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COSMO General Meeting

Five Applications

Sibiu, 2-6 Sept 2013

Jacques Ambühl

Plan

- Use of COSMO-7 data to generate power production forecasts for photovoltaic plants
- Towards operational Clear Air Turbulence diagnostics with COSMO-7
- Dispersion forecast for nuclear pollutants
- Gale warnings with genetic algorithms using COSMO-2 data
- Optimization of sequential sailing decisions based on COSMO-2

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Use of COSMO data to generate power production forecasts for photovoltaic plants

Dominik Büeler ETHZ IAC

Jacques Ambühl, Meteo Swiss; COSMO GM 2013

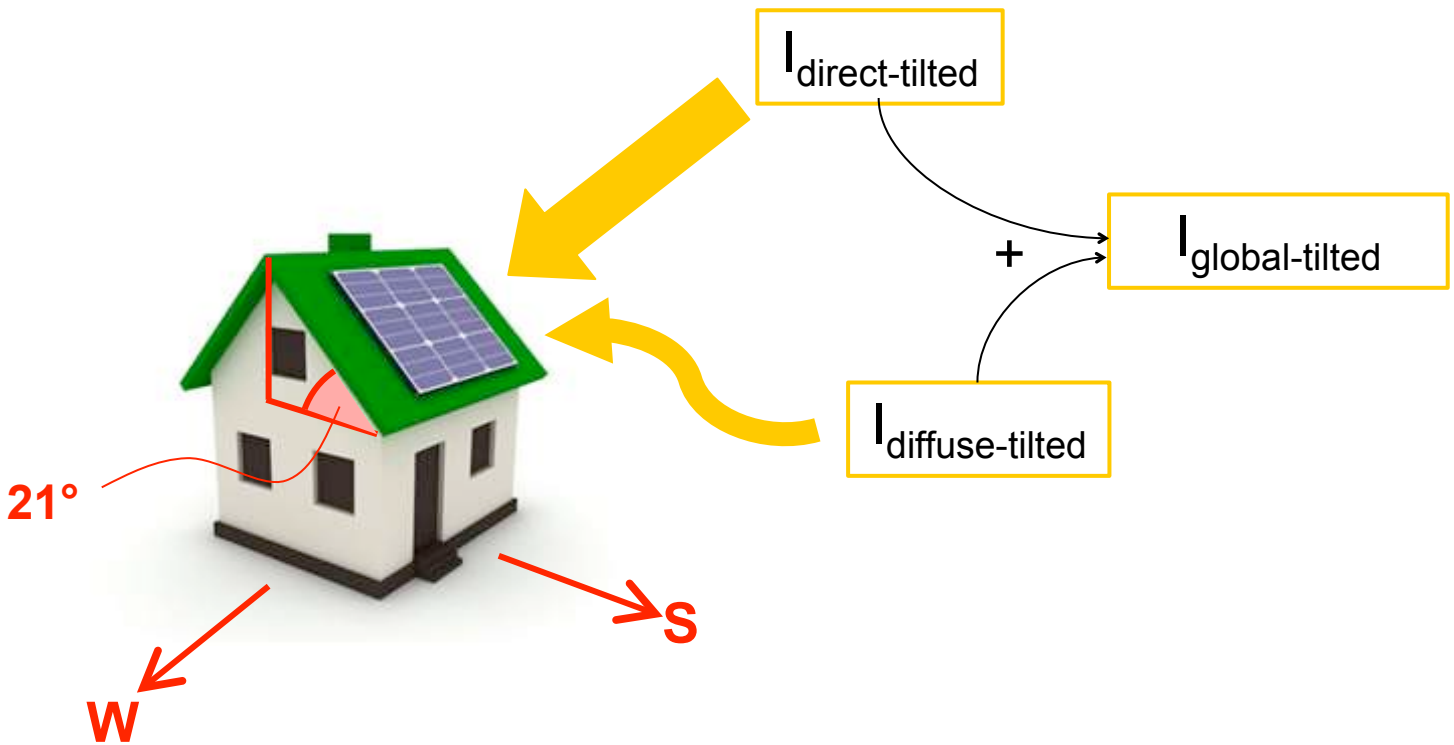
- Generate day-ahead power production forecasts for a Swiss wide system of photovoltaic (PV) plants in 15-min resolution based on COSMO
- Benefit of COSMO (mainly irradiance data) in meeting the needs of the energy sector for highest-resolution weather prediction data both temporally and spatially
- Quantification and discussion of meteorological and technical errors / uncertainties associated with a PV power production forecast based on COSMO

Data	Source	Temporal resolution	Spatial resolution
COSMO-2	MeteoSwiss	1 h	2.2 x 2.2 km
Satellite	MeteoSwiss	15 min / 24 h	1.1 x 1.7 km
Surface observations	MeteoSwiss	10 min / 24 h	SwissMetNet Stations
PV metadata	ewz	-	PV plants
PV production data	ewz	15 min	PV plants
Balancing energy prices	Swissgrid	15 min	Switzerland

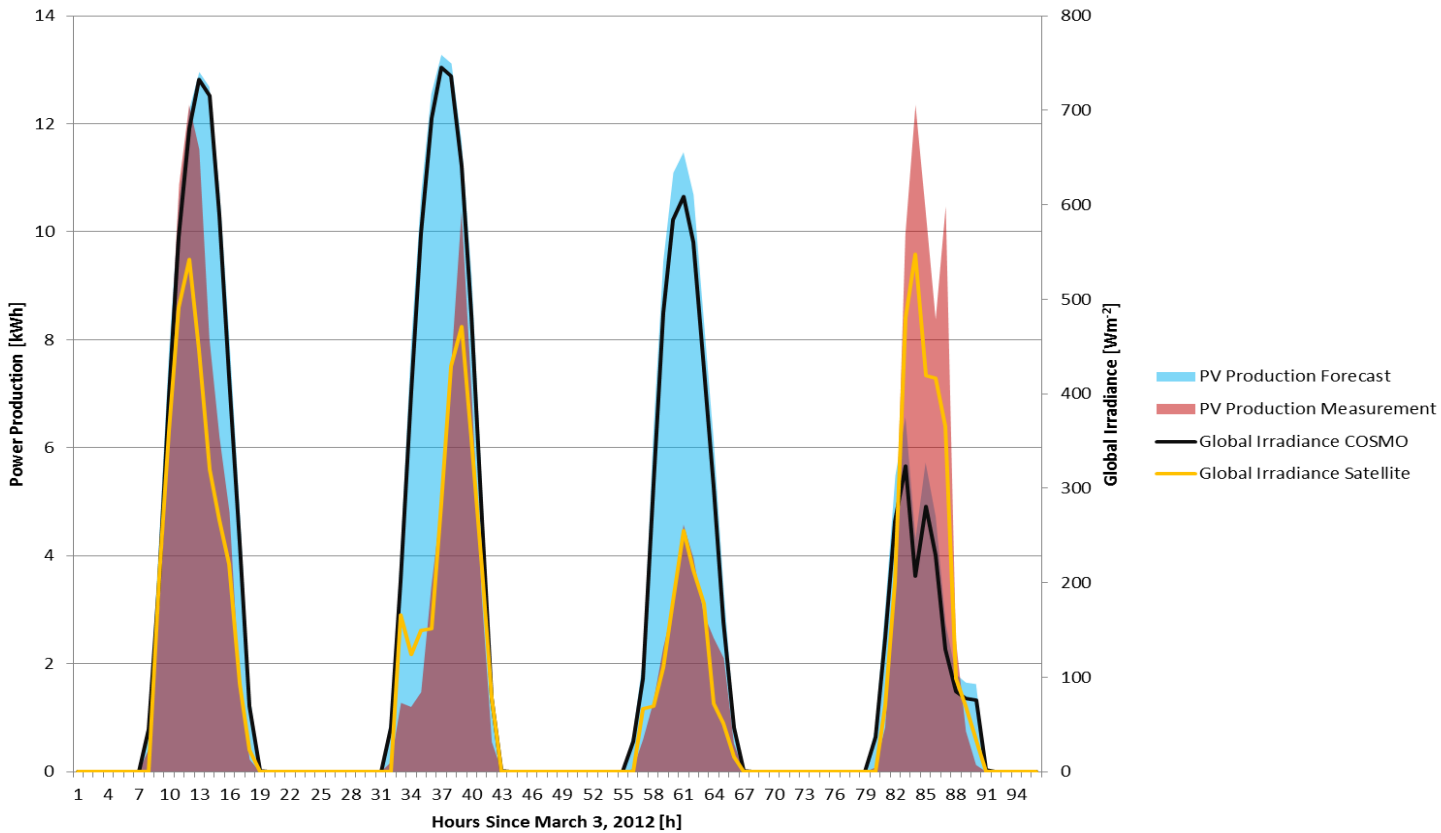
→ *COSMO-2: most representative grid point for each PV plant location as data basis*
→ *Satellite: closest grid point for each PV plant location as data basis*

→ *All data are available for the years 2010 – 2012*

Method «Tilted»: direct and diffuse irradiance on a horizontal plane (from COSMO-2) are transformed on a tilted and oriented PV surface and summed up to the global irradiance

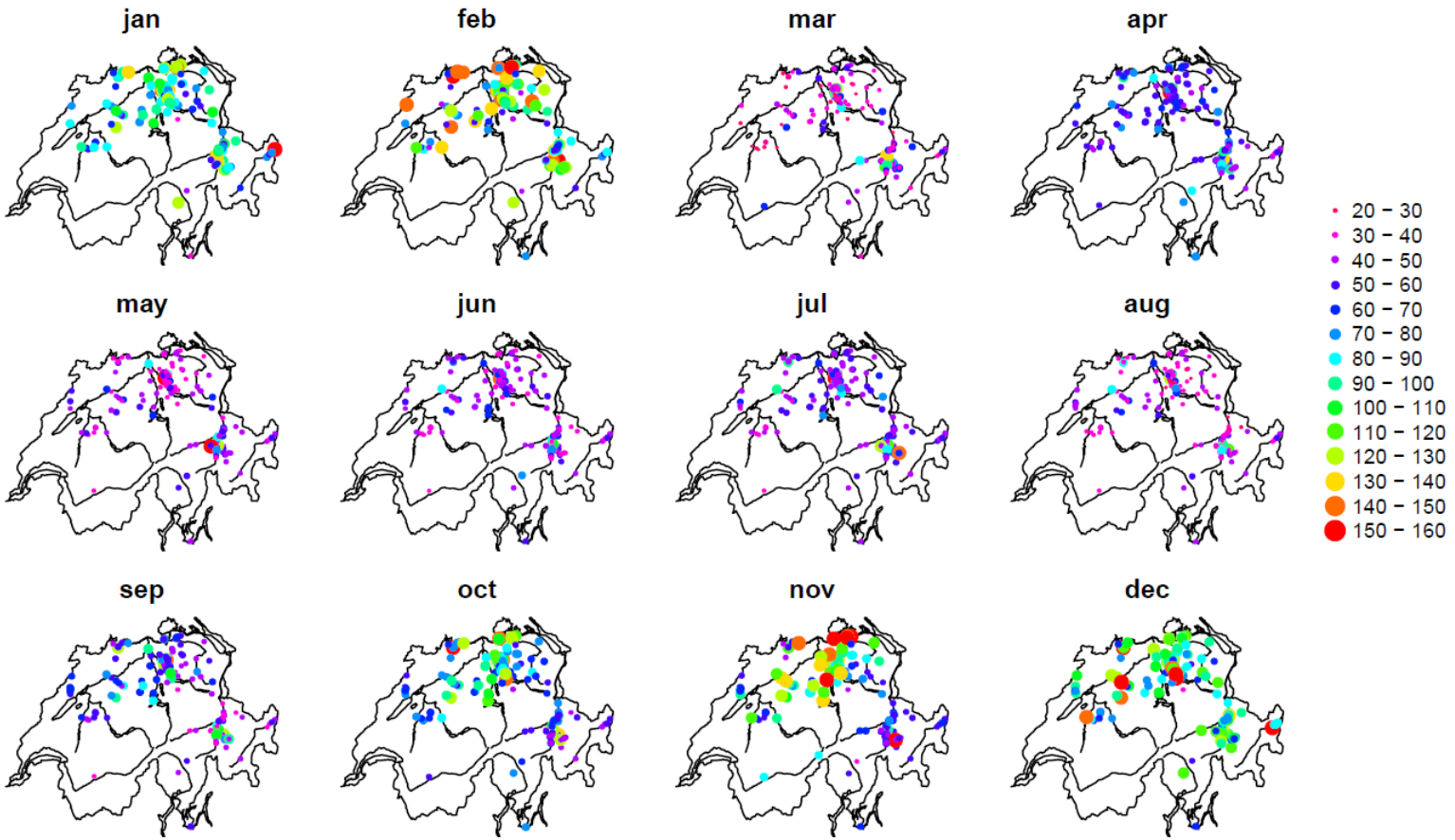


PV forecast verification: «Tilted» | time series example | March 3 – 6, 2012



Jacques Ambühl, Meteo Swiss; COSMO GM 2013

PV forecast verification: «Tilted» | RMSE | 2012 | corrected (only for prod. > 0.5 kWh)



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Towards operational Clear Air Turbulence diagnostics with COSMO-7

Fabian Binder ETHZ IAC

Jacques Ambühl, Meteo Swiss; COSMO GM 2013

- CAT Indexes:
  - Gradient Richardson Number RI
  - Ellrod & Knapp Indexes TI1 & TI2
  - Trend Term DTV
  - Divergence Modified Turbulence Index DTI ∋ {TI1, DTV
  - Turbulent Kinetic Energy (TKE)
- Opt. Thresholds
  - RI: 0.7; TI2: 4.0E-6 [s^{-2}]; TKE: 0.6 [J]; DTI: 7.0E-6 [s^{-2}]
- Trade off between thresholds and Volume event
- Tests in 2014

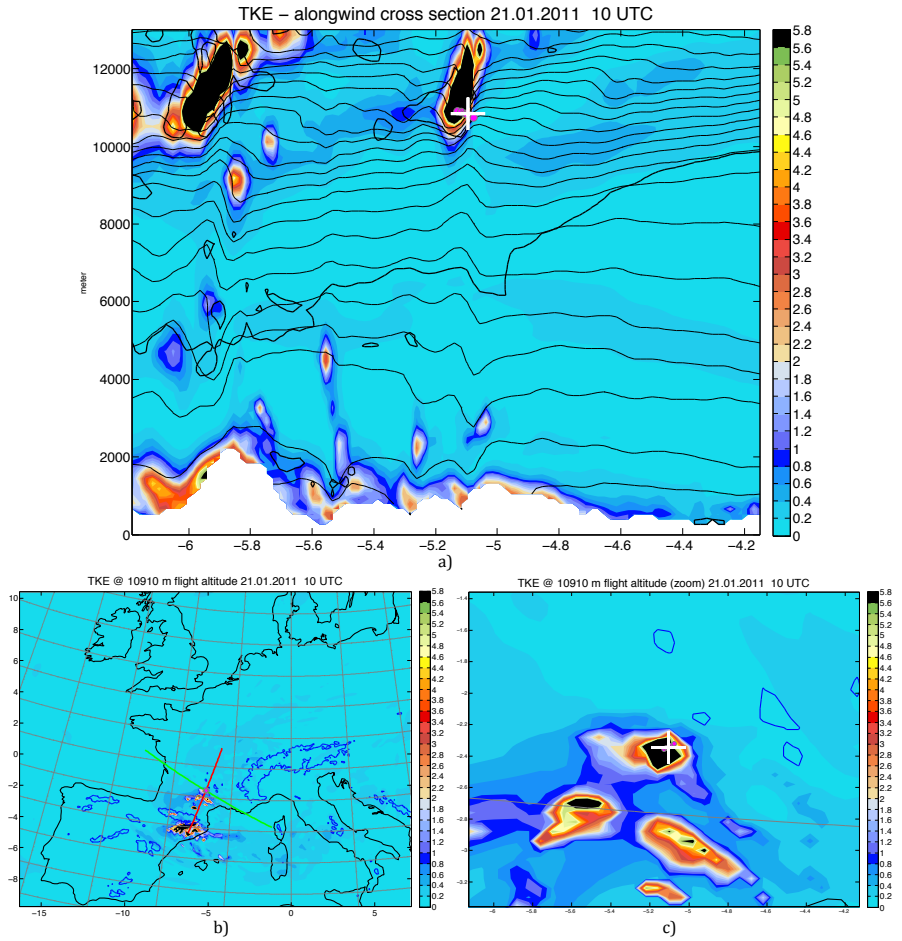
Example CAT Event 21.01.2011:

Massif Central (F):

Mountain Gravity Wave

Source: Swiss Airlines, Flight Data Management

Outcome: objective warning tool for aviation forecasters



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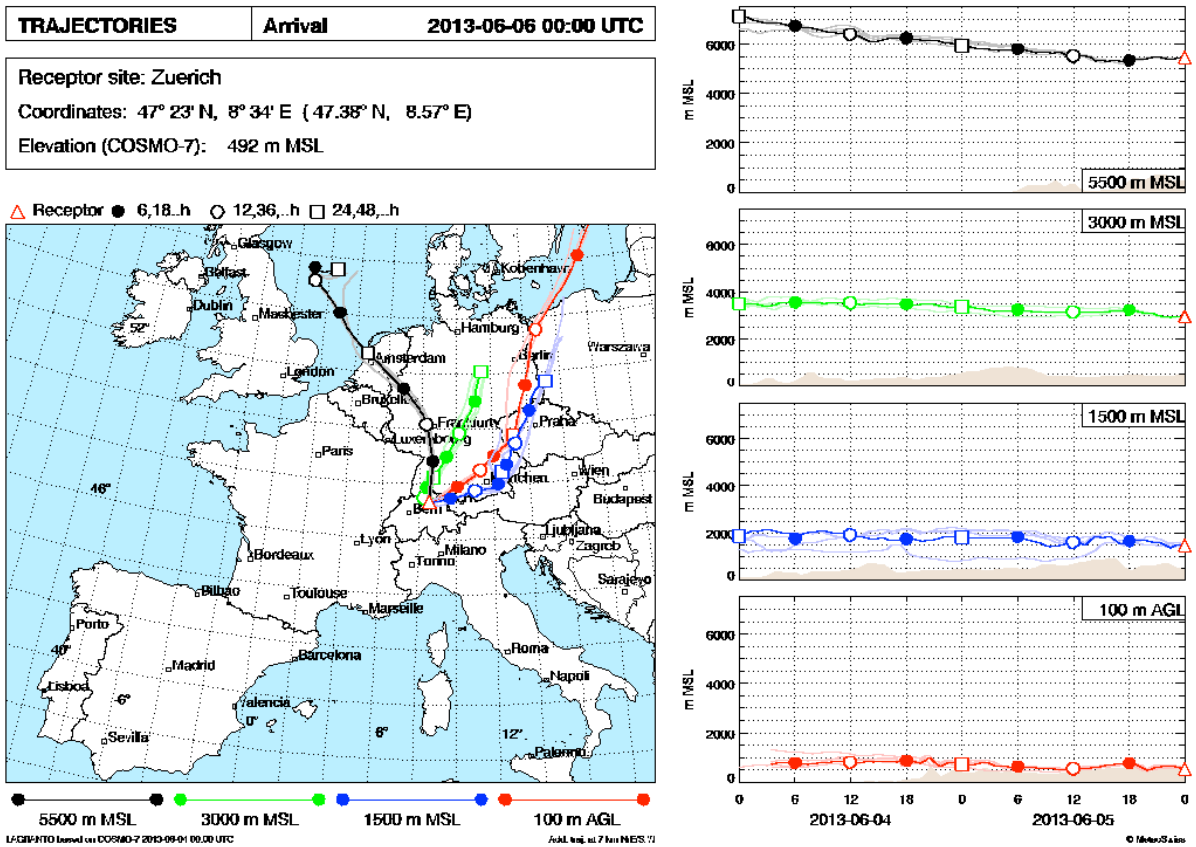
Dispersion forecast for nuclear pollutants

Pirmin Kaufmann
MeteoSwiss, Federal Administration

COSMO-7

Dispersion path of an air parcel starting from Zürich

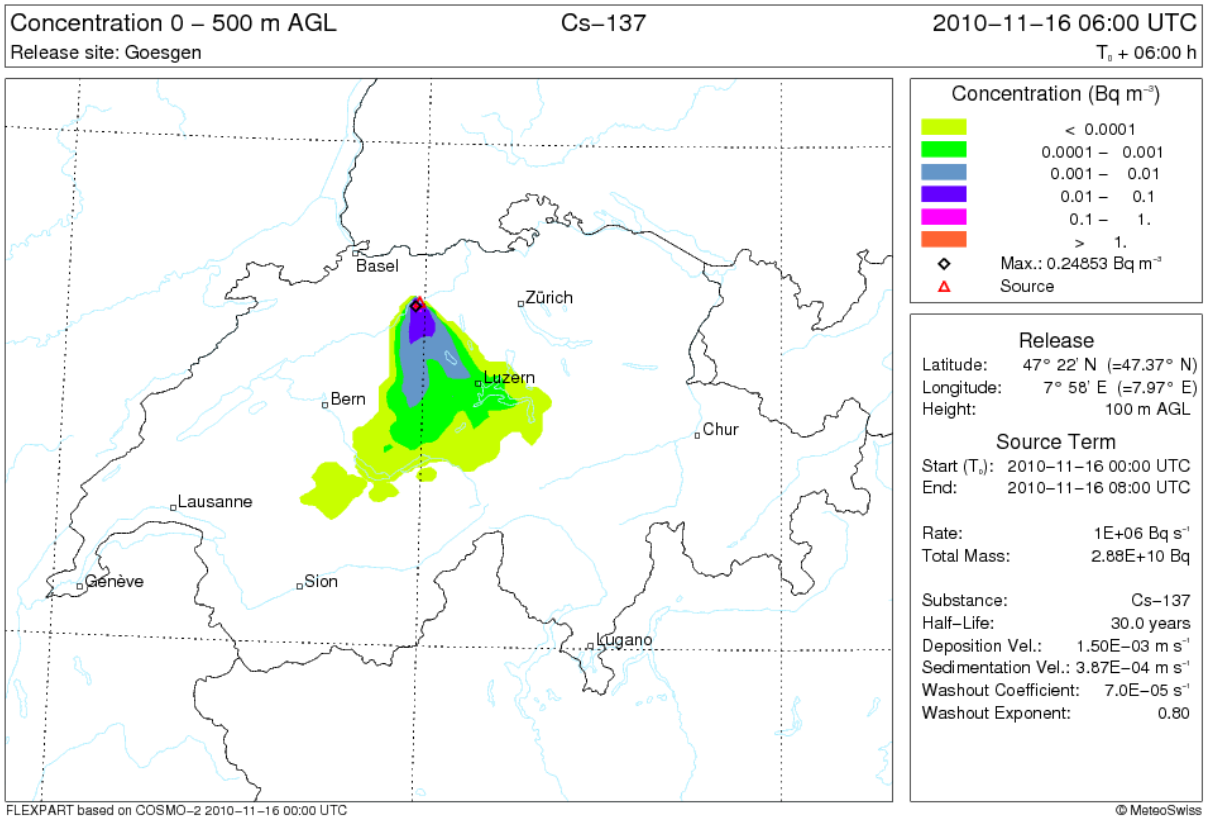
Fast estimation



COSMO-2

Dispersion & concentration of radioactive pollutants starting from Gösgen.

Comprehensive simulation



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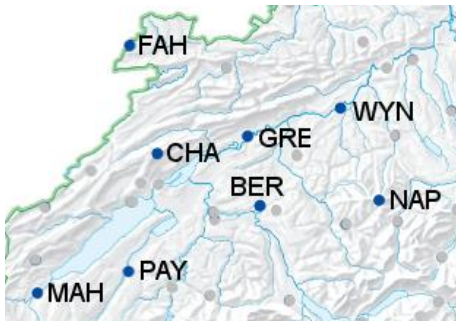
Gale warnings with genetic algorithms using COSMO-2 data

Roman Voisard, Manuela Züger Uni ZH AI Lab
Lysiane Mayoraz ETHZ IAC

Herds dynamics: nowcasting of gales with genetic programming



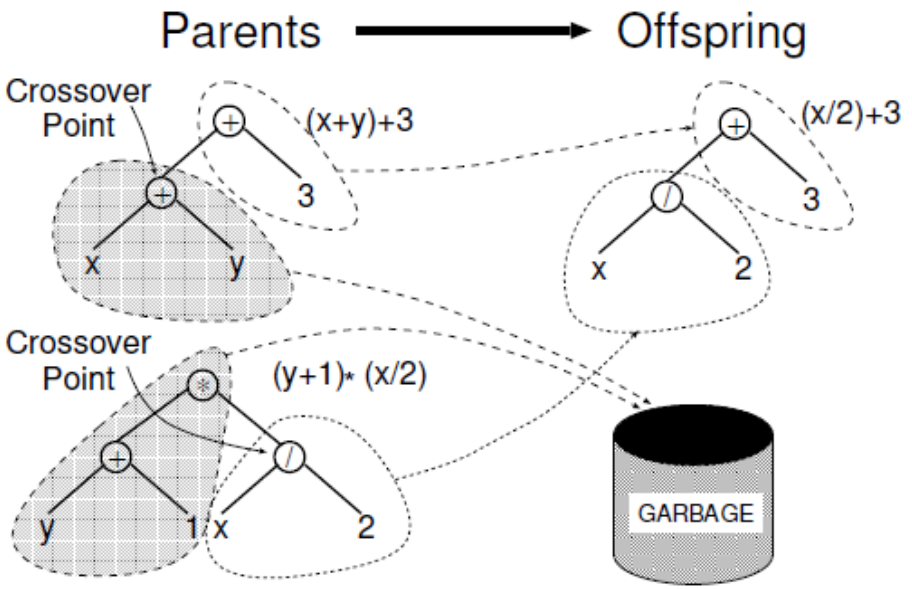


Figure 7: Example of sub tree crossover (Poli, Landon, & McPhee, 2008)

300 - 1000 generations

1000 individuals per generation

ensembles with 20 individuals

System under further development

```
divide.evaluate(pow.evaluate(fmo, 7.598043337179606), dmo)
```



```
    Depth = 3
    Fitness = 5487.260577858043
    Hit Rate = 98.25662482566248
    FalseAlarmratio = 44.15378517637733
    TestFitness = 5450.160304096759
    Test Hit Rate = 97.48603351955308
    TestFalseAlarmratio = 44.092911493792556
```

```
plus.evaluate(5.295243401974644,
exp.evaluate(minus.evaluate(pow.evaluate(8.235782453080361,
min.evaluate(sine.evaluate(tt40), 7.224975929882489)),
exp.evaluate(sine.evaluate(multiply.evaluate(log.evaluate(pow.evaluate(log
.evaluate(5.426030439601154), exp.evaluate(2.016302169365234))),
minus.evaluate(1.5110163068855542, tt60))))))
```

```
    Depth = 10
    Fitness = 803.8617518559158
    Hit Rate = 13.94700139470014
    FalseAlarmratio = 42.363112391930834
    TestFitness = 431.4222138055109
    Test Hit Rate = 9.427374301675979
    TestFalseAlarmratio = 54.23728813559322
```

Herds dynamics: nowcasting of gales with genetic programming

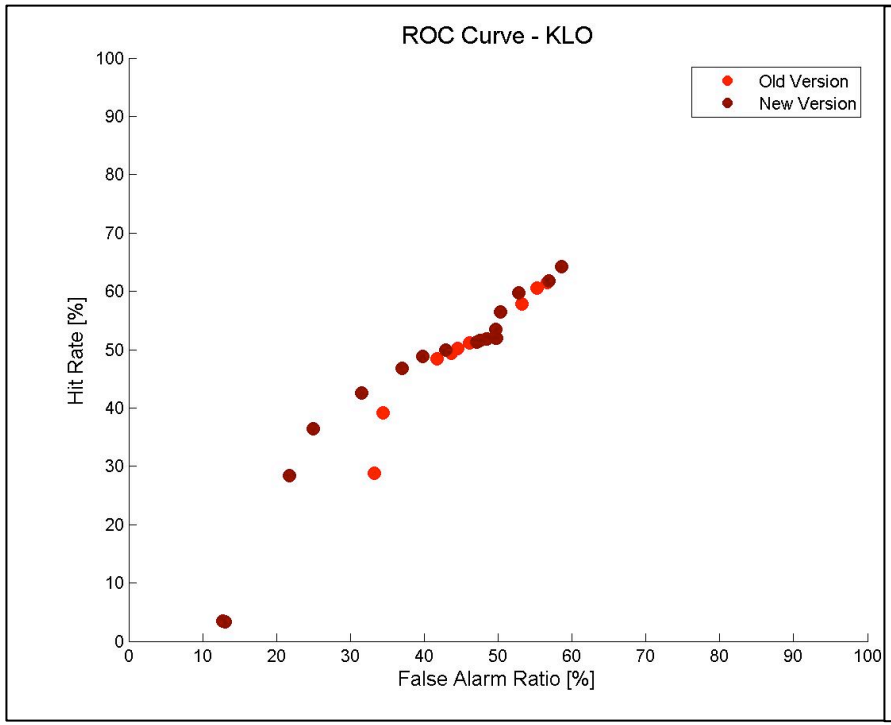
```
div
plu
ifE
d00
d60), 5.7217590097084, 4.168310361526711)),
pow.evaluate(max.evaluate(plus.evaluate(multiply.evaluate(multiply.evaluate(pow.evaluate(minus.evaluate(f20, plus.evaluate(qf40,
7.074758580356248)), 3.9596438991780456), max.evaluate(exp.evaluate(tt40), mmo)), multiply.evaluate(tp40, d20)),
ifElseThen.evaluate(3.5117337093986056, pow.evaluate(max.evaluate(min.evaluate(f00, plus.evaluate(7.0407142440130235, tp40)),
log.evaluate(minus.evaluate(8.215013810404919, 5.686086056525813))), ifElseThen.evaluate(minus.evaluate(tp60, exp.evaluate(f00)),
max.evaluate(fmo, 2.077248774619843), ifElseThen.evaluate(qf40, ifElseThen.evaluate(d60, f40, tt40, tt60), 9.819823338454908,
ifElseThen.evaluate(0.1293375089801585, 6.171938941943528, tp60, tpt)), ttt)),
min.evaluate(sine.evaluate(sine.evaluate(min.evaluate(4.356468293326104, 3.7643533991009437))), log.evaluate(8.924252353471719)),
tpt)), qf60), minus.evaluate(divide.evaluate(pow.evaluate(sine.evaluate(max.evaluate(sine.evaluate(plus.evaluate(f60,
4.901973747799307)), multiply.evaluate(d60, 4.444514844502521))), 2.8856566954867113), ifElseThen.evaluate(3.5282325518722955,
divide.evaluate(min.evaluate(d00, qf60), qf40), 2.782942429981783, ttt)), minus.evaluate(1.5471842086219156,
1.4214887917363217))))), minus.evaluate(exp.evaluate(f00), min.evaluate(d60,
max.evaluate(max.evaluate(plus.evaluate(multiply.evaluate(log.evaluate(sine.evaluate(plus.evaluate(qf40, tt20))),
multiply.evaluate(tp60, qf40)), minus.evaluate(tt60, 7.393229781243173)),
max.evaluate(multiply.evaluate(sine.evaluate(log.evaluate(mmo)), log.evaluate(log.evaluate(min.evaluate(divide.evaluate(f20,
2.5355487159252474), exp.evaluate(tp60))))), d20)), mmo)))), max.evaluate(dmo, d20)),
log.evaluate(min.evaluate(plus.evaluate(ifElseThen.evaluate(qf20, tp40, minus.evaluate(fmo, divide.evaluate(mmo, fmo)),
max.evaluate(dmo, mmo)), 4.703888157585869), max.evaluate(6.941210952688398,
ifElseThen.evaluate(multiply.evaluate(6.1221500448510655, min.evaluate(plus.evaluate(1.9720986506835103, 2.4887295465961987),
ifElseThen.evaluate(exp.evaluate(multiply.evaluate(0.7940071865385323, qfe)), plus.evaluate(d40, qf20),
sine.evaluate(7.759870749566222), multiply.evaluate(plus.evaluate(1.6441563478507293, f60), tt40)))), f60,
multiply.evaluate(tt40, plus.evaluate(multiply.evaluate(plus.evaluate(exp.evaluate(ifElseThen.evaluate(max.evaluate(qfe,
log.evaluate(2.795088277634706)), qf20, ifElseThen.evaluate(qf40, sine.evaluate(0.5427474597208304),
divide.evaluate(4.891146685200969, tp40), divide.evaluate(9.211053729636866, d20)), 3.3613880147278485)),
max.evaluate(minus.evaluate(2.1476839510359813, 6.224490292998265), min.evaluate(ifElseThen.evaluate(tp20,
pow.evaluate(6.055036006277885, 5.624835015943659), min.evaluate(1.2461272501542653, 9.388307443376117), f20),
pow.evaluate(pow.evaluate(tp20, d60), sine.evaluate(5.278444724215593))))), f00), sine.evaluate(ttt))), qfe))))),
min.evaluate(qfe, 4.608298012209561)), min.evaluate(min.evaluate(fmo, divide.evaluate(log.evaluate(max.evaluate(tt60, tp60)),
1.9858918908009104)), log.evaluate(pow.evaluate(log.evaluate(max.evaluate(8.79562243801495, dmo)), ifElseThen.evaluate(d60, tp20,
qf20, 5.589801634828774))))), qfe), 9.036110890239984, pow.evaluate(6.12076610093759, 4.5673174527558995))))
Depth = 20
Fitness = 5045.881402259277
Hit Rate = 99.86052998605301
FalseAlarmratio = 49.47071277346507
TestFitness = 5042.2535211267605
Test Hit Rate = 100.0
TestFalseAlarmratio = 49.57746478873239
```

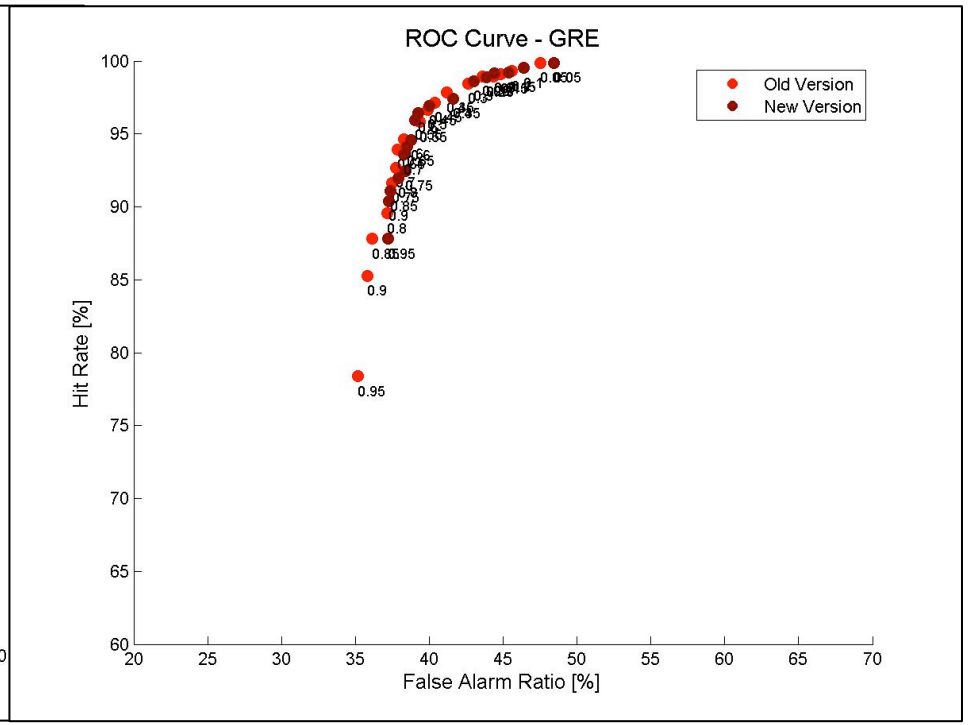
Jacques Ambühl, Meteo Swiss; ECAM2011

Herds dynamics: nowcasting of gales with genetic programming

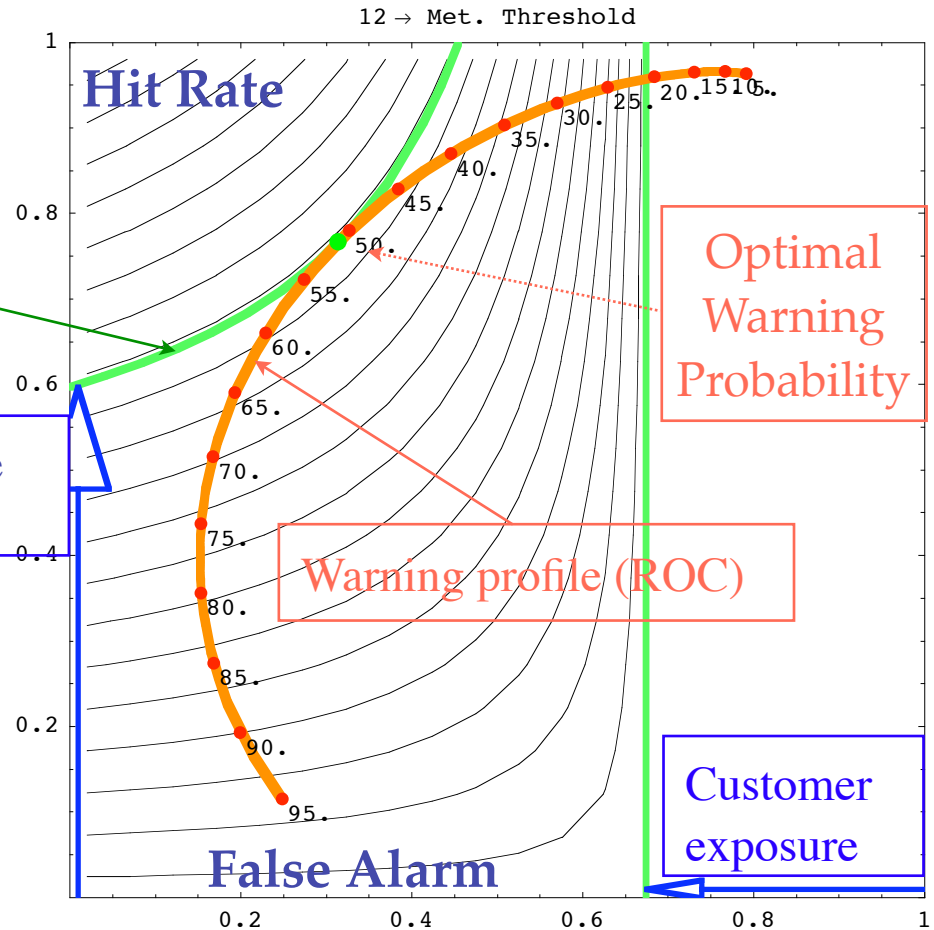
Left: Kloten, without COSMO (only Observations)

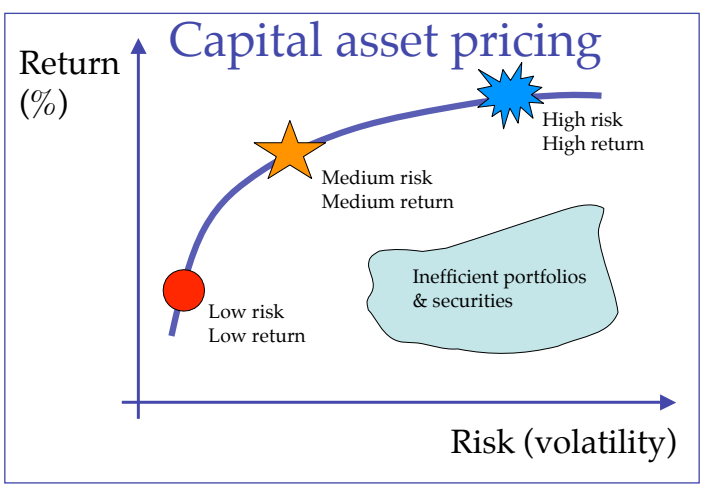
Right: Grenchen, with COSMO (FieldExtra) and Obs





ROC vs Efficient Frontier





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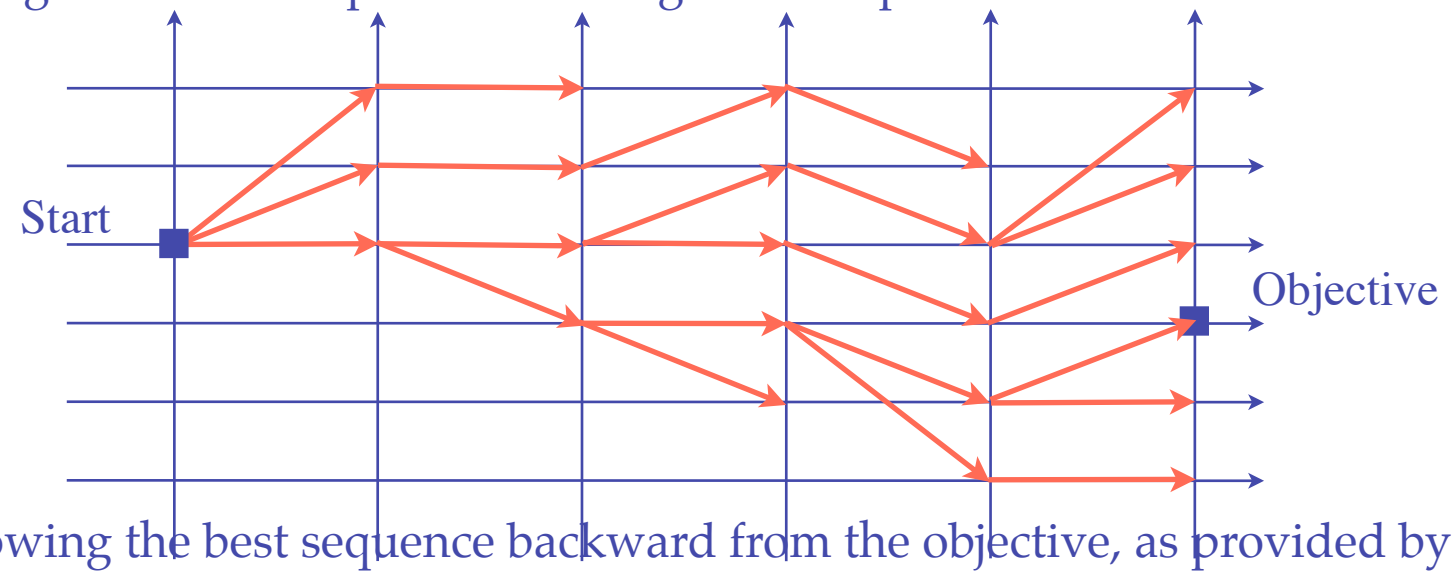
Optimization of sequential sailing decisions based on COSMO-2 forecasts

Jacques Ambühl

Sequential Decision: Dynamical Programming

Seeking forward for options: building a tree of potential decisions



Following the best sequence backward from the objective, as provided by the tree

Optimization of weather dependent sequential processes

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Right:

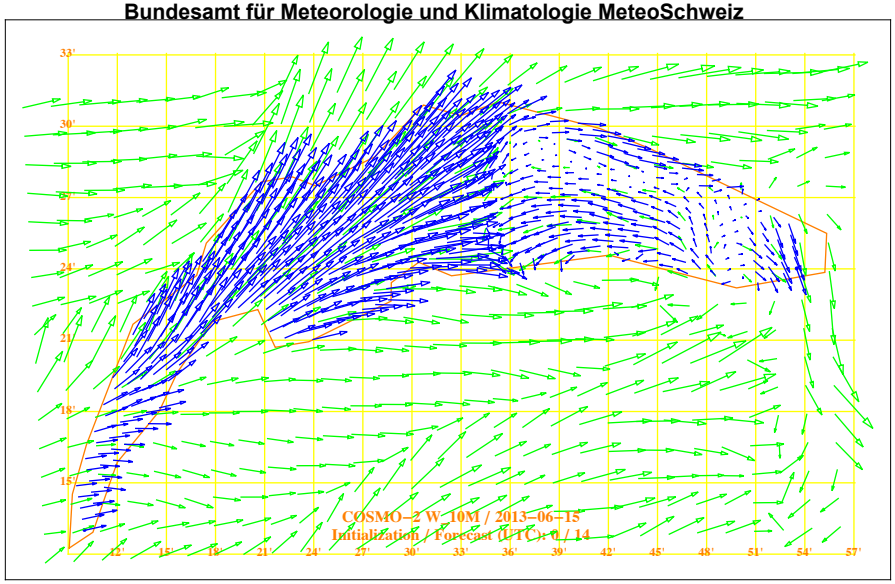
COSMO-2 10m Windfield

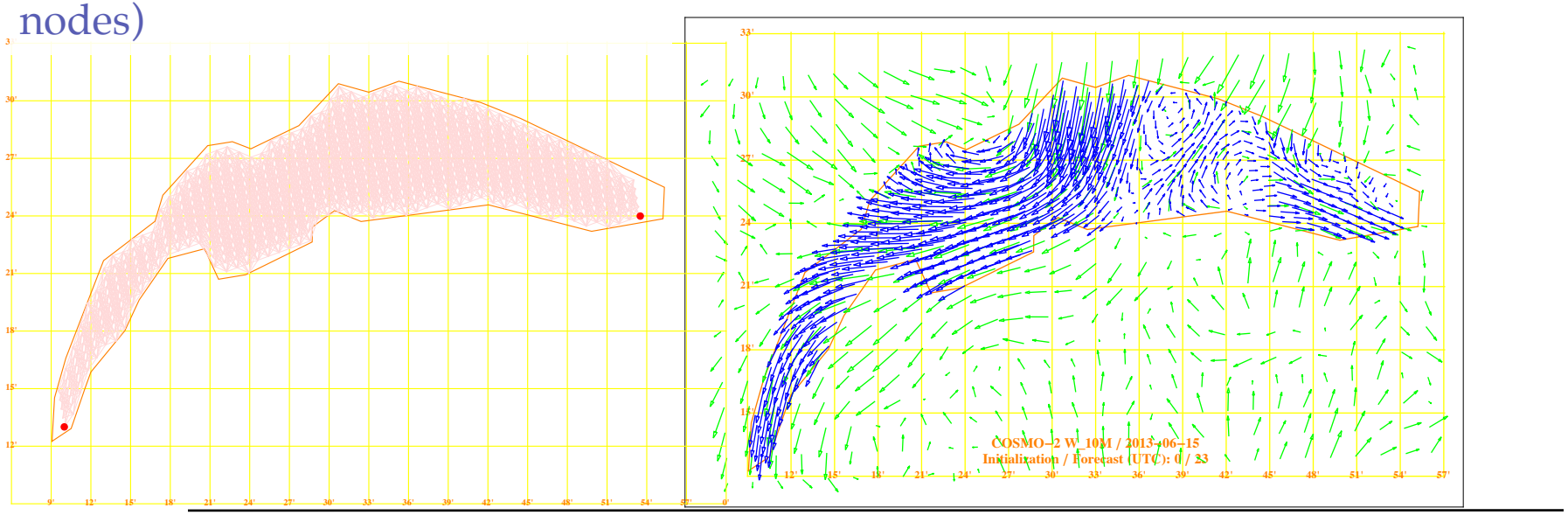
(Extraction: FieldExtra)

Below:

Decision network

(with departure and arrival nodes)





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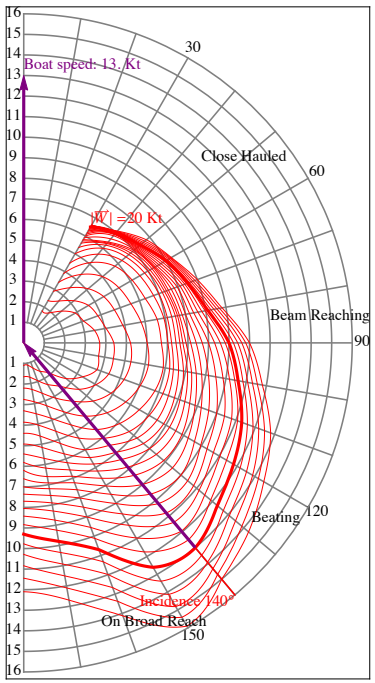
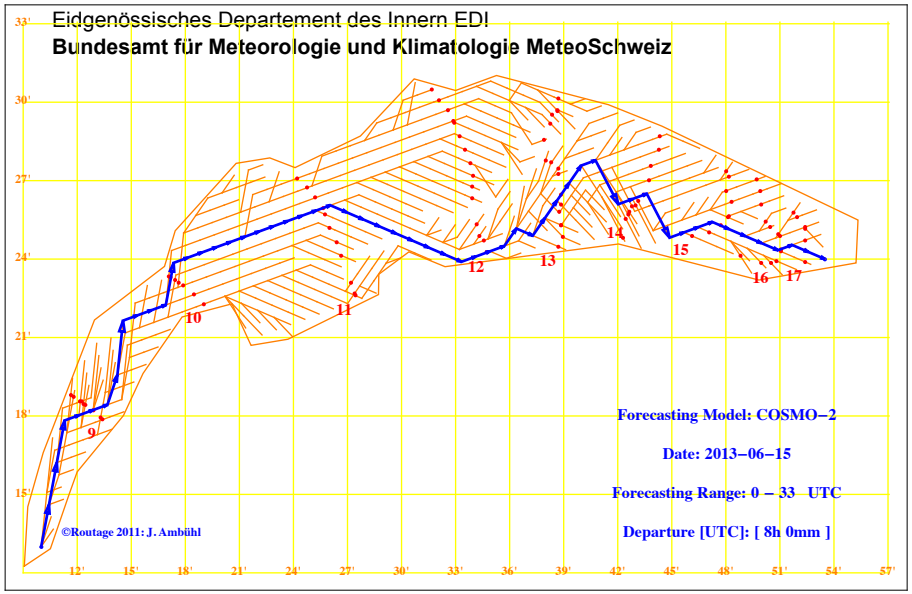
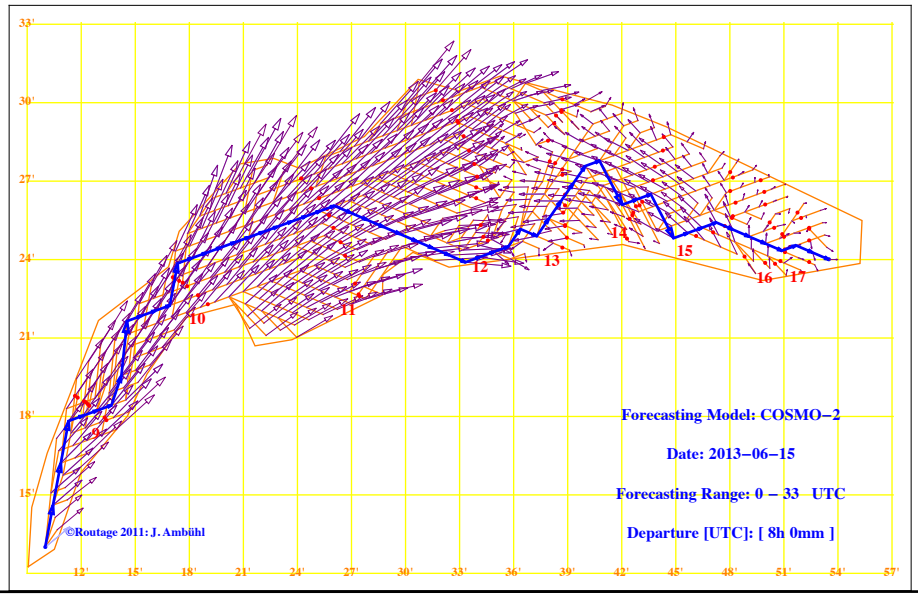
Right: Decision tree and optimal route

Below: Polar diagram of the sailing boat (customer profile)







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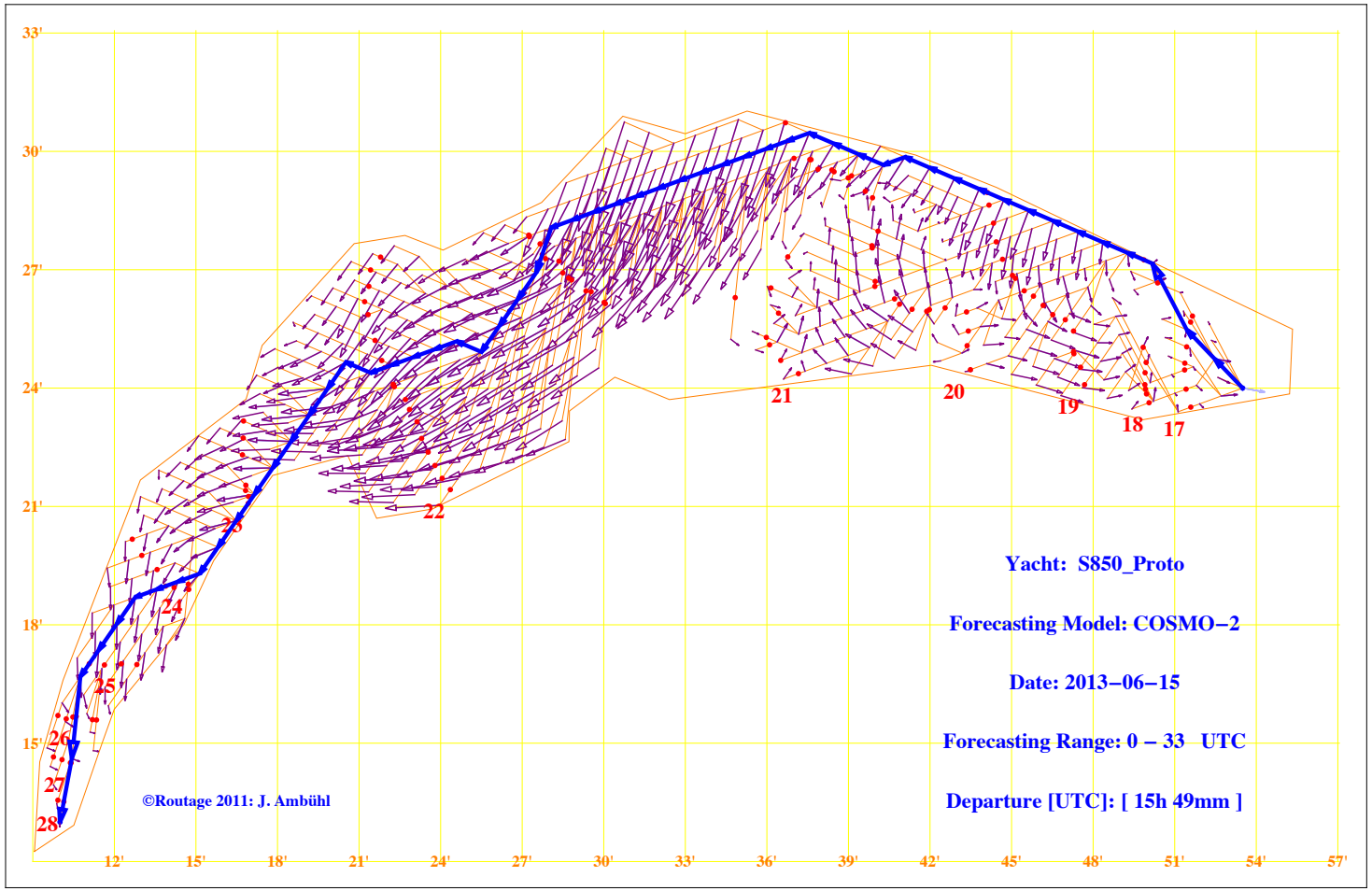
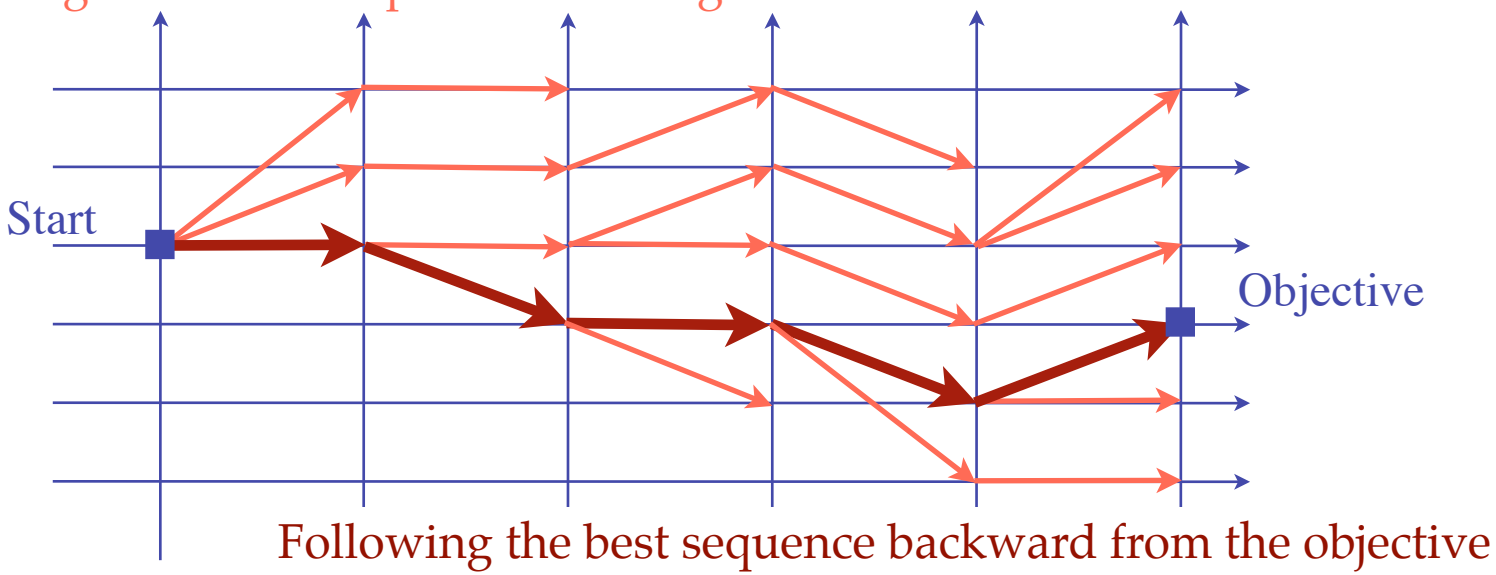


Sequential Decision: Dynamical Programming

Seeking forward for options: building the tree



Classical technique in financial & energy trading

Alinghi, America Cup (EPFL, Prof. Dalang)

Conclusions

- The Customer profile is the yardstick in any optimization process
  - in terms of her/his/its outcome
  - and exposure (risk profile)

- Three fields of competence are merged
  - Probabilistic forecast
  - Bio-inspired artificial intelligence
  - Financial inspiration

- "Computer to computer" service
  - MeteoSwiss, COSMO applications: 110 Gbytes data / 24 hours

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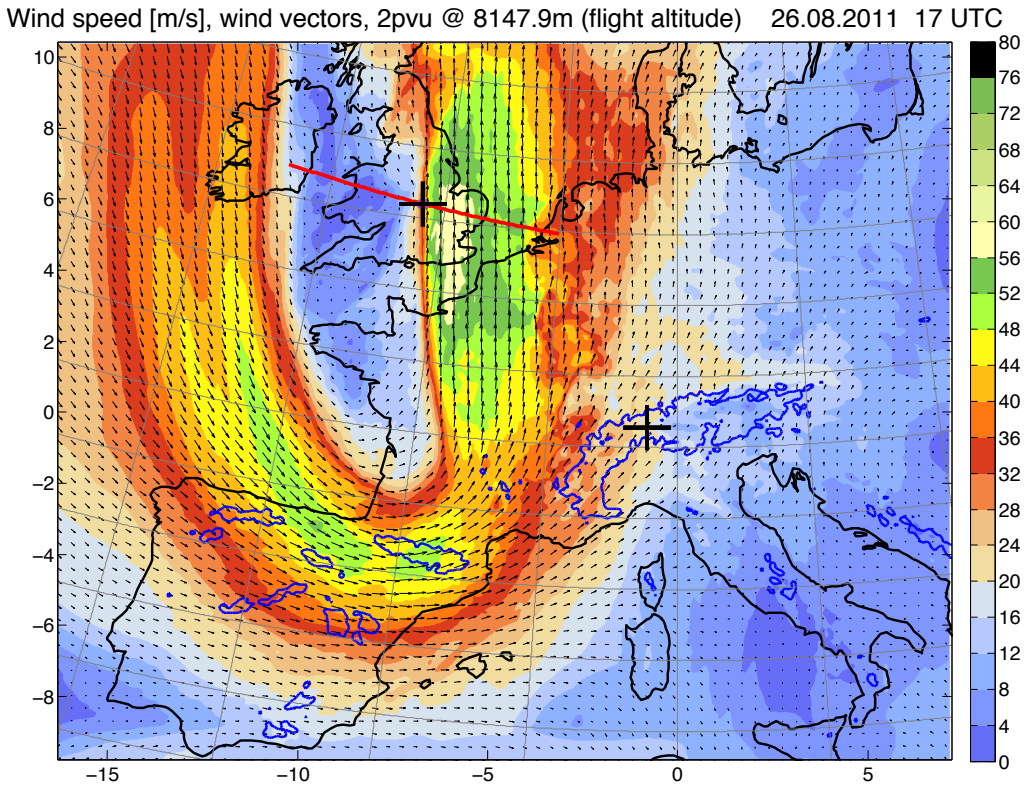
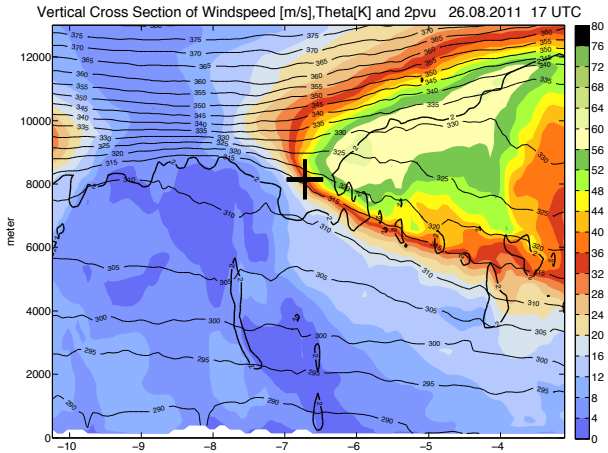
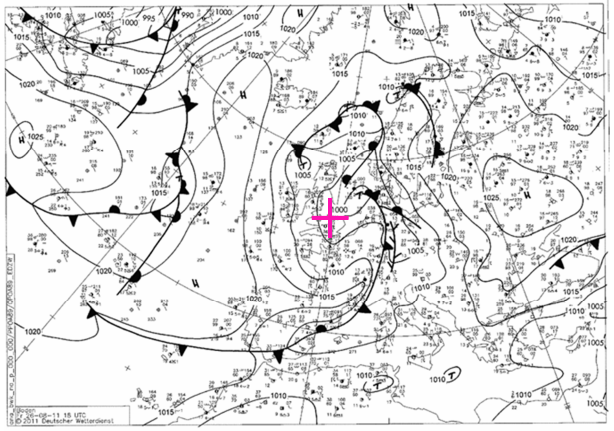


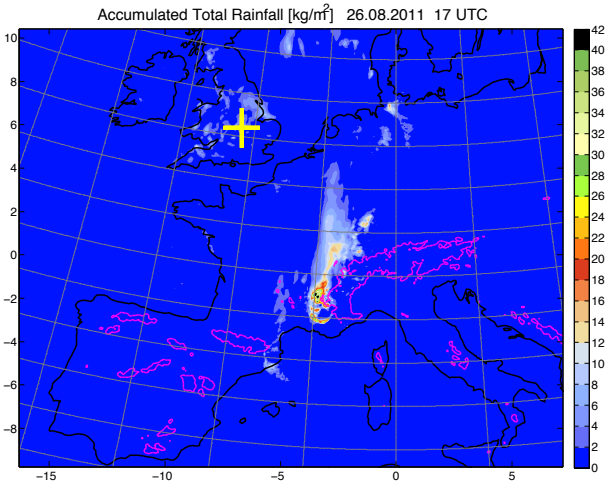
Jacques Ambühl, Meteo Swiss; COSMO GM 2013


Vertical Cross Section of Windspeed [m/s],Theta[K] and 2pvu 26.08.2011 17 UTC
meter

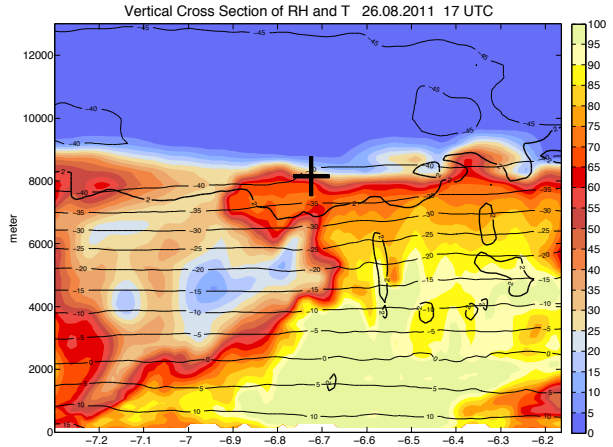
a)



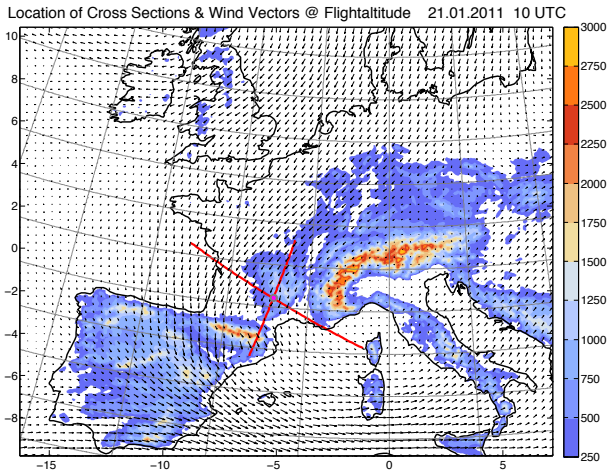
b)


Accumulated Total Rainfall [kg/m2] 26.08.2011 17 UTC

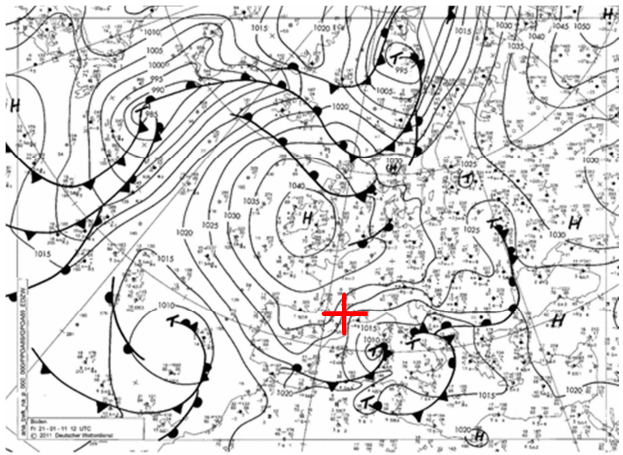
c)


Vertical Cross Section of RH and T 26.08.2011 17 UTC
meter

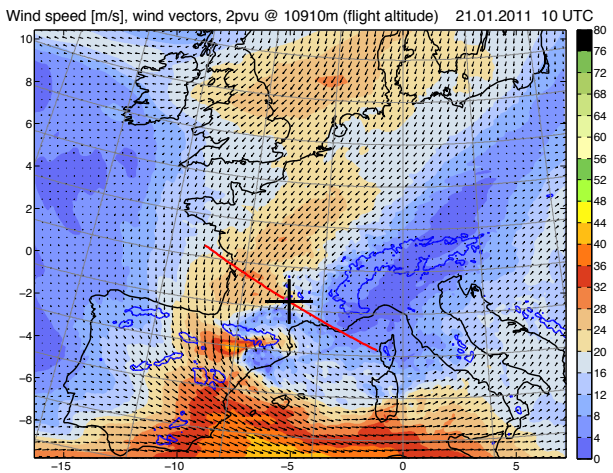
d)



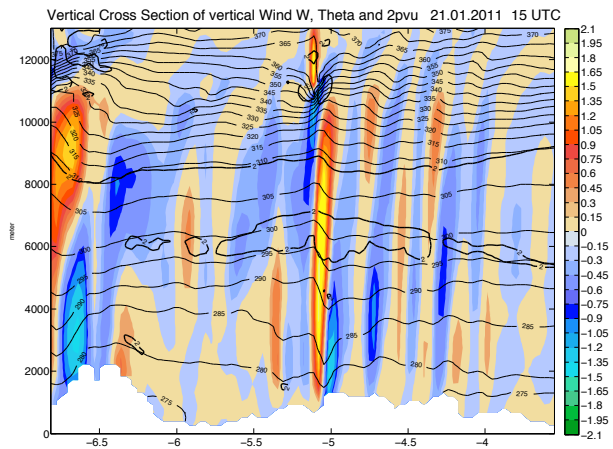
a)



b)



c)



d)

Jacques Ambühl, Meteo Swiss; COSMO GM 2013