UFO

ULTRA FAST WIND SENSORS

Sources of Weather Datalink (Mode-S EHS, ADS-B) & Radar/Lidar Data Ingestion in High Resolution Forecast Models

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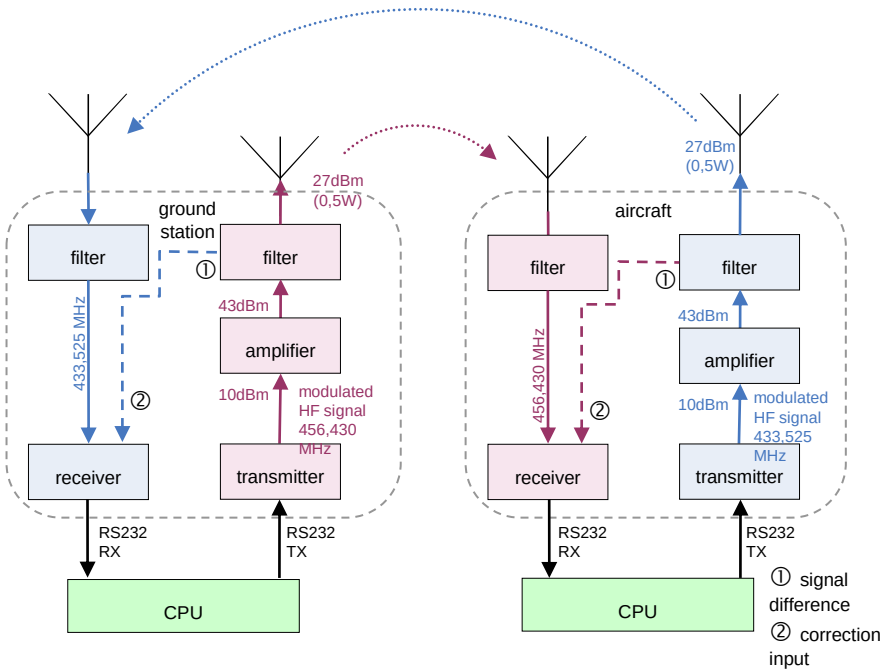
ADS-B data link

- **ADS-B data downlink from a/c according to future standards (RTCA-DO339*)**
  - **including Eddy Dissipation Rate (EDR)**



Data Item Ref. No.	Description	# of bits	Unit	Accuracy / Resolution	
I01	Time	32	msec	1	msec
I02	latitude (comb. GPS/INS)	64	deg	10/1	m
I03	longitude (comb. GPS/INS)	64	deg	10/1	m
I04	Pressure altitude	32	m	5/0,2	m
I05	Radio altitude	32	m	1/0,1	m
I06	A/C speed (TAS)	32	m/s	0,3/0,01	m/s
I07	A/C heading	32	deg	0,4/0,1	°
I08	Angle of attack	32	deg		
I09	Slip angle	32	deg		
I10	Wind speed	32	m/s	0,3/0,08	m/s
I11	Wind direction	32	deg	2/1	°
I12	Static temperature (fast)	32	°C	0.4/0.01	°C
I13	Static barometric pressure	32	hPa	0,05/0,02	hPa
I14	Eddy Dissipation Rate	32			
I15	Humidity	32	%	2/0,01	%

*:Aircraft Derived Meteorological Data via Data Link for Wake Vortex, Air Traffic Management, and Weather Applications Operational Services and Environmental Definition (OSED)

ADS-B data link

- **EDR calculation according to Labitt***

$$EDR = \sqrt[3]{\epsilon} = \frac{\left(\frac{R \cdot T_t}{\Delta t}\right)^{1/3} \cdot \left(\frac{\kappa-1}{2\kappa}\right)^{2/3} |\Delta q|}{C^{1/2} \cdot \left(1+\frac{q}{p_{stat}}\right)^{\frac{\kappa+2}{3\kappa}} \cdot \left[\left(1+\frac{q}{p_{stat}}\right)^{\frac{\kappa-1}{\kappa}} - 1\right]^{2/3} \cdot p_{stat}}$$

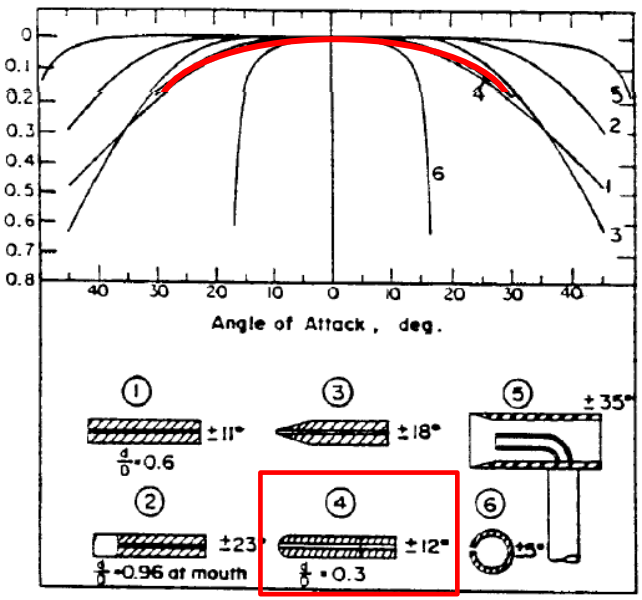
  - only depending on total temperature, dynamic pressure and static pressure
  - values available on aircraft with good accuracy

- **other EDR calculations possible, but depending on accuracy of available on-board data**

*:Labitt: , M.: Coordinated Radar and Aircraft Observations of Turbulence, FAA-RD-81-44, Project Report ATC-108, Lincoln Laboratory MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 26 May 1981

ADS-B datalink

- **airborne wind measurement**
  - **True airspeed (TAS)**
    - with current pitot-static tubes negligible error within flight envelope
  - **wind speed accuracy**
    - calculated based on TAS and ground speed
      - ground speed accuracy depends on connected/used sensor
        - GPS/INS
        - DME/DME/INS
        - DME/VOR/INS
        - VOR/VOR/INS
        - INS/INS



ADS-B datalink

- **airborne wind measurement**
  - **wind direction accuracy**
    - for a/c not having side slip vane*
      - calculated based on TRUE Heading and TRUE Track
        - TRUE Heading depends on used INS
        - 0.2° for modern ADIRU, but up to 10° allowed for e.g. magnetic standby instruments
        - TRUE track based could be based on position accuracy
          - GPS/INS
          - DME/DME/INS
          - DME/VOR/INS
          - VOR/VOR/INS
          - INS/INS
        - TRUE track accuracy also based on update rate

*: most a/c only have alpha vanes

Mode-S EHS

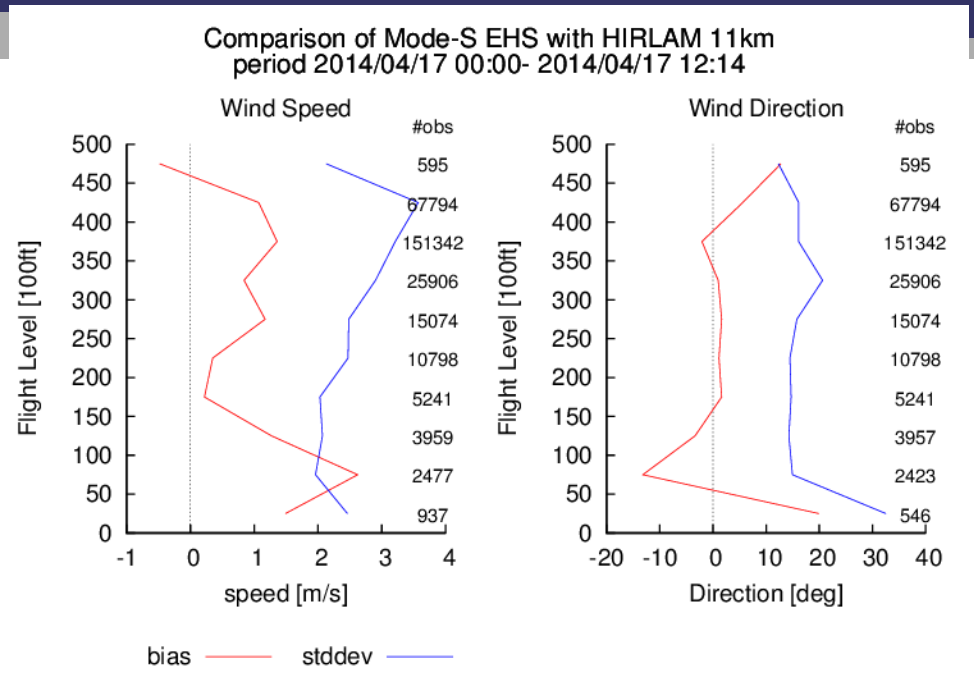
Mode-S EHS

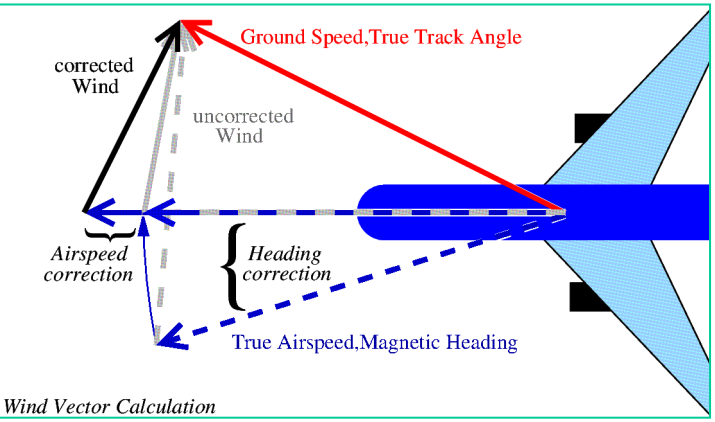
BDS_{50}

- true track angle
- ground speed
- true airspeed (➔ correction)

BDS_{60}

- Mach number (+ TAS ➔ temperature)
- Magnetic heading (➔true North + aircraft correction)

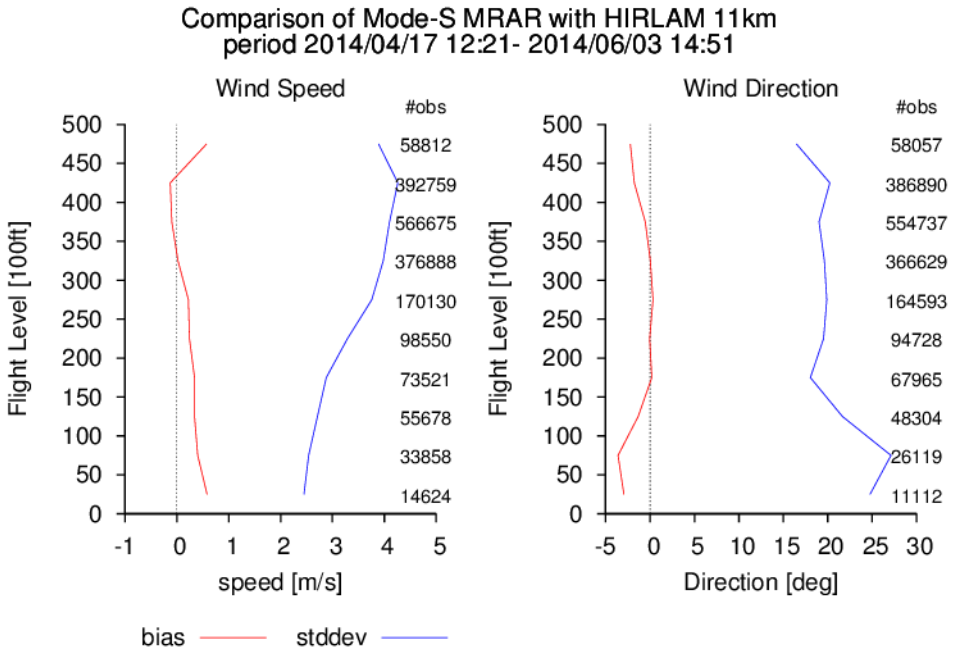


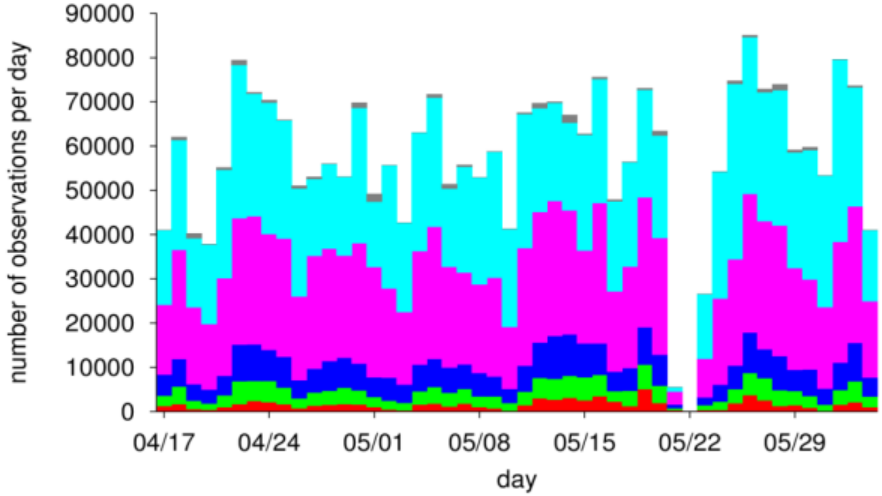


Mode-S MRAR observations

BDS_{44} Meteorological routine air report (MRAR)

- Direct information on wind and temperature
- Not Mode-S EHS mandatory ➔ 5-10% of the aircraft



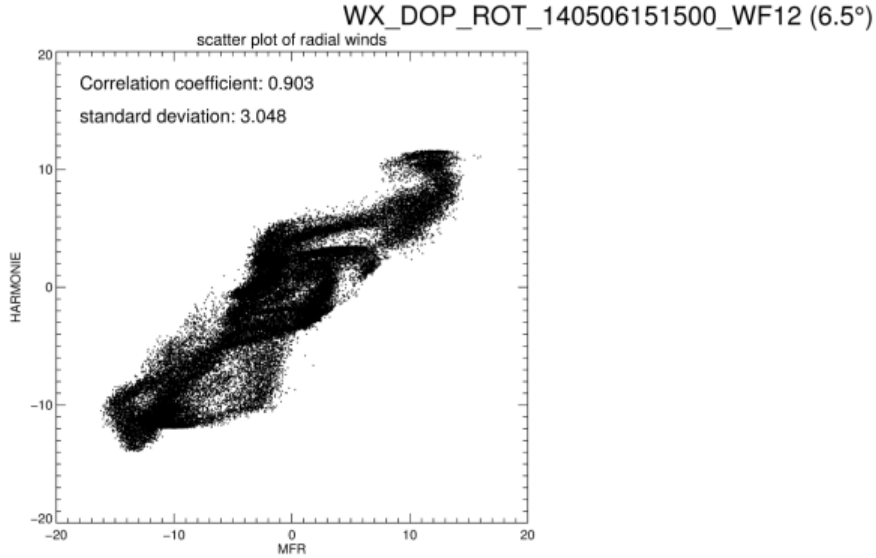


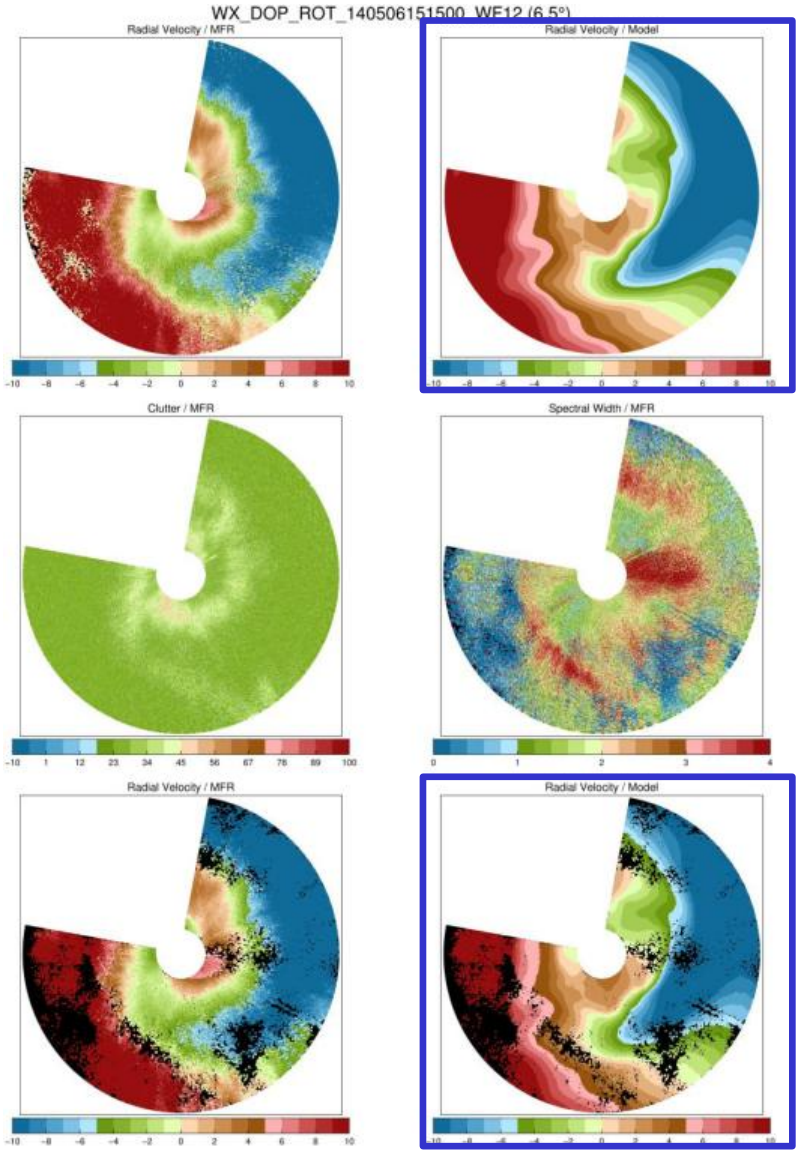
MFR radar observations

MFR radial velocity validation

Model = ☐

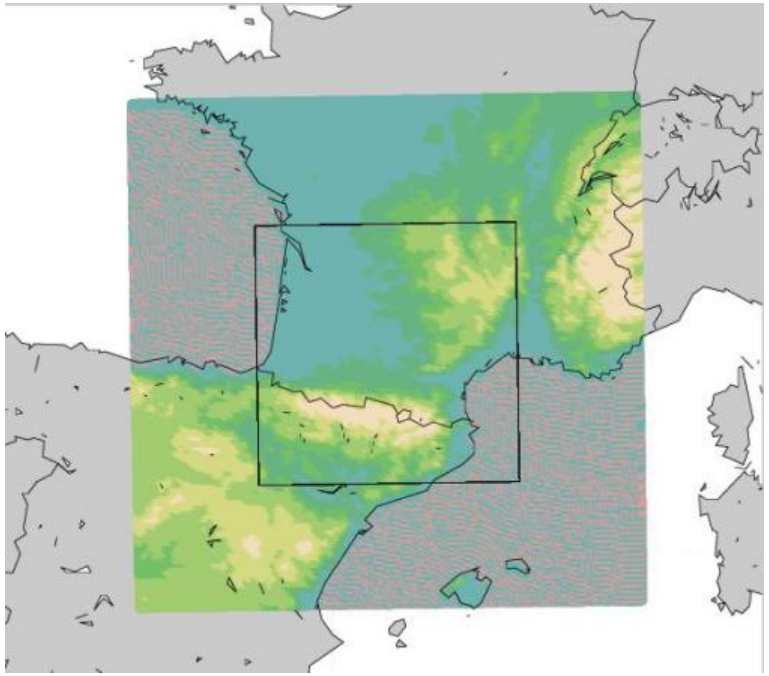
- **Spectral width is used as quality indicator**
- **Very small scales not resolved by Harmonie model**





Harmonie numerical weather prediction model

- **Special Toulouse-trial setup**
- **Period 2014/05/01 – 2014/06/03**



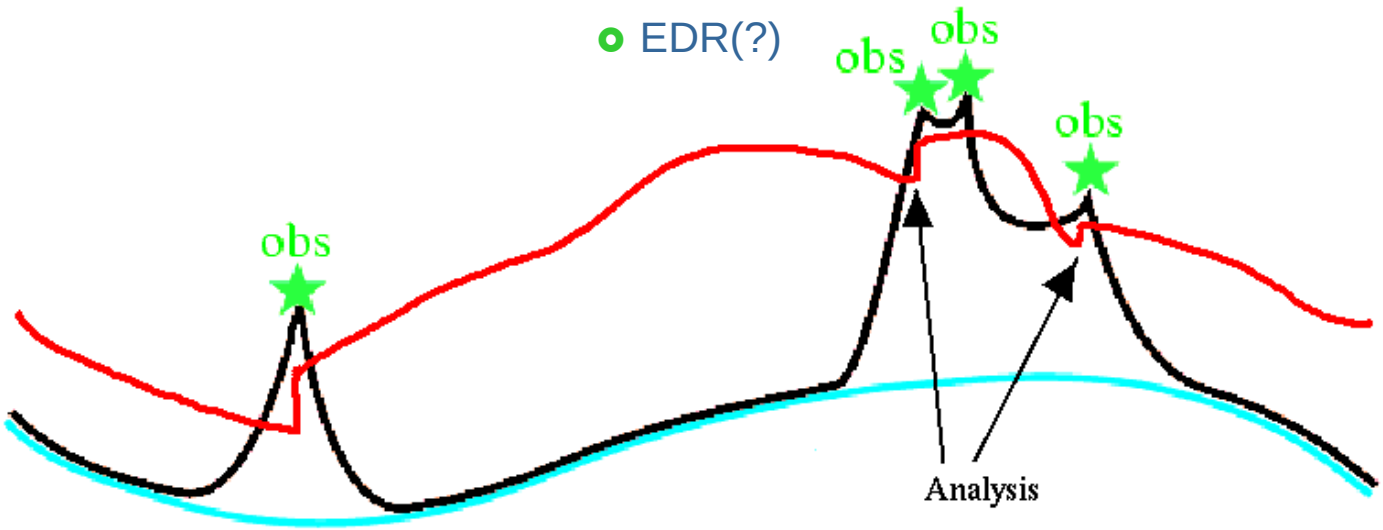
	Nestor	Nested
Grid	200x200 5km	500x500 1km
Cycle	3 hours	1 hour
Lateral boundaries	ECMWF hourly	Nestor 15 min
Observations	Temp/aircraft/ synop	Temp/aircraft/ synop
Assimilation	3DVAR 3 hour window	3DVAR 1 hour window

3DVariational Analysis

Analysis is constructed from weighted sum of a First Guess (from previous cycle) and observations

Observations

- **3DVAR operational**
  - Radiosonde (T/wind/hum)
  - Surface P/T
  - AMDAR (T/wind)
- **3DVAR research**
  - Mode-S EHS/MRAR
  - Radar/LIDAR radial winds
  - EDR(?)



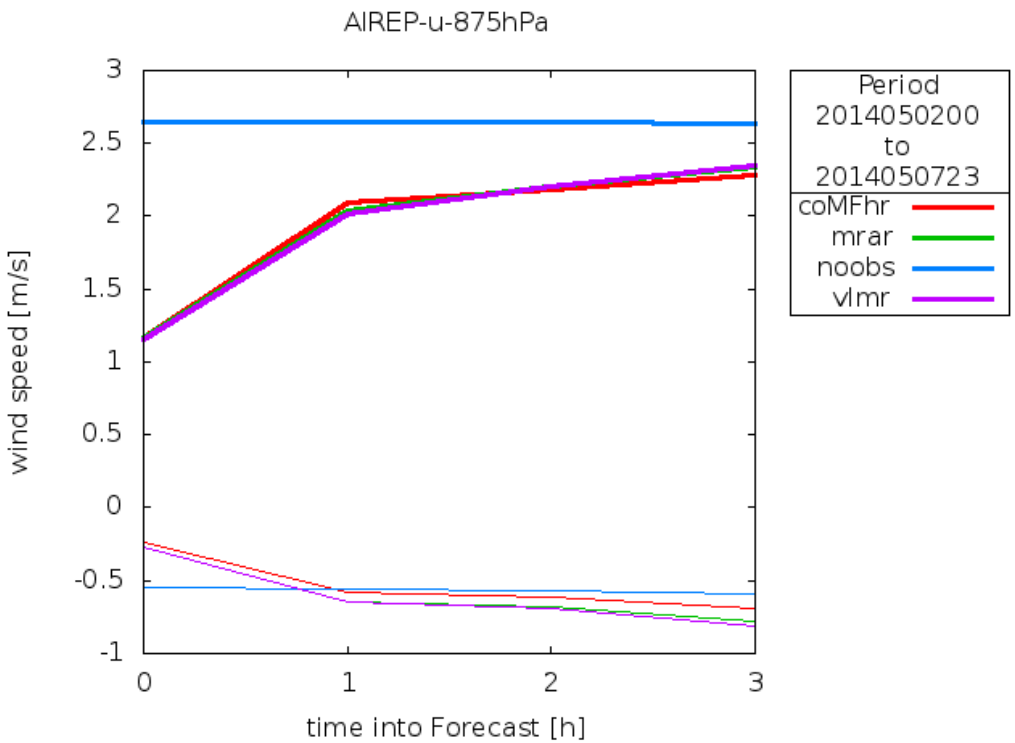
Impact on Aircraft observations

Experiments

- Downscaling: **noobs**
- Conventional obs MF: **coMFhr**
- + Mode-S MRAR : **mrar**
- + LeoSphere WindcubeV2: **vlmr**

Comparison with u-AIREP

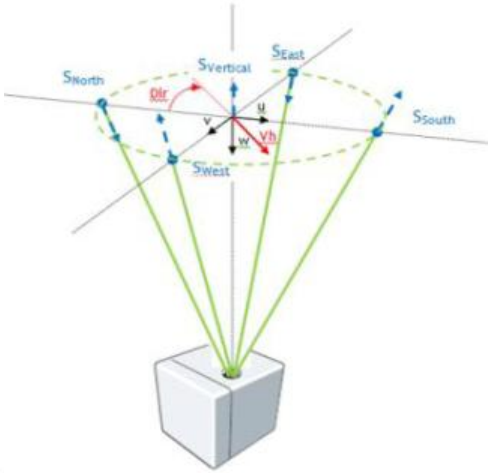
- Used in all active experiments
- Adding observations slightly improves the skill of the model wrt AIREP obs.
- Note the persistent bias!

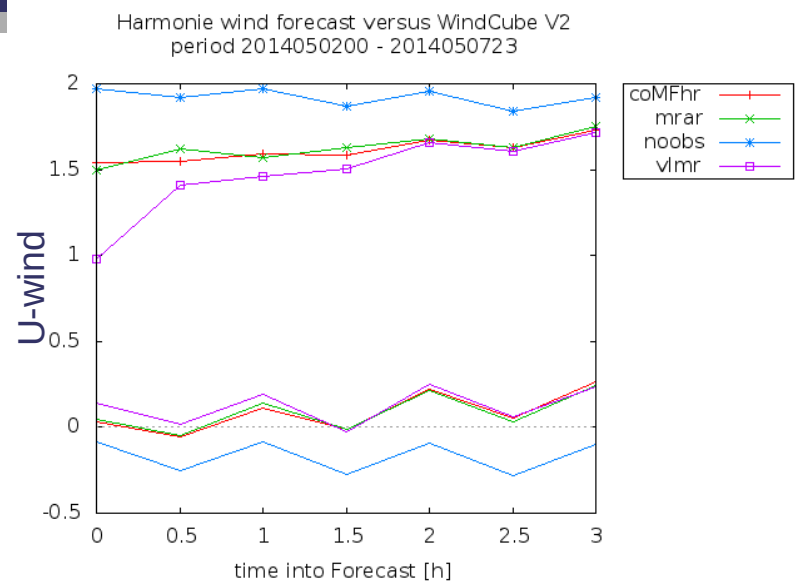


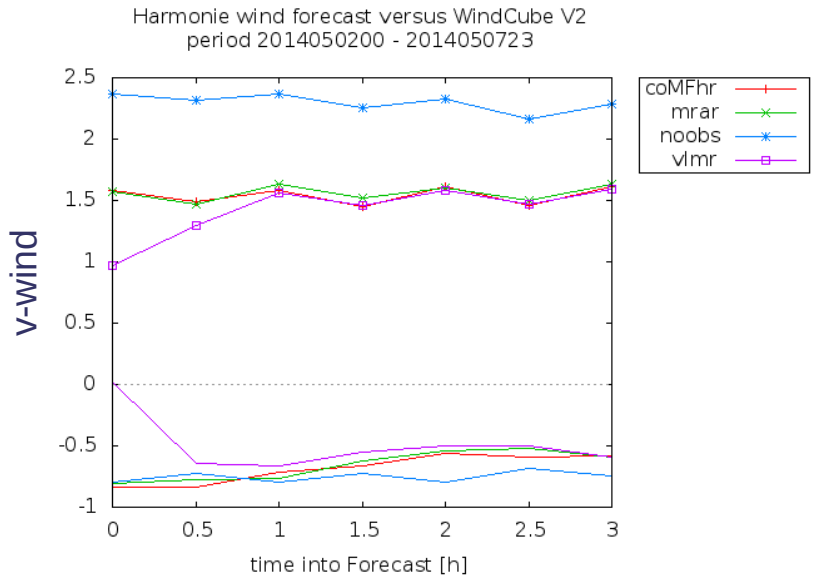
Impact close to TLS

Comparison with WindCubeV2

- **Positive impact locally**
- **U-wind component**
  - Reduction in Standard deviation up to 2 hours into the forecasts
  - Small persistent bias
- **V-wind component**
  - No impact after 1 hour
  - Persistent bias







Conclusions

- **ADS-B downlink format described**
  - Some words on wind accuracy
- **Mode-S EHS and MRAR are accurate observations**
  - Suitable for assimilation
- **Data Fusion of UFO observations**
  - Neutral impact from Mode-S MRAR when compared to AIREP
    - Amount and coverage not optimal
  - (local) positive impact from Windcube V2
    - Bias issue?