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STATUS AND RESULTS OF OSEs

Siberian RAOB Distribution for Maximum Information Content

(Submitted by Dr. O.M. Pokrovsky,
Main Geophysical Observatory, Russia)

Summary and Purpose of Document

The purpose of the document is to inform the Expert Team on the progress in optimization of the Siberian RAOB (site number and its location) to provide the maximum information content with regard to NWP and climate monitoring tasks.

ACTION PROPOSED

The meeting is invited to take into account information presented in this document and discuss issues related to evolving of Siberian RAOB site distribution and preliminary proposal on its redistribution to maximize information content.

1. Introduction

1.1. The Siberian RAOB network was substantially reduced after the economic crisis of 1998. There were only 5-6 sonde launches per day at early 1999. Later restoration process began and was carried out step by step. By January 2003, Roshydromet provides about 30 launches per day in Asian part of Russia. But most of them were concentrated around several industry or civilian centers. More uniform RAOB site coverage is very desirable, but some scientific substantiation should be developed to recommend a new design for optimal RAOB distribution.

1.2. This report contains both approach description and its application results. Optimization method, as well as information model have universal nature and might be applied to arbitrary observing system (homogeneous or complex). Preliminary recommendation for the Siberian RAOB redistribution is discussed to maximize information content.

2. Information content estimation

2.1. Theoretical background. Shannon information theory and its generalization (Gelfand, Yaglom, 1957) to the case of multidimensional fields is implemented to quantity evaluate of the measurement data information content.

2.2. Information model of observing system. This model was developed to establish a relationship between the measurement data and estimated variables (meteorological fields) by means of operator, which depend on observing system parameters – control variables: number and site locations, measurement error statistics: magnitudes and correlation features.

2.3. Regioning. Spatial range allocated for the analysis and the forecast of meteorological fields should be split into a set of homogeneous regions (HR) in such a way that within each of them, usual assumptions on stationary and isotropy of meteorological fields are approximately valid.

2.4. Optimization problem for observational system. To state this problem, it is necessary to select a qualitative criterion and develop some search technique to minimize a cost functional. We applied a criterion of minimum of the root mean square approximation of meteorological fields by set of measurements delivered by observing system. As the information model is a regression equation with coefficients depending on network configuration, our task is to minimize the residual, which compose a cost function. To minimize the cost functional, we implied Boolean function minimization technique, which requires several tens of iterations to achieve an optimal solution.

3. Implication to Siberian RAOB network optimization

3.1. Regioning. Our study showed that there are, at least, 10 HRs, which cover Russian Siberia and Far East areas. The largest in size HR covers Western and Eastern Siberia. More small-scale HRs are related to Polar and North-East domain, as well as Kamchatka Peninsula and Pacific Islands. There is a specific seasonal dependence of HR size and location. It was found drifting phenomenon of some HRs to North and to East in spring and summer. As RAOB should provide NWP and climate tasks, we consider the low oscillation patterns related to following known teleconnections: Scandinavian (S), Polar/Eurasian (PE), West Pacific (WP), North Pacific (NP), Pacific transition (PT) (Barnston, Livezey, 1987). The“S” pattern consists of a primary circulation center, which spans Scandinavia and large portions of the Arctic Ocean, north of Siberia. Two additional weaker centers with opposite sign to the Scandinavia center are located over Western Europe and over the Mongolia/ western China sector. The PE pattern reflects major changes in the strength of the circumpolar circulation, and reveals the accompanying systematic changes, which occur in the midlatitude circulation over large portions of Europe and Asia. During Winter and Spring, the WP pattern consists of a north-south dipole of anomalies, with one center located over the Kamchatka Peninsula and another broad center of opposite sign covering portions of southeastern Asia and the low latitudes of the extreme western North Pacific. Therefore, strong positive or negative phases of this pattern reflect pronounced zonal and meridional variations in the location and intensity of the entrance region of the Pacific (or East Asian) jet steam. This wave structure is most evident in the Fall, when it extends downstream along a quasi great-circle route into the western United States. The NP pattern consists of a primary anomaly center, which spans the central latitudes of the western and central North Pacific, and weaker anomaly region of opposite sign, which spans the eastern Siberia, Alaska and the intermountain region of North America. The PT mode consists of a wave-like pattern of height anomalies, which extends from the Gulf of Alaska eastward to the Labrador Sea. Our analysis proved that each of above dipoles or triples is related to HR set derived in our study. This fact gives an independent confirmation that regioning scheme for Siberia RAOB provides a selection of observing information in a way, which supplies a low oscillation analysis for atmospheric circulation. This fact also gives an additional argumentation that minimal RAOB network, representing set of HR, provides the most stable (to measurement error) numerical NWP.

3.2. RAOB distribution dynamics. The Siberian network has been reducing since 1992 (beginning of economic reforms). It continues as controlled process till the end of 1998. Despite of sonde number reduction, the total information content of the joint observing system with regard to the temperature and height fields was increasing due to the substantial increment in information content, which was achieved by remote sensing system contribution. Later, an abrupt reduction in number of sonde stations was caused by financial crisis. At this lowest point, a number of daily sounding was dropped to 5-6 over the Asian territory of Russia. This dramatic down in Siberia RAOB led to considerable reduction of total information content retrieved from both conventional and satellite observing system with respect to this vast area. Afterward, the set of Siberian sonde stations began the slowly update. Nonetheless, its total number is much lower than it was at the middle of ninetieth years. The information content increment is much lower than might be expected. Therefore, there is a problem of how to redistribute very restricted resources of RAOB network over vast territory to achieve the maximum information content.

4. Recommendation to Siberian RAOB network redistribution: Preliminary remarks. Current RAOB configuration comparison against HR set showed that some of HRs located at Artic coast, North-East and East areas are not represented by any sonde stations, but in contrast to the other HRs, include more than one site. Missed sites (as we showed in our previous reports) provided a considerable contribution in the forecast over North-East Pacific Ocean, Alaska and North-West of Canada. Moreover, these site observing data represent information allowed to trace climate indexes WP, NP and PE, which are of importance for short-term climate forecasting in Western Hemisphere. Some recommendations were developed to achieve an optimal redistribution of RAOB stations in above regions. These recommendations were based on implication of optimization procedure described in item 2. There was a list of several areas, which should be represented in RAOB network to describe the main meteorological field features of local and global scale. This list includes the following areas: Kamchatka (a pole of WP dipole), Kolyuma and Yakutia Pacific coast, Central of East Siberia (Siberia anti-cyclone range), Peninsula Chukotka and Taimyir Arctic coast, East-Siberian Islands, Far East, Pacific North Kuril and Sakhalin Islands. These areas correspond to the set of HRs found early. In the study, were used two competitive statistics for periods: (i) 1970-1979 and (ii) 1980-1989, which were provided by most reliable sonde measurement data over Siberia. The first one corresponds to the end of global cooling climate period, second – to the beginning of new warming epoch. In spite of these differences, the optimization results were surprisingly stable in account for network configuration. Invariance of optimal network configuration features was also checked against intra-annual variability of height fields. We showed that the present network configuration does not include four important areas: Peninsula Chukotka and Taimyir Arctic coast, East-Siberian Islands in Arctic Ocean, Pacific North Kuril Islands. It is necessary to note that in the Soviet time (before 1990), RAOB network covered all of these areas. The absence of accurate data in the above areas partly corresponding to zones of low atmospheric oscillations leads to substantial losses in GOS information content with respect to challenges of both weather and climate prediction problem. It was also proved by comparison of objective analysis error distribution in various spatial scales between current and redistributed networks. Additionally, we should keep in mind that satellite information on atmospheric temperature profiles is not sufficiently reliable for two reasons: considerable impact of cloudiness on outgoing radiation during most part of year and positive trend in cloudiness amount found in recent climate change researches. Therefore, the study’s conclusion includes multi-variant scheme for RAOB move into missing HRs, keeping in mind possible practical difficulties arising in restoration of station settlement and accommodation in the domain without permanent habitants living after ten years. Certainly, these actions will require considerable financial investments.