Creating a Numerical Weather Prediction-Based Infrastructure for Research and Operations in Brunei

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Creating a Numerical Weather Prediction-Based Infrastructure for Research and Operations in Brunei

- Motivation and background
- Approach
- Examples
- Project plans and status

Other Presentations of Related Work

Conference on Interactive Information Processing Systems:

- **10A.4 Implementation and Operation of Mesoscale Numerical Weather Prediction Modeling Systems**

Conference on Hydrology:

- **4.5 Flooding Forecasting in the City of Rio De Janeiro Using Historical Data**

Conference on Transition of Research to Operations: Successes, Plans, and Challenges:

- **TJ25.6 Enabling An Advanced Numerical Weather Prediction Model for Operational Forecasting in Rio De Janeiro**

Conference on Weather, Climate, and the New Energy Economy:

- **3.2 Methodology for Analyzing and Comparing Weather Forecasts for Use in Business Applications**
- **571 On-Going Utilization and Evaluation of a Coupled Weather and Outage Prediction for Electric Distribution Operations**

Motivation and Background

- Improve understanding of weather- and climate-related issues in Brunei Darussalam
- Impact of weather-induced disasters (e.g., flooding)
  - Doing coupled modelling with data sets from Brunei for flood forecasting, soils, crop yields
- Impact of climate change
  - Rainforest and local weather
- Explore alternate energy resources
  - Solar and wind farms
- Build research capacity for both environmental and computational sciences at the Universiti Brunei Darussalam (UBD)

Geography of Brunei

- Location: northwestern Borneo
  (04º 53' N, 114º 56' E)
- Land Statistics
  - 161 km of coastline
  - 5770 sq km areal coverage (500 sq km is water)
- Four districts: Belait, Brunei-Muara, Temburong and Tutong
- About 400,000 people

- Most of Brunei is a fertile (80% forest), hilly lowland, with the exception of the mountainous areas in the east
- Numerous rivers drain the inland regions, including the Belait, Pandaruan and Tutong
- Coastal areas along the South China Sea are a wide swampy plain
- Complex terrain and rainforests throughout Borneo
- Consideration of the “Borneo Vortex”, which occurs during the northern hemisphere winter when cold fronts from Siberia blow across the South China Sea and interact with the Equatorial trough and is modulated by the Arctic Oscillation and the El-Niño-Southern Oscillation.

Brunei Natural Disaster Events

- 1962: Major flood
- 1980s: Fires in water village
- 1987: Rasau gas blow-out in Belait District
- 1991: Poor air quality resulting from Mount Pinatubo eruption in the Philippines
- 1998: Regional haze
- 1999: Flash flood during La Niña
- 2008: Temburong flash flood
- 2009: Extensive flash flood in Muara, Tutong and Belait districts

The number of flood prone areas in Brunei could increase in the future due to heavy rainfall, rising sea levels, increasing urbanization

20 January 2009 Flash Flood in Brunei

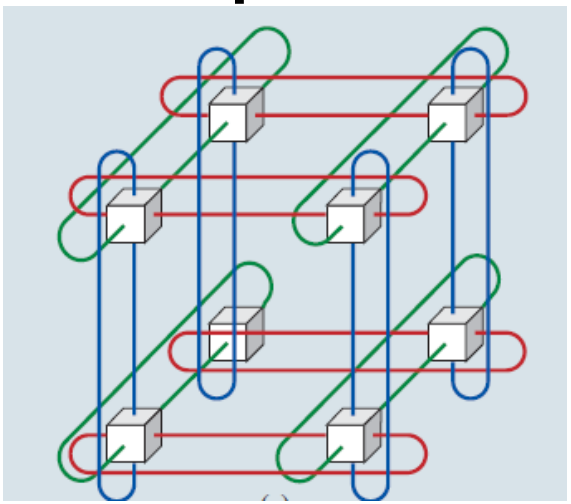
- Heavy rainfall for 4 to 5 hours with a record 145.8mm in 24 hours.
- Widespread disruption of electric distribution, transportation and communications systems

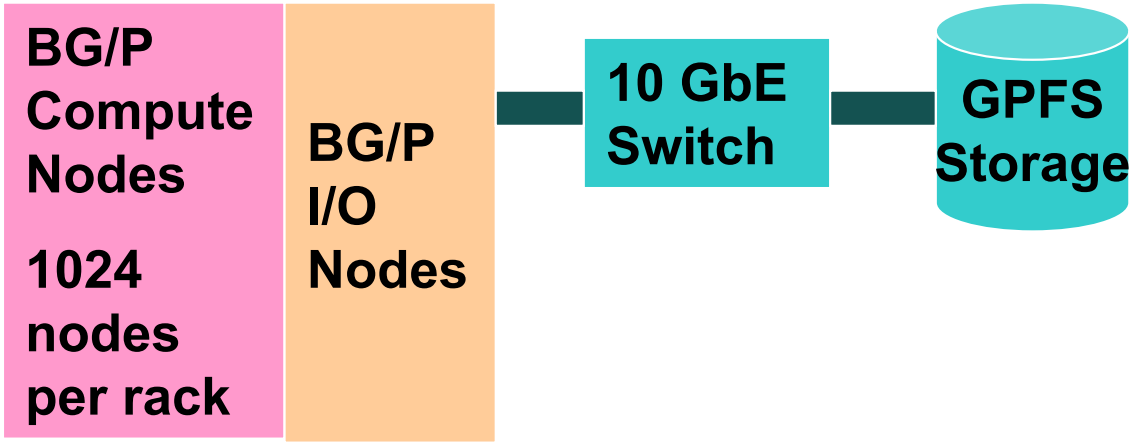
Approach

- Create a core NWP-based forecasting system focused on Brunei
  - End-to-end process (user to meteorology) tailored to business needs, leveraging "Deep Thunder" work at IBM Research
  - Operational infrastructure and automation with focus on HPC, visualization, and system and user integration
  - 48-hour forecasts at high resolution
  - Foundation for coupled business applications (analytics and visualization) with actual end users to address usability and effectiveness and for atmospheric and computational research
- Retrospective analysis of key, historical events
  - Many numerical experiments to enable effective model configuration for research and operations, addressing computational and physics issues as well as verifiable hindcasts

Computing Platform for Brunei – IBM Blue Gene/P

- Each rack of Blue Gene/P has 1024 compute nodes (13.9 TF peak)
  - Each compute node has four PowerPC 450 cores @ 0.85 GHz containing 2GB memory
  - Up to 16 I/O nodes for file I/O per rack
- Compute nodes connected through a 3d torus network for point-to-point messaging at 435 MB/s per link





- Operational forecasting and research/development (weather, coupled weather-flood, weather-wind models, etc.)

Simplified *Deep Thunder* Processing Data Flow for Brunei

NOAA (NCEP)

- **Global Forecasting System**: T574L64, 8 days
- Ensemble model, 4x/day, various products and resolutions
- Spectral, spherical solution

Observations

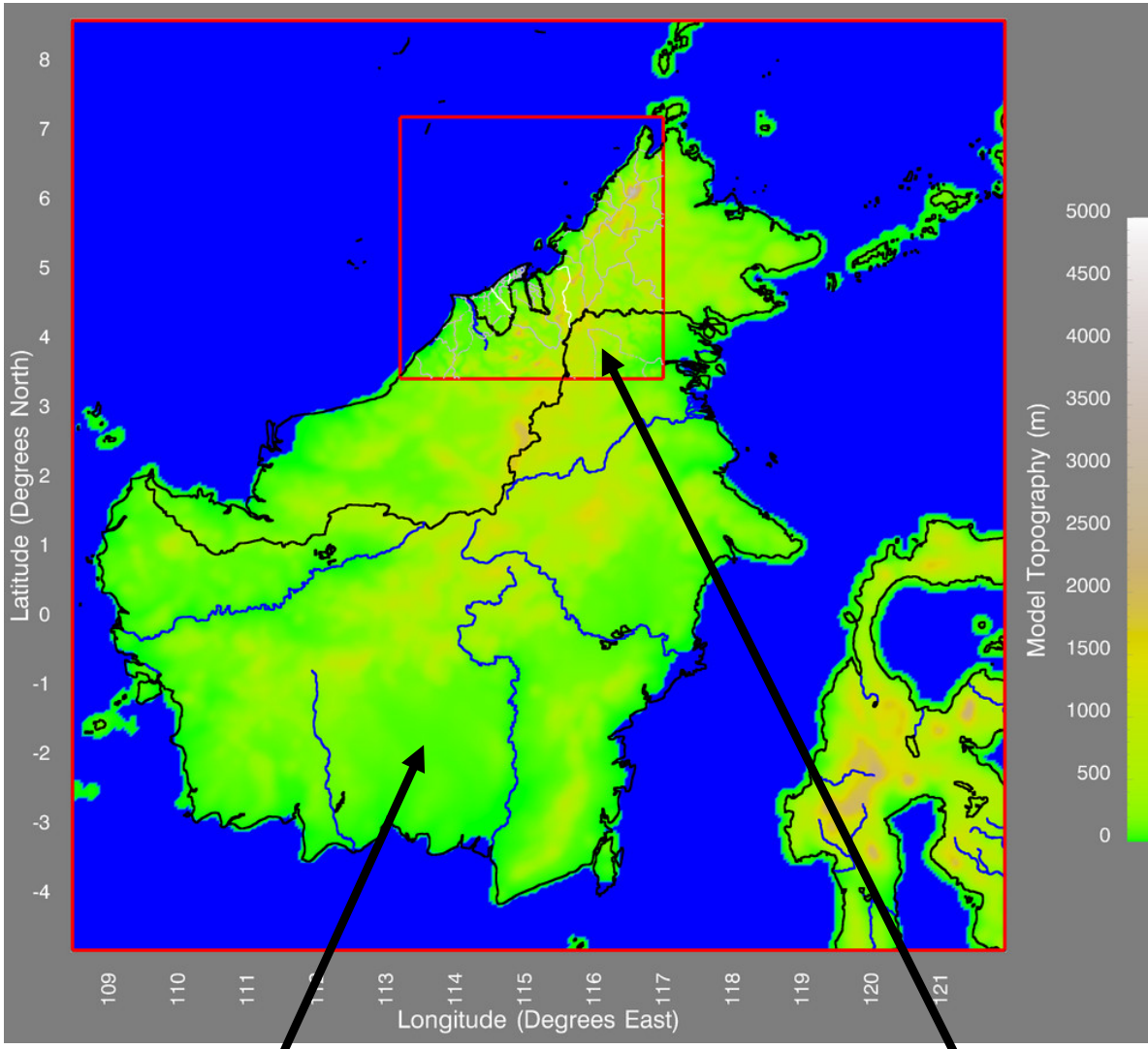
Surface Observations and Local Radar

Data Used to Generate

- Boundary conditions
- Initial conditions
- Forecast verification
- Calibration of model and observations

Weather Model Configuration

- **WRF-ARW Community Model (v3.2.1)**
  - Three 2-way nests at 13.5, 4.5 and 1.5 km horizontal resolution focused on Brunei
  - 45 vertical levels with ~10 in the planetary boundary layer to ensure capturing of orographic effects
  - 48 hour runs once daily (initialized at 0 UTC)
  - NOAA GFS for background and lateral boundary conditions
  - SRTM-based model orography
  - 1/12-degree SSTs
  - Thompson double-moment 6-class microphysics, RRTM long wave radiation, GSFC short wave radiation, YSU PBL, NOAH LSM, Kain-Fritsch cumulus



Innermost Two Nests with Model Orography

20 January 2009 Flash Flood in Brunei

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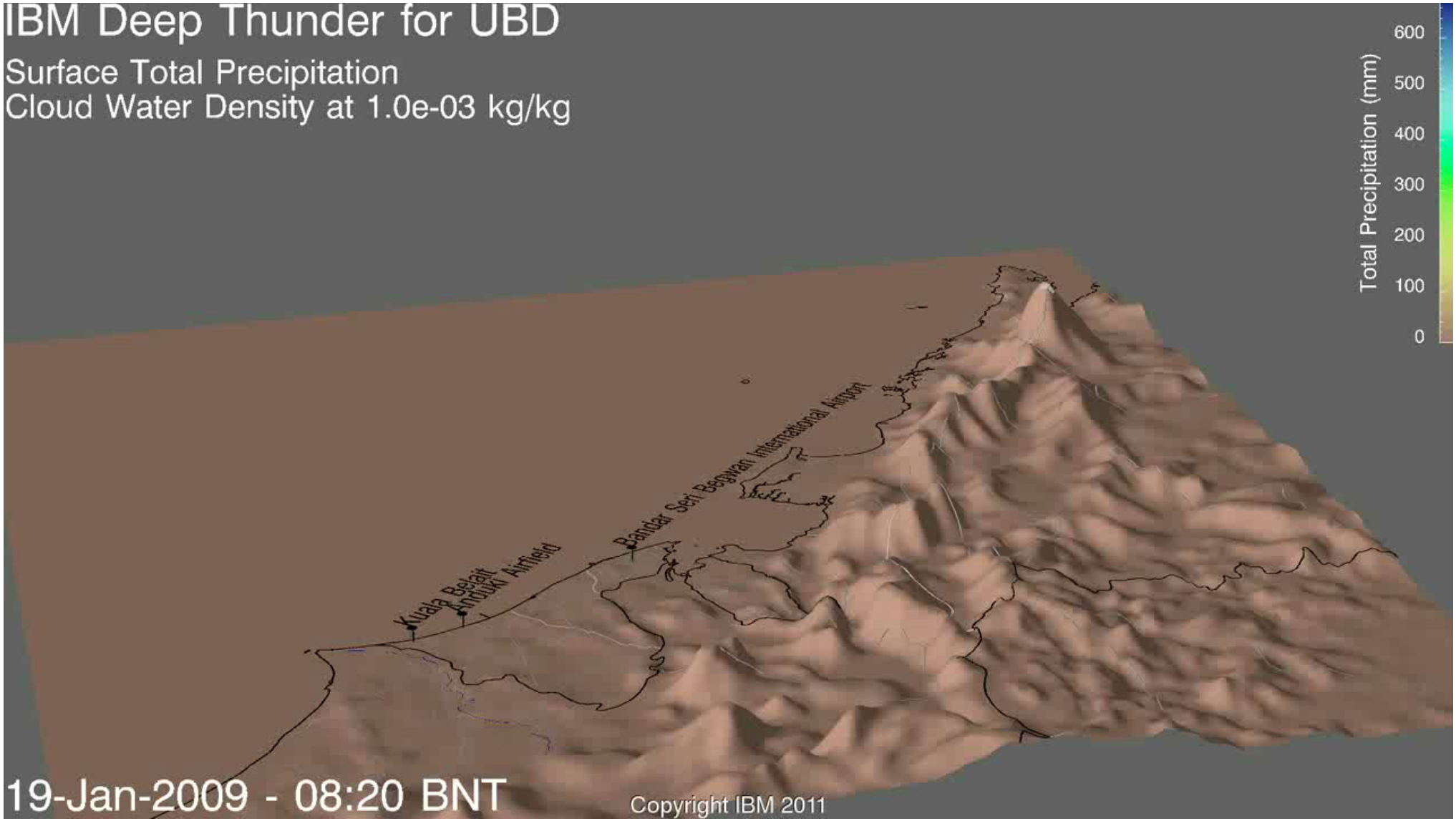
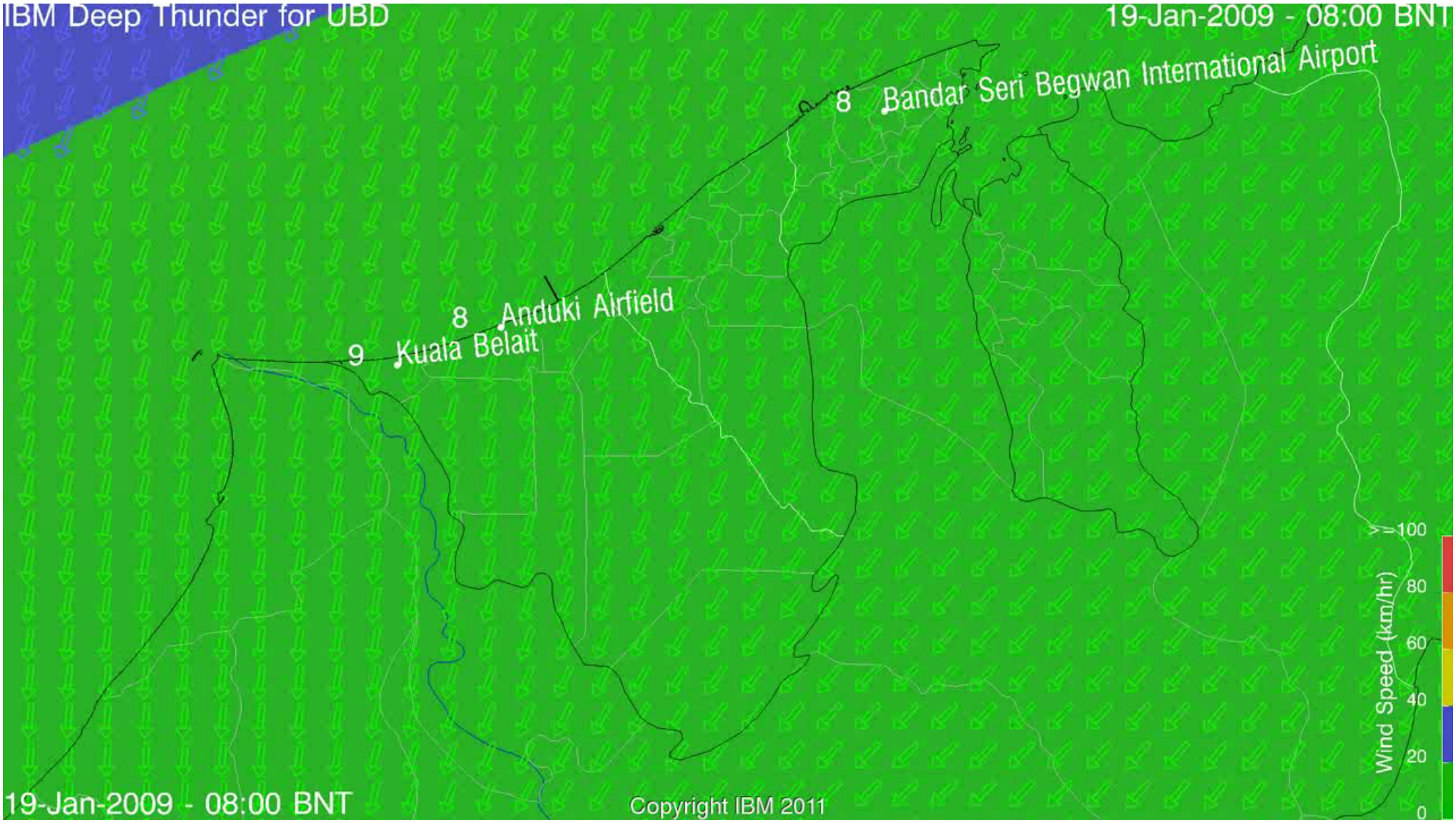
Hindcast of the Severe Rainfall Event of 20 Jan 2009 at 1.5 km Resolution



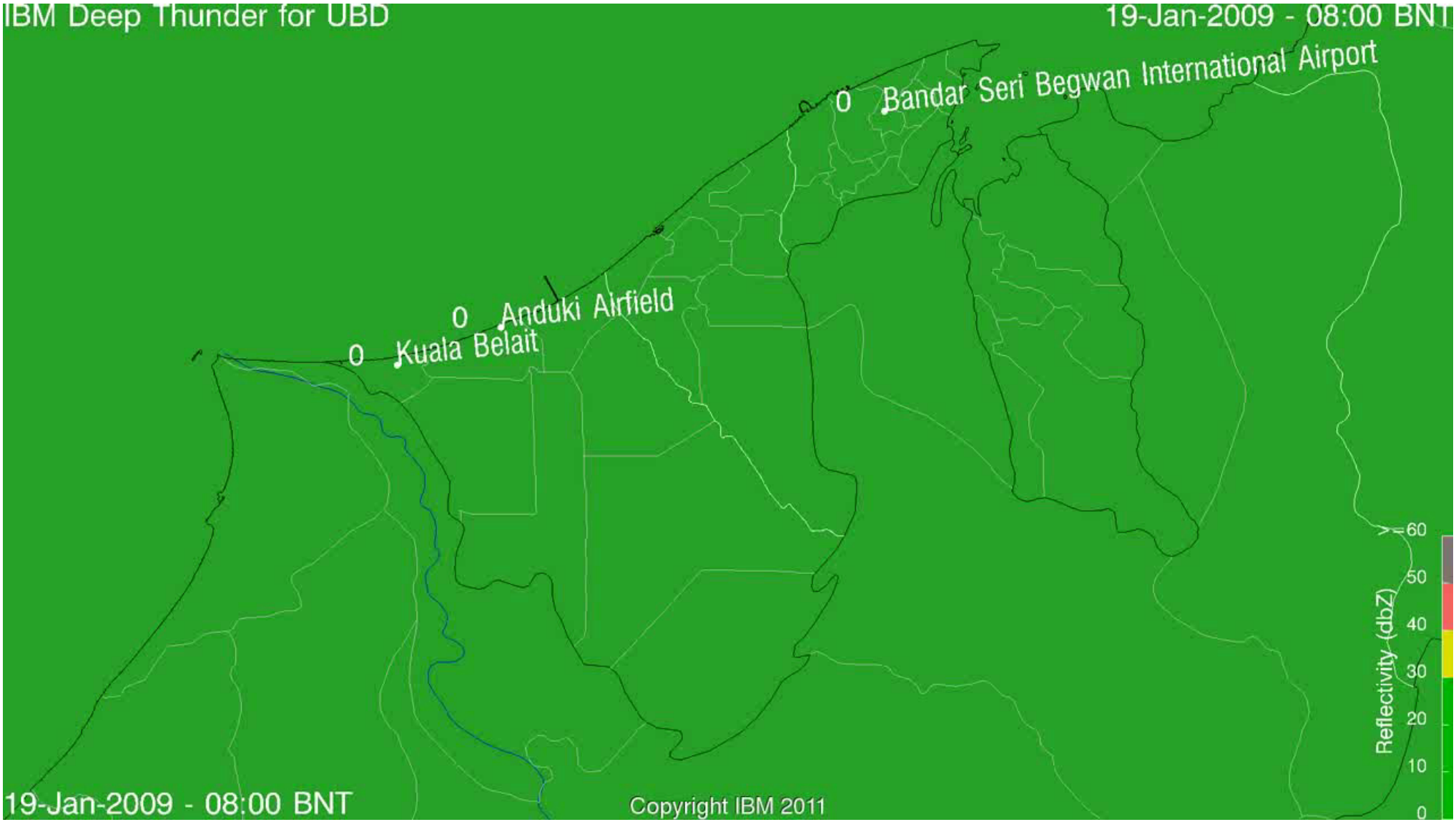
Animation of three-dimensional forecasted clouds with terrain surface and precipitation

Hindcast of the Severe Rainfall Event of 20 Jan 2009 at 1.5 km Resolution



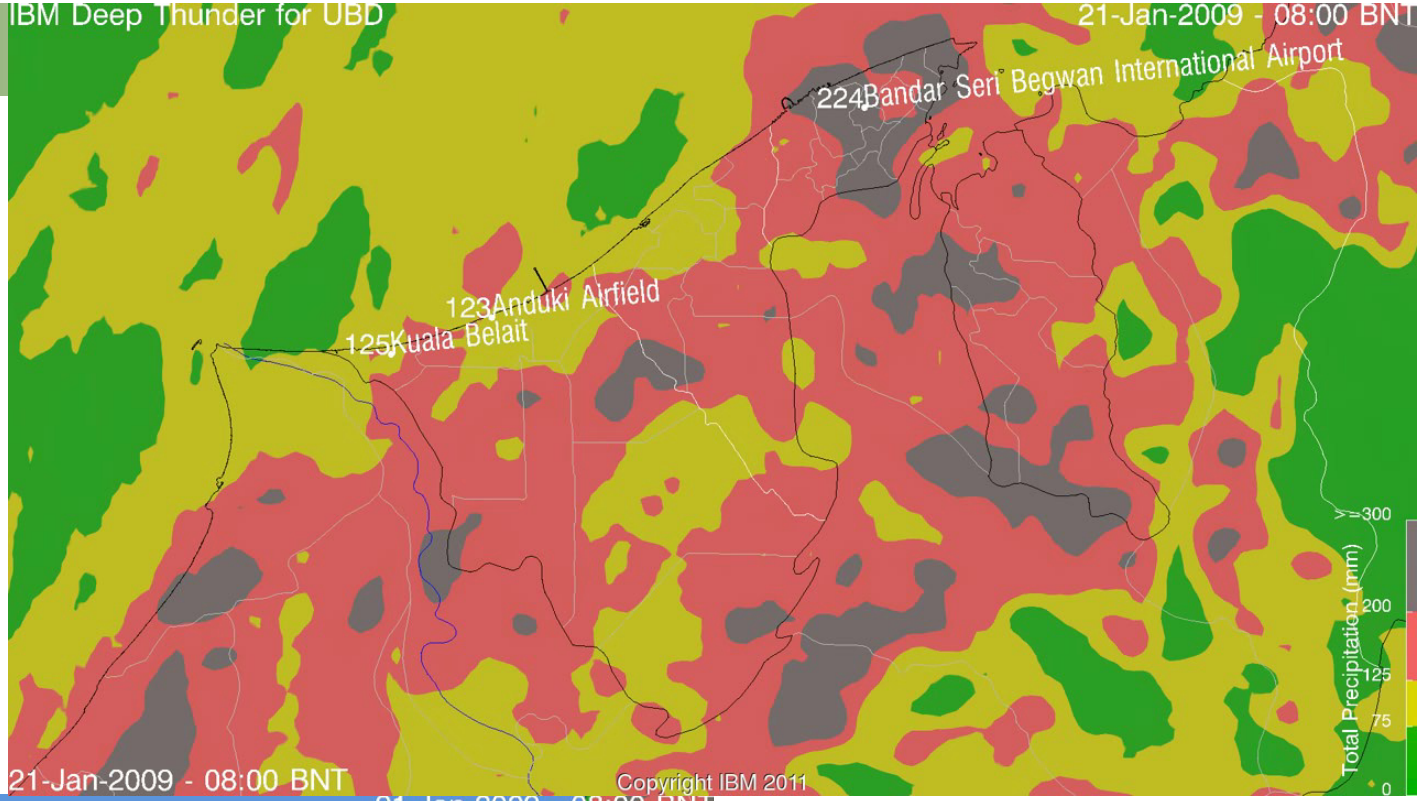
Animation of forecasted winds

Hindcast of the Severe Rainfall Event of 20 Jan 2009 at 1.5 km Resolution

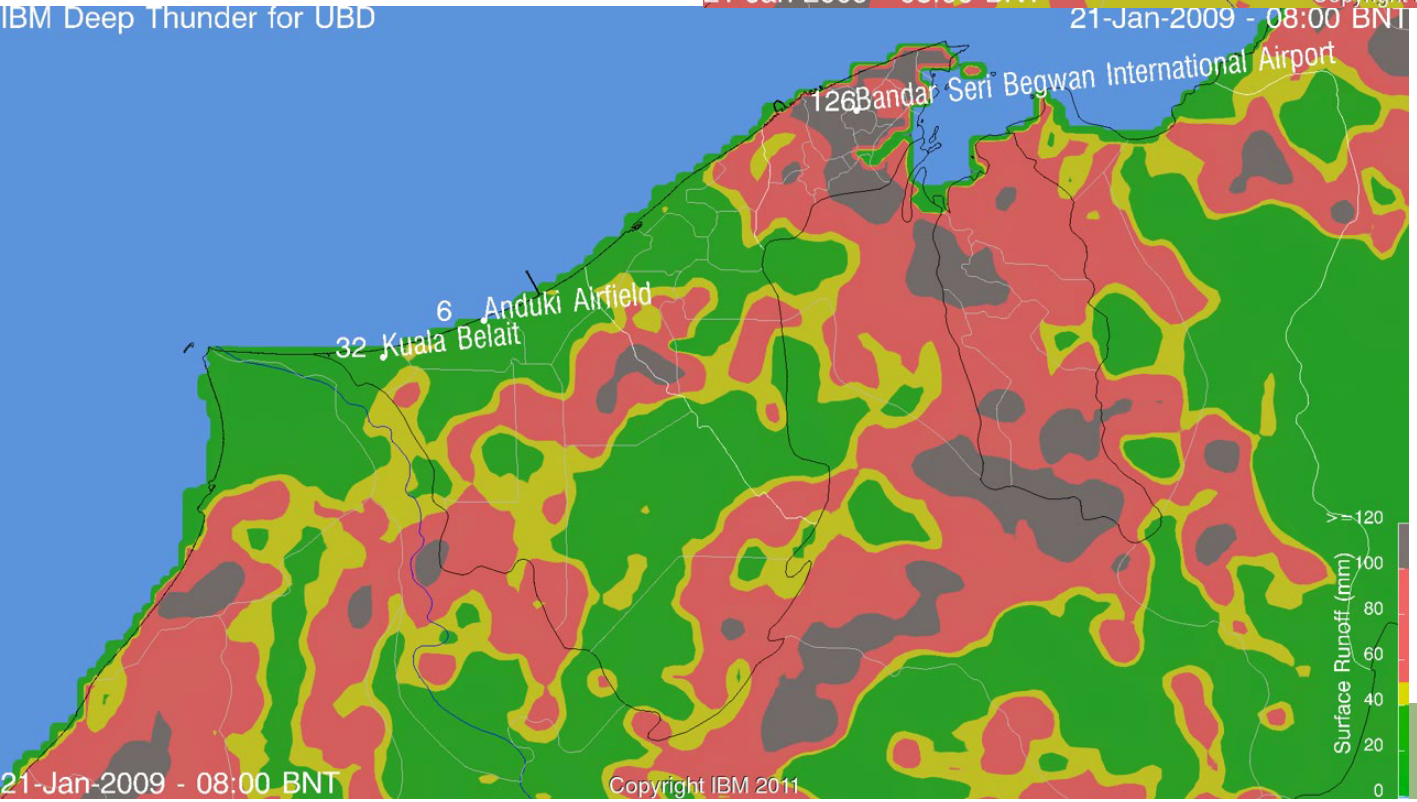


Animation of storm intensity

Hindcast of the Severe Rainfall Event of 20 Jan 2009 at 1.5 km Resolution

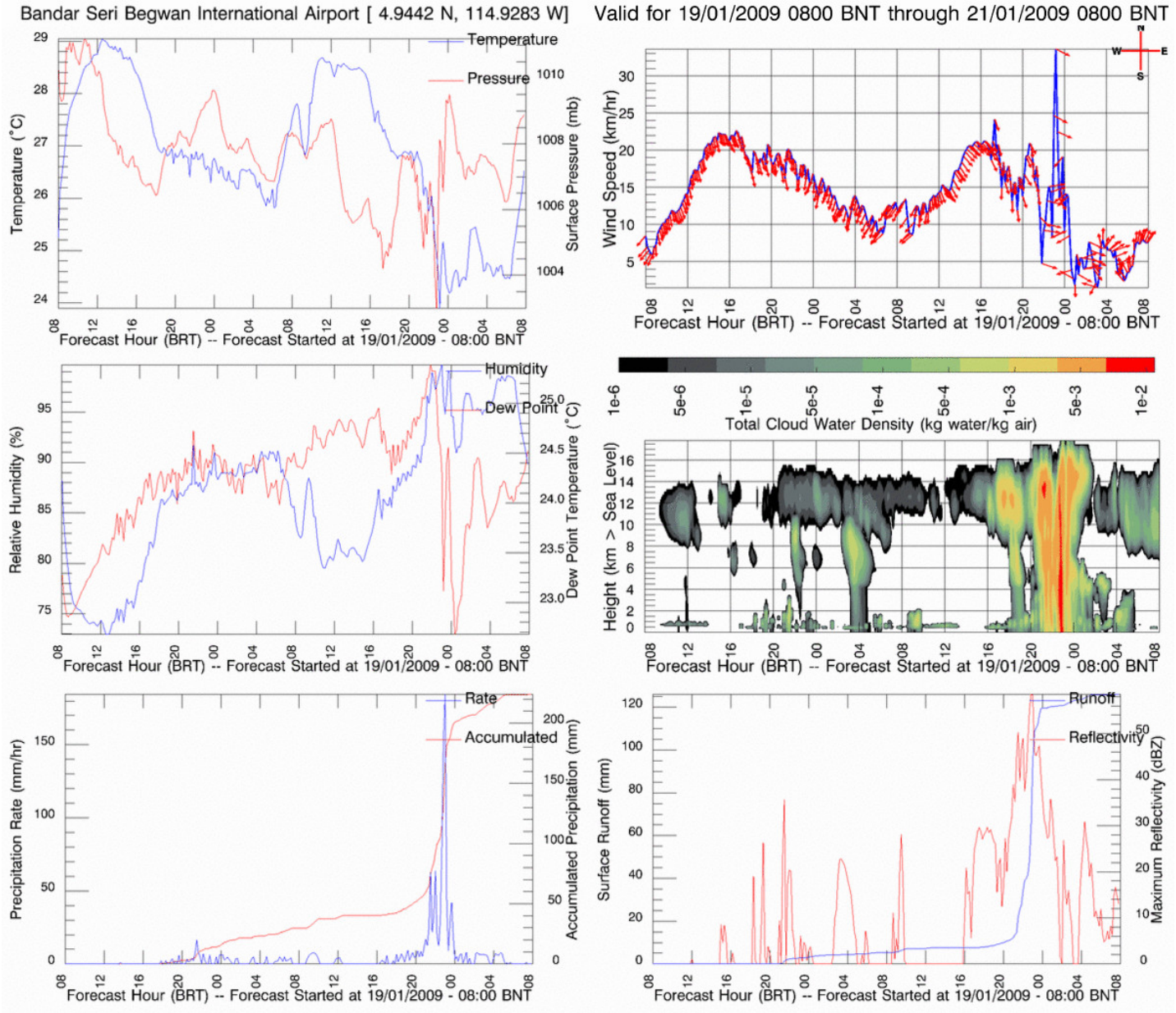


Rainfall Totals



Runoff Totals

Hindcast of the Severe Rainfall Event of 20 Jan 2009 at 1.5 km Resolution



Site-specific forecast at the location of a weather station

Project Status and Future Work

- **R&D enabled regular high-resolution weather modelling starting in October 2011**
  - Retrospective analysis of key events
  - Basic model configuration defined
  - 48-hour forecast generating daily (initialized at 00 UTC) on the Blue Gene/P at UBD
- **On-going R&D**
  - Refining weather model
  - Exploring availability of data for model input and verification
  - Coupling of weather and hydrology model
  - Modelling of tropical phenomena that involves scale interaction
  - Simulation and understanding of monsoon-driven convection
- **R&D to enable direct flood prediction, driven by the meteorology**
  - Enabling an hydrology model, coupled to the meteorology for direct flood prediction, leveraging work done in Rio de Janeiro and New York City, and high-resolution surface data from the Brunei government

Backup Slides

Climatological Characteristics of Brunei

- **RAINFALL: High with average 2800mm observed (range: 2300 – 4000 mm)**
  - Higher rainfall in the interior region due to geographic effect (higher altitude)
  - Two well-known monsoons in the southeast Asia: Northeast (Dec-Mar,rainfall peaks in January, heavy intense rain events), Southwest (June-Oct, relatively less intense, continuous rainy season)
  - Rains are mostly in the form of thunderstorms with high intensity and localized distribution along the ITCZ (Inter Tropical Convective Zone) originating from localized small scale convection cells
- **AIR TEMPERATURE: Mostly uniform with very little seasonal variation (mean 27.5 C) while increased cloudiness in Dec-Jan results in slight decrease in temperature whereas the peaks are found in so called dry months (Mar-Apr) and elevated interior is cooler**
- **RELATIVE HUMIDITY and EVAPORATION: Very high humidity throughout the year with average of 92.6 % (Range: 89%-95%) and evaporation depending on wind, air temperature and relative humidity (maximum in dry months Mar-Apr)**
- **WINDS : Usually low winds with exception of squalls during the thunderstorm. Most common is 4-8 m/s. Wind direction is north to northeasterly during Nov-Mar and south to southwesterly during Apr–Oct**
- **FLOODING: There are three main classifications**
  - River Flood plain : Flood flows exceeds capacity of the river channels.
  - Tidal flooding : Occurs during Nov-Jan during extreme / high tides with the worst combination when high tides coincide with surges due to storm and wind conditions
  - Local floods are as a result of obstruction to channel

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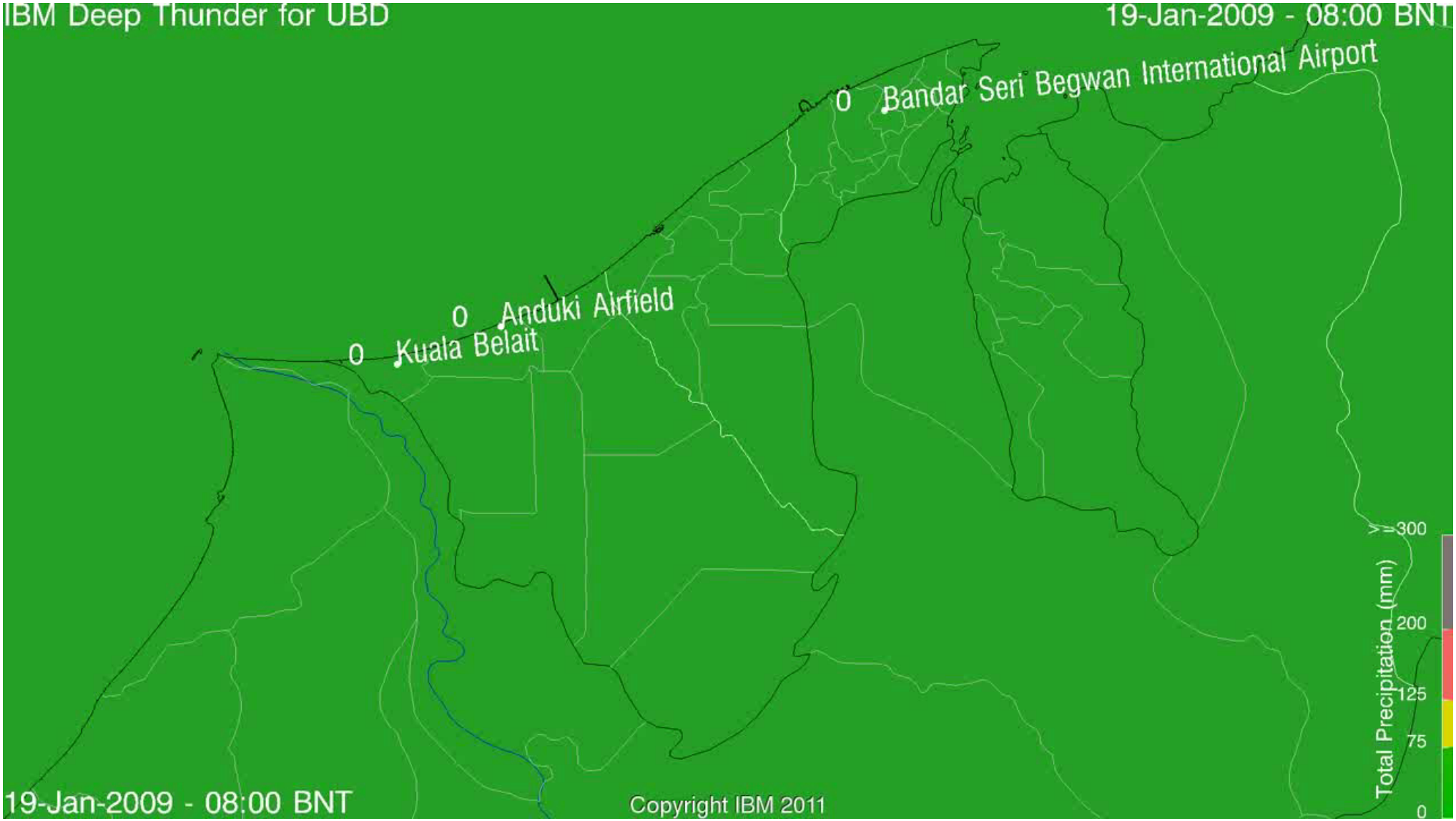

Animation of forecasted precipitation

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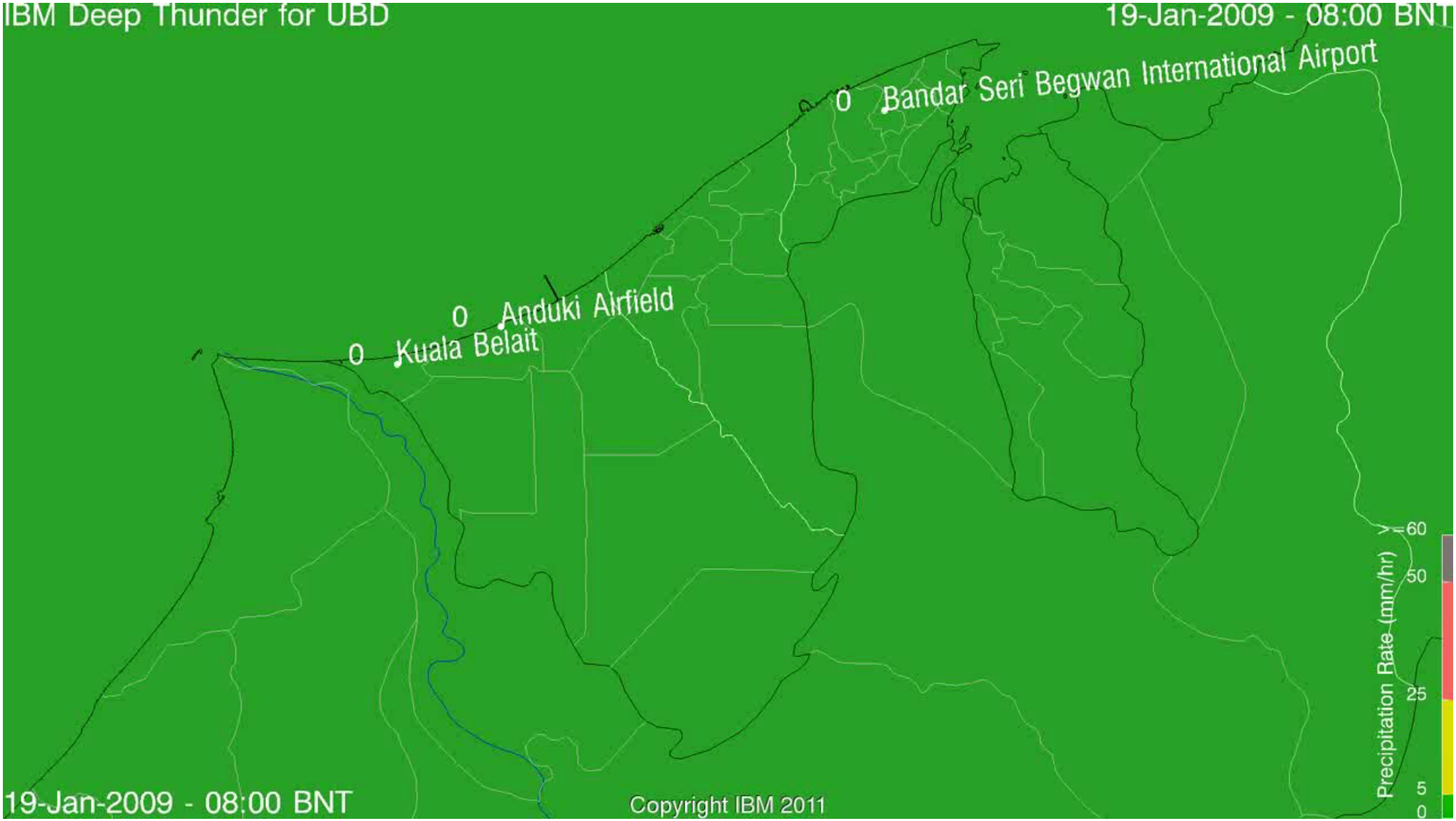
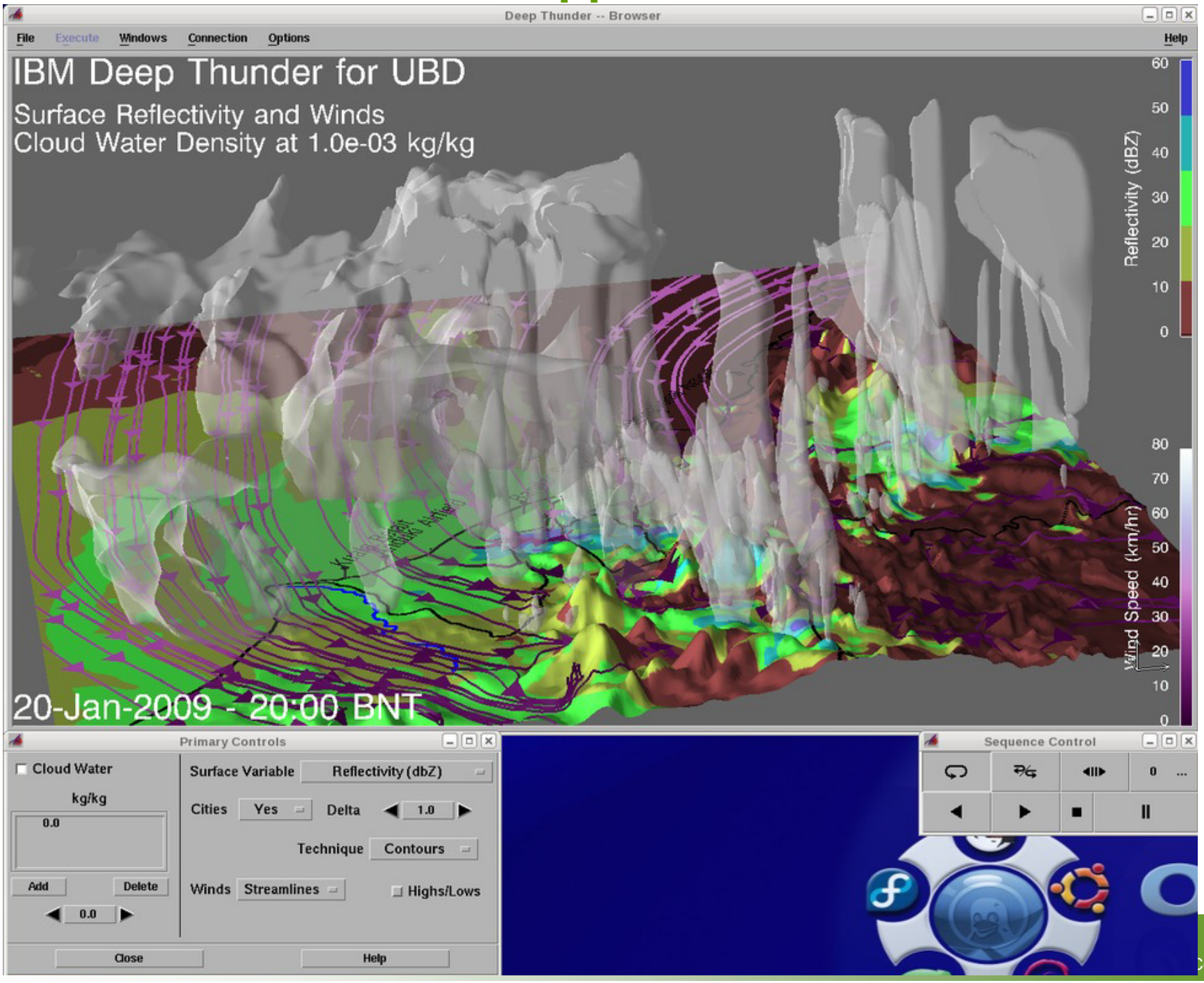


Animation of forecasted precipitation rate

Interactive 3d Visualization Application



Interactive 3d Visualization Application