Learning about small-scale atmospheric structures through recurrent infrasound events

SnT 2019 — CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

T3.5-P39

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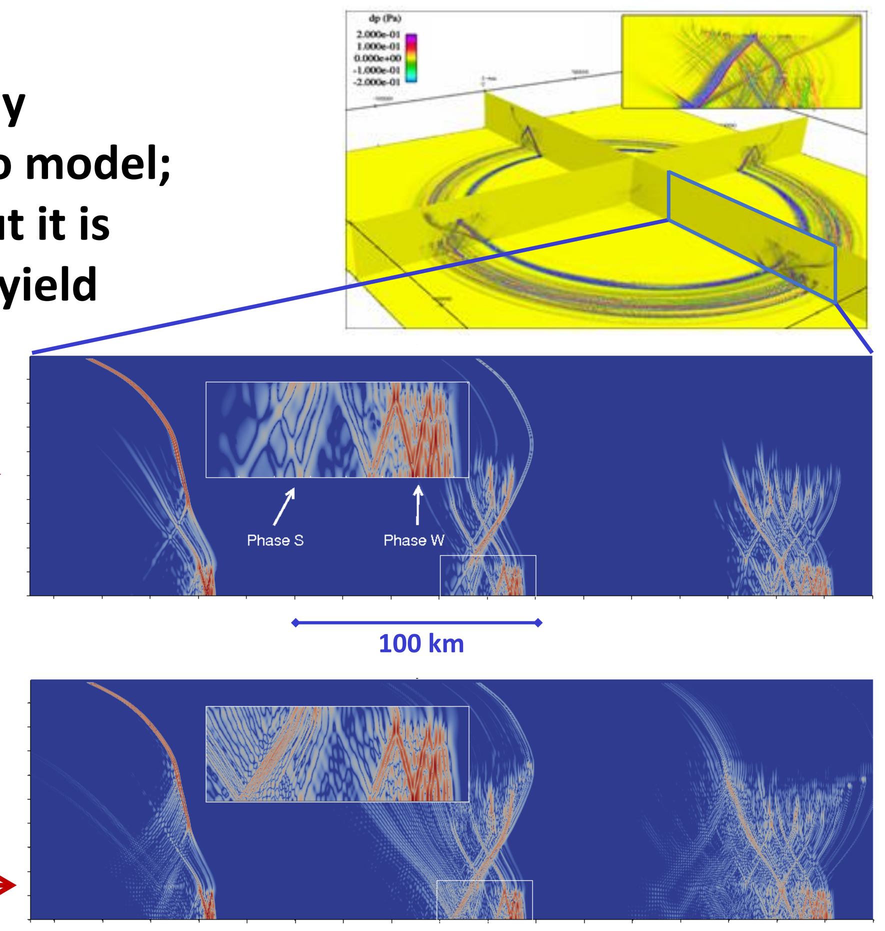
1. INFRASOUND PROPAGATION MODELING

Infrasound propagation is usually modelled through:

- Solving partial differential equations, but governing equations are only partially known and exhibit multiscale interactions that are difficult to model;
- Using empirical models inferred from data (e.g., attenuation laws). But it is difficult to produce models that work with a small amount of data or yield predictions with reliable confidence.

In many infrasound applications, subgrid-scale Gravity Waves (GWs), often referred to as "small" structures, are superimposed to given atmospheric specifications, using spectral schemes. In this work (see also T1.1-P17) two alternative GW models are considered:

- LW (Long-Waves), which is a multiwave scheme, currently in use in the French Global Climate Model LMDz → section 3
- SW² (Short-Waves), which is a new version of LW, with parameters calibrated using infrasound detections → section 4



Impact of LW (top) and SW2 (bottom) on infrasound

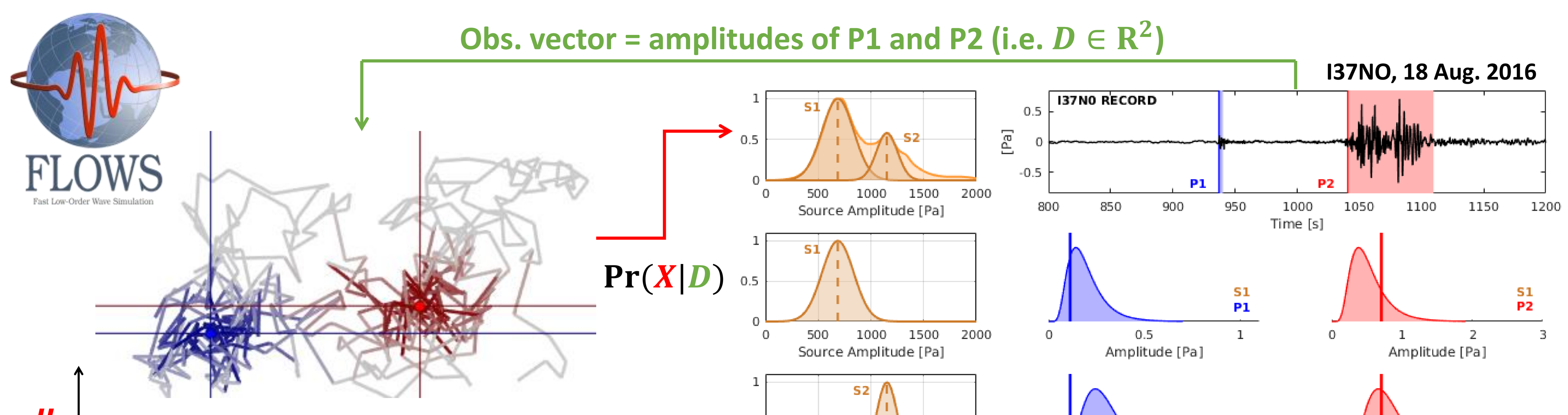
2. BAYESIAN CALIBRATION OF GRAVITY WAVES

Main idea of Bayesian inference: derive the posterior probability as a consequence of two antecedents: a prior probability and a likelihood function derived from a statistical model for the observation.

$$\Pr(X|D) = \frac{\Pr(D|X)}{\Pr(D)} \Pr(X)$$

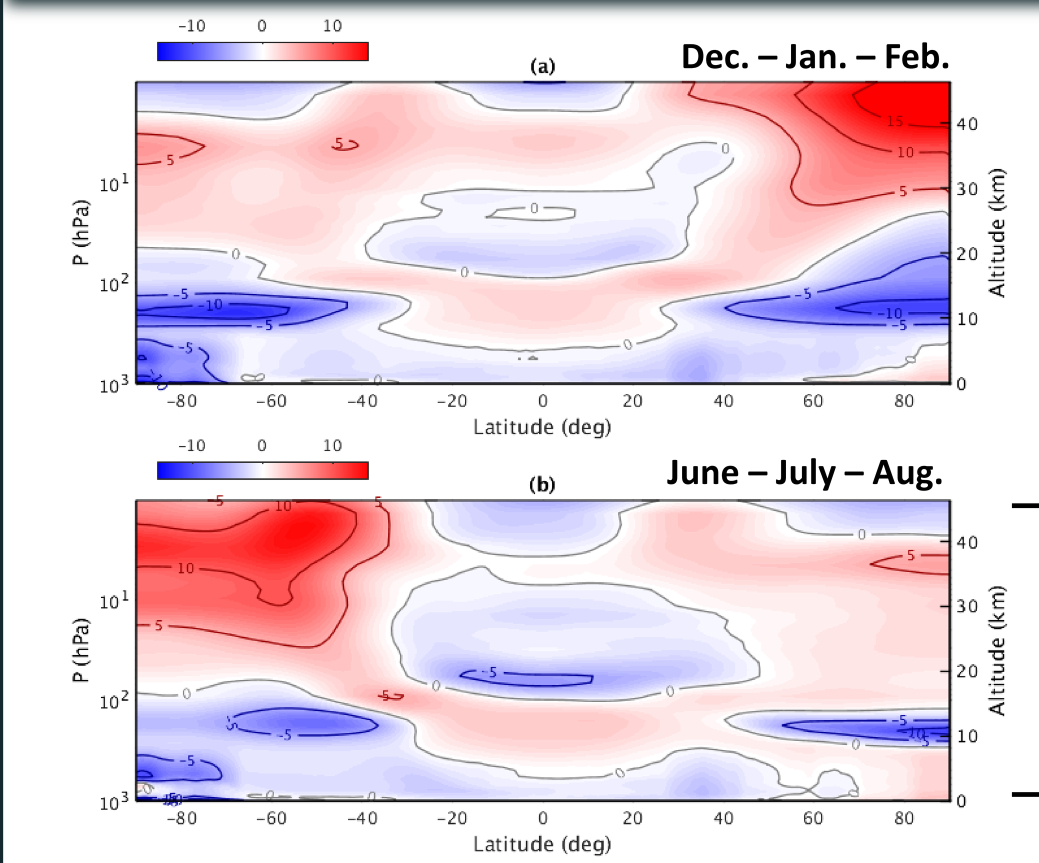
- $\Pr(D|X)$: How probable is D given that X is true?
- $\Pr(X)$: How probable was X before observing D?
- $\Pr(D)$: How probable is D under all possible hypotheses?
- $\frac{\Pr(D|X)}{\Pr(D)}$: impact of D on X

where X can either describe the event properties (e.g., source amplitude) or the GWs. Without GWs, the probability density function (pdf) for X exhibits several peaks, thereby rendering any decision difficult (since each peak S_j in the pdf of X explains a specific observation). Recent works at CEA have shown that calibration of GWs, as a first 'Bayesian' step, leads to better estimates of the event properties.



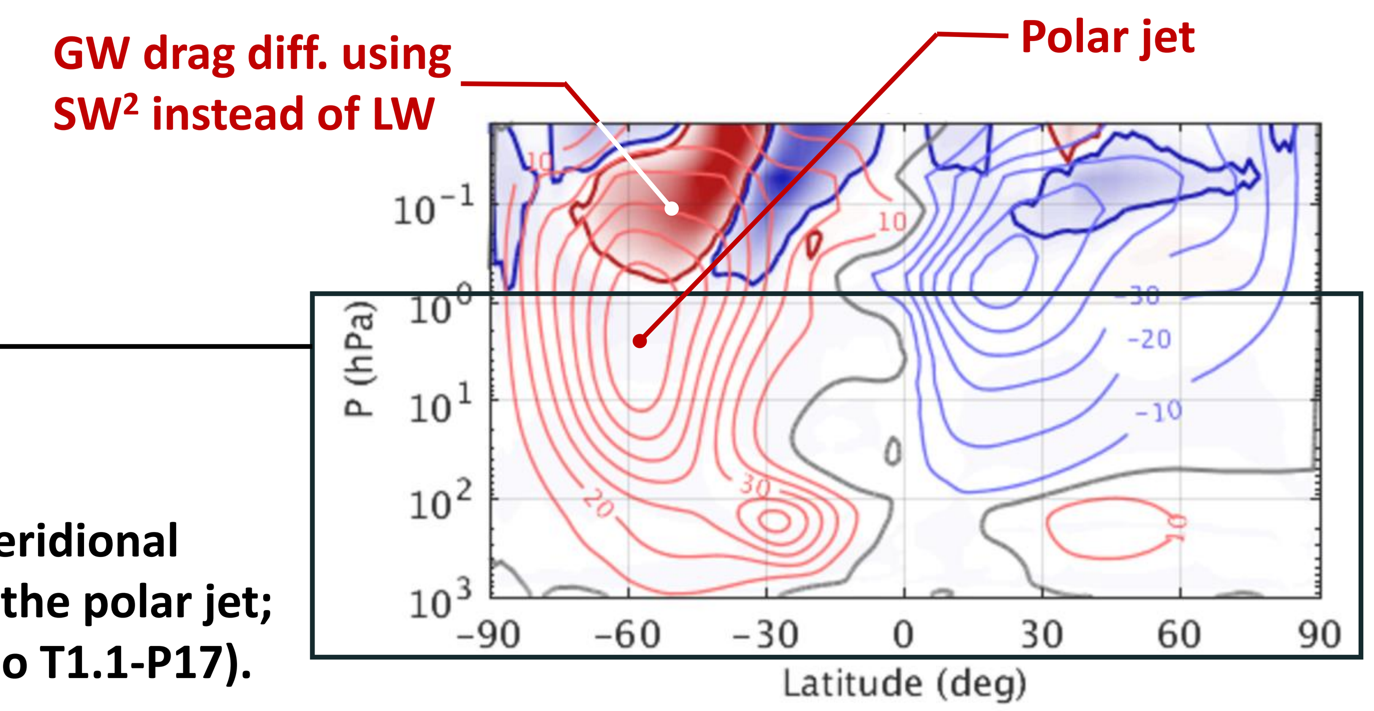
A Markov Chain Monte Carlo to estimate $X \sim N(\mu, \sigma)$ from D.

3. ON THE WEIGHT OF GRAVITY WAVES IN GLOBAL CLIMATE MODELS



Comparaisons between simulated (LMDZ + LW) and observed temperatures (ERA-Interim) over 15 years (1996 – 2010).

- Stronger cooling (up to 15 K) produced by synoptic and transient planetary wave breaking;
- Common bias of polar night jets not having enough equatorward tilt at the tropopause.

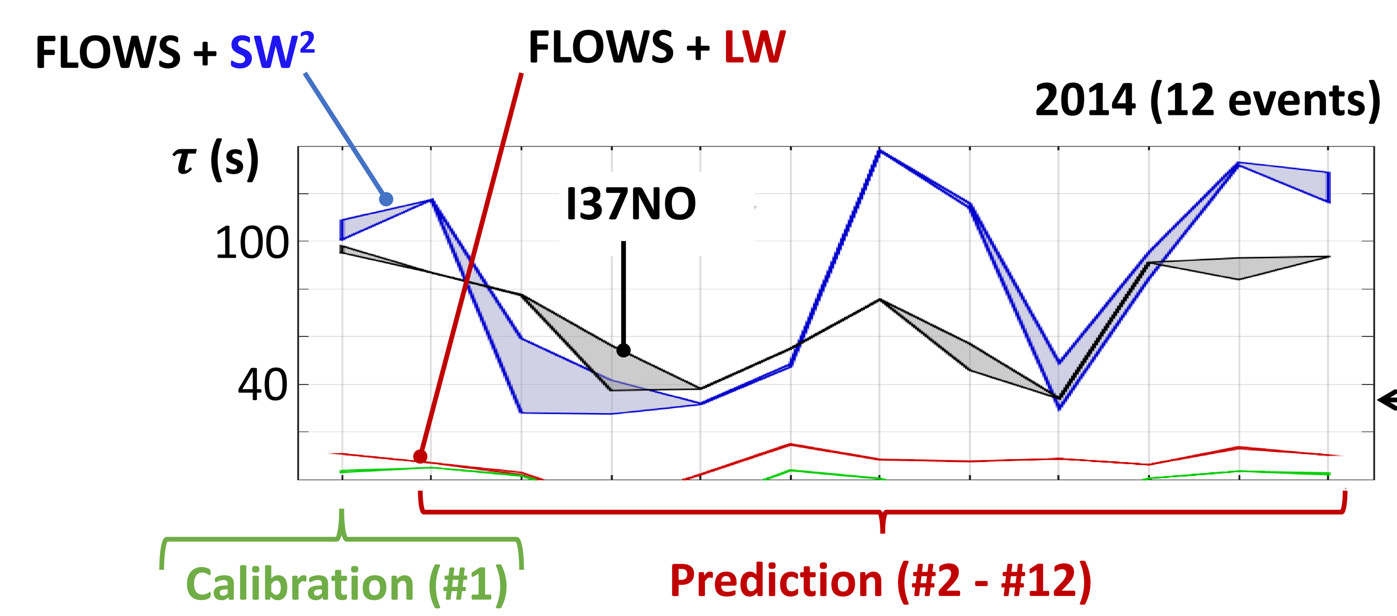


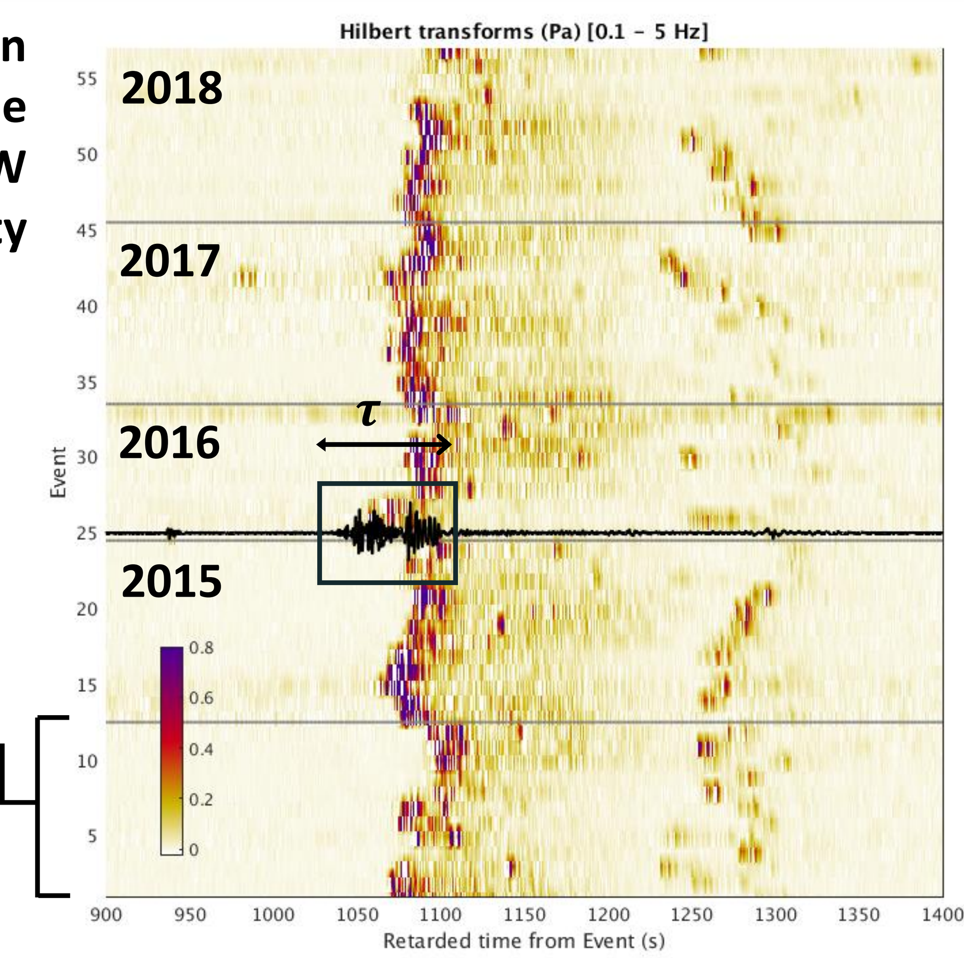
Is SW² really better than LW?

- From a climatological point of view YES. The meridional gradient of GW drag restores the inclination of the polar jet;
- The temperature anomaly is weakened (see also T1.1-P17).

4. HUKKAKERO CAMPAIGNS AS A TOOL TO UPDATE GRAVITY WAVE FIELDS

Recurrent infrasound detections (e.g., Hukkakero campaigns [2]) can be used to calibrate the parameters of SW² using the duration of the stratospheric arrival recorded on day #1. The calibrated GW parameterization SW² is then used to predict the duration variability over the whole period (here 12 events, 2014).





What have we learnt so far?
Adding calibrated GWs improves the numerically obtained durations of stratospheric arrivals over a period which is much larger than that used for calibrating the GW model. In a sense, the calibrated GW model (SW²) has learnt from recurrent infrasound events to "adapt" its prediction to regional sources of GWs. The resulting (updated) GW model can be used together with FLOWS for localization and association (see T3.5-P79).

Ref.: [1] Ribstein, Millet, Lott, de la Camara, *Subm. to JGR*. [2] Näsholm, Gibbons, Kvaerna, T1.1-P17, *Science & Technology*, 2017.

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