Wake Encounter In-Situ Flight Tests in Cruise - Wake Characterization

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DLR Weather & Flying Final Colloquium
14th & 15th March, 2012

Overview

- DLR´s wake encounter flight test campaign in the W&F project (2011)
- Evaluation method & results
- Wake Characterization Sheet

Objectives of Wake Encounter Tests

(a) gathering in-situ flight test data behind different airliners in cruise

(b) determination of wake characterising parameters from encounter test data: *strength, descent, and lateral vortex spacing*

(c) validation of the flight dynamic model of a swept wing configuration for wake encounters

DLR Falcon D-CMET

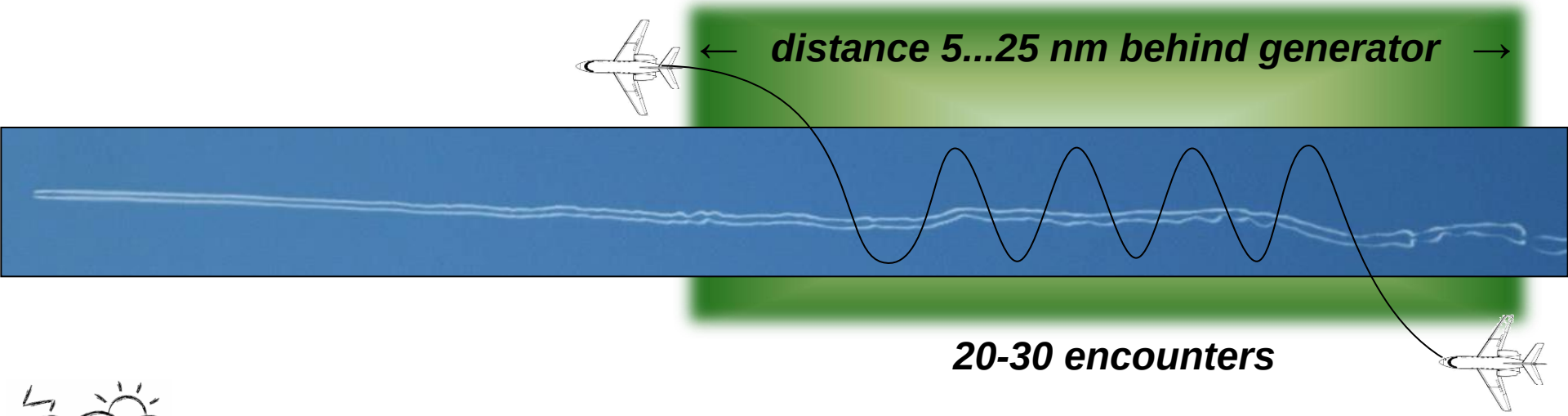
Cockpit view during flight test

Involved Partners

- **DLR Institute of Flight Systems (Braunschweig)**
- DLR Flight Test (Oberpfaffenhofen)
- Deutsche Flugsicherung DFS (Karlsruhe & Langen)
- DLR Institute for Atmospheric Physics (Oberpfaffenhofen)
- Messwerk (Braunschweig)
- Airlines
  - Lufthansa (DLH)
  - Scandinavian Airlines (SAS)
  - Austrian Airlines (AUA)
  - KLM Royal Dutch Airlines (KLM)
  - Wizz Air (WZZ)
  - Brussels Airlines (BEL)
  - Belavia Airlines (BRU)
  - Norwegian Air Shuttle (NAX)
  - Malev Hungarian Airlines (MAH)

Flight Test Task

„Fly
lateral wake encounters
behind cruising airliners,
as many as possible,
and close to the cores
of both vortices“



Falcon 20 D-CMET

Measurement Equipment for Wake Encounter Flights

GPS

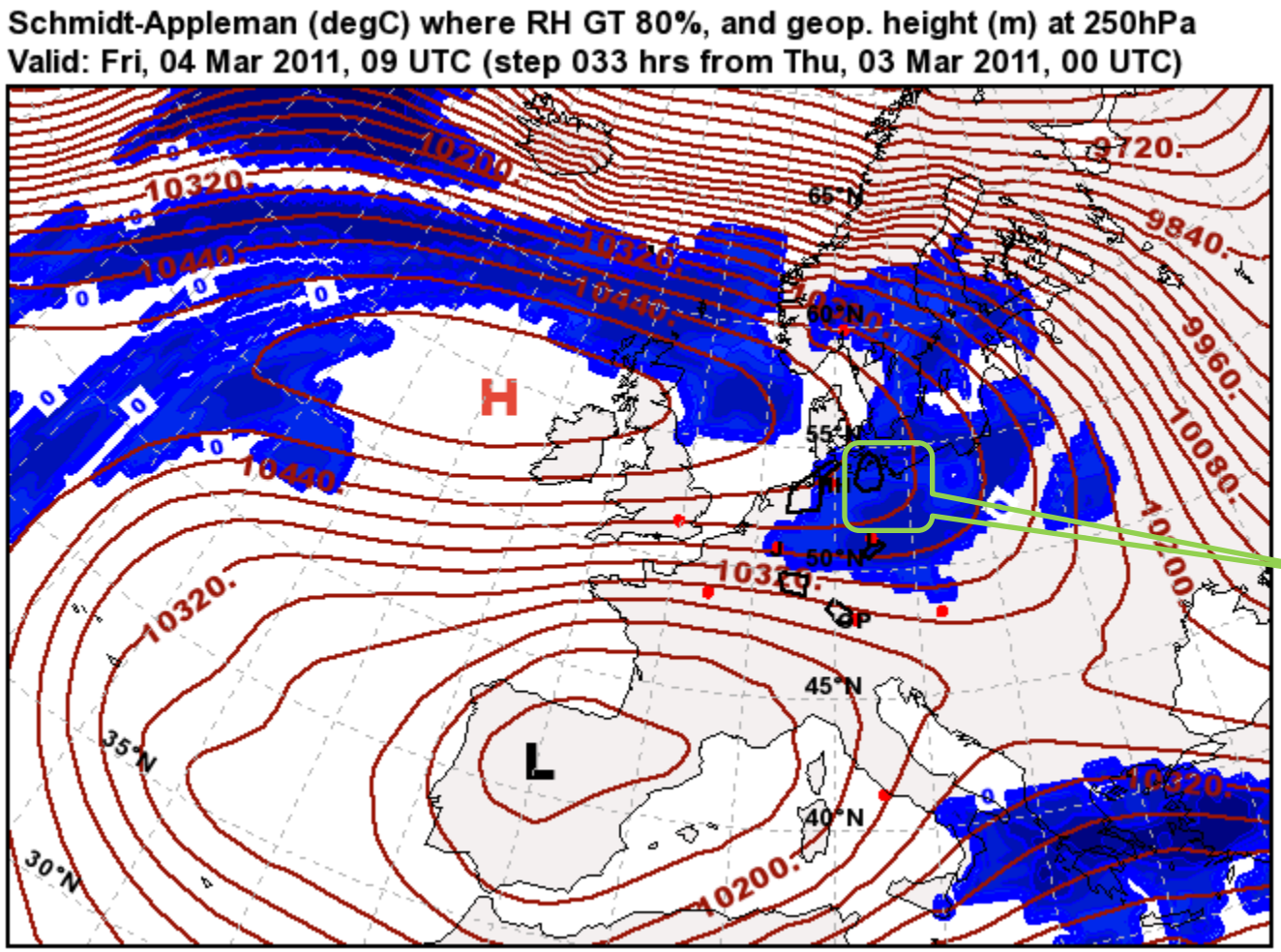
Pilot´s inputs:
- column
- wheel
- pedal

Flow direction:
- Alpha
- Beta

Air data:
- Static/dynamic pressure
- Temperature
- Mach number
- altitude, airspeed

Inertial reference system:
- linear accelerations
- rotational rates
- Euler angles

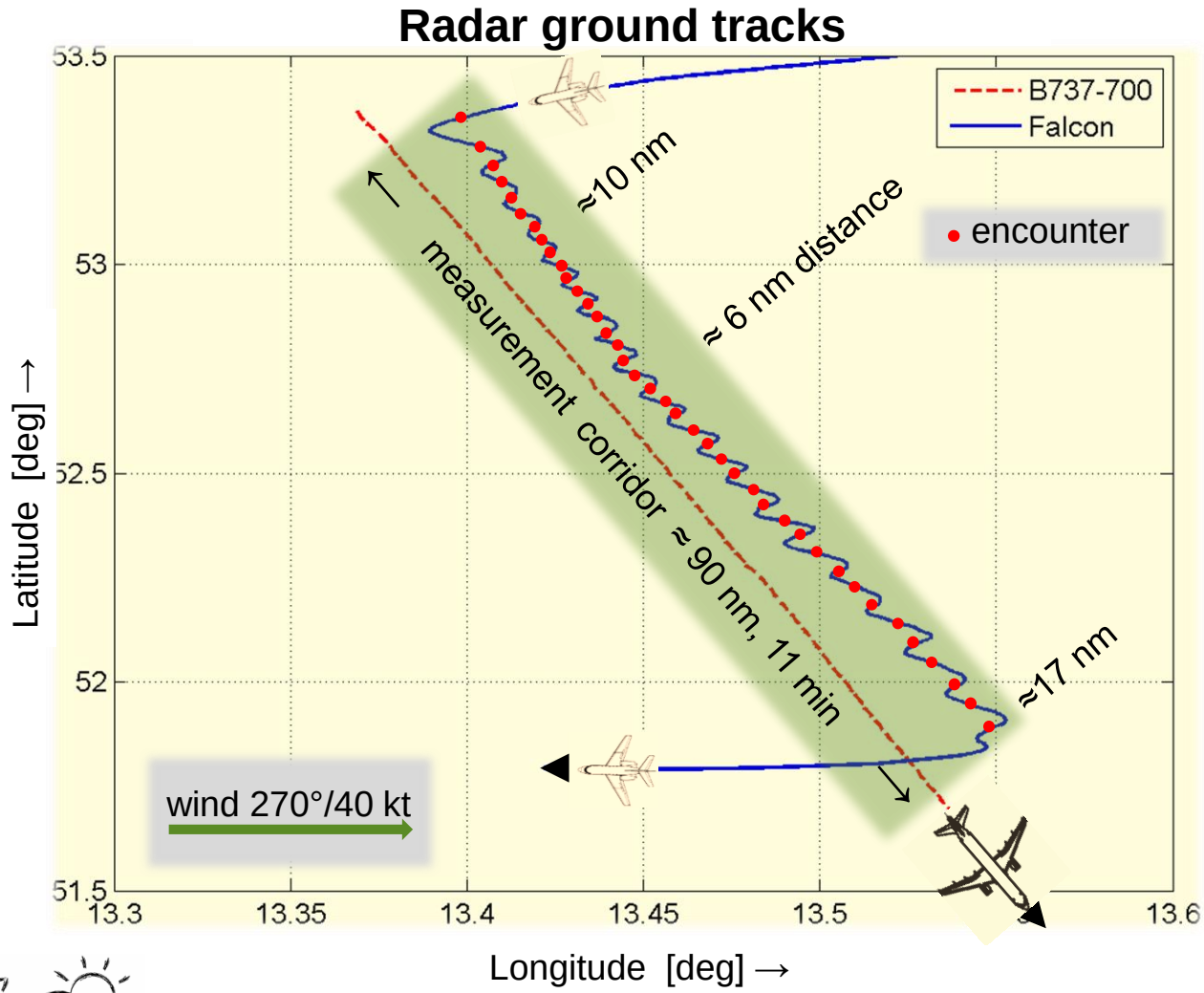
Contrail Forecast



250 hPa
FL340

flight test area

Wake Encounters Behind a B737-700



Airliner data

(transmitted once)

- aircraft type
- actual mass
- airspeed
- heading
- wind speed & direction

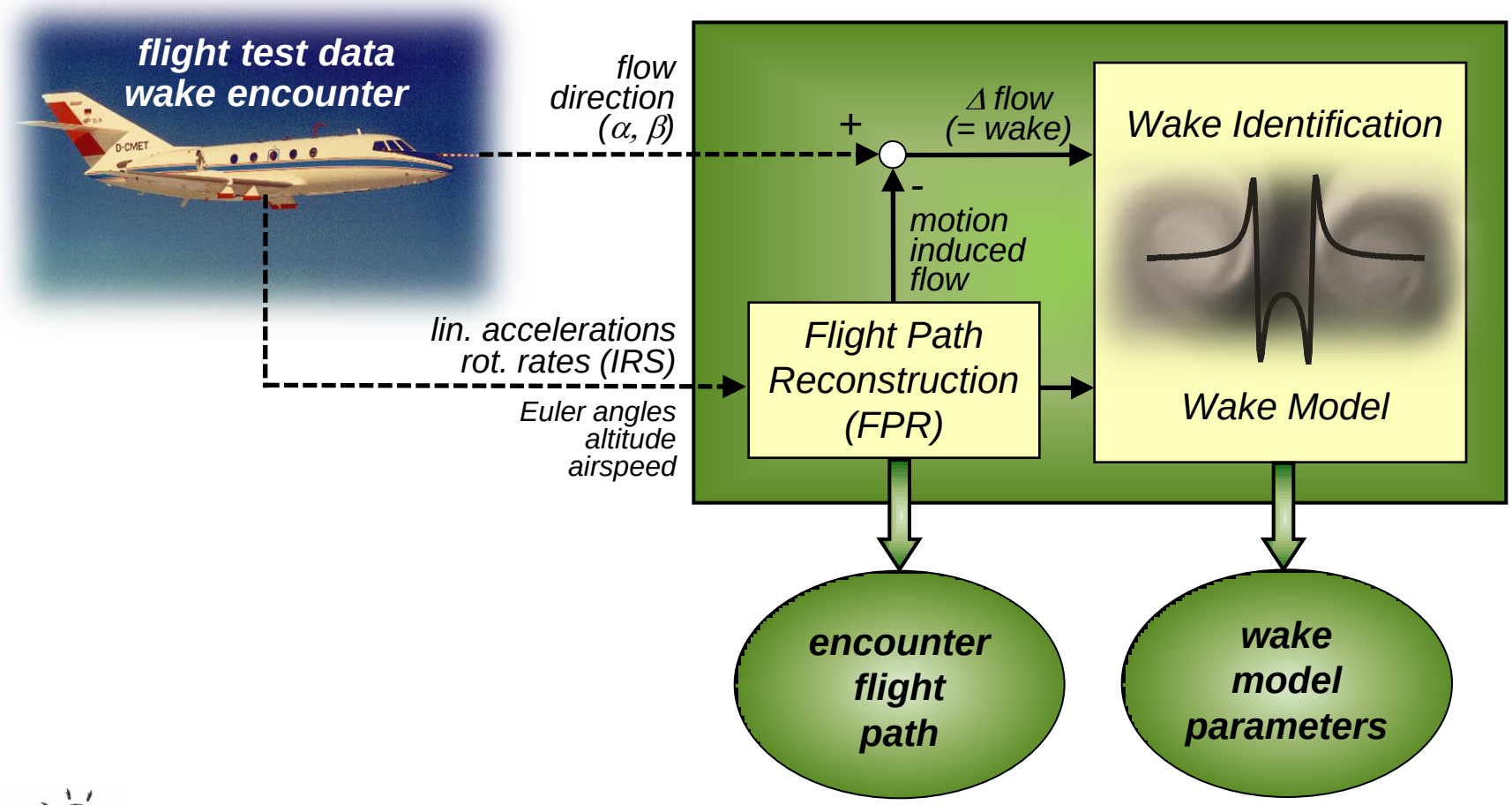
Wake Encounter Behind a B737

Encounter Statistics

	type	mass [t]	FL	number of encounters
1	CRJ-900	32	350	10
2	CRJ-900	30	370	9
3	Fokker 70	31	330	13
4	Fokker 100	36	350	8
5	B737-500	45	350	11
6	B737-400	50	360	9
7	B737-700	49	350	32
8	MD-82	58	340	20
9	B737-700	50	370	39
10	A319	58	370	15
11	B737-300	49	350	24
12	A320	62	360	12
total				*202*

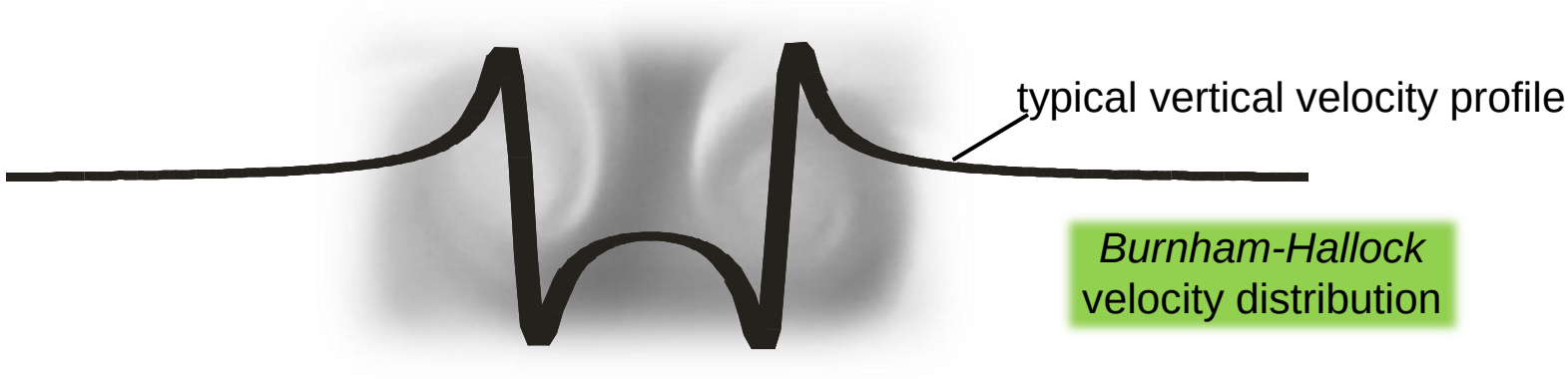
Single Encounter Evaluation: Method

Characterization of Instantaneous Wake State



Single Encounter Evaluation: Wake Model

- superimposed tangential velocities of two counterrotating vortices:



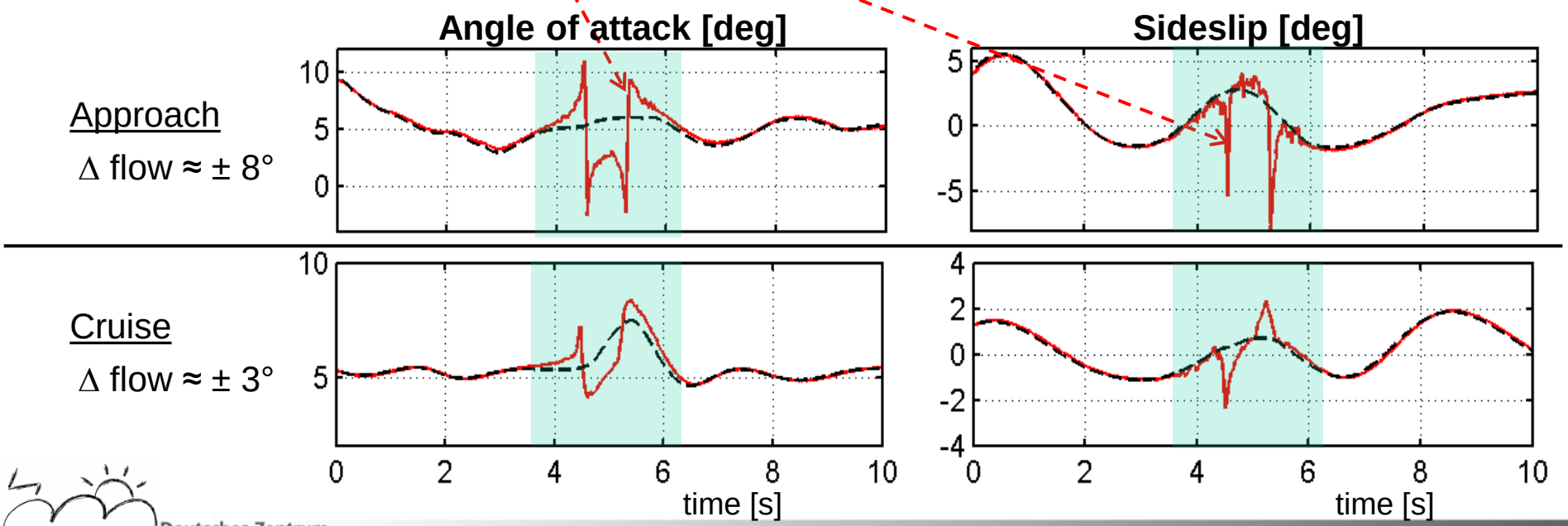
- identification of model parameters **for each single encounter:**
  - (1) circulation
  - (2-3) left & right vortex altitude
  - (4-5) left & right lateral vortex position (= vortex spacing)

  - *(6) optional: core radius*
  - *(7) optional: wake system orientation*

  } *only with appropriate flow instrumentation*

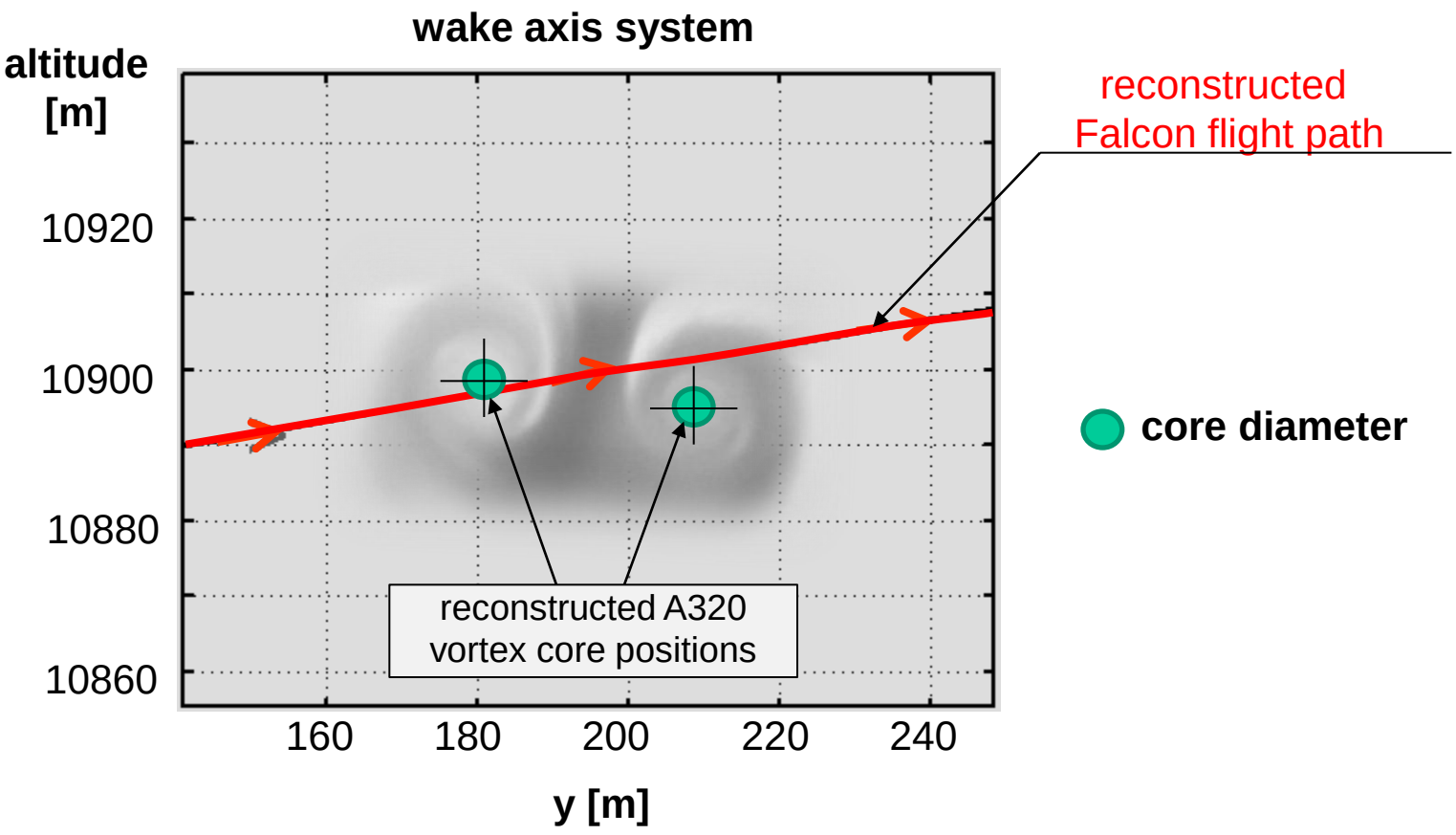
Typical Flow Measurements (Lateral Encounter)

Approach / Cruise Flight

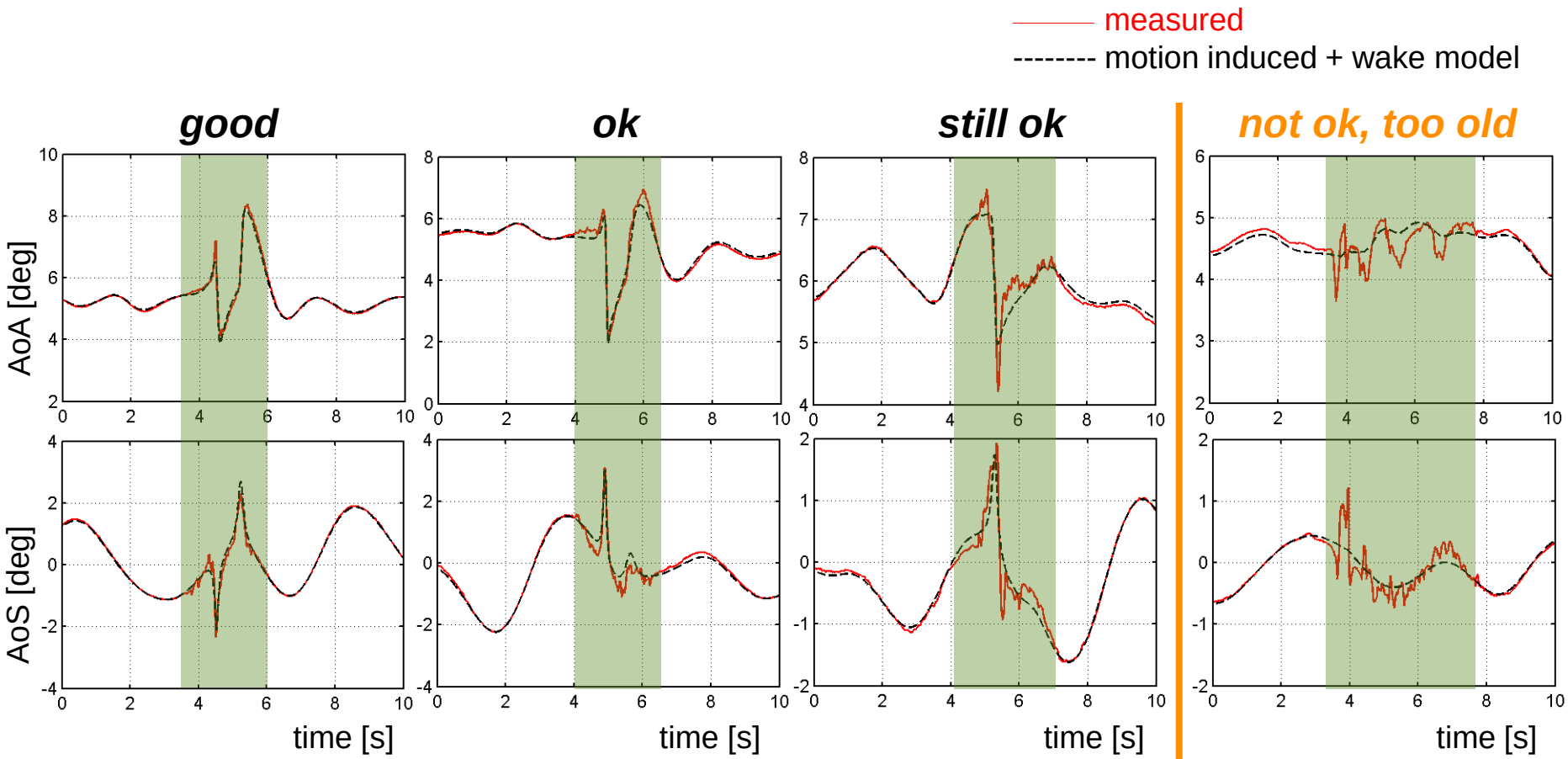


Result: Wake Position Reconstruction

Single Lateral Wake Encounter Behind an A320



Result: Wake Model Fit to AoA/AoS Measurements



► *2/3 of encounters: ID possible*

Wake Identification Results for One Measurement Sequence

„Wake Characterization Sheet“

Circulation

all identified single encounter vortex circulations (left = right vortex) compared to theory

Lateral vortex spacing

all identified lateral positions of left & right vortices in wake axis system (projection on x/y wake plane) compared to theory

Wake descent

all identified vortex z-positions relative to generator Flight Level

optional generalization:

MTOW extrapolated circulation:

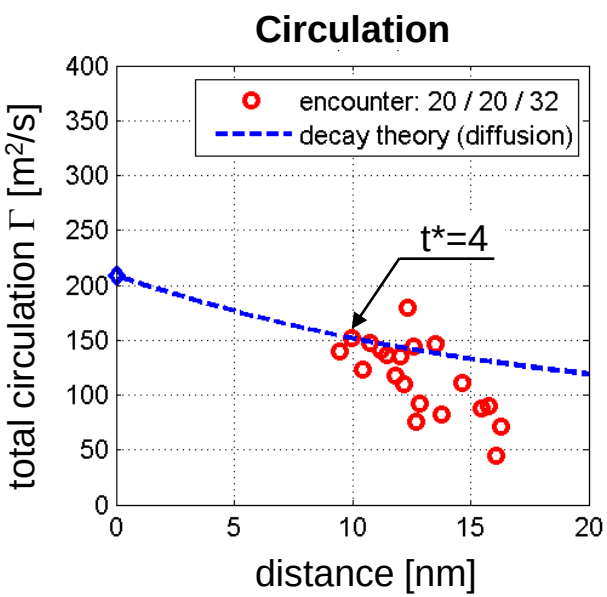
linear mass scaled circulation to achieve comparable results

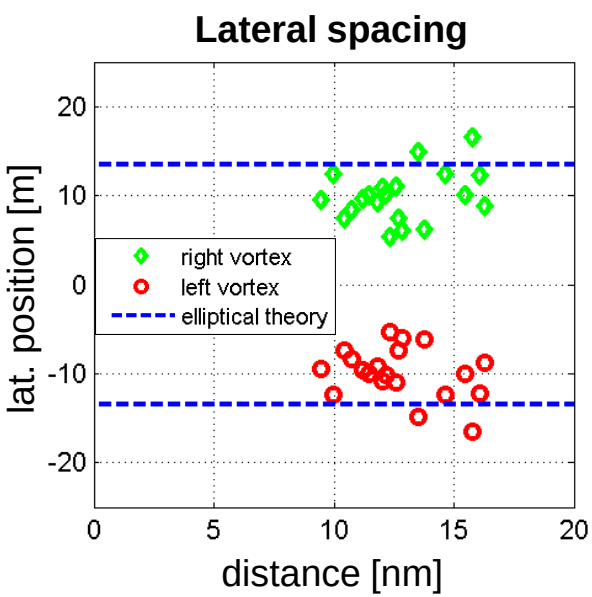
Wake Characterization Sheet

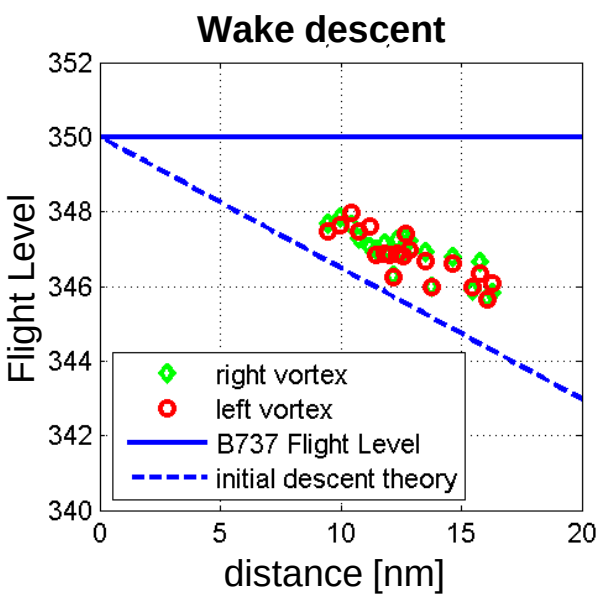
Boeing B737-700

Date: 30/3/2011
Wind: 265° / 31 kt
Duration: 11 min
Configuration: CLEAN

Cruise: FL 350
Weight: 48 t
Heading: 140°
TAS: 429 kt







Conclusions & Outlook

- High quality wake encounter flight test data now available for research: *202 encounters behind 12 different ICAO MEDIUM aircraft in cruise*
- DLR´s evaluation method for wake characterization was successfully applied to cruise flight test data
- A „*Wake Characterization Sheet*“ is proposed with focus on *wake strength, wake descent, and lateral vortex spacing*
- International interest on the flight test data & evaluation results (e.g. FAA)
- Presentation invited at WakeNet USA meeting (Memphis) this month