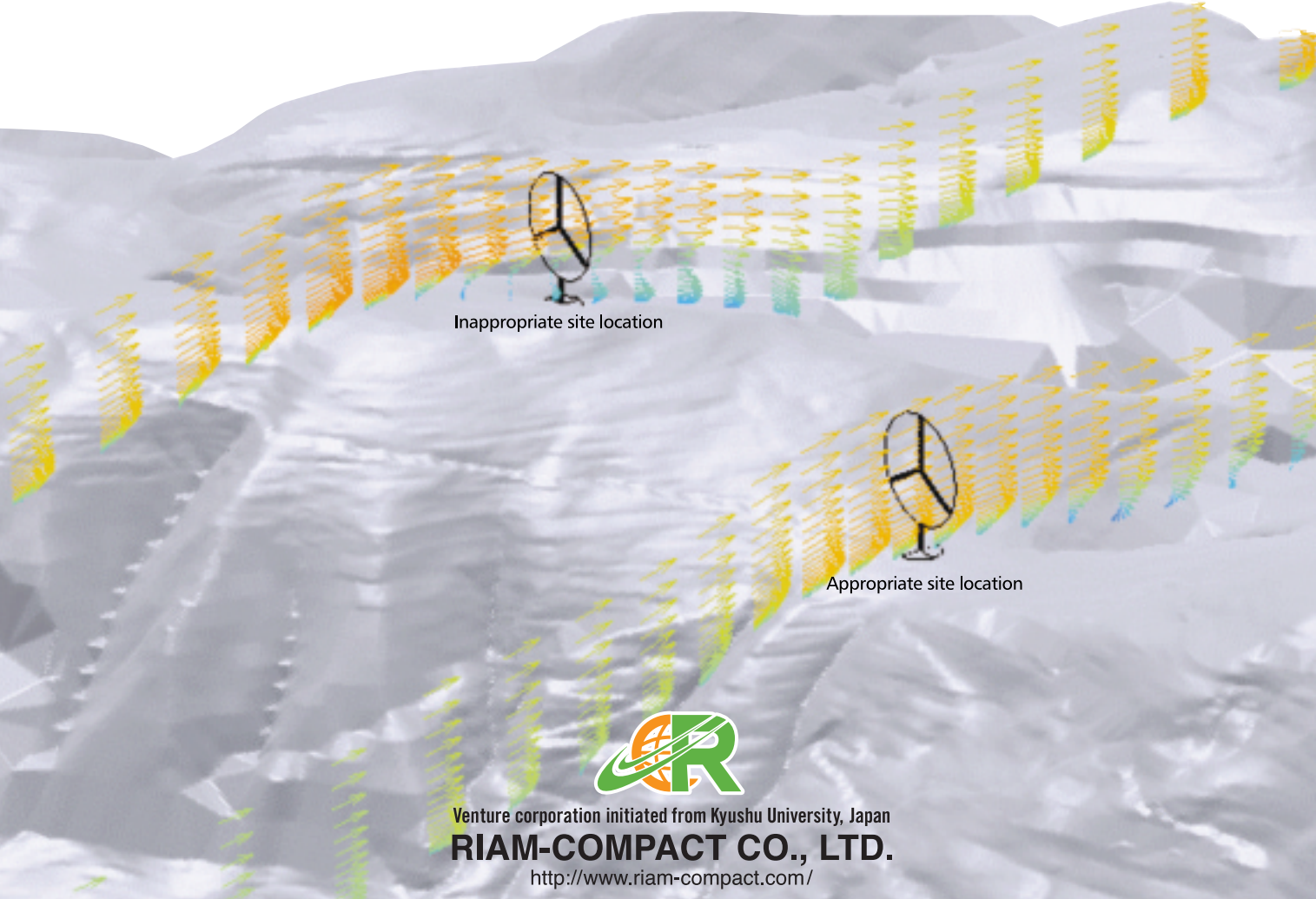# RIAM COMPACT

Non-stationary, Non-linear Wind Synopsis Simulator [**RIAM-COMPACT® Natural Terrain Version**]

Runs on a single PC or laptop

Software that visualizes wind and supports your wind power site selection

Inappropriate site location

Appropriate site location

Venture corporation initiated from Kyushu University, Japan

RIAM-COMPACT CO., LTD.

http://www.riam-compact.com/

Key factors are "animation display" and "rigorous project evaluation"

To prevent global warming, a substantial reduction in CO_2 emissions has become an urgent issue. Accordingly, the effective use of wind power energy (natural energy) is attracting attention as a clean and environmentally friendly solution. In Japan, the number of wind power generation facilities has been rapidly increasing to achieve the goal of 300 million kW of wind generated energy in 2010. These wind power generation facilities range from those with a few wind turbines to large wind farms with dozens of wind turbines. The generated energy output from a wind turbine is proportional to the wind speed cubed. Therefore, accurate selection of sites with favorable wind conditions, even to the pin-point level, is very important. Like many parts of the globe, the topography of Japan is mostly characterized by mountainous areas and complex terrain with few flat areas. This circumstance dictates the constructions of wind power generation facilities in topographically complex areas such as mountainous regions. Therefore, topographical effects such as flow impingement, flow separation, flow reattachment, and reverse flow (Figure 1) need to be taken into consideration for selecting sites for wind turbine construction. Future projects on wind power generation facilities will require rigorous and highly accurate evaluations of the site-specific wind conditions.

With this background, we have developed RIAM-COMPACT® (Research Institute for Applied Mechanics, Kyushu University, COMputational Prediction of Airflow over Complex Terrain), an innovative non-stationary, non-linear wind synopsis simulator, with "animation display" and "rigorous project evaluations" as key factors. Wind characteristics and wind disturbances over complex terrain (terrain-induced turbulence) are two of the major issues to be considered for the installation of wind power generation facilities. Accordingly, the simulator is equipped with an easy-to-operate capability to visualize wind characteristics in the form of animation. The simulator also facilitates the intuitive comprehension and evaluation of terrain-induced turbulence prior to the installation of wind power generation facilities. Additional features of the simulator include 1) the estimation of the annual energy generation (kWh) and the utilized capacity (%) and 2) a display of the wind rose and vertical profile of wind speed at the construction sites of wind turbines.

■ **Topographic effect on wind**
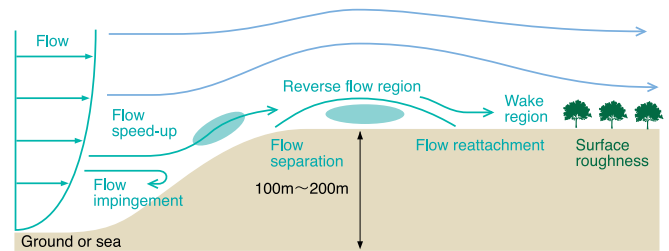
■Main features of RIAM-COMPACT® software

1 Non-stationary, non-linear fluid engineering CFD (Computational Fluid Dynamics) model.

2 Based on an LES (Large-Eddy Simulation) turbulence model that is considered more promising than a RANS (Reynolds-Averaged Navier-Stokes) turbulence model; "wind paths" and "wind disturbances" over complex terrain can be simulated and animated.

3 Applicable for all kinds of flat and complex terrain throughout the world with a powerful reciprocal linkage between GIS (Geographical Information System) and CFD.
(**Utility Model: "Fluid analysis support system," registration number: 3128436**)

■What do "non-linear" and "non-stationary" mean ?

Result of the non-stationary, non-linear model, RIAM-COMPACT®

Eddies of various sizes (wind disturbances)
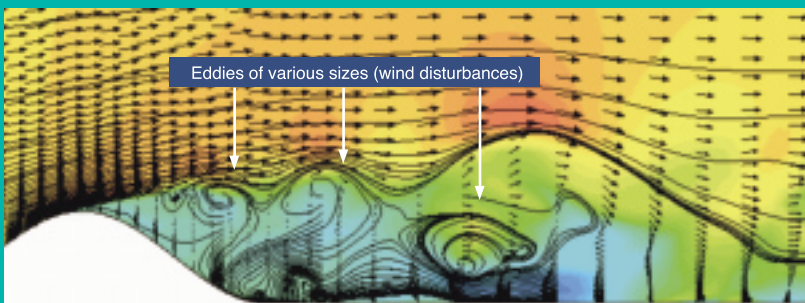
Non-stationary, non-linear models such as RIAM-COMPACT® simulate the wind flow that matches the wind flow that we experience every day. The wind disturbances can be understood intuitively. Non-linear models are applicable for both flat terrain and steep complex terrain.

**Comparisons of various models for predicting wind conditions**

Stationary eddies only
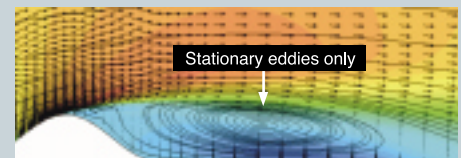
Result of a stationary, non-linear model
Stationary, non-linear models simulate the same results but are averaged in time.

Reverse flow region is not captured
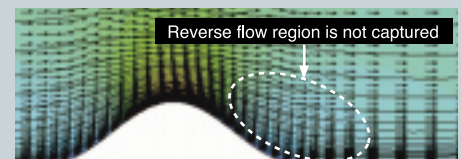
Result of a linear model
Linear models are designed for flat terrain. When applied to steep topography, flow separations (reverse flow regions) cannot be predicted.

RC-Elevgen   Computational grid generation software
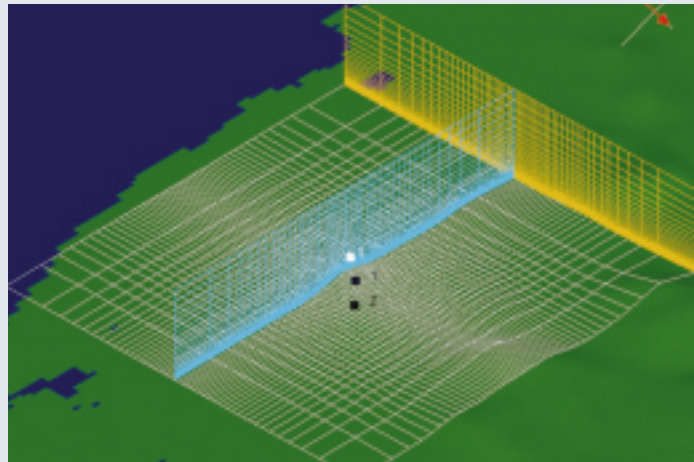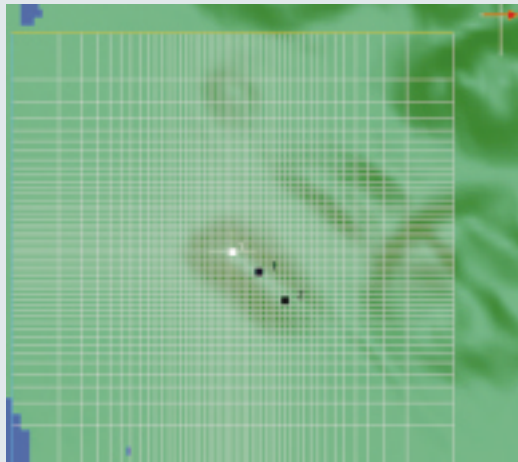
Features of computational grids ■ Horizontal direction: orthogonal
■ Vertical direction: high concentration close to the surface and terrain following

Example: Askervein Hill, UK

The 50m MEM elevation data of the Geographical Survey Institute of Japan and the 10m HGF elevation data of Hokkaido-chizu. Co., Ltd. can be used. (Please note: These elevation data need to be purchased separately.)

RC-Elevgen accepts high-resolution elevation data (GIS elevation data, latitude and longitude ASCII elevation data).
(Please note: These elevation data need to be purchased separately from RIAM-COMPACT, Co., Ltd.)

These data were created for points of interest from paper maps, CAD (Computer Aided Design) data in DXF (Data eXchange Format), and satellite data.

The grid widths in the horizontal and vertical directions can be modified (variable grids).

RC-Elevgen is capable of outputting the longitude and latitude data of the computational grid points.

Locations of observation poles and wind turbines can be displayed as symbols by specifying the decimal longitudes and latitudes of their locations.

Computational grids for 16 wind directions can be saved all at once.

RC-WindmillMaker   Turbine diagram generation software
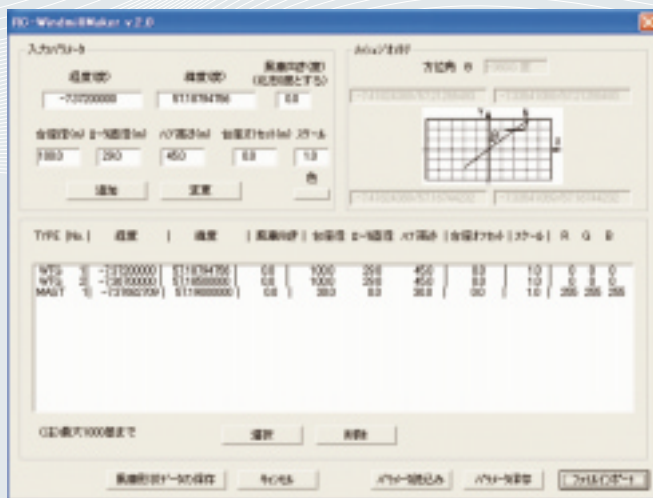
Up to 1,000 wind turbines can be created and viewed in 3D as in the figure below.

Specification of wind turbine locations in decimal latitudes and longitudes.

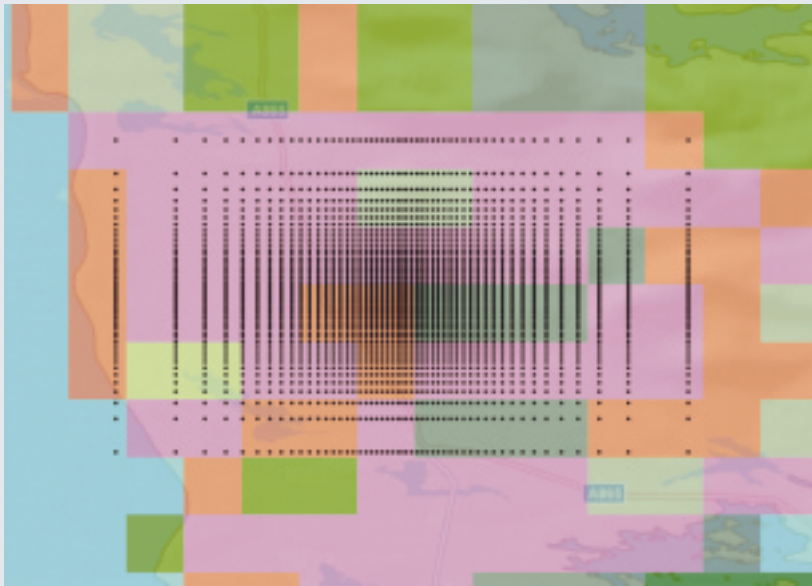Wind directions can be set by user.

Rotor diameters can be set by user.

Tower or pole heights can be set by user.

A result viewed with the computational result visualization software RC-Scope. (Example: Askervein Hill, UK)

RC-RoughnessMaker   Surface roughness supplementary service

※Colors indicate land use.
※Black points indicate computational grids.
　(Example: Askervein Hill, UK)

Based on geodetic coordinate data created by the user, land use data (surface roughness information) for the computational grid points can be obtained on-line.

When the land use data (surface roughness information) are entered into the wind field solver, the influence of the surface roughness can be included in the simulation.

(Please note: This service requires a user-specific ID and password that will be issued after signing an annual maintenance contract.)
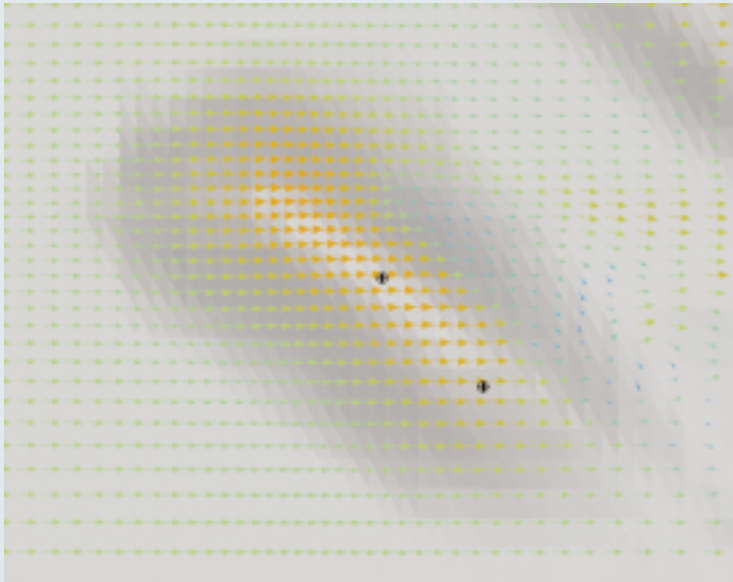
RC-Solver   Wind field solver
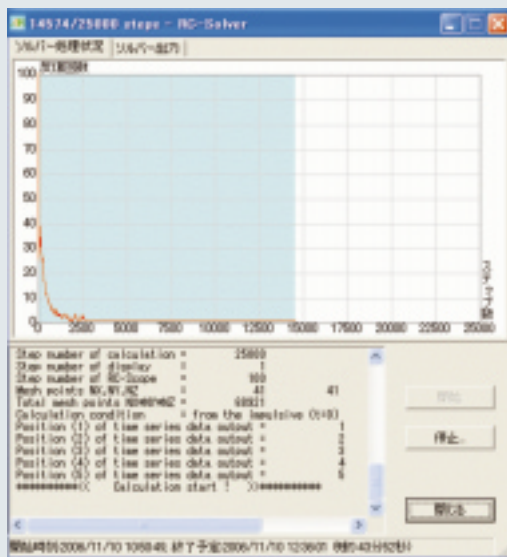
RC-Solver is compatible with Intel multi-core CPU processors and capable of high-speed automated parallel computing.
(e. g.　a computation that involves on the order of 100,000 grid points requires approximately 30 minutes.)

A computation can be started by specifying only a few computational parameters, input files and an output folder.
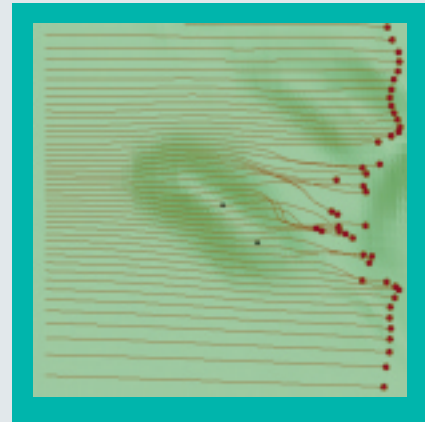
Time-series data of the three components of the wind velocity can be output from as many as 50 selected grid points.

RC-Scope   Computational result visualization software
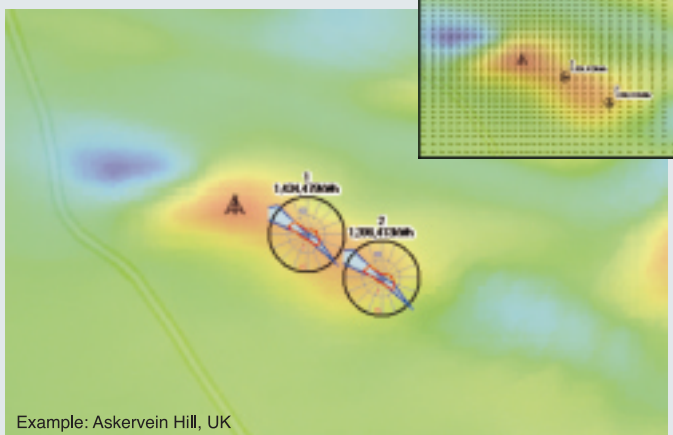

Example: Askervein Hill, UK

The following techniques to visualize various flow properties are available on the standard edition of RC-Scope.

- ■ Computational grids
- ■ Velocity vectors (left figure)
- ■ Isolines, isosurfaces
- ■ Color shading
- ■ Streamlines
- ■ Pathlines
- ■ Streaklines
- ■ Trajectories of tracked particles (upper figure)
- ■ Timeline
- ■ Surface path rendering
- ■ Volume rendering

RC-Explorer   Energy generation estimation software

Example: Askervein Hill, UK
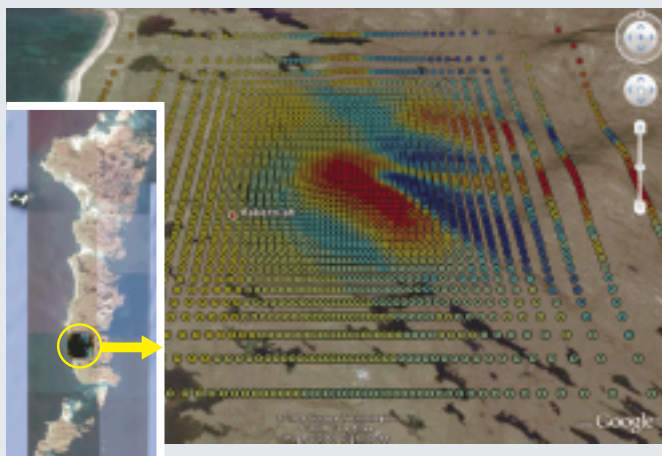
Annual energy generation (kWh), utilized capacity (%), and wind roses can be calculated from the 16 wind direction dependent simulation results entered into the system. In this procedure, the correlation of the simulated results and observed data is taken into consideration.

Wake loss can be output. (Currently under development)

The calculated variables and diagram listed above can be viewed on a map. (upper figure)

RC-Explorer has the capability to report data in XML (eXtensible Markup Language) format.

Wind roses and vertical wind velocity profiles can be output for any wind turbine location.

Wind maps can be output for any height.

RC-Explorer can output composite wind maps for 16 wind directions (local wind maps) that account for the occurrence frequency of wind conditions observed in the field.

RC-Explorer can output the blow down and blow up angles within the swept area of the wind turbine.

Wind synopsis data can be output in Google Earth format. (Currently under development, lower figure)

The design wind speed for the location of a wind turbine can be evaluated using methods compliant with "Guidelines and descriptions for the structural design of wind power generation facilities and supporting objects: 2007" (Japan Society of Civil Engineers) and "Guidelines and descriptions for architectural loads (2004)" (Architectural Institute of Japan).

Fields of application for RIAM-COMPACT® Natural Terrain Version

1 Wind engineering applications
- Investigation on the generation mechanism of topographically induced severe local wind in mountainous regions
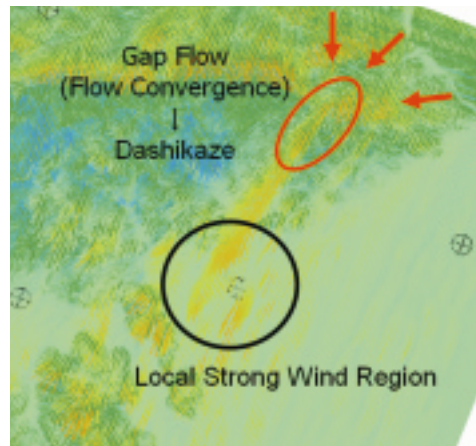- Countermeasures against wind disasters in the vicinity of transmission line towers in mountainous regions
- Countermeasures against typhoon-induced wind disasters on historical buildings
- Countermeasures against tornado-induced wind disasters

2 Railroad applications
- Development of a support system for safe railroad operation in gusty and severe wind conditions
- Countermeasures against wind disasters in the vicinity of railroads and creation of wind condition maps

3 Aviation and shipping applications
- Wind synopsis assessment for airport construction on isolated islands
- Prediction of wind conditions for a docking support system for supertankers

4 Forestry applications
- Creation of hazard maps (specifying severe wind areas) as a part of countermeasures against typhoon-induced wind disasters
- Prediction of forest fire spread
- Prediction of advection and dispersion of forest fire smoke, volcanic gases, atmospheric pollutants, and pollen

5 Leisure applications
- Information delivery service aimed at yacht racing, fishing, golf, and ballooning
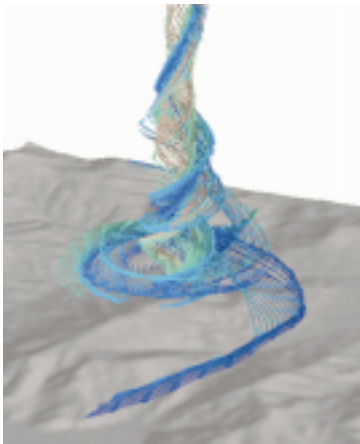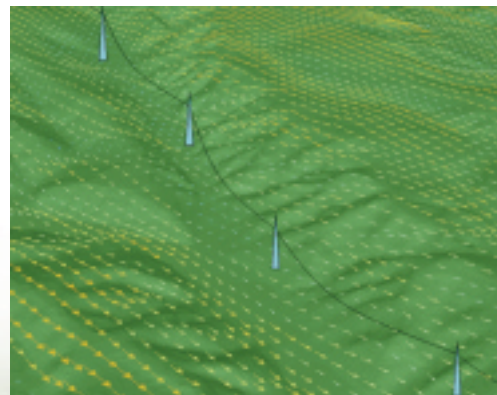

Countermeasures against
tornado-induced wind disasters

Investigation on the generation mechanism of
topographically induced severe local wind in mountainous regions

Prediction of advection and dispersion of volcanic gases
(Example: Miyake Island)

Countermeasures against wind disasters in the vicinity of
transmission line towers in mountainous regions

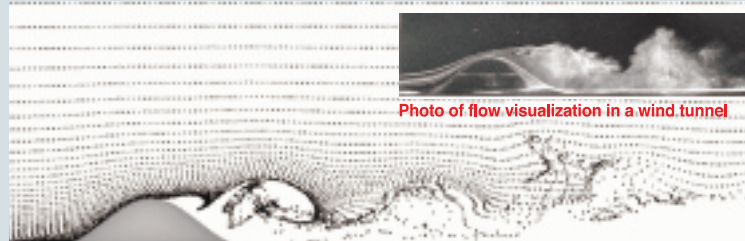## Structure of RIAM-COMPACT® Natural Terrain Version software

	Names of individual software packages	
Pre-processing	1) RC-Elevgen	Computational grid generation software
	2) RC-WindmillMaker	Turbine diagram generation software
	3) RC-RoughnessMaker	Surface roughness supplementary web service
Solver	4) RC-Solver	Wind field solving software
Post-processing	5) RC-Scope	Computational result visualization software
	6) RC-Explorer	Energy generation estimation software

● The natural terrain version of RIAM-COMPACT® software can be run on Japanese and English Windows environments.

 Recommended CPU (Central Processing Unit): Intel Core2 or Core i7 Series
 Recommended OS (Operating System): Windows XP
 Recommended memory size: 2GB
● The standard edition includes 1) to 6).

Comparisons of the computational speed of the wind field solver (go.exe)

Photo of flow visualization in a wind tunnel

Intel Core i7-965 Extreme Edition, 8core 0.72
Intel Xeon Quad X5482 3.2GHz, 8core 1.10
Intel Core 2 Extreme Quad Q6850 3.0GHz, 4core 1.16
FUJITSU LIMITED Supercomputer VPP5000 1PE Standard value

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3
Computational speed

● Benchmark testing: Comparisons of computational time under the same conditions
● Example: 3D simulation of complex turbulence field around an isolated hill
● Number of grid points: 260 x 121 x 71 (approximately 2.2 million points)
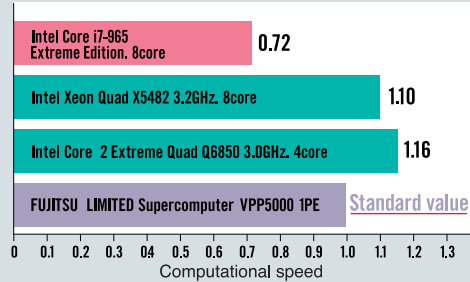
Examples of RIAM-COMPACT® Natural Terrain Version software sales

● Eurus Energy Japan Corporation
● Japan Wind Development Co., Ltd.
● Numerous wind power generation companies, national research institutes, and universities in Japan and abroad
● Numerous cases of consulting service for sites in Japan and abroad, utilizing the RIAM-COMPACT software

RIAM-COMPACT® Natural Terrain Version software development consortium

Company name	Person in charge	Address	E-mail
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West Japan Engineering Consultants, Inc. (http://www.wjec.co.jp/)	Yasushi Kawashima	TEL +81-92-713-6003	y-kawashima@wjec.co.jp
Environmental GIS Laboratory Co., Ltd. (http://www.engisinc.com/)	Ryo Araya	TEL +81-92-847-0105	araya@engisinc.com
FS Consulting Co., Ltd. (http://www.fsconsulting.co.jp/)	Hiroaki Fujimoto	TEL +81-83-987-3216	nf@c-able.ne.jp

Descriptions and references for RIAM-COMPACT® Natural Terrain Version

1. T. Uchida and Y. Ohya, Numerical simulation of atmospheric flow over complex terrain, J. Wind Eng. Ind. Aerodyn., Vol.81, pp.283-293, 1999.
2. T. Uchida and Y. Ohya, Large-eddy simulation of turbulent airflow over complex terrain, J. Wind Eng. Ind. Aerodyn., Vol.91, pp.219-229, 2003.
3. T. Uchida and Y. Ohya, Micro-siting Technique for Wind Turbine Generator by Using High Resolution Elevation Data, JSME International Journal, 「Environmental Flows」, Series B, Vol.49, No.3, pp.567-575, 2006.
4. T. Uchida and Y. Ohya, Verification of the Prediction Accuracy of Annual Energy Output at Noma Wind Park by the Non-Stationary and Non-Linear Wind Synopsis Simulator, RIAM-COMPACT, Journal of Fluid Science and Technology, Vol.3, No.3, pp.344-358, 2008.
5. T. Uchida and Y. Ohya, Micro-siting Technique for Wind Turbine Generator by Using Large-Eddy Simulation, J. Wind Eng. Ind. Aerodyn., Vol.96, pp.2121-2138, 2008.

Software packages currently under development

Pre-processing
7) RC-GeoConverter Elevation data conversion software
■ RC-GeoConverter is capable of converting input elevation data into DEM (Digital Elevation Model) format that can be input to the computational grid generation software RC-Elevgen.
■ The elevation data acceptable as input for RC-GeoConverter are the elevation contour data from WAsP (Wind Atlas Analysis and Application Program) and CAD elevation data in latitude-longitude coordinates.

Post-processing
8) RC-Forecaster Energy generation forecasting software
■ RC-Forecaster is capable of real-time simulations of energy generation with the use of GPV (Grid Point Value) meteorological data available from the Japan Meteorological Agency.

Optional tool
9) RC-GPVanalyzer GPV data analysis software
■ RC-GPVanalyzer is capable of providing various statistics about GPV data including the GPV data available from the Japan Meteorological Agency.

Optional tool
10) RC-Observer Observed wind data analysis software
■ RC-Observer is capable of analyzing the wind data from the wind observation system of NRG Systems, Inc. for variables including the following: annual average wind speed, annual occurrence frequency of wind directions, wind-direction dependent average wind speed, power index, turbulence intensity, the Weibull parameters, wind power density, utilization rates of individual wind turbines, energy generation of individual wind turbines, and utilized capacity.
■ RC-Observer is equipped with the capacity to automatically create reports (monthly and annual) on the above data for the New Energy and Industrial Technology Development Organization (NEDO) of Japan.
■ RC-Observer is capable of outputting bi-hourly time-series data of wind conditions to be input to the energy generation estimation software, RC-Explorer.

※7) to 10) above need to be purchased separately. Please contact a sales agent for the price of each product.

※7) to 10) above are currently under development and 1) to 6) above are continuously being improved. Software development is mainly performed by RIAM-COMPACT Co., Ltd. with cooperative efforts from Environmental GIS Laboratory Co., Ltd., West Japan Engineering Consultants, Inc., and FS Consulting Co., Ltd. The technical core of RIAM-COMPACT®, the computation execution module (go.exe), and a part of the energy generation estimation software, RC-Explorer, were principally developed by Dr. Takanori Uchida of the Research Institute for Applied Mechanics, Kyushu University. An exclusive license of the pertinent components has been granted to RIAM-COMPACT Co., Ltd. by Kyshu TLO Co., Ltd.

Runs on a single PC or laptop

Software that visualizes wind and
supports your wind power site selection

RIAM COMPACT

Non-stationary, Non-linear Wind Synopsis Simulator

[RIAM-COMPACT® Natural Terrain Version]

■ Origin of the development

Venture corporation initiated from Kyushu University, Japan

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Sales agent