Oscillating Processes in Soils

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It is proposed to begin systematic studies of oscillations in soil processes including the probable influence of the earth tides on the temporal dynamics of soil properties. Seasonal and quasi-3-yr periodical interrelationships in the system ‘precipitation - groundwater depth - groundwater salinity - soil salinity’ are discussed.

1 Introduction

It was reasoned that the ability to ‘survive’ during the course of the evolution is unique to oscillating systems, processes, and objects [10]. As soil is a biotic/abiotic natural system, of special interest is recognition of oscillations in soil processes including exogenous and self-oscillating periodicities. In particular, modeling of soil evolution would require knowledge of long-term periodicities in soil processes.

However, as far as we know, only two natural exogenous cycles are understood in soil science: (a) the circadian short-term periodicity modulated by circadian rhythms of the solar radiation and air temperature; and (b) the circannual medium-term periodicity modulated by circannual rhythms of the solar radiation, air temperature, and precipitation. The Earth’s rotation and its revolution around the Sun are clearly responsible for daily and yearly variations in soil temperature and soil moisture [7, 9]. Other (quasi-)periodic fluctuations in temporal dynamics of soil properties are not understood.

2 Oscillations of soil salinity

The Caterpillar method, a variant of a singular spectrum analysis (SSA) [6], was used to detect hidden regularities in the temporal dynamics of soil salinity in the Canadian prairies associated with interaction of climatic conditions, groundwater regime, and land use at a field scale [4]. SSA was applied to a dataset including: daily records of the solar radiation, air temperature, soil temperature, and depth to groundwater (Dgw); monthly records of the total precipitation and electrical conductivity of groundwater (ECgw); and bi-monthly records of soil electrical conductivity for 0-60 cm (ECe_h) and 0-120 cm (ECe_v) depth increments.

We found that in the region under study the temporal variability of soil salinity is formed by its seasonal and quasi-3-yr cycles controlled by similar cycles of the groundwater depth and salinity, which in turn are caused by related periodic impulses of the precipitation. The quasi-3-yr cycle prevails. The interaction of the seasonal and quasi-3-yr cycles leads to the intricate overall picture of the temporal dynamics of soil salinity.

In the seasonal cycle, the system ‘precipitation - groundwater depth - groundwater salinity - soil salinity’ proceeds as follows (Fig. 1a). The maximal level of the precipitation is reached in late May - early June. The maximal rise of the water table is reached in August, that is, about 2 months after the precipitation peaked. The seasonal oscillation of ECgw is in phase with the seasonal oscillations of Dgw: the higher shallow water table, the higher groundwater salinity. Beginning in 1995, the soil salinity peaks in the late September, that is, approximately 1.5 months after the maximal ECgw was reached. The mutual arrangement, or phases of the seasonal cycles of the precipitation, groundwater depth, groundwater salinity, and soil salinity are constant.

In the quasi-3-yr cycle, ECe peaks about 14 months after the maximal rise of the groundwater (Fig. 1b). Most likely, this cycle of Dgw is a response to the 3-yr periodicity of the precipitation observed in the region.

Distinct manifestation of two cycles of different origin (i.e., the seasonality controlled by the revolution of the Earth around the Sun, and the 3-yr cycle of unknown genesis) illustrates a hierarchical concept reasoning that processes of different origin, as a rule, correspond to different spatial and/or temporal scales. It is notable that the potent and relatively frequent seasonal oscillation of the groundwater level has caused a near prompt, but relatively weak response of the soil salinity (Fig. 1a). At the same time, the gradual and relatively rare exposure of the 3-yr oscillation of the watertable level has led to the delayed, but relatively pronounced response of ECe (Fig. 1b). The distinct responses of the soil may reflect a ‘buffering’ effect of soil capillary processes [4].

The application of SSA to time series of soil and groundwater salinity demonstrated its large potential to reveal hidden temporal regularities in relatively short and rough time series. Seasonal and quasi-3-yr periodical interrelationships in the system ‘precipitation - groundwater depth - groundwater salinity - soil salinity’ were captured with SSA only.

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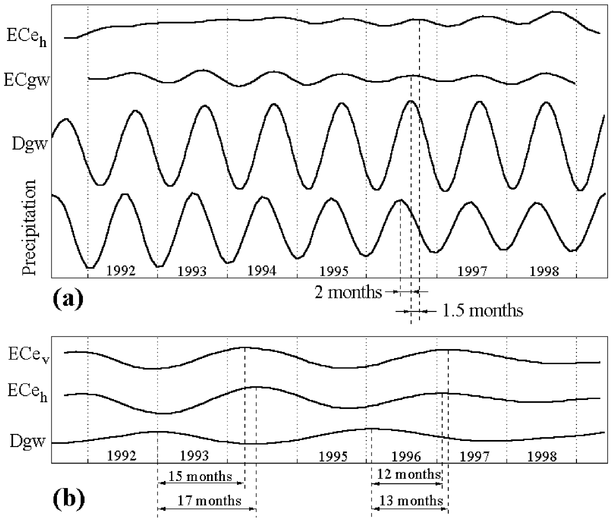

Fig. 1. Relationships between oscillations of the total precipitation, Dgw, ECgw, and ECe: (a) the seasonal cycle, (b) the 3-yr cycle.

3 Do the Earth tides influence soils?

Besides cycles of the solar activity causing long- and medium-term periodicities in natural processes (e.g., 11-yr and 22-yr cycles), a source of medium- and short-term exogenous cycles is the gravitational interaction of the Earth and Moon generating oceanic, atmospheric, and terrestrial tides [8]. There are three main tidal periods: lunar semidiurnal (12.42 hr), lunar synodic (29.53-day), and lunar nodal (18.6-yr). Atmospheric and oceanic tides, changing transport of heat due to movement of water mass, modulate precipitation [1, 3]. The earth tides periodically trigger (micro)seismic, volcanic, and geyser activity [8], release deep-seated gases [2, 13], and change groundwater level [5, 11]. Chronobiological exo-endogenous rhythms of land plants include tidal oscillations [12, 15].

Since soil is not a closed system, the earth tides would be expected to cause some weak fluctuations in soil processes and temporal dynamics of soil properties depending on groundwater depth, soil moisture content, soil gas composition, and plant processes (e.g., transpiration). However, to the best of our knowledge, an influence of the earth tides on soil processes and properties remains unknown, except for coastal soils where the periodical action of seawater is clear [14]. We believe that the time is right to begin investigation of the probable impact of the earth tides on soil as an integral part of the biogeosphere. SSA offers a unique opportunity to study oscillations in soil processes.

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