Gravity waves over the eastern Alps during IOP–10:

In-situ and remote sensing data compared with a high resolution simulation

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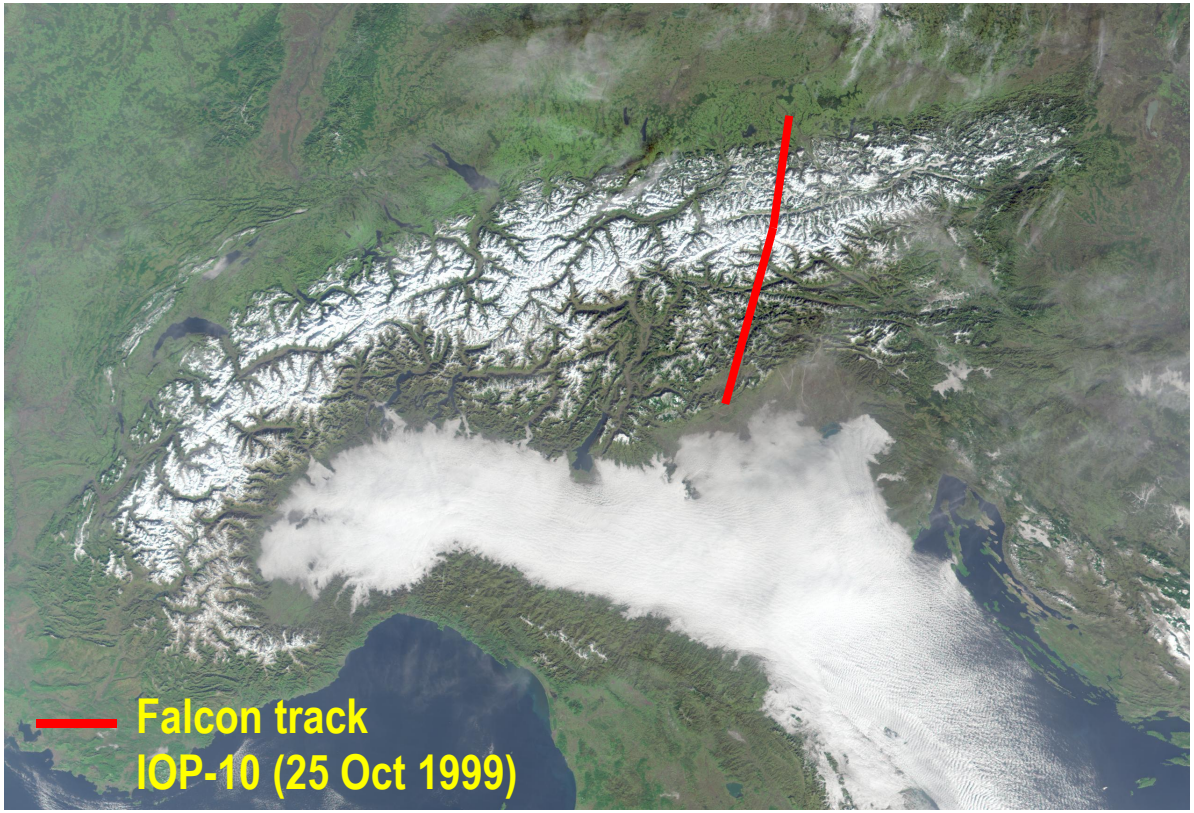


Why are mountain/gravity waves relevant ?

- **they generate coherent and extended vertical motion fields (in contrast to „local“ thermals)**

atmosphere is „rather horizontal“ – 40000 km : 40 km = 1000 : 1

jetstream vs. mean upward motion – 50 m/s : 0.5 m/s = 100 : 1

- **updraughts > 5 m/s are special and worth to be investigated**

Which quantities to look at ?

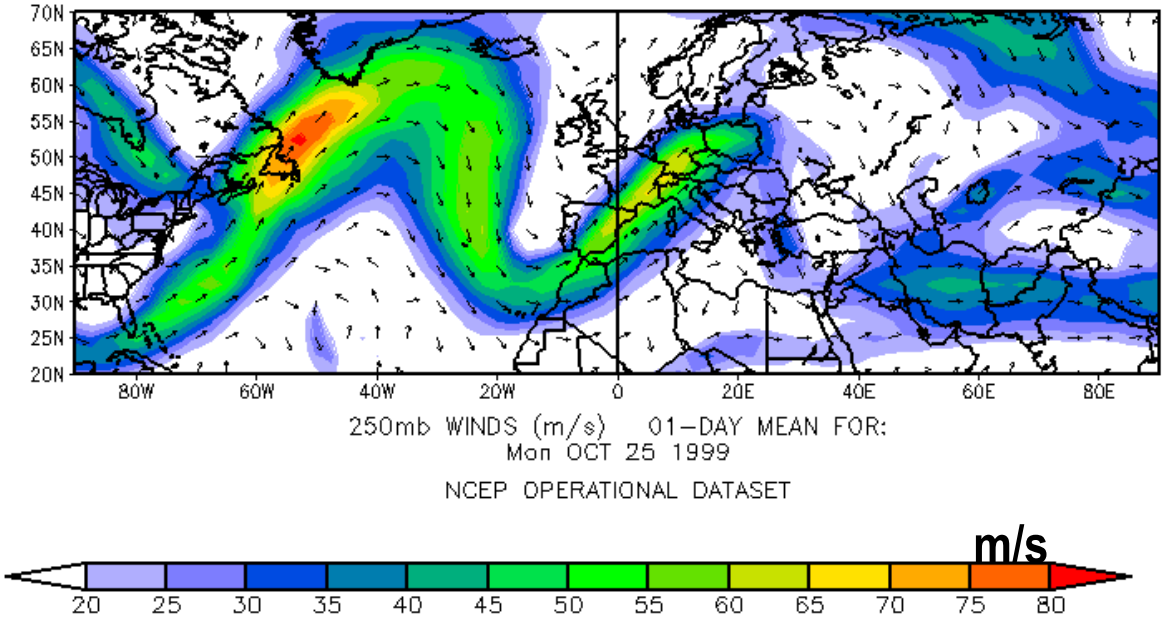
- **potential temperature**
- **vertical velocity**

Specific questions

- **are there indications for wave breaking ?**
- **to what extent can observed cloud decks be simulated ?**
- **rôle of three-dimensional topography ?**

Alps at the end of the Atlantic storm track

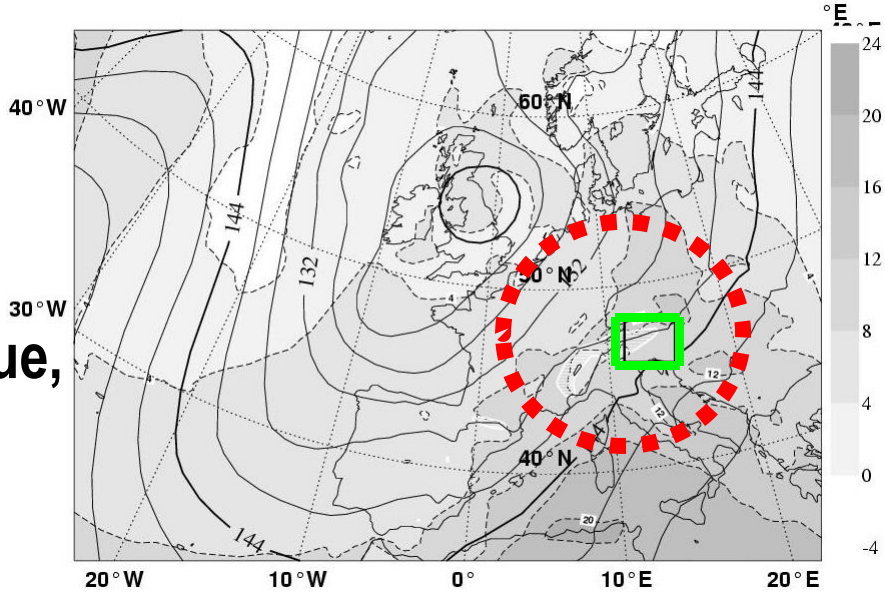
NCEP 250 hPa winds across the Atlantic

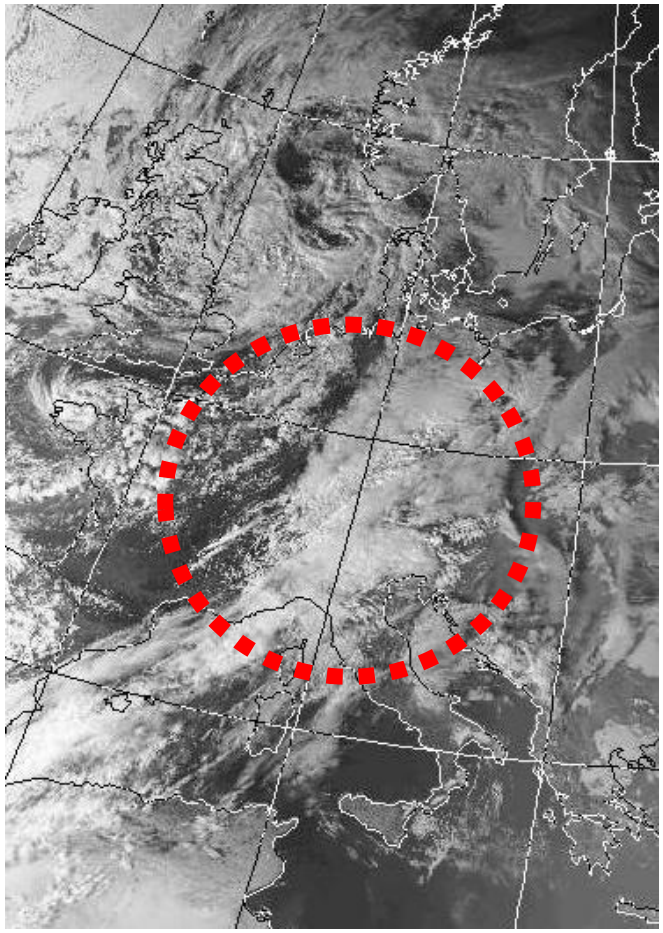


EC re-anal. for 00 UT

T (850 hPa)

warm tongue, foehn enhanced

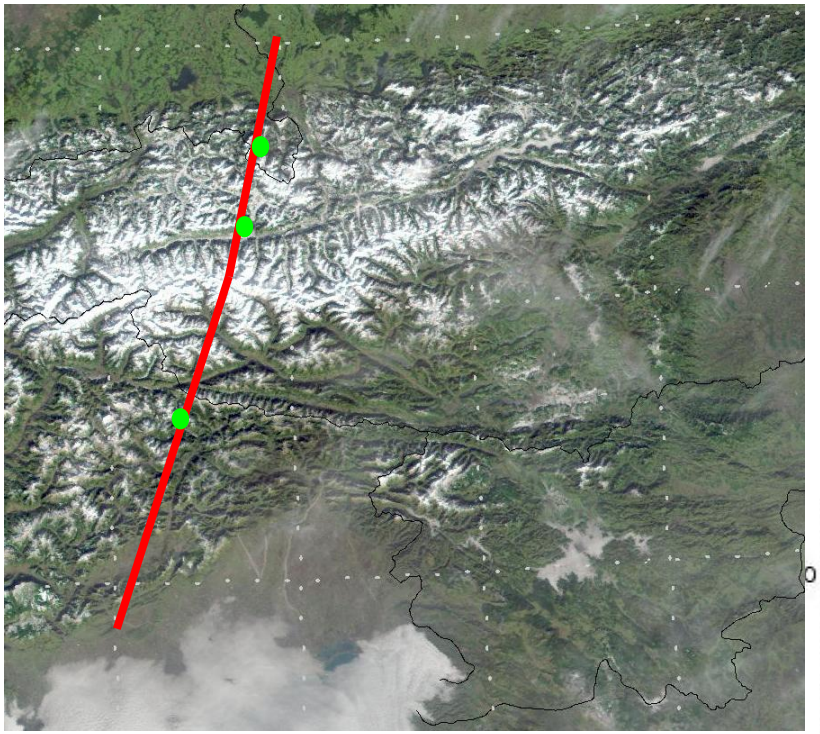


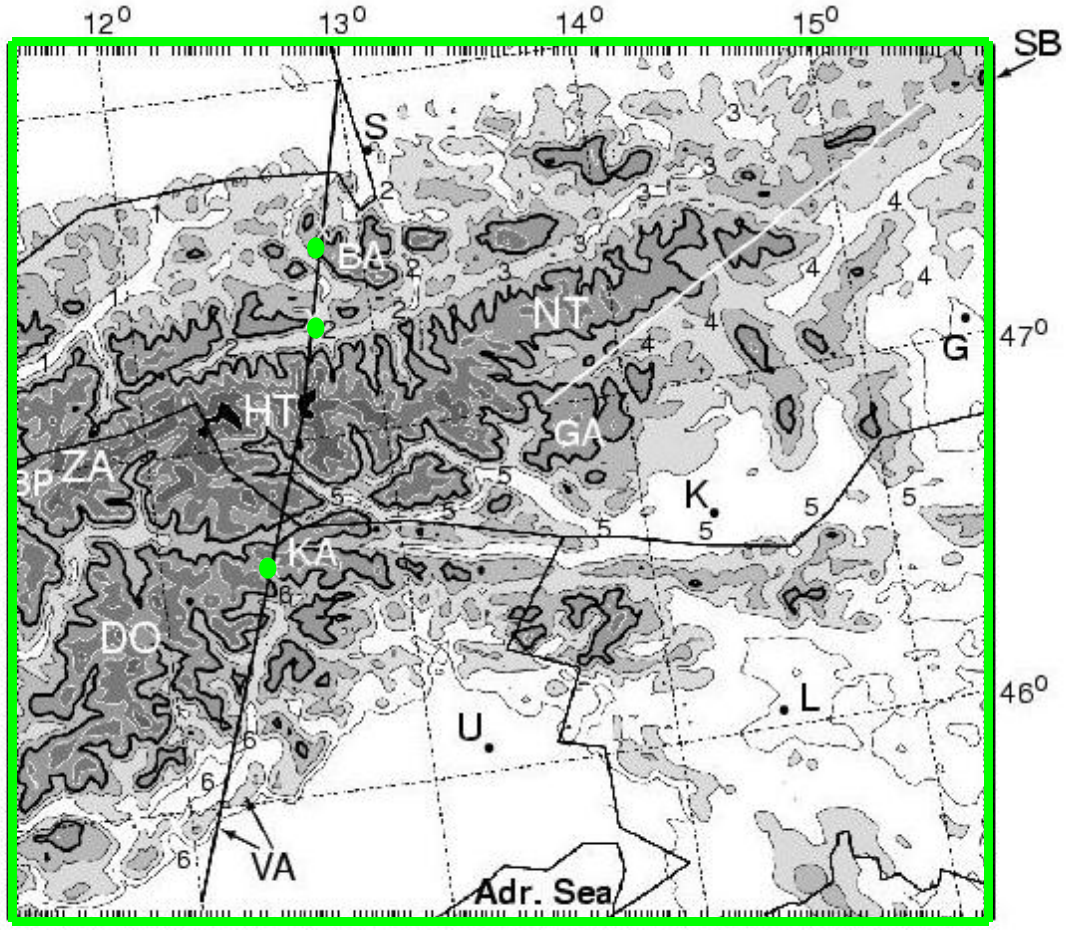


NOAA visible 14:33 UT, frontal clouds above central Europe

Eastern Alpine region ...

... in satellite view (300 m resolution; MODIS on TERRA; 02/02/02)

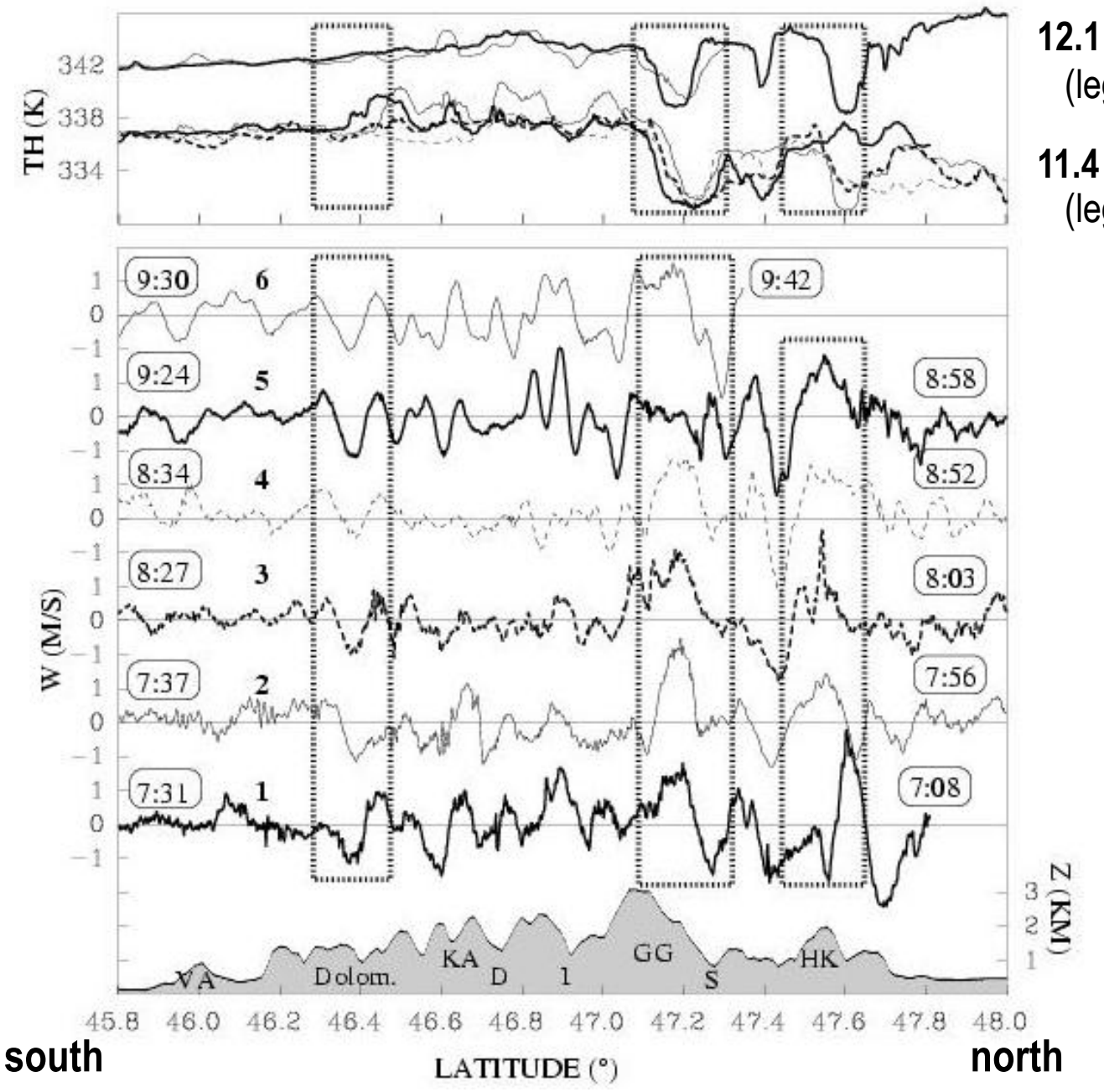




... as 3rd nest in Meso–NH (2 km resolution)

Meso–NH: non-hydro., nested, full-physics research NWP model of Météo France & Lab d'Aérologie

Waves in Falcon level: 6 legs within 2 h 34’



12.1 km
(legs 5, 6)

11.4 km
(legs 1 – 4)

potential temperature

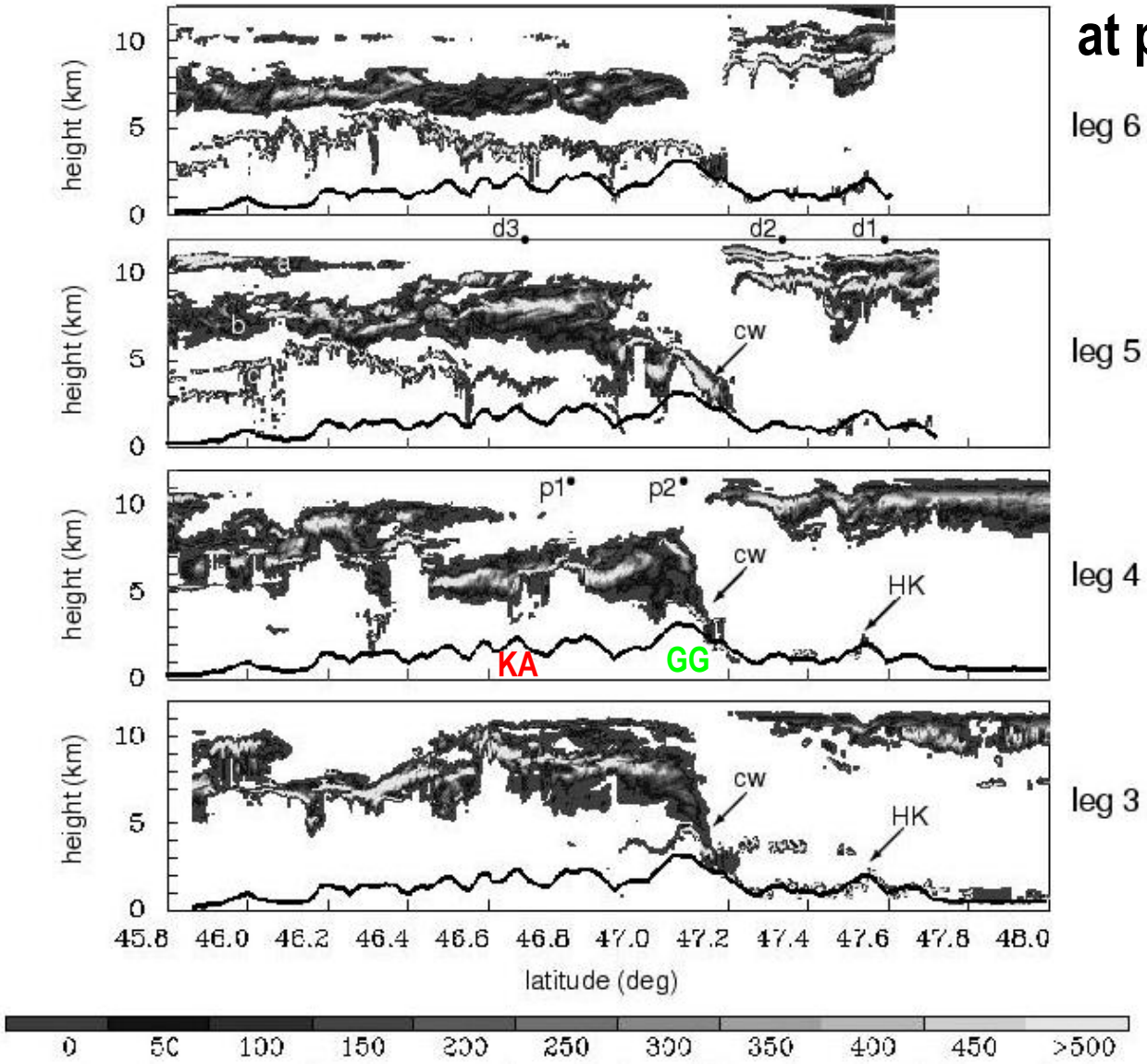
vertical velocity

Topographic features:

VA	Venetianer Alpen
Dolom.	(östl.) Dolomiten
KA	Karnische Alpen
GG	Großglockner
HK	Hochkalter
D	Drau
I	Isel
S	Salzach

Wave seen in cloud layers: Lidar vs. camera

Backscatter of up to 3 layers, at places also from ground

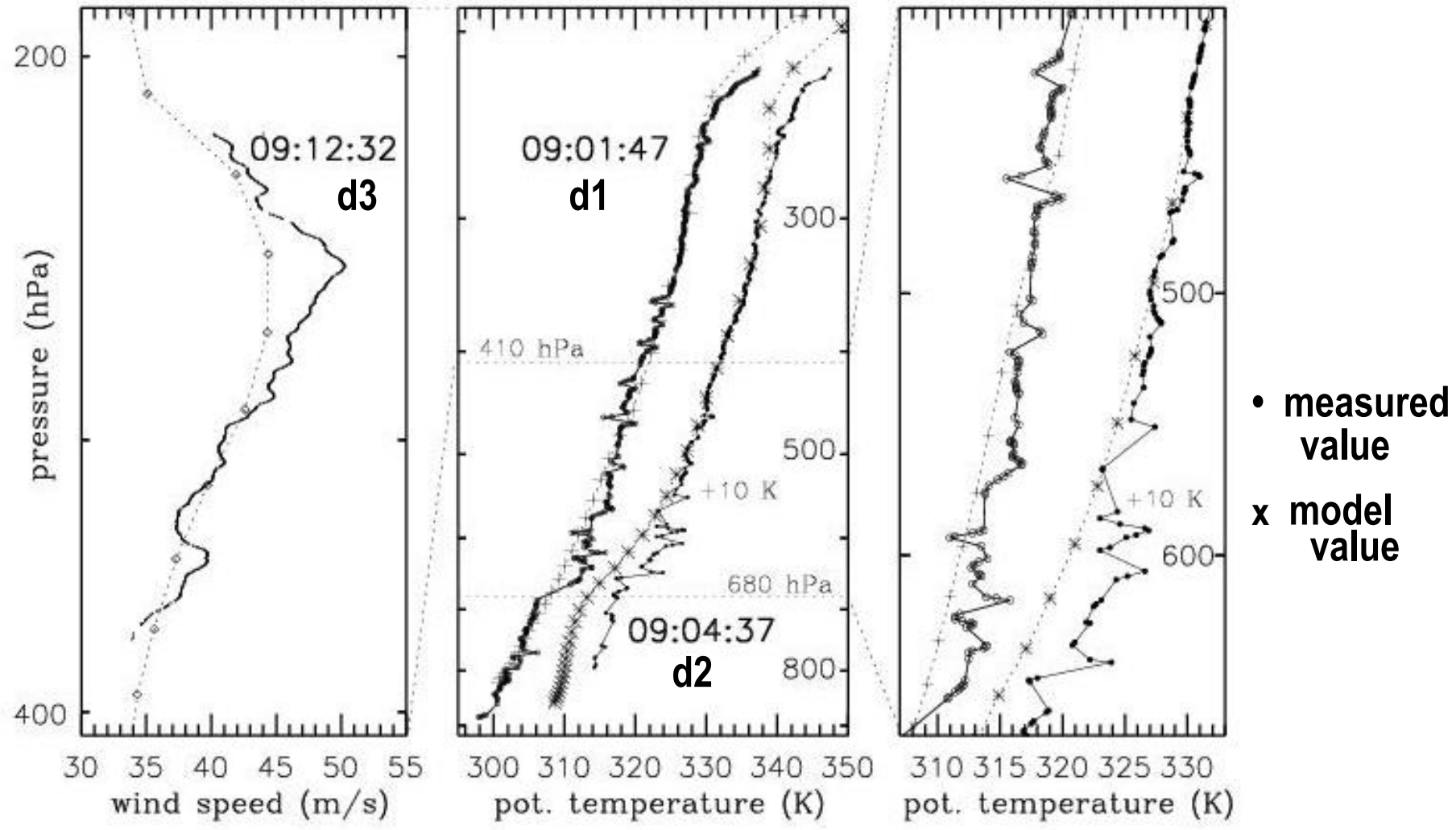


above **GG**, view tow. W (p2 in leg 4)

above **KA**, view tow. N (p1 in leg 4)

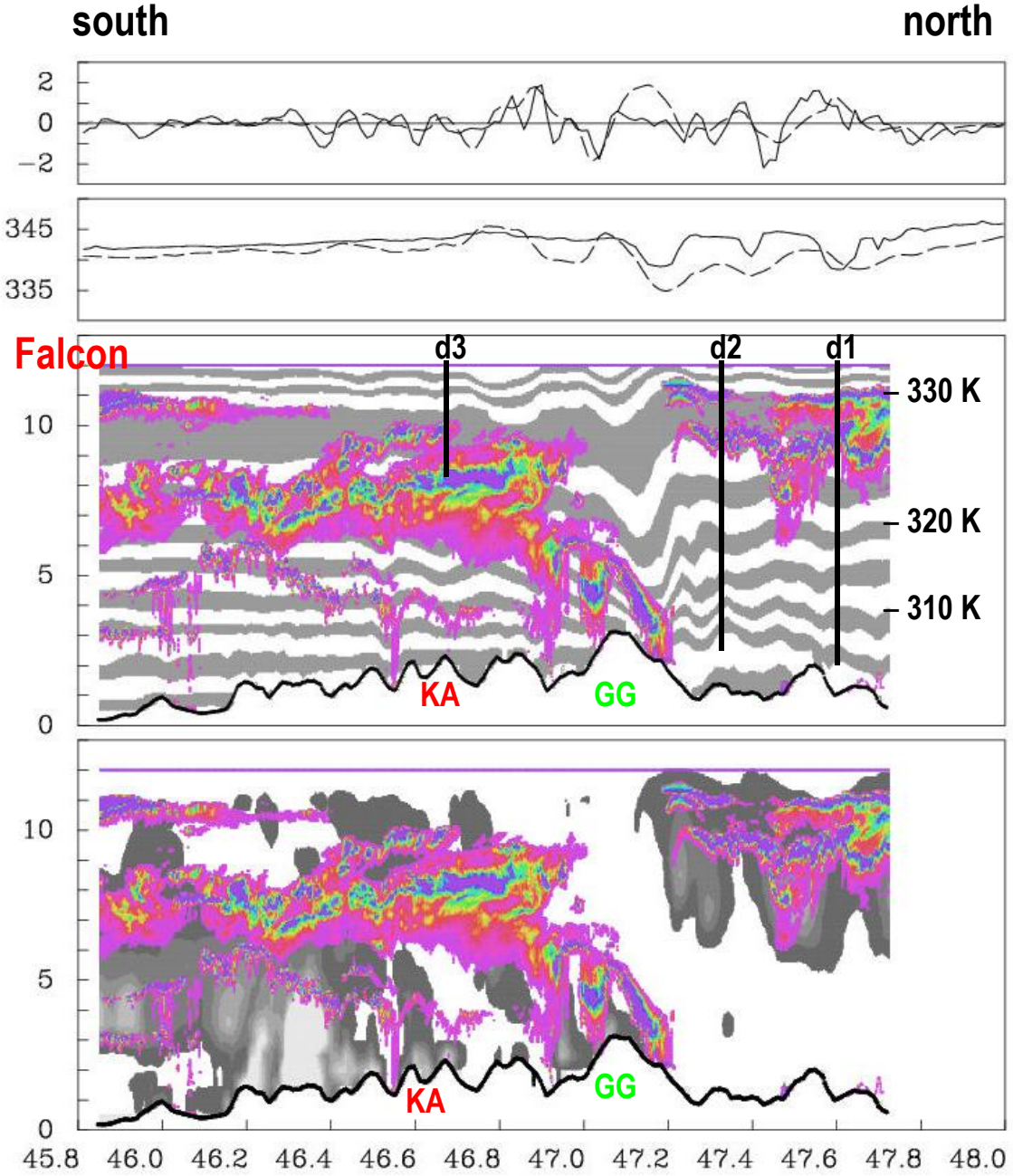
3 dropsondes along leg 5: Measurement vs. model

Jet nose | **2 fast falls** (no wind) | zoom: **wave breaking?**



- **measured value**
- **x model value**

Measurement vs. simulation: leg 5



Falcon level (12.1 km)

vertical wind

___ measured

----- simulated

potential temperature

1–d

Data curtains **2–d**

„Lidar clouds“

versus

waves

in simulated

potential temperature

(position and depth of drops)

„Lidar clouds“

versus

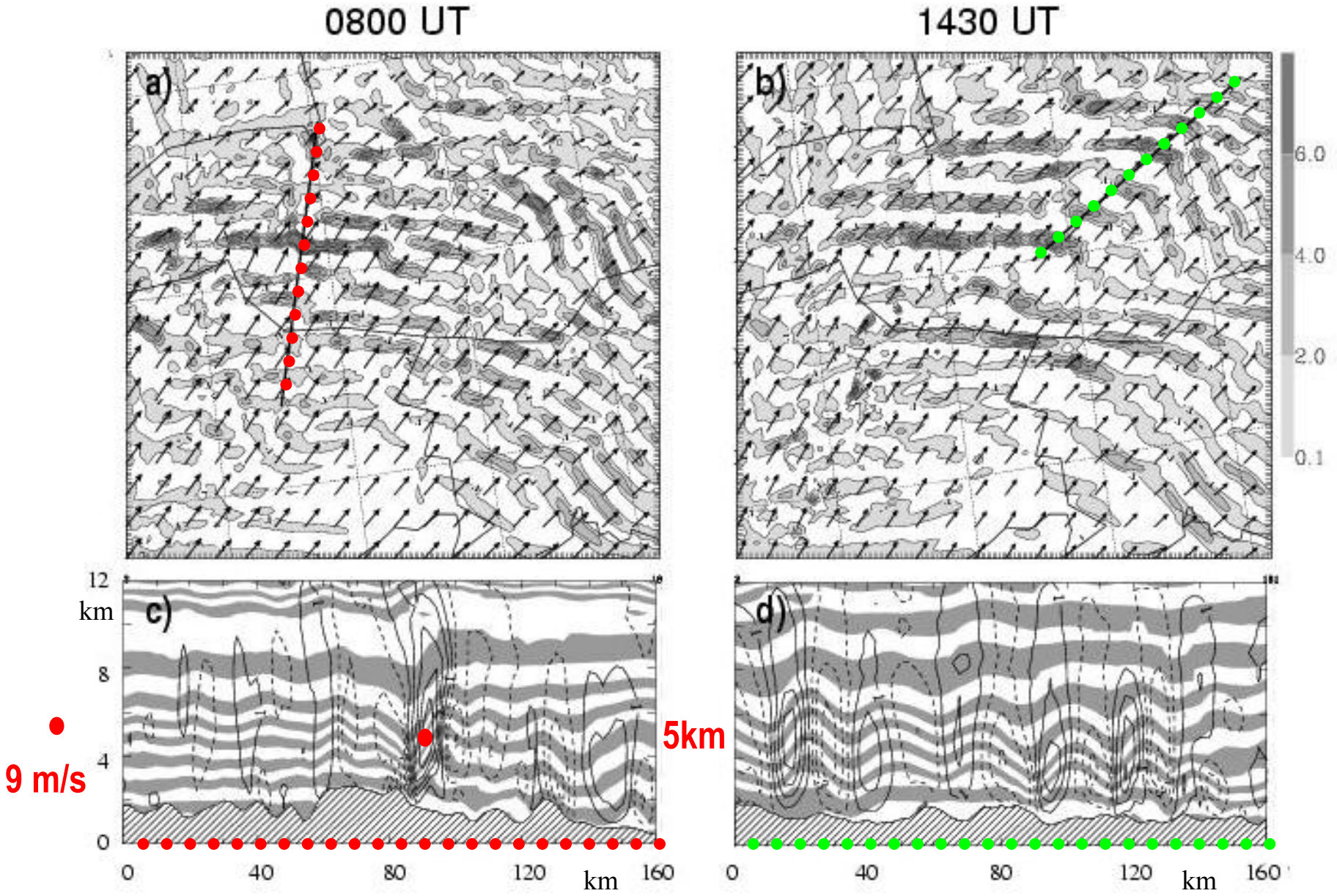
simulated clouds

(condensed water,
solid and liquid)

sensitive on **initialisation**

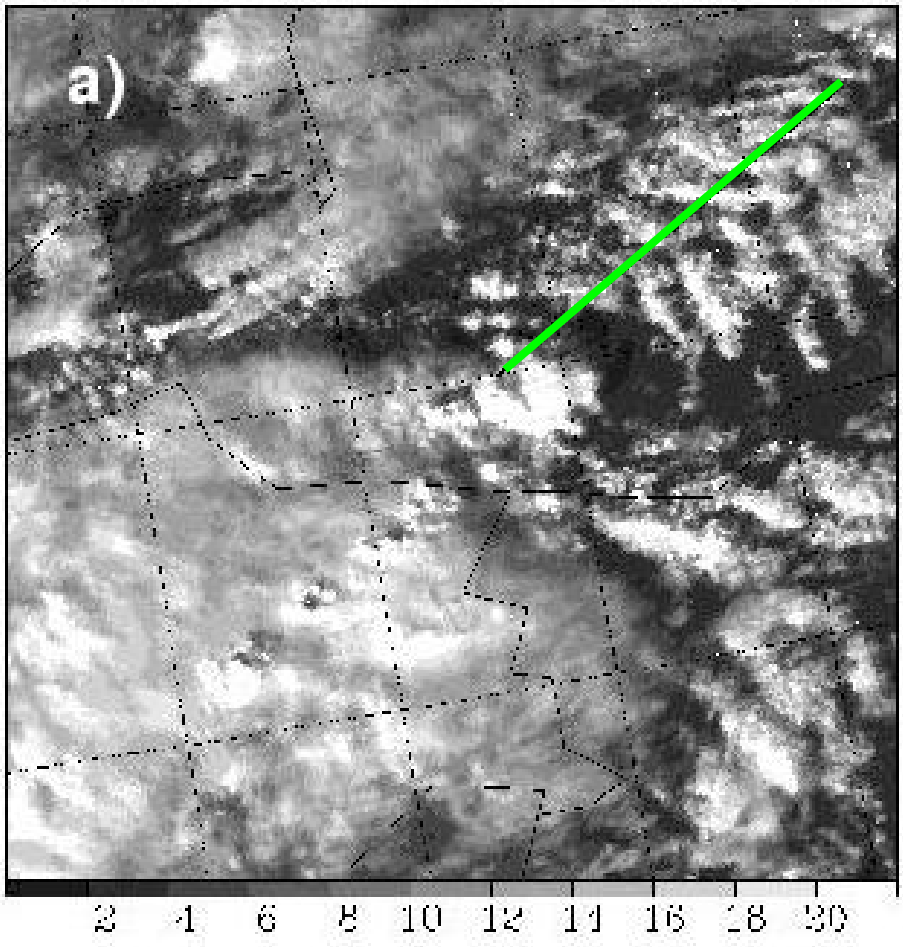
(ECMWF or ARPEGE)

simulated vertical motion bands: time development



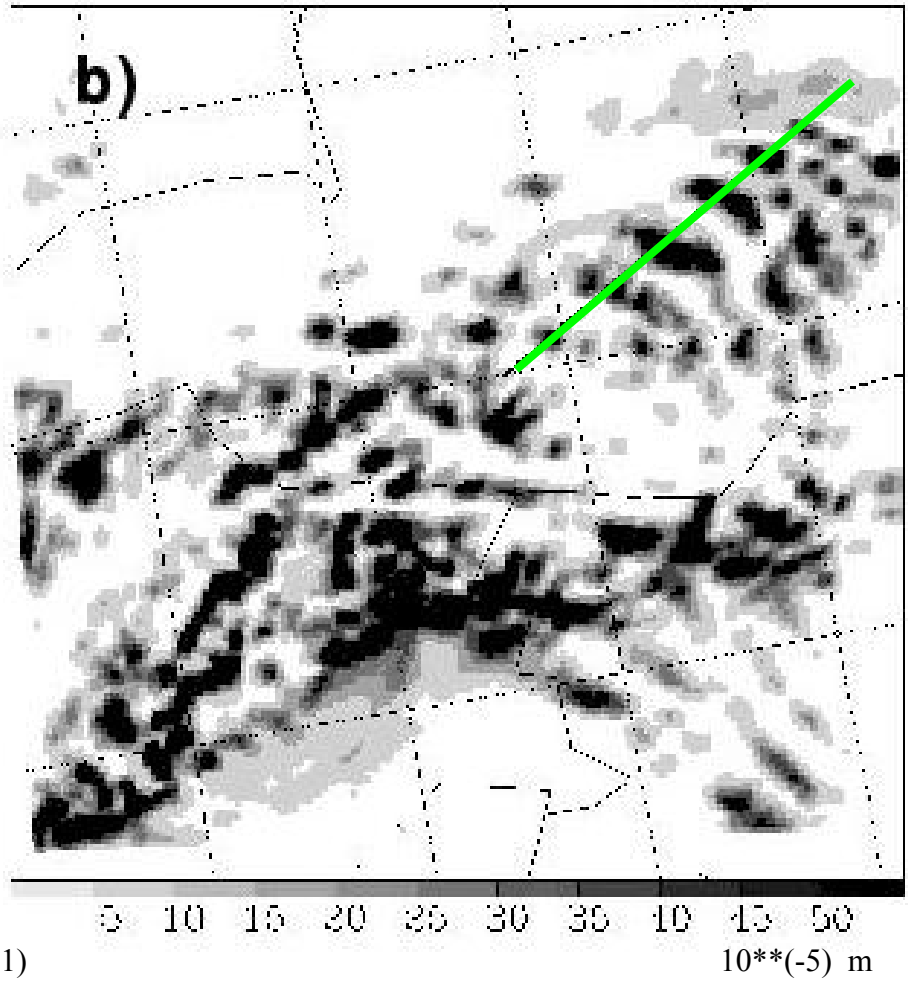
cloud bands at 1430 UT

NOAA: AVHRR

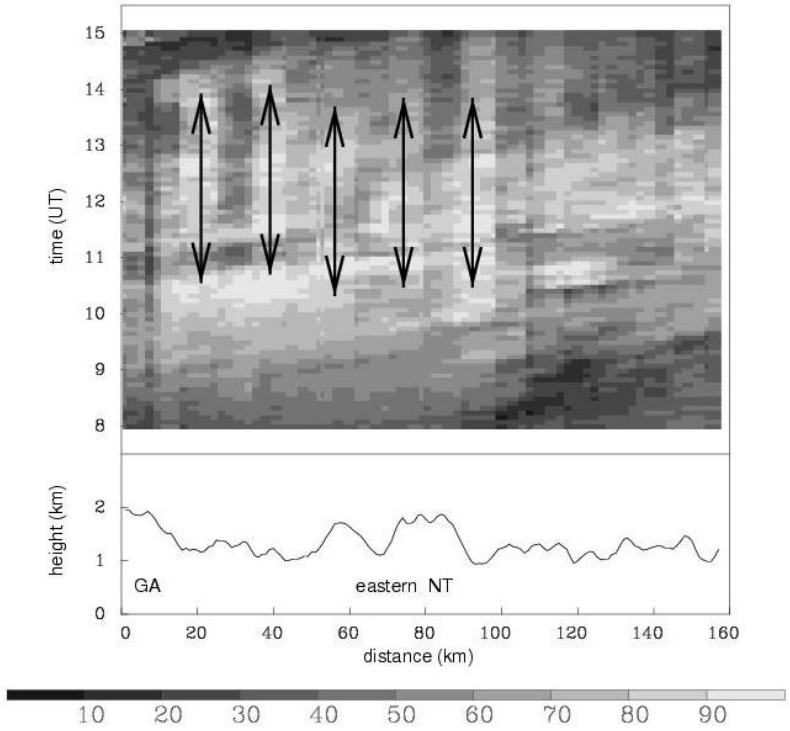


visible channel

Meso-NH



Condensed cloud water
(vertically integrated)



Stationarity

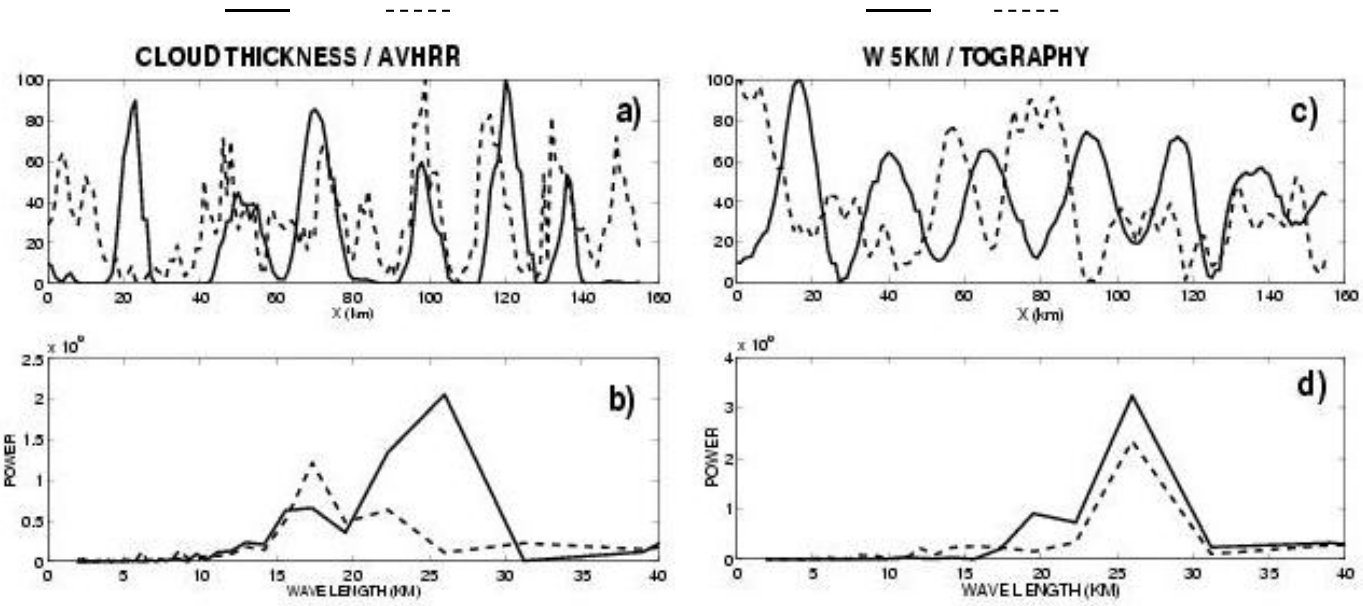
Meteosat : rapid scans every 5 min:

Hovmöller diagramme along the wind

Wave train

physical space

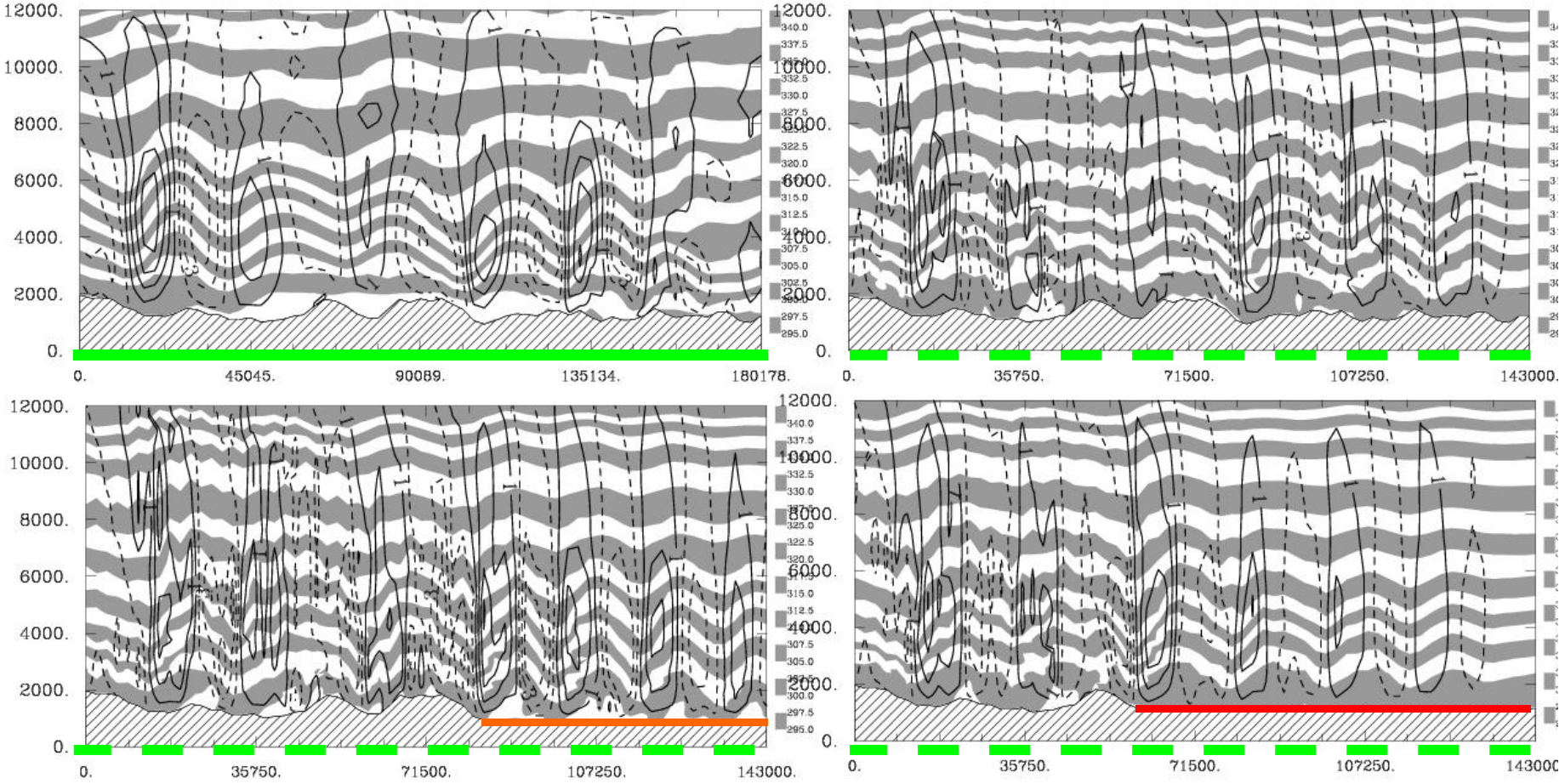
Fourier space



trapping vs. continuous orographic forcing

section from 3–d simulation

section from 2–d simulation



2–d simulation, shorter plane

2–d simulation, longer plane

... apparently play both effects a rôle

Conclusions

- **IOP-10 contained wave breaking , but not fully sampled**
- **cloud decks and cloud gap are simulated** (more work needed)
- **3-d topography re-enhances trapped waves**

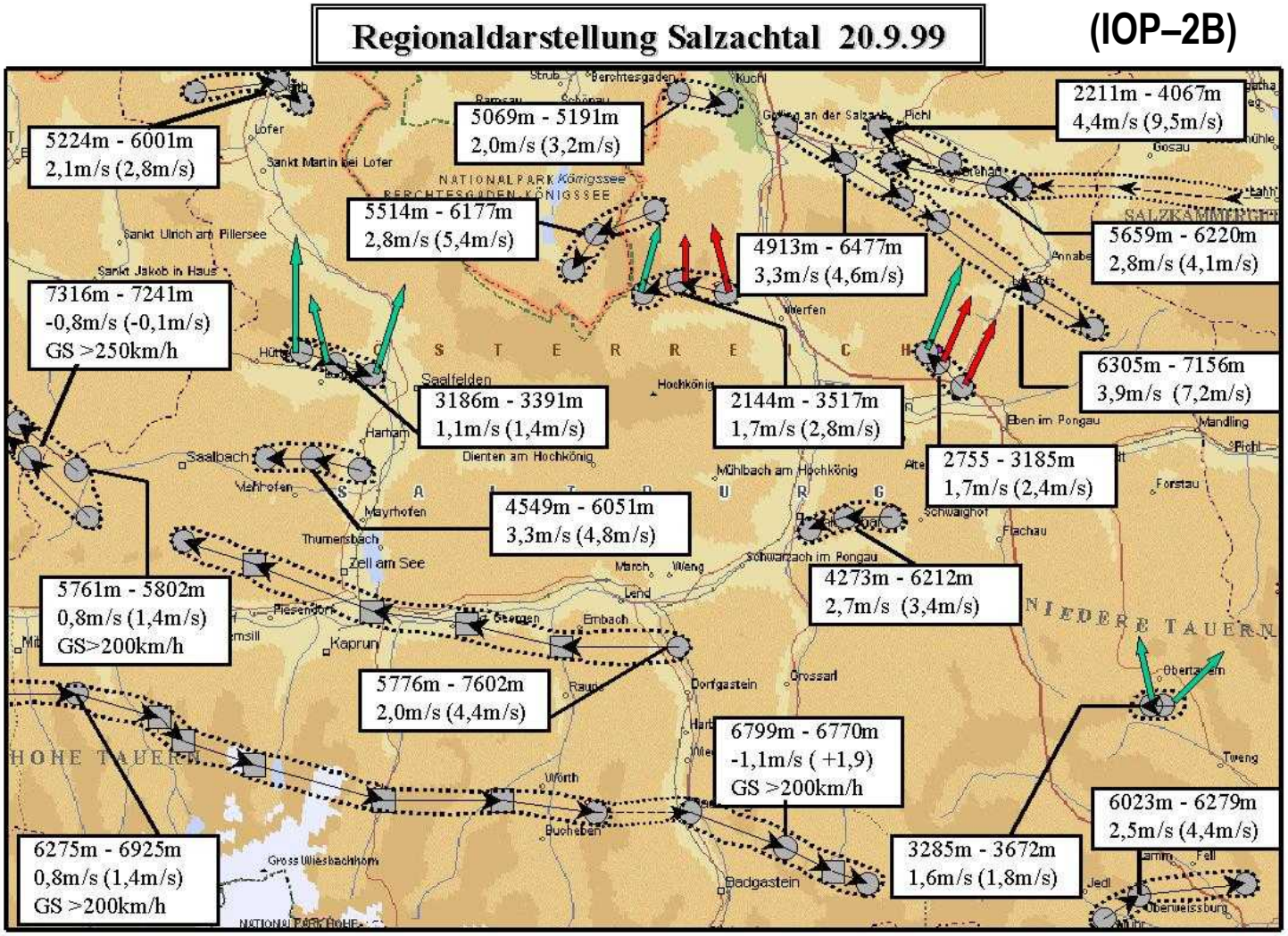
Gravity waves above the Alps

- **a long standing topic** (more than 60 years development)
- **MAP–SOP produced unprecendeted data sets**
- **simulations are getting peers to (high-tec) measurements**
- **phenomenological approach chosen** (what can be seen?)
- **quite something remains to be evaluated and understood ....**

Thanks to: Gorazd POBERAJ, Andreas FIX (DLR, Lidar)
Reinhold BUSEN (DLR, dropsondes)
*full text in QJRMS, **129**, 2003, Jan. B (No. 588), 777-797*

and the sport freaks ...

... continue to fly and to measure as well



B. Forstner, 2001, Master thesis , Vienna University:

„Untersuchung von Gebirgswellen durch Auswertung von Segelflug- und Radiosondendaten.“

Aim: 2000 km wave-glider-flight Alps–Tatra–Ukraine