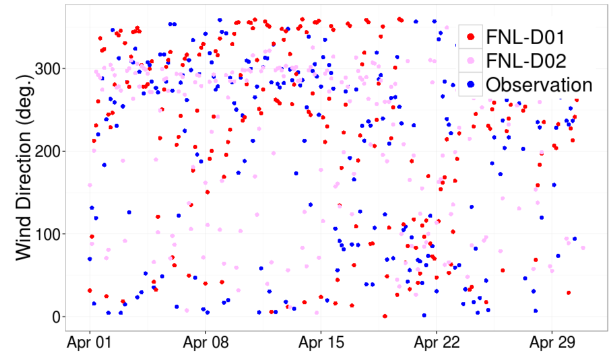






Wspd



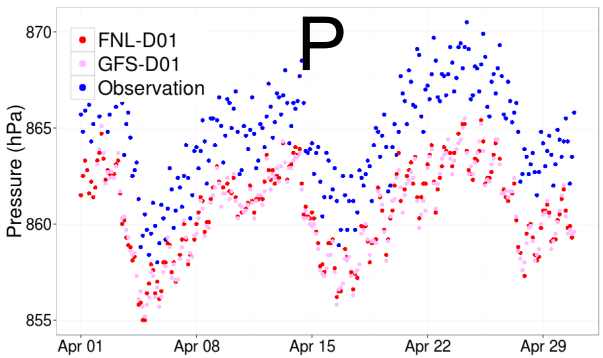


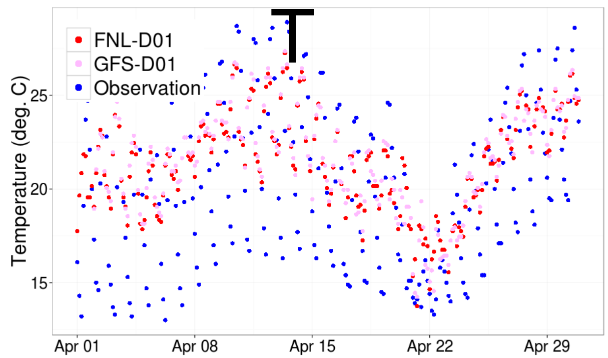
WDir

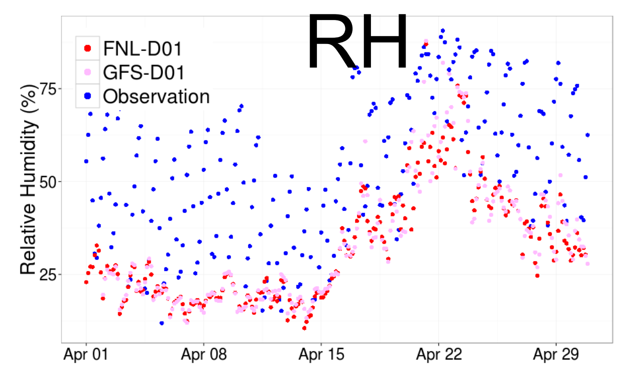
Variable	Sensitivity Run	RMSE	Bias	Corelation Coefficient
Pressure	FNL (D-01)	4.114	-3.858	0.836
Pressure	FNL (D-02)	3.945	-3.690	0.846
Temperature	FNL (D-01)	3.871	1.300	0.527
Temperature	**FNL (D-02)**	**4.088**	**0.626**	**0.459**
RH	FNL (D-01)	26.370	-20.967	0.600
RH	FNL (D-02)	25.243	-18.597	0.584
Wspd	FNL (D-01)	5.468	4.790	0.304
Wspd	**FNL (D-02)**	**2.942**	**1.666**	**0.275**

Model Initialization – Kathmandu Valley FNL versus GFS forecast

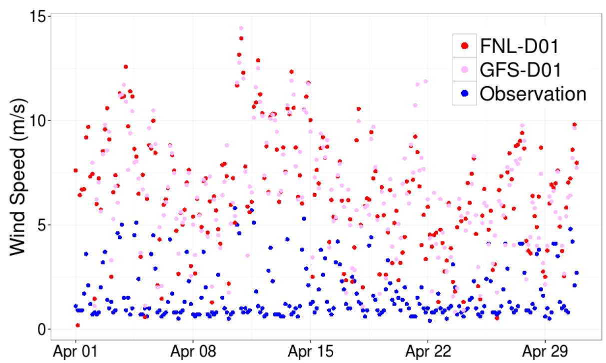
ICIMOD

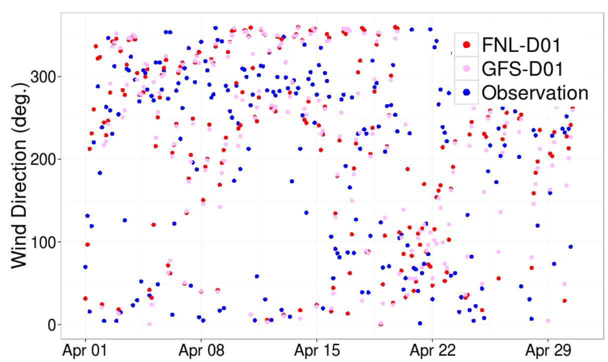






Wspd





WDir

Variable	Sensitivity Run	RMSE	Bias	Corelation Coefficient
Pressure	FNL (D-01)	4.114	-3.858	0.836
Pressure	GFS (D-01)	4.202	-3.950	0.840
Temperature	FNL (D-01)	3.871	1.300	0.527
Temperature	GFS (D-01)	3.913	1.420	0.532
RH	FNL (D-01)	26.370	-20.967	0.600
RH	GFS (D-01)	26.166	-20.187	0.588
Wspd	FNL (D-01)	5.468	4.790	0.304
Wspd	GFS (D-01)	5.485	4.795	0.270

Conclusions

ICIMOD

- **Hindu Kush Himalaya Region**
  - Observation data scarce region
  - Development and wellbeing of the region very sensitive to weather, air quality and climate
  - Limited knowledge on regional scale NWP model performance
- **Model Evaluation**
  - **Temperature:** The model is able to capture the annual temperature variability at the surface sites with site specific positive and negative biases. Upper air monthly mean data analysis for temperature also shows positive and negative biases. Surface sites show RMSE values of ~4 C while upper air data shows RMSE values of ~1 C
  - **RH:** The model shows negative bias at two surface sites and at all upper air station data. High altitude surface site shows positive bias. Surface site RMSE for RH ranges from 26 – 40% while upper air data for RH ranges from 6-16%.
  - **WindSpeed**: Model shows both positive and negative biases at the surface sites as well as upper air data. RMSE values for surface sites range from ~3-6 m/s while upper air data show RMSE values ranging from 1.3 to 2.3 m/s.
  - **Wind direction:** Remains a challenge for the model at or near surface while monthly mean wind direction is well captured at upper altitudes.
- **Model sensitivity**
  - During the month of April, model does not show substantial improvement in meteorology parameters at Kathmandu site except for wind speed when comparing 25x25 km to 5x5 km model resolution.
  - Statistics at Kathmandu site do not show significant difference between model initialization with FNL versus GFS forecast data.

Thank you

The Atmosphere Initiative at ICIMOD

ICIMOD

- Established in January 2013. Working areas:

A. Improving knowledge about **emissions:** inventories, socio-economic drivers.

B. **Atmospheric processes and change:** Observatories, field campaigns, modelling (including weather and pollution).

C. **Quantifying impacts**: on climate, cryosphere, water resources, agriculture, tourism, livelihoods.

D. Assessing **mitigation options** (for example how to rebuild Kathmandu's brick kilns with feasible cleaner technology).

E. **Capacity building:** Supporting PhD students, hosting short courses (eg. WRF-Chem tutorial).

F. **Outreach and networking:** educational materials, films, regional meetings.

G. **Policy recommendations** at national, regional and global levels.