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Fourier analysis of short-period water level variations in the Rotorua geothermal field, New Zealand

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Abstract

The results of a Fourier analysis of water level measurements recorded near the nationally significant Pohutu Geyser in New Zealand are reported. Their analysis clearly identifies periodic pressure variations induced by barometric, gravity, thermal, anthropogenic and subsurface disturbing influences, which can be used as a benchmark for identifying and quantifying detrimental changes in behaviour. A report is given on the performance of Fourier analysis on synthetically generated signals with different levels of white noise and discrete impulses. We were able to attribute periodic variations to various disturbing effects and quantify the magnitude of these changes. Diurnal and semi-diurnal variations for both anthropogenic and barometric disturbing influences are shown to have amplitudes in the range 2.8–5.2 mm-H_2O while earth tidal amplitudes are less than 1 mm-H_2O.

Keywords: Geothermal aquifers; Fourier; Periodic variations; Water level; Surface manifestations; Human impact; Rotorua; New Zealand

1. Introduction

Natural features in geothermal fields have periodic pressure variations induced by barometric, gravitational, thermal and subsurface disturbing phenomena; these variations can serve as a benchmark against which to determine the possible impact of human activity. The accurate monitoring of these periodic variations can provide an early warning of anomalous pressure

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Nomenclature

CV	coefficient of variation
K_1	lunar solar diurnal tide
M_2	principal lunar semi-diurnal tide
N_2	larger semi-diurnal lunar ellipse
O_1	principal lunar diurnal tide
P	pressure (mm-H_2O)
R^2	Pearson correlation coefficient
rand(0, 1)	random number between 0 and 1
S_2	principal semi-diurnal solar tide
snr	signal-to-noise amplitude ratio
t	time (s)
T	period (s)
wl	water level (mm)
x	variable
$X(\omega)$	Fourier transform

Greek letters

ϕ	phase lag (radians)
μ	mean
σ	standard deviation
ω	angular velocity (radians/s)

Subscripts

baro	barometric
baro_corr	barometric-corrected
ed	exponential drift
tide	gravity tide
wn	white noise

changes and therefore reduce the time needed for resource managers to assess the effect of any nearby heat and mass extraction on the geothermal surface manifestations being monitored.

At Rotorua in New Zealand (Fig. 1) there has been considerable interest shown (Allis and Lumb, 1992; Bradford, 1992; Burnell, 1992; Environment BOP, 1999; Scott and Cody, 2000) in the magnitude of anthropogenic disturbance to the nationally significant Whakarewarewa geothermal area, which includes New Zealand's pre-eminent geyser named Pohutu. In 1987 concerns over anthropogenic influence led to the closure of all wells over 70 m in depth sited within 1.5 km of the Pohutu geyser.

The aim of this study is to use Fourier analysis to examine water level measurements for periodic variations with periods of 24 h or less. Water levels were recorded over a two-year period in a 256-m deep well, RR777, located about 1 km from the Pohutu geyser. The analysis is used to provide a comparative assessment of characteristic variations in water level.