ENRI's R&D Topics on Space Weather, Extreme Weather and Evaluation Study of Weather Impacts on ATM near Airport

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Introduction

Earth's atmosphere and aviation impacts

- Ionosphere
  - Propagation delay in GNSS (Global Navigation Satellite System) signals
  - Effects on Integrity and availability of GNSS-based air navigation system

  => Mitigation of ionospheric impacts using space weather information
- Extreme and local weather condition around airport
  - Severe weather: reduction of airport capacity
  - Detailed local weather information: requirement of a new operation to reduce aircraft separation to avoid wake vortex

  => Reliable weather prediction information within a time scale of an hour
- ENRI's R&D topics
  - Space weather concept especially for the low latitude region
  - Air traffic flow around a congested airport under severe weather
  - Airport-based Lidar system for avoidance of wake vortex
  - Evaluation study of weather impacts on ATM near airport

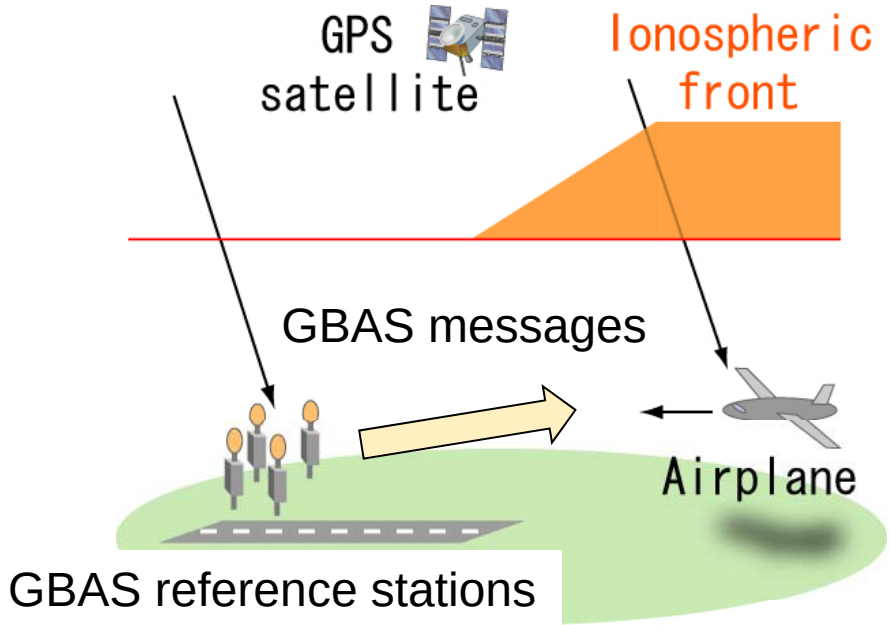
Space weather
GNSS-based air navigation system

- Expected to support accurate and efficient 4-dimensional trajectory from gate-to-gate
- Very high requirements are defined by ICAO
  - Accuracy, integrity, continuity, and availability
- Augmentation systems are required
  - SBAS (Satellite-based Augmentation System)
  - GBAS (Ground-based Augmentation System)
  - ABAS (Aircraft-based Augmentation System)
- Currently only L1 frequency signal can be used for air navigation

Space weather

Ionospheric effects on GNSS-based navigation

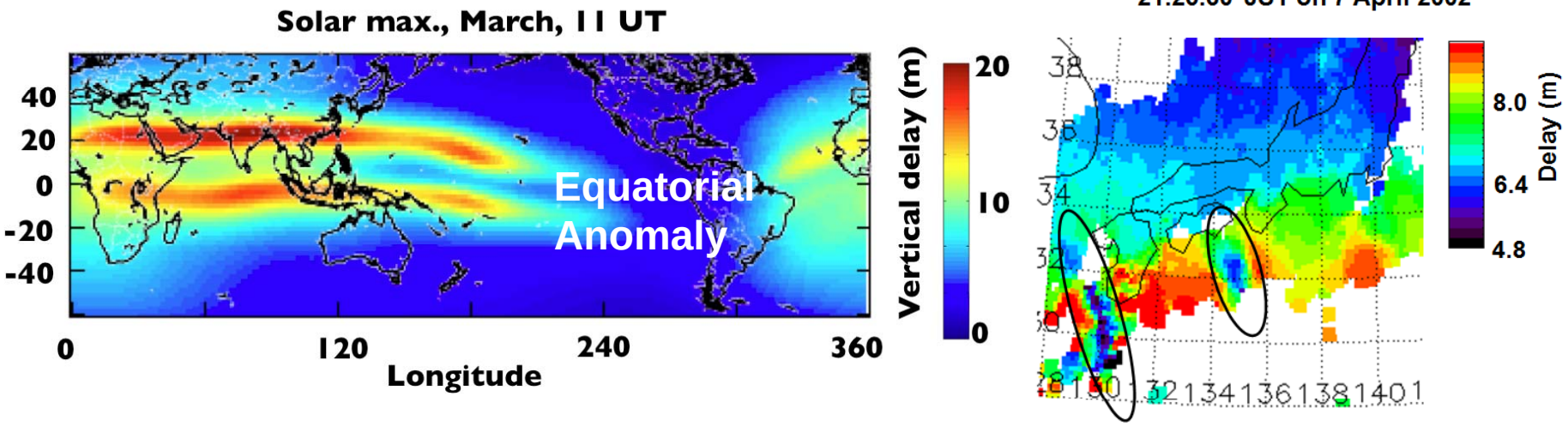
- Spatial decorrelation of ionospheric delay: A major error source and risk for GBAS and SBAS which are based on differential GNSS technique
- Number of available satellites: An important factor related to availability against ionosphheric disturbances



Space weather

Ionospheric effects on GNSS-based navigation

- Plasma bubble in the low magnetic latitude region
  - Frequently occurred at nighttime in spring and autumn depending on solar activity with a period of about 11 years
  - Large spatial gradient in ionospheric delay
  - Reduction of number of available satellite due to Scintillation
  - Structure: several thousand km in longitudinal (North-South) direction



Plasma bubble

Space weather
ENRI's R&D activities

- Development of ionospheric threat mitigation algorithm for GNSS-based air navigation
  - Utilize space weather information
    - Not limited to self-contained systems
    - Integrity consideration
  - Five-year program from April 2015 to March 2020
  - Concept of space weather utilization suitable for the low magnetic latitude region
  - Ionospheric anomaly mitigation technique for GNSS with space weather information
  - Feed back to ICAO Space Weather ConOps
- Supporting Ionospheric Studies Task Force (ISTF)
  - Established in the ICAO Asia-Pacific Region in 2012
  - Ionospheric data collection and sharing
  - Regional ionospheric threat models for GBAS and SBAS

Extreme weather

Air traffic flow around a congested airport

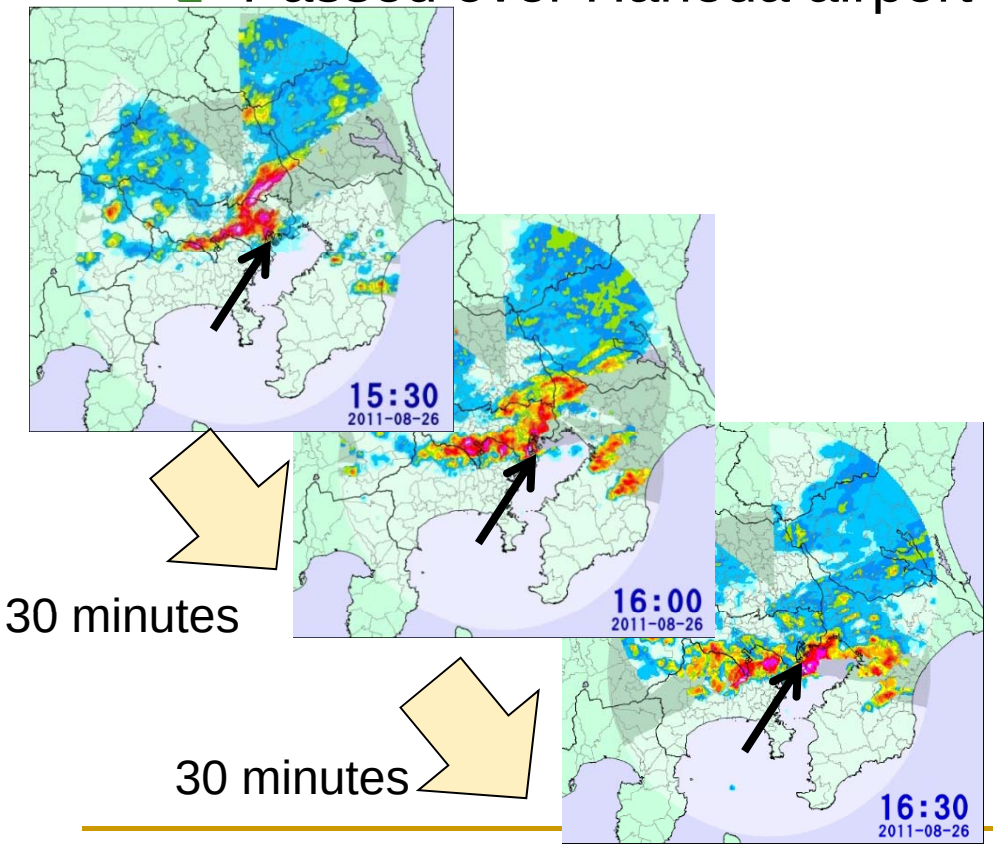
- Severe weather near airports
  - Worse conditions for departure and arrival aircrafts
    - Low visibility due to heavy rain
    - Wind shear, lightning, etc.
  - Abrupt changes in local wind
- Impacts on air traffic flow
  - Reduction of airport capacity
    - Avoidances from storm cells
    - Runway closure / Go-around due to low visibility
  - Runway switches due to a local wind direction change
- Clarification of requirements
  - Future monitoring system
  - Forecast information with suitable leading time and reliability to arrange air traffic flow

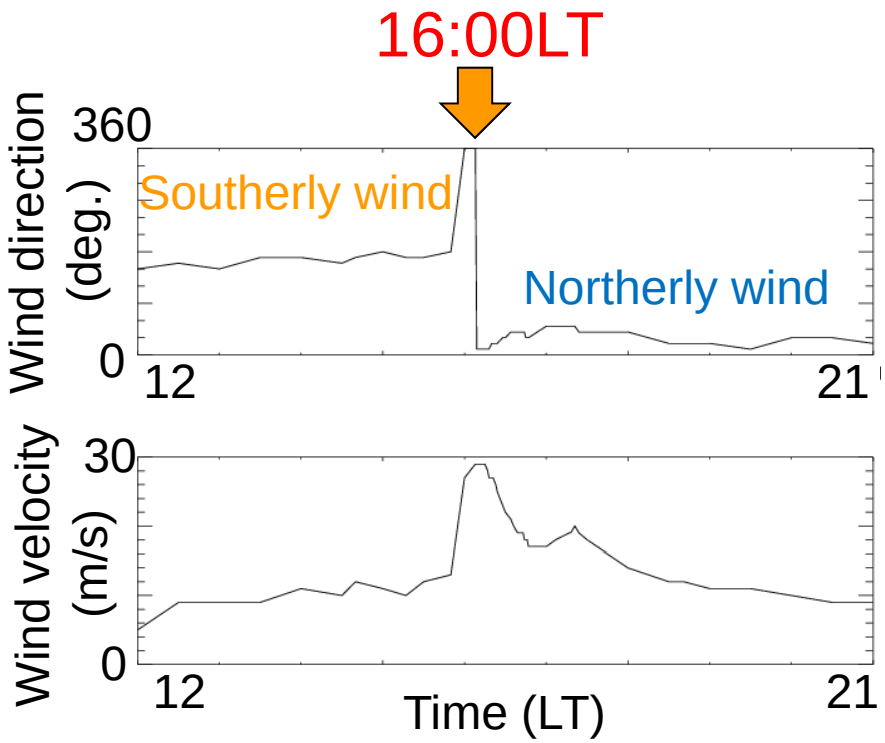
Extreme weather
Investigation of Air traffic flow

- Haneda airport
  - Tokyo metropolitan area
  - The current arrival and departure slot of 447,000 per year
- XRAIN
  - A network of multi parameter radars (X-band) over Japan
  - Operated to observe rainfall by MLIT (Ministry of Land, Infrastructure, Transport and Tourism)
- ENRI's Secondary Surveillance Radar (SSR) mode S
  - Aircraft trajectories
  - Located 25 km away from Haneda airport
  - DAPs (Downlink Aircraft Parameters) data
- Comparison
  - Severe weather area from XRAIN
  - Air traffic trajectories from ENRI's SSR

Extreme weather
An example case on Aug. 26, 2011

- Heavy rainfall in Tokyo metropolitan area
  - Passed over Haneda airport around 16:00LT



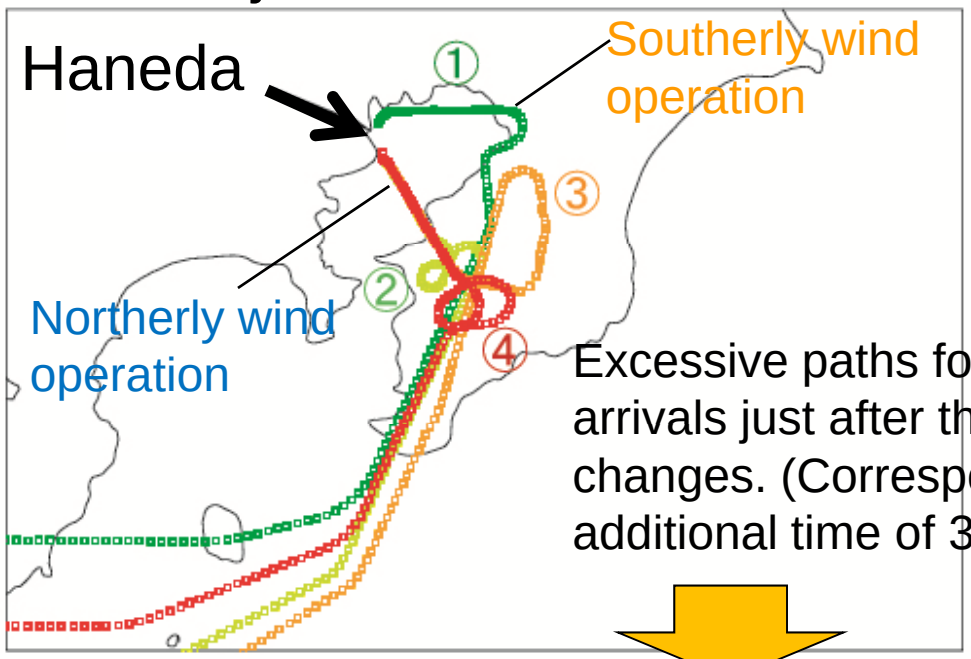


XRAIN data base : http://www.mpsep.jp/MPradardata/mpradar.html (Read on March 1, 2015)

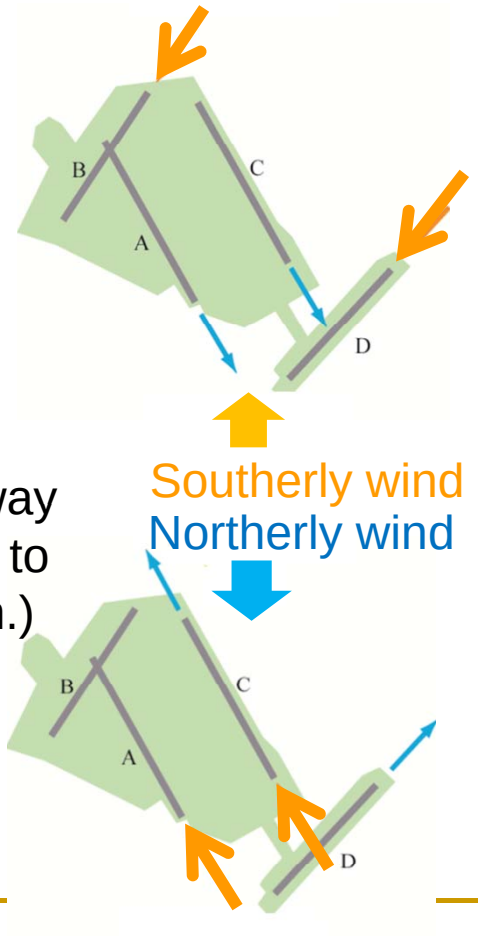
Extreme weather
Impact on runway changes

Runway changes: 30 minutes earlier than actual time of a wind dir. change

Trajectories of Arrivals



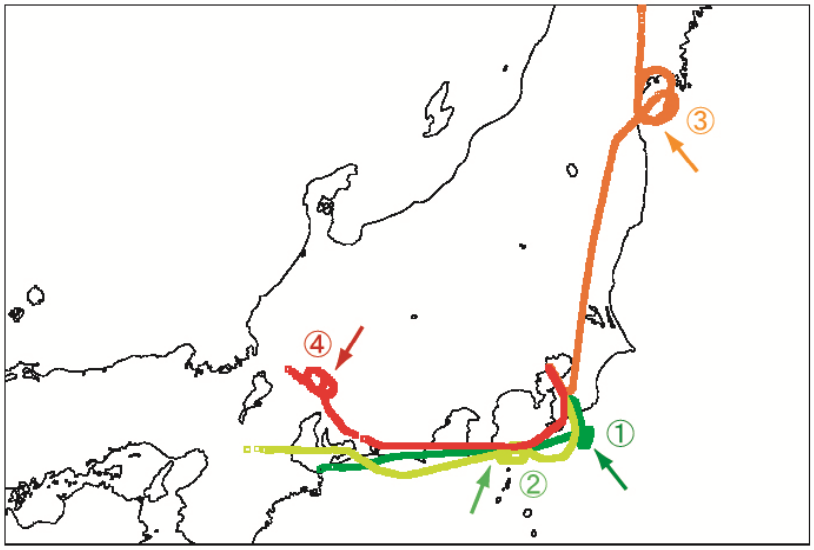
Excessive paths for three arrivals just after the runway changes. (Corresponding to additional time of 3~9 min.)

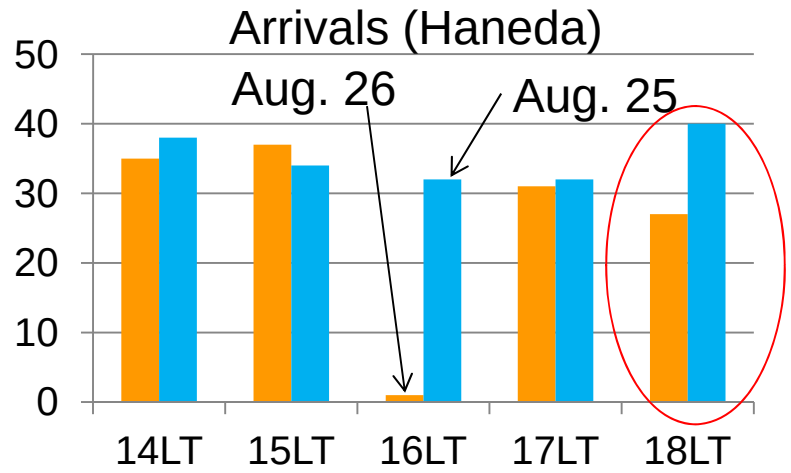


More reliable wind prediction helps for minimizing the additional time by aircraft speed control on En-route

Extreme weather
Impacts on reduced airport capacity

Holding aircrafts

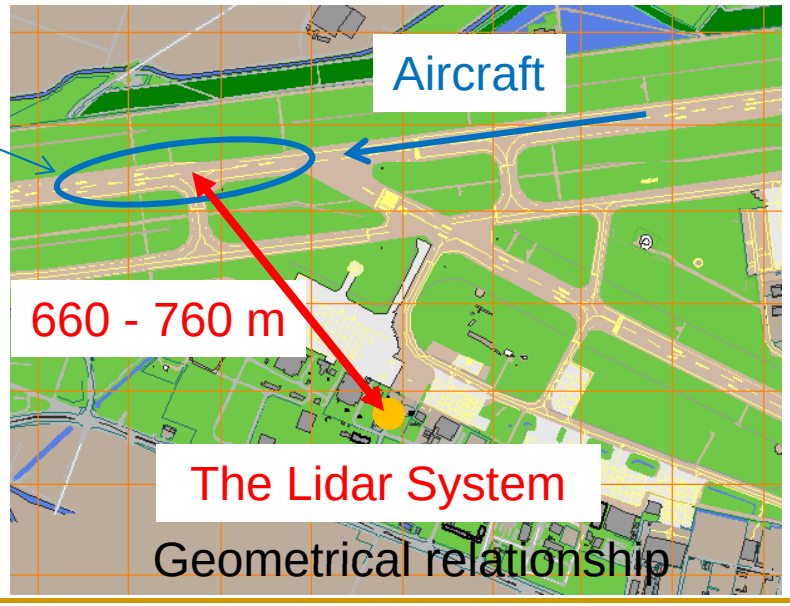




- Detailed analysis is being continued from various viewpoints
- Only one arrival at 16:00~17:00LT: Over 30 aircrafts were holding
- Almost of all arrivals at 17:00~18:00LT : Holding aircrafts
- Deviation in the number of arrivals at 18:00~19:00 suggests prediction of accurate recovering time from the stormy condition helps to reschedule flights for waiting aircrafts at departure airports

Local weather: Airport-based Lidar system for avoidance of wake vortex

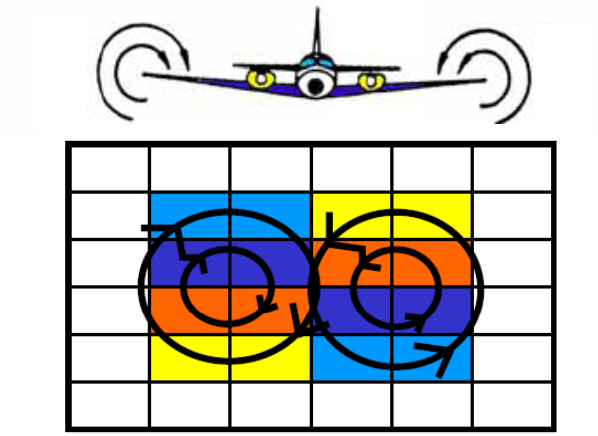
- A Lidar (Light Detection and Ranging) system was installed on a roof of a building bordered on Sendai airport
  - To detect and observe wake vortex including its temporal changes
- The first observation was performed in 2004
  - Feasibility study reducing separation for departure
- Data accumulation activities
  - In May 2012, Restarted in cooperation with Mitsubishi Electric Corp. after a blank of a few years



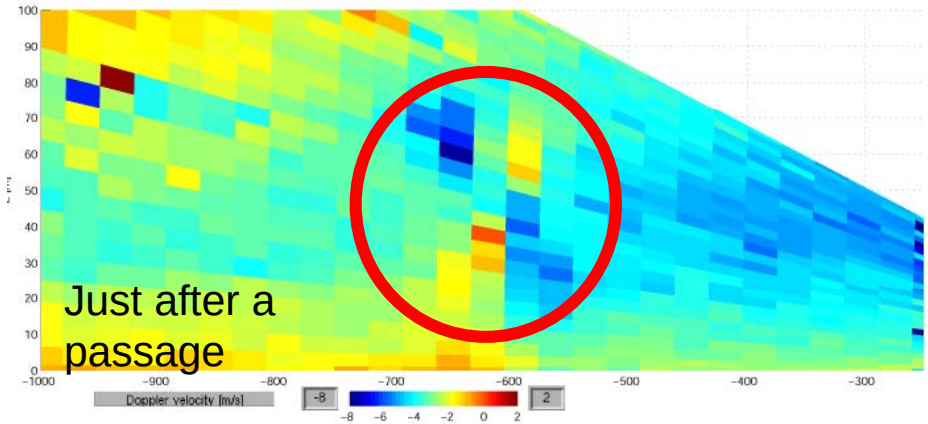
Geometrical relationship

Local weather: Airport-based Lidar system for avoidance of wake vortex

- A sample event of wake vortices caused by a departure of B747



A pattern of wake vortices



T. Komatsubara, et al., 2005

- A collaborative research to evaluate wake vortex effects on aircraft
  - Institute of Fluid Science (IFS) of Tohoku University
  - Japan Aerospace Exploration Agency (JAXA)
- Total of 620 cases for departures during April 2006 and May 2009
  - Examined relationship among residence time of wake vortices and meteorological conditions such as cross wind velocity (Kato et al., 2009)

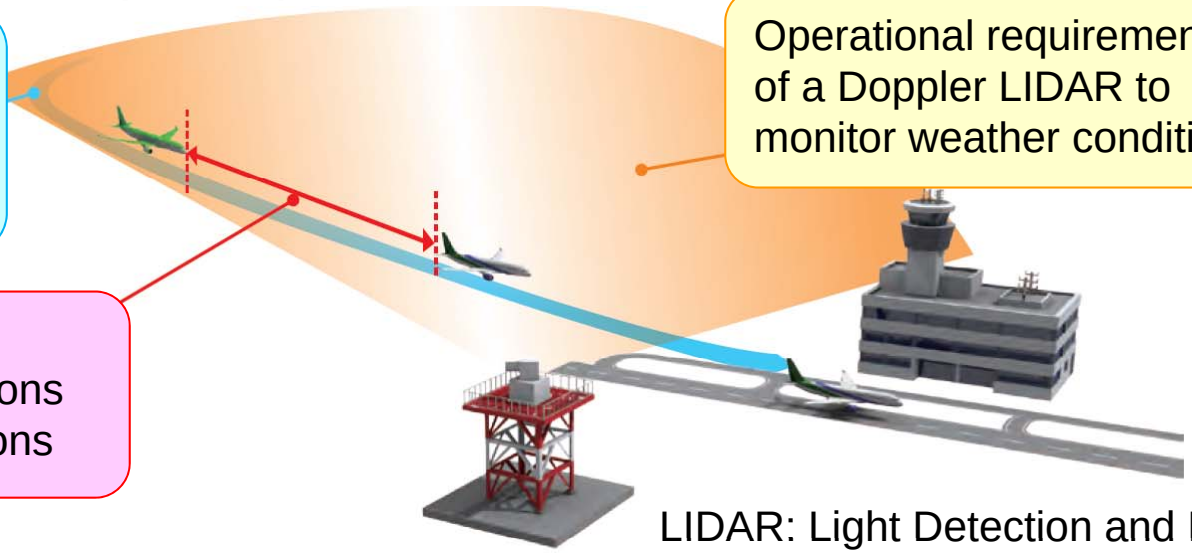
Evaluation study of weather impacts on ATM
A new research program

- Investigation of relationship between arrival aircraft separations and head wind conditions
- A more efficient flight path applicable only under its allowable weather condition
- Operational requirements of a Doppler LIDAR to monitor weather conditions for advanced flight procedures

=> Enhancement of airport capacity

Efficient flight procedures only under “allowable” weather conditions

Relationship between arrival aircraft separations and head wind conditions



Operational requirements of a Doppler LIDAR to monitor weather conditions

LIDAR: Light Detection and Ranging

Summary

- ENRI conducts R&D programs for space and extreme weather to support 4D-trajectory operation
  - GNSS-based seamless navigation services
  - Safety and efficiency under various meteorological conditions
- Scope for space weather
  - Mitigation technique of ionospheric effects on GNSS using space weather information
  - Space weather concept especially for the low magnetic latitude region
- Scope for extreme and local weather
  - Reliable prediction information within a time of an hour is important
  - Minimize impacts on air traffic flow around a congested airport under severe weather
  - Increase airport capacity by monitoring local weather condition by airport-based Lidar system for avoidance of wake vortex
- Evaluation study of weather impacts on ATM near airport
  - A new research program has started