Turbulence project

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Summary

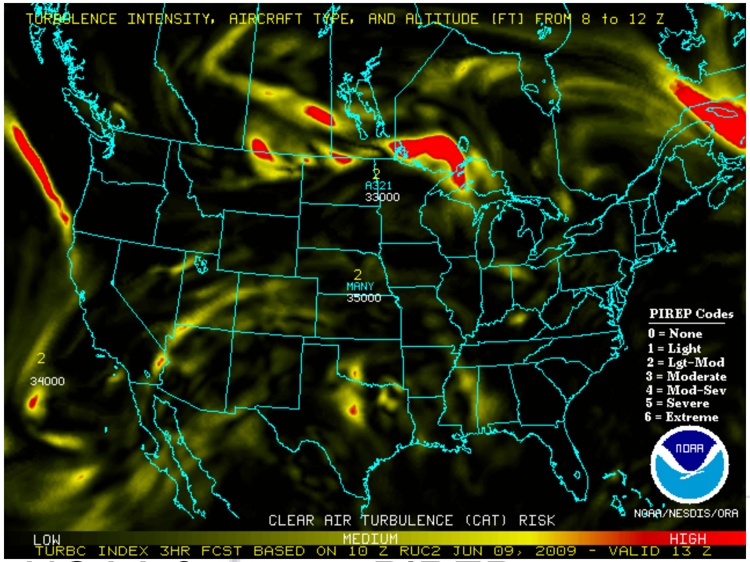
- What is turbulence
- Observed data from instruments in the airplane: IT and DEVG
  - IT, a turbulence index, categorized
  - DEVG , vertical gust index, continuous values
- Forecasted data from ALADIN model:
  - 2 indices calculated: Ellrod 1 and Ellrod2
- Contigency table for each indices
- Importance of the domain of verification

What is turbulence?

- Sudden updraft or downdraft
- Generated by rising air
- Usually associated with Cb-clouds
- Fronts (embedded Cb)
- Convective cells (Cb-clouds)
- Mountain lee waves
- Low pressure area updraft (Cb-clouds)
- Usually appears with some other weather phenomena eg. rain in CB-cloud shows in onboard radar or lenticular (”almond”) clouds of lee waves can be visually observed
- → can be detected

What is Clear Air Turbulence, CAT

- Downdraft and updraft very violent (+100m/s^2 to -40m/s^2)
- Effects on the plane:
  - Damages on the structure of the plane
    - 1966 BOAC 707 crashed to Mt Fuji, lee wave
    - obs 70kts on top of Mt Fuji
  - Passengers and crew could be injured
- In clear air = INVISIBLE



NOAA forecast+PIREPs

Observed data : turbulence indices from AMDAR

- AMDAR (Aircraft Meteorological Data Relay) data is composed by messages automatically emitted during the flight by some commercial aircraft (T, p, WS and WD)

- DATA:
  - Position, temperature, wind, pressure
  - Sent most of the time during take off and landing, less information during the flight
  - IT, Turbulent intensity, depending on the type of plane (larger plane -> more inertia -> IT smaller value)
  - DEVG Derived Vertical Gust, NOT depending on the plane
  - Measurements from wind speed and angular heading changes

DEVG Value	***Intensity***
Less than 2m/s	no
from 2 to 4.5 m/s	Light
from 4.5 to 9 m/s	High
Higher than 9m/s	Intense

IT Value	***Intensity***
$IT < 0.15g$	no
$0.15g \leq IT < 0.5g$	Light
$0.5g \leq IT < 1g$	Moderate
$IT > 1g$	Severe

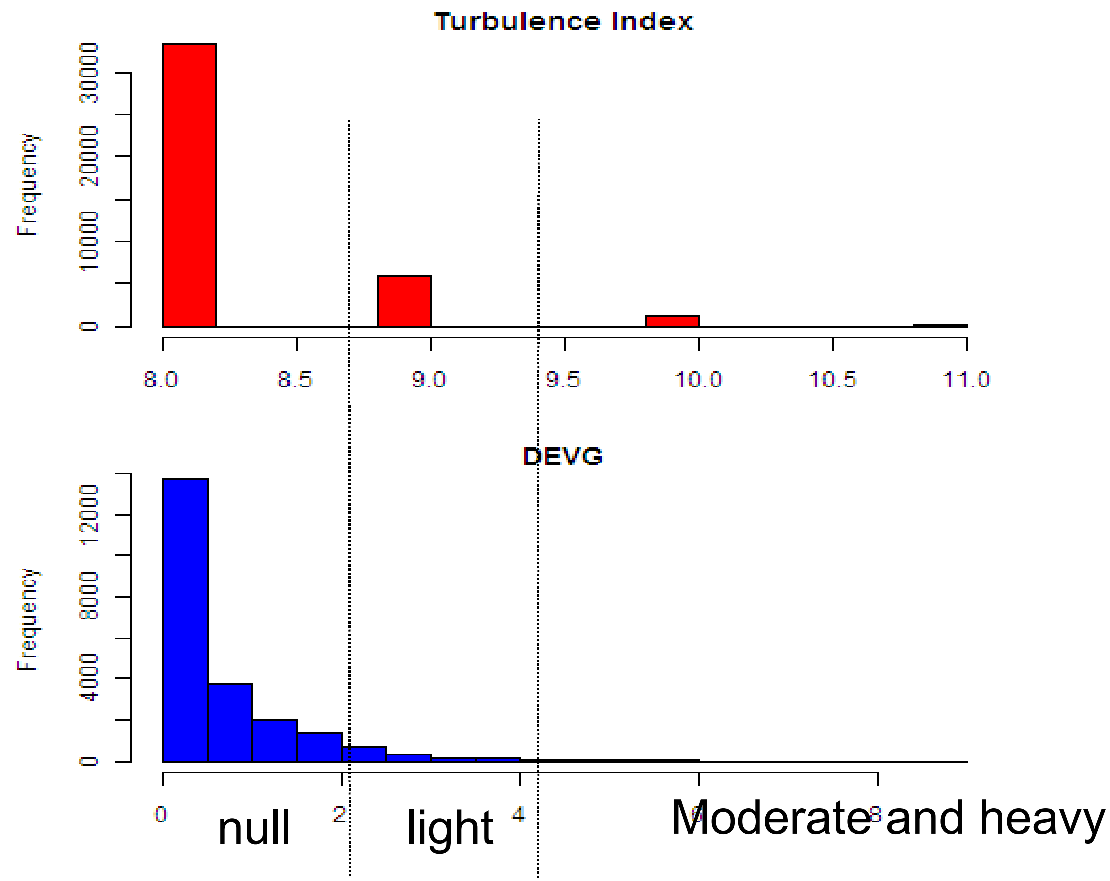
AMDAR DATA

- DATA SET :
  - During 40 days (20/11/2005-31/12/2005)
  - Several airlines
  - 50000 messages

- Preparation of the data set
  - Convective situations are omitted by using lightning impacts (in a circle of radius 50km around the data and in a time interval of ½ hour)

- The observation sample sizes are NOT the same, some values are missing (no measurement), but the same order of magnitude: DEVG 22000 and IT 41000

Observed data

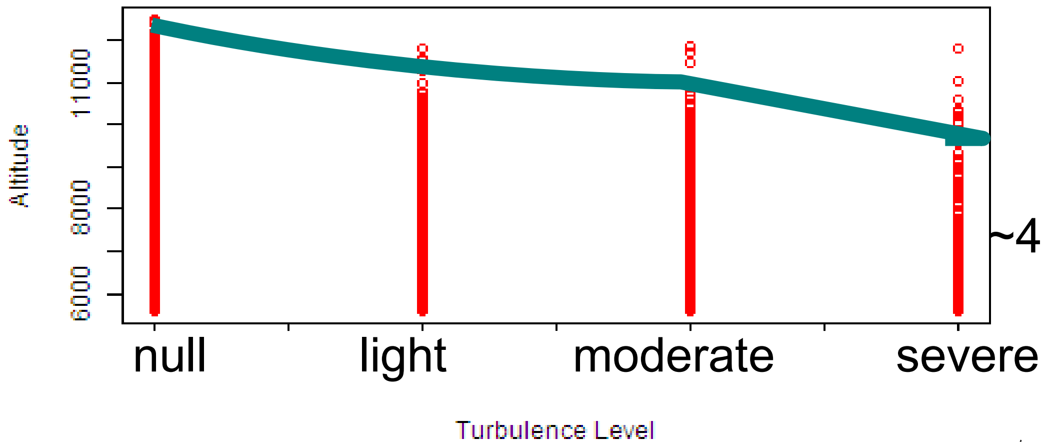


Low number of turbulence events

Observed data repartition

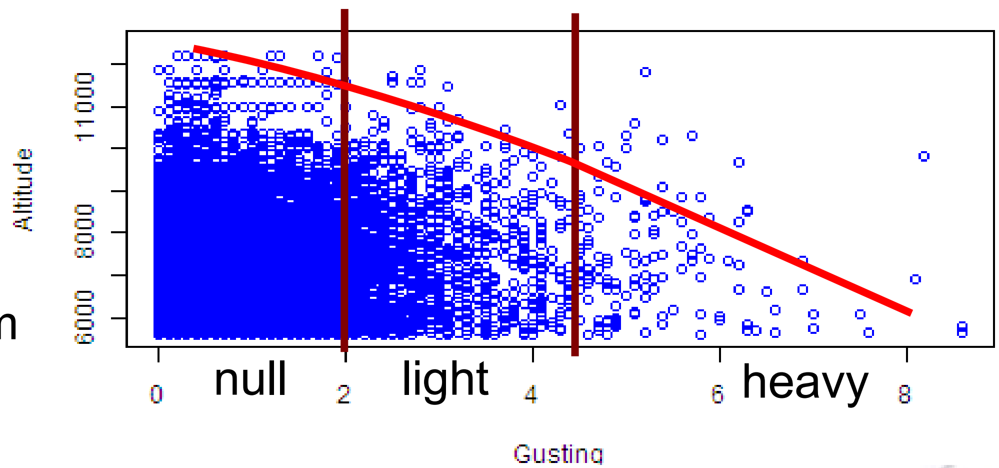
- Classification of severity depending on the altitude

Decrease of severity with decreasing altitude



~41000 observations

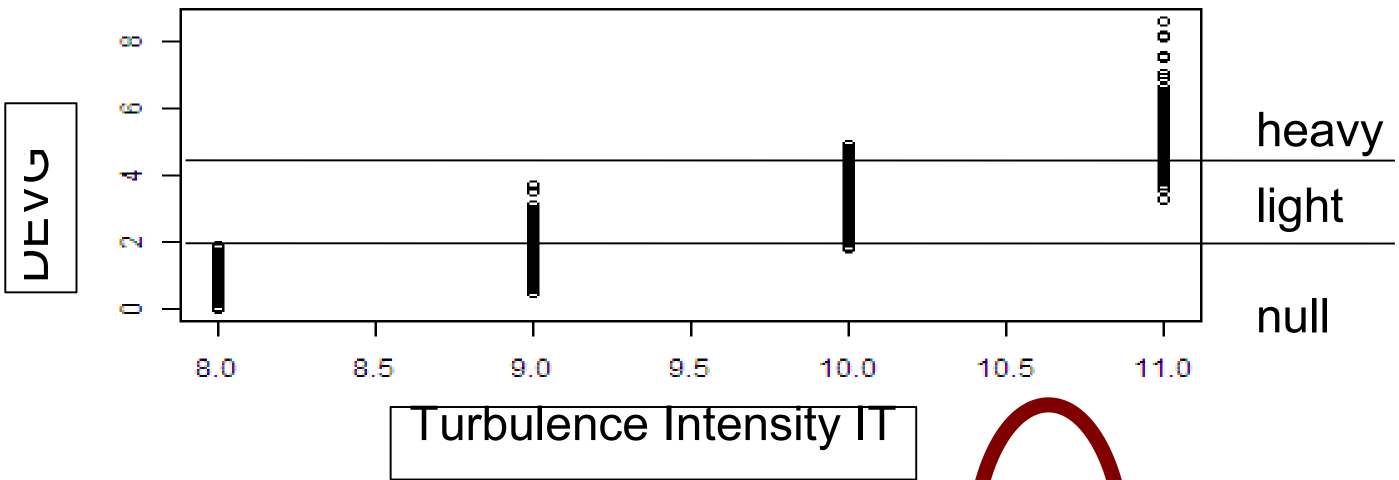
Maximum for heavy turbulence at 6000- 8000m
BUT
Large variation



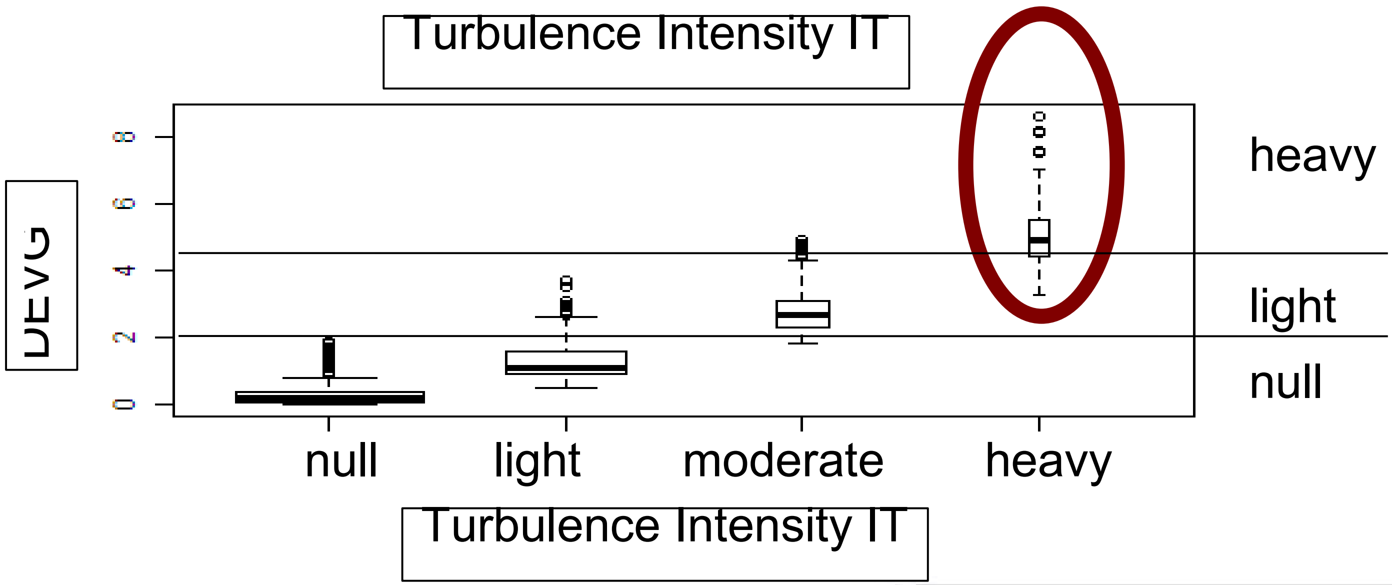
~22000 observations

Observed data

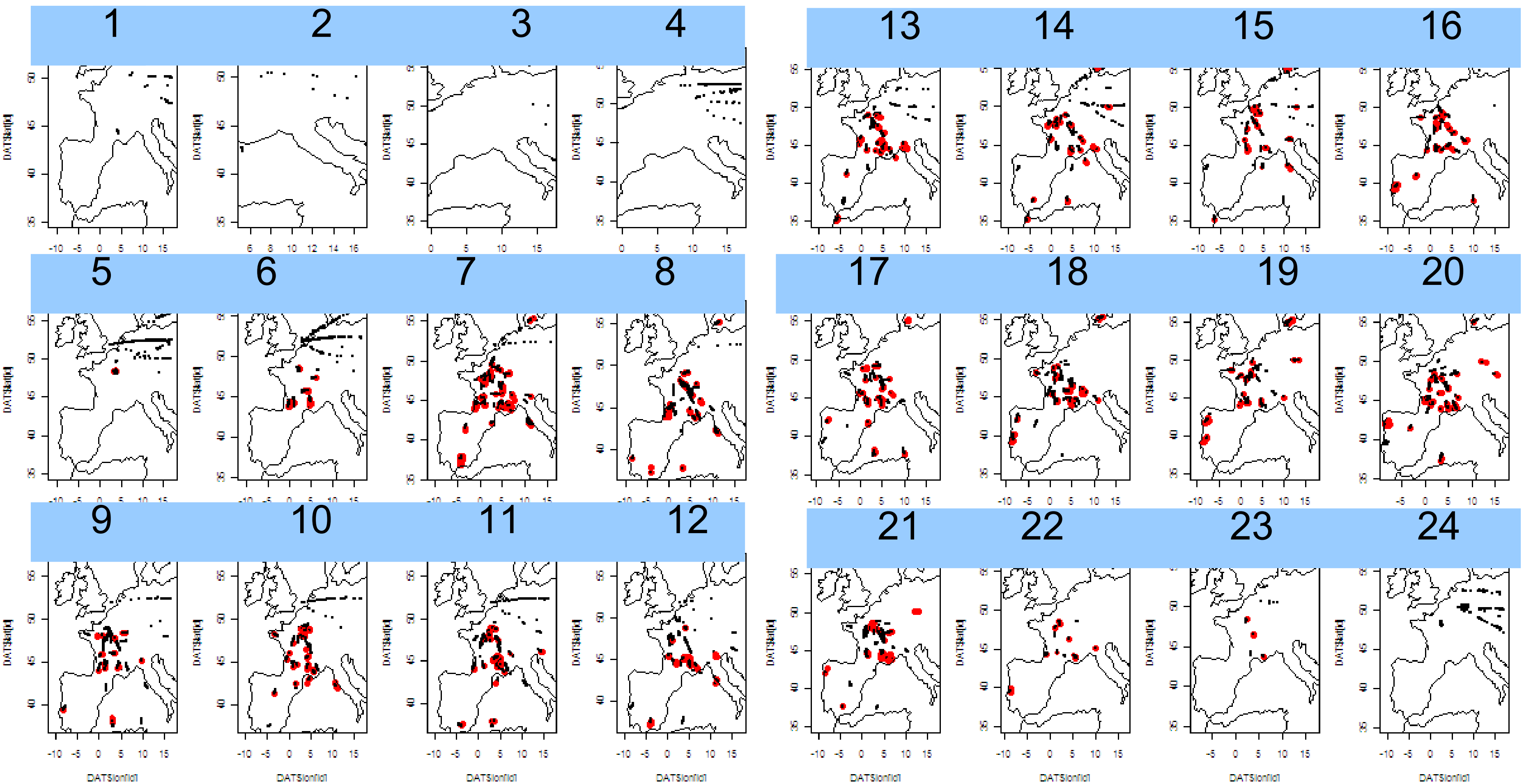
- Correlation between turbulence from DEVG and IT



- Boxplot with whiskers (sample dependent variation limits, not 5% and 95%

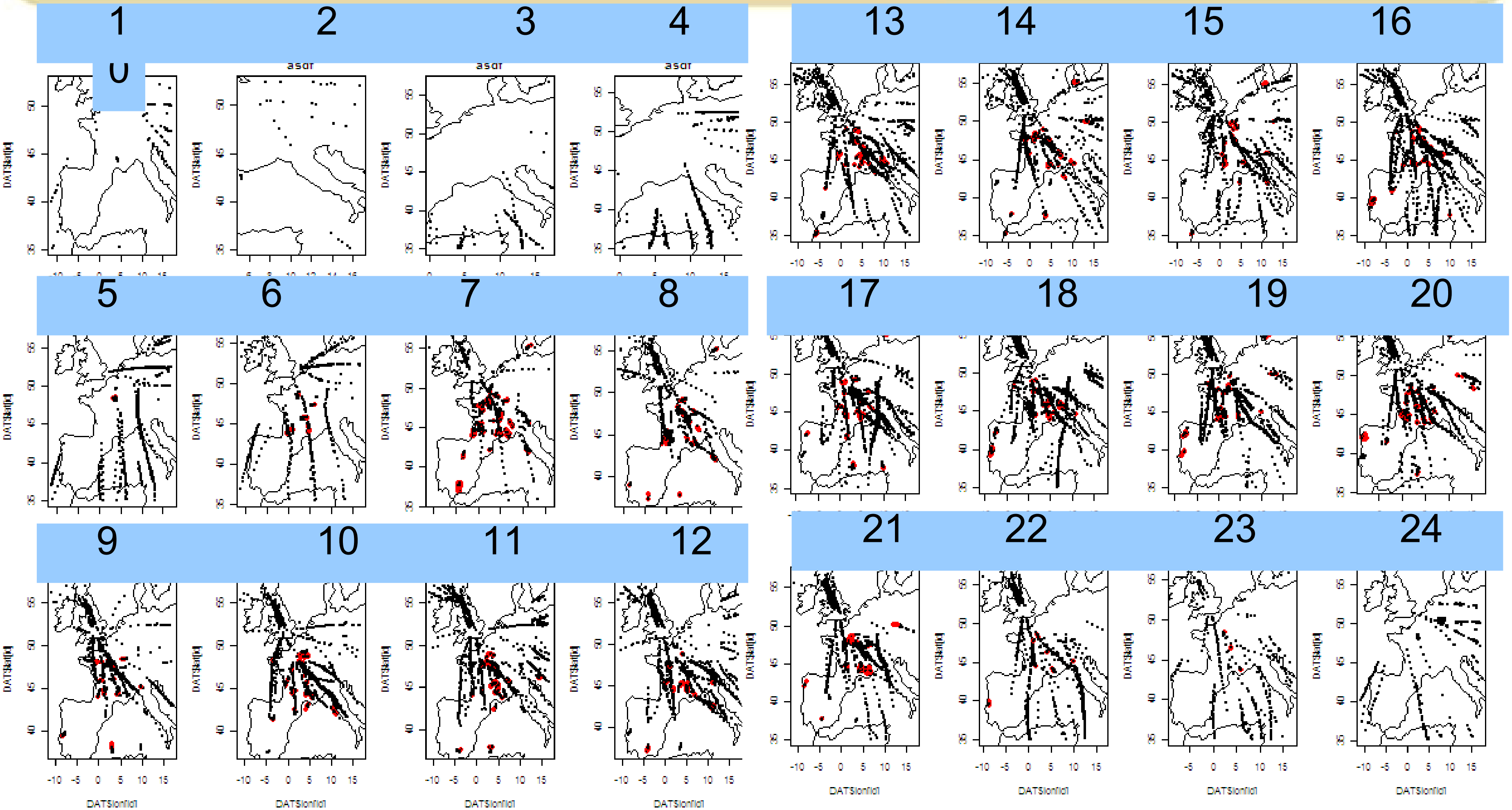


Hourly obs of DEVG, Derived Vertical Gust



- NO turb during night 00-04 hours, few at 05 and 22-23
- Developed at 07, quite consistent during the day
- Convective driven?

Hourly obs of IT, Turbulence Intensity

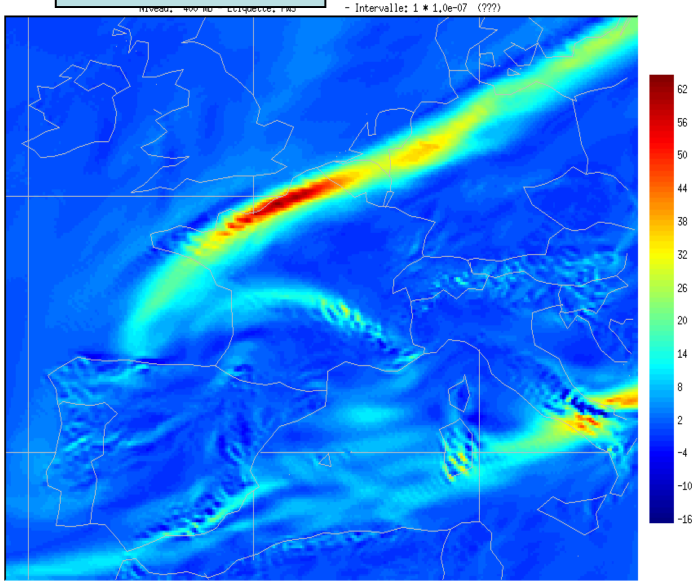


- Similar to DEVG

Forecasted data (from MODEL) : 2 turbulence indices

MODEL

ELLROD 2



Prevision 00 heures valide 06:00Z le 25 janvier 2007

Ellrod2 $= Sv * (DEF - CVG)$

ALADIN

Resolution

0,1°

4 networks

6 levels :

500, 400, 300,

250, 200, 150 hPa

Sh : cisaillement horizontal

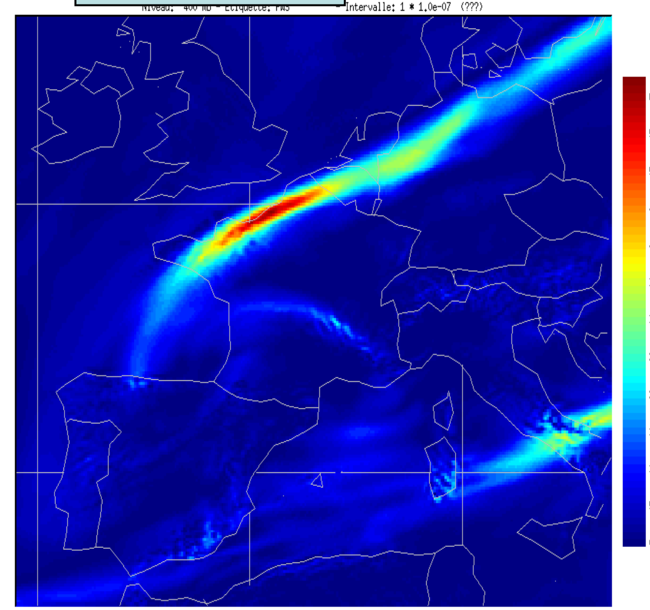
Sv cisaillement vertical

Dst: stretching deformation

Dsh: shearing deformation

$DEF=(Dsh^2 + Dst^2)^{1/2}$

ELLROD 1



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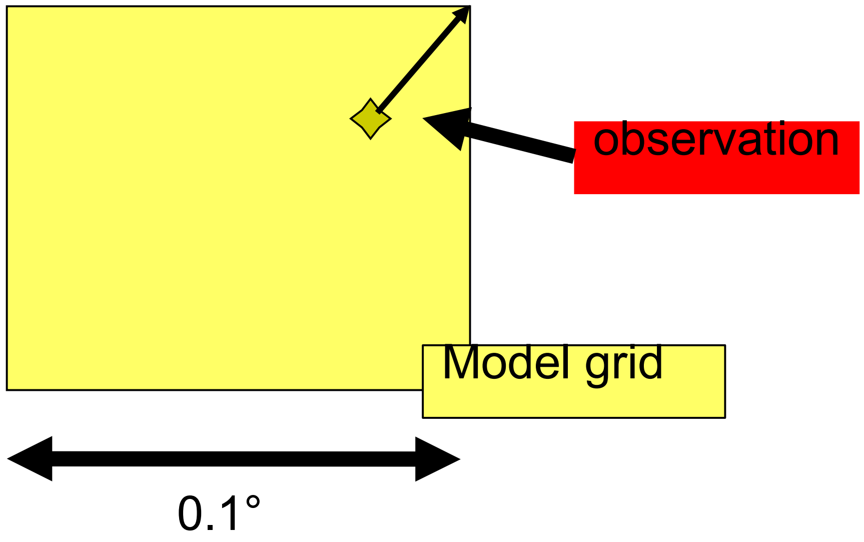
Ellrod1 $= Sv * DEF$

Remarks

- Observation correspond to the nearest grid point
- A grid =0,1° about 10 kms
- Pilots try to avoid the conditions



First results

OBSERVATION ***No EVENT/EVENT***

ELLROD1

DEVG

	yes	no	total
yes	5	582	587
no	117	21672	21789
total	122	22254	22376

FAR=0,02 POD=0,04

Portion correct=0,97

Turbulence INDEX

	yes	no	total
yes	69	785	854
no	1264	38481	39745
total	1333	39266	40599

FAR=0,02 POD=0,05

Portion correct=0,95

ELLROD2

	yes	no	total
yes	5	690	695
no	117	21564	21681
total	122	22254	22376

FAR=0,02 POD=0,04

Portion correct=0,97

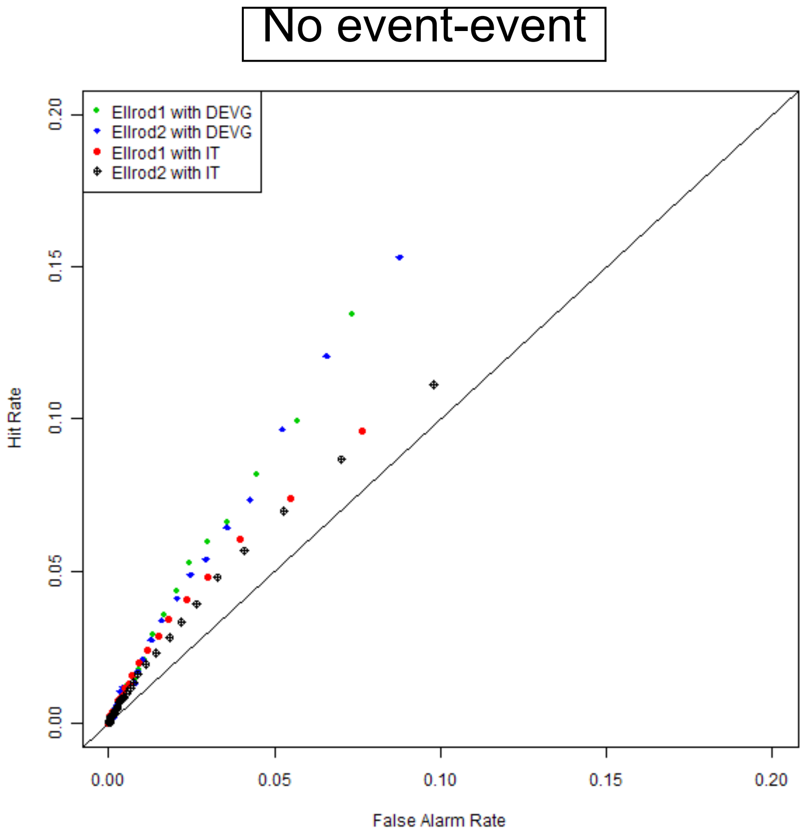
	yes	no	total
yes	70	1096	1166
no	1263	38170	39433
total	1333	39266	40599

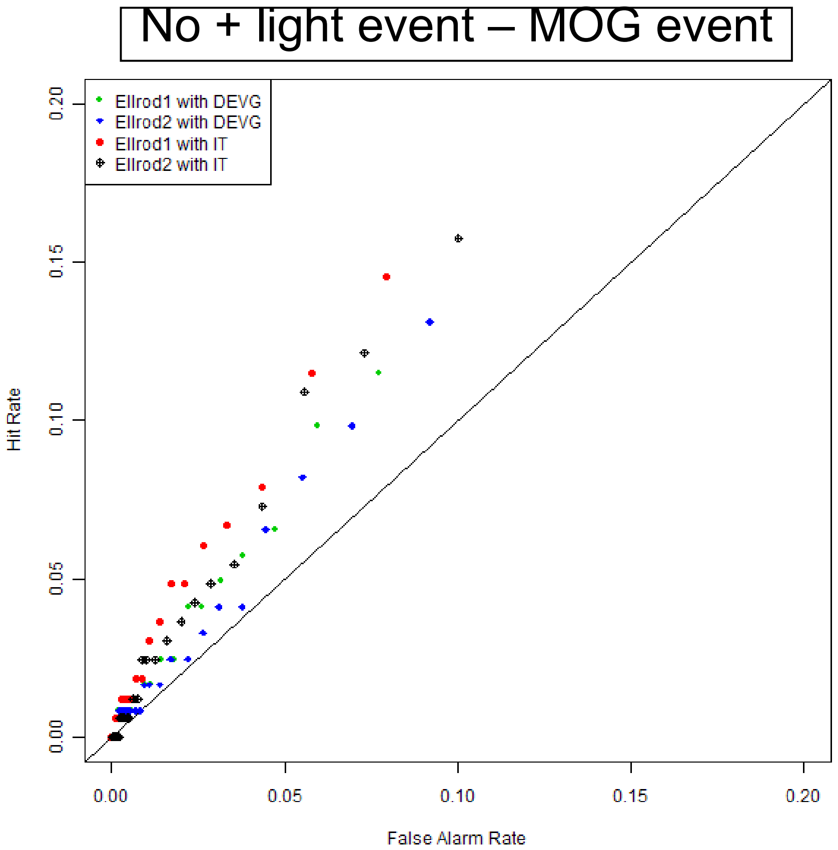
FAR=0,03 POD=0,05

Portion correct=0,94

ROC Curves

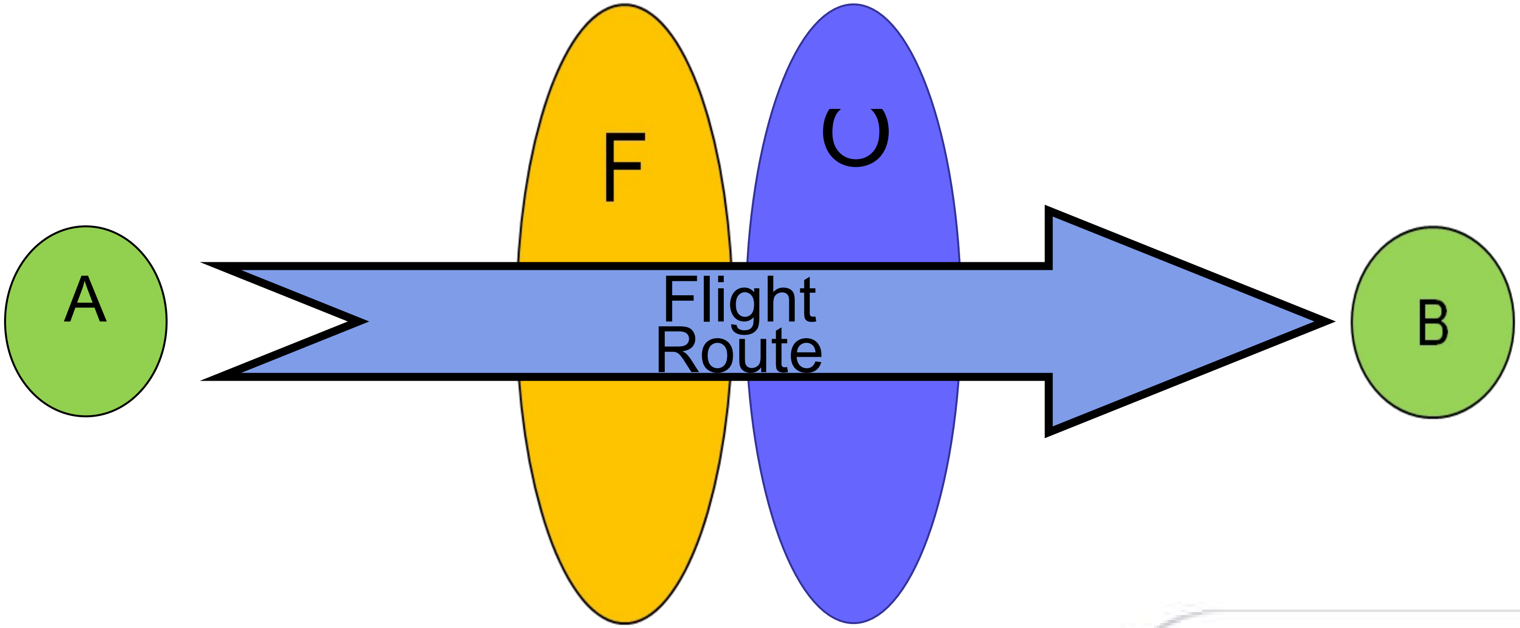
Different levels for the numerical index





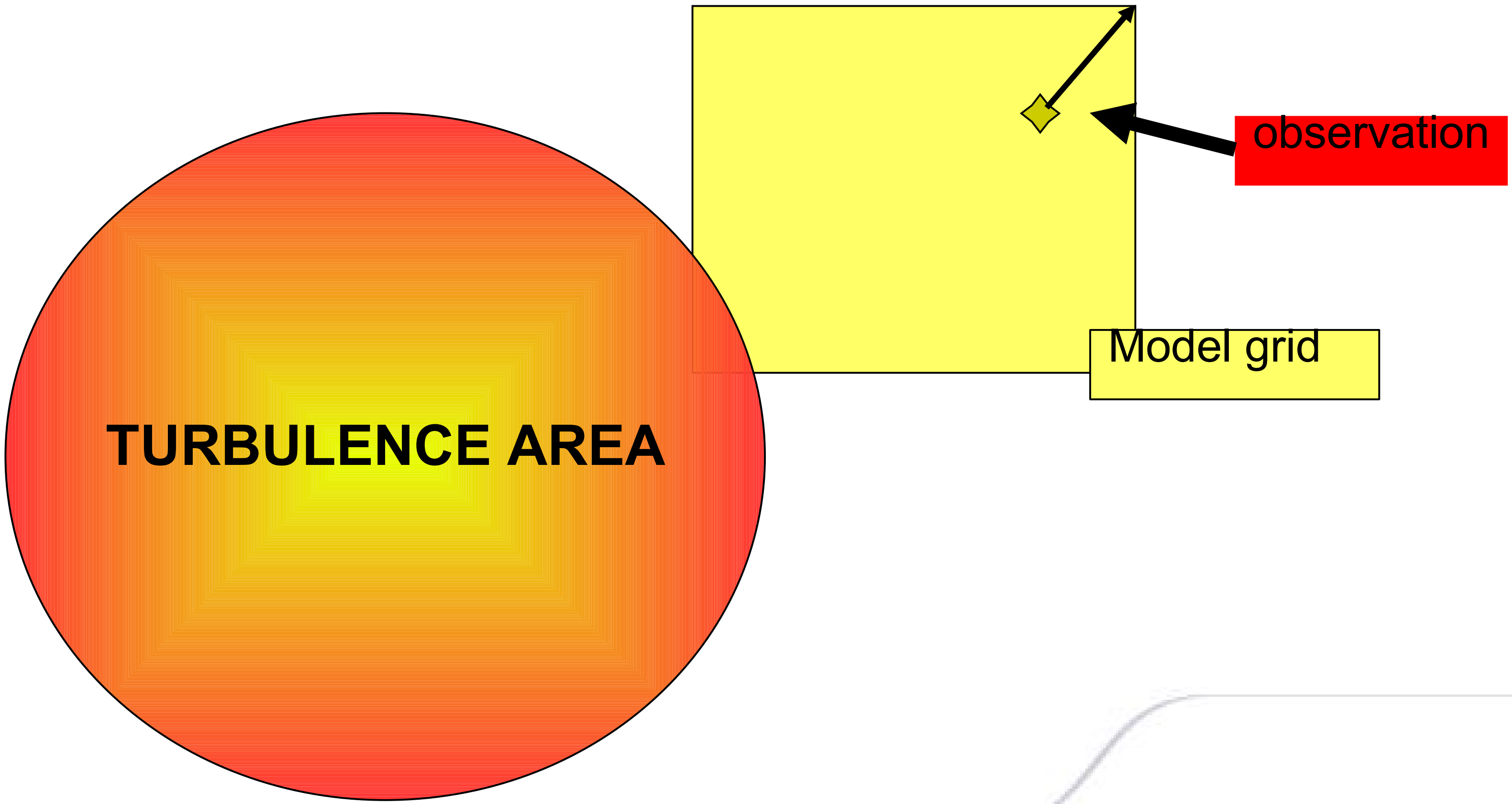
Remarks

- Low number of turbulence event does not mean that turbulence does not exist, but that pilots try to avoid this areas
- The forecasted data is the nearest grid point to the observation. Better to make an area verification, it could be best appropriate for the user.

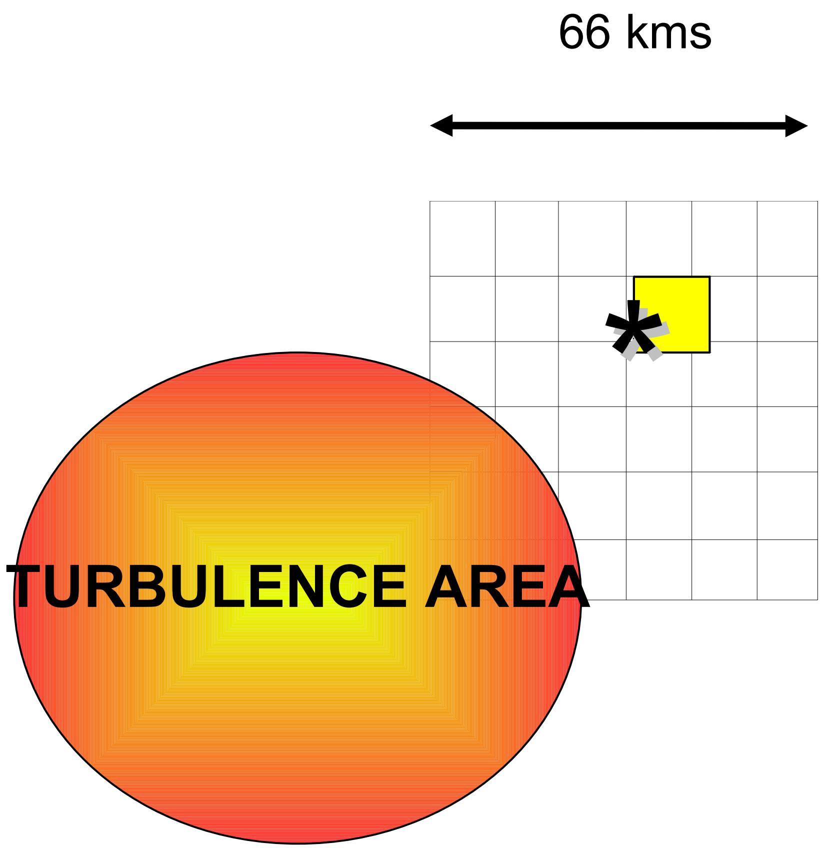


Remarks

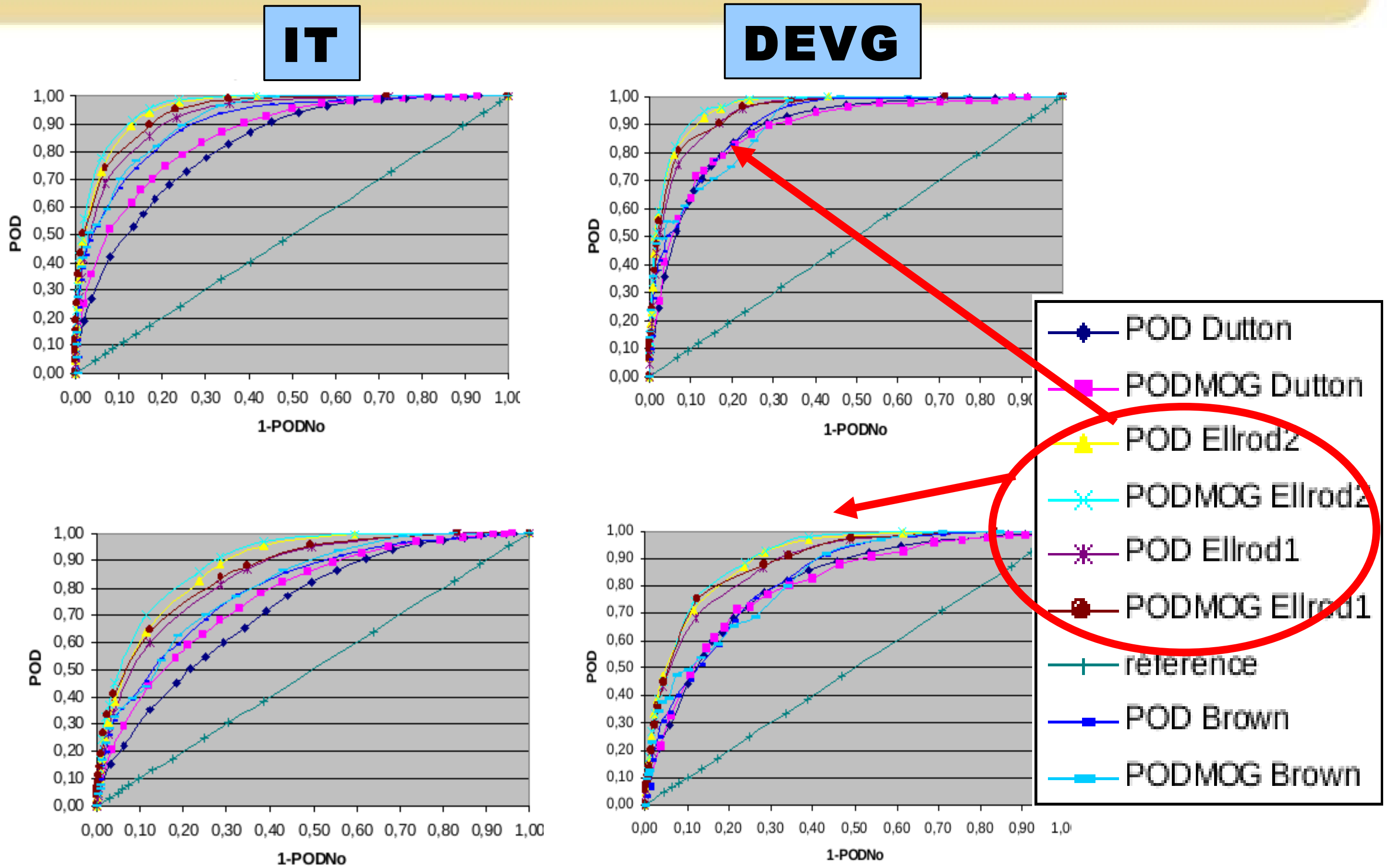
- Observation correspond to the nearest grid point
- A grid =0,1° ~11 kms
- Pilots try to avoid the conditions



Size of the domain of comparism



Results - larger area



100pts
~ 50km around the plane

36pts
~ 30 kms around the plane

Increase the size of the verification domain improves the results

Conclusions

- POD~0,03 very low
- FAR~ 0,05 very low
- % correct = ~ 95% (show this number to Management)

- Rare observations: pilots avoid turbulence regions if they are known (eg. South pacific from New Zealand to USA)
- The scale of the turbulence phenomena has a effect on the verification:
  - Upper air JET = about 100-200 kilometers across
  - Mountain waves 50-100km
- Convection 10-50km (scale would fit the data and only some observed turbulence was in mountainous regions)
- Fine grid scale in model creates meso-scale phenomena in model, this fine scale creates a lot of non-events:
  - 95% correct, because most are non-events (no obs, no fcst)
- → Increase the grid size , increase in POD
- →Verification method has to be adapted to the scale and the user.

Questions ?