A Dynamical Statistical Downscaling Procedure for Local Wind Climate Assessment

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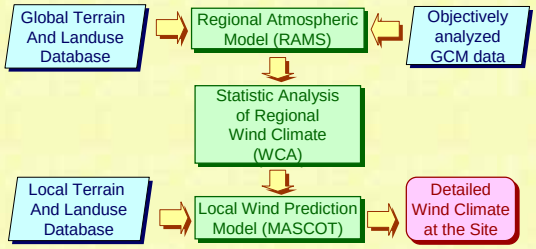
The concept of Dynamical Statistical Downscaling Procedure

Basic Ideas

- A local wind climate assessment method for mountainous area was proposed to take the effect of atmospheric stability and the local circulation such as sea-land breeze and mountain-valley wind into account.
  - First, regional wind for one year is dynamically predicted with regional atmospheric model.
  - Then, regional wind climate is calculated by statistical analysis.
  - Finally, local wind climate is predicted with non-linear wind prediction model.
- This method is named Dynamical Statistical Downscaling (DSD) Procedure.
- The advantage of DSD Procedure is ability of taking the effect of local circulation into account compared with Statistical Dynamical Downscaling.

The flow chart of the procedure



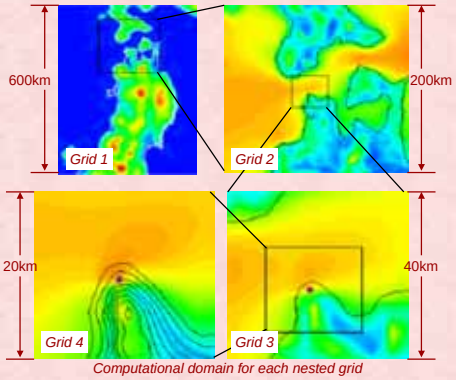
Regional wind climate

Regional Atmospheric Model RAMS

RAMS (Regional Atmospheric Modeling System) was used to simulate regional wind, which has the following characteristics:

- Non-hydrostatic equation
- Reynolds-averaged primitive equations
- Cloud and vegetation models
- Parallel computation

Calculation domain and boundary condition

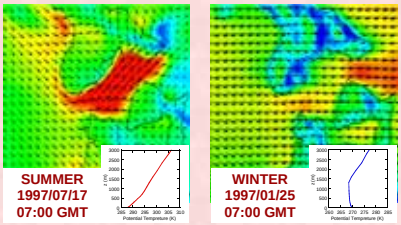


Computational domain for each nested grid

The contours in grid 1 show the elevation of terrain and those in the other figures show the annual mean wind speed

- Objectively analyzed data of GCM was used as the boundary and initial condition.
- Four level nested grids were used, which have the horizontal resolution of 8km, 4km, 2km and 1km respectively.
- The simulation was carried out for one year (1997).

Calculated regional wind climate



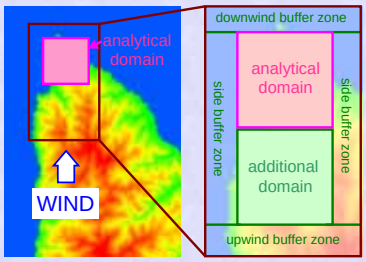
Predicted wind field at Tsugaru Strait, north of Japan

- The atmospheric stability has seasonal variation and this causes different wind pattern.
  - On a summer day, the wind direction is forced to change along the Tsugaru Strait.
  - On a winter day, the wind tends to blow over mountain.
- However, the estimated annual mean wind speed has the error of 25.4 %, since the resolution of small scale terrain is not enough.

Local wind Climate

Local Wind Prediction Model MASCOT

A non-linear model MASCOT (Microclimate Analysis System for COmplex Terrain) was used to estimate the effect of local terrain on wind climate.

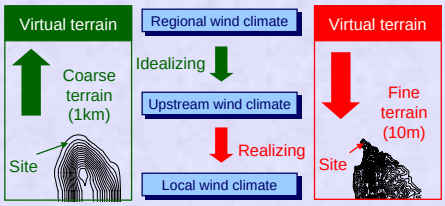


The computational domain for local wind prediction

- MASCOT is based on non-linear Navier-Stokes equations.
- A new boundary treatment methods are adopted to minimize the boundary effect and to consider the influence of upwind terrain

Idealizing and Realizing Approach

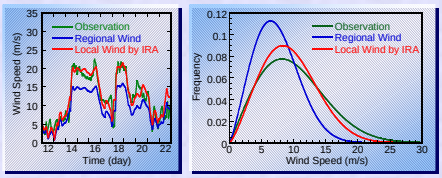
Idealizing and Realizing (IR) approach was proposed to take the effect of small scale terrain into account.



The concept of Idealizing and Realizing Approach

- First, wind over the terrain with coarse resolution used in RAMS, was predicted by MASCOT.
- Then, the correction factor (*C*) and turning of wind (*D*) are used to convert the regional wind climate to upstream wind climate.
- Finally, upstream wind climate is converted to local wind climate using *C* and *D* obtained from predicted wind field over the terrain with fine resolution.

Local Wind at Tappi Lighthouse



Time series of wind speed *Frequency distribution of wind speed*

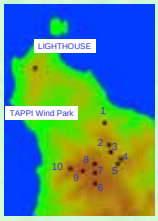
- Local wind climate predicted by IR approach shows good agreement with the observation. The prediction error of annual mean wind speed is reduced from 25.4% to 3.5%.

Application

Overview of the Site

Tappi Wind Park consists of ten wind turbines, all of which are installed on complex terrain.

Tappi Wind Park



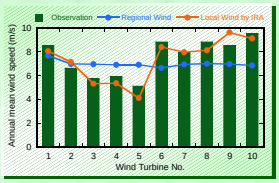
The layout of wind farm

- The wind speeds and directions at each turbine are strongly affected by steep and complex terrain.

Predicted Annual Mean Wind Speed

Local wind at each turbine is predicted by present method and compared with the observation obtained from the anemometer located at the top of the nacelle.

Predicted wind field over complex terrain at the Tappi Cape



Annual mean wind speed at each wind turbine

- The local wind climate predicted by the present method shows good agreement with the observation.
- The effect of the complex terrain is well demonstrated compared with that from regional atmospheric model.

Conclusion

- A new concept for local wind climate assessment was proposed and verified at Tappi Cape.
- Regional wind predicted by RAMS favorably simulates the effect of stratification and large scale terrain. However, it might contain large error due to the limitation in resolution.
- Local wind climate predicted by non-linear wind prediction model MASCOT and IR approach shows good agreement with the observation.
- The advantage of this procedure is to give an accurate local wind prediction in mountainous area and to take the local circulation into account.