ASII-GW („Automatic Satellite Image Interpretation – Gravity Waves“)

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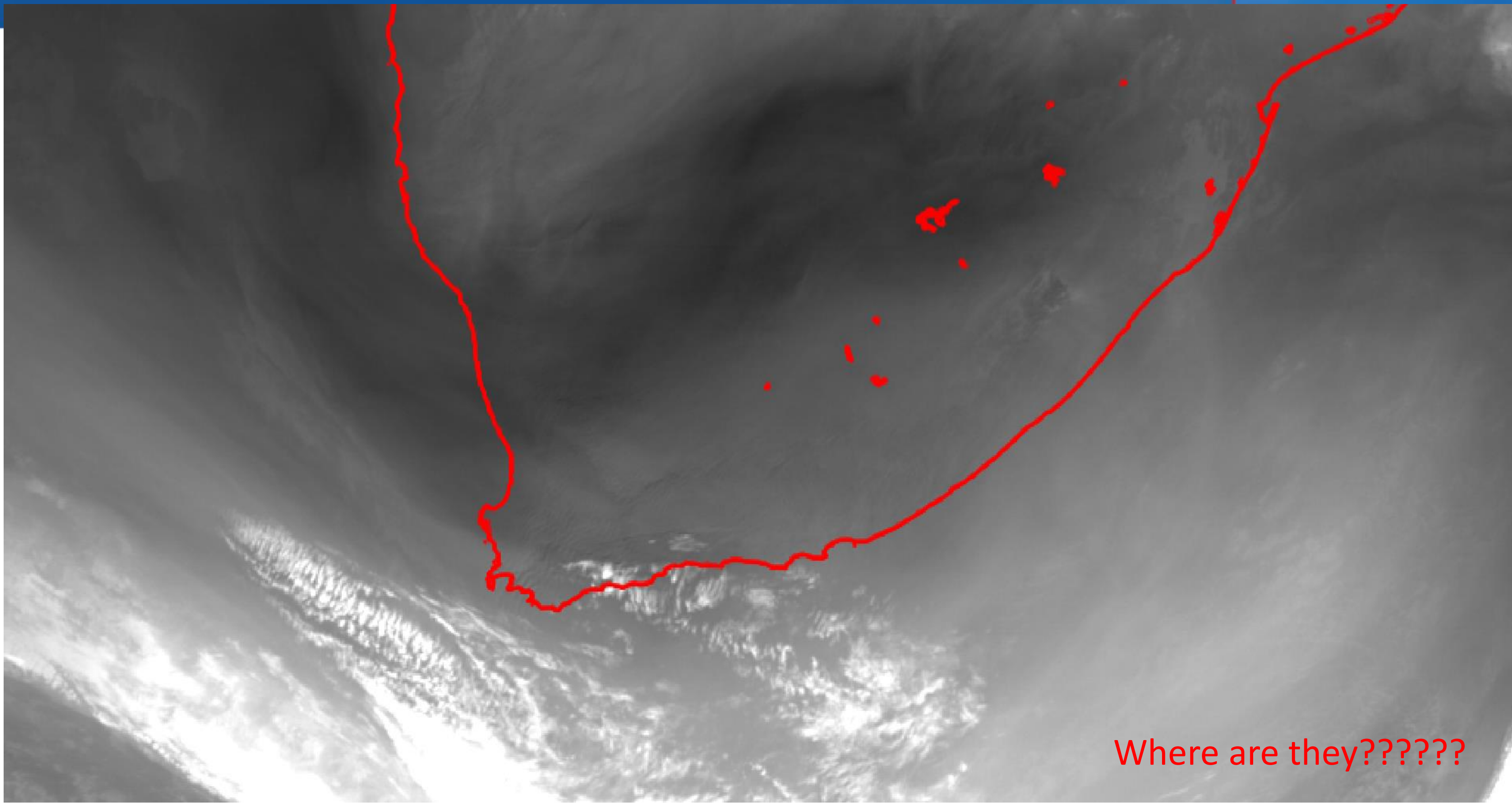
Background

ASII-GW („Automatic Satellite Image Interpretation – Gravity Waves“) shall be released as a brand-new component of the forthcoming Nowcasting-SAF software package NWC/GEO v2018 (under the ASII-NG („Next Generation“) umbrella, coupled with ASII-TF („Tropopause Folding“) – presented in the next talk!)

Potential motivation for gravity wave search

From Keller et al. (2015)

The challenge - search for gravity wave ripples in WV7.3



(Southernmost part of Africa, (29 June 2017, 1400 UTC)

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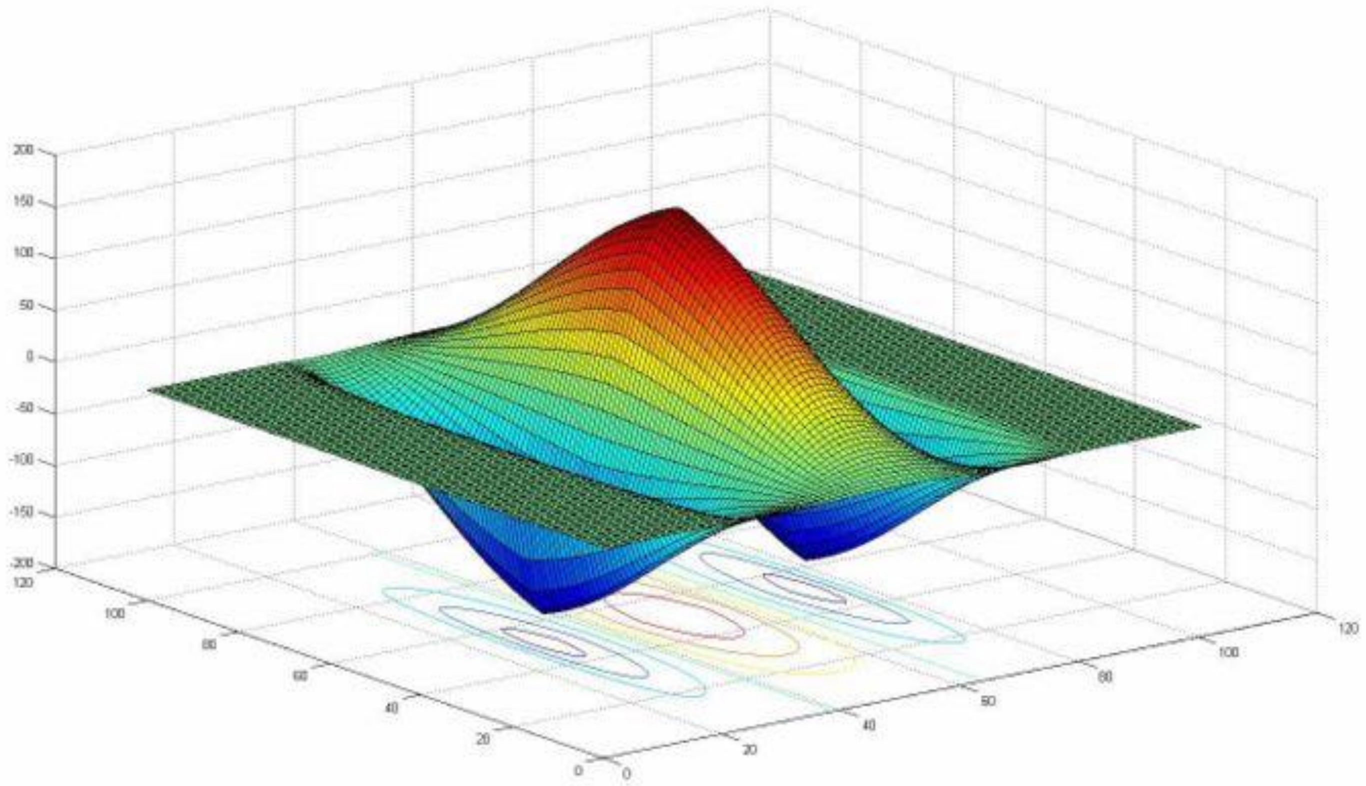
ASII-GW: Motivation

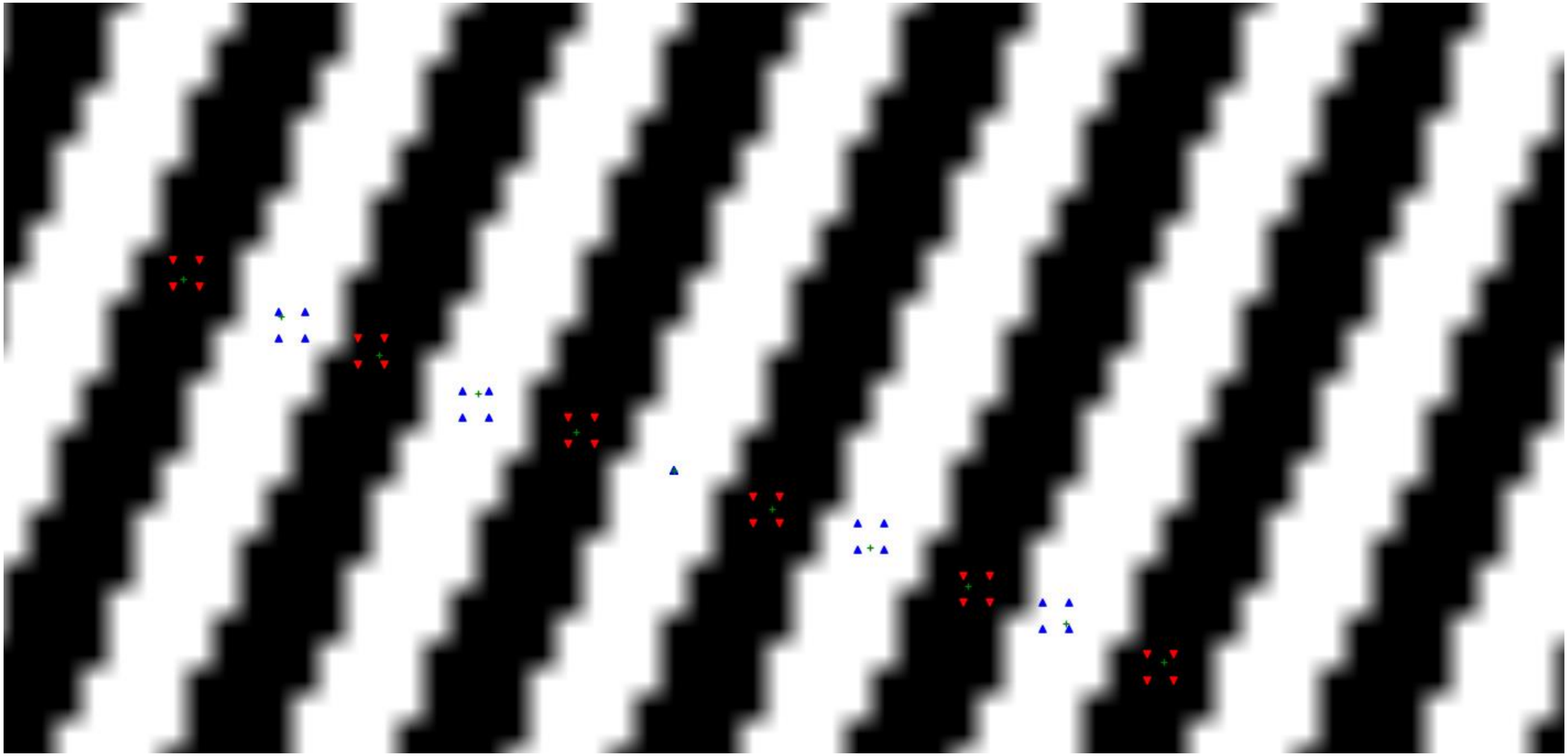
- Gravity waves may become unstable, eventually resulting in the notorious “clear-air turbulence”
- Often reflected (only) in the WV image as a grating pattern (alternating bright and dark stripes)
- The fluctuations are fairly weak, however, so it is not easy to spot them in standard image visualizations
- Therefore: automatic pattern recognition, adapting models from the 1990’s (that tried to mimic the response of visual neurons of monkeys in case of spotting parallel lines)

Algorithm, step 1: Apply a Gabor filter onto the WV7.3 image



Algorithm, step 2: Apply the grating cell operator

Verifying that we have alternating positive and negative Gabor filter responses of comparable magnitude



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The necessity of the grating cell operator (from Petkov and Kruizinga, 1997)

a) image to be analysed
b) the Gabor filter alone (as well as probably any other operator describing brightness variability)
c) Gabor filter plus subsequent grating cell operator

a b c

ASII-GW: Method

- The Gabor filter / grating cell operator is run for several orientations and wavelengths
- The signal density is translated into a probability-of-occurrence (0-100%, for every pixel)
- More algorithmic details can be found in Jann (2017)
- After the automatic detection directs to the right areas, one can achieve displays like the following one (highlighting the gravity wave-induced WV patterns through some tailored image enhancement!):

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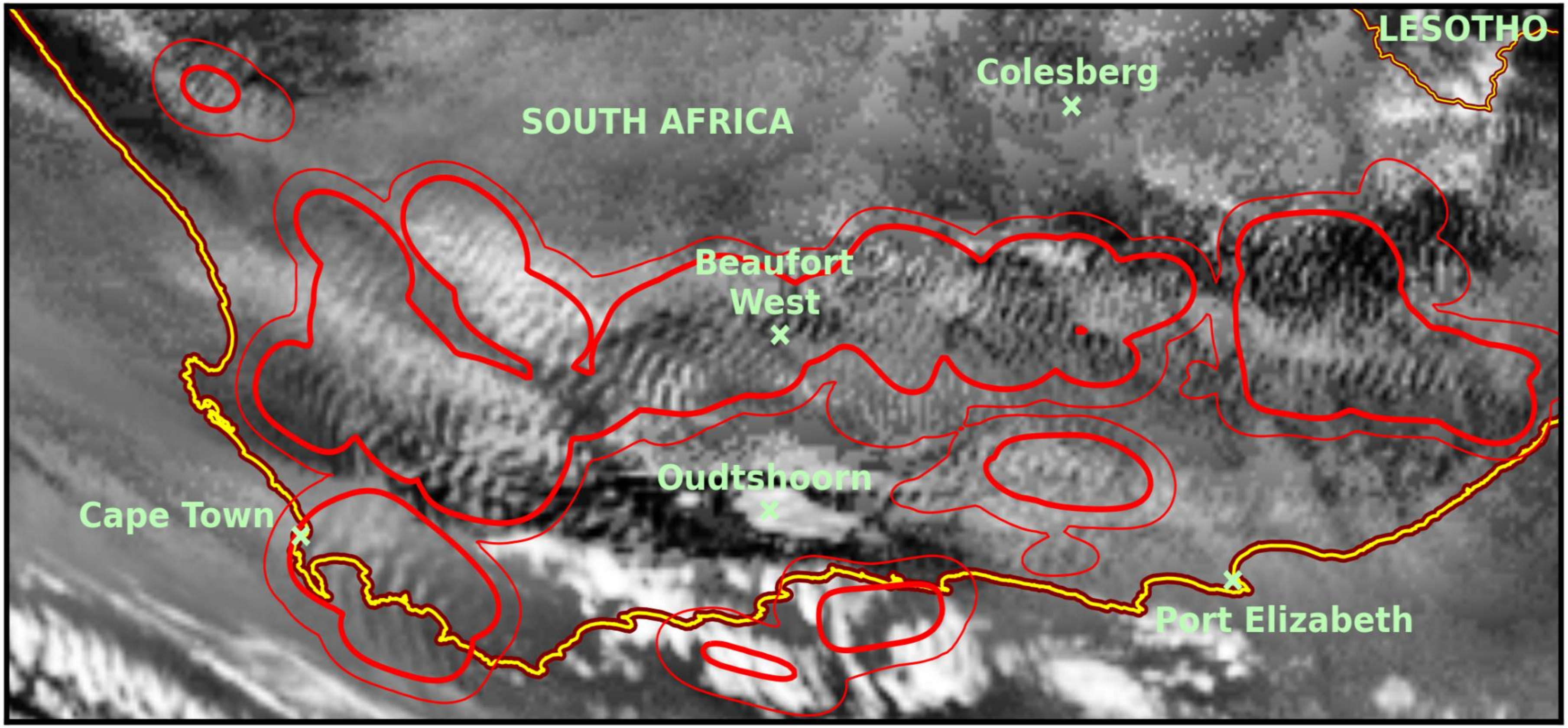
MSG-1/IODC analysis, 29 June 2017, 1400 UTC



(Red isolines refer to the signal density of the ASII-GW pattern recognition algorithm)

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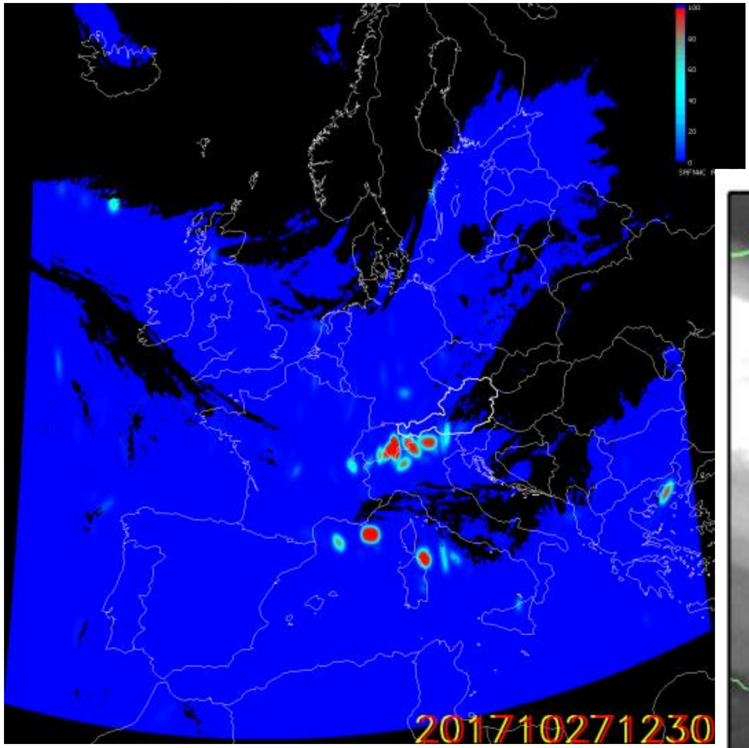
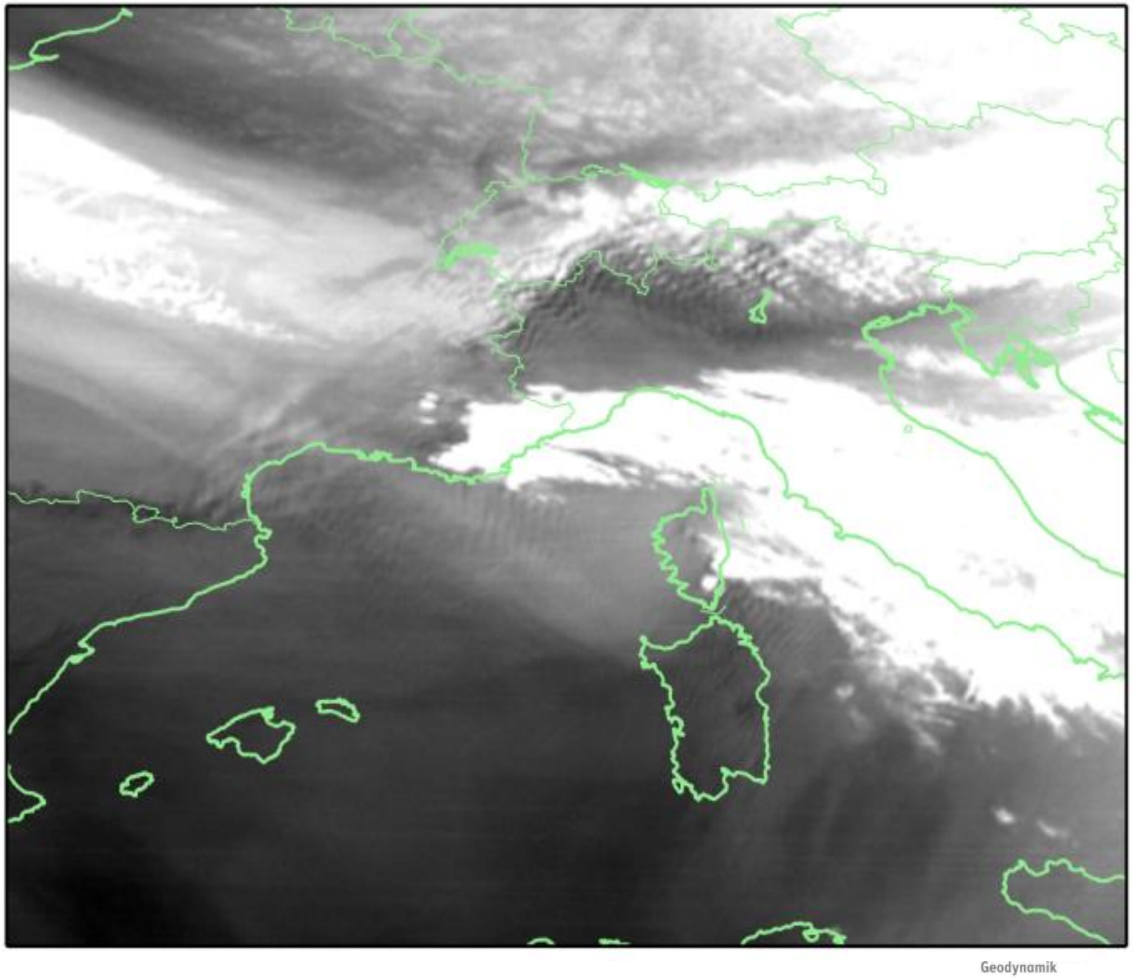
An actual ASII-GW probabilities output



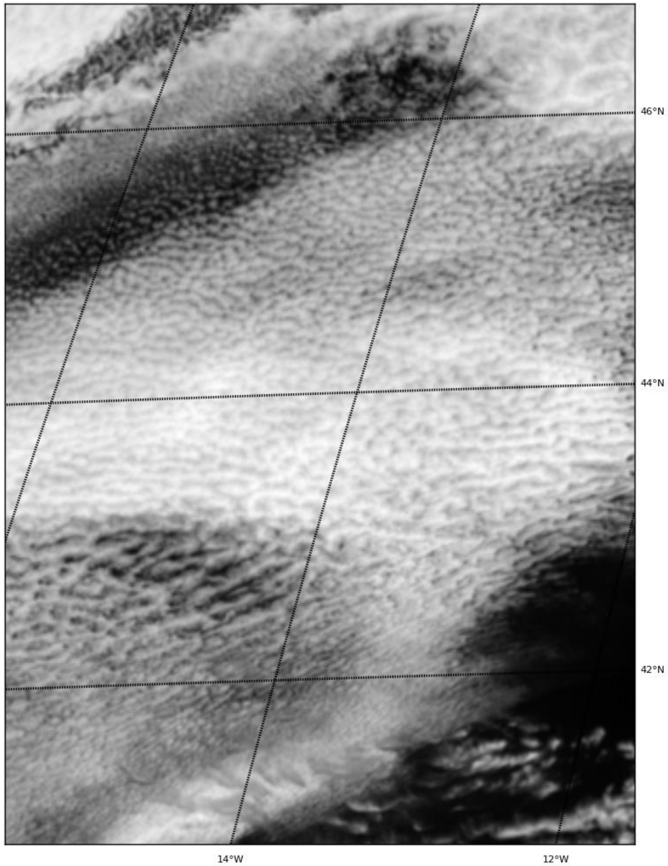


What ASII-GW does (and does not) for you

- It does NOT claim to detect areas of turbulence
  - there are other mechanisms leading to turbulence
  - nor is any gravity wave necessarily breaking into turbulence
- It does NOT claim to detect all gravity waves
  - they are not necessarily in the right height to become visible in WV7.3
  - MSG SEVIRI's spatial resolution is not high enough to capture them all
    - ➢ warning from Wimmers et al. (Wea.Forecasting, 33, 139-144), based on looking at AHI/ABI: *„With such an abundance of gravity wave activity suddenly in view in a geostationary image, the new challenge for forecasters is no longer where to find gravity waves because of their potential for turbulence, but rather how to distinguish turbulence-generating gravity waves from more common, benign gravity waves."*
- **<u>Its value (today) is to obviate the tedious subjective search for the grating patterns in WV7.3</u>**

WV7.3 chosen because marine Stratocumulus is less disturbing…

…whereas the algorithm does not appreciate patterns in HRVIS such as this one, and yields strong false-alarm signals:



Outlook

- With MTG, higher spatial resolution of WV imagery will become reality over Europe as well (ASII-GW even in NWC/GEO v2018 is already fit for Himawari AHI input)
- Algorithmic enhancement exploiting the information about the prevailing texture direction (the one with the highest Gabor filter response) →
  - Reduced risk of false alarms
  - Better perspectives to apply the same algorithm to IR and VIS imagery.

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Literature

References:

Jann, A. (2017): Detection of gravity waves in Meteosat imagery by grating cell operators. *Eur. J. Remote Sens.*, **50,** 509-516.

Keller, T.L., Trier, S.B., Hall, W.D., Sharman, R., Xu, M., & Liu, Y. (2015): Lee waves associated with a commercial jetliner accident at Denver International Airport. *J. Appl. Met. Clim.,* **54,** 1373-1392.

Petkov, N., & Kruizinga, P. (1997): Computational models of visual neurons specialised in the detection of periodic and aperiodic oriented visual stimuli: bar and grating cells. *Biol. Cybern.,* **76,** 83-96.

Wimmers, A., Griffin, S., Gerth, J., Bachmeier, S., & Lindstrom, S. (2018): Observations of Gravity Waves with High-Pass Filtering in the New Generation of Geostationary Imagers and Their Relation to Aircraft Turbulence. *Wea. Forecasting*, **33,** 139-144.

A different concept of automatic GW detection:

HINDLEY, N.P., SMITH, N.D., WRIGHT, C.J., REES, D.A.S. & MITCHELL, N.J. 2016. A two-dimensional Stockwell transform for gravity wave analysis of AIRS measurements. *Atmospheric Measurement Techniques* **9:** 2545–2565.

WRIGHT, C.J., HINDLEY, N.P., HOFFMANN, L., ALEXANDER, M.J. & MITCHELL, N.J. 2017. Exploring gravity wave characteristics in 3-D using a novel S-transform technique: AIRS/Aqua measurements over the Southern Andes and Drake Passage. *Atmospheric Chemistry and Physics* **17:** 8553–8575.

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